What the Clubs are Doing

Club Reports for inclusion in this feature should not exceed 250 words in length, and should be received not later than the 14th of each month for inclusion in the subsequent month's issue.

THE MODEL RAILWAY CLUB

THURSDAY, September 28th, was the first Track Night since the holiday season, and was well attended. Voting took place in accordance with the rules of the Models Competition, which resulted in Colonel R. Henvey, C.M.G., D.S.O., Mr. C. R. Wood and Mr. L. R. Ellis winning first, second and third place, respectively. Thursday, October 12th, was the date of the Annual Rummage Sale. A very large number of models and parts of models were on view, the selling of which provided a very interesting evening.

Fixtures for November were as follows: Thursday, November 9th, General Meeting. Thursday, November 23rd, Track Night. Full particulars of the Club may be had from Hon. Secretary, J. C. Watts, 85 Wood Vale, N. 10.

ILFORD AND DISTRICT MODEL RAILWAY CLUB

THE Club commenced its winter programme with the Annual Dinner at the Gatehouse Restaurant, Ilford, on September 12th, a very enjoyable evening being spent by all present.

On Saturday, the 18th, we were entertained by our President at his country house, where we spent an enjoyable time operating his 7½-in. gauge garden railway. Our sincere thanks are due to Dr. and Mrs. Watts for making the time spent so happy.

On Wednesday, October 4th, we had a very welcome visit from Mr. Shepherd, of the Wimbledon Club. A very instructive and entertaining evening was spent in hearing of some of the humorous and interesting side-lines of real railway working. The fine spirit of model engineering was amply shown by the fact that he travelled up from the South coast to speak.

The Club extends a very hearty welcome to all interested in model railways to pay us a visit. The chief item last month was a lantern lecture on the Romney, Hythe and Dymchurch Railway at the Club Headquarters, Richmond Hall, Grosvenor Road, Ilford, at 8.15 p.m.

Further particulars will be gladly sent upon application to the Hon. Sec., R. L. Riddle, 19 Northfield Road, E.6.

THE MODEL ENGINEERS AND WIRELESS SOCIETY
(LIVERPOOL AND SOUTHPORT)

THE object of this Club is to assist all those interested in model engineering and radio by means of lectures, debates, meetings, etc., and to provide a centre and workshop for those wishing to carry out practical experiments.

The first meeting of the Winter Season will be held on Tuesday December 12th, at Southport, when the rules and programme will be discussed. The meeting-place will be announced in the *Liverpool Echo* and *Southport Visitor* on Saturday, November 25th.

Subscription is 7*s.* 6*d.* per annum (under 19, 3*s.* 6*d.*) Entrance fee is 2*s.* 6*d.*

The meeting on December 12th will be preceded by an interesting scientific lecture.

Those interested should not fail to attend this meeting and anyone interested in (1) wireless, (2) model railways, (3) model aeronautics, (4) mechanics, (5) electricity, should communicate immediately with C. C. H. Turner, 62 Zetland Street, Southport, enclosing stamp for particulars.

Note.—Mr. Turner will receive on behalf of the Society, queries and problems from any reader of PRACTICAL MECHANICS. Address all problems (enclosing stamp for reply given free) to C. H. Turner (Problems), 62 Zetland Street, Southport.

STREATHAM COMMON MODEL RAILWAY CLUB

OUR clubroom at 201 Gleneldon Mews, Streatham High Road, is open every evening for members' use. Each night has been allotted to a definite object, and in December, Monday, Wednesday and Friday evenings are devoted to Track Nights. Tuesdays and Saturdays are devoted to Workshop Nights, and the Friday evening meetings are as follows:

December 1st: "Cornish Riviera" Lantern Lecture. Notes read by W. F. Gentry, Esq.
" 8th: Talks and Demonstration Meeting.
December 15th: "Britain's Largest Railway" Lantern Lecture. Notes read by the Chairman.

We have had two very interesting lectures already. One by Mr. W. H. Hart on "My Engines" and another by W. F. Gentry, Esq., on "Mass Production to Super Detail," describing what can be done to a Bing 2–4–0 tank locomotive.

We welcome new members and any friends to our meetings. Further particulars from General Secretary, L. J. Ling, Brooke House, Rotherhill Avenue Streatham, S.W.16.

THE PARK MODEL AIRCRAFT LEAGUE

MEMBERS of the above Club have been flying on Tooting Common for the past eighteen months. Permission has now been granted to fly on Mitcham Common, and a branch has been started there. The two flying grounds are within easy reach of Balham, Clapham, Croydon, Hackbridge, Mitcham, Norbury, Streatham, Tooting and surrounding neighbourhoods. The Mitcham Common ground is situated at the terminus of the 5 and 50 'bus routes and the tramway from Croydon to Mitcham passes the field. Present membership number is 48. Entrance Fee, 2*s.* 6*d.* Annual subscription, 3*s.* seniors and 2*s.* school members. Further details will be sent to any interested Aeromodellist on application to the Hon. Secretary, 112 Rodenhurst Road, Clapham Park, S.W. 4.

Next evening meeting at the Streatham Hall on Friday, January 5th.

Annual General Meeting and Election of Officers on Friday, February 2nd.

THE BRITISH INTERPLANETARY SOCIETY

MEETINGS for the reading and discussion of papers of the above Club [on Rocketry and kindred subjects are held at 81 Dale Street, Liverpool, in Room 15, on the 2nd Floor, from 6.30 to 9 p.m. every other Friday from November 10th. Subscription: Fellows, £2 2*s.* per annum; Members, 10*s.* 6*d.* per annum; Juniors, under 21 years, 5*s.* Subscriptions are payable quarterly. All members will receive free copies of the Journal of the Society, which is published quarterly, and contains news of developments in matters of interest to the Society. President: Mr. P. E. Cleator, A.M.I.R.E., A.M.I.E.T. Honorary Secretary: Mr. Leslie J. Johnson, 46 Mill Lane, Old Swan, Liverpool, 13.

THE NORTHAMPTON COLLEGE OF TECHNOLOGY, EXPERIMENTAL AND MODEL ENGINEERS

WILL all interested, residing in Northampton and district, wishing to become associate members of the above, please communicate with Mr. J. Parsons, 67 Broad Street, Northampton?

THE WIMBLEDON AND DISTRICT MODEL RAILWAY CLUB

THE above club is holding its annual exhibition at its Headquarters, Locomotion Hall, High Street Mews, Belvedere Grove, Wimbledon, on December 13th–16th.

The Show will be open from 5.30 p.m. to 10 p.m. on Wednesday, Thursday and Friday, and 11 a.m. to 10 p.m. on the Saturday. There will be something to interest everyone interested in model railways, including a working layout of models of the Rainhill Trials.

Tickets may be obtained from the undersigned at 7½*d.* post free, or at the Hall, 90 High Street Mews, Belvedere Grove, Wimbledon.

SHEFFIELD AERO CLUB

THE above Club is anticipating reviving the activities early in the new year by holding Model Flying competitions. It was founded on February 8th, 1911, when some fine duration records were accomplished by Mr. R. E. Rayner with R.O.G., 108 seconds, and Mr. G. Askew 125 seconds with hand-launched machines. Early in 1913, two brothers, Messrs. G. H. and C. Dewsnap, built a full-sized glider; it aroused a great deal of interest in which some wonderful flights were accomplished. The late Mr. W. E. Colver was President; he presented three Cups to the Club for competition.

Anyone interested in the construction and flying of model aeroplanes should communicate with Mr. Cudworth, 25 Randall Street, Highfields, Sheffield, 2.

Part of the showrooms of A. W. Hambling & Co., the suppliers of model railway and wireless accessories.

What the Clubs are Doing

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STREATHAM COMMON MODEL RAILWAY CLUB

OUR Clubroom at 201 Gleneldon Mews, Streatham High Road, is open every day of the week for members' use. Each night has been allotted to a definite object, and every Tuesday and Saturday evenings the workshop is in use. On every Wednesday, Thursday, Friday and Monday (with the exception of February 5th) the track is in operation. On February 5th we had a Lantern Lecture: "Liverpool Overhead Railway," by I. Macnab, Esq. Important Announcement: Our Third Annual Exhibition will be again held at 70 Conyers Road, Streatham, S.W.16, on Friday, April 20th (6.30 p.m. till 8 p.m.), and Saturday, April 21st (3 p.m. till 8 p.m.). Tickets may be obtained from the Secretary, or any member now, price 3*d*. each (inc. Tax). The Exhibition includes examples of members' work, a passenger-carrying railway in operation on both days, a workshop in operation at certain times, and the Club track. Various sideshows and amusements. Please book the dates now, and come along.

The Club magazine, "The Rocket," is now ready, and can be obtained price 5*d*. post free.

Secretary: L. J. Ling, Brooke House, Rotherhill Avenue, Streatham, S.W.16, will gladly send particulars to anyone interested.

THE PARK MODEL AIRCRAFT LEAGUE

TOOTING. MITCHAM

A WELL-ATTENDED evening meeting was held at the Streatham Hall on Friday, January 5th last, when Mr. G. S. Broadway read a paper entitled "Some Points in Construction," which was followed by a very instructive discussion.

The Annual General Meeting and Election of Officers was held on Friday, February 2nd at 7 o'clock. On Friday, March 2nd, Mr. D. J. Jordan has kindly consented to read a paper on "Flying Scale Model Aircraft." In spite of the foggy weather and short afternoons, the flying meetings are still very well attended, and visitors may be sure of a hearty welcome. Full details of the League may be obtained from the Hon. Secretary, 112 Rodenhurst Road, Clapham Park, S.W.4.

THE MALDEN SOCIETY OF MODEL AND EXPERIMENTAL ENGINEERS

THE progress has been very satisfactory. Among the present members there are two experienced engineers who are a great assistance to the Club.

We have been engaged during the past few weeks in erecting our own lighting plant, which is now in full working order, we are also fitting up shafting to drive a lathe and drilling machine and a small circular saw.

We shall be organising an Exhibition during the coming Spring, when we hope to have a good show of members' models and work on view, and also some large working models, including an automatic coaling plant.

We are also considering the building of a locomotive testing track, which should appeal to new members that are interested in model locos.

The subscription is 3*s*. a month, which will be reduced as membership increases. If there are any readers residing in Malden and the surrounding districts who are interested in model engineering or engineering generally, we shall be very pleased to hear from them.

I should like to point out that there are no members under eighteen.

Communications should be addressed to the Secretary, R. W. Blake, 31 Idmiston Road, Worcester Park, Surrey.

THE MODEL RAILWAY CLUB

A FEATURE of the track nights on November 23rd and December 7th was the large number of new models shown as competition entries. One member was responsible for five L.M.S. models in 7 mm. scale, including two locomotives, two goods' wagons, and a bogie passenger coach. The large track was in great demand, and good running by 7 mm. and 3½ mm. scale models was demonstrated. A member had four locos. on the track, with one of which he hauled tremendous loads.

The Club Social on December 14th was a great success, and our many visitors were treated to a comprehensive display of members' work. Outstanding items were Southern Railway goods' rolling stock (7 mm. scale) in great variety, and L.N.E.R. stock (also 7 mm. scale), including several Great Central locos. and three fine single-wheelers of N.E.R., G.N.R. and G.E.R. designs, respectively. An interesting film on American railway practice was shown, while the social character of the evening was emphasised by the exhibition of other films in lighter vein. These films were made available through the kindness of Mr. W. J. Bassett-Lowke.

An unusual method of construction was demonstrated at a recent meeting, when four locos. constructed from Bristol board were shown. Special treatment of this material gave a finish to the painting that was remarkably good.

Full information concerning the Club may be had from the Hon. Secretary, Mr. J. C. Watts, 85 Wood Vale, N.10.

THE BRITISH INTERPLANETARY SOCIETY

SUCCESSFUL meetings were held on December 15th, 1933, and on January 5th, 1934. The former meeting was primarily concerned with the composition of the Journal of the Society, which has since been published. A competition was held to provide a suitable design for the cover. This was won by the Hon. President, Mr. P. E. Cleator, A.M.I.R.E., A.M.I.E.T., F.R.S.A., who came forward with the futuristic design now adorning the front page of the Journal. On January 5th, 1934, the Hon. Vice-President, Mr. Colin H. L. Askham (G6TT) took the Chair in the absence of the Hon. President, who is at the moment in Berlin on a visit to the German Society, the Verein fur Raumschiffahrt, the Secretary of which is Herr Otto Willy Ley. A talk was given at this meeting by the Hon. Vice-President, in collaboration with Mr. J. Davies (G20A), on "High Frequency Radiation and Interplanetary Communication," which proved most interesting, and led to much discussion on the possibilities. Meetings continue to be held at 81 Dale Street, Liverpool, 2, Room 15, Second Floor, at 6.30 p.m. Meetings are held fortnightly from January 5th, 1934, on Fridays, at the above time. Communications should be addressed to L. J. Johnson, 46 Mill Hill, Liverpool, 13.

LATEST NOVELTIES

(*Continued from page* 235)

tainer. When the emergency light is no longer required the connecting cord can be again plugged on to the generator. It costs 4*s*. 6*d*. complete. [37]

The "Sportocular" Binocular Glasses

THE "Sportocular" is a pair of small binocular glasses mounted in a comfortably fitting imitation shell frame arranged to fit the eyes like a pair of spectacles. They are so devised that no undue pressure or discomfort arises from use even after a long period. A neat focussing device is fitted to the object glasses, and when once they are set no further adjustment is necessary. They are an ideal companion for the spectator at cricket, football or rugby matches, at theatres or races. They are worn with comfort, and leave both hands entirely free. The weight is 2½ oz., and the magnifying power is that of ordinary full-size field glasses, namely, three diameters. They cost £3 10*s*. complete in leather case. [38]

HALF HOURS WITH THE MICROSCOPE

(*Continued from page* 226)

and floated off on the liquid to one side until the final part is obtained. It should then be removed to a fresh quantity of liquid and prepared for mounting as described last month. Remember that alcohol hardens animal tissue, and therefore will prove most desirable when removing the nervous systems of small animals or insects. Vegetable matter will have to be thoroughly softened in order to avoid tearing, and dilute caustic soda solution will be most useful, although it must not be used for too long a period (or in too strong a solution) owing to its bleaching properties. When the required part has been obtained, mount it as previously described, and attach a label to the slide upon which the date of mounting should be entered. This will prove extremely interesting to look back upon in years to come, and it would also be very useful to try and obtain a commercial slide of a similar subject for comparative purposes.

What the Clubs are Doing

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WEST MIDDLESEX AMATEUR CINE CLUB

Headquarters: 105 Uxbridge Road, Ealing, W.5.
Hon. Secretary: Hugh P. B. Davies, 105 Uxbridge Road, Ealing, W.5

ALTHOUGH this is the first report we have made in these columns of "Practical Mechanics," it is not because we are a newly-formed society, so let us introduce ourselves forthwith.

The Club was formed in October 1929, and has since that date held regular weekly meetings, at which we have always had good attendances. The main object of our existence being the furtherance of amateur cinematography in all its branches, we cordially invite visitors to our meetings which are held every Tuesday at 8.15 p.m. at the above address. Anyone who is interested should communicate with the Hon. Secretary as we still have vacancies for new members, having set ourselves no fixed maximum membership, and our Secretary welcomes correspondence with fellow enthusiasts throughout the world. All the films the Club has so far produced have been made on 16 mm. stock, but a 9·5 mm. section of the Club has recently been formed, who are now making preparations for their first production, the shooting of which they hope to be able to embark upon in the near future.

STREATHAM COMMON MODEL RAILWAY CLUB

MEETINGS are held every night of the week at 201 Gleneldon Mews, Streatham High Road, S.W.16, from 6.30 p.m. to 10 p.m. We shall welcome any readers or friends to any one of our meetings. Meeting March 14th: "Talks and Demonstrations." Mondays, Wednesdays (except 14th) and Fridays are Track Nights; Tuesdays, Thursdays and Saturdays are Workshop Nights. The track has now been started upon, being laid with steel rail and cast chairs to replace the existing tin-plate. A portion of it is hoped to be on view at our Exhibition. The Club's Magazine, "The Rocket," for March, is now on sale: Price 5*d*., post free. Enlarged Number. A very interesting lecture was given at the Club Room recently by Ian Macnab, Esq., assisted by L. T. Catchpole, Esq., on "The Liverpool Overhead Railways." The lecture was illustrated by some very interesting slides.

Club Exhibition.—This year, as in previous years, the Club is holding its Annual Exhibition at 70 Conyers Road, Streatham, on April 27th (6.30 p.m. to 8.30 p.m.) and April 28th (3 p.m. to 8.30 p.m.). Admission 3*d*. All readers are very welcome. Attractions include a Passenger-carrying Railway, Exhibition of Members' Work, a Fun Fair, etc., etc. A special ticket competition is being arranged by the Club. Holders of tickets will notice a number on them. The lucky number, which will entitle the holder to a year's free supply of "The Rocket," will be drawn on Friday, and the holder is requested to take his half-ticket with that number on it at the Sweet Stall on either day. Tickets can be obtained from any member or through the Secretary. Will You help to make this exhibition a success?

To those who bring up models for testing. We are very pleased for you to do this, but as our track is laid to one standard, the New Alloy Wheels, some models may not be able to run upon the track.

Secretary: L. J. Ling, Brooke House, Rotherhill Avenue, Streatham, S.W.16, who will, on request, forward a copy of "Concerning Ourselves," post free.

THIRD ANNUAL EXHIBITION,
at 70 Conyers Road, Streatham.

April 27th (6.30 p.m. to 8.30 p.m.) and April 28th (3 p.m. to 8.30 p.m.). Admission (both days) 3*d*. (inc. tax). The Exhibition includes the members' work during the last year, a ride on a 5-inch passenger-carrying railway, ticket competition for the lucky number on the ticket, various competitions, etc., etc. Tickets can be obtained now, price 3*d*. from any member, or through the Secretary, L. J. Ling, Brooke House, Rotherhill Avenue, Streatham, S.W.16, who will be glad to supply full particulars of the Club to anyone interested.

THE MODEL RAILWAY CLUB

OUR approaching exhibition at the Central Hall, Westminster, during Easter week, April 3rd to 7th, occupies the attention of all our members. Track night, February 8th, gave an indiction of the amount of work being put in on new models, when a large array of most interesting items was on view. An electrically driven L.M.S. eight-coupled freight engine (4-mm. scale) attracted special attention amongst the many models in this smallest size. This loco. has a very low gearing of 32 : 1, and pulled a total weight of some 19 lb. An "Underground" station in 3½-mm. scale was shown complete with concealed lighting and posters. The new L.M.S. "Pacific" is receiving the attention of three members at least. Probably the most interesting model of the evening was, however, a 7-mm. scale motor coach of the late L.B.S.C. railway type, in which the reversal of the pantagraph is effected by remote control, all the necessary electrical mechanism being secured to the underside of the roof. A very novel item was a display card showing various types of chain slings as used in the goods yards on the Southern Railway.

A most interesting evening was spent on January 25th, when a lecture on "Locomotives of the Southern Railway" was given by Mr. J. Clayton, M.B.E., M.I.M.E., from the Chief Mechanical Engineer's Department of the Southern Railway. Copious lantern slides were shown, as also films showing track details and a run to Brighton on the new electric line as additional matters of interest.

Hon. Sec. Mr. J. C. Watts, 85 Wood Vale, N. 10.

THE BRITISH INTERPLANETARY SOCIETY REPORT

MEETINGS were held on January 19th and February 2nd. At the former meeting the President, Mr. P. E. Cleator, had just returned from Berlin where he had been visiting the German rocket experts, notably Herr Willy Ley and Herr Nebel. During his stay he visited the Raketenflugplatz and was shown the experiments in progress, and given a description of the progress that is being made in the science of rocketry in Germany. Experiments, said Mr. Cleator, are being made on a very sound basis and with a view to their ultimate practicability. The results are tabulated, so that if eventually any exploit is contemplated there will be little difficulty in determining the factors involved.

A list of rocket experts throughout the world was obtained from Herr Ley, and it is anticipated that they will co-operate with the British Society.

At the meeting on February 2nd, considerable progress was reported. Various technical journals had interested themselves in the project of a rocket car, while much publicity had been given to the Berlin visit. Evidently the importance of this has been realised both from the point of view of co-operation in a common scientific object and also of international friendship.

An informal talk was given by the Secretary on "The Mysteries of Venus and Mars," and led to considerable discussion. The Society was also informed of the very great possibility of a considerably bigger and better Journal.

A notable addition to the membership of the Society is the famous French engineer, M. Esnault-Pelterie. This promises closer co-operation between the British, French and German engineers.

Meetings continue to be held at 81 Dale Street, Liverpool, 2. The office is on the Second Floor, Room 15, and the meeting starts at 6.30 p.m. Meetings are held fortnightly on Fridays, every other Friday from February 16th, 1934. Leslie J. Johnson, Hon. Secretary.

THE BIRMINGHAM MODEL RAILWAY CLUB

THE Annual General Meeting was held at Christ Church Schools, Gt. Charles Street, on January 16th, at which the progress of the Club was reviewed and its programme for the present session discussed.

The first Club Night took place on February 1st, and was well attended. The attraction of the evening was a hauling competition: clockwork *versus* steam.

Other Club Nights were arranged as follows:—

Tuesday, February 13th. March 1st: Track running, and also a talk by Mr. R. H. K. Wickham, entitled "What the Railways Have Done Since 1929."

March 13th: Electric Loco. Haulage Competition.

THE PARK MODEL AIRCRAFT LEAGUE

A MOST interesting evening was spent on March 2nd last, when Mr. Jordan, Vice-president, read a very instructive paper on "Flying Scale Models." To many of us some quite new methods of construction were introduced, and we are expecting to see some experimental models in the near future as a result.

The next meeting will be held on April 6th.

The following is a list of P.M.A.L. open competitions for the season at which we shall be pleased to welcome any aero-modellist.

April	15	Duration . . .	Mitcham
,,	29	Distance . . .	Tooting
May	6	Seaplane . . .	Wimbledon
,,	13	Duration . . .	Mitcham
,,	27	Aerial Golf	Tooting
June	3	Scale and Semi-scale .	Tooting
,,	17	Duration . . .	Mitcham
July	15	Duration . . .	Mitcham
,,	22	Speed . . .	Mitcham
,,	29	Weight Carrying	Tooting
August	26	Duration R.O.G. .	Mitcham
September	9	Climbing . . .	Tooting
,,	23	Duration . . .	Mitcham
October	7	Steering . . .	Mitcham
,,	21	Duration . . .	Mitcham

Full details may be obtained from the Hon. Secretary: Mr. F. H. Dillistone, 112 Rodenhurst Road, Clapham, S.W.4.

Place an Order with your Newsagent for "PRACTICAL MECHANICS" to be regularly delivered!

What the Clubs are Doing

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THE BRITISH INTERPLANETARY SOCIETY

THE most successful meeting of the Society to date was held in Liverpool on Friday, September 7th. Five new members were admitted into the Society, including one lady.

Suggestions had been received from several members about the future form of the Journal, and these were discussed at length. It was decided that the October issue would appear in the usual form, but before the following issue was published the matter would be discussed more fully.

The question of copies of lectures becoming available to members was also discussed, and a definite line of action was decided upon.

A very friendly letter of co-operation and goodwill sent by Herr Ing. Guido Pirquet, of Vienna (Fellow of the B.I.S.), a prominent Continental experimenter, was read to the members by the Secretary.

A fierce and most interesting discussion took place between the President, Mr. P. E. Cleator, and the Vice-President, Mr. Colin H. L. Askham, over the future policy of the Society as to the election of representatives in foreign societies. After a long verbal duel the matter had to be referred to the next meeting.

The problem of a branch in London was considered, as such a branch had been proposed. It was decided to establish such a branch when the membership in London justified one.

INSTITUTE OF SCIENTIFIC RESEARCH

WE wish to announce our new programme of work for the winter months. Meetings will be held regularly on alternate Saturday afternoons, and one visit will be arranged for each month.

The laboratory will be open to members and visitors on Monday evenings, and the library will be open on Monday and Thursday evenings.

We are also forming a Correspondence Section, and any person in the British Isles or abroad who is interested in any branch of science should get into communication with the Secretary, Mr. D. W. F. Mayer, 20 Hollin Park Road, Roundhay, Leeds 8.

"SIR JOHN SHELLEY CUP" CONTEST

THE Sir John Shelley Cup Contest for power-driven model aeroplanes was held on August 26th, at Fairey's Great West Aerodrome. All the five models competing were powered with the petrol engine. This is a fair indication of the year's progress, as last year's contest produced only one starter. Nevertheless, this type of model is still in its infancy, and much coaxing of refractory power units and long waits between flights reminded one of the early days of full-scale flying.

The winner, Capt. Bowden, appears to have got a good lead on all other enthusiasts. It was worth the somewhat tedious journey to Fairey's to witness his effort alone. The machine, a high wing, named "Blue Dragon" (Atom Minor engine), was built for the contest, and had just completed a few short tests. In the contest it took off in about 4 yd., climbed rapidly in small circles, and was soon a tiny speck in the clouds. It was timed for 12 mins. 48 secs. "out of sight," and is estimated to have reached a height of several thousand feet. The owner pursued it in his car as far as Staines, and saw it gliding down in the distance after a 19 min. flight, but so far the landing-place has not been located.

Second in the contest was the high wing "Flamingo II.," flown by Mr. F. Harris. The 14 c.c. engine was the work of Mr. Harris, a senior power-boat trophy winner. The best flight was 3 mins. 42.5 secs.

Third came Mr. J. W. Bishop's huge biplane, "Endeavour," with a 25 c.c. engine. This machine flew very steadily and climbed quite well. Its best effort was 3 mins. 25 secs.

STREATHAM COMMON MODEL RAILWAY CLUB

OUR Clubroom at 201 Gleneldon Mews, High Road, Streatham, is now open three nights a week, on Tuesdays, Fridays and Saturdays, from 6.30 p.m.

We are anxious now to increase our membership and will for one month only—October—grant membership to anyone over sixteen years of age free of any entrance fee. Full particulars of membership and details of the club are contained in our four-page publication, "Concerning Ourselves," a free copy of which will be sent post paid to anyone requesting particulars of the club.

Our stand at the recent "M.E." Exhibition held the interest of many visitors, and models that were exhibited gave a good representation of members' work.

We shall be pleased to welcome any readers to come down and visit our clubroom by arrangement with the Secretary.

An invitation form to our next lecture will be given to anyone interested.

The Rocket, our quarterly journal, is now ready and can be obtained price 5d., post paid, from the Secretary now. This contains full club news, together with interesting items of real railway news.

Full particulars from the Secretary, Brooke House, Rotherhill Avenue, Streatham, S.W.16.

Catalogues and Publications Received

OUR FREE CATALOGUE SERVICE

To save readers trouble, we undertake to send on catalogues of any of our advertisers. Merely state on a postcard the number (or numbers) appearing at the end of the paragraphs below and address it to "Catalogue," PRACTICAL MECHANICS, Geo. Newnes Ltd., 8/11 Southampton Street, Strand, London, W.C.2. Where advertisers make a charge, or require postage, this should be sent with applications for catalogues. No other correspondence whatsoever should be enclosed.

A New Radio Feature

THE TECHNICAL & COMMERCIAL RADIO COLLEGE, Cromwell House, High Holborn, advise us that they have recently introduced into their College course a number of additional lessons, dealing with the design of the modern superhet and the use of the new types of valves of the multi-electrode type for frequency changing and A.V.C. in such circuits. They also give instructions dealing with the adjustment and servicing of modern superhets and other receivers. [64]

The 1935 Whitfield King Stamp Catalogue

THE new edition, which is right up to date, is an improvement upon its predecessors in several respects, being printed on thicker and better paper, and certain alterations have been introduced in regard to lay-out which make for clearer reading and easier reference. The size of the pages has also been slightly increased to accommodate the number of new stamps recorded without becoming unduly bulky.

The binding has been improved and strengthened and an innovation which, no doubt, will be welcomed by retailers is an attractive jacket, this being a novelty so far as stamp catalogues are concerned.

Although compiled upon simple lines for ready reference, it is not primarily a simplified catalogue, since it records essential particulars, including watermarks of every issue of the world's postage and air mail stamps. Only minor variations of colour, perforation, etc., are excluded, these being of no interest to the average collector.

The catalogue is now on sale, and despite the cost of improvements and increased size there is no alteration in the retail price, which remains at 7s., and it is obtainable from the above firm's address at Ipswich. [65]

A Valuable Valve Guide

A COPY of the 1934–35 Osram valve guide, published by the General Electric Co. Ltd., has just come to hand. Since its introduction in 1926, this valve guide has proved its popularity and utility by an increasing circulation year by year amongst wireless enthusiasts.

The rapidly multiplying number of valve types on the market to meet modern circuit developments has set its own problem, which is to compile a reference booklet providing complete technical information and working data for each type, and yet retaining a handy pocket size. This little publication certainly achieves this aim with success.

The 1934 Osram valve guide solves the problem for the technical reader by giving full tabulated data of all the Osram ranges of valves, and at the same time offers a clear guide to the non-technical reader as to which valve is most suitable for every stage in a modern set.

In addition to the data charts, the Osram valve guide contains much helpful information, circuit diagrams, and useful description of the application of modern valves. A copy can be had on application to the General Electric Co. Ltd., Magnet House, Kingsway, W.C.2. [66]

The 1935 Gibbons Stamp Catalogue

THE Jubilee edition of the Stanley Gibbons Postage Stamp Catalogue is specially notable for the fact that a number of rare stamps are now priced for the first time, no less than £131,892 worth of *extra* prices having been added in this way. Market fluctuations are indicated by the fact that 23,990 prices have changed during the past year—about 10 per cent. of the whole.

To provide space for the 2,000-odd stamps which represent the world output for the twelve-month, over fifty extra pages have been added, though no alteration has been made in the price at which the catalogue is sold.

For the convenience of collectors, the list of Egyptian stamps has been reinstated in Part I., which is now described as "British Empire (with Egypt and Iraq)." Typical plate varieties in the earliest British issues are now illustrated, and it is noticeable that there has been a sharp rise in the prices quoted for many of the older stamps of Great Britain. The catalogue is obtainable from Messrs. Stanley Gibbons Ltd., 391 Strand, London. [67]

BY ROCKET THROUGH SPACE

NEWNES

PRACTICAL MECHANICS

JANUARY

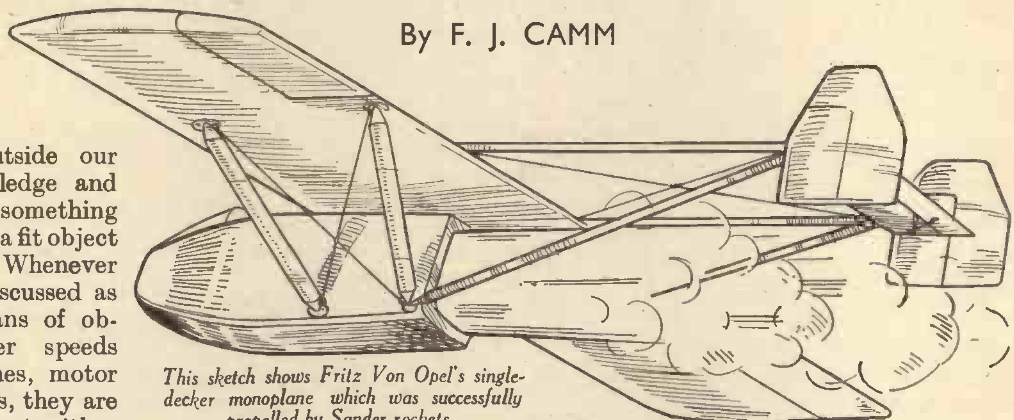
6D.

PACKED WITH FASCINATING ARTICLES & ILLUSTRATIONS ON ALL PRACTICAL & SCIENTIFIC SUBJECTS

ROCKETS—THE POWER OF THE FUTURE

It Would Seem that Practical Limits have been Reached in the Speeds of Cars, Aeroplanes, and Steam Ships. Is Rocket Power Feasible? In this Article We Show that it is More than a Qualified Success and and that Rocket Power will be Used in the Future.

By F. J. CAMM



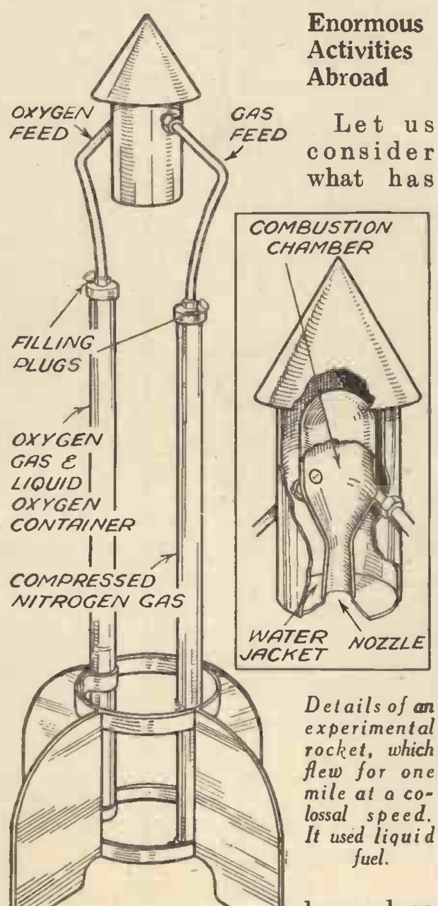
This sketch shows Fritz Von Opel's single-decker monoplane which was successfully propelled by Sander rockets.

THERE is always a tendency to regard a new suggestion outside our present knowledge and experience as something grotesque and a fit object for derision. Whenever rockets are discussed as a possible means of obtaining higher speeds with aeroplanes, motor cars, and ships, they are dismissed almost with a snigger or considered as a piece of schoolboy fiction. It was so with wireless, and with television, with motor cars, and with aeroplanes. It has been so with rocket flight. We cannot, however, continue to so regard it in view of the facts which I place before you in this article.

Prophetic

When George Stephenson named his early locomotive the "Rocket" he was more prophetic than he knew. The "Rocket" seemed like a rocket in those days, for it was faster than anything the public had known before. Mechanical travel was not then born. Speed is purely relative and what is considered fast to-day is considered slow to-morrow.

When an early motor car travelled at forty miles an hour it was considered that the ultimate had been reached. Doctors stated that a human being could not live at the speed of sixty miles an hour. Trains and aeroplanes have all travelled at speeds of over 100 miles an hour, and so we must consider in view of the practical limits set by modern methods whether even higher speeds are possible and, if so, how obtainable. We must not forget that it still takes nearly four days to travel from here to America. A long time! It takes at least seven hours to travel from London to Edinburgh. An eternity! Is there any limit to speed? Actually it is considered that speed cannot travel faster than sound, but we have a long way to go before we can travel at the rate of 1,100 ft. a second.



Details of an experimental rocket, which flew for one mile at a colossal speed. It used liquid fuel.

Enormous Activities Abroad

Let us consider what has been done with rockets. In America, Russia, France, England, and Germany there have been enormous activities in the development of the rocket engine with liquid fuel. Opel, Valier, and others have conducted successful experiments with rocket cars in Germany. Successful experiments with rocket aeroplanes and rocket boats have taken place in America.

It is chiefly in connection with air travel that the possibilities of rockets are being investigated. Already the Interplanetary Society is actively engaged on the problem. It has members in every country in the world.

Rocket Propulsion

The great point in favour of rocket propulsion is the fact that there is no engine in the ordinary sense of the word, the rocket body being propelled forward by the exploded fuel. Of course, such fuels as gunpowder and similar "firework" components were found to be both weak and bulky. The most suitable system up to now is founded on the ignition of a fuel such as petrol, benzine, or alcohol in an atmosphere of oxygen. The explosive force and power generated are simply terrific. If you look at the illustrations you will see the idea in diagrammatic form, the particular rocket there illustrated being designed to act like a shell, carrying a load of explosive substance in the forward compartment which would detonate on impact.

A Rocket Car

An illustration shows the same idea as used by the famous German experimenter, Max Valier, in 1930. This car, despite the simple nature of the power plant, developed nearly 200 h.p. and lapped the course at Tempelhof Aerodrome, Berlin, for seven circuits at an average speed of 90 miles per hour. It was an impressive sight as the vehicle tore along with a roar like artillery in action and a 6-ft. spear of white-hot incandescent gas shooting out behind it. Apart from the steering and brakes, the sole control was a lever which controlled the valves regulating the supply of liquid oxygen and fuel. Unfortunately the driver was killed some time after while experimenting with the use of oil, instead of spirit, as fuel. The rocket, as a successor to the engine, is, however, a tried and proven fact, and while not likely to supplant the latter for ordinary use, opens up an entirely new sphere of potential travel.

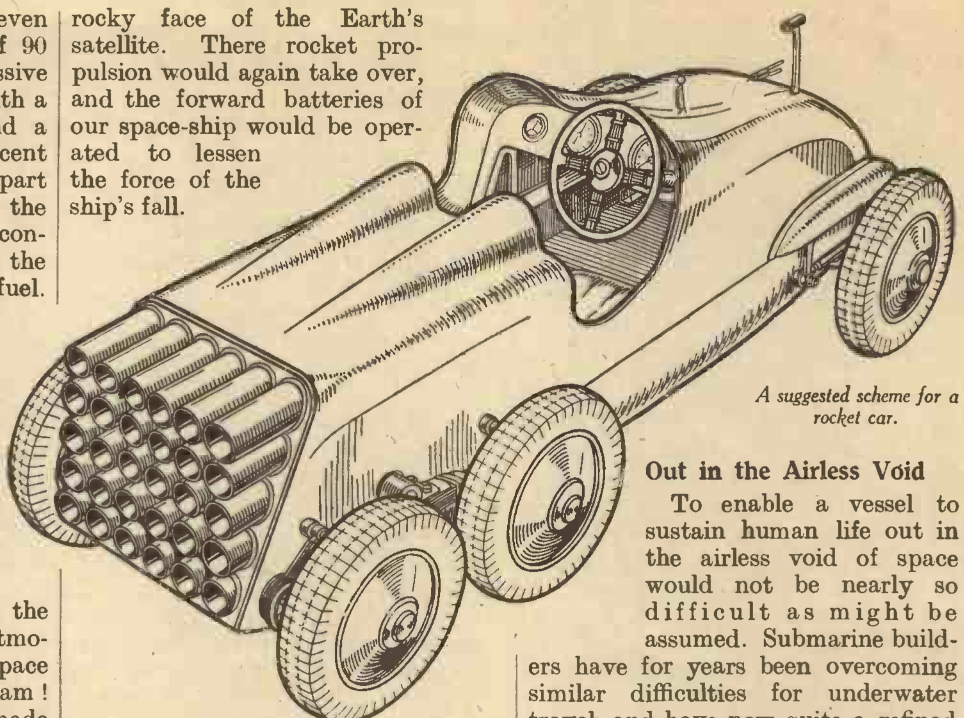
For the first time in history, the idea of travelling beyond the atmosphere and into the realms of space has become more than a mere dream! Already preparations are being made to launch a huge rocket moonwards; and here the fuel used will be still more powerful, being a jet of hydrogen gas burning in an atmosphere of oxygen. As every schoolboy knows, both these gases are now available in liquefied form, which means an immense volume of gas in a very small space.

Travelling to Mars

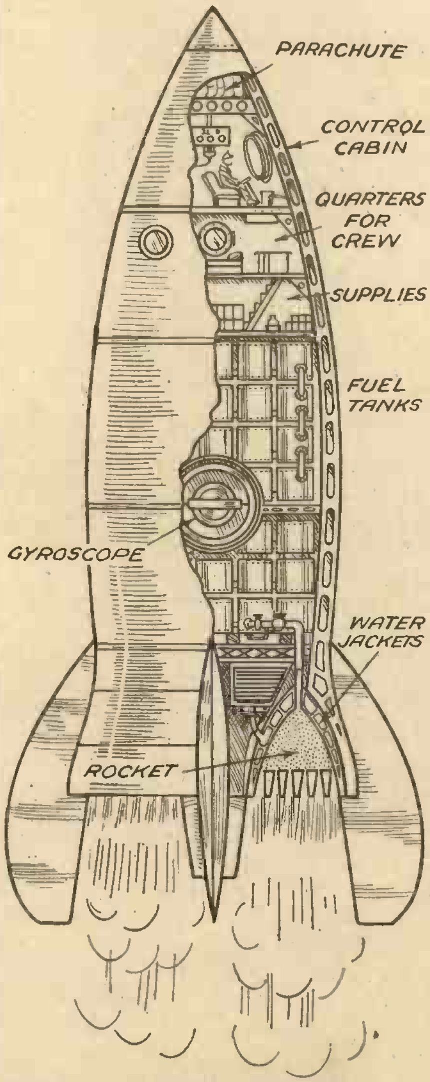
Before mankind is ready to step into a luxurious space-ship and voyage to Mars in comfort, many years may pass and much painstaking work must be done, but make no mistake, the possibility of space travel is in sight!

Just what are the obstacles to be overcome? Briefly, they are gravitation, the vacuum (so called) of space, and distance. When the first space-ship is launched its objective will undoubtedly be the Moon, as being the nearest celestial body and situated some 240,000 miles away, a mere nothing for inter-stellar space.

Yet that "mere nothing" is decidedly formidable, judged by Earth standards, for at 50 miles an hour—roughly the speed of the London-Brighton express—it would take over 200 days, or about seven months' continuous travelling to get to the Moon. Fortunately—once beyond the Earth's atmosphere—there would be no resistance and speed would pile up to a dizzy figure as the pull of Earth's gravity lessened and that of the Moon increased. When the neutral point between the gravitation of Earth and Moon were passed, difficulty would be to slow up, and so avoid crashing into the bleak and rocky face of the Earth's satellite. There rocket propulsion would again take over, and the forward batteries of our space-ship would be operated to lessen the force of the ship's fall.



A suggested scheme for a rocket car.



Section of a rocket-flying ship, which has been successfully demonstrated in Germany.

Out in the Airless Void

To enable a vessel to sustain human life out in the airless void of space would not be nearly so difficult as might be assumed. Submarine builders have for years been overcoming similar difficulties for underwater travel, and have now quite a refined and stable technique for providing heat, oxygen, light, food, and other necessities of life in a hermetically-sealed hull. In emergency, the driving of stale air through lime-water, and heating of potassium chlorate to liberate oxygen, will keep air breathable for quite a long time. Submarine practice, too, would be invaluable if once the Moon were reached; for air-locks could be built in the vessel's wall, for exit and entry without leakage of air on to the airless desert of the Moon, just as diving-locks on a submarine permit safe entry for divers while under the surface.

For exploration of the Moon's arid surface an adapted form of diver's suit and helmet could easily be evolved. The atmospheric pressure required by man is only 15 lb. to the square inch, while divers' suits are now made to withstand enormous pressures.

And after the Moon?

Why, Mars, of course! That nearest neighbour of ours who twinkles so redly at us, who has a definite atmosphere of some sort, and whose strange "canals" have puzzled astronomers for years, would be a goal worth reaching.

Is Mars Inhabited?

That question, which has been debated times without number, would be answered once and for all. As Mars is much smaller than the Earth, it is presumed to have cooled down millions of years before our globe did, and therefore the Martian intelligence may be assumed to be far ahead of

A rocket car capable of travelling at 80 m.p.h.

our own. Now, if Martians have developed on the same lines as the human race, and are so far ahead of us in evolution, why have they not, long since, solved the problem of interplanetary travel and visited our world? Either they did so long before our globe came into the period of recorded history, and they have died out, as a race, long ago; or intelligent life has developed on entirely different lines to that on Earth. It is feasible that intelligence may have been housed in an insect form, and in this case the instinct of travel, might never have been evolved.

A further step in the development will be mail rockets; such a rocket could carry 1 cwt. of letters from London to New York in less than half an hour, and the cost of transport would be astonishingly small.

The rocket mail express service might therefore be not only a valuable innovation, but would also work very economically and provide an excellent source of revenue for the countries concerned.

Leaving the Earth

Whether it will be possible within any reasonable space of time to leave the sphere hemming in the earth, and rush onward to another heavenly body, by earthly expedients, cannot yet be determined. At all events, further attempts with liquid fuel must first lay the technical foundation for the further development of the stratosphere rocket.

In the literature on this subject expansive calculations and plans for future stratosphere airships have already been made. These would be composed of several large liquid fuel rockets, and would have to attain a speed of 7 miles per second in order to penetrate the heavy sphere round the earth.

Thus we see that the problem of travelling in the stratosphere is mainly a question of speed. And this is a question of fuel, and the rocket motor which converts it into energy.

The Stratosphere

The stratosphere and the empyrean beyond, with the constellations, stars, satellites, planets, and other heavenly bodies, have formerly been the special preserves of the astronomer, the realms pierced only by high-power telescopes, the object of skilled observation and conjecture based upon the recurrence of certain phenomena, and on which we have built our theses as to the constitution and order of the universe, of which the earth is but a minute and unimportant part.

The Rocket Ship

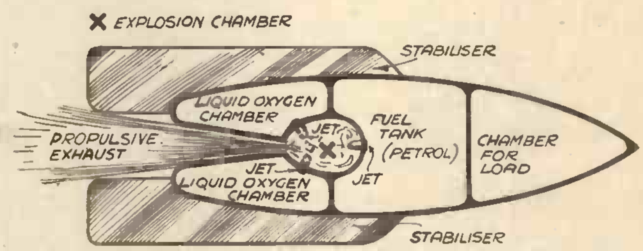
No lighter-than-air vessel could ascend for more than a limited altitude, the extreme limit being in the nature of 30 miles. Hence science has directed its attention to an entirely new type of space ship propelled on the rocket principle. It is necessary to remember that travelling in the upper regions requires much less power than that expended in travelling through the air, and ultra-high speeds for very small expenditure of power are thus possible once we leave the atmosphere. Fog and snow, lightning and storms do not exist in the stratosphere, and thus there must be additional safety in travelling at these high altitudes. If we could travel, via the stratosphere, a journey between England and Australia, which at the present time takes a matter of days by ordinary aircraft, would take but a few hours. In fact, the extreme limits of the earth could be reached in a maximum of two or three hours.

Speed in a Vacuum

The first practicable experiments in rocket propulsion or, to use a more accurate term, reaction propulsion, really commenced in the year 1919, when Prof. Goddard published the results of his experiments made with rockets propelled in a vacuum.

Briefly, he found that a pistol or rocket fired in a vacuum kicks back or recoils even more so than in the open air, and thus disproved the old idea that a rocket depended for its action by pressing back, so to speak, on the air. We have already seen that no form of space ship making use of an ordinary airscrew could function in a vacuum or the partial vacuum of the upper regions, since it could not produce tractive effort unless it operated in air; and in this vital principle discovered by Prof. Goddard we have the basis of design for a space ship.

The recoil of a rocket or a pistol or a gun obeys Newton's Third Law of Motion—that action and reaction are equal and opposite. The momentum of a bullet fired from a pistol will be equal to the momentum of the recoil of the pistol. Momentum, it must be remembered, is the product of the mass (or weight) of the body times its velocity; hence, since the mass of the pistol is considerably greater than that of the bullet, its velocity will be considerably less than that of the bullet. If you multiply the speed of its recoil by its weight this will be found to equal the weight of the bullet multiplied by the speed of the bullet. This principle of motion applies in ordinary air; it is even more effective



Sectional view of a boat propelled by rockets. Small toys are available which demonstrate the principle.

Stratospheric rocket as developed in Germany. Would rise 15 miles and attain a speed of 600 m.p.h. with 200 lb. load.

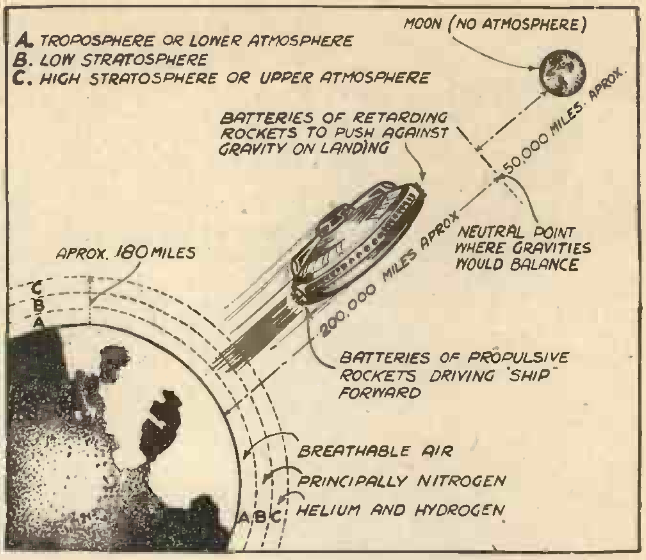
in a vacuum, and reaches maximum efficiency in it.

Reaction Propulsion

We have thus arrived at the point where it has been demonstrated that the only practicable means of travelling through the vacuum of space is by means of reaction propulsion. We have also seen that enormous speeds are possible in a vacuum with a very small propelling effort, and, in fact, an even rate of consumption of the fuel used to impart reaction propulsion will provide the ship to which such apparatus is attached with a velocity which increases every second.

No Sensation of Speed

Bearing this in mind, we must remember that Nature has apparently provided us in advance with the ability to travel at these colossal speeds of several hundreds of miles an hour, since it is well known that we do not possess any sensation of speed. This may sound startling, but if you recall that every moment of our lives every human being is travelling at a constant speed around the sun of 65,000 miles an hour, and that we are quite unaware of it, you will more easily understand the point. We are only conscious of speed when it exists in relation to something else. If you draw the blinds of a railway carriage in which you are travelling, you will be unable to say with certainty which way you are going, and if the train could be made vibrationless you would not feel any sensation of motion. We only become sensitive to changes of speed. Once your car has attained a certain speed and is kept at that speed, you cannot feel the pressure of the back of the seat. Directly the car slows down, you are aware of the fact by a tendency to shoot forward, and if you violently accelerate, your back presses hard against the back of the seat. You experience a somewhat similar sensation in a lift, either when it is starting or when it is slowing down. But during the *constant speed* portion of its travel you are unaware of its direction of motion.



The rocket principle will probably be applied to space travel. If rockets cannot propel the craft beyond the neutral point, it would be marooned there.

The Limit in Speed

Thus, we have now demonstrated two important facts: firstly, that reaction propulsion is possible and has been demonstrated; and secondly, that human beings are able to travel at enormous speeds without danger. Without going into mathematics, it can be stated that the limit of human endurance in speed is the free falling velocity of 32 ft. per sec./per sec. which for a period of 5 minutes mounts up to 6,000 miles an hour. The problems to be solved in high speed space flight are thus those of starting and stopping, and there is really no limit—*in space*—to the speed at which a human being can fly. There is a practical limit to speed through *air*, and this limit is set by the friction of the machine passing through the air and the heat generated by it. But, this friction would not exist for more than a few miles—at most 50—and representing a few seconds, it can therefore be ignored. In support of this fact, it must be remembered that a meteor or falling star does not become visible until it enters our atmosphere, thus proving that in its descent it must pass through a vacuum, and hence no friction is generated. This alone causes it to glow as soon as it enters the atmosphere.

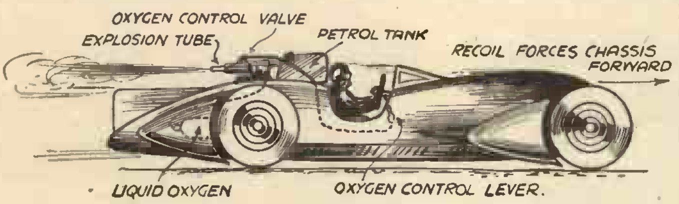


Diagram showing the arrangement of Max Valier's car, successfully demonstrated in Berlin in 1930. It attained a speed of 90 m.p.h. The combustion chamber was no larger than a soda-water bottle.

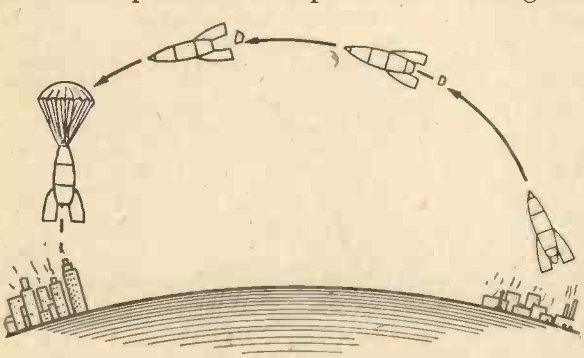
Actually, the density of the air becomes rarefied at an altitude of about 5 miles. At 8 miles the air density is so low that it causes the blood to ooze from the pores of the skin and from the ears, the eyes freeze, and usually there is loss of consciousness.

Sounding balloons, equipped with delicate recording apparatus, have ascended without a pilot to an altitude of over 22 miles, and provided valuable data without risk to life. One important fact is that the density of air decreases by a half for every 3½ miles ascended, and that temperature drops 1° Fahrenheit for every 900 ft. ascended.

It is, therefore, easily calculated that when the lower fringe of the stratosphere is reached, the density would be only about one-tenth of the density at the surface of the earth, whilst at the top of the stratosphere it would be only one sixty-seven-thousandth.

These facts are here set on record to enable the reader to understand the principles upon which future stratospheric ascents and space flight will be based, and to indicate that, as a result of the pioneer work already done, such are now within the realm of practical possibility.

We must grow accustomed to the thought that all travel to-day is relatively slow, and that the tendency is for everything to be speeded up. There is no other means of creating faster travel, except to use the stratosphere. The world grows smaller as the speed of travel increases, and who can say that, when all nations live in closer time-proximity to one another, the problems which beset the world will thus be solved?



The proposed rocket mail. Calculated time for London-New York, 28 minutes. Landing effected by means of parachute.

TO THE MOON IN A SPACE SHIP

NEWNES

PRACTICAL MECHANICS

MARCH 1939

6D

TO THE MOON IN A SPACE SHIP

The Shortest Space-Ship Voyage is the Journey to the Moon, and Below is Given Details of a Suitable Ship that might be Capable of Accomplishing the Journey

IN designing a space-ship the designer has a completely different problem from that involved in the design of any other means of transport. A motor car, railway train, aeroplane or ship consists basically of a vessel and a fuel tank, in the tank being placed the fuel required for a journey or journeys. The shortest space-ship voyage, however, is the journey to the moon, and with the most optimistic estimates of the fuel energy and motor efficiency the quantity of fuel required will still be such that the fuel tank would require to be much larger than the rest of the ship. Consequently, we must revert to the old system of petrol cans, so designing our ship that the cans can be attached outside the ship and thrown away when empty. We find by careful calculation that with the best fuels and motors that we can afford it will require about 1,000 metric tonnes (a metric tonne is roughly equivalent to an English ton) of fuel to take a 1 tonne vessel to the moon and back, so our designers' problem has been to design a 1 tonne space-ship with containers for 1,000 tonnes of fuel attached outside and detachable.

Rocket Motors

The nature of rocket motors has also affected the design considerably. With such motors as aero-engines, a larger unit can be made lighter in proportion to its power than a small unit, but in the case of rocket motors, quite the reverse is the case; in fact, the proportionate weight of rocket motors rises so steeply that a motor of more than 100,000 h.p. is hardly feasible, and as the lifting of the 1,000 tonnes at the start calls for many millions of h.p. this requires a considerable number of small units. Again, since the cost of the motors is less than the cost of the fuel required to bring them back, and as only a few small motors will be required to land the one tonne ship on its return against over a hundred large ones at the start, the motors are jettisoned after use.

For a maximum fuel economy, anything which is to be jettisoned should be jettisoned as soon as possible, and this has led to the cellular space-ship design, with hundreds of small units each comprising a motor and its fuel tank, and each so attached that as soon as it ceases to thrust it falls off. This early detachment of all dead weight has resulted in an enormous increase of efficiency over earlier designs, and has reduced the fuel required for a return voyage to the moon from millions of tonnes to thousands of tonnes.

Solid Fuel

Owing to the large number of small units, it is possible to start a motor and run it until its load of fuel is exhausted, controlling both thrust and direction by the rate at which fresh tubes are fired. This makes it possible to use solid fuel for the main thrust with consequent considerable saving in weight, and giving the additional advantages that the strength of the fuel helps to support the parts above and its high density makes the ship very compact. Liquid fuel motors are, however, provided for stages requiring fine control, and also steam jet motors for steering.

Fig. 4 shows a section through the head of the space-ship. The approximately hemispherical portion (to the downward pointing cone) is the life container. The portion between the two cones contains the air-lock, air-conditioning plant, heavy stores, batteries and liquid fuel and steam jet motors, etc. Below this are the solid fuel tubes for the return voyage. The whole of the remainder of the vessel (Figs. 1 and 3), consists of the tubes for the outward voyage, which have to be jettisoned by the time of arrival at the moon.

Not Streamlined

It will be seen that there has been no attempt to streamline the ship. The form of the ship has been largely dictated by other considerations, and as compared to the terrific power needed to lift the vessel out of the earth's gravitational field the total air resistance is quite negligible (less than 1 per-cent.), but this does not matter greatly. The diameter of the front of the ship is determined as being the smallest reasonable size for the life container. (It should be noted that this design is for a very small space-ship, about the overall size of a large barge. On larger ships this restriction will be somewhat modified.) The diameter of the rear of the ship is determined by the firing area required. Too small an area calls for excessive pressure in the motors, and consequently excessively heavy construction. The two diameters being approximately the same has led to the straight-sided form. An increase in central diameter would mean improved streamlining, but this would only decrease the resistance below the velocity of sound, and this is only a small proportion of the whole.

The Design of the Nose

On the other hand, the straight-sided form gives the greatest strength, which is of major importance, and also serves to minimise frictional heating. The main body of the space-ship, comprising the motor tubes, is hexagonal in shape; this form giving the closest possible stacking of the tubes.

The form of the nose is intended not so

much to reduce the resistance at low velocities, as to split the air at high velocities (several times the velocity of sound), so as to maintain a partial vacuum along the sides. The frontal paraboloidal portion seen in Figs. 1, 3, and 4, is a reinforced ceramic carapace, capable of withstanding a temperature of 1,500 degrees Centigrade in air, and by its form the frictional heating is made a maximum on this portion and minimised on the sides. The carapace (which, of course, has no portholes) is detached once the vessel has got away from the earth.

The tubes are stacked in conical layers for greater structural stability, since, apart from the vessel proper—the top portion—the whole strength lies in the tubes, and these are not rigidly fixed together, but simply stacked and held in position by one-way bolts and light webs.

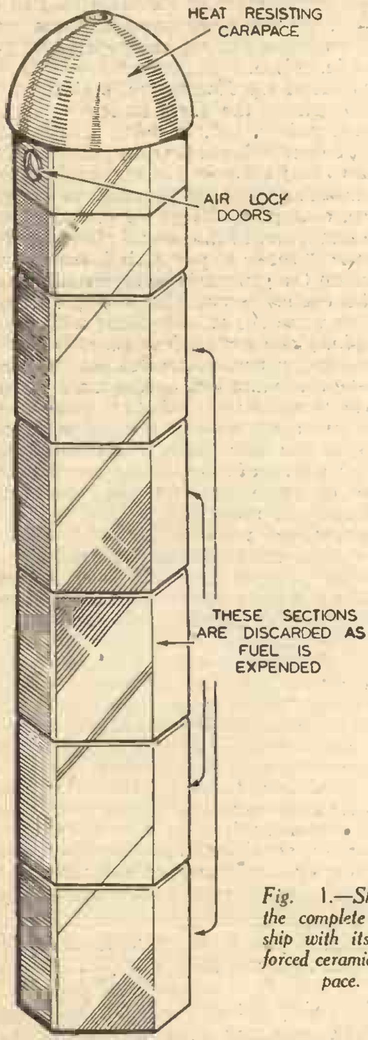


Fig. 1.—Showing the complete space ship with its reinforced ceramic carapace.

Firing Order

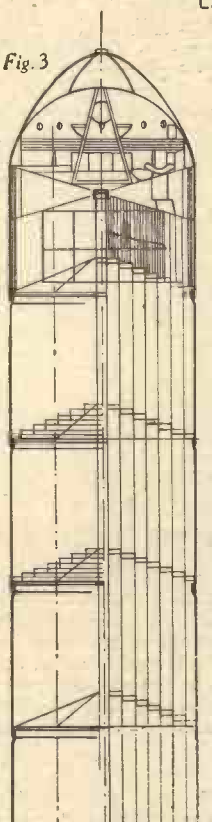
The firing order of the tubes is in rings starting from outside and progressing inwards towards the centre. While the motors are firing their thrust holds them in place; when expended the acceleration of the ship causes them to be released from position and they drop off. Those in the inner rings of the bank not yet used do not position themselves for release until their firing thrust carries them a fractional distance up the release bolts. A light metal sheath embraces the outermost ring of tubes; this and the webs are discarded when the whole of the previous bank of motors has been jettisoned.

Fig. 2 shows maximum periphery of the carapace. The top half of the diagram (Fig. 2) represents a section through the large motor tubes stacked in banks; these are used to obtain release from the earth. The lower half, Fig. 2 shows the medium and small tubes used for deceleration at the moon (the ship, having been turned end to end, approaches stern first). Fine control for the actual landing is provided by the vertical liquid fuel motors seen within the two cones in Fig. 4 and about the hexagon angles in Fig. 5. The upper bank (Fig. 4), is used for the return journey.

Artificial Gravitation

Adjacent to the top of the liquid fuel motors are shown four of the tangential tubes. These are necessary in order to provide the crew with artificial gravitation, which is achieved by rotating the ship (approximately 1 revolution in 3½ seconds). The g. value desired is therefore under control of the crew. Not only is this artificial gravitation considered a necessary precaution (the physical affect of long periods of no-gravitation being at present unknown), but in any case haphazard rotation of the vessel would almost certainly take place, making navigational observations impossible. Hence control of rotation is essential. Again, before the moon landing can be attempted it is necessary to stop rotation in order to prevent disaster to the ship when it touches ground.

Fig. 3



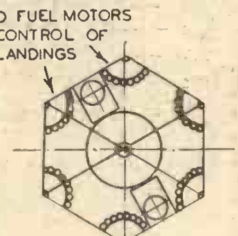


Fig. 5

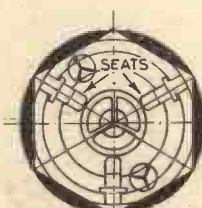


Fig. 6 PLAN OF SEATING

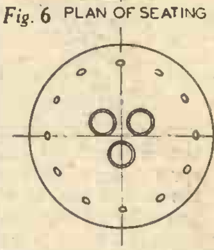


Fig. 7 PLAN OF PORTHOLES

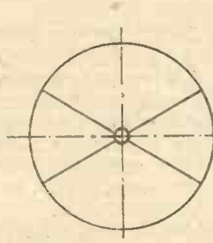


Fig. 8

Figs. 3 and 5 to 8.—A sectional view of the space ship showing the liquid fuel motors, plan of seating, plan of the portholes and the segmented carapace which is discarded after passing out of the earth's atmosphere.

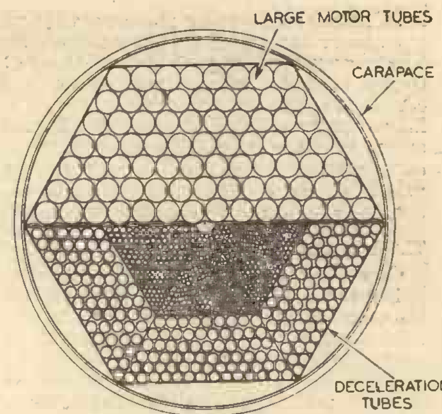


Fig. 2

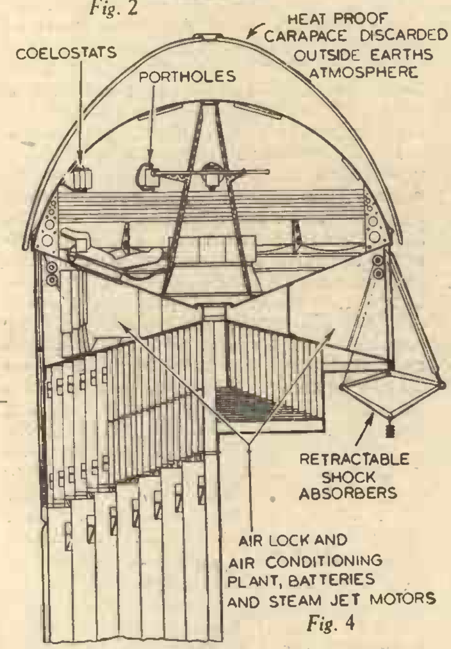


Fig. 4

Figs. 2 and 4.—(Above) Showing the large motor tubes and deceleration tubes. (Below) A sectional view showing the living quarters of the crew, etc.

It is not anticipated that the space-ship can be so accurately manœuvred that its landing will be without shock. Hydraulic shock absorber arms are, therefore, incorporated; one of these being shown attached to the frame on the right-hand side of Fig. 4. These are normally collapsed within the hull, and are extended just prior to landing.

Stability Control

The firing of the motor tubes is carried out by an automatic electrical selector system, but manual control is used for navigational corrections. The ship, being in rotation, is kept thrusting in the correct direction, but this does not prevent "wobble" if firing is not equal on all sides. Manual control of stability is maintained during the first few seconds of ascent, and after that a pendulum contactor automatically controls stability. The main wiring cable to the tubes is led down a central column, provided at each bank level with a plug connection which breaks away when its purpose has been served and is then jettisoned.

The hemispherical front of the life-compartment (Figs. 3 and 4), is of very light nature; this being made possible on account of the protective carapace above. The segmented carapace (Fig. 8) is, of course, discarded after passing out of the earth's atmosphere, and protection of the life-compartment shell is not needed for the ascent from the moon. The return into the earth's atmosphere will be done at low velocities, hence heating of this shell will not be excessive.

The Life Compartment

Owing to the small scale of the diagrams it has not been possible to show many of the fitments and accessories within the life-compartment, but the following can be noted. Fig. 4 shows one of the seats for the crew of three. These can also be seen pointing radially in Fig. 6. The controls for firing are placed on the arms of the chairs, and the chairs themselves move on rails round the life-compartment. The crew recline on these chairs with their heads towards the centre of the ship and a circular catwalk is provided for them round the circumference of the chamber (Figs. 3 and 4).

For observation purposes, ports are provided in the dome of the life-compartment (one shown in Fig. 4 and twelve in Fig. 7). Under the flange of the carapace, in the rim of the floor of the life-compartment are the back-viewing ports; these are covered during thrusting periods. Three forward-viewing ports in the top of the life-compartment shell are also provided (see Figs. 4 and 7). It should be noted that observation of direction cannot be made during the initial thrusting period in ascent from the earth—it being impossible to look backwards through the tail-blast of the ship—the carapace prevents vision in other directions, and in any case the period is too short to allow of stellar observations. Therefore navigation during this period must be done entirely by means of internal instruments, which consist of an altimeter, speedometer and accelerometer.

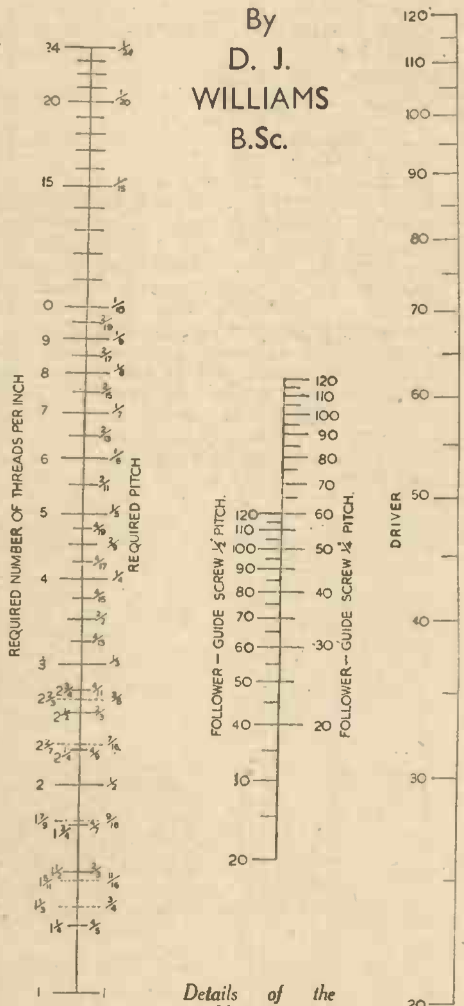
Essential Instruments

Another essential is, of course, a chronometer, and a gyroscope ensures maintenance of direction. A suspended pendulum provides indication of "wobble" and modified sextants and range-finders are used to determine position. These instruments are placed in convenient juxtaposition to the crew. The cylindrical objects shown just above the catwalk, against the ports (Fig. 4) are coelostats. These are synchronised, motor-driven mirror devices something similar to a stroboscope, and it is by means of these that a stationary view of the heavens is provided for navigational observations while the ship is in rotation. The girder structure in the centre of the life-compartment is a support for the light shell and also serves to carry navigation instruments. In Fig. 1 beneath the carapace and in Fig. 6 can be seen the spidered outer and inner doors respectively of the air-locks shown in Fig. 5.

Published by courtesy of the British Interplanetary Society, 88, Grays Inn Rd., W.C.1.

THE USE OF THE NOMOGRAM FOR SCREW CUTTING

By D. J. WILLIAMS B.Sc.



Details of the Nomogram.

THIS Nomogram gives the required combination of change wheels to cut from one to twenty-four threads per inch on lathes having guide screws of ¼-in. or ½-in. pitch. In accordance with the principle of the Nomogram, a straight line drawn across the three scales joins three related points, but, in using this chart, it must be remembered that the portions of the scales lying between the graduations have no meaning. This is because, in the first place, change wheels go up in multiples of five teeth, and in the second place, portions of the "threads per inch" scale, lying between the graduations, represent threads which cannot be cut with a simple train of wheels when the lathe is fitted with a ¼-in. or ½-in. guide screw. The chart is correct, therefore, only when the straight line passes *exactly* through a graduation mark on each of the three scales.

When the thread given by a certain combination is required, a straight edge, or better, a strip of celluloid carrying an inked line, is made to join the appropriate graduations on the "driver" and "follower" scales, when it will cut the third scale at the corresponding graduation which may be read as "threads per inch" or the "pitch."

When it is required to find the combination of wheels which will give a certain pitch, a method of trial and error must be used. The graduation representing the required pitch is joined to that representing a "driver" chosen at random. If the straight edge passes exactly through a graduation representing a "follower," then that combination is the correct one to use. If not a new "driver" should be tried. A little practice makes this process an easy one, especially if it is remembered that, generally speaking, fine threads require small "drivers" and coarse threads big ones.

SCIENCE NOTES

A Clean Sheet

THE cinema screen is, in this country, every week, the cynosure of at least 40,000,000 eyes. That takes into account the usual allowance of two eyes to each patron of the picture theatre. It is, therefore, important that a screen should be used which makes a good impression. The devisor of an improved screen has aimed to produce one which is non-inflammable, non-resonating, and insensitive to moisture. It is suitable for daylight projection or may be tinted to correct the colour impinged on the screen by the illuminant used in projection, and to transform it so as to throw a light similar to that of daylight.

The sheet has, as a base, woven translucent spun glass. Its appearance resembles that of artificial silk. Being composed of spun glass, which does not absorb humidity, the screen can be washed with water, and no further treatment, we are told, is required to keep it at all times in first class condition from the points of view of both light and sound.

Giving Cameras Time

A RECENT development in connection with the camera has for its object the regulation of the rotating disc. I understand that the rotary shutter at present in use gives, in addition to time exposures, only one fixed speed for instantaneous exposures. This, in a poor light, may be inadequate. It is, therefore, desirable to furnish means for increasing the duration of a snapshot exposure. With this end in view, the inventor has devised a camera with a rotary disc shutter having at its edge one or more corrugations. There is also a timing lever to engage the corrugations, so as to reduce the speed of rotation of the disc. And the timing lever is forked to form a jaw, between the teeth of which the disc is loosely held.

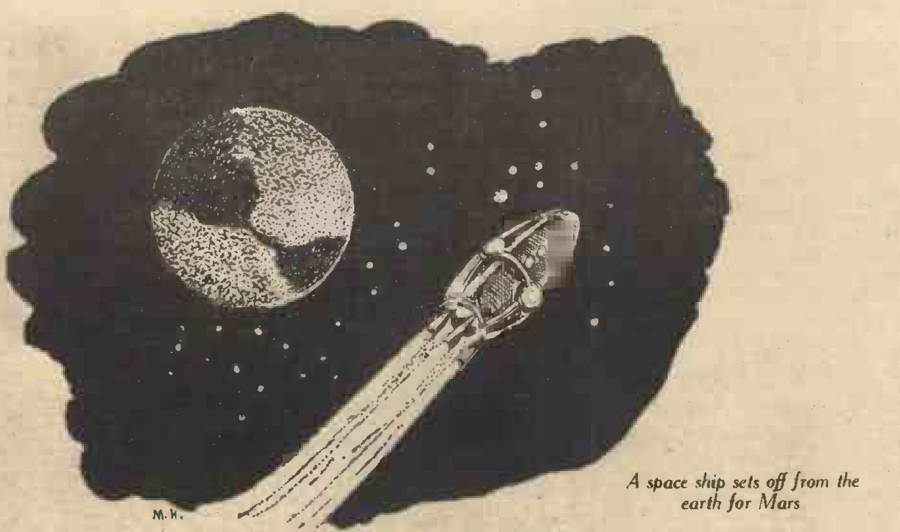
Make-up for Pictures

THE colouring of photographs, prints and lantern slides requires an implement which will not scratch. It also needs one which is particularly adapted to deal with a glossy surface. A new non-abrasive colouring pencil has been patented in the United States, and it is claimed for it that it has the necessary qualifications for picture-tinting. There is a stick of fibrous material capable of absorbing moisture. The stick is impregnated with an aniline dye in absorbed condition and soluble in water. This is capable of penetrating the glossy surface of the object to be coloured. Consequently, the stick may be used after the manner of a brush simply by dipping it in water. By means of this fountain pencil, if I may so term it, pictures can be treated somewhat in the style in which the ladies make up their faces.

DYNAMO.

BEYOND THE GRAVITY FIELD

The Cold Facts about the Prospects of Interplanetary Travel



A space ship sets off from the earth for Mars

ONE curious fact which becomes apparent in reading through the history of human discovery is the extraordinary prevision which enables men to visualise the actual form of an invention long before anyone has come within miles of realising it as an actual possibility.

Readers who have seen the prints of "Henson's Aerial Steam Carriage," which was patented in the 1840's, will have been struck by the way in which the ingenious Henson anticipated in his design the pusher monoplane of seventy years later.

I mention this ability of the inventive mind to foresee the inevitable course of human ingenuity because there are men working to-day on a problem that has long captured the imagination of mankind; the problem of interplanetary flight.

A number of the most important difficulties in the way of rocket-flight (to which the interplanetary pioneers are pinning their faith) have been overcome. In Europe, Willy Ley is the leading "rocketeer," author of a number of works on the subject of interplanetary flight, and the founder of an international space-travel society.

In Soviet Russia, Tsiolkovsky has interested himself with marked success in the same pursuit. The former air-ace, Major-General Udet, has taken keen interest in the question of rocket-flight, and the movement has received considerable support from the German Government.

Now let us see what are the major problems involved in achieving rocket-flight to the extent where interplanetary travel becomes possible.

First, the question of power. This, unless some genius learns to liberate atomic energy in larger quantities than is at present possible, will be supplied by the high explosive force of (in all probability) a mixture of liquid oxygen and liquid hydrogen, kept under extremely high pressure and released into the firing chambers, from which the ignited gases are expelled through the rocket tubes.

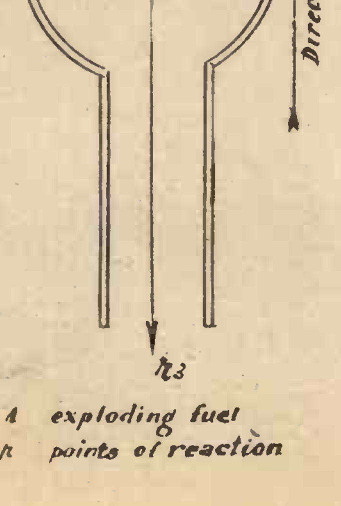
Why rockets stand supreme in the list of all possible motive-agents is because a rocket will travel in a vacuum. A glance at the sketch will show the reason for this. Think of a rocket in flight, with the exploded gases rushing out of the rocket-tube.

When the fuel is ignited it shoots out of the opening at very high velocity. In a flight through air, the resistance of the atmosphere to the escaping gases *pushes* the rocket forward: in the near or total vacuum of space this resistance does not exist, so that as far as the force of the escaping gases is concerned there is a total loss of energy here.

But, examining the sketch, you will see that on being ignited the fuel explodes in four directions of impact: through the opening, against the sides, and against the front wall of the firing-chamber. In free space, as there is no air for the gases to react against, the gases rush out unimpeded.

In the second and third reactions—against the sides of the firing chamber—the reactions neutralise each other. But with the fourth reaction—against the forward wall—the explosive force actually *pushes* the rocket forward. So that even with the loss of energy caused by the absence of an atmosphere the rocket can still travel in a vacuum.

Diagram illustrating the four directions of impact when the rocket-fuel is ignited



It is probable that when interplanetary flight does arrive rocket-ships will use retractable wings in order to take advantage of the earth's atmosphere while they are still within it.

As to the speed that must be attained in order that the ship may be able to overcome gravitational force and leave the earth's gravity-field—well, this is a simple problem in mathematics, giving the "velocity of escape" as 4.90 miles per second. There is also another important point to be remembered. We should naturally, in attempting to leave the earth, take advantage of the eastward equatorial rotation of .28 miles per second so that, in order to leave the earth in an eastward direction above the equator, we should need to attain a velocity of no more than 4.62 miles per second.

Nor is this figure—high as it seems—impossible to achieve even with ordinary molecular energy, and the rocket-flight pioneers are not discouraged by a necessary speed of four and a half miles per second. Indeed, the main difficulty in establishing interplanetary travel on a sound basis will not arise in any problems of engineering, but through the danger of the asteroid belt—countless mineral particles, ranging in size between pebbles and lumps of ore several miles long.

They are all that remains of what was once a planet, exploded in some cosmic catastrophe. They represent a great danger to the space-traveller of the future, and much ingenuity will be needed to overcome this peril.

The dangerous effects of the "cosmic rays" are well known now, but the space-ship will probably be supplied with a double skin containing ozone, a very thin layer of which is all that protects us here on earth from these rays' harmful effects.

These are the main problems. Modern experience has shown that speed in itself is not dangerous to the human system: only acceleration—or sudden acceleration, rather.

CHANGE OF NAME

IN the last three issues of "Practical Mechanics" announcements have appeared on behalf of the Delta (Nottingham) Manufacturing Company of Nottingham.

Owing to an infringement, it has been mutually agreed that this firm's name and the name of its products shall be changed. The firm in future, will be known as the Homray Projector Company, and its products marketed under the name "Homray"; the address remains as before, 46 High Pavement Nottingham, England.

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PRACTICAL MECHANICS

Owing to the paper shortage "The Cyclist" and "Home Movies" are temporarily incorporated

Editor : F. J. CAMM

VOL. IX. APRIL, 1942 No. 103

FAIR COMMENT — BY THE EDITOR

Launching Aircraft by Rocket

OUR cover subject this month does not represent some fantastic and untried idea. Rockets and jet propulsion are practical ideas, and only the stress of war prevents further experiments upon them. We must concentrate upon aircraft and systems which are already in production, but scientists all over the world continue to experiment with jet and rocket propulsion. The great advantage of launching aircraft by what is sometimes erroneously called the reaction principle is that the necessary climbing velocity in order to quickly reach a high altitude can be attained in but a fraction of the time taken in the ordinary way. An aeroplane once the engine is started has to taxi over the ground for some distance before it can lift, and once it is off, it takes some further time for it to obtain its maximum climbing speed. The method of launching aircraft shown on the cover has been successfully demonstrated, and if the war prophets prove unfortunately to be right, and that the war will be a long one, there can be no doubt that before it is over, rocket launching will be rather more than an idea whose practicability has been demonstrated. We are not, of course, able to deal in greater detail with the system, but our cover does give a general idea of the method. When details are released we shall follow our usual practice of giving detailed drawings and a full description.

Making Cosmetics at Home

WE recently published an article on the making of Cosmetics and Toilet preparations at home. We did this to help those who are finding a difficulty in purchasing the usual commercial preparations. Readers will understand, however, that it is illegal to manufacture and offer for sale toilet preparations unless the person concerned has for a considerable time been engaged in so doing. It is a serious offence to manufacture cosmetics unless you comply with the law. Some readers have asked us to give them the formulae for commercial preparations, but this we must decline to do. Nor can we undertake the analysis of samples submitted.

Queries

READERS are continuing to send in queries without the Query Coupon, and sometimes without a stamped and addressed envelope. We cannot deal with them. Every question must be accompanied by the current coupon, three penny stamps, and a stamped and addressed envelope. The query service is intended for those who purchase the paper and by none other. We have not a responsibility to answer questions addressed to us by those who have never purchased the paper, but who turn to us when they are in difficulty. It sometimes happens that a reader wishes to ask two sets of questions in a month. He has sent the coupon with his first batch of queries, and is therefore without a coupon when he sends in the next. In such a case the reader should quote the date of his previous letter. Our Advice Bureau cheerfully and promptly deals with all letters from its readers. Another point. We cannot undertake to answer letters dealing with articles that have appeared in other journals. Such letters must be addressed to the Editors of the journals concerned.

Issues Out of Print

WE are receiving many applications for issues of this journal which are out of print, and which contain articles which continue to be topical. In certain cases we are prepared to re-print the information, and we now invite our readers to address a postcard to us listing those articles which they would like so reprinted. The order of selection will be the order of popularity decided by the cards. One issue which has been in particular demand in recent months is that in which we described how to make a Battery Electric Clock. This article has been reprinted twice. It is pointed out that whilst the blueprint gives sufficient information without further description, to those with technical knowledge, it is insufficient for others. Accordingly, we have prepared a second blueprint showing the construction in perspective and in greater detail. In future, therefore, two sheets of blueprints will be issued in connection with the electric clock, costing 2s. inclusive. Those who already have the first sheet may obtain the second for 1s.

The Engineer's Vest Pocket Book

WE now have supplies of the Engineer's Vest Pocket Book at 7s. 6d. or by post 8s., from The Publisher, George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. It measures 5 in. by 3¼ in. by ¾ in., is neatly bound in dark blue close-grained leatherette with gold lettering, gilt edges, and round corners. It consists of 600 pages of valuable facts, formulae, and memoranda of the greatest use to engineers, draughtsmen, fitters, turners, planning and progress men, etc. There is a great deal of the contents which has never been published before. The book is fully indexed and contains also a Buyer's Guide.

Indexes

The index for Volume 8 is now ready, and can be obtained for 9d. post paid, from the Publisher, address as above. Difficulty may now be experienced in getting the issues bound by those who usually undertook this work. We can still supply the binding cases at 4s., including index and title page, and no doubt local bookbinders will undertake the work. Now that paper is scarce, readers should take care to preserve their copies, for back issues in most cases are not obtainable.

The Electric Bicycle

APROPOS the article on the Electrically propelled Bicycle, which we gave in our issue dated March 1942, readers should note this is a mechanically propelled vehicle and as such is subject to the Road Fund Tax. It must, therefore, carry Number Plates, and on the rear side handlebar a Licence Holder with the current licence. Applications should be made for the necessary forms to the County Council of the District in which the reader resides.

B.B.C. Records

THE B.B.C. normally uses three methods of recording—the M.S.S.-Watts Disc System (for Studio and Mobile Car Recording); this employs metal-based blanks with a coating of nitro-cellulose (referred to as cellulose acetate) which after cutting can be played back immediately up to about 25 times without marked loss of quality. This is in contrast to the wax master method used in ordinary gramophone recording, which requires electrolytic processing and pressings made for reproduction purposes. Re-recorded copies and solid stock pressings can be made from the M.S.S.-Watts Disc.

Another system used by the B.B.C. is the Marconi-Stille magnetised steel tape method which is a development of the original Blattnerphone invented by Ludwig Blattner. This system is almost confined to recording rehearsals and programmes shortly after their event, but which are not of permanent interest. The novel feature of this method is that the recording can be washed out or obliterated from the tape which can thus be used over and over again.

The third system is the Phillips-Miller in which the recording medium is an opaque coating on a film strip or tape. This is cut by a sapphire stylus so that a transparent track of variable area is produced. This is reproduced photo-electrically. The record is compact and permanent with a normal playing time of about 15 mins. per spool, and this system is used for high quality recording. No doubt sooner or later this latter system will be used to replace the present gramophone discs.

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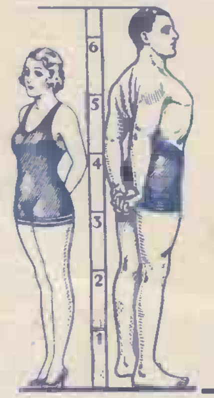

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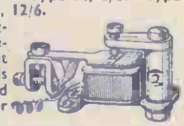

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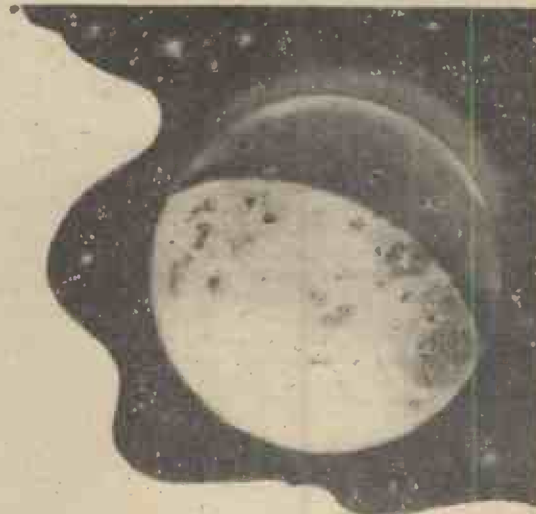
If We Visited the Moon



This article is not so fantastic as it sounds. In all probability it will not be many centuries now—wars and "crises" permitting—before the first rocket leaves for the moon. Soon afterwards, no doubt, the pioneer newsreel cameraman will follow to take the most sensational photographs ever known. Here Professor A. M. Low describes the conditions likely to be encountered by the explorers. Professor Low, among other things, is President of the Interplanetary Society, President of the Institute of Patentees and inventor of the first radio-controlled aeroplane.

ONCE upon a time, as the fairy tales say, it was considered very wrong for any scientist to hint that the future could be predicted. Not predicted in the fashionable manner of those who connect one's existence with a tall man and a dark moustache—rather in the sense that scientific efforts can be foreseen, and are very definitely useful as part of ordinary research.

Electrical engineers forecast the probable demands upon their station's current output by the simple process of plotting curves, by visualising the rate at which supplies have been increased, and by noting points on this curve of progress. They say, "if for 20 years, each month has shown a 1 per cent. increase in output, it is reasonable to suppose that, other things being equal, another 1 per cent. increase will occur in the next month." Even stockbrokers adopt this method. Technicians knew the exact pressure at which hydrogen could be liquefied long before the apparatus was available to secure such a result in practice. The automobile engineer knew the temperature in the cylinder of an engine, by plotting curves between the rate of temperature rises in conjunction with positive movement, years before these flaming gases were introduced to a thermometer.

Our artist's impression of a rocket-ship travelling through space towards the moon.

Prejudice

Now all this had a very great bearing upon the, at present fantastic, idea that films of a Martian world will one day, in the far dim future, be made possible. Always assuming that we can rid our minds of that horrid thing called prejudice, and remember that we are still very little better than savages—wild men, with hair on our bodies, throats which closely resemble those of our ancestor the fish, nails and claws like any other inhabitant of this earth. There are many classic examples of prejudice. Only 60 years ago in some countries poor old women were accused by children of witchcraft or of turning themselves into rabbits, and other strange practices. On this evidence they were wrapped in sheets and dragged through horse ponds, suffering death at the stake if they chanced not to sink. Eighty years ago doctors said that a speed of 60 m.p.h. would be fatal to the human heart, the Admiralty agreed that steam would be fatal to the British Navy, and, almost latterly, a great wireless expert opined that radio would never have any commercial value!

It seems strange that with such glaring cases of stupidity a love of the antique should have so retarded civilisation when 60 years ago the craftsmen existed who could have easily made a radio set, and only lack of imagination prevented this invention. I have been reminding myself that Antony might easily have met Cleopatra as she stepped from a Handley Page bomber, while only the accident of time has prevented us from possessing a gramophone record of his funeral oration for Caesar.

Life on Mars!

Those people who say pyramids are wonderful cannot realise that they could be built to-morrow if it were worth while, and if we did not mind bricking up a few odd slaves during construction. It is a valuable lesson to look at an illustrated paper of 20 years ago and to note that change is the only factor in life which we can appreciate. So let us consider our films on Mars and our trips to the moon. Remember that it is vanity which makes us believe that the only life must exist on earth. Human life is not necessarily important, and I believe that if we had never seen a fish we might say they were impossible creatures, and how could life exist without air to breathe?

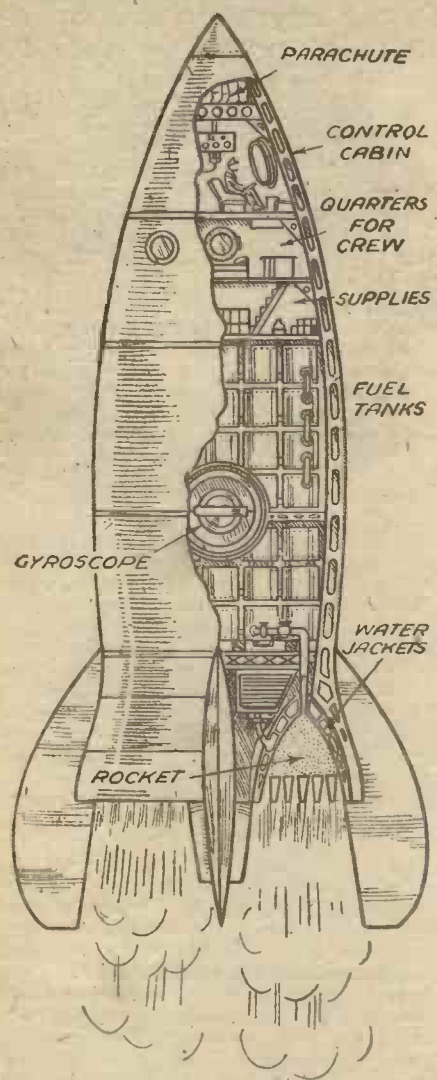
In Mars there is water, oxygen, and warmth. Why should there not be life? Perhaps on that older planet there is better life than our own. Just as Africa has produced people of a different colour, so it may chance that as life developed from the sea to produce animals and ourselves as branches of the same tree, totally different forms of sentient being may live, and fight, and love. In Mars the conditions may have developed creatures who see by heat, whose touch may be more delicate than that of the worm, whose hearing may be by some vibrational movement as infinitely different from our own as that of a bird when compared to our own relative deafness.

Conditions on the Moon

On the moon there is very little oxygen, and I think that it is in lunar regions that "interplanetary" films will be first obtained in some dim distant age. But we can see very easily what conditions will be met for we know that, to take one example, gravity is less than upon the earth. The cameraman would find it easier to run than to walk. Each little step might carry him far into the air. His body will be so relatively light that the hardest rock would feel more comfortable than a feather bed, and he would live in a perpetual mask fed by oxygen as though he were passing through some gigantic A.R.P. test of the most atrocious kind. Even now, there is an Interplanetary Society with branches all over the world, realising that if such research is foolish it would be infinitely more stupid not to undertake it while there is still time.

Rocket-like Space Ship

Even the journey will be an adventure far greater than anything yet conceived by the mind of man. The cameraman will travel in a rocket-like vessel, propelled like a rocket and carrying no wings. A system, incidentally, which has appealed to such experts as Lindbergh and Roe for ordinary aeroplanes, a system already operated on many successful terrestrial flight experiments. This space



Section of a rocket flying-ship, which was successfully demonstrated on the Continent a few years ago.

ship will start from the earth, not like the bullet from a gun in which the occupants would inevitably be crushed, but by increasing velocity as the solid propulsive fuel is gradually ignited by electrical means. Steering will be through side jets or through rockets, and the cost has been estimated for the return journey at approximately £250,000. Not much more than that for a small ship which sails for New York and at a cost not much greater than a trip by rocket to New York, itself an almost more difficult problem.

In such a space machine there will be a period when no normal gravity applies. Unless the ship were given a twisting motion the occupants might float about inside for several days, and although the total time occupied in the journey would be rather less than a week, a speed of nearly 33,000 m.p.h. would have to be given to the shell for the first four minutes, in order that the load of fuel carried would not be excessive. From this point onwards the velocity would be sufficient (I am quoting entirely from the records of the Interplanetary Society's Research Director) to carry the machine into an orbit where the gravity of the moon would draw them towards its surface. It is a fearsome thing to realise that without gravity it might be difficult to swallow or to eat halfway across the void, and to realise that until oxygenated foods had been invented, the film unit would have to live entirely on its own imported oxygen. Wonderful perhaps, but not more wonderful than what we see all around us already accomplished by Nature, and by man.

Camera Requirements

Some of the conditions to be met by the cameraman of the future are certainly somewhat queer. His instruments will be carried in carefully padded boxes, and en route he will be insulated from heat and cold as though he were in some form of vacuum flask. On the sunlit side of the moon he would be reasonably comfortable, but in the shadows he would suffer very much from cold in spaces where there was no air to distribute the heat. I think he would find it very difficult to fall down and hurt himself, and I am sure that if he dropped his camera, it would fall as softly as a bit of down. Mountain climbing would be most attractive for he could leap 20 or 30 ft. at a time in comfort. I am told that in his trip he will be as safe from meteors in the vastness of space as one is in a London street from the chance fall of an aeroplane in the sky.

Every detail has been calculated by the Interplanetary technical committee men, who have prepared for this trip for many years. They say there is not the slightest doubt of success, if only money was available to an extent which is often used to finance two or three famous films. Even the amount of fuel required has been calculated. It is in the region of 900 tons of which 50 are used to overcome air resistance on leaving the earth during the first 20 miles. One hundred tons would be sufficient to lift the load for 300 miles, while the remainder is used to overcome the earth's gravitation and to build up the velocity of the rocket ship.

Fantastic Conditions

It could indeed be a strange land for our film. Far stranger than any country on earth—a world with no atmosphere, no seas and no soil—a country in which we would have to employ our whole energy in producing the very things that Nature gives so freely upon this earth. But physical work would be easy in a plane where gravity is relatively unknown. Oxygen to breathe, water to drink; carbon dioxide and hydrogen to feed plants would have to be made with difficulty from rock, so that these commodities, free to us, would be as valuable as gold on the surface of the moon.

Conditions would be fantastically different from those we know. At low air pressures tea could only be made in an autoclave and drunk almost at once before it could cool. Trains would all be driven by electricity, while roller skates or even pogo sticks would be a safe means of travel. An occasional night's sleep, perhaps, is stated by authorities to be all that is necessary about once a month, to satisfy our habit. It is said that weather will be non-existent, with winter sports every morning and cooling drinks in the afternoon.

Million Horse-power Jets

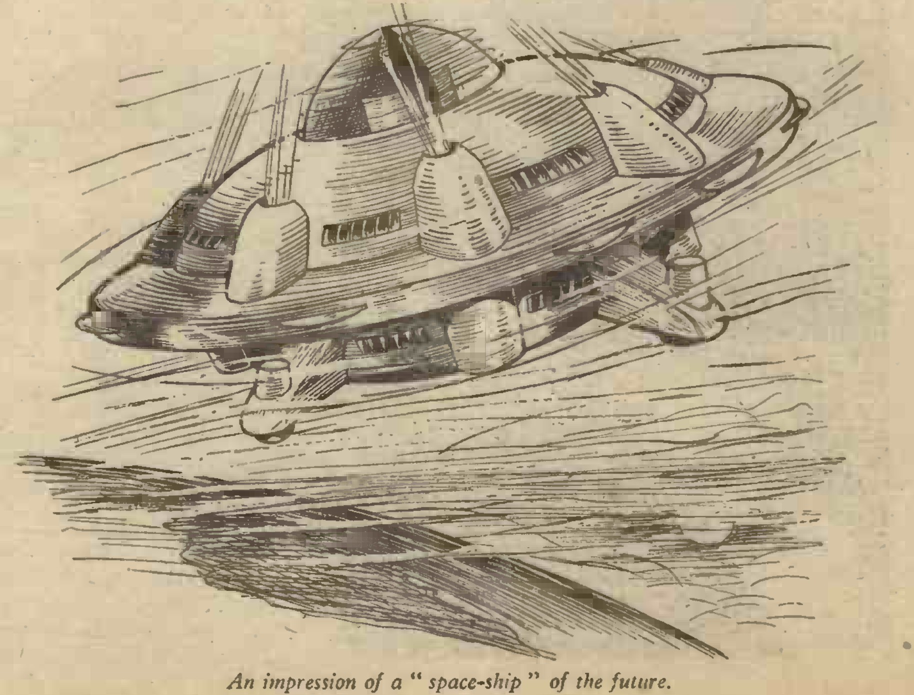
One must not be too confident, but I believe that when the space men first step from the hemispherical room in the nose of the vessel from which most of the million horse-power gas jets had been jettisoned on the way, they would find a mass of shimmering sunlit rocks beside which the richest flower gardens of the earth would be dowdy waste land. Above this brilliantly lit landscape will be a jet black sky, spangled with an incredible number of vividly coloured untwinkling stars. The night would be a blaze of glory by earth light sixty times as bright as full moonlight, radiating from an apparently gleaming earth—solid looking, blue-white, misted and ringed with red.

Tennis would be a game so fast only a few would dare attempt it. Ice hockey must be reduced to a crawl and football so slow as to seem ridiculous. Golf might be possible with a smoke bomb for a ball after a moderate drive of three miles, while bare-fisted boxing might be a gentle pastime if the ring was covered with a net to prevent the recipient of an upper-cut sailing over the audience.

Air and Water

Fountain pens might be cheaper than pencils, and sheets of aluminium might take the place of paper. Champagne would be no dearer than tea, but tobacco might be entirely prohibited, owing to the high cost of replacing the polluted air. As far as can be seen, air and water would be part of a social service supply, and income tax must undoubtedly exceed 18s. in the £.

On second thoughts I have decided to take these figures from my friends of the Interplanetary Society for granted, for although I shall certainly attend the first lunar news film, I am determined to encourage a number of people (whose names I will gladly provide in confidence) to make this trip.

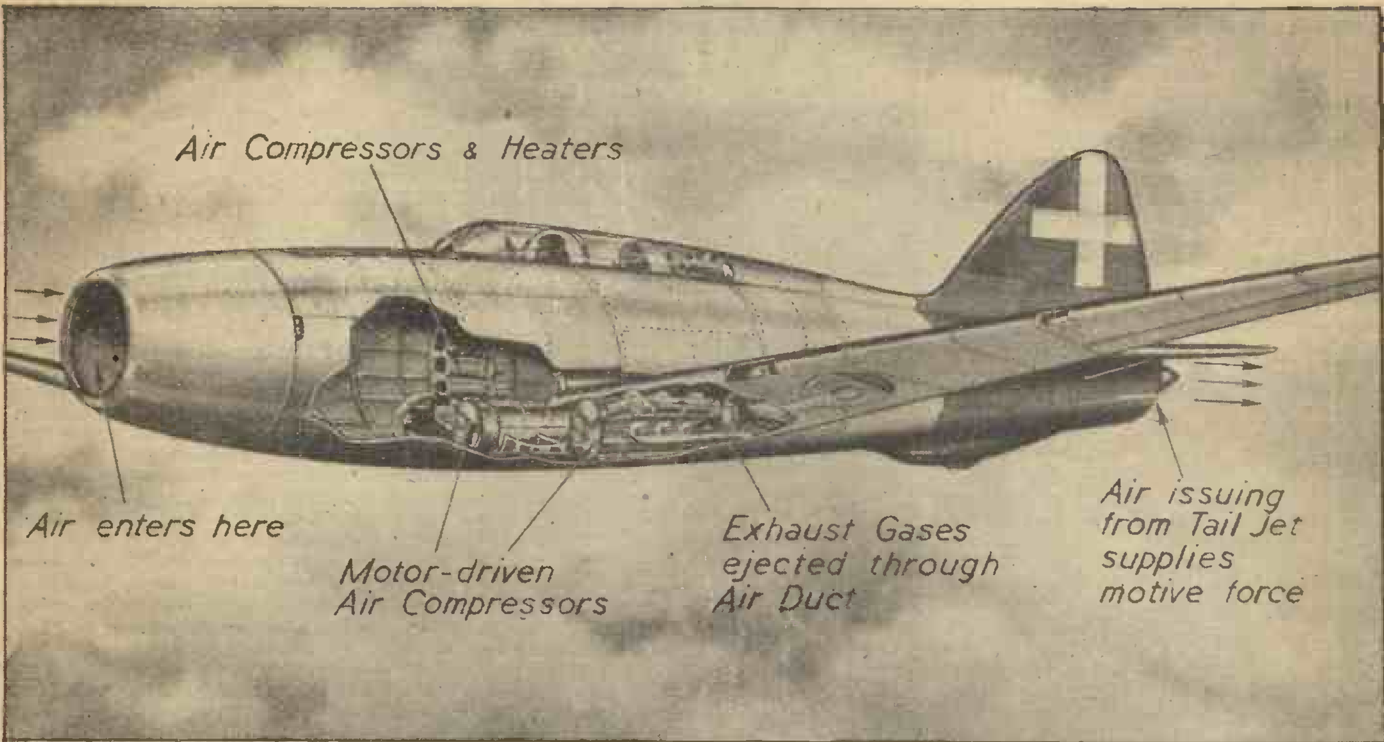


An impression of a "space-ship" of the future.

The Reaction Motor

Notes on the Possibilities of This Form of Propulsion for Aircraft of the Future

By K. W. GATLAND



The Italians in August, 1940, at the Taliedo Aerodrome, flew the Caproni-Campini C.C.1 jet-propelled aeroplane, and it was flown by Colonel Mario de Bernardi. Experiments have continued since that time, and in 1941 Signor Secondo Campini designed and constructed a jet-propelled aircraft on somewhat larger lines. The new machine is known as C.C.2, an illustration of which is given above. It is a two-seater aircraft with pilot and observer seated in tandem, and it is of low wing design with outward retracting undercarriage, and enclosed cockpit, and single fin and rudder. It has no airscrew, and weighs about 11,000lb.

FREIGHT transport in the post-war world will undoubtedly have vigorous competition between sea and air-borne methods. Although it is true that under present-day conditions a small fleet of aircraft would be required to transport a cargo equivalent to the amount taken by a single merchant vessel, speed of transit is a factor high in consideration. Upon the cessation of hostilities it must be to a great measure the air freighter (which at first would probably be suitable converted heavy bombers and troop transports) that will bring relief to the subjected peoples of Europe and Asia. The advantages of air transport over the merchant vessel are truly considerable. High speed, coupled with the ability to bring supplies far inland without the trouble and time taken in unloading, reloading and conventional slow transport methods, are factors of great importance. For the aircraft to adequately serve humanity as the tool of progress, however, much further technical development is required to enable such machines to carry the heavier loads required for really practical freight transport operation, without sacrificing speed. Aircraft efficiencies much in excess of those realised to-day by the best machines in the class cannot be appreciably increased, due to the serious limitations of the engine-propeller combination. Various devices, such as the multi-blade and contra-rotating propeller and the supercharger, bring certain, but limited, gains in efficiency, mainly by enabling the aeroplane to operate at altitudes where the rarefied nature of the atmosphere presents less resistance to its passage.

Thermal-jet Propulsion

This deficiency in the orthodox power plant has brought an increasing amount of interest recently to the subject of thermal-jet propulsion. Already the principle has realised practical application as the motive drive for the Italian-built "Caproni Campini" monoplane which flew successfully, after initial tests at the Forlanini Airport, from Milan to Rome, a distance of 168 miles, in November, 1941. With the advent of the jet-propelled machine, communication is likely to be made more rapid, the aircraft gaining, with development, more and more advantage from high altitude operation in those regions of the stratosphere, economy in fuel expenditure, where air supplied to the jet unit under compression is still of sufficient density to support combustion, and where air resistance is so greatly diminished. The jet machine will, in all probability, initially evolve as the somewhat conventional type of aircraft—with wing installed motors. The layout of the jet plant lends admirably to snug installation, the compressors and operating motors (which may be exhaust driven turbines) being sunk deep within the wings, with the addition of an air scoop, possibly arranged in elliptical form, for a short length along the leading edge. The illustration on the front cover gives a conception of the possible form such transport aircraft will take —being not altogether dissimilar to the present-day machine, although streamlining is likely to be taken much farther on the considerably larger aircraft which can be confidently expected with the development of the more efficient jet motor.

While the thermal motor is confidently expected to produce greater efficiencies than the conventional internal-combustion engine, the limitations with regard to altitude are more or less parallel, due to the need for inducting sufficient air to support combustion. Consequently, the development of the thermal jet propulsion is not likely to produce great speed increases due to operation within relatively dense atmosphere, which is the main barrier to further progress. Speeds in the region of 750 m.p.h. appear to be the limit for atmosphere flight expectations, for it is at and around this velocity that "shock waves" (compressed air particles) are built up which set up prohibitive structural stresses, possibly even resulting in the complete fracture of the more vulnerable surfaces—tail plane, etc.

Jet-rocket Reaction Unit

A recent preliminary investigation into the problems of high altitude flight by the Astronautical Development Society, has ultimately produced a basic specification for a power unit, intended not merely for operation within the atmospheric region, but also capable of functioning at high efficiency in vacuum. This is proposed by means of an inter-combined thermal jet-rocket reaction unit—the thermal section operating to an altitude of approximately 45,000ft., at which height the rocket component commences to function to propel the craft still higher. The advantages of such a combination are considerable. High efficiency, with relatively low fuel expenditure, are formidable prophetic features of the design. By employing thermal-jet reaction within the bounds of the more dense regions, and true rocket propulsion above the thermal restricted regions, a high efficiency-economic ratio is maintained under all conditions of flight. The fuel for thermal power units need not be petrol, or in fact any of the highly refined spirits, for paraffin, tar oils and any similar product of the hydrocarbon range would probably do equally as well. Even solid fuels, such as coal dust, cannot be ruled out as impossible alternative fuel forms. Rocket plant fuels can be either of the "liquid" or "solid" category—petrol, or similar fuel, being combusted with oxygen, stored in highly concentrated liquid form in the case of the former, and in the case of the latter, a combustible mixture (either powder, plastic or paste) with oxygen-bearing content. Due to the relatively high cost and the difficulties of storing oxygen in liquid form, greater attention has been paid in recent years to the development of the plastic "cartridge." These fuel cartridges can be injected into the reaction chamber by means of a specially designed feed. Groups of injector feeds working with alternate pulsating action would be able to maintain a constant propelling thrust. Thus by the further development of reaction power plants, the era of really cheap world-wide travel may soon be realised.

Rocket Bombs and Shells

Amongst other things, the rocket, useful in times of peace (as indeed in war) as the seaman's life-line has, for instance, been used extensively against aerial attack to enable high-explosive shells to be "shot" to ever increasing heights. This is an important factor when the increasingly higher operational altitudes of both fighter and bomber aircraft are considered. It is not altogether impossible, moreover, that the German 88-millimetre gun, used extensively in the early Middle East campaigns, was in reality a "projector" firing rocket shells. These guns were reported to be widely responsible for the destruction of many of the heavily armoured Allied tanks by the high penetrating force of the shells.

Rocket bombs also have been employed by both the Russians and Germans. The rocket principle applied to aerial bombs enables the missiles to strike hard on the target, gaining greater penetration and destructive power than the conventional type of similar weight. Another advantage of the rocket bomb is its ability to travel on a level parallel with the ground. It is possible, for instance, to pitch it ahead from an attacking aircraft without the need for getting within range of the anti-aircraft defences ringing the target.

Assisted Aircraft Take-off

The rocket principle, again, has been applied to the aeroplane for assisted and catapult take-off purposes, which enables defence machines to take off, and climb to the altitude of interception, within a much shorter space of time. Here again high-altitude bombing has to some great measure been made less effective.

Rocket Mails

Rocket mails, a practical solution to speedy delivery over difficult country, are yet another example of the versatility of the reaction principle. Although rocket mail services have not been used extensively in the past, it is no mere conjecture that with the further development of the reaction motor services will be established to enable mails to be projected with accuracy from country to country, the projectile and containers being landed gently by parachute when the "target" is reached. Perhaps the most successful example to date was the mail service instituted over mountainous country between the towns of Berne and Basle, Switzerland, which was in regular operation before the war. Hitherto rocket mail attempts have been made with relatively small projectiles, guided by fins, but experiments have shown that if the rocket is rotated about its axis, by either offsetting the exhaust tubes or by the addition of exhaust deflector vanes, a gyroscopic stabilisation force is set up, which enables the rocket to maintain its predetermined course, and is far less affected by atmospheric variation.

The Lunar Space-vessel

The moon rocket has been the subject of much fantastic speculation during the past decade or so, perhaps the most notable examples being given in novels by Jules Verne and H. G. Wells. Although such works make exceedingly interesting and exciting reading, however, for the most part the conceptions of such authors are completely devoid of technical reasoning, and consequently a completely false interpretation of the possibilities of inter-planetary communication has been built up which has resulted in the subject being regarded with ridicule by the general public. By the publication of the "Preliminary Investigation into the Problems of Space Flight," by the British Interplanetary Society, the subject has been considerably lifted out of the realm of the "fantastic."

The layout of the space vessel, which is the main feature of the investigation, gives a really convincing engineering conception of the project, which has been the subject of serious planning over a period of several years. Cellular construction is the chief feature of the design, which is in reality a series of closely packed tubes (honeycomb fashion) filled with plastic fuel compound. These tubes are fired in clusters, at the control of the operator in the pressure cabin at the nose of the "ship," and are automatically jettisoned with the completion of each firing phase. It can be readily appreciated that as the vessel continues out into space against the earth's diminishing gravitation, by the jettisoning of irrelevant material the "ship" is made constantly lighter and substantial economy in fuel expenditure is effected. The complete "ship" is designed to rotate about its axis, which, as well as providing stability, establishes an artificial gravitation within the vessel to enable the crew to function in a relatively normal manner under constantly changing natural gravitational conditions during the flight.

Landing

Landing is effected by a complete reversal of the vessel—end on to the lunar surface, which is commenced some way off from the satellite for the jets to sufficiently retard the "ship" against the not inconsiderable velocity which has been built up during the journey out. When the vessel is sufficiently close to the surface it descends, the lunar gravitational attraction and jet reaction striking a balance some few feet from the surface, whereupon retractable hydraulic shock absorbers come into play and the vessel is brought to rest.

After exploration, with the aid of special heated pressure suits, the crew are able to jack the machine into position for re-firing. The vessel is able to leave with far greater ease than from earth, due to the lower gravitational attraction.

Upon approaching the earth's atmosphere the "ship," having only the weight of the pressure cabin, auxiliary equipment, crew and the remaining rocket tubes, is once more reversed, the speed being retarded until contact with atmosphere is made, when the supporting parachute is released and the control cabin and crew float gently to earth.

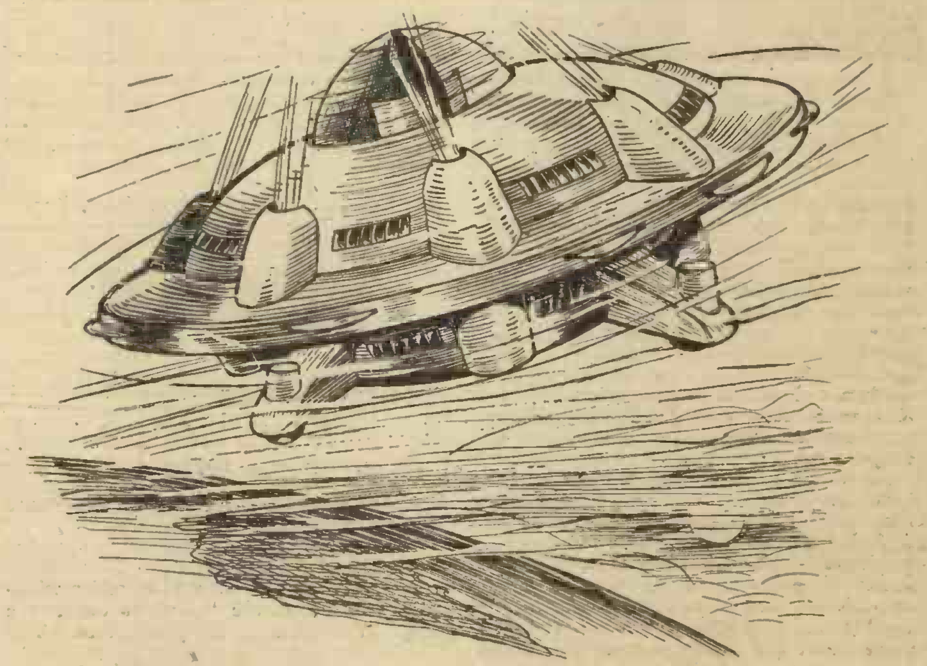
During the initial "climb" through atmosphere, at the commencement of the flight, a heat-resisting carapace is attached, moulded to the contour of the nose, to prevent excessive heat generation, due to friction.

Rotational braking when landing, manœuvring and course alignment can be effected by means of special steam reaction and rocket reaction units. Visual observation during the rotational condition can be made by means of the special "Coelostat" viewing apparatus, also designed by the B.I.S. This system, which is an adaptation of the stroboscope, has been demonstrated satisfactorily at South Kensington Museum.

Although the above brief summary of the project and the conception of operation leaves much to the imagination, it is apparent that the B.I.S. conception of an inter-planetary space vessel is based on a sober understanding of the subject.

Further research during post-war years by the combined efforts of the British Interplanetary Society, the Astronautical Development Society and the Manchester Astronautical Association should do much towards the realisation of interplanetary communication. A rocket test site is proposed for joint post-war research, where the new plastic fuels and reaction units can be proved.

When the day of the space-vessel finally arrives, the world will reap great benefit from the knowledge the reaction machine will unfold.



Our artist's impression of a "space-ship" of the future.

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PRACTICAL MECHANICS

Owing to the paper shortage "The Cyclist," "Practical Motorist," and "Home Movies" are temporarily incorporated.

Editor: F. J. CAMM

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FAIR COMMENT — BY THE EDITOR

Jet Propulsion

WE are glad that this country has at long last announced to the world the result of our experiments in reaction propulsion, or to give it its popular name "jet propulsion." Too often do we allow other countries to steal our thunder, but in this particular case we got in first. We have, of course, known for many years of the experiments, but we have not been permitted to publish them, although we have dealt with the subject in a general way for the past five years. In fact, we have published more about it than any other periodical. We have always believed that a more direct method of using the calorific power in fuel which is released by combustion could be used in a more effective and a less wasteful way, as well as in a more direct way than through the complicated and loss-producing petrol engine where pistons, cranks, valve gear, pumps, airscrews, superchargers, and oil coolers are necessary, and each of which absorbs power. The efficiency of the average heat engine is probably not much more than 20 per cent. Now the principle of using reaction for propulsion is by no means new.

Hero's Steam Turbine

HERO, of Alexandria, produced his famous reaction steam turbine 50 years or so before the birth of Christ. An illustration of the cylindrical boiler, with four spouts from which the steam escapes, appears in most textbooks on physics. However, the principle has not been used much, except by model makers, and it was not until the German, Fritz Von Opel, experimented with rocket cars in Germany (experiments which ultimately caused his death), that interest in the subject was renewed. From that point hundreds of patents have been taken out, but most of these were in connection with machines intended for astronautical travel.

A few years before the war Caproni, in Italy, produced the Caproni-Campini Monoplane which flew successfully after initial tests at the Forlanini Airport from Milan to Rome, a distance of 168 miles, in November 1941.

With the advent of the jet-propelled machine, communication is likely to be made more rapid, the aircraft gaining with development more and more advantage from high altitude operation, in the stratosphere and troposphere, in economy, and fuel expenditure where air supplied to the jet unit under compression is still of sufficient density to support combustion, and where air resistance is so greatly diminished. The layout of the jet plant leads to snug installation, the compressors and operating motors (which may be exhaust-driven turbines) being sunk deep within the wings, with the addition of an airscrew.

There are certain illusions in connection with jet propulsion which have to be dispelled. The first is the very prevalent one that this form of aircraft obtains its power by virtue of the jet pushing on the air. It does not any more than does a rocket. It is well known that a rocket operates more efficiently in a vacuum than in the air.

We were astonished to hear a speaker in a recent broadcast repeat the fallacy. The blind leading the blind!

Rocket Principle

JET propulsion is the expression used to denote all the various applications of the rocket principle which have been devised up to the present day, since they all depend upon the operation of one and the same national physical law, namely, that of the conservation of momentum. Momentum denotes the amount or quantity of motion in a body, and it is measured by multiplying together the mass of the moving body and its velocity. Everyone knows the well-known formula that $M = mv$. Thus we may imagine two bodies in motion together at different speeds. One is a light body moving at a higher speed, and the second a heavier body moving at a lower speed, yet it would be possible for each to possess the same momentum.

Consider, now, what happens when a cannon is discharged. Before discharge, gun and shell are at rest. After firing, the shell is given a high velocity in a forwards direction and thus it acquires momentum. The cannon, also, acquires exactly the same amount of momentum, but in the opposite direction. Since, however, the mass (or weight) of the cannon is very many times that of the shell, it follows that the actual backwards motion of the former is very small, and is readily absorbable by means of the recoil mechanism with which it is equipped.

Imagine, again, that you are standing on ice with glass-bottomed shoes on your feet, and that you are firing bullets from a particularly heavy rifle, the firing always being in the same direction. Provided, in this instance, that you kept your balance, you would find that gradually you were moving backwards on the ice surface in a more or less perfectly straight line.

Fundamental Law

IN every case the fundamental law is the same, e.g., that when any fluid or body escapes from a vessel the vessel acquires a momentum equal to that of the escaping fluid or body, but in the opposite direction. Hence, the vessel tends to move in a direction opposite to that of the escaping gases or fluid. The idea of propelling sailing vessels by means of backwards projected jets of water can be traced back as far as the year 1729. In 1866 the Admiralty made comparative trials of two vessels. The first, the *Viper*, of 1,180 tons of displacement, was fitted with the screw propeller system. The second, the *Waterwitch*, of 1,161 tons displacement, had a system of jet propulsion on the lines described above. It was found that the propulsive efficiency of the propeller system was far superior to that of the jet system, and in another series of trials, conducted with small boats, which was made nearly 20 years later by Thornycroft, the marine engineer, the same conclusions were reached.

One of the great advantages of jet propulsion for ships and aircraft is that it gives an almost vibrationless means of travel. It is also less noisy, although in the case of aircraft there is an unpleasant whistle similar to that of a boiling kettle. On account of the lack of vibration, it was proposed towards the end of the last war to employ this system of ship propulsion in submarine detecting vessels whose motion through the water would thus be rendered practically noiseless.

Prospects

THIS briefly is a description of experiences to date and an explanation of principle. As details are revealed so shall we publish them. In the meantime the announcement that we are successfully flying for training purposes aircraft of this type is an encouraging sign that England can produce secret weapons, too. Unlike the Germans, we announce it when it is a *fait accompli*. It is not part of our war of nerves to make wild statements about secret weapons which do not eventuate. Here are further opportunities for young men interested in aeronautics to get in at the start of a new science and a new industry, and in a period which has seen so many startling developments—the telephone, the gramophone, aeroplane, wireless, television, the photo-electric cell, the motor-car, and the turbine.

We have set these facts down to give our readers a true impression of jet propulsion, and to correct the erroneous statements which have appeared in the newspapers and been given in broadcast speeches by those who obviously do not understand the subject.

42 Belfast Rd

HISTORY OF ROCKET PROPULSION

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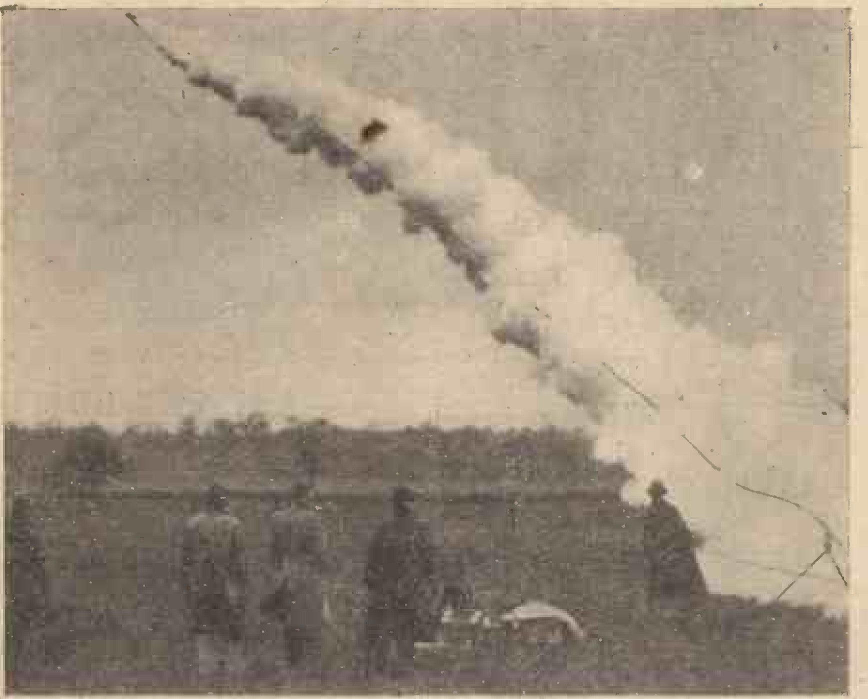
JULY 1944

Rocket Propulsion

Its History and Development

By K. W. GATLAND



Schermuly multiple rocket electrically fired. Range 350yds. with 1in. circ. line.

Introduction

BEFORE commencing upon the survey of rocket development, it is desirable, on the outset, to define the two *reaction* systems — "*true-rocket*" and "*thermal-jet*." The former, "true-rocket," is the simplest type of thermodynamic engine comprising a pressure-tight chamber, with an escape orifice, containing, or fed with a fuel with oxygen bearing content either as an integral part or as a separate component. There are two distinctive types of rocket motor. The earliest and most familiar is the powder fuel rocket, where the combustion chamber serves also as the fuel store. Examples of this type are the display ("firework") rocket; the rocket life-line, and the A.A. Battery rocket projectile. There are, however, obvious limitations governing the use of this rocket system—namely, the constantly changing chamber volume, and the limited period of reactive effort. The other rocket motor embodies a combustion chamber distinctly remote from the fuel, this being contained separately and supplied at a controllable rate, thus ensuring *constant* chamber volume, and a period of firing far exceeding that of the former. This motor form generally employs a liquid fuel, with oxygen (liquid) as the "supporting" element for combustion, but the "cartridge" fuel injector and certain variants of this system employing solid or paste fuel components come under the same category. In the other reaction system, the thermodynamic engine employs a solid or liquid fuel, burnt in a medium of highly compressed air *inducted from the atmosphere.* This is the "thermal-jet" reaction means, with which we are not concerned in this history.

The principle of *reaction* is common to both "true-rocket," and "thermal-jet" systems, tractive motion being effected by virtue of the reaction of the exhaust efflux on the producing plant, in accordance with Newton's Third Law of Motion.

It is obvious from the foregoing that, whereas the "thermal-jet" propulsion plant is limited for operation to the bounds of atmosphere (due to the need for inducting air to support combustion), the "true-rocket" motor is capable of penetrating the atmosphere, to operate in space itself. Indeed, once free of atmosphere, the rocket would operate at highest efficiency since the atmosphere has a "damping" effect acting to reduce the velocity of the exhaust gases. It is the mass velocity of the exhaust efflux that determines the reactive effort.

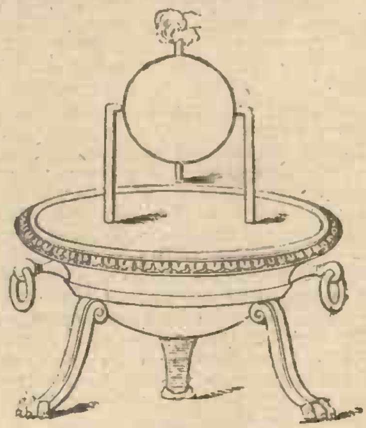


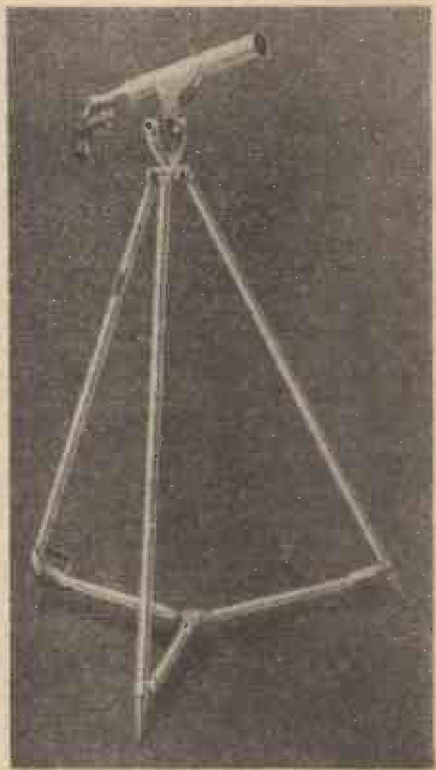
Fig. 1.—Hero's "æolipile."

It is of interest to note that the reaction principle was actually first demonstrated at the beginning of the Christian era by the Alexandrian philosopher, Hero. The apparatus employed, known as the *æolipile* (Fig. 1) consisted of a hollow sphere, into which were fitted two right-angle tubes on opposite sides. This was centrally mounted and free to revolve on two supports, one of which was hollow, to permit steam, generated in a "boiler" positioned below and supported over a fire, to flow into the sphere and out at high pressure through the escape tubes, thereby setting up a reactive force to rotate the vessel.

Finally, as a caution, it is desirable to point out that rocket experiments in time of war are an offence against the Defence Regulations. Formula relating to fuel compositions contained in this article series are included solely to illustrate the trend of development.

The Beginning

It is known that the origin of pyrotechnic compounds dates back to well before the B.C. era. A feasible theory of the evolution of combustible mixtures is held to be in the use of saltpetre (found in abundant natural supply in China and India), for which certain primitive Eastern tribes probably first found a use in the curing of meat. It is likely that the first discovery of the substance as a combustible was during the process of cooking, a small amount perhaps being accidentally dropped on the fire and, as the result, a sudden observed conflagration. The next step would appear obvious in the adoption of the newly found substance for fire-making, and wood being the first known combustible, the natural inclination would therefore be to combine the two. However, man at that period possessed no means whereby wood could be reduced to a workable medium, at least in any quantity, to obtain a comparatively uniform mixture, but



The Schermuly pistol rocket apparatus.

Fig. 2.—Chinese "rocket" arrow (A.D. 1220).

some further consideration, no doubt, would suggest the utility of partially burnt wood, and ultimately, in later development, charcoal.

Whether or not sulphur, or brimstone, was later incorporated in the mixture is uncertain, but it is established that a composition known as "Chinese Fire" (which contained the two base substances previously mentioned) was employed in the East long before the Christian era. An allied compound developed in Greece at about the same time was "naphtha," probably a composition of brimstone, pitch, resins, fats, and possibly crude saltpetre.

It is likely that these substances were first used in war as an incendiary weapon—being contained in clay balls, or small bamboo tubes, ignited and flung at the enemy. It might well have been in this way that a primitive "grenade" developed, as the result of explosions caused by confinement of the burning mixture. However, in all probability, the early "gunpowder" substances were not recognised as propellant medium until after the birth of Christ. It is conceivable that the first indication of propulsive effect came as the result of filling incendiary compound into bamboo rods, which ignited and used against the enemy as "javelins," or "arrows" (fired from the bow) might well have been observed to propel themselves, due to the reactive effect of the burning mixture. Thus it is probable that, in further course of time, the "fire-arrows," as the incendiary rods were later termed, developed into the "rocket-arrows" (Fig. 2), to which reference is made in a Chinese document of the year 1220 A.D., describing their use against the Mongols during the battle of Pieping.

Roger Bacon

Roger Bacon, an English monk, in the year 1242, first made known the composition of true gunpowder: Saltpetre 41.2; charcoal 29.4; and sulphur 29.4. It should not be considered, however, that the ingredient proportions then given have remained unchanged until the present day. The modern gunpowder affords an interesting comparison in this respect, approximating to: Saltpetre 75.0; charcoal 15.0; and sulphur 10.0. As previously mentioned, compounds of similar character to gunpowder had been employed in the East from almost the dawn of recorded history, and in consequence, Bacon cannot be credited as the discoverer of gunpowder. However, he undoubtedly played a considerable part in its development, and greatly enhanced its power by careful attention to the ingredient proportions of the composition and also by the purification of saltpetre.

Further Developments

Credit for further early development is due to a certain German engineer, K. Kyeser von Eichstaedt, who concluded with success many rocket experiments, using varying proportionate gunpowder mixtures, in the year 1405. Some fifteen years later, an Italian, Joanes de Fontana, is held to have conducted similar tests, and is even reputed to have designed a rocket chariot.

In the middle 1400's, the rocket was employed somewhat extensively as a weapon of war, being used against the English in the defence of Orleans in 1429; during the siege of Pont-Andemer in 1499; against Bordeaux in 1452, and Gand in the year following. A technical paper, entitled "Treatise upon several kinds of War-Fireworks," published in France in the year 1561, describes the use of rockets in the previously mentioned campaigns, and suggests a rocket case of varnished leather, as an alternative to the paper and bamboo cases used up to that time. Towards the close of the century, the rocket projectile was employed against cavalry, and also for sky illumination purposes. A document by Hanselet, written in 1630, contains references to rockets bearing a form of grenade, apparently intended to produce a similar effect as the modern light shrapnel shell.

Operating No. 2 rocket hand-fired pistol. Range 250 yds.

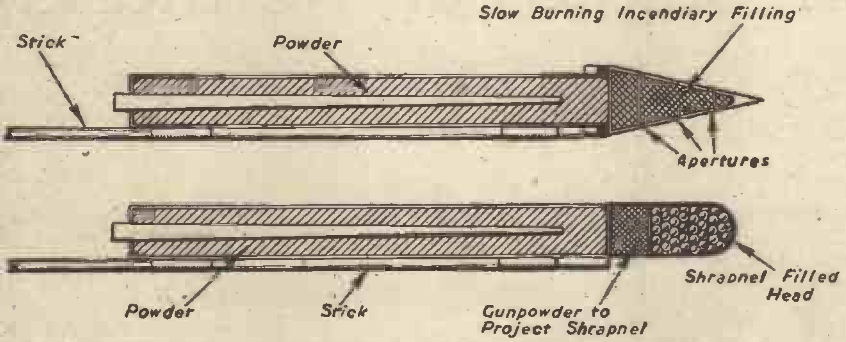


Fig. 3 (Above).—Congreve rocket (early 1800) and (below) a shrapnel anti-troops rocket.

Historical references exist which indicate a large scale use of rocket projectiles against Philippsburg in 1645, during the Thirty Years War, and accounts suggest that they played a substantial part in bringing about the eventual downfall of the city.

A treatise, published in 1650, "Great Art of Artillery," by C. Siemienowitz (Poland), contains a reference to a work of some 90 years earlier on the use of "fireworks" for military purposes, which is said to have given details of rockets up to 100lb., describing their construction.

Experiments carried out in Berlin in 1688 record rocket projectiles of gunpowder composition: Nine parts potassium nitrate (saltpetre); four parts sulphur; and three parts charcoal. The cases were of wood, linen covered for strength, the finished rockets being of 50lb. and 120lb. capable of carrying explosive charges of some 16lb.

It is significant to note, in passing, that as early as 1710, the use of rockets for "firing to the moon," was suggested by a Frenchman, Cyrano de Bergerac.

In the book "Asiatic Researches" (Vol. 3), published in the late 1700's there is given an account of the battle of Paniput (India),

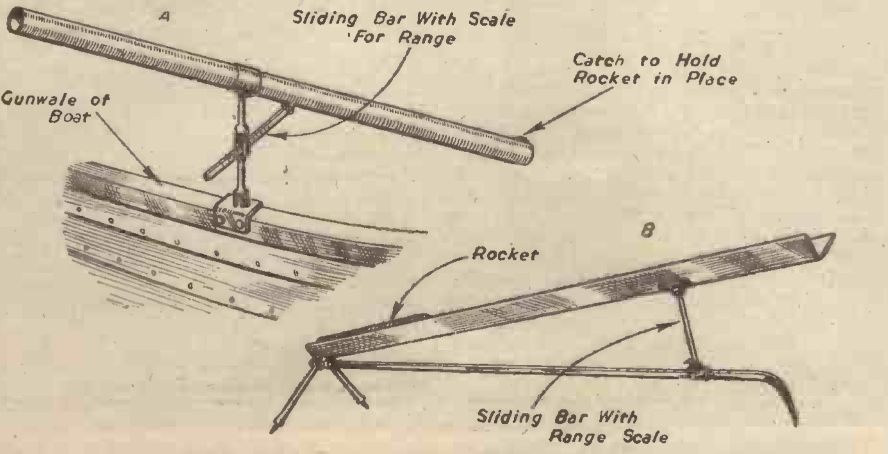


Fig. 4.—A rocket launching tube for use on boats, and (below) a launching trough for land use.

in 1761, in which the following paragraph is included: "As the Rohillas had a great number of rockets, they fired vollies of two thousand at a time, which not only terrified the horses by their dreadful noise, but did so much execution also, that the enemy (the mahrattas) could not advance to the charge."

According to accounts of the India campaigns, rockets were also used extensively against the British cavalry, towards the close of the eighteenth century. It is reported that the rockets employed were iron-cased, 8in. long and 1½in. in diameter, with a spiked nose, and balanced by a bamboo, or iron rod "stick" approximately 8ft. in length. The projectiles were hand thrown by specially trained "rocketeer" troops. Such was the effect of the Indian rocket weapon that militarists returning to England suggested the development of rocket artillery for the British Army.

English War-rockets

Experiments were commenced at the Royal Laboratory, Woolwich, in the early 1800's, by General Desaguliers. It was about the same time that Col. William Congreve, an artillery authority of some standing, first became interested in rocket artillery, and commenced a private investigation of composition proportions, and case efficiencies. As the result of subsequent experiments, Congreve obtained permission to use the laboratory at Woolwich, and there constructed several military rocket projectiles which when tested proved highly satisfactory, and realised practical application, with varying success during the European wars of the early nineteenth century. During the Napoleonic Wars, incendiary rockets, designed by Congreve, played a conspicuous part in the fall of Boulogne, in 1806, and also in the devastation of a portion of the French fleet, the projectiles being fired in salvoes from twenty-four specially constructed "projector" boats, which were conveyed to the scene of engagement by parent vessels. The rockets used, intended primarily for marine warfare, contained a liquid-incendiary substance within a sharp-pointed nose, which on impact squeezed out a light through a number of radial holes drilled in the rocket head, liberally coating the target with fire. The pointed nose enabled the projectiles to stick to whatever they hit, and the devastation that such weapons were able to inflict on the all-wooden sailing vessels of that period, for instance, is easy to imagine. A year previous, Congreve had actually gone out with naval vessels, intending to witness his rockets in action against the French flotilla then anchored at Boulogne, only to be disappointed, weather conditions at the time of engagement being such to prohibit their use.

In 1807, rocket projectiles, once more, proved their worth, both on land and afloat, in the siege of Copenhagen, playing a considerable part in the city's downfall. The projectiles used were 32 pounders, capable of bearing explosive or incendiary charges ranging from 8 to 20lb. for a maximum distance of two miles, some 120,000 being used in the assault. Congreve is credited with the introduction of iron-cased rockets in 1808, although certain reports suggest their use earlier, possibly in the Boulogne attack two years previous. The rocket case was of iron sheet, gunpowder filled, the complete projectiles weighing up to 24 pounds, including a charge of either explosive or incendiary composition (Fig. 3). Launched from inclined iron tubes (Fig. 4), and guided by the conventional balancing "stick," tests proved that ranges of over two miles were easily attainable with rockets of the larger type.

In the year 1810, the first important technical paper on the subject of rockets was published, "On the Motion of Rockets," by W. Moore, London, which contained a mathematical investigation of rocket motion and trajectories.

(To be continued.)

Motor Chief on Roads to Be

OUR road engineers must have more vision, scope and encouragement to tackle the problem of traffic in an imaginative and logical way, Sir Miles Thomas, vice-chairman of the Nuffield Organisation, told the Engineering Industries Association in the course of a luncheon address, "Britain's Future Lies With Engineers," in Birmingham.

Nobody would imagine, he said, that it would be either safe or serviceable to carry gas and water through the same pipe. So with roads: it was illogical to make urgent, purposeful, high-powered vehicles fraternise with mercurial pedestrians and volatile cyclists on the same strips of roadway. Safety would only come through segregation; and only by that means would we get the real, time-saving advantages that the development of the automobile could provide, plus the degree of human safety in travel that we simply must attain.

Invasion Ships Off Normandy Coast

This photograph, taken as Allied invasion ships approached the coast of Normandy, shows a Rhino ferry, loaded with trucks and ambulances, leaving a tank landing craft for the beaches.

of the primary conductors will be about 0.029 square inch, and the secondary conductors about 0.055 square inch. If rectangular conductors are used the total cross sectional area of the primary winding per phase will be 220 × 0.029 = 6.4 square inches, and for the secondary 61 × 0.555 = 3.35 square inches, giving a grand total of 9.75 square inches. Ample space should, therefore, be provided in the core indicated in Fig. 2.

Parallel Windings

Eddy currents are created in the conductors as well as the core, this loss being approximately proportional to the square of the leakage magnetic flux density, to the total weight of copper in the transformer, and to the square of that dimension of the individual conductors which is normal to the path of the leakage flux. In transformers of high capacity it is usual to reduce eddy currents by limiting the dimension of the conductor normal to the leakage flux path, by subdividing the conductors and insulating the various portions from each other. Difficulties may arise if the various parts of each conductor are not equally disposed with respect to the core; for example, if the parts of the conductor are not of equal length or not linked with the same magnetic flux, the volt drop in each parallel circuit may be unequal. Parasite currents will then circulate between the parallel circuits which will tend to cause overheating and loss of efficiency. To overcome this trouble the sections of conductor are usually transposed during winding, in such a way that each portion from terminal to terminal occupies each different position with respect to the core. For the 23 k.V.A. transformer under consideration, however, the conductors are

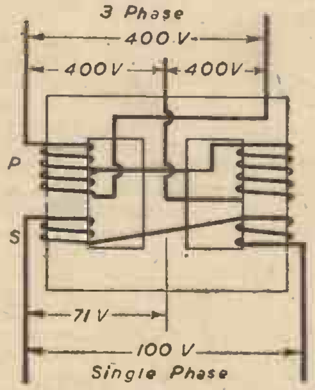


Fig. 5.—Tee connection for three-phase to single-phase conversion.

reasonably small, and such subdivision is not necessary.

Transformers form a convenient means of converting supply phases as well as voltages and currents. For example, it is possible to convert three-phase to six-phase, two-phase to three-phase, two-phase to six-phase, or three-phase to single-phase. It is also permissible to convert three-phase voltages by the use of two separate single-phase transformers.

Three-phase to Single-phase Conversion

Three-phase to single-phase conversion may be necessary when a fairly high single phase load is required, which the supply authority will not permit to be connected across two supply mains on account of the resulting unbalancing of the supply phases. One method employs a three-phase primary connected in open delta, the secondary windings being in series with one winding reversed. This transformer is shown in Fig. 4, and it will be seen that the centre limb of the three-limb core is unwound. On the secondary side the induced voltages in the two windings are two-thirds of a cycle out of phase, so the secondary terminal voltage is 1.732 times the voltage of one of the windings. This means that the number of secondary turns must be correspondingly increased, and the k.V.A. of the transformer must be 15.5 per cent. greater than the actual kilowatt output on a load of unity power factor. On such a load the power factor of the current in one of the secondary wind-

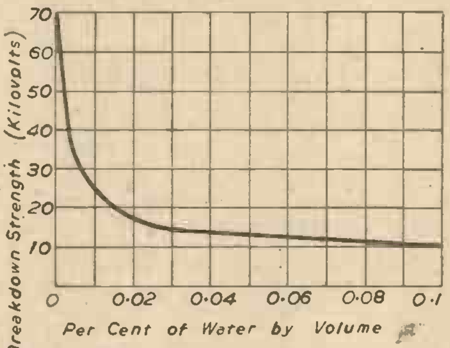


Fig. 6.—Effect of moisture on breakdown strength of transformer oil.

ings is 1/12th of a cycle in advance, and in the other secondary winding is 1/12th of a cycle lagging behind the voltage.

The tee transformer employs a three-limb core, the centre limb, which is unwound, having a cross sectional area 41.5 per cent. greater than that of the outer limbs. The voltages in each of the secondary windings are a quarter of a cycle out of phase with each other, and the terminal voltage is, therefore, 1.414 times the voltage of one secondary winding alone. The transformer k.V.A. must be 41.5 per cent. greater than the kilowatt output at unity power factor on the secondary side. With both types of connections for three-phase to single-phase conversion, the transformer does not distribute the single-phase load equally over the three-phase supply.

Transformer Oil

The oil used in transformers should be specially selected mineral oil, a typical specification for Class B oil stipulating that the breakdown voltage between 0.5in. diameter spherical electrodes 0.15in. apart shall not be less than 30,000 volts; that the acid value, measured in milligrams of KOH to neutralise one gram of oil, shall not exceed 0.2; and the closed flash point shall not be less than 145 deg. C. As may be seen from Fig. 6, a very small amount of moisture will reduce the breakdown strength of the oil to a considerable degree.

Moisture may be absorbed by the insulation of a transformer during or before winding, and should be removed by drying out. For this purpose resistance units may be placed in the transformer with its oil and supplied with a controlled current, so the temperature at the top of the oil does not exceed about 80 deg. C. Alternatively the transformer may be heated by supplying a reduced voltage to one of its windings, the other windings being short circuited so the transformer is heated by its own losses. During drying out, insulation resistance tests should be made by means of a megger at frequent intervals, the tests being made between the core and primary and secondary windings, and also between the primary and secondary windings.

The Jet Induction Augmenter

THE true-rocket propulsion means is extremely wasteful in atmosphere, but it has been shown that efficiency can be considerably improved by the provision of thrust augmenters.

The principle on which the air augmenter functions is that air is drawn into the rocket by virtue of an area of negative pressure created by the flow of the exhaust efflux, the effect being to produce a relatively low velocity, high mass final efflux, as against the high velocity, low mass efflux of the unaugmented "free-jet" system.

Resistance at supersonic velocities. Whereas the resistance of a streamlined body moving through air at a speed below that of sound is largely accountable to form (frictional) resistance; at supersonic speeds the air flow suffers a sudden change of transition, affecting a local increase in both pressure and density, producing a compression region at the nose of the body, resulting in turbulence taking the form of conical sound waves, which constitute the main drag. There is in addition a secondary turbulence produced at the rear of the body due to suction.

In view of the above considerations a new sounding rocket layout has been proposed (see diagram), combining the following advantages: (a) The layout improves jet efficiency by the provision of two stage augmentation (second stage augmenter increases mass flow in the more dense regions—later jettisoned at appropriate velocity). (b) Stability is effected by axial rotation and relative location of the C.G., and C.T., thereby dispensing with weighty and delicate gyro-stabilising mechanism. (c) Location of the augmenter duct at the nose acts to reduce head resistance by partial induction of compressible region.—*Official Bulletin of the Combined British Astronautical Societies.*

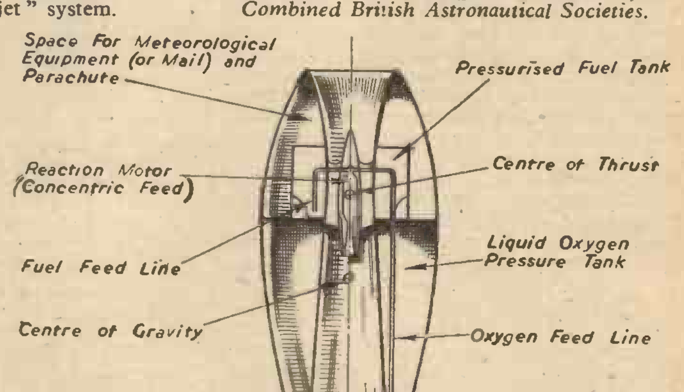


Diagram showing the component parts of a jet induction atmosphere-augmented sounding (or mail) rocket.

load, and the ratio of transformation is reduced to a greater degree; this is due to the fact that the transformer windings have more reactance than resistance. It is, therefore, important to design the transformer to keep the reactance to a minimum for an inductive load. In most cases the primary voltage will be fixed so the primary volt drop will reduce the secondary terminal voltage below the value indicated by OV_s.

On the other hand if the secondary load circuit had a high capacity, such as a condenser, the conditions would be somewhat as indicated in Fig. 8. In this case the secondary current will actually be in advance of the secondary voltage. The same notation is adopted and it will be seen that this type of load causes the secondary terminal voltage to increase, and at the same time the ratio of transformation is increased.

The simplest way of dealing with a transformer which has a transformation ratio of more than one is to employ different scales for the primary and secondary values. For instance, if the secondary voltage is half the primary voltage, one inch on the primary voltage vector could represent 50 volts, and 25 volts for the secondary. One amp. primary current could be represented by the same length as two amps. secondary current. By this means all currents can be considered equally effective as regards magnetic effects, since the secondary currents are increased in practically the same ratio as the turns are reduced. If one inch represents 5 amps. primary current in a 1 to 2 step-down transformer, it could also represent 10 amps. secondary current. This will be quite in order since 10 amps. increase of secondary current will necessitate 5 amps. increase of primary current to restore the magnetising ampere turns, if the losses are neglected.

Rocket Propulsion

Further Notes on Its History and Development.

By K. W. GATLAND

(*Continued from page 332, July issue*)

IN 1812 an English Army Rocket Brigade was formed, which subsequently gained marked success at the siege of Leipsig in 1813, and also during the Battle of Waterloo, two years later.

After witnessing trials of Congreve rockets at London, in 1813, Austrian army officials succeeded in influencing the Austrian Government, who, a year or so later, established a sizable factory for the purpose of war-rocket manufacture at Weinerisch-Neustadt.

It is desirable to emphasise, before proceeding further, that the rockets developed up to this period were of very low thermal efficiency, decidedly unstable in flight, and, in consequence, inaccurate in trajectory. It was not until Congreve introduced fins, superseding the balancing "stick," that the rocket began to show any marked gain in technical advancement. However, the invention of this stabilising means cannot be actually credited to Congreve, as the idea was first given by Frezier, a French artillery engineer, in his technical book on armaments, published some years previous to the practical development, who also anticipated in the same work, a later refinement of Congreves, the "two charge rocket," to which reference will be made later.

Perhaps the most notable contribution to the science of rocketry, prior to the twentieth century, was the invention of the axially rotated rocket projectile. This rocket system, first developed in America in 1815, displaced both the balancing "stick" and the "fin," the exhaust apertures being spaced in a circle, and drilled offset to the line of thrust, instead of normal to it, as in the "stick" and "finned" principle. Needless to say, this refinement aroused much interest amongst rocket authorities throughout the world, and attention was focused towards its further development. In England Congreve developed many rockets of similar character to the American design, rotation being similarly imparted by virtue of offset thrust.

It was in the year 1826 that Congreve patented a method whereby a series of rocket cases were laid in line within a single containing tube, so that the charges became ignited successively, to thus obtain an increased duration of firing. This method, however, was first conceived by Frezier, as previously mentioned, and has since become known as the "step-rocket" principle.

Congreve was later knighted for his work in connection with English rocket artillery, and subsequently assumed the position of Controller of the Royal Laboratory, Woolwich.

At about the same period rockets of greater efficiency than those previously used in war were employed against the Turks by the Russians, who developed a battery launching system which fired several explosive rocket projectiles at one loading into the enemy lines in much the same way as the Russian rocket batteries operate to-day.

The Rocket Life-line

Although being employed for lighting and signalling purposes at sea, the rocket had found its greatest use in war, and the first evidence of its application actually being instrumental in saving life, instead of destroying it, was in 1826, when four rocket life-line stations were set up at various points on the Isle of Wight coast known to be most perilous to shipping. The rockets employed were designed by Dennett, of Newport. The rocket-line, however, had been first advocated by Trengouse in 1807, but, owing to the employment of the Manby life-line mortar system, which had then just come into extensive use at coastguard stations all round the British Isles, the true merits of the rocket for the purpose of life-saving were overlooked, and it was not until 1855 that the rocket finally came into its own, displacing the Manby mortar, the rockets used ranging in weight from ½lb. to 2lb. The advantages of the rocket over its contemporary are obvious. The rocket projector, for instance, is considerably more compact than the mortar apparatus and, in consequence, more portable. Still more important, the path of the line is traced out by the rocket exhaust—a great advantage, especially at night. Although it was not until 1870 that universal adoption was finally achieved, the rescue rocket since that time has been instrumental in saving over 14,000 lives. The 6lb. rockets of that period were capable of carrying a ½in. hemp line for distances of approximately 1,050ft.

In 1841, S. Golightly proposed a reaction propelled projectile intended to employ steam as the propellant. However, although his idea was correct in principle, the design was not technically sound, but, allowance being made for the period of invention, his scheme was, nevertheless, a remarkable one.

In the year 1844, William Hale designed and patented a rocket projectile stabilised by axial rotation, the exhaust apertures being practically tangential at the side of the case. The rotary stabilisation principle was further developed during the following years. Macintosh, in 1853, for instance, evolved a firing method in which the launching tube was initially rotated to impart rotation to the rocket prior to flight. A year later Court patented a design in which the exhaust impinged on small vanes inclined to the rocket axis. Fitzmarice, in the same year, developed the method of causing rotation by the action of air pressure on a "spiral" shaped head.

It was about the middle of the century that the rifled cannon came into use, due mainly to the endeavours of General Rodman and W. E. Woolbridge in America, and with its subsequent universal adoption, the war rocket quickly fell from favour.

Step-rocket Line Carrier

However, a great deal of rocket research continued, although mainly in connection with the rocket lifeline. In 1855, Col. Boxer, of the Royal Laboratory, Woolwich, further developed the "step-rocket" as a line-carrier (Fig. 5). This he evinced by placing two rocket charges in line within a single case. When ignited the first charge carried the projectile until its fuel was exhausted, at which stage it fired the second, and was blown off, the rocket thereby gaining additional impetus in flight, substantially improving the range.

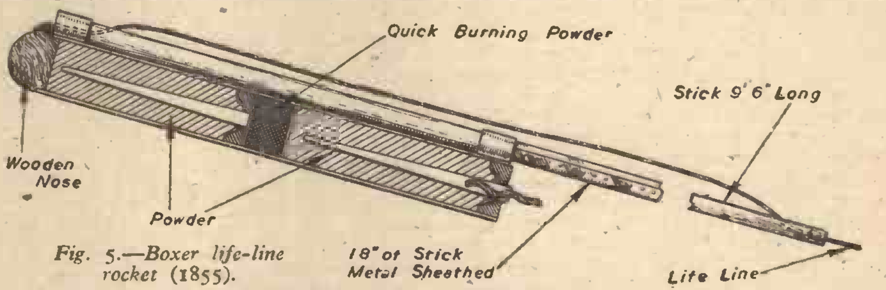


Fig. 5.—Boxer life-line rocket (1855).

A rocket-propelled airship was proposed in 1860 by Betty, an American engineer, but was not, however, proceeded with beyond the design stage.

In the year 1863 William Hale published a technical paper, "A Treatise on the Comparative Merits of a Rifled Gun and a Rotary Rocket," and a few years later further developed the axial rotation principle. Instead of offsetting the exhaust apertures as the Americans, Congreve, and he himself had done previously, Hale provided metal shields (Fig. 6) inclined over three escape holes drilled normal to the axis of the rocket, on to which the exhaust gases impinged, creating a rotary motion. With reference to the diagram, the screwed safety cap was fitted only for purposes of storage, in order that the rocket would explode should spontaneous combustion take place. These type projectiles were of two sizes, and named after their inventor—"Hales 9 and 24-pounders."

Misconceptions of Space-flight in Literature

Although Jules Verne, in his great work of fiction "From the Earth to the Moon," published in 1866, suggested rockets to retard the space-vessel depicted by providing reaction tubes at the nose of the craft, neither he, nor H. G. Wells in "The Shape of Things to Come" (published some years later) suggested the rocket means for propulsion—instead the impossible "space-gun" being employed for projecting the craft beyond the Earth's gravitational influence—in much the same way as a bullet fired from a gun.

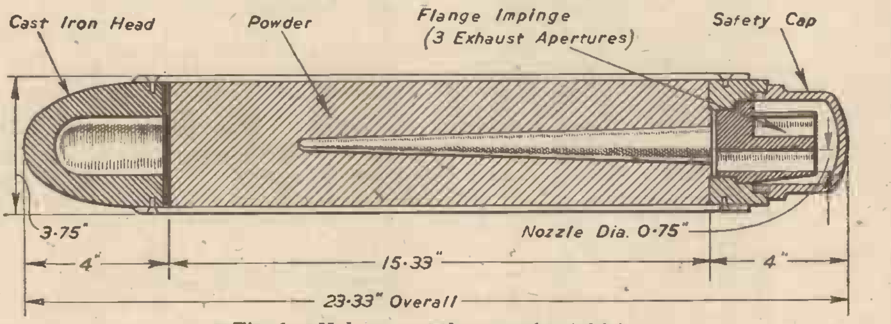


Fig. 6.—Hale 24 pound war rocket (1863).

The obvious fallacy of the "space-gun" principle is in the severe shock acceleration at take-off in order to attain an initial speed of 6.95 miles per second (release velocity), which beyond all measure of doubt would be instrumental in instantly crushing the occupants to death. Another obvious point is that friction caused by the rapid passage of the vessel through the atmosphere would be prohibitive. The rocket, on the other hand, would not need to develop such severe acceleration, due to the fact that a rocket vessel would carry its own propulsive means, the application of energy being spread over a considerable period, and acceleration built up gradually within bearable physical limits. The greatest velocity would be achieved far beyond the Earth's atmosphere belt, and, in consequence, the frictional effect would be by no means as severe. It is curious that having readily available the knowledge of elementary mechanics, these great writers of science-fiction did not realise the impracticability of their fictitious creations, for had they given the subject serious practical consideration prior to writing, the rocket means would have shown itself the only truly feasible method of achieving the conquest of space and, in consequence, further enhanced the value of their work.

The above comments of scientific literature have been included not so much for historical significance, but rather as a convenient point to clarify some of the early fallacies connected with the subject of space-flight, and interplanetary communication.

The First Rocket Aeroplane

A Russian, Niballchitch Kibaldchitch, in 1881, designed what might be termed the first reaction propelled aircraft. In actual fact, he recorded the basic design while imprisoned for being concerned with five others in the assassination of Czar Alexandra II, while awaiting the result of the trial, and the inevitable "Death Sentence." However, his drawings and manuscripts were not discovered until long after his death, actually in 1918, and although the ideas contained were certainly revolutionary for their day of origin, they were naturally enough of little practical consequence at the time of their finding.

It is indeed surprising to find in a book, "Half Hours in Air and Sky," published by James Nisbet and Co., in 1899, the true principle of rocket motion defined, as follows:

"In the infancy of physical science it was hoped that some discovery should be made that would enable us . . . to pay a visit to our neighbour, the Moon. The only machine independent of the atmosphere, we can conceive of, would be one on the principle of the rocket. The rocket rises in the air, not from the resistance offered by the atmosphere on its fiery stream, but from internal reaction. The velocity would, indeed, be greater in a vacuum than in the atmosphere, and could we dispense with the comfort of breathing air, we might with such a machine transcend the boundaries of our globe and visit other orbs."

When it is considered that even to-day the principle of rocket motion is constantly being misinterpreted, often by reputable engineers, the significance of this short paragraph written by an unknown author, is truly remarkable.

Experimental Work

Reverting to the rocket as a line carrier once more, a great deal of experimental work was conducted by various individuals in Britain towards the close of the nineteenth century, resulting in considerable improvement of this type of sea-rescue apparatus. Many of these developments were represented in trials of line-throwing appliances conducted by a sub-committee of the Advisory Committee of the Board of Trade, in which numerous forms of life-saving equipment were demonstrated. It is of interest to note that not only were various types of rocket-line apparatus tested, but in addition, line-throwing guns, drift buoys, kites and balloons. The most promising equipment proved to be a portable rocket apparatus designed by William Schermuly. This apparatus, consisting of a launching trough (into which the rocket carrier was placed), supported by a stand and fixed direct to a line-containing box, was initially tested under the auspices of the sub-committee in 1908 at Greenhithe, on board the "Warspite." The apparatus was set up on the rail of the ship, and fired, in the surprisingly short time of 2¼ minutes, contact being made with the shore some 200 yards distant, using a 2lb. rocket. Further Schermuly rocket line-carriers were tested in this and subsequent trials, later tests being conducted in October of the same year on the Tyne, when even better results were obtained in respect to setting up and firing, in one particular case, preparation taking only one minute, the 1lb. rocket employed bearing a line for 177 yards, a notable achievement for a light rocket. Another rocket of 6lb. set up and fired in 1½ minutes, successfully projected a line for 321 yards. The proved efficiency and extreme portability of the apparatus, which weighed complete only 40lb., were all the more notable in the fact that the tests were carried out single-handed. As the result of the 1908 trials, the Schermuly line-carrying apparatus was approved by the Board of Trade, and to-day, developments of this pioneer portable sea-rescue equipment constitute an important emergency item on all British and a very large number of foreign ships.

The Beginnings of Modern Research

The first to seriously suggest the rocket as a means for interplanetary communication would appear to be a Russian scientist, Konstantin E. Ziolkowsky. His first technical paper on the subject of rocket motion was published in the scientific journal, "Nautschnoje Obosrenije," in 1903, in which he pointed out the functioning principle of reaction, illustrating theoretically that a rocket could operate in vacuum.

In 1907, a French engineer, Esnault-Pelterie, commenced a mathematical investigation into the possibilities of space flight. The work was expanded in 1912, and later submitted to the Société Française de Physique.

Also in 1912 an American engineer, Dr. Robert Goddard, of Princeton University, after a considerable theoretical investigation of rocket motion commenced in 1909, successfully demonstrated that a rocket could function in space. This was arranged by firing a rocket charge within an evacuated glass tank, and the impulse measured, due care being taken at the same time that gaseous rebound did not affect the recording. The result indicated a slight increase in the thrust factor, in comparison with that obtained under normal atmospheric conditions. Thus it was finally proved that instead of being the medium which effects propulsion, the atmosphere actually has a "damping" effect, acting to lower the velocity of the exhaust efflux, thereby reducing efficiency. Much of

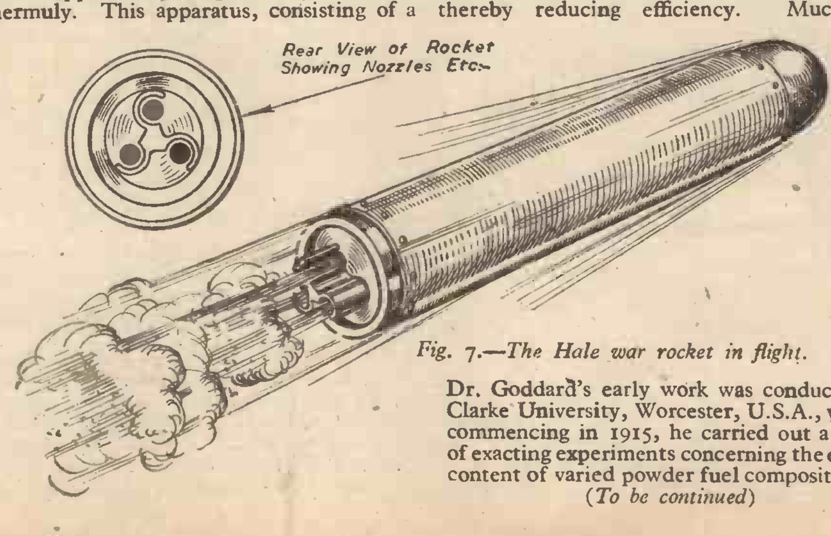


Fig. 7.—The Hale war rocket in flight.

Dr. Goddard's early work was conducted at Clarke University, Worcester, U.S.A., where, commencing in 1915, he carried out a series of exacting experiments concerning the energy content of varied powder fuel compositions.

(*To be continued*)

Rocket Propulsion

Its History and Development

By K. W. GATLAND

(Continued from page 375, August issue)

THE war of 1914-18 found the signal and illumination rocket (the latter ejected a parachute flare at the peak of trajectory) used extensively on the fighting fronts, and towards the end of the conflict a special message-carrying rocket projectile was developed, which found its greatest use for maintaining communication between advanced troop elements.

Rockets projected from aircraft were also employed during the war for destroying observation balloons and airships. The projectile, which was of the conventional "stick" balanced type, consisted of a simple tubular case containing gunpowder propellant compound, and incorporated at the "head" a number of barbs which enabled the missile to cling to the fabric of the target, the rocket exhaust being sufficient to fire the highly inflammable hydrogen gas contained.

The first operational aircraft to employ rocket projectiles as offensive armament appeared in 1915. This machine, a Henry Farman, carried ten rockets, these being electrically fired from small tubes situated on the outermost interplane struts, five either side. Several Newport Scouts were later fitted to carry eight rocket missiles mounted and fired in similar manner.

In 1917, the Vickers aircraft group developed a special single-seat, pusher type, rocket-firing aircraft (the Vickers F.B.25), designed as a defence machine intended to counter Zeppelin attack. However, this 'plane did not realise operational service, due to the introduction of incendiary ammunition for use in the ordinary aircraft machine-gun.

An interesting suggestion aimed at the increase of the flight efficiency of shells, particularly rocket shells, was put forward by Chilowsky in 1915. In order to reduce drag at high speed, he advocated the projection of a flame ahead of the projectile in order to raise the temperature of the air locally at the nose, the heated air thereby becoming less dense. For instance, it has been estimated that by means of the combustion of 10 gm. of phosphorus, it is possible to halve the resistance of the standard 75 mm. F.N. projectile.

The "Thrust Augmenter"

A French engineer, Henri F. Mélot, whose work, although being concerned solely with the development of thermal-jet power units, produced in 1917 an interesting design (Fig. 8) incorporating a multi-nozzle device of progressively increasing dimensions emulating from around the nozzle of a combustion chamber, the motor employing inducted air, with petrol as fuel. This "stage" nozzle served to induct air to augment the thrust of the propulsive jet, and was tested under the auspices of the French military authorities during the latter stages of the last war, though with no definite success. The principle upon which the device functioned was that air was sucked into the unit by virtue of an area of negative pressure created by the exhaust flow from the producing plant being expanded through a venturi "diffuser" tube, which thereby increased the mass flow of the efflux. Since the war, the "thrust-augmenter," as the device was later termed, was further developed by Mélot and others. In 1927 the Mélot "augmenter" system was tested at the Langley Memorial Aeronautical Laboratory, U.S.A., the results of which proved conclusively the efficiency of the device. It is quite probable that, by careful design, the "thrust-augmenter" may in later development provide the means for operating the "true-rocket" system in atmosphere at a practical efficiency.

Further Goddard Research

Mention of Dr. Robert H. Goddard's early researches has already been made, and in 1919 the findings of these initial investigations and experiments were published in the form of a report to the Smithsonian Institute —"A Method of Reaching Extreme Altitudes" (Smithsonian Miscellaneous Collections, Vol. 71, No. 2). Investigations at the Clarke University were maintained during 1919 and for some years following, the immediate aim being the establishment of a firm foundation from which it would be possible to base the design of a practical sounding rocket, capable of penetrating to heights prohibitive to the balloon and the aeroplane, for the purpose of providing much-needed data of atmospheric conditions at extreme altitudes.

Dr. Goddard is reputed to have conducted preliminary research concerning liquid fuels (which are capable of being throttled to

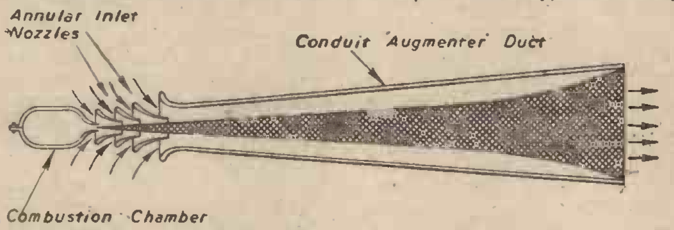


Fig. 8.—Mélot type thrust augmenter. Air is sucked in at the sides by virtue of negative pressure created within the conduit duct by the fast-moving exhaust efflux.

the combustion chamber under direct control, thereby maintaining a constant chamber volume throughout the entire firing period), in 1922, when he first put forward the suggestion of employing petrol as fuel, burnt in a medium of oxygen, this latter element being contained in concentrated *liquid* form. It should not, however, be concluded that liquid propellant owes its origin to Goddard alone, for Professor Oberth, as early as 1914, is held to have proposed liquid oxygen and liquid hydrogen as a plausible rocket fuel.

The process concerned in the reduction of a gaseous element, such as oxygen, to the liquid involves the gas first being highly compressed. Once a sufficient pressure has been attained, the gas is suddenly allowed to expand, thereby reducing the temperature, and by means of a series of such processes the gas finally assumes liquid form, in the case of oxygen at 182.9° C. Special vacuum containers, of the Dewar or "thermos" type, are required for storage as vaporation quickly takes effect, acting to return the liquid to its original form at normal atmospheric temperatures.

Two more pioneers of modern rocket development were an Austrian, Dr. Hermann Oberth, and Dr. Walter Hohmann, of Germany, whose early theoretical researches, unlike Goddard's, dealt almost entirely with the rocket in space. After extensive investigation, a treatise was finally developed in 1923 in which Oberth set out a technical observation of the rocket as a means for interplanetary communication. This work was later published as a book entitled "Die Rakete zu den Planetenräumen" (92 pp.).

Reverting once more to the French rocket pioneer, Esnault-Pelterie, a lecture was delivered by him to the main assembly of the French Astronomical Society on June 8, 1927, the subject-matter concerning both the aspect of altitude sounding by rocket, leading to the possibilities of the interplanetary space-vessel. A year later the lecture was published as a book entitled "L'Exploration par Fusées de la Très Haute Atmosphère et la Possibilité des Voyages Interplanétaires," and in 1930 this work, considerably expanded to include in addition to its original matter an extensive mathematical investigation covering rocket performance and trajectories, was published under the title of "L'Astronautique" (249 pp.). The work remains to this day the greatest theoretical treatise of rocket propulsion yet produced.

In June, 1927, the world's first successfully organised rocket research group, the "Verein für Raumschiffahrt, E.V." (Society for Space Navigation), was formed in Breslau, Germany, due mainly to the endeavours of Max Valier and Ing. Johanes Winkler, and it was not long after inauguration that the society listed amongst its members such renowned names as Professor Oberts, Dr. Hohmann and Willy Ley.

Rocket-car Trials

The society commenced active experimentation a year after its formation, the first series of tests concerning the propulsion of road vehicles, and although the experiments concerned can hardly be said to have contributed greatly toward the technical advancement of rocket propulsion, considerable public interest was nevertheless aroused.

This early work was sponsored by a notable German car manufacturer, Fritz von Opel, probably with the view in mind that the sensational nature of the experiments would serve as a good advertisement for his more conventional products. At all events, the first rocket car to be developed by the society was tested on March 12, 1928, at the Ruessilsheim racing circuit, and a month later a similar test took place as a public demonstration. The car itself, designed by Max Valier, was of light construction, and powered by twenty-four individual gunpowder charges, each weighing twenty-six pounds. These charges, specially manufactured for the test by Ing. F. W. Sander, were arranged in "block" form behind the single driving seat, firing taking place in sequence. Ignition was either accomplished electrically or by means of a clockwork timing device.

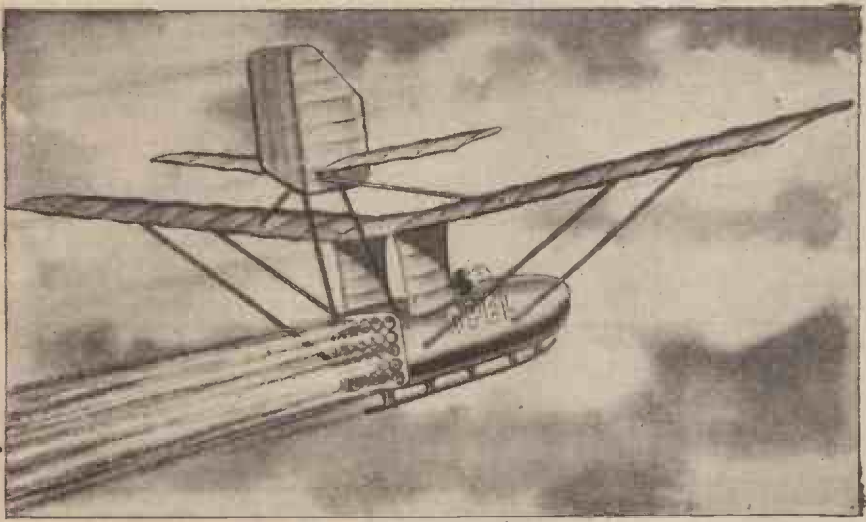
Von Opel's Experiments

On May 23, 1928, with von Opel himself at the wheel, a further public demonstration took place, on this occasion at the Avus

Speedway, Berlin. From a standing start, the car is recorded to have accelerated to a velocity of 60 m.p.h. in five seconds, attaining a maximum speed of 131 m.p.h.

So pleased was von Opel by the success of the Avus Speedway trial that he sponsored three more rocket cars, these being constructed before August of the same year. Unfortunately, due to an accidental explosion, the fourth car was seriously damaged shortly after its completion, but the remaining two satisfactorily completed their respective trials, although the results obtained did not in any way compare with those achieved on May 23. Further types were run on rails, and in one particular instance a speed of 62.5 m.p.h. was attained within 5 seconds from a standing start.

A particularly interesting point was that "retaining planes," emulating stub wings, were fitted to a later Opel rocket car. These projected outwards from a point behind the front wheels, and were set at a negative incidence, the object being that, as the car gained speed, air pressure would act upon the planes and so restrict any lifting tendency.



The Opel rocket-propelled aircraft (1929).

The First Rocket Aircraft

On June 11, 1928, the first man-carrying rocket aircraft flight was made, the machine employed being a light tail-first type Rhön-Rossittengesellschaft glider, powered by two large powder charges, and piloted by Friedrich Stahmer. The flight in question was commenced from a point in the Rhön mountains, the 'plane travelling for nearly a mile before descending. Later a further and much sturdier machine of tailless form was constructed which incorporated four propellant tubes.

Rocket Mails

In July of the same year an Austrian engineer, Ing. F. Schmiedle, conducted experiments aimed at the development of a rocket mail-carrier. Six experimental rockets were constructed, and subsequently tested in free flight, delicate registering instruments being housed within special nose compartments. Unfortunately, the sixth rocket exploded, destroying every item of its valuable load.

As the direct result of these preliminary experiments, Schmiedle established in 1931 the first officially recognised rocket mail service, projecting his mail-carriers for a distance of two miles over mountainous country connecting the two Austrian towns of Schöckel and Radegund with a high degree of accuracy. In fact, so confident were the authorities in this rocket postal service that even registered letters were entrusted to the Schmiedle service for delivery.

A parachute enabled the projectile, which contained the mail in a nose compartment, to reach the ground without damage, being automatically released as the rocket ceased firing.

Further German Experiments

On July 18, 1928, Max Valier himself tested a specially built all-wooden car of his own design, attaining a speed of 112 m.p.h., using gunpowder as propellant. Two further tests were made later, and during the latter he achieved a velocity of just over 130 m.p.h. before disaster overtook him, the car overturning at speed and ending as a complete wreck. Happily, no serious injury was sustained.

Undaunted by the car mishap, Max Valier continued his experiments, and on February 3, 1929, conducted trials of a rocket-propelled sleigh on the ice-covered Lake Starnberg, Germany. In this test a maximum velocity of 235 m.p.h. was attained, and Valier, highly pleased with the success of this latest venture, next resolved to take the air in a rocket 'plane. His plans involved the actual design of a special machine capable of spanning the Channel, which he hoped to fly, from Calais to Dover, but for a variety of reasons the project was never developed into reality.

On September 30, 1929, Fritz von Opel himself piloted a rocket glider, specially designed by Ernest Hatry, powered by some twenty Sander gunpowder charges. In this craft von Opel attained a maximum speed of 85 m.p.h., the machine flying for a distance of one and a half miles at a more or less constant altitude of 50 feet. Unfortunately the 'plane was rather severely damaged on landing, but fortunately the pilot escaped without serious injury.

However, although widespread interest was attracted by these full-scale tests of powder-driven rocket vehicles and aircraft, the Verein für Raumschiffahrt E.V. engineers soon began to realise that nothing of real technical value was being gained. Nevertheless, it had to be admitted that the experiments did act to emphasise one very important point, namely, that the degree of control attainable using powder fuel was practically negligible, as once the propellant charge was fired the reactive thrust of any one charge could not be increased or diminished at will. Thus it is probable that these experiments considerably hastened the inevitable introduction of *controllable* liquid fuels; but we must turn to America for the first practical demonstration of this unique fuel form.

Fuel Liquids

Dr. R. H. Goddard is credited with the initial application of fuel liquids, the particular experiment concerning the firing of a rocket projectile nine feet in length and twenty-eight inches in diameter, employing liquid oxygen, with petrol as propellant. The projectile, which contained special light meteorological instruments, was fired from a 40-foot high steel tower, the test being carried out on the outskirts of Worcester, Mass., on July 17, 1929. Although the projectile exploded after reaching an altitude of nearly 900 feet, the test was considered to have been highly successful, so much so that Goddard received a donation equivalent to the sum of £20,000 from the late Daniel Guggenheim for the continuance of liquid propellant research, although only after extensive investigation of his claims.

After assisting in the preparation of another technical rocket work, "Die Möglichkeit der Weltraumfahrt; Allgemeinverstandliche Beiträge zum Raumschiffartsproblem" (344 pp.), Professor Oberth greatly expanded his first treatise, "Die Rakete zu den Planetenräumen," and in 1929 a new 431-page edition was published.

Also, in 1929, the REP-Hirsch award, a fund originated by Esnault-Pelterie and a wealthy banker, André Hirsch, was established, which aimed to encourage the development of the newly born science of *astronautics* (space-flight) by the annual award of a sum of 10,000 francs, to either the author of a most original technical literature or in recognition of an especially significant experimental work. A committee, comprising many eminent scientists of the French Astronomical Society, was formed to assist in the selection, and in its initial sitting of June, 1929, this body was unanimous in recording the first award to Professor Hermann Oberth.

Research in the U.S.S.R.

In Russia, as indeed in many other countries, the developments of European and American rocket research workers were being followed with ever-increasing interest, and finally, in 1929, two U.S.S.R. rocket research groups were formed—one the Moscow G.I.R.D., founded by Ing. I. Petrovitch, and the other the Leningrad G.I.R.D., founded by Professor N. Rynin and Dr. Jakow I. Perlmann. Professor Rynin later contributed a comprehensive work entitled "Interplanetary Traffic" (9 vols.), which did much to promote Russion interest in the possibilities of space-flight. The Russian engineer, K. E. Ziolowsky, too, had not been idle since his preliminary work of 1903, and many more original papers by him were published concerning both the application of the rocket principle for rapid terrestrial transport, and also as a means for achieving interplanetary communication.

Liquid Fuel Rocket Car

It is of interest to recall yet another German rocket car development, this time the propellant employed being liquid oxygen, with denatured methylated spirit as fuel, in accordance with Professor Oberth's investigations. The reaction motor, into which the propellant mediums were pressure fed, was designed by Dr. Paul Heylandt and scaled barely seven pounds. Tests proved it capable of developing a maximum of 50 h.p. In April, 1930, an initial trial was held at the Tempelhof Aerodrome, Berlin, in which the car accelerated to a maximum speed of 60 m.p.h., and although the velocity attained was not half that reached by the earlier powder fuel vehicles, in consideration of the fact that the constant volume combustion chamber was then in its most embryonic stage, the test was concluded to have been highly successful.

Rocket Propulsion

Further Notes on Its History and Development

By K. W. GATLAND

(*Continued from page 411, September issue*)

SHORTLY after the Valier liquid fuel car trials of April, 1930, the original vehicle was adapted to greater power by the provision of an improved Heylandt rocket motor. Trials of the car using the new reaction system were scheduled for May 17th.

It was while carrying out a final check of the fuel tank capacity, just prior to the initial test, however, that an accident occurred—Max Valier being instantly killed when an explosion completely wrecked the vehicle. Thus, at the age of 35, a brilliant career was brought to a most untimely end. In memorial of this great rocket engineer, David Lasser (founder of the American Interplanetary Society) dedicated his book, *The Conquest of Space*, published in 1931: "To Max Valier, the first to give his Life for the Conquest of Space."

Coupled with the success of Dr. Goddard's early work in the field of liquid propellant research, the very promising results achieved in the Valier car trials, using the Heylandt constant volume combustion chamber, undoubtedly did much to promote widespread interest in the possibilities of liquid rocket fuels.

Solid Fuels and their Control

As has been mentioned earlier, the German rocket vehicle and aircraft experiments served to emphasise the point of limited control in the employment of the solid fuel, illustrating effectively that, once ignited, it is virtually impossible to regulate the reactive effort of any single powder charge. Opel and Valier, of course, had achieved a certain though small degree of control by the simple procedure of employing a *number* of ordinary powder charges, firing them in sequence; but, as will be readily appreciated, this solution was by no means adequate for truly practical purposes.

The firing duration of this system, too, had severe limitations. As an example, it is of interest to note that a single 10lb. charge of the rocket battery employed in the 'plane in which Fritz von Opel made his memorable flight of 1929 operated for a period of only 25 seconds while developing an average thrust of 53lb.

The solid propellant is generally contained *within* the "combustion chamber" (a tube closed at one end and constricted to form a narrow orifice at the other), and upon ignition the fuel burns rapidly without exploding, the gases developed exerting considerable pressure inside the chamber before their final ejection in the form of a high-velocity efflux.

A German design evolved in 1930, developed on the lines of the liquid propellant constant volume combustion system, provided a pressure feeding arrangement in which it was intended to actually *pump* powder fuel into a combustion chamber from a separate containing tank. However, the device when tested proved unreliable in operation, mainly because of the high-feed system pressure, which invariably caused premature explosions while the fuel was being forced into the combustion chamber.

It was Dr. Goddard, however, who provided the most satisfactory solution to the problem of solid propellant control in a reloading mechanism which has since become known as the "cartridge injector." This device consisted essentially of a combustion unit, which recoiled under the action of thrust, and by means of its travel successive charges of nitro-cellulose powder were automatically fed, reloading being effected in much the same way as in a rapid-fire gun. Much of the early work concerned with the "cartridge injector" was carried out in 1918—at about the same time as Dr. Goddard's early powder researches, mention of which has already been made. Later, however, the device was improved to enable a greater number of cartridges to be fired than had hitherto been possible. This particular motor formed the basis of a design for an unmanned rocket projectile intended to penetrate to outer space and reach the moon. Its arrival on the lunar surface was to have been marked by the firing, on impact, of a flash powder charge, the rocket being directed to fall on that portion of the moon in shadow. It was considered that the combustion of merely a few pounds of flash powder would be sufficient for astronomers on earth to recognise the projectile's arrival. Dr Goddard's figures give the total initial mass for such a projectile as eight to ten tons.

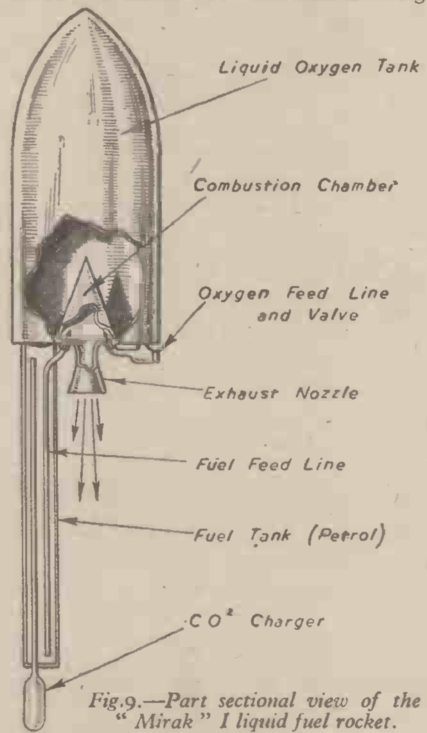


Fig.9.—Part sectional view of the "Mirak" I liquid fuel rocket.

Tiling Powder Rocket

Mention has already been made of the highly successful Schmiedle postal rockets, which employed powder as fuel; but this experimenter was by no means alone in his adherence to the solid propellant. Ing. Reinhold Tiling, for instance, carried out several highly successful powder rocket experiments during the early 1930's, and many of his rockets proved well able to rise to heights of over a mile, attaining speeds in excess of 700 m.p.h. A rather interesting feature of the Tiling projectile was that instead of providing a parachute for landing, a retractable rotor blade device was fitted, operated by means of a clockwork timer, the rocket wafting down to earth emulating the autogyro. Other Tiling projects included winged projectiles, and although not of a very great size—one particular type being 4ft. 6in. in length and nearly 7ft. span—their performances were highly creditable. Many of Tilings rockets were mail-carriers, and one of his most successful postal "shots" took place in 1931, when a projectile containing 200 items of mail was "shot" for a distance of nearly 6,000ft. Two years later, in October, 1933, while engaged on research concerning some 40lb. of powder, Ing. Reinhold Tiling, and three assistants, were killed as the result of a sudden explosion which destroyed the small building in which they were working. This tragedy provided dramatic proof of the severe instability of pre-mixed fuel, and undoubtedly did much to hasten the decline in interest amongst rocket authorities of the solid propellant. Nevertheless, Tiling was by no means the last to employ fuel powders, as it is intended to show in a subsequent article.

The Oberth Step-rocket

Meanwhile, Professor Oberth was busy developing a theoretical basis for flight in interplanetary space, his investigations being based on the *step-rocket* principle.

The space-vessel proposed by Oberth consisted of three *steps* (independent rocket units, each containing their own fuel and motors), the calculations being based on the most powerful fuel available—liquid oxygen/liquid hydrogen.

The weight disposition was calculated as follows: For the first *step* (at the head of the vessel) he proposed a total weight of 80 tons; 60 tons fuel, 10 tons structure and 10 tons payload (crew and equipment), this being the smallest of the *step* units. The second *step*, attached beneath the first, would include 480 tons of fuel and 80 tons structure, bringing the combined weight of the two to 640 tons. To this a third and final *step* was added, consisting of 3,840 tons of fuel and 640 tons structure, makiug the total initial mass weight for the complete vessel 5,120 tons.

It must be borne in mind that the initial mass of 5,120 tons would be sufficient only to gain release velocity from the earth's gravitational influence, and would not provide for return. To enable the vessel to return to earth a fourth *step* would be required, and, working to the same ratio, this would bring the total weight of the initial mass to 40,960 tons—clearly, not a truly practical solution.

Oberth conceived the operational sequence as follows: The third *step* would be employed first, the 3,840 tons of fuel contained being sufficient to impart to the complete vessel a velocity of 2½ miles per second. As soon as the fuel in this step had been consumed the empty structure would provide only dead weight to the vessel, and would therefore be detached and either destroyed by explosives or returned gently to earth by parachute in order to minimise risk to life and property.

The vessel, now consisting of two steps, is travelling at a velocity of 2½ miles per second, and weighs merely 640 tons. The second *step* would next be operated, the 380 tons of fuel contained permitting a further rise in speed of 2½ miles per second. Once more, when the fuel in this *step* is exhausted, the dead weight would be jettisoned, leaving the first and final 80 ton step with a momentum of 5 miles per second. Of this, 60 tons is fuel—sufficient to increase the velocity to 7 miles per second, and so obtain gravitational release.

From the above it can readily be appreciated that the key to economic space flight is in the jettisoning of irrelevant material as the vessel proceeds against a constantly diminishing gravitational influence. The vessel is made progressively lighter, and in consequence a considerable economy in fuel is effected. Thus an interplanetary vessel not designed on the *step* principle would be of even greater initial mass than the Oberth conception.

It should not be concluded from the above that an interplanetary space-vessel must necessarily be of such proportions as in the case given. Nor does the solution remain alone in the discovery of some as yet unknown fuel of high energy characteristic. The answer is involved in many considerations, chief amongst which are—(a) the development of rocket combustion motors of high thermo-mechanical efficiency, and (b) provision of the highest possible fuel/weight ratio.

Film "Girl in the Moon"

On behalf of the Verein für Raumschiffsfahrt E.V., Professor Oberth gave technical assistance in the production of the German Ufa film "Frau im Mond" (Girl in the Moon) adapted from the novel by the well-known German authoress, Thea von Harbon. For filming purposes, a sizeable model space-ship was built, and in recognition of Oberth's part in the production, and also to gain publicity for the film, the Ufa group sponsored the building of a large liquid fuel altitude rocket. Unfortunately, for financial and other reasons, construction was never finally completed. Nevertheless, the film when finished in the early 1930's was a complete success, and undoubtedly did much in the way of publicity for the German society.

The "Mirak" Programme

The constant volume combustion chamber employing liquid fuel had shown great promise in the early tests of the type conducted by Goddard, Heyland and Valier, and this success undoubtedly influenced the Verein für Raumschiffsfahrt engineers in their decision to conduct a detailed series of experiments to determine the most efficient combustion chamber forms, and the most satisfactory methods of liquid propellant feed.

The first series of experiments (known as the "Mirak" programme) covered the development of a number of small rocket units, these being originated with the view of obtaining empirical data upon which to base the design of further rocket motors on a more exacting basis. The "Mirak" (lesser rocket) rockets were not designed with the intention of their being fired in free flight, but rather for rest on a special proving stand, a device with which it is possible to record such essential data as the thrust reaction and the exhaust velocity, the former being registered direct by means of a sprung attachment, the latter being computed from the thrust and amount of fuel consumed. This particular proving stand served a dual purpose in that, should the rocket units satisfactorily conclude their ground trials, by means of a launching attachment they could be actually shot in free flight.

"Mirak" I: Design

Work on the first liquid fuel rocket of the experimental programme, "Mirak" I (Fig. 9), was commenced early in 1930, a main feature being that a gas (pressure) system was provided for feeding the propellant.

The design incorporated a tankage space in the form of a stream-lined nosing shell, wherein the liquid oxygen was contained, a combustion chamber of conical form being situated within, its efflux nozzle protruding centrally from the tank base. Off-centre to the nozzle a single tube containing fuel petrol was situated, at the extreme end of which was fitted a small CO^2 pressure charger for feeding the fuel. Valves incorporated in the feed lines connecting the respective tanks to the combustion chamber were provided for controlling the rate of delivery.

As has already been mentioned, liquid oxygen evaporates rapidly at normal atmospheric temperatures, and good account of this peculiarity was taken in the design, it being found that the self-developed pressure would be amply sufficient to force the oxygen to the combustion chamber without additional aid. Heat from the combustion chamber served to increase the rate of evaporation, the liquid oxygen acting in reverse as a coolant for the motor.

Materials

Particular attention was required in the choice of materials. It was found, for instance, that many metals were apt to become brittle in contact with liquid oxygen, and this factor naturally set a problem in the construction of the tank. At the other end of the scale the construction of the combustion chamber, too, demanded careful attention. A material was required capable of resisting the intense heat likely to be generated, and one also that would not disrupt under high pressure.

After due consideration, it was decided to employ, in this first design, duralumin for both the oxygen and fuel tanks, and a special heavy copper alloy for the combustion chamber.

Trials

The first "Mirak" was completed well before the end of the year, and, although tests proved it a satisfactory first step, several preconceived design notions were severely shattered.

The most obvious fault was found to be in the shape of the combustion chamber, which, due to its form, severely restricted the exhaust flow. Efficiency suffered from incomplete combustion, and, in the light of initial trials, it became apparent that the combustion chamber lacked space at the top for the gases to mix adequately prior to their ejection from the nozzle.

After a series of exhaustive tests, "Mirak" I exploded. An examination of the remains showed that the explosion had been caused by the too vigorous expansion of the liquid oxygen, resulting in the development of excess pressure, which had burst the oxygen tank. It was obvious that heat transmitted from the combustion chamber had been the direct cause.

The Raketenflugplatz

While trials of the first "Mirak" were proceeding, officials of the Verein für Raumschiffsfahrt E.V. were engaged in the searching out of a suitable site for the establishment of a permanent rocket research station, where possibly dangerous experimentation could be carried out at a safe distance from habitation.

In the autumn of 1930 a stretch of land ideal for both ground and free-flight tests was finally secured at Reinickendorf, a suburb of Berlin; and there in September of that year the society established their experimental headquarters under the name Raketenflugplatz (rocket-flying field), where later buildings were erected and the rockets actually constructed.

(*To be continued*)

ITEMS OF INTEREST

20,000 Atlantic Crossings

THE twenty-thousandth transatlantic air crossing since the war began was recently made when an aircraft landed at an R.A.F. Transport Command airfield in Scotland. The flight was accomplished by an aircraft of British Overseas Airways Corporation North Atlantic return ferry, operated by B.O.A.C. to the requirements of Transport Command.

Most of these crossings have been from east to west over the Atlantic, and have been made by British, Dominion, American and Allied aircrews. The twenty-thousandth crossing emphasises the enormous increase in freight and passenger air traffic, as well as in the delivery of new aircraft, between America and the United Kingdom.

From the autumn of 1940 until Christmas Eve, 1943, the Atlantic had been flown 10,000 times. By the middle of May, 1944, the figure was 15,000, and now, less than three months later, another 5,000 flights have been achieved.

The majority of the aircraft delivered to the United Kingdom has been produced in the United States and the balance in Canada. Behind the achievement of the twenty-thousandth crossing is a story of organisation and high endeavour.

Vehicles and tanks coming ashore from a landing craft during the embarkation of British troops in Italy.

Rocket Propulsion

Improved "Mirak" and "Repulsor" Rockets

By K. W. GATLAND

(*Continued from page 22, October issue*)

ON July 2nd, 1930, the Verein für Raumschiffsfahrt E.V. engineers conducted preliminary trials of a new constant volume combustion chamber, designed by Professor Oberth, known as the "Kegelduse" (cone nozzle) type. Tested on a special proving stand, the motor recorded a thrust of approximately 16lb., constant for 90 seconds, operating at an estimated thermal efficiency of 6.3 per cent.; not a highly satisfactory result.

"Mirak" II—Development

Fortified by experience gained from the trials of its predecessor, the second Mirak (Fig. 10) remained essentially the same, improvements being in the provision of a valve within the liquid oxygen tank, designed to relieve excess pressure; and in the shape and make up of the combustion chamber. A ceramic liner was provided inside the combustion chamber as a precautionary measure aimed at the prevention of combustion heat effecting a too vigorous expansion of the liquid oxygen. The combustion chamber in this design was cylindrical and in order to gain a certain desired strength factor, a lining of steel was also provided on a copper alloy base.

An attempt to provide internal cooling of the combustion chamber was also made by the substitution of an alcohol-water mixture, in lieu of petrol, as fuel.

Despite the many improvements made, however, after a number of tests, "Mirak" II suffered the same fate as its former stable companion; the oxygen tank exploding due to the inadequate function of the relief valve.

"Mirak" III

Later in 1931, yet a third "Mirak" (Fig. 11) was produced at the Ratenflugplatz, and as with its immediate predecessor, several design modifications were embodied.

A considerably more efficient combustion chamber of a much improved internal shape was the main feature of the new design, which incorporated, in addition, a special cooling system; the motor being finned externally to provide a greater radiation surface. The complete unit, motor and coolant, was in this design mounted outside the liquid oxygen tank—positioned symmetrically below, about the rocket axis. The increased capacity oxygen tank fitted was provided with a pressure relief valve as before; designed to function at a pressure of 90lb. per square inch.

The feed system, too, was improved; a second tank, containing compressed nitrogen, being fitted in lieu of the carbon-dioxide pressure "charger" previously employed. A reversion to petrol as fuel was also made.

This third model, when subsequently tested, proved highly successful in operation, responding perfectly in every way, without exploding.

The "Repulsor" Rockets

After the tests of "Mirak" III were completed, the Society engineers continued with their development work, building several more rockets rather more ambitious both as regards design and size. These rockets were termed "Repulsors"; the first of the type, constructed in the spring of 1931, being designed by engineer Klaus Riedel, essentially for the purpose of free flight test.

The rocket motor of "Repulsor" I consisted of a combustion chamber, distinctly similar to the one employed in the "Mirak" III; housed within a water coolant jacket. This assembly formed the nosing shell. Below, and separated from the motor nosing, were fitted two thin tubular tanks, one containing petrol, with pressure charger, the other liquid oxygen.

Connecting the combustion chamber, and nosing, to the tanks were feed lines, the

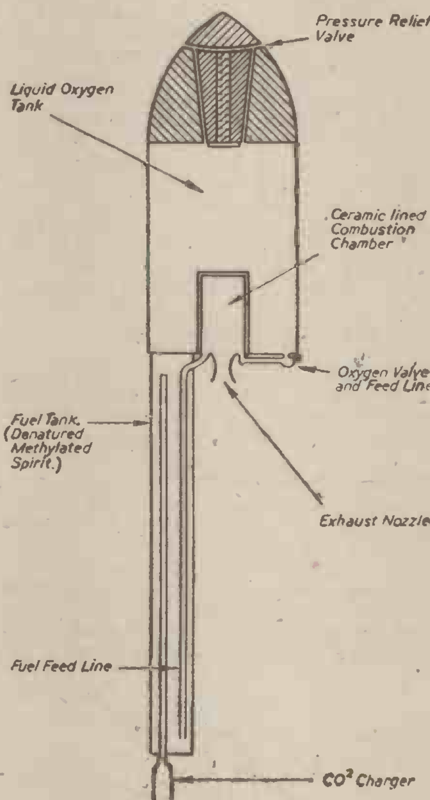


Fig. 10.—Sectional diagram of the "Mirak" II rocket.

tanks being supported beneath by rigid metal struts. The all-up weight of this first rocket of the "Repulsor" series was 250lb.

After initial trials of its motor on the proving stand, "Repulsor" I was fired in free flight on May 14th, 1931. No parachute was provided for descent. Unfortunately, the rocket did not rise vertically, but took off slantwise, striking a small building during its path of flight. Nevertheless, the rocket rose to a height of nearly 200 feet, but was not sufficiently stable, and spun in the air, jettisoning most of the water from the cooling jacket, prior to its return to earth. Examination showed that a hole had been burnt through both the side of the combustion chamber and the outer casing of the water jacket.

A second "Repulsor" (Fig. 12) was built, and was ready for test by May 23rd. This particular model did not differ greatly from its predecessor, the only alteration being the elimination of the heavy support struts. Circular aluminium "hoops" were fitted in their stead, the tanks being supported solely by means of the rigidity of the feed lines. Again, no parachute was fitted.

When fired, "Repulsor" II climbed vertically to about 200 feet, before curving over, slowly losing altitude, and ending in the branches of a tree some 2,000 feet from the point of take-off. A further "Repulsor" was built before the end of the month, and this time a parachute provided to enable a safe return. The design was essentially the same as the former rocket, the only difference being that the tanks were located closer to the rocket axis, in an attempt to improve stability.

The third "Repulsor" was fired in June, and attained a height of over 15,000 feet. Unfortunately, the parachute was released too early in the flight—while the motor was still functioning, and was torn away. The rocket covered a distance of nearly 2,000 feet, in a well-stabilised flight, before hitting the ground as a complete wreck.

In all, more than 30 "Repulsor" type rockets were built, and most of their tests were recorded as highly satisfactory. Some of the later rockets were termed "one-stick Repulsors," and differed considerably from the early types, the main distinguishing feature being that both tanks were placed in line about the vertical axis. The first rocket of this type was free-flight tested in August, 1931, and attained an altitude of practically 33,000 feet; a parachute opening at the peak of trajectory, wafting the rocket gently back to the ground.

Rocket Motor Tests

While work on the "Repulsors" continued, another section of the Society concerned itself essentially with the development of the rocket motor combustion chamber. These investigations resulted in the construction of a number of highly efficient rocket motors of varied internal shapes, which were subjected to stringent test on the Society proving stands. Specially constructed reaction units of highly durable metals were thoroughly tested, and many of the special heat-resisting steels and alloys produced up to that time were quickly disposed of as practical combustion chamber materials. A number of rocket motors, constructed of materials considered to be highly satisfactory for the purpose, literally disintegrated into a mass of white hot sparks, after being on test for merely a few seconds. Others, fired for their respective runs, were so severely scarred internally that they had to be discarded as useless for further experiment. Nevertheless, several successful rocket motors were produced during 1931, most of these being constructed of aluminium. By the end of 1933, over 500 individual ground tests had been satisfactorily concluded at the Ratenflugplatz. Six large Oberth designed rockets were also built during this period, but did not prove so efficient (relatively) as the third "Mirak," and "Repulsor" types, although on occasions thrust values of over 450 lb. were recorded during tests.

End of the Verein für Raumschiffsfahrt E.V.

At one time, during the peak of its career in 1929, the Verein für Raumschiffsfahrt E.V. had a total of nearly 2,000 members on record. However, by 1933, the Society's numerical strength was considerably changed, only 200 members remaining. Due to the consequent depletion of funds, publication of "Die

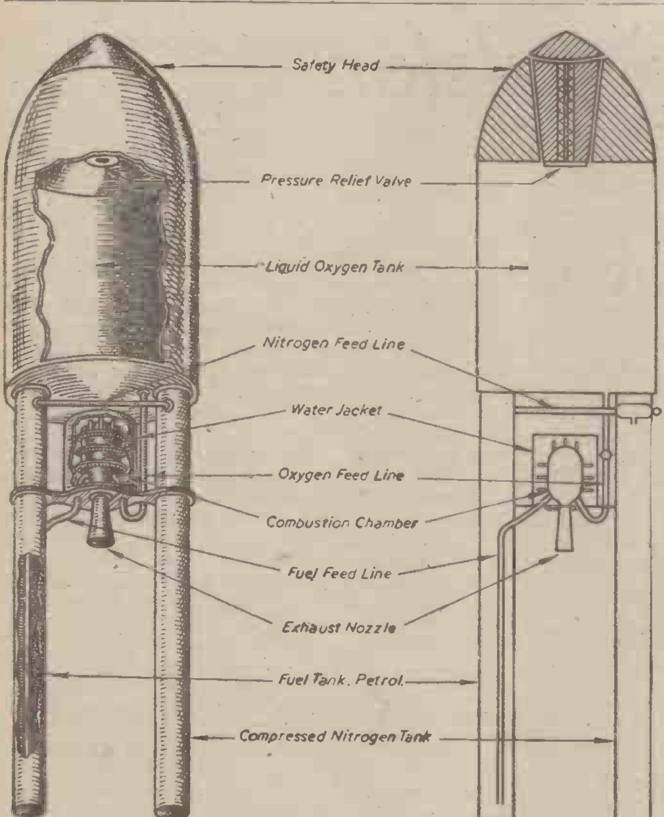


Fig. 11.—Exterior and sectional diagram of the " Mirak " III rocket.

Rakete," the Society journal, was indefinitely suspended early in 1933. Towards the end of the year, the position had grown considerably worse and the Society was facing the prospect of disruption.

Not only were troubles restricted to lack of funds; prominent members were accused of using the Society for personal gain, and there were also questions of extravagance.

While this dispute was at its height, Willy Ley (one time vice-president of the Society), together with a number of his associates whose interests in the development of the rocket were less superficial than the rest, disassociated themselves completely from the Verein für Raumschiffsfahrt E.V. A short time after, the Society was dissolved.

The German Interplanetary Society

Ley's idea was to form another research group around the nucleus of rocket enthusiasts which remained, in order that the work of years should not fade with the name of his former Society, and with the aid of another German organisation, the E.V. Fortschrittliche Verkehrstechnik (Society for the Progress of Traffic Technique), a Society interested in all forms of propulsion, success in this direction was achieved. A proposal was put to Dr. Otto Steinitz, the founder of that Society, to the effect that the Ley group should amalgamate with the E.V. Fortschrittliche Verkehrstechnik, with the view to establish the projected coalition as the German Interplanetary Society. This proposal was readily accepted by the Steinitz organisation, which at that time was also in precarious straits with regard to funds. Thus substantially augmented numerically, the new Society grew slowly but steadily in strength, and by the spring of 1934 the total membership had risen to about 200. Regular publication of the Society journal, " Das Neue Fahrzeug," was also possible by the increased income, which although adequately sufficient to satisfy this problem, was not, however, large enough to finance practical experimentation. Nor was this the worst of their problems; the rise of National Socialism throughout Germany did not make the problem of maintaining the Society an any too easy proposition, and complications with the military authorities soon arose, making the prospect of further progressive research virtually impossible.

In 1935, Willy Ley, together with H. Scharfer, another engineer of the Verein für Raumschiffsfahrt E.V., and other fellow countrymen quick to size up the situation, quitted the German scene, travelling to the U.S.A. There Ley continued his researches; but mention of this more current work will be made in a subsequent article.

On the other side, Hermann Oberth, von Opel, and many others prominent in German rocket development, remained in Germany, getting caught up in the Nazi ideals. (Unofficial reports have indicated that the German long-range rocket weapon, " V-2," is an Oberth creation.)

In this way, free German research came to an end, later rocket development being catered for by special Government departments under a cloak of extreme secrecy.

An Austrian Research Society

Another European rocket society, the Oesterreichische Gesellschaft für Raketentechnik (the Austria Society for Rocket Technique) was formed on August 16th, 1930, in Vienna. Investigations were concerned largely with theoretical research of the problems connected with interplanetary communications; engineer G. von Pirquet, the Society's vice-president, featuring prominently in this work. A similar fate as that which befell the German Society, however, brought about disruption of this group but a few years after its formation.

Fig. 12.—Diagram of the " Repulsor " II rocket.

The American Interplanetary Society

In the spring of 1931, a year after the formation of the American Interplanetary Society, the president, G. E. Pendray, travelled to Germany and visited the Ratenflugplatz. There he witnessed a number of tests of the " Repulsor " type rockets, and gained much valuable experience, both concerning the design and construction of liquid fuelled rockets, and also of the organisation of the Society itself.

Upon his return to New York, Pendray set about a policy of reorganisation, combining ideas of his own society with those of the German group, and finally succeeded in the establishment of an experimental programme to cover the development of a series of liquid fuelled rocket units.

As might be expected, the first rockets constructed by the Society engineers were not highly original in design, but incorporated many features proved by the German " Repulsors." A great deal of acutal test experience was required before technical improvement became a practical possibility, but within a relatively short space of time the Society successfully constructed and proved as highly satisfactory, a number of rockets embodying many original design innovations.

A.I.S. Experimental Rockets Nos. 1 and 2

The first rocket, Experimental Rocket No. 1, fuelled by petrol with liquid oxygen, was tested in November, 1931. For the purpose of this, and subsequent tests, the Society engineers constructed a small proving stand.

During the initial firing, however, an accident occurred in which parts of the combustion system were damaged. In view of the mishap, the Society's first rocket was not put to further test. Instead, a number of components, which included the motor and tanks, were used in the construction of Experimental Rocket No. 2, the design and building of which occupied the Society for a year and a half. After a number of proving stand trials, the rocket was finally fired in free flight on May 14th, 1933.

The rocket was fired out over the sea from the Society's proving ground at Staten Island, New York, and exploded upon reaching a height of approximately 250 feet. An examination of the wreckage found that the liquid oxygen tank had burst, despite the fact that a relief valve was fitted—the direct cause being the heat from the combustion chamber had effected an excessive expansion of the contents.

Rocket Propulsion

Further Details of American Research : The First British Rocket Society

By K. W. GATLAND

(*Continued from page 50, November issue*)

SINCE its formation in 1930, the American Interplanetary Society published a monthly *Bulletin*, but in May, 1932, the title of this was changed to *Astronautics*—a journal to-day heralded as the finest of its kind. From that time until January, 1933, the Society's official publication continued to appear each month, but in order to reduce expenditure, issue has since been made at quarterly intervals. Economy thus achieved financially, a more elaborate research programme was drawn up, and in September, 1933, the construction of three more rockets was begun.

In the Spring of the year following, however, the Society changed its name, the term "Interplanetary" being discarded in favour of the more conservative American *Rocket* Society, a change made in the belief that many prospective members considered the Society's space-crossing ideal unattractive at that early stage of technical development; nevertheless, it was emphasised that the alteration by no means meant to infer a general abandonment of the interplanetary idea.

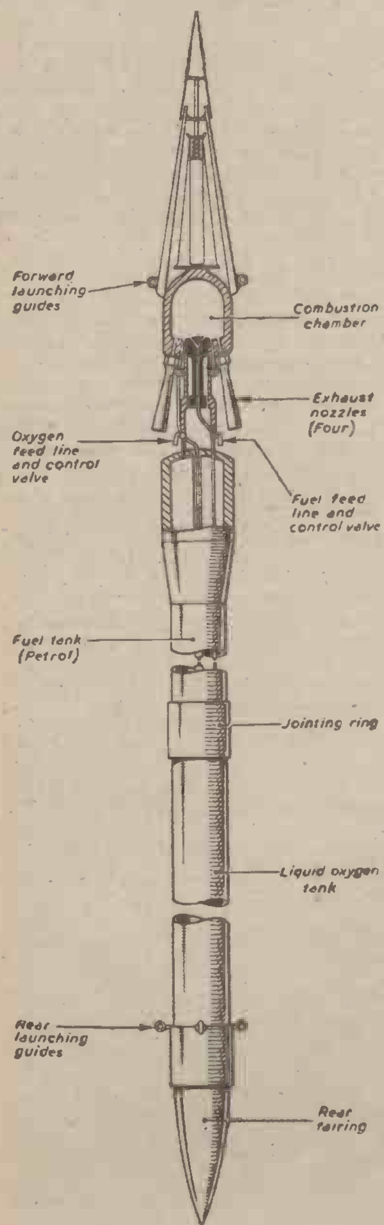


Fig. 14.—*Experimental rocket No. 4, of the American Rocket Society* (1934).

A.R.S. Revised Research Programme

For the prosecution of the new development programme, the A.R.S. Experimental Committee was divided into three sections, and certain research engineers made responsible for the individual design and construction of the three projected rockets, the following, many now well known among rocket authorities, being prominently featured: Experimental Rocket No. 3, G. E. Pendray (at that time President of the Society), A. Africano and B. Smith; Experimental Rocket No. 4, L. Manning, C. Ahrens, A. Best and J. Shesta; and Experimental Rocket No. 5, N. Carver, H. F. Pierce, and N. Schachner.

A.R.S. Experimental Rocket No. 3—Design

The general layout of the Society's third rocket (Fig. 13) was, to say the very least, original.

The combustion chamber was located at the rocket "head," the top of which formed externally a conical nosing. The motor was built in two halves for easy replacement should any damage be sustained during testing runs.

A nozzle of high expansion ratio extended the entire length of the rocket, and for almost half its depth the nozzle was jacketed by the petrol tank, which served as coolant for the nozzle throat, the heat dissipation acting conversely to vaporise the fuel, and facilitate the feed problem.

The liquid oxygen tank was positioned concentrically within the outer rocket shell, and by this arrangement the volatile "supporting" element was adequately insulated from combustion heat. The space between the two tanks was employed for storage of compressed nitrogen, employed for feeding the fuel.

Supported about the lower portion of the rocket, a venturi duct, or "thrust augmenter,"—a device designed to increase thrust and provide stability during flight—was fitted.

A.R.S. Experimental Rocket No. 4—Design

Rocket No. 4 (Fig. 14) differed considerably from the former design; the motor, located at the rocket "head," incorporated four nozzles inclined laterally to eject the exhaust away from the narrow section tanks. The fuel tank was supported directly beneath the motor, and the liquid oxygen tank below this.

The complete rocket, fitted with nose and tail fairings, measured 7ft. 6in., the maximum cross-sectional diameter being only 3ft.

A.R.S. Experimental Rocket No. 5

In the fifth rocket project a feeding system was evolved which dispensed entirely with the compressed gas "charger"; instead, the expansion of the *liquid oxygen* being employed as the fuel pressure medium. This was arranged by the simple procedure of housing both liquids within a common cylindrical tank, the two fluids being separated by a movable piston. Pressure due to expansion of the liquid oxygen caused the piston to rise in the cylinder, so applying the pressure to the fuel, the pressure within the oxygen compartment at the same time remaining adequately sufficient to provide self-feed of the "supporting" element. The reaction motor was fitted, as in Rocket No. 3, at the "head" of the projectile, serving the dual purpose of combustion chamber and nosing.

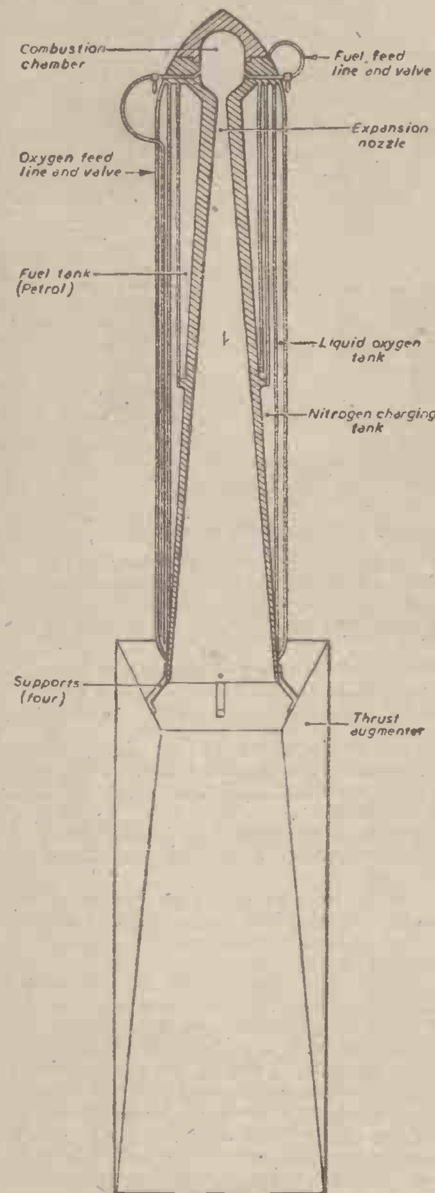


Fig. 13.—*Experimental rocket No. 3, of the American Rocket Society* (1934).

A.R.S. Experimental Rocket No. 4—Trials

The first rocket to be completed, Experimental Rocket No. 4, was put to preliminary stand test on June 10th, 1934, the trial taking place at the Society's proving ground, Staten Island, New York. As a result, a fault was found to be that the inlet ports to the combustion chamber did not allow for an adequate supply of fuel, which resulted in oxydation and "burn out" of the motor.

Another motor was constructed, and the

Professor Hermann Oberth and others of the Verin für Raumschiffahrt E.V. In the foreground is one of the early "Mirak" type rockets. The other is an altitude rocket developed by Oberth (1931).

necessary alterations to the feed system carried out, but it was not until September 9th that the rocket was finally launched in free-flight.

The test was reported in the October issue of *Astronautics*, describing the flight as follows:

"Directly the valves were opened, the rocket leaped from the launching rack. Almost vertical flight was maintained for nearly 300 feet, at which point the rocket turned rather sharply out to sea. It was at this point, observers assume, that the burned out nozzle failed, shifting the direction of the propulsive forces acting on the rocket. The rocket rapidly sloped over until it was headed directly towards the water. Shortly after the change of direction, it began to 'hunt.' It struck the ocean with a terrific splash, the force of the impact bending the upper part."

During test, the rocket rose to a maximum height of 382 feet, and attained a speed well in excess of 600 m.p.h.

The projectile was recovered and examination of the motor revealed that one of the four nozzles had suffered severe burning rear of the "throat" with the result that the reactive balance had become upset, thus affecting the rocket's stability. Due to this defect, the parachute release mechanism did not function.

The term "hunt" referred to in the official test report may require elaboration. This is merely an expression meant to convey the manner in which a projectile may be observed to deviate from side to side as the result of compressibility, built up at the nose, when its forward speed is in the sonic region. The swerving is a natural inclination to dodge this local compression area.

This problem has since been overcome, to some extent, by the employment of automatic stabilising devices, such as the highly successful gyro/vane system tested during the Goddard rocket trials of 1935.

In the light of experience gained from the tests of Experimental Rocket No. 4, the A.R.S. Experimental Committee concluded that a great deal more routine ground test work was necessary before any practical gain could result from the firing of Rockets Nos. 3 and 5.

As the rocket motor had been the chief fault in every experiment hitherto conducted, the main effort was directed toward the general improvement of the propulsion unit.

Reaction Motor Tests

At the Society's proving grounds at Creswood, on April 21st, 1935, the first series of individual motor tests was made, and a number of motor forms embodying both long and short nozzles were put through their paces on the proving stand. The results of various tests were, however, by no means conclusive. It was found, for instance, that the length of the nozzle did not have material effect on the developed thrust of a given combustion chamber. Some measure of improvement was found when varying feed pressures were tried; it was discovered, for instance, that efficiency was greatest if the fuel was introduced into the chamber at a *high* presssure.

The most satisfactory results of the day's work were obtained during the second test conducted, when a maximum thrust of 59lb. was recorded, the chamber pressure being 300lb. For this particular experiment, a short nozzle was fitted. The maximum firing period was 17 seconds.

As the result of these and subsequent motor trials, a considerable amount of empirical data has been obtained for the research files of the Society. Such is the reliability of this data that most features of performance can now be predetermined during design, the test results being mere confirmation of the calculated figures. These methods of calculation will be discussed in a subsequent article.

British Rocket Development—Limitations

In Britain, the development of the rocket can hardly be said to have received encouragement—officially, the use of liquid oxygen for purposes of rocket experimentation is prohibited. The sole range of propellant available for research in this country must come within the bounds of the specified term "approved composition"; that is, certain fuels of the "solid" or powder variety. Yet the restrictions do not end here; under the obsolete Explosives Act, 1875, any experimental rocket, if the experimenter wishes to "keep within the law," though it employs as fuel "approved composition," may be put to test only if the following conditions are satisfied: (a) The firing range must be sanctioned by the local police authorities concerned. (b) The design of the rocket must be approved by the Secretary of State, through his advisers, and (c) The filling of the rocket must take place in premises licensed under the Explosives Act, 1875. It is stated that approval could not, under any circumstances, be given for the use of the liquid oxygen-hydrocarbon propellant; small wonder that to-day, apart from the developments of our American associates, we find the enemy alone using technically progressive rocket weapons.

The First British Rocket Society

Despite the fact that almost insurmountable difficulties lay in the path of the would-be British rocket experimenter, thanks to the determination of one, P. E. Cleator

Valier rocket car, powered by the Heylandt constant volume combustion motor, being charged with liquid oxygen prior to a test (1930).

(author of a foremost rocket literature in the English language, "Rockets Through Space," pp. 246, Allen and Unwin, 1936), the first and probably still the most renowned rocket organisation yet formed in this country, the British Interplanetary Society, was brought into being in 1933. As a beginning, important Press contacts were made, and thanks to resultant publicity, interest in the new science of astronautics was slowly but surely aroused all over the country.

The first official meeting of the Society took place on October 13th, 1933. The founder, P. E. Cleator, was unanimously acclaimed president, while C. H. L. Askham became vice-president, and L. J. Johnson, secretary. The number of persons in attendance at this intial assembly of the Society was six. By the end of the year the membership figure has risen to 15, and due to added publicity provided by the first issue of a Society *Journal*, which for some months was reflected in the National Press, the Spring of 1934 found the Society's numerical strength at 29.

The group's chief problem at that early stage was one of limited finance—publication of a *Journal* at regular intervals was hardly possible on the subscriptions of so few, leave alone to allow for practical research. Various avenues were exhaustively explored in the attempt to gain financial support, but with no success. Finally, in desperation, the Government was approached, and this is what P. E. Cleator has to say of the move in his book, "Rockets Through Space": ". . . The Air Ministry evinced not the slightest interest. The Under-Secretary of State, in refusing to discuss the matter, explained that although rocket experimentation abroad was watched with interest, scientific investigation into its possibilities have given no indication that jet-propulsion could be a serious competitor to the internal-combustion engine and the propeller of the aeroplane. In the circumstances, there could be no justification for spending either time or money on rocket experimentation. . . ."

Here is a classic example of the handicaps which oppose progressive thought in this country. To-day, we can judge for ourselves how wise was that official decision; the German Messerschmitt Me. 163 rocket-propelled fighter, and thermal-jet aircraft, bears adequate testimony.

Further Goddard Research

Soon after the Guggenheim grant made in 1929, Dr. R. H. Goddard set up an isolated laboratory near Roswell, New Mexico, and there continued with his experimental research.

Work at Roswell consisted largely of routine tests of rocket motors and feeding systems, and apart from a brief report, which appeared in the American Rocket Society Journal, *Astronautics*, September, 1934, little information of Goddard developments was forthcoming:

"The work consisted in the construction and flights of a number of models designed primarily to test operation rather than reach great heights. Flight speeds in excess of 400 m.p.h. were obtained. . . ."

In March, 1935, however, information was given of the free-flight trial of a large meteorological rocket, which incorporated a unique stabilising device.

During an initial trial on May 31st, the rocket rose to an altitude of 7,500 feet, attaining a velocity in excess of 700 m.p.h., the time taken in reaching the peak of trajectory being 14.5 seconds. The gyro-stabilising system embodied was designed to operate when the rocket axis deviated more than 10 degrees from the vertical, and at this angle the controlling mechanism brought into play vanes which acted to deflect the rocket exhaust, and so momentarily offset the thrust reaction, to return the projectile to its true flight path.

A motion film taken of the ascent shows the rocket shooting upwards, the action of the stabliser being clearly marked by the undulation of the projectile as it is constantly corrected to the vertical. Further tests of the gyro-controlled projectile took place in October of the same year. The height reached on this occasion was 4,000 feet.

The rockets tested in 1935 weighed from 58 to 85lb. No particular attention was given to obtaining lightness of construction.

Goddard Motor Trial Results

During the test of a certain liquid oxygen/petrol fuelled reaction motor, weighing 5lb., the combustion chamber being 5.75in. internal diameter, a maximum thrust of 289lb., and an efflux velocity of 5,000 feet per second, were recorded. The motor developed 1,030 h.p.

A report of Dr. Goddard's research progress, principally concerning the Roswell experiments, was published in 1936 under the title *Liquid Propellant Rocket Development*, 10pp., Smithsonian Misc. Collections 3381.

(To be continued.)

Letters from Readers

Engineer-built Houses

SIR,—I have read with great interest your series of articles on engineer-built houses, and I am very glad to know that engineers are at last going to interest themselves in the building of houses.

After the last war the engineers tackled the motor-car and not only greatly reduced the cost of cars but also improved both their performance and looks, and I hope they will do the same for houses.

I have noticed that when unloading bricks for house building they are taken five at a time and thrown from hand to hand, and have often wondered why bricks are not made five times as large as they are now. If they were it would surely save cost in building.

Also, why take, say, a door in plain wood and hang it and then paint it with a brush under the worst possible conditions. Surely it would be better to spray-paint it in a factory and take it to the site ready for hanging.

The bombings we have endured have, I feel sure, sickened a lot of people of the very thought of plaster ceilings, and also of plaster on walls, and I hope we shall see plastic boards in place of plaster.

There are many things in the houses we have had to live in that can be improved and money saved by alternatives, and I, for one, am very glad to see that at long last some brains and new ideas are to be introduced into the building trades.

A. H. BENTLEY (Horsham).

Power for Traction

SIR,—I would like to point out an error made in reply to a reader's query, which appeared in your issue of PRACTICAL MECHANICS dated November, 1944.

Your correspondent states that the resistance to the motion of a pneumatic-tyred vehicle on normal road surfaces is the sum of:

(a) Total weight (lb.) divided by 20.

(b) Total weight (lb.) divided by the gradient factor.

(c) Frontal area (sq. ft.) multiplied by $\left[\frac{\text{speed (ft. per sec.)}^2}{25}\right]$

(d) Total weight (lb.) multiplied by acceleration in ft. per sec. and divided by 32.2.

The force required to accelerate the car, however, is not given correctly by (d), as no allowance is made for the acceleration of the engine parts, road wheels, and the whole of the transmission system.

The force required to accelerate the above mentioned masses is given by:

$$F=\frac{\frac{1}{r^2}\left\{I_A+G^2I_B\right\}\times f}{g}$$

where F=Force (lb.), r=effective radius of road wheels (ft.), f=acceleration, g=32.2, I_A=moment of inertia of road wheels and transmission system (lb.—ft.^{2}), G=gear ratio $=\frac{\text{Speed of engine (r.p.m.)}}{\text{Speed of wheels (r.p.m.)}}$, I_B=moment of inertia of engine parts (lb.—ft.^{2}).

This force F should be added to (a), (b), (c) and (d) when calculating the required tractive effort.

—F. L. ELLIS, G.I.Mech.E. (Oxford).

"Catalin"

SIR,—We have noticed in your November issue of PRACTICAL MECHANICS that a correspondent has inquired about information concerning the material "Catalin," and that you have stated that "Catalin" is a proprietary product manufactured and marketed by the Catalin Corporation of America.

We would advise you that "Catalin" has been manufactured and marketed in Great Britain by this Company since 1937. It is a proprietary product and, as you say, is manufactured by the controlled chemical interaction of Phenol (carbolic acid) and Formaldehyde (formalin). The material is then cast into sheets, rods, tubes, etc., for special castings of particular designs. "Catalin," as distinct from mouldings (i.e., Bakelite), is produced with or without a filler to make transparent, translucent or opaque objects by a casting process.—CATALIN LIMITED (Waltham Abbey).

All About the "V-2"

Provisional Details of the Rocket Weapon Vergeltungswaffe No. 2. New Realms of Scientific Endeavour Opened Up

By K. W. GATLAND

NOW that the official "veil" has been lifted on the use of the second Nazi "V" weapon—the long-range rocket shell—we are to some extent free to comment on the technicalities involved.

At the outset, forgetting for a moment its sinister purpose, let us admit directly that "V-2" is an engineering achievement of indisputable brilliance. It is an achievement, too, that will have great bearing on scientific progress in the years of peace to come, by penetration to great altitudes to return with data of conditions existent in the so far uncharted reaches of the atmosphere, and later, by excursions into space itself. But let us trace this further trend of development in logical steps.

"V-2"—Adaptation for Altitude Sounding

The long-range rocket weapon "V-2" is not an instrument designed for the purpose of attaining great heights; the altitude reached is one merely sufficient to carry it, presumably from launching sites located within Reich territory, to districts of Southern England radiating from the Greater London area. The missile is required to "fly high" to achieve *distance* at the minimum expenditure of power.

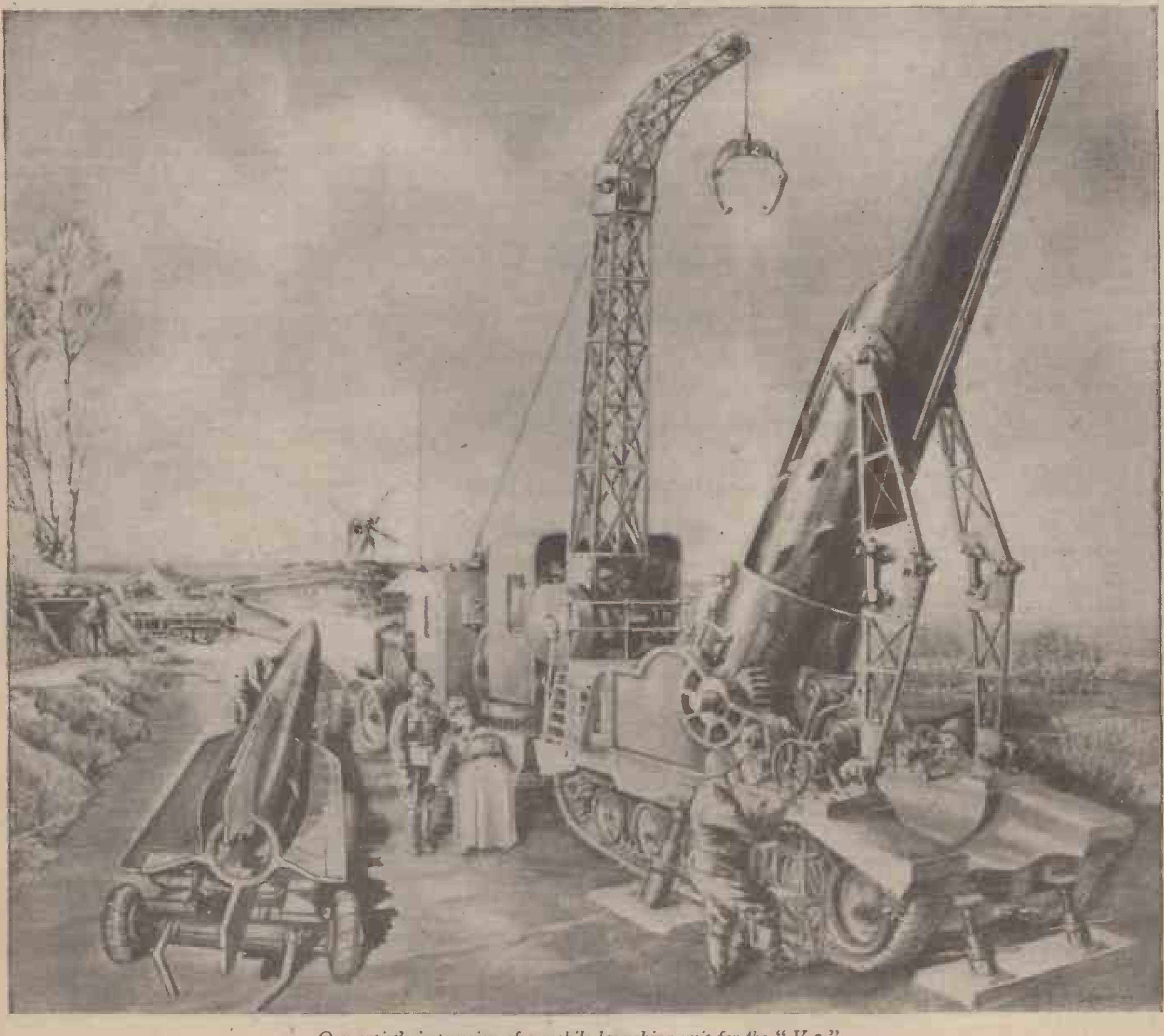
As a weapon of war, the rocket projectile is called upon to carry an explosive load; in this particular instance a war-head of something a little under one ton. It is obvious that if the projectile were used essentially for altitude sounding, this weight of explosive could be replaced by mere *pounds* of delicate meteorological and physical science recording apparatus, the reduction in carrying load adding considerably to the rocket's performance.

We can pursue this question of peacetime adaptability still further. Let us assume the initial mass of the projectile "V-2" to be 15 tons, and the propellent liquid oxygen, with alcohol as fuel. Working from these bases, it is possible to calculate with a fair degree of accuracy details of performance if the missile were projected *vertically*. The figures thus derived give a velocity during ascent of something in excess of three miles per second; the height attainable between 750 and 800 miles.

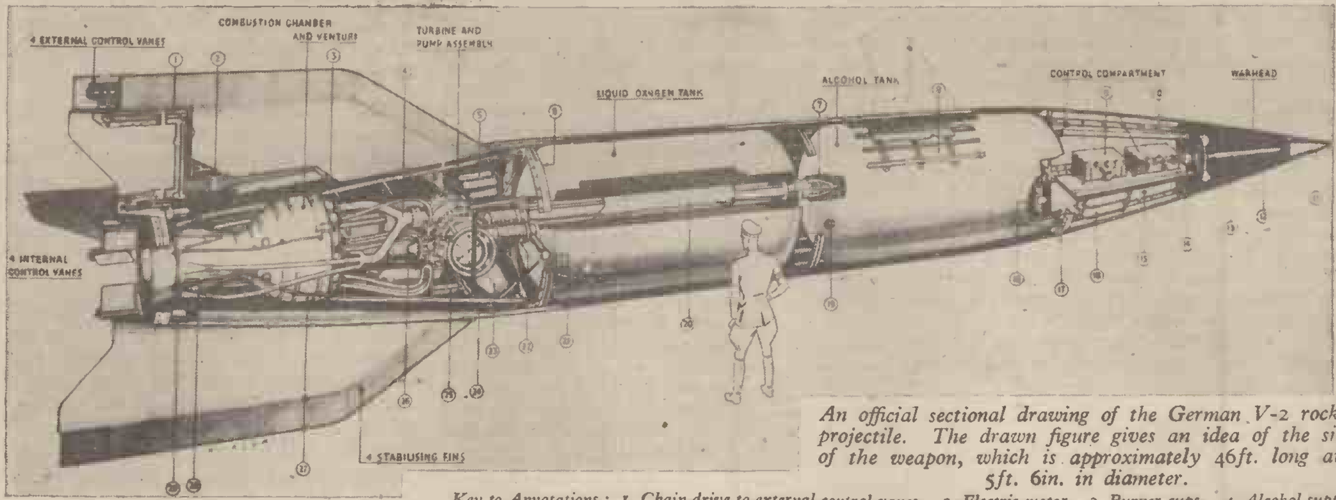
Taking the case still a stage farther: if the war-head were replaced by a self-contained rocket of similar fuel/mass ratio, designed to discharge from the carrier projectile at its maximum velocity, the small rocket would be well able to overcome the earth's gravitational influence and escape from this planet altogether, never to return.

"V-2" In Practice

Working from the most elementary basis, the force required to lift a mass of 15



Our artist's impression of a mobile launching unit for the "V-2."



An official sectional drawing of the German V-2 rocket projectile. The drawn figure gives an idea of the size of the weapon, which is approximately 46ft. long and 5ft. 6in. in diameter.

Key to Annotations: 1. Chain drive to external control vanes. 2. Electric motor. 3. Burner cups. 4. Alcohol supply from pump. 5. Air bottles. 6. Rear joint ring and strong point for transport. 7. Servo-operated alcohol outlet valve. 8. Rocket shell construction. 9. Radio equipment. 10. Pipe leading from alcohol tank to warhead. 11. Nose probably fitted with nose switch, or other device for operating warhead fuse. 12. Conduit carrying wires to nose of warhead. 13. Central exploder tube. 14. Electric fuse for warhead. 15. Plywood frame. 16. Nitrogen bottles. 17. Front joint ring and strong point for transport. 18. Pitch and azimuth gyros. 19. Alcohol filling point. 20. Double walled alcohol delivery pipe to pump. 21. Oxygen filling point. 22. Concertina connections. 23. Hydrogen peroxide tank. 24. Tubular frame holding turbine and pump assembly. 25. Permanganate tank (gas generator unit behind this tank). 26. Oxygen distributor from pump. 27. Alcohol pipes for subsidiary cooling. 28. Alcohol inlet to double wall. 29. Electro-hydraulic servo motors.

tons, with an acceleration factor of 1 g., must be something in the region of 30 tons. Under such conditions, the jet flow of the rocket motors would be only 12lbs./sec., assuming a jet velocity of 6,000 feet/sec., and if the initial weight of fuel were ten tons, this would supply the motors for 30 minutes.

The previous deduction is, of course, purely hypothetical. In practice, the jet flow would probably be in the region of 140lbs./sec; the weight of propellent five or six tons, and the period of firing, at the very maximum, about two minutes. Working to these figures, the thrust reaction calculates to 1,680 tons, and therefore an acceleration of 100 g. This acceleration factor would be almost doubled toward the end of the flight, and, making the necessary corrections for air resistance, the velocity would lie between three and four thousand miles per hour.

Launching

As regards the question of launching the rocket weapon, until such time as more complete details are released by the authorities, we must rely upon the accuracy of information derived through neutral sources, principally Sweden, and also from Holland.

Correspondents in Sweden have described the launching installation as a concrete "well," sunk 80 feet within the ground. Into this the projectile is lowered, and, if the report is correct, actually charged with propellent before being subsequently fired from the "well" along guide rails formed into the concrete side structure.

Information from Dutch sources, on the other hand, suggests that the projectile is merely "stood upright" on concrete slabs, and fired direct. It is quite probable, of course, that both launching systems are employed. There has also been a suggestion that special portable launching installations have been in use.

Directional Control and Trajectory

Whatever its method of take-off, there can be little doubt that the rocket is initially fired vertically in order to surmount the more dense regions of the atmosphere as quickly as possible.

To maintain a vertical flight path, gyroscopes, acting on airstream and exhaust vanes, are employed, operating on the same principle as the Goddard gyro/vane stabiliser (see PRACTICAL MECHANICS, December, 1944, p. 101).

It is also likely that a system of radio-control is used to set the projectile on a final parabolic trajectory, again by the employment of gyro/vane controlling mechanism.

The rocket motors continue to fire until a certain predetermined velocity is attained, and at that precise instant an integregating accelerometer is used to "cut-out" the power. The projectile then "coasts" under momentum for the balance of the distance, the airstream vanes automatically correcting any deviation from the pre-set path.

It is possible that beam transmitting apparatus is included in the equipment of some projectiles, as with the "V-1" pilotless aircraft, for determining the position of the missile.

Upon entering the more dense strata, compressibility friction, due to the passage of the missile at supersonic velocity, causes the forward part of the rocket to be heated considerably, and to the observer the rocket plummeting to earth emulates a meteor, or "shooting star." This com-

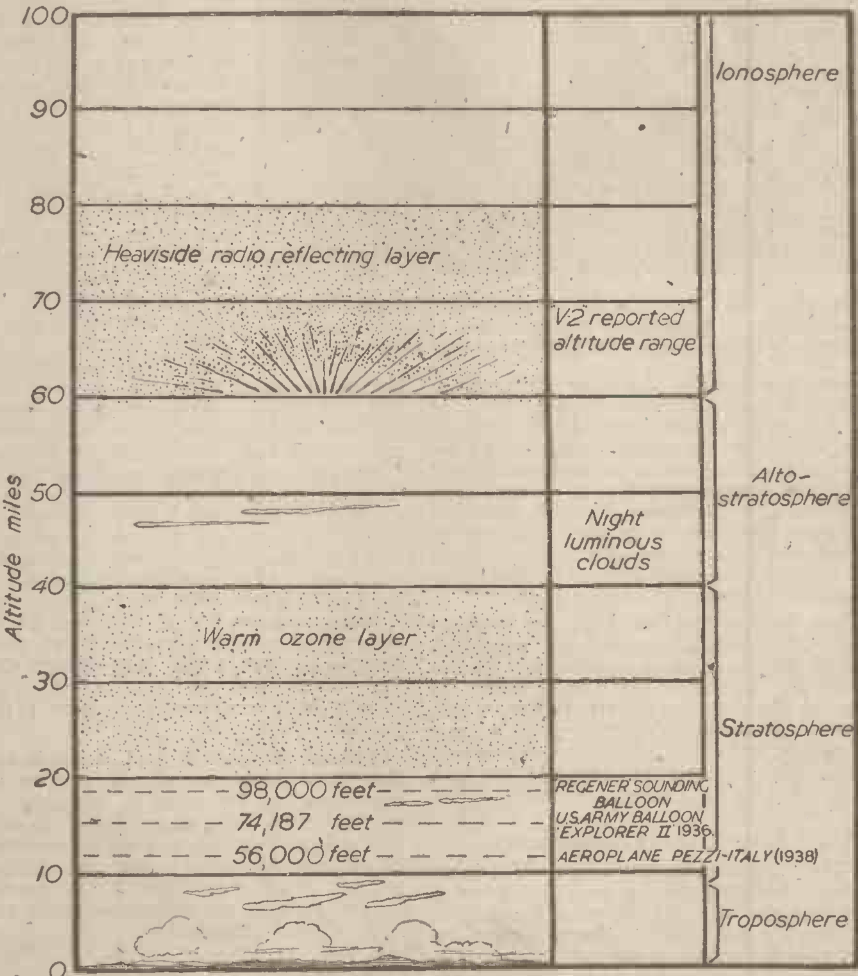


Chart of the atmosphere. Comparisons of past altitude achievement with that of the "V-2" rocket projectile.

pressibility is undoubtedly responsible for the many mid-air explosions which have occurred, although some form of heat resisting carapace is probably provided at the rocket "head."

The Power Installation

The power unit would appear to be a multi-engine arrangement, consisting of between 15 and 20 individual reaction motors of the constant-volume type. This system of propulsion would thus allow for a fine measure of propellent control, and, in addition, would permit the rocket to function even if individual motors were to "burn-out." Each motor is arranged to fire into a single large convergent-divergent chamber, where expansion of the gases generated in the combustion chambers takes place, prior to their final ejection. Propulsion is effected, not, as so often erroneously purported, by the "reaction of the exhaust on the atmosphere," but in accordance with Newton's much used "Third Law of Motion," which states, in effect: "For every action there is always an equal and opposite reaction." In the case of a rocket, the gases ejected forcibly rearwards *react on the producing plant.*

Part of a "V-2" bomb which fell in Southern England recently. This part has a metal casing between 2 and 3ft. in diameter, and contains a turbine engine, the fuel pump and 18 propelling jets.

For feeding the fuel, hydrogen peroxide and calcium permanganate are employed, which serve to generate superheated steam to drive the turbine. The turbine serves to operate the fuel and oxygen pumps, which extract the propellent components from their respective tanks, and feed them at constant and high pressure, in correctly metered proportion, to the combustion unit.

"V-2" Disposition of Components

The illustration on page 115, which is an official Air Ministry drawing based on a thorough investigation of parts found both in Britain and Belgium, shows clearly the layout of the main components:

The explosive charge—less than one-twelfth the total weight—is contained at the rocket "head." Directly behind is situated a control compartment, in which the radio control and D/F equipment are contained; with the control gyros still farther behind. Aft of these come the fuel and liquid oxygen tanks, in that order; then, the turbine and pump assembly. From the latter emanate feeder lines, which connect to the combustion units and also to supplementary fuel burners in the convergent-divergent venturi.

Four efflux control vanes, which act under gyro control, are fitted to deflect into the efflux stream, regulating the projectile's course by virtue of offset thrust. In addition to these, four large stabilising fins—which extend from the rear for almost a third of the rocket's length—are provided, and at the rear tip of each is incorporated a small vane for atmosphere control, also functioned by the gyros.

Construction

The rocket structure is built up on the monocoque principle; consisting of closely spaced circular forming members, with longitudinal "U" section stringers.

As with the "V-1" pilotless aircraft, sheet and formed steel are used extensively. The propellent tanks are of dural construction.

Development

The reported flight path of the "V-2" projectile bears considerable resemblance to the scheme originally proposed by Professor Hermann Oberth, as outlined elsewhere in this journal; but whether or not Oberth is the technician chiefly responsible for "V-2" is still very much a matter for conjecture. It would appear far more likely that Rudolf Nebel, one time prominent engineer of the Verein für Raumschiffsfahrt, and staunch supporter of the Nazi Party, is the mind behind the development of the long-range rocket weapon. Although Nazi himself, Oberth—Rumanian by birth—had a pacifist outlook, and was a distinct hater of Germans.

Most of the preliminary work on German long-range rocket weapons, during the present conflict, has been carried out at Peenemunde, the German research station on the Baltic, and also, though on more moderate scale, at the more remote experimental sites in Norway, principally at Hardangerplata.

Initial work on "V-2," it is thought, was commenced early in 1942, though, of course, modern German rocket development dates back far beyond the war period, as has already been recounted to readers of this journal.

Toward the close of 1943, it would seem that mass production of the weapon was commenced in fair quantity, but thanks to the continued force of the Allied air offensive, which included, in addition to attacks on the many important manufacturing plants, several assaults on the Baltic research station, development and manufacture must have suffered considerably.

Conclusions

The practical demonstration by the Germans of a rocket projectile of such spectacular performance makes the advent of "V-2" undoubtedly the most memorable achievement in the history of *astronautics.*

The peacetime implications of the development cannot be too strongly emphasised. In its present form, "V-2" must attain an altitude of between 60 and 70 miles. The greatest height previously reached by any man-made contrivance was 98,000 feet, by an unmanned sounding balloon. (See chart on previous page.)

A rocket with the performance of the German long-range missile, fitted with meteorological and specific scientific instruments, would be capable of doubling our present knowledge of the state and nature of the atmosphere at great altitudes. The data thus received would make possible long-range weather forecasts of conditions at lower levels, and would, in effect, raise meteorology to the status of an exact science.

The investigation of electronic phenomena would also be possible. There has never been so many conflicting theories advanced as in the investigation of *cosmic radiation,* for instance. Scientific authorities are generally agreed that these rays have their source in outer space; but by what means has never been directly classified. Moreover, the effects on the human system of cosmic bombardment have, too, never been conclusively defined. A theory has been advanced that the cosmic rays have considerable bearing on the human organism, influencing growth, life-span and general health. It has been said that their effects on earth are "damped" to a certain degree by the density of the atmosphere, and that the intensity of the radiation becomes greater as the atmosphere thins with altitude. Others assert that the effects noticeable at ground level are produced by secondary radiations resulting out of cosmic bombardment on the atmosphere, and that the rays beyond the limits of the atmosphere have no harmful effect.

THE LONG-RANGE ROCKET SHELL

Overall Length	46*ft.*
Max. Shell Diameter	5*ft.* 6*in.*
Total Weight (fully charged with propellent	12-15 *tons*
Weight of Explosive Charge	1,900*lb.*
Weight of Propellent, Liquid oxygen	11,000*lb.*
Ethyl Alcohol	7,500*lb.*
Power unit	*Convergent-divergent combustion unit with 18 individual combustion chambers.*
Present range	200 *miles*
Time, under power	2 *mins. approx.*
,, from launching to impact	5 *mins. approx.*
Max. Speed	3,000 *m.p.h.*

With further development, it should well be possible, almost certainly within the present century, not only to provide conclusive answers to these "scientific unknowns," but to bring about manned flights into space, and ultimately to achieve man's greatest potential conquest, the power to travel between the worlds of the Solar System. In the time between the present day and the achievement of interplanetary communication, many of the unfathomable mysteries of the universe which have eluded solution for so long will be laid open to us in our constant search for positive knowledge. "V-2" is without doubt a first practical step toward the "conquest of space."

Rocket Propulsion

Mails by Rocket: Rocket Propelled Aircraft

By K. W. GATLAND

(Continued from page 101, December issue.)

MANY new research groups and individuals featured prominently in the development of rocket science during the middle 1930's. Apart from the rocket organisations previously mentioned, three more such groups were formed; in the U.S.A., the Cleveland Rocket Society, established in 1933, and the Peoria Rocket Association (Illinois), and in Holland, the Stichting Nederlandes Rakettenbouw (Dutch Rocket Society), both founded during 1934. The Cleveland Society was originated by Ernst Loebell and E. L. Hanna. The former was a prominent engineer of the German Raketflugplatz, before becoming nationalised as a U.S. citizen.

In 1935, another valuable contribution was made to the available rocket literature, by the publication of *L'Astronautique Complement*, R. Esnault-Pelterie, A. Lahure, Paris, a supplement to Pelterie's monumental treatise of 1930.

Zucker experimenting before the German military in 1933.

Gerhard Zucker

Another advocate of the rocket as a mail carrier was German born Gerhard Zucker. This experimenter conducted his initial postal rocket trials in 1933, when he established a successful delivery over the Hartz Mountains, N. Germany. Subsequently he demonstrated large powder rockets before the German military authorities.

A year later, in May, 1934, Zucker travelled to England, and during his stay carried out several mail rocket experiments. None of these further tests, however, can be said to have been crowned with great success.

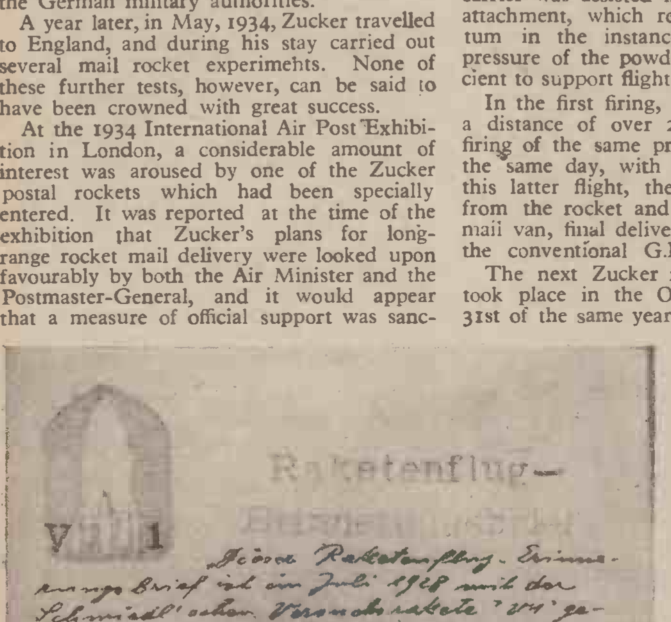
At the 1934 International Air Post Exhibition in London, a considerable amount of interest was aroused by one of the Zucker postal rockets which had been specially entered. It was reported at the time of the exhibition that Zucker's plans for long-range rocket mail delivery were looked upon favourably by both the Air Minister and the Postmaster-General, and it would appear that a measure of official support was sanctioned, at least for the initial tests of rocket mail carriers in this country.

First Trial

The first trial of a mail rocket in England took place near Rottingdean, Sussex, on June 6th, 1934. The rocket projectile used in this particular experiment contained over 1,000 letters, and was fired from an inclined wooden launching rack. The rocket carrier was assisted into flight by a catapult attachment, which rendered initial momentum in the instance before the reactive pressure of the powder charge became sufficient to support flight.

In the first firing, the rocket travelled for a distance of over 2,600 feet. A second firing of the same projectile took place later the same day, with similar success. After this latter flight, the mail was transferred from the rocket and taken to Brighton by mail van, final delivery being made through the conventional G.P.O. service.

The next Zucker rocket mail experiment took place in the Outer Hebrides on July 31st of the same year, the intention being to link the islands Scarp and Harris, in the Western Isles.



World's first flown rocket message, by Schmiedl's postal carrier "V.1." A translation of the message is as follows: "ROCKET-FLIGHT-COMMEMORATION LETTER. This rocket-flight-commemoration letter was flown with the Schmiedl experimental rocket 'V.1' in July, 1928. With the rocket 'V.1' were sent 19 such letters, which were all numbered consecutively; this commemoration letter bears the number 14. Schmiedl."

The rocket used in this trial was of a larger type than its predecessors, and within a hinged nose compartment were contained 1,200 letters. Again, powder was employed as a propellant. Unfortunately, however, the rocket exploded before it could lift from the launching rack, and was completely destroyed, and tattered and charred remnants were all that remained of its postal cargo. A further and similar test was later carried out in the Western Isles, but this, too, was culminated by an explosion.

Mainly because of these failures, official support of the Zucker postal rocket experiments was withdrawn. Indeed, while carrying out a later rocket trial in the Isle of Wight on December 25th, 1934, the police intervened and stopped the launching of a rocket intended to reach the mainland, on the grounds that official permission had not been sanctioned. It was made clear that the test could not take place unless the projectile was made to fall into the sea, off-shore of its destination.

In order to meet the requirements of the authorities, Zucker was forced to reduce the propellant charge. When fired, the rocket rose successfully from the launching rack, but lacked sufficient power, and wind blew it from its course. The mail, which landed in Pennington Marshes, was recovered and taken to Leamington for normal G.P.O. delivery. Had the Isle of Wight trials been allowed to take place as originally planned, it was considered that success might finally have been achieved. As it was, the difficulties imposed by the British authorities made it obviously clear that no further gain would result from remaining in the country, and early in 1935 Zucker returned to Germany. Since that time, news on any further activities has been entirely lacking. This year, however, the *Sunday Express*, quoting the German *Hamburger Nachrichten*, published a report concerning an announcement that Herr Gerhard Zucker had been shot by the Gestapo for trying to communicate to a foreign Power secrets of German rocket developments.

Mail-carrying Rocket Aircraft

Small, power-driven rocket 'planes were employed by the German J. K. Roberti in mail experiments carried out in 1935-36.

One of these aircraft, flown just prior to the German postal-rocket ban, was launched from Duinbergan, on June 4th, 1936. The 'plane, which represented the most ambitious mail carriage experiment conducted by Roberti, had an overall length of five feet, and a wing-span of nearly six feet. The weight of the aircraft, fully laden with 2¼lb. of mail, was just over 6½lb. Particular care was taken in design to ensure that structural weight would be the very minimum.

A small catapult-assisting device was employed for the take-off, and when fired the 'plane rose perfectly, flying in the direction of Knocke. Unfortunately, due to a

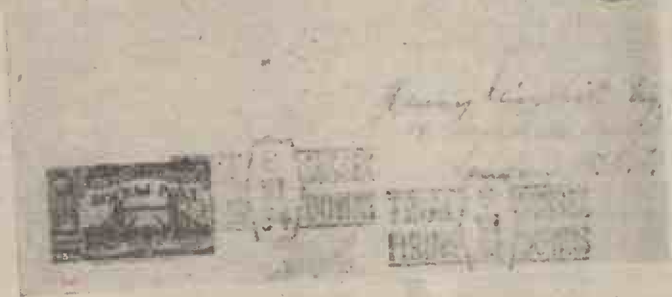
Reproductions of Rocket Flown Envelopes and Cards

Card carried by Schmiedl's 'N.3' in 1935, showing parachute descent. Signed by Schmiedl.

Card flown by the first U.S. rocket 'plane at Greenwood Lake, N.Y. (1936). Signed by Willy Ley.

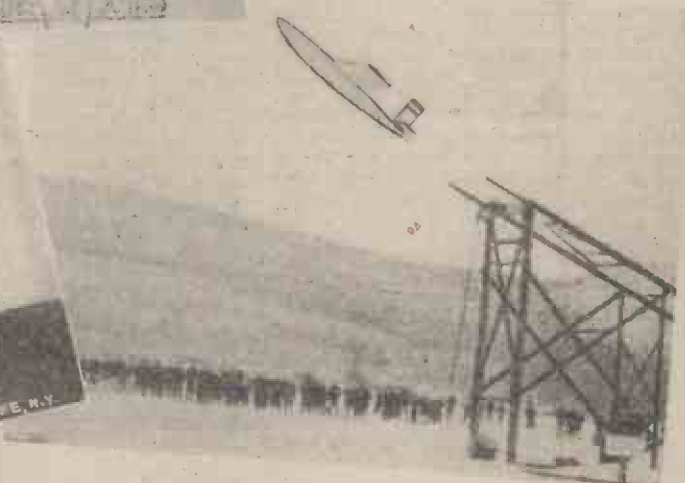
(Below) Envelope carried by a Zucker rocket in a night firing experiment at Hasselfelde (1933). Signed by Zucker.

World's first trial under postal authority, Cuba, 1939.



(Right) Letter flown in Zucker's first postal rocket experiment in Gt. Britain —Sussex Downs, 1934.

The first U.S. rocket 'plane in flight at Greenwood Lake (1936).



Rocket 'plane leaving the launching installation at Greenwood Lake, N.Y.

structural weakness, both the wing installed rocket units tore loose from their mountings after a few seconds' flight, continuing as projectiles, and fell several miles distant. The fuselage of the 'plane crashed into a boulevard near Knocke-Zoute.

Tail-less Rocket 'Planes

Other experiments, conducted at Wesermünde, concerned the propulsion of small, unmanned tail-less rocket aircraft, designed by Herr Espenlaub and Herr Sander. The latter will be remembered as the manufacturer responsible for the propellant charges of the Valier-Opel rocket car and 'plane experiments.

A rocket aircraft of this type, towed into the air by a conventional light aeroplane, and released at a height of approximately 60 feet, travelled for a distance of one and a quarter miles. This tail-less machine was fitted with a single powder propellant charge installed on the centre-line, at the c.g. The wings, which were swept back to the tips, incorporated large controllable dual purpose aileron/elevators at the trailing edge, close to the wing tips, and also, vertical stabilisers, one at the extremity of each wing.

Liquid-fuelled Rocket Aircraft

Perhaps the most interesting and technically progressive rocket 'plane mail trials, made to date, took place at Greenwood Lake, New York, U.S.A., during the winter of 1936. The motors of these rocket 'planes, of which there were two, were designed and built by Nathan Carver, of the Reaction Research Laboratories, New York, and prominent member of the American Rocket Society. The propulsion unit, which Carver termed the "concentric feed reaction motor" (Fig. 15), employed liquid oxygen, with denatured alcohol as fuel, and incorporated a unique pre-mixing system, by which the oxygen was introduced directly from the motor "head," the fuel entering through an annular manifold. By this system the oxygen is surrounded by a layer of fuel which acts as insulation, and functions to prevent oxidation of the chamber walls, which are protected until the propellant is adequately mixed, and combustion is virtually complete. the principle of the "concentric feed" motor is shown in Fig. 16.

Concentric-feed Reaction Motor—Initial Tests

Theoretical consideration prior to construction set the desired minimum reaction of the rocket motor at 35lb., with a firing period of 30 seconds.

A number of the Carver concentric-feed motors were subsequently built, with interchangeable nozzles and chamber sections, and numerous proving stand trials conducted, the various motor sections being interchanged until the desired specifications were met. During a final test run, which took place on January 2nd, 1936, the motor recorded a thrust reaction of 41lb., operating for a period of 37 seconds, thus amply fulfilling the requirements. Further details of the test are as follows:

Motor—General Particulars

Propellant, denatured alcohol, 3.35lb.; liquid oxygen, 7.23lb. Tank pressure throughout, 150lb. Motor (material, brass and monel), overall length, 15.5ins.; weight 2.5lb. Nozzle (material, monel), length 4ins., throat diameter, .50in., orifice diameter .75in.

Proving Stand Data

Reaction (first test run), 34.50 seconds, 40lb. Second test run, 2.50 seconds, 50lb. (Due to the burning out of a plug, the nozzle was blown off at the beginning of the second firing run.) Impulse, 1,517lb./sec. Average jet flow, 28lb./sec. Average jet velocity, 4,700 ft./sec. Average fuel input, 850,000 ft. lb./sec. Average jet output, 96,000 ft. lb./sec. Thermal efficiency, 11 per cent.

Rocket Aircraft—Design and Trials

The 'planes themselves, designed by Willy Ley and F. W. Kessler, were of the high wing cantilever type, 11ft. in length, with a wing span of 14ft. 6ins. The mails were

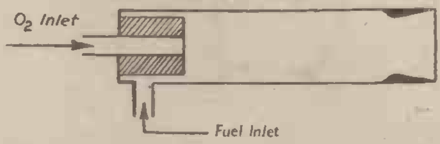


Fig. 16.—Principle of the concentric-feed rocket motor.

housed within a hinged nose compartment, and the liquid oxygen and fuel tanks positioned about the machine's centre of gravity. The reaction motor was fitted within the extreme end of the fuselage, the nozzle protruding from the rear.

For the actual flight trials entirely new motors—duplicates of the most successful motor form previously tested—were specially constructed.

The initial free-flight was scheduled to take place on February 9th, 1936, between Greenwood Lake, New York, and Hewitt, New Jersey, and a special catapult installation was previously assembled for the launching. This took the form of a large inclined track along which the rocket 'planes were intended to take off from a trolley cradle, drawn to the top by a hawser. Unfortunately, due to unforeseen technical difficulties, the test did not take place on the date planned, causing a postponement of two weeks.

On February 23rd, after necessary alterations had been carried out, the aircraft were finally launched. The first 'plane rose successfully from the launching apparatus and climbed away steeply, unfortunately so much so that it ultimately stalled and dived to the lake surface, slithering along the ice before taking to the air a second time for a brief flight, although the motor was severely damaged.

The second aircraft was launched directly from the ice and took off evenly, but, unfortunately, the wings lacked rigidity and one broke off completely. The motor continued to function, however, and drove the 'plane a considerable distance across the lake. The machine was actually airborne for 17.8 seconds.

Although these rocket 'plane trials could hardly be said to have been successful, failure was entirely due to weaknesses in the aircraft themselves, and was no reflection on the Carver concentric-feed motor, which functioned perfectly at all times.

Rocket Terrestrial Transport

A prominent member of the Austrian rocket group, Ing. Dr. Eugen Sänger (University of Vienna), has contributed a number of important theoretical works on the subject of rocket-propelled aircraft. Sänger featured largely in the development of certain high-speed (supersonic) wing sections and body forms, and was among the first to propose practical aircraft forms for operation at forward speeds in excess of sound.

The propulsion of *aircraft* by rocket power presents many problems. To obtain optimum efficiency, the rocket reaction means must operate at high speeds, and in vacuum —clearly, the atmosphere is the prime limiting factor.

On the other hand, it has been argued by the advocates of the *projectile* transport 'craft that this form of conveyance would provide a far greater economy than the machine employing lifting surfaces for terrestrial purposes. Among those who have suggested the rocket projectile are Max Valier and Prof. Oberth.

Oberth's theoretical conception made provision for commencing the flight vertically so as to impose the minimum air resistance. At an altitude of between fifteen to twenty miles, the projectile, having attained a certain desired acceleration factor, would be turned towards its destination. The balance of the journey would then be made under momentum, the 'craft, upon entering the more dense atmosphere, descending in a similar manner to the orthodox aeroplane, or gyro-plane.

As has been mentioned earlier, Dr. Eugen Sänger is another theorist of rocket aviation, and his writings comprise the most complete mathematical investigations yet published on the subject.

Unlike Oberth, Sänger suggests ascent of the rocket 'craft at thirty degrees, and although the time taken to reach a given altitude is greater, distance is covered at the same time. Other details of performance closely resemble the methods suggested by Oberth; both advocated the employment of supporting 'planes for the descent and landing.

The results of these initial investigations are given in *Racketen-Flugtechnik*, Eugen Sänger (220 pp. R. Oldenbourg), Munchen and Berlin, 1933.

The illustrations which accompany this article are reproductions from collections of the well-known air mail specialist, F. J. Field, and are included by the courtesy of Francis J. Field, Ltd. (philatelic dealers), Sutton Coldfield, Birmingham. Some are of actual specimens of flown mail, and these comprise a valuable historic record of the memorable experiments made by the pioneers of the postal rocket.

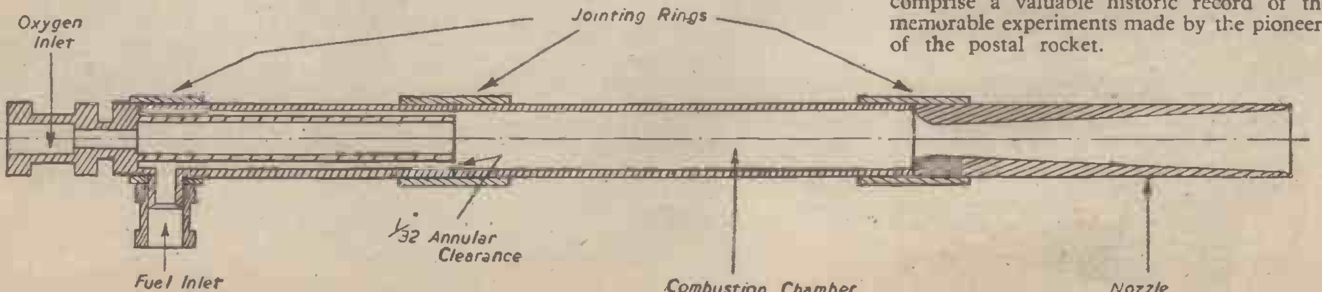


Fig. 15.—Sectional diagram of the Carver concentric-feed motor as used in the rocket mail-'plane trials, Greenwood Lake, N.Y. (1936).

Rocket Propulsion

Further Details of German Development : Rocket Research in Scotland : War Rockets in Spain

By K. W. GATLAND

(*Continued from page 158, February issue*)

APART from his work concerning high speed aircraft forms, Sänger also carried out an extensive series of rocket motor tests. These he commenced in 1931 under the auspices of the University of Vienna. As the result of this work, a reaction unit of distinctive performance was developed; one capable of continuous function for periods of anything up to 30 minutes. A diagram of the Sänger constant-volume motor unit is shown in Fig. 17 and leading dimensions are as follows: Combustion chamber, approximately 2ins. spherical diameter; exhaust nozzle, length 10ins.; throat diameter, .25ins.; mouth diameter, 2ins. The motor and the nozzle throat were surrounded by a coolant jacket, the oxygen and fuel both entering the combustion chamber at the motor head. A light diesel fuel oil was employed as fuel. Prior to entering the combustion chamber, the fuel was passed through the jacket as coolant fluid, and forced from the tanks by means of a Bosch type diesel injector pump. The fuel-feed operated at exceptionally high pressures, ranging between 450 and 2,200 lb./sq. in. Because of the high injection pressure, the combustion chamber received additional strength through the transmission of combustion stresses to the outer casing of the coolant jacket, via the high pressure fluid. With this point in mind, Sänger was able to design the combustion chamber with a minimum safety factor; and as a result, the chamber walls were quite thin.

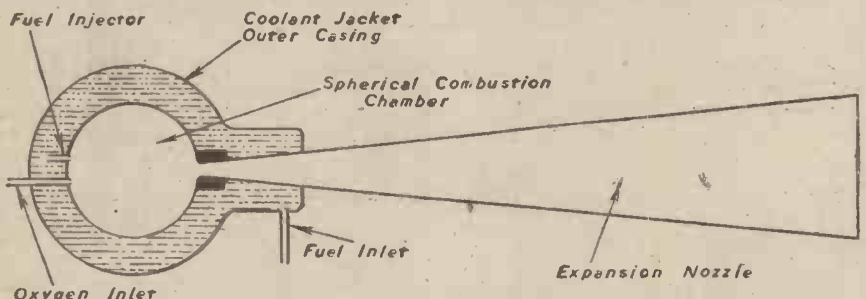


Fig. 17.—Diagram of experimental constant volume rocket motor developed by Dr. Eugen Sänger.

The motor was tested on a simple proving stand, the thrust being indicated on a spring recording device. On several occasions, the motor developed a thrust reaction in excess of 55lb—the exhaust velocity varied between 6,600 to 11,500 ft./sec. During certain tests, compressed oxygen was employed in lieu of the liquid form.

British Research

The early development of rocket propulsion in Gt. Britain owes much to a group of enthusiastic engineers who carried out extensive experimentation in Scotland during the 1930's.

However, their initial investigations and rocket trials date back to the 1914-18 war period, when preliminary work was conducted on the raising of the rocket's efficiency by the use of *thrust augmenters*. During these primary trials it was found that the developed thrust of a rocket projectile, fitted with a venturi augmenting device, could be almost double that of a "free-jet" rocket of identical mass.

The thrust augmenter is merely a device employed in atmosphere to "augment" the mass flow of the rocket efflux, by the injection of atmospheric air into the combustion exhaust stream. It should be noted that if the rocket motor were able to function with anything approaching 100 per cent. efficiency, the thrust augmenter would be of no value because the exhaust gases would be at a minimum temperature upon emerging from the nozzle mouth, and, therefore, incapable of heating the inducted air. The injection of air into the gas stream should preferably be made before expansion is complete, allowing for further expansion after the air and efflux gases are mixed.

For the efficient function of the thrust augmenter a proportion of the heat energy of the fuel is utilised in raising the mass of inducted air to jet velocity, thereby reducing the amount of energy available for conversion to kinetic energy in the efflux itself. The net result is that there is produced a low velocity, high mass, efflux of burnt fuel and inducted air, instead of the high velocity, low mass, efflux of the un-augmented rocket power element.

Small-scale Rocket 'Plane Experiment

At Glasgow, in 1920, a demonstration was given of a simple tail-first model aeroplane propelled by a single powder-rocket charge. The 'plane flew for a distance of nearly three miles in the phenomenal time of *one minute*.

The fuselage of the model was merely a cardboard tube, 3ft. in length, and of constant section, 4ins. diameter. The propellant charge was contained within a steel-cased cylinder supported inside the fuselage tube at the aft end, and so placed that relative air entering at the nose flowed around the power charge, and passed out through the rear. The special nozzle had a jet discharge of 40 grains per second.

A mainplane of lifting section—4ft. span—with no dihedral, was fitted at the rear, while the horizontal stabiliser was similarly attached at the nose. Both aerofoils were "parasol" mounted, their mounts functioning as vertical stabilisers.

Intensified Research in Scotland

As the result of further experiment, more advanced types of rocket-powered model aircraft were produced. One particular model, fitted with a float attachment, was tested out across Loch Lomond and flew for more than five miles.

The persons mainly responsible for this further research were G. Aldred Roberts, J. J. Smith, J. Dennis, and, later, P. Blair—a specialist of military rockets. Their prime aim was to produce small-scale, ultra-high-speed rocket aircraft by the development of thrust augmenters.

In order to overcome the many difficulties imposed by working close to habitation two separate experimental sites were set up in open country—one in Cumberland, the other in Sutherlandshire. At these two places the group erected workshop buildings, and there, making use of most limited building resources, a great number of small-scale rocket aircraft and projectiles were constructed.

One of the first undertakings of the group after the completion of the experimental sites was the building of a large, rotary type, proving stand. With the aid of this very necessary apparatus a great number of individual ground tests were performed. Details of performance were derived by means of a stroboscopic device for direct optical observation; and also a small recording cine-camera.

However, before relating details of the subsequent experimentation, a word about the propellant used. For technical reasons it was decided to employ "gunpowder" charges, and these were obtained commercially. Their manufacture followed the usual practice of pyrotechnics in that water in the charge served to minimise the risk of explosion, and the incorporation of linseed oil and lead oleate mixture limited the rate of evaporation. By this method it was made possible for complete rocket units to be kept in store for quite lengthy periods with a reasonable degree of safety.

As a further precautionary measure the rocket unit—consisting of a thin steel case and metal nozzle—was so designed that excessive pressure—about 400 to 500lb./sq. in.—would split the casing at the nozzle attachment (see Fig. 18), and thus merely

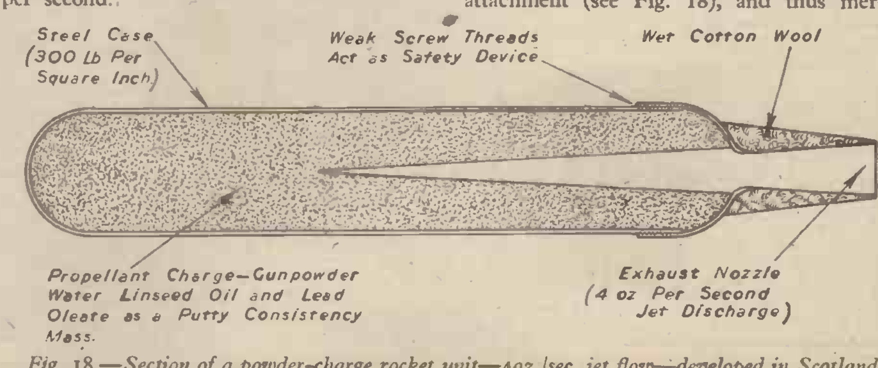


Fig. 18.—Section of a powder-charge rocket unit—4oz./sec. jet flow—developed in Scotland.

result in a mild explosion that did no serious damage.

In practice, the charges had to be made at least a week before use, and they would remain safely effective for three or four months. Many of the charges kept beyond this period either exploded, or, when put to test, failed to develop sufficient pressure to function the augmenter system with any degree of efficiency.

These brief observations serve to add further emphasis to the points already stressed regarding the severe instability of pre-mixed fuels.

Test Results

The rocket trials themselves were mostly made in conjunction with the proving stand. In these experiments the rocket unit under test was fired from a "starter tube." This was merely a tube of constant section—closed at one end—with an internal bore something in excess of the external diameter of the rocket unit. The principle of the "starter" is simply that the rocket, during its passage through the tube, serves to induct air through the tube "mouth," due to an initial vacuumatic effect created by the rocket exhaust within the tube. The air drawn into the tube is expanded by the rocket efflux, resulting in high pressures acting on the rear of the projectile to "push" it from the muzzle, much in the same way as a shell fired from a gun.

Most of the tests of units with augmenter attachments were made on the rotary apparatus, and during the course of numerous firings several highly conclusive figures were obtained of relative efficiencies in the employment of single and multi-stage augmenters. In the great majority of cases the entire augmenter attachment was torn off by the high velocity air flow. During one particular experiment, in which a three-stage augmenter was tested, the third stage was broken away at about 350ft./sec. The second and first stage augmenters were likewise torn off at velocities approximating to 800 and 1,000ft./sec., respectively.

Nozzles

Three type sizes of nozzle featured in the early work. The smallest used—40 grain/sec., jet flow—was designed for use with a charge case, 10ins. in length, and 1.5ins. internal diameter, which housed a propellant charge slightly in excess of 8 ozs. Another size nozzle—$\frac{1}{4}$ oz./sec., jet discharge—was fitted with a case, 5ins. long and 3ins. diameter, and contained a powder charge of just over 1lb.

The 40 grain/sec. rocket unit, without augmenters, developed a thrust of approximately 1lb. With augmenters fitted, the same unit proved itself capable of a consistent thrust of 6lb., and in one particular test a 40 grain/sec. augmented unit achieved a thrust of 10lb.

The larger type nozzles were ribbed externally, and, on test, wet cotton wool was pressed around the outside, which served as coolant for the vulnerable nozzle "throat." Used in conjunction with augmenters, this cooling system was only called upon to function during the first few moments of a firing run, after which the forced draught—due to the augmenter—served to remove the burnt wool, and, subsequently, cool the nozzle by air flow. The 40 grain/sec. nozzle, however, had no initial water cooling. Instead, a thin spun monel-metal jet was fitted. Otherwise, the nozzles were machined wholely from pure copper, although cast aluminium was also tried and found quite satisfactory.

Rocket-assisted Bi-plane

As a demonstration of the capabilities of a small rocket unit fitted with augmenters, a suitable unit was fitted to a D.H. Tiger Moth, and by its aid was successfully assisted into flight. The device had an overall length of 11ft., and was 1ft. 10ins. in diameter, weighing just over 33lb. Merely 1*lb.* of propellant powder supplied the propulsive jet, and the unit, in complete operation, developed a reactive thrust of 150lb. up to 50 m.p.h. The power rating fell to only 100 h.p. at 100 m.p.h.

The Scottish group attribute these remarkable results, not entirely to the use of augmenters, but also to the metal, "de Laval" type, nozzles developed by G. Aldred, which gave a thrust three times greater than that of a similar commercially obtained rocket charge. By the use of augmenters, this reactive force was further multiplied more than ten times, while the same type augmenter device, fitted to a commercial rocket of identical charge, merely gave a thrust increase of three.

It is of particular interest to note that firing runs of over 30 *minutes* were obtained by the group, using nine individual rocket units fired in sequence and operated on the same principle of feed as the automatic revolver. With this device, it was found quite possible to maintain a constant thrust of 450lb. at velocities up to 900ft./sec. The complete unit, fully charged with propellant, weighed less than 750lb., more than half this figure constituting fuel. The power ratio was thus a little under 1lb./h.p.

Another experimental device employing a nozzle with a jet discharge of 2lb./sec., is attributed to have developed fully 6,500 h.p. The jet velocity was given as 7,000ft./sec. With thrust augmenters, this gave a thrust of six tons at forward speeds up to 80 m.p.h. The complete propulsion unit, which weighed two tons, had an overall length of 40ft., with a maximum diameter of 20ft.

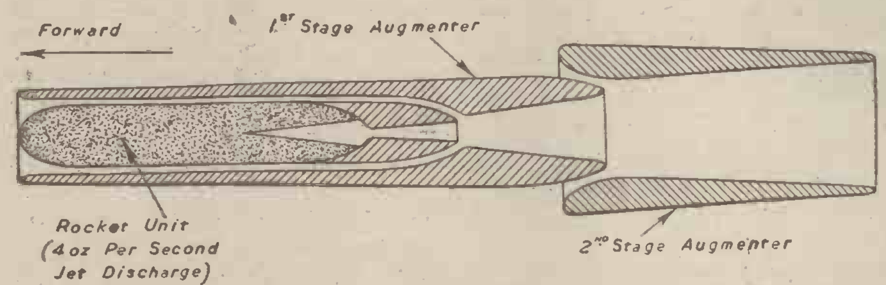


Fig. 19.—Sectional view of powder charge rocket unit with 2-stage augmenters—developed in Scotland (1936).

Rockets in the Spanish Civil War

Mr. P. Blair—previously mentioned in connection with the Scottish research—working in Spain during the Civil War, took part in the development of several types of military rockets. The great majority of these were high explosive carriers, employing a liquid fuelled, constant volume, motor. As in the Scottish experiments, the rockets were fitted with thrust augmenters, and fired from a "starter tube." The launching apparatus, shown diagrammatically in Fig. 19, was a portable arrangement, and in order to absorb the thrust recoil in the starter tube the back end was not closed; instead a wood and cardboard cylinder, filled with water—which closely fitted the bore of the tube—was pushed into the rear. The backward pressure built up behind the rocket was taken by the block, which was ultimately blown out from the tube; the crew having previously taken cover at the sides.

The rocket projectile, shown in Fig. 20, employed paraffin as fuel, with liquid oxygen. It incorporated a one-stage augmenter, with a tail stabilising spinner. The initial weight of the projectile, fully charged with propellant, was approximately 48lb. At the time of impact, on target, this weight was reduced to 30lb., due principally to consumption of the fuel and oxygen, and also, because the augmenter and spinner were always torn away in flight by the pressure of the forced draught air flow. The projectile was ejected from the starter tube with a muzzle velocity of about 500 or 550ft./sec., and accelerated at between 2 and 3g. on a high trajectory.

"Hot-spot" Ignition

The motors were fired by a development of "hot-spot" ignition, and, to facilitate starting, also pre-heated with oxy-acetylene flame jets.

A smaller version of the same type projectile, which weighed only 10lb., was fired from a 50 mm. starter tube. These rockets had an extremely accurate trajectory and were effective in a high percentage of hits at 3,000 yards. At this range, their impact velocity was over 2,000ft./sec.

These experiments with liquid fuelled war rockets proved clearly that by the proper use of the starter tube and thrust augmenters fully 80 per cent. of the fuel required in raising the speed from 0 to 2,000ft./sec. could be saved.

Apart from the high explosive rocket, the Spanish Civil War saw the employment of powder charge rockets, containing propaganda leaflets, which were fired over the opposing lines. Similarly, "leaflet rockets" were used during the Russo-Finnish conflict, and also by the Germans in the invasion of Denmark in 1940.

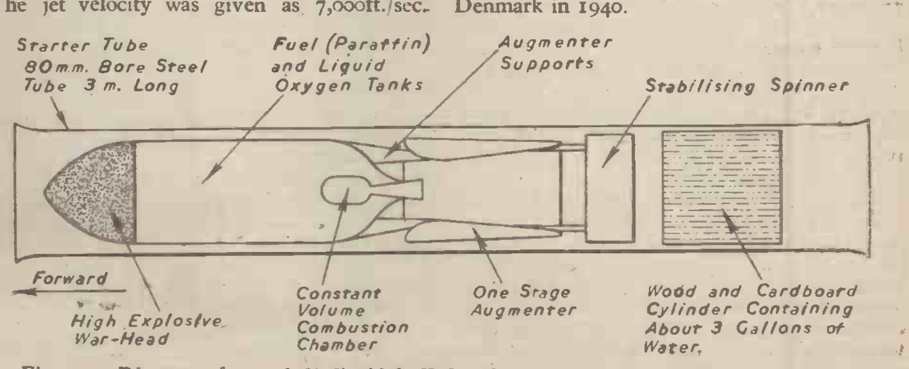


Fig. 20.—Diagram of one of the liquid fuelled rocket projectiles developed by P. Blair, and used with effect by Government forces in the Spanish Civil War.

Rocket Propulsion

Rocket-mail Experiments—in India and Cuba: Modern "Rocket-line" Apparatus

By K. W. GATLAND

(*Continued from page* 201, *March issue*)

SINCE 1934—until after the outbreak of the present war—experiments with rocket mail carriers have been conducted in India; these due to the efforts of a small group of individuals, headed by Stephen H. Smith, of Calcutta, secretary of the Indian Air Mail Society.

Although this group constructed, and fired, in all well over 150 rocket carriers, the experiment for which they are best known was one made in commemoration of the Coronation, on May 12th, 1937.

The "Coronation Rocket," which was 7ft. in length and contained 200 items of mail, was shot from the reclaimed grounds beyond Alipore. Just prior to the actual mail flight, a small pilot rocket was fired off in order to determine the nature of the wind above ground level. It ascended from the special launching rack—designed for the "Coronation" mail carrier—at about 45 deg., and landed half a mile distant.

In accordance with the observed flight path of the pilot rocket, the launching apparatus was reset, and the large mail carrier fitted for firing. When ignited, the "Coronation Rocket" rose swiftly, against a stiff wind, to land well over a mile from the point of take-off. The mails were immediately recovered and taken by car to a Calcutta post office, where final delivery was made through the normal postal service.

The Indian experiments, however, were by no means all concerned with the carriage of mails. Many of Smith's rockets have been employed in emergencies to carry foodstuffs and first-aid equipment. Such carriers have been used with good effect on many occasions; in delivery across rivers swollen by monsoons, and by bringing supplies to families isolated through widespread flooding.

Specially designed rockets have also carried livestock, including live fowl, and even a snake. These tests were made to gain some idea of the effects of rapid acceleration on living organisms. As a result it was found that the relatively low accelerations of the Smith rockets had little adverse effect on the occupants. The carrier rockets were landed by parachute.

Although Smith can hardly be said to have developed original rocket mechanisms of any great significance, in many ways he improved upon some of the devices originated by the earlier postal-rocket pioneers. As Schmiedle, in Austria, had done before him, Smith built several postal rockets on the "step" principle. These consisted of two distinct sections, each section containing both propellant and mail, designed to deliver their individual postal loads at two separate destinations, situated in the path of flight. Accuracy was achieved through varying the amount of powder in the rocket charges; and by means of a parachute, released as soon as the fuel became exhausted, each section was wafted gently back to the ground at the appropriate point.

Other methods employed in India included a "boomerang" rocket designed to take-off, discharge its mail, and then return to the point of ascent. Smith also constructed "telescopic" mail carriers, designed to vary their carrying capacity in accordance with different types of cargo.

Mail Rockets in Cuba

In October, 1939, some of the most enterprising postal-rocket experiments yet made are stated to have taken place in Cuba under the auspices of the Club Filatelico de la Rep. de Cuba (Philatelic Club of the Cuban Republic).

According to the *Airpost Journal*, one particular experiment concerned the firing of a large postal rocket from the Army Target Field, Havana, to Matanzas, a distance of about 50 miles. It is unfortunate that, apart from a newspaper report, which described the trial as "completely successful" essential details of the rocket and its performance are entirely lacking.

Of particular significance, however, is the fact that these experiments were officially recognised by the postal authorities—three such firings took place in October, 1939, on the 1st, 3rd and 15th.

Postal-rocket experimentation has also taken place in many countries other than those already mentioned; including Holland, Belgium, France, Luxemburg, Italy, Yugoslavia, North Africa, Mexico, and Australia.

mails were ultimately recovered and delivered through conventional postal channels—a letter taken aloft in a toy kite, and then posted for normal delivery, would have as much significance. Few indeed of the postal-rocket experiments had any official character—admittedly, in some cases, the trials were viewed with "official interest," but it was invariably little more than just that. Many philatelists and collectors of historical proofs were naturally intrigued by the revolutionary mode of rocket transport and were quite prepared to pay large sums for the flown covers. In actual fact, many of the flights concerned could easily have been duplicated by any "scientifically inclined" schoolboy, and, indeed, often have.

There were, of course, certain notable exceptions. Quite a number of the rocket carriers embodied design features which had definite bearing on development; the parachute landing mechanism, the "step" principle, and winged rockets, among other

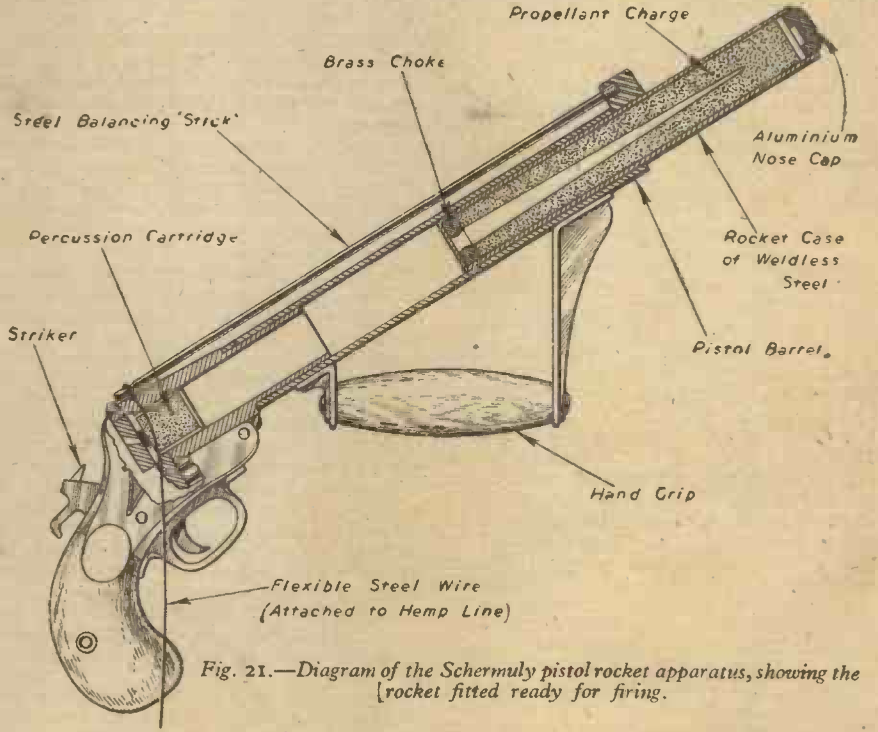


Fig. 21.—Diagram of the Schermuly pistol rocket apparatus, showing the rocket fitted ready for firing.

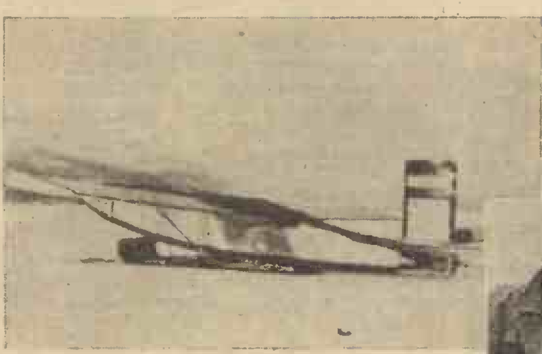
These further references conclude the historical record of the postal rocket. It is unfortunate, however, that in almost every instance there is complete lack of information concerning the rocket carriers themselves and their performance.

The great majority of these experiments concerned powder rockets in their most elementary forms, and many of the individuals responsible had neither the development of the rocket, nor the betterment of postal communication at heart—as promoters, they were solely interested in the financial return. Satisfaction was theirs if the rocket carrier flew for merely a few feet; no one could say that the covers they later offered for sale, had not been actually flown. It mattered little, therefore, whether the distance covered was rated in feet, or miles; in any case, the

innovations such as the launching catapult, owe much to the work of the postal-rocket pioneers. Among those whose work in this regard deserve special mention are the following: Schmiedle (Austria, Yugoslavia), Zucker (Germany, Great Britain, Holland, Belgium), Smith (India), and the Carver group (U.S.A.), as well as those responsible for the experimentation in Cuba. These authorities either carried out, or at least centred their efforts toward, the carriage of mails in competition with the normal delivery service—by projecting mails over difficult country, across water expanses, and in cases of emergency. Under such conditions, the mails carried obviously have a genuine historical interest, and British collectors of such material are fortunate in that the world's largest representative stocks are available in

The Greenwood Lake Rocket 'Plane Trials (1936)

Interesting pictures of pre-war experimental flights with postal rocket 'planes, including the Roberti machine



One of the rocket 'planes tied to the sledge on which it was conveyed to the launching site.

Willy Ley (who designed the 'planes), clad in an asbestos suit, addresses the cameramen.

Six-year-old Gloria Schleich christening the aircraft prior to the launch.

The postal cargo being packed aboard.

Charging the tanks with liquid oxygen.

The second 'plane in flight after taking off directly from the ice. (A photograph showing the first flight trial was given in "Practical Mechanics," February, 1945, p. 157.)

The mail is retrieved from the damaged aircraft after the wing had fractured due to structural weakness.

(Above) Willy Ley fires the fusee.

(Left) The German experimenter, J. K. Roberti, preparing a powder-rocket trial in Holland, 1934.

(Right) The Roberti rocket, instead of rising, is blown to pieces on the launching rack.

this country (Francis J. Field, Ltd., Sutton Coldfield, Birmingham).

Modern Rocket-line Design Methods

Although the requirements of the rocket-line carrier are not so critical, technically, as in most of the types previously mentioned, it is obvious that certain aspects of performance demand particular attention. This is especially true since upon the effectiveness of the apparatus may well lie the difference between life and death during emergency at sea.

The authority chiefly responsible for the development of rocket-line apparatus during the present century is the Schermuly Pistol Rocket Apparatus, Ltd., a firm whose beginnings date back to the early 1900's in the work of the late William Schermuly, reference to which has already been made. (PRACTICAL MECHANICS, August, 1944, p. 375.)

The pioneer apparatus of W. Schermuly has its counterpart to-day in the Schermuly pistol rocket apparatus, which is the first equipment of its kind to be approved by the Board of Trade. In recent years, the pistol appliances have achieved almost universal adoption, and now comprise a principal emergency item on all British, as well as a very large number of foreign, ocean-going vessels. Well over 100 coastguard stations, extending all round the British shores, are similarly equipped.

Both large and small ships, as well as the shore stations, are catered for by the various sizes of apparatus which have been made commercially available. Essential details of the types and sizes at present in use are given n the accompanying table.

Rocket-line Sea Rescue Apparatus

The efficient design of sea-rescue rocket apparatus is conditioned by several important factors. The greatest of these is obviously, dependability—under all conditions of weather and emergency.

One of the most severe problems to be countered is—or rather was—*damp.*

SIZES AND PARTICULARS OF SCHERMULY PISTOL ROCKET APPARATUS

No. 1 Size	Range in calm weather	300-350 yds.
	Nominal weight of rocket	6 lb. approx.
	Length of rocket body	19 ins.
	Diameter of rocket body	2 ins.
	Lines..	½ in. circ., hemp line with a minimum breaking strain of 350 lb. each 350 yds. long.
No. 2 Size	Range in calm weather	220-250 yds.
	Nominal weight of rocket	2¼ lb. approx.
	Length of rocket body	13 ins.
	Diameter of rocket body	1⅝ ins.
	Lines..	½ in. circ., hemp line with a minimum breaking strain of 350 lb. each 250 yds. long.
No. 3 Size	Range in calm weather	130-150 yds.
	Nominal weight of rocket	1 lb. 2 oz. approx.
	Length of rocket body	8½ ins.
	Diameter of rocket body	1¼ ins.
	Lines	⅜in. circ., hemp line with a minimum breaking strain of 350 lbs. each 150 yds. long.
No. 4 Size	Range in calm weather	130-140 yds.
	Nominal weight of rocket	1 lb. 2 oz. approx.
	Length of rocket body	8½ ins.
	Diameter of rocket body	1¼ ins.
	Lines	⅜in. circ., hemp line with a minimum breaking strain of 240 lb. each 250 yds. long.

The early line-carrier rockets, which had paper cases, were fired by matches—no easy matter under storm conditions; and more difficult still if the fuses were made damp by a watery atmosphere. For this reason the rockets sometimes failed to "fire," and lives were lost when, had a more efficient appliance been available, they might well have been saved.

It was this reason that inspired Schermuly to develop the "weather-proof" pistol rocket line-thrower (Fig. 21); an apparatus in which are combined the principles of both the *gun* and the *rocket*. With reference to the diagram, details of operation are as follows: The tubular case of the rocket is of weldless steel, fitted with a brass choke. It has a "piston" fit in the pistol barrel. The rocket is not fired directly from the barrel, but rather ejected by means of the firing of a small percussion cartridge, which serves to force the rocket from the muzzle by virtue of gas pressure—in the same way as a shell fired from a gun—the heat generated subsequently effecting combustion of the rocket charge immediately upon leaving the discharging apparatus. The rocket, thereby, derives an initial impetus which adds materially to its range.

The diagram is sufficient to illustrate the weatherproof characteristic. The powder charge is completely enclosed, and, therefore, immune to damp. Faultless operation is thus ensured under all conditions.

The object of the hand grip is not only to facilitate steady aim but also to aid correct elevation; the relative position of the grip and the pistol barrel being the approximate elevation for the range of the particular size of apparatus concerned.

The smaller types can be fired directly from the hand, with no other support, but as a precaution against the blast of the rocket, an asbestos gauntlet is provided as part of the equipment.

The largest pistol projector requires slight external support because of the greater recoil. A special tripod is available for the mounting of this apparatus (as shown in the opening article of this series—*Practical Mechanics*, July, 1944, pp. 330-1), but in many instances this is more a convenience than a necessity, as a hand rail or even a taut line would serve the aim just as effectively.

In addition to these highly creditable factors, there is still one other—*portability*. The Schermuly apparatus is remarkably light and far less cumbersome than contemporary line-throwing equipment; it can be carried, and fired, single-handed.

The Boxer apparatus affords an interesting comparison in this respect; its weight complete—including rockets, hawsers, buoys, and ropes—is 16 cwt. Because of this, it is impractical to carry the modern Boxer equipment aboard ship; which it is necessary to transport by trailer on land. The largest Schermuly appliance has a total weight of 60lb., which includes the projecting pistol, rockets, lines and waterproof containers—the apparatus complete packs up into a box less than 2ft. square.

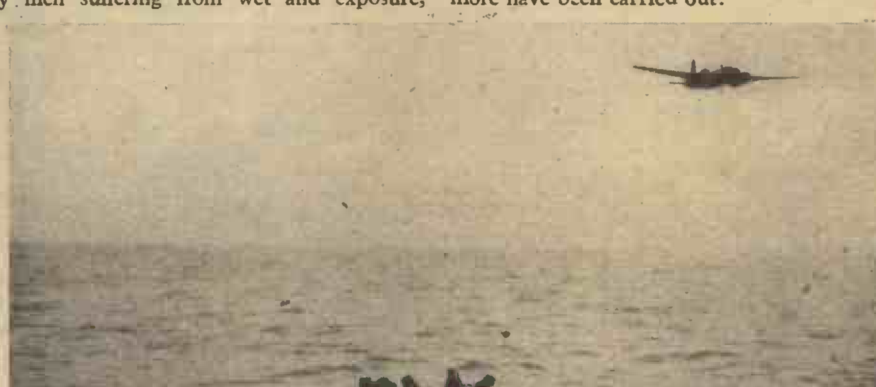
Because of its compactness, the Schermuly projecting gear has a varied use; it can throw a line with extreme accuracy and rapidity, and its use is not limited to the coastguard and the seaman. The apparatus has been used with effect by the Fire Departments in gaining access to points beyond reach of the escape ladder. The pistol rocket is also so designed to fire Very signals.

It is rare indeed that any mechanism overcomes completely all the problems entailed in its operation. The Schermuly apparatus is one such device, as thousands of seamen are able to testify; many of whom owe their very lives to its ingenuity.

(To be continued.)

Rescue by Airborne Lifeboat

RESCUE from the sea by lifeboats dropped from aircraft is now a feature of the work of R.A.F. Coastal Command Air/Sea Rescue Service. Lifeboats fitted with two 4 h.p. two-stroke engines, containing everything needed by men suffering from wet and exposure, such as warm waterproof clothing, food, and medical supplies, are dropped from a height of 700ft., suspended by six parachutes. The first rescue by airborne lifeboats was made on May 6th, 1943, and since that date many more have been carried out.



The crew in a dinghy making for the lifeboat dropped by a Warwick aircraft seen flying overhead.

Rocket Propulsion

The American Rocket Society : Rocket Motors on Test

By K. W. GATLAND

(*Continued from page 224, April issue*)

AFTER the trials of the A.R.S. Experimental Rocket No. 4, no further liquid-fuelled types were constructed for free flight, that is, not until 1939.

The Experimental Rocket No. 3 was never actually fired because of charging difficulties. Similarly, Experimental Rocket No. 5 was not prepared for test, due in this particular case to the results of earlier proving trials which had brought out severe failings in the design.

Since the building of these types, only ground trials of liquid-fuelled rocket propulsion units have been made, although complete powder rockets have been developed for stability trials and tests of alighting mechanism, for the purpose of which, free-flight firings are obviously essential.

The more current experimentation of the American Rocket Society comprises what is undoubtedly the most exhaustive technical development yet conducted outside the secrecy of the Government laboratories.

In view of the technical significance of this work, it is perhaps desirable to go into the various designs and test procedures a little more fully than in the previous discussions.

The Truax Rocket Motor

Among the most successful types developed by the Society to date is the water/fuel-cooled constant-volume motor (Fig. 22), designed by R. C. Truax.

The motor, designed to employ liquid oxygen, with petrol as fuel, was built almost entirely of nickel steel. Its chief attribute is in the unique cooling system, which combines a fuel circulation in a double walled nozzle " throat," with direct water injection into the efflux stream. This latter process is effected through an annular slot formed into the inside of the nozzle " throat." The fuel is introduced at high pressure, and has its inlet through the nozzle coolant jacket. From this, a fuel feeder line connects the nozzle jacket to a small pre-mixing chamber at the motor " head "; the fuel entering at the side. Just prior to injection, the fuel is " atomised " by its forced passage through a small centrifugal whirl fitted within the feed line. The oxygen, which enters the same pre-mixing chamber directly from the motor " head," is thus homogeneously mixed with the fuel prior to entering the combustion chamber. Both the fuel and water are forced to the motor under air pressure; and at the commencement of operation each is supplied under fully 700 lb. per sq. in. This pressure is subsequently regulated, at full operation, to 200 lb. per sq. in., and 160 lb. per sq. in., for the fuel and water respectively.

The Truax Motor on Test

The complete unit, which was first tested at Annapolis, Md., in December, 1937, had, for recording, simply a beam balance. Because of the necessity of having the operator within some 15ft. of the combustion unit—for reason of safety—the complete set-up was given a hydrostatic test up to 1,000 lb. per sq. in. The motor and testing scale on the one side, and the fuel tank, water tank, air compressor with containing tank (oxygen was not employed during the initial trials), ignition gear, etc., and operator on the other, were divided by a steel sheet.

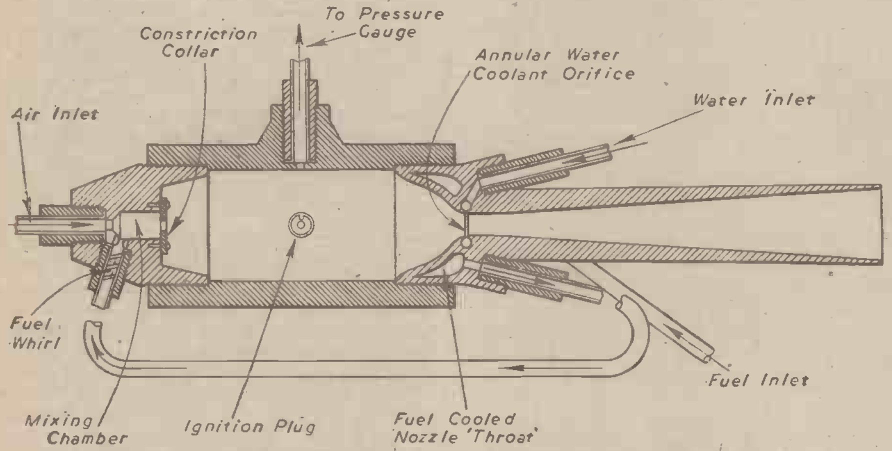


Fig. 22.—Sectional diagram of the Truax fuel and water-cooled motor (1937).

The testing sequence was as follows: Air is first supplied to the feeding lines, the ignition circuit cut in, and with the fuel and water tanks fully pressurised at 700 lb., the inlet valves operated. Air for combustion was then introduced at a slowly developing pressure; but unfortunately, in the initial test, the motor refused entirely to respond.

A second attempt was immediately made, using the same functioning sequence, the sole difference being that the motor and fuel supply lines were first raised in temperature to red heat by oxy-acetylene flames. The fuel system was again pressurised and air supplied in slowly increasing quantity until the attainment of the required combustion proportion. On this occasion, the motor did fire, but in no way so effectively as had been hoped; its sound emanated a motor-cycle engine—a loud continuous popping. However, with slight adjustment of the supply valves, the motor was at length made to function with a steady roar, but only for a few seconds before reverting to its previous irregularity.

In view of these failings, the motor was stripped down in a search for possible fault. Consideration showed that it might be the case that the fuel supply had been affected by the momentary pressure built up during the intermittent explosion periods, and the constriction collar in the mixing chamber was replaced by a smaller one, the intention being to cause a greater pressure prior to ignition. When put to further test, however, the motor did not even function.

In the next test, the restriction collar was removed entirely. The motor was again set up, and, after pre-heating the chamber, the fuel and air supply were once more cut in. Within a few seconds of adjustment, the motor finally burst into life, but first only with the same popping noise as had resulted earlier. Slowly the supply pressure was modulated, and then, suddenly, at a certain minute adjustment, there came at last a loud, smooth roar; the sound indicative of continuous combustion. Almost immediately it became necessary to operate the nozzle coolant system because of the rapid rise of temperature which accompanied proper combustion. The water coolant device proved highly effective, cooling the motor instantly, and in subsequent trials the inlet was left slightly open.

Test Results

At the commencement of proper function, the combustion pressure rose to 50 lb., and by effecting a gradual increase of the input pressure—at the same time due care being taken to maintain the correct propellant ratio—a pressure of 150 lb. per sq. in. was finally achieved.

Had oxygen been employed instead of air as the " supporting " medium, it was considered that the motor would quite easily have reached the designed chamber pressure of 300 lb. per sq. in. As it was, the inlet ports were too small to allow the air to build up sufficiently.

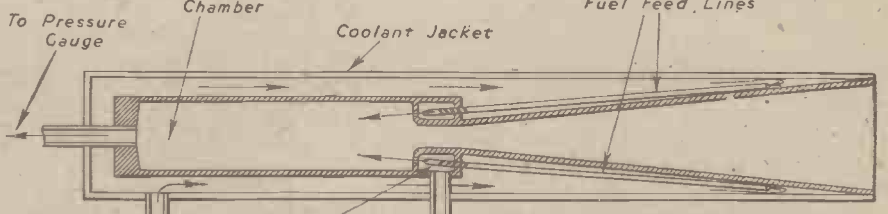
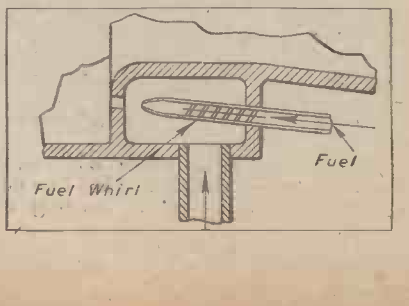


Fig. 23.—Sectional diagram of the Truax fuel-cooled rocket motor (1938).



Several further firing runs were made later in which, by an interchange of valves, even greater steadiness of control and burning was achieved. It is indeed unfortunate that the testing apparatus employed in these particular experiments was not more elaborate. There were, for instance, no facilities for determining such necessary characteristics as the constant thrust factor or the amount of fuel consumed, and, therefore, the thermal efficiency. However, R. C. Truax—who conducted the tests—reporting in *Astronautics*, April, 1938, pp. 9-11, made the following general observations, which, for our purposes, are in many ways as conclusive as the recorded figure: "The matter of determining the proper fuel mixture caused no concern; the motor would not run on an improper mixture. While the rocket motor was in full operation without water, there was neither smoke nor flame issuing from the nozzle mouth. This probably indicates excellent combustion and complete expansion. In fact, with the jet at full power an observer put his hand about a foot and a half from the nozzle, and so little heat remained unconverted that he was able to hold it there (though with considerable effort) without injury."

There is no doubt in the success of the cooling system. The amount of water consumed during the testing was about half that of the fuel, but a reduced quantity would undoubtedly serve to cool the nozzle with little effect on the operating effciency.

As already mentioned, the fuel consumption was not directly recorded, but it has been estimated that a total of about 10 gallons was used to run the motor, intermittently and at varying powers, for six or seven hours of testing.

The Truax Fuel-cooled Rocket Motor

A further Truax motor (Fig. 23), developed early in 1938, featured a fuel-cooled combustion chamber and nozzle, with reverse fuel injection.

As can be seen from the diagram, the component layout is extremely simple and no elaborate "contouring" of the chamber and nozzle firing faces is involved. Distinctions in the design are complete fuel cooling, and the provision of a propellant premixing system at the nozzle "throat."

The design is such that the fuel enters from the side, near the motor "head," circulating through the coolant jacket down to the nozzle "mouth" prior to entering the pre-mixing chamber at the nozzle "throat" through feed lines. Small centrifugal whirls fitted in the lines "atomise" the fuel prior to its injection. The oxygen enters the pre-mixer from the side, where both propellant components are well mixed, prior to their injection into the combustion chamber—towards the motor "head"—through small bore holes. A small ignition plug, fitted in the chamber wall, serves to initiate combustion.

The fuel-cooled Truax motor was shown in England when the designer visited London and delivered a lecture to an assembly of the British Interplanetary Society in July, 1938.

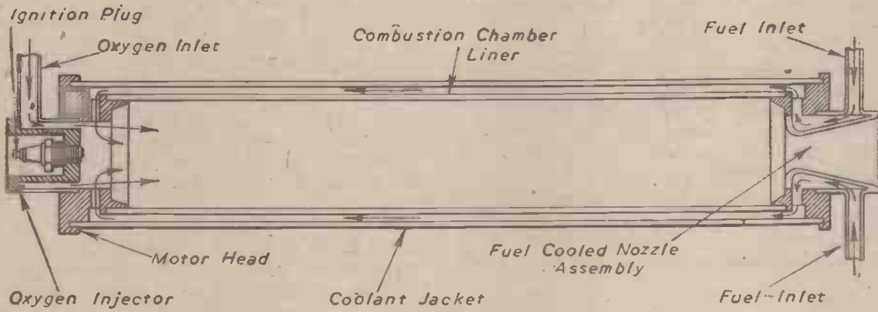


Fig. 24.—Sectional diagram of the Wyld self-cooled tubular regenerative motor (1938).

The Wyld Rocket Motor

As with the motors previously described, the point of significance in the Wyld regenerative motor (Fig. 24) is its unique cooling system. Again, petrol is used, with oxygen, as propellant.

With reference to the diagram: the fuel enters the motor at the double-walled nozzle, flowing round the combustion chamber, through the jacket "manifold," and is introduced, for combustion, at the motor "head." The oxygen is fed from a radial injector and enters from just above the fuel inlets, which inject from radial holes at the sides. By this arrangement, the fuel acts to cool both the nozzle and chamber, and, conversely, to vaporise the fuel by pre-heating, with a resultant improvement in combustive efficiency. The complete motor weighs only 2lb.

The Wyld Motor Under Test

The motor was tested on December 10th 1938, the recording apparatus being the American Rocket Society Proving Stand No. 2.

Fuses, along with gunpowder loosely packed into the nozzle, were used for ignition. When fired, the gunpowder caused the exhaust to appear first as a large yellow flame, which immediately shortened into a "spear" of blue as the liquid propellant caught. At the same time, the reactive thrust rose to 90 lb., which figure remained steady on the recording dial for 13.5 seconds, until the liquid oxygen became exhausted in the supply tank.

Upon examination the motor showed no sign of defect, apart from slight melting and erosion at the chamber "head" and liner, which had occurred about an inch from the injector ports.

Empirical Performance Data

The performance figures of the Wyld regenerative motor, derived from proving stand test, as from the period of efficient combustion, are as follow: Maximum reaction, 91lb.; alcohol feed, 0.084lb./sec.; oxygen feed, 0.34lb./sec.; tank pressure, 250lb./sq. in.; chamber pressure, 230lb./sq. in.; maximum exhaust velocity, 6,870ft./sec.; maximum thermal efficiency, approximately 40 per cent.; and jet energy, 310,000ft./lb. sec.; or 565 h.p.

Further trials of the same motor were made in August, 1941, when the American Rocket Society experimental committee conducted three exacting firings at their Midvale, N.J., proving grounds.

In the first firing, the motor functioned for 21½ seconds, consuming during that time about 12lb. of propellant. The jet appeared as a violet flame approximately 3ft. in length; the motor operating with a deep roar interspersed by sharp detonations which occurred at intervals of about five seconds. These regular explosions caused considerable vibrations, which, as well as shaking the proving stand, were actually felt by those taking part in the test. The phenomena which were in attendance throughout the three testing runs, caused no hurt to the motor.

The second test was concluded with similar results as the first, though the firing duration was bettered at 23 seconds.

The final firing was by far the most satisfactory, lasting for a period of 45 seconds, and, despite the use of a leaner propellant mixture, the motor recorded a maximum thrust of 135lb.

The average thrust for the three firings was approximately 125lb., while the tank and combustion chamber pressures were 250lbs.

One further point of interest arising from the trials was that, due to a misfire in the initiation of one of the firings, unignited propellant ejecting from the nozzle developed a thrust of almost 50lb. on its own account.

These figures are among the most favourable ever recorded by the American Rocket Society. Coupled with the fact that the motor functioned almost without damage, this data shows clearly the increased reliability obtainable in the development of liquid-cooled rocket propulsion units. A similar, though admittedly less ambitious motor, it will be remembered, was produced a number of years earlier by the German engineer, Dr. Eugen Sänger.

A Mosquito of Coastal Command being loaded up with rockets while final adjustments are made to the machine preparatory to taking off.

Rocket Propulsion

Further Rocket Motors Tested by the American Rocket Society : The Wyld Sounding Rocket

By K. W. GATLAND

(*Continued from page 267, May issue*)

ANOTHER test type produced by Truax was an uncooled propulsion unit developed under the auspices of the U.S. Naval Engineering Experimental Station, Annapolis.

Steel was used throughout in its construction, the convergent-divergent steel formed nozzle being protected by a refractory lining of alumina. Unlike the other Truax rocket units, this motor—designed to burn petrol as fuel, with oxygen obtained from compressed air—incorporated no cooling system.

Despite the lack of coolant, however, the motor proved highly effective under test; the efflux velocity being in the region of 5,000ft./sec., and during the most successful firings this resulted in a thermal efficiency of 40 per cent.

The Piecewiez-Carver "Nozzle-less" Rocket Motor

There was, too, a further concentric-feed motor developed jointly by N. Carver and C. Piecewiez. The former will be remembered for his work in connection with the concentric-feed propulsion unit of the Greenwood Lake mail-carrying aircraft. (PRACTICAL MECHANICS, February, 1945, p. 158.) In fact, the Piecewiez-Carver motor bore much resemblance to Carver's earlier design.

In the developed type the oxygen enters the combustion chamber through an axial opening in the motor "head," while the fuel alcohol is fed as a surrounding spray. The motor was actually designed to investigate the function of a liquid-fuelled reaction unit having no nozzle of the conventional tapering type, and the comburent efflux simply ejects through a length of constant section monel tubing, 8in. long by ½in. diameter.

The fuel and oxygen feed, particularly the method of supply control, is achieved both simply and effectively. The propellant components are introduced to the chamber through two lengths of copper tubing, each with a different bore, and so designed to provide just the required combustion ratio. Other than the variations of tube section, and the provision of inlet valves, there are no other devices or constrictions on the feeder lines, the injection ports being so proportioned as to provide a full tube-bore area.

Test Results

The motor's initial firing took place at Midvale on June 8th, 1941.

As there was no provision for internal ignition, the motor was fired by an internal fuse and an alcohol soaked asbestos strip. Prior to the firing, the supply pressure was adjusted to 300lb./sq. in., although, when the firing had commenced, this modulated to 260lb. sq. in., and remained constant. This was presumably the result of pressure drop in the feeding lines and regulating valves; no allowance having been made for the rapid flow.

When the motor was fired in testing the jet appeared as an enormous flame emanating from the "mouth" of the tubular orifice, and instead of the deep throated roar associated with the trials of more efficient types, the Carver-Piecewiez motor emitted a loud hissing noise. Clearly, combustion was largely effected as the mixture was leaving the nozzle; the combustion chamber merely acting as a mixing space.

According to "Astronautics," August, 1941, combustion lasted for eight seconds on a charge of 5.5lb. liquid oxygen and 9.8lb. alcohol. The reactive thrust was spasmodic at first, but settled down during the latter half of the testing run to about 42lb., when the jet velocity was approximately 600ft./sec. After the test the motor and feed lines were found to be frosted; confirmation that burning had not taken place inside the combustion chamber.

The Africano Refractory-lined Rocket Motor

Although many details of the refractory-lined motor, designed and built by A. Africano, are not available for publication, the data as derived from proving stand test is of particular interest. The Africano motor, in fact, achieved a record for the American Rocket Society during proving tests at their Midvale, N.J., testing grounds, in June, 1941, when a maximum thrust of over 260lb. was recorded.

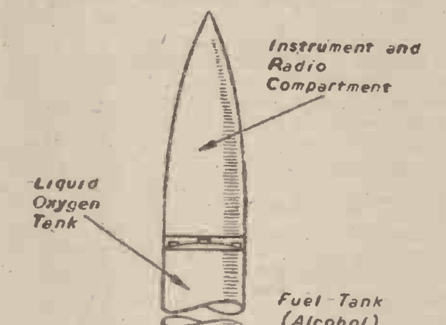


Fig. 24.—Diagram of the Wyld sounding rocket (1938).

The motor, which has a total weight of 23.5lb., incorporated a refractory liner of 8.5lb. Actually, in this instance the weight has little significance as the test motor was unnecessarily bulky and, in any case, intended purely for ground experiment. It has been estimated that only 4.5lb. of base structure was required to withstand combustion stresses with a reasonable factor reserve. The nozzle has a cone angle of 6 degrees; the "throat" being 15/16in. diameter, and the "mouth" diameter, 1.5in.

The designed chamber pressure was approximately 172lb./sq. in., for expansion to atmospheric pressure at 14.7lb./sq. in.

Test Details

On test, the Africano motor employed liquid oxygen, with denatured alcohol (11,000 B.T.U.) as fuel; the feeding being arranged through a gas system functioned by a nitrogen charging bottle.

Although it was reported that the test resulted in a maximum thrust in excess of 260lb., the true figure is not known because of the limitations of the recording instrument on the Society proving stand, which had provision for only 200lb. thrust. When the thrust gauge was later examined it was found that the mechanism had been badly strained, and was inaccurate for further work. A fair estimate for the maximum thrust figure was given by the designer as 280lb.

Upon ignition, the motor fired with a terrific roar, and immediately the gauge needle began to rise on the recording dial, falling back momentarily before continuing under pressure from the motor. This peculiarity, common to several motors tested by the society, is accounted to an initial explosion, which produces a pressure wave, temporarily cutting the fuel input. At only 2½ seconds of firing, the motor recorded a thrust of 85lb. The duration of combustion, which was limited by the amount of fuel available for test, was 12 seconds and the average thrust reaction, 184lb.; the amount of propellant consumed under these conditions being one gallon of denatured alcohol, and approximately 7lb. of liquid oxygen. The best performance was recorded in the ninth second of combustion; the jet velocity at that time being estimated at 7,050ft./sec., and the average flow about 5,140ft./sec.

At the period of maximum thrust, the jet flame could be observed at a distance of 150ft. from the nozzle "mouth," when a standing wave form was apparent near the nozzle, each being 4.6in. apart.

It was unfortunate that, just as the motor recorded maximum reaction, a portion of the refractory lining cracked and a great deal of the ceramic material was forced out through the nozzle. The figures given above cannot, therefore, be taken as highly accurate as the performance was affected by the increased nozzle area, which resulted in an increase of the jet flow. It was therefore impossible to gain any truly conclusive evaluation of the motor's performance.

The M.I.T. Liquid-oxygen Cooled Rocket Motor

Following the Africano motor test, a reaction unit developed by the Massachusetts Institute of Technology Rocket Research Society was bolted on the proving stand. The M.I.T. research group, then newly formed, is composed largely of students, some being connected with the institute in a research capacity, while a very few are entirely independent of the M.I.T. The rocket group, which carries out its work independent of the institute, was founded by Mr. E. C. Doyle in 1940.

The motor under review, which was designed by Mr. R. Youngquist, employed liquid oxygen as cooling medium and incorporated a jacketed lower chamber portion and nozzle. The liquid oxygen, after its passage through the coolant jacket, is finally injected for combustion as an annular gas spray toward the motor "head." The alcohol fuel, which is fed direct, is introduced in similar manner.

To aid starting, an alcohol soaked rag was tied in way of the nozzle and ignited. The propellant feed valves were then operated, and the motor fired effectively, emitting a loud roar.

The motor functioned for 13 seconds, returning a thrust of approximately 35lb. constant for the entire testing run. Unfortunately, however, just as the feed supply became exhausted, an explosion occurred which tore a large hole in the side of the motor and broke off the feed lines. A possible explanation of this was the detonation of an internal fuse, which had been left in the chamber from an earlier attempt to initiate combustion. This theory is substantiated by the fact that no part of the brass fuse casing was found after the incident.

The combustion chamber pressure throughout was 125lb., and the feeding pressure 250lb.

A.R.S. Rocket Motor

Concluding the day's experimentation, a replica of the motor which had powered the early American Rocket Society rockets, Nos. 1 and 2, was fitted for testing.

Designed jointly by H. F. Pierce and G. E. Pendray, the unit consists of a small egg-shaped combustion chamber, with inlet ports situated near the nozzle to inject toward the motor "head."

The motor is completely encased by a steel sheet-formed water jacket.

On test, firing was accomplished by an external fuse; the motor operating for fully 48 seconds—a duration record for the society—while developing a maximum reactive thrust of about 35lb. Apart from slight erosion close to the nozzle "throat," the motor was found to be undamaged.

Tests of the original motor in November, 1932, resulted in a maximum thrust of approximately 60lb., with a firing duration of 20 seconds, without injury to the chamber or nozzle.

Conclusions

From the foregoing it will be readily appreciated that the American Rocket Society has contributed much towards the development of liquid propellant rocket units, and remembering that the research was financed entirely by membership dues, and small sums donated by the experimenters themselves, what they have accomplished is truly remarkable.

These small test motors, which have now been developed to the stage when they can be operated repeatedly without burning out, are now considered to be sufficiently durable to power meteorological rockets for purposes of routine soundings of the upper atmosphere. The greatest height yet achieved by any man-made device is 98,000ft.—prior to the advent of "V2"—and this altitude, reached by a small Regener sounding balloon, is not likely to be much bettered by any device dependent on the atmosphere for lift.

The Wyld Sounding Rocket

Working from data obtained from the tests of his "regenerative motor" (see Fig. 24 PRACTICAL MECHANICS, May, 1945), J. H. Wyld published in 1939 the designs of a new sounding rocket. From the diagram, Fig 25, it can be seen that the projectile is of the tail-drive type; ballistically streamlined, and gyroscopically stabilised.

The rocket shell is cylindrical, with an ogival nosing and a conical tail fairing, the overall length being 9ft., and the maximum shell diameter, 5in. Four elliptical stabilisers—6 in. wide and 8in. overall length—are fitted just above the tail fairing, which incorporate movable rudders functioned by the gyros. These stabiliser fins are of ⅛in. plywood, and pick up on studs attached to the rocket body.

The weight of the rocket empty is approximately 17lb., but this figure is increased to 35lb. when fully charged with propellant, 11.25lb. of liquid oxygen, and 6.75lb. of ethyl alcohol. Both tanks are filled, under complete loading, to a little more than half their full volumetric capacity.

Layout of Components

The propellant tanks are arranged in tandem; the upper tank, containing the liquid oxygen, being of monel, while the other is built of chrome-moly steel. The oxygen feed line, it will be observed, passes through the fuel tank.

As a precautionary measure, a safety disc, designed to fail at a certain critical pressure, is fitted in the oxygen tank.

For feeding the propellant, nitrogen gas is initially fed into both the oxygen and fuel tanks until a tank pressure of 250lb./sq. in. is reached. The inlet valve is then closed, and the feed lines disconnected. The tanks are, of course, pressurised on the launching, or test, apparatus, and the projectile fired immediately upon the attainment of the specified pressure.

The Gyro-stabiliser

The gyro is so designed to hold a true course within 10 degrees. It has a diameter of 4in. and is mounted at its centre of gravity on small gimbals. The complete unit has a weight of ¾lb.

Prior to a free flight test, the gyro is run up to an initial 10,000 r.p.m., and at this speed its momentum is sufficient to serve effective control for the entire flight period. In consequence, no integral driving motor is required.

According to the designer, the control device is made up as follows: The lower end of the gyro axle carries light valve rods. These connect to small slide rods, which, in turn, control the motion of servo-cylinders sliding on stationary piston rods, there being two such cylinders fitted at right angles. Each of these control one of the rudder shafts through rudder levers and they are supplied with pressure via two flexible tubes leading to the gas-space in the fuel tank. A small auxiliary tank (not shown in the diagram) is employed to supply pressure after firing has ceased and the pressure in the main tank is exhausted.

Another novel feature is the parachute ejecting method. As can be seen from the diagram, the parachute compartment is located at the rear of the rocket—just above the gyro—and by this arrangement the rocket is brought to the ground nose first.

The gyro itself acts as the parachute release. An insulated ring is fitted about the vertical axis of the gyro, so that when the rocket curves at the zenith of its trajectory, the ring deflects and makes contact, so closing an electrical circuit which fires an ignition fuse embedded in the powder charge of the ejecting device. This is simply a short tube, containing the charge, separated from a small pilot 'chute. The pilot 'chute, is, of course, attached to the main supporting parachute, which it pulls out through an access door in the containing compartment. This method of release, incidentally, was first suggested by Mr. Street, of Providence, and Mr. H. F. Pierce (A.R.S.), both working independently.

As a safety measure, an auxiliary device, which functions under tank pressure, is also provided, being so designed that release cannot occur until the propellant is exhausted.

Although no details of any flight trials are available—presumably the war caused a postponement of construction—the rocket is estimated to be capable of an upward range of a minimum of three miles.

Payload

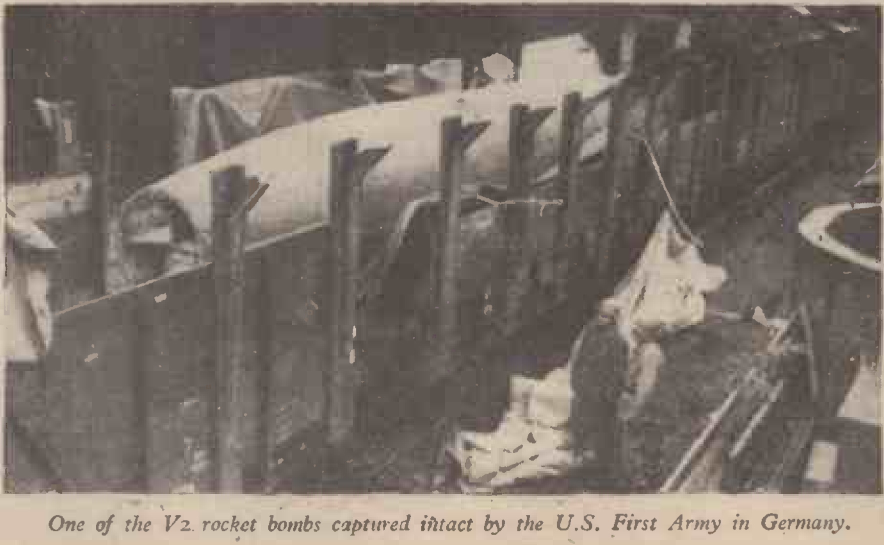
There is provision for a payload of 2lb., which would consist of meteorological recording apparatus, and possibly a light radio transmitter. Whether a suitable apparatus, effective, yet sufficiently light and compact, is available for a rocket of this size is questionable, but, in any case, transmitters will be a very necessary fitment in the larger sounding projectiles now under development. These rockets will be located by radio, making use of two ground receivers, the position being calculated by triangulation.

Operating Costs

The cost of each firing has been estimated to be in the region of 25 shillings; this being the cost of propellant.

Manufacturing costs, too, would not be great for such a small rocket, but it is obvious that if we are to produce the larger rockets, which are the sole means of charting the upper reaches of the atmosphere, such development cannot be achieved through the sheer enthusiasm and technical ability of "amateur" investigators alone. The rocket has now reached a point where no appreciable gain can result from "private enterprise" that is not backed by substantial funds, and we can conceive no rocket society whose membership would yield the huge sums required. It now remains for State subsidy to provide the necessary financial support for this further important development.

(*To be continued.*)



One of the V2 rocket bombs captured intact by the U.S. First Army in Germany.

of it, in very much the same way as they are happening at that time.

We instruct the rocket pilot to "step on it." He does so. Very soon we are travelling at the speed of light, which is approximately 186,000 miles a second. Just before attaining this rocket velocity we glance at our telescopic screen, and, to our horror, we chance to witness a tragedy being enacted on earth. A man is murdering his wife. We see him, knife in hand, about to plunge it into her body. But, strangely enough, as we fly away from the earth at exactly light's velocity the cruel murderer never seems to complete his wicked task. Our telescopic picture is "held" like a "still" in a cinema drama. We travel outwards for days, for weeks and even for months and years still keeping very precisely in step with the speed of light, yet the picture still persists. The man is still murdering his wife. He never finishes the job so far as our telescopic screen is concerned.

Record of a Tragedy

Why is this? Well, obviously when any action takes place on the earth's surface the light rays which proceed from it travel outwards into space with an absolutely constant velocity of 186,000 miles per second, and if, by means of our imaginary space rocket, we travel abreast with those light rays and keep up with them in velocity, then we shall continually witness the scene or record which those light rays carry with them. Thus we may travel for years at the speed of light in our space rocket, and have continually on our telescopic screen the spectacle of the man murdering his wife because we are ourselves actually keeping in step with those light rays, whereas, far away from us on the earth, the man may have been hanged for his crime years ago.

Suppose, however, that instead of travelling with the speed of light we bring additional power into operation in our space rocket, and so increase its rate of travel that our rate of progress through space becomes actually greater than the velocity of light?

Inverting Time

In these circumstances, an extraordinary state of affairs would take place. We should, in a way, be able to invert time and to witness the past, or, at least, a moving record of it, for, by travelling out into space faster than light we should be able to overtake light rays which had left our earth before we had embarked from it. And, consequently, the faster we travelled in excess of the speed of light the more long-departed light rays from the earth would we overtake. Hence, on our automatic telescopic screen we would witness a sort of cavalcade of past history taking place on the earth, or, on our selected area of the earth. By suddenly decreasing our rocket speed to that of light we should be able to "hold" any required screen picture for as long as we required. Thus, we should, given these fantastic means, be able to examine at leisure any stage of the earth's historical record in which we were particularly interested. We could, for example, witness any selected moment of the Battle of Waterloo for hours together if we so had the mind.

Similarly, by decreasing the speed of our space rocket below that of the speed of light, past events would recede from our screen view and the apparent future would gradually build itself up, for, under those circumstances the light rays projected from earthly scenes would gradually overtake our travelling rocket.

Thus, whilst travelling freely in our space ship, past and future would have apparently little meaning, for, by altering our speed we should be able to mix them up to our hearts' content. We should literally be "playing with time."

Time, therefore, although its real positive nature eludes us, is a relative sort of thing. It cannot exist by itself. It depends on the existence of matter, and, very likely, on the presence of space. Certainly, also, its manifestations are greatly modified by motion through space.

It looks, therefore, as if Time, Matter, Space and Motion are all intimately associated, for we are never able to experience any one of these entities separately and independently of the others.

Time, apparently, began. So, also, does it seem likely to end. But, seemingly, it will be the last of all material attributes to end.

"*Tempus edax rerum*" (time consumes all things) said the old Latins. They were right. It is only the unchangeable entities which can withstand Time's continual corrosion.

Rocket Propulsion

Power Rockets : Stability Trials and Details of Alighting Methods : Range Sighting

By K. W. GATLAND

(*Continued from page 316, June issue*)

FURTHER to the development of liquid fueled rocket units, the American Rocket Society has carried out numerous exacting tests of powder charge rockets; principally in order to gain practical experience of stabilising methods and the function of alighting mechanisms.

Powder Rocket Trials in 1935

The experiments which P. van Dresser and A. Africano conducted near Danburg, Connecticut, in 1935, have thrown much light on the relative effects on stability by varying the location of the centre of thrust.

The initial flight tests concerned a projectile of elementary form having the motor at the extreme rear, and this model also served to test a simple parachute release gear, the 'chute compartment being placed at the rocket "head" and joined to the charge casing by a length of dowel. Four small guide fins were fitted at the rear.

A second rocket was somewhat more elaborate, the power charge being contained within an aluminium body shell. It had a fully loaded weight of 3½ lb., of which 1¼ lb. constituted the rocket charge. There was provision for modifying the centre of thrust from the nose to the centre of mass and the tail, and under the changed conditions the weight distribution was kept constant by the simple procedure of moving a pair of ring weights along the outer shell. The idea of altering the position of the power element was to gain comparative data on the flight stability under these varying conditions.

On test, however, the rocket proved a complete failure. It was found that the effective thrust was almost halved when firing took place through the shell, and with the motor mounted in any position other than at the tail the efflux melted the aluminium of the body tube.

Tests of the simple tail-drive rocket gave far more conclusive results, and about 12 free-flights were made in conjunction with a 10ft. catapult apparatus.

It was unfortunate that, through bad co-ordination of timing in the release of the catapult and the ignition of the powder charge, the rocket was often fired from the rack not under the most optimum conditions, with the result that the performance was appreciably less than the calculated figure (as derived from the available thrust impulse and mass). In the majority of tests the altitudes reached varied between 200 and 250ft., but in one particular flight, when the timing was exactly right, a height of over 400ft. was attained. The rocket showed itself quite stable, and ascended on a trajectory which, in the majority of flights, did not deviate more than 20 or 30ft. from the vertical.

Parachute Release

The most useful result achieved, however, was from the tests of the alighting gear. The parachute in this particular model was of silk, 32in. in diameter, with a 2in. vent hole in the centre. There was also a small pilot 'chute of 10in. square, and this was attached to the top of the main supporting canopy by four shrouds secured equally around the vent.

When packed ready for use, the main shroud line was coiled beneath the 'chute pack and fastened to a bolt in the bottom of a tubular container situated at the "head" of the rocket. The pilot parachute was loosely packed at the top, and a ballistic shaped aluminium nosing was then fitted, not too tightly, over the compartment.

The device was so designed that the parachute would not release when the rocket was accelerating or travelling in a vertical ascent. When the projectile reached the apex of its trajectory, however, and turned over under the slowing influence of gravity, the lateral air resistance developed during its fall served to blow off the light nosing and thereby expose the pilot 'chute. This was readily caught by the air flow, so pulling out the main parachute from its container.

In order that the device should be sensitive in operation, two small vanes were fitted externally—at the rocket "head"—and these served to increase the lateral resistance.

This method of release is, of course, suitable only for light rockets, and in the tests reviewed the device functioned perfectly in practically every instance.

While on this subject of alighting mechanisms, it is as well to trace briefly their development. The parachute has, of course, long been used for display purposes; the idea was probably first conceived by the Chinese pioneers of pyrotechnics early in the Christian era. The rocket star-shell, for instance, uses a number of small parachutes from which are suspended coloured display "fires" and this principle was adapted in the 1914-18 war, when the "flaming onion," or magnesium flare, first came to be used extensively.

Professor Goddard is credited with the initial application of the parachute in liquid fueled rockets, and his first successful experiment took place on July 17th, 1929, when a rocket, complete with a camera and barometer, was safely wafted to the ground. In more recent work, he is said to have perfected a parachute release gear of faultless operation.

The German experimenters employed parachutes in their early powder rockets—particularly the mail-carrying versions—and the Verein für Raumschiffahrt E.V. fitted them to the "Repulsor" liquid-fueled types, as also did Johannes Winkler in his liquid fuel rocket of 1932.

Some of these earlier rockets simply had a slow burning fuse to function the release gear while others incorporated a clockwork "photographic" timer. The pressure within the propellant tanks has, too, been employed as the release medium, effecting operation through a spring-loaded plunger when the fuel is consumed and the feed pressure has dropped to zero.

In the more recent and larger type rockets, the parachute release is effected by the firing of a small powder charge, similar to the method employed by J. H. Wyld in his 1939 sounding rocket. (PRACTICAL MECHANICS, June, 1945, page 316.)

Other devices recently developed are functioned by air pressure, in the operation of a trip mechanism by a barometric pointer. Release is arranged to take place at a height previously determined from the performance calculations, the trip device either ejecting a pilot 'chute through the release of a compressed spring, or causing the explosion of a small charge.

Yet other release devices have been advocated which would work under rapid negative acceleration—at the time when a rocket which had just ceased firing was slowed up by atmospheric resistance. This factor, coupled with the rocket's curving trajectory at the flight apex, it has been suggested, would cause any free body in the rocket to be forced upwards, and so enable the function of a pendulous device, or some form of escapement mechanism, in conjunction with a spring or "shot" ejecting gear.

Tiling "Flying Rocket"

Finally, in this short summary of alightment apparatus, the patented design of Reinhold Tiling (U.S. Patent 1,880,586, Tiling, Osnabruck, Germany, 1932) cannot go without mention.

The method as fully outlined in Tiling's specification does not involve the parachute, but makes use of stabilising fins which, at the end of firing, hinge at a set angle of incidence, to form supporting blades. By this means, the rocket is brought to the ground as a gyro-plane.

The Tiling "flying rocket" (Fig. 25), as the device is termed, is of form simply a finned rocket with the propellant charge contained conventionally within the body shell, having provision for mail in the nose. Equally spaced around the shell are fitted four stabilising fins which project some distance from the rear, and each of these are so built to hinge outwards from a point just aft of the body.

Having served their initial purpose of maintaining the rocket in stabilised flight throughout the duration of combustion and propulsive momentum, the free part of the fins are automatically brought almost horizontal (relative to the vertical body axis), at the same time setting a slight positive incidence. The rocket is thus wafted to the ground by the reaction of air on the supporting "planes," which causes rotation about the body axis.

The Tiling specification suggests also the provision of four auxiliary rocket units fitted to discharge tangentially from the body. These are intended to become operative shortly before the rocket reaches the ground, and have the effect of creating a lifting force opposing the free fall due to the "powered" spinning of the rocket.

Whether or not Tiling ever put his "flying rocket" to actual tests is uncertain. Certainly he built, and demonstrated with no small success, several "winged rockets" of particularly unique design, but they differed greatly from the patented form. In the tested version there were four long fins; but these were rigid and did not fold. Instead, two other fins were fitted which pivoted from near the after part of the rocket body, and were folded back snugly beneath the horizontal stabilising surfaces during ascent. When firing and upward momentum had ceased, they automatically snapped open, thereby transforming the rocket into a glider.

Why Tiling should have employed this rather cumbersome and heavy arrangement in preference to the gyro type "flying rocket" is not clear. It is true, nevertheless, that the "winged" version had a creditable performance, often rising above 2,500ft.

Further Stability Trials

A further series of powder rocket trials took place at Pawling, N.Y., in October, 1937, under the auspices of the American Rocket Society Experimental Committee. Again, stability formed the subject of the experiments, which were centred toward searching out flight phenonema both during propulsion under power and momentum, for various conditions of the centre of thrust, the centre of gravity and the centre of lateral area.

The rocket bodies were constructed by H. F. Pierce, simply of balsa wood and cardboard tubing; being designed from various suggestions put forward by members of the Society. Commercially obtained charges of 12oz. loaded weight (comprising 6oz. powder), served as the propelling element, each rocket having a single charge which fitted into a central tube in the body.

Firing took place from a special launching rack, the rocket under test being attached to a small trolley which ascended the apparatus under thrust along a single guide rail. Ignition was either performed electrically or through a touch fuse. Each flight was ciné photographed in order that a subsequent study of trajectories could be made at leisure.

Of the seven rockets tested, two were outstanding both in respect to the altitude reached and their flight stability, as the accompanying table (Fig. 26) shows. It will be noticed that both types were the lightest in weight, thereby making more effective the impulse of the charge and so producing increased rate of acceleration. Another point of significance is that the centre of propulsion was forward to the centre of gravity and the centre of lateral area.

Experiments at Mountainville, N.J.

Following up the stability question, the Experimental Committee of the American Rocket Society carried out further trials of small-scale powder rockets in September, 1939, from a prepared test site at Mountainville, N.J.

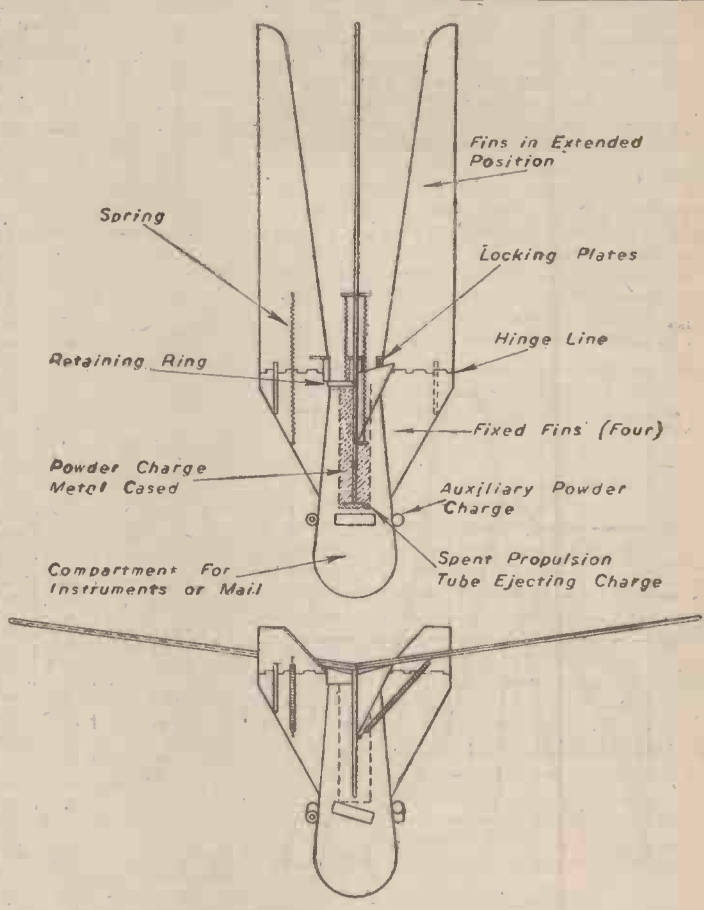


Fig. 25. Diagram of the Tiling "Flying Rocket," showing the two fin positions. Firing of the ejecting device forces out the propellant charge with retaining ring. This action deflects the locking plates, and the stabiliser fins automatically collapse to form "supporting planes."

The models tested were based on the results of the earlier Society experimentation at Pawling, and, as then, balsa and cardboard were used in construction. The launching apparatus bore much resemblance to the single-rail type which had proved itself in the former trials.

It is of interest to point out that, in this, and the majority of free-flight experiments previously discussed, the altitude figure was derived from the use of special sighting instruments developed on the principle of the surveyor's theodolite. The system requires two remote sighting locations spaced at a known distance. In the trials under review, this length was 1,100ft. on a straight line 50ft. west of the launching point. The location "A" was 800ft. to the south, and location "B" 300ft. to the north. The altitude is calculated in accordance with the simple formula:

$$H = \frac{b}{\cot A \quad \cot B}$$

where H is the altitude in feet, b is the base line of the two sighting locations in feet, cot A is the observed angle from location "A," and cot B is the observed angle from location "B."

According to A. Africano, who participated in the test sighting, the Society instruments were operated as follows: When the rocket, seen through the eyepiece and cross hairs, was observed to reach its maximum altitude, a small indicator carried along in one direction by the upward motion remained in place at this point and the angle could then be read leisurely on a graduated quadrant, and noted. This method gives the altitude of a horizontal line formed by the intersection of two planes rotating about shafts set parallel to each other. While it does not locate the point definitely in space, as in the method used at Staten Island in 1934, where two vertical and two horizontal angles were measured, it is sufficient for present purposes. The instruments were later adapted for an automatic angle and time recorder with which it is possible to calculate the vertical acceleration and velocity in addition to the upward range.

To return to the rockets themselves, the propulsive charges were obtained commercially, and being the ordinary display rocket type their weight and thrust characteristics were known only approximately. In consequence, the results achieved in free flight were, in many ways, inconclusive.

The rocket charges used in these particular tests were designated by the manufacturer 2lb., 4lb. and 6lb., but their actual weight was considerably less. Writing in *Astronautics* (November, 1939), Mr. A. Africano, who conducted a private investigation of the values attainable from these size commercial charges, states that the 6lb. type shows an increase of thrust from 0 to about 40 lb. along a smooth curve in about one second, and he points out that the form of the reaction curve would, in all probability, prove to be similar for the other sizes. Mr. Africano reports the weight of powder in the 6lb. size as approximately 12 oz. The maximum thrust of the 4lb. charge which contains 4.8 oz. of powder, he gives as about 20lb., and the duration of reaction one second. The powder weight of the 2lb. charge is stated to be 2 oz., but no figure for thrust is available.

Some two years later the Experimental Committee carried out tests of similar commercial charges of the 3lb., 4lb. and 6lb. size, and their conclusions are set out graphically in Fig. 27.

The designations of these charges follow the usual practice of pyrotechnics in that a lead shot of diameter equal to the charge represents the weight. The *actual* weight of the 3lb. charge is 0.6875lb., of which 0.250lb. is black gunpowder, the containing cylinder being 11.oins. long by $1\frac{11}{16}$ins. diameter, with a nozzle diameter of $\frac{7}{16}$in. Concerning the 4lb. type, the true weight is 0.906lb., of which 0.406lb. constitutes powder. This size has a case of 12.oins. by $1\frac{7}{8}$ins., and a nozzle diameter of $\frac{3}{8}$in. The last size investigated, the 6lb. charge, has a weight of 1.5 lb., of which 0.656 lb. is powder. It is 13ins. long by $2\frac{1}{8}$ins. diameter and has a nozzle orifice of $\frac{3}{4}$in.

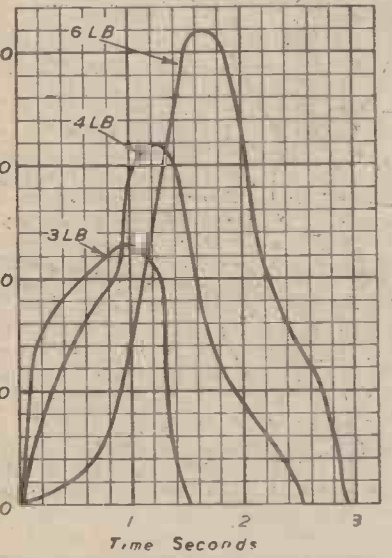


Fig. 27.—Thrust curves derived from proving stand tests of black powder rocket charges manufactured by the U.S. Unexcelled Manufacturing Corporation.

Model No.	1	2	3	4	5	6	7
After protype design of	Pierce	2 Step	Africano	Goodman	Wyld	Shesta	Repulsor
Distance from nose of rocket to centre of propulsion, inches..	15.9	28.0	8.0	14.0	39.0	59.0	14.0
Distance from nose of rocket to centre of gravity, inches	19.0	28.0	15.0	39.0	33.0	43.0	24.0
Distance from nose of rocket to centre of area, inches..	22.0	28.0	19.0	50.0	25.0	35.0	22.0
Overall length of body, inches..	44.0	68.0	33.0	94.0	49.0	68.9	48.0
Initial weight of rocket, lbs.	1.19	2.27	1.19	2.16	1.85	1.72	2.28
Maximum altitude, feet (approximate)..	1,500	600	1,500	400	200	300	100
Time of ascent, seconds	7	5	5	5	4	4	3
Time of descent, seconds	3	4	3	4	4	3	2

Fig. 26.—Table of results of tests.

Model No.	Maximum Altitude, feet.	Time of Flight, seconds.	Total weight of Model, ounces.	Charge size, comml. "lb."	Body length, inches.	Maximum body diameter, inches.	Distance, nose to centre of gravity.	Distance, nose to centre of area.	No. of fins.	GENERAL REMARKS.
5	403	5 (up)	11.2	2	12.0	1.50	—	—	1 (Stick)	Lost in clouds.
6	—	—	5.6	2	12.0	1.75	7.625	11.125	4	Exploded over rack.
7	25	13	6.0	2	12.0	1.50 (Sq.)	7.75	10.50	4	Horizontal flight—400ft.
8	650	—	6.0	2	11.375	1.50	7.50	9.75	4	Better result expected.
9	56	—	9.0	2	14.75	1.25	9.625	11.50	4	Exploded over rack.
10	86	2.5	11.2	4	15.0	2.0 (Sq.)	9.50	10.50	4	Looped.
11	150	6	10.7	4	13.75	2.0	7.875	9.25	4	Horizontal, then looped.
12	620	12	18.7	4	17.875	1.875	12.125	15.50	2 (Sticks)	Cap ejected at flight apex.
13	235	8	25.0	4	28.125	1.75	18.125	19.125	4	Weighted model.
14	—	—	20.5	4	28.125	1.75	18.625	19.125	4	Caught in rack.
15	196	9	24.0	4	17.0	1.875	15.875	17.75	2	Excess frontal area (9 sq. ins.).
16	503	6 (up)	16.0	4	18.25	1.875	12.0	—	3	Lost in clouds.
17	725	19	34.0	6	23.625	2.375	16.25	16.0	4	Second best performance.
18	524	10	22.0	4	12.5	4.0	8.5	—	3	Over Observer "B's" zenith.
19	206	7	—	—	—	—	—	—	4	Exploded in flight.
20	75	6	37.0	6	30.5	4.0 (Sq.)	22.0	—	4	Excess frontal area (16 sq. ins.).
21	174	8.5	14.0	4	16.0	1.875	10.5	14.75	4	Fins broke off in flight.
22	145	10	12.0	4	13.5	1.875	8.25	11.50	3	Horizontal flight.
23	531	7 (up)	12.5	4	13.25	1.875	8.125	11.50	3	Swung into wind.
24	125	6	17.0	4	14.875	2.875	8.50	9.50	3	Launched late.
25	582	15	14.0	4	26.75	1.875	18.75	16.25	4	Fin area at extreme rear.
26	66	4	13.5	4	12.625	1.875	7.875	—	4	Looped (fin area at nose).
27	1930	24	39.0	6.2	25.25	2.375	18.50	21.50	8	Shows efficiency of two-
27	2nd step alone		9.0	2	12.75	2.375	7.75	8.0	4	step principle.

Fig. 28.—Table of results of 23 individual firings.

Firing Results

In the above table (Fig. 28) is shown, for easy comparison, the results of the 23 individual firings. Of these, rocket No. 27 is of particular interest, being of the two-step type. It consisted of two distinct sections, each a self-contained propulsion element—the main component having a 6lb. charge of commercial origin and the other a similar 2lb. charge. In this type the two sections are connected, and the larger fired first. Having consumed its fuel in raising the small component, a connecting fuse fires the latter, which automatically disengages and accelerates away from the expended "parent" rocket.

Another unusual type, rocket No. 26, had fins fitted forward of the centre of mass, but this model proved markedly unstable on test.

Other rockets, Nos. 6 to 11 and 21 to 27, were lightened by the removal of part of the charge casing, and to this is attributed the explosions of models 6 and 9.

(*To be continued.*)

Projectiles from Space

Nature's Bombardment of the Earth

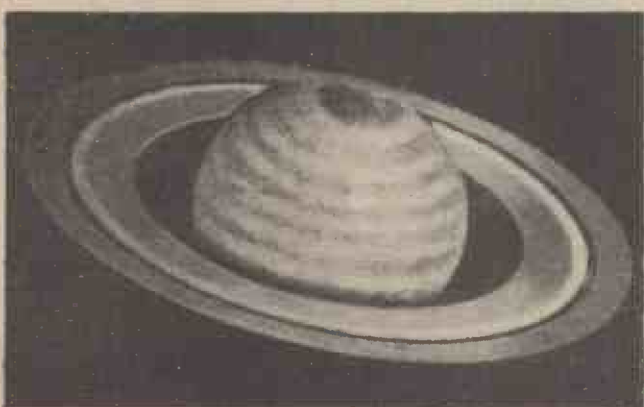
By F. J. STIRLING

Halley's Comet, the most famous of these celestial visitors which seem to be so closely associated with meteor production.

THE stray "shooting stars" which dash across the heavens every night seldom reach the earth's surface. Twenty miles above our heads they become so completely burnt out by the friction of their headlong flight that they fall silently, gradually and imperceptibly to the ground in the form of a fine, impalpable dust.

As most of us are aware, these so-called shooting stars which career about the skies at night are obviously not stars at all. Imagine them merely as fragmentary lumps of hard metallic and rocky matter, the size, perhaps, of a football and, maybe, often considerably larger, glowing vividly at a height of anything between 20 and 70 miles upwards in the atmosphere, which present to us ground-dwellers the transitory appearance of stars falling earthwards from their celestial moorings.

Technically, a shooting star is called a "meteor." If it succeeds in reaching the earth's surface and is large enough to handle, it is then termed a "meteorite."



A telescopic view of the planet "Saturn," whose remarkable ring system is composed of innumerable meteors of flying particles encircling the planet.

We might, perhaps, look upon meteors as Nature's *V1's*. They are projectiles which reach us from space. In this fact lies their tremendous interest from a scientific point of view because they prove to us that our globe, as it steadily and ceaselessly sails along in its appointed orbit round the sun, does not pursue an uninterrupted course. Indeed, Nature is prodigious with her *V1's*, for a fairly recent estimate made by the astronomical department of Harvard University, U.S.A., suggests that upwards of a *hundred billion* meteors fling themselves into or are otherwise drawn into the earth's atmosphere every 24 hours. The majority of these meteors are invisible to the naked eye, but they can be witnessed by telescope observers as they dart across the fields of their instruments. These astronomical will-o'-the-wisps must necessarily be very small when they first contact the earth's atmosphere, no greater in size than, say, a paving sett or a cobblestone. Nevertheless, were it not for the fact of the earth's atmosphere which so effectively brakes their velocity and, in the majority of instances, entirely destroys them, these visitants from space would constitute *V1* projectiles indeed, for life on the surface of our planet would hardly be livable if it were subjected to a continuous and uninterrupted hail of high-speed metallic or mineral projectiles such as meteors or shooting stars comprise.

Meteor Velocities

The visible path of a meteor's flight is seldom longer in duration than three seconds. A few last longer, and many have a shorter appearance, but three seconds is a good average duration for any sizable shooting star. In view of a meteor's fleeting visiblity, it is an extraordinarily difficult matter for even a trained astronomical observer to make an estimate of its velocity. Usually, however, it is reckoned that a slow-moving meteor travels at about 7 miles per second, whilst a rapid meteor may touch a velocity of 50 miles per second.

Meteors differ in colour. Some are red, orange or yellow. These are the slower-moving varieties. But there are other meteors which burst with dazzling brilliancy as they fly through the upper regions of the air. These, the blue or the white meteors, travel the fastest, the friction of their flight through the atmosphere raising them up to white heats.

It seems most likely that the average meteor becomes visible when it is about 80 miles above the earth's surface. Unless this flying lump of rock is of more than average size it burns itself out completely when it arrives at about 20 miles above the earth.

Sometimes a meteor leaves a luminous haze or trail in its wake, a luminescent streak across the sky which lasts for a minute or two after its headlong flight. The cause of this phenomenon is quite unknown, but it is definitely not an optical illusion.

Origin of Meteors

Whence come these strange yet commonplace projectiles from the skies? It seems pretty certain that there exists in space streams or rivers of these flying stones, each stream or meteor river flowing round the sun or round the earth in a highly elliptical path or orbit. Consequently, the earth, at certain regular intervals in its journey round the sun, cuts through these meteor streams, the result being at those times a more intense meteor bombardment of the earth than at other times.

A telescopic view of a portion of the moon's surface as seen from an apparent distance of 90 miles. Note the large crater-like formations which are supposed to be due to the impact of large meteorites. They are all similar in formation to "Meteor Crater" in Arizona.

During the month of August meteoric displays may be expected between the tenth and the eleventh day. These meteors contact the earth's atmosphere at a point in a constellation of stars known as *Perseus*. From this fact, these regular August meteors are called the "Perseids." Similarly, the meteors which occur regularly about November 14th are seen originating in the region of the constellation *Leo*. They are thus known as the "Leonids."

The fact that these regularly recurring meteors appear to originate from a mere point in the heavens is due to an illusion of perspective just as is the apparent convergence of a railway track in the far distance. Actually, the paths of the meteors are perfectly parallel and our earth usually cuts directly or obliquely across them.

There are astronomers and scientists who say that the meteor streams which pass around the sun in well-defined orbits are formed from the residues of comets. Other theorists, on the other hand, assign their origin to past explosions of one or more planets, the flying debris having been attracted by the sun and aligned by its gravitational influence into orderly streams. There may be some truth in this suggestion, for it has been proved that the extraordinary rings of the planet Saturn consist of nothing other than a number of encircling meteor streams, the streams being about 50 miles thick. Very probably these rings originate by the past explosion of a satelite or moon of Saturn, the flying particles being gravitationally collected by the parent planet and whirled around its equator, thus providing us with the spectacle of Saturn being surrounded by apparently solid rings.

Meteor Crater, Arizona, U.S.A. Nearly a mile wide, this enormous crater was caused by the impact of a huge meteorite in prehistoric times.

Quite apart, however, from the regular meteor streams which the earth encounters annually, our globe is the target of countless "stray" meteors which reach it at all times of the night and day. Naturally, we cannot see meteors outside the earth's atmosphere even with the largest telescopes because they are relatively so small and because, being imbued with the deadly cold of outer space, they do not shine by their own light. But the fact that our earth receives daily so enormous a number of these projectiles seems to suggest that the term "empty space" is very much of a misnomer and that, in reality, inter-planetary space is populated by almost inconceivable numbers of rocky lumps and chunks varying in size from the dimensions of a cricket ball to that of a small mountain, all of them hurling themselves in various directions with velocities far exceeding that of a rifle bullet.

Inter-planetary Travel

There is no doubting the fact that such considerations must be thoroughly well taken into account by any future means of inter-planetary travel from the earth, for it is obvious that the impact of myriads of these space projectiles upon any mechanically-powered earth rocket-ship would have the most serious consequences unless special precautions could be devised to minimise their effects.

Meteors which succeed in penetrating the earth's atmosphere and in falling to the ground are known technically as "meteorites." When picked up, the majority of them are roughly globular in shape and are covered with a black, glossy coating, giving them a sort of varnished or enamelled aspect.

In composition, meteorites can be divided into two distinct varieties—mineral and metallic. The mineral meteorites are mostly made up of silicates, through which is diffused iron oxide or iron silicate, whilst the metallic meteorites are composed for the most part of metallic iron contaminated with silicate material.

Iron, therefore, in one form or another, is a characteristic constituent of all meteorites. So also is nickel, for it is always present in association with the iron. Cobalt is another metal, too, which has been detected in meteorites. So also have magnesium, sodium and potassium.

Some meteorite fragments have been found to contain metallic gold. One or two have shown the presence of diamonds, although in merely microscopic form. Most interesting of all, perhaps, is the fact that a few meteorites have contained carbon together with hydrogen.

To the chemist and to the scientist generally, all meteorites are unique as being the only heavenly bodies which Nature permits us to touch and to handle, to investigate chemically and microscopically. We may view the moon, stars and planets through telescopes, we may calculate their motions with an astonishing degree of accuracy, but, as yet, we have never been able to approach them at close quarters. In the meteorite, however, the scientist has in his own hands a fragment of "sky-stuff" which he is able to examine leisurely and to his heart's content.

Meteorites, as we have seen, have brought to us iron, magnesium, silicates and other common materials of our own earth. They have never, however, contained any unknown substances. It is therefore possible that some time they might do so and that we might discover in a meteorite, if not a new element (for that seems hardly possible), at least an unknown modification of an existing one.

Life on a Meteorite?

Then, again, can a meteorite bring life to our planet? Can it present us with strange seeds of life-forms which, as yet, we know not of? Can the meteorite projectile, after surviving its passage through the earth's atmosphere, bring to us new and terrible diseases of a malignancy yet unknown?

The answer to all such questionings is simply that we do not know. Meteorites, as we have seen, may contain carbon and hydrogen, both of these elements being essential to life as we know it. Perhaps a meteorite may yet bring to our earth an organic material, that is, a substance made up of carbon, hydrogen, oxygen and nitrogen, the four elements of life. If so, then many possibilities will arise before us.

It has been seriously suggested that the original germ of life came to this planet on the back of a meteorite, so to speak, this scientific theory asserting that life on our earth was originally transferred from some other planet by the agency of a space projectile or meteor. The theory has its possibilities, but it is not very probable.

No trace of bacteria has ever been detected upon freshly fallen meteorites. That does not, however, imply that if bacteria do exist in extra-terrestrial regions it would not be possible for a meteor projectile to convey them to us, for many meteors are porous in inner structure and hosts of living germs could readily store themselves away in even one single microscopic pore provided that the right conditions were present.

Against this suggestion the reader will, no doubt, point to the fact that meteors are heated to incandescence during their flight through the earth's atmosphere and that no life form is capable of withstanding such temperatures. Such is undoubtedly the case, yet, curiously enough, after a meteor has fallen it often rapidly becomes covered with a layer of ice consequent upon the fact that its inner core is at an extremely low temperature.

Space Temperature

We know that a temperature approaching absolute zero (minus 273 deg. C.) reigns in open space. Thus, small bodies travelling through this space will be more or less heatless—that is to say, they will attain a uniform temperature of approximately absolute zero. Now, although a meteor during its passage through the earth's atmosphere becomes heated up to white heat, the velocity of its flight is so rapid that the meteor itself, if it is of any respectable size, has not time to become uniformly heated before it reaches the ground. Thus, although its surface area may have attained glowing incandescence for a few seconds, its inner core still remains many degrees below ordinary zero, thus making possible the characteristic ice formation after the meteor has rested on the earth for a short time.

The question, therefore, seems to be not so much whether it is possible for living bacteria or other minute forms of life to withstand intense heat but, rather, whether these specks of living material will survive after being subjected to intense cold.

The problem, however, has never been decided. No one has yet found bacteria in the pores of a meteorite. Perhaps such life forms may never be discovered therein. But if a meteorite were ever found to be bacteria-contaminated, such a fact would at once open up the engrossing possibility of strange plant seeds, unknown fungi and germ spores and even the minute origins of malignant diseases yet unknown to us being conveyed to our planet haphazardly by means of a meteor projectile from remote outer space.

The flash of a large meteor past the telescope camera.

Nature's V2s

There is yet another possibility worthy of consideration in relation to the subject of these space projectiles. It is the fact that if we dub as V1 the ordinary meteorites which reach us, Nature has up her sleeve a number of very nasty V2s which she occasionally inflicts upon our earth with somewhat disastrous results.

Nature's V2 is the over-sized meteor, the space projectile which is something of the nature of a flying mountain and which, occasionally in recorded history, has been proved to hit the earth squarely and forcibly and with serious consequences.

The last recorded of these natural V-2s fell in the northern wilds of Siberia on June 30th, 1908. It devastated an area of several square miles, trees being completely burnt up and the ground for miles around being pitted with craters, some of them 150ft. in diameter. The sound of the meteorite's impact was recorded at several British meteorological stations, but its exact significance was not realised until later. The impact shock was also registered in Germany.

In Arizona there is the famous Meteor Crater, a huge depression in the earth nearly a mile in diameter and some 600ft. deep. This, in prehistoric ages, was caused by a similar meteorite impact to the Siberia one of relatively recent years, except, of course, that the Arizona impact must have been much more severe. In the latter instance, the huge hurling mass of meteorite material must have buried itself hundreds of feet below the ground, in which position it has been proved still to remain. Many expeditions have been made to Meteor Crater for the purpose of prospecting the buried meteorite, which is accredited with containing large amounts of platinum and gold, but none of them yet has in any way succeeded.

Now, the fact is that it is possible for such enormous masses of material to encounter the earth brings with it the question as to how far it may be possible or likely for our planet to suffer a major disaster by the impact of a still larger mass of meteorite material.

We have, of course, no possible notion of how much of this "flying mountain" material may be present in interplanetary space, nor have we, as yet, any means of detecting the presence of such dangerous debris. We know that the planet Mars has two revolving moons or satellites, one of which, *Deimos*, is barely 10 miles in diameter. Possibly, therefore, *Deimos* was once a meteor which rushed in to bombard the Martian planet but which was "captured" by the gravitational influence of that planet and made to revolve around it in a permanent orbit.

Flying Mountains

Moreover, there may be, and undoubtedly are, other Deimoses in space, although those which we know (constituting the smaller members of the asteroid family of planets) revolve in well-defined orbits. One of these, *Hermes* (discovered in 1937) is, perhaps, not more than a mile or two in diameter, but of all the heavenly bodies, apart from the moon and the meteors which fall to the earth, it is the one which comes the nearest to us, swinging at one point in its orbit to within 400,000 miles of the earth, which is less than twice the moon's distance from us.

Another recently discovered asteroid or planetoid is *Adonis*. Another is *Amor*. *Adonis* seems to have a diameter of less than half a mile. It is literally a flying rock, irregular shaped and it appears to travel through space merely by turning itself over and over.

Hermes, *Amor*, *Adonis* and others of their kin approach the earth, but they never leave their appointed orbits around the sun.

What, however, if one of these miniature planets took it into its head when approaching the earth to make a flying leap at our planet? It would at once constitute a space V-2 *par excellence*. *Adonis*, *Amor or Hermes* might, perchance, consist of solid platinum or gold. Nevertheless, if they happened to hit the earth, great havoc would necessarily be wrought, particularly if the point of impact coincided with a populous region of our globe.

London, Paris or New York, for instance, would fare badly under the impact of even a half-mile-diameter planet, let alone that of a larger-sized projectile. And even if such an unwelcome space visitor buried itself deeply in the bed of the ocean, the result would be felt on all the continents, for a gigantic tidal-wave would at once hurl itself around the earth, bringing destruction and suffering wherever it went.

Fortunately, there seems to be very little chance of our earth being hit by an asteroid broken loose or by a similar sized chunk of extra-terrestrial matter. Yet the possibility remains and it cannot be denied.

Space projectiles, therefore, may bring us new materials, new compounds, perhaps some elementary forms of life, or, as we have just seen, possibly a serious disaster. The chances, however, are quite unpredictable.

Items of Interest

Model Engines from Red Cross Tins

GRANDFATHER clocks which kept accurate time, high-speed cookers, water pumps, stoves and chimneys, suitcases, cupboards, plates, mugs, steam and petrol engines—these are just a few of the things which R.A.F. prisoners of war in Germany made from Red Cross tins.

The tins were so highly prized that when parcels were shared lots would be drawn to decide who should have the tin.

Cooking stoves with forced draught created by belt-driven fans were made which could boil two pints of water in 45 secs.

One airman made a miniature petrol engine, with a tea-cup sized cylinder block, with cooling-fins cast from the melted-down solder of the Red Cross tins. Ignition was by a cam-operated push-rod which struck a flint.

Life-saving Packet for R.A.F.

ONE of the many problems which have confronted British scientists during the war has been of particular interest and importance to R.A.F. pilots and aircrews.

Early in the war, the Royal Air Force was faced with the fact that, with the possibility of much of the air war being fought above water, those airmen who had the misfortune to "ditch" were in danger of dying from thirst while adrift.

Those who crashed far from land were sometimes difficult to locate, and needed a specially large supply of water if they were to survive. In hot climates and tropical waters, fresh water is a greater necessity than food. Many suggestions were tried out during the research which went on in the early days.

Two important considerations, space and weight, had to be borne in mind in producing emergency "desalting" equipment to be carried—first in an aircraft, and then in a small dinghy.

Compact Desalting Apparatus

Eventually, chemists of the Permutit Company, Chiswick, working in association with the Ministry of Aircraft Production, produced a desalting apparatus in a simple and compact form, suitable even for weak or wounded men's use.

The apparatus is in the form of a box about the size of a half-pound packet of tea. The box is made of transparent plastic, and is used as a drinking vessel.

Inside is a collapsible bag. And all the "ditched" airman has to do is to take out this bag, pour in a quantity of sea water, drop in some cubes, close the bag, and, after a period, squeeze fresh water through a spout at the bottom of the box.

When all the fresh water has been squeezed out, the bag is rinsed in the sea and is then ready to produce another supply. Every part of the apparatus has a safety cord to prevent its loss in rough seas.

The process was devised by British scientists, who passed on the details to the United States. The Americans have now developed a similar apparatus.

Over 20,000 of these boxes have been sent to Eastern Air Command, South East Asia. Each of these, though taking up less space than a pint of water, will produce four and a half pints.

They will be packed into the dinghies carried by all aircraft flying over the sea, several being provided for each member of the crew.

Ranging Hellcats on the flight-deck of one of H.M. escort carriers now serving with the East Indies Fleet. The lift is rising and the flight-deck handling party wait until it is flush with the deck to push the Hellcat into position.

Rocket Propulsion

Further Details of U.S. Research : The American Rocket Society and its Affiliates : The United States Rocket Society

By K. W. GATLAND

HAVING covered the work of the American Rocket Society in fair detail; and before going on to review the research of the more recent contemporary U.S. groups, a word about the Society's present-day activities. As might be supposed, war conditions have largely forced the abandonment of any specific technical development programme, and many of the Society's members are engaged on research in the Government laboratories, helping along the rocket's development under the most satisfactory conditions of finance and labour.

Within the Society research is maintained to some extent by theoretical work, occasionally supplemented by small-scale experimentation. It will be readily appreciated that any more extensive practical work carried out by the Society, with its limited resources, would be rather insignificant at the present time, when war sponsored research into reaction propulsion systems is proceeding under conditions which promote large-scale and rapid technical development.

Basis of Wartime Development

The Society's aim throughout its existence has been the encouragement of scientific research and the engineering development of reaction propulsor devices and their application to the problems of transportation and communication, and, in recent times, this has been extended to include the military application of rocket power.

That the American Rocket Society is the most widely renowned group of its kind is no over-statement. In many ways its research has formed the basis for the design of the military rockets which have proved so effective in the hands of the Allied land, air and sea-borne forces, and, in this regard, it should be remembered that while the American group and similar groups throughout the world were struggling along with their researches under most unfavourable conditions of finance, responsible Governments remained apathetic to talk of rockets and reaction flight in general. It is well that so much experimentation had been privately conducted in pre-war years. Had this not been the case the Nazi authorities, quick to realise the rocket's vast possibilities in the work of the free-German Verin für Raumschiffahrt E.V., and whose experiments were commenced years before the outbreak of the war, might well have made the position of the German military forces a far less precarious one.

Affiliate Groups——

There are three rocket groups affiliated to the American Rocket Society, although much of their research is carried out independent of the parent body. Of these, the New York, Westchester Rocket Society, is the most long established, having its foundation in 1936.

In the years prior to its affiliation the group conducted a theoretical study of alighting methods, other than the parachute, suitable for adaption to the rocket projectile. Of the types investigated the gyro-plane type rotor was considered worthy of investigation.

A start was made with the construction of a 10ft. diameter rotor, and other sizes of

(*Continued from page 344, July issue*)

varying design were subsequently built and tested in free-flight. These experiments made it clear that the available data concerning the design and theory of the gyro-plane rotor were inadequate for rocket use, and, in consequence, further tests were carried out with the object of determining the effect of dihedral and attack angle changes, as well as wing loading of rotor blades during vertical ascent.

In a report to the American Rocket Society, N. Limber, writer and prominent member of the Westchester Society, has pointed out that when considering efficiency and desirability, the rotor, when compared with the parachute, is somewhat inferior both as regards weight and compactness. In conducting further tests, Mr. Limber says that it is hoped to prove or disprove certain apparent advantages the rotor system may offer, principally decrease in drift, and greater dependability.

Water Cooled Rocket Unit

The group has also designed several liquid-fueled rocket motors. One of these propulsion units, which has reached the construction stage, embodies a 1in. nozzle constriction, and is one of the largest of its type yet produced by the rocket groups.

The unit, which is built of monel, brass and dural, features a special system permitting the attachment of various liquid oxygen feeding ports. The combustion feed, too, is somewhat unique in that the propellant is first allowed to expand in a mixing chamber, prior to entry into the combustion chamber. Cooling is arranged through the feeding of water from a radial slot, which results in the formation of a protective layer of superheated steam around the inner wall of the firing chamber adjacent to the nozzle "throat."

The Society's more recent investigations have concerned supersonic flow and its effect on the flight efficiency of projectiles.

California Rocket Society

The initial experiments of the affiliate California Rocket Society, like the majority of tests previously described, concerned the powder rocket, its stability and the methods of parachute release. These further trials took place in May, 1941, and again, the powder cartridges were obtained commercially.

A simple beam balance, built by members of the group, served to gain for the experimenters some knowledge of the thrust values of the charges, and this consisted simply of a steel bar, pivoted off-centre, and calibrated by applying various known weights along the free end. During testing, a stop watch was placed close to the thrust indicator and a ciné camera focused on the two instruments.

The initial series of ground trials concerned the standard commercial 8lb. charge with 11/16in. diameter fireclay nozzle, and a first firing recorded a thrust duration of 1.5 seconds. Unfortunately, a fault in the sighting of the camera left the thrust figure uncharted. A second test was made with a rocket charge to which had been fitted a specially constructed steel nozzle having a length of 2.50in. and a "throat" diameter of 9/16in. When fired, the charge exploded the case after only 0.1 second burning, due, obviously, to the reduced nozzle orifice.

A ½in. diameter fireclay nozzle, 2in. in length, featured in the third experiment, but this burned out almost immediately after ignition. A final test was made with an unmodified charge weighing 25oz., of which 12oz. constituted black powder. This fired for an effective period of 2.0 seconds and the scale showed a thrust of 27lb. at maximum combustion. It burned for a further 8 seconds at zero thrust.

Free-flight Research

A month later, experimentation was carried out with powder rockets in free-flight. Each of these was fitted with a parachute, which was packed into a compartment at the nose; the nosing being placed lightly on top. The release action, in this instance, depended upon the "spring" of the parachute's own compression, which acted to throw off the nose cap when the rocket was slowed up at the flight apex.

Several firings were made to test the efficiency of this release method, and quite satisfactory results were achieved; the parachute being ejected at the peak trajectory in almost every instance.

The group later carried out experiments with powder rockets each fitted with a small gyroscope, but due to the very limited burning time of the propulsion charges, the flight results were largely inconclusive.

Conclusion

The firing duration of the 8lb. commercial charge was obviously not adequate for the majority of flight tests. It was further proved inadvisable to modify the standard charge either by the removal of part of the casing, or through the constriction of the nozzle orifice beyond the designed diameter.

Fluid-solid Fueled Rocket Motor

Unlike the majority of U.S. groups, the California Rocket Society has maintained its technical development programme throughout the war period, and research in the 1943 period concerned the constant-volume rocket motor. Outstanding in this work are several motor developments of a type which employ a liquid-solid propellant, and tests have already shown promise of very high efficiencies in the fully developed version. It is unfortunate that essential details, both as regards design and test results of these units have not been made available for publication.

The Yale Rocket Club is the more recent affiliate group, and its work to date has largely comprised the building and free-flight tests of powder rockets.

The G.A.L.C.I.T. Rocket Research Society

The Guggenheim Aeronautical Laboratory of the California Institute of Technology has established a special section for the development of rocket propulsor systems. In fact, the group's inception dates back to 1936; those chiefly responsible being F. J. Malina and J. Parsons, of the Halifax Powder Company.

During the year of inauguration little of a practical nature was carried out, most of the early work being centred toward gaining a thorough understanding of the subject from the development of known principles and propulsion methods in the light of the more current test results; these, principally due to the American Rocket Society.

In more recent years tests have been conducted of several constant-volume liquid-fueled motors, and also a powder motor, powered by successive impulse.

For the test of such units the group has constructed three proving stands; and the most ambitious of these is shown diagrammatically in Fig. 29. The measurement of thrust reaction in this particular arrangement is achieved through the use of a development of the torsion balance, using heavy feed lines as the torsion member. A lever made up of these tubes supports the motor under test and also extends forward of the torsion member, being balanced by a beam and counterweight. A dial gauge, functioned by an extension on the beam balance, is operated when the thrust of the motor causes rotation about the torsion member.

This system of recording has resulted in the attainment of exceptionally high accuracies; the instruments fitted to the apparatus recording, in addition to the developed thrust, such data as the combustion chamber pressure; propellant feed-line and cylinder pressures; rate of flow of combustibles, and the test duration. The gauges are, of course, ciné photographed throughout the testing period, thereby enabling later study of the results.

Carbon Built, Liquid-fuel Motor

One of the most novel types of several constant-volume rocket motors produced by the G.A.L.C.I.T. is shown in Fig. 30. It is, of course, a liquid propellant motor, and is notable in that all combustion faces are of carbon. In this particular instance, the combustion chamber and nozzle were machined from carbon electrode, and the motor encased tightly within a steel jacket, to which the combustion loads were transmitted. This consisting simply of a cylindrical liner with plates bolted down firmly at each end.

On test the motor recorded a chamber pressure of 300lb./sq. in. for a period of one minute, and a subsequent examination showed that the nozzle "throat," which originally had a diameter of .136in., suffered only an enlargement of .015in. under the erosion of the exhaust efflux.

Successive Loading Powder Motor

A particularly interesting series of experiments, aimed at the development of a powder rocket motor of the constant-volume type, were conducted by J. W. Parsons, of the G.A.L.C.I.T. Rocket Research Society, and E. S. Forman; the work covering a period of years.

In work of this nature there are, of course, two distinct systems to consider; the slow-burning powder as applied in pyrotechnics, etc., and the rapid burning type demonstrated by Prof. R. H. Goddard. The latter has shown promise of higher efficiencies, and used in conjunction with a suitable motor and feeding arrangement, it would provide a well controlled and even rate of combustion with a thrust duration effective for periods comparable with the liquid propellant rockets.

The development of an efficient mechanism for the successive injection and firing of small charges is, of course, the principal factor, and many problems are attendant in the design of such apparatus. There must, of necessity, be provided access in the combustion chamber for the entry of the powder charges, and during the individual firings this must be closed, with a gas tight seal. When it is considered that the injecting and sealing action must invariably take place several times a *second*, the design difficulties can be well appreciated.

The function of this type motor is more in the nature of rapid, individual explosions than a continuous expansion as associated with the more conventional liquid fuel rocket engine. This means that while the heat energy of the powder used is relatively low, the comburant gases are ejected at a considerable velocity, thereby permitting high thermal efficiencies.

Goddard Research

Although Goddard is reputed to have developed an automatic powder motor reloaded by thrust recoil, no performance data has been made available. In the absence of this information, the results of his initial experiments with individual charges are fair indication of the efficiencies attainable. Using a commercial "pistol" powder classified "Infalilble" (9.0259 gm. mass) as a single charge

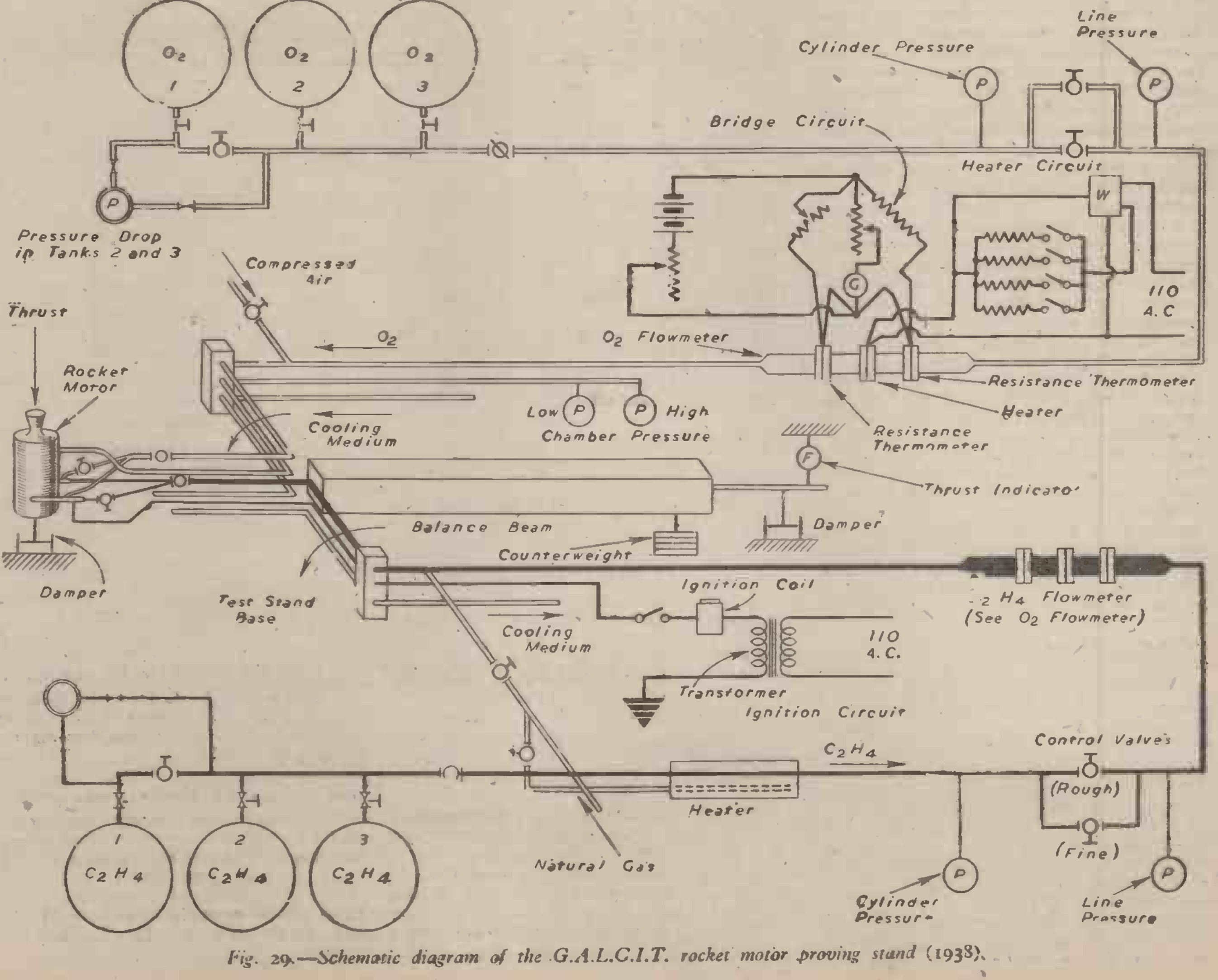


Fig. 29.—Schematic diagram of the G.A.L.C.I.T. rocket motor proving stand (1938).

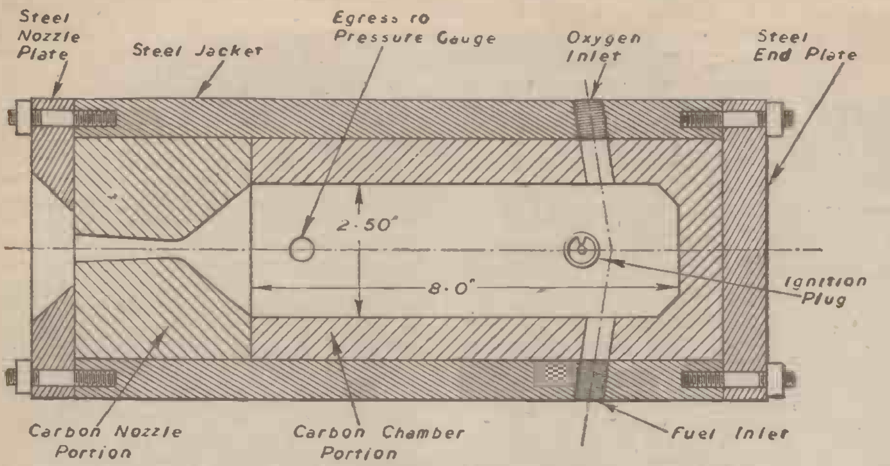


Fig. 30.—Constant-volume rocket motor with firing faces of carbon, produced by the G.A.L.C.I.T. Rocket Research Group, California, U.S.A.

compressed into a small experimental combustion chamber (length of chamber, 2.28 cms.; internal diameter, 2.6 cms.; length of nozzle, 16.29 cms.—de Laval type), proving tests recorded an exhaust velocity of 7,987 ft./sec., and an efficiency of 57.25 per cent.

The above figures illustrate the most satisfactory case arising from the use of a well-designed firing chamber, and incorporating an efficient nozzle which permitted optimum expansion of the comburant gases.

More Recent Experiments

The Parsons-Forman preliminary experiments dealt with two single-charge combustion chambers (Fig. 31). These were made in order to gain data of the following all-important factors—(a) The effective exhaust velocity and thermal efficiency of the powder charge rocket obtainable with various powders. (b) The effect of chamber pressure on the thermal efficiency. (c) Methods of varying the chamber pressure. (d) Chamber and nozzle design, and (e) The effect of various methods of ignition and the physical state of the powder.

The original single charge motor, constructed of chrome-molybdenum steel, comprised simply a tube of heavy gauge having a nozzle at one end, and a screwed block at the other. It had a combustion chamber of ½in. diameter and two interchangeable nozzles of 3/16in. and ⅛in. diameter "throat" respectively, with a 6 deg. flare angle.

The second motor was similar, though somewhat larger and of increased strength. It had a machined combustion chamber of 1in. diameter, and a nozzle of ¼in. diameter orifice having a flare of 9½ deg. A Ludlum Seminole steel, treated to withstand a tensile stress of 130,000lb./sq. in., was used throughout.

In the first type, the powder, after its compression in the chamber, was fired by a simple touch fuse, while in the latter model, ignition was performed electrically, and a wad fitted in the "throat" orifice to improve the combustion pressure.

Test Findings

A commercial black powder (Hercules-Laflin and Rand FFG), having a theoretical velocity of 7,900ft./sec. and nitro-cellulose powder (Hercules "Bullseye" smokeless powder), with a theoretical velocity of 10,600 ft./sec. featured in the testing.

Using these propellants, an exacting series of firings showed that the efficiencies of the test motors compared most favourably with the Goddard single-charge chambers. It was found, too, that an increased jet velocity, and efficiency, resulted from a decreased nozzle diameter, by an increased powder weight, and through the provision of wadding fitted at the nozzle "throat."

These factors, it will be noted, are those which tend to increase the chamber pressure.

After repeated firing, using the large chamber, a serious erosion of the nozzle "throat" became apparent, and this resulted in a marked decline of efficiency, and, as might be supposed, considerable fouling was caused by the black powder, which was entirely absent in the use of the smokeless variety.

With a well-designed motor, and using a pure fuel compound (nitro-cellulose), ash

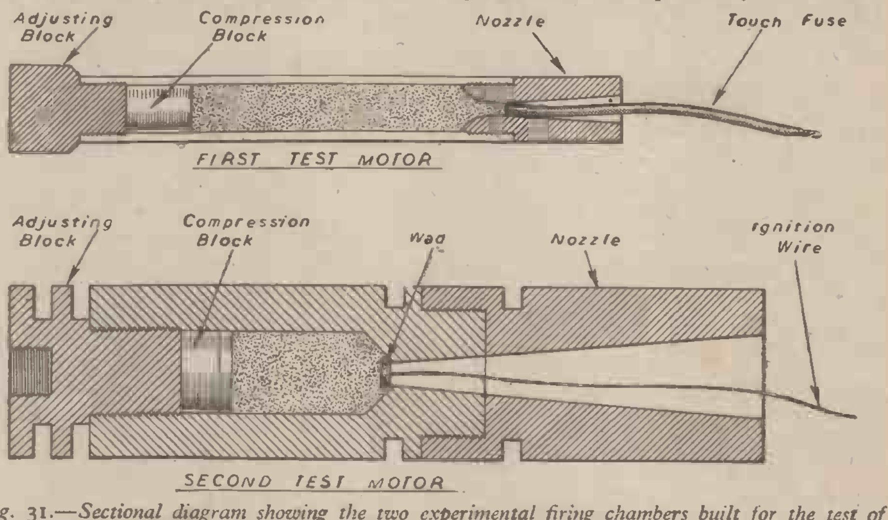


Fig. 31.—Sectional diagram showing the two experimental firing chambers built for the test of "shot" powders (Parsons and Forman, California, U.S.A., 1938).

produced in combustion should only be condensed after the effluent had been ejected from the nozzle.

It is of interest to note that there was no serious heating at any time during the experiments; the motors being only slightly warm to the hand after successive firing. This is accounted to the high speed of gas ejection in that the individual charges did not remain in the chamber for a sufficient period to create high temperatures. The small-grained, rapid-burning smokeless powders are more completely combusted and produce a swifter release of pressure. The duration of combustion, under the prevailing test conditions of smokeless powder, is estimated to lie between 1/5,000 sec. to 1/10,000 sec., which permits kinectic conversion to take place with the minimum heat loss.

More recent work has involved the construction of an automatic injection mechanism, and in addition to providing stand tests, it is hoped to employ this motor for flight research. Participating in this development, the efforts of F. J. Malina and H. S. Taien (both of the G.A.L.C.I.T. Rocket Research Society), Mr. Spade, of the Ludlum Steel Co., and Mr. H. N. Marsh, of the Hercules Powder Co., should not go without mention.

The United States Rocket Society

Although having its formation as recent as 1942, the United States Rocket Society is fast becoming a prominent astronautical body, despite the fact that its present function is purely academic. The group's principal aim during the war years has been the building up of a substantial membership, and this is largely composed of technicians, both of American industry and the armed forces.

Because of war conditions, it has, quite naturally, been found impossible to direct any programme of specific technical development, and in the interim period before practical experimentation is a possibility the coalition of information and data, the formation of discussion groups, and lecturing, comprises its principal wartime activities.

The founder, Mr. R. L. Farnsworth, has written as a first official work of the Society a review and bibliography, "Rockets—New Trail to Empire." This is a useful reference to the numerous U.S. technical literatures of rocket propulsion, and has undoubtedly done much in the way of publicity for the group.

Rocket Propulsion

Pre-war Experimentation in Britain

By K. W. GATLAND

(Continued from page 374, August issue)

THE Manchester Interplanetary Society was the second organised British rocket group, having its inception in the summer of 1936, due to the efforts of Mr. E. Burgess (now president of the Combined British Astronautical Societies). Its function was entirely independent of the pioneer British Interplanetary Society, whose existence did not become widely known until some years later. Contact did not, in fact, materialise until after the original Manchester Society had been dissolved and another group, the Manchester Astronautical Association, inaugurated in its place.

Prior to its dissolution, the former Manchester Society carried out numerous experiments with powder charge rockets, and of these several are worthy of mention. It will be remembered that in the majority of similar experimentation previously mentioned, the propellant charges were obtained commercially, and while this was also true of the early months of the Manchester group's activity, their later research also concerned the manufacture of special charge cases as well as the charge filling.

Of the experiments conducted, the most promising lines of development were those resulting from the investigation of methods of combustive control in powder charge rockets and the flight stability of rocket projectiles.

The production of charge cases, too, formed an important part of the Manchester group's research during the 1936-7 period and many of these, fitted with special nozzles and heat-resistant liners, were proved during test greatly superior to similar charges of commercial origin. As an outcome of this research, there were also developed several original methods of loading and compressing the propellants, which resulted in increased steadiness of burning and a subsequent improved combustive efficiency. Later test firings were made with rockets which embodied various devices intended to control the rate of combustion.

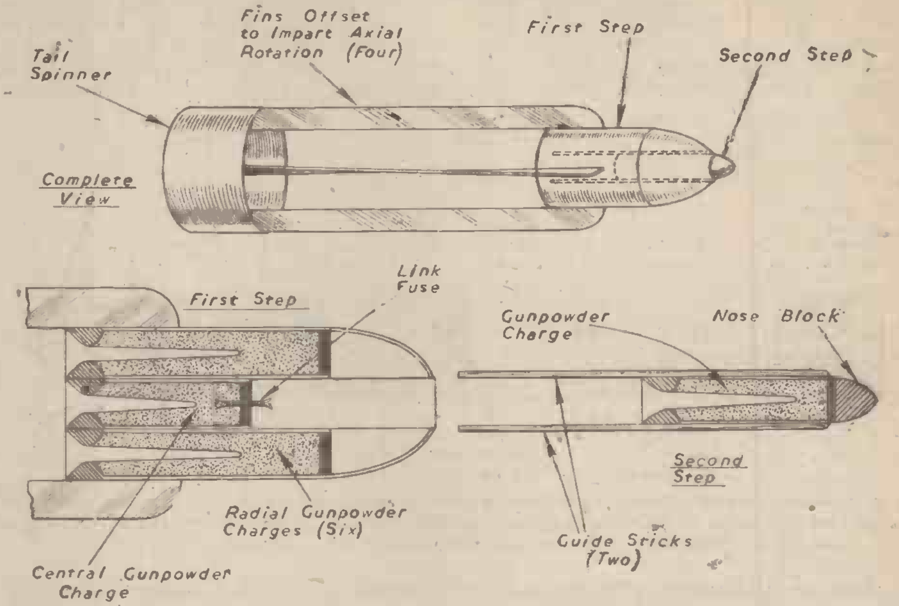


Fig. 33.—Diagram of two-step powder rocket, developed by the Manchester Interplanetary Society (1936).

Stability

The initial experiments concerned the flight trajectory of rocket projectiles, and a number of types were produced and flight tested with a view to determine the particular method of stability best suited to function under normal conditions of atmosphere.

There are several methods of achieving this stability, and the society found its most satisfactory results in axial rotation—created either by offset vanes fitted in the efflux, or airstream, or through the offsetting of grouped rocket tubes, or nozzles. Other models were fitted with the more conventional straight-set, stabilising fins and spinners. A selection of the types which featured in the testing is shown in Fig. 32.

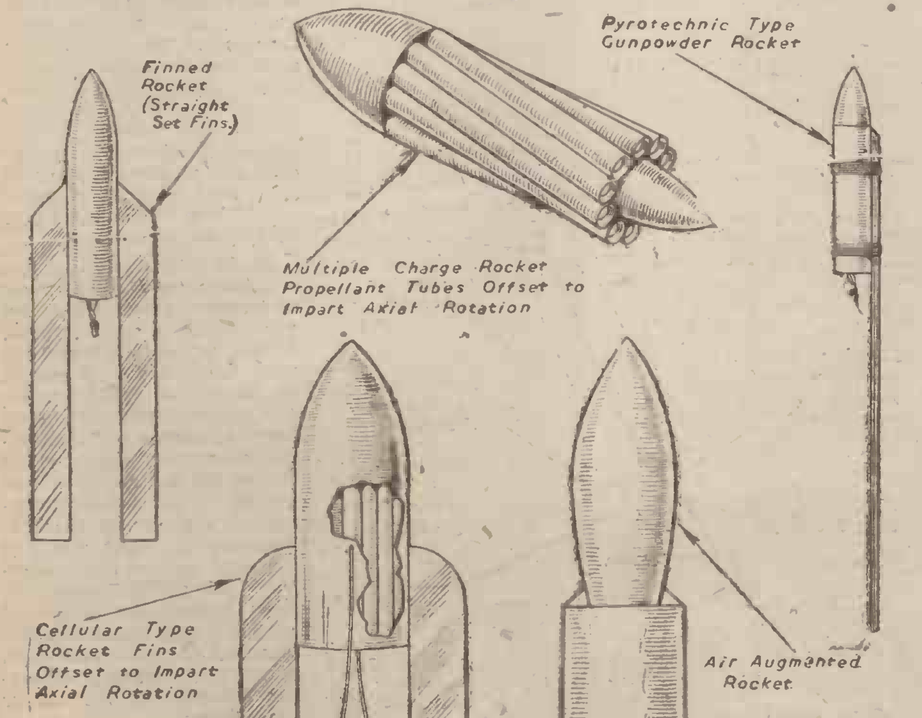


Fig. 32.—Methods of stability control found most effective by the Manchester rocket groups.

Control of Combustion

The rockets constructed to test firing and combustion-control methods comprised several of the "step" type and, of these, a model having two propulsor components (Fig. 33) gave a highly creditable and stable performance.

The first "step" comprised seven individual black powder charges arranged in a cellular construction and fused so that the firing of the tubes took place in the order "four," "three." The second component, a single charge rocket, was fitted to form the rocket nosing, and designed to fire from the "carrier" rocket at the latter's greatest velocity. This was arranged through an interconnecting fuse ignited from the central charge.

Stability of the original component was achieved by the provision of offset airstream fins which causes rotation about the body axis. The second "step" embodied two balancing "sticks," but depended also upon the angular momentum which it derived from the parent rocket.

It will be appreciated that the main point of significance with this type of rocket is that the small component is released in combustion at a high velocity, and therefore its function is so much nearer the maximum propulsive efficiency.

A firing test carried out at Manchester in December, 1936, gave good illustration of this point. The complete rocket, propelled by the lower component, reached a height of between 150 to 200 feet before the release of the second "step," which accelerated at such a rate as to render its trajectory invisible to the observers. The small rocket was not recovered after the experiments.

Fuel Developments

Working in conjunction with a pyrotechnical expert, the late Lt.-Col. W. T. Southam, the experimental committee of the Manchester Society developed several black powders of various constituencies, for use both with paper formed and metal charge cases. These experiments, which were commenced in December, 1936, involved the society for a year, and although their results can hardly be said to have contributed greatly towards propellant development, several of the powders proved highly effective for the type and were the means of testing several original propulsion systems.

During the course of this research a number of public demonstrations involving the flight testing of rockets, both paper and metal, were undertaken by the society at Manchester. It was, in fact, while testing under these conditions before a large crowd who, despite repeated warnings, would not retire from the launching site, that an accident occurred in which several of the bystanders were slightly injured by fragments of an aluminium rocket which exploded on the launching rack.

This incident brought court proceedings against the society, and the findings showed that an infringement of the Explosives Act of 1875 had been caused by the admixture of potassium chlorate in a black powder composition which comprised the base chemicals, potassium nitrate, sulphur and charcoal. The union of potassium chlorate and sulphur was the offending act, any propellant of this constituency being decidedly unstable and liable to instantaneous detonation.

A few months later the Manchester Interplanetary Society was dissolved, to be followed almost immediately in December, 1937, by the inception of another group, the Manchester Astronautical Association. The founders were E. Burgess and the late T. Cusack, two prominent members of the former society.

The work of the new Manchester group was more or less a continuation of the earlier research, with the emphasis again towards the improvement of combustive control in powder rockets.

An interesting development aimed at improving the performance of single charge rockets is shown in Fig. 34. It will be observed that the propulsion charge is divided into a number of separate compartments, the powder in each being insulated by layers of combustible felt. The propellant sections are made as capsules, each of which has a conical-formed base of rapid burning powder, the idea being to produce the largest possible area of burning.

The main advantage of this arrangement is that any slight explosion which were to occur would limit the disruption of the fuel to one section, whereas a similar happening in a conventional "fuel store" rocket would invariably explode the entire filling.

The diagram shows a development of the original scheme which the experimental committee tested in August, 1938. The trial rocket had four fuel compartments and a conventional paper case, although an extended nozzle and fireclay choke were fitted. No parachute was incorporated in the test type.

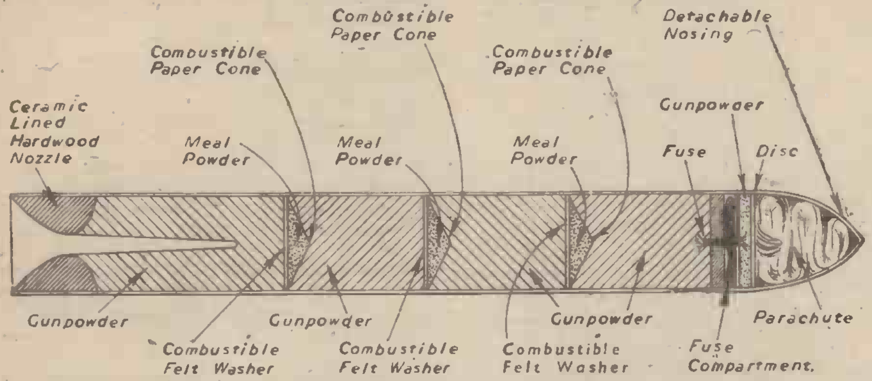


Fig. 34.—Diagram of a powder rocket having four charge compartments. This system is intended to prevent disruption of the entire propellant through isolation of the burning section. Developed by the Manchester Astronautical Association from a German idea (1938).

Cellular Construction

Tests of cellular rockets followed, and in these the association found its most satisfying results.

In essence, the cellular method of rocket construction means simply a power unit composed of a number of "fuel store" charges arranged in lateral contact, each a complete propulsion element in itself and having individual means of ignition. The rocket illustrated (Fig. 32) had merely a single-bank cellular arrangement, but other types have been produced in which several banks of cellules are employed. In this latter instance the expended tubes are automatically jettisoned, succeeding tubes being fired upon their release until the entire propulsion system is expended. It will be readily appreciated that this removal of dead mass brings about a progressive improvement of the fuel/weight ratio, and a parallel increase of the propulsive efficiency.

The combustive control is another factor that is much improved by cellular construction. It is obvious that the thrust of the unit can be increased or decreased at will by the firing of varying numbers, or different sizes, of cellules.

Apart from light "retaining" members, the cellules themselves compose the structure, and the strength of the rocket is very largely dependent upon the density of the propellant and the cellular formation. The need for any involved and weighty arrangement of forming members is thereby eliminated.

The model tested in the Manchester experiments was a single-bank cellule rocket, and this proved to be one of the best stabilised of any type produced during the entire period of active research. Stability in this instance was achieved by the offsetting of four small fins to the air-stream, which caused rotation about the body axis. In order to ensure stability during the initial moments of ascent, the launching device had means for pre-rotating the rocket, thus enabling correct function from the instant of release. This was simply a turntable with a length of metal rod projecting from its centre, mounted to a base platform, and the rocket, which had a metal sleeve built in along its axis, fitted over the guide rod and rested on the turntable (Fig. 35). The turntable was rapidly rotated just prior to launching, thereby imparting an initial spin to the rocket, which was maintained in flight by air reaction on the fins.

Only one problem of significance arose from the cellular tests. This involved burn-out of the power element, in that should one of the cellules burn through, it was capable of destroying the entire make-up of the cellular unit. A later series of firings, however, proved the remedy to be dependent entirely upon the efficiency of tube construction and, using carefully prepared tubes, these further trials gave no evidence of burn-out.

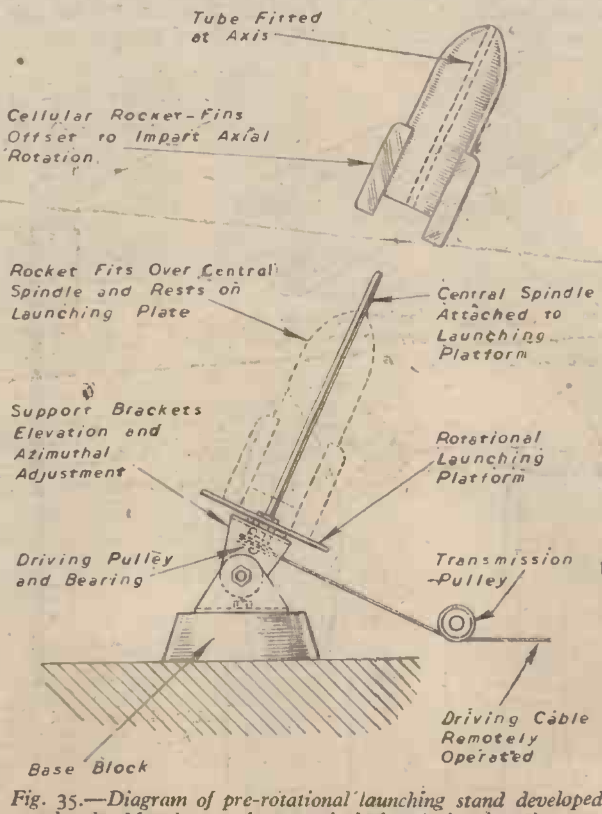


Fig. 35.—Diagram of pre-rotational launching stand developed by the Manchester Astronautical Association (1938).

In the autumn of 1938 the association constructed a light air-augmented rocket (Fig. 36) powered by a single charge. In this model four small fins were fitted at the aft end of the body shell, and attached over these, and extending from the rear, was a cylindrical augmenter tube, which also served as a stabiliser. On test the rocket showed a particularly high rate of acceleration, and the flight was well stabilised with a high trajectory. As in the majority of flight experiments conducted by the group, the rocket was launched from a metal tube. A two-rail launching apparatus featured in the earlier experiments.

The foregoing is a review of the pre-war experimentation conducted by the Manchester rocket groups. A great deal remains to be said of their work during the war period; but first, a word about the investigations of contemporary organisations which functioned in Britain in the years leading to the outbreak of hostilities.

The Paisley Research Group

Among the early rocket groups whose activities largely concerned the practical was the Scottish, Paisley Rocketeers' Society, a student body of some twenty members, subsequently affiliated to the Manchester Astronautical Association. Its inception took place in February, 1936, and working under the direction of its founder-president, Mr. J. D. Stewart, the group carried out a programme of technical development which involved the design, manufacture and testing of various powder charge rockets.

Of these perhaps the most significant were the rockets produced for aerial survey. The first model of this type was fired in August, 1938, and its initial weight, complete with a miniature camera and parachute was only 9oz. The operation of the camera was achieved through the pull on a wire cable, which connected the parachute shrouds and the shutter, and thereby ensured the function of the shutter at the same time as the ejection of the parachute, when the rocket was at its peak trajectory. In this first flight trial the rocket rose to a height of approximately 300ft. before ejecting its parachute, and landed at a point 600ft. from the launching rack. Although in this test the camera operated as arranged, the photograph secured showed only sky.

A second rocket was constructed, and as in the previous model, the camera was fitted at the nose, with the lens aperture at the side, the sole difference being the provision of a small mirror fixed above the lens at an angle of 45 degrees. This arrangement ensured that the resultant picture was of what lay below the rocket at the instant of the parachute's opening.

Further trials were made with a rocket having a parachute and camera which operated on the ejection of the expended propulsion charge—this latter arrangement was adopted in order to lessen the rate of descent by reducing the weight and so ensuring that the camera, and any other delicate equipment carried, reached the ground with the least chance of damage. Other models, of light construction and not fitted for delicate apparatus, simply incorporated an ejecting device to free the propellant case, and no parachute, thus making the rockets so light that they dropped without harm. The loss of momentum which occurred with the release of the case, however, caused an appreciable reduction of the range. A solution would appear to be the provision of a simple time fuse, set to discharge the case at the peak trajectory.

Stabilised

The society carried out still further tests of rockets stabilised by rotation, and though of simple construction and small size, several of these proved highly effective, both as regards range and accuracy of trajectory.

The first model of this type comprised simply three small powder charges grouped around a short length of dowel, each unit set at a slight angle to the longitudinal axis. This rocket, whose initial weight was $\frac{3}{8}$oz., travelled a distance of 250ft. in well-established flight before assuming a spiralling trajectory, due presumably to the reduction of the rotational velocity as the fuel became exhausted. Its final range was a little under 500ft.

A second rocket, having four inclined tubes and no central stick, travelled a distance of 150ft. Its path of flight was at first irregular, but became more stable as the angular rotation increased, the poor range being accounted to excessive drag created at the commencement of flight.

To overcome the initial instability the society built a special launching apparatus for pre-rotating the rockets, similar, in fact, to the one developed earlier by the Manchester group. When pre-rotated, the models rose smoothly and were quite effective until the latter stages of flight, when "spiralling" would invariably occur. In some instances the oscillatory motion was apparent under power as well as during momentum, and it is likely that this was caused by unequal thrust in the tubes and through the rocket shell not being truly symmetrical.

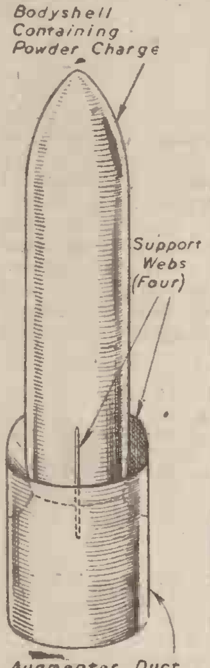


Fig. 36.—Air-augmented powder rocket by the Manchester Astronautical Association (1938).

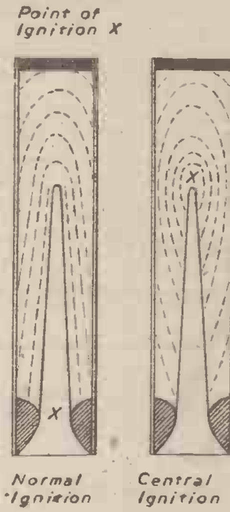


Fig. 37.—Diagram showing burning lines in conventional powder charge, and one centrally ignited. Paisley Rocketeers Society (1939).

Later experiments concerned the thrust augmenter and, using standard $\frac{3}{8}$oz. charges, flight trials showed a generally improved performance in the use of "augmented" tubes, despite their greater weight, also that rockets thus fitted were capable of sustaining a more accurate trajectory. The latter factor may be accounted jointly to an increased mass effluent and the stabilising effect of the augmenter "spinner."

Commercial Charges—Unmodified and Developed

The charges used during the entire period of the Paisley group's active research were obtained commercially, and while in the majority of tests these were unmodified, in certain cases the tubes were fitted for "central ignition" of the propellant.

In the accompanying diagram (Fig. 37) are shown the progressive burning phases in powder charge rockets, and indicates both the firing faces as formed in the conventional tube and those of a tube centrally ignited.

Proving stand tests have shown that the latter method of ignition provides a marked increase in thrust, and this is attributed to the greater burning area and a more uniform rate of combustion.

The thrust figures as derived from four proving tests of standard $\frac{3}{8}$oz. rocket charges are as follows: using unmodified tubes, $1\frac{7}{8}$lb.; 2lb.-tubes "centrally ignited," $2\frac{1}{8}$lb.; $2\frac{1}{8}$lb.

Improved performance also resulted from the use of an extended fire-clay nozzle ($\frac{1}{2}$in. long, 14° flare angle), fitted to unmodified standard charges, but unfortunately, in the absence of proving stand data, it is impossible in this instance to give any comparative figures.

(*To be continued*).

In the Far Eastern theatre of war a famous Artillery Regiment carried out repairs to their medium guns on the field. The illustration shows a gun crew hauling a gun barrel into position.

Rocket Propulsion

A National Rocket Society: The British Interplanetary Society: The "Lunar Space-vessel"

By K. W. GATLAND

(*Continued from page 417, September issue*)

As may be gathered from the foregoing, particularly with respect to the development of powder rockets, a great deal of the research carried out by one group has invariably been nothing more than a duplication of another's prior efforts.

The early rocket groups worked very largely in ignorance of any other similar bodies, and comparisons of their records make it obvious that the continuous repetition of experiment which ensued among the various rocket societies caused much waste of effort, time and money, and hence the rate of pre-war development was a slow process. Only under war conditions, when ideas and resources have been pooled and fostered by unlimited research grants, has anything approaching the ideal been attained in rocket engineering; but the lessons learned from wartime methods are not likely to be forgotten.

A National Rocket Society

It is clear that there is a definite need in rocket engineering for the establishment of a central body, possibly a coalition of the existing rocket societies, whose principal function would be the collection of experimental reports and technical data under a suitable reference system. This would provide intending experimenters of a particular problem with a complete history of any previous work conducted and possibly form the basis for more advanced research.

An organisation such as this would not, in view of the great technical advances of recent years and the limited finances available within the society, hope to sponsor active research, but would give every aid to manufacturers of commercial rockets—particularly those who will be concerned with the development of meteorological rockets, who would in their own interests become Associates of the Society.

Apart from the manufacturers, the group would be open for membership to any person interested in rocket development, and offer various grades of admittance rated on age and technical ability. It would also publish a regular journal keeping its members informed of latest advances in the many fields of rocket research, and, in fact, foster the development of the rocket engine and astronautics in similar vein to the Royal Aeronautical Society, whose pioneer work for aviation has had great bearing on the evolution of heavier-than-air flight.

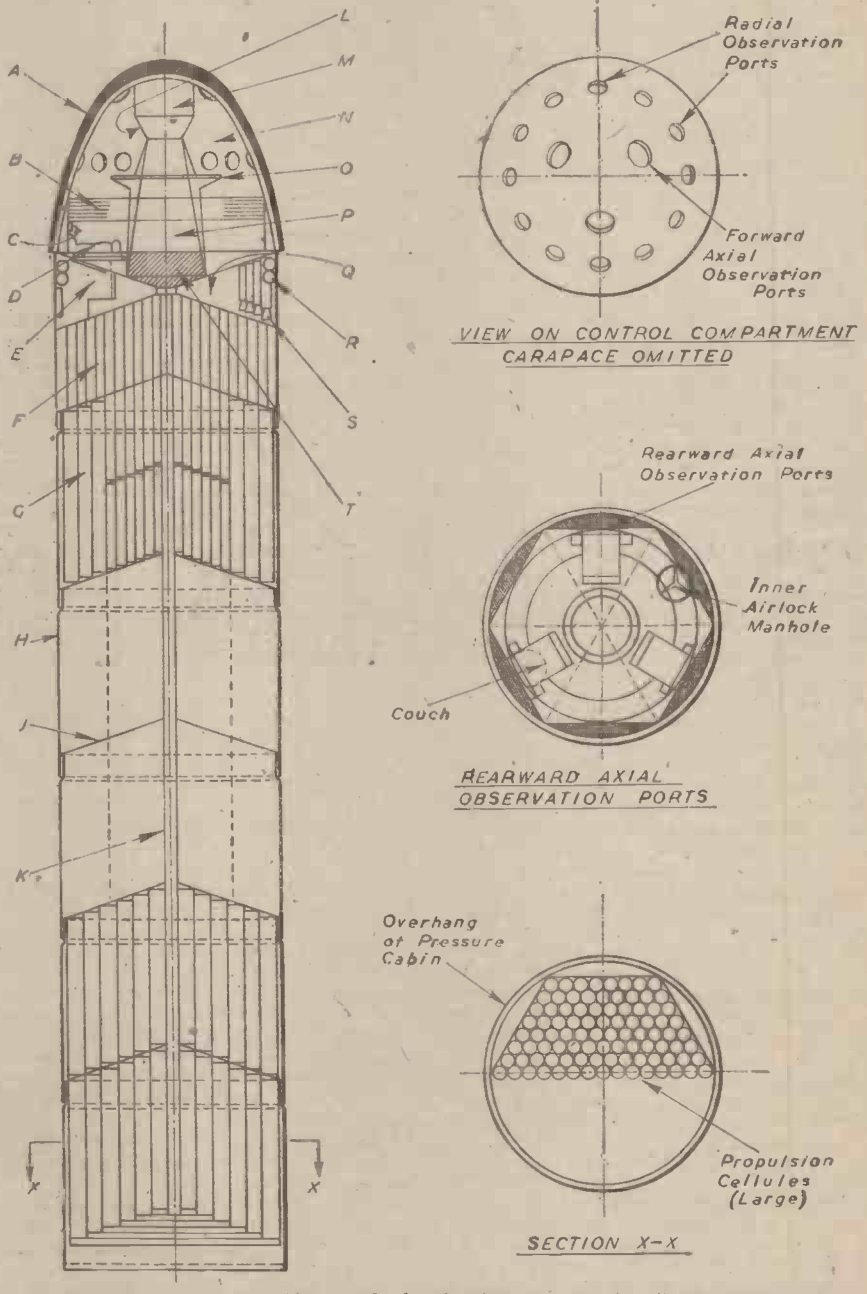
Already a beginning has been made in this direction by the amalgamation, early in 1944, of the two existing British rocket groups, the Manchester Astronautical Association and the Astronautical Development Society, under the title Combined British Astronautical Societies. This is the first positive step toward complete unification, and it is planned that the large national organisation which it is hoped will be the ultimate result of this merger will be recognised by all and sundry, engineer and layman alike, as *the* authority on *astronautics*. In this way it will be possible to direct the development of the science with a minimum financial outlay, and at the same time obtain the fullest advantage from the societies' knowledge and labour.

Other Pre-war Groups

Beside the rocket groups already mentioned, there was also, prior to the war, a Leeds Rocket Society, organised by H. Gottliffe in 1936, and a Hastings Interplanetary Society, inaugurated at about the same time by J. A. Clarke. Unfortunately, both were in existence only a few months.

The Junior Astronomical Association, too, whose headquarters was at Glasgow, added an astronautical section in 1938. The J.A.A., however, ended its activities with the war.

Some mention has already been made of the British Interplanetary Society, and a great deal more remains to be said of this pioneer body whose theoretical studies, prior to the groups' dissolution with the outbreak of hostilities in 1939, have undoubtedly con-



A.—Heat resistant carapace (jettisoned after leaving atmosphere). B.—Walkway. C.—Firing control. D.—Navigator's couch. E.—Airlock.—F.—Propulsion cellules (small). G.—Propulsion cellules (large). H.—Cage. J.—Thrust web. K.—Cable duct. L.—Instrument panel. M.—Parachute compartment (for earth alightment). N.—Shell of pressure cabin. O.—Handrail and supports. P.—Food and tool lockers. Q.—Air, water and liquid fuel tanks. R.—Torque jets. S.—Axial liquid fuel control rockets. T.—Ignition power pack.

Fig. 38.—Sectional diagram of the British Interplanetary Society's "Lunar Space-vessel" conception (1938).

tributed much toward the evolution of the extra-terrestrial rocket. Before going on to review this work, however, a word about the Society's function and of those responsible for its success.

The British Interplanetary Society

Through the enterprise of P. E. Cleator, founder and first President of the B.I.S., Liverpool became the birthplace of astronautics in Great Britain, and from there the first journal of the then new-born science was published in January, 1934. That issue, a six-page official Society booklet, not outstanding in appearance and simply illustrated by hand-carved blocks, will long be remembered by those few engineers whose "revolutionary" ideas were first expressed in its pages.

For a year or two the development of the journal was the Society's prime activity, and with time the "booklet" became increasingly more dignified in appearance, having articles by specialist technicians of almost every branch of science. Its size, too, was much improved, and interest was further stimulated by the inclusion of photographs and line drawings—an achievement not easily maintained by a small amateur group.

In 1936, a branch of the B.I.S. was established in London and the inaugural meeting took place on October 27th.

At about the same time, P. E. Cleator, through pressure of other business, was forced to relinquish the Presidency.

Almost a year later, in the autumn of 1937, the headquarters of the B.I.S. was transferred to London, and at its first City General Meeting, Professor A. M. Low was voted the Society's second President. This post he held throughout the remainder of the group's activity.

In August, 1938, the Society set up a Midlands branch, and early in 1939, as already mentioned, the Manchester Astronautical Association and the Paisley Rocketeers' Society were granted affiliation. This latter agreement brought about increased benefits to members of each group, principally through an exchange of publications. It also involved a better balance of research due to the improved liaison.

In the summer of 1939, meetings of the B.I.S. were held at both the Royal Aeronautical Society and the Science Museum, Kensington. At these places, the Society showed particularly high attendance, which continued on the same level until September when the outbreak of hostilities brought the work of the B.I.S. to an untimely close.

The B.I.S. Space-vessel

The research for which the British Interplanetary Society is best known concerns their theoretical study which culminated in the provisional design of what has been termed the first practical engineering conception of an interplanetary "Space-vessel"—a work which occupied the Society for a year and a half.

Had the war brought no great advances in the field of rocket development, the very mention of "interplanetary communication" would have invariably been met with scepticism, but to-day, in the light of the outstanding strides made in recent years, particularly in the development of the V-2 rocket weapon, there must be few who remain unconvinced of these vast possibilities inherent in the rocket projectile. The V-rocket has given striking evidence in support of the pre-war B.I.S. declaration that, given the necessary backing, an exploratory journey to our satellite, with provision for landing on its surface and returning to earth, could be undertaken with present knowledge, engineering facilities and materials. Such an expedition, it has been calculated, would occupy three weeks, and the Space-vessel design has been based on accommodating a crew of three for that period. The implications of the V-2 rocket have already been mentioned in my previous writings ("All About The V-2," and "More About The V-2," PRACTICAL MECHANICS, January and February, 1945), in which stress was laid on the plausibility of adapting a V-rocket of slightly improved fuel-load as a two-step rocket, the smaller component replacing the explosive head. The calculations, based on an initial overall mass of 20-30 tons, show that the second step having discharged at the "carrier" rocket's greatest velocity would be capable of increasing its speed (approximately 5 km./sec.—3 m.p.s.—at release) to 11.2 km./sec.—7 m.p.s.—the velocity of gravitational escape. By careful timing of the experiment, the small rocket could be made to crash on the Moon.

It must be emphasised that the B.I.S. design is intended to be no more than an intelligent engineering conception of what the B.I.S. Research Committee considered in pre-war days as practicable using then known methods. As has already been pointed out, much advance has been made under stress of war, and doubtless many improvements due to this work will be incorporated when the British group can allow more time to such development.

As yet, nothing of a detailed nature has been attempted, apart from the design and construction of certain radical instruments affecting navigation, which were considered necessary to prove the basis of the design. Much of this work, unfortunately, will need to be duplicated owing to the destruction of the finished apparatus during an air-raid early on in the war.

The Propulsion System

From the diagram (Fig. 38) it can be seen that the layout is somewhat of a departure from any previously conceived "space-rocket." The vessel is designed to use solid propellant, which it embodies in myriads of separate "motors" set in cellular formations, permitting fully 90 per cent. of its mass to comprise fuel. Of this method of construction something has already been said. A principal advantage, it will be remembered, is the elimination of heavy forming members in the rocket structure through the arrangement of the cellular charges in lateral contact. Apart from the life compartment at the rocket "head," the entire strength lies solely in the propulsion charges, which are stacked in conical layers for optimum structural stability. There are six primary layers, or banks of cellules, each hexagonal in section (see Fig. 38), and this arrangement provides the closest possible packing of the charges.

The propulsion cellules, each a precision made "fuel-store" rocket motor, are assembled in groups of varying sizes and powers within the banks, and their ignition is set by an automatic relay causing the tubes to fire in rings according to a pre-calculated sequence.

As can be determined from the diagrams, the largest charges, those employed for take-off and the building up of initial acceleration, are contained in the first firing bank.

When ignited, the thrust of the cellules causes them to lift fractionally from the release pins (which lock each tube in place until firing takes place) until they are expended, when, due to the vessel's acceleration, they disengage and drop away. As each bank is reduced, the light webbing structure and release gear are similarly jettisoned, which all adds to bring about a steady improvement of the fuel-weight ratio—a further important advantage of cellular construction.

The B.I.S. design provides for the greatest possible strength obtainable in a cellular formation, and clearly the maximum fuel density in this arrangement largely dictates the external form—as will be observed, streamlining is conspicuous by its absence.

The nose form is designed not so much to reduce resistance at low speeds but to "part" the air at supersonic velocities and produce a partial vacuum along the sides so as to overcome the effect of frictional heating which might otherwise prove disastrous through detonation of the fuel. The nose attachment, which is provided to fit over the nosing portion of the life-container, is envisaged as a detachable carapace of reinforced ceramic compound. This is intended to withstand the main effect of friction and to release immediately the "Vessel" has risen beyond the atmosphere layer.

The cross-sectional diameter of the body shell is determined by the smallest practical size for the life-container; having in mind provision for the crew of three and the essential requirements, pressure conditioning, controls and instruments, etc., etc., and also the minimum firing area required. The latter consideration is highly important, as if the area were too small, the greater power necessitated would cause excessive pressures in the cellules and entail a heavier construction. Obviously, a balance must be found between the most ideal condition in each instance and the final dimension developed accordingly.

Stability

Since only 0.1 per cent. of the Lunar flight would lie within the bounds of atmosphere, the "Vessel" is provided with no fins or wings as adorn the hyperthetical "space-ships" of popular conception. Working on an acceleration of 2g., the limits of the earth's atmosphere would be passed within three minutes. At this same rate of acceleration, a further period of four minutes would realise gravitational release, and having attained release velocity at approximately 2,410 kms., the ignition would be cut and the "Vessel" allowed to travel under momentum until such time as its forward speed were checked prior to the landing manœuvres. From the time of liberation, the "Vessel" would reach the Lunar orbit within 45 hours.

Stability in the B.I.S. conception takes effect in axial rotation; the "Vessel", rotating once in every three seconds. As the experiments with model rockets have shown, the instance of greatest directional instability is that immediately following launching, and accordingly, a system of launching has been developed which will provide pre-rotation at the required angular momentum.

Artificial Gravitation

The "Vessel's" rotation will also assist by stimulating a gravitation condition during the period of momentum, which is necessary to avoid nervous and digestive disorders that might otherwise render the crew insensible.

As has already been mentioned, the "Vessel's" acceleration would at no time exceed 2g.; a figure easily borne for prolonged periods. This question of acceleration and its effect on the human system is one which has caused much controversy, and there are many who still hold the view that a rocket must necessarily travel at accelerations prohibitive to the carriage of living beings. The truth is simply that, as centrifuge tests have shown, a well protected man in good physical condition is able to withstand accelerations up to 6g. for quite long periods.

Provided with special suits and drugs it should be possible to better even this figure; but it is unlikely that rockets will ever be required to operate at more than about 5g.

(*To be continued*)

Rocket Propulsion

Further Details of the B.I.S. Space-vessel : The Lunar Flight

By K. W. GATLAND

AS has been emphasised earlier, the development and selection of a propellant in the B.I.S. Space-vessel conception cannot be governed by thrust yield alone. The cellular method of construction relies upon a high fuel density to provide its structural stability; and the "otherwise ideal" propellant may also be grossly unstable, liable to detonation. The problem is, obviously, no slight one, and much extensive research will doubtless be necessary before the "Lunar propellant" becomes reality.

A beginning, however, has already been made in the work of a research chemist, Dr. A. M. J. Janser, officer of the pre-war B.I.S. Council and member of the Technical Committee, whose researches have resulted in the development of certain original propellant forms which bear much promise in a cellular arrangement. These can be described as fuels which embody an oxygen-bearing organic substance of viscous consistency with a finely comminuted metal dispersed therein. Many exacting checks remain to be made before anything definite can be expressed of such compounds. What can be said, however, is that the factor of efficiency approaches more closely the theoretical value than any of the more conventional propellants previously tested. There are several metals and metaloids which release very great energies on oxidation, and the comparative values and corresponding exhaust velocities of these, as well as those tested by Dr. Janser, are given in the accompanying table.

The "Life-container"

The crew's compartment presents another factor of design that requires most careful consideration. It must be provided with means for sustaining an artificial atmosphere, sufficient to satisfy the needs of three for three weeks.

The B.I.S. suggest the solution to this problem lies in the use of hydrogen peroxide. This, they assert, would be carried as a syrupy viscous liquid that could be broken up into air and water either by the application of heat or by catalytic action; one molecule of which can be readily split up into one molecule of water and half a molecule of oxygen. Thus, not only is a continuous supply of oxygen issued into the life chamber, but also a supply of water is maintained which alone would satisfy the needs of the crew. It is found that 34lb. of hydrogen peroxide yields 16lb. of oxygen and 18lb. of water, and 1lb. of oxygen occupies 13 cu. ft. at N.T.P., which is sufficient for one man who is normally active for a period of six hours. Working from this basis, approximately 500lb. of hydrogen peroxide will provide sufficient oxygen for three men for 20 days, while allowing also a small surplus for emergency purposes. This same quantity of peroxide will also yield about three pints of water per man each day for 20 days, and allow a little to spare for chemical purposes and other uses.

In this arrangement, weight is saved by the use of one storage tank for two commodities, and also entails a saving in space, since the two substances could never be stored as compactly as when they are in chemical combination. Furthermore, only one set of controls would be necessary to regulate both air and water.

As a precaution against a possible break-

(*Continued from page 20, October issue*)

down of the peroxide water/oxygen plant, a small amount of liquid oxygen would also be taken. This would also be necessary as an air supply for the "space-suits," which the crew would use outside the Space-vessel while on the Lunar surface.

Navigational Instruments

One problem solved invariably presents another. The "Vessel's" axial rotation

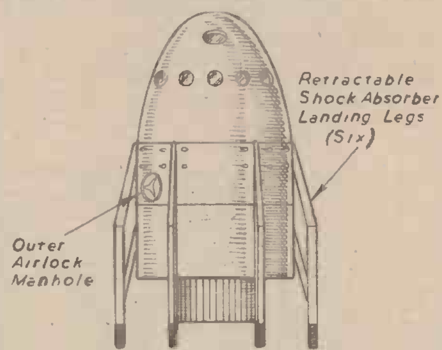


Fig. 39.—Space-vessel, as it would appear after alighting on Lunar surface.

means that the control compartment is also revolving, and although, as already observed, this condition serves to stabilise, and also stimulates an artificial gravitation, it does not facilitate the navigational problem. First, however, the one other principal advantage—*gravitation.* In order to gain this condition, it will obviously be necessary for the crew also to be rotating—the gravitational effect being stimulated by centrifugal force. The crew are, therefore, accommodated on full-length couch type "chairs," radially fitted, which rotate on rails round the life-compartment, and the navigators recline on these with their heads towards the "Vessel's" axis. There is also provided a circular catwalk for them to move round the circumference of the chamber.

The main ignition controls are fitted to the arms of the "chairs," while the navigational instruments, altimeter, speedometer, accelerometer—all functioned by impulse—are mounted on a central pillar in full view of the crew.

The difficulty lies in the fact that, under these conditions, the field of vision will be rotational, and since from time to time the crew will need to make navigational observation, this must be converted to one both stationary and accurate.

A satisfactory solution was found in the development of a system of rotating mirrors—a development of the stroboscope—and the B.I.S. have already constructed a successful test instrument along these lines. The new device has been termed the "coelostat."

The apparatus is fitted on the central control assembly (see Fig. 38) so that direct view in three directions is permitted: (a) axially, away from the firing face (three viewing ports, situated near the apex of the life-container shell); (b) axially, towards the firing face (viewing panels provided in that section of the "Vessel" where the circular life-container floor overhangs the hexagonal main body shell), and (c) radially (12 viewing ports provided in the dome of the life-container, circumferentially spaced equally at 30 degs.). The presence of the ceramic nosing carapace will mean that the ascent through the atmosphere will have to be made without external vision. This is no great problem, however, as the navigational corrections would, in any event, be best left until after the predetermined thrust phase.

The Lunar Flight

Navigational requirements made it desirable for the launching to take place from near the Equator.

The "Vessel" would ascend from a special launching installation, and be pre-rotated at a designed rate of one revolution every three seconds. This rotation would be maintained throughout the voyage—a duration of almost four days.

Acceleration would be applied to obtain "release velocity" (6.95 miles per second) within 7½ minutes, and the "Vessel" would emerge from the extreme limits of atmosphere after three minutes. At this stage, the ceramic nosing would be jettisoned, and as the propulsion cellules become expended, these, too, would drop away, together with their retaining structure and shell segments.

Having attained "release velocity," power would be cut off; momentum carrying the machine to the Lunar orbit. It is during this period that any navigational corrections would be made.

Still travelling under momentum, the "Vessel" would be steadily slowed by the influence of the Earth's gravity until the transitional point of the opposing gravities—Earth and Moon—is reached. Once beyond this, however, the Lunar influence would come into effect, causing the machine to accelerate toward the Moon's surface. During this period of natural acceleration, the "Vessel" would be turned completely through 180 deg., so that, in preparation for the landing, it approaches the surface stern first. This manœuvre may appear, at first thought, a somewhat delicate operation, but taking into consideration the absence of atmosphere, and remembering that the acceleration at this period would not be very great, the difficulties involved are really slight. It would, of course, be necessary to check the machine's axial rotation before applying lateral forces, employing sensitive steam jets in both instances. This would involve a loss of stimulated gravity, although a limited gravitational "pull" would have effect from the Moon.

Once the turning manœuvre had been fully executed, further banks of cellules would be fired to retard the "Vessel's" speed. These would exert a negative acceleration and serve to further stimulate artificial gravitation within the machine.

The immediate approach to the surface would be made in conjunction with special instruments developed on the basis of time, and rate of negative acceleration. There would also be an instrument to check height, similar in application to the "echo sounding" device used at sea. The individual readings would need to be automatically integrated. In this way direct figures would be shown of the "Vessel's" position, relative to the surface, at every instant of descent, and the thrust modulated accordingly, ultimately, to just balance the Lunar gravitation a few feet above the point of alightment. The force of landing would be taken by six hydraulic shock-absorber "legs," and if correctly done, this should not be excessive, allowing a reasonably level surface. The "Vessel's" mass will have been reduced to less than a third at the time of landing (Fig. 39), and, in consequence, will allow a fine degree of control, with a minimum expenditure of fuel.

The return would be made in much the same manner as the outward journey, although, of course, there would be no launching device or means of pre-rotation. The "Vessel" would simply thrust off on its landing "legs," allowing steam jets to set up the axial stabilising spin as soon as possible. This solution is considered practicable only through the decreased masses involved, and the diminished gravity, which enable the rocket to attain Lunar release velocity with considerably less expended energy than in gaining exit from the Earth. Once this figure is reached the "Vessel" would be allowed to coast under momentum, and having re-passed the area of gravitational equilibrium, would accelerate in free fall towards the Earth. Having attended to any necessary navigational adjustments earlier in the momentum phase, the "Vessel" would be again completely turned about its axis, and further cellules fired to retard it to a safe velocity for re-entering the atmosphere. Having consumed almost completely the propulsive cellules, any reserve that remained would be jettisoned to further lighten the "Vessel."

Once at a specified distance from the surface the supporting parachute would be released, and the life-container, housing crew and records, brought gently to the ground (Fig. 40).

Space-vessel Development Programme

The B.I.S. Space-vessel conception was developed for the express purpose of obtaining a bird's-eye view of the space-flight problem as a whole. Thus, the preliminary design of a space-rocket was commenced; a work started during 1937, and which occupied the B.I.S. technicians for over 18 months.

It was presupposed that certain essential conditions must be met, and the "Vessel" designed to satisfy these conditions. In this way it was readily determined within reasonably close limits where contemporary knowledge would require supplementing by further research. The limitations imposed can be classified as follows: (a) The voyage should serve a definite scientific purpose, and the crew and equipment should be the minimum that could serve that purpose. (b) That provision should be made to allow a reasonable chance of the successful return of the participants. (c) That every danger that could be foreseen should be provided against as far as was practicable; and (d) That no assumption should be made as to the possible development of new fuels or materials of construction that might not reasonably be expected to be developed from those in existence. Having concluded the provisional design of the Cellular-space-vessel, the Technical Committee of the B.I.S. published a report of its findings in the Society "Journal" (January, 1939), and appended a further recommendation to cover an extension of the research programme for the purpose of investigating the following points: (1) The exact experimental verification of the laws of rocket reaction to show how the power developed by a rocket motor was determined and governed by the method of combustion. (2) That a given list of fuel combinations should be tested to discover the maximum energy available, and the best

Propellant	C	V
C to CO_2	2,220	4.3
C to CO	1,050	2.9
$H_2(1/2\ O_2)$	3,240	5.2
$C_2H_2(2\text{-}1/2\ O_2)$	2,880	4.9
$C_2H_4(3\ O_2)$	2,580	4.6
$CH_4(2\ O_2)$	2,400	4.5
$C_6H_6(7\text{-}1/2\ O_2)$	2,430	4.5
$C_2H_5OH\ (3\ O_2)$	1,970	4.0
$H_2S\ (1\text{-}1/2\ O_2)$	1,380	3.4
$C_{14}H_{10}\ (16\text{-}1/2\ O_2)$	2,500	4.6
B (B_2O_3)	3,980	5.8
Al (Al_2O_3)	3,850	5.7
Mg (MgO)	3,590	5.6
Si (SiO_2)	3,000	5.1
Ca (CaO)	2,720	4.7
P (P_2O_5)	2,580	4.6
Metal Sol.	2,300	4.4
Cordite	1,240	3.2

C = Calories per gramme of reaction mixture.
V = Exhaust velocity in km/sec. – 1.

Various propellants tabulated to show comparative efficiencies, including those tested by the B.I.S.

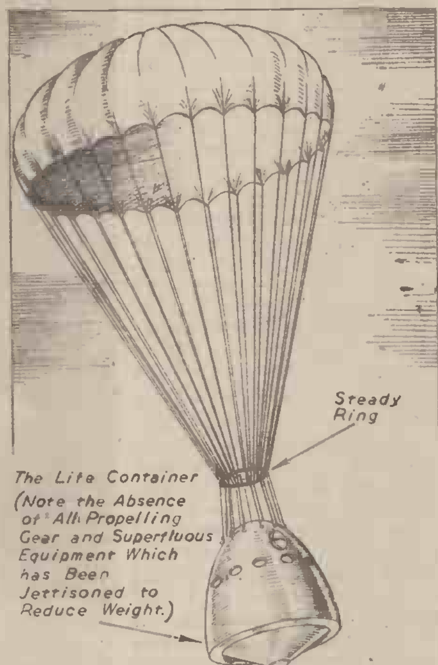


Fig. 40.—The "Vessel," having decelerated against gravity to zero at a safe distance within the earth's atmosphere, descends by parachute.

means of preparing and igniting the fuels. Also, that the results of the tests be applied to the production of improvements in the performance of rockets used for life-saving, signalling, etc., etc. (3) That the results of the foregoing experiments should be applied to the design of high-altitude atmosphere sounding rockets bearing recording instruments for the purpose of recording the extent and density of the atmosphere, and the prevalence and density of cosmic radiation. (4) That a mathematical treatment of the dynamics of space-flight should be prepared in such a form as to establish the navigational procedure and power requirements of the Lunar Trajectory. (5) That working models of the instruments, and such original mechanical devices as were embodied in the Report should be made to ascertain their efficiency in so far as circumstances made this possible; and (6) That the physiological aspects of certain conditions the space-navigators might encounter should be investigated as far as possible.

This second part of the programme was curtailed by the outbreak of war, which caused the British Interplanetary Society to abandon its activities in September, 1939. A Nuclear Committee, however, remained in existence, and although little active participation in the science was possible for some little while following the formal disbandment, in more recent years this body has recommenced theoretical work in the form of calculations of the exact masses and cellule powers involved in the Lunar Space-rocket. Other investigations have concerned the calculation of space-rocket trajectories, and similar research connected with spacial navigation.

A National Society?

This same Committee, two years before the conclusion of the war in Europe, was busy formulating plans for the official re-inauguration of the Society, and in league with the remaining British rocket groups the Astronautical Development Society and the Manchester Astronautical Association (now coalesced under the title, Combined British Astronautical Societies), preparations are now in hand for the amalgamation of the three groups under a common heading.

During the war small craft of the Light Coastal Force did invaluable work in sinking, destroying and capturing enemy supply ships, escort vessels and E-boats. Our illustration shows one of these small fighting craft, a British motor-torpedo-boat, at speed in heavy weather.

Rocket Propulsion

Rocket Propelled Aircraft: Research with Models

By K. W. GATLAND

(*Continued from page 51, November issue*)

THE outbreak of hostilities, too, had much effect on the activities of the other British groups—the Manchester Astronautical Association and the Astronautical Development Society (the latter was not given a title until 1941, being originally a small local group)—and although it did not cause their disbandment, there was an immediate curtailment of active research under the Defence Regulations Act, 1939, which made the preparation and firing of rockets during the war illegal.

Thereafter theoretical research became the vogue, and much valuable work has been conducted during the war years of which detailed reports have been published on the following subjects: (a) The fundamental design of rocket aircraft; (b) The design development of meteorological sounding rockets; and (c) An investigation of reloading systems in "solid" fueled rocket units.

Rocket Aircraft

In the first issue of the Manchester Association's Journal, (*Spacewards*, Vol. 1, No. 1, August, 1939), were published the initial sketches of a single-seat rocket aircraft, suggested by the M.A.A. Research Committee (Fig. 41). This conception was intended merely to form the basis for a report of the engineering and aerodynamical problems involved in the development of high speed, high altitude aircraft, and as such the actual design was not pursued in detail. It was, however, necessary to carry out a preliminary design procedure in order to estimate the essential dimensions and weights for the purpose of approximating the performance.

The machine in question (Fig. 41) differed in many ways from the orthodox. A high-wing aircraft, its fuselage was short and stubby, with horizontal surfaces swept back well beyond the rear. The vertical stabiliser, fin and rudder emanated from just aft of the nose cabin and, similarly, swept beyond the fuselage, while the main-plane—of low aspect ratio, two-third ellipse plan-form—was positioned almost centrally along it.

Instead of the conventional landing wheel arrangement, a double skid alighting gear was attached beneath the fuselage.

A small pressure control cabin was situated at the nose, and in the space immediately below, two small tanks, one oxygen, the other alcohol—intended to feed a small rocket motor firing forward and downward—were fitted. This unit was provided for flight manœuvring and landing.

A battery of propellant tanks occupied the space behind the cabin, and at the extreme rear was fitted the rocket propulsor.

Three-quarter front view of the M.A.A. flying scale-model rocket aircraft. Note the radial air intake cowling over the rocket jets.

The Propulsion Unit

The driving motor was something quite new in rocket units, and solved the propellant feed problem very simply. Instead of employing a gas charging system, or pressure pumps, which would necessitate an auxiliary driving motor, a fuel injector system was devised in which the oxygen and fuel were centrifugally fed to a multi-chamber propulsor under the axial rotation of the complete unit. The centrifugal injector is shown in Fig. 42. It is an example of an entirely self-feed arrangement

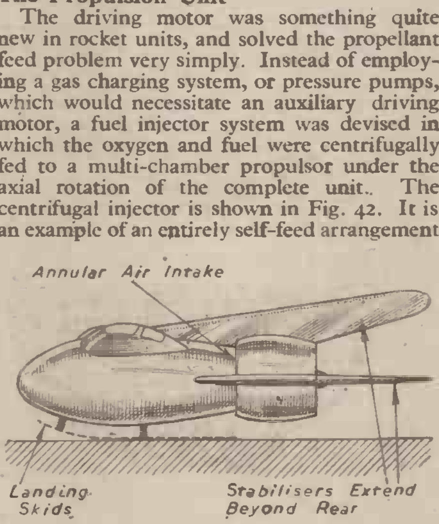


Fig. 41.—Suggested scheme for an air-augmented rocket aircraft. Air is injected over exhaust jets and expanded to increase the mass effluent.—M. A. A. (1940).

and apart from the initial priming of propellant, the unit is completely automatic in operation, requiring no additional power services.

With reference to the figure, the rotary portion of the injector consists essentially of the centrifugal feed unit, and a number of reaction chambers, which are axially offset, and equally spaced around it. The system is designed to function as follows: A few seconds continuous supply of fuel and oxygen are initially primed to the reaction chambers by means of auxiliary pressure chargers. These are housed within the conical tail fairing. The ignition circuit is then closed and the rocket chambers fired, causing the unit to rotate due to the offset thrust. This immediately affects pressurisation of the fuel tanks through the rotation of the oxygen feed shaft, and the pump geared from it; at the same time the oxygen feed valve is automatically released, permitting the fuel and oxygen to pass to the centrifugal unit where delivery is made to the reaction chambers in correctly metered proportion, and at constant and high pressure.

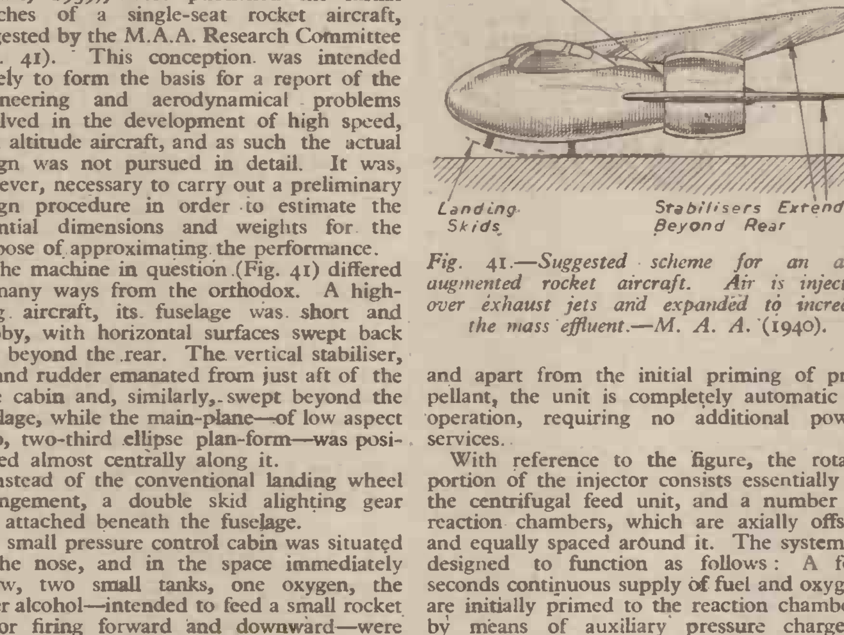


Fig. 42.—Sectional diagram giving details of the M.A.A. centifugal feed rocket-motor (1940).

Model Research

Several models of the aircraft were constructed, mainly for the purpose of gaining some idea of its stability, but, unfortunately, only the initial flight trials of a first powder driven model were possible owing to its completion only a few weeks before the outbreak of hostilities.

At that time plans had been formulated for the construction of a large oxy-alcohol powered model, but the war left this particular project unstarted.

A later model was fitted with a thrust augmenter located behind the centre of gravity and the centre of thrust, attached over the propelling jets. Gliding trials, however, proved this arrangement unsatisfactory in that it had a detrimental effect on stability. Although the augmenter maintained the model on a direct course during sustained flight, this ideal condition remained even when the machine nosed downward for landing, when such a condition became by no means ideal as the 'plane was incapable of levelling out. The obvious remedy was to provide the intake for the augmenter forward of the centre of gravity and thrust, and modifications were made to the basic design to provide for this.

Shortly after the cessation of hostilities in Europe, the improved model was flown under power, and showed itself capable of rapid and well stabilised flight.

The propulsion unit in the models comprised, in each instance, eight individual powder charges. Four of these were termed "primary" and the remainder "secondary," being alternately placed on a circle in order to balance the thrust, and slightly inclined to impart axial rotation.

The primary charges are, of course, provided for the initial acceleration, and the secondaries for maintaining level flight once the requisite height has been attained. To achieve this, the primary units were provided with a more energetic powder composition than the secondaries, each firing phase being a duration of four seconds.

Complete references to the calculations arrived at of the machine's performance are

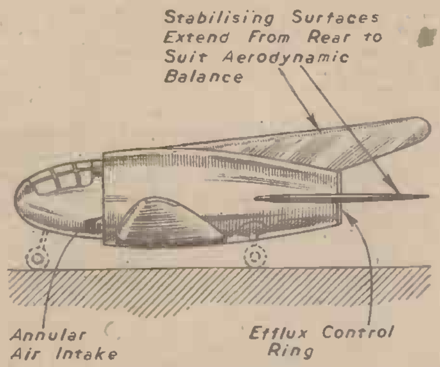


Fig. 43.—Suggested layout for an air-augmented rocket aircraft. Air is inducted and expanded by the exhaust stream in a secondary "expansion chamber."—A. D. S. (1941).

given in the journal, *Spacewards*, January to October, 1940, Vol. 1, Nos. 2, 3 and 4, Vol. 2, No. 1.

The Astronautical Development Society

This is a convenient stage to introduce the work of the Astronautical Development Society, as its early researches were very much akin to those of the Manchester group.

The A.D.S., formed in July, 1941, by the writer and Mr. H. N. Pantlin, around the nucleus of a small local group at Surbiton, Surrey—whose activities date back to the summer 1938—was originally an independent organisation.

In January, 1942, however, contact was established with the M.A.A., and within a short while, in August of the same year, the two societies were provisionally amalgamated. This resulted in an agreement to the effect that, in order to facilitate a more "localised" programme of research for each group, the M.A.A. should govern the rocket interest of northern England and Wales and Scotland, while the A.D.S. administered to the southern counties.

The membership total of the Manchester group at that time was the very low figure of 13, while that of the A.D.S. was little better at 25. The war brought about a severe reduction in members, and both groups had definitely seen better days. The increased strength arising from the merger, however, had almost immediate effect and, by 1943, the total membership was over 100. That year, too, saw the issue of a combined journal and bulletin; the title of the former remaining *Spacewards.*

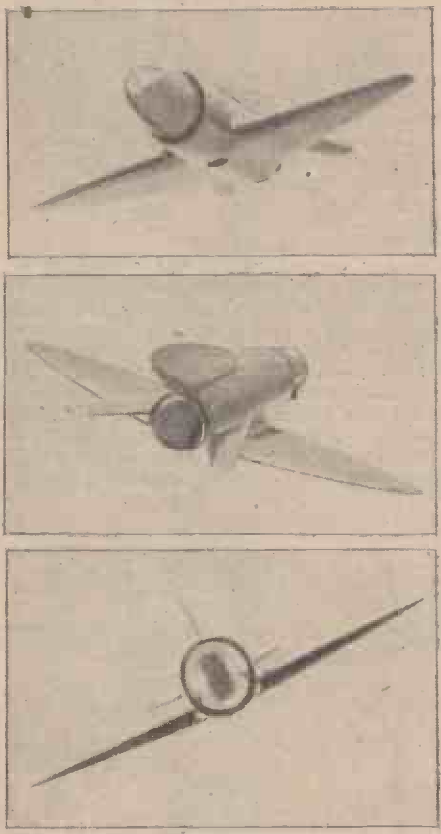
Although the pre-A.D.S. local group carried out free-flight tests of small powder rocket units, these were, in essence, very similar to those conducted by the Manchester groups, and were very largely pure duplication.

The first really significant work of the society proper was the investigation of problems associated with the development of rocket aircraft, and this survey was commenced in complete ignorance of the very similar research which was being pursued, at the same time, in Manchester. When notes were compared later, it was found that almost identical principles had been evolved by the two independently working groups.

The M.A.A. concluded its rocket 'plane investigations shortly after the amalgamation, to commence a mathematical survey of sounding rocket trajectories, leaving the A.D.S. to continue the original line of work.

Unlike the M.A.A. rocket 'plane conception, the A.D.S. model (Fig. 43) had a low wing and an augmenter intake placed near the nose. Its only outward similarity was the tail assembly, which comprised two horizontal stabilisers, and a single dorsal fin, swept back beyond the rear fuselage. These surfaces were intended purely as *stabilisers*, and as such they were not fitted with control aerofoils. Instead, directional control was effected by the simple procedure of providing an efflux discharge ring within the nozzle mouth, free to swivel—at the control of the pilot—in any direction, up, down, or sideways, so that the exhaust impinged, thereby causing offset thrust and controlling the 'plane's flight with the same effect as rudder and elevators. The wing was fitted with ailerons in the usual way.

The cabin formed the nose of the aircraft, and a large clear-view Perspex type hood was fitted in keeping with the nose contour, intended to afford a wide angle field of vision.



Three views of the original air-augmented rocket 'plane model developed by the A. D. S., and built by a member of the society, Mr. D. Ashton. Photographs by Mr. H. J. Kendrick, Surbiton.

The propellant tanks were well dispersed about the centre of gravity; the main fuel tank being immediately behind the cabin, while two additional containers were placed just outboard of the wing roots. A large cylindrical liquid oxygen tank extended from the nose fuel tank to the motor at the rear end of the fuselage.

A Turbo-thrust-feed Motor

The liquid fuel motor provisionally developed for the original A.D.S. model was, too, somewhat unique in design, and as with the M.A.A. "centrifugal injector," the propellant feed problem was solved quite simply. Similarly, once set in function, the unit would operate continuously at a constant feed pressure until the propellant was exhausted.

The feed system in the A.D.S. motor (Fig. 44) was arranged through a turbine driven pump, the turbine being fitted directly inside the combustion chamber at the back, and functioned by the thrust pressure of the expanding gases. A hollow shaft, fitted through the axis of the turbine, passed out through the rear wall of the chamber, and from this was geared the oxygen and fuel pumps.

The end of the shaft fitted into the oxygen delivery tank, in which it rotated on a sealed bearing, allowing the oxygen to pass through the shaft to the combustion chamber. The oxygen pump served to pressurise the liquid oxygen tank, and thus it was ensured that the oxygen entered for combustion at a high and uniform pressure.

The fuel—similarly forced from its tanks under pressure from the pump—prior to entering the chamber was utilised in cooling the nozzle. After passing through the jacketed portion, having been conveniently vaporised by the absorbed heat, it was fed for combustion, entering from two inlets placed behind the turbine.

On the reverse side of the turbine was fitted a centrifugal impeller blade system intended to fling the fuel out into the chamber from the back of the turbine vanes, and in this way the oxygen issuing from the shaft was isolated from the chamber walls until the propellant was adequately mixed. Thus, the danger of oxidation, the main cause of earlier motors' disruption, was thought to be largely eliminated.

A multi-chamber liquid-fuel motor—designed on the same principle as the M.A.A. "centrifugal injector"—was later proceeded with and in this it was arranged to feed the propellant centrifugally through rotating the complete unit by offset thrust. In view of the large masses involved, however, and the likelihood of excessive torque, a model of the unit was not constructed, although a model aircraft employing a similar powder system was successfully flown, prior to the official formation of the society.

Rocket Aircraft Development

The conclusions derived from the M.A.A. and A.D.S. investigations, covering the

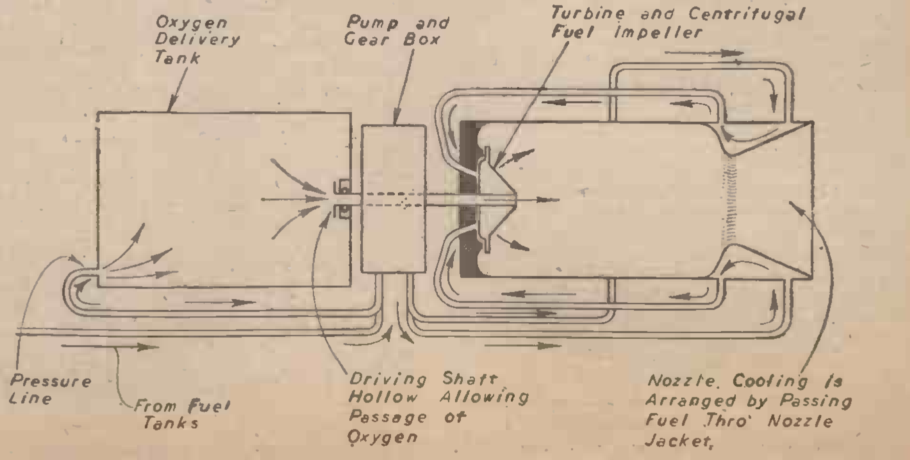


Fig. 44.—Diagram of the turbo-thrust-feed rocket propulsor system, developed by the Astronautical Development Society, 1941.

essential disadvantages and advantages of the rocket system applied to aircraft, may be jointly summed up as follows: For reason of a limited duration of power, due to the heavy rate of propellant consumption, the aircraft powered by what we may term "chemical rocket propulsion," is not likely to realise commercial application. Against this, however, there is the implication of *controlled* atomic power.

The "uranium bomb" has given dramatic illustration of the vast powers available in atomic disruption, and clearly, once this energy can be harnessed for direct *reaction*, we will have at our disposal a highly powerful and economic propulsor agent, not only adequate for all terrestrial uses, but also capable of fuelling the most enterprising "interplanetary space-vessel."

Many technical difficulties remain, however, before the liberation of this energy can be moderated; and there are also several associated problems which will invariably arise in its application—principally, the very high temperatures and pressures that are likely to be raised in an "atomic generator," and the necessity for providing suitable screening against the harmful radiation emitted in the bombardment of the radio-active U-235 isotope.

This subject is too vast in its possibilities to pass over hurriedly, and a more detailed account will be given in a later article.

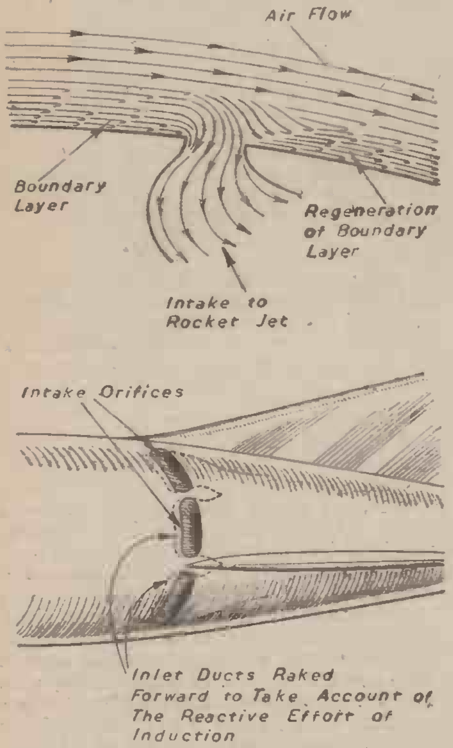


Fig. 45.—Diagrammatic view and section showing abstraction of boundary layer.

The Thrust-augmenter

Apart from the high fuel consumption in chemical rocket units, the second disadvantage, directly associated with the first, is their inability to function without profuse waste of energy at low speeds, and within the atmosphere. Hence the importance given to the *thrust-augmenter*, which aims to increase the mass flow while decreasing the speed of ejection. The need for providing entry for the augmenter forward of the C.G. and C.T. has already been mentioned, but it is obvious that this involves a large area of ducting, which naturally would add materially to the drag due to friction. The better solution would appear to be the use of inlets flush to the skin, and, in this form, stability would not be impaired even though they were located in the rear fuselage. Not only would this arrangement solve the intake problem, but it would also bring about a useful increase of the form efficiency due to the removal of *boundary layer.*

Boundary Layer Control

The total drag of an aircraft is made up in two components: (a) skin friction, and (b) the formation of a turbulent wake. The form of the aircraft, of course, determines the character of pressure distribution about its surface, and, with careful streamlining, these changes in pressure can be arranged to take place gradually, so that the transition of laminar flow into turbulence is close to the rear of the body, and results in a narrow wake. Under such conditions the resistance due to turbulence composes only a very small part of the total drag, the remainder being due to surface friction; the boundary layer, which has effect over almost the entire surface.

The boundary layer is formed as the result of frictional forces which arise between the surface and the air, represented by the resistance which each particle offers as it moves past others. The air particles immediately adjacent to the surface adhere, while those of subsequent layers, less able to resist the air flow, progressively obtain the speed of free air, the degree of frictional retard diminishing as the distance from the surface increases. This results in the formation of a thin layer of vortices over the surface, which, at the point of transition, suddenly effects a change, and the air particles in the boundary layer assume a vigorous swirling at right angles to the direction of flow, causing the turbulent wake.

The location of the intake is, therefore, most effective just forward of the point of transition, so that the depth increment of the boundary layer is reduced and the separation into turbulence delayed. Investigations have shown the most efficient intake arrangement for this purpose to be simple, wide slots, set at right angles to the skin contour, and flush in the surface, as shown in Fig. 45. The diagram gives some idea of the boundary layer formation in this region, and indicates the method of abstraction to the rocket propulsor.

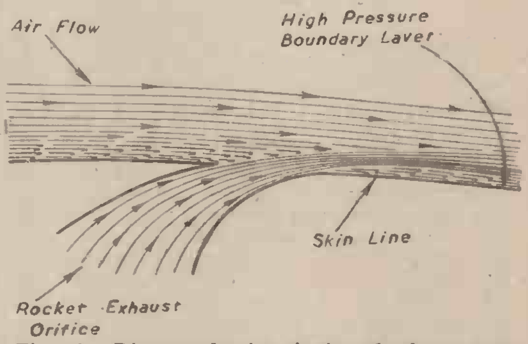


Fig. 46.—Diagram showing ejection of exhaust on to skin surface. This action accelerates the boundary layer and delays separation of flow.

It is also a possibility to discharge the combustion effluent on to the outer surface in order to speed the boundary layer as a further means of delaying the separation. In this instance, the expulsion orifice is most efficiently arranged with its leading edge fined sharply to blend with the skin line, so that the gases are ejected tangentially to the skin curvature (Fig. 46).

These methods of controlling the boundary layer are, of course, most beneficial when applied in thermal-jet, and air-augmented rocket systems, because of the large volume of air to be exercised in the propulsors, and the large mass flow available in ejection.

(To be continued)

From Bombers to Furniture


Another British factory is switching over to peacetime production. In the illustration workmen in the background are assembling parts of a Mosquito fighter-bomber, while others in the foreground are making utility furniture in one of the assembling bays of the Walthamstow factory of F. Wrighton and Sons.

Rocket Propulsion

The Super-sonic Aircraft : Atomic Propulsion

By K. W. GATLAND

(*Continued from page 95, December issue*)

NOT only did the society's investigations cover the practicability of abstracting boundary layer by the suctional effect of the rocket exhaust, but a scheme was also developed by which it was intended to increase the mass delivery to the propulsor by the incorporation of a compressor. The improved induction, of course, would have its result in a more efficient abstraction of the boundary layer.

The compressor is driven directly by an internal thrust-turbine, connected on a common shaft, the system being a derivation of the thrust-feed turbine unit (Fig. 44), discussed earlier. In this instance, however, the propellent feed is effected by the incorporation of an auxiliary power motor and pump.

The original layout provided a light petrol reciprocating unit for this purpose, but it is now considered more desirable, in view of the V2 development, to use a light H^2O^2 superheated steam turbine.

The propulsion unit proposed is shown diagrammatically in Fig. 47. The four principal advantages of the "thrust-turbine" power unit over the exhaust-turbine motor can be set down as follows: (a) reduced risk of erosion and "burn-out" of turbine; (b) absence of rotor in gas stream allows improved velocity and conformity of exhaust flow; (c) the injection system provides a true "concentric-feed" arrangement, and facilities a better mixing of the propellent and (d) transmission losses are at a minimum.

The thrust-turbine/compressor unit, besides its use in an augmented rocket system is, too, suitable for adaptation in a light thermal-jet motor. A unit designed on these lines for model research is shown diagrammatically in Fig. 48.

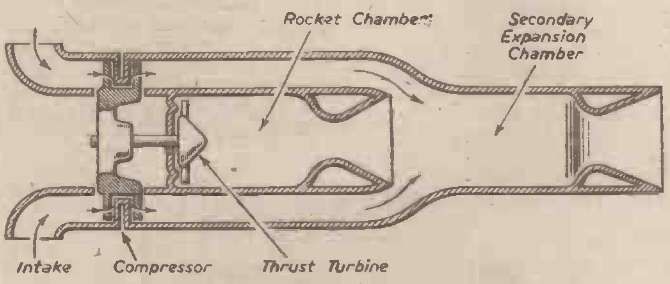


Fig. 47.—Diagrammatic illustration of the thrust-turbine/compressor air-augmented rocket unit.

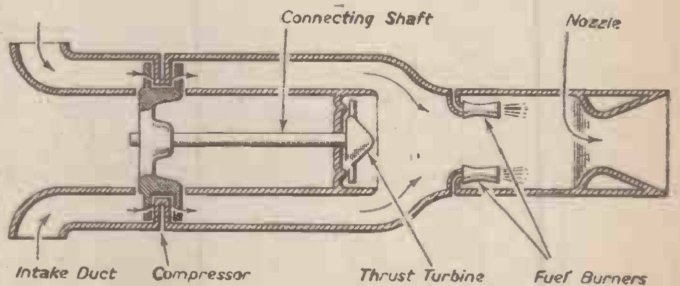


Fig. 48.—Diagram showing the thrust-drive turbine in a thermal-jet propulsor arrangement.

More General Observations

The remaining essential advantages the rocket powered aircraft would appear to hold over all other forms of propulsion are summarised in the accompanying schedule. (1) The power is applied in "direct reaction," there being no frictional transmission losses. (2) Advantages are presented with respect to altitude. Whereas contemporary power systems require atmospheric air to support combustion, the rocket system functions independent of the atmosphere, and, indeed, operates at maximum efficiency within a vacuum. (3) Owing to the improved thrust/weight ratio, the rocket system lends admirably to complete submergence, and facilitates a reduction in aerodynamic drag. It would, for instance, be ideal in an all-wing layout. (4) The less weight and greater simplicity of the power plant allows reduced installation space for a given thrust H.P. (5) The rocket motor functions without vibration, and torque is virtually eliminated. (6) It is capable of operating at maximum propulsive efficiency almost immediately after ignition. (7) The absence of an airscrew, as with the thermal-jet machine, enables the rocket aircraft to be of low build. (8) Location of the propulsor enables a better position of the pilot. (9) The simplicity of the rocket motor facilitates servicing and maintenance, and (10) it is a possibility to combine the thermal-jet and rocket systems, allowing independent function. A rocket propulsor, for instance, would be most desirable for accelerating a heavily laden aircraft into flight. This would allow a greater wing-loading due to an increased weight of fuel than would normally be possible for take-off. Another scheme might be the operation of the "jet" system up to its maximum effective ceiling, and the use of a rocket component above this region.

The Super-sonic aircraft

The question of aircraft flight in the ballistic speed range involves another limiting factor.

At super-sonic velocities there are not only profile drag and induced drag to be considered, but also a wave resistance which arises from an approach of the air speed to the speed of sound. When this limit is reached the air flow suffers a sudden change in character due to compressibility which has effect in an increase of the pressure and density, with accompanying severe increase of drag, and, in the case of an aerofoil, decrease in lift.

This problem of air compressibility is an aerodynamic phenomenon with which the propeller designer has had to contend for years. It has resulted in a limiting of the tip speed and the development of large area, thin section blades, which permit a low angle of attack. Despite these refinements, however, a compressibility wave is sometimes formed at the tip of the propeller blade, because the tip travels a great deal faster than the aircraft, due to its rotary and forward motion.

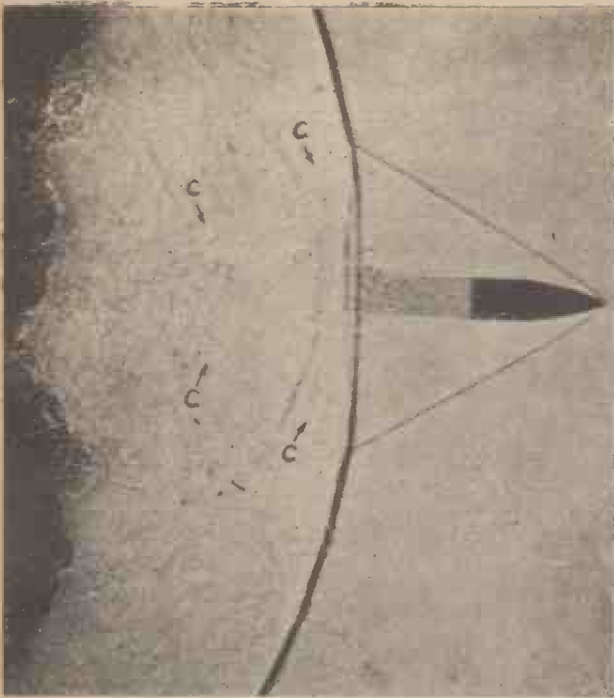
Reinhold Tiling during a demonstration of his folding-wing rocket aircraft at Hanover, Germany, in 1931. They were powder fuelled and capable of rising to heights varying from 1,500 to 2,500ft. ("Practical Mechanics," July, 1945, page 343.) Shortly before the explosion which caused the inventor's death in 1933, Tiling had announced his intention of building similar rockets to span the English Channel.

The designer of fighter aircraft, too, has need to be conscious of compressibility. In present-day machines this takes the form of what we may term "local compressibility," which is common where contour changes occur. The speed at which the air flow changes is termed the "critical speed." This is normally lower than the sonic velocity, because the local air speed relative to the body may have attained this value at some points of the surface.

Ballistic Research

Experiments with shells and bullets have provided valuable empirical data, which, in many ways, is useful in investigating the problems of super-sonic aircraft motion.

In this research, screens are arranged in the firing path so that, as the projectile passes though, its time at each stage can be recorded. Thus it is possible to obtain



Photograph of a bullet in flight, showing compression waves. The bullet is 11in. from the gun muzzle—a .30 calibre Springfield rifle was used in the experiment—and, travelling in the region of 3,000ft. per second, has outdistanced the discharge waves. Note the deflection of the conical bow waves in the explosion wave area, indicated by the arrows "C"; also the stray powder particles which have created compression waves on their own account. (*Taken by P. P. Quayle, of the American Bureau of Standards*). *Courtesy of Kodak, Ltd.*

the velocity at each section by process of differentiation, and further differentiation, also with respect to time, will yield a figure for the acceleration at each section. This acceleration will, of course, be negative, and after the effects of gravity have been taken into account the final result will be the retardation due to air resistance.

Some interesting points arise from the figures thus obtained. Firstly, it is found that the drag is dependent upon several variables, and in the case of bodies moving with a velocity less than that of sound it is given by the formula of aerodynamics, namely:

$$D = kd.\ p.\ S.\ V^2.$$

where kd is the shape coefficient, p is the specific mass of the air, S is the maximum cross-sectional area of the body, and V is the velocity at which the body is travelling relative to the air.

Since we are taking the case of super-sonic motion, it is necessary to add a further coefficient to the equation. In experiment it has been found that this coefficient is constant at unity until the sonic velocity is approached. Its value then increases rapidly and reaches a maximum value of approximately 3.3 when V/v_s is just greater than unity. Since V/v_s increases beyond unity, the value of the coefficient falls, until it may again be regarded as a constant for velocities of over five or six times that of sound. The value of the coefficient will then be in the region 2.3 to 2.5, and the equation for drag can then be rewritten as:

$$D = kd.\ K.\ p\ S.\ V^2$$

Having shown that the value of the coefficient K is dependent upon the ratio between the velocity of the projectile and that of sound, it now remains to ascertain the values of the other terms of the expression.

When S represents the maximum cross-sectional area of the body, the other coefficient kd is found to depend upon the shape of the body. For a spherical shape it is approximately .106, reducing to .047 for a streamline body. Between these values there are, of course, very many others for diverse shapes, and the exact value for a given body will need to be found by means of wind-channel tests.

The remaining term, p, represents the specific mass of air at the place considered, and for varying heights it is found to follow an exponential law:

$$ps = p_0.e^{-h.s}$$

where p represents the specific mass at zero altitude, s is the height in metres, and h is a variable coefficient dependent upon s.

The form of the air flow about a projectile travelling at super-sonic velocity is shown in the accompanying photograph. It can be seen that a compressibility region is built up at the nose of the body. Because of this the oncoming air has a denser region to traverse, and instead of passing evenly over the body the flow takes the form of hyperbolic sound waves, originating a short distance from the nose. This compression wave initially moves with the speed of the body, and in reducing to normal sub-sonic values produces the "bow wave" which constitutes the main drag. The curvature of the wave is indicative of the compressibility flow, and the velocity is

Fig. 49—Sänger "super-sonic" wing section.

damped exponentially, as shown by the straightening of the compression curve and its gradual dissipation to sub-sonic values.

There is, in addition, a sound wave produced by the rear of the body due to rarefaction.

The above, of course, is only the barest outline of the problems involved, and that only in so far as the body shape is concerned. There is yet the effect of compressibility on the aerofoil surfaces to consider.

Compressibility and the Aerofoil

The *wave resistance* is independent of the aspect ratio, and both the induced drag and the wave resistance are proportional to the square of the lift, depending on the Maché number (ratio of flight velocity to sound velocity). As a general observation, the greater proportion of the total drag in super-sonic flow for normal aspect ratio is due to wave resistance, while the induced drag represents only a small proportion of the total.

The aerofoil theory at super-sonic velocities is virtually opposite to that employed in the sub-sonic range. Whereas at sub-sonic speeds a relatively blunt contoured nose secures the most efficient results, the super-sonic aerofoil demands a knife-edge nosing.

At ballistic speeds, the body with the greatest penetration from the aerodynamic point of view is the flat plate of infinitely small thickness. The hyperthetic case for two dimensional frictionless flow can be expressed:

$$\text{Lift Coefficient} = C_L = \frac{4}{\sqrt{\left(\frac{V}{a}\right)^2 - 1}} \propto$$

where V is the flow velocity; a, the sound velocity; V/a, the Maché number in the undisturbed field, and $\propto$, the angle of incidence, assumed small.

The resistance coefficient, under these same conditions, is given by:

$$C_D = C_L \propto$$

and in the case of frictionless flow, the gliding coefficient is thus independent of the Maché number, as:

$$C_G = \frac{C_D}{C_L} = \propto$$

These simple equations are adequate to illustrate the case, but the actual calculations involved in super-sonic *aerofoil* theory, as might be expected, are considerably more involved. This subject is naturally beyond the scope of the present writing, and the reader desiring further information is referred to the specialised papers and books which have become generally available in recent years.

The super-sonic flow thus demands an entirely original aerofoil shape, and the most practical form has been found in the development of a conical section, the drag of which decreases as the apex angle is reduced. A super-sonic section accorded on these lines is shown in Fig. 49. It will be seen that whereas in the sub-sonic aerofoil every effort is made to reduce turbulence by maintaining a sharp trailing edge, the opposite is the case for super-sonic flow. A necessary quality at high speed is that the wing should be thin with the maximum thickness well aft. This is because the compressibility flow will always break away from the surface shortly behind the mid-section of the aerofoil, involving the trailing edge in pronounced rarefaction.

The outline form of a super-sonic rocket aircraft as envisaged by Dr. Eugen Sänger, the reputed Austrian engineer, is some indication of the practical application of these principles. The illustration (Fig. 50) is taken from an investigation of super-sonic 'plane motion, which Sänger carried out during the early 1930's, and included in this are detailed calculations relating to the proposed trajectory for such a machine. Because of the need for gaining maximum distance and

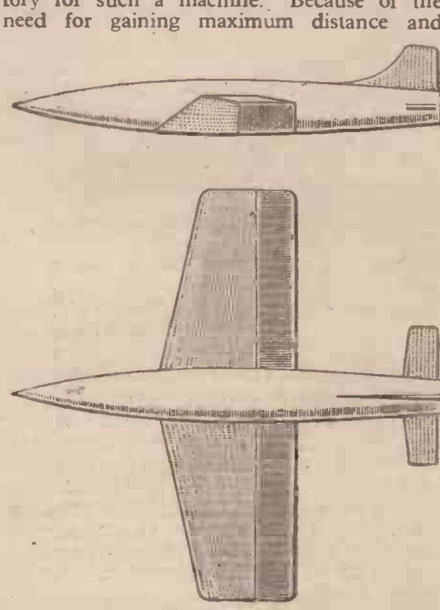


Fig. 50.—An impression of the super-sonic rocket aircraft suggested by Dr. Eugen Sänger, Austria (1933).

Rocket Propulsion

British Sounding Rocket Developments

By K. W. GATLAND

(*Continued from page 135, January issue*)

THE rocket projectile as a means of long range, high speed, transit is no recent idea. It was, in fact, the pioneer rocket engineer, Professor Oberth, who first set down the specifications for such a vessel, which he did as long ago as 1931.

It is of interest to note that the flight control and trajectory of Oberth's hypothetical rocket bear much resemblance to the methods originally adopted in the V2 rocket shell.

The ascent was arranged vertically in order to overcome the main drag effects of the atmosphere in the least time. Having maintained a direct path to an altitude of 30 miles, the vessel's course would be reset at a predetermined angle, and at the desired speed (the requisite angle and maximum velocity would vary with the distance to be covered) the motor "cut," allowing the balance of the journey to be made under momentum. The maximum height of the parabolic flight curve was calculated to be in the region of 100 miles.

The trend of development points the way conclusively to the ultimate evolution of the rocket projectile. The orthodox aeroplane has already reached a reasonable limit of speed efficiency beyond which it is impracticable to proceed.

The operation of aircraft above the compressibility limit, as we have already seen, is a reasonable possibility, but only if the efficiency of the rocket engine, when working in atmosphere, can be substantially improved. It may be that this obstacle will be completely overcome by the development of the atomic reaction engine, and if so, then the many lesser problems associated in this development should be quickly solved.

It is only when the Sänger flight system is considered that the practicability of operating *chemically* powered rocket aircraft in the super-sonic range strikes feasible, and this obviously is merely an interim step leading ultimately to the true projectile craft.

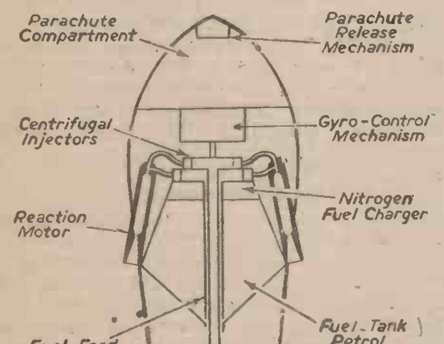


Fig. 51.—Diagrammatic layout of the original M.A.A. design for a sounding rocket (1939).

The Sounding Rocket

Apart from sea-rescue, *meteorological sounding* is another specialised peacetime use that the rocket is now serving. The war has been the means of accelerating this development, and already much important data has been accumulated in this way.

Prior to the rocket, all meteorological and specific soundings of the atmosphere had been made by (a) the small "pilot" sounding balloon, (b) the small radio-sounding balloon, (c) the manned balloon, and (d) the aeroplane. Each of these methods serves a distinct purpose. The first mentioned is simply a free balloon, which is sent aloft and its course followed by a ground observer using a theodolite. In this way the direction and strength of wind can be estimated; and there are also other purposes which these small balloons serve. An instrument called an "anathermoscope," for instance, can be carried, which is used for anticipating fog conditions. It consists of a delicate thermostat attached beneath the balloon, and when an abnormally warm layer of air is encountered at a certain height—the condition which normally precedes fog formation—the contacts close, and either effect the release of a paper parachute or light a signal lamp. The ground observers, with the aid of the theodolite, are then able to determine the height of the warm air layer, and also to calculate the time at which fog will begin to form.

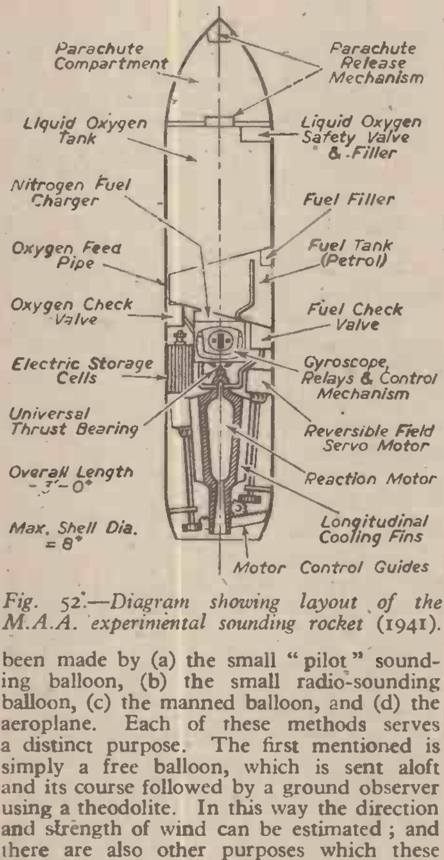


Fig. 52.—Diagram showing layout of the M.A.A. experimental sounding rocket (1941).

The radio-sounding balloon is, of course, more elaborate, and it is generally employed for high-altitude sounding. The instruments carried measure air pressure, temperature and humidity, and each are linked to a midget radio-transmitter, which emits continuous signals. These are picked up and recorded at a ground receiving station. The hydrogen-filled balloon, which is normally between 3ft. and 4ft. in diameter, bursts at an altitude of about 35,000ft., the instruments and radio descending by parachute.

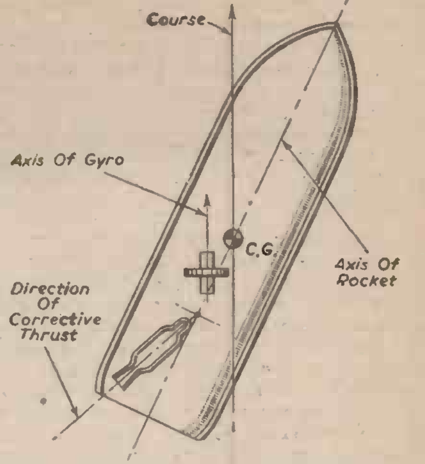


Fig. 53.—Principle of the gyroscopic corrective control adopted in the M.A.A. sounding rocket (*Fig.* 52).

More specific soundings, of course, require different instruments, and some balloons are used which carry aloft light glass containers which return with samples of air taken from the stratosphere. Since certain of these balloons are capable of reaching heights of 20 miles and more, their importance is very great indeed.

Manned Balloons

The manned balloons, as employed by Professor Piccard and Capt. Orville Anderson, although not capable of altitudes as great as the free-sounding balloon, are, too, very valuable, particularly since the varying conditions through which they travel can actually be *experienced*. The apparatus they are able to carry is, of course, heavier and more varied, and the fresh knowledge that is gleaned from these flights invariably has an immediate bearing on many fields of science. The study of the radio-reflective, Heaviside and Appleton Layers, and the effects of natural electronic emissions is, for instance, of immense value in radio technique; but this is only one example of how the results of high altitude sounding can be applied in the practical sense.

Finally, there is the aeroplane, and it is this method that is employed for most routine soundings of the lower atmosphere for the purpose of computing the day-by-day weather forecasts. For several years past Gloster "Gauntlet" meteorological aircraft have been used for this purpose. A recording instrument, termed the "psychrometer," is attached to one of the inter-plane struts, and this, too, automatically registers the pressure, temperature and humidity.

Although the rocket should ultimately prove of great use as a meteorological instrument, its principal work will undoubtedly be in the sounding of extreme altitudes where the atmospheric pressure is too low for the balloon to penetrate.

The greatest height reached previous to the rocket was by a small sounding balloon released by Russian experimenters, which carried its instruments to a height of 25 miles. This may not be strictly true, however, as calculations show that the shells from "Big Bertha" may have reached as high as 34 miles.

The rocket will enable soundings to the limits of the atmosphere and into space itself. In this connection, the adaptation of the V2 projectile as a sounding rocket has already been suggested, and it will be remembered that the calculations for the modified version

A motor to the design illustrated, but built entirely of steel, has been prepared for test, and it is proposed to make this the feature of a series of experiments soon to be carried out. It will not, of course, be possible to use liquid oxygen, as this would cause an infringement of the Explosives Act, and it is likely that compressed air will be employed instead.

Although it is not anticipated that the complete sounding rocket will be constructed, it is hoped that a further design, incorporating several of the characteristics of this model, will soon be ready as the result of a new investigation now proceeding under the auspices of the Combined British Astronautical Societies. The existing design was intended merely as a practical example on which could be based the development of larger and more useful sounding rockets. The dimensions of the preliminary model have been maintained at the lowest practicable limit, and in considerations of size it will be appreciated that its performance is highly credible.

IT is with regret that we record the death of Professor Robert Hutchins Goddard, who passed away recently in a U.S. hospital as the result of a throat operation.

As readers of this journal will already be aware, Goddard was the pioneer of modern rocket development. It was he who first conceived the "constant-volume" rocket system, which he successfully demonstrated in the world's first firing of a liquid-fuelled rocket at Auburn, Mass., on March 16th, 1926.

Many equally significant researches are due to him, both in previous and subsequent experiments. Readers will recall, for instance, the unique successively loading powder motor, which was one of Goddard's earliest achievements.

When war came to America, Goddard turned his capable hands to the military rocket, his work resulting in several of the highly-effective rocket weapons which contributed so large a part toward the eventual overthrow of the Axis.

Inventions of Interest

By "Dynamo"

Potato Peeler

AN inventor has been devoting his attention to an improved way of peeling potatoes. He points out that there has been a method of skinning this useful vegetable by subjecting it to a sudden blast of heat of an intensity sufficient to cause collection of free moisture or vapour beneath the skin. Disintegration and removal of the skin is then effected by a cooling treatment by means of jets of cold water or air or by mechanical friction, or both of these operations.

In prior proposals heat treatment has been carried out by using a current of hot air or gas derived from an oil or similar burner at a high temperature. This action produces the separation of the skin from the pulp, but it also dehydrates and coagulates the layer beneath the skin.

The aim of the new method is to retain the whole of the pulp in a completely raw state. This system is distinguished from its predecessors by heat treatment in a closed vessel with steam at only a moderate temperature. This lasts only a short period, sufficient to swell the tissues of the skin, but insufficient to cook any part of the pulp.

The potatoes are then suddenly cooled by means of a fluid at a low temperature. This causes contraction and disintegration of the skin and thus simplifies its removal by mechanical friction.

Adjustable Golf Club

AN application for a patent relating to golf clubs has been accepted by the British Patent Office. The inventor asserts that there have been several proposals concerning a universal golf club in which the angle of the striking face of the head may be adjusted infinitely or into one of a predetermined number of possible positions. Thus the player is enabled to strike his ball to various distances without having to carry a quantity of different clubs.

He affirms that previous ideas have not been entirely satisfactory. This was due to the difficulty of adjusting the head of the club, its unorthodox appearance and its inability to endure continuous use.

The inventor has aimed to devise a golf club head in which the angle of the striking face may be varied between predetermined limits and yet is of normal appearance.

The head is rotatable in order to vary the angle of the striking face by means of an element slidable on a keyway under the control of the rotatable element. The last-mentioned may be turned round by the hand of the player.

To describe the invention more particularly, an extension or stem is made fast to or integral with the club shaft at a suitable angle. It is provided with a key-way or spline. Along this is slidable an element having an external spiral thread or splines engaging corresponding keys or splines in a bore in the head. In this is a rotatable gear operable externally of the head and engaging cross teeth in the slidable member, so that rotation of the gear moves the slidable member along the spines, and the spiral splines, by engagement with those of the head of the club, cause the head to rotate.

In such an arrangement it is impossible to rotate the head except by manual rotation of the gear.

So robust is the construction that it will last for a very considerable period.

The information on this page is specially supplied to "Practical Mechanics" by Messrs. Hughes & Young, Patent Agents, of 7, Stone Buildings, Lincoln's Inn, London, W.C.2, who will be pleased to send free to readers mentioning this paper a copy of their handbook, "How to Patent an Invention."

Pliable Toast Rack

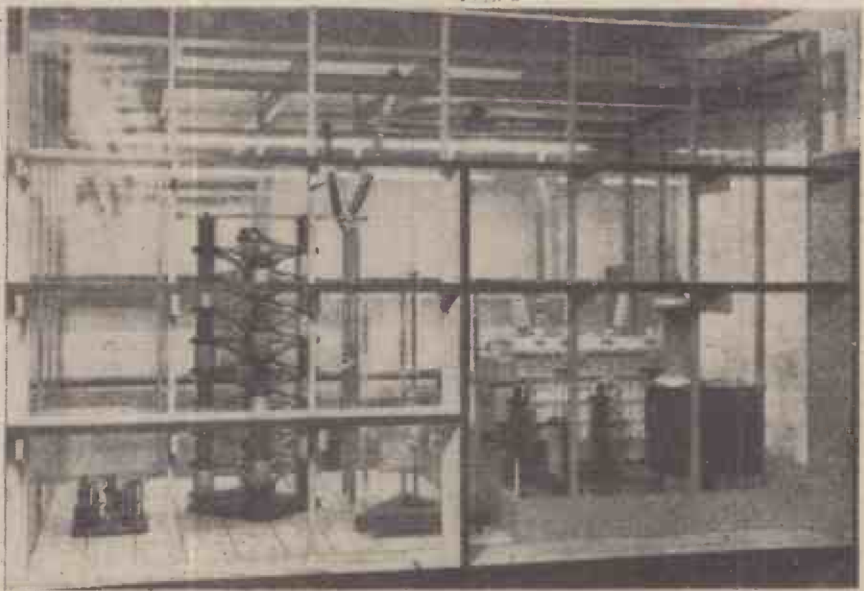
AN accommodating variation of that familiar object of the breakfast table, the toast rack, has made its advent.

As a rule the toast rack is constructed with fixed rigid partitions regularly spaced apart. Consequently, unless the bread is cut uniformly, some slices may be too thick to be fitted between the partitions, whilst others are so thin that they are in danger of falling out while the rack is moved; for example, when the toast is handed to a person at a table.

These disadvantages have been borne in mind by the inventor of this improved toast rack, and he has thought out a rack qualified to accommodate slices of toast of varying thickness which are held firmly when the rack is moved.

A further characteristic is the possibility of the removal of the partitions for the purpose of cleaning the rack. Yet another feature is an arrangement whereby it can be packed flat.

The device includes a base and a number of partitions, each of resilient construction or mounted resiliently on the base, so as to be capable of gripping the pieces of toast placed between the partitions.



A model of the high-voltage laboratory at The English Electric Company's Stafford works, showing a 132kV. grid transformer, and a 132kV. air-blast switch under test. An exhibit at the recent "War Activities" Exhibition.

gave a maximum altitude attainable of 500 miles. Since the practical extent of the atmosphere is in the region of 200 miles, it is clear that in this development we have a means of sounding adequate for all scientific purposes.

From the experience gained in the development, handling and performance of the V2, the design and construction of sounding rockets of high reliability are certain, and, of course, these could be fitted with radio-transmitting gear in much the same way as the radio-sounding balloon. The example given of converting the V-shell for this purpose is primarily intended as evidence of what can be accomplished with a mechanism that has been proved and is available to-day. There is obviously much scope for the specific development of sounding rockets, and no doubt these will range from light meteorological types to the larger models which will ultimately be used to probe the fringe of atmosphere in search for proofs of the many controversial theories that exist, principally about the cosmic ray and other electronic phenomena. Whether or not the remaining V-rockets that are available will be converted for these latter purposes is yet to be seen. There seems no reason why they shouldn't be so employed. The cost of conversion and fuelling would indeed be cheap exchange for the invaluable data they would provide.

A brief account of sounding rocket developments in the U.S.A. has already been given (*Practical Mechanics*, June, 1945, pp. 315-6), and apart from the investigations of the American Rocket Society and Professor Goddard there is little evidence of any other pre-war research.

In Britain, too, work in this direction has been slow, and, again, it is the rocket societies that have provided the most detailed account. The initial investigations of sounding rockets are due to the Manchester Astronautical Association, whose work in this connection was started in January, 1941.

The investigation began with a mathematical survey in which the characteristics and performance of a hypothetical sounding rocket were calculated. This occupied the association for several months, and from the experience gained the design of an actual rocket was next attempted.

M.A.A. Sounding Rocket Developments

The first scheme produced was for an oxy-petrol rocket stabilised by axial rotation (Fig. 51), and from the diagram it will be seen that the design provides for nose-drive, the propellent feed being arranged in similar manner to that adopted in the M.A.A. centrifugal injector.

A parachute is provided at the nose, and a gyroscope supported immediately beneath for the purpose of maintaining stability. The motor assembly, below, comprises four concentric feed combustion units equally disposed around the circumference and axially inclined to impart the required spin. The petrol and oxygen are fed from their tanks through tubular shafts which extend from the feed unit. It will be observed that the oxygen line is fitted within the petrol shaft, the petrol being fed around it.

The performance calculations show that it would be necessary for the rocket to be 8ft. in length, and the maximum shell diameter 3ft. 9in. As this appeared unreasonable for the height that the rocket could be expected to reach—the performance estimation gave a figure approaching 40,000ft.—the entire design was scrapped and work commenced on another rocket.

The second scheme (Fig. 52) differs in several respects from the original. Its chief difference is that stability is not effected by spinning, but through the offsetting of a

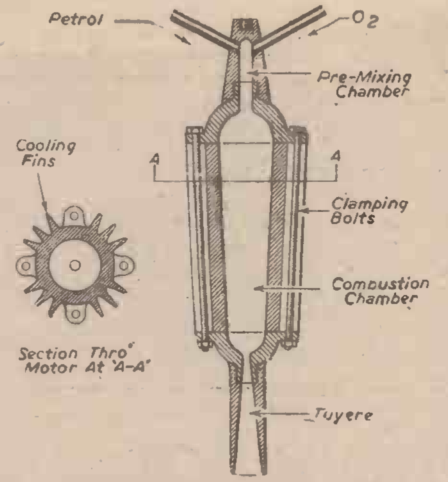


Fig. 54.—Rocket motor No. 4—developed to power the M.A.A. sounding rocket, as shown in Fig. 52.

single rocket motor, which is regulated by gyroscopically controlled electric motors.

The gyro-control is so designed to function immediately the rocket deviates from its true path, and at once alters the direction of thrust to oppose the deviation, thereby returning it to the original path of flight.

To achieve this movement, the motor is pivoted at the "head" on a universal thrust bearing, and at the nozzle end, held in place by a system of slides and ratchets. This ensures easy movement of the motor in any direction around the central pivot to apply thrust at angles ranging to 15 degrees from the normal thrust line. The method of control is apparent from the diagram (Fig. 53), reversible field electric motors being used to actuate the rocket chamber.

No motive power is provided in the rocket for functioning the gyroscope, since the

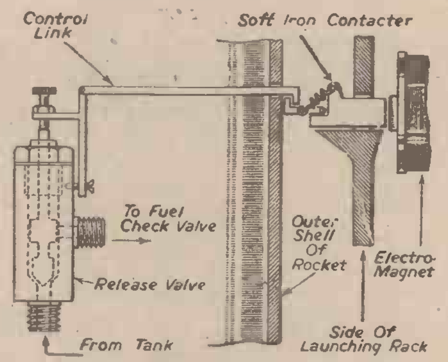


Fig. 55.—Part-sectional diagram of a remotely controlled propellent feed mechanism.

period of powered flight is only a matter of 43 seconds. It is considered, therefore, that a ground motor would suffice to build up the desired rotational velocity, allowing the inertia of the gyro to maintain control during the time of thrust.

The Rocket Motor

The driving motor (Fig. 54) was designed for construction in a light aluminium alloy, being internally sprayed in order to obtain a thin coating of steel as protection against the high combustion temperatures. The chamber is built in five sections: mixing chamber, "head" portion, central portion, "throat" portion, and nozzle. This facilitates replacement should any one of the components "burn-out," or become otherwise damaged during testing. It also enables varying sizes and shapes of chamber section to be tried as well as different nozzles.

The outer sides of the chamber portion are ribbed by longitudinal fins.

Cooling of the motor is arranged by the induction of air from inlets flush to the skin, and the air is introduced by means of the negative pressure caused by the rush of the exhaust gases, thus effecting a swift cooling flow past the reaction motor.

The liquid oxygen and petrol are contained in duraluminium pressure tanks, and these are designed to allow, as far as possible, unrestricted flow to the motor.

The feeding of the liquid oxygen is a simple matter, because of its low temperature of liquefaction and the ease with which it vaporises. The method is the same as that employed in the early German experiments. The "Mirak" rockets, it will be recalled, relied upon the self-feed characteristic of liquid oxygen, as did also many other types developed by the Verin fur Raumschiffart. The only difficulties then were: (a) the liability of the tanks to explode under the considerable pressures developed, and (b) the inconsistency of the feeding pressure. In the M.A.A. design these problems are overcome to a large extent by the provision of high pressure tanks, and the use of check valves in the feed lines to stabilise the rate of flow to the rocket motor. An emergency relief valve is fitted to the oxygen tank, but it is not anticipated that pressure would be developed to the critical point within the period from fuelling to flight.

The fuel is introduced in a similar manner through the pressure of an inert gas (nitrogen) acting directly on to its surface.

A parachute is housed in the nose of the rocket, and this is released by the action of a mechanism adjusted to function when the air pressure inside the lower shell is built up to a predetermined figure as the rocket falls back to the ground. Its descent would naturally be tail-first, because when the tanks are empty the weight is largely disposed at the rear. Should, however, the rocket descend nose first, due to accident, a small clockwork "timer" is also fitted to ensure that the return is made without damage.

General particulars of the design and the calculated performance figures are as follows: The total weight of the rocket is 50.0lb., of which 22.5lb. comprises fuel and 27.5 "payload." Its overall length is 35.0in., and the maximum shell diameter 8.0in.

The jet flow is estimated at 0.464lb./sec., and the jet reaction 53.280lb. Other items of interest are the reaction chamber pressure, 700lb./sq. in.; fuel tank pressure, 1,050lb./sq. in; jet velocity, 5,000ft./sec.; time of power, 43 sec., and the total height attainable 47,000ft. within 78 seconds.

Launching Procedure

As has already been mentioned, the controlling gyro must be run up to its designed rotational speed just prior to launching, and this is arranged through a flexible drive, the auxiliary motor being held at the side of the rocket. This is, however, but one of the operations which must be attended to in readiness for firing. Previously the fuel and oxygen tanks must be filled. The feed control valves must, of course, be closed during this time, but opened again just prior to ignition. The method adopted by the M.A.A. is shown in Fig. 55.

Finally, a last-minute check must be made to ensure that each of the three tanks—propellent and feed—are fully charged, and that the pressure in the oxygen tank has been developed to the degree required for self-feeding. The parachute release gear must not be overlooked, and only when all these checks have been made is the rocket ready for firing.

Rocket Propulsion

Rocket-assisted Take-off : Successive-feed Powder Motors

By K. W. GATLAND

(*Continued from page 176, February issue*)

A GREAT deal has already been said of the development of successively loaded powder motors, but the units concerned have largely been the outcome of research in the U.S.A.

In Britain, similar research has been conducted by the Astronautical Development Society, and this has involved investigations of the recharging mechanisms for both the slow-burning and rapid-burning powders.

The principal difficulty associated with powder fuels has always been their limited duration of firing, and in the development of the successively loaded motor much hope is held to remedy this deficiency.

Assisted Take-off Rocket Units

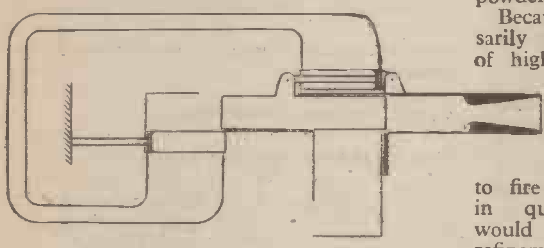
The use of rockets to assist fighter aircraft and heavily laden bombers and transports into the air without the need for long runways is to-day common knowledge.

Almost without exception the units employed are simple cordite rockets. The standard charge contains 26lb. of propellent within a steel casing of about 40lb. weight, 40in. long and 5in. in diameter, with a ⅛in. wall thickness. Short nozzles are fitted, 4in. in length, the throat to mouth diameters enlarging from approximately 2in. to 4in.

The thrust yield of these charges is slightly more than 1,000lb., and the energy per lb. of cordite, therefore, a little greater than 41lb.

The rockets are mounted in batteries of two to four, generally either side of the fuselage, close in to the wing roots. They are usually capable of maintaining a thrust constant for about four seconds, and, once expended, automatically release from their mountings and drop away.

In trials carried out in the U.S.A., a navy *Avenger*, was fitted with four "Jato" assisting rockets, each capable of a thrust of 330 h.p., and it was found that these cut down the take-off run by as much as 60 per cent.



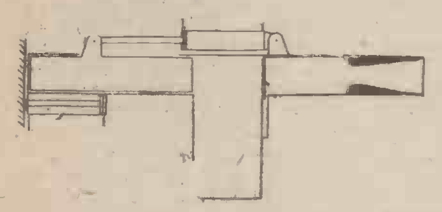


Fig. 56.—Diagrams showing two positions of an improved cartridge injector.

It is of interest to note that the Sander 10lb. powder charges, used by Fritz von Opel in his rocket glider of 1929, each developed a thrust of 53lb., effective for 25 seconds. Other single charges produced by Sander were capable of thrusts exceeding 600lb., but only for three or four seconds.

A high thrust, it will be appreciated, is only possible at the expense of the effective thrust duration and the burning rate can be moderated by the type and consistency of the powder employed.

Because of the necessarily limited duration of high thrust powder charges, it is obvious that some form of constant feed device, able to fire several charges in quick succession, would be a valuable refinement. Before going on to discuss units of this kind, however, a word about an interesting liquid fuel accelerating gear, developed in 1943 and used extensively by the Luftwaffe.

The Walter Bi-fuel A.T.O. Gear

The Germans sought to overcome the limitations of the powder charge by the use of a bi-fuel assisted take-off unit, known as the Walter 109-500.

The device employed 80 per cent. pure hydrogen peroxide with a permanganate catalyst, the peroxide being contained in a spherical tank and fed to a single combustion chamber under pressure from air bottles. Its fully charged weight was only 600lb.

The motor operated at an average thrust of 1,200lb., the power lasting from 24 to 28 seconds.

Two of these units were fitted, one below each wing, being jettisoned and parachuted to the ground for re-use, once combustion had ceased. Since only "chemical combustion" took place within the chamber, the same unit, recharged, could be used several times before corrosion took serious effect.

"*Strut Psychrometer." An instrument used on meteorological aircraft for recording pressure, temperature, and humidity.—Courtesy of the Meteorological Office, Air Ministry.*

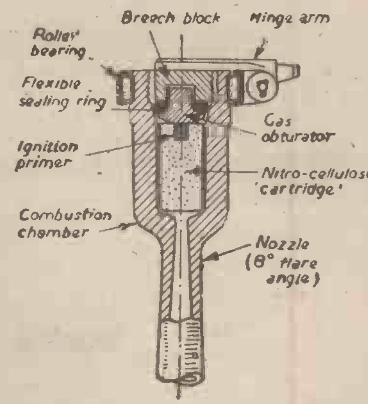


Fig. 58.—Detail of firing chamber and seal mechanism of rapid fire "cartridge" motor.

A modified version of the Walter 109-500 was fitted in the Hs. 293 "glide-bomb," used for attacks upon Allied shipping.

A Successive Feed Motor for Slow-burning Powders

An outline of the more critical design problems to be overcome in the evolvement of a suitable device has already been given in the references to Professor Goddard's early researches with rapid-burning powders (PRACTICAL MECHANICS, August, 1945, pp. 373-4), and it will be recalled that, although much in detail has been previously conducted concerning chamber and nozzle efficiencies, information is entirely lacking of the reloading mechanism itself.

Work towards evolving a small motor, capable of the repeated injection of quantities of slow-burning powder to a single combustion chamber, was commenced in 1941, and credit for this and subsequent development is largely due to Mr. A. M. Kunesch and the writer. The outcome of an initial survey was a first self-operating design in which powder fuel was intended to be fed in the form of "cartridges" (Fig. 57).

With reference to the diagram, it will be seen that the unit is made up of the following components: combustion chamber, door, breech, cartridge, pump, pneumatic jack, and injector rod.

The "injector" was designed around a specially prepared "plastic cartridge" which had no separate case and burned away com-

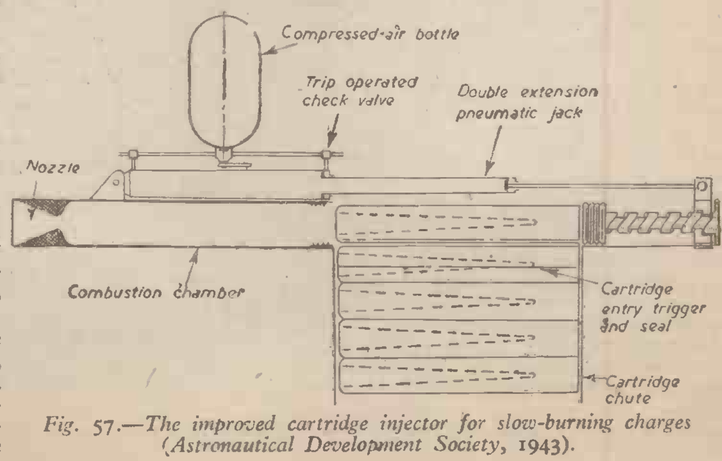
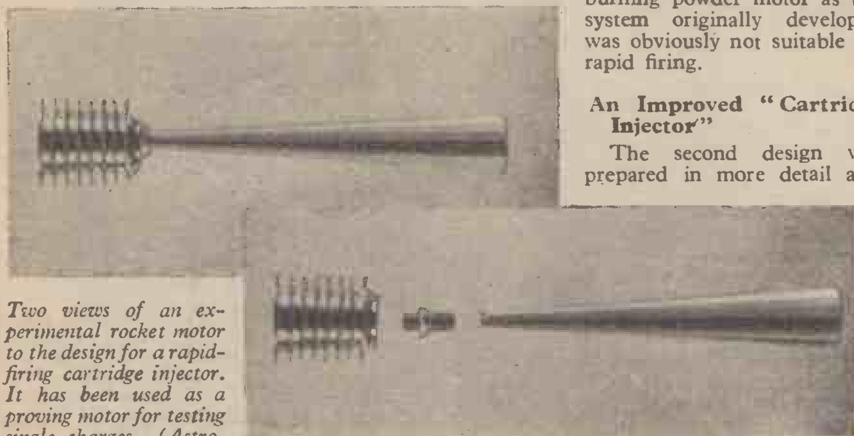


Fig. 57.—The improved cartridge injector for slow-burning charges (Astronautical Development Society, 1943).

pletely. The desired structural form resulted from an organic admixture to certain fuel powders, and using this process it was found that rocket propellents could be formed readily into any desired shape or size.



Two views of an experimental rocket motor to the design for a rapid-firing cartridge injector. It has been used as a proving motor for testing single charges. (Astronautical Development Society, 1943).

Experiments with charges of this nature have shown that no residue remains after firing, it being found that ash produced in combustion only condensed outside the nozzle. This is particularly important in view of the fouling which occurs after the firing of gunpowder, and which would seriously impede the proper function of a repeating mechanism.

Apart from the special powders tested, it is also possible to bond nitro-cellulose powders—cordite, for instance, may be conveniently formed by the admixture of acetone.

An impression of the "injector" can be best gauged from an explanation of its operation. The firing sequence is as follows: a cartridge is initially primed to the combustion chamber when the "reaction carriage" is at its foremost travel—as shown in Fig. 56. The chamber seal door is then closed by a cam action and the cartridge fired, causing the complete unit to recoil along runners to a bearing plate. During this action air pressure is transferred from the supply pump (situated beneath the carriage) to the pneumatic jack, which actuates the injector rod and retains it at the rear of the carriage. A second cartridge is then free to enter the breech.

Once the thrust of the primed charge has fallen below a certain value, recoil springs return the carriage to its original position, pressure being transferred back to the supply pump, while air is forced out into the other side of the injector jack to move the rod forward. The door is then rapidly opened and closed to allow the second cartridge to enter for combustion. From this point the operating cycle is continued automatically.

The conclusions of the initial survey gave clear indication that the two types of powder—slow and rapid burning—would require entirely different injection mechanisms. In view of this, it was decided to proceed first with the slow-burning powder motor as the system originally developed was obviously not suitable for rapid firing.

An Improved "Cartridge Injector"

The second design was prepared in more detail and presented an altogether more practical solution. Perhaps most important of all, the effective sealing of the firing chamber—a problem ignored in the early design—was most satisfactorily overcome. Another refinement was that the recoiling feed action was eliminated.

The improved "cartridge injector" (Fig. 56), though basically the same as the original, incorporated several entirely new features. It comprised the following main items: combustion chamber, breech, cartridge entry chute, cartridge entry trigger and chute seal, pneumatic jack, check cocks (two required), compressed air cylinder, and breech block/injector.

As may be gathered from the diagram, the motor is designed to operate under controlled pressure from an air bottle. The air is fed through trip-operated control cocks which alternately direct pressure to move the breech block/injector backwards and forwards under the action of a pneumatic jack. As will be seen from the diagram, the breech block, which seals the chamber, also forms part of the injector movement.

At the rearmost travel of the injector a cartridge is allowed to enter the breech. The air pressure is then applied to return the jack piston, which pushes the injector forwards and inserts the charge. The breech block at the injector head is then screwed in to seal the combustion chamber under the action of the "Archimedes screw," and the cartridge electrically fired.

Immediately the thrust of the charge commences to decline, pressure from the air bottle moves the jack piston backwards, and the injector head automatically unscrews and travels to the rear, allowing a further charge to rise into the breech.

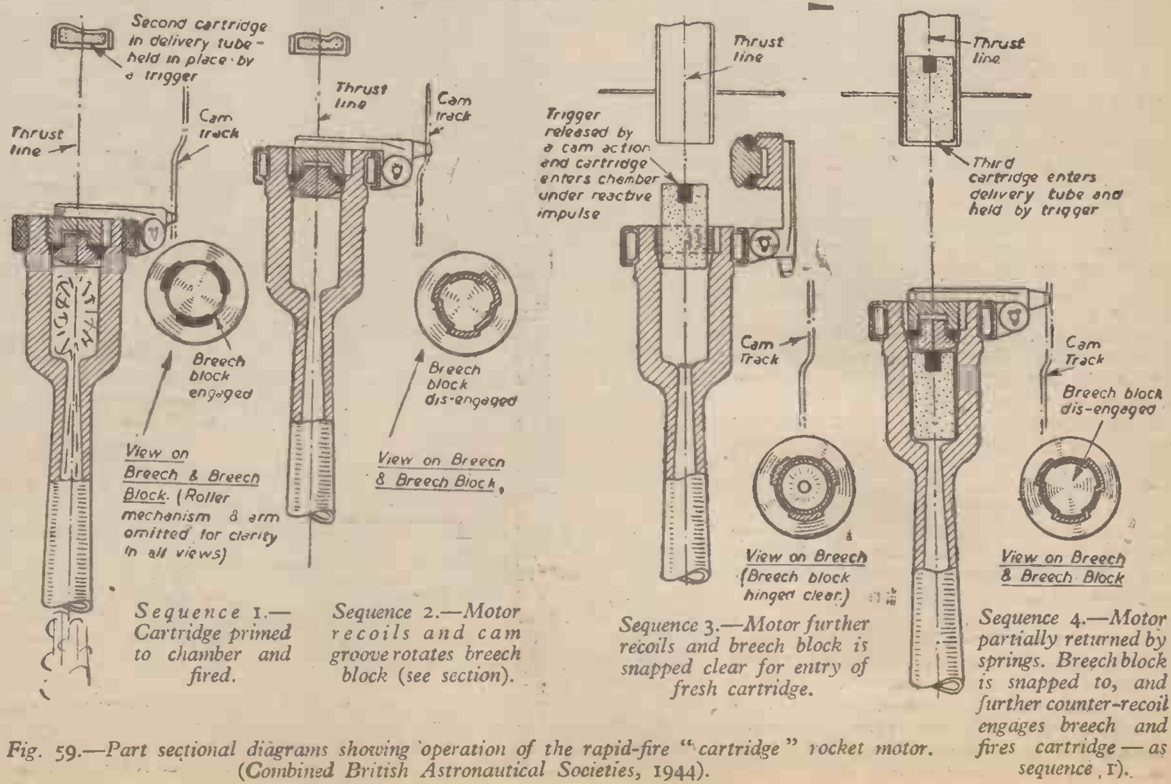
It would probably be necessary to incorporate vents around the chamber seal to prevent "blowback" of thrust pressure as the chamber is opened preparatory to the injection of a fresh charge. Otherwise, the gas temperature may be sufficient to ignite the charge before its entry into the chamber. The unit described is intended to fire five three-second cartridges, but for units employing more charges it would be necessary to jacket the combustion chamber with liquid coolant.

Whether or not an A.T.O. system of this type would be preferable to fixing the same number of single charges to fire in sequence is debatable. The one principal advantage of the reloading device is that the thrust line is constant, and as reloading would be almost instantaneous, the whole question largely resolves into a matter of reliability, weight and installation space.

The Rapid-fire Rocket Motor

The rapid-firing cartridge motor is altogether different from the units previously described, having been designed to power a light, high-altitude sounding rocket.

In this arrangement the cartridges are fed at the rate of 20 per second, but each charge weighs only ¼oz., as compared with the charges of several pounds specified in the slow-firing designs. Because of this, the mechanism which feeds the cartridges can be appreciably lighter, and it is this factor that largely accounts for the high rate of fire. It has, in fact, been estimated that



Sequence 1.—*Cartridge primed to chamber and fired.*

Sequence 2.—*Motor recoils and cam groove rotates breech block* (*see section*).

Sequence 3.—*Motor further recoils and breech block is snapped clear for entry of fresh cartridge.*

Sequence 4.—*Motor partially returned by springs. Breech block is snapped to, and further counter-recoil engages breech and fires cartridge—as sequence* 1).

Fig. 59.—*Part sectional diagrams showing operation of the rapid-fire "cartridge" rocket motor.* (*Combined British Astronautical Societies,* 1944).

the total weight of the moving parts would not exceed 15oz.

The combustion chamber (Fig. 58) is designed to recoil along runners, and the cartridges are fed by the inertia. There is an opening breech-block to allow the cartridges to enter the chamber, which is rapidly opened and closed under the action of a cam mechanism operated by the recoil.

The chamber is returned by strong springs which compress as the motor recoils under thrust, and the charges, having separate ignition primers, are fired electrically by a simple "make and break" circuit.

The breech-block is constructed with interrupted threads. This enables the breech to be disengaged and re-engaged by a slight turn of the roller bearing to which the hinged arm of the breech-block is attached.

The Combustion Chamber and Nozzle

The combustion chamber is particularly small, its internal length being only 1in. by ½in. diameter. These surfaces are finely machined and polished to reduce frictional losses, and thus any excessive heating of the chamber is avoided.

A high operating efficiency is therefore maintained over the entire period of combustion, and while it is rare for a liquid-fuelled motor to greatly exceed a chamber pressure of 500lb./sq. in., the rapid firing "cartridge" motor is designed to permit the exceptionally high pressures of 30 to 45 *thousand* lb./sq. in.

This largely accounts for the high efficiency, which is, of course, due to the rapidity of combustion and the greater expansion and less dissociation of the gases.

To suit these conditions the size of the motor is limited, but, nevertheless, the dimensions of the unit here discussed are well within the bounds of the practical. Indeed, the thermal efficiency would be improved by slightly "scaling up" the chamber, due to the reduced heat loss. This is because the chamber area increases by four to the weight of the charge, eight times.

A high-expansion tapered nozzle, 7.25in. long, is fitted which embodies an 8 degree flare angle, expanding from .125in. at the throat to slightly more than 1in. at the mouth. It is not quite a straight taper, as at the mouth end the angle is decreased to form a short parallel length, and this refinement—originally adopted by Professor Goddard—ensures that the high-velocity gases fill the cross-section throughout the entire nozzle length. Without this change in contour a discontinuity of flow would be produced at the points where the gases leave the wall of the nozzle and result in the formation of eddies with a consequential loss of unidirectional velocity.

In comparison with the machine-gun—a useful guide in this work—heating effects would be less critical. In the gun the bullet creates considerable friction and confines the propelling gases in the barrel (at a temperature of 2,000 deg. C.), whereas in our particular case there is no friction save that of the gas itself, which escapes almost instantly.

It is thus obvious that the rocket motor will permit the firing of considerably more cartridges than a machine-gun before getting to *critical heat*—the temperature at which the propellent is ignited merely by contact with the combustion chamber.

Explanation of Diagrams

The diagrams (Fig. 59) represent the firing sequence of the motor, and is self-explanatory. Sequence "1" shows the motor as it appears at its rearmost travel, a cartridge having just been fired. The breech block is, of course, engaged in this position, and a fresh cartridge is held in place at the bottom of the feed tube.

In the second view the motor is shown partially recoiled, and it will be seen that the breech-block has been rotated so that it is completely disengaged under the action of the cam track.

The third sequence depicts the motor in full recoil, with the breech-block snapped clear and the feed trigger released to allow the second cartridge to enter the chamber under the inertia of recoil.

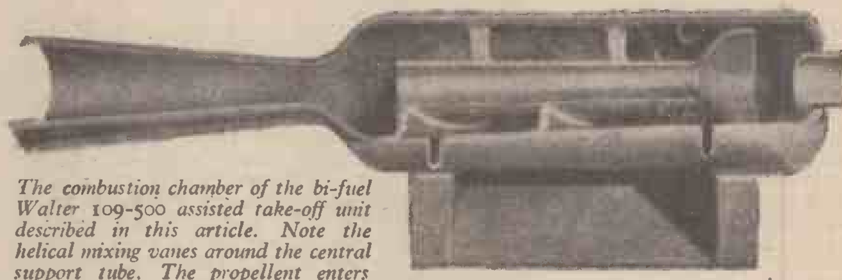
Finally, the motor is shown partially returned by the recoil springs (these are omitted in the diagram), the breech-block being snapped to, but the threads not yet engaged in the breech. At this point a selective mechanism allows a third cartridge to enter the delivery tube.

At the rearmost travel the motor appears again as sequence "1," the breech-block re-engaged, and the second charge fired as the first.

Performance

Previous tests of single-shot motors of similar chamber and nozzle forms have shown that it is reasonable to expect jet velocities of 7,000 to 7,500ft./sec., and since the chamber proposed is somewhat larger than the test types, the maximum figure should be nearer the mark.

Using ⅛oz. cartridges, the jet flow works out at 2½oz. per second, and assuming a jet velocity of 7,500ft./sec., the thrust would be approximately 36½lb. Although the jet flow and thrust values are not great in comparison with other motors, the fact that the chamber is of midget proportions and the complete unit so very light ensures a high operating efficiency.



The combustion chamber of the bi-fuel Walter 109-500 assisted take-off unit described in this article. Note the helical mixing vanes around the central support tube. The propellent enters through a stainless steel nozzle at the head, and thrust is derived through chemical reaction resulting from H_2O_2 and calcium permanganate.

A Solid-fuelled Sounding Rocket

The possibilities of the unique cartridge motor in a sounding rocket arrangement are illustrated in Fig. 60. As will be seen, the unit can be very compactly accommodated, and there appears no reason why such an arrangement should not prove highly effective.

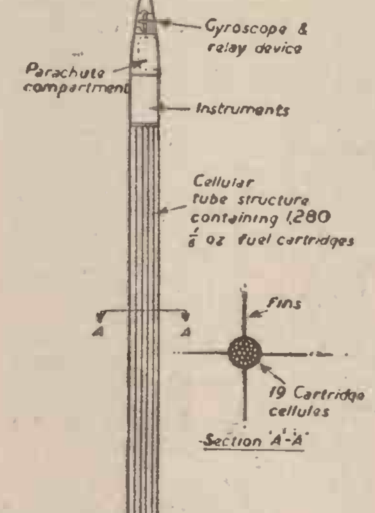


Fig. 60.—*Suggested layout for a successively loading "cartridge" rocket.*

In the projected design the fuel container comprises 19 individual ½in. i/dia. cellules, arranged on a honeycomb plan for maximum structural strength and fuel capacity.

Basing the size of the rocket on 10lb. of fuel (or 1,280 cartridges), it should be possible to build the cellules and shell of bonded plastic, as affording a ready finish and greater resistance to denting than a much thinner metal case and tube structure of the same weight. A plastic case and the desired number of cellular feed tubes would weight about 5lb.

The motor, having a weight of 2lb., plus 1lb. of instruments, makes the total for the main components in the region of 18lb.

The rocket would have an initial acceleration of 1g., and a final acceleration of approximately 3½g., and, using 1,280 charges, the firing duration would be 64 seconds.

(*To be continued*)

AUTOMATIC GUN COCKER

A NEW device which has been submitted to the British Patent Office concerns guns in which cocking during firing is effected automatically by gas pressure obtained from the barrel of the gun.

In the larger guns, it is stated by the inventor, after the supply of ammunition has been exhausted and a fresh supply has been introduced, the initial cocking cannot be effected by hand. It has been subjected to pneumatic treatment, but this method, asserts the inventor in question, is somewhat complicated.

The object of the new device is an improved and simplified means for the initial cocking of the gun.

The invention comprises a hydraulic pump supplying pressure fluid to a cylinder containing a plunger which performs the cocking operation. There is also a plunger-type automatic valve loaded through a lever having two positions: (1) where the valve is closed and loaded against the pump delivery pressure and (2) where the valve opens a by-pass passage to release the pump delivery pressure and is not loaded to return to its service position, so that such return must be effected by hand.

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PRACTICAL MECHANICS

Owing to the paper shortage "The Cyclist," "Practical Motorist," and "Home Movies" are temporarily incorporated.

Editor: F. J. CAMM

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FAIR COMMENT—BY THE EDITOR

The British Interplanetary Society

IT is not so many years ago that the Interplanetary Society was regarded with scorn by so-called scientific people. The V-1 and the V-2 and the atomic bomb have, however, placed the society in the forefront of scientific institutions. It has a most important duty to perform in disseminating knowledge on this modern scientific subject.

The Interplanetary movement commenced in this country in October, 1933, when P. E. Cleator founded the British Interplanetary Society with headquarters in Liverpool. E. Burgess in June, 1936, formed the Manchester Interplanetary Society, and a journal, *The Astronaut*, appeared in April, 1937. Thereafter followed the Paisley Rocketeer Society in Scotland, the Leeds Rocket Society and the Hastings Interplanetary Society. Then occurred an internecine conflict resulting in the formation of the Manchester Astronautical Association in December, 1937, followed by the disbanding of the Hastings and the Leeds groups.

The outcome was the production of a common bulletin which also contained news of a Midlands group of B.I.S. members.

A few months before the war the M.I.S. voluntarily disbanded and the P.R.S. followed suit. The B.I.S. continued and convened an emergency meeting at the commencement of hostilities at which it was decided that the society should cease to function for the duration of the war. The M.A.A. thus became the only functioning body by holding its meetings and issuing periodically a journal under the title of *Spacewards*.

Astronautical Development Society

THERE was another group of interplanetary enthusiasts operating at Surbiton, Surrey, known as the Astronautical Development Society, and our contributor, K. W. Gatland, was responsible for its organisation. Contact between these two societies was made in 1941 and in early 1942 a joint monthly bulletin was issued followed in October, 1942, by the joint journal *Spacewards*.

There resulted an affiliation of the two organisations resulting in the Combined British Astronautical Societies in 1944. Regular meetings of this body were started in September, 1944, and a few months later the possible amalgamation of the B.I.S. and the C.B.A.S. was discussed. Many other meetings followed, and on June 13th an informal but important meeting of the B.I.S. took place in London at which it was decided to reform the society and apply for incorporation. In the following June the prospects of forming a national society were discussed. At a later meeting this was unanimously decided upon and L. J. Carter was authorised to prepare a Memorandum and Articles of Association and to make the required application for the incorporation of the British Interplanetary Society. The certificate of incorporation was obtained on December 31st, 1945, from which date the B.I.S. commenced its activities.

We set these facts on record because, living as we are in the midst of history, it is proper that future generations should know how the interplanetary movement started. The early days of the Royal Society of Arts, the Institution of Mechanical Engineers and many other learned societies, are punctuated by the same difficulties as have beset this new movement. We have no doubt that in one hundred years' time the B.I.S. will be regarded with the same scientific reverence as the other learned societies. Certainly it has justified the vision, the energy and the enterprise of those who have sponsored the movement, and the wisdom of those who saw that there was strength in unity and none in division and separate rivalries.

The personnel of the B.I.S. is composed of scientific people, not cranks, and it has a most important task to perform in educating the public to the possibilities of the atomic era and the rocket era as well as the jet-propulsion era in which we all now live.

No doubt as time goes on the terms of membership will be made more difficult, and it behoves all those who have a genuine scientific interest in the subject to get into touch with the British Interplanetary Society whose registered offices are at Albemarle House, Piccadilly, London, W.1.

Radio Noises

IT has long been accepted that, since the sun emits electromagnetic waves in the form of light and heat, it must also emit radio waves of extremely weak intensity. Normally, this intensity is so feeble as to be quite undetectable on radio receivers in the 1 to 10 metre band.

But it has been recently found by British radio workers that, when there is a big and active sunspot group on the sun the solar radio emission can be increased up to 100,000 times in the 1 to 10 metre band; and this radio emission can then be detected on sensitive receivers on the earth's surface. It is natural to assume that these abnormal bursts come, not from the sun's disc as a whole, but from the localised active sunspot area. Many present-day Army receivers, particularly those used in radar, are now so sensitive that they can detect this abnormal solar emission, when it occurs, if their receiving aerials are pointed in the direction of the sun. The effect produced on listening in headphones or loudspeakers is that of a hissing noise, hence the term "radio noise."

At present there is a large and important group of sunspots on the sun's disc which can easily be seen by the naked eye, looking through smoked glass. This group, according to the Astronomer Royal (Sir Harold Spencer Jones) is the largest observed since 1926. Since the sun itself is rotating (it makes a complete rotation in 27 days) it was expected that the sunspot group would cross the central meridian on February 5th last, Solar noise from it was detected by Mr. J. S. Hey and his colleagues, Maj. S. J. Parsons, Maj. J. W. Phillips and Mr. G. S. Stewart, of the Operational Research Group, Ministry of Supply, on January 30th, on their equipment in Richmond Park. Through the kind co-operation of Lt.-Col. H. A. Sargeaunt (Superintendent, Operational Research Group, Ministry of Supply) a continuous watch has been maintained. Valuable assistance has been given by Army operators, mainly from A.A. Command. It is believed that this is the first time that the noise phenomenon has been continuously studied in this way.

The Demonstration of Solar Noise

THE demonstration of solar noise had been arranged by Sir Edward Appleton, G.B.E., K.C.B., F.R.S., and the Operational Research Group, Ministry of Supply. The solar "noise" was demonstrated as a disturbance on a cathode-ray screen such as is used for the delineation of radar echoes. It was also demonstrated as an audible hissing noise on a loudspeaker and on a measuring instrument which indicated the strength of the radiation. The wavelength of the receiver used was about 5 metres. Proof that the radio noise comes from the sun was demonstrated using a directional aerial.

It has long been known that sunspots affect short-wave radio transmission because they cause abnormalities in the ionised reflecting layers in the upper atmosphere. We now know that when sunspots become active the sequence of events is somewhat as follows:

(a) First, the enhanced radio noise is heard. The radiation causing this noise travels with the speed of light, and travels from sun to earth in about eight minutes.

(b) The radio noise is usually followed by and associated with short-wave "fade-outs." These are due to the formation of an absorbing "blanket" underneath the Heaviside layer so that radio waves are strongly absorbed there. This "blanket" is due to a burst of ultra-violet light and causes a fade-out of from half to one hour's duration.

Rocket Propulsion

War Developments—the Field Rocket Projectile

By K. W. GATLAND

(*Continued from page* 211, *March issue.*)

HAVING related the achievements of private individuals and research organisations unconnected with governments, let us now investigate the innumerable military rockets which saw service during World War 2.

Mention has already been made of the fact that in the years leading to the outbreak of hostilities the Allied Governments—and the British Government in particular—remained apathetic of the research that was then undergoing open and rapid development at the hands of the amateur rocket societies.

We have seen, too, how the newly formed National Socialist Government, in 1934, instituted a purge on Germany's privately established rocket groups, confiscating their records and throwing into concentration camps all those technicians who refused to co-operate in formulating the rocket to the Nazi plan.

In the closely-guarded rocket laboratories, workshops, and testing grounds that resulted from the ascension of the National Socialists, the fruits of years of painstaking research by honest and well-meaning technicians—whose aims were none more sinister than the outcome of the meteorological sounding rocket and the rocket mail carrier—were minutely investigated. Upon their work, in fact, was largely built the military research programme, which many years later had its result in Peenemunde—the Baltic research station. There, as is now well known, originated the V-2; power units for innumerable rocket interceptors, remotely controlled air to air, ground to air, air to ship, winged "flak" rockets and projectiles; and many others to come, had the war not ended when it did.

When war came to Britain the followers of "Blimp" were eventually swept aside, and pursuing the path of the pre-war amateurs the Government war rockets slowly but surely evolved, as also did similar rockets in Russia and the U.S.A.

Classification of Types

The developments of the war have been so numerous and varied that, to avoid confusion, it will be necessary to abandon the accustomed sequence and to detail each type of rocket device separately from first to the most recent.

There are nine main types of rocket weapons and devices, and it will be most convenient to deal with them in the following order: (a) field projectiles; (b) aircraft firing projectiles (R.P.); (c) ground to air "flak" projectiles; (d) air to ship "flak" projectiles; (e) ground to air "flak" projectiles (manned); (f) long-range projectiles; (g) assisted take-off accelerators (A.T.O.), and (h) rocket propelled aircraft.

The Field Rocket Projectile

Undoubtedly, the points of greatest significance about the field rocket projectile are its light weight, its portability, and the ease with which it is constructed with a minimum of skilled labour. A similar calibre gun, on the other hand, would be appreciably weighty, difficult to manœuvre, and require for its building special materials, a large variety of complex shaping machines, and highly skilled forgers and machinists.

The rocket has one disadvantage: it can only be considered accurate at close range. With present methods of stability and control—in cases where the latter exists—the rocket projectile is hopelessly inferior to the orthodox shell over distances of more than half a mile. This must not be taken to infer that it will always be so. Much hope is held in the development of radio-acoustic "self-directing" devices for use against vehicles, ships, and aircraft. The "Schmetterling"—Germany's V-3—was to have been acoustically homed into bombers. The designer of this unique air weapon, Professor Wagner of Junkers, in fact, considered the weapon to be so effective that he predicted the destruction of one Allied bomber for every missile that the Germans launched.

The small close-range rocket, however, lacks nothing. It is sufficiently accurate for anti-tank use, and is easily transported and operated in difficult country, in many cases single-handed, requiring little more than a simple tube for its launching. One of the German rocket projectors, in fact, was named the "stove-pipe," so great was the resemblance to common stove-piping. Again, compare the gun with its complex rifling, breech and firing mechanism, its great weight and relative immobility.

In a multiple launching arrangement the rocket has, too, become a valuable barrage weapon. Who will forget the sight of fiery trailed "flak" rockets arcing up into the night sky at the first approach of Nazi bombers or V-1s? The British Z-batteries went into full-scale action in 1943; but had *serious* work started on their production—really, a simple matter for the right people—even at as late a time as 1939, who knows how much damage, death and suffering might have been averted from our cities and towns, so poorly defended at the time of the "blitz"? The rocket-projectors, so simple and effective an answer, arrived too late to stem the main attacks of the Luftwaffe—*yet almost identical projectors had been in use for firing amateur research rockets years before the war, both in Britain and America.*

It has been openly admitted that the development of the Z-battery involved seven years of research. A useful comparison is the Russian launcher and projectile with which "Stormovik" IL-2 aircraft so successfully turned the Nazi "spearheads" at Stalingrad. This projector, which was among the first rocket weapons to be used in the war, was officially reported to have been developed and produced *within twelve weeks*. It is well known, also, that the Soviet forces used multiple land projectors at Stalingrad.

The least that can be said of the British development is that it gives added emphasis to the need for a central pool of rocket data and literature, from which Government technicians and amateurs alike could draw information. As we have had cause to mention earlier, much original work has been done with rockets, but much more has been duplication.

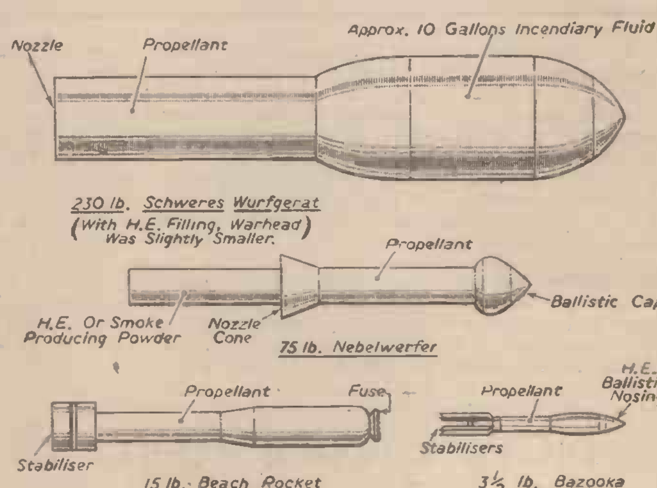


Fig. 61.—Four of the most prominent field rockets used during the war. (Scale .05in. = 1.0in. approx.)

The "Katusha"

The "Katusha" was actually the first rocket weapon of the war, being itself a development of a multiple rocket device which had been employed by the Russians against the Turks as long past as 1830.

It was used with disastrous effect on the Nazi forces at Stalingrad, where it was considered to have been a key weapon in the city's defence. The projectiles, which were fired in quick succession from batteries of launching ramps, burned "solid" propellant, had an overall length of between 5 or 6ft. and a weight (including explosive head) of about 50lb. Their burning time was less than two seconds.

Another Russian weapon in use at about the same time was a small-calibre anti-tank projector which fired 30 armour-piercing rocket shells simultaneously. The launching tubes were mounted in five rows of six on a light carriage and set to discharge the rockets over a fairly wide area. It was, of course, ideal against massed tank formations.

First German Field Rocket

The Germans first employed rockets in the field on the Russian Front.

They were initially used as smoke curtain projectiles, although it was not long after that explosive and incendiary rocket carriers made their appearance.

Later it was announced that Rommel was employing anti-tank rockets in Libya, and this type was also used by the retreating German armies in Tunisia and Italy.

The Schweres Wurfgerat

The chemical and incendiary rockets developed by the Germans were of two main types. First the large rockets of 12½in. and 10in. calibre, which were employed in the Schweres Wurfgerat (heavy throwing engine). The former was an incendiary carrier, while the latter contained high explosive, and both types had an effective range of 2,000 yards.

A unique feature of this projector was that the transit case was also the launching rack, from which the rockets were fired at any desired elevation.

At first, however, they were launched singly, but eventually cases were assembled together in two layers of three to form a six-ramp projector, and the complete set-up mounted on a gun-carriage. Ignition was achieved electrically by successively firing squibs.

The projectiles used in this launcher, as we have already observed, were of two classes. Both, however, were to the same basic design, although the head of the explosive rocket was slightly smaller than the one having an incendiary filling. The warhead of the 12½in. calibre type contained a little more than 10 gallons of incendiary fluid.

Attached behind the warhead was a propellant tube of smaller calibre which housed a double-base powder, somewhat similar to cordite. Stability was achieved by axial rotation caused by offset exhaust apertures in the base-plate.

The total weights were 180lb. and 230lb. respectively.

The Schweres Wurfgerat was largely used in Italy, and, mounted on motor-trucks, it was employed to quell risings of Polish patriots in Warsaw. Towards the close of the European war, however, several of these projectors were captured by the Czechs and used effectively against Nazi forces surrounded in some Channel ports.

Nebelwerfer 41

The second main rocket type was smaller, being of 6in. and 8in. calibre, and used in the Nebelwerfer 41 (Smoke-thrower Model, 1941). In this device the projectiles were launched from steel tubes, which were mounted in groups of six on small gun-carriages. Firing was accomplished electrically, with a delay of one second between each round.

Unlike the projectiles of the Schweres Wurfgerat, the propellant in the 6in. calibre type was housed in the rocket head, exhaust being made through 24 tangential nozzles in a conical centre-section. The explosive, or smoke-producing powder, was contained within a tubular tail-section.

Stability was, of course, effected by axial rotation, but was in part due to the placing of the centre of reaction forward of the centre of gravity.

The nozzle cone had a diameter of 6in.; the propellant and rear tubes slightly less. The rocket's overall length was 3ft. 6in.

A sheet steel ballistic nosing was also fitted, and it is of interest to note that its maximum cross-sectional diameter was greater than that of the propellant tube. This, presumably, was chiefly intended to stabilise the rocket while in the launching tube, the nozzle cone having about the same dimension.

It has already been mentioned that the nose form is the essential feature for consideration at near-sonic and super-sonic velocities. This is because of the compressibility region that is built up at the front of the body, which takes the form of hyperbolic sound waves and constitutes the main drag. Because of this and other practical considerations, such as explosive capacity, balance, etc., little account has been given to maintaining a smooth body line aft of the nosing in the majority of war projectiles. For a more detailed account of compressibility phenomena, the reader is referred to an earlier article in this series, PRACTICAL MECHANICS, January, 1946, pp. 133-135.

The smoke-curtain projectile was the first of the type to be used in action, and weighed slightly less than 75 lbs. The Germans later employed the rocket fitted with a modified aft container of explosive in place of the smoke-producing powder. The latter were used at Stalingrad and Veliki to supplement field howitzers, and had a range of about 7,000 yards and an average velocity of 1,000 feet per second. They weighed approximately the same as the smoke-producing rockets.

The 8in. calibre model had a more orthodox appearance. The explosive was contained in the nose, and the propellant at the rear. Stability was again obtained by body rotation, exhaust being made through off-set holes in the base-plate of the propellant tube.

It weighed 200 pounds, and was credited with a range of approximately 9,000 yards.

British and U.S. Developments

A development of the Z-battery projector (which will be detailed in a later article) was employed during the decisive El Alamein battle in order to concentrate a great fire power against the German Army, which was then going all out for a break-through into Egypt.

It is significant to note that while the Germans apparently favoured rockets stabilised by axial rotation, the British and American rockets were un-rotating and stabilised by fins. There is no doubt that both systems have disadvantages, and one that is most noticeable is a pronounced tendency for finned projectiles to turn into the wind. Conversely, there is a small loss of propulsive efficiency in causing body rotation.

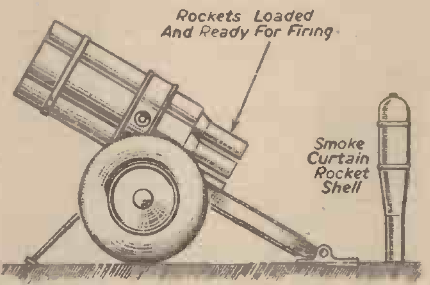


Fig. 62.—The Nebelwerfer: a six-barrelled rocket projector mounted on a wheeled chassis.

The principal single-unit anti-tank projectors were, of course, the American "Bazooka" and the German "Panzer Fist." These were the lightest projectors used during the war, and both could be fired single-handed, although they were generally operated by a team of two.

First, because it was by far the most significant, the "Bazooka"—officially known as "Rocket Launcher, A.T.M. 1." Apart from the Russian "Katusha," it was undoubtedly the most important field rocket of the war and saw large-scale service in Europe as well as in the Far East.

The "Bazooka" was essentially a close-hand weapon—300 yards was its limiting range. It was developed to the specification for a light, easily transported rocket projector having the fire power of a large calibre gun and capable of being operated by, at most, two men. How the requirement was met is now past history, but it is as well to recall that this and similar rocket weapons were decisive instruments in the final overthrow of the Axis.

As previously mentioned, the projector was operated by a two-man team—the launcher, who carried the 12 lb. firing tube, and the loader, who had care of the projectiles, which he carried in a special compartmented canvas bag.

The launching tube, open at both ends, was about 4ft. 2in. long and less than 3in. in diameter. A shoulder stock was fitted to the tube, and this contained two ordinary dry-cell flashlight batteries used in the ignition of the projectile. Launching was initiated by a normal type trigger placed forward of the stock. A hand grip was also attached close to the mouth.

Preparatory to loading, the launcher assumed a "one knee down position," having the projector over his right shoulder, into which the stock fitted snugly. The projectile was then inserted into the aft end of the open tube by the loader, who catched it with a wire retaining device to prevent it from slipping out backwards. He would then step to the side of the projector and move a small contact switch from "Safe" to "Fire," finally tapping the launcher on the shoulder to signal readiness for firing.

The loader would, of course, take due care that he was well to the side and clear of the rearward blast effect of the projectile when it was eventually fired.

The launcher, having sighted his target, depressed the firing trigger, and with a blast of flame rearward from the tube, the projectile sped rapidly towards its objective. The projectile was so designed that it ceased firing before emerging from the tube, and thus the launching crew were not affected in the slightest by flame or blast. There was little or no recoil.

Although the missile's striking velocity was quite low, it had great penetrative ability. This was because the explosive was detonated on impact, with the result that a hole was blown through the armour plate and the interior of the tank filled with blast, which was generally fatal to all within.

The projectile of the "Bazooka" was about 20in. long, had a maximum diameter of 2¼in., and an approximate weight of 3½lb. It was stabilised in flight by six fixed sheet-metal fins.

The explosive was contained within a ballistic nosing, and around this was fitted a thin band of copper, necessary for the ignition circuit. A wire connected the battery, trigger switch and contact box, and through the moveable contact arm the current was transmitted to the copper band on the projectile. A further connection was made from the band to an electrical ignition squib, fixed within the nozzle of the propellant chamber. The other end of the wire attached to the squib was grounded to the projector.

German Anti-tank Weapons

The German counterpart of the "Bazooka" was the "Panzerfaust" ("Panzer Fist").

It was hardly comparable, however, for its effective range was little more than 50 yards. Although not the main German rocket weapon for the purpose, it was, nevertheless, supplied in quantity to the Volksturm for delaying tanks.

The principal anti-tank projector was much larger, having a tube of about 6ft. in length and 6in. diameter. Unlike the "Bazooka," a heavy metal shield was fitted to the launching tube in order to guard the crew from blast and flame. A hole in the shield, in which was mounted a frame sight, enabled the launcher to direct his fire in conjunction with a second sight on the muzzle of the tube.

Although the weapon was rather heavy and had to be supported during firing, it was claimed that it could be carried by one man. In principle, both these German weapons were similar to the "Bazooka."

Rocket Projector Boats

The next important development was the rocket-firing boat. These craft were used to support troops in landing operations and, as such, no apology is offered for including them under the head of "Field Projectile."

The rocket-boats first went into action during the British invasion of Sicily, much to the consternation of the defending troops. Their value once proved, they were later adopted by the U.S. Navy, and figured prominently on D-Day during the assault upon the European continent. Similar boats were used in the landings on Walcheren, and also in the Pacific, where they materially assisted in the invasion of the Philippines, Iwojima and Okinawa.

The vessels originally employed for projecting rockets were ordinary tank-landing craft.

The projectors were mounted in the fore of the vessel and, prior to firing, all but one of the crew had to retreat below decks in order to evade the terrific blast. The operator was specially clad.

These steel rocket-boats carried hundreds of explosive rockets, which were fired in overlapping salvos from the fixed projectors in which they were stowed. They were launched at about 50 to 60 degrees, about a dozen or more at a time.

Other launching systems were later developed in which the rockets were able to be fired individually or in rapid succession. Each projector consisted of a double pile of six rockets so placed that the bottom one of each pile was in the firing position on the launching rails. The rockets were fired successively by electrical impulse and, as the first shot away, the whole pile dropped down so that the next rocket entered the firing position and was launched, whereupon a further rocket entered for firing, and so on, until all were expended. These projectors were mounted in groups of four along the sides of the ship. In certain instances, two sets of launchers were mounted on lorries for use on land.

The projectiles used in these launching systems weighed 15lb. The explosive head had a diameter of 4½in. to which was attached a cordite-filled propellant tube of 3in. diameter. A 4½in. diameter circular stabiliser was fitted at the extreme rear.

A 5in. projectile was later developed, as well as one of even larger calibre, but details of these are, unfortunately, lacking.

The value of the rocket-firing ship was, of course, in that it enabled a weight of fire to be directed comparable with that of a modern battleship. It was not a weapon of great accuracy, however, but was, nevertheless, ideal from the point of view of laying concentrated fire on relatively large areas.

(To be continued)

The Gloster Meteor IV

Constructional Details of this Record-breaking Aircraft

Front view of the Gloster Meteor jet-propelled aircraft.

THE Meteor IV—a twin-engined, jet-propelled, single-seater fighter—is a low wing monoplane of all-metal construction, with tricycle alighting gear and two Rolls-Royce Derwent Series V engines.

The whole aircraft is built on a "unit" system, thus:

- Fuselage nose.
- Front fuselage (with nose wheel, pilot's cabin and magazine bay).
- Centre section (with the centre plane aerofoils, the two undercarriage units, the two nacelles and fuel tank bay).
- Outer planes (each with ailerons and detachable tip).
- Rear fuselage (complete with tail portion, which includes the lower fin).
- Tail unit (consisting of upper fin, upper and lower rudders, tail plane, and two "half-elevators").

The fuselage nose houses the gun camera and nose-wheel mounting structure, and is otherwise a fairing which has special side panels to resist the gun blast.

Solid Bulkheads

The basis of the front fuselage structure is two fore-and-aft vertical diaphragms and three solid bulkheads. The nose-wheel mounting structure is on the first or nose-wheel bulkhead. The internal structure is sealed between the nose-wheel bulkhead and the seat bulkhead to form a pressure cabin on later aircraft. The third or front spar bulkhead is used to bolt to a similar bulkhead in the centre section. The centre section and the rear fuselage are of semi-monocoque construction; and two rearmost frames of the rear fuselage are extended upwards to form posts for the lower fin and to give attachment points for the tail plane and upper fin.

The main plane is a two-spar, stressed-skin structure. The centre section spars are spaced by six major ribs, interspaced with lighter skin ribs. Each engine nacelle is built of two main frames attached towards the outer ends of the spars. The two undercarriage bays, the upper and lower air brakes and the flaps are all between the nacelles and the "centre fuselage." The outer planes, which are joined to the centre section at both spars, have plate and lattice type ribs. The internally mass-balanced ailerons are all-metal structures with automatic balance tabs. The outer plane tip is detachable for production and replacement reasons.

The components of the tail unit are of stressed-skin construction. The high tail plane, necessitated by the jet from the propelling nozzles, splits the rudder into two parts. Trimming tabs are fitted to each "half-elevator" and to the lower portion of the rudder.

Hydraulic Undercarriage

The hydraulically operated, levered-suspension tricycle alighting gear consists of two independent undercarriage units which retract inboard and a nose-wheel unit which retracts rearwards, the wheel itself being housed between the rudder pedals in the front fuselage. In addition to the normal electrical indicators, there is a mechanical downlock indicator for the nose-wheel unit, showing just forward of the windscreen.

The stick-type control column has a hinged spade grip, and the rudder pedals have parallel action. Trimming tabs are operated by normal-type hand wheels.

Power Units

While the earlier Marks of Gloster Meteor aircraft were fitted with Rolls-Royce Welland jet-propulsion engines, the later Marks are fitted with Rolls-Royce Derwent engines. This engine was a record breaker from the outset, in that it was designed and the first engine was on test within a period of three and a half months, developing no less than 2,000 lb. thrust at 16,500 r.p.m.

Each engine is mounted between two centre section ribs using trunnion-type side mountings, one of which is free to float sideways to allow for expansion.

The engine is steadied at the rear by a "diamond" bracing, which again will allow for expansions. The generator (port nacelle), the hydraulic pump (starboard nacelle) and the vacuum pumps (both nacelles) are driven by auxiliaries—drive gearboxes, each mounted on the front spar in front of its respective engine, and from which it is driven by an extension shaft. The self-sealing fuel tank is divided by a transverse diaphragm; each compartment normally feeds one engine, but there is an interconnecting balance cock which is normally closed. The feed to the burners is maintained by external electric (tank mounted) and engine-driven pumps.

A central drop fuel tank is carried beneath the centre section as required. The oil system for each engine is self-contained, there being no airframe oil tank. The engine-driven hydraulic pump operates the alighting gear, flaps and air brakes. An emergency hand pump will operate all services.

The pneumatic system operates the gun cocking gear and the undercarriage brakes; there is no nose-wheel braking. There are two air containers in the rear fuselage; no compressor is fitted.

Power for the electrical system is supplied by a 24-volt, 1,500-watt, engine-driven generator on the port engine, charging two 12-volt accumulators. An electrical remote control two-way radio is mounted in the rear fuselage. Beam approach and I.F.F. installations are also fitted.

Armament

The armament consists of four 20 mm. belt-fed Hispano guns mounted in the outer structure of the front fuselage and fired electrically by a selective "wobble" button on the spade grip. The four ammunition tanks (one for each gun) are in a magazine bay, immediately behind the pilot, with ready access for re-arming. A gun camera is mounted in the fuselage nose fairing, and the control for this camera is incorporated in the gun button and may be used without the guns if required.

Other equipment includes a combined cabin pressurising and heating system, a gun heating system, windscreen de-icing and de-misting and an oxygen system.

Meteors are now being fitted with full photographic equipment and are being tropicalised.

Rocket Propulsion

Japanese War Rockets : Rocket-firing Tanks : Airborne Rockets

By K. W. GATLAND

(Continued from Page 256, April issue).

Display of weapons showing how the "Bazooka" compares in size with the rifle-grenade launcher next to it. The Verey pistol and flare launcher are also in the exhibit.

ALTHOUGH the Japanese appear to have been in the process of developing jet-assisted take-off units, and at least one turbine-compressor jet fighter—the "Kikka"—there is little evidence of any similar work with rockets. The "Baka" suicide 'plane, some experimental copies of the German Me. 163, and a small variety of field weapons were the only rocket devices they produced.

In the years before the war very little of scientific affairs was allowed to leak out of Japan, and although it is known that some research with rockets had been conducted, it is not clear on what scale.

It is reasonably safe to say, however, that no liquid-fueled rockets were experimented with, either before or during the war, and although some of the larger pre-war powder rockets were controlled by radio, their means of propulsion was invariably little improvement on the pyrotechnic rocket.

The Japanese were slow in producing rocket weapons, and it was not until the closing months of the war that they came to be used on anything like a large scale.

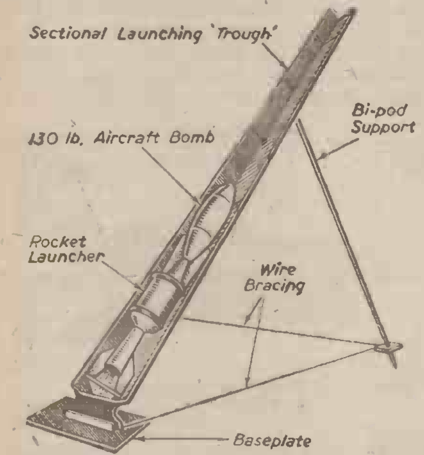


Fig. 63.—The "model 10 rocket launcher" captured on Saipan.

Rocket Launcher Model 10

One of the first Japanese rocket weapons was captured at Saipan, and, oddly enough, it appears to have been the only specimen of its type ever used in action.

This was the "Model 10 Rocket Launcher," shown in Fig. 63. It comprised simply an elevated wooden trough of right-angle section, supported at three points—by two tubular legs at the front and a small steel base-plate at the rear.

This crude structure was intended for launching an ordinary 130lb. aircraft bomb, which was propelled from the trough by a specially designed launching rocket placed behind it.

The launching rocket had a "canister" nosing, which housed three sticks of smokeless propellant weighing 13lb. A long divergent exhaust nozzle emerged from the rocket chamber, and attached outside the mouth were three steel fins. A flat cap, fitted at the nose, was slotted to hold the fins of the bomb.

The rocket was fired by a percussion striker screwed into the base of the trough, which the launching crew operated remotely by means of a lanyard.

Although no degree of accuracy could be claimed for the Model 10 launcher, it was said to have been capable of projecting the 130lb. bomb for distances ranging from 770 yards at a minimum angle of 30 degrees to 1,300 yards at 50 degrees.

A 20 cm. Rocket Projector

It appears that the Japanese favoured the "trough" to the tubular launcher, and this is borne out by the discovery of several light rocket projectors at Leyte. (Fig. 64.)

These resembled "production" equipment far more closely than the Model 10, although they were still remarkably crude when compared with similar Allied weapons.

The launching trough, which was in three sections, was formed of 3/16in. iron. It was supported by four tubular legs, two at the front and two at the rear, and could be adjusted to permit ranges from 450 metres at 60 degrees, the elevation being checked on a simple scale fixed to the side of the trough.

The projector fired a 20 cm. rocket that resembled a long shell, having an almost constant section. Its explosive was contained conventionally within a ballistic-shaped head, and seven sticks of smokeless propellant were housed at the rear in a motor body which screwed on to the back of the explosive compartment. As with the German rocket shells, stability was achieved through axial rotation, caused by the offset thrust of six nozzles set at 25 degrees to the rocket axis. The percussion cap, which initiated combustion, was screwed into the centre of the baseplate and, as in the previous rocket, was detonated by a lanyard.

There appears to have been no protection from blast, and it is assumed that the launching crew were well clear when firing took place.

A 44.7 cm. Explosive Rocket

Large rocket shells were later discovered during the American drive on Manilla, and these were found to be to the same design as the 20 cm. projectile, though of 44.7 cm. calibre. The large rocket measured 5ft. 9in., of which over half comprised the explosive head. The propellant container was charged with 40 sticks of smokeless powder, and the complete projectile weighed approximately 1,800lb.

It was spin-stabilised, six offset holes again being responsible for the rotation.

Improved "Jap" Rocket Equipment

There appears little doubt that, towards the close of the war, the Japanese were producing highly effective rocket shells, in many ways superior to contemporary German and Allied missiles. They, nevertheless, failed hopelessly in the manufacture of a satisfactory launcher.

The light and compact "Bazooka" was by far the most decisive rocket weapon of the Far Eastern conflict, despite its small size. This was very largely due to the conditions of the fighting, which demanded little more in the way of field ordnance than the mortar and the close-range rocket.

A tube-launcher was found later by

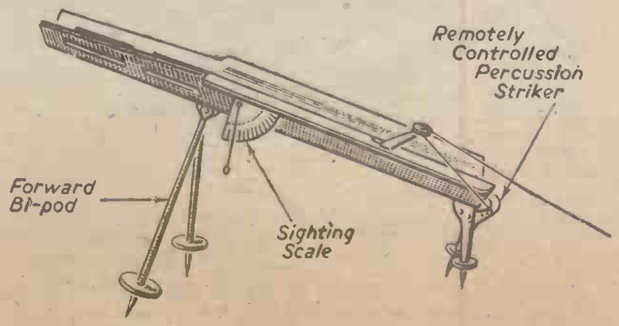


Fig. 64.—Several "trough" launchers of this type were found by American forces on Leyte. They fired 20 cm. explosive rockets.

American forces on Iwo Jima, and although somewhat cumbersome, it was an improvement.

The barrel, which had an overall length of 8ft., was assembled in two halves with a connecting collar, and was supported by two front legs and a rear base-plate. A simple catch was fitted at the rear of the open tube to prevent the projectile from slipping out of position once it had been inserted by the loader. The assembly was completed by a standard mortar sight.

The elevation scale indicated a minimum launching angle of 18 degrees, with a maximum of 65 degrees, and at full elevation the 20 cm. rocket had a range of 2,000 yards.

When stripped down into main components the tube-launcher—which, completely assembled, weighed 550lb.—could be transported by three mules.

Rocket-firing Tanks

When D-Day eventually arrived in Europe rockets were used in their thousands, and there is no doubt that in the development of field rockets the Allies had far surpassed the Germans.

Soon after the initial landings had been established the first rocket-firing vehicles began to make their appearance; lorries and cars had multiple projectors, and similar apparatus was mounted on light gun-carriages.

Last, and most formidable of all, were undoubtedly the rocket-firing tanks. These were used in the final assault upon the Reich fortress, firing explosive rockets in quick succession from multiple launching tubes.

Another launching arrangement, employed on Sherman tanks, was the aircraft rail-type projector. Two launchers were fitted, one either side of the tank, which fired the same 60lb. explosive rockets that were used on the Typhoon and Beaufighter.

Rocket-firing Aircraft

The first aircraft to fire rockets was the Russian Stormovik 1L2. Later, the two-seat Stormovik 1L3 and the Lagg 3, Mig-3 and Yak-1 single-seat fighters were similarly fitted.

It was these machines that figured prominently in the defeat of the Nazis at Stalingrad by their unremitting assaults upon tank columns. The rockets were housed under the wings on rail-type projectors and were fired electrically. They sped away at about 800 feet per second, and were proven capable of penetrating seven inches of armour plate.

A double-base propellant similar to cordite was used in airborne rockets, and this was generally in the form of several sticks inserted lengthwise into the propellant chamber. It was thus assured that a fairly constant area was exposed to combustion, with the result that initial velocities were high. The burning time was, at maximum, two seconds.

A German anti-tank projector resembling the " Bazooka " captured south of Caumont, July, 1944.

Air-to-air Rockets

Although the Germans did not place great importance in the rocket-firing aircraft for attacks upon land and sea targets they, nevertheless, produced several unique airborne launchers for firing explosive rockets into Allied bomber formations.

In May and June, 1943, the first fighters to be so equipped made their début. They included such established types as the Focke-Wulf 190, JU 88, Me. 109 and Me. 110, all of which had been specially modified for the purpose.

As the Allied formations swept closer to the Reich during the summer months the rocket attacks grew ever more vigorous and a situation developed which must have caused the air strategists no little concern.

The new Luftwaffe tactics enabled the launching aircraft to attack from beyond the 1,000 yards range of the .50in. machine-guns which were the bombers' main defence against normal fighter interception. The close-knit formations, which provided each machine with an effective coverage of fire under normal circumstances, were easy prey for well-aimed rockets.

The Luftwaffe achieved its greatest success during the Schweinfurt raid of October 14th, when 60 heavy bombers of the 8th U.S. Air Force failed to return to base. The Nazi fighters circled around the formations at high speed, laying their aim without interference whilst well out of range of the bombers' protective fire.

Whatever their method of evasion, the bombers were equally prone to destruction. Breaking formation or spreading widely were no solutions because lone bombers fell easy victims to fast-flying machine-gun and cannon firing fighters. Their pilots had no alternative but to maintain formation, hoping all the time that the range was too great for accuracy.

The days of the rocket launching fighter, however, were numbered. In both Britain and America fighters were being produced which were capable of escorting bombers all the way to and from their targets. In a large number of cases existing machines were modified, and high performance fighters began to appear which embodied stream-lined " overload" fuel tanks suspended from beneath their wings. This naturally added considerably to their endurance.

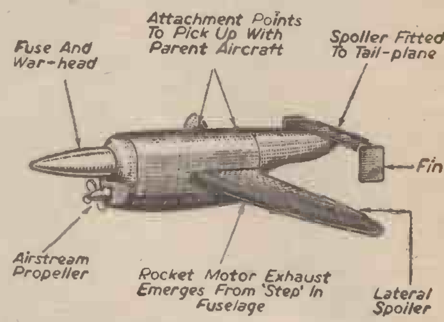


Fig. 65.—The Henschel 298—an experimental air-to-air weapon produced towards the close of hostilities.

The " overload " tanks were used before the internal tanks so that they were expended of fuel at as early a period in the flight as possible, whereupon they were jettisoned. Thus, as the formations approached the target area the escorts became fully combatant.

In later raids, it was the German fighters that took the greatest toll, and Allied bombers, ringed by numbers of protecting interceptors, returned to base almost unscathed.

Further Details of the Rocket-firing Aircraft

The single engine fighters, such as the Focke-Wulf 190 and the Messerschmidt 109, had single projector tubes, one beneath each wing. They fired 2.5in. rocket shells. Four to six wing launchers were fitted to the twin engine aircraft, and these fired the larger 6in. and 8in. shells. In a few instances, it was noted that some bi-motor

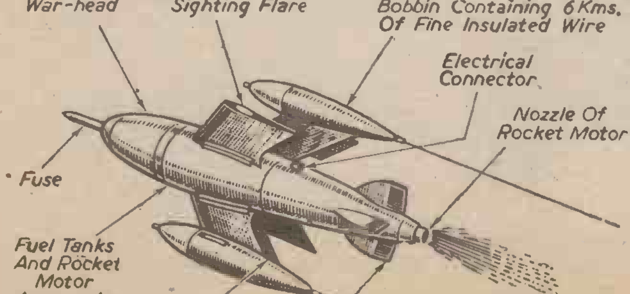


Fig. 66.—Another German project for air-to-air interception—the X-4

'planes had launchers mounted under the fuselage.

A number of the projectiles used on aircraft were the same or slightly modified versions of the explosive rockets used by the Wehrmacht. An example was the 6in. rocket shell used in the Nebelwerfer 41, (*Practical Mechanics*, April 1946, p. 255). This, it will be recalled, embodied the propellant in the rocket head, exhaust being made through a number of tangential nozzles in a conical centre-section. The after part of the projectile contained the explosive charge. The rocket had a length of 3ft. 6in., and weighed approximately 75lb. Its maximum range was in the region of 7,000 yards.

These rockets used a double base powder, similar to cordite, and in every case stability was caused by axial rotation.

The larger 8in. projectile was a development of the 21 cm. cannon shell, having a

Among the first British aircraft to be fitted for R.P. was this Hurricane Mk. II. C. Note the heavy " blast-plate " on the wing undersurface, and the two-rail launchers which were a feature of all early installations.

propellant container added behind the explosive charge. It had a range of approximately 9,000 yards, and weighed 200lb.

At the close of hostilities in Europe at least two new air-to-air weapons were in course of production. These were large missiles, entirely different from the earlier "rocket shells."

One type, the He. 298, resembled a small aeroplane, and the other, the X-4, was a finned rocket projectile. Both were to have been controlled remotely from parent aircraft.

The Henschel 298 (Fig. 65), stable companion to the He. 293 anti-shipping rocket glider, had a liquid fueled motor, and was guided to its target by radio. Its development was commenced early in 1944.

In order for it to be aimed easily, the missile was released from its parent aircraft at a height slightly more or slightly less than the target formation. It had an effective range of 1½ miles, and was exploded by a proximity fuse.

The He. 298 appeared as a mid-wing monoplane. Its fuselage was narrow and deep, and there was a "step" approximately two-thirds from the nose, from which the exhaust emerged clear of the tail. The wings were tapered towards the tips and had slight sweepback. A wooden tail-plane was attached high at the rear of the fuselage, at the ends of which were fitted square-cut fins of non-aerofoil section, projecting downwards. Control spoilers were provided on the wing tips and tail-plane.

A thin, conical warhead protruded forward from the top of the fuselage nosing, and a small air-stream propeller was fitted below as power for the electrical services. Two lugs were disposed about the centre of gravity for attachment to the parent aeroplane.

The missile had a wing span of 4ft. 2¾in, and a tail span of 21in. Its length was 6ft. 7in., and the fuselage had a width of 7½in. and a maximum depth of 16in. The all-up weight was 210lb.

The He. 298, along with a selection of other aerial weapons, was included in a display of German aeronautical developments on view to technicians at the R.A.E., Farnborough, last autumn. A large part of the exhibition was, earlier this year, removed to the Science Museum, South Kensington, to form the "Exhibition of German Aeronautical Developments."

The missile, shown in Fig. 65, was sketched at Farnborough, and observant readers who visited the Kensington exhibition will have noted that the tail-plane of the same exhibit appeared inverted, the horizontal stabiliser *below* the fuselage and the fins projecting *upwards* This was somewhat perplexing, and inquiries made at the exhibition brought no solution. As there is an obvious need for the tail to be high to clear the rocket exhaust, however, it is suggested that the missile shown there had been wrongly assembled.

Another air weapon in quantitive production at the time of the defeat was the X-4 (Fig. 66), perhaps the best example of an "aerial torpedo" that the war produced.

It embodied a well streamlined metal body, upon which were mounted four "wings" equally spaced around the circumference, about half-way along its length. A small cruciform tail-plane was attached at the rear. The nose of the missile contained a 110lb. warhead, which was detonated by a fuse

A striking contrast in cleanness of design is the " zero-length " launching installation which is now a Service fitment on the latest Hawker Tempests. In this system there is no " rail " : the rockets simply shoot off from the hook-retainers on which they are loaded.

in an 11in. extension, and the centre section housed a bi-fuel liquid propellant, which was fed to a single rocket motor at the extreme rear.

Perhaps the most unique point about the X-4 was that right up to the moment of detonation it was linked to the parent aircraft by two 0.22 mm. wires, which trailed out as the missile sped towards its target. The pilot of the controlling fighter was thus able to transmit electrical impulses direct to the missile: his signals worked electro-magnetic spoilers attached to each of the tail fins, permitting full longitudinal and lateral control.

Two bobbins, each capable of paying out fully six kms. of wire, were fitted to the tip of the lower port and upper starboard wings, and flares were attached to each of the remaining wings for sighting purposes.

The missile was carried by Focke-Wulf

Demonstrating the " Bazooka." The loader inserts a rocket into the rear of the projector tube held by the kneeling sergeant.

fighters on a modified version of the 70 kg. bomb rack. It had a top speed of 620 miles per hour.

Allied Rocket-firing Aircraft

In the summer of 1944 it was disclosed that four types of British aircraft had been modified to fire rockets. The Typhoon, Beaufighter, Hurricane and Swordfish were each fitted with eight launching rails, four beneath each wing, from which the same number of rockets were fired, either in pairs or as a complete salvo of eight. The launching aircraft experienced no recoil.

The projectile itself consisted of a heavy-gauge steel case, containing a charge of cordite sticks—it was stabilised by four small fins attached at the rear, and the warhead, which could be either high explosive or armour-piercing, was screwed on at the nose.

A number of American aircraft were later fitted for "R.P." (the Service abbreviation for "rocket-projectile"), among which the Thunderbolt, Lightning, Mustang, Tomahawk, Airocobra and Dauntless achieved outstanding success in the Far Eastern war theatre, notably in attacks upon Japanese shipping and troop concentrations.

The development of rocket launchers was carried out in Britain by the Projectile Department of the Ministry of Supply, and first tests were made with Hurricanes at the Aberdeen Proving Grounds, Scotland, during 1942.

In America the initial experiments were conducted at Wright Field, where, early in 1942, firing tests were made with a Curtis P.40, which had been fitted with two heavy-gauge steel projector tubes, one beneath each wing.

As might be expected, the early work was extremely hazardous, because of the ever-present danger of fire resulting from the rearward blast. This risk was minimised in early installations by the provision of a heavy steel "blast-plate" on the under-surface of the wing, local to the projectors. The precaution was dispensed with when improved, low-drag, launching rails and mountings were developed, which projected slightly deeper below the wing skin than previously. This was the British way.

The Americans overcame the difficulty by using tubular launchers extending to the trailing edge of the wing, which enclosed the blast and ejected it rearwards, clear of the structure.

The tubes, of which three were usually carried beneath each wing, were constructed of a special light-weight plastic, developed by technicians of the General Electric Company. They were 10ft. in length, having a bore of 4½in., with a wall thickness of ⅛in. Each unit of three weighed 450lb.

Weighing 40lb. apiece, the rockets employed with this launching system had an overall length of 3ft., and were a sliding fit in the launching tubes. They were spin stabilised by the reaction of the airstream on six small offset fins attached at the rear, which were collapsed when the rockets were inside the launcher. This calibre rocket shell, known as the M8, was credited with an effective range of 4,000 yards.

More recently American aircraft have begun to appear which embody "zero length" launchers, similar to those fitted to recent Hawker Tempests.

The principal advantage of the rocket projectile over the conventional light bomb for terrain and marine attack is the greatly increased *impact velocity*. Whereas a normal bomb will strike the objective at approximately the same speed as the attacking aircraft, the rocket-accelerated "bomb," because of its inherent power, will arrive at the target at a considerably improved velocity, and thereby obtain a greater penetration.

Another point of significance is the reduced liability to error in sighting. The combined action of gravity and forward motion result in the normal type bomb falling with a curved trajectory, while the rocket-driven projectile is able to maintain a highly accurate flight path, coinciding very nearly with the line of sight. The pilot dives his aircraft directly at the target with the aid of a normal type gunsight, looses his missiles, pulls up and over the objective and is quickly out of range of local defence. Meanwhile the rockets have struck, and, if aimed true, have dealt destruction out of all proportion to the explosive weight. The war-head of the British projectile, for instance, was only 60lb.

The effectiveness of the R.P. has been demonstrated over a wide range of uses during the war, but its possibilities have by no means been exhausted. The complete absence of recoil means that the sole limiting factor to projectile size is the aircraft carrying load, and, in consequence, it is not unreasonable to assume that, if need be, rocket-projectiles bearing explosive charges rated in several hundreds, perhaps thousands, of pounds could be developed.

(To be continued)

DEVELOPMENT OF THE GAS TURBINE

(Continued from page 271.)

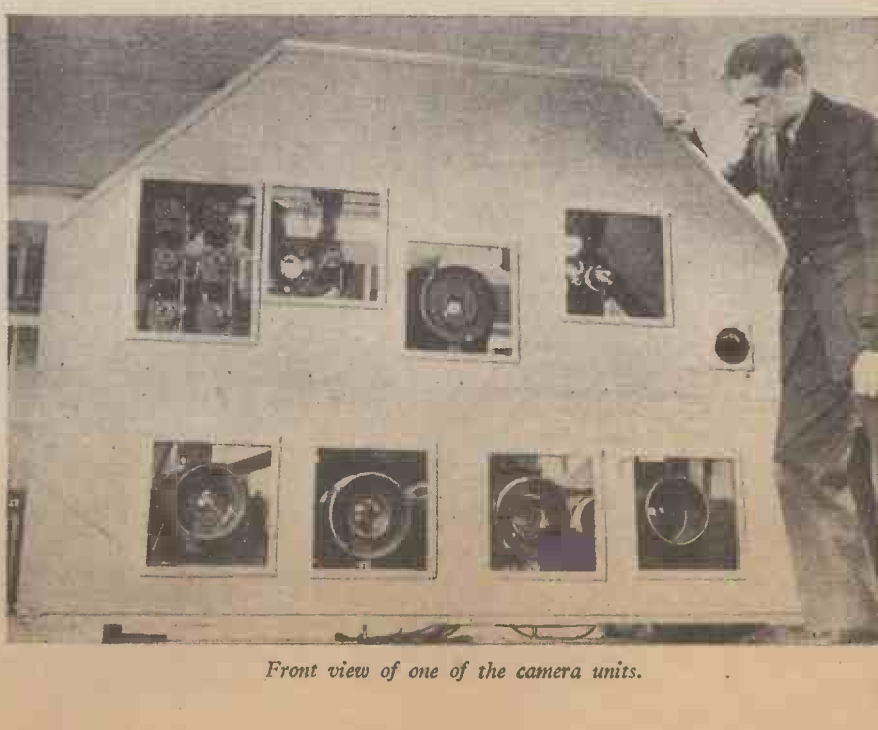
this type. As far back as May, 1944, the "Derwent" engine, subsequently known as the "Trent," was equipped with a spur reduction gear and tested for shaft horse-power. In March, 1945, it was hangar tested complete with airscrew, and in September, 1945, it was undergoing flight trials installed in the Gloster "Meteor."

The "Trent" was thus the first gas turbine engine with airscrew to be manufactured in the world, and the first to fly in any aeroplane. It may even at the present time be the only gas turbine-airscrew engine to have flown.

The Rolls-Royce "Trent" engine follows the general design of the "Derwent," with of course, the addition of the reduction gear through which the airscrew is driven. It is purely an experimental engine developed to gain experience with the jet/airscrew combination. The five-blade airscrew of small diameter will be noticed in the accompanying illustration, five blades being necessary to absorb the power. A smaller number of larger diameter blades could not be fitted on account of the low undercarriage of the Gloster "Meteor."

Cameras for Recording Atomic Bomb Blast

The accompanying illustration shows one of the camera units that will be used to photograph the blasts when atomic bombs are dropped on a "guinea-pig" fleet of warships at Bikini Atoll in the Pacific next month. The unit is made up of a number of cameras, all of which will be operated by remote control. The units will be set up on steel 100-foot towers ringing the warships, and controlled from a "magic box" by radio on a warship outside the danger zone. Cameras are left to right: (top), nest of six gun cameras; 35 mm. motion picture camera; F-56 8¼ inch Aerial camera; Mitchell 35 mm. motion picture camera. Bottom (left to right) row of cameras: F-56, 40-1 inch; F-56, 20-1 inch; F-56 20-1 inch and F-56 40-1 inch. The small circular opening at right is the "Magic Eye," which will operate all the cameras by the flash of the bomb itself should the radio remote control fail to work. The size of the unit can be gauged by comparison with the U.S. Lieutenant seen in the illustration.



Front view of one of the camera units.

The Helicopter of the Future

It is difficult to forecast how the helicopter will be developed during the next ten years, but it is certain that the essential features of controllability, safety and a high degree of efficiency which must be built into any aircraft to make it a commercial proposition are being carefully considered. The mass-produced, low-priced machine will only become available after a long and intensive development programme has been carried out by manufacturers in general, and it seems reasonable to suppose that industrial and commercial undertakings will absorb a large percentage of the helicopters produced in the next three or four years. Their requirements will probably be a general-purpose machine, capable of landing in very confined spaces, and enabling executive staff to be transported quickly and safely in any weather conditions for business purposes. The cruising speed will probably advance to around one hundred and twenty-five to one hundred and fifty miles per hour, and the maximum speed is expected to be approximately twenty to thirty miles per hour in excess of this speed.

Development will bring about fuel economy both in the reciprocating engined helicopter and the jet-driven types of machine. Controls must be simplified—the engine oil cooler shutters should be thermostatically controlled, and one single control column should govern the engine air intake, speed of the main rotor, the inclination of the rotor assembly from the horizontal, the pitch of the rotor blades and at the same time obtain automatic control of the anti-torque rotor. The rotor clutch control and free-wheeling device should also be incorporated in the single control column, and if possible the clutch should be automatically operated so that the lifting rotor revolves only after the engine has attained a predetermined number of revolutions and power output. Weight must be kept down to a minimum, but at the same time it will probably be necessary to provide general radio equipment, sound-proofed heated cabins, adjustable seats, rotor blade and windscreen de-icing equipment, and quickly-interchangeable landing gear so that a machine may alight on water, mud, snow, ice, sand or land.

Folding rotors should be an optional feature, as many private owners would possibly be deterred from purchasing a helicopter that required a large storage space. Incidentally, this must be accomplished in such a way that it is not necessary to have a Government A.I.D. inspector to pass the aircraft for flight each time the rotor blades are unfolded. Retractable landing gear may be provided, but the additional complication and expense hardly justifies the increase in speed and improved manœuvrability that would be attained. Jet-actuated helicopters will be developed, and it is expected that machines with rotors driven on the reaction principle, and a propulsive jet in the rear of the fuselage, will soon make an appearance.

When the helicopter eventually replaces the automobile, as it most surely will, an efficient and comprehensive service and spares organisation will be a deciding factor in the selling power of a machine. It will be imperative that spare parts are available quickly and easily, and repair personnel must be capable of flying and testing machines. Many products to-day have a limited appeal to the public in general through badly organised service departments, and it will not do to make helicopters available to large numbers of people until repair organisations are ready to deal with every eventuality at very short notice. It is the writer's belief that this is one of the main factors which will decide the success of a manufacturer's product. If it should be found to be possible to swing the main rotor to an approximately vertical plane, and be able to fly on it, the helicopter would become the fastest and safest aircraft in the world.

The autogiro, invented by Don Juan de la Cierva. This machine was the forerunner of the helicopter, but unlike the latter machine it cannot hover, as the rotor is not power-driven. Our illustration shows a "Direct Control" autogiro ready for a demonstration flight at the London Air Park, Hanworth, Middlesex, in April, 1933.

Stratosphere Rocket Tests

THE British Interplanetary Society have recently released details of a test rocket, to be followed by a 15ft. rocket intended to reach a height of 100 miles—nearly twice the height reached by a German V2.

It is planned that both rockets shall radio to earth reports of meteorological and other conditions encountered. Both are to descend to earth by parachute, and the reports will be submitted to scientific institutions. The duralumin test rocket, 6ft. 2in. tall, is to use kerosene instead of the alcohol fuel of the V2. Its target will be 60,000ft., but it will be fired merely to test construction and general design. Opportunity will be taken to try out the short-wave radio-reporting apparatus, which the designers are confident will withstand the initial "take-off." The cost of the first rocket will probably be only a few hundred pounds, but the full-size edition will cost about £15,000.

Sherman Tank Carried in a Bag

MANY strange devices to deceive the enemy were produced at the Camouflage Development and Training Centre during the war. One of the most successful was the mimic Sherman tank that can be inflated like a barrage balloon.

Twelve men and three trucks can, within half an hour, erect 360 tanks, carry them into position and draw the enemy fire from the real armament. When deflated these mock Shermans can be packed in a valise little larger than a cricket bag. They weigh only 170lb. against the 35 tons of the real article, and can be pumped up by a tiny and easily-carried petrol motor.

The dummy tanks were used with great success in the fighting in the Middle East, in Italy and in Germany, and were designed to deceive the enemy at a distance as short as 500 yards.

Our illustration shows how four men can easily place one of these dummy tanks into battle position.

Rocket Propulsion

Ground-to-air Rockets : American Guided Missiles

By K. W. GATLAND

(*Continued from page 278, May issue*)

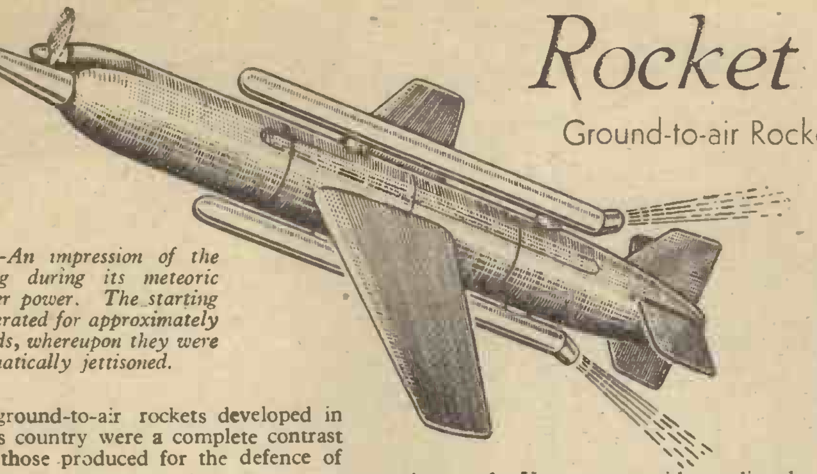


Fig. 68.—An impression of the Smetterling during its meteoric climb under power. The starting rockets operated for approximately four seconds, whereupon they were automatically jettisoned.

THE ground-to-air rockets developed in this country were a complete contrast to those produced for the defence of the Reich.

The British Z-batteries, which had their first large-scale demonstration in 1943 and were key weapons in the defence system evolved to combat the "flying-bomb," were the essence of simplicity. They comprised simply a rotational base platform on which were supported two adjustable launching rails, and each projector was operated by a crew of two, loader and firer.

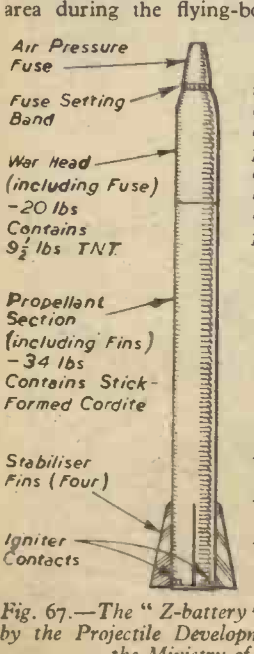
The Z-rockets, which were approximately 6ft. long and 4in. in diameter, burned stick-formed cordite, and were fired electrically. A 20lb. warhead comprised the nose section, and four small guide fins were fitted at the tail (Fig. 67).

Operation

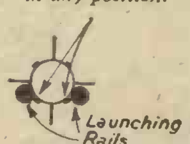
The projectiles having been loaded, the crew took up their positions, one on each side of the platform. The direction and elevation set, the firer then depressed the firing lever, and the missiles would streak away, perhaps climbing as high as 20,000ft. to reach their objective. The operators were protected against flame and blast by steel side screens, which were adequate cover from the rockets as they sped away from the rails above their heads. Reloading was generally a matter of a minute, or slightly less.

Although intended primarily as a barrage weapon, the Z-projector had provision for direct sighting against ground-straffing aircraft.

The Home Guard was largely responsible for manning the Z-batteries of the London area during the flying-bomb attacks, when numbers of V1s were either directly exploded in flight or sufficiently deflected by blast to crash harmlessly in open ground. In a multiple arrangement, with 48 projectors to a site, they encompassed the target with a veritable "minefield" of blast and shrapnel, from which few aircraft, piloted or otherwise, emerged unscathed.



The two lower brass igniter contacts are engaged by steel contact pins on the projector to complete electrical circuit for launching. The four contacts enabled the projectile to be fired in any position.



Total weight : 56lb.
Max. ceiling : 20,000ft.
Burning time : 4 secs.
Max. launching angle : 80 degs.

Fig. 67.—The "Z-battery" rocket. Produced by the Projectile Development Department of the Ministry of Supply.

The Germans, however, found no such simple solution. Actually, theirs was a more difficult problem owing to the high-flying "Fortress," among other high performance bombers, which were pressed into service at an early stage of the Allied bombing plan. Germany's defence clearly demanded something more than cordite rockets.

It was obvious that explosive missiles able to range to 40,000ft., perhaps more, would be needed, and needed quickly, if the devastating assaults on the crucial Rhineland areas were to be checked before German industry became an irreparable ruin.

To this end the production of three distinct classes of defensive weapons was set in hand, as follows: (a) high performance jet and rocket-propelled fighters, (b) air-to-air rocket firing aircraft, and (c) ground-to-air rocket missiles. All had an important place in an elaborate defence system to protect the Rhineland, and there appears little doubt that had it been possible for the Germans to bring this plan to early fruition the pages of history would have told a very different story. As it was, the scheme was still very incomplete at the time of the collapse.

The threat to industry and transport had become so acute as the result of the first few months' air battering that even aircraft firms and their design staffs were brought into the scheme to provide explosive missiles ; not only this, but factories that for years had been producing equipment for the army were switched to the manufacture of component parts.

Examples of the weapons produced by aircraft builders were the air-to-air missile Henschel 298 (described in the previous article), the Messerschmitt designed Eizian (Gentian), and the Schmetterling, which was made the responsibility of Junkers. All three embodied wings, and the Eizian, of which little information is available, appeared as a small version of the Me.163, with four motor units.

The three other principal ground-to-air weapons, however, would be more correctly termed "projectiles." The Rheintochter R1 (and later the R3, an improved version) was a massive rocket shell designed on the "step" principle, and the Wasserfall resembled a scaled-down version of the A4 long-range projectile. Finally, there was the manned projectile Bachem BP-20 Natter (Viper), which, like most of the other projects, was still undergoing experiment at the war's ending.

The Schmetterling

Designed by Professor Wagner, of Junkers, the Schmetterling (Fig. 68) was to have been homed to its target by radio. The Germans considered the accuracy of the missile to be such that one Allied bomber would have been destroyed by every one they released. It was obviously the key weapon of the scheme, and, as such, bore the ominous designation "V3." Its development was A1 priority, and at the time of the defeat the weapon was ready for quantitive production.

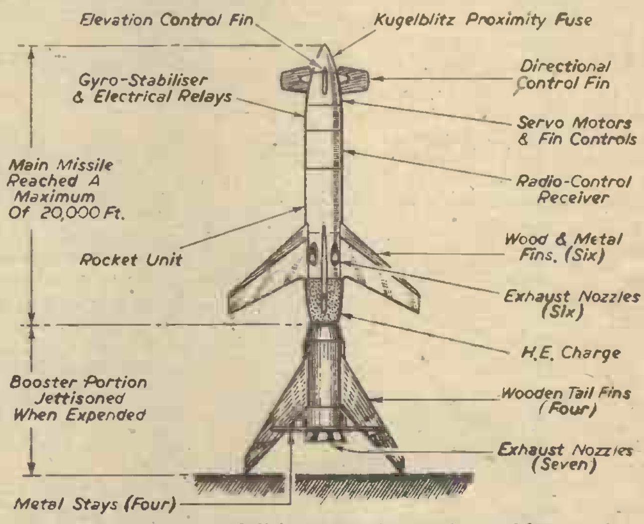


Fig. 69.—Part-sectional diagram showing the internal layout of the Rheintochter R.I.

The Schmetterling appeared as a small mid-wing aeroplane. It embodied a long cylindrical fuselage and a short-span wing attached approximately half-way along its length. A cruciform stabiliser unit was fitted at the tail-end.

The fuselage was assembled in sections, each section housing one of the main components, and, with a 55lb. warhead, which extended from the port side of the nosing, its overall length was 13ft. 1¼in. A small air-stream propeller was fitted at starboard as power for the electrical services.

In the section directly behind the warhead were a compressed air tank and radio. The second and third compartments contained propellant tanks, and the after-most section housed the control gear and main rocket motors. The latter could be either two 109-558 or two 109-729 bi-fuel units, employing 98 per cent. nitric acid with 57 per cent. m-xylidine plus 43 per cent. triethylamine, which gave a duration at full thrust of 33 seconds. This, incidentally, was also the propellant of the X-4 described in the previous article.

The method of wing construction was unique in that the structure was *cast* as a complete unit, including the main spar, trailing edge and six main ribs. There were also diagonal webs interlacing the ribs and a tubular member extended from the fuselage through the two innermost ribs as the main wing fixing. The structure was covered with a thin light-alloy skin, and spoilers were attached at the trailing edge near the tips for lateral control.

The tail unit was also cast and covered in the same manner as the wing.

The missile was launched by two dry-fuel rocket units, one attached above the fuselage and the other below. These rendered a high initial acceleration, and when their propellants became exhausted, within about four seconds, they automatically disengaged and dropped away.

The production model had a wing span of 6ft. 2in. and a tail span of 3ft. 3in. The all-up weight was 970lb., which was reduced to 55lb. after the A.T.O. rocket had been jettisoned.

The performance figures speak for themselves: ceiling, 50,000ft.; range, 20 miles with a maximum speed of 620 miles per hour.

The Rheintochter R1

Another interesting ground-to-air development was the Rheintochter R1 (Fig. 69), designed by Rheinmetall Borsig. A massive two-step rocket, weighing almost 1½ tons, it was intended to be directed to its target by two radar plots, one on the target bomber and the other on the projectile, correlated by a ground operator.

The R1 had a total length of 18ft. 10½in., of which approximately one-third comprised the second stage "booster" portion. The main missile measured 11ft. 10½in. and was 1ft. 8in. in diameter. It embodied six large fins having a total span of 8ft. 8in., which swept back 40in. from the leading edge. They had a root chord of 2ft. 8¾in. and a tip chord of 10in. Four controlling fins, linked to operate in opposed pairs, were fitted at the nosing, the top and bottom fins for directional flight and the lateral fins for elevation.

From nose to tail, the first stage comprised the following main components: proximity fuse, control fin motors, gyroscopes, radio directive gear, rocket unit (with six outward inclined exhaust venturis), and, finally, aft of the tail fins, a 50lb. charge of high explosive.

The "booster" unit was 4ft. 10½in. long and 22in. in diameter. Inside was a powerful dry-fuel rocket unit which exhausted from the rear through seven nozzles. Four fins were also fitted, having a total span of 7ft. 3in., a 2ft. 8½in. root chord and a tip chord of 12in.

The control fins and fixed stabilisers were of thin section and constructed largely of wood. A heavy gauge metal covering was embodied in the after surfaces of the six fins on the main missile.

It is of interest to note that the trailing edges of the two sets of stabilisers were not finished off sharply as is the case in normal aerofoil practice and on other missiles, but were cut square to thicknesses narrowing from 1½in. at the root to ⅜in at the tip. The controlling fins were similarly tapered from a root thickness of ½in. to ¼in. at the tip. This construction follows closely the theory of the Sänger super-sonic aerofoil (PRACTICAL MECHANICS, January, 1946, p. 134), in which, it will be recalled, the section is thin with a knife-like leading edge and the maximum thickness well aft. It is this type of section that has the greatest penetration at speeds in the region of sound, the reason being that the compressibility flow will always break away from the surface shortly behind the mid-section of the aerofoil, involving the trailing edge in pronounced rarefaction.

The Rheintochter R1 was launched from an inclined ramp, the second stage "booster" being used for initial propulsion. This became expended of fuel at an approximate height of two kilometres, whereupon it was automatically jettisoned. At this

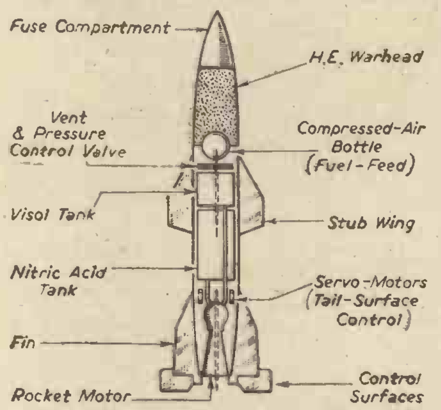


Fig. 70.—The Wasserfall. This part-sectional diagram gives some idea of the layout of the main components.

juncture, the main portion of the missile would further accelerate under its independent power to reach a maximum speed of approximately 1,000 miles per hour.

Despite its majestic appearance, the projectile had an effective ceiling of only 20,000ft. It employed dry-fuel in both stages—diglycoldinitrate—but in an effort to improve the range the R3 version had a liquid bi-fuel unit in the main missile.

The Wasserfall

An offshoot of the A-1/A-10 projectile development programme at Peenemunde, the Wasserfall (Fig. 70) clearly resembled the V2. It was, of course, smaller, having a length of 24ft. and a maximum diameter of 3ft., but nevertheless appeared enormous as an A.A. rocket. Its fully loaded weight was in the region of 3½ tons. There were also four short-span wings attached about halfway between the nose and tail, and, as with the V-rocket, four air-stream fins with controllable tail surfaces were fitted at the rear as well as movable graphite vanes in the jet. In first experimental models, these control aerofoils were operated by a Siemens K.12 automatic gyro-pilot.

Propulsion of the Wasserfall was by the reaction of visol and nitric acid, which fed into a single combustion chamber mounted in the tail.

Less than 50 of these missiles were fired in free-flight, and of these only 12 were successful. Needless to say, they were not used in action.

A scale model of the missile was on view at the British Museum, South Kensington, during the "Exhibition of German Aeronautical Developments" held there earlier this year.

The model in question, which was stated to be a quarter the size of the actual weapon, had apparently been hurriedly disposed of in the local pond at Nordhausen at the time of the surrender. It was found when the area was later investigated by the Allies, and still bore traces of dried mud on its green painted surface.

U.S. Guided Missiles

It is perhaps not widely known in this country that several types of guided missiles were produced in America. The majority of these were to original designs, and at least one was proved to be superior in general performance to its best German counterpart.

The design of these ground-to-air, air-to-air, air-to-ship weapons was put into the hands of a Government establishment known as the Naval Aircraft Modification Unit's Pilotless a/c Division.

The entire development was carried out by this Division, including the research and testing of rocket propulsors, intermittent and turbo-jet power plants, radio-control, target-seeking and telemetering devices. A number of the missiles incorporated television "eyes" which enabled the controller on the ground or in the parent aircraft to view the progress of his charge on a television screen and to guide it into the target by radio-control. The Germans were definitely far behind the Americans in matters of radio-control and target-seeking, though they were obviously more advanced in rocket technique.

A particularly interesting rocket missile was "Little Joe" (Fig. 71), a radio-guided anti-aircraft weapon which could be launched

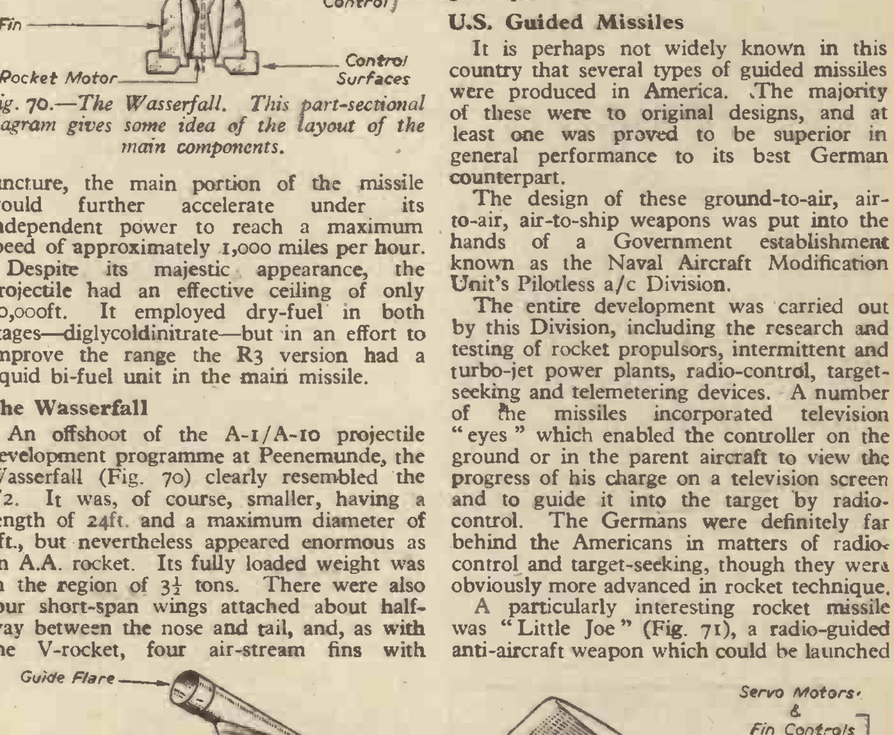


Fig. 71.—"Little Joe." Not the prettiest of aerial weapons, but one that did much to counter the Japanese "Baka" suicide 'plane.

either from the surface or the air. It was originally designed to combat the Japanese "Baka" suicide 'plane, and was powered by four main rocket charges and one 1,000lb. thrust Jato starting unit.

"Little Joe" was an ungainly weapon, and one of the first guided missiles that America produced. Four square-cut stabilisers were attached at the rear, two of which had controllable aerofoils, and four smaller fins were fitted around the nosing in a similar fashion to the arrangement on the Rheintochter R1. The main rocket units were equally spaced around the tail-fins, and the one Jato rocket was housed within the after section of the projectile body, the nozzle emerging from the rear.

The missile incorporated a 100lb. war-head, which was detonated by a proximity fuse.

Radio-guided Winged Missiles

Equipped with television and radio-controlled, the rocket powered "Gorgon" KAZN-1 (Fig. 72) was fired from the surface against flying targets, from the air to surface targets, and from air-to-air.

In terms of aeronautical practice, its design was unorthodox in that the horizontal stabiliser was situated at the nose, the main plane at the rear. The vertical stabiliser extended equally above and below the rear fuselage.

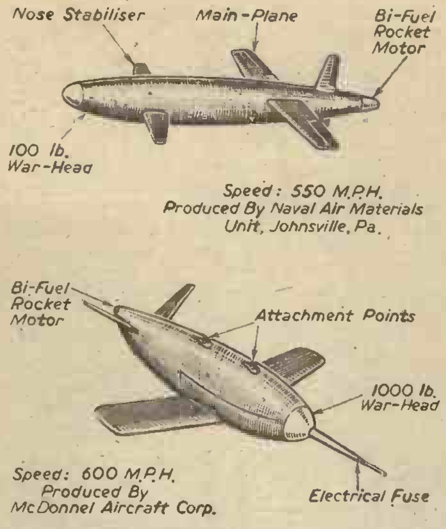


Fig. 72.—The Gorgon (above) and the Gargoyle below); two examples of American winged missile development.

The fuselage was 16ft. in length and nicely streamlined, the wings tapered and 11ft. in span. Wood was used throughout in its construction, including the laminar flow wings, which were to standard design and interchangeable with other missiles.

The power unit was patterned on the German bi-fuel acid-aniline rocket engines, which propelled the "Gorgon" at a maximum speed approaching 700 miles per hour.

Another missile in this class was the "Gargoyle" (Fig. 72), a miniature low-wing monoplane with a heavily dihedraled tail plane which served the dual purpose of vertical and horizontal stabilisers. It sped towards its target at approximately 650 miles per hour under power from a single bi-fuel rocket unit, a flare in the tail assisting in its sighting. Like the majority of other missiles, it was guided remotely by a radio control unit, either from the ground or from the air. *(To be continued)*

The Design of Induction Motors

Brief Notes Forming a Useful Guide

By H. SPARKE

When designing an induction motor to satisfy the requirements of any given set of conditions, it is generally very useful to obtain an approximate idea of its probable principal dimensions.

Particulars of the supply, such as voltage, frequency and number of phases must be known, and also the B.H.P. and speed of the motor, to suit the individual case.

Number of Poles

The relationship between the number of poles, synchronous speed and the frequency is given by the formula :

$$p = \frac{120\sim}{n}$$

where

$\sim$ is the frequency.
n is the r.p.m.
p is the number of poles.

No. of Poles	Synchr. Speed	Actual Speed
2	3,000	2,900
4	1,500	1,440
6	1,000	970
8	750	725
10	600	580

The actual speed is always slightly less than synchronous speed, between 2 and 5 per cent.

Size of Rotor

Assuming that 2 per cent. of the gross power will be wasted in heat in the rotor, for every kilowatt of power there will be 20 watts wasted in the rotor, so that there will have to be 20 sq. in. of rotor surface per kilowatt of power, or 15 sq. in. per horse-power. This condition is slightly better in large motors, and slightly worse in smaller machines.

The working surface of the rotor is π DL, where D is the diameter and L is the gross length of the core.

Therefore, $\frac{\pi DL}{H.P.} = 15$ and DL = 4.77 H.P., or, in other words, the product of length and diameter of core must be approximately five times the horse-power.

The relative values of L and D are determined after next considering the speed. Where the r.p.m. required from the motor is not known the following formula may be used :

$$D = 220\sqrt{\frac{H.P.}{V}}$$

This gives a good value for D in inches where V is the permissible peripheral velocity in ft./min. In deciding the value of V, 4,000 ft./min. is a safe value for motors up to 50 h.p. and as the diameter increases the peripheral speed can be increased to double this value for large diameter rotors.

If, however, the r.p.m. is known, by virtue of the number of poles and frequency of supply, the diameter is therefore dependent upon the surface speed. Dividing this surface speed by the r.p.m., we arrive at the length round the periphery, after which dividing by π the resulting diameter is arrived at in inches.

When arriving at the bore of the stator core it is vital to keep the air gap as small as possible, .04in. is sufficient and 1/16in. in a machine of 50 h.p.

Windings

Before an appropriate winding is finally arrived at, the voltage must be considered. The simplest method is to apply dynamo principles, and to fix the number of conductors in series in terms of their lengths and speed and strength of the field they cut.

When a three-phase winding is connected in delta, the voltage across the windings of one phase will be line voltage, but if star connected will be .58 of the line voltage. There is a positive advantage in star connection, as in the case of the stator, by so doing it is possible to use a thicker wire with fewer turns than would be possible with delta connection.

Consequently, not only is the room taken up by insulation less, but the winding labour is reduced.

Current

The voltage of supply being fixed, the method of grouping fixes the voltage on each of the phases separately. Knowing this and also the total watts supplied, and assuming a probable power factor cos ϕ, a value for c, the current in each branch can be approximated

$$w = \sqrt{3}\, v\, c \cos\phi$$

$$c = \frac{w}{\sqrt{3}\, v \cos\phi}$$

Efficiency

For a 5 h.p. machine w will be equal to 5 × 746 = 3,730, but assuming a full load efficiency of 88 per cent. the watts to be supplied will have to be 4,238 in order to yield 5 h.p. The duties of the stator are to carry the current to provide in each of the three phases a B.E.M.F. equal to the supply voltage.

Stator Conductors

The calculation of stator conductors is carried out by use of the formula :

$$(V_1 - V_2) \times 10^8 = q\, B\, \lambda v_1$$

where

V_1 = voltage across each phase.
V_2 = volts lost in resistance of stator conductors.
q = breadth coefficient.
B = flux density.
λ = total length of conductor in cms.
v_1 = linear periphery speed (synchronous) in cms./sec.

Lost volts may be taken as 5 per cent. for small machines.

Rotor Conductors

Considering the ironwork of the rotor, the total length of laminated iron parallel to the shaft is the same as the stator, and the clearance between the two having been settled as small as possible, where the number of poles are numerous the centre portion of the laminated discs are inoperative. This allows for the laminated portion of the rotor to be constructed as a ring mounted upon a spider. The number of rotor conductors should be different to the number of slots on the stator, so that there is no tendency at starting or at any speed below synchronous for the motor to cog magnetically.

The greater the cross section of the rotor conductors the greater will be the efficiency of the rotor, provided sufficient iron space is also allowed. There is nothing to be gained by making the total cross section greater than the total cross section of the stator, and in practice is a little less.

These conductors are of solid copper, and only lightly insulated, and can be put into much less space than the stator conductors, and for this reason the rotor slots are generally smaller than one half of those in the stator

Rocket Propulsion

Anti-shipping Missiles : the "Baka" Suicide 'Plane : German Aircraft Developments

By K. W. GATLAND

(Continued from page 320, June issue)

Fig. 73.—The "Bat." This was the first and only missile of the war to incorporate a radar "self-directing" scanner.

ALTHOUGH it must be admitted that many of America's guided missiles were based on German research, the Germans by no means had the monopoly of ideas in this development.

The "Bat" (Fig. 73), one of the rocket powered missiles, produced in quantity and used effectively against Japanese shipping, was actually *self-directing*. It had the appearance of a miniature high-wing monoplane, and contained within its blunt nosing a radar target-seeking device against which evasive action by the enemy was useless.

The aircraft chosen to operate the missile was the Naval PB4Y-2 Privateer, and priority modification was set in hand at Consolidated Aircraft to provide two special carriers, one beneath each wing.

A large number of Privateers equipped with "Bats" were ready before the final overthrow of Japan, and no time was lost in using them in action. The missiles were released, one at a time, from well outside the range of defensive fire, and were presumably directed to the vicinity of the target by radio-control. Instead, however, of depending upon the remote controller for final delivery, the "Bat" was able to search out its own target and to guide itself directly in to the vessel its sensitive radar "eye" had first located.

This 12ft. long missile was responsible for sinking many thousands of tons of shipping, being the only weapon of the war to be fitted with the radar-scanner "brain."

The Henschel 293

It was, of course, the Germans who first demonstrated the anti-shipping "glide-bomb." Their most successful missile in this class was undoubtedly the Henschel 293 (Fig. 74); it was, in fact, the first of all aerial missiles, being initially used against Allied shipping in the Bay of Biscay during the autumn of 1942. It later appeared in the Mediterranean, particularly near Anzio.

Certainly, the Hs. 293 was a unique weapon, coming as it did before the era of the "V" developments. In it were combined for the first time in any warcraft a bi-fuel rocket unit and a radio-controlling gear, the latter being operated by the crew of a parent aircraft.

The controlling aeroplane, usually a Dornier 217, remained out of range of defending fire, yet at a distance that permitted direct sighting of the target. A flare was fitted at the tail of the missile to assist the controller. Designed by Prof. H. Wagner, of Junkers, the Hs. 293 was about the same size as the American "Bat," 11ft. 8in. long and 9ft. 6in. in span. It had the appearance of a small mid-wing monoplane, with the tail-plane high on the rear fuselage and a single fin extending forwards along the centre-line.

A detonator projected from the nose, behind which was the 1,120lb. war-head. The radio directive gear was contained in the centre section, with the gyroscope, power generators and batteries at the rear. The propulsion unit was housed complete in an underslung nacelle.

The weapon weighed 1,730lb. when fully charged with 1,120lb. of propellant. It had a controlled range of 5½ miles and flew at a maximum speed of 375 m.p.h.

Propulsion was by the reaction of H_2O_2 and calcium or sodium permanganate in a modified version of the Walter 109-500 assisted take-off motor. In this system hydrogen peroxide and an aqueous solution of the permanganate are injected under pressure from air bottles into a single reaction chamber. The catalytic action of the permanganate decomposes the H_2O_2 to steam and oxygen at 480 to 500 degrees Centigrade, yielding an average thrust of 1,500lb. for twelve seconds.

There was also an alternative motor which burned gaseous oxygen and methonal.

The missiles scored a certain initial success until a satisfactory antidote was found in the development of a radio device for jamming the controlling signals.

Another Henschel development was the Hs. 294, an air-launched missile which entered the sea at approximately 275 m.p.h., to explode below the surface. It was guided to hit the water at 100 to 130ft. from the target vessel, shed its wings and motor, and penetrated beneath the ship, being detonated by a proximity fuse.

The "Baka" Suicide 'Plane

The "Baka" or Kamikaze 'planes were the Mikado's last desperate challenge to Allied sea-power in the Far Eastern waters. They were initially operated from the island of Okinawa against shipping in the Ryukya area, and several were found intact when the island was subsequently taken by U.S. forces.

A remarkably small 'plane to be piloted, the "Baka" was only 19ft. 10in. long. Its low aspect ratio wings were 16ft. 5in. in span, and the tail span 7ft. 1in.

The fuselage was well streamlined, and the pilot was accommodated about two-thirds from the nose. His cockpit embodied a clear-view hood, which appeared large in comparison with the rest of the machine, of all-metal construction, the body structure having a covering of thin gauge light alloy. In the nosing was a 1,200lb. charge of tri-nitro-anisol explosive, and behind the pilot three dry-fuel rocket units, which propelled the "Baka" in its final "death-dive" at a maximum speed of

This "Baka" 'plane was found on Yontan airfield, Okinawa. Its capture may have saved an Allied warship—certainly the life of a Jap.

630 miles per hour. Each unit weighed approximately 260lb., of which 97lb. comprised fuel and fired for about eight seconds. The maximum thrust developed by each propulsor was 1,760lb., and the jet velocity, therefore, a little more than 4,700ft. per second.

The all-wood, ply-covered wings were placed mid-depth of the fuselage, forward of the cabin, and the tail-plane was set high at the extreme rear, with square fins at the tips.

The "Baka" was equipped with a liberal array of instruments, comprising an air-speed indicator (served by a pitôt head, which protruded from the port wing), altimeter, compass, fore and aft level indicator, rocket ignition selector and ignition buttons, circuit test switch, and a base fuse arming handle.

The pilot was supplied with oxygen during his brief flight, and protection was afforded by two 5-16in. armour panels, one on the floor of the cockpit and the other at his back. Normal "stick" and foot controls worked the ailerons, elevators, and fin rudders.

It was a surprisingly well-built aeroplane considering the short period of its operation, and had a high-gloss finish. The colouring was dark green on the upper surfaces, light grey beneath.

The Betty 2-2, a development of the Betty 1-1, was the aircraft initially used to parent the "Baka." The standard version of this two-engined medium bomber was able to carry two torpedoes in lieu of bombs. It was powered by two Mitsubishi Kasei 21 air-cooled radials, each capable of 1,800 h.p. at sea-level, which gave the machine a top speed of about 330 m.p.h. and a maximum range of 2,700 miles. These figures naturally suffered slight reduction when the "Baka" was carried.

A special carrier was installed below the fuselage near the c.g. of the aircraft, which held the 'plane snugly above the depth of the lowered undercarriage, permitting normal take-off. The undercarriage and all services were fully operable, as also was the protective armament, three 7.7 mm. machine-guns and two 20 mm. cannon.

The cockpit projected into the bomb-bay, and the twin fins and rudders fitted alongside the bomber's fuselage. The Betty 2-2 was particularly ideal for the job, as bomb-bay doors were not normally fitted. Another bi-motor aircraft, the Peggy, was reported to be operating the "Baka" during the later stages of the war.

The Kamikaze Corps

The fanatics who kept the "Baka" 'planes hammering away at Allied carriers and capital ships from the early summer of 1944 were, of course, inspired to the "supreme sacrifice" by their peculiar religious cult. The Japanese had grown up to the philosophy that to commit suicide was to be assured of a place among the gods. Even their nursery stories reflected the apothesis: "The Forty Knights of Ronin" tells of a band of knights who set out to avenge the death of their leader, and, each having accomplished his particular deed of valour, rounded off the episode by committing "hari-kari" with the sanctified sword.

Large numbers of their warriors during the war died self-inflicted deaths rather than suffer the "disgrace" of capture; similarly, it was not uncommon for pilots of orthodox fighters to dive their 'planes headlong into Allied bombers in preference to returning unsuccessful.

The men of the Kamikaze Corps went to their deaths as a well-trained unit. Their initiation involved months of calm instruction in the handling of gliders, and they eventually flew in specially built "Baka" trainers which landed on skids. Few of the pilots were more than 20; the majority ended their lives at an earlier age, and there appears to have been no lack of volunteers.

Having completed their training and before being assigned to their missions, the pilots, their heads shaven, were consecrated in a priestly ceremony. This involved a kind of religious carnival in which the people joined, honouring their heroes with flowers as pilots and priests paraded through the streets of Tokyo.

Eventually the fateful day arrived, and, locked within their separate cockpits, with the emblem of their unit painted boldly on the nosings of their machines—a cherry blossom, for instance, was the insignia of the Cherry Blossom Unit—the pilots were airborne on their last flight.

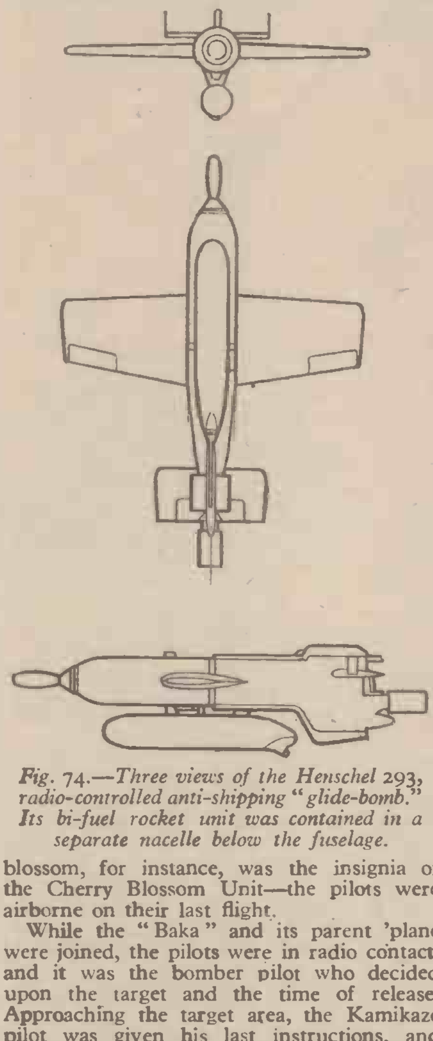


Fig. 74.—Three views of the Henschel 293, radio-controlled anti-shipping "glide-bomb." Its bi-fuel rocket unit was contained in a separate nacelle below the fuselage.

While the "Baka" and its parent 'plane were joined, the pilots were in radio contact, and it was the bomber pilot who decided upon the target and the time of release. Approaching the target area, the Kamikaze pilot was given his last instructions, and the 'plane cast loose from about 10,000ft.

The pilot did not use his rockets immediately, but glided in to his objective, bringing them into operation one at a time to increase speed for the final assault; then, weaving and diving to evade defensive "flak," he plunged headlong to his death.

Although the damage inflicted by suicide attacks was not as great as one might have expected, it is nevertheless true that a number of the "Baka" pilots succeeded in exploding their tiny aircraft on the decks of warships. The great majority, however, were either shot out of the air by the barrage of defensive fire or made to miss their targets completely, crashing harmlessly into the sea.

Whatever the outcome of the attack, the fate of the pilot was certain; the "Baka's" delicate fuses detonated on the water as easily as against the steel of a warship.

German Aircraft Developments

The turn of the air war in favour of the Allies brought an ending to heavy bomber production in Germany, and the entire industry was switched to the production of high-speed single and twin-engined interceptors. Only when the practicability of jet-propulsion was demonstrated did work again proceed with "heavies," and even then development was restricted to one or two firms. These aircraft were to have been operated from great heights, and in order to achieve bombing accuracy provision had been made in the original designs for guided missiles to be carried. The first of these new types to reach the prototype stage was the Junkers 287. This machine was said to have a range of 1,000 miles with a bomb load of 4 tons and a top speed in the region of 550 miles per hour.

Fighter Production

The production of fighters proceeded along the three distinct paths of power-plant development, (a) the conventional internal combustion engine, (b) the jet-propulsion unit, and (c) the bi-fuel rocket propulsor.

The most prominent in class (a) were, of course, the veteran Messerschmitt 109 and the Focke Wulf 190. At least three newer propeller fighters were in course of production.

In the jet-propulsion class were the Messerschmitt 262—the first jet machine to be used operationally—the Heinkel 162 or Volksjaeger (People's Fighter), the Arado 234, and a unique tail-less fighter designed by the Horton Brothers. A number of other jet interceptors were in project stage, while many prototypes of more advanced designs were still incomplete at the time of the surrender. Of particular interest is the fact that two of these projects were purely research aircraft intended to test various aerofoil sections and wing plan-forms at speeds in the region of $M = 1$. One of the research machines was designed for the fitment of alternate wings of 0 deg., 25 deg. and 35 deg. sweepback, and with these it was hoped to determine a degree of sweep-back optimum for flight both at high and low speeds. The other was to have been a twin-boom aircraft with the space between the booms utilised to test high-speed wing profiles.

Compressor-less Jet Interceptors

Another machine in class (b) was one projected by Lippish—undoubtedly the most unorthodox jet aircraft that has yet undergone serious investigation. A flying-wing in the very essence of the word, its design was based on the phenomenal top speed of 1,500 m.p.h., "g" effects being reduced by the pilot occupying a prone position. The wings were swept back sharply, the air to be taken in through a duct in the nosing.

It was intended to accelerate the 'plane into flight with dry-fuel rockets, and compression of the air was to have been entirely due to the ram effect of the high speed and not the result of rotary compressors. There was, of course, no turbine, and whereas most jet systems employ a liquid hydrocarbon to raise the air temperature, this was to have been accomplished in the Lippish machine by the use of carbon blocks, pre-heated to incandescence and rapidly loaded into the expansion chamber just prior to flight. The A.T.O. rockets having imparted the initial speed, the high velocity air-draught would ensure that the heat of the carbon was maintained in much the same way as bellows inflame a fire. The air was thereafter heated by the glowing carbons and the effluent ejected from the rear through a long, narrow slit in the trailing edge.

This system was said to be capable of maintaining a useful thrust for three-quarters of an hour, and in the closing months of the war the German technicians had suc-

A corner of a hangar at the Yokosuka Naval Air Station, Japan, where the Kamikaze pilots underwent their training. The machines in this picture are all trainer versions of the notorious "Baka," having ballast in place of H.E., and fitted with landing skids.

ceeded in the development of an improved motor in which the effective life of the heating substance had been almost doubled, simply by incorporating liquid fuel sprays above the carbons. The fuel tank was to be built within the single vertical fin.

Other compressor-less jet projects were fighters to be powered by liquid-fuelled propulsive ducts, including a high-speed helicoptor of unorthodox layout, which was to embody a duct unit in each tip of its three rotors.

All jet systems which depend upon induced ram pressure and are not resonant operating (e.g., as the Argus Rohr 014, propulsion unit of the "V1") are termed "athodyd"—the abbreviation of "aero-thermodynamical-duct." The simplest of all thermodynamic engines, the working portion is simply a venturi-shaped tube, having no moving parts and fitted solely with fuel burners and means of ignition. The duct contour is, of course, based on the performance desired of the motor.

Operation of the Athodyd

When the duct moves forward under the thrust of assisting rockets, air commences to ram into the intake at high pressure. The fuel burners, placed about a third from the intake, heat and expand the air, and the resultant high velocity gases are ejected from the rear as the reactive jet.

The greater the speed of the athodyd, the higher is its efficiency. Its possibilities for operating aircraft at sonic and supersonic speeds are enormous, and small test units have already been operated in America within these speed ranges.

In aircraft, however, its use will always be in conjunction with an auxiliary motor, and an integral rocket unit has already been tried by the Germans and found highly effective. A simple athodyd unit was employed with the rocket motor placed in the mouth of the duct, and it was found that a 50 per cent. increase in thrust was registered without actual burning of the fuel in the duct. This was largely cancelled, however, by the increased drag.

The rocket and duct combined were then tested for maximum thrust conditions, and the duct only for cruise purposes. This brought about a 100 per cent. increase in the cruising endurance over that of the bi-fuel rocket motor used in the Me. 163, and it was, in fact, proposed to replace the cruising unit on rocket powered fighters by a composite motor of this type. The development, however, arrived too late for operational use.

(To be continued)

Notes and News

Gun-fire Control

NOW that peace prevails, naturally we do not expect so many war inventions to be contrived. But military devices are not absolutely in short supply. Here is one relating to machines and particularly to gun-fire controlling mechanism.

The inventor points out that in the case of machine-guns mounted on aircraft, economy in the use of ammunition is desirable in view of the difficulty of carrying great quantities on aeroplanes. This is especially so when machine-guns of large calibre fire, for example, explosive shells. It is therefore sometimes desirable to employ short bursts of fire. But, owing to the rapidity of the fire of modern machine-guns, the number of rounds fired should be limited. This is not possible without some means for stopping the fire after the desired number of rounds have been fired.

The new invention has for its principal object the provision of mechanism for limiting to any desired value the number of rounds fired upon one continued depression of the firing button or trigger.

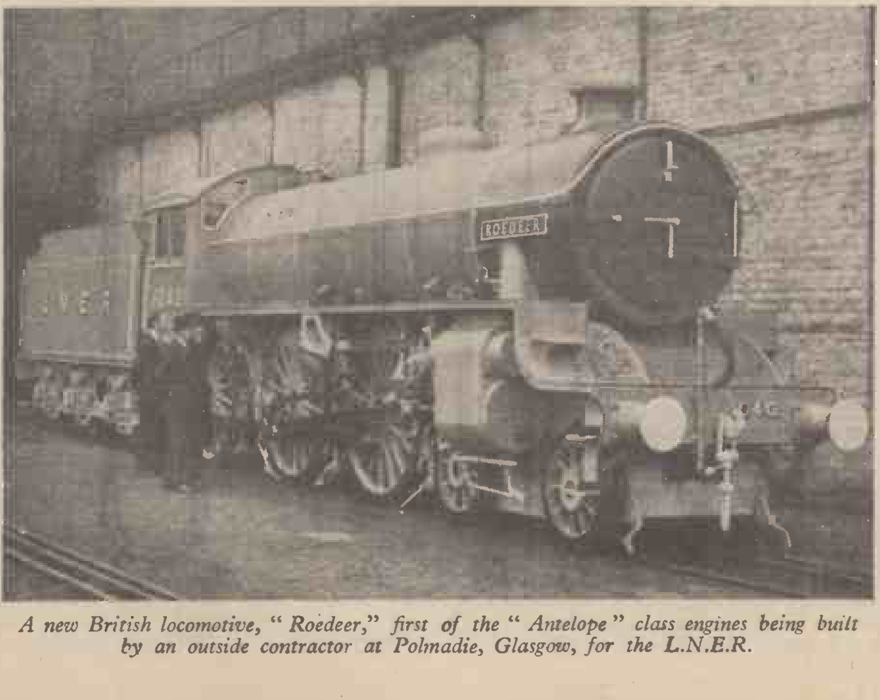
The device comprises electro-magnetic or electro-dynamic means for effecting directly, or through a relay, withdrawal of the gun sear, and an energising circuit for the electro-magnetic or electro-dynamic means, including a normally open firing switch, arranged to be closed by depression of the firing button. And there is a normally closed control switch arranged to be opened by a control member, when the latter has been moved forward a predetermined number of slips. This corresponds to the rounds fired by mechanism operated by the recoil of the gun or by the movement of a gun component during the firing cycle.

New High-speed Wind-tunnel

WITHOUT the modern wind-tunnel the task of the test pilot would be much more complicated and dangerous. At the Royal Aircraft Establishment at Farnborough, the new high-speed wind-tunnel is proving invaluable in testing aircraft models and component parts in varying atmospheric and wind conditions similar to those that might be experienced in any part of the world.

Work on the wind-tunnel was commenced in 1938, and over 1,000 tons of steel were used in its construction. The tunnel is 130ft. long and has a diameter of 37ft., while its 4,000-h.p. fan can produce a wind velocity of over 600 m.p.h. During tests a great heat is generated, and a brine circulation plant is used for cooling the shell of the wind-tunnel.

Full-size aircraft are not tested in the tunnel, but it is possible to use quarter-size models for making a close study of the characteristics of the airflow in relation to the aircraft's fuselage, nacelles, and controls.



A new British locomotive, "Roedeer," first of the "Antelope" class engines being built by an outside contractor at Polmadie, Glasgow, for the L.N.E.R.

Rocket Propulsion

Rocket-powered Interceptors : Early Walter Bi-fuel Engines

By K. W. GATLAND

(*Continued from page 347, July issue.*)

The Ju. 8-263. This was a Messerschmitt project turned over to Junkers for development and manufacture : prototypes only were produced, the surrender bringing a halt to further work.

THE autumn of 1944 saw another type of interceptor in action with the Luftwaffe, rocket powered and possessing phenomenal climbing ability. This was the Messerschmitt 163B, a tailless fighter which, including the time involved in take-off, took less than four minutes to reach a height of 40,000 feet.

Its outstanding performance under climb, however, was badly offset by a poor endurance. The period of flight under power at full throttle was little more than four minutes, and although it was possible to extend the actual flight duration by alternate bursts of power and gliding, the machine could not stay in the air for much longer than half an hour.

The fact that the Me.163B had a rate of climb seven or eight times greater than the best Allied fighters was no guarantee of its success. Its limited endurance did not permit sufficient time to make an effective interception, and certainly, once having flashed past the level of the bomber formations, there was little chance of challenging the target again. The aim, nevertheless, was to shoot up the formations during the almost vertical climb and, if fuel permitted, to circle above the bombers and attempt a second interception during a dive.

The tailless aeroplane pioneer, Dr. Alexander Lippish, is credited with the design of the Me.163, of which there were four versions : (a) trainer, 163A ; (b) fighter—operational, 163B/O ; (c) fighter—operational improved, 163B/1 ; and (d) fighter—development, 163C.

The machines of the 163 series were the first step in fighter design toward the ideal all-wing layout, and apart from the fact that each sub-type employed a slightly different power unit, the addition of a separate "cruising" motor and a pressure cabin in the 163C were the only principal differences. There were, however, slight variations in length and span.

The Messerschmitt 163B

It was the 163B versions that Allied pilots encountered over Germany, for the "C" sub-type did not proceed much farther than the prototype stage.

The fuselage was short and stubby, and the wings, which were set midway along its length, swept back at 23 degrees to compensate for the absence of a tail-plane. A single vertical fin with normal rudder control was fitted on the centre-line at the rear.

Of all-metal construction, the fuselage housed the rocket engine in the tail-end. The cockpit was placed about a third from the nose and was faired by a large "Plexiglas" moulded hood. At the rear of the pilot was the main oxidiser tank (containing hydrogen peroxide) which with two small self-sealing tanks in the cockpit gave a total capacity of 270 gallons.

The basic structure of the wing, main and auxiliary spars, was of wood. The covering was entirely dural and fixed slats, 7.17 feet in length, extended along the leading edge. Two split flaps of 7.73 sq. ft. area, with a minimum downward angle of 45 degrees, brought the landing speed down to 100 m.p.h.

The fuel, a hydrate-methanol solution totalling 130 gallons, was carried in two wing tanks.

The armament comprised two Mk. 108 30 mm. cannon mounted in the wing roots which each fired 60 rounds, and the pilot was protected by 15 mm. armour plate at front and rear, the nose of the machine consisting of a detachable cone of armour.

A heavy metal skid was fitted for landing and this retracted into a fairing beneath the fuselage. There was also a small retractable tail-wheel which interconnected with the rudder for taxying the 'plane in conjunction with wheels fitted to the skid. These main wheels were also used in take-off, being jettisoned once the machine was airborne.

The electrical services were supplied by a 2,000 watt "windmill" generator fitted in the centre of the armoured nose.

The instruments, which were carried on normal type "dashboard" panels, covered a fairly wide range and included an altitude-compensated air-speed indicator, rate of turn indicator, and all normal navigational equipment. The power unit registered on a composite accelerometer/thrust indicator, and there were other instruments which recorded the fuel feed pressures and tank capacities. An indication of low level in the tanks was given by red warning lights, and a fire warning device was also fitted.

Controls

The thrust of the HWK 109/509A1 engine of the Me.163B/O was controlled by a throttle fitted on the port side of the cockpit. There were five settings, "Off," "Idling," and three stages of power ranging from 220lb. thrust in the lowest gate to 3,520lb. at the maximum setting.

The necessity of providing a composite aileron/elevator control in the wings made the design of the flying control system somewhat unorthodox. In full lateral movement, the control column operated the composite aerofoils (these are known as "elevons") as ailerons. A true longitudinal movement functioned them as elevators, while diagonal motion of the column brought about the operation of only one elevon effecting roll and pitch.

Performance

The machine flew at a maximum speed of 515 m.p.h. at sea-level, while at heights greater than 13,000ft. this figure was increased to 558 m.p.h. Although there was apparently no great difficulty in its control, the pilot had nevertheless to keep a careful watch on his air-speed indicator, as any too violent acceleration around the 550 m.p.h. mark was likely to initiate a sudden downward pitch.

A run of a little more than 700 yards was required in take-off to gain 65ft., and the 'plane climbed away at approximately 450 m.p.h., reaching a height of 20,000ft. within 3.04 minutes. The maximum ceiling was reached at 40,000ft. after 3.98 minutes, further altitude being impossible because the cockpit was not pressurised.

The leading dimensions of the "B" sub-types were as follows : length, 18.7ft. ; span, 30.5ft., and the overall height, 8.2ft. The gross wing area was 211 sq. ft. ; the wing loading at take-off, 42.9 lb./sq. ft., and at landing, 21.9lb./sq. ft.

The Messerschmitt 163C

The 163C version embodied a cruising motor in addition to its main rocket engine, and this, the HWK 509 A2, was found to be much improvement on the single HWK 509 A1 and HWK 509 B units of the earlier sub-types. It developed a maximum thrust of 3,970lb., plus 660lb. from the auxiliary unit. The endurance under full throttle was raised to 12 minutes, the operational ceiling to 52,500ft., and the time entailed in reaching 40,000ft. was an improvement of 96 seconds on the climb of the 163B/O. Its maximum flying speed was approximately 600 m.p.h.

The machine carried 5,570lb. of propellant, and the addition of the cruising motor and pressure cabin put the all-up weight at 11,300lb.

In an effort to further improve the range and endurance, the fighter versions were, on occasions, towed up to interception height behind orthodox fighters. This was not the usual practice, however, as the prime utility of the 'plane was in its ability to climb from the ground and reach combat height almost within sight of the oncoming formations. It was essentially a fighter for the defence of specific targets and normally could not be expected to patrol.

ROCKET ENGINE	PROPELLANT	PERFORMANCE thrust—min. to max.	APPLICATION
R11/203	"T" and "Z" stoff	220lb. to 1,650lb.	Me. 163A
HWK 109/509 A1 ..	"T" and "C" stoff	220lb. to 3,520lb.	Me. 163B/O
HWK 109/509 A2 ..	"T" and "C" stoff	220lb. to 3,970lb., plus 660lb. (cruise)	Me. 163C
HWK 109/509 C ..	"T" and "C" stoff	220lb. to 4,400lb., plus 880lb. (cruise)	Ju. 8-263

Table I. Power units of the Messerschmitt 163 series.

A close-up of the retracted landing-skid and jettisonable take-off chassis of the Messerschmitt 163B.

The Trainer Version

The training of pilots was made in a lower-powered version of the fighter, the 163A.

A development of the HWK 109/500 Walter assisted take-off motor (PRACTICAL MECHANICS, March, 1946, p. 209), the R11/203, was fitted in the trainer, and propulsion was by the reaction of H_2O_2 and calcium permanganate. The maximum fuel capacity was approximately 3,300lb., which gave the machine an endurance under power of a little more than three minutes, and a 20,000ft. ceiling. The thrust was controlled through a normal type throttle box, from 220 to 1,650lb.

The Ju. 8-263

A little higher in the scale of development was the Ju.248, a single-seat rocket fighter similar in conception to the Me.163C. The machine was, in fact, a development of the 163 series, but had been handed over to Junkers for production to allow Messerschmitt to go ahead with no fewer than eight other project aircraft, chief amongst which was a new version of the Me.262 fitted with a Walter rocket unit in the tail.

The 248 was later reclassified 8-263 to obtain consistency with the original series. Several improvements considered desirable from the standpoints of production and operation were incorporated, and although the machine bore a strong resemblance to its forebears, it had been cleaned up aerodynamically by the provision of an entirely redesigned fuselage.

The incorporation of a retractable undercarriage eliminated the bulky landing skid and tail-wheel fairing which made the 163's appear clumsy, and this resulted in a well-faired fuselage, the contour of which was smooth and unbroken save for the "bubble" hood placed near the nose. Of semi-monocoque construction, the fuselage fitted a pressure cabin and housed most of the propellant. There were three tanks for the peroxide oxidiser which totalled 352 gallons, while the fuel tanks, containing 185 gallons, were divided, one in the fuselage and four in the wings. In order to ensure a minimum change in the position of the c.g., it was necessary for the tanks to be emptied in a particular order.

Production was facilitated greatly by the use of 163B wings, suitably modified to take the increased fuel load, while the fin and rudder were also standard assemblies of the 163 series. The switchover to the 8-263 would, therefore, have involved no great loss in output.

Apart from the engine these were the principal differences. The HWK 109/509C, developing a maximum thrust of 4,400lb. plus 880lb. from the cruising unit, gave the machine a maximum speed of 620 m.p.h. in level flight. It climbed at the rate of 13,800ft. per minute at sea level, reaching its ceiling at about 50,000ft.

The machine had an all-up weight of 11,340lb., which was reduced to 4,640lb. by the consumption of the propellant. Its overall length was 26ft., and the wing span 31.2ft., an increase over that of the 163B caused by the greater width of the fuselage.

The wing loading was 59.4lb./sq.ft. at take-off, which naturally reduced with the combustion of the propellant. At the time of landing with tanks empty, the figure was 24.2lb./sq.ft.

The engines which propelled these aircraft hold much promise for development in conjunction with athodyd units of the type described in the previous article, and by far the most important were those of the HWK 109/509 series (see Table 1).

The Walter Bi-fuel Propellants

Commenced in pre-war days as a private venture, the HWK 109/509 engines were developed by Dr. Walter, of Kiel, being the first fully controllable rocket power units ever to be employed in flight.

It will be recalled that in every case of experiment with liquid fuels before the advent of the Walter units, the oxidiser had always been liquidised oxygen. In service aircraft, however, the use of liquid oxygen would present several difficulties, for although when burned in conjunction with a suitable hydrocarbon it is capable of releasing tremendous energies, the low temperature at which it liquefies (−182.9 deg. C.) means that extreme care must be taken in its storage, transport and handling.

When contained at normal temperature in anything other than a "Thermos" or Dewar storage bottle, it is rapidly reconverted into gas, and unless the tank is pressurised and relief valves are incorporated, there is every possibility of the mounting pressure causing a violent explosion.

These difficulties are not easy to overcome at the best of times, and when a fighter aircraft is considered, which has to be fuelled some time before it actually takes off, the problems become almost insuperable.

Another important factor concerns the materials used in the construction of the tank and feed system, which must be carefully selected as many metals change their physical characteristics at such low temperatures. There are many accounts on record telling of experiments which have been completely ruined by the disruption of the containing tanks and feed lines by this highly volatile liquid.

It was for these main reasons that the Germans strove to produce an entirely new oxidising agent—one that could be handled without overmuch caution by Luftwaffe ground personnel. The V-2 rocket was, of course, a fundamentally different matter, because fuelling and launching took place within a specified time and the weapon was operated by specially trained crews. The use of liquid oxygen, even then, was nothing like 100 per cent. reliable, and several of the missiles exploded as the result of a too vigorous expansion of the oxidiser.

Hydrogen Peroxide

The investigation of various propellant forms involved the German chemists in research for several years, and four oxidisers—gaseous oxygen, nitrous oxide, nitric acid, and hydrogen peroxide, were eventually put forward as the most suitable for rocket-powered interceptors and guided missiles. A further elimination after extensive tests established hydrogen peroxide as the oxidiser for the Me.163, Ju.8-263, Bachem Ba.349, etc., and it was also employed as an auxiliary fuel for the turbine-pump feed in the V-2, as well as in the rocket fighters.

The substance had not been previously considered by rocket experimenters because it had hitherto not been available in sufficient concentration. Its production at 80 per cent. purity was certainly a great achievement and brought full justification to Walter's theories. Actually, the Germans had succeeded in the purification of the liquid to over 90 per cent. strength, but in this state it was found to be dangerously unstable. The compromise, therefore, was *concentration* with a reasonable safety factor; yet, despite this, Me.163's often blew up.

The fuel component in the case of the HWK 109/509 engines was a solution of 57 per cent. hydrazine hydrate, 30 per cent. methanol and 13 per cent. water.

When brought together in the combustion chamber, the two liquids undergo a violent and spontaneous combustion; there is no

CODE	COMPOSITION	APPLICATION	
		In Conjunction with:	For:
A-stoff ..	Liquid oxygen	Ethyl alcohol	
Benstoff ..	Ethyl alcohol	A-stoff	A-4 long-range rocket
C-stoff ..	57 per cent. methanol, 30 per cent. hydrazine hydrate, and 13 per cent. water	T-stoff	Me.163 fighter series—main propellant
T-stoff ..	80 per cent. hydrogen peroxide	C-stoff	
Z-stoff ..	Saturate aqueous solution of calcium (or sodium) permanganate	T-stoff	Walter A.T.O. units; A-4—as turbine generator for fuel pumps; Hs. 293, and Me.163A
Salbei ..	98 per cent.—100 per cent. nitric acid	Tonka, Visol, Petrol J-2, Diesel oil, etc or C-stoff	Wasserfall, B.M.W. rocket engines, etc.
Tonka 505b	57 per cent. oxide-m-xylidine	Salbei	B.M.W. engines
Tonka 505c	43 per cent. triethylamine	Salbei	B.M.W. engines
Visol ..	Butyl ether (with 15 per cent. aniline)	Salbei	Wasserfall, Enzian, etc.
J-2	Coal oil	Salbei, etc.	Various jet and rocket engines
—	Gaseous oxygen	Methanol	Alternative propellant for Hs.293, etc.

Table 2.—Details of some of the main propellants used to power German rocket fighters and missiles.

ignition in the normal sense, the propulsive gases resulting from purely chemical reaction. All rocket engines which operate on this principle are termed "cold" units to distinguish them from the earlier "fuel-burning" types.

A list of the principal fuels and oxidisers used in fighters and missiles is given in Table 2, and it will be seen that the peroxide oxidiser was known by the code, "T-stoff," and the fuel solution, "C-stoff."

First Experimental Walter Engines

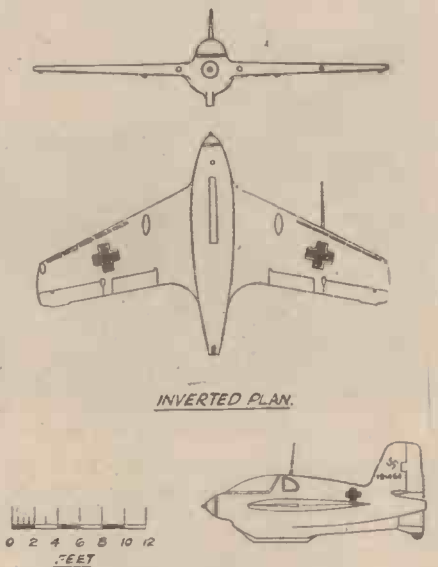
The Reichsluftfahrt-Ministerium assigned the designation 109 to all important jet and rocket engines, the second figure indicating the type and specific model. Thus, numbers in the second group between 001 and 499 inclusive applied to jet motors, whilst those from 500 to 999 were allotted to rocket units.

The first experimental engine of the 163 series was built in June, 1941—an air-cooled variable-thrust unit embodying a H_2O_2 turbo-pump feed system. Its fuel developed a maximum thrust of 1,650lb. for a specific consumption of 36lb./lb. thrust/hr.

This was the forerunner of the HWK 109/509.A1 employed in the Messerschmitt 163 B/O, which went into production with very little alteration to the original design. There were, of course, several lesser offshoots of this development which evolved in the shape of propulsion units for aerial missiles, auxiliary power units for gliders and assisted take-off motors. It will be recalled that the initial use of a bi-fuel unit of the "cold" type was in the Henschel 293 anti-shipping "glide-bomb," first operated during the summer of 1942.

Two main problems confronted Dr. Walter when he first set out to productionise his engines.

The first concerned the building of a combustion chamber capable of withstanding temperatures up to 2,000 deg. Centigrade, and in this, the designer was tackling a



The Messerschmitt Me. 163 B.

problem which had hitherto been only partly solved by earlier researchers. It is true that Sänger, and the Americans, Carver, Truax and Wyld, had developed some promising liquid fuel motors in which, by various refinements, the possibility of burn-out had been very much reduced, but they were, nevertheless, hardly comparable with the large-scale engines that Walter had in mind. In any event, the motors produced by the American Rocket Society could not stand up to repeated firings, and few were capable of withstanding combustion at full thrust for more than 30 seconds. It was, in fact, often the case that motors were so damaged after one firing that they had to be entirely rebuilt before it was possible to test them again.

It was obvious that for a service aircraft, which perhaps may be called upon to fly off to intercept several times during a single day, a motor would be required to operate for quite lengthy periods without need for extensive servicing or replacement. The development of rocket fighters would certainly not have been considered had it not been possible to produce a power unit able to be operated at full thrust for 30 minutes without deterioration.

It was fortunate for Walter that the development of the V-2 long-range rocket (otherwise known as the A-4), under von Braun, had involved similar research. A great deal of data on combustion systems had been amassed since the commencement of the "A" series in 1933, and this must have been of immense value to the designers of the Me. 163. It is, in fact, not unreasonable to assume, from the similarity of the power unit of the A-4 and the HWK 109/509, that the two engines were basically a parallel development.

The A-4 had, too, involved a great deal of research with feed systems, and it would seem that this was largely the solution to Walter's other principal headache, borne out by the fact that the H_2O_2 turbine driven pumps in the HWK engines were of an almost identical pattern to those employed in the long-range rocket.

(*To be continued.*)

Electro-mechanical Differential Analyser

A 100-ton Calculating Machine

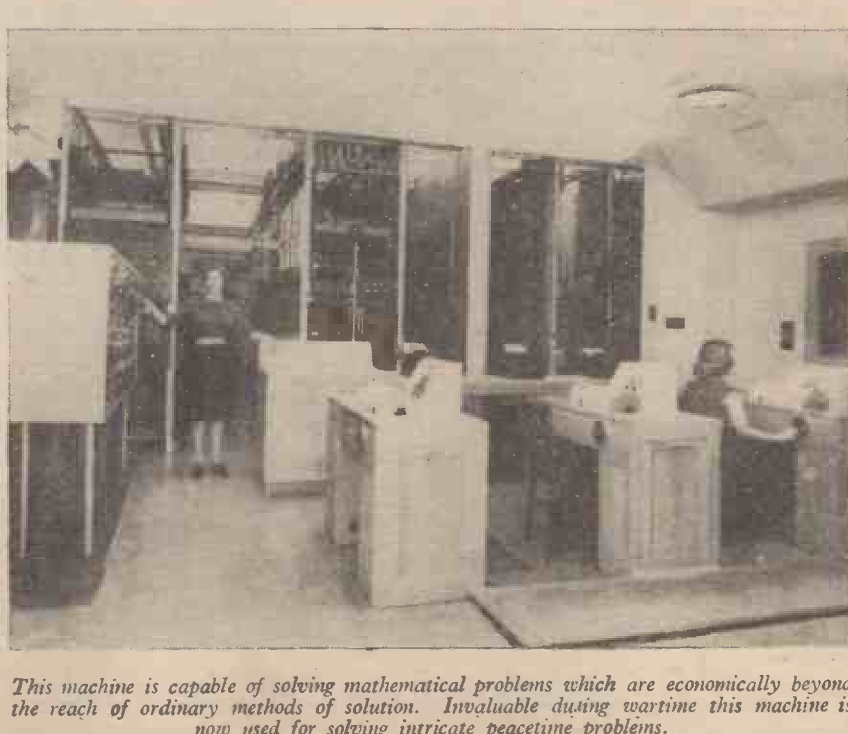
THE illustration on this page shows an electro-mechanical differential analyser, a 100-ton calculating machine installed at the Massachusetts Institute of Technology in America. It was designed for the solution of scientific and industrial engineering problems and worked for three years on important war projects which included computation of range tables for the guns of the U.S. Navy.

Peacetime Problems

Its wartime service now over, the machine has now turned to its original objective, the solution of peacetime problems in a field of usefulness which includes every branch of science and engineering. The panels in the background contain approximately 2,000 electronic valves, several thousand relays, about 150 motors, and nearly 200 miles of wire. In front of the panels are automatic electric typewriters which record numerically the solution of complex differential equations, while in the foreground graphic solutions are drawn in the form of curves on revolving cylinders.

Transmitting Devices

At the left are transmitting devices through which mathematical data is introduced to the machine on perforated paper tapes. The analyser not only relieves human brains of the time consuming drudgery of difficult calculation and analysis, but solves mathematical problems which are economically beyond the reach of ordinary methods of solution.



This machine is capable of solving mathematical problems which are economically beyond the reach of ordinary methods of solution. Invaluable during wartime this machine is now used for solving intricate peacetime problems.

Rocket Propulsion

The HWK 109-509 Walter Engines

By K. W. GATLAND

(*Continued from page* 388, *August issue*)

The only rocket powered interceptor to see service during the war, the Messerschmitt 163BO was fitted with an HWK 109-509A1 Walter engine. This photograph shows the landing skid and tail-wheel fully extended. The main wheels, attached to the skid, were jettisoned once the machine was airborne.

THE design of the Walter aircraft engines was *regenerative*; that is to say, the fuel component of the liquid propellant was circulated prior to its injection for burning through a cooling jacket encompassing the combustion chamber and nozzle. In this arrangement the fuel acts to cool the motor, and, conversely, to vaporise the fuel by pre-heating, with the result that there is a marked gain in the thermal efficiency.

Another important factor of regenerative design is that the inner wall of the combustion chamber can be quite thin and yet withstand full combustion stresses.

One of the first experimenters to employ this system was the German, Dr. Eugen Sänger, who first demonstrated his fuel-cooled rocket motor in 1931. This unit has been fully described in an earlier article (PRACTICAL MECHANICS, March, 1945, p. 200), and it will be recalled that the one essential requirement was a high pressure fuel-feed system, and that Sänger achieved his very successful results in the use of a Bosch diesel pump which permitted pressures within the jacket of 450 to 2,200 lb./sq. in. As the fuel-feed pressure must necessarily be greater than that resulting from combustion, the stress directed on the firing wall of the chamber acted toward the axis of the motor. Thus, the inner wall was of a much thinner section than could otherwise be employed, and of an appreciably higher order of conductivity. All outward directed pressure was absorbed by the outer shell, which could be of heavier construction as it was not subject to extremes of temperature. This explains the reason why no particularly high-grade steels were used in many of Germany's most efficient rocket motors, including the V-2, when motors employing highly durable materials in their construction but not regenerative operating, were disrupted after merely a few seconds' firing.

Since the time of Sänger's early experiments, a number of other motors employing the same principle had been developed, many of which were featured in tests carried out by the American Rocket Society.

It was, in fact, Nathan Carver, a member of this group, who provided a further important contribution toward solving the problem of motor burn-out, which when combined with Sänger's scheme made the possibility of efficient liquid rocket engines a certainty.

This was, of course, the "concentric-feed" principle which Carver first demonstrated

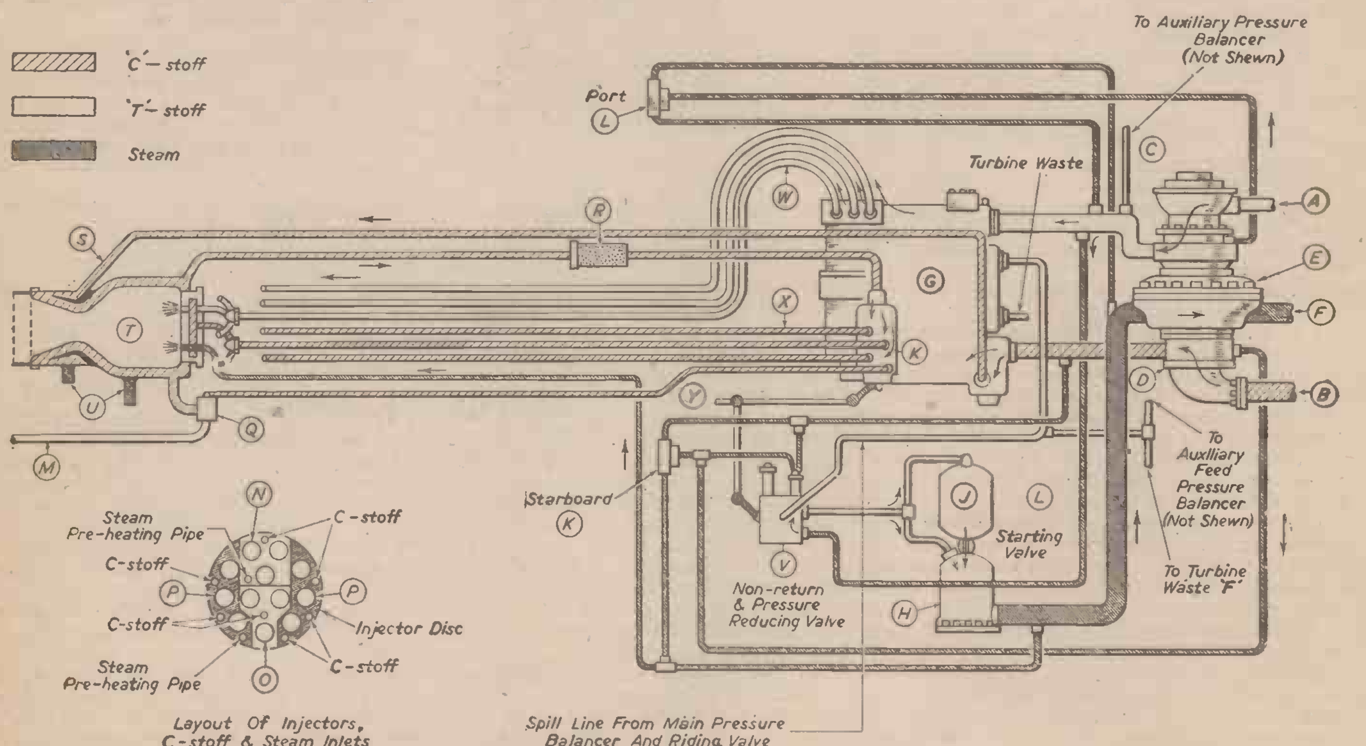


Fig. 76.—Diagrammatic layout of the HWK 109-509C—main system. The cruising motor has been omitted for clarity.

A. T-stoff inlet from tanks.
B. C-stoff inlet from tanks.
C. T-stoff pump.
D. C-stoff pump.
E. Turbine.
F. Steam exhaust from turbine.
G. Distributor. (Main pressure balancer.)
H. Steam producer.
J. Starting reservoir.
K. Control valve.
L. T-stoff to turbine.
M. Scavenge pipe.
N. Stage one.
O. Stage two.
P. Stage three.
Q. Scavenge valve.
R. Filter.
S. C-stoff inlet to jacket.
T. Combustion chamber.
U. Supports for auxiliary motor.
V. Turbine control valve.
W. T-stoff feed lines.
X. C-stoff feed lines.
Y. Pilot's control lever.

NOTE: All notation in the text refer to this figure.

during the small-scale rocket aeroplane trials at Greenwood Lake, N.Y. in 1936 (PRACTICAL MECHANICS, February, 1945, p. 158) and which was later taken up with even greater success by other technicians of his Society, principally, R. C. Truax and J. H. Wyld. His associates, in fact, produced several concentric-feed regenerative types which in conception were essentially nothing less than small-scale versions of the power unit of the V-2.

As the result of similar and more intensified

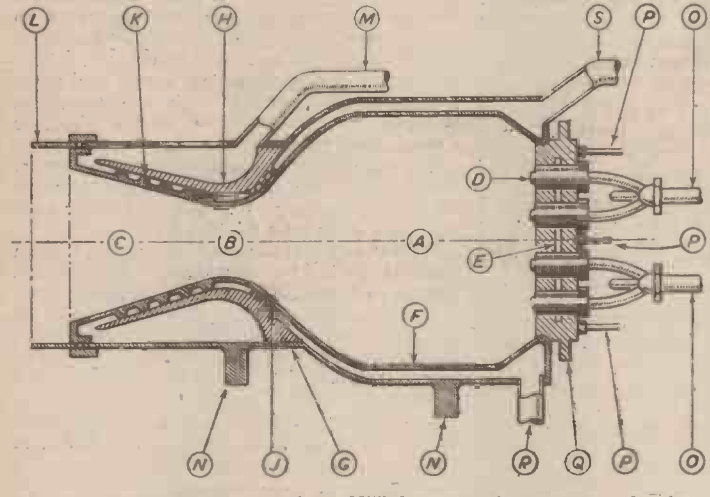


Fig. 77.—Sectional diagram of the HWK 109-509C combustion chamber.

- A. Combustion chamber.
- B. Nozzle throat.
- C. Nozzle mouth.
- D. Injector.
- E. Orifice for C-stoff entry into injectors.
- F. Inner shell of combustion chamber.
- G. Outer shell of combustion chamber.
- H. Concentric-flow section.
- J. Helical vanes on concentric-flow section.
- K. Helical vanes on inner shell.
- L. Outer shell over nozzle.
- M. Coolant inlet.
- N. Supports for auxiliary motor.
- O. T-stoff inlets.
- P. C-stoff inlets.
- Q. Injector disc.
- R. Drain pipe.
- S. Coolant outlet.

research which was proceeding under military supervision in Germany, the prototype engine of the A4 long-range rocket appeared, and with it the motors of the Messerschmitt 163 series.

The HWK 109-509 Walter Units

The HWK 109-509 engines (the HWK 109-509C main system is shown in Fig. 76) comprised two main sub-assemblies: (a) the rocket motor, and (b) its turbine-driven pumps, accessories and controls, separated by approximately 4ft. of feed lines, these being completely encased by a metal conduit which transmitted the thrust. In the case of the 109-509A1 unit, the total weight (less propellant) was only 814lb., while the amount of T-stoff and C-stoff necessary to operate the Messerschmitt 163BO during its four minutes period of powered flight was 3,418lb. and 1,031lb. respectively.

The combustion chamber (Fig. 77) was constructed of rough forged carbon steel, being of cylindrical section rounded at the head and flowing into a convergent-divergent expansion nozzle. Its length was approximately 11in., the internal diameter 9.50in., the volume 825 cu. in., and the throat area of the nozzle 5.15 sq. in.

The inner walls were only ⅛in. in thickness, yet able to withstand temperatures of nearly 2,000 deg. C. and pressures approaching 24 atmospheres. An ⅛in. average gap separated the inner and outer walls of the motor through which the C-stoff coolant flowed.

Of rolled carbon steel construction, the outer shell of the motor was seam-welded, the nozzle being joined to the chamber portion at the mouth. A 6.50in. diameter disc, on which were mounted the injector valves for the propellant, was also welded—at the head of the chamber.

Situated in the space between the inner and outer shells of the nozzle was a concentric flow section, ensuring a rapid and even flow of coolant around that most vulnerable portion of the motor. This was an aluminium alloy casting and embodied three helical vanes situated to coincide with the convergent section of the nozzle, intended to swirl the C-stoff evenly around the liner in its path to the fuel injectors. A further set of five vanes was attached to the outer surface of the liner at the divergent section.

The propellant entered for combustion at the chamber head, passing through twelve pressure actuated valves mounted on the disc plate. The latter was machined from carbon steel bar, while the separate injectors, which screwed into the plate, were of stainless steel.

Operation of the Motor

The oxydiser passed down the centre of each valve, but upon entering the chamber, was deflected outwards from the axis by means of a cone.

This cone was obviously the crucial part of the injector, and being spring loaded, not only prevented blowbacks but also acted as a regulator.

It will be seen from the figure that the supply of fuel to the motor was through a main distributor (G), and that a pipe first brought the C-stoff to the coolant jacket. The fuel solution, having circulated around the motor, was then filtered and delivered back to the distributor, passing through a control valve where its pressure was regulated prior to being fed for combustion. All of the pipes, to and from the motor, passed inside the metal thrust conduit, the fuel pipes branching out into subsidiary feeds just before reaching the head of the combustion chamber. These, of course, fed into the twelve injectors.

Apart from flowing through a filter and control valve in the distributor, the T-stoff fed directly from the pump into the chamber. There were seven inlets and these led into a cavity inside the injector plate, the fuel passing again through filters and then into the injectors via an annular orifice surrounding the deflector cone, finally entering the chamber and mixing with the oxydiser. Combustion took place spontaneously at the deflector cones, each injector providing its own "concentric-feed."

The T-stoff underwent vigorous decomposition, liberating nascent oxygen, which was burnt with the alcohol as the main source of heat. Actually, the violent reduction of the peroxide, under heat and catalytic action, also released mass in the form of superheated steam, adding materially to the weight of the exhaust.

In order to overcome the possibility of explosions when the motor was expended of propellant, it was necessary to drain any C-stoff that remained from the coolant jacket. This was catered for by a pipe which passed from the jacket at a point beneath the chamber to a valve (Q). All the while the turbine-drive of the pumps operated, this valve was closed, but when the pumps ceased to function and pressure fell off, the valve was allowed to open and the remaining fluid in the jacket passed out through the scavenge pipe (M)

Starting

The starting procedure consisted first in working the pumps, but this did not entail releasing propellant to the combustion chamber with its voracious consumption of approximately 1,000lb. per minute. The pilot initiated the turbine drive by moving the lever of his control quadrant to "Idling," energising the starter motor and opening the tank flow-cocks. This electric starter, which was geared direct to the turbine shaft, drove the pumps at low power, causing the feed-lines to fill with propellant. The pressure, however, was not sufficient to overcome the valve setting in the main T-stoff line to the steam producer, which activated the turbine.

In units which were not fitted with electric starters, there was an auxiliary starting reservoir which contained sufficient T-stoff to operate the turbine for six seconds, thereby allowing time for peroxide from the main supply to reach the steam generator. A bypass line fed back a small quantity of peroxide into the steam generator (H), and the turbine quickly developed sufficient power in the pumps to operate the normal feed to the steam producer. The bypass then automatically cut out.

This procedure was necessary each time the motor was re-started after the aircraft has been gliding with power off.

The Steam Generator

The steam generator comprised a porcelain-lined pressure vessel with a wire cage fitted inside in which were distributed a number of porous pellets impregnated with calcium permanganate and potassium chromate. From the reservoir, the T-stoff fed by gravity into the generator, where, upon meeting the catalyst, there resulted a violent decomposition into super-heated steam and gaseous oxygen. Actually, the peroxide was sprayed on the catalyst from the top of the generator, and the cage itself rested on a perforated sheet of metal near the floor of the container. A large pipe conveyed the steam from the base to the nozzles of the turbine, and after operating the rotor, the waste gases were vented to atmosphere.

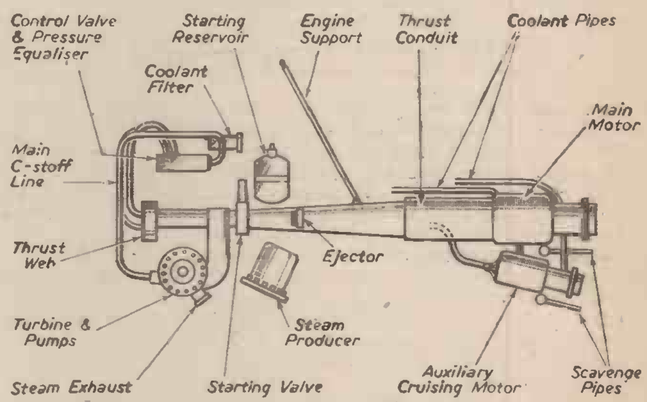


Fig. 78.—Diagram showing the layout of the main components in the HWK 109-509C Walter bi-fuel rocket engine.

In the developed engine HWK 109-509C, two small pressure lines ran from the main steam pipe to convey pressure to the ejector valves (K and L), which were provided for the purpose of extracting air from the pumps when the power has been cut for any reason. This was, of course, a safety measure to prevent airlocks and to afford protection from explosions which might otherwise have occurred. The steam used here was eventually exhausted into the combustion chamber, being also used to pre-heat the fuel during starting operations.

The Turbine-pump

In order to maintain pressures of the order of 350-360lb./sq. in. in the feed lines and motor jacket, it was obvious that the solution did not lie in the use of gas-operated pressure chargers. The difficulties confronting the designer of a mechanical driven pump were enormous, and had it not been found possible to use concentrated hydrogen peroxide as the steam producer, it is doubtful whether either the rocket fighters or the V-2 would have performed anything like as well as they did, for reciprocating engines and the extra fuel entailed meant so much more unwanted weight.

The pumps of the HWK 109-509 were called upon to supply over 20 lb. of propellant for every second the motor was operating under conditions of maximum thrust and at a pressure sufficient to maintain a combustion chamber pressure of over 350lb./sq. in.

The turbine group comprised a single-stage turbine with two centrifugal impellers mounted on a common shaft at either side. Machined from chrome steel, the 10in. diameter turbine rotor was housed within an aluminium alloy casting. The T-stoff impeller was manufactured from 13 per cent. chrome steel, while the materials of the fuel impeller were not so critical so long as copper was avoided in the alloy. It was, however, usual to employ aluminium or aluminium alloy, although chrome steels with an optimum percentage of 18 to 21 chromium was a possible alternative. Their housings were also of chrome steel.

For the remainder of the feed system, the hydrogen peroxide lines were of aluminium alloy, though, of course, not containing copper, while the fuel solution was carried by pipes of mild steel.

From "Idling" to "Power"

Immediately sufficient pressure was registered on an indicator in the cockpit, the pilot moved his throttle lever into the first gate. This caused the propellant to feed through three of the injectors (N). The second power phase brought into operation three additional injectors, while the third and final setting functioned the remaining six.

In the case of the improved HWK 109-509 motors, there was in addition to the main rocket motor a cruising chamber, the complete layout of which is shown in Fig. 78. The auxiliary chamber, which was supported beneath, was also regenerative, but had only three injectors. It operated at a fixed power, the 109-509C version developing fully 880lb. thrust.

For climb, both chambers were operated to obtain maximum power, but for cruising, the main motor could be cut out, the use of the auxiliary chamber providing a better solution than simply throttling back on the main system. This enabled a given thrust in the lower power setting to be taken over by the smaller chamber, with the result that efficiency was much improved and a lower propellant consumption obtained.

Performance Data

In the combustion chamber, the chemical energy of the propellant was converted to heat energy, 1,430 C.H.U. being theoretically available for each pound consumed. The maximum thrust resulting from the main chamber was 4,400lb. with a combustion pressure of 353lb./sq. in. and a chamber temperature of 1,950 deg. C.

With the thrust averaging 3,700lb., however, the temperature was reduced to between 1,750 and 1,900 deg. C. The propellant ratio was then between 3.7 and 3.3 to one.

The thermal efficiency was found to be in the region of 28 per cent. at maximum thrust, falling to something less than 10 per cent. at the maximum setting. This poor value of efficiency was, of course, favourably offset by the inclusion of the cruising chamber in newer designs. The reason for this is obvious in that the smaller throat area and chamber volume permitted higher pressures than would have been possible in the larger motor with the same number of injectors in use.

(To be continued.)

Items of Interest

Exhibition of Non-utility Furniture

EXPERTS met in London on April 25th to look at some 1,000 designs for non-utility furniture submitted for inclusion in the Government-sponsored "Britain Can Make It" Exhibition, which opens this month at the Victoria and Albert Museum.

Permits will be issued for the timber required for constructing the selected designs, and from this range of furniture the final selection for the exhibition will be made.

New furniture will be an important feature of the exhibition—displayed in furnished rooms and in nurseries, gardens, offices, and restaurants.

Since there will be complete freedom in the choice of materials for the furniture exhibits, British manufacturers will have the opportunity of showing that the restrictions of the war years have not affected their leadership in design and craftsmanship. It is anticipated that some of the furniture selected will be based on the wartime advances in new techniques and new materials.

The large number of entries for this section is evidence of the keen interest displayed by British manufacturers in the "Britain Can Make It" Exhibition. It is also a remarkable tribute to the resiliency with which British furniture manufacturers are facing problems of reconstruction.

Non-utility post-war developments in all kinds of consumer goods will be shown at the exhibition, which is being organised by the Council of Industrial Design and financed by the Government. No space is being sold, for all exhibits are to be carefully selected to illustrate the best in British industrial design. Selections for other sections of the exhibition will be made later in the summer.

The exhibits are to be chosen by experts drawn from a panel of selectors under the chairmanship of Lord Woolton.

The Audiometer

THE audiometer was first used to record sound in 1910. Since then it has recorded traffic, Dame Nellie Melba, H.M. the King, Chamberlain, Churchill, gunfire, Hitler's voice and most imaginable sounds. It operates by direct recording, unlike the "talkie." Used in study of Underground Railway noises and for the silencing tests on Imperial Airways. This instrument made the first known records of London's traffic long before era of talking pictures. (See illustration below.)

Comfort for Air Transport

TO add to the comfort of passengers travelling in an aircraft means have been devised to minimise transmission of sound and other vibrations to the interior of the cabin and other compartments of an aeroplane.

A further object is an improved method of regulating the temperature of the cabin.

The invention comprises an aircraft compartment in which an inner cell or chamber is suspended through the medium of resilient vibration—damping members attached to members of the outer frame. The arrangement is such that except at the points of its suspension, the inner cell compartment is entirely surrounded by an airspace sealed from the outer atmosphere.

The transmission of sound and other vibrations depends to a large extent upon the existence of rigid physical connections. And, in order to prevent or at least minimise such transmission, it is important that the smallest practical number of suspension mountings be employed. Then the conducting efficiency of such physical connections as are essential can be reduced by incorporating resilient damping means at the minimum cost of added weight.

The device provides also for circulating through the aforementioned surrounding air space of the compartment a current of air or gases in such a manner that it flows over the outer surfaces of the inner cabin. The temperature is regulated above or below the atmospheric temperature which it is desired to maintain in the cabin.

Portable Fire Alarm

WHEN people retire to bed at night the remains of fuel in the grate are sometimes left burning. In these circumstances sparks from the grate are a not uncommon cause of a fire.

To guard against such a contingency, there has been devised a portable fire alarm which can be placed on the hearthrug. In case of fire, this automatically sounds an alarm of sufficient duration to awaken the occupants of the house.

As no electrical connections have to be made, the device is readily portable, and can be carried from one room to another and used where it is most required.

Sound wave photograph of an atomic bomb explosion. Taken on the audiometer by Prof. A. M. Low. This is a visual record of the greatest underwater explosion ever known.

Rocket Propulsion

The Ba. 349 "Natter"

By K. W. GATLAND

(*Continued from page 422, September issue.*)

HIGH in priority during the desperate months leading to Germany's final overthrow was another rocket-powered interceptor, the Bachem Ba. 349 "Natter" (Viper).

This machine resulted from a specification issued by the German Air Ministry towards the close of 1944 for a rocket propelled aircraft to defend specific targets. Four firms competed in the design, each producing a prototype: Heinkel, a type known as "Julia"; Junkers, the "Walli"; Messerschmitt, the Me 1104; and Bachem, a machine provisionally known as the BP. 20. The latter project was eventually accepted for development and given the designation Ba. 349, while the rest were dropped.

As closely akin to a guided missile as to a fighter aircraft, the tender for this design was submitted by Dr. Eric Bachem, founder of the Bachem Werke G.m.b.H., at Waldsee-Würtemberg.

Bachem based his design on a vertical take-off and an exceptionally high rate of climb.

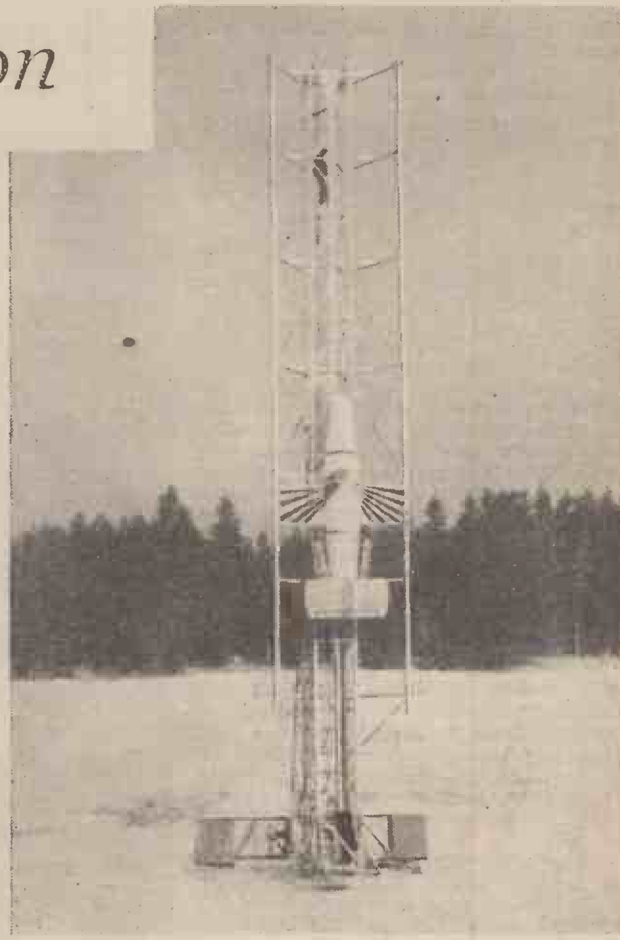
To satisfy these requirements, it was decided to concentrate on the speed factor and to effect no compromise such as maintaining a reasonable wing loading for usual flight manœuvres and landing. The design, in fact, was such that landing by normal means was impossible, and it was at first planned to sacrifice the complete aircraft.

The latter problem was overcome quite simply. It was arranged that the pilot abandoned the machine immediately after pressing home his attack and descended by parachute, the after section of the fuselage (containing the motor and accessories) following him down in a similar fashion, to be collected and later re-built into another "Natter." At least, that was the intended operation, but on the one occasion that the Germans carried out a manned test, the cockpit hood blew up when the machine was only 300ft. from the ground, causing it instantly to turn over and plunge to earth, the rockets still firing at full power. Needless to say, the pilot was instantly killed.

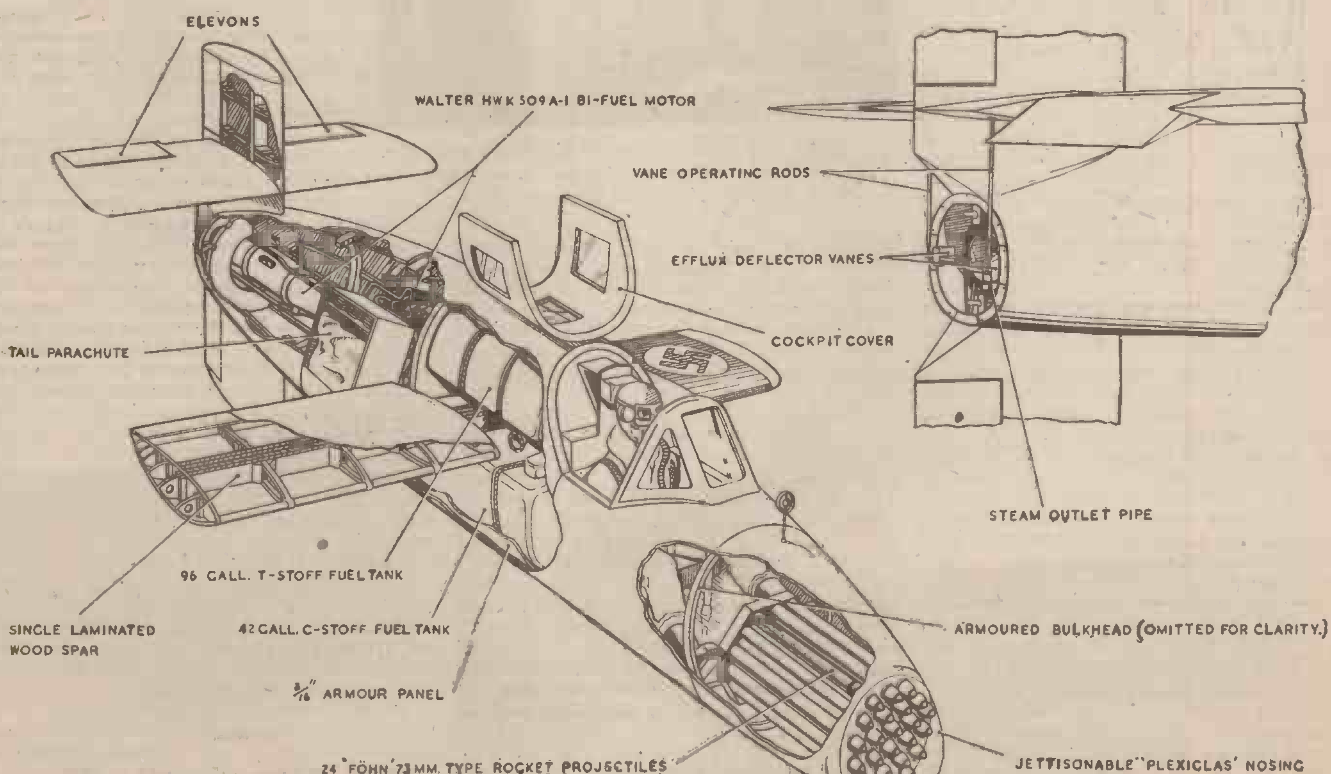
All other ascents were made under the control of auto-pilots.

The Ba. 349A

Powered by an HWK 109-509A1 Walter engine, the first production version of the "Natter" flew at a maximum speed of 540 miles per hour, climbing at the rate of 35,800ft. per minute to reach its ceiling at 49,000ft.



This picture gives a good idea of the small amount of space required to operate the "Natter." Intended to be launched from bombed sites, parks, or any convenient space near the factory it was assigned to defend, the Ba. 349B climbed at the phenomenal rate of 37,000 feet per minute.



A part-sectional drawing of the Ba. 349A "Natter," showing the simple construction of the airframe and the layout of the main components.

The construction of the fuselage was entirely of wood, being of semi-monocoque design, with a laminated wood skin, stringers and formers. It was built in two main sections and the pilot was installed inside a heavily armoured cockpit immediately behind his main armament of explosive rockets in the nose. These were mounted in a quadrangular or hexagonal frame (according to the calibre of the rockets used), the heads being faired by a "Plexiglas" domed nosing during flight, which was blown preparatory to firing by explosive bolts. In addition to the rocket armament, which could be either thirty-three R4M R.P., or twenty-four of the larger Föhn 73 mm. type, some production versions mounted two Mk. 108 30 mm. cannon.

For protection, there was the bullet-proof windscreen, and two armoured bulkheads at front and rear of the pilot, while the sides of the cockpit and fuselage local to the propellant tanks were also screened by 3/16in. armour panels. This heavy armouring, coupled with the small frontal area and high speed of the "Natter" made it almost invulnerable to harm from bombers' defensive guns.

The main controls were a control column, rudder pedals, auto-pilot and throttle box, whilst mounted on the front cockpit bulkhead were two buttons, one for firing the R.P., the other causing ejection. Levers for jettisoning sections of the aircraft were also fitted close at hand.

At the rear of the cockpit were two propellant tanks—96 gallons of T-stoff above and 42 gallons of C-stoff below—and farther aft still, the fuselage parachute, turbine pumps, accessories and, finally, the rocket motor.

The short-span wings, which did not detach from the fuselage, embodied a continuous laminated wood spar passing between the tanks, with wooden ribs, and metal-sheathed tips. There were no ailerons.

The tail-assembly, which was built in a similar manner to the wings, comprised fin and rudder area both above and below the fuselage, with the tail-plane itself mounted well above the centre-line on the topmost fin. The elevons, fitted on the tail-plane, were, of course, functioned by the control column, serving the dual purpose of elevator and aileron.

An interesting point about the control system is that the elevons were linked to corresponding vanes which worked in the exhaust stream at the rocket nozzle. Thus, not only were longitudinal and lateral movements made more sensitive by the offset reaction which resulted when the vanes were deflected, but flight with "hands-off" was excellent under the control of the automatic pilot.

This method was yet another having its origin in the V-2 research at Peenemunde, and its application in the "Natter" certainly contributed greatly toward its well-stabilised climb. It will be noted in this regard also that no attempt was made at wing sweepback, despite the high speeds involved.

By the close of hostilities, the Germans were masters of high speed aerodynamics and had the very best of equipment for such research, having regard for both "tunnel" testing and actual free-flight experiments with aircraft they had specially built.

The Messerschmitt 163—Germany's first rocket interceptor—was not, however, a particularly good example of their work. One problem not easily overcome was the large degree of washout required at the wing tips which, though necessary as part of the general stability, did not contribute to the performance when the machine was throttled beyond the 500 m.p.h. mark. The incorporation of washout made for excellent handling qualities at low speeds, but although the wings were swept back to improve stability and to delay compressibility effects nearing the sound velocity, this factor was the one largely responsible for the machine becoming uncontrollable at M=0.82.

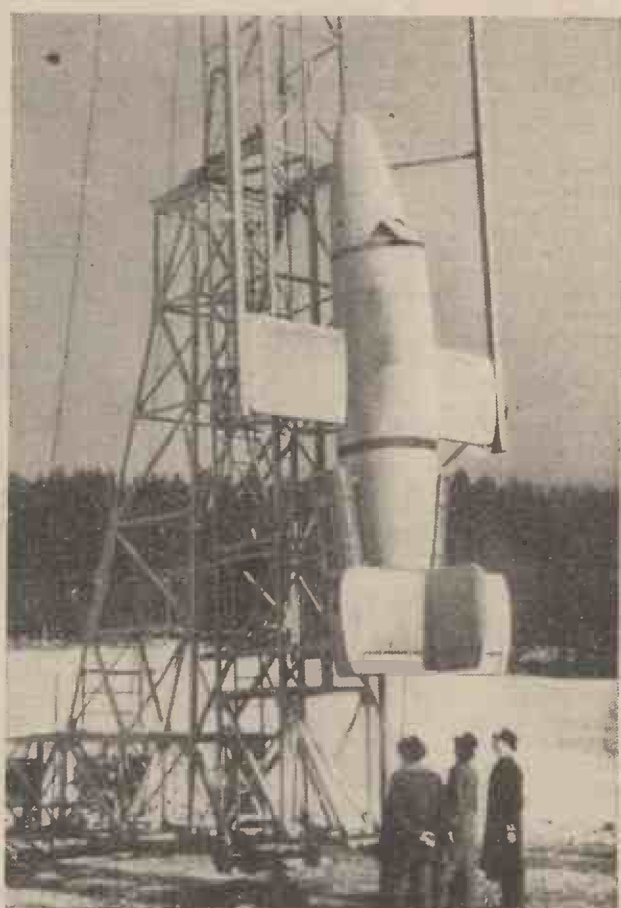
The German technicians, however, took no chances with the "Natter." They knew the urgency of its development, and consequently did not embody features that might break down in trials and cause delays in production.

Despite the fact that elevons displaced the more normal wing ailerons and tail elevators, the control system was really not that much untried. It had, in fact, proved highly effective in the Messerschmitt design, and coupled with the exhaust-vane stabilisers the results were very satisfactory.

The exhaust-vane system, incidentally, is likely to play a large part in maintaining control at trans-sonic and super-sonic speeds, and it will be interesting to watch developments.

The Bell Aircraft Corporation has, in fact, already produced an aircraft with which it is hoped soon to penetrate the sound barrier. This is the XS-1, fitted with a ram-jet "athodyd" and rocket booster, but the technicians in charge of its testing programme are first making certain of the 'plane's behaviour with "power-off." The machine has already accumulated several hours' flight time, having been taken up to height beneath a large bomber and released to obain first-hand knowledge of its stability and general handling qualities at low speeds. Only when complete data has been obtained in glide flight will the machine be tried under power: "Controllability is the big unknown," said Lawrence D. Bell, president and general manager of the company; "Should our pilot discover dangerous flight characteristics in the speed-of-sound range, it will be possible for us to continue our flight programme through the use of radio-control, a device we have brought to a high state of perfection in co-operation with the Army Air Force. We are prepared to substitute robot control for our pilot at any time it may be desirable."

Precise details of this machine have not yet been made known, but there can be little doubt that the best features of German research have been incorporated, and it may well be that the control system has been adapted from the "Natter."



All set for take-off. The tips of the wings and lower fin of the "Natter" were strengthened to run in the three guide rails of the 80-foot launching ramp.

The overall length of the Ba. 349A was 21ft. 3in., the span 13ft. 1in., and the wing area, 51.6 sq. ft. From tip to tip, the vertical stabiliser measured 7ft. 3in.

Operation

Launched almost vertically, the machine rose from its 80ft. ramp under power from dry-fuel A.T.O. rockets mounted on the fuselage at the tail-end. Although it was usual to use four units each developing 1,100lb. thrust and operating for 6 seconds (probably the Walter 109-505 di-glycol powder type), the Schmedding 553 producing 2,200lb. thrust for 12 seconds was the alternative. In the latter instance, only two charges were employed, and these were the units originally developed in the final research of the BP-20 prototype. The initial acceleration was slightly greater than 2g., and the rocket assisters were jettisoned at a height of about 5,000ft., by which time the main bi-fuel engine was developing full power.

The take-off ramp was pivoted near its base so that it could be brought horizontal to enable the "Natter" to be conveniently loaded from its transport; the tips of its wings and lower fin having been strengthened to run in the three guide rails.

Upon receiving the usual warning of raiders approaching, the pilot climbed into his cockpit and was elevated by his crew into the launching position. The course of the bombers was to be checked by a standard radar predictor, and the setting passed direct to the auto-pilot in the interceptor through an electrical link broken at the instant of take-off. Thereafter, the machine was steered automatically on the pre-set course until the pilot took over to make corrections to his flight path caused by the movement of the bombers since the time of launching. The course of the raiding aircraft was, of course, radioed from the ground to assist the pilot in his manœuvres.

Closing in on the bombers, the pilot jettisoned the plastic nose fairing exposing his rockets. His machine drew rapidly to firing range and levelling up with the aid of a simple ring and bead sight, the nose racks were suddenly empty, with flame and blast encompassing the target.

Evasive action by the bombers would have been difficult because breaking formation would have meant lone bombers fighting off conventional patrol fighters without the covering fire that would otherwise have been afforded by supporting machines. Thus, had it been found possible to guide the fast climbing "Natter" with a reasonable degree of accuracy, there can be little doubt that its development would have been most beneficial to Germany's air defence.

Having expended his armament, the pilot was no longer able to control his aircraft because of the displaced C.G.

The remainder of the story suggests little more than a fight for survival. The pilot's first action was to operate a lever, which detached the complete nose section of the machine. When the air pressure had carried it clear, the pilot, still sitting in his seat, was exposed in the open. By this time he had snapped open the buckle of his harness and the operation of the second lever then caused the ejection of the tail parachute. This applied a violent braking effect on the aircraft, pitching the pilot forward out of his seat, whereupon—after perhaps being in the air for barely two minutes—his parachute opened automatically, and he was wafted back to the ground. At the same time, the remaining section of the interceptor divided and the more valuable portion, containing the engine and accessories, also descended beneath its separate parachute for re-use.

It is clear that the job of a Luftwaffe pilot towards the close of hostilities was no basis for planning a future.

Production of the "Natter"

The "Natter" was produced in two type series, the original production version, Ba. 349A, and a development, Ba. 349B.

There was little difference between the prototype (BP. 20) and the early production models, and all that was noticeable to the observer was a modified lower fin. This was short and brought forward in Bachem's original design, but in production the vertical stabiliser was square-cut and almost equal in length above and below the fuselage. The only other alteration was that, on some machines of the "A" series, an austerity engine had been substituted, the HWK 109-559.

Originally projected at the time when recovery of the power plant had not been considered, this unit embodied an uncooled combustion chamber, a simplified pumping arrangement and was without electric starting. Its development was obviously no mean achievement, despite the fact that it was only called upon to operate for two minutes. The motor, which probably embodied a ceramic liner in place of the cooling jacket, delivered a maximum thrust of 3,750lb. and was equally as controllable as the more durable types.

The Ba. 349B, of which there were only a few produced by the time of the defeat, was propelled by an HWK 109-509D Walter engine. This unit was not vastly different to the "C" version, having an additional "cruising" chamber which, operating with the main chamber, gave the machine a maximum speed of 621 miles per hour at 16,400ft. and boosted the climb to 37,300ft. per minute. The all-up weight was 4,920lb., only 120lb. greater than the earlier model, and the wing loading at take-off 95.5lb. per sq. ft., reducing to 37.6lb. per sq. ft. when expended of propellant. Flying at an average of 495 miles per hour, and by careful use of the two chambers, the machine could be operated under power for four and a half minutes.

The overall length of the "B" sub-type was 20ft. 7in., all other leading dimensions remaining as in the Ba. 349A. Thus, the wing area, too, was unchanged. The all-up weight at take-off, including four dry-fuel assisted take-off units totalling 1,000lb., was 4,925lb., reducing to 1,940lb. at the time of break-up for landing. The parachute for landing the tail fuselage and motor weighed 88lb. At take-off the wing loading was 95.5lb. per sq. ft., diminishing to 37.6lb. per sq. ft. with tanks dry.

Designed from the mass-production view-point and using only semi-skilled labour in its construction, the machine was not sufficiently advanced in production to see service during the war. Its development had apparently been greatly hampered by Allied air assaults, and eventually, in view of the highly satisfactory results achieved in tests of the rocket-boosted Messerschmitt 262 jet-fighter, production orders were cancelled.

The Heinkel "Julia"

Of the three designs for rocket interceptors rejected in favour of Bachem's "Natter," the Heinkel "Julia" would seem to have been the most promising.

The general layout was really quite orthodox despite a prone piloting position, and although launching was vertical the 'plane was able to glide and land in the normal manner. Again, sweepback and all unconventionalities were avoided, the obvious intent being to produce a simple and easily produced structure. It did not, however, incorporate the degree of simplicity that Bachem's team had embodied in the "Natter." It is true that the airframe of the "Julia" was more to the form of a normal fighter, but the fact that the 'plane could be operated repeatedly did not carry much weight with the German Air Ministry. It was obvious that the loss of an easily replaced interceptor did not matter so long as Allied bombers were knocked out before they had a chance to reach their objectives. In any case, the pilots of local defence interceptors were fortunate to find a suitable landing field within gliding range and forced landings would invariably "write-off" a returning machine as surely as if it had been abandoned in mid-air.

A "Natter" streaks skywards under the control of its auto-pilot. The climb was assisted in the initial stages by four dry-fuel rockets which contributed 4,400lb. thrust. These fired for six seconds and were jettisoned at about 5,000 feet, leaving the internal bi-fuel Walter engine to operate for the remainder of the flight at a maximum thrust of 3,520lb.

(To be continued.)

Technical and Scientific Register

A RECENT meeting of the Electrical Engineering Committee was attended by Sir Arthur Fleming, Col. Sir Stanley Angwin, Mr. J. R. Beard, Mr. W. K. Brasher (secretary, Institution of Electrical Engineers), Mr. E. S. Byng, Mr. C. W. Marshall, Mr. E. A. Mills, Mr. H. J. Nunn, Dr. C. C. Paterson and Mr. C. Rodgers (B.E.A.M.A.).

Amongst the various questions considered by the committee were proposals for securing employment for men who joined the technical branches of the Forces immediately on graduation and are now being demobilised. They have not previously had industrial experience, but many have had the advantage of commissioned service in technical corps and have shown qualities of leadership and initiative which should be of great value to industry. Suggestions made by the committee are likely to lead to experimental schemes of training in industrial concerns with a view to preparing these ex-Service personnel for responsible posts after training. The committee realise that adequate pay arrangements will be required in order to make training schemes of this kind economically practicable.

The committee stressed the importance of developing still further the close co-operation which already exists between the Ministry's Technical and Scientific Register and the Professional Engineers Appointments Bureau, and expressed the hope that industry generally would make use to the fullest possible extent of the facilities offered by the register.

The Technical and Scientific Register of the Ministry of Labour's Appointments Department, which is operating from York House, Kingsway, London, W.C.2, has the benefit of the guidance of advisory committees, composed of leading representatives of the various professions catered for by the register, to ensure that it is providing the greatest possible service to employers seeking professionally qualified technical and scientific staff, and to those seeking appointments.

The chairmen are Sir Arthur Fleming (electrical engineering), Sir William Stanier (mechanical engineering), Sir Peirson Frank (civil engineering), Sir Robert Pickard (chemistry), Sir Lawrence Bragg (scientific research) and Mr. T. E. Scott, F.R.I.B.A. (Architectural and Public Utilities Advisory Committee, including surveying, town planning and valuation).

Rocket Propulsion

Details of Three Further Rocket-fighter Projects

By K. W. GATLAND

(*Continued from page 13, October issue*)

This is the HWK 109-509A1, first bi-fuel rocket engine to be fitted in service aircraft. It was produced in large quantities at the Heinkel works during 1944, and drawings were subsequently acquired by Japan at a cost of 20,000,000 Reichmarks.

THE "Natter" was an altogether better solution, and it was *simplicity*, coupled with considerable *fire-power* in the shape of explosive rockets, that put Bachem points ahead of his competitors.

The "Julia," however, was a good runner-up, if only for the fact that it was designed to take off vertically.

On the ground and approaching from the side it would have been difficult to convince an observer that the "Julia" could climb at over 39,000ft. per minute, or, indeed, was anything more enterprising than a glider. A glider, of course, it was when the tanks had been drained, but with the HWK 109-509B Walter engine firing from the tail its *cruising speed* was nearly 500 miles per hour.

Design Features

Main identification features were the high wing location and the absence of a protruding cabin. The pilot was accommodated in a prone position at the extreme nose, and, hence the line of the fuselage was unbroken save for two landing skids, one beneath the cockpit and another about half-way between nose and tail. The fuselage, nevertheless, was not so refined aerodynamically as the more normal high-performance fighters, and its design, as in most machines of its type, was obviously very much a compromise between capacity within and streamlining without. The propellant, comprising 1,550lb. T-stoff and 490lb. C-stoff, was contained in tanks grouped about the c.g., and the machine's weight after take-off was 4,040lb., the wing loading 67.6lb./sq. ft., reducing to 27.0lb./sq. ft.

The wing had a span of 15.1ft. and an area, including anhedral tips, of 77.5 sq. ft. The wing fixing was high and about mid-way along the 23ft. length of the fuselage.

Operational Aspects

Designed to take-off along a vertical ramp, the "Julia" was assisted into flight by four 1,100lb. thrust di-glycol powder rockets, the initial acceleration being slightly in excess of 2g, and the rate of climb during the early phase 39,400ft. per minute.

The speed fell off from about 620 miles per hour just after take-off to 560 miles per hour at 36,000ft.

In comparison with the "Natter" the fire power of this machine was remarkably small. Two 30mm. cannons only were carried, housed in blisters one on either side of the cockpit and having 60 rounds per gun.

It is true that in this machine it would have been difficult to house a battery of explosive rockets without causing a disastrous movement of the c.g., after they had been fired, but apart from suspending them from beneath the wings, there appeared to be no easy solution. Wing mounts were not very desirable because of the extra drag that they would involve, and no doubt this was the main reason for fitting the two cannons.

If the rapid-climbing rocket interceptor is to hold a place in future defence systems, however, it is obvious that its fire-power must be substantially improved, and consequently the explosive rocket may be expected to displace the cannon shell. This implies the development of expendable or semi-expendable types, and the trend is evidenced by a report that large numbers of fighters, following the general design of the "Natter," are being produced for the Russian Air Force. It is well known that a great deal of research has been conducted since the surrender at Peenemunde, where Russian and German technicians now work side by side.

Of further interest is the fact that the "Natter" (along with the Me. 163B) was found under construction in Japan, drawings having been dispatched from Germany by submarine. The manufacturing rights of the Walter 109-509A1 engine had been previously acquired in 1944 at a cost of 20,000,000 Reichmarks.

The two remaining rocket types were the EF-127 "Walli" (Fig. 80), a Junkers project, and the Messerschmitt 1104 (Fig. 81), both of which had normal flight characteristics, taking off on jettisonable wheels and landing on skids. They were each to be powered by the standard HWK 109-509B Walter engine.

The Me. 1104

This small fighter was another that might easily have been mistaken for a light glider. The fuselage, 18ft. in length, was almost cylindrical in section, rounded at the nose and slightly tapered towards the tail. A tall oblong fin and rudder emerged vertically from the centre-line of the rear fuselage, and the square-tipped plane was attached to the fin just above the root.

A well-faired cockpit was placed about a third from the nose with a shoulder wing fixing for the 20ft. 4in. span mainplane, which, like the tail surfaces, was square cut.

The all-up weight was 5,300lb. at take-off, including 1,980lb. T-stoff and 660lb. C-stoff, and the initial wing loading 75.5lb./sq. in.

Without resorting to auxiliary rockets, the take-off run was only 170 yds., the designed rate of climb being the same as that specified for the "Julia," 39,400ft. per minute. The initial acceleration was 1.45g., and, having climbed to 40,000ft., the machine was said to be capable of gliding a distance of over 50 miles, which was usually ample to reach a landing base. The difficulty, however, was that the glide range was appreciably less should the motor cut out at a lower altitude.

The armament was limited to *one* MK.108 30mm. cannon, with 100 rounds.

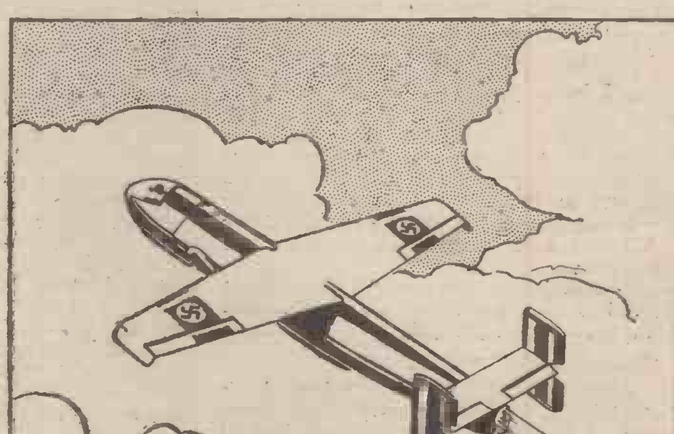


Fig. 79.—The Heinkel "Julia," in which the pilot occupied a prone position. Like the "Natter," it took-off along a vertical ramp.

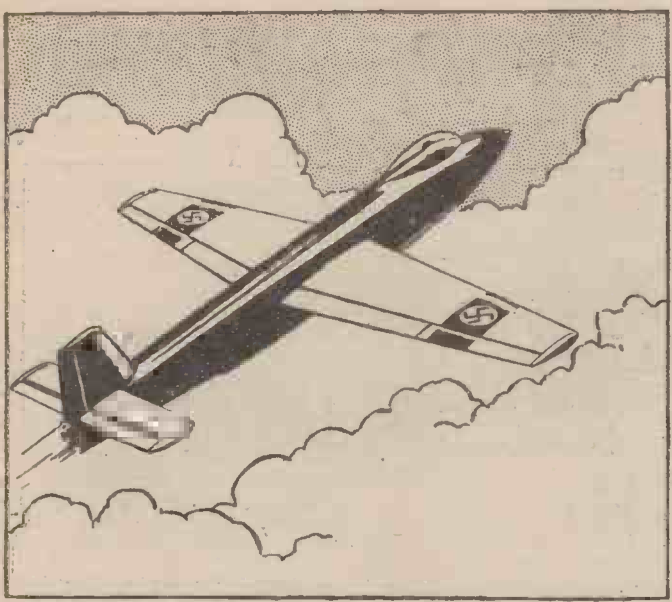


Fig. 80.—The Junkers "Walli." A better-looking aeroplane than its contemporaries, but lacking in many respects.

The "Walli"

There could be no excuse for mistaking the purpose of the "Walli." Its fuselage was cylindrical in section, pointed at the nose, narrowing towards the tail, and mounted high at the tail end was an oblong stabiliser with a single vertical fin and rudder. The short span wings were even more to the rear than in the previous designs, the root fixing being slightly below the fuselage centre-line.

As was the case in the Me. 163 and Ju. 8-263, a small wind-driven generator at the nose supplied the electrical services, whilst the pilot's cabin just aft of this was covered by a nicely designed "clear-view" hood.

Weighing 6,450lb. when fully fuelled, the machine was airborne within 370 yds. This was from a standing start, unaided by rockets or any other catapulting device, and rising from the ground at the rate of 26,000ft. per minute, the pilot experienced a maximum acceleration of only 0.67g.

The maximum speed achieved in level flight at sea-level was in the region of 630 miles per hour, but at 36,000ft. this figure had dropped to 560 miles per hour.

All other essential details, weights and dimensions, are as follow: propellant, T-stoff 2,400lb. and C-stoff 1,100lb.; weight (immediately following take-off), 6,140lb.; and weight (dry) 2,720lb. The wing loading at take-off was 68.0lb./sq. ft., reducing to 28.8lb./sq. ft. at the time of landing. The wing was only 20.7ft. in span with an area of 95.7 sq. ft.

It was intended to use two 1,100lb. thrust A.T.O. rockets acting for six seconds in the production version.

The armament was precisely the same as fitted in the "Julia," two Mk. 108 cannon firing 60 rounds per gun.

Summing Up

Despite many admirable points, it is obvious that these fast-climbing interceptors also embodied weaknesses, summarised as follow: (a) the limited duration of flight under power, (b) the need for a horizontal take-off run in the "Walli" and Me. 1104, (c) the small fire-power of all machines other than the "Natter," and (d) the increased liability to error in sighting due to the high speed of engagement.

Apart from (a) the semi-expendable "Natter" suffered none of the disadvantages, as obviously (d) did not apply as the machine was in essence a piloted missile—and a very effective one at that.

It was also obvious that to be fully effective these machines should take off from the precise spot from which they could rise directly in way of the attacking bombers as they formed for their "run in." Had it not been found possible to arrange vertical launching, special take-off strips would have had to be constructed and, of course, this was largely impossible within the suburbs of most cities. The only other alternative was to use the standard air-fields, most of which were placed on the outskirts of industrial areas, and whereas rocket fighters could be operated from these, their small-powered endurance did not permit them to cover all points of the compass. It thus became essential to disperse these interceptors more or less in a circle around the more vital potential targets, leaving the use of airfields to the jet and propeller fighters, which were less affected by their disposition at take-off.

Future Defence Methods

The exceptional climbing rate is, of course, the most favourable advantage, especially in view of the present trend towards jet-powered bombers, which should prove able to range abroad with almost the same fleetness as present patrol fighters.

Such high-speed invaders will not allow much time for even jet fighters to fly off and climb to interception height. It will therefore become increasingly more the job of the guided missile, and (though perhaps only as an interim measure) the expendable interceptor, to check the initial assault, leaving the rocket-boosted "jets" to engage where possible, but coming into full play as the bombers turn for home.

Eventually, with the further development of radar guiding technique, there is no doubt that the human element will be eliminated altogether, making obsolete the orthodox fighter; but then by the same token so also will the piloted bomber have become a weapon of the past. It is no secret—although only because rocket experiments are difficult to conceal—that technicians in each of the principal nations are pressing ahead with research to make the long-range rocket strategically accurate. Already, in fact, the establishment of a regular Atlantic rocket-mail service, England to America, is officially contemplated, not as a possibility of the remote future, but in terms of a few years' further development. The long-range mail rocket obviously is not far removed from the war rocket, with its more sinister cargo of plutonium explosive.

The significance here does not remain alone in terms of a weapon with better potentialities for destruction. From the political viewpoint we may find the rocket of infinitely greater value than a thousand Peace Conferences, for few nations, no matter how ambitious in outlook, would wish to enter into a war in which atomic bombs could be so simply exchanged on all sides.

Walter Units—Early Tests

These few details of German attempts at rocket interceptor design are sufficient to give some idea of the faith the German Air Ministry placed in the Walter engines, which, contrary to general belief, were not purely a wartime development.

It is, in fact, surprising to find that the first flight tests of a T-stoff rocket unit took place in the autumn of 1936; the 'plane a small primary trainer, the Heinkel 72 "Kadett."

This pioneer motor was exceptionally small, and very simple. The T-stoff (concentrated hydrogen peroxide) was fed by air pressure into a single combustion chamber which itself was filled with a paste catylist. Combustion was, of course, spontaneous, and although the thrust was virtually constant, a degree of control was afforded by an "on"-"off" lever which worked a cock in the compressed air line.

A thrust of 150kg. (330.7lb.) was obtained for a specific consumption of about 9g/kg/sec., the power lasting for some 45 seconds.

This was quite an achievement in those early days, but the D.V.L. pilots who carried out the tests were not that much overawed by the results. The thrust and power duration were reasonable, but these factors were greatly outweighed by the lack of control. This was apparent from the outset, and consequently no very extensive flight trials were made with this installation. Instead, research was directed towards perfecting a suitable *liquid* catylist, and eventually success was found in the use of Z-stoff, a saturate aqueous solution of calcium (or sodium) permanganate.

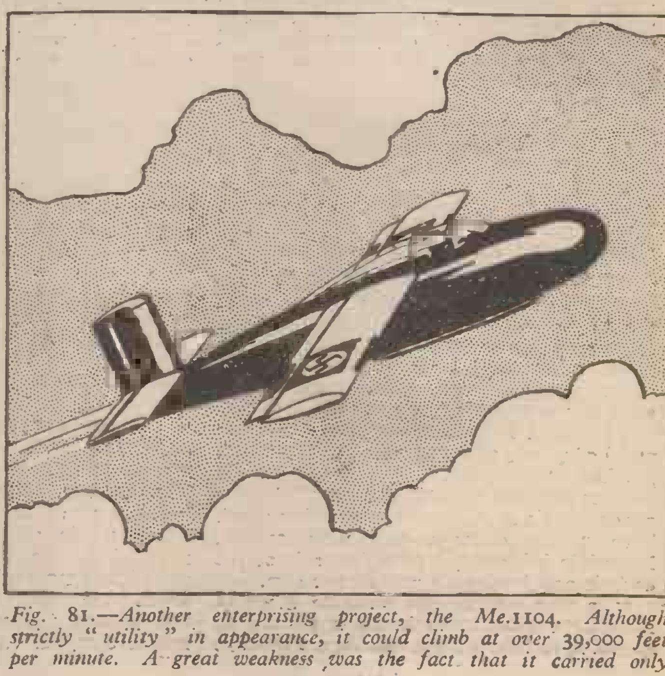


Fig. 81.—Another enterprising project, the Me.1104. Although strictly "utility" in appearance, it could climb at over 39,000 feet per minute. A great weakness was the fact that it carried only one cannon.

A new motor was then built, and after a series of bench tests was fitted in a F.W.56 "Stösser." The results of flight trials at Neuhardenberg in the summer of 1937 proved beyond all doubt the efficiency of the system, but it was somewhat surprising that again no attempt was made at varying the thrust. It was, however, an easy matter to throttle two liquids, and this further refinement was left to later development.

The Z-stoff was fed by air pressure in precisely the same manner as the peroxide, the two components coming together in the ratio of about 1 : 20 to yield 300kg. thrust for 30 seconds. A specific consumption of approximately 10g/kg/sec. was maintained throughout.

From this point on, progress was largely in the perfection of details, with Walter working at Keil mainly responsible for the fundamental research. Then, with the coming of war, another experimental factory was set up at Beerberg, in Silesia, where in 1942 Dr. I. N. Schmidt was put in charge of development. It was here that most of the prototype Walter engines were built and bench tested before being handed over to the Heinkel works at Jenbach for production. Flight tests were carried out at Peenemunde, Rechlin, Lechfeld and other airfields in the Beerberg area.

Among the first service aircraft to be fitted with controllable rocket boosters were the Messerschmidt 109E and the Junkers 88. Both of these installations were, however, experimental, and it was not until late 1943 that the rocket engine was sufficiently developed for operational use.

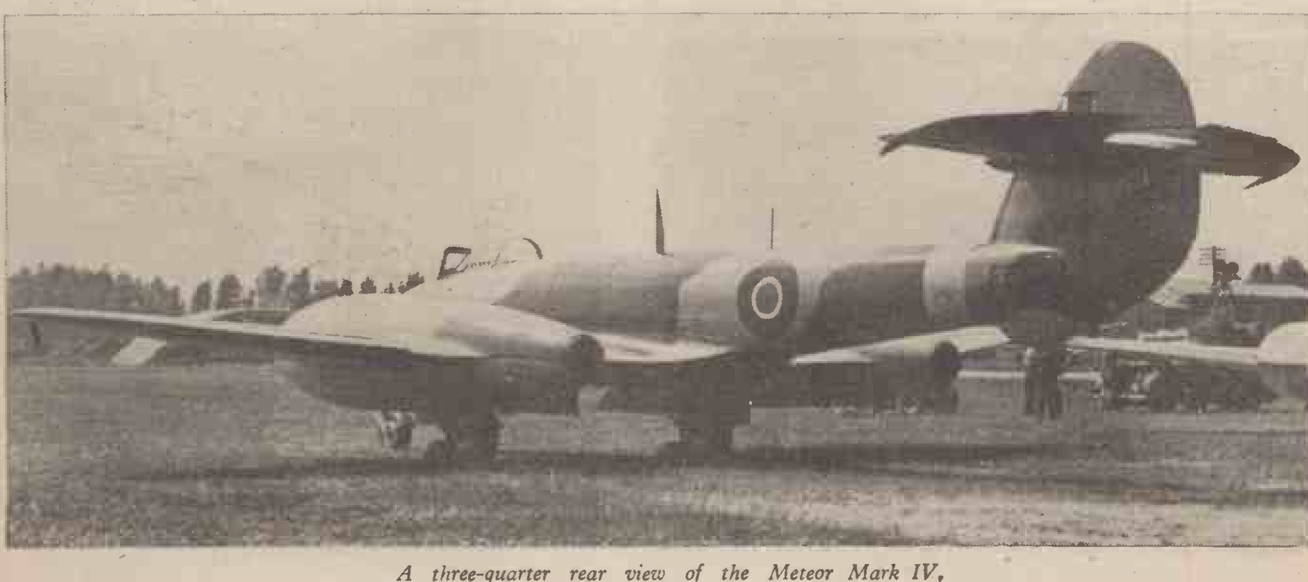
(To be continued)

The Air-speed Record

The Meteor Mark IV in flight, piloted by Group Captain E. M. Donaldson.

THE attempt to raise the air-speed record above the 606.25 miles an hour established on November 7th, 1945, was made on Saturday, September 7th this year, and a new record of 616 miles an hour was established over the three-kilometre course between Bognor Regis and Worthing. The speeds for the four laps flown by Group Captain Donaldson were 623, 610, 623 and 609 miles an hour, giving an average of 616 miles an hour. Squadron Leader Waterton averaged 614 miles an hour in four laps in a similar machine. The aircraft were similar to those used for the previous record, namely Gloster Meteor Mark IV fighters, powered by two Rolls-Royce Derwent Mark V jet-propulsion engines. The thrust of the Derwent V engine, as fitted in the standard service machine, is 3,500lb., but the jet-propulsion units used for the previous record were adjusted to give 3,600lb. thrust. For the latest record the thrust was given as 4,200lb.

Group Captain Donaldson checking up on the controls of the special Meteor IV.



A three-quarter rear view of the Meteor Mark IV.

Rocket Propulsion

Projected Rocket and Composite Rocket-athodyd Fighters

By K. W. GATLAND

(*Continued from page 53, November issue.*)

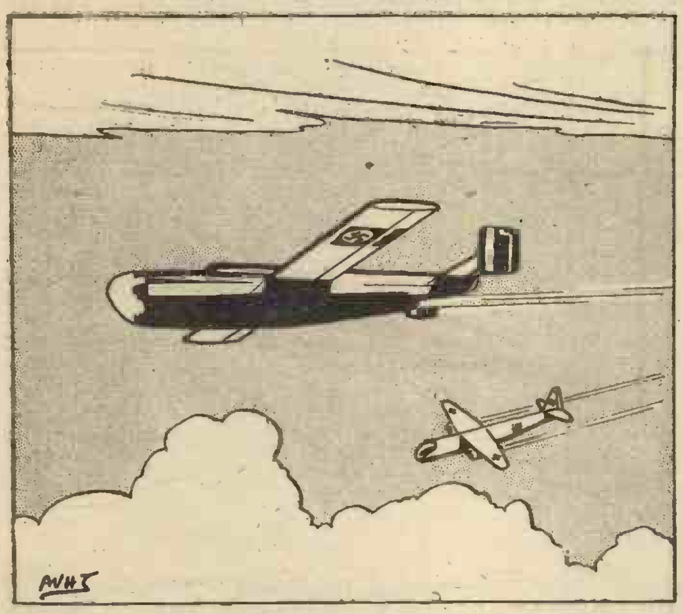


Fig. 82.—An Arado development in early stages of production at the time of the surrender. This tiny rocket fighter was to be carried into action beneath a jet-powered bomber.

ANOTHER special purpose fighter making use of the Walter 109-509A1 rocket engine was found under construction in the Arado works. This was an exceptionally tiny monoplane (Fig. 82), and its small proportions can be gauged from the fact that it could not accommodate the rocket unit in the extreme tail, a "step" having been embodied in the lower fuselage through which the exhaust emerged at a slight downward angle.

The mainplane had a high root fixing, and twin fins were fitted at the tips of an oblong tailplane. A prone piloting position helped to reduce the cross-sectional area of the fuselage and to delay critical "g" pressures, but most interesting of all was that it was intended to operate the machine from a jet-powered bomber.

Test flights had, in fact, already been made, using the then newly produced Arado 234C-1 as the parent. This four-engined "jet" was a particularly enterprising aeroplane, for despite a fully fuelled weight of 24,200lb., its maximum speed (between 530 and 550 m.p.h. at 20,000ft.) was greater than most of the fighters which accompanied Allied bombers. The tiny Arado fighter was fixed beneath its broad fuselage and, under combat conditions, would have been released just out of range of enemy fire.

In comparison with the designs which other manufacturers had in stages of project, the Arado development seemed no great departure from the orthodox. It was just another bold attempt to "out-fly" Allied aircraft, but like the majority of its contemporaries, came a trifle too late.

A further interesting project was the D.M.2 (Fig. 83), a rocket-powered flying-wing. Again, intended as a high-speed interceptor, this particular design was originally the work of Professor Lippisch, and was based on a standard pattern which had been evolved as the result of extensive tests with rocket-driven research models.

It was not simply a "tail-less" machine. There was no fuselage at all, the all-wing structure, thick in section at the root and tapering sharply towards the tips, sweeping back within a contained angle of 60 deg. A large vertical fin emerged on the centre-line at the rear.

The pilot was accommodated in a semi-prone position entirely within the contour of the wing section, and there was no cabin "blister" or other excrescencies to spoil the shape. His cabin afforded excellent vision in all directions except rearwards, the nose being completely covered with "clear-view" Plexiglas. Flight at high altitudes was made possible by pressurisation, supplied by three large oxygen cylinders.

The propulsion unit was of a type similar to that employed in the early versions of the Messerschmitt 163, known as the Walter R2-211. Its main difference was a more slender combustion unit to suit the thin wing section, having a smaller chamber and a long tapering nozzle. The tanks, designed to have a total capacity of 8,000 litres of T and C stoff, were naturally disposed over the c.g., so that balance would not be upset as the propellant was consumed.

A retractable tricycle undercarriage was embodied, the nose-wheel folding directly backwards between the pilot's heels, while the two main wheels came upwards, rotating through 90 degrees to lie flat in wells situated at the sides of the grouped engine accessories and behind the main propellant tanks.

It is obvious that the landing speed would have been high, and for this reason the designer had embodied a large flap area. The flaps, in fact, extended almost the entire length of the trailing edge, and it would appear that the outer pair also operated as elevons (single aerofoils serving the dual purpose of elevators and ailerons). A 2in. gap separated all control surfaces from the main structure, wing and fin, and this refinement in the case of the flaps was probably to increase the lift when they were lowered for landing as it permitted air from the upper wing surface to be deflected downward to supplement the under flow. The increased mass of air deflected when the elevons and rudder were operated made for increased sensitivity, which was particularly desirable for a machine of this type at low speeds.

The control column, which, owing to the prone piloting position was only about 1ft. 6in. high, was coupled to a servo gear to compensate for the decreased leverage.

Although no performance figures are available, it is obvious that the machine was intended to operate at high speeds, possibly bordering on supersonic speeds. It was, however, only one of several all-wing projects designed to Lippisch formulæ.

Another was an athodyd powered fighter with rocket booster (Fig. 84), said to be capable of travelling at 1,500 m.p.h. The remarkable feature of this machine was the fact that it used no fuel other than blocks of carbon, these being set inside a simple "straight-through" duct and preheated to incandescence just prior to flight. The pilot was to be installed near the nose, lying prone, the air entering from a central intake being ducted around his slim cockpit and flowing to the single heating chamber.

Launching was to have been by powerful assisted-take-off rockets, the machine accelerating along an inclined ramp, and once the air began to ram into the intake the high-velocity draught would serve to inflame the carbon, raising its own temperature in the process. At high speeds, large masses of air would be continually ramming through the duct and at a pressure so great to make any mechanical means of compression entirely superfluous. Expansion in the heating chamber would be rapid as the result of the intense heat thrown off by the carbon, the resulting jet finally emerging through a narrow slit in the trailing edge.

As far as is known, only model research had been conducted, but the numerous free-flight tests the Germans had been able to make in the few months available to them

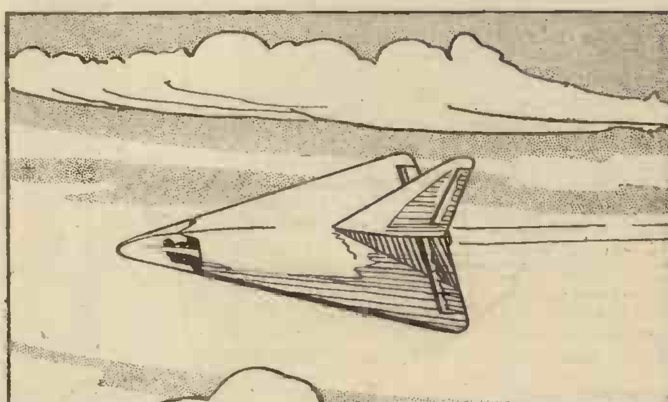


Fig. 83.—From research with flying models came this design for a rocket-driven "flying-wing," the D.M.2.

prior to the surrender would seem to have been particularly encouraging. The original experiments using carbon alone permitted a flight of 45 minutes' duration, but employing a paraffin spray to prolong the life of the heating blocks, the period of power was said to be virtually doubled. With this system, however, there would have been little opportunity for varying the thrust, although two possibilities that come to mind are the obvious ones: (a) of varying the area of the exhaust duct, and (b) the provision of bypass ducts so that a proportion of the air could be deflected away from the heating chamber should it be desired to "throttle-down."

A further machine making use of athodyd propulsion was one projected by the Focke-Wulf company (Fig. 85). This was a type not far removed from the normal high-performance fighter, though with two outstanding differences, namely, a 45-degree wing sweep-back and the unique mounting of its two propulsive ducts.

The fuselage was exceptionally slim, tapering smoothly to almost a point at the nose. The shape of the rear was almost identical but the provision of a rocket unit had necessitated a slightly larger section towards the tail. A neat "Plexiglas" hood emerged slightly more than half-way back from the nose, the single fin joining the line of the cabin and projecting beyond the fuselage end.

The tail-plane itself raked back at an even greater angle than the wings, and at its tips were fitted the two 4.4ft. diameter athodyds, an arrangement made possible by their light weight. This must have involved something of a nightmare for the company's stress department, and it is clear that the necessity for a strong angular transport member was the main reason for the acute tail sweep-back. It did not, however, interfere with the control system, which remained orthodox with normal rudder and elevators.

The Walter bifuel rocket engine developed a thrust of 6,600lb. and was to be used in take-off to accelerate the machine to the speed at which the ram pressure was sufficient to operate the ducts. A kerosene fuel was specified as the heating agent, the resulting jet to provide a 680 m.p.h. top speed at sea-level and a climbing rate of 31,000ft. per minute at 3,000ft. If, however, the 'plane was climbed to 36,000ft., the maximum speed in level flight would fall to 590 m.p.h., and naturally the climbing rate also suffered a loss, reducing to 5,100ft. per minute.

In consequence, it is suspected that the rocket system would have its main purpose in boosting the climb, and it is obvious that it would have been employed also in landing as athodyd units cut out at about 200 m.p.h.

At sea-level, the machine was said to be able to fly under full power for 13 minutes, but this could be much improved by a direct climb to 36,000ft., when 43 minutes' endurance could be expected.

The main weights and dimensions given in the design tender are as follows: an empty weight of 5,900lb., and a fully loaded weight (including fuel and pilot) of 12,000lb. The wings had an area of 205 sq. ft.

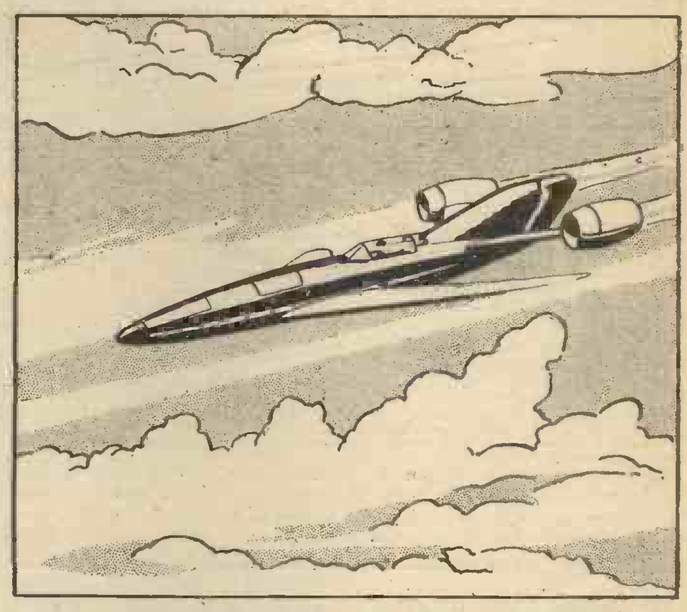


Fig. 85.—A "tail-drive" athodyd project from the Focke-Wulf stable.

A High-speed Helicopter

As the war in Europe drew to a close, yet another design for an athodyd fighter was taking shape in the Focke-Wulf project office, this time a high-speed helicopter (Fig. 86).

Of all the schemes, this was by far the most unorthodox, for it was an entirely new approach in aircraft design. The machine embodied a nicely streamlined fuselage with the pilot contained in the extreme nose, but there all semblance of conventionality ended. It was intended to stand vertically on wheels mounted on its four fins and tail fuselage and to take off from that position with the aid of a three-blade rotor which revolved *around the fuselage*. This rotor was unique in itself, for it had no means of internal drive. Its propulsion arose from athodyds mounted at each blade tip, and once started by rockets these would cause the rotor to spin round at high speed.

The launching procedure would consist first in driving the rotor up to a speed at which the athodyds could operate. The blades would be set to give zero thrust during this operation and thus the ducts could be functioned without causing the machine to lift.

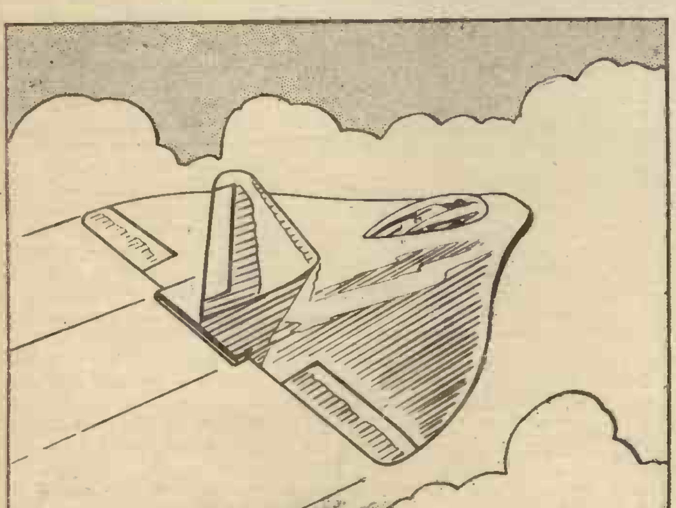


Fig. 84.—1,500 miles per hour—and on no other fuel than solid carbon. That was the estimate made by Professor Lippish for this athodyd-powered "flying-wing."

Within a few seconds the ducts would be working smoothly and the pilot had then only to operate a control to cause the blades to assume a slight angular pitch sufficient for the machine to rise gently upward. The vertical speed could be increased to a maximum of about 75 m.p.h., and having gained sufficient height, the machine would be turned into a horizontal path by deflecting its rudders and elevators, appearing as in Fig. 86.

An increase in the blade pitch would progressively improve the forward component of the duct thrust, the rotational speed of the rotor naturally falling as the result of the greater load.

At sea-level, the maximum speed expected was 620 m.p.h., the rotor operating at 520 r.p.m., which in terms of the speed would be 690 m.p.h. The initial rate of climb quoted is 25,000ft. per minute, with an endurance of 0.7 hours and a 400-mile range. At an altitude of 36,000ft., however, the forward speed would be 520 m.p.h., the duration 2.3 hours, the range 1,100 miles, and the climbing rate only 4,000ft. per minute.

The descent was just the take-off procedure in reverse, the machine coming to rest gently on its tail—or so it was said. How it was proposed to remove the pilot from his precarious position remains a mystery.

The *profile drag* of this design was said to be about one-fifth that of a normal machine of the same dimensions, but the *induced drag* would have been twice as great as a wing equal in span to the diameter of the rotor—37.4ft. The ducts themselves were little more than 2ft. in diameter and involved practically no resistance.

The structural weight was 7,000lb., somewhat greater than that specified for the previous Focke-Wulf project, while the all-up weight at take-off was 11,400lb.

Other Athodyd Proposals

The projects illustrated in these pages were by no means the only ones to be based on athodyd propulsion. There was, for instance, the Heinkel P.1080, a tail-less machine with swept-back wings and two duct units, 16ft. long and extending quite two-thirds its overall length, fitted at each wing joint.

At the Skoda works was being planned an athodyd fighter in which a 31ft. Saenger duct formed the basis of its bulky fuselage. The general layout, however, was orthodox, with a mid-wing fixing and a single vertical fin on which the tail-plane was mounted just above its root fixing at the rear.

A nose cockpit enclosure was incorporated above the intake duct in which the pilot was to lie prone. There was provision for a heavy calibre cannon to be mounted just above his head, and a large capacity fuel tank, also installed on top of the duct, took up a position over the aircraft's c.g.

The machine was estimated to have a sea-level speed of 630 m.p.h., with a maximum thrust of 9,700lb.

Yet another proposal was for an adaption

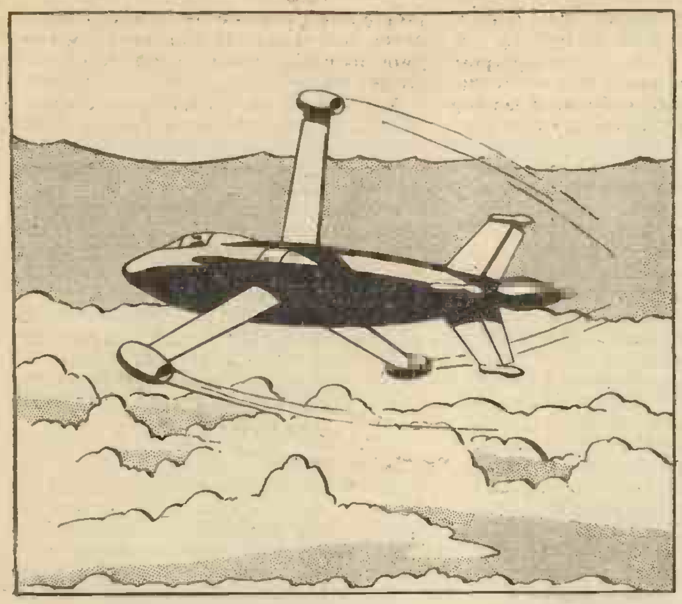


Fig. 86.—Another Focke-wulf project, this time a high-speed helicopter. Three athodyds were to drive its rotor, but most unorthodox of all, the machine was to stand vertical on wheels fitted in the tail-end. It would rise directly upward and then operate in horizontal flight, travelling at a maximum speed of 620 miles per hour.

of the Messerschmitt 262 with two Saenger athodyds in addition to its standard Jumo 004 turbo-jet units. The performance figures derived for this combination, however, were not particularly encouraging. The maximum speed at sea-level was estimated to be 620 m.p.h., but the climb to 36,000ft. would have taken over six minutes with fuel consumed within 40 minutes.

Summary

The foregoing is some slight indication of what promises for the future, though undoubtedly a great deal of further research will be required before the athodyd becomes a practical means of aircraft propulsion.

In very high-speed aircraft, the prospects are particularly great, for it has been calculated that at speeds upwards of Mach 1.4 and at a height of 40,000ft., the athodyd will develop a greater thrust per square foot of frontal area than the most efficient turbo-jet.

There are, however, serious obstacles. Even at quite high forward velocities, the athodyd's fuel consumption is between 50 to 100 per cent. greater than that of the mechanical-compression type.

It loses power with height because, unlike the rocket and turbo-jet, it is not "supercharged." The performance figures quoted for the Focke-Wulf "tail-drive" fighter tell their own story; a reduction of 90 m.p.h. from top speed at sea-level was registered at 36,000ft., while the climbing rate for the same conditions involved a loss of 25,900ft. per minute. For efficient operation, it is clear that a rocket booster is essential, and although extra tankage would be required to contain the rocket propellant, the fuel needed for the athodyd could be much less.

The higher the speed of the athodyd, the greater is the thermal efficiency. A speed of 1,300 m.p.h. at sea-level would produce an intake pressure of about 60lb./sq. in. (a figure which compares favourably with the 4-to-1 compression ratio of our best turbo-jets) with the fuel consumption then also a more reasonable proposition.

The U.S. Navy Department was one of the first to produce working examples of the athodyd. A number of various applications have been tried, and among the most successful were athodyd projectiles weighing 70lb. and capable of speeds up to 1,500 m.p.h.

An interesting point about them is that they required no auxiliary fuel feed. The fuel was contained simply within a double-walled liner positioned over the heating chamber, and it was only necessary to pre-heat this tank to cause the fuel to start issuing through the burner jets as the result of its own expansion.

Ignition

The jets were ignited immediately and the missile fired into the air with the aid of its auxiliary rocket. Its speed would quickly become sufficient for the ram pressure to take over, the high temperature created by the burners in the pressurised region producing expansion and jet reaction. The self-feeding process naturally continued throughout.

(*To be continued.*)

Modern Abrasives

Their Composition, Manufacture and Uses

THERE is no doubt of the fact that man has always been an abrasive-using animal. For, from far back in the mists of remote antiquity there have come to us man-made tools and implements which, crude although they may be, show unmistakably the marks of a rubbing-down process which has been applied to them.

The stone arrow, the ancient axe, the first attempts at the fashioning of knives and other metallic cutting instruments must all have been submitted to some process of grinding and shaping, and, indeed, on many of these prehistoric articles the actual marks of the grinding implement can be plainly seen.

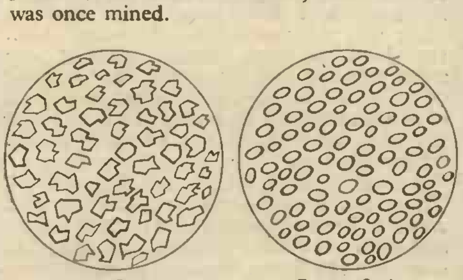
The earliest form of grinding, which, incidentally, has persisted right up to the present day, consisted in the rubbing of one thing over another, as, for instance, the frictional contact of one stone across another one of similar or, perhaps, harder texture.

Common Grindstone

The common grindstone forms an example of this, the earliest of abrasive operations. Actually, however, the grindstone as an abrasive agent is not a very efficient article, for it neither grinds nor cuts. The traditional grindstone merely rubs the article against it and exerts rather a haphazard tearing-away action on the object than a true grinding effect.

The first real scientific advance in the application of abrasives came with the more general utilisation of emery and its making up into compact stones and grinding wheels.

Emery is, of course, a naturally occurring mineral which has been known (yet surprisingly little used) for thousands of years. It occurs plentifully in Greece and, indeed, it derives its name from Cape Emeri, in the Greek island of Naxos, near which it was once mined.



Emery grains wear round with frictional rubbing, but grains of silicon carbide (carborundum) split under friction and continually present fresh cutting edges.

In composition, emery is an impure form of aluminium oxide mixed with iron oxide. It is reasonably tough without being unduly brittle and, although at the present time it has to meet much competition from the synthetic abrasive agents, it still retains its many large-scale and commercial uses.

Powdered flint used at one time to be a favourite abrasive, but such material is now less used, in view of the varying nature of its composition and physical characteristics.

Garnet

Garnet, however, is a natural abrasive material which still has its uses. In composition it is a silicate of aluminium mixed with iron oxide, resembling in this direction the precious stone, which is a crystallised form of it. Abrasive garnet, however, usually occurs in the form of a gravel, which is washed, ground, and carefully graded as to particle size and employed either as a substitute for emery or in admixture with it.

Sand, of course, has long been employed as an abrasive, as witness, for example, the now almost traditional sandpaper. So, also, have powdered glass, brick dust, and similar materials, although, strictly speaking, the particles of these substances exert a tearing rather than a true abrasive action.

The era of modern abrasive materials was initiated, perhaps, by the coming of carborundum, or silicon carbide, a material which was invented by the American chemist, Edward Goodrich Acheson, in 1891. This nowadays well-known and, indeed, indispensable material is made by fusing in an electric resistance-furnace a mixture of coke and sand, together with a little salt to make the mass more readily fusible and a small quantity of sawdust to render it porous.

During the 36 hours of continuous fusing which the manufacture of carborundum requires, a temperature of no less than 3,500 degrees C. is reached, a terrific heat

Rocket Propulsion

Problems of High-speed Flight : Research Aircraft

By K. W. GATLAND

(*Continued from page* 89, *December*, 1946 *issue.*)

IN the six previous articles, emphasis has been on the rocket-fighter and the possibilities of the simple ram-jet athodyd. There is still much to be related of the strictly military aspect, but in order to obtain a more complete idea of the problems which, in view of the close proximity of the sonic "barrier" to aircraft speeds, now face designers of fighters, it will be desirable to investigate the methods by which data is obtained to base the design of new types.

Prior to the advent of jet-propulsion, designers were little worried by compressibility. It is true that shock waves were occurring at local points on the aircraft, for instance, behind underslung radiators and at wing joints, but by careful streamlining most of the troubles were satisfactorily overcome.

The position to-day is far more perplexing. In the past it has always been the power plant that has lagged behind, and, very largely, it was the structural designer to whom credit was due in improving performance of aircraft. Now, the case is completely reversed. No longer has the airframe designer to wait patiently for the engine manufacturer to coax a few more horsepower out of his already highly tuned product.

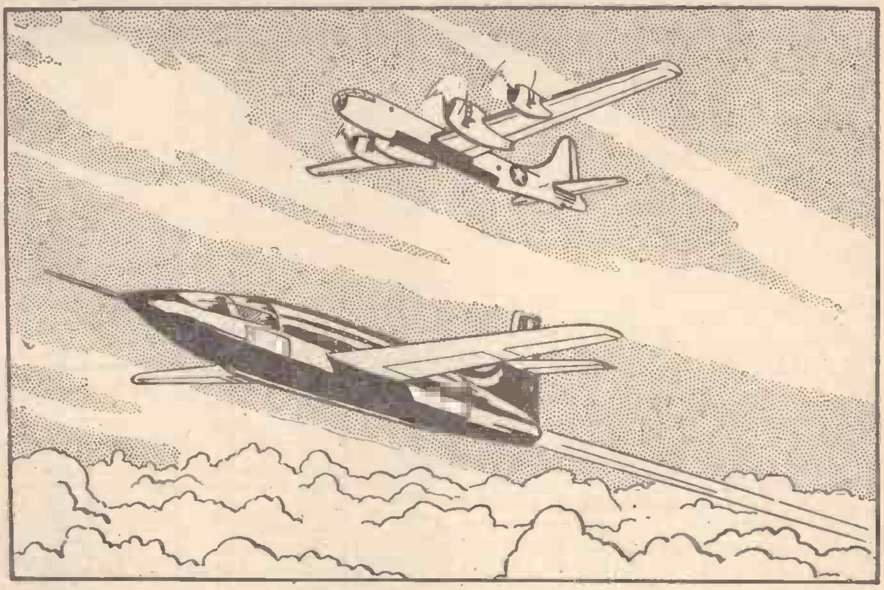


Fig. 87.—An impression of the Bell XS—1 after its release from a specially modified B.29. In forthcoming tests it is hoped to attain speeds in excess of sound and to fly at over 15 miles' altitude.

It is a fact that many jet and rocket engines now in production have quite considerable *reserves of power* which literally dare not be used because structures and controls are not yet ready to withstand such great stresses as would be imposed at anything approaching full throttle. So rapid is the rate of engine progress that aeroplanes in project a year or two ago and now approaching production stages will, in the light of new design technique, soon be ready for the scrap heap. Witness the cancellation by the Air Ministry of the Miles M.52 contract.

Dangers of Compressibility Shock

The dangers of flight near the sonic region were made only too clear in the tragedy which overtook Geoffrey de Havilland while testing the D.H.108 tailless research aeroplane. An explosion in the 3,500 h.p. "Goblin" engine was the popular theory for the mishap, but this was soon discounted by de Havilland technicians. The more likely explanation is that the machine was flying at a speed approaching sound values and compressibility caused its break-up, possibly upon encountering an air-pocket. The vibrations set up in the airframe under such conditions would have been considerable.

What then, one may ask, is the best shape for such high-speed aircraft? The answer to this question is open to argument, but high in consideration is the true "flying wing," for in this form the weight could be spread more uniformly over the span. The cantilever wing and tailplane are the most vulnerable in orthodox aircraft because the air-flow is always tending to lever them from the fuselage, and therefore a self-contained structure containing engines, fuel tanks and all other miscellaneous equipment evenly distributed across a single expanse of wing would be far less likely to receive a mortal blow as the result of compressibility. The D.M.2, reviewed in last month's article, is an excellent example of this type.

Higher flying speeds thus introduce a problem of great magnitude—the risk of "flutter." Whereas at moderate foward speeds the air always has a damping effect and causes any vibration (started perhaps by a gust or a sudden movement of the controls) to die out rapidly, the opposite is often the case when travelling at speeds upwards of 500 m.p.h. The damping qualities of the air may disappear or, worse still, actually contribute to *building up* the vibrations with increasing amplitude, when the beats can then become so violent that fracture of the structure follows within a very short time. It is, therefore, obvious that the aircraft which go out to pierce the sonic "barrier" (about 760 m.p.h. at sea level) will have involved some knotty problems for the design and stress technicians who conceived them.

The structural problem, however, is by no means the designer's only headache. His efforts are required to perfect new control systems, both to maintain stability and permit manœuvres at high speeds, and yet enable safe flying in the low speed register.

At present there seems no alternative other than to produce "compromise aircraft," which means that form (exterior) efficiency must always be impaired by the need for a reasonably moderate landing approach. In any event, there does not appear to be a great future for aircraft which fall out of the sky at 170 m.p.h., as the Miles M.52 supersonic research aeroplane was intended to do.

Flying Wings and Supporting Jets?

To satisfy both structural and aerodynamical problems at high speeds, the flying wing layout then emerges as the logical development. Small wing area, knife-edge sections, acute sweep-back—these are the more obvious requirements for trans-sonic and supersonic flight, making the aeroplane efficient in reducing drag at high speeds but, alas, poor in qualities of lift at the time of landing. An ultimate solution may be found in the use of turbo-jets balanced by three-axis gyros to provide an upward or supporting thrust, permitting the aircraft to hover and descend slowly in the same manner as a helicopter; but this is mere speculation as yet. However, there does not appear to be an alternative answer, unless one considers folding or partly retracting wings; but few to-day would suggest that either of these schemes was practicable.

There is little doubt that as flight loads rise and wing areas diminish—as it seems logical to expect in the attainment of increasing speed —landing will present one of the pilot's greatest hazards.

Fig. 88.—Small athodyd ram-jets have been fitted experimentally to the Bell X—83, development of the "Airacomet."

Friction

The difficulties that manifest themselves when flight in or above the speed-of-sound range is considered are truly enormous. Not only has the structure to be of herculean strength and the control system such as to permit safe flying at all speeds but *friction* also gives rise to concern.

The heat generated by air buffeting may be as much as 400 degrees at 1,500 m.p.h., and so it is reasonably safe to say that pilots and crews will need refrigeration. A solution to some degree, however, is found in flight at great heights. At 80,000 feet, for instance, the outside temperature will be 67 degrees below zero and thus, in order to eliminate as much bulky refrigeration machinery as possible, forthcoming test flights are being planned to take place between 60,000 and 80,000 feet up. Eventually, it is reasonable to expect that all flights by long-distance jet-driven aircraft will be in the stratosphere, for not only does the heating problem find partial solution but drag reduces with altitude. At 60,000 feet the drag for a given speed would be approximately one-fourteenth as much as it would be at sea-level, or, in other terms, only one-fourteenth of the power would be required for propulsion. A climb to 80,000 feet and the resistance becomes one-twentieth that at sea-level, one-half that at 60,000 feet.

This would be an encouraging prospect but for the fact that the efficiency curve for the jet-engine begins to fall off around the 60,000 feet mark. The turbo-jet and the athodyd require vast volumes of air to operate, and again the compromise path is the only one left open. Whether the rocket engine, which—at this stage it is surely unnecessary to stress—operates independent of atmosphere, will eventually rectify this state of affairs is yet to be seen, but its voracious appetite in fuel would seem to limit its application in all normal conceptions of commercial aircraft. A ceiling of 55,000 feet, at least, should give a reasonable operating efficiency for high-speed turbo-jet and athodyd-driven airliners, and this is some consolation.

Definitions

In this vast study that is opening up in flight at ballistic velocities, it is inevitable that new terms will creep in to augment the already extensive aeronautical vocabulary. Already, aerodynamisists have presented us with several additions, and it will be as well to explain some of them. *Mach number*, for instance, is the relation of flight speed to the speed of sound, M=1, and hence, *Machometer*, an instrument recording the relation of flight speed to the speed of sound. More familiar are the speed zone terms: *subsonic*, less-than-sound; *trans-sonic*, range of speed lying between M=0.8 and M=1.2; *supersonic*, faster-than-sound; and then, *compressibility*, phenomenon occurring as flying speed approaches sound values, causing sudden change in density and pressure with accompanying increase in drag and decrease in lift. *Shock waves* are a wave formation—the outward (and under certain conditions visible) sign of compressibility.

Having summarised briefly some of the problems related to flight at trans-sonic and supersonic speeds, it is now possible to investigate matters a trifle more fully in the light of work that is proceeding with high-speed research aircraft, both manned and unmanned.

Undoubtedly the most significant of these special types is the Bell XS-1, a machine said to be capable of 1,500 m.p.h. at 80,000 feet altitude. Some confusion had arisen in early descriptions of this project, for it was originally said to be athodyd-driven and to incorporate a rocket booster, but a recent Press release by the manufacturers has now clarified matters and an impression of the machine is given in Fig. 87.

The XS-1 has a strong outward resemblance to the Miles M.52 supersonic research aircraft (work on which was abandoned last February), but its power derives from four bi-fuel rocket engines and not from turbo-jets or athodyd ram-jets. A possible explanation is that confusion arose from the fitment of athodyd units at the wing tips of a Bell XP-83, development of the "Airacomet" (see Fig. 88), which, incidentally, crashed during a recent test flight.

The fuselage is packed tight with fuel tanks, and the pilot, clad in a pressure suit, fits snugly into the bullet-shaped nose, which had actually been designed to suit the dimensions of Jack Woolams, the firm's test pilot. Short-span thin-section wings and tail-assembly are also the vogue.

The machine had already completed satisfactory glide tests, having been taken up to about 30,000 feet beneath a specially equipped B-29 and released. Woolams was loud in his praises of its flying qualities, and so successful in fact were considered the preliminary tests that preparations were in hand for the first flight under power.

Everything went according to plan—until the tragic news was received that Woolams, having entered a special P-63 in the Bentix Trophy Race, had crashed to his death.

Now, with a new pilot at the controls, a further series of glide tests will be necessary, and it may be months before thoughts can again be directed toward powered testing.

When, however, the XS-1 eventually drops away from its parent B-29 and for the first time shoots away under power, it will not be just a "do-or-die" attempt to out-fly sound. The beginning of another testing phase, doubtless even more extensive than the previous glide flights, will have begun, and only when the machine has performed satisfactorily at moderate subsonic speeds and the pilot has gained some experience of flight at really great altitudes will it be reasonable to expect the throttle to be pushed into "maximum boost."

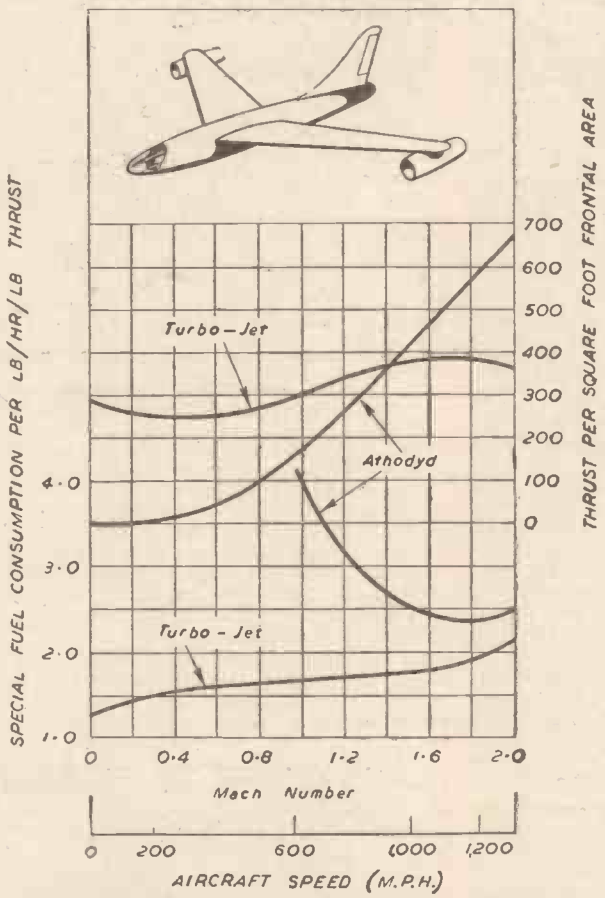


Fig. 89.—*A graph prepared from figures given by Dr. S. G. Hooker, of Rolls-Royce, Ltd., comparing a high-output turbo-jet with an athodyd ram-jet at 40,000ft. altitude. In the inset, the author illustrates a logical development, a tailless fighter with athodyd units at the wing-tips, and a booster rocket in the tail fuselage.*

The voracious consumption of its motors will limit the duration under power to within a few minutes, but, nevertheless, having been released at a height of about 35,000 feet, the pilot is expected to climb to between 70,000 and 80,000 feet before making his bid for maximum speed.

The XS-1 has been constructed by the Bell Aircraft Corporation with co-operation from the Material Command of the Army Air Forces at Wright Field and the National Advisory Committee for Aeronautics. The four bi-fuel rocket engines were built by the Reaction Motors, Incorporated, a firm inaugurated during the war and which was responsible for many of the power units of American guided missiles.

A recent disclosure suggests that the new unit develops 6,000lb. thrust at sea-level and that its development occupied the firm in research for four years. It is more powerful than any of the Walter bi-fuel engines and has a far greater operating efficiency.

The unit may be presumed to be a developed version of the 1500N4C, weighing 210lb., and consisting of four cylinders, each capable of delivering 1,500lb. thrust. Each cylinder contains an igniter, combustion chamber and expansion nozzle.

What fuel the machine carries has not yet been made known, but it is probably an alcohol compound with liquid oxygen.

Low Speed Research with Supersonic Aerofoils

An attempt to obtain reasonable lifting characteristics in supersonic section wings at low forward speeds is seen in the tests of a full-scale wing and tailplane of the projected M-52 on a Miles M.3B "Gillette" Falcon, basically a Falcon Six four-seat monoplane powered by a D.H. Gipsy Six Series II in-line engine.

The fuselage of the developed Falcon is the sole link with the commercial version, and even the fully trousered undercarriage, originally rooted in the wings, has been replaced by a strutted chassis fixed around the cabin under-fairing. This has elminated any possibility of turbulence in the air flowing over the "knife-edge" bi-convex wings, which, incidentally, were of all-wooden construction and high-gloss finished.

By the time all modifications had been completed the Falcon was a single-seater, with the cockpit fitted out with a formidable array of special recording instruments and two additional fuel tanks. Flight tests were commenced in August, 1944, and when the machine was satisfactorily trimmed an M.52-type tailplane with independent elevators was fitted. This arrangement, however, was eventually displaced by a special "all-moving" tailplane.

The comparative figures for the two versions are given below, with the Falcon "Gillette" data quoted in parentheses for easy reference: Dimensions: Length, 25ft. (25ft.); span, 35ft. (29ft.); height, 6ft. 6in. (7ft. 9in.);

wing area, 181 sq. ft. (160 sq. ft.); weights: empty, 1,550lb. (1,730lb.); loaded, 2,525lb. (2,500lb.); performance (speeds): maximum, 180 m.p.h. (164 m.p.h.); landing, 40 m.p.h. (61 m.p.h.).

Work on this enterprising little research aeroplane was abandoned when the contract for the M.52 was cancelled. The data obtained from its numerous flights, however, must have proved of immense value in designing the parent machine, and in view of the vast speeds expected of future aircraft it is obvious that more and more attention will need to be paid to research toward ensuring safety in flight at low speeds.

Control Problems

Then there is the problem of maintaining control at *high* speeds. In orthodox aircraft, the first effects of compressibility manifest themselves at about 500 m.p.h.; controls stiffen and become sluggish, and as speed increases still further, the pilot has great difficulty in manœuvring his aircraft.

Several possibilities have been suggested, and one of the most promising is illustrated in the fitment of "drag rudders" at the tips of the new XP-79B flying-wing fighter. These consist of small open ducts, the area of which can be moderated independently. To cause a change in direction to port, it is necessary only to restrict the flow through the port duct. The drag built up on that side then naturally results in the machine turning.

A similar scheme is the fitment of small rocket motors at the tips, but this would be rather wasteful in fuel.

In future high-speed aircraft, especially in fighter types, there is little doubt that athodyd ram-jets will occupy the space at the wing tip, with turbo-jets or rocket units mounted inboard, either in the fuselage or at the wing roots. It should then not prove too difficult a matter to incorporate the principle of the "drag rudder" in the athodyd motor. A device to vary the area of the intake would satisfy the problem admirably.

The light weight of the athodyd makes it ideal for installation at the wing tip (see Fig. 89), and, indeed, this is the logical step to expect from the successful carriage of "overload" fuel tanks and bombs in this manner, an arrangement first tried on the "Shooting Star" and which is now common practice in the U.S. Wind tunnel tests have shown it to be a most efficient location owing to the inevitable formation of vortex. A streamlined protuberance at the tips, therefore, involves no great increase in drag, and with athodyds the form efficiency may be expected actually to benefit.

(*To be continued.*)

Science Notes

By Prof. A. M. LOW

IT will be interesting when the cinema gives us a reasonable imitation of stereoscopy. Perfect colour, extreme speed, with probably a few smells thrown in. Some of the films that I see are a terrible waste of our celluloid that ought to be devoted to discovery. Not so long ago there was a great discussion as to how a fly landed on a ceiling. Did it fly upside-down, or did it do a somersault at the last moment? High-speed pictures have soon illustrated that these charming insects either make a half-loop or half-roll, as our pilots say, a few inches from the ceiling, thus making a perfectly good six-point landing. Yes, they have six legs. For many years Plato gave the number as four, which was considered to be so logical that no one ever troubled to look. That probably was an early instance of the bad method of learning by alleged logic instead of by the best of all systems—that of scientific observation. The fly, I should mention, has free feet, which can easily hold on to the small hills and dales of a whitewashed surface. Under a microscope, a ceiling looks like the mountains on the moon, a razor edge like a saw, and the most beautiful skin in the world like a rather ancient toad. As I explained before, everything is relative, and beauty is in the eye of the beholder. I want to make it clear that the fly knows that also.

Are You Wrong?

IT is extraordinary that popular errors should last so long. Lightning is not attracted by your penknife on the table. A few miles of air are much more important. But that is the interesting point. There is nearly always some slight truth in a fallacy. To suppose that a small piece of steel could make any difference to a lightning flash is ridiculous, but it is true that the lightning would prefer to pass through steel rather than air. The sun does not put out the fire, but makes it more difficult for you to see whether the little flame is there, and prevents your discovering so quickly that the wretched thing has gone out. Pokers leant against a grate do not increase the draught, but I suppose they would do so to an extent that could hardly be measured by the most sensitive instrument. I often think that some of the most laughed-at sayings of our grandmothers were very true. At one time it was common practice in the West of England to scrape the mould from a copper kettle which had been left in a dark cellar and to use this mould for curing septic wounds. Humiliatingly like penicillin, is it not? We all know that bee venom is an important medicament, but I am sure that doctors who had said so forty years ago would have been condemned as quacks. "The hair of the dog that bit you" is a very common phrase, yet to dissolve the hair of a cat and to inject the resultant liquid has proved very useful in the diagnosis of asthma. Many sufferers are greatly affected by the presence of a cat. I am no believer in witch doctors, but when they used to stick pins into a wax image it is not impossible that this was merely a mascot which helped them to concentrate thought, and that the result was mildly inimical to their enemy. No doubt a far more common case was the surreptitious dose of poison, but I would not like to state that the witches, on the other hand, were quite all nonsense. One should be very careful before stating a fact without adding: "Or so it seems to me."

Don't Hurt the Snail

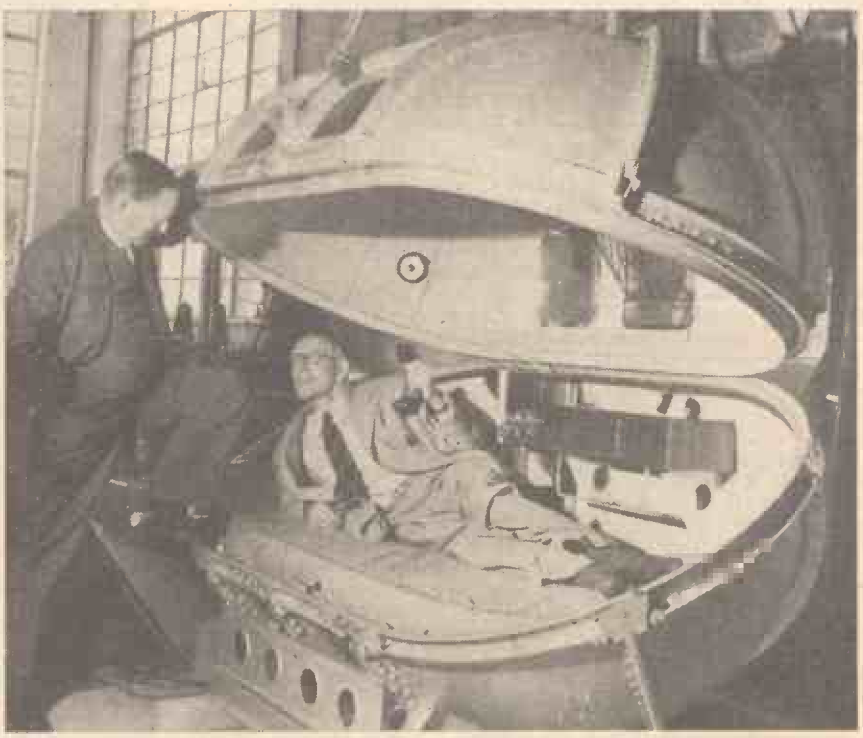
NATURE designed her products so much better than any human being could hope to emulate. Nature also knows all about speed. A jet of water travelling fast could knock a hole in you; travelling slowly it is fars ofter than butter.

Put a razor blade edge upwards and a snail in front of it. The snail will climb over that blade using its own lubrication so that tiny particles of mucous substances act as roller bearings. It moves so slowly that it will safely traverse a bridge which even a fakir might find very troublesome.

Child's Play

HERE is a simple problem to which any child should be able to give an answer; yet it is one which can puzzle all of us very easily.

When a fast bowler is practising spinning a ball can the ball progress faster after its first bounce than the speed at which it is originally thrown? I should say "yes," because he might throw it very slowly, but with so high a speed of rotation that upon contact with the ground its peripheral velocity would be far higher than the rate of its forward motion. So it will jump forward or sideways.



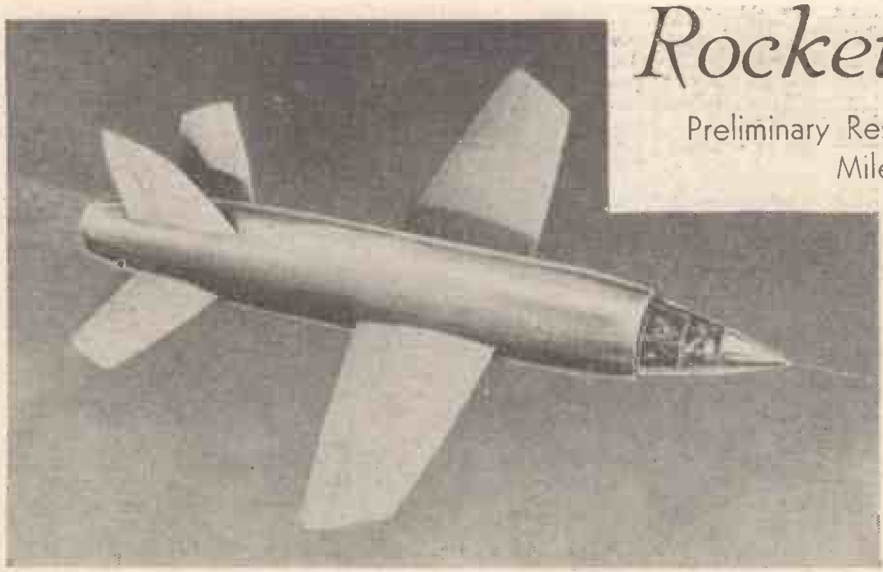
This Easter-egg-shaped pressure chamber was specially designed for Mr. Winston Churchill when his doctors had warned him of the danger of his flying at a greater height than 8,000 feet. The cabin is fitted with a comfortable couch, ash trays, cupboard, bookshelf and telephone.

Rocket Propulsion

Preliminary Research With the "Natter": The Miles Trans-sonic Project

By K. W. GATLAND

(*Continued from page 129, January issue*)



An impression of the completed prototype, M.52, designed to reach 1,000 m.p.h. in level flight at 36,000 feet and climb to that height within one and a half minutes.

IT will be recalled that an exhaust-vane system, working in conjunction with tail-plane elevons, was the control arrangement finally adopted in the Ba.349 "Natter." The reason was that in spite of an initial acceleration of about 2g., the speed at which the machine climbed from its launcher was generally no more than 35 m.p.h., and hence, the airflow over wing and tail during the period contributed little to control and stability. The condition was further aggravated by the rearward position of the c.g. when the A.T.O. rockets were mounted at the tail; actually as far aft as .60 of the wing chord.

To offset the instability which had been observed during early tests of the BP-20 prototype, auxiliary surfaces one metre square were attached by means of explosive bolts to each tip of the tail stabilisers, and these were blown off simultaneously with the dropping of the spent take-off rockets. This modification temporarily increased the tail-span to 14.8ft.

After jettisoning, the c.g. moved forward to between 18 and 25 per cent. of the chord (depending upon the amount of fuel and armament) and the remainder of the flight was invariably well stabilised.

Exhaust-vane Stabilisers

In order that the two conditions should be properly investigated, a proportion of the trial launchings was made with auxiliary tail-tips and part without.

These tests, however, were greatly hampered by the inefficiency of the Schmidding boost rockets: explosions resulting in the total destruction of aircraft were not infrequent, and the firing duration of those rockets which acted varied by as much as 100 per cent. from charge to charge. A few of the ascents were nevertheless successfully carried out, and although the increased tail-area did steady the near vertical climb, Bachem and his technicians were not entirely satisfied.

It was H. Bethbeder—credited as co-designer of the "Natter" with Bachem—who suggested the exhaust-vane system, and this would have displaced the tail-tip gear had the machine gone into service. Two vanes were fitted in a test machine, and these interconnected with the tail elevons so that—for instance—a pulling back on the stick raised both air-stream and gas-stream controllers. The significance of this arrangement, however, was when the machine flew under the control of an auto-pilot, for in the almost vertical climb, any deviation from true course would automatically bring about a corrective movement of the controls and a return to the original flight path

In the early stages of the ascent, as previously stressed, the air flowing over the wings and tail was moving relatively slowly, and this gave the air-stream controllers little opportunity for proper function. The gas-stream, on the other hand, was always fast moving, and thus the thin metal vanes set in the exhaust were effective both at high and low forward speeds, so long as the engine continued to function. At least this would have been the case had it been found possible to construct the vanes with sufficient durability, but despite hollow construction and internal water cooling, they invariably burned up and disappeared after the first 30 seconds of flight.

This should not be taken to imply that exhaust stabilisers could not be built with improved reliability. The experiments which Bethbeder conducted were necessarily hurried, and there is little doubt that given time for development a liquid cooled system could be made to work effectively throughout the full thrust period.

The Auto-pilot

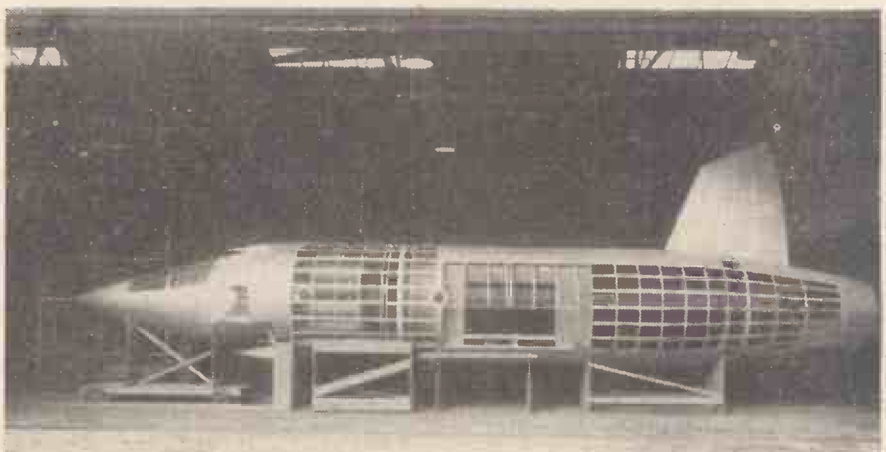
Another fault in the initial testing of the "Natter" was that the three-element auto-pilot was unreliable, and in the few flight tests made with the device the elements would not properly synchronize, with the result that ascents were erratic and far worse than in earlier launchings, when the controls were simply preset and locked.

In the majority of test-flights, small aileron-type tabs were fixed to the wings, so that the 'plane executed slow rolls during the climb above some 650 feet, when an altitude of about 9,000 feet was usually attainable.

Glide-testing the "Natter"

Some interesting data were forthcoming when glide tests were conducted. A BP-20 was ballasted to a gross weight of 3,750lb., with the c.g. at 25 per cent. of the chord, and towed to an altitude of 20,650 feet by a Heinkel He. 111. It was then released, and in the time available for glide before the pilot baled out, the following characteristics were noted: that (a) Stability was excellent and controls light and well co-ordinated for indicated air-speeds between 125 and 440 m.p.h.; (b) There was no rolling moment due to sideslip, and no apparent yawing moment due to the differential deflection of the elevons to produce roll; (c) The rate of roll was estimated at one revolution per second; (d) At 250 m.p.h. a full circle could be turned in approximately 20 seconds; (e) The controlled stalling speed was 125 m.p.h. indicated air-speed, which occurred at an angle of attack of about 30 degrees; and, perhaps most significant of all, (f) that the handling and flying qualities were judged by the pilot to be *superior* to those of any of the standard German single-seat fighters.

This particular flight might well have ended in disaster, for when the pilot operated the break-up control in order to gain his exit from the aircraft (which should have detonated the explosive bolts and released the complete nose section) it failed



This full-scale mock-up of the Miles M.52 shows clearly that most of the fuselage space was to be occupied by the special power jets engine and augmenter.

to work, and he had to battle his way out through the cockpit enclosure.

Although the release functioned smoothly in two earlier unmanned glide tests (when the gear was worked by a timer) it was not 100 per cent. reliable, and on later models was replaced by one having a purely mechanical action.

Miles Trans-sonic Development

It is now opportune to investigate the Miles M.52 project aircraft, for although the contract for the full-scale machine was cancelled in February, 1946, its form design remains in the Vickers rocket-powered research model now undergoing flight tests. A great deal has been heard lately of these experiments in which, it will be recalled, the aim is to penetrate the "sound barrier" in level flight, and therefore no apology is offered for including details of the interesting "jet" aeroplane which led to its development.

The decision for Britain to build a piloted aircraft for free-flight research at trans-sonic and supersonic speeds was taken by the Air Ministry in 1943. It was well known at the time that German aerodynamicists were advanced in similar projects, and for that reason no time could be lost in meeting the possible threat of "faster-than-sound" fighters and bombers from across the Channel.

The "flying-bullet" is an apt name for the Miles project. Its design was the outcome of extensive calculations governing the flight of shells and bullets and of research with special laminar flow "bi-convex" wing and tail sections.

The Project Stage

Armed with as much data on ballistics as they had been able to obtain, the Miles project engineers set about the task of shaping the fuselage. A three-stage jet engine and its fuel would obviously take up most of the space and naturally largely governed the cross-sectional diameter and length. The rest was a matter of suitably refining the shape to involve minimum resistance and to provide a cabin and suitable intakes for the engine.

Meanwhile, other technicians whose job it was to investigate wing form were busy with their own calculations and research, carefully refining out a special bi-convex aerofoil, strong yet thin and knife-edged for travel through the trans-sonic zone while embodying reasonable slow-flight characteristics.

The technical difficulties were immense, but with a basic pattern finally evolved, the next step was the construction of a complete model for wind-tunnel tests. This phase of the proceedings was the one in which the theories and calculations were put to a thorough check. Fortunately, only a few minor alterations were necessary to pass the shape as satisfactory, and the project was soon ready for handing on to the general design offices where the work was carried on in detail.

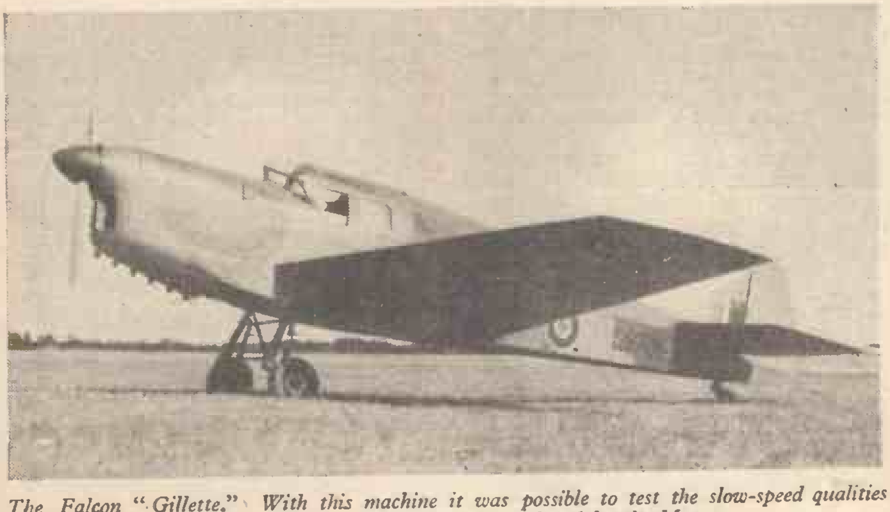
The bullet-like lines of the M.52 are well displayed in this model of the Miles trans-sonic project.

Not only had the Miles technicians virtually to formulate a new aerodynamical theory but they had to devise a control system fully workable in the subsonic register, but equally effective when flying in the region of the trans-sonic and above. It was also necessary to furnish the pilot—placed in the aircraft's pointed nose—with an automatic means of escape in the event of emergency.

A moveable tail-plane was provided for maintaining trim during flight at the various speeds because, under certain conditions of flow, the normal trailing-edge type control ceases to function satisfactorily. The arrangement was tested at low speeds on the Miles "Gillette" Falcon, described in the previous article and illustrated on this page.

The main-plane, 27 feet in span and mid-set on the 33 foot fuselage, is the thinnest cantilever wing structure ever attempted. A set of dive recovery flaps only 3in. deep and 12in. long were to be fitted on the undersurface.

The materials used in the construction of the airframe and wings were naturally of much higher strength characteristics than usually employed; a high-tensile steel structure with a heavy gauge high-duty alloy as covering.



The Falcon "Gillette." With this machine it was possible to test the slow-speed qualities of the special wing and tail-plane developed for the M.52.

The Power Jet W2/700 plus No. 4 Augmenter

The power plant—23ft. long and 3ft. 6in. in diameter—was designed and built by Power Jets (Research and Development) Ltd Its rated power is the equivalent of 17,000 b.h.p., but as will be seen, this was substantially improved by the incorporation of a ducted fan and augmenter.

There are three stages, the first consisting of an orthodox jet unit with centrifugal blower and turbine, the latter serving an additional purpose (stage two) as a ducted fan, bringing in a separate supply of air through intakes placed just behind the main annular air-scoop. The air from this source is then mixed into the main "jet" stream which flows on through a length of ducting where supplementary fuel burners are placed. In this third "augmenter" stage, further expansion (and hence, acceleration) of the stream takes place before its final ejection, thereby adding materially to the thrust of the basic engine.

A special tubular structure provides mounting for the engine and also secures the cabin.

The Control Cabin

It was anticipated that testing should begin at 50,000 feet altitude and the cabin was pressurised to provide for this.

The seat for the pilot was placed directly upon the cabin flooring and his feet raised above floor level, the nose wheel retracting into a housing between them.

The controls were naturally servo-assisted. The expected control loads on the M.52, said Mr. Miles, were approximately 100 times greater than those experienced on even the largest of present day aircraft. And yet, despite the small size and great weight of this machine, it was expected to be easily manageable both at high and low speeds. The all-up weight was calculated to be about 8,200lb. at take-off, with a wing loading of 58lb. sq.in., and this implies a high landing speed; 170 m.p.h. with a two-mile landing run were the figures quoted. Special tyres and wheels, in fact, had to be designed to withstand the shocks involved.

Emergency Escape

To allow the pilot a reasonable chance of survival should any mishap occur during testing, the complete nose-section was made detachable, its release to be effected by means of cordite charges which would blow the cabin (with pilot still housed within) clear of the aircraft. Cleats filled with the explosive were to be fixed to the cabin supports which would be sheared by the touch of a button. A large parachute, packed in the rear end of the cabin, would then automatically open and bring the speed down to a safe value for the pilot to bale out in the normal manner.

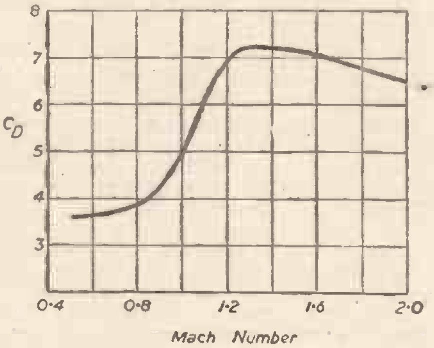
Recording Equipment

The aircraft having its sole purpose in research, many of the instruments had to be specially developed. The micro-observer, for instance, was intended to measure and photograph electrically all the readings required, this with the aid of sensitive Tinsley galvanometers on which there were 24 separate readings. Another special apparatus was a cathode-ray oscillograph to measure the strains produced in certain fundamental positions of the structure, photographing the results.

A full complement of 18 instruments, in addition to a transmitting compass and oxygen control, would have furnished complete data of flight conditions through the "sound barrier," and as the whole would be registered on film, the pilot had no other concern than control his aircraft. In the past are the days when test pilots grappled with knee pads, hurriedly scribbling down instrument readings with one hand while endeavouring to maintain control with the other.

Contract Cancelled

The reason why the contract for this enterprising machine was cancelled when the detail design was 90 per cent. complete,



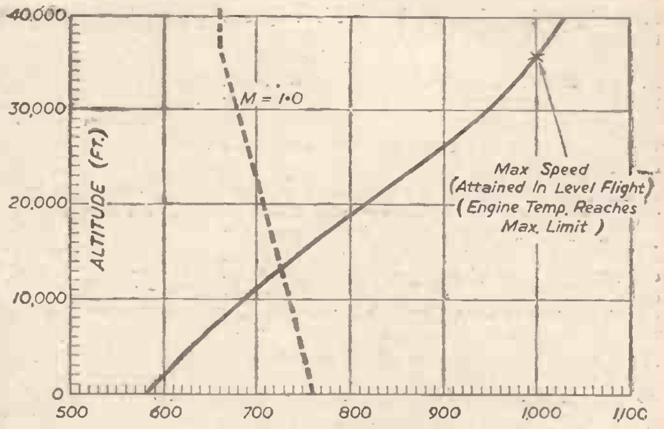
The aerodynamic "curve of fate," showing how drag increases in travel through the trans-sonic zone.

with all assembly jigs finished and component assembly well under way, the engine ready for installation in the airframe, is officially stated to be "economy."

Not a particularly convincing explanation this, especially in view of the obvious military importance of the development—unless, of course, the design is outmoded by recently acquired technique. The athodyd, for example, was virtually unknown at the time when the M.52 specification was drawn up (now nearly four years ago), and hence an athodyd research aeroplane might well be on the stocks "somewhere in Britain."

From the purely aerodynamical standpoint, the design compares favourably with the best the Germans had to show, although it is true that the Delta flying-wing layout (and wing sweep-back in general) was coming into prominence, and again this may have sufficient justification for abandoning the Miles venture.

Whatever may be the true reason for that vital decision, it must have come as a bitter blow—and one entirely "out of the blue"—to F. G. Miles and his design staff, pioneering as they were in an entirely new field of development. There is no doubt that an aeroplane such as the M.52 is a much needed item of equipment at the present stage of research, which could provide answers to innumerable aerodynamical problems. It would pave the way to the immediate development of aircraft capable of supersonic speeds, as fighters, mail and passenger transports—and although the spirit of the Miles project lives on in the Vickers trans-sonic model, there is a whole lot of difference between shooting off pilotless models through that perplexing zone of speed and actually *experiencing* trans-sonic conditions.



Graph showing maximum speed of the Miles M.52 with power jets W2/700 plus No. 4 augmenter.

The Vickers models will help. Of that there is no question, but they can only be supplementary to a manned research aeroplane. Whether this can be taken to imply that work on the M.52 will at length be recommenced, or that another research aircraft is taking shape behind the guarded curtain of security, it is impossible to say. But that the work so successfully undertaken at the Miles Aircraft, Ltd., has provided unparalleled data on the theory of trans-sonic flight and of the formidable constructional and installatory problems involved is unquestionable; a genuine credit to British design.

(To be continued.)

Mathematics as a Pastime—2

The Square Root Emerges.

By W. J. WESTON

GET your ruler to measure lengths, your set-square to set out a right-angle, and your compass to cut off lengths.

You know that x^2-y^2, the difference of two squares, is resolved into the factors $(x+y)(x-y)$, the sum of the numbers multiplied by the difference of the numbers: (99^2-98^2) is $(99+98)(99-98)$, that is 187. You can, therefore, express any number whatever as the difference between the squares of two numbers that differ by one. Thus:

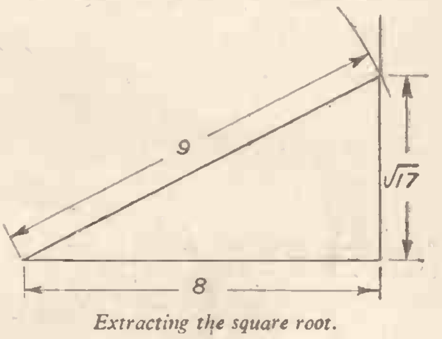
9 is (5^2-4^2), that is $(25-16)$,
17 is (9^2-8^2), that is $(81-64)$,
20 is $(10\frac{1}{2}^2-9\frac{1}{2}^2)$, that is $(110\frac{1}{4}-90\frac{1}{4})$.

You know, too, that the square on the side opposed to the right-angle of a right-angled triangle equals the sum of the squares on the two sides containing the right-angle.

Well, to lighten your work, apply those truths. For it is not the finding of a thing, but the making something of it when it is found, that is of consequence.

Suppose you want the square root of 17, for example, of (9^2-8^2), that is. Draw your horizontal 8 units long (centimetres are convenient as the units). Erect a vertical at one end of the line. With a length of 9 units in your compass stretch from the other end of the horizontal to the vertical.

Read off your upright; if you have worked with care, you find that $\sqrt{17}$ is slightly more than 4 centimetres and 12 millimetres, slightly more, that is, than 4.12. Test the matter by finding the square root in the traditional way—that is, by applying the truth $(a+b)^2=a^2+2ab+b^2$.



Extracting the square root.

$\sqrt{17}$:

```
              17 (4.123
              16
81             100
                81
822            1900
               1644
8243            25600
                24729
                  871
```

We find the nearest square below 17: this is 16, of which 4 is the square root. Our a then is 4 and our a^2 is 16. The 1 remaining out of 17 must, therefore, be $2ab+b^2$; and, by inspection, we find that b must be 1. For $(8+.1)\times.1$ is .81. So we proceed, taking as a the part of the root already found, and finding b by inspection.

Of course, you remember that the interpretation of two consecutive digits like 42 differs from the interpretation of two consecutive letters like ab: the first is 4 tens+2 units, the second is $a\times b$. If a is 4, and b is 2, then ab is 8 and not 42.

That this result is accurate enough you will see by reversing the process: that is, square 4.123:

```
      4.123
      4.123
  ---------
      12369
      8246
     4123
    16492
  ---------
  16.999129
```

This is as near to 17 as makes no matter.

(To be continued.)

Rocket Propulsion

Early German Transonic Research : 1,500 m.p.h.-plus Project Aircraft from Bell and Douglas

By K. W. GATLAND

(*Continued from page* 158, *February issue.*)

Chalmers H. Goodlin, Bell's twenty-three year old chief test-pilot, hopes to fly a developed XS-1 at 1,700 m.p.h. over 15 miles up.

FOR obtaining data at transonic flow speeds, the wind-tunnel is little more than useless. There is considerable interference in the working-section between the walls and from the model supports; and hence the reason for what in comparison with the static model is a costly item of equipment, the unmanned free-flight research aircraft.

First German Experiments

First of these special types was the "Feuerlilie," developed by German aerodynamicists. Actually, this did not signify a specific machine but was a group designation which covered at least three distinct models. They were originally intended as ground-to-air missiles, and all three, the Hechte, the F.25 and the F.55, were designed by Rheinmetall-Borsig and developed at the Hermann Göring Research Institute, sunk deep below ground in the forest of Volkenrode, near Brunswick.

F.25

Driven by powder fuel, the F.25 appears to have commanded most attention and some twenty models were launched between 1941 and 1943.

The drawing (Fig. 92, top) shows the external layout and it will be seen that swept-back wings, with tip fins, were mounted mid-depth of its slim and nose-pointed fuselage. They were of section N.A.C.A. 0009, swept back at 40 degrees and set at zero incidence to the body axis. The tail assembly was rather unusual in that a separate fin and rudder extended both above and below the rear fuselage. Each carried a tail-plane, the upper one having movable elevators adjustable for each flight. The machine was roll stabilised by a gyro-servo mechanism, working through electro-magnets which moved ailerons at the wing tips.

The rocket motor, which could be either a 109-505 or 109-563 di-glycol type, delivered a thrust of 1,100lb. for six seconds. With its aid, the model was launched from a ramp set at 60 to 80 degrees and could reach a maximum speed of 720ft. per second.

Leading particulars for the F.25 are as follows: length, 6.56ft.; fuselage diameter, 9.85in.; span, 2.95ft.; wing area, 3.84 sq. ft., and the all-up weight, 264lb.

Design of the F.55

The F.55 (Fig. 92, bottom) was a larger machine and tailless, weighing 1,040lb. Its wings, tipped by large square-cut fins, swept back at 50 degrees and were 8.20ft. in span with an area of 26.2 sq. ft. The fuselage, 21.6in. in diameter, had an overall length of 15.75ft.

First tests were made using a booster rocket, jettisonable as a first stage, in addition to its driving charge—both di-glycol burning. The booster section, thrusting at 4,400lb. for six seconds, was first embodied as a fixture on the rear fuselage, but this brought trouble straight away, for unless a vertical or near vertical ascent was adopted, the missile became unstable immediately after leaving its launching ramp. The obvious remedy was to split the large boost rocket into smaller units, mounting them as close to the aircraft's c.g. as possible, and this was done, using four 1,100lb. thrust rockets with satisfactory results. One such model, in fact, having risen to 15,700ft. from a launch at 70 degrees, flew for 4.66 miles. Its final speed (at the time of impact) was M=1.25.

Later flights were planned in which a liquid-fuelled power plant displaced the second stage powder rocket and using 90 kg. of oxygen and 50 kg. of alcohol, it was found that a thrust of approximately 1,100lb. could be maintained for 25 seconds. A di-glycol boost rocket contributed 6,600lb. thrust for the first two seconds of flight, whereupon it automatically released and dropped off. The bi-fuel unit then, thrusting on its own account, would take over and the machine flying under the control of its auto-pilot usually remained stable throughout its complete run. Any rolling tendency was continually and automatically corrected by deflection of the ailerons. Fore and aft stability was said to be particularly good.

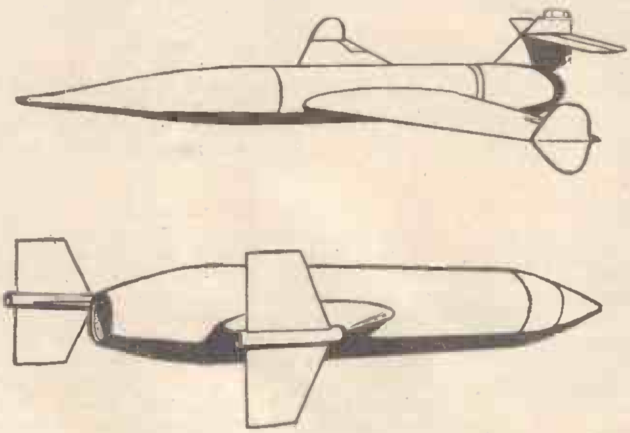


Fig. 92.—Two models of the "Feuerlilie" series, the F.25 (top) and the F.55. Flares, fitted on the fin or wing tips, were sighting aids for ciné-theodolite operators.

Hechte

Hechte was actually the first of the "Feuerlilie" series and it might well have taken its place in the Rheinland defence system had its development not been guided into other channels. The ground-to-air weapons that followed the early "Feuerlilie" models, however, embodied many of the features proven in the Hechte and F.25, and much of the data found its way into the hands of the full-scale aircraft designer.

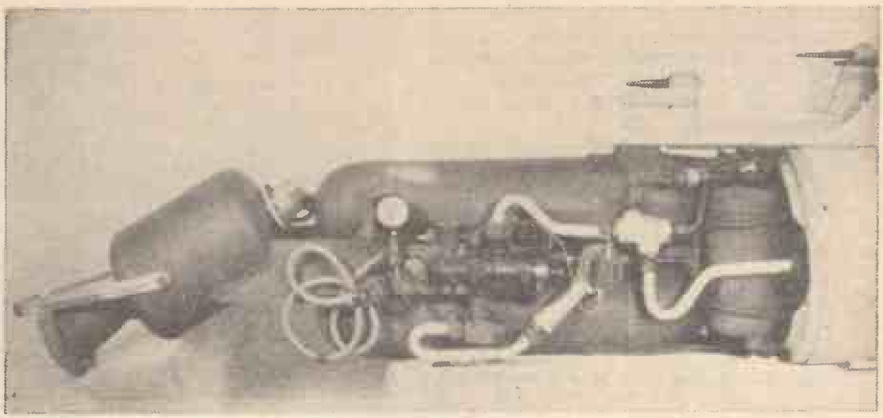
The Hechte and the F.25 appear to have been almost identical in both size and shape, the only main difference being the power unit. Here again a bi-fuel propellant was the integral driving force, though not as in the F.55. The Hechte used a "cold" system operating on T-stoff and Z-stoff (80 per cent. solution, H_2O_2 and calcium or sodium permanganate), which gave 132lb. thrust for from 20 to 25 seconds. The maximum speed attainable was about 920ft. per second, and as with the F.25 and F.55, roll stabilisation was effected by ailerons through a gyro link.

Some General Particulars

Work on the larger model (the F.55) had only just commenced when Germany collapsed, and there is no evidence of the liquid-fuelled version having flown, though several were almost completed. The solid-fuelled model was further advanced, and there are several complete examples. One of these, tested by technicians of the U.S. Army shortly after the occupation, is said to have risen successfully and to have remained stable and on course up to its maximum Mach number of 1.25, despite the conventional wing-section (again N.A.C.A. 0009) and normal type ailerons. This particular model weighed 1,000lb., and its di-glycol rocket, fitted internally, developed fully 13,000lb. thrust. From a comparison of these figures and those given earlier, it would seem that there were several size charges specified for this type.

A ciné-theodolite was employed to follow the course of these midget research missiles, though this system seldom proved reliable. The plotting involved a double differentiation which, despite the greatest care by both operator and calculator, was a very inaccurate process, and although the German technicians strove to improve the mathematics of the problem, by analytic differentiation and the fitting of high-degree polynominals to the trajectory curve, they still could not better their results. The ideal solution, that of transmitting data from the model "air-to-ground," was not practicable at the time of the experiments although research was proceeding at the D.V.L. (Deuteches Versuchsanstalt für Laftfahrt) in an attempt to perfect a radio transmitter for this and similar projects.

Since the war's ending, Allied technicians have perfected the "telemeter" with which it is possible to check with unparalleled accuracy, and at long range, the performance of pilotless missiles and aircraft. Each Vickers-Armstrong transonic model embodies one of these units capable of transmitting six instrument readings *simultaneously*. The data thus obtained has no comparison with that recorded in Germany during the war years and there is much to be expected from its further use in manned aircraft. This will be all the more apparent when full details of the Bell transonic experiments can be published.



Forerunner of the bi-fuel rocket engines used in the "Feuerlilie" models was the T-stoff and Z-stoff motor of the Henschel H.S. 293 "glider bomb." It developed 1,500lb. thrust for 12 seconds.

XS-1, First Tests

Latest news of the Bell XS-1 supersonic research aircraft is that a first flight under power has already been made. Others, in fact, may have already taken place by the time these words are in print.

Taken up beneath a specially adapted B.29 "Super-Fortress," the machine was cast off at 25,000ft., and then releasing propellant to *one* of the four combustion chambers, the pilot succeeded in reaching a maximum level speed of 550 m.p.h.

In announcing this Major E. J. Huber, of the Headquarters Army Air Forces, gives the designed top speed as 1,700 m.p.h. at an altitude of 80,000ft., with the maximum thrust available from the four-unit bi-fuel rocket engine, 6,000lb.—1,500lb. each chamber.

Design Features

Like the Miles M.52 project, the XS-1 has a ballistic-shaped fuselage and no wing sweep-back. Basically, the difference between these two designs is not great, though, naturally, as one was "jet" and the other is "rocket," the similarity remains only in the exterior shape. Actually, the fuselage of the Bell machine is rather more plump looking than its British counterpart, which is due to the need to provide tankage for the rocket propellant, 8,177lb. of liquid oxygen and alcohol.

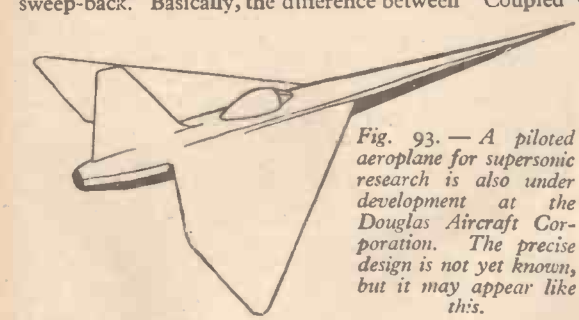


Fig. 93. — A piloted aeroplane for supersonic research is also under development at the Douglas Aircraft Corporation. The precise design is not yet known, but it may appear like this.

The overall weight of the prototype (fully fuelled, all test equipment installed and with pilot) is 13,069lb. For all that, it is not a big aeroplane, as will be observed from the photographs; the length of the first test machine is 31ft.; its span 28ft., and the height (from ground to fin tip) 10ft. 10in.

There are apparently to be at least two of these research aeroplanes, the first a "flying test-bed" for the second. The earlier version, moreover, will not be capable of reaching the speed for which it was designed because of the substitution of an alternative power unit.

A Gas-charged Engine

Originally, the engine for the prototype was to incorporate a fuel system similar to those employed in the Walter bi-fuel units, in which the propellant would be forced for combustion by a turbine driven pump. A series of design problems has unfortunately delayed the development of this particular item, and as it was obvious that the machine would be complete in all other respects long before the pump and ancillaries became available, it was decided to install an entirely different system. The method adopted was "gas charging," an arrangement reminiscent of the early German "Mirak" and "Repulsor" experiments, in which gaseous nitrogen, contained under high pressure, is used to force both fuel and oxygen from their tanks into the combustion chambers.

The gas pressurised system is naturally inferior in many respects to the mechanically actuated feed. In the prototype machine, the motor is limited to a duration of only 2.5 minutes when operating at full thrust, whereas with the turbo-pump, its maximum power could be maintained for 4.2 minutes. Coupled with this, the top speed attainable with the alternative power plant is estimated to be 1,000 m.p.h., at 60,000ft., instead of the 1,700 m.p.h. velocity at 80,000ft., as originally specified. In addition, the rate of climb claimed for the machine when fitted with a turbo-pump, 45,000ft. per minute, falls off to 28,000ft. per minute when the pressurised engine is substituted.

An 8g Pullout

When Bell Aircraft Corporation first undertook the contract for a supersonic research aeroplane—and that was in the spring of 1945—the following minimum performance requirements were specified. First, an 8g pullout at an indicated air-speed not exceeding 500 m.p.h.; then, an 8g pullout at minimum speed; a proof of the specified endurance at rated thrust, and take-off (from the ground) and climb to 35,000ft. under its own power. Finally, the machine must respond satisfactorily to control at Mach=.80.

These characteristics are now being proved. Afterwards, the 'plane will be accelerated by stages into the transonic speed zone and then, if everything goes well, the throttle will be opened wide in an attempt to confirm the designer's most ambitious estimate. This does not necessarily imply that the same basic design as recently tested will remain unaltered at transonic and supersonic speeds. The probability is that several modifications (principally in wing form) will be embodied as fresh data is brought in from each successive test flight.

The pilot's task under transonic flight conditions—when his attention must be one hundred per cent. on his controls—is considerably relieved by the telemeter, which transmits readings of air-speed, acceleration, aileron position and elevator position to a ground station throughout the entire duration of the test.

Control and the Strength Factor

An interesting feature of the control system is that the setting of the tail-plane can be adjusted during flight, and as this might normally prove hazardous at transonic speed, special flutter dampers have been designed to minimise the danger from this source. The movement is brought about by a powerful mechanical actuator. For the rest of the controls, they are apparently orthodox.

During the early phase of testing, the XS-1 will be checked comprehensively by officers of the National Committee for Aeronautics. One of their instruments is an oscillograph with which they will be able to determine the strains sustained by structural members of the wing and tail. The normal pre-flight inspections, too, will be carried out with infinite care, for there can be no room for oversight of the slightest defect. At the speeds this machine will fly, nothing can be left to chance and the ground personnel have a great responsibility.

The XS-1 has been designed to withstand 18g. (or an acceleration of 18 times the force of gravity), and clearly becomes the strongest craft ever to fly. The wings, for example, have a skin *machined* from aluminium alloy, having a root thickness greater than ½in., tapering off to about ⅛in. at the tips. Its limitations, in fact, are much more in the make-up of the pilot than in the structure of the machine.

The Pilot

The man whom it seems will be the first to outfly sound is Chalmers "Slick" Goodlin, Bell's twenty-three year old chief test-pilot. He succeeds Jack Woolams who was killed on August 30th, 1946, when a special P.39 racing 'plane which he was grooming for an air race crashed out of control into Lake Ontario. The reason for this most unfortunate mishap is given as tail failure.

Goodlin, a native of Greensburg, Pa., learned to fly at the early age of sixteen, later serving with the R.C.A.F. and the R.A.F. from February, 1941, before his transfer to the U.S. Navy in December, 1942. After his honourable discharge from the Service, he joined Bell Aircraft Corporation, and has been test flying since January, 1944.

A Douglas Project

News of progress with the XS-1 is followed by rumours of another research aeroplane, similar in purpose but very different in design, a project by the Douglas Aircraft Corporation. The machine is said to be rocket powered and as nearly a "flying-wing" as it is possible to obtain in a small high-performance type.

Actually, the need for containing comparatively large proportions of rocket propellant makes some form of fuselage essential in these thin-wing research aircraft; and then there is always the installation of pilot and controls to be considered. The Douglas project, in all events, is mainly wing, but with a slim pencil-like fuselage which projects for some distance beyond the root leading edge, tapering away to a point at the nose. The body form is naturally less slim toward the rear where the pilot is accommodated, presumably along with the main tanks and rocket motor. A single vertical fin and rudder emerges conventionally from the rear fuselage and there is no tail-plane.

The prototype Bell XS-1 with which it is hoped soon to reach 1,000 m.p.h. at 60,000 ft. Its engine comprises four separate combustion chambers—each capable of 1,500 lb. thrust— d operating on only one, the machine has already flown at 550 m.p.h.

The above few particulars of what promises to be an interesting aeroplane are indicated pictorially in Fig. 93. The drawing is not intended as an accurate impression of the design, but rather to illustrate the likely arrangement of such a machine as the one described.

The reason for the length of fuselage forward of the wing can be explained quite simply. At trans-sonic speeds, the highly refined nose will have the effect of breaking down the shock "front" so that the air accruing in the conical bow wave thrown off from that region hits the leading edge of the wing at considerably reduced velocity. The reduction in flow speed is further assisted by the pronounced sweepback of the wings with the result that the overall drag is greatly decreased and the lift suffers not so drastic a drop. Stability also derives a benefit in that change in trim during travel from one speed zone into another is not so marked. At least, that is the theory!

The "needle-sharp" nosing on a swept-back layout should prove effective in countering at least some of the more major problems which will arise when pilots come fully to grips with sound. It will be interesting to learn more of this Douglas venture and also to discover the truth of a report that most of the main U.S. aircraft builders are actively preparing programmes of research which call for "faster-than-sound" piloted aircraft.

(To be continued)

Glues, Cements, and Adhesives—2

Cold Glues, Pastes, Gums and Their Uses

By "HANDYMAN"

(Continued from page 120, January issue)

BY the word adhesive I refer to all such "sticky stuffs" as employed for uniting paper, cardboard, leather and smaller wooden objects to each other, and, naturally, the liquid and other cold glues which ordinarily would have been considered in the last article may be classified with the adhesives: the gums, the liquid fish-glues and starch pastes.

Liquid Glues

There is nothing much to say about the making of these glues, except that they are derived from bones and offal of fishes, and that the edible isinglass is a highly refined product made from selected parts of the fish, bearing much the same place in relation to common fish-glue that gelatine does to animal-glue. Isinglass, however, is sometimes used for the finer cements, and is therefore not an adhesive in the ordinary sense of the word, except where it is used in the making of "court plaster," an adhesive silk for cut fingers. Liquid fish-glues are supplied in collapsible tubes in all sizes and qualities and under various trade names. Seccotine is the forerunner of this most convenient form of adhesive, and a small tube is obtainable for a few pence.

The liquid glue is known under the name of "Croid," and is a quality of cold glue which, besides having a general utility, is to be recommended for small joinery and other woodwork where a small quantity of the agglutinant is required at a time. It is excellent for model-making purposes.

Using Liquid Glues

As in the case of hot glues (carpenter's hide glues) the minimum amount of cold glue should be used in making a joint, and perfect contact between the two parts is essential to the strength of the job. Rubbing the objects together to exclude the superfluous adhesive is therefore recommended. If there is bad contact between the united parts, the area of the exposed glue is considerable and dampness in the atmosphere can more easily penetrate and weaken the joint. This may not be quite so serious a matter with glues of the nature of "Croid" or "Seccotine" as with carpenter's glue, which is most susceptible to atmospheric changes, but there is bound to be some detrimental action on the adhesive if the joint is not a close one. Grease is an enemy of all adhesives, and therefore surfaces which are to be attached to each other should be free even from the natural oils which are present on the fingers. In winter, cold glues are more viscous—even hard—and if, when the tube is squeezed, the adhesive comes out in a sort of crystallised form, it should not be used without slightly heating. In a cold room, or on a winter's day, it is best to place the tube of adhesive in a cup of hot water for a few minutes before using. Seccotine tubes are usually supplied with a metal peg with a looped handle end, which is replaced in the nozzle after use. This is the simplest and best device to prevent loss of glue and to ensure a ready flow when the glue is required to be used again. Where this sort of stopper is not provided, as in the cheaper qualities and sizes, a small nail or a stout household pin will serve the same purpose.

Pastes

These are usually made from one of the flours or starch and there are innumerable recipes in common use. Dextrine is a manufactured substance which is almost identical with starch and is sometimes termed "British Gum." The granules in starch and flours are insoluble in cold water, but when heated with water of a temperature of about 75 deg. Fahr. these granules split up and adhesive "glutens" and "albumen" are formed. Both these substances possess powerful adhesive qualities, and the paste is of a double tenacity when they are both liberated. Decomposition of flour and starch pastes is due to the fermentation of the cereal constituents, and therefore preservatives are necessary. Pastes made from farina (potato starch) are not so strong as wheat or rye flour pastes, and sometimes the addition of one of the glues is resorted to. With the hide glues such a paste is more liable to putrefaction. The mixing of pastes with silicate of soda (common "water-glass" or "preservatives") can be tried, but the difficulties of keeping them are increased. Such pastes tend to liquefy when they are put into closed retainers.

The preservatives for pastes are carbolic acid, oil of cloves, camphor and other essential oils. In using that powerful disinfectant, "Lysol," as a preservative in home-made flour paste, I found that it destroyed the adhesive value of the paste—especially if the quantity was overdone—and turned the paste quite brown. I now use nitrobenzine. This is a chemical strongly smelling of almonds and is an admixture to many brands of office pastes.

Cold-water Paste

Liquid ammonia and other alkalies have the power of causing such separation, and wheat, flour or potato starch can be converted into a mass of stiff paste, which will dry up. The resultant horn-like mass will not decompose and can be ground up into a powder. This powder, usually sold as "cold-water paste," can then be mixed with water into a paste as required. The only drawback to this stuff is that the presence of the strong alkali may cause the paste to adversely affect coloured objects.

(To be continued)

Rocket Propulsion

The Vickers-Armstrong Project—Pilotless Aircraft for Transonic Research

By K. W. GATLAND

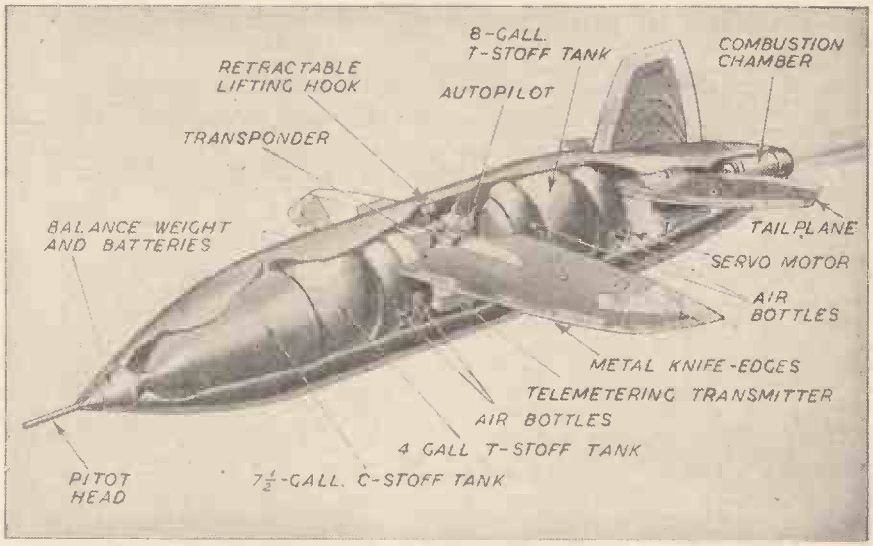
(*Continued from page 194, March issue.*)

THE first fully controlled aeroplane to achieve supersonic flight is almost certain to be American. There can be no doubting the success of the Bell XS-1 during its recent powered trials, and with at least three other machines featuring in the U.S.A.A.F.'s "S" (for sonic) programme, it would seem that some interesting times are ahead at Murac Flight Test Base, California. The Bell Aircraft Corporation is reported to have in hand a swept-back wing version of the XS-1, the XS-2, with Douglas developing an XS-3, a near "flying-wing," and Northrop a similar project known as the XS-4.

British Research Progress

It would be interesting to know exactly how all this compares with British research. On the surface, our progress seems slow. The Miles M.52 might well have been in the air *before* the XS-1 had its contract not been cancelled; and nothing further has been heard of the enterprising programme of research which features pilotless models built by Vickers-Armstrong, Ltd., first reported last July. The folly of passing judgment on the basis of public knowledge, however, is obvious.

In any event, a logical series of experiments with controlled models seems a proper *first* step. The ideal shape for transonic flight is yet a matter for experiment, and full-scale research at this critical stage seems in many ways a gamble—in life, material and man-hours. The tragedy which overtook Geoffrey de Havilland at speed in the D.H.108 is surely sufficient justification for not plunging directly into the design of piloted aircraft for even faster travel. This, however, is not to excuse the scrapping of a project so advanced as the M.52, with its detachable cabin ensuring reasonable safety for the pilot.



Sectionalised drawing of the Vickers-Armstrong rocket-propelled transonic aircraft.

The Vickers-Armstrong Project

The research programme which Sir Ben Lockspeiser, Director-General of Scientific Research (Air) at the Ministry of Supply, has before him should endanger no one, and yet provide complete data on a large variety of wing forms—and therefore virtually different aircraft—while involving minimum expenditure.

There are likely to be several models produced, each with some different arrangement of wing and tail, some tail-less, but all retaining the same bullet-like lines of fuselage.

The first model to come from Vicker's works at Weybridge was basically a 0.3 copy of the Miles M.52, and no doubt this has been produced mainly for static tests. Only when complete reliability is assured, both as regards its aerodynamic qualities and the accuracy of the air-to-ground recording system, can it be expected that models of other shapes will follow. In all essential respects, it serves the same purpose as the prototype of a full-scale aircraft, though the simile is not quite accurate. It was said at the R.A.E. when the model was first exhibited that five others would be built to this design.

The complete series will probably not be ready until sometime later this year.

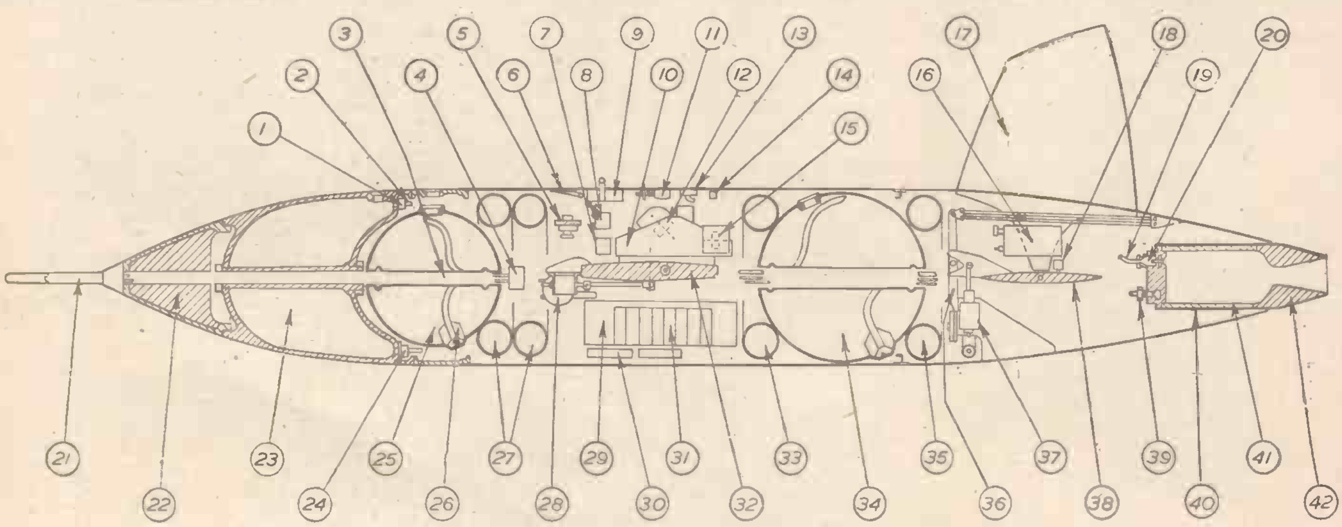


Fig. 94. Diagram of rocket-propelled aircraft giving nomenclature of component parts.

1. Non-return Valve in Air Pipe.
2. Air Pressure Pipe.
3. Pipe Conduit.
4. Air Speed Indicator.
5. Reducing Valve.
6. Hot Air—External Supply.
7. Longitudinal Accelerometer.
8. Normal Accelerometer.
9. Suspension Hook, Retracted.
10. Automatic Pilot.
11. Rocket-starting Starting Switches.
12. Position Gyroscope.
13. Electric External Services.
14. Air External Supply.
15. Rate Gyroscopes, Roll and Pitch.
16. Radar Transponder.
17. Fin.
18. Reactance.
19. Hydrogen Peroxide Inlet.
20. Mixing Valve and Burner.
21. Pitot Head.
22. Balance Weight.
23. Fuel—Alcohol Hydrazine Hydrate.
24. Safety Diaphragm.
25. Hydrogen Peroxide.
26. Anti Cavitation Vanes on Outlet Pipe.
27. Air Supply for Pressurising Tanks.
28. Servo motor for Ailerons.
29. Telemetering Six Channel Unit.
30. Oscillator.
31. Batteries.
32. Mainplane.
33. Air Supply for Pressurising Tanks.
34. Hydrogen Peroxide.
35. Air Supply for Controls.
36. Locking Device for Tailplane.
37. Twin Servo Motors.
38. Tailplane.
39. Alcohol Fuel Inlet.
40. Combustion Chamber.
41. Polygon Lining.
42. Carbon Venturi.

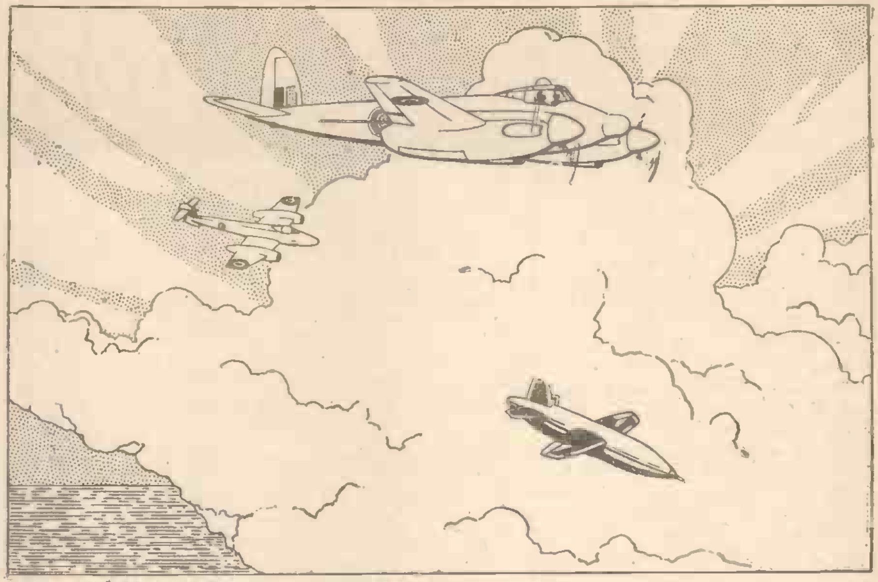
"Operation Transonic"

The scene for the actual flight experiments is set 36,000ft. above the Atlantic, a few miles west of the fringe of Cornwall, and a similar distance north of the Isle of Scilly.

Each model will be taken up to height beneath a specially adapted "Mosquito" and released during level flight at 400 m.p.h. A single point suspension on the c.g. line of the missile is provided to secure the model beneath the 4,000lb. bomb-bay of its parent. To eliminate the drag that it would otherwise incur, this lug is spring loaded and immediately after release retracts flush with the skin surface.

The parent aircraft having dropped its load, climbs away sharply so that the slipstream of its propellers will have little chance of upsetting the model's trim. The auto-pilot in the missile comes into action immediately and a clockwork mechanism causes it to dive at an angle of 10 deg. for a period of 15 seconds before levelling out. There is a loss in altitude of about 1,000ft., which must be conceded to ensure undisturbed air and steadiness in the missile.

As soon as the missile assumes level flight, a diaphragm bursts and releases air pressure to the propellant system, feeding T-stoff and C-stoff in correctly metered proportions to the single combustion chamber. The mixture is self combusting and the resulting thrust drives the model up to sonic speed within the space of 18 seconds. It then continues to accelerate up to its maximum Mach number of 1.3 (at 35,000ft.) which is reached in a total time of 70 seconds.



A "Mosquito" releases a Vickers-Armstrong model as a "Meteor" races in to take cine-pictures.

Section of combustion chamber for Vicker's rocket unit, showing the carbon venturi.

The propellant exhausts at this point and a horizontal glide of about 2-1/2 miles follows. Then, having decellerated to subsonic speed, the auto-pilot locks down the tailplane and the model plummets into the sea. From the time of release it will have covered over 22 miles in level flight, having attained maximum speed (880 m.p.h.) after travelling some 12 miles.

The course of each missile will be plotted by radar from a station in the Scilly Isles. This is arranged quite simply, a signal transmitted from the ground being picked up by the missile's *transponder* and retransmitted on a different frequency. At the same time, the pilot of a Gloster "Meteor" will attempt to obtain cine-photo's, and thus a complete picture of what happens during each test will be built up.

Advantages of Air Launching

The Vicker's models represent a considerable advance over those of the German "Feuerlilie" series; and not only because of their remarkably simplified power plants.

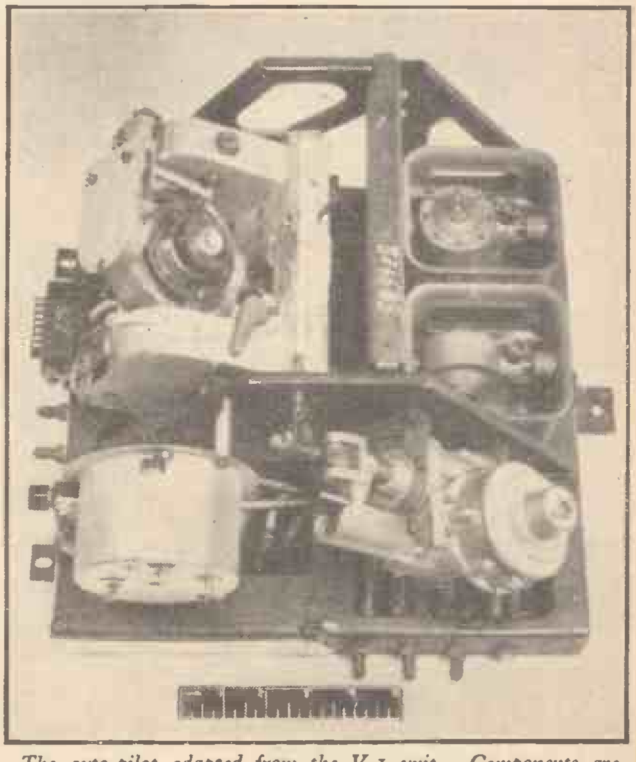
A rocket will operate with maximum efficiency only at *high speed* and in rarified atmosphere, preferably in *vacuum*. The Germans achieved the former ideal with di-lycol boosters, but by no means could they operate their missiles at effective altitude. It was not a case of no suitable aircraft being available. There would have been no difficulty in converting an Me.110, for example, to carry them up into comparatively rarified strata—the great problem was to obtain data from the models once they were released.

The German technique depended upon tracing the trajectory of models by means of cine-theodolites which, with air launching, was obviously out of the question; and having no such device as the telemeter, there was no ready solution. The use of graphical recorders within the models might have been a way out but for the fact that there was no apparent method of retrieving them in one piece. More often than not, a small crater in the ground would mark the resting place of a model and so there seemed no future in integral recording. Radio-control, with the possibility of bringing the models into a reasonable landing was likewise no salvation; the effective controlling range was not sufficiently great, and size and weight were also against it.

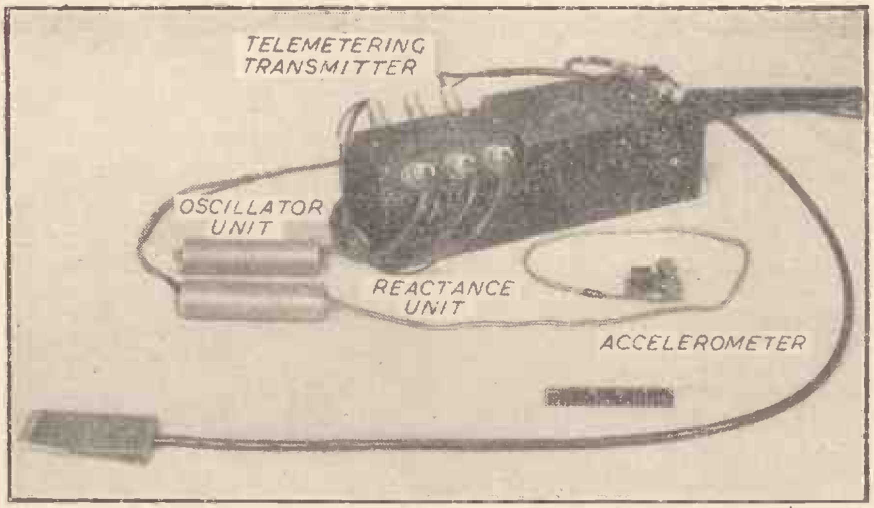
It is surprising that the only real solution, that of ejecting the instruments with their recording drums and landing them by parachute, does not appear to have been attempted. Such a device need not have been excessively complicated.

The Vicker's models operate under no such handicap. Despite their small size—the "first off" was only 11.83ft. long and 8.1ft. in span—each has its own telemeter which transmits six simultaneous readings; of dynamic pressure, static pressure, normal acceleration, longitudinal acceleration, combustion chamber pressure and tailplane angle. These signals are picked up by the ground station where the data is recorded and later tabulated to give comparative figures of performance for the entire series.

Accuracy and *simplicity of operation* are the key-notes of the telemeter which is becoming important in all flight test work. With parallel progress in radio-control, it should soon become possible to carry out the testing



The auto-pilot adapted from the V-1 unit. Components are as follow: (top left) position control gyro; (bottom left) clockwork mechanism; (top right) pitch control gyro; (centre right) roll control gyro; and (bottom right) altitude control unit.



The telemetering transmitter. The input leads for the six measurements are clearly shown. Note also how the metal insert in the wing leading edge is utilised as an aerial.

of full-size aircraft entirely by remote control. Perhaps this course will be adopted after the complete programme has been flown off, and data is available for the design of a full-scale transonic machine.

The Vicker's Project in Detail

The three main features that technicians of Vicker's and the R.A.E., Farnborough, are building into their transonic missiles are: (a) a bi-fuel rocket system based on the German "cold" units, yet of greater simplicity and improved efficiency; (b) an auto-pilot, and (c) the all-important telemeter. It is clear that German research has contributed much to the *detail* design, and yet it is the refinements made in the rocket system and the incorporation of the telemeter that, coupled with air-launching, have made these models outstanding.

The Rocket Unit

One of the most striking features of the rocket system is the simplicity of its combustion chamber. It is truly a remarkable piece of work and comprises only four main parts. The size and make up of the unit can be gauged from the accompanying photograph and it will be seen that there is a steel outer casing, swaged down at one end into which a machined carbon venturi fits. A ⅜in. thick polygon insert protects the walls of the chamber and both this and the nozzle are set in position with a special ceramic paste, the joint being smoothed off to ensure good flow conditions. The injector plate, with its three stainless steel inlet nozzles, completes the assembly—the result, a perfect job without a single rivet or bolt. Approximate dimensions of the carbon nozzle are: throat diameter, 1.5in. mouth diameter, 3.5in., and the distance from the minimum throat diameter to the mouth, 4in.

The thrust developed by this motor is 209lb/lb. fluid second; the specific consumption, 17.2 lb/lb. thrust hour, and the actual temperature rise, 1,750 degrees Centigrade. As already mentioned, the unit operates on T-stoff and C-stoff, the same propellant as used in the Messerschmitt 163. These comprise hydrogen peroxide of 80 per cent. concentration (T-stoff) and a combination of 57 per cent. methyl alcohol, 30 per cent. hydrazine hydrate, 13 per cent. water. A small amount of potassium cuprocyanide is added to the C-stoff to catalyse the peroxide, thereby ensuring spontaneous combustion of the two components when they meet in the chamber. The actual fuel/peroxide ratio (by weight) is 0.300.

The swaged end of the rocket motor is exposed to the airstream at the missile's rear. There are two spherical tanks for the T-stoff, having a total capacity of 12 gallons, while 7½ gallons of C-stoff are carried in an annular casting at the nose. Three tubular tanks in the shape of rings (in a word, "toroidal") comprise the other main items of the propellant system, supplying air to pressurise the propellant tanks. A fourth toroidal container is provided as an air drive for the gyroscopes. The location of these components will be apparent from the drawing, Fig. 94.

It will be seen also that a pitôt head projects from the nose of the missile and that the readings are conveyed to an air-speed indicator placed just aft of the small T-stoff tank, the capillaries being taken through the centre of each of the forward tanks. A similar arrangement allows for the passage of feed lines and electrical leads through the aft T-stoff tank.

The longitudinal accelerometer, normal accelerometer, and auto-pilot are all situated above the mainplane, with the six channel telemetering unit, oscillator and batteries beneath. The radar transponder is mounted above the tailplane.

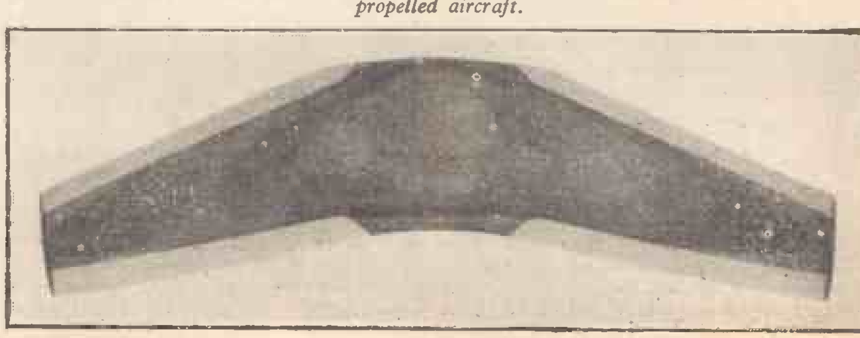
Constructional Detail

The fuselage shell is of light steel, 18in. in diameter with an ogival nosing and tapered towards the rear. The supporting and stabilising surfaces are all true bi-convex sections, the mainplane constructed in laminated mahogany, and the tailplane and fin in laminated birch.

An ingenious feature of the wing make-up is that stainless-steel "knife-edges" are bonded into the upper surface of the leading edge, serving the purpose of aerials for the telemetering transmitter, with similar profiles of light alloy let into the lower surface of the trailing edge and at the tips. There are also light alloy plates bonded into the centre of the top surface and others near the aileron cut-outs to strengthen the structure. The tailplane and fin embody similar inserts, those in the leading edge of the former being utilised for the radar transponder.

Both wing and tailplane are single-piece units passing through the fuselage. The wing is rigidly fixed at 0 degrees 33 minutes to

(Above) Mahogany wing, and (below) birch tailplane for the Vicker's transonic rocket-propelled aircraft.



Birch wing for the Vicker's transonic rocket aircraft.

the body axis, and the aileron links (from servo unit to the aileron lever arms) are taken through internal channels. Like the arrangement for the Miles M.52 (and also in the Bell XS-1), the tailplane is "all-moving." It is pivotally anchored so as to obtain elevator effect under the action of its servo motors, having a range of movement 8 degrees down and 5 degrees up. The lower part of the fin, rooted approximately a quarter the overall length of the fuselage from the rear, provides a point of pivot for the tailplane.

Conclusions

It is inevitable in a research undertaking of this nature that many alterations will be necessary before final perfection is achieved. The telemeter, for example, though a development of far reaching importance, is still virtually untried (especially in a machine of model proportions) and if, in the course of preliminary trials, its accuracy should be found anything less than 100 per cent., the missiles will not be acceptable for their exacting job. It will obvously be no use building the complete series of models if no account can be made of their performance.

New technique presented by the use of a transponder may prove equally troublesome.

No doubt there have been, or are yet to be, free-flight tests of the preliminary models to ensure good flight and control characteristics, after which it may well be that some components will require modification, perhaps complete redesign. Thus, the experimental work may be expected to continue for some time until, in the light of further flight tests, the design is found to possess no apparent fault. However, as nothing has been heard of the project for some time, it seems likely that a fair amount of the ground work is by now completed.

Those contributing to the Vickers-Armstrong project are to be congratulated on a very plausible approach to some difficult problems. The programme is admittedly less spectacular than the American, but it is nevertheless of great importance and may still pay dividends should tests prove the A.A.F.'s "XS" series premature.

(To be continued)

A 12ft. All-wood Canoe

Constructional Details of an Inexpensive Craft for the Amateur Canoeist

By R. J. CHAMBERLAIN

An easily-made craft designed for speed and buoyancy.

THIS canoe has been designed for speed, extra buoyancy and grace in shape. It is made entirely from wood, such as deal. This helps to keep the craft light in weight and, despite the softness of deal timber, it is strong—much stronger than a canvas-covered canoe.

It has a large water-tight compartment at the bow and three smaller water-tight compartments aft. Thus, in the event of a capsize, the canoe will not sink should it become flooded with water. In any case, every canoeist should be a person who can swim, particularly if fond of "coasting" around a seaside resort or crossing large inland lakes.

To fully appreciate the length of the canoe illustrated, a distance of 12ft. should be marked out on the ground. It may be considered that the craft is too long, but one feels a sense of greater security in a 12ft. canoe than, say, a 9ft. model. Indeed, some canoes are over 14ft. long.

The length of 12ft., with a beam (width) of approximately 24in. and a bow depth of 14in. and a stern depth of 8in. ensures that the canoe is suitable for carrying most individuals. It is intended for a single passenger only, but if a craft is wanted for two youths, it is a comparatively simple matter to build the craft as a double-seater type. This could be done by extending the fore end of the cockpit to the nearest forward hull-former framing, extending the length of the three footing laths and adding extra cross-pieces to make the extra seat. This alteration in plan may, be it noted, have effect on the construction of the craft, as described in this article, and the reader must make allowances, and use his own ideas.

A Suggested Design

To be quite frank, the sizes, drawings and shapes are presented more with a suggestive view in mind rather than a set principle. The construction is on the simplest lines possible with wood. Having got the general idea, the reader can no doubt plan his own particular canoe.

He should, to make his craft graceful, adopt the long, tapering bow and the "angled" deck and hulls. Wooden canoes with vertical hulls and bottoms identical in size and shape as the decks are easier to build, but lack a graceful, streamlined appearance.

The extremely high bow means that one can dash through fairly high waves in a choppy sea with a minimum of splash or spray. The cockpit coaming is an extra form of breakwater. Due to the shape of the deck (which slopes at each side from the centre) water trickles off almost immediately. And since the bottom is much narrower than the deck width, the craft, unlike the equidistant-sided type, will "settle" better in the water. These points must, therefore, be borne in mind.

The Bottom Shape

To lay the "keel," prepare the bottom piece. This consists of two 10in. wide by ½in. thick shelving boards tongued and grooved together, or alternatively, dowelled together, using ¼in. dowelling and marine (waterproof) glue.

It is advisable to adhere the boards together unshaped and, when the glue dries, trim the joint with a smoothing plane and then proceed to mark the curvature shape. This is best done with a long lath of wood which bends easily. The lath is affixed with a nail at one end of the joint, kept out to width at the centre with another nail, then bent to the joint of the board at the other end and nailed. The bent lath serves as a guide for the pencil.

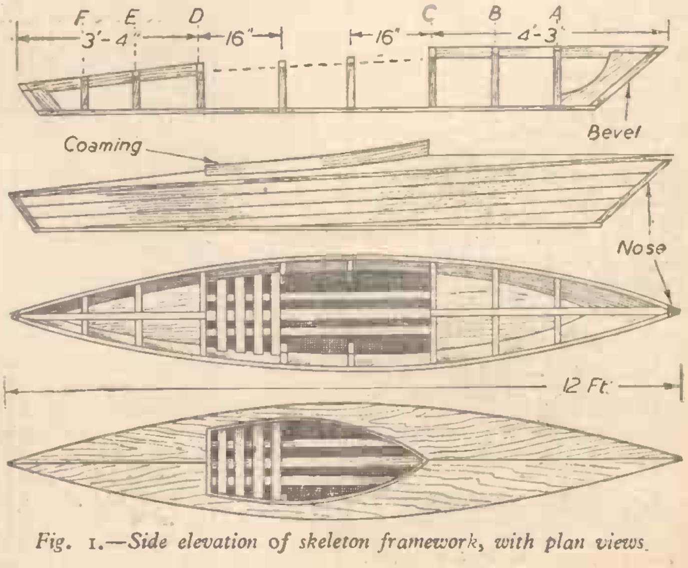


Fig. 1.—Side elevation of skeleton framework, with plan views.

Rocket Propulsion

German Rocket Gliders

By K. W. GATLAND

(Continued from page 231, April issue)

A FEW more months of work unhampered by the Allied air offensive and technicians of the German Research Institute for Sailplanes could have produced a rocket-boosted reconnaissance aeroplane.

This was the project DFS.228, a large single-seat glider (Fig. 95), which, during bursts of thrust, was reckoned to achieve speeds up to 560 m.p.h., and be capable of operating over England at heights well beyond the reach of flak and fighters. Its designed ceiling was 15 miles, and from that height the pilot could theoretically observe ground areas within a radius of 300 miles. The machine would thus have been particularly valuable for charting the explosions of flying-bombs and V-2 rockets.

The DFS. 228V-1 mounted on its parent aircraft. The two machines were designed to fly together up to an altitude of 35,000 feet, when the glider would release and climb away under its own rocket power.

In operation, the DFS.228 would have flown "Mistel" fashion on top of a Dornier Do. 217K, separating at 35,000ft. Its pilot could then more than double his height by firing spasmodic bursts from a bi-fuel rocket in the glider's tail, afterwards resorting to rocket power only if difficulty was experienced in maintaining effective altitude. The amount of propellant in the tanks permitted barely three minutes' sustained thrust, but as the wing loading dropped from 28 to 12lb./sq. ft. as the tanks were drained—and the propellant would be nearly all consumed in the climb to peak altitude—this, coupled with the speed inherited from the rocket, should have resulted in a reasonably flat glide, despite the low air density.

Having reached his ceiling, the pilot could afford to lose half this height before again thrusting the rocket, but by that time he would probably have completed the reconnaissance and be well set into the journey back to base.

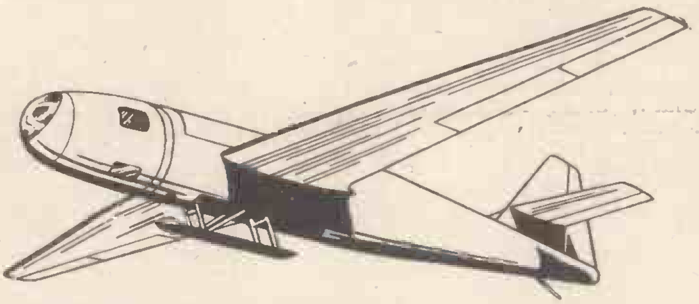


Fig. 95.—The DFS. 228. A ceiling of 15 miles with a top speed of 560 m.p.h. were the figures quoted for this rocket-booster reconnaisance glider.

The specification for the DFS.228 was first issued in 1941, and had the institute not been burdened by work given higher priority this glider might well have figured in the late war. As it was, the machine's development was delayed, and it was not until 1943 that the German Air Ministry gave orders for its immediate production.

Transonic Rocket Gliders

The DFS.228, designed by Dipl. Kracht and his staff, was actually the most advanced of several other rocket and jet-boosted gliders, among them the DFS.346 and DFS.1068, of which there were four versions of the latter. The accompanying table gives such particulars of these aircraft as are available. Each was intended for transonic and supersonic research and followed the same general pattern as the DFS.228; and hence the reason for explaining the reconnaissance glider at this stage.

However, before continuing, it will be as well to mention something of the D.F.S. itself.

Origin of the D.F.S.

The German Research Institute for Sailplanes had its beginnings in the early "twenties"—at the time when Germany, having lost her right to an air force under the terms of the Versailles Treaty, was fast becoming glider conscious. It was not that commercial aircraft were denied under the ruling; the war had evoked widespread interest in aviation, and the country's economic position simply did not leave anything over for the construction of pleasure aircraft. Gliders, however, were different. They could be built by any worthwhile engineer and, above all, could be turned out cheaply.

It was thus that gliding became one of Germany's foremost sports and to serve the needs of glider and sailplane enthusiasts, ever demanding improvements, the Forschungs Institut für Segelflug (Sailplane Research Institute) was founded in 1924.

The tragedy was that the Institute should have laid the foundation for the Luftwaffe, as it surely did, when Hitler saw fit to snub the binding treaty and embarked upon his programme of recreating the German "war machine."

Meanwhile German science was fast perfecting another form of aerial attack, the long-range rocket, which, ludicrous as it was tragic, was no infringement on the terms of the 1918 surrender—organised rocket development started in 1927 (see PRACTICAL MECHANICS, September, 1944, p. 441). It is significant to recall also that at least two rocket-powered gliders had flown before 1930.

Shortly after its formation, the Institute was established at Darmstadt, the name being changed to Deutsche Forschungsanstalt für Segelflug (German Research Institute for Sailplanes), referred to by the letters D.F.S. The original purpose of the group was to investigate, on a sound scientific basis, the aerodynamics and uses of gliders. However, the scope of the Institute was considerably widened in later years, and at the time of its occupation by the Allies it was subdivided into several research sections devoted to specialised studies of flight, both powered and power-less.

In 1939 the D.F.S. was moved to Braunschweig, and then finally, in the summer of 1940, to Ainring, in Upper Bavaria, by which time it had been fully developed as one of Germany's ten major aeronautical research stations.

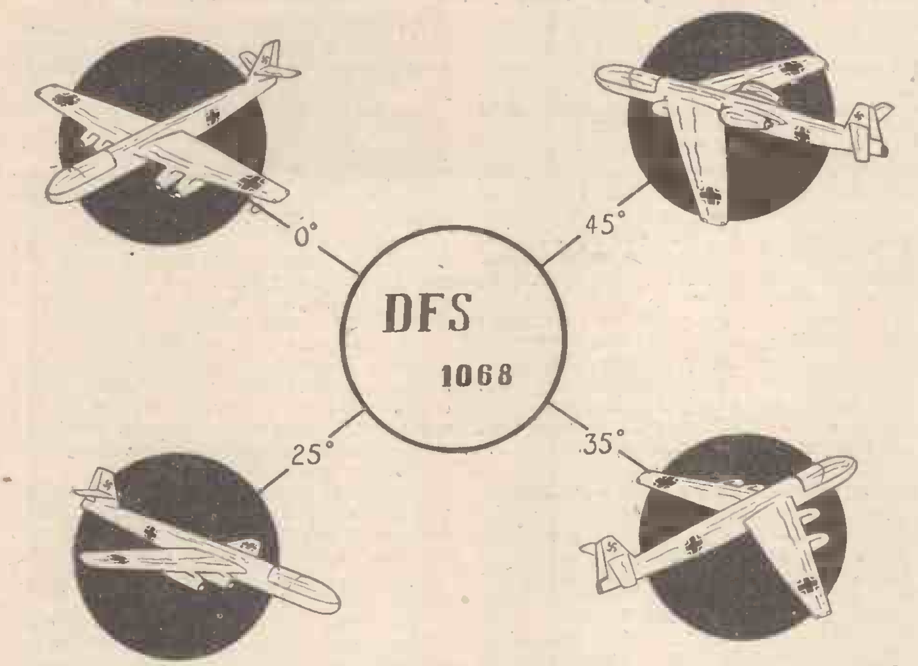
Key Technicians of the Institute

At the head of the D.F.S. "family tree" was Director W. J. O. Georgii (Prof., Dr., Dr. Eng.), formerly professor of flight meteorology and aeronautical research at the Technische Hochschule in Darmstadt; his deputies numbered two, Dipl. Temme on the technical side and Ing. Stamer representing the management.

Each of the ten technical departments had its own leading specialist, as noted in the following list, which will also serve to convey some idea of the institute's increased significance in recent years: (1) Institute for aerodynamics, Prof. Ruden; (2) Institute for glider construction, Dipl. Kracht; (3) institute for flight tests, Ing. Stamer; (4) institute for aeronautical equipment, Prof. Fischel; (5) Institute for physics of the atmosphere, Dr. Höhndorf; (6) department for high frequency, Dr. Folsche; (7) laboratory for special engines, Dr. Eisele; (8) department for engines, Dr. Sänger; (9) photographic section, Dipl. Harth; and (10) central workshop, Ing. Erbskorn.

Administration was in the hands of Herr Rauber.

Needless to say, most if not all of these technicians are now absorbed in various research activities adding to the technological advantage of the United Nations. Among



These four aircraft, descendants of the DFS. 228, were intended for research at Mach numbers between 0.8 and 1.2. Particulars of engines and propellants are given in the accompanying table.

the names that readers may have recognised is that of Dr. Sänger, pioneer rocket engineer and aerodynamicsist. In his book, the Technique of Rocket Flight, published in the days of bi-planes (1931), Sänger set out the fundamentals for a supersonic aircraft, and, as will be gauged from Fig. 50 (PRACTICAL MECHANICS, January 1946, p. 134), time has proved him a no mean prophet. His original research with liquid-fuelled rocket engines at the University of Vienna was none the less amazing; like the V-2 power plant, Sänger's engine of the early 1930s was fuel cooled. It operated on a refined diesel oil and liquid oxygen and was capable of thrusting continuously for periods of anything up to 30 minutes; in those days an unprecedented feat.

There still remains much to be said of Dr. Sänger, especially in his work at the Research Institute for the technique of Rocket Flight at Tauen, where, in 1936, rocket engines of 100 tons thrust were under project along with suitable airframes for withstanding travel at Mach numbers between 3 and 30. When, later, Sänger was incorporated into D.F.S., his main work consisted in developing the Lorin "athodyd" engine.

Beginnings of the Reconnaissance Glider

A complete account of the D.F.S. would fill volumes, and, in any event, by far the greater proportion of the work concerned slow-flight research, which is no concern in this writing. Sufficient to say of the experiments which led up to the rocket-gliders is that by 1940 a newly discovered technique, termed "wave-gliding," was permitting motor-less flights into regions of the substratosphere. A sailplane had been successfully operated up to 38,000ft. in 1939 and, but for the ill-effects of cold and reducing atmospheric pressure on the pilot, it was evident that the machine could have flown still higher. Its flight depended upon rising waves which had been found to occur behind ranges of mountain when certain wind currents were prevalent.

There is a story told in Germany that illustrates vividly the possibilities of "wave-gliding," to say nothing of its hazards. It

Type No.	Description and Purpose	Power Plant	Propellant	Dimensions length	Dimensions span	Wing Area	Wing Loading loaded	Wing Loading empty	Speed/ Mach No.	Operational Ceiling	Range Safe	Range Max.	Remarks
DFS 54v-1	High-altitude research glider for testing pressure-cabin and emergency escape technique. Experimental prototype of DFS 228v-1	None	None	29ft. 5in. *	65ft. 6in. *			3.4 lb./ sq. ft. *					One completed and flown
DFS 228v-1	Reconnaissance glider, rocket-assisted, and similar in general conception to DFS 54v-1	Walter 109/509D rocket unit	T. and C. stoffs	34ft. 7in.	57ft. 6in.	323 lb./ sq. ft.	28 lb./ sq. ft.	12 lb./ sq. ft.	560 m.p.h. (max.)	75,000ft.	460 miles	650 miles	One (at least) completed and successfully tested under glide
DFS 228v-2	Identical to DFS 228v-1 but with couch for prone piloting in lieu of upright seating												One completed but destroyed during air-raid
DFS 332	Rocket-boosted research glider with twin booms, for testing various wing sections at high Reynolds numbers	Two Walter 109/501 rocket units	T. and Z. stoffs with petrol (burnt with liberated O_2)										One partially completed at Ainring
DFS 346	Rocket-boosted glider for transonic and supersonic research at high altitudes. Similar to DFS 228v-2 but with 45 deg. wing sweepback	Walter 109/509D rocket unit	T. and C. stoffs						Between .8 and 2.0	100,000ft.			Under construction by the firm Siebel at Halle
DFS 1068 v-1	Glider with turbo-jet and rocket boosters for transonic and supersonic research at high altitudes—no wing sweepback. (See illustration above)	Four Ju. 004 or four He. SO.11 turbo-jets, plus one Walter 109/509D rocket unit	J-2 (brown coal-oil) and T. and C. stoffs						Between .8 and 1.2	50,000ft.			
DFS 1068 v-2	As DFS 1068v-1 but with 25 deg. wing sweepback	As in DFS 1068v-1, less rocket unit				Almost completed by the firm Wrede at Freilassing, subsequently destroyed during an air-raid			.8 and 1.2	50,000ft.			
DFS 1068 v-3	As DFS 1068v-1 but with 35 deg. wing sweepback	As in DFS 1068v-1				Partially constructed by the firm Wrede at Freilassing, subsequently destroyed during an air-raid			.8 and 1.2	50,000ft.			
DFS 1068 v-4	As DFS 1068v-1 but with 45 deg. wing sweepback	As in DFS 1068v-1							.8 and 1.2	50,000ft.			

Figures marked thus: * are unchecked.

Table showing the nine glider projects which the D.F.S. had under development at the time of the surrender.

concerns two pilots of the Horten company who, intent on obtaining some first hand data of the buoying currents which they knew swept up from the Hartz mountains, contrived to ascend with them. Each took a separate Horten tailless glider and, after cutting loose from their respective tow cables, they entered the lower reaches of a rising stream. The immediate result was an unbelievably swift ascent which would have done credit to a high-powered fighter. So great, in fact, was the force at which they were driven that both were left nothing to do but hold their craft steady while each watched his altimeter as the needle rose, clocking thousands of feet altitude.

The aim had been to reach 20,000 feet and, coming up to that level, they set their controls for the long glide back to base—*but there was no response.* With noses pressed hard down and lift spoilers in full operation, the gliders continued to rise unchecked and, try as they may, their pilots could do nothing about it.

The reduced pressure and extreme cold at still greater heights were more than they dare risk and rather than gamble on the gliders becoming freed from the rising currents before they blacked-out and were frozen, the two men took what seemed the logical course and baled out.

One of the machines was flying higher than the other and its pilot was the first to jump. Watched by his companion, he dropped away and despite the freezing temperature, which by that time must have rendered his fingers almost useless, he succeeded in pulling the rip-cord. His parachute was seen to blossom out, but as suddenly as it had arrested his fall, so the vicious air current again took charge and he was blown upward, to be frozen to death somewhere in the sub-stratosphere.

The second pilot was more fortunate. Although he too decided to bale out and was again borne up for some distance when his canopy opened, the rising stream must have carried him near its fringe for at length he slowly began to descend. He lived to tell this remarkable tale, but so severely frostbitten were his hands that one of them had to be amputated. This, of course, is a very sketchy summary of the incident, but it does serve to indicate the nature and extent of the phenomenon.

In these and other tests, German pilots had broken all established altitude records for gliders, but that was incidental; their exploits had been watched with keen interest by the Luftwaffe chiefs.

To the D.F.S. eventually fell the task of designing a special pressure cabin; and thus was born the idea for a true stratosphere glider, and with it the possibility of reconnaissance from heights inaccessible to fighters.

Design Problems

The designers of the DFS.228 had three principal aims: to provide (a) the lightest possible structure, to contain (b) a pressure cabin, and (c) a controllable Walter rocket system.

It should be mentioned that there were two versions of this machine, the first having normal upright seating and the other—the one described—embodying its pilot prone. However, the design was initially built under the type number DFS.54, with which an extensive series of glide tests had been made before constructing the DFS.228V-1. (See the table on page 267).

At first, the incorporation of a pressure cabin in a glider, whilst still retaining in it reasonable soaring qualities, seemed entirely out of the question. There was obviously no use attempting to adapt systems of existing high-altitude aircraft for any one was far too heavy and would have put the wing loading up prohibitively. Thus, entirely original research was called for to achieve the seemingly impossible in providing superlight pressurisation, upon which depended the ultimate success or failure of the entire project.

A consideration of the weights involved in this extra equipment made it clear that a desired wing loading (all fuel gone) of 12lb./sq. ft. was impossible with a wing area of anything less than 300 sq. ft. The final figure worked out at 323 sq. ft. Other leading dimensions were: length, 34ft. 7in., and span, 57ft. 6in.

To assist in keeping the overall weight down to within practicable limits more than usual attention was given to eliminating unnecessary mass in the glider's structure. The bulkheads, stringers and spars were almost entirely fashioned from hardwood, and equipment was reduced to a minimum.

DFS.228V-2—Design of the Fuselage

The fuselage was cylindrical for the greater part of its length, having a rounded nose and a tapered after section.

The nosing housed the pressure cabin and took the form of a two-wall metal cylinder, the ends of which were sealed by a strong rear bulkhead and a moulded "Plexiglas" windscreen. There was no mechanical load whatever imposed upon the shells, the liner serving to withstand pressures within the cabin, whilst the outer skin was relied upon to check external forces. A satisfactory insulation was found in the use of aluminium foil packed into the space between the cabin walls—a similar arrangement now used to limit radiation in certain "prefab" houses.

Accommodation for the pilot was provided by a tubular metal couch attached to the rear bulkhead, on which he lay full length. This was a great improvement over the seating in the sub-type V-1 and, as well as affording better vision, it greatly facilitated the task of pressure sealing. To allow entry into the cabin, the nose—complete with couch—was designed to slide forward a distance of 3ft., and by this means all possible strain was eliminated from the delicate cabin walls.

The prone piloting position naturally involved a rearranged control system. It was necessary to place the rudder pedals at the rear of the couch, whilst a short control column was fixed at the front on the pilot's right, with trimming and throttle controls on his left.

The cabin, because of its light make-up, did not permit internal pressures greater than a figure corresponding to conditions at 26,000ft., and this made a separate oxygen supply essential. It was capable of holding a differential pressure of about 6lb. sq. in., with a loss of only 3 per cent. in 24 hours; the rotating joints through which the control rods emerged were the source of greatest leakage. There being no piston engine (or other suitable power plant) to drive pumps in the pressurisation system, it was necessary to install compressed-air bottles, and a point of interest is that the pilot's breath actively assisted the charging, undergoing a drying process before its reintroduction.

A means of heating was another problem, but this was eventually overcome by providing a tube through which cold, dry air was introduced, with slow-burning cartridges—ignited at frequent intervals—employed to apply heat.

Aft of the cabin in the glider's centre fuselage section, double-skinned with ply. and insulated, contained two Zeiss infra-red cameras; behind them were the C-stoff and T-stoff tanks and pumps and ancillaries which, complete with a single combustion chamber (housed in the rear of the tail), comprised the Walter 109-509D rocket engine. A hinged door extended along the top of the entire centre section, providing a convenient means for servicing the propellant system and cameras.

Housed in the lower part of this section was also a metal landing skid which faired flush with the skin during flight and was extended manually prior to landing.

Wings and Tail

Arrangement of the lifting and stabilising surfaces was orthodox, attachment for the wings being slightly lower than mid-depth of the fuselage, whilst the tail-plane bolted to the single fin a short distance above its root.

The wings were built up on a single laminated wooden spar, with hardwood ribs and ply covering. Two sets of fabric-covered ailerons were provided on each, the inner pair to operate as flaps during the landing approach. There were also lift spoilers, four in all, fitted on both the upper and lower surfaces.

The tail-plane and fin—the former adjustable—were also constructed in wood, with fabric-covered rudder and elevators of conventional design.

Escape from High Altitudes

There was obviously no future in baling out under stratospheric conditions, and the extreme operational ceiling of the DFS.228 demanded more than usual safeguards. A pressure suit had been suggested as a ready means for satisfying both pressurisation and escape problems, but for some reason it was not proceeded with.

It was arranged for the pilot to effect his release by severing his cabin from the aircraft, which he was to accomplish by operating a lever, detonating four explosive bolts. The cabin would fall away nose-first, trailing a small parachute to keep it upright, and thus it was possible to maintain pressurisation until the pilot had descended to a safe altitude. A barometric capsule then set in operation a piston and cylinder—actuated by compressed air—which thrust the couch and transparent nose forwards, at the same time freeing the pilot from his harness.

A static line attached to the cabin opened the pilot's parachute as he jumped clear.

Spreading Out

The Allied air offensive caused the Institute's personnel to disperse, and most of their equipment was found in cellars and barracks at the Ainring airfield, at dispersal laboratories and workshops at Reichenhalle, Feisenderf and in other neighbouring villages. Still more D.F.S. gear was uncovered in farmhouses and castles in the Ainring area.

This policy, however, did not prevent the destruction of some of the group's most treasured projects, including the prototype DFS.228V-2.

(*To be continued*)

PRACTICAL MECHANICS
EDITOR F. J. CAMM
OCTOBER, 1951
VOL. XIX. No. 214
Owing to the paper shortage "The Cyclist," "Practical Motorist," and "Home Movies" are temporarily incorporated.

FAIR COMMENT

By The Editor

Is Interplanetary Travel Possible?

EVER since the imaginative fiction of Jules Verne and H. G. Wells there has been an increasing belief in scientific circles that in time we shall be able to visit the moon and some of the other planets which are part of the mysterious Universe. Our knowledge of them at present is scientific conjecture. Practice has been made to fit theory. Our only knowledge of the planets is what we have gained by calculation and by visual examination by means of an astronomical telescope. Perhaps before this century closes a space ship will enable us to visit the moon, which is only 240,000 miles distant, and we shall have ascertained how far our conjectures have been right.

From a practical and from scientific points of view a space ship which could make the journey is not an impossibility. The experimental work would be costly, of course, and no doubt in the attempt there will be loss of life as in the early days of flying. Such a risk would not act as a deterrent. There are plenty of volunteers who would be willing at the present time to undertake the journey if the space ship were available.

The British Interplanetary Society has been steadily examining the problem over a long period of years. Its members are trained scientists well able and qualified to undertake the design of an interstellar ship. The movement is growing in importance, as was evident from its recent lecture session in London, where prominent interplanetary specialists gave lectures disclosing the present state of our knowledge and progress.

Professor Lyman Spitzer, of the Princeton University Observatory, agrees that while it appears possible to project a multi-step rocket into a close orbit about the earth, the next step of proceeding from this orbit to the surface of the moon or another planet and back would require at present prohibitive quantities of conventional propellants. In other words, we shall have to discover a new propellant. Perhaps atomic power will supply the answer.

The application of nuclear energy to heat up a propellant in a conventional type of rocket, however, does not appear to offer a substantial improvement on the chemical rocket because of limitations of temperature and power rating, which prevent the achievement of very high exhaust velocities and the high thrusts needed to lift vehicles against planetary gravitational fields.

In the case of an interplanetary ship operating between a circular orbit around one planet and a similar orbit round another without making a landing, it is possible to employ a new principle which might effect great economies in the amount of propellants and materials which must be carried up into the orbit.

This principle depends on the fact that such a ship can be propelled by very low thrust, whence it is possible to use high exhaust velocities without involving excessive power production. The high velocity exhaust stream would be obtained by accelerating a beam of ions in an electric field, power being provided by a nuclear reactor. Professor Spitzer gave as an example a ship developing an exhaust velocity of 100 km./sec. and a thrust sufficient to provide an acceleration of 0.3 cm./sec. Such a ship could undertake a total velocity change of 30 km./sec. with a mass ratio of only 1.3. The useful mass ratio of the vehicle would be 150 kW/tonne. This ship would be a small one weighing 10 tonnes, the energy source being a 1 tonne U235 or a PU239 reactor producing heat energy at the rate of 4,500 kW. To avoid heavy radiation shields one envisages the vehicle as a separate pilotless power section, towing by means of thin wires a light control car containing the crew at a distance of 100 km. Alternatively, a long cylindrical construction might be adopted with a shield at the end of the pile facing the control car. The atomic pile might use a heavy water both as a moderator and as a working fluid to drive a steam turbine and a D.C. generator. Waste heat from the condenser would be dissipated by radiation from a fin 1,000 sq. metres in area at 450 deg. K. The heat would be taken into the working fluid at 900 deg. K. to ensure 50 per cent. thermal efficiency.

Nitrogen would be used as the propellant, since it could be collected from the atmospheres of a number of planets. A potential difference of 740 volts would be required to accelerate nitrogen ions to a velocity of 100 km./sec. and a total current of 2,000 amperes would be required to produce the necessary thrust. This potential would be applied between two mesh screens 1 mm. apart, and thermionic emission of electrons from the outer screen would ensure electrical neutrality. The area of cross-section of the beam would need to be about 7 sq. metres to avoid space charge limitation. Communication between a space ship of this type and a planetary surface would be achieved by means of a satellite vehicle of conventional type. The interplanetary ship would have to be carried up to the orbit in the first instance by means of a booster rocket weighing perhaps a few thousand tons. In making a landing on a planet such as Mars a winged rocket might be used carrying to the surface the propellants needed for the ascent.

The suggestion has already been made in America that a stratospheric platform should be built as a sort of starting-off point and on which would be "land" instruments, radar apparatus, and transmitting and receiving equipment so that communication could be maintained between the aerial platform and the crew of the space ship.

Of course, there are other suggestions for space ships, such as step rockets, that is to say a series of rockets joined one behind the other to the control car, each rocket being fired at certain intervals of time in order to complete the space journey.—F. J. C.

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INTERPLANETARY TRAVEL

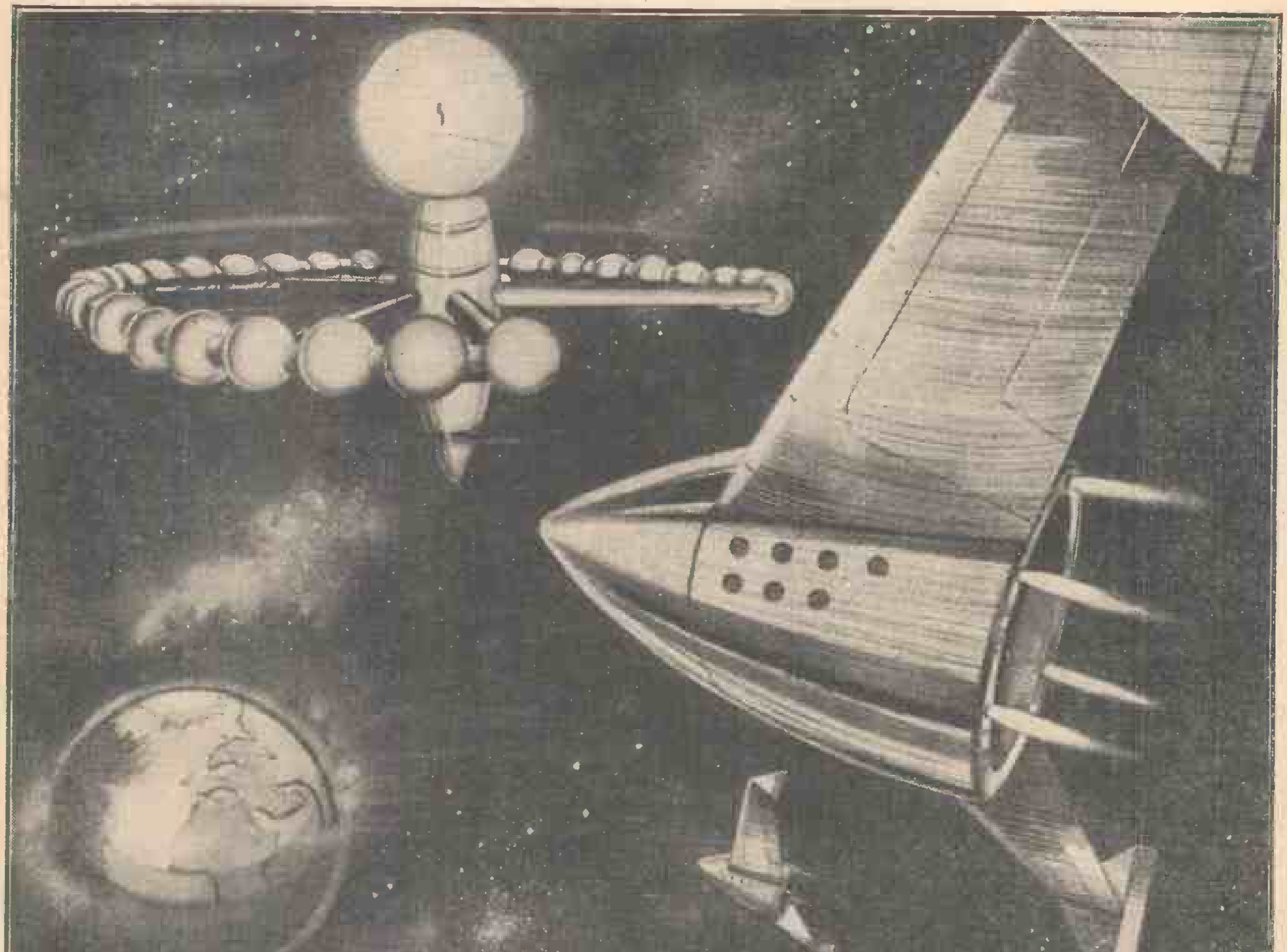
NEWNES

PRACTICAL MECHANICS

1/-

EDITOR : F. J. CAMM

NOVEMBER 1951



PRINCIPAL CONTENTS

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WORLD OF MODELS
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CYCLIST SECTION

PRACTICAL MECHANICS
EDITOR F. J. CAMM
NOVEMBER, 1951
VOL. XIX. No. 215
Owing to the paper shortage "The Cyclist," "Practical Motorist," and "Home Movies" are temporarily incorporated.

FAIR COMMENT By The Editor

A College of Technologists?

THE position of Great Britain as a leading industrial nation is being endangered by failure to secure the fullest possible application of science to industry, and this failure is partly due to deficiencies in education. Those are not my words, but those of the Percy Report published in 1945.

The Government heeded those warning words to some extent and the number of students taking technological subjects at universities is double that for the year 1939. Some universities have started post-graduate courses in technology. Unfortunately these courses do not go far enough, and, after six years, industry is still perilously short of skilled men in the higher grades, and shorter still of skilled men in the practical crafts.

The universities are not well equipped to provide academic training in technology.

The Government recently published a White Paper on technological education in which it states its acceptance in general terms of the recommendation of the National Advisory Council on Education for Industry and Commerce which were made in a report issued by the latter body in November, 1950.

One of the suggestions in that report was that a Royal College of Technologists should be founded to encourage the development in suitable technical colleges of advanced courses at first-award and post-graduate standards.

The report also recommended that increased financial assistance should be given to the colleges and also that the new courses should be framed in close co-operation with industry. The Government has decided, however, that the title should be College of Technology, and that it should be established, at the first stage at any rate, without any responsibility other than the granting of an award and the approval of the courses.

It is my view that the result which it is intended to achieve would be more easily attained by starting a number of such colleges throughout the country, and which would in time achieve international reputation equivalent to those of similar colleges in other countries.

The Zurich Hochschule and the Massachusetts Institute are the type of college I have in mind. Until the college has attained status of this sort it cannot attract students of the highest calibre.

Six valuable years have gone by in which such colleges could have made progress towards international recognition.

In the report of the Council it is stated "an evolutionary method should be adopted in the development of higher work and research in the colleges, whereby advanced courses are concentrated, as speedily as building conditions permit, in colleges which are in a position to transfer elsewhere the whole or the greater part of their junior and less advanced work." Conditions in the colleges should be such as will attract good students and the right kind of staff.

The White Paper rejects the recommendation of the Percy Report for the setting up of technological universities, the reason given being the estimated cost of £6,000,000. This seems to suggest that the College of Technology will have to struggle along on a small Government grant. As there are 66 colleges in England, Scotland and Wales to share the grant it is obvious that we cannot expect rapid or spectacular results.

COAL BY PIPELINE?

THE experiences of the past 10 years in the supply and distribution of coal has drawn attention to a problem which seems insoluble. The National Coal Board's Central Research Station is giving attention to the possibilities of coal as a chemical and as a synthetic or reconstituted fuel. This, however, must remain a long-term project. For many years we shall continue to obtain coal by direct methods of hewing. No doubt in the future all coal will be ground to powder at the coal-face and be pumped to the surface in water. It may possibly be distributed to industrial areas by pipeline.

Coal dust and fine coal is already being mixed with a suitable binder or aggregate to produce briquettes which give more heat than lump coal and are cleaner, freer from dust, and uniform in size and quality. Already a press has been designed to make cobble briquettes weighing about $1\frac{1}{2}$ lb. each. It has been installed at Cardiff and is producing five tons of such briquettes an hour. No doubt if this system was developed quickly it would help to solve our coal problem.

INTERPLANETARY TRAVEL

MY article last month (augmented this month in an article containing fuller information on pages 46 to 48) has aroused great interest in interplanetary travel. Readers have expressed surprise that developments in astronautics have gone so far.

The British Interplanetary Society, which was founded in 1933 to promote the development of interplanetary exploration and communication by the study of rocket engineering, astronomy and other associated sciences, now includes among its members many British and foreign workers prominent in these fields. The society organises meetings, lectures, exhibitions and film shows to spread technical knowledge and to bring home to the public the limitless possibilities of rocket propulsion and the ultimate implications to human society of the crossing of space. Membership is open to all interested in the subject, no technical or other qualifications being required. Fellowship is open to those who possess scientific, technical, or professional qualifications.

In America, where considerable progress has been made, the American Rocket Society performs a similar function.—F. J. C.

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The Present State of the Science and the Latest Ideas in Astronautics Reviewed

By F. J. CAMM

ASTRONAUTICS refers to the new science of flight beyond the atmosphere, and travel to other worlds. Because it has been the subject of fiction by scientific authors such as H. G. Wells it is still regarded by some as a fantasy which will never fructify.

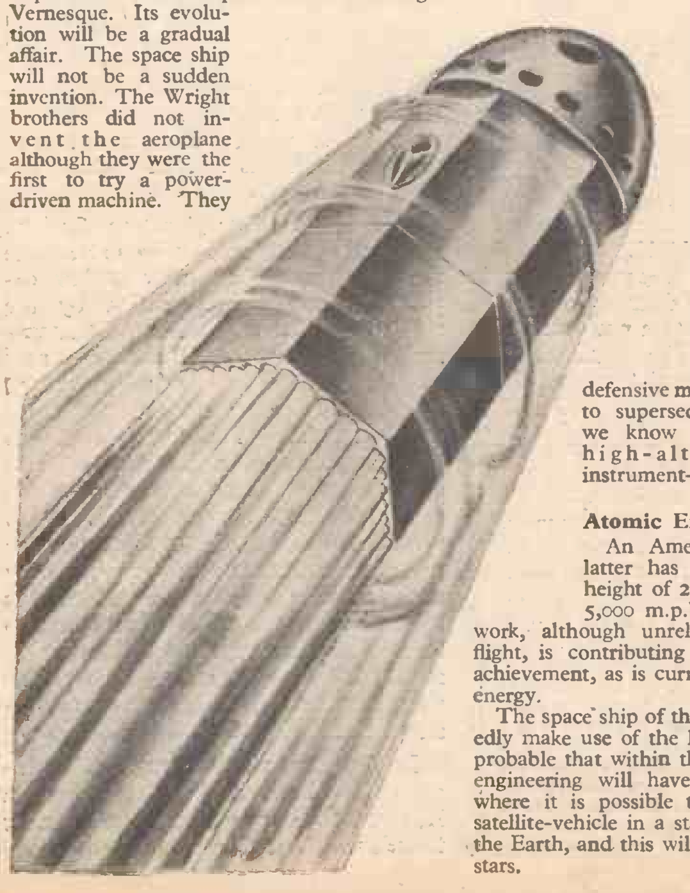
Similar views were held concerning the sister science of aeronautics, about radio, and certainly about television. Yet television is a far more remarkable achievement than the construction of a device for travelling to other worlds. There is no scientific reason why after a process of gradual development and evolution a space ship should not be successful.

We know a great deal to-day about travelling through the air, into the Heavyside Layer, the troposphere and the regions beyond. As with every other scientific development, such as the motor-car and the aeroplane, the invention is forecast many years before it reaches practical development.

Often it is because of some missing link; in the case of the motor-car it was the internal-combustion engine. The past 50 years have been most remarkable in scientific developments. Each new discovery or invention improves existing devices. Thus radar, radio and television have made flying safe.

With all this knowledge in a number of unrelated directions at our command it only requires a co-ordinating effort to apply it in new directions. The raw materials for space travel have been produced, and they now require unification. Space travel is no longer Vernesque. Its evolution will be a gradual affair. The space ship will not be a sudden invention. The Wright brothers did not invent the aeroplane although they were the first to try a power-driven machine. They made use of and co-ordinated the knowledge which had been gained by dozens of individual experimenters.

The subject is now being studied very closely, as was apparent from the recent International Congress on Astronautics which took place in London during September, and at which a number of scientists of international repute gave their ideas as to how the space ship should be constructed.



Rocket Propulsion

It was generally agreed that the rocket affords the means, the only one so far known of realising the dreams of Jules Verne and H. G. Wells. It is now well known that a rocket is more efficient in the vacuum of outer space and at high flight speeds than it is within the atmosphere. Another great advantage is that it can generate enormous power for little weight and size of engine. The power/weight ratio cannot be equalled by any other form of motive power.

The V2 used by the Germans during the war, for example, was four times as powerful as the "*Queen Elizabeth*." Some of the early pioneers of astronautics were Goddard in America, Oberth in Germany, Esnault-Pelterie in France, Tsiolkovsky in Russia, and small amateur societies, mainly in Germany and America, endeavour to carry on the work.

In World War Two Germany made great use of rocket engineering. To-day it is being actively developed all over the world for assisting the take-off of aircraft, for the propulsion of aircraft at extreme speed and heights (the American Bell XI rocket plane was the first to fly faster than sound, and its successors are intended to fly at several thousand m.p.h. and at altitudes of hundreds of thousands of feet); for offensive and defensive missiles, likely eventually to supersede military aircraft as we know it to-day; and for high-altitude research by instrument-carrying projectiles.

Atomic Energy

An American example of the latter has already climbed to a height of 250 miles at a speed of 5,000 m.p.h. This experimental work, although unrelated to interplanetary flight, is contributing data for its eventual achievement, as is current research on atomic energy.

The space ship of the future will undoubtedly make use of the latter. It is more than probable that within the next 20 years rocket engineering will have advanced to a stage where it is possible to establish an Earth-satellite-vehicle in a stable close orbit around the Earth, and this will be the first step to the stars.

Once the Earth-satellite-vehicle has been established flights by piloted rockets several thousands of miles into space will follow. There will be flights circumnavigating the Moon without landing on its surface, first by robot projectiles carrying television and later by piloted craft, flights to the Moon by piloted space ships landing tail first on its airless surface using the braking effect of their rocket jets, then taking off again and returning to Earth, where a safe landing may be made by using wind within the atmosphere.

There will also be flights to other planets of the Sun's family. First to Mars and Venus because they are nearest. A century or more hence no doubt the planets of other suns—the distant stars—will be visited.

Many involved technical problems, however, need to be solved before that is possible. When the Great Adventure commences depends entirely on the funds and the facilities made available for the task. But astronautical engineers expect the first piloted return flight to the Moon to take place before the end of the present century. After all it is 42 years ago since Blériot crossed the Channel. It could happen sooner if a concerted attack were made on the problem, such as the effort which is being made in connection with the atomic bomb.

The "Earth-satellite-vehicle"

The theme of the technical sessions of the Second International Congress on Astronautics was the Earth-satellite-vehicle, or orbital rocket, because this represents the first great objective on the way to interplanetary flight.

The American Government has already announced that it is seriously studying the Earth-satellite-vehicle, which has many practical uses, both for military and civil purposes. (Ref. statement by J. V. Forrestal, U.S. Defence Secretary, in Report to Congress, Dec., 1948.) The first artificial satellite to be established will undoubtedly be nothing more than a small radio-controlled rocket carrying automatic instruments for research purposes, capable of sending its readings back to earth by radio.

Piloted rocket craft will follow later; they could leave their circular orbits at will; by reducing speed with rocket jets firing in the direction of motion, and land back on Earth using wings like normal aircraft.

The principle of the Earth satellite is very simple. A good analogy may be obtained by tying a stone to a piece of string and whirling it round in a circle. The stone keeps travelling in the circle because the inward tension in the string balances the *outward* centrifugal force produced by the stone's motion.

In exactly the same way a body circling the Earth at the right speed would remain at a constant distance, in a state of equilibrium. This time the outward centrifugal force would be balanced by the invisible, but very powerful, pull of gravity.

The nearer the satellite to the Earth, the more rapidly it would have to move to maintain itself. Just outside the atmosphere, a few hundred miles up, the required speed is about 18,000 m.p.h.

Moreover, once the satellite had been given its initial speed it could never lose it again, since there is no air-resistance in power, and could never fall down—any more than does the Moon, which stays in its orbit for exactly the same reason.

It is important to realise that the satellite would *not* stay up because it is "beyond the pull of gravity" as is sometimes stated. The pull of gravity (like the tension of the string in the analogy given earlier) is essential to prevent it from flying off into space.

Thus a rocket guided into the correct circular path around the Earth could shut off its motors once it had reached the required speed and remain orbiting the Earth for ever in perfect safety. The satellite could be established at any distance, but for technical reasons it would be easier to place it as near the Earth as possible—as long, of course, as it was outside the atmosphere and thus immune to air-resistance.

The value of such orbital rockets would be:

(a) as research observatories beyond the atmosphere, for physicists and astronomers. (Study of cosmic ray primaries, and astronomical observation without hindrance from our semi-opaque atmosphere, etc.)

(b) as observatories for meteorologists, who could "see" the Earth's weather system developing, and thus make more accurate forecasts—a use probably of particular interest to the British!

(c) as radio relay stations, capable of receiving short-wave signals from the Earth's surface and rebroadcasting them to reach round the curvature of the surface, so removing the limitation on range which the horizon normally imposes for ultra-short-wave transmission. This would permit world-wide reception of television, or "frequency-modulated" radio (free from atmospherics), also the radio guidance of military missiles over longer ranges.

The floating platform under construction. Parts are ferried in freighter rockets. The artificial planet is balanced against gravity like the moon.

(d) as military bases for reconnaissance, or even for launching projectiles.

The Space-station

Eventually, a large manned "space-station" might be constructed from components ferried out to the required orbit by rocket craft. Space ships might also be refuelled, while waiting in such orbits, from tanker rockets climbing up from the Earth's surface to meet them. Both these seemingly fantastic developments would be practicable, because any object, once established in the orbit, would have the effects on it of both gravity and velocity balanced out; it would have no apparent weight, and would "float" in space. Connection between one rocket and another, in a circular orbit in which both were "Earth-satellites," would also be entirely feasible. Although both would be moving at tremendous speeds, their *relative* velocity would be zero.

It is the value of these orbital techniques in connection with refuelling future space ships which makes them so interesting and important for interplanetary flight, apart from the fact that the practical uses of orbital rockets, in themselves, afford a powerful reason for obtaining support for astronautics in the early stages of the subject.

Men who will build a space-station from which the moon can be reached, will take off in a winged rocket like this, poised ready for launching.

Mr. L. R. Shepherd, Ph.D., in his lecture before the British Interplanetary Society, said that it is now generally agreed that the requirements of a vehicle, making a non-refuelling return-flight to the Moon or other planets, are too severe to be met by existing methods of propulsion. However, if one could accumulate sufficient fuel and materials in a close orbit about the Earth, it would be possible to proceed from there to the surface of the Moon and back.

The attainment of a circular orbit at a height of 500 kilometres above the Earth's surface would not prove too difficult. A three-step rocket with an exhaust velocity of 3 km/sec., an effective mass-ratio of <50, and a ratio of initial mass to payload of *c*300 should be capable of achieving this orbit.

This performance is not outside the range of present techniques. However, we should need to do better before proceeding on to the next stage of interplanetary flight, otherwise we should be forced to carry out a "lift" involving hundreds of flights by satellite vehicles before we had accumulated sufficient materials in the orbit. Improvements would be required, both in the performance of the satellite vehicle and in the subsequent interplanetary vessel in order to bring the project down to a reasonable economic level.

Improvements in the satellite vehicle might be achieved with chemical propellants or might lie in the application of nuclear energy. In the case of the inter-orbital vehicle, however, one might go to a new principle, making use of very high exhaust velocities (~ 100 km/sec.) at very low accelerations ($\sim 10^{-3}$g). This could be done in an "ion-rocket," employing a propulsive jet consisting of a beam of electrically-accelerated ions. Such a vehicle would not be capable of landing on the surfaces of planets, but would be capable of executing large velocity changes with low mass-ratios, operating exclusively between satellite stations—for example, between an Earth-satellite and the tiny Martian moons, Deimos and Phobos.

Space-flight might therefore be carried out in two types of vehicle, viz., satellite vehicles having low exhaust velocity and high thrust operating from surface to orbit, and interplanetary space ships having very high exhaust velocity but very low acceleration operating between orbits. Permanent orbiting space-stations might be included in this scheme to act as the junctions between the two types of vehicle, but they would not be essential to the scheme. Space-stations and ion-rockets might draw propellants and other massive materials from bases on small satellites or the asteroids to avoid having to lift these through large gravitational potentials.

The Four Regions

The aerodynamics of a space rocket must take into consideration the fact that during

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FAIR COMMENT
By
The Editor

Woolly Views About Space Travel

I MUST gently chide the new Astronomer Royal, Prof. Richard vander Riet Woolley, for his recently expressed views on interplanetary travel. Prof. Woolley was chief assistant to the retiring Sir Harold Spencer Jones and he has been director of the Commonwealth Observatory at Mount Stromlo, Canberra. Prof. Woolley described himself as a straightforward scientist and as such he should not make the mistake of so many scientists before him of being dogmatic about the future. It is only possible to be dogmatic about the past. Only a quarter of a century ago those who forecast that we should be able to sit in our homes and watch a play taking place in a studio miles away were considered mental cases. Less than 60 years ago those who thought that we should fly in the air were considered mad. The medical profession thought that the motor car was impossible because, as they said, the heart could not withstand a speed of 60 miles an hour. Prof. Woolley referred to as "utter bilge" (most unscientific language) talk about the future of interplanetary travel. In support, he said that he did not think that "anybody would ever put up money to do such a thing. It would be enormously expensive. But if the next war could be won by the first chap getting to the moon and by that alone, some nation might put up the enormous amount required. I cannot give any idea how much it would cost, but it would be a very large sum indeed. It is all rather rot."

This is all rather "woolly" talk, and I am astonished that a scientific man should express such views, especially when those views are against the weight of scientific fact. He does not say that space travel is impossible, but merely that it will not take place because no country will put up the money! Quite apart from the general sloppiness of his phraseology, which is hardly that of one scientifically trained, he has no right whatever to presume that some country will not put up the money. The sum involved, in fact, for Prof. Woolley's information, would be considerably less than we are spending on the atomic bomb. Prof. Woolley, if he lives the normal span, will live to eat his words, and they will be quoted against him.

Like Lord Dowding, who incidentally has not accepted my challenge to an open debate on the subject of flying saucers, Prof. Woolley indulges in generalities and personal opinions, unbacked by any scientific evidence, and he rejects all of the scientific evidence in favour of interplanetary travel. The phrase "utter bilge" more appropriately applies to his own remarks, and as in the case of Lord Dowding, I also issue a challenge to him to an open debate on the subject.

I can, however, support his views about flying saucers, with the slight distinction that where he does not believe in them, my view is that I do not believe in them in so far as they are advanced as visitors from other planets. Any aircraft manufacturer could make a flying saucer. Prof. Woolley just does not believe in them, anyhow, and he supports this statement with a story. "I was wakened up about 3 a.m. by the R.A.F., who asked about an object at 3,000ft. due west. I hopped out of bed and had a look, and then I missed my chance. I should have said 'Take off, boys. It's the Russians.' Instead, I had to tell them it was the planet Mars."

The Astronomer Royal, no matter who he may be, is not in the best position to express views such as these. Is Prof. Woolley suggesting that the launching of artificial satellites during the International Geophysical year is utter bilge, and that this country is wasting its money on such a project? It is noted that Prof. Woolley's views are contrary to those of the man he succeeded, Sir Harold Spencer Jones, who has said that reaching the moon would be "well worth while." It seems a great pity that in taking over his new office Prof. Woolley should have made such absurd remarks which are quite contrary to the weight of scientific evidence.

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Who Invented the Wheel?

THE great controversy which has ranged round the authorship of Shakespeare's plays has become a national hobby. Did Bacon write them, or Marlowe, or Jonson? The opening of the tomb of Sir Thomas Walsingham, who was the patron of Marlowe, may yield, although I doubt it, some information on the subject. Whilst the country, however, has always been concerned with literary mysteries of this sort (even Boswell's papers were found after a search) no one has bothered to trace the origin of some really fundamental scientific discoveries, and I would put the wheel at the top of the list. Who first invented the wheel? Who first discovered that by mounting a slice off a tree-trunk, roughly rounded, large loads could be transported by human beings as well as animals? Who first discovered that by cutting notches round the circumference positive gear ratios could be obtained? It was Archimedes who first discovered the principle of the lever. "Give me a lever and I'll lift the world!" he said. Who first discovered the method of casting? There are hundreds of examples of cast articles made in copper, silver and gold, dating to centuries before the Christian era, as the opening of Tut-ank-amen's tomb revealed. Should we not be more concerned with these things than with who wrote the Shakespeare plays? My personal opinion is that Shakespeare did not write any of them. He was the Cochran of his period. He bought plays at a time when it was a scandal to be associated with "rogues and vagabonds," as actors were then considered. Who first taught the art of recording thought by means of writing, and reproducing them by means of the diptych? These are problems just as interesting as the authorship of the Shakespeare plays.—F. J. C.

THE EVOLUTION OF GUIDED MISSILES

No. 3.—Rocket Motor : Performance Figures for Various Engines : Turbo-jet Engine : Choice of Propulsion Method : Aerodynamic Form, Flight Performance and Control : Mounting of Control Surface

By G. W. H. GARDNER, C.B.E., B.Sc.

(Director-General of Technical Development (Air), Ministry of Supply)

Rocket Motor

THE rocket motor is also simple in the sense that in the solid-propellant version there are no moving parts at all and in the liquid-fuel version the only moving parts are associated, as in the ram jet, with fuel-supply and control. Aerodynamic problems associated with air swallowing are absent and motors can be tested up to full thrust on the ground with less extravagant facilities. In addition, because of its independence of the surrounding atmosphere, thrust at altitude is maintained; in fact, it increases somewhat as the atmospheric pressure falls. Fig. 22 shows the variation of thrust of a rocket and turbo-jet engine with altitude. The chemical problems associated with rocket propulsion are, however, more acute and because the specific fuel consumption of rockets is many times greater than that of air-swallowing engines great endeavour is made to employ higher flame temperatures to reduce this deficiency. Flame temperatures commonly used are about 2,500 deg. K. and the employment of even higher temperatures would introduce more severe engineering problems arising from heat transfer from the gases to the structure.

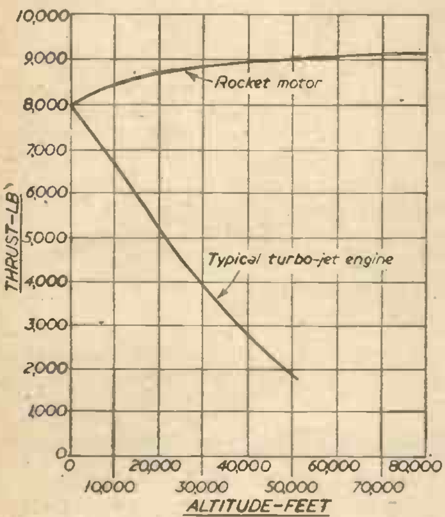


Fig. 22.—Variation of maximum thrust with altitude of a rocket motor and a turbo-jet engine.

The other main avenue for improvement is the use of propellants which produce gases of low molecular weight. In this instance the performance is inversely proportional to the square root of the molecular weight. Fuels now available can be pressed, extruded or cast in the solid form. Liquid-hydrocarbon fuels, in association with highly concentrated hydrogen peroxide, liquid oxygen or nitric acid, are also used. Work on rocket motors has led to some most interesting mechanical developments. The development of the high-speed fuel pump and its associated bearings and seals due to Barske is worthy of note. Another notable development is the successful welding and heat treatment of thin high-tensile steel sheets in cylindrical form to provide casting for solid-propellant motors. Cylinders of 70-ton steel 0.063in. thick have been made in this way to withstand a pressure of 1,500lb. per sq. in.

TABLE 1.—SOME PERFORMANCE FIGURES FOR VARIOUS ENGINES

Engine	Thrust horsepower	Specific power, thrust h.p. per lb. weight of engine	Overhaul period	Distance travelled, nautical miles
V.2 liquid-fuel rocket	627,000 (at $M=5.2$)	281	60 seconds	13
Aircraft turbojet: Future	35,000 (at $M=1.5$)	9.5	600 hours	500,000
Present	8,700 (at $M=0.9$)	3.5	600 hours	240,000
Aircraft piston	1,080	0.54	600 hours	180,000
4—6—2 steam locomotive ...	1,800	0.009	18 months	130,000
Modern geared steam turbine (marine)	9,100	0.008	1 year	122,500
Geared steam turbine (R.M.S. *Queen Mary*)	104,000	0.0035	1 year	202,000

Table 1 indicates, by comparison with examples of engines of other types, the enormous thrust horsepower achievable with the rocket motor for an extremely low weight. The V.2 liquid-fuel motor was remarkable in giving a thrust of 69,000lb. for a dry weight of only 2,235lb. complete. The speed reached by the missile after about 60 seconds, when the motor had completed its task, was approximately 5,000ft. per sec. ($M=5.2$). The engines are listed in Table 1 in order of specific power and, while it is of course, unfair, in view of the diverse duties and operating speeds of the vehicles which these engines propel, to compare performances from this aspect only, some interesting, if incidental, arguments can nevertheless be developed. For example, the very high specific power of the rocket is consistent with its very short designed life. On the other hand, the overhaul period of the aircraft turbo-jet engine is only 600 hours by comparison with a year (equivalent to about 7,200 hours' operation) for the geared steam turbine (marine) engine (which again might explain their relative specific powers), but further examination reveals that whereas the aircraft engine might easily have covered 240,000 nautical miles the ship engine installed in, say, a fast cargo boat would perhaps only have covered half this distance.

Turbo-jet Engine

In the past 10 years the thrust per unit area of British turbo-jet engines has

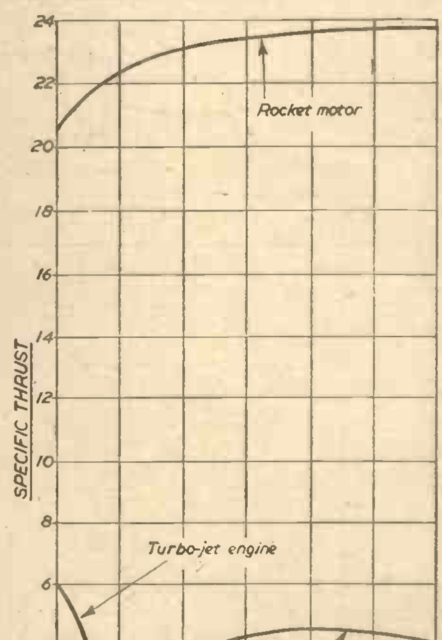


Fig. 23.—Specific thrust and rocket motor, turbo-jet engine and ram-jet at cruising altitude. Specific thrust=(net thrust at cruising altitude)/(engine dry weight).

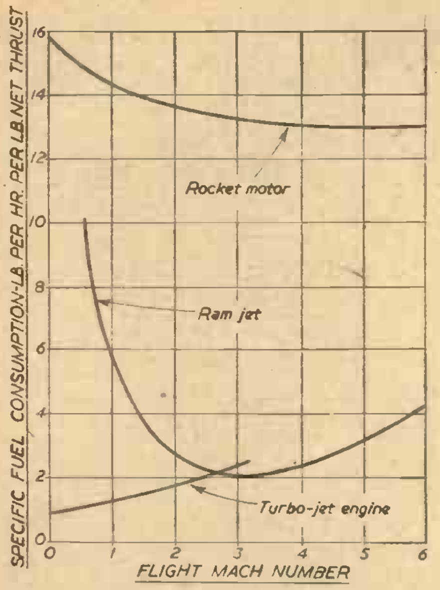


Fig. 24.—Specific fuel consumption of rocket motor, ram-jet and turbo-jet engine.

been increased six times, their specific weight has been halved and their specific fuel consumption reduced by 20 per cent. Nevertheless the turbo-jet does not yet compete with the rocket or ram jet as a means of propelling relatively short-range defensive missiles. We shall see better where it fits by examination of Figs. 23, 24 and 25.

Choice of Propulsion Method

Fig. 23 shows the outstanding merit of the rocket motor in terms of thrust divided by weight at all speeds by comparison with the turbo-jet engine and ram jet.

Fig. 24 shows the penalty in terms of fuel consumption of using a rocket motor and shows the superiority of the ram jet at speeds greater than $M=2.5$.

Fig. 25 shows the range superiority of the turbo-jet engine at moderate speeds and of the ram jet at the highest speeds.

In calculating the points on the curves just described an arbitrary relation between speed and height has been adopted. $M=2$ is assumed to occur at 60,000ft. and $M=4$ at 80,000ft.

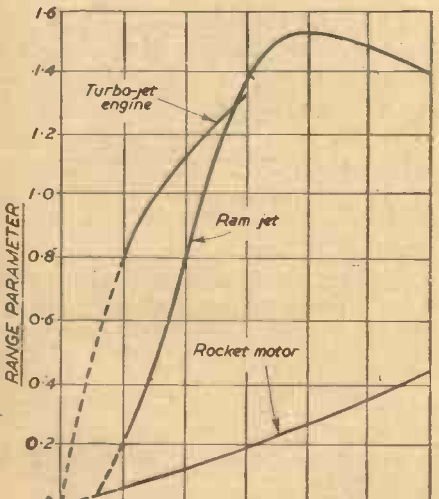


Fig. 25.—For a given ratio of initial to final weight and of lift to drag, range is proportional to the range parameter. At subsonic speeds lift-drag ratios are about three times those at supersonic speeds. The graph shows the range parameter plotted against speed.

It is clear that the rocket motor is most suitable for use as the boost to give an acceleration of, say, 25*g*, for, say, 2 seconds, and to achieve a speed of about one and a half times the speed of sound.

It is efficient to discard the boost motor carcase after the fuel is burnt, thereby reducing the weight and drag of the missile, and a solid fuel system fits this requirement most conveniently. Fig. 26 shows a cluster of boost motors after separation in flight.

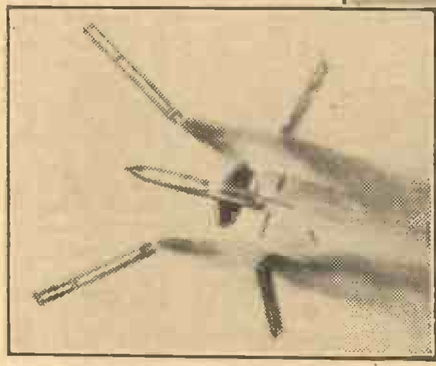


Fig. 26.—Separation of boost motors in flight.

It is found that the weight of the boost motors is of the same order as that of the missile, and since it is important to keep this weight as low as possible great attention must be paid to the choice of propellant on the one hand and, on the other, to the reduction of deadweight consisting of the metal container, the nozzle, stabilising fins and other fittings. Work on methods of manufacture of very thin-walled tubes must be continued, including the possible use of plastics for this and for the nozzle.

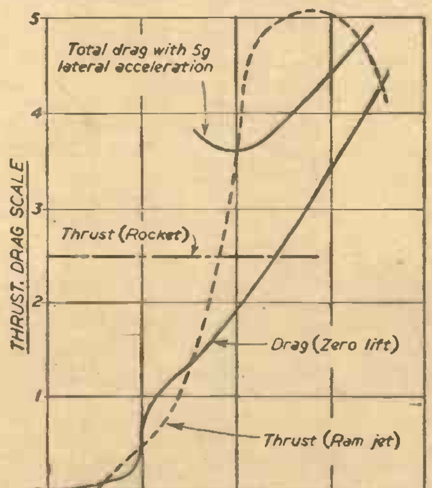


Fig. 27.—Thrust and drag curves for ram-jet and rocket missiles.

There is little doubt that the rocket motor provides the best main propulsive unit for very short short-range missiles or for those required to operate at very great heights. As missile range increases above about 20 miles the ram jet becomes more suitable, and at ranges greater than 100 miles the turbo-jet engine may have a place within limited height and speed boundaries.

Aerodynamic Form, Flight Performance and Control

To establish the aerodynamic form a vast amount of basic aerodynamic data are required on air forces exerted on aerofoils and bodies of different shapes and sizes over the whole speed, height and manœuvrability range of the missile. One must deduce from these data, and check in wind tunnels or by full-flight experiment the forces and moments generated on combinations of those components. A typical deduced curve is shown in Fig. 27, which shows the total drag force on a missile plotted against speed. The sharp rise in the curve in the region of the speed of sound is due to the rise in the value of the drag coefficient in this region. Thrust curves for ram-jet and rocket motors can then be superimposed, chosen to ensure the required acceleration in straight flight and the excess thrust available to counter the additional drag induced in manœuvres.

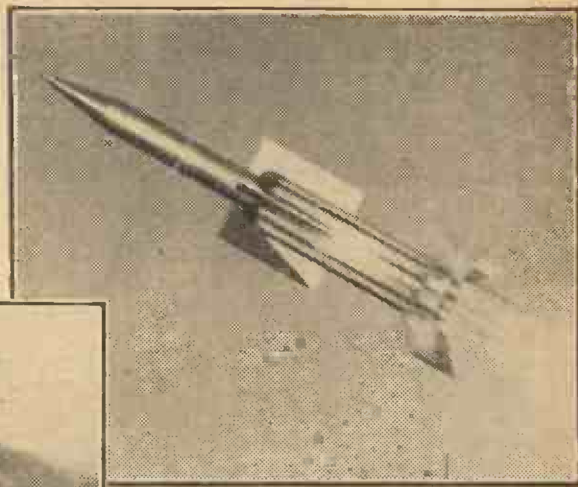


Fig. 28.—Cruciform wing configuration.

Finality can be reached only after the closest consideration of the control problems. An example is the choice between a four-wing or cruciform configuration and a two-wing system as used on aircraft (Fig. 28). The cruciform system enables wing incidence to be applied simultaneously in two directions at right angles to each other and a turn can thereby be induced in any required direction with a lag depending only on the time required to apply wing incidence. The other scheme, commonly known as "twist-and-steer," first requires the missile to be banked

(*Continued on page 265.*)

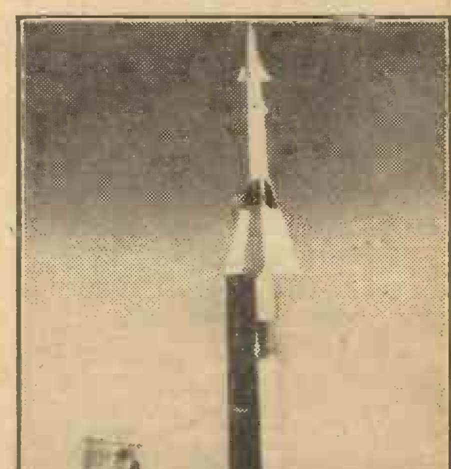


Fig. 29.—United States Army Ordnance missile, "Nike."

until its wings lie in a plane at right angles to the required direction of turn and then requires the application of incidence in that direction, the whole process thereby involving more time lag.

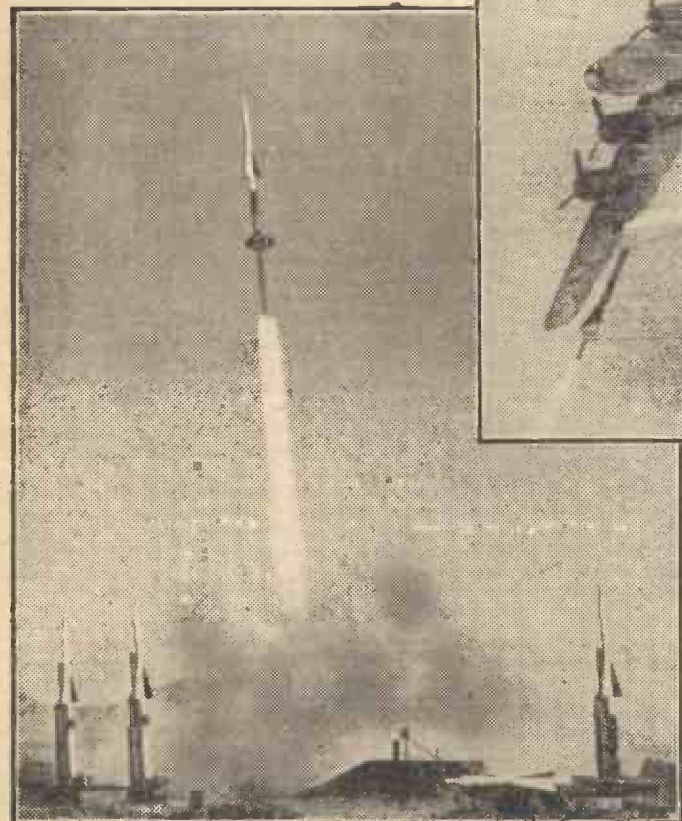


Fig. 30.—Launching of " Nike."

Fig. 31.—" Nike " approaches target aircraft.

Alternative Systems

Clearly, these alternative systems present the automatic-control designer with very different problems, not the least of which is the avoidance of the situation where an underdamped twist-and-steer system, trying to steer steadily towards its target, would necessitate frequent excursions of just less than 180 deg. bank.

Possibly the most difficult aerodynamic problem is to provide satisfactory aerodynamic controls and to minimise the forces required to operate them. The lift force which is generated on 1 sq. ft. of lifting surface in a free airstream at M=2 and at 10 deg. incidence is 2,400lb. at sea level and unfortunately the centre of pressure changes with speed. It is necessary, therefore, to select the hinge line carefully so as to minimise the servo-power required to move a control of this kind very quickly. Even with care the peak requirements of a twist-and-steer control system for a missile of this kind can amount to 10 or 20 h.p.

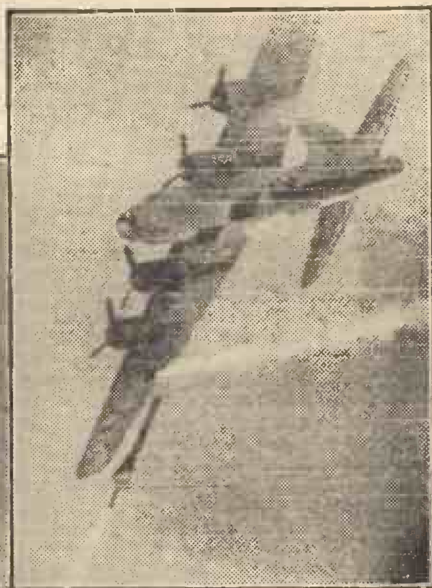


Fig. 32.—" Nike " engages the target.

Mounting of Control Surface

Another effect arises if the control surface is mounted, as in most aeroplane controls, as a flap behind a fixed surface. When the control is deflected the moment due to the lift force reacts on the fixed surface and causes it to twist and apply a moment on the missile in opposition to the control moment. Control reversal can result from this effect. This can be minimised by ensuring that the fixed surface is adequately stiff in torsion, or avoided by using all-moving control surfaces separate from any other fixed surface. This effect is termed " aero-elasticity " and the effect increases in severity as flight speeds rise. Another most troublesome aero-elastic effect emerges in the form of body flexure. Modes of oscillation can be generated which are, unfortunately, detected by accelerometers and gyroscopes in the control system, and which can thereby induce unwanted missile movement.

Fif. 33.—" Nike " explodes.

A Complex Servo-loop

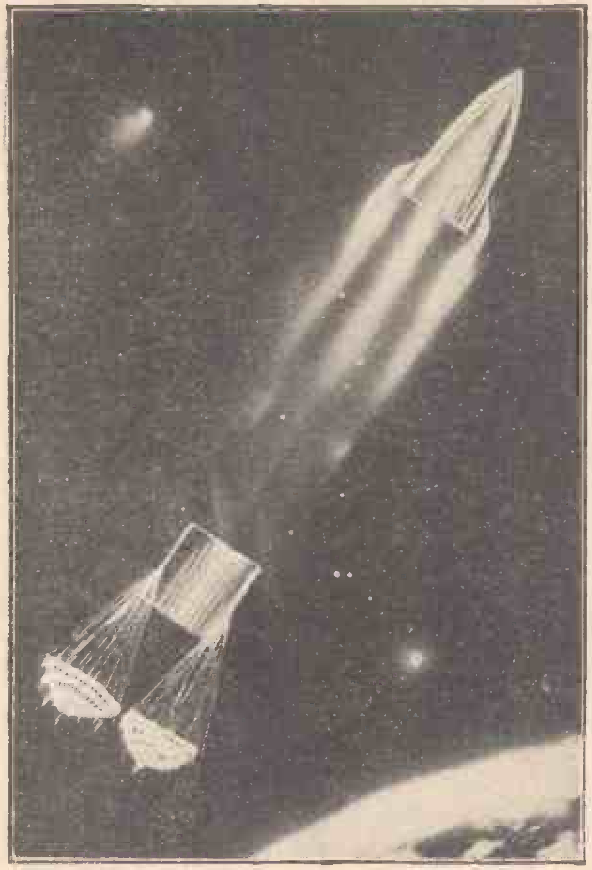
It is becoming apparent that the guided missile is a complex servo-loop in which the reaction of the function of every component is felt through the loop and into which much spurious and disturbing information is injected, for example, by aero-elastic effects, radar " noise " and movement of the target. It remains for the automatic-control designer to close this complex loop.

Fig. 34.—Target aircraft afire.

Fig. 35.—Aircraft disintegrates.

The objective of the development of a ground-to-air missile is shown in Figs. 29-35. These depict the United States Army Ordnance missile " Nike " engaging a four-engined unmanned bomber target.

(To be continued)



Booster step—portion of a freighter rocket that assists propulsion —falls away in mid-air. Braking parachutes reduce speed before landing.

its operation flight in four different regions is necessary—the subsonic, the transonic, the supersonic, and the condition encountered at great heights. Different laws of flow apply to each of these four regions, which complicates the aerodynamic design.

For the subsonic the drag is largely determined by the body fineness ratio and smoothness; as the transonic is entered, there is a sharp rise in drag coefficient (up to 10 × the low-speed value), and accurate lift calculations can be made by the Ackeret-Busemann method. Bodies with ogival nose shape and thin, wedge-shaped aerofoils are best. Swept-back wings are advantageous between $M=0.8$ and 1.2, but the rocket will not operate long in this region. Straight wings should therefore probably be used, unless the landing glide dictates otherwise, which is doubtful.

In the supersonic, Newton's laws, derived from the collision of particles with an inelastic body, govern the lift and drag. Flat-plate aerofoils are theoretically best, though for constructional reasons wedge-sections should again be used; aerodynamically, this regime is not far removed from the transonic.

At great heights drag coefficients rise again, but the dynamic pressure will be negligible in practice, hence the aerodynamic forces will be so very small that they are even considered useless for initial braking prior to landing.

Below 50 kilometres, however, lift/drag ratios of 6 to 8 are considered attainable for landing manœuvres using aerodynamic braking. It is thought that fears of excessive aerodynamic heating are groundless.

During take-off, the maximum total resistance will occur at a height of 8 to 10 kilometres, where the flight Mach No. is about 1.5.

It is important to repeat that the satellite vehicle would not stay up because it is "beyond the pull of gravity," as is frequently stated. The pull of gravity is essential to prevent it from flying off into space.

The Value of Orbital Rockets

Summarising the foregoing it will be seen that a rocket guided into the correct circular part around the earth could shut off its motors once it had reached the required speed, and remain orbiting the Earth forever in perfect safety. The orbit could be established at any distance, but for technical reasons it would be easier to place it as near the Earth as possible, as long as it was outside the atmosphere and thus immune to air resistance. The value of such orbital rockets would be:

1. As research observations beyond the atmosphere, for physicists and astronomers. (Study of cosmic ray primaries, and astronomical observation without hindrance from our semi-opaque atmosphere, etc.)

2. As observatories for meteorologists, who could "see" the Earth's weather system developing, and thus make more accurate forecasts—a use probably of particular interest to the British!

3. As radio relay stations, capable of receiving short-wave signals from the Earth's surface and re-broadcasting them to reach round the curvature of the surface, so removing the limitation on range which the horizon normally imposes for ultra-short-wave transmission. This would permit world-wide reception of television, or "frequency-modulated" radio (free from atmospherics), also the radio guidance of military missiles over longer ranges.

4. As military bases for reconnaissance, or even for launching projectiles.

Eventually, a large manned space-station might be constructed from components ferried out to the required orbit by rocket craft. Space ships might be refuelled, while waiting in such orbits, from tanker rockets climbing up from the Earth's surface to meet them.

You may feel that these suggestions are fantastic, but they are quite practicable, because any object once established in the orbit would have the effect on it of both gravity and velocity balanced out. It would have no apparent weight and would float in space. Connection between one rocket and another in a circular orbit in which both were earth satellites are also entirely feasible. Although both would be moving at tremendous speeds their relative velocity would be zero.

It is the value of these orbital techniques in connection with refuelling future space ships which makes them so important for interplanetary flight, apart from the fact that the practical usage of orbital rockets in themselves afford a powerful reason for obtaining support for astronautics in the present early stages of its development.

Thus it will be seen that the development of rocket propulsion and the application in the near future of atomic power to rockets has transformed the whole subject of astronautics from a scientific dream to an imminent reality. Anyone who attended the second four-day International Congress of Astronautics which took place in London in September of this year, where eminent scientists expressed the views which I have summarised here, could not have been left in any doubt about that.

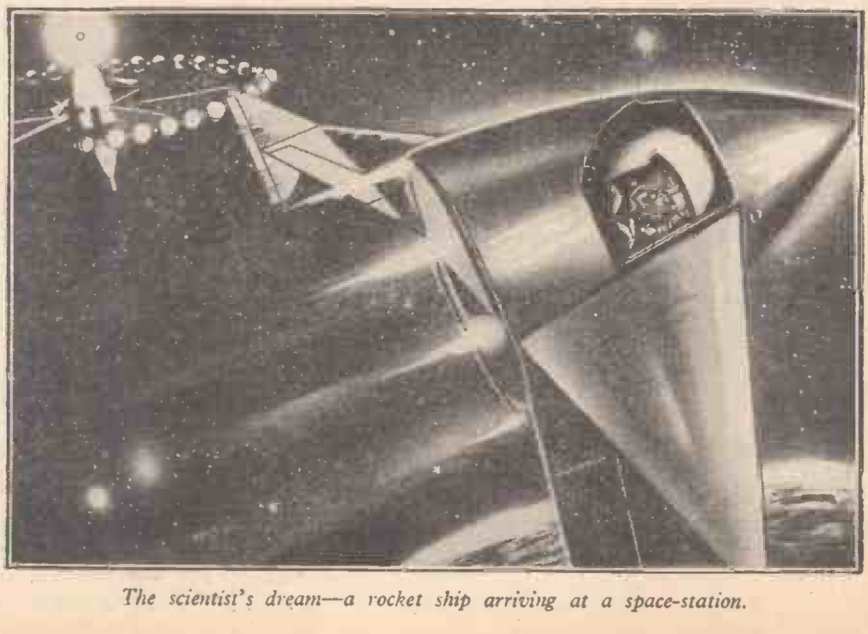
Increased Speed of Flight

Since the Wrights first flew on the 17th December, 1903, we have seen the speed of flight advance from 30 miles an hour to those well in excess of the speed of sound, and astronautics is at the present time in a state comparable to that of aviation in the days of the pioneers. There is now little doubt that space travel will be realised before the century closes.

The increasing membership of the British Interplanetary Society is an indication of the growing interest. Like all new industries and sciences, lack of finance is the retarding force which prevents more rapid development. Experiments are costly, and they have to be financed privately. Perhaps a Carnegie or a Nuffield will arrive and fund a project to build the first experimental space ship.

This journal, more perhaps than any other in the world, has in the 20 years of its existence done a very great deal to draw attention to this new field of scientific endeavour.

We have regularly published articles on the subject including one long series which gathered together all of the available knowledge. It is to be feared, however, that there are many, as was the case with the early days of the aeroplane, radio, and television, who regard the subject with an amused twist of the lip.



The scientist's dream—a rocket ship arriving at a space-station.

THE SPACE SATELLITE PROJECT

Some Recent Gleanings on the Subject

By FRANK W. COUSINS, A.M.I.E.E., F.R.A.S.

THE Russians and Americans have reached accord in one field of human endeavour—the satellite programme for the International Geophysical year 1957 to 1958. They are to work together in elaborating each country's programme and they hope to standardise the means for observing the satellites once they are launched. This good news was announced at the termination of the great 50-nation Barcelona conference. *The Times* special correspondent, writing from Barcelona on September 16th, 1956, reported that the Russian satellite, like its American counterpart, is being designed for the measurement of pressure and temperature as well as for the observations of cosmic rays, micrometeorites, the electromagnetic field and solar radiation.

Both countries have agreed that the same or similar telemetering systems will be used in the satellites to transmit the information back to the earth. Common equipment is to be installed round the earth for keeping watch on all satellites as they move in their Keplerian elliptical orbits in outer space.

The Americans confirmed at the Barcelona conference that "up to 12 satellites" may be launched during the year. Dr. F. Whipple, a leading figure in the American satellite team and director of the Astrophysical Observatory of the Smithsonian Institution, is committed to make one successful satellite flight at least. The first launch will almost certainly take place before January, 1957.

The first satellite will be launched into an orbit lying between 40 deg. on either side of the Equator (see PRACTICAL MECHANICS, November, 1955 and April, 1957). The tracking is to be both optical and by radio. The optical camera is of the Schmidt pattern, described in PRACTICAL MECHANICS, April, 1953. According to Dr. Whipple "it will be able to track a tennis ball in a given orbit." The camera has an aperture of 20in. Approximately a dozen cameras are to be made and each one is reputed to cost $70,000. Very generously the Americans have offered half of the cameras to countries along the first orbit but outside the Western Hemisphere.

A "Bulletin for Visual Observers" is obtainable from Dr. Fred Whipple, Director, Smithsonian Astrophysical Observatory, 60, Garden Street, Cambridge, 38, Mass., U.S.A. This might be of interest to any of the readers of P.M. living in areas where the satellites will be visible.

The Vanguard Rocket

In October, 1956, for the first time in history, space flight and satellites figured in the august proceedings of the International Astronautical Federation with astronautical engineers delivering papers.

The most interesting details, relevant to our present enquiry were those given by Mr. N. E. Felt on "The Vanguard Satellite Launching Vehicle." The Vanguard is a three-stage vehicle with no fins. Guidance and stability are to be attained by using a gimballed rocket motor. The vehicle has a total length of 72ft., diameter 45in., and a take-off gross weight of 22,600lb. The first stage is being built by the famous Glenn L. Martin Company and it will be powered by a rocket motor using liquid oxygen and petrol as propellants.

The second stage uses white fuming nitric acid and unsymmetrical dimethyl-hydrazine. The motor in the second stage is gimballed as for stage No. 1.

The third stage is a solid-propellant rocket and this will contain the 20in. spherical satellite, which is shielded by a cone to reduce and, if possible, prevent aerodynamic heating.

Orbit Details

The Earth Satellite as designed by Dr. Herbert R. Pfister is shown in Fig. 1. This model, now on display in the Hayden Planetarium, New York, is 18in. in diameter and weighs 25lb. "Exact" figures quoted are not in full agreement but to aid the imagination it is not far from fact to say that any one of the satellites will have a speed in orbit of 18,000 m.p.h., 300 miles above the earth and will circle the earth for 15 days to a year before losing speed and disintegrating in the more dense atmosphere as it spirals inward.

The satellite will orbit the earth once every 90 minutes. The earth rotates "under" the satellite orbit and the orbit is displaced westward some 20 deg. during each 90-minute revolution. The satellite will travel over a band from 35 to 45 deg. south latitude to the same north latitude.

The intended orbital distance of 300 miles above the earth may not be attained. Slight accumulated errors of height, angle and velocity will transpire to give an elliptical orbit having a nearest approach of not less than 200 miles and a furthest extension of not more than 1,500 miles.

For a 300-mile distant orbit of circular form the life of the satellite is calculated to be approximately one year. For a 200-mile distant orbit, 15 days, for 100 miles, less than one hour.

Satellite Construction

The satellite is to be a highly polished

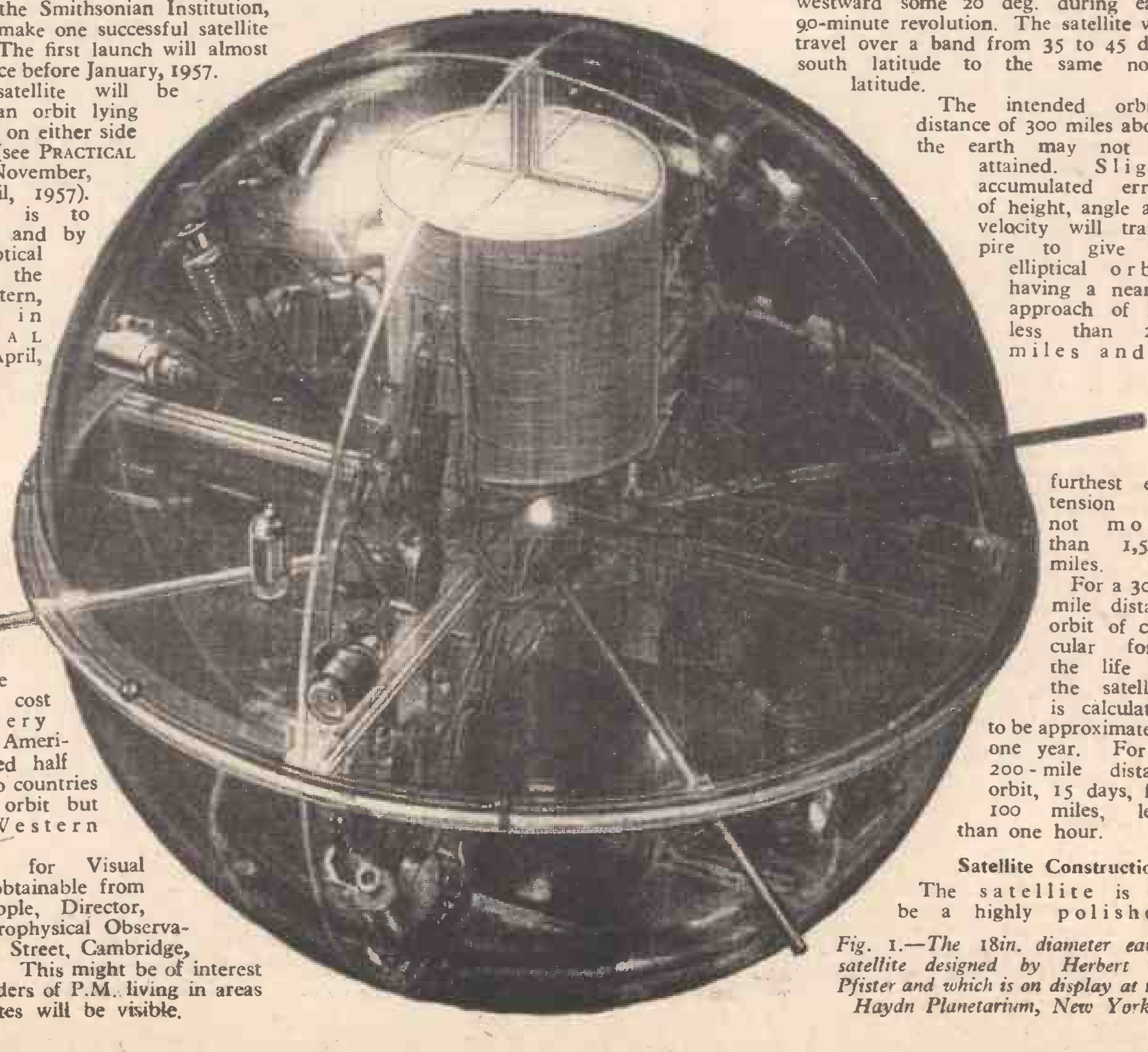


Fig. 1.—The 18in. diameter earth satellite designed by Herbert R. Pfister and which is on display at the Haydn Planetarium, New York.

sphere of 20in. diameter, weighing 21½lb. Mr. Robert L. Stedfeld gives the following information.

The shell of the satellite will account for half the all-up weight. The remaining 10lb. will include a radio tracking oscillator and transmitter, telemetering equipment, antennas and instrumentation.

The shell, *per se*, will be of magnesium metal formed into two hemispheres. The first shell has been spun from AZ13B magnesium alloy of 0.064in. thickness. The outer surface is to be contour machined and highly polished to a 4 micro-inch finish, to aid optical tracking when it is in its orbit.

The Instruments

A minitrack radio tracking system will be incorporated.

Miniaturised instruments have been developed.

(*a*) A pressure gauge comprising a bellows-actuated potentiometer to determine whether a meteorite punctures the satellite's skin. With a range of ± 15 p.s.i. the cylindrical gauge is only 1in. long, 1in. in diameter and weighs 1½oz.

(*b*) An erosion gauge which is a semi-transparent Nichrome ribbon evaporated on glass is placed on to the satellite's skin. It measures erosion caused by, *inter alia*, dust. As the ribbon wears away its resistance increases.

(*c*) A temperature gauge containing semi-conductor thermisters, able to measure changes in temperature from −140 deg. C to +150 deg. C.

(*d*) A Submeteoric Collision Microphone, which is a very small microphone behind a sounding diaphragm on the satellite's surface. A memory device stores the information until it can be transmitted.

(*e*) Lyman-Alpha equipment, which is used to detect and transmit ionization produced by far ultra-violet solar flare radiation.

Meteor Penetration

The question of meteor penetration of the satellite skin has been discussed by Dr. Ovenden. He makes the following observations. "Some 75,000,000 meteors enter the earth's atmosphere every day. With radar we can observe small meteors, down to a few tenths of a millimetre in diameter. All these observations (plus our knowledge of shooting stars) lead us to a law of meteor distribution. It is a simple law. It says that small meteors contribute just as much matter to the total meteor population as do large meteors, their smaller mass being just compensated by their larger numbers. Using this law we can estimate the number of meteors smaller than those that we can detect directly. According to these figures a small satellite with a skin about .01in. thick and a diameter of about 3ft. should be punctured by a small meteor once every few months."

If the satellite gets into the 300-miles distant orbit the pressure gauge and Submeteoric Collision Microphone should not be unduly busy.

Analysis of Future Trends

Prior to the establishment of a manned satellite, the work to be achieved in the coming experiments is of inestimable value. The environmental hazards of cosmic radiation, meteors, solar heat (and the absence of it) and weightlessness will be able to be calculated from precise information.

The second problem for a manned satellite is the one of safe return to the earth's surface. The relative speed of five miles per second between the orbiting vehicle and the earth's surface must be brought to zero. Obviously this will be done by allowing the satellite to transfer its energy to the atmosphere. But the process must be controlled with precision lest the satellite absorbs too much energy in the form of heat.

Mr. T. R. F. Nonweiler has addressed himself to the study of skin heating, and in a paper presented to the International Astronautical Congress entitled "Skin Heating During Re-entry of Satellite Vehicles to the Atmosphere" he makes the following observations. Particular attention to the flight plan and overall design can greatly simplify the problem of kinetic heating. Nose temperatures need not be greater than 1,000 deg. C. The greater the skin thickness the lower would be the maximum temperature, but in practice there would always be a limit to the allowable thickness. The emissivity of the outer surfaces will need to be made as high as possible.

Moon Satellites

The next logical step after the small satellites have given up their data will be the setting up of Moon satellites. Mr. R. W. Buchheim has calculated their orbits. For a stable retrograde orbit (opposite in direction to the Earth/Moon system) an initial accuracy of altitude and velocity 20 times greater than that required by the Vanguard project is necessary. For a direct orbit, that is one in the same direction of rotation as the Earth/Moon system, this accuracy would again need to be doubled. Mr. Buchheim has shown that satellites of visual magnitude 10 to 6 would have to be 132ft. to 832ft. dia., and assuming the skin to be made of aluminium foil 0.0001in. thick the weight would be 79lb. to 3,140lb. A rocket vehicle with an overall weight of about 1,000,000lb. would be needed to project a 500lb. pay-load from the earth on to a trajectory of the type required.

It is a sobering thought in the dawn of the Geophysical Year to record that the prophetic dreamers—*Ziolkovsky*, 1903, in his "The Exploration of Cosmic Space by Reaction Machines," *Goddard*, 1919, in his "A Method of Reaching Extreme Altitudes" and *Oberth*, 1923, in his "The Rocket into Interplanetary Space" had the main concepts fully clear in their minds. The main concepts of fundamental character propounded were (and still are):

(*a*) Escape from the earth is possible by the application of a moderate acceleration over a substantial period of time.

(*b*) Such acceleration can be produced in vacuums by a rocket.

(*c*) The rocket must have high thermal efficiency, i.e., high velocity of ejected matter, and consist mainly of propellant material.

(*d*) High thermal efficiency is to be obtained most readily from the chemical combustion of liquid fuel.

It is clear that man is still a long way technically from desporting himself in space. But even the most ardent critics of space travel have to admit that the sounding board is now ready. It is with great excitement that we await the correlated data from the midget spheres.

Painting from a Balloon

FROM France comes news of a novel way of painting ceilings of large halls and cupolas or naves of churches; it was instituted by a Paris firm of decorators for painting the cupola of the new church of Yvetot. The idea is of a small platform fixed on the top of a balloon inflated with hydrogen. The painter is hoisted to the roof by pulley and cable and lowered into the 4ft. square platform. He can be moved from place to place by a man on the ground holding a guide rope.

New Magnetic Observatory

HARTLAND has been chosen for the site of a new Magnetic Observatory (erected as part of the Royal Greenwich Observatory), because artificial magnetic disturbances in the vicinity are few. Electrification of the railways and the spread of industry has caused the Observatory to be moved twice, first from Greenwich to Abinger in Surrey, and now to Hartland in Devon.

Instruments are being installed that will record continuously fluctuations in the direction and intensity of the Earth's magnetic field. These variations are closely associated with "magnetic storms," auroral displays and phenomena occurring on the Sun.

Water-repelling Treatment for Masonry

A NEW treatment which makes brickwork and masonry completely water-repellent has been perfected in the Evode, Ltd., Laboratories, Common Road, Stafford. It is a colourless solution based on a silicone resin and is called Evosil. One treatment, it is claimed, will last many years, but the material is not intended to remedy existing defects, such as bad jointing, cracks, etc.

Weather Charts by Radio

A MUFAX Chart Recorder, for displaying facsimile picture transmissions of weather charts, is now on exhibition in the Science Museum.

The recorder, which has been lent by the makers, Muirhead and Co. Ltd., reproduces a whole chart in 35 minutes or less, depending on the speed setting, and throughout the recording the progressively growing chart is visible on a flat platen.

The exhibit can be shown in operation and will normally be used to record the transmissions broadcast from Dunstable Meteorological Station at 12.10 hours and 16.50 hours.

Bridge Has Ray Warning

SO many accidents have occurred to high vehicles trying to pass under a 9ft.-high bridge in Burton-on-Trent that a special ray warning device has been installed.

Nothing happens so long as the ray is unbroken, but should a vehicle over 9ft. high cross it, a large illuminated sign will appear, saying, "Stop, you cannot pass under bridge," a klaxon horn will sound, and a red light will be directed towards the vehicle.

Germs Survive 50 Years

WHEN bacteriologists made tests of the soil in the Antarctic last year, they found tetanus germs left by the horses in Captain Scott's expedition 50 years ago. They had lain dormant for half a century.

New American Aircraft

THE Bell X-2 supersonic aircraft is powered by the first throttleable rocket engine to be developed in the U.S. and has flown at over 1,900 m.p.h. (faster than the muzzle velocity of many projectiles !).

To avoid serious loss of strength in the airframe due to heat build-up caused by air friction, the plane was fabricated with a skin of heat-resistant stainless steel on its wings and tail.