m/r AUGUST, 1957

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

AN AMERICAN AVIATION PUBLICATION

In This Issue:

PROGRESS IN SOLID ROCKET PROPELLANTS

NORTHROP NEW BUILDING NEAR FINISH

Full Occupancy In Late Summer

(HAWTHORNE, CALIF.) Partially occupied now, the new Northrop Engineering and Science Center at Hawthorne, latest step in a gigantic modernization and expansion program, is almost completed. Engineers and scientists of the Northrop Division of Northrop Aircraft, Inc., are ready for the big move into this beautiful, multi-million-dollar, glass and steel six-story building in late summer.

Architect's rendering of the Science Center is pictured above. Every convenience and facility will be provided for human well-being and comfort, in keeping with Northrop's theory that an engineer can do his work most efficiently in pleasant surroundings. Northrop has long maintained that an airplane or missile is only as good as the engineers who design it.

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missiles and rockets

Magazine of World Astronautics

August, 1957 Volume II, No. 8

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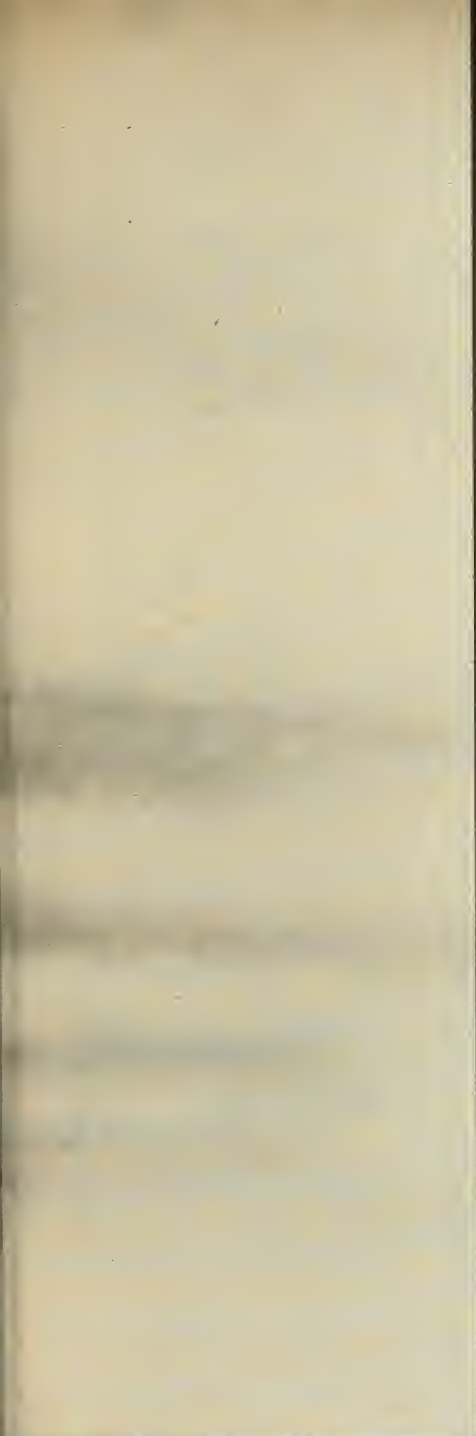

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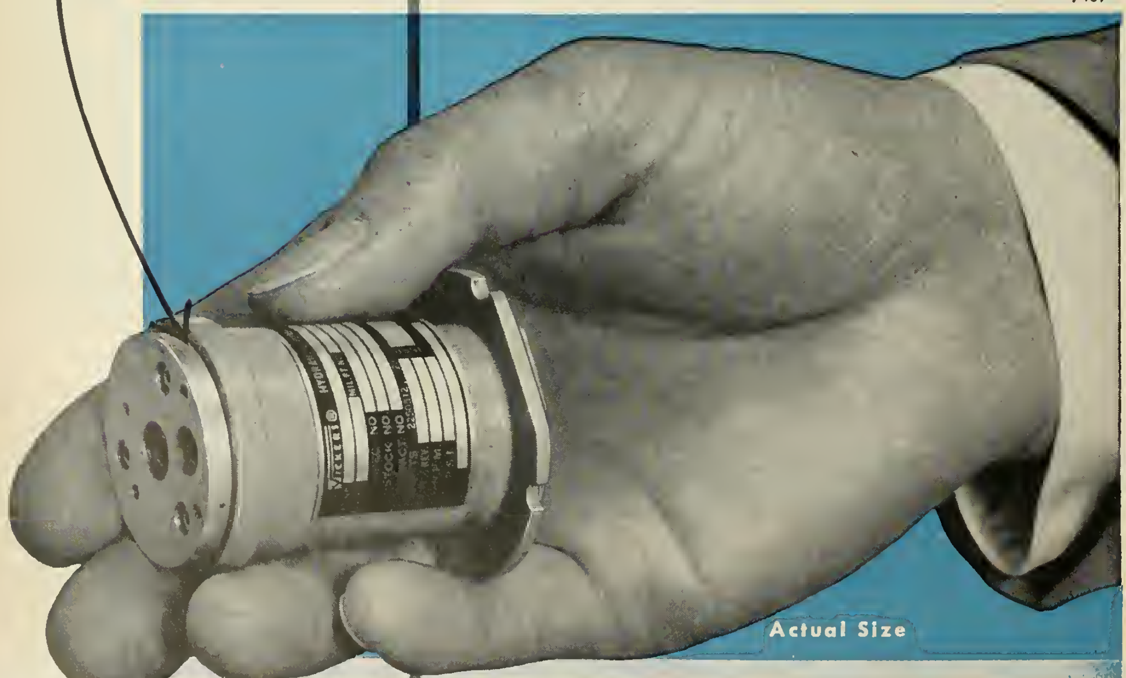

A large expansion program now in its early stages means large opportunities for additional engineers at Vickers. Write for information.

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missiles and rockets

Magazine of World Astronautics

Space Flight Without Red Tape

America's first space flight attempt is to be an Air Force venture using Army hardware and Navy methods. Industry and private scientists will put the vehicle together and instrument it. First of all, this is indicative of the fact that a unified group of our foremost research establishments must be coordinated into one central agency for successful pursuit of the astronautics challenge. Project *Far Side* is only the beginning. In scope, however, the project is more sophisticated than Project *Vanguard*. And in terms of politics it is far more interesting.

Space flight is not a glamorous little game that can be played by anyone just for glamor's sake. The Defense Department cannot arbitrarily choose any single individual or any single one of the services to supervise this country's overall aims to conquer the black yonder of space. The significance of such programs is too important in terms of expenditures and prestige. American industry certainly would not compliment the Defense Department if DOD should fail to make a thorough canvass of possible unification of efforts, talents and funds.

The Air Force Office of Scientific Research is to be commended for undertaking Project *Far Side*. Obviously, AFOSR recognizes the necessity for coordination and unification as essential ingredients for the project's fulfillment. Most important, however, is that the industry and military enthusiasts behind Project *Far Side* are aiming to penetrate outer space without political red tape—by picking the best methods and hardware available without caring which Service made them.

Project *Far Side* is simple. It is worthwhile. It is indicative of what a coordinated military and industrial effort can and will achieve with a minimum of expenditures and complexities. It uses off-the-shelf military hardware. No basic component for the rocket vehicle has to be redesigned, nor re-contracted. No expensive preflight tests are required. It does not cut into existing programs. When the first *Far Side* rocket is fired some time next month, the vehicle will be "live."

Far Side represents thousands of dollars rather than millions. Here we are working with simple, solid-propellant rockets instead of a combination of intricate liquid systems requiring five, six or more propellants or combinations of propellants.

Project *Far Side* makes the *Vanguard* project look like a hydra-headed monster. This also applies to such timid matters as releasing information to the public. The taxpayer, who is immensely intrigued by the idea that we are about to challenge outer space, does not understand why he cannot get the information on Project *Vanguard*.

But he does not know that every single word to the public must be cleared by all of these: the prime contractor; Naval Research Laboratory's Technical Information Office; the Chief of Naval Research; Office of the Chief of Naval Information; Office of Public Information of Department of Defense (including representatives of Army, Navy, Air Force and DOD); the Central Intelligence Agency; State Department; National Science Foundation; and the National Academy of Sciences (U.S. Committee for the IGY). This web of red tape on information is the big talk and the top sarcasm of the industry.

It is good that the Air Force is set on proving that we can spend less of the taxpayer's money and cut down the red tape on this country's first space flight project. And that there is no politics involved. It will pay. The public will expect the Air Force Office of Scientific Research to continue to pursue the space flight challenge in the future . . .

ERIK BERGAUST

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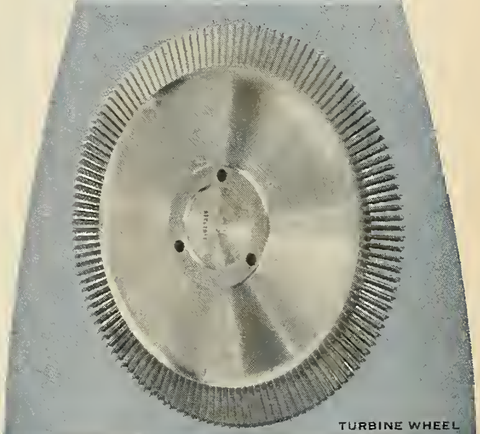

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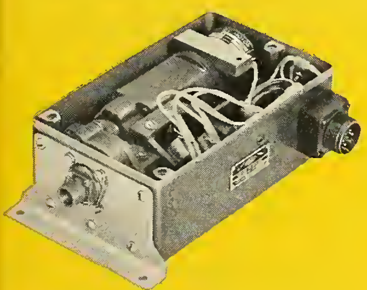
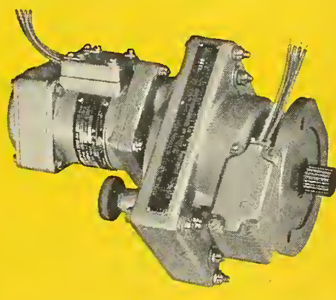
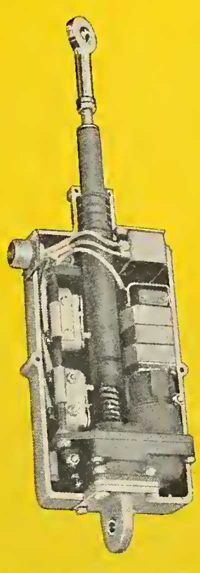
Type: D-925 Rotary Actuator for Missile Fin. **Output:** 400 inch-pounds @ 64 RPM, 24 volts, 27 amps. **Duty Cycle:** 1 minute on, 10 minutes off; **Gear Reduction:** 135 to 1 in 2.25" length; **Weight:** 6.75 lbs. **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-8609 for motors.

Type: D-818 Leading Edge Flap Actuator; **Weight:** 20.5 lbs. **Normal Operating Load:** 6,000 lbs.; **Maximum Operating Load:** 12,000 lbs. **Ultimate Static Load:** 24,000 lbs.; **Stroke:** 3.15"; **Rate of Travel:** .33" per second; **Amperes:** 3 amps at 480 cycles on 200 volts at the 6,000 lbs. load. **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-7969A for motors.





Type: D-892 Power Package; **Size:** $7\frac{1}{8}$" x $4\frac{7}{16}$" x $2\frac{3}{4}$". **Output:** 28 volts D.C., 1390 RPM at take-off shaft, 18 inch-oz. torque. **Weight:** $3\frac{3}{8}$ lbs.; Operative in ambient temperatures to 250° F. **Meets Military Specifications:** MIL-A-8064 for actuators, MIL-M-8609 for motors.



Type: D-868 Rotary Actuator; **Weight:** $9\frac{7}{8}$ lbs. **Power:** 200 volt, 400 cycle, 3-phase motor. **Ambient Temperature Range:** −65°F. to +400°F.; **Shaft Torque Limit:** Adjustable. **Load:** 1,650 inch-lbs. maximum to approx. 2 RPM on 1.5 amps. **Meets Military Specifications:** MIL-E-7894 and MIL-A-8064.

Type: D-607 Transport Door Actuator; **Weight:** 4.5 lbs. **Stroke:** 6.25"; **Operating Load:** 450 lbs.; **Ultimate Static Load:** 7150 lbs. tension; **Speed of Stroke:** under 450 lb. load—0.3" per second. **Size of Power Section:** $2\frac{1}{4}$" x $4\frac{1}{2}$" x $8\frac{3}{16}$". **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-8609 for motors.

Type: D-822 Trailing Edge Flap Rotary Actuator; **Weight:** 35 lbs. **Normal Operating Load:** 26,000 inch-lbs. **Maximum Operating Load:** 52,000 inch-lbs. **Ultimate Static Load:** 75,000 inch-lbs.; **Travel:** 45 degrees at .625 RPM; **Amperes:** 4 amps at 26,000 inch-lbs. at 480 cycles on 200 volts. **Frequency Range:** 380 to 420 cycles. **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-7969A.

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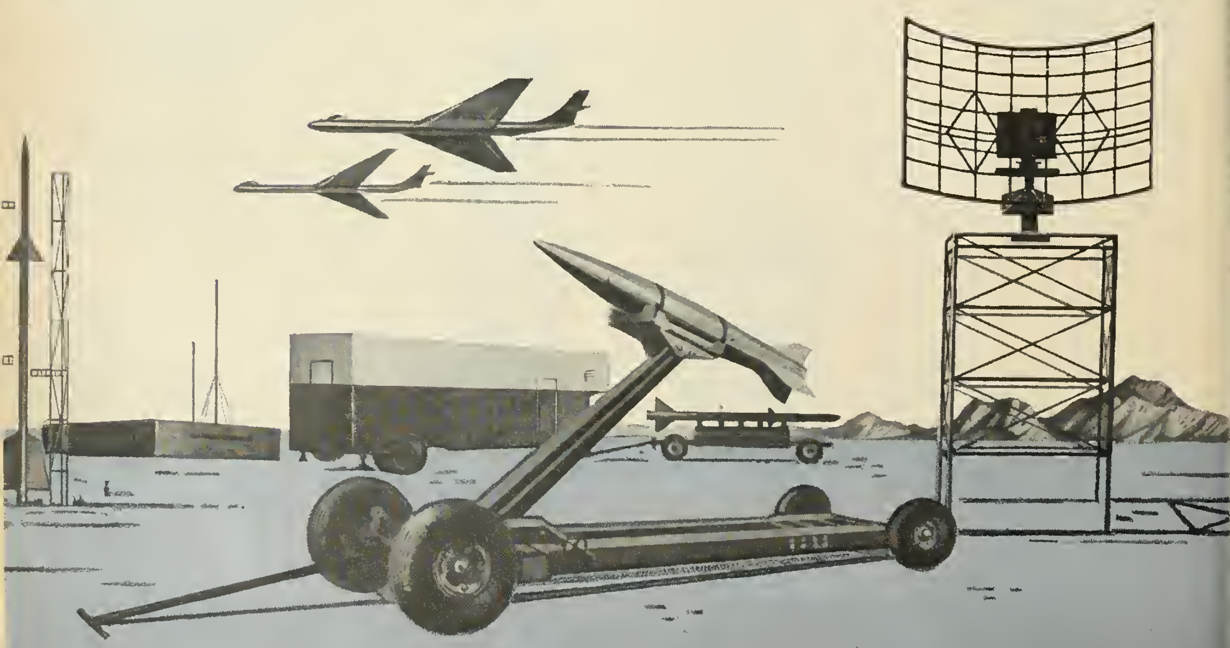

news and trends

special features

rocket engineering

missile production

industry spotlight

next issue:

LIQUID PROPELLANTS & EXOTIC FUELS

cover picture:

Lacrosse, *Army's lightweight tactical missile now in production, rests on its launching rack aboard an Army truck. The ground-to-ground weapon is powered by a Thiokol solid propellant rocket motor and will be used to supplement air or artillery attack on enemy strong points in the field. Lacrosse is Army's most sophisticated missile and utilizes a command guidance system in conjunction with a forward observer. See articles on pages 112 & 121.*

columns

departments

photo credits:

Aerojet, 80, 81; Aeroneutronics, 47; AF 42, 52; AFOSR, 48; Ankers, 45; Army 70, 87, 113; Grand Central, 88, 89, 90; Grotnes, 102, 103; E. Hull 20, 78, 106, 131; Interstate, 105, 106; Navy, 131; Phillips, 97; Rocketdyne, 124; Thiokol, 112, 113, 121.

fast fuel transfer

FOR MISSILES

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REPRESENTATIVES: *West Coast: William E. Davis, Box 642, Inglewood, Calif.*
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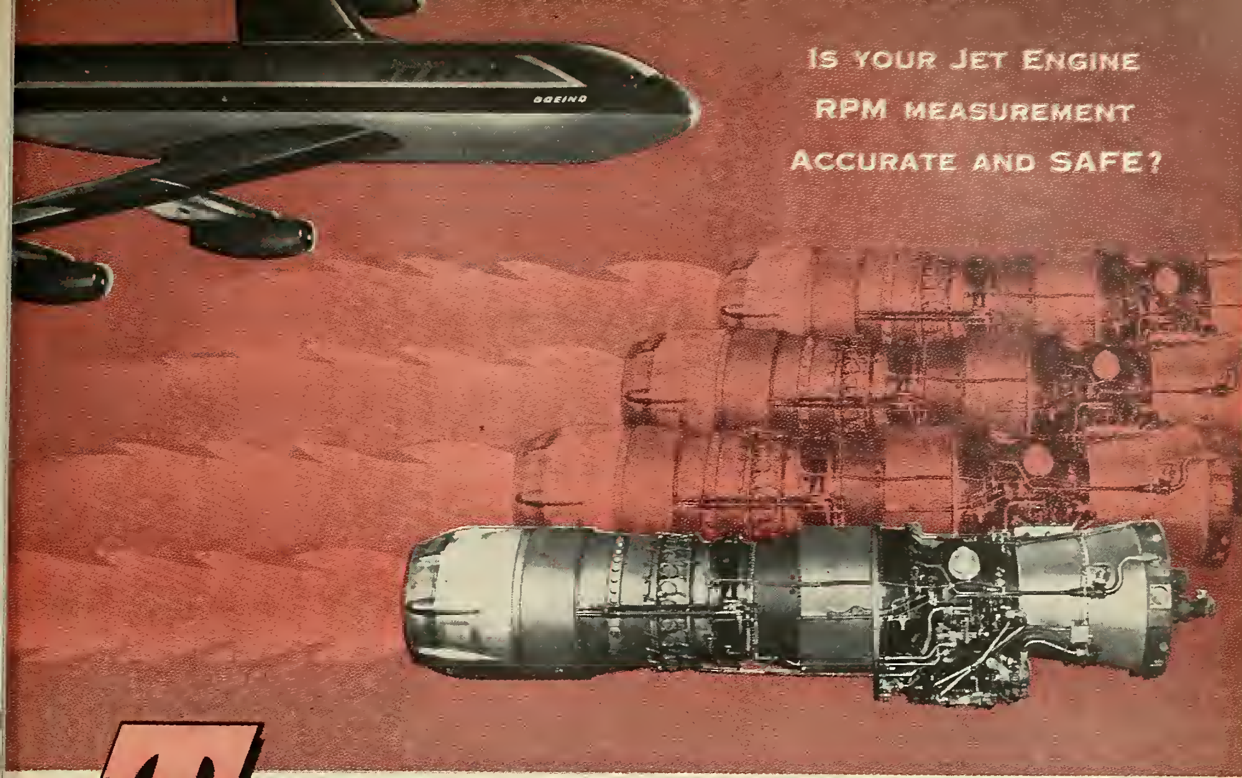

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letters

Praise for m/r First Special Issue

To the Editor:

Better and better! Suggestion: The coverage on missiles in the July issue was good. How about a future feature covering the available research missiles, such as Aerobee-Hi, Dan, X-17, etc. This should be as complete as possible, including size, weight, c.g., cost, etc. It would be even better if the page layout allowed margin for cutting out, for inclusion in notebooks.

Second Suggestion: A continued series on missile components; for example, solenoid valves, turbine pumps, telemetry packages, gyros, and so on. Basic theme: a system can be no better than its components.

R. P. Haviland
General Electric Co.
3198 Chestnut Street
Philadelphia 4, Pennsylvania

Thank you. A missile component issue is coming up.—Ed.

To the Editor:

Congratulations on the color spread entitled "To Probe Tomorrow" in last month's edition of MISSILES AND ROCKETS magazine. This functional use of color vividly portrays the research tools in GE's Aerosciences Laboratory.

Incidentally, I believe your readers should know that the Aerosciences Laboratory was initially established to provide research for the development of Air Force Ballistic Missiles under the direction of the Air Force Ballistic Missile Division, commanded by Major General B. A. Schriever, in Inglewood, Calif.

J. C. Hoffman
Manager-Product Information
GE MOSD
3198 Chestnut Street
Philadelphia 4, Pennsylvania

To the Editor:

Is it possible to obtain 25 copies of Dr. Wernher von Braun's article "Space Travel and Our Technological Revolution" as published in your First Annual Engineering Progress issue?

J. M. Schneider
The Cincinnati Shaper Co.
Hopple, Garrard, and Elam Sts.
Cincinnati 25, Ohio.

Reprints are in the mail.—Ed.

To the Editor:

Your July m/r guest editorial, "Science and Common Sense" could not have been more appropriate for your engineering progress issue. Also appropriately, it was written by the world's

Checking m/r galley proofs: Dr. Theodore von Karman, right, with m/r's exec. editor.

greatest exponent of the subject "science and common sense"—Dr. Theodore von Karman.

Only too often the work of the theoretical physicist is not implemented by the engineer due to the lack of technological intuition on the part of the business executive who authorizes and directs the activities of the engineer.

Those who profess to have management expertise have singularly failed to provide a program of technical enlightenment for the business executive. It is typical of Dr. von Karman that he would have the wisdom and common sense to discuss this problem.

I have the temerity to suggest that you run a series of articles on the subject.

Andrew G. Haley
Haley, Wollenberg & Kenehan
1735 DeSales Street N.W.
Washington 6, D.C.

To the Editor:

I am writing to tell you of my appreciation of m/r's recent coverage of Army missile activities and particularly to the activities of the Corps of Engineers in support of various missile programs.

The article "Missile Progress by the Corps of Engineers" by Major General

MOTOROLA RADAR PICKETS IN THE "DEW-LINE" FENCE

Stretching 3,000 miles across the Arctic, special Motorola radar systems stand alert, ready to sound a warning at the first indication of an air attack over the polar cap.

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Circle No. 9 on Subscriber Service Card.

David H. Tulley, and the accompanying editorial box, in the July issue will do much to give industry and the public a better understanding of the Army Engineers' part in the missile program.

E. C. Itschner
Major General, U.S. Army
Chief of Engineers
Washington 25, D.C.

To the Editor:

Since m/r first appeared last year many of us here at Maxson have watched it carefully.

The July issue contains a terrific amount of information, particularly the First Annual Guided Missile Encyclopedia, beginning on page 123. This round up is the best job along these lines that we have yet seen. We wonder if reprints of this section are available. If so, we would appreciate having ten copies for distribution to our key personnel and engineering staff.

Keep up the good work.

S. H. Goldstein,
The W. L. Maxson Corp.,
Contracts Division
475 Tenth Ave.
New York 18, N. Y.

Thank you. The reprints are in the mail.—Ed.

To the Editor:

I was very pleasantly surprised to find in your July 1957 issue the "Guided Missile Encyclopedia."

I am an instructor in the U.S. Army Ordnance School and have spent countless hours trying to compile something similar for use in my instruction.

Is it possible to get about five reprints? We can sure use them.

Cutt R. Wild
Lt., Ord. Corps
U.S. Army Ord. Sch.
Box 195, APG, Md.

In the mail.—Ed.

To the Editor:

I have just returned from a trip to many of the Air Force Research and Development Command centers located throughout the nation. It was interesting to me to note the many copies of Missiles and Rockets that I saw on desks while visiting scientists at these various development centers. I think this is more than adequate proof of the job that m/r has done in covering this most important field . . .

Joseph C. Groth, Jr.
Executive Assistant to the President
Winzen Research Inc.
8401 Lyndale Avenue South
Minneapolis 20, Minn.

To the Editor:

I congratulate you on your excellent magazine. As a laboratory technician interested, but not yet connected with rocket propulsion in England, I find m/r of great interest and value. I also very much appreciate the advertising sections of this periodical, which presents in one issue more interesting information on missile components and developments than in several months of British aeronautical magazines.

This is, of course, due to the very high level of security on guided missiles in this country. Consequently British lay-


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Grand Central provided the multiple ARROW rocket power-plant for the two-stage HTV (Hypersonic Test Vehicle) developed by Aerophysics Development Corporation for the United States Air Force. This vehicle approaches a speed of Mach 7 within two seconds, and is used for obtaining hypersonic data on rocket stability, aerodynamic heating, and air pressure distribution.
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men have had to look to other quarters for their literature. Apart from the journal of the British Interplanetary Society very little information is available on current missile developments in this country. However, you have stepped in and very nicely filled the gap. I wish you every continued success.

Raymond A. Harraway
38 Waldeck Street
Reading, Berkshire,
England

Publication of Considerable Impact

To the Editor:

I would like to take this opportunity to compliment you on your publication. As an organization with eleven plants and laboratories actively engaged in missile work, we have followed the magazine from its very beginning. It is quite apparent that it is a publication of considerable impact . . . and might well have even more significant importance in the future . . .

The check list of special selections which you published this year is, I think, a very fine idea and one which should be repeated at intervals.

Alan Craigue
American Machine & Foundry Co.
1101 North Royal Street,
Alexandria, Va.

Pictures Suitable for Framing

To the Editor:

Minneapolis-Honeywell Regulator Company, Aeronautical Division, has recently completed construction of a new plant here in St. Petersburg. This plant has been set up for research and development on inertial guidance controls.

Because of our field of interest, we are most anxious to obtain pictures of missiles to place on the walls of various departments. We don't know where to go for pictures of this type and are wondering if perhaps you could help us. Any information as to possible sources would be most appreciated.

Mrs. Virginia Batchelor, Librarian
Minneapolis-Honeywell
Regulator Co.
St. Petersburg, Florida

Most companies in the missile business probably will be happy to provide you with glossy photos etc. Write to their Public Relations departments. Also, try General Astronautics Corp., P. O. Box 26, Oyster Bay, N. Y.—Ed.

Wants NACA Technical Note

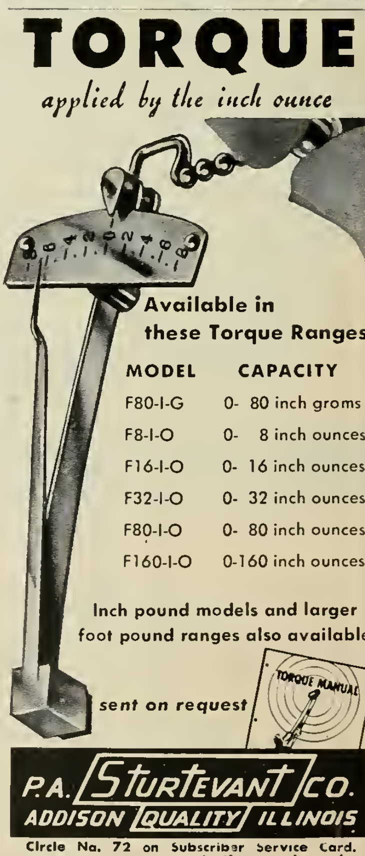
To the Editor:

We are subscribers to your publication and we read in the June issue, page 100, an article regarding the new method of manufacturing by the NACA.

Could you be so kind and ask this Committee to send us their technical note No. 3827 referred to in the mentioned article; we do not know the address of the NACA.

Jean Gallay
Usines Jean Gallay S.A.
Chemin Frank Thomas
Geneve, Switzerland

Address of the National Advisory Committee for Aeronautics (NACA) is 1512 H St. N.W., Washington 25, D.C. —Ed.



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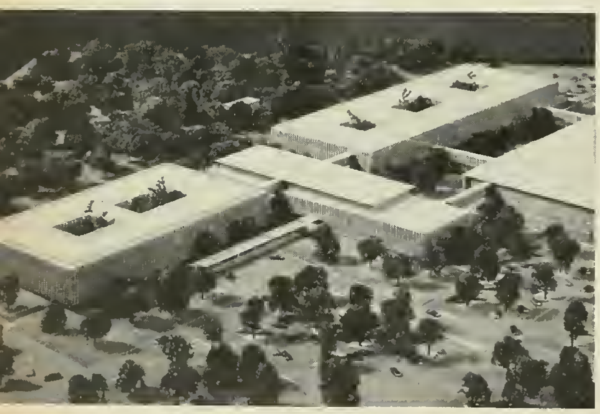
Dr. Dorothy M. Simon, Technical Assistant to the President of Avco Research and Advanced Development Division, addresses a colloquium of the Advisory Group for Aeronautical Research and Development (NATO) in Cambridge, England.



The Science Center for Avco's Research and Advanced Development Division, as seen in the architects' scale model, is now under construction in Wilmington, Massachusetts, a suburb 15 miles northwest of Boston's cultural hub. Scheduled for completion in early 1958, this ultramodern laboratory will house the scientific and technical staffs of the division.

Avco's new research division is now offering unusual and exciting career opportunities for exceptionally qualified and forward-looking scientists and engineers in such fields as:

Science:

Aerodynamics · Electronics · Mathematics · Metallurgy Physical Chemistry · Physics · Thermodynamics

Engineering:

Aeronautical · Applied Mechanics · Chemical · Electrical Heat Transfer · Mechanical · Reliability · Flight Test

Write to Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Division, 20 South Union Street, Lawrence, Massachusetts.

THE NEED TO KNOW

Man has long been motivated by the need to know—to what lies beyond the oceans, the mountains and the sky; to what elements make up the earth's crust and what forces co the universe. Many questions have been answered, but a knowledge increases and the boundaries of our space expand questions are asked.

In the AVCO laboratories, exploratory work is under w many fields of physics, physical chemistry, metallurgy, an gineering. Basic research and development are continuing in where we have already made contributions: high-speed ae namics, ICBM re-entry problems, physics and chemistry c heat transfer, electronic applications to advanced radar computing, and high-temperature materials.

New ideas for future work are being discussed by the cre scientists and engineers who are members of this division scope of these new problems is so broad that the joint effo those from many disciplines are required for their solution future promises to be challenging.

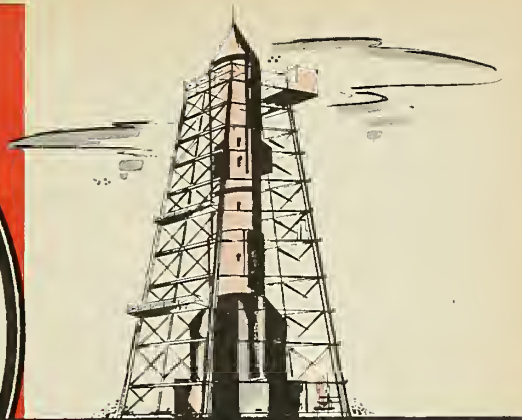
A new research and development center, designed to g proper physical environment and to provide the facilitie equipment needed, is under construction. The center is lo near large universities to make available educational opportu and wide professional contacts.

In the short period of our existence as a research and develop division, much has been accomplished—problems have solved and we have learned to work together. Now we are l ning to broaden the scope of our work and to add our con tions to the technical world, thereby strengthening the po of America and helping to satisfy man's need to know.

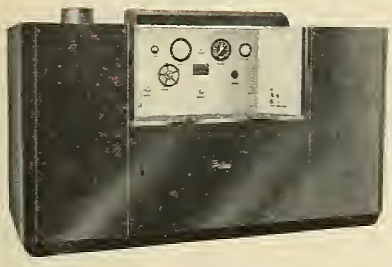
Dorothy M. Simon

Dr. Dorothy M. Simon
Technical Assistant to the President

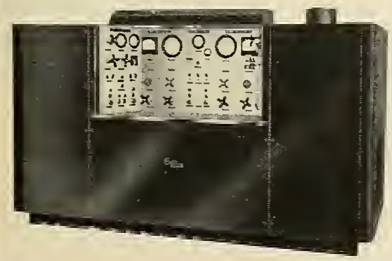
AVCO
RESEARCH & ADVANCED DEVELOPMENT



IN THE *Final Countdown*



Hydraulic Power Source and Auxiliary Testing Units produced for Martin-Denver play an important role in Martin's Missile Projects.



Martin-Denver uses Sun-built Hydraulic Power Source and Auxiliary Equipment in its important missile projects.

Up to the moment the "Fire" button is pressed, a missile is still reliant on the ground support that has prepared it for flight.

Countless tests, checks and rechecks have been made of its power, guidance and weapons systems. Electrically, electronically and hydraulically it is not yet self-sustaining—it must depend upon unfailing auxiliary equipment which fosters its flight.

Just as there is no margin for error in the performance of components once the missile is airborne, so, too, must the ground support equipment function with flawless perfection—the kind of perfection born only of engineering know-how—pride and quality of workmanship.

Sun's engineering and manufacturing capabilities are synonymous with critical precision—infallible performance. Whether it be ground support and auxiliary equipment to prepare a giant bomber, a super-sonic fighter or an intercontinental missile for its appointed mission—look to Sun for major assistance in development and swift "on schedule" production.

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Los Angeles Aeronautical Division: 6701 SEPULVEDA BLVD., LOS ANGELES, CALIFORNIA

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Simmonds

LIQUID LEVEL SENSING SYSTEMS keep Rockets ready for INSTANT LAUNCHING

Before the "FIRE" signal is given, a rocket or missile stands ready on the launching platform, frequently for a considerable time. Yet it must be ready to fire at any time, in spite of the evaporation of the highly volatile fuel and oxidizer liquids.

To keep fuel constantly up to capacity, Simmonds Liquid Level Sensing System senses when the fuel goes below a prescribed level. Automatically, the System then actuates a valve to add more fuel, shutting off when "full" level is reached. This process is continuous until the rocket is launched.

These Simmonds Systems have no moving parts—are shock, vibration and corrosion resistant—operate on low power consumption. They operate in any aircraft fuel, hydraulic fluid, jet engine oil and other liquids and liquified gases, meeting all MIL specs. Detailed literature on request.

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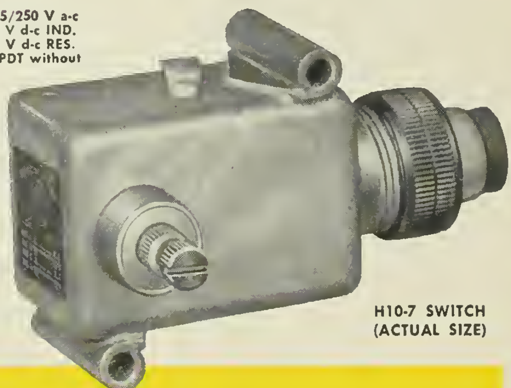
SAN FRANCISCO
SUNNYVALE–
38 MILES FROM
SAN FRANCISCO
SAN FRANCISCO
PALO ALTO
SUNNYVALE
SANTA CRUZ TEST BASE–
50 MILES FROM
SAN FRANCISCO
SANTA CRUZ
TEST BASE
VAN NUYS–
22 MILES FROM
LOS ANGELES
VAN NUYS
LOS ANGELES

PROVEN PERFORMANCE

in a hermetically sealed

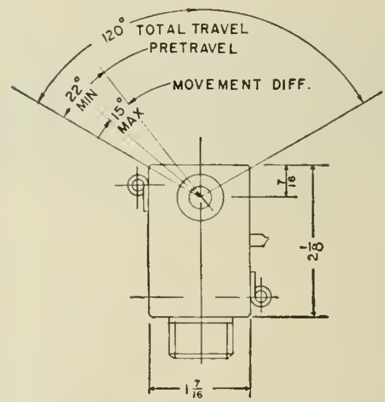
ROTARY MOTION SWITCH

10 AMPS @ 125/250 V a-c
10 AMPS @ 28 V d-c IND.
15 AMPS @ 28 V d-c RES.
Simultaneous DPDT without adjustment.



H10-7 SWITCH (ACTUAL SIZE)

- A seal — not a packing — bonds shaft to case.
- Leakage rate LESS than 1 micron per cu. ft. per hour! Full rating up to 75,000 ft. altitude.
- No-slip splined shaft — adjustable or fixed actuating arm.
- Permits 120° rotary travel — a minimum of 50,000 cycles!
- Long overtravel eliminates need for fine adjustment; permits greater flexibility in linkage action.
- Tough, drawn-steel case. Rigid two-bolt mounting.



The many switching jobs done *best* by rotary-motion limit switches can now be done even better! Electro-Snap's new shaft seal gives you *positive* hermetic sealing, simplifies mounting, saves weight and space, and provides a full 50,000 cycle minimum life.

Elimination of external cranks, cams, links, and other gear to translate rotary to linear motion (as is often done to permit use of hermetically-sealed, lever type switches) reduces weight, space congestion, and the need for tedious adjustment. This simplicity gives you greater freedom in locating interlock and indicating switches on rotary mechanisms; allows positive linkage attachment.

Ice, altitude, rain, or corrosive atmospheres cannot effect this Electro-Snap switch sealed in a dry, inert gas. The steel case protects against shocks; prevents loss of the hermetic seal—also permits tight draw-up on mounting bolts without "springing" the case.

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ELECTRO-SNAP
SWITCH & MFG. CO.
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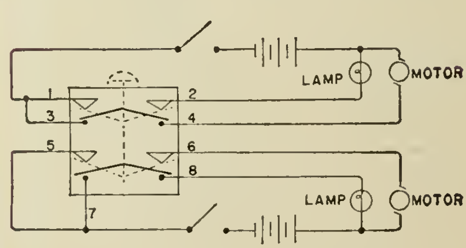
TYPICAL CIRCUIT



1-2—Remote Lamp indicates when arm is fully returned.

3-4—Motor driving linkage counter clockwise 120°.

5-6—Switch stopped motor at predetermined position.

7-8—Remote lamp indicates arm at full travel position.

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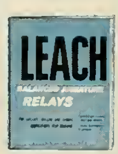


when and where

AUGUST

IAS Naval Aviation Mtg, U.S. Grant Hotel, San Diego, Calif., Aug. 6-10.

Heat Transfer Conference, Penn. State U., University Park, Pa. Sponsor: American Society of Mechanical Engineers, Aug. 11-15.

Symposium on Liquid and Solid Helium and the Statistical Theory of Helium, Ohio State U., Columbus, Sponsor; AFOSR/SRQB—Dates tentative, Aug. 15-22.

Modern Industrial Spectroscopy, Second Annual Special Course, Arizona State College, Tempe, Ariz., Aug. 19-30.

International Ignition Conference, Bendix Scintilla Div., Sidney, New York, Aug. 20-22.

Western Electronics Show & Convention, Cow Palace, San Francisco, Calif., Aug. 20-23.

Int'l Science Radio Union (URSI), 12th General Assembly, Boulder, Colo., Sponsors: AFOSR/SRY, NAS, NRC, ONR, SCEL, Aug. 22-Sept. 5.

American Rocket Society, Symposium on Transport Properties in Gases at High Temperatures and High Pressures, Northwestern U., Evanston, Ill., Sponsors: AFOSR/SRQA, ARS, SQUID, Northwestern U., Aug. 26-28.

American Mathematical Society Meeting, Penn State U., University Park, Pa., Aug. 26-30.

American Sociological Society Annual Mtg. Shoreham Hotel, Washington, D. C., sponsored by AFOSR, Aug. 27-29.

Experimental Aircraft Assn. annual Fly-in and convention, Curtiss-Wright Airport, Milwaukee, Aug. 30-Sept. 1.

SEPTEMBER

Theory of Analytic Functions Conference, Institute of Advanced Studies, Princeton, N.J., Sponsor: AFOSR/SRDB, Sept. 1-14.

Royal Aeronautical Society & Institute of Aeronautical Sciences, 6th International Aeronautical Conferences, Folkstone & London, England, Sept. 1-15.

Society of British Aircraft Constructors, Ltd., 18th Flying Display and Exhibition Royal Aircraft Establishment, Farnborough, Hampshire, England, Sept. 2-8.

International Union of Geodesy and Geophysics. General Assembly, (IUGG), Toronto, Sept. 3-14.

American Physical Society Mtg, Boulder, Colo., Sept. 5-7.

American Chemical Society Mtg., Hotels Commodore, Statler, Park Sheraton, New York, N.Y., Sept. 8-13.

Second Annual Course on Investment Castings, Massachusetts Institute of Technology, Cambridge, Mass. Sept. 8-13.

Aircraft Div. of the American Society for Quality Control, annual conference, Mark Hopkins Hotel, San Francisco, Sept. 9-10.

Twelfth Annual Instrument-Automation Conference & Exhibit, Cleveland Auditorium, Cleveland, Ohio, Sept. 9-13.

American Statistical Association Annual Mtg., Atlantic City, N.J., Sept. 10-13.

Biometric Society Mtg., Atlantic City, N.J., Sept. 10-13.

Institute of Mathematical Statistics Mtg., Atlantic City, N.J., Sept. 10-13.

Damage Criteria For Shock and Vibration Conference, Cambridge, Mass., Sponsors: AFOSR/SRD (HOST), Interservice Technical Committee on Shock & Vibration, Sept. 12-13.

American Society for Testing Materials, 3rd Pacific Area National Mtg., Sheraton-Palace Hotel, San Francisco, Calif. Sept. 13.

Michigan Aeronautics Conference, sponsored by U. of Michigan transportation Institute, Western Michigan U. and the Aero Club of Michigan, Alpena, Mich. Sept. 26-27.

OCTOBER

Aircraft Production Forum & Aircraft Engineering Display, National Aeronautics Meeting, Hotel Ambassador, Los Angeles, Oct. 1-5.

National Electronics Conf. and forum on electrical research, development and application, Chicago, Ill., Oct. 7-9.

NACA Lewis Propulsion Lab. Triennial Inspection, Cleveland, Ohio, Oct. 7-9.

International Astronautical Federation, 8th Annual Congress, Barcelona, Spain, Oct. 7-12.

ARDO Fifth Annual Science Symposium, Interdepartmental Auditorium (across street from AFOSR hqs). Host Center: AFOSR, Oct. 8-9, Washington, D.C.

Society for Experimental Stress Analysis Nat'l Fall Convention, El Cortez Hotel, San Diego, Calif., Oct. 9-11.

National Noise Abatement Symposium, Sherman Hotel, Chicago, Ill., Oct. 10-11.

Canadia Institute of Radio Engineers Convention-Exposition, Automotive Bldg., Exhibition Park, Toronto, Canada, Oct. 16-18.

ASME Conference on New Developments in the Field of Power, Americus Hotel, Allentown, Pa., Oct. 21-23.

Canadian Aeronautical Institute/IAS Mtg., Montreal, Canada, Oct. 21-22.

Computer Applications Symposium, sponsored by Armour Res. Foundation, Hotel Sherman, Chicago, Ill., Oct. 23-24.

Aircraft Electrical Society annual aviation display, Pan Pacific Auditorium, Los Angeles, Oct. 24-25.

Aeronautical and Navigational Electronics 4th Annual East Coast Conf., sponsored by Baltimore Section. IRE and the Professional Group on Aeronautical and Navigational Electronics, Fifth Regiment Armory, Baltimore, Md., Oct. 28-30.

Association of the U.S. Army Third Annual Mtg., Sheraton-Park Hotel, Washington, D.C., Oct. 28-30.

American Nuclear Society, Henry Hudson Hotel, N. Y. Oct. 28-31.

NOVEMBER

Military-Industry Guided Missile Reliability Symposium, Naval Air Missile Test Center, Pt. Mugu, Calif., Nov. 5-7.

Third Aeronautical-Communications Symposium, Utica, New York, Sponsored by IRE-PGCS, Nov. 6-8.

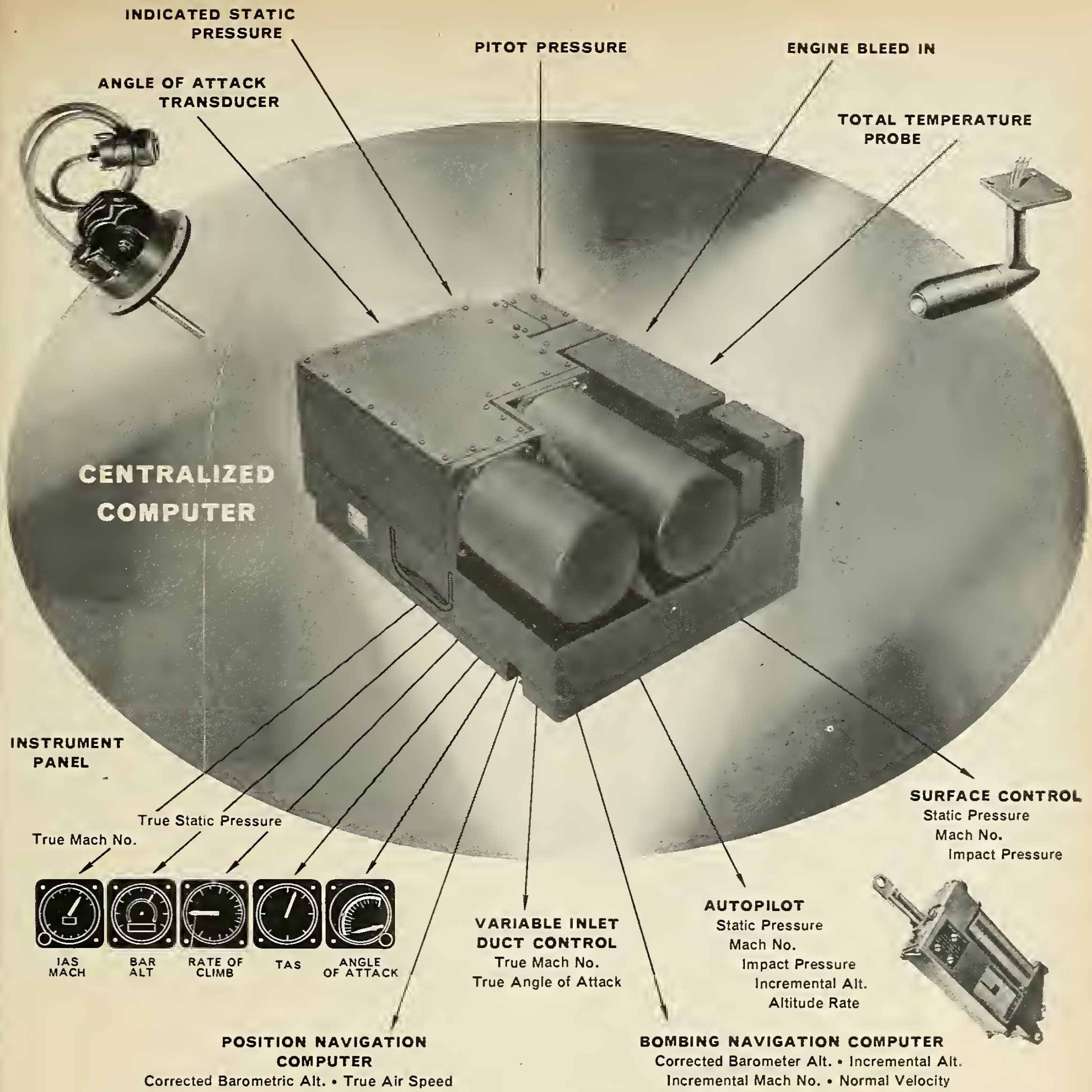
IAS Weapons System Management Mtg., Statler-Hilton Hotel, Dallas, Tex., Nov. 7-8.

DECEMBER

ASME Annual Mtg., Hotel Statler, New York, N.Y., Dec. 1-6.

American Rocket Society Annual Mtg.. Hotel Statler, New York City, Dec. 2-6.

ARS 1957 Eastern Regional Student Conf.. Sponsored by the Polytechnic Institute of Brooklyn Chapter, Hotel Statler, New York, Dec. 6-7.



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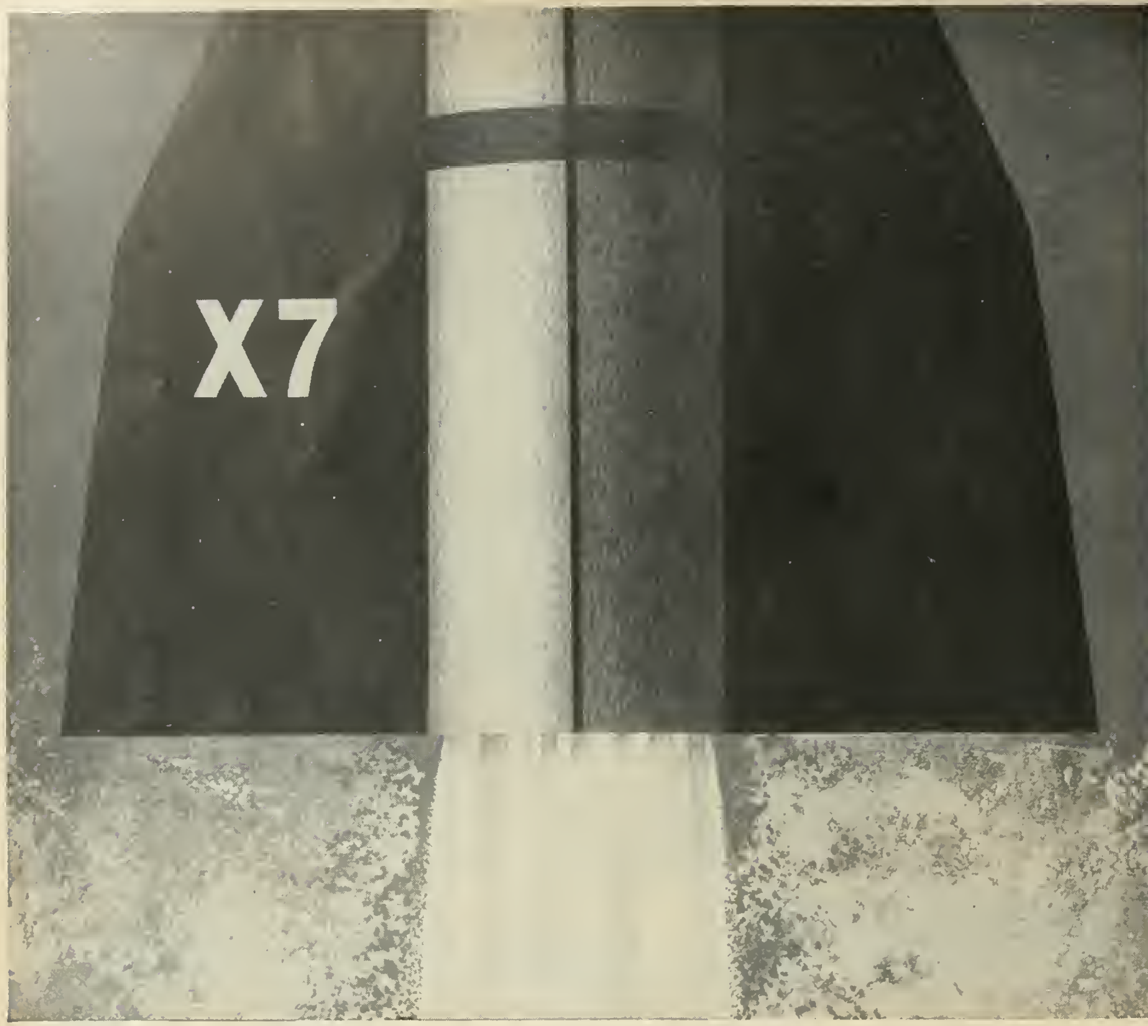
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Precision Titanium, Stainless

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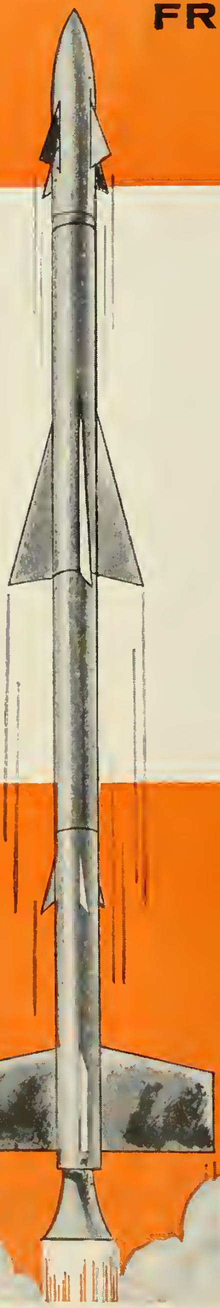

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which describes the experience, facilities and personnel of the Jet Division.

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Soviet IGY Rocket Program Revealed

Claim Satellites Soon; Moon Rockets by '60

In a formal statement by the Russians to U.S. IGY headquarters, the following outline of the Red program for launching of sounding rockets and satellites is revealed:

"The program of the USSR for the IGY includes studies of the atmosphere of the Earth by launching rockets and man-made satellites . . .

"As is known, vertical sounding of the atmosphere by means of rockets has been in progress in our country for a number of years.

"During the IGY we intend to continue and develop this work . . .

"In the Soviet Union, during the IGY the first launching of a man-made satellite with scientific purposes will be made.

"At present there are a considerable number of proposals by Soviet scientists about the employment of rockets and man-made satellites for this or that measurement. The proposals cover practically all the main questions of the physics of the upper layers of the atmosphere and other problems.

"This research is to consist mainly of the following:

"1) Structural Parameters of the atmosphere:

"Measurements will be taken of the pressure, temperature and density of the air at various altitudes and also of the structure of the atmosphere. Together with the measurements of the density taken by manometers, certain data will be obtained by observation of the orbit of the satellite . . .

"2) Optical Properties: The measurements will be made of the altitude and the brightness of the fluorescence of individual layers of the atmosphere, the scattering of light in the atmosphere . . . as well as the optical phenomena on the horizon.

"3) Ultra-violet and X-ray Radiation: The air envelope is a filter for the solar radiation. The atmosphere passes light beams with a wavelength not less than 0.29. The penetration of rockets and satellites into the upper layers of the atmosphere will enable us to study the ultra-violet and X-ray sections of the solar spectrum . . .

"4) Corpuscular Solar Radiation and Aurorae: Corpuscular emission of the sun calls forth sporadic violent variations of the Earth's magnetic field and disturbances in ionosphere . . .

"Solar corpuscules evince several other phenomena in the upper layers of the atmosphere, for instance aurorae . . . It is intended to measure the intensity of the solar corpuscular radiation, to determine the nature of the corpuscules, the velocity of their penetration into the atmosphere, both at calm and during big active processes on the Sun.

"5) Cosmic rays: It is known that the primary cosmic radiation, in the main, consists of hydrogen nuclei (protons), helium (particles) and, in much smaller number, of heavier nuclei (carbon, nitrogen, oxygen, etc.). One of the properties of the primary cosmic radiation is the similarity between the curve of the average distribution of the elements in the cosmos and the curve of the distribution of the shares of the primary component of cosmic radiation. Such elements as lithium, beryllium, boron, are rare in nature and the question regarding the number of their nuclei in the primary cosmic radiation has not been studied by experiment . . .

"Classed with the same range of questions should be the study of the variations of cosmic ray intensity at various altitudes and in different geographical regions.

"6) Ionospheric Physics: One of the problems regarding the structure of ionospheric layers is the determination of concentration of ions. It has been established by experiment that the co[n]centration varies with altitude. In t[his] connection, of great interest are t[he] data on the ionization of the atm[os]phere along the orbit of the satellite, [and] along the trajectory of the rocket.

"The study of the radiowave p[as]sage through the ionospheric layers w[ill] in a great measure improve our know[l]edge of the electronic density, and a[lso] regarding the degree of radiowave f[ad]ing. As to other ionospheric measu[re]ments there will be mass-spectromet[ric] measurements of the ionic content [of] the ionosphere with a view to the d[e]termination of its structure . . .

"7) Magnetic Fields: The short p[e]riodic variations of the magnetic fi[eld] of the Earth are at present associat[ed] with the systems of electrical curre[nts] flowing in the upper layers of the [at]mosphere. Modern data says that rin[gs] of such currents are located in Auro[ral] polar zones (in northern and southe[rn] latitudes) and around the equator.

The proof of the existence of th[ese] currents, their nature and the causes [of] their origin are an important task [of] scientific measurements to be made [by] the satellite . . .

"8) Micrometeors and Meteorit[es]: The problem of micro-meteorites is [of] great scientific and practical imp[or]tance. On the one hand, the presen[ce] of micro-meteorites in the upper atm[os]phere predetermines a range of phy[si]cal processes influencing the state [of] the atmosphere. On the other ha[nd] micro-meteorites and meteors pres[ent] certain danger for the satellite. Calcu[la]tions show that even small partic[les] with a velocity of 50-70 km per seco[nd] can break through the casing of t[he] satellite. Therefore, it is important [to] know the concentration in space a[nd] the energy of micro-meteorites . . . [To] solve this task instruments recordi[ng] the impacts (impact detectors) of m teorites will be installed in the rockets and the satellites.

"9) **Physical and Chemical Processes in the Upper Atmosphere:** It is intended to launch different chemical reagents with the rockets into the upper atmosphere and to study the processes originating during their interaction with the surrounding medium.

"The entire geophysical equipment designed for the investigation of the upper atmosphere is housed in various containers. Some of the containers make up the vanguard part of a rocket with the instruments which is detached from the rocket following a certain time after termination of the engine operation. These Containers reach the altitudes up to 200 km. The containers are equipped with radio telemetry or instruments with immediate photographic recording. In the latter case the containers are saved . . .

The vertical firings of the rockets with a purpose of studying the upper layers of the atmosphere will be conducted in three zones located approximately along the meridian 50°-60° E.

First zone—the Arctic, the Franz Joseph Land, 80° N.

Second zone—middle latitudes of the USSR, 50-60° N.

Third zone—the Antarctic, mainly in the area of Mirny, 50-60° S.

The launching of the satellites will be made from the USSR at a small angle to the meridian. The satellite will revolve around the Earth and will be consequently observed in all the areas of the Earth except the central areas of the Arctic and the Antarctic.

Rocket Distribution by Zones and Years

First zone—1958—25 firings.

Second zone—1957—30 firings, 1958—40 firings.

Third zone—1957-58—30 firings.

"At every firing of a rocket or the launching of a satellite a definite volume of the upper atmosphere investigations is being covered. When the rockets take up the containers of the first type, the study if made of the structural parameters of the atmosphere and of its optical properties, of the ultraviolet and x-ray parts of the solar spectrum, of the ionospheric phenomena and micro-meteorites.

"When containers of the other type are taken up with the rockets, the range of problems studied includes the corpuscular solar radiation, aurorae and also the physical and chemical processes in the upper layers of the atmosphere. When launching the man-made satellites the programme includes geophysical, physical and astro-physical experiments in various combinations, and also other investigations such as the observation of the relativity theory effect, the study of the shape of the Earth.

"The firing of the rockets and the satellites will be conducted approximately evenly throughout the International Geophysical Year mainly on World Days and on occasions of active solar processes, Special World Days."

The official Soviet schedule calls for the first research rocket activity around the moon by the early 1960s. This is announced by Yu. Khlebtsevich, chairman of the Soviet Technical Committee on Radio-Television Guidance of Rockets. These moon rockets will carry no humans, only radio and TV installations to report data back to the Earth.

The first unmanned rocket to the moon will be a small tank containing a laboratory — "a tankette-laboratory," Khlebtsevich calls it. This can be sent on its flight with no more than 250 tons of fuel.

"Moving upon the moon's surface," explains the Soviet scientist, "the tankette will incessantly take films and relay them to the Earth as television.

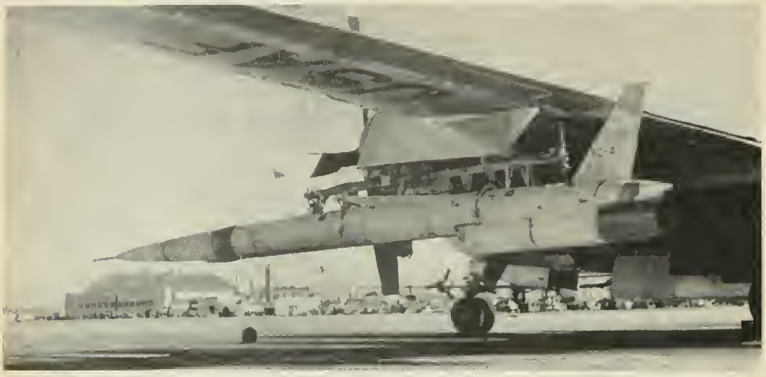
Circle No. 47 on Subscriber Service Card.

AF Reveals XQ-4 Supersonic Target Drone

The turbojet XQ-4 target drone, partly released from security wraps, marks an outstanding advance in the development of high speed targets. Developed by Radioplane Co., a subsidiary of Northrop Aircraft, Inc., the XQ-4 will provide a more reliable evaluation of present air defense systems.

Resembling a scaled-down *Snark*, the drone will travel at supersonic velocities above 60,000 ft. It has both ground and air launch capabilities and is recoverable by three-stage parachute over land or water. XQ-4 is approximately 35 ft. in length and 2 ft. in diameter. Payload volume is sufficient to accommodate special tracking, scoring and photographic or television reconnaissance installations.

Several highly successful flight tests have been achieved at Holloman Air Force Base, N. M. All tests were conditioned by the Radioplane Co.



USAF XQ-4 supersonic target drone shown mounted on the wing of a B-50 launch aircraft. Except for short thin wings, it bears a remarkable resemblance to the SNARK.

RATO Costs Reduced H_2O_2 Still Expensive

As reflected in a recent purchase order by the Navy Bureau of Ordnance, solid propellant RATO costs have taken a welcome drop. In the order Aerojet will deliver 22,630 units (15KS-1000) plus some spare igniters for about $155 a piece. Thus, hardware plus propellant cost for this unit is about $1.07 lb.

On the other hand, hydrogen peroxide is still an expensive item. Redstone Arsenal purchased 52,500 lbs. (half 90% CP-rest, 76%) for $29,859. This represents an average of $.57 .lb or about $.80 for the 90% material.

Martin Orlando Plant Nears Completion

Martin Company's Orlando plant, covering a 7000 acre tract and containing 500,000 square feet in four buildings, takes shape southwest of the city. The plant, under construction since April 2, will produce small weapons, guided missiles and electronics components. Scheduled for completion late this year, the facility will turn out *Lacrosse*, *Bullpup* and the Missile Master system.

Nickerson Assigned to Panama Canal Zone

Col. John C. Nickerson, Jr., former technical coordinator at Army Ballistic Missile Agency, Huntsville, Ala., has been transferred to the Panama Canal Zone where he will have access to nothing more classified than "confidential." Thus closes one of the most colorful chapters in the still-running ballistic missile serial: Army vs. Air Force.

Col. Nickerson had been accused of espionage. perjury and failing to safeguard classified material. The more serious charges of espionage and perjury were withdrawn, however, when he pleaded guilty to the lesser counts.

Nickerson wrote "Considerations on the Wilson Memorandum," wherein he compared Army and AF progress in missile development and detailed why Army should have responsibility for firing Intermediate Range Ballistic Missiles. Little in the document would probably have been considered by a court of law as "classified" from a military security viewpoint. Politically, however, it was "too hot to touch." Col. Nickerson sent copies to selected Members of Congress, certain Washington columnists and MISSILES AND ROCKETS magazine.

Trouble began when a newspaper columnist caused it to be brought to Defense Secretary Wilson's attention. He demanded an immediate investigation by Army Secretary Brucker.

The crux of the prosecution's case, however, was not this document. In what was a completely unsolicited and apparently naive effort to provide m/r with background information on the Army's missile progress, he mailed certain official documents via registered mail to this magazine. Each was clearly marked "Secret" and was returned unread via registered mail to the sender. Army investigators, however, found a transcript of the covering letter from Nickerson to m/r. The prosecution based its main case on the fact that Nickerson sent these documents to unauthorized persons.

Col. Nickerson was fined $1500 and suspended in rank for one year. Huntsville citizens took up a collection to pay his fine and legal costs.

Redstone Equipment Stored Underground

HUNTSVILLE, Ala.—A housecleaning operation at one of the world's most modern scientific installations, Redstone Arsenal, has used ancient means to achieve its purpose.

River barges and caves are being used to store more than 500 tons of heavy strategic production equipment which was shipped here following World War II for storage against possible future needs.

The Redstone Arsenal's Tennessee River docks were used for the first time for outbound freight in the shipment of 179 pieces of machinery, some weighing as much as 15 tons, via a circuitous but economical route to a vast cave near Atchison, Kansas, for storage. The operation is said to have saved the Army $20,000 as compared with the cost of other transportation.

The Redstone docks are normally used to receive shipments of materials from the atomic plant at Oak Ridge, Tenn., which is upstream on the vagabond Tennessee River that has its source in North Carolina and winds up as a tributary of the Ohio River near Cairo, Ill. The Ohio then flows into the Mississippi. The Redstone barges followed this route, turned up the Mississippi into the Missouri River and delivered their freight at Atchison above Kansas City. Five days were required for the operation.

The .docks at Redstone are also used to receive shipments from the Muscle Shoals plants of Reynolds Metals Co.

First *Redstone* Battle Group Activated

HUNTSVILLE, Ala.—The first battle group for field operation of the big *Redstone* bombardment missile will be activated by the Army here on Sept. 9th. It will consist of about 600 men, a battalion divided into two batteries. Each battery will be equipped with one mobile launcher for the 60-foot missile.

The new group will be formed around the 217th Field Artillery Battalion which has been in training for a year to develop field operating techniques for the *Redstone*. The group will also include the 630th Ordnance Company and the 580th Engineer Company.

Lacrosse Course Concluded Aug. 6

HUNTSVILLE, Ala.—The Army will have 150 well-trained teachers for maintenance and fielding of the new *Lacrosse* anti-aircraft and artillery missile when a special course of instruction ends here in early August. They will be deployed immediately to White Sands Proving Grounds, New Mexico, to the Artillery Guided Missile School, Fort Sill, Okla., and to the Marine Corps where they will teach the missile techniques to other instructors.

Far Side: Bargain Counter Space Exploration

America's first stride into interstellar space will begin with the quiet softness of a gentle Kona breeze. In fewer than 60 days on a Polynesian atoll in the Central Pacific, a glistening 3,750,000 cubic foot polyethylene balloon will be hooked to its payload, filled with helium and at the precise moment, cut loose. Several hours later and 100,000 feet above the earth's surface, the four first stage motors of Project Far Side's space exploration vehicle will fire with a combined thrust of 160,000 pounds. The straining balloon will be ripped assunder, and for the next few minutes the tiny transmitter in the missile's nose will telemeter back measurements of space conditions within "the immediate environment of earth"—up to some 4000 miles out.

This will be the first of six Project Far Side firings planned for this fall. Though none will include a try at the moon, success of the series will certainly put this next on the list. It is a coming objective of major scientific importance.

MISSILES AND ROCKETS magazine announced exclusively in its April issue this year that AFOSR was working on various moon rocket projects. Far Side is the beginning. The details of this

MISSILES AND ROCKETS editors Norman Baker and Seabrook Hull examine cosmic ray sensor and circuitry to be launched with the instrumentation in Air Force Office of Scientific Research Project Far Side's space exploration vehicle. This circuitry is designed under contract by Maryland University. In the inset is the full instrument package with battery, transmitter, other circuitry. Aeronutronics Systems, Inc. makes the complete unit.

Here's the answer to prototype parts and short run production . . .

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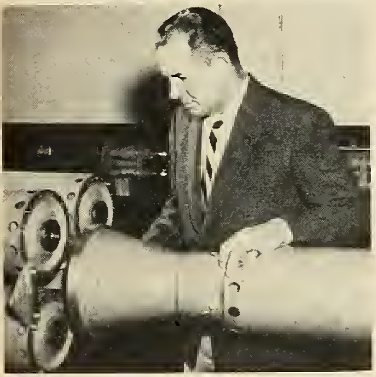
historic project have been confirmed to m/r by Brigadier General H. F. Gregory, Commander, Air Force Office of Scientific Research, Air Research and Development Command.

If Project *Vanguard* is costly and encumbered in a plethora of red tape, Far Side is pleasantly simple and might have lifted its cost figures out of a mail-order catalogue (see editorial, p. 11). Consisting of 10 solid propellant rockets divided 4-1-4-1 into four stages, the Far Side vehicle uses strictly off-the-shelf items.

Stage one consists of a cluster of four *Recruit* rockets built by Thiokol Chemical Corp. Stage two is a single *Recruit*, and is located centrally forward of the first stage. Stage three, tacked onto the nose of number two, is a cluster of four *Arrow II* rockets made by Grand Central Rocket Co. *Arrow II* is a souped up *Loki*. The fourth stage, a single *Arrow II*, is nestled concentrically in the third stage. Both the *Recruit* and *Loki* were originally developed under U.S. Army contracts.



Project Director Herbert L. Karsch, Aeronutronics Systems, Inc., examining forward end of the first and nozzle of the second stage of the Far Side vehicle. The motors are RECRUITS. Note last two stages beyond.

The overall length of the vehicle is about 23 feet. Its diameter ranges from less than two feet at the first stage (excluding cruciform fins of less than 20 inches net additional total span) to about eight inches for the second stage and less than 12 inches for the clustered third and fourth stages. The weight of the vehicle itself is 1900 pounds. Including its launching cage, external power supply and radio gear, etc., the weight that will be carried aloft by the balloon comes closer to 2300 pounds.

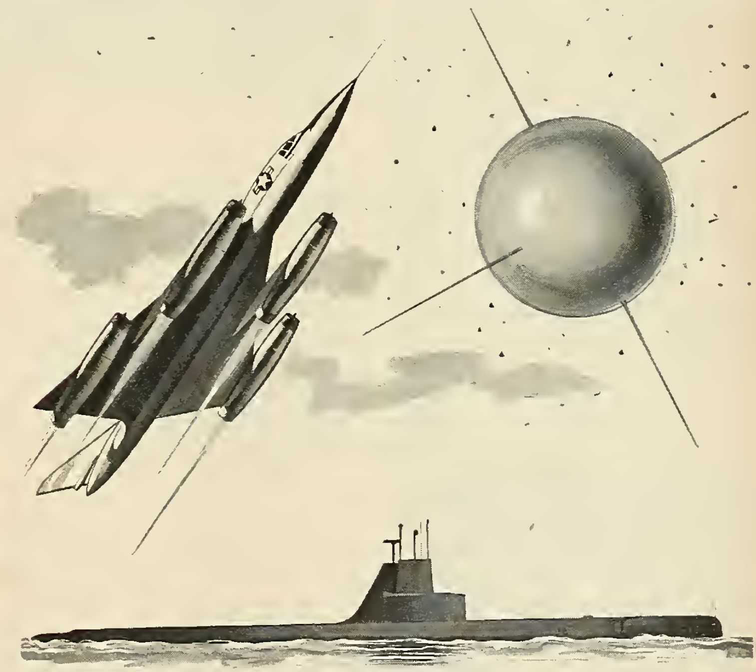
The balloon itself weighs another 1500 pounds and reaches a diameter of 200 feet at altitude. It was designed and is manufactured by the Mechanical Division of General Mills, Inc.

The Far Side rocket vehicle's payload will consist of an instrumented package roughly six inches long, four inches in diameter and weighing about three-and-a-half pounds. The main measurements to be made will be ion density, magnetism and cosmic rays. All will be single-purpose measurements. The entire instrument package will be enclosed in white foam of density three pounds per cubic foot. All circuits are 100 per cent instrumented.

Actual on-board cosmic ray instrumentation, including geiger detector tube, high voltage supply for the geiger counter, scale of 64 with associated preamplifier and emitter circuits. Power consumption is 100 milliwatts. In charge of this phase of the work is Maryland University's brilliant young astrophysicist, Dr. S. Fred Singer, described by AFOSR as "one of the nation's leading authorities in the field of upper atmosphere research." The instrumentation is being put together by University of Maryland students under Dr. Singer's direction.

The Ford Motor Co. subsidiary, Aeronutronics Systems, Inc., is prime contractor for Project Far Side and is responsible for designing, fabricating and firing the vehicles. Far Side Project Manager for Aeronutronics is Herbert L. Karsch.

Project Monitor for Far Side is AFOSR's Director of Advanced



Four-stage Far Side rocket plus its firing platform are mounted on a truck prior to hooking onto 3,750,000 cubic foot General Mills balloon in preparation for June test flight.

Studies, Dr. Morton Alperin, who emphasizes the importance of obtaining heretofore unavailable data vital to the AF of today and tomorrow.

The actual altitude that will be reached by the Far Side rocket can only be estimated. Current lack of knowledge of the precise density distribution at ultra-high altitudes makes reliable calculations difficult. However, the four stages will fire for a cumulative time of 26 seconds (eight seconds actual firing time plus coasting stages) with a maximum acceleration of 200 g's. During this period the missile is expected to achieve a velocity in excess of 17,000 miles an hour—out where Mach Number is a meaningless unit.

Those participating in the project forecast only that the final stage will achieve a distance out from Earth of "from 1000 miles to several times that distance."

If current estimates of "air" density in space and of the diminishing effects of gravity are anywhere near correct and if the solid propellant rockets work as they should in the pressureless, highly ionized environment in which they will be firing—the expected distance is calculated at between 4000 and 5000 miles. The mean distance of Moon from Earth is 239,000 miles.

However, at 5000 miles out, the force or acceleration due to gravity, is only a little over six feet per second per second, compared to 32 on the earth's surface, and reducing steadily with the distance from the earth's center. No official suggestions have been made by AFOSR that it would take only "a little more push" to get a vehicle into the Moon's gravitational field. However, some of those closely connected with the project have admitted freely that it is not beyond the limit of either current balloon or off-the-shelf solid propellant knowhow to use this method for either orbiting or impacting the moon.

Scientists recapture first project Far Side test load after it reached 106,000 feet before dropping back to earth by parachute. First business shot is scheduled for September.

Rocket Trends

by Erik Bergaust

MID-OCTOBER MAY MARK the "turn of the century" for U.S. missiles . . . Complete shake-up by that time by the Department of Defense is understood to have been ordered by the White House to eliminate duplications and to step up efficiency in development . . . Some will lose, some will win . . . *Triton*, for instance, might get the ax, although this may be due to the rapid advancement in solid propellant technology.

AIR-TO-GROUND MISSILE RACE is on. Air Force officials seem to think Rascal-type missile (with improved range, speed) will be the next thing for boosting our strategic retaliation capability. Tomorrow's big bombers (including our B-52s) will become missile carriers exclusively. Industry is now bidding on new air-to-ground bird . . . In the lead, coming down the home stretch: Lockheed and North American . . .

DID WE MISS THE BOAT IN THE IRBM-ICBM race with Russia? It is said that had we poured the same money into a solid propellant program, we could have had operational IRBM's and ICBM's by now. Just as the solid *Nike Hercules* is replacing *Nike Ajax*, we can do the same for the IRBM-ICBM. And we probably will . . .

UNDERWATER MISSILE RACE is getting hotter and hotter . . . look to lithium as important underwater missile "fuel". If you want some capital gains from promising chemical suppliers to the solid field you might want to try Foote Mineral, American Potash & Chemical, or Lithium Corp. They will be making all the lithium perchlorate which is the hottest item to hit the solid propellant field. AmPot is the favorite since it will also cash in on the boron fuels, though Foote is a major lithium supplier to AEC.

RELIABLE SOURCES SAY Standard Oil Co. (Ind.) wants somebody to take over its Seymour, Ind. activities for solid propellant work . . . American Rocket Co. is said to be seeking somewhat smaller pile for its current expansion program.

RED CHINA MAY BECOME SOLID ROCKET PRODUCER since they will buy the following important rocket chemicals from Britain and Norway: ammonium nitrate, cellulose nitrate, lithium compounds, potassium chlorate, potassium dichromate, potassium nitrate, potassium permanganate, sodium chlorate, sodium dichromate, sodium nitrate, and sodium perchlorate . . . University of Moscow is working on the acceleration of lithium, sodium, potassium, rubidium and caesium ions as potential space rocket propulsion systems.

DOUGLAS AIRCRAFT ABOUT TO BECOME LEADER of U.S. missile builders? Stepped-up NATO missile negotiations (most NATO missiles will be Douglas birds . . . *Nike, Honest John* etc.) and recent successful tests of AF's atomic MB-1 . . . plus BIG *Nike Hercules* contract coming up . . . indicate Douglas will take missile production lead for a good while.

COKEBOTTLE DESIGN CONCEPT (area rule) may be employed in missiles. Army missile men are reported to be considering Marilyn Monroe-shaped IRBM's and even ICBM's to lick early drag problems . . .

The *Vanguard* Engine Passes Qualification Test

As far as power plants are concerned, Project *Vanguard* is ready to go. At least that's the status insofar as static qualification tests are concerned. Three of the four *Vanguard* engines under contract to The Martin Co. have passed with flying colors. Rumors are, however, that the fourth company, Allegany Ballistics Laboratory (subsidiary of Hercules Powder Co.), wants out.

General Electric Co.'s long-in-doubt first stage engine, m/r has learned, passed its complete qualification test "without having to replace anything"—not one single part.

Aerojet-General, so far, has had two second stage engines accepted—the first on April 24 and the second on May 16.

Grand Central Rocket Co. has not only had its third stage engines accepted, but one has flown with "100 per cent perfect" results.

These facts remove a major factor of doubt from the possibilities of success of Project *Vanguard's* efforts to place a man-made earth satellite in an orbit during the International Geophysical Year. Though the need for refinements may become apparent as the first and second stage engines are subjected to actual flight tests, it must be heartening to Naval Research Laboratory and Martin that at least they work on the ground. It's a big step towards consummation.

GE's first stage engine has completed between five and ten full duration tests of 150 seconds each without any parts having to be replaced. GE believes that this places the life of their engine over that of any other engine of comparable performance. Nearly all the engines called for in the contract have been delivered.

Reason for failures of the first three engines delivered appears to be (believe it or not) that they had gotten rusty . . .

The fact that Aerojet General reports only two engines accepted so far indicates that this company is probably not so far advanced as GE in production. Development, however, appears to have been completed. *Vanguard* test vehicle TV-2 will probably be fired in a few days and will be the first flight test of GE's first stage. Soon thereafter, TV-3 will be fired, including a GE first and an Aerojet second stage. This should occur within six weeks.

Aerojet-General, in developing the thrust chamber for its second stage engine, worked out a system of wire wrapped aluminum tube construction with amazing weight to size advantages. This system is regeneratively cooled.

Assuming everything else to be in a similar state of preparedness as these three engines, it would seem that the possibility of advancing the date for a first business try at getting the 20-pound sphere in an orbit has improved. Statements, however, from those in authority in the project continue to be cautious—"in the spring of 1958; before the end of the IGY, etc."

Meanwhile, unofficial Lockheed Aircraft spokesmen would have you believe that an upward misfire of the third stage of an X-17 had already placed man's first uninstrumented satellite in orbit. Concern grows lest Russia in fact places a satellite in orbit on September 17, the 100th anniversary of Soviet space flight pioneer Tsiolkovsky's birth. This would be embarrassing. Meanwhile, Air Force Office of Scientific Research is piling Army rockets together in an attempt to accomplish man's farthest excursions into outer space.

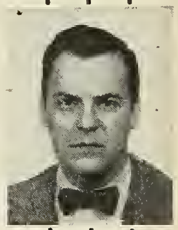
Recruit's and *Loki's* for Outer Space

Five *Recruit* and five *Loki* rockets will be assembled into four stages to complete the AFOSR's Project *Far Side* space flight vehicle (this issue, p. 45). Reliability of rocket powerplants should not be a factor threatening project postponement or malfunctions during actual launch operations. Evaluation test firings will be eliminated on Project *Far Side*. All shots will be for real.

And still there is no word of what Redstone Arsenal is doing with all its *Recruits*.

Missile Business

By Seabrook Hull



SECRET CONTRACTS SECRETLY ARRIVED AT, lack of competitive bidding and tax supported facilities for private industry are main reasons behind current Congressional efforts to change military procurement rules. Some figures Congress doesn't like: Of $13.6 billion total military buying in first nine months, 1956, 92 per cent was by negotiation instead of advertised bid; 39 per cent was negotiated in secret; and 22 per cent required a substantial initial investment of government funds. All-told, 17 exceptions to normal procurement procedures had been invoked to justify these actions. Congress aims to cut that list sharply. Law may pass this year. It would hit missile procurement heavily.

Passage would make it tougher for Services to direct procurement where they want it to go, for whatever reason. Company contracting officers would have to get used to new rules, bid closer to the cost line and in general become adept at more rough-and-tumble ways of doing business.

A PERMANENT ARMS INDUSTRY—anathema though it may be to traditional American concepts—may be the best answer. Business and procurement methods that work best in temporary all-out conditions of a conventional "hot war" obviously leave much to be desired over 20-to-50 years of cold war. A really comprehensive new look may be required.

FOREIGN SALES OF U.S. MISSILES will be largely handled through regular U.S. military channels. This doesn't mean, however, that it wouldn't pay U.S. missile makers to do a little personal salesmanship with NATO officials in position to make decisions. This could influence NATO-wide determination of West European missile requirements.

Two countries for sure, Britain and West Germany, and maybe Luxembourg, will pay their own way and may buy directly from manufacturer.

Only missiles that have been announced as being "cleared" for export are *Nike*, *Matador* and *Honest John*.

Possible big market exists for enterprising missile maker that comes up with a low-cost "prestige" missile for sale in Middle East, South America. These countries would like to have their armed forces geared to the missile age but could never afford high-cost, complex birds such as those being developed for U.S., NATO, etc.

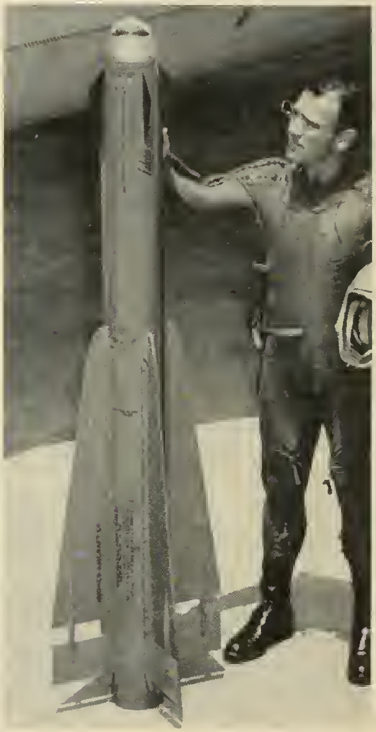
MEANWHILE, COMPETITION PATTERN IN MISSILES develops. Japan's applied for permission to manufacture Swiss Oerlikon-56 rockets. French have radio-guided anti-tank SS-11, renamed it SS-22 and are trying it out as an air-to-air missile. Norway boasts air-to-underwater *Tern*. Sweden is buying Australian ground-to-air *Jindiviks*. Prices count abroad.

DEATH OF *NAVAHO* plus forecast death of Navy's *Triton* project carry serious implications for "next step" development in air transport; could kill all development on large ramjets. Similarly, one of most practical approaches to regular manned space flight involves attainment of initial high velocity with ramjets before cutting in ion propulsion. There are other factors, both military and civil, that leave proposed abandonment of advanced air breathers open to serious doubt. Development of effective anti-ICBM missile will obsolete a lot of costly hardware overnight, and cause a serious flip-flop in the balance of power—unless U.S. has something else in its arsenal, like *Navaho* or *Triton*.

Hughes Latest *Falcon* Has Infra-red Seeker

The latest in the *Falcon* GAR air-to-air missile series is now in operation as a U.S. Air Force defense weapon. New *Falcon,* GAR-2A, is equipped with an infra-red radiation seeker greatly increasing the kill rate over earlier *Falcons.* GAR-2A is actually a GAR-1D with the IF guidance system replacing the radar system.

All-weather interceptors, F-102A, F-89H, and F-101, will carry both IF and radar equipped *Falcons* to insure kills under all weather conditions. Missiles will be fired in salvos of three to six as a condition of calculated kill



probability of 80-90%. The pilot may select the type and number of missiles to be fired once the control system has established the target.

Air Force officials announced that they would continue to hold the Navy *Sidewinder* in high regard as armament for day fighters. "The *Sidewinder* is a more simple weapon while the *Falcon* GAR-2A is more sophisticated and versatile". Main objection to the *Sidewinder* apparently is its length—requiring external installation.

Test firings of the new weapon were made at Holloman Air Development Center, N. M. For these tests *Matadors* and F-80s served as targets. Although all tests were conducted without warheads, each intercept destroyed the target.

INTERNATIONAL NEWS

By Anthony Vandyk

Swiss Reveal Details of Oerlikon AAM

Oerlikon has released full information on its 5-cm and 8-cm aircraft rockets with folding fins. These rockets are for use not only against aircraft but also against ground targets such as armored vehicles, armor trains, artillery. Oerlikon describes the distinctive features of its armament as: (1) quickness in action; (2) excellent accuracy; (3) high lethal power. It points out that the rockets are: (a) safe to transport; (b) capable of being stored for an indefinite period; (c) extremely safe to handle.

Multiple launchers are used for the rockets. The launchers are made in various shapes (one was illustrated in the July m/r, page 83) and with various capacities according to the type of aircraft and mission required. A typical launcher containing 76 5-cm rockets weighs about 660 lbs. empty or 1200 lbs. loaded. The launcher has no effect on the flight characteristics of the aircraft except for slightly reducing speed. It may be dropped in emergencies.

The rockets are electrically ignited by means of a selective triggering built into the cockpit and can be fired singly or in automatic fire. To avoid mutual interference during flight when firing in automatic fire, the rockets are fired in pairs at time intervals of 0.1 seconds.

During a demonstration for a foreign air force Oerlikon reports that 72 5-cm rockets with folding fins were fired from Meteor Fighter in a series of automatic firings from air to ground to demonstrate the killing power and firing accuracy of the weapon. The firing started at altitude of approximately 4000 ft. and ended at an altitude of about 1500 ft. The total firing time was approximately 3.5 seconds. The rate of fire is equivalent to 1200 rockets per minute. During the demonstration the rockets were dispersed over an area about 60 ft. long and 25 ft. wide. A total of 24 hits were made on a cloth target measuring 19 ft. by 19 ft.

The following technical data referred to the 8-cm rocket with folding fins: initial weight, 20½ lbs.; maximum velocity (fired from ground), 2756 ft. per second; weight of explosive (Hexal), 2 lbs.; thrust (approx. 1 second), 1587 lbs.; burning ends after approximately 1411 ft.; length of rocket 3 ft. 11¾ in.; armor guessing ability, 1 ft. 2½ in.

The rocket is manufactured by Oerlikon in the following versions: practice rocket (inert), practice rocket with marking charge; explosive rocket with impact fuze; and armour piercing rocket with hollow charge.

The folding fins open approximately 0.05 seconds after leaving the launching tube. During this period the rocket covers a distance of approximately 10 ft.

The characteristic properties of the rocket motor are: rocket motor with parallel beam jet; spring actuated folding fins in which all fins open

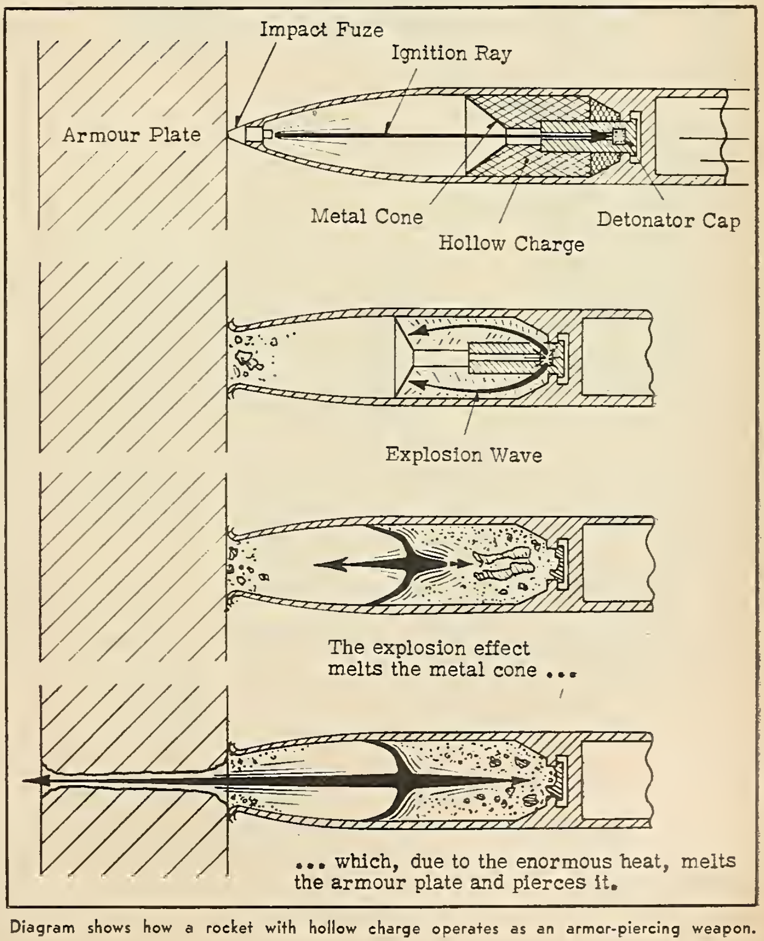


Diagram shows how a rocket with hollow charge operates as an armor-piercing weapon.

simultaneously by direct action; slight twist due to guide veins inside the nozzle; and electric ignition by means of a contact ring at the end of the nozzle.

Mitsubishi Electric Machinery Co., Ltd., has applied to the Japanese government for permission to pay Buehle Contraves & Company of Switzerland for the patent rights for the production in Japan of Oerlikon guided missiles. A provisional agreeement gives Mitsubishi all the patent rights for the production in Japan of the *Oerlikon-56* and its fire control system.

The Swiss firm is asking 8% as patent rights of the *Oerlikon* missiles and 5% of the revenue from sales of launchers and firing control system. The contract is to be valid for 15 years. It will be two or three years before Mitsubishi can start mass production in Japan of guided missiles because of government permits, preparations and completion of final contracts with the Swiss firm.

The Japanese Defense Agency this fall will import a complete set of *Oerlikon-56* rockets and a launcher from the Swiss firm at a cost of $1,-080,000 with the aim of studying and testing the Swiss weapon.

Soviet Space Plans Spelled Out

From the various statements by Soviet officials and scientists, particularly from Academician Eugene K. Fedorov, chairman of the IGY's Soviet committee for rocket and satellite research, and his associate I. P. Bardin, we glean the following items regarding the artificial Soviet satellite to be launched into outer space:

There will be several such satellites, of varying weights and sizes, but the average diameter will be about 18 inches.

Each satellite will be launched at a slight angle to the meridian. Its speed will be 18,000 miles an hour. It will complete its circle of the globe in about 90 minutes. Its orbit will cover almost the entire globe. It will travel near but not over the Arctic and the Antarctic.

Aboard the best of their satellites the Soviets will install equipment to measure the air's density; the number and energy of micrometeorites; the composition and energy of cosmic rays, electrons, gamma rays, and rays causing the Northern lights. Radio-television will automatically relay this data to the earth.

Since relay energy on some of the satellites will be limited, the information will be signalled only at certain intervals.

Russians Study Cosmic Medicine

Cosmic medicine, Russians explain, is that new branch of aviation medicine which deals with the effects of heights and speeds upon man in his future rocket flights. A recent issue of *Sovetskaya Aviatsia* devotes an article on this subject by V. Malkin, described as "candidate of the medical sciences," a physician with an advanced degree.

Having ascended to a great height and having overcome the force of the earth's gravity, a rocket will "come out to its cosmic trajectory, its motors will cease their work," and its astronautic personnel "will find themselves in a state of imponderability, that is, without weight," writes Dr. Malkin.

Already now, the Soviet physician points out, in experimental flights within the limits of the stratosphere it is possible to create these conditions for a period of two to three minutes. This is because in such flights "made along a parabola" the centrifugal force for a time balances the force of the earth's gravity. Experiments with aviators have already shown that some men can successfully withstand the effect.

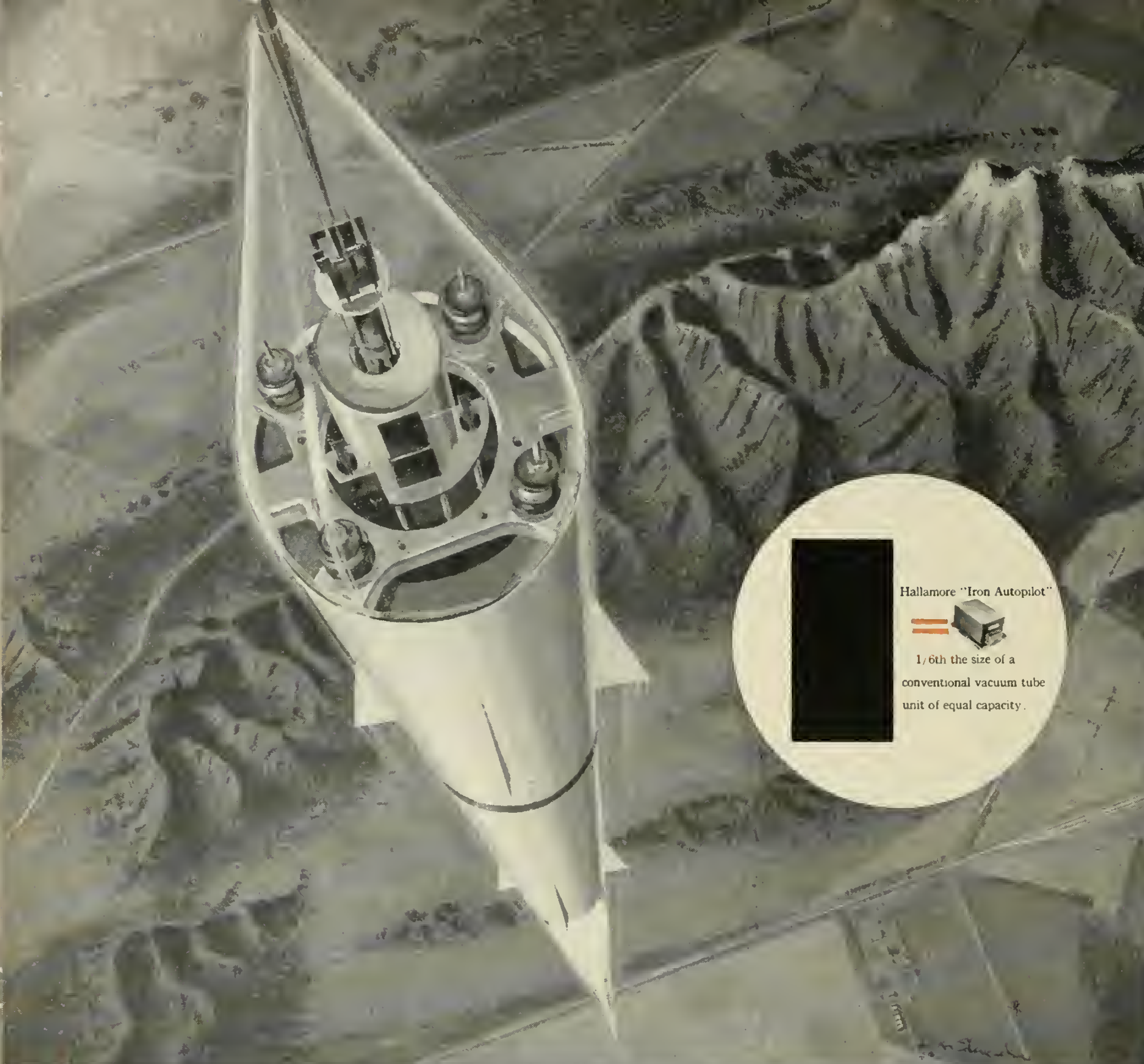
Several tests have been conducted where the pilot experienced the condition of weightlessness for several seconds.

Red Rockets for Venus

Russian scientists expect to send unmanned rockets to Venus within the next ten years. Instruments in the rockets, according to Radio Moscow, will record photographs of the planet's surface before it lands in order to prove or disprove the existence of life on the planet.

To ponder the question of what plants and other low forms of life may or do exist on Mars and other planets involves no idle theorizing, say the Soviets. Such discussion has a highly practical relevance since we are on the threshold of journeys to those planets and our interplanetary travelers of the bright tomorrow must indeed know what life, if any, they may encounter on Mars, Jupiter, Saturn, and Uranus and whether they themselves can survive there on landing.

This is the opinion of Professor G. A. Tikhov of the Alma-Ata Observatory in the Soviet Kazakhstan in Central Asia, in charge of the Astrobotany Sector of the Kazakh Academy of Sciences. He reveals that "one of the basic conclusions of our observations is that Mars does have plant-life, which circumstance we can announce with sufficient certainty."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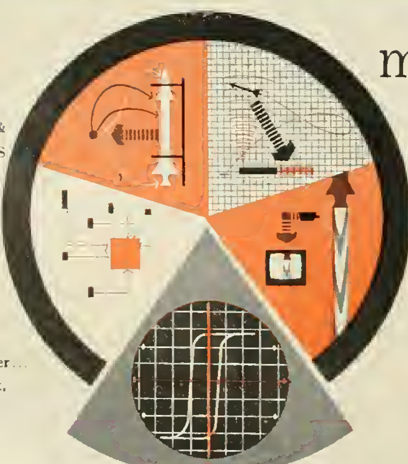


World Astronautics

By Frederick C. Durant III

A number of member societies of the International Astronautical Federation have local sections in various parts of their country. At last count the ARS has 31. The DGRR of Stuttgart has branches in Baden-Wurtemberg, Berlin, Hamburg, Hannover-Niedersachsen, Hessen, Nordbayern, Nordheim-Westfalen, Oberbayern, Saarland and East Germany. The British Interplanetary Society has 5 sections: Midlands, North-Western, Scottish, Western and Yorkshire. The Palskie Towarzystwo Astronauticzne of Warsaw has sections in Cracow, Wrocaw, Bydgoszcz and Katowice. At last report the Yugoslav Astronautico Drustvo based in Belgrade has a branch in Zagreb with groups forming in Sarajevo, Skopje and Ljubljana.

•

The DAR rocket group of Bremen has announced plans for a fifth anniversary celebration 27-29 September. The firing of solid propellant oil-spray rockets (m/r April '57, p. 88) will be a feature of the program.

•

The German Museum of Munich is reestablishing an Aviation Wing and is searching for historical material. The search is on to locate rocket weapons captured by the Allies which might be made available for display. The remarkable rocketry achievements of the Germans during World War II represent a significant period in the evolution of astronautics. It seems appropriate that technical evidence of this historic work be assembled for posterity.

•

Correspondence and contacts in Korea, Greece, Rumania, India and Pakistan indicate interest and a desire to organize astronautical societies in these countries.

•

Academician Leonid I. Sedov, President of The Commission of Astronautics of The Academy of Sciences, Moscow, attended the Third Symposium on Cosmical Gas Dynamics at Cambridge, Mass., recently.

•

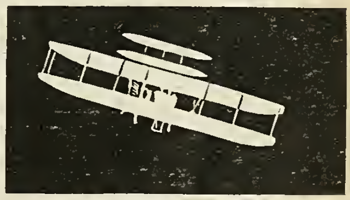
A few years back it was possible to add to one's library every new book pertaining to rockets and space flight without straining the pocketbook. Such is no longer the case. Recent publications, however, include some musts. Willy Ley's *Rockets, Missiles & Space Travel* (Viking Press) has appeared in a new edition, enlarged and updated. As a reference work it has no peer.

•

Criterion Books has just published *Man Among the Stars* by German science writer Wolfgang Mueller, translated from his successful *Du Wirst die Erde sehn als Stern*. Mueller is not hesitant to contemplate upon historical trends, psychology, religion and philosophy and their relationship to astronautics.

•

The Navy officially opened the U.S. portion of International Geophysical Year by firing a *Dan* rocket to an altitude of approximately 75 miles from the San Nicholas Island facility of their Air Missile Test Center, Point Mugu, California. The rocket, one of 14 to be fired during the next few months, is equipped with 20 pounds of instrumentation for the study of Lyman alpha radiation, "soft" X-rays of one to two Angstroms in magnitude and gamma rays emitted during solar flare periods. It is hoped that the results of the firings, when integrated with other measurements made during the IGY investigations by the 62 cooperating nations, will enable scientists to determine the relationship between solar flares and radio fadeout.



Three Missiles Produced By French Firm

SNCA du Nord, one of the larger French manufacturers, has given some information on the production status of its missiles. The SS-10, SSM, and the CT-10 target missile are currently in production. The former is designed as an anti-tank weapon. The French company states that it will soon start production of a refined version of the SS-10, the SS-11. Also to go into production is an improved CT-10, the CT-20. The third new production item is the Nord 5103, an AAM. SNCA du Nord expects to receive export orders for its three new production missiles in addition to contracts from the French government.

For its expanded production program, SNCA du Nord will enlarge its facilities at Bourges and will hire more staff. The company at present employs a staff of 8000 at its four plants—Bourges, Les Mureaux, Meaulte and Chatillon.

SNCA du Nord's reports give no details of future projects other than mentioning the fostering of "important developments" and the "confirmation of the future of the company in the field of missiles."

The company regrets that its Gerfaut and Griffon experimental aircraft are not to go into production but it stresses that the experience obtained with ramjets due to use of these aircraft will be useful in the development of future missiles.

Animal Experiments Announced by USSR

Experiments with small animals sent up in rockets (dogs in the Soviet Union, monkeys and mice in the U.S.) have already yielded much valuable data on the physical state of the animals when the latter became "non-weight" for a few seconds or minutes. The rockets' automatic equipment gave doctors the information they needed on the animals' breathing, blood pressure and heart behavior.

Dr. Malkin declares that each such animal's "vestibular apparatus, that is, the nervous system signaling to the central nervous system about the body's position in space," was substantially disturbed in its functions and thus played an important role in the disorientation of the animal while in rocket flight.

But the most worthwhile experiments so far in "cosmic medicine" involve man's imponderability or non-weight status. Dr. Malkin writes of 16 aviators achieving this non-weight condition during a special experimental flight, for 30 to 45 seconds at a time.

Behind the Curtain

By Dr. Albert Parry

One fact above all others is apparent from the latest Kremlin shakeup: Without Zhukov and the other marshals standing behind him, Khrushchev could not have won. However, Zhukov strengthened the political role of the Soviet armed forces even more than he consolidated Khrushchev's power and policies. The Soviet military may not want war, but they certainly want more "diverse atomic and hydrogen weapons, powerful rocket and jet armament of various kinds, including long-range rockets."

But Soviet *talk* of peace is always with us. The current Sixth Five-Year Plan, 1956-60, calls for "a considerable expansion of titanium production"—for peaceful aims only.

Comrade F. Kharakhorin in the Moscow *Trud* presented an article with the significant title; "Titanium, the Metal of the Future." He declared that the USSR's titanium industry has been created comparatively recently, since World War II. "From the carbide of titanium and wolfram, with the addition of metalic cobalt, alloys are obtained whose hardness is nearly that of diamonds. These remarkable materials for cutting instruments are being prepared at the Moscow Combinat of Hard Alloys."

Yet, fangs are bared from time to time in no uncertain manner. The very day that Danish Defense Minister Paul Hansen announced in Parliament that Denmark had accepted the American offer of *Nike* and *Honest John* guided missiles, as part of the joint defense aid program, and that the Danes would be given U.S. missile training, radio Moscow blared (in English) that something was rotten in the capitalistic Kingdom of Denmark also, that Denmark was creating "a grave menace" for herself by accepting U.S. guided missiles, and that the future might bring upon Denmark "the retaliatory blows meant for an aggressor."

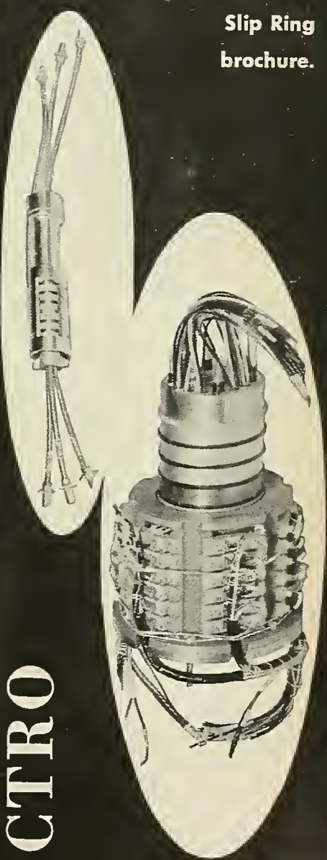
Krokodil, Moscow's humor magazine, attacks a Florida travel bureau for running an ad in the *Miami Herald* announcing "sale of tourist tickets for the moon, Mars and Saturn, first such flight now planned for 1987." The Red satire periodical, accuses the Florida concern of "profiteering". But it also argues that the 150 Americans who responded to the ad must have been attracted by the promise that "no passports will be required . . .

Red Prague officially announces its gratification that "the U.S. has chosen a star map made by Dr. A. Becvar of Czechoslovakia for recording the position of its satellites."

The Czech government also claims a geophysical laboratory some 4500 feet below ground (in a mining pit at Brezove Hory), believed to be the deepest observatory in the world. It is equipped to register movements of the earth's crust caused by the force of gravity of the moon and the sun. The depth provides freedom from surface disturbances.

An electronic computer of the Soviet Academy of Sciences "can click out in a day or a week that which a hundred mathematicians can solve only in a year." This is revealed by V. Safonov in recent issue of the Moscow *Literaturnaya Gazeta.* He adds, however, that it is used only to some 20 per cent of its capacity. The other 80 per cent of the wonderful electronic brain remains idle until Red rocket men have more theories for the machine to test and new tasks to perform.

The Soviets are now considering the proposal of some of their astronautic scientists to reorganize the Lesgaft Natural Science Institute in Leningrad into the Institute of Cosmo-Biology, to study "all problems connected with a possible development of life on other planets, also with conditions of human existence in and en route to such worlds."



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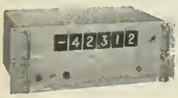
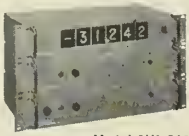


an AC-DC digital voltmeter...



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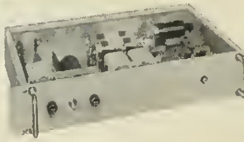

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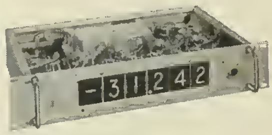

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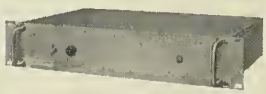

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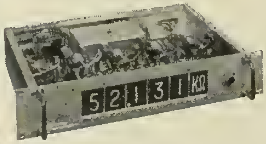

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Washington Spotlight

By Henry T. Simmons

Cancellation of the North American *Navaho* program last month came as no surprise to those familiar with the Air Force's financial plight. The strictures on USAF spending dictated elimination of a major project and military logic did the rest. *Navaho* was mouse-trapped between the Northrop turbojet *Snark*, which should be operational by 1959 and the intercontinental ballistic missile which *may* be operational by the early 1960's. The decision may be a wise gamble, but few would argue that it is a comfortable one. It means the U.S. won't have a supersonic intercontinental missile delivery capability until the ICBM materializes—and that, unhappily, may be long after the arrival date now scheduled.

•

The *Navaho* flight test program was plagued by an unusual share of bad luck. Four XSM-64 test vehicles have been fired from Patrick AFB, Fla., since last December and all failed. No. 1 aborted because of the failure of a rate control gyro; No. 2 tore away part of its launching apparatus, lost booster thrust and failed to ignite its ramjets; No. 3 burned up when the boosters quit inexplicably after a couple of seconds. On the fourth and last attempt in June, the booster motors fired for 42 seconds and then quit. Though the vehicle was traveling at an estimated velocity of Mach 1.6, this still wasn't fast enough to light off the big Curtiss-Wright ramjets.

•

Additional firings of *Navaho* test vehicles may be authorized by the Air Force for research purposes if costs can be held down. It is understood that North American has about 12 more XSM-64's in various stages of completion. Assuming NAA can lick the premature stoppage of its booster motors and accelerate the vehicles to the ramjet ignition point, the remaining XSM-64's could provide valuable data on the behavior of large ramjets under true environmental conditions.

•

Loss of the *Navaho* program means that Rocketdyne has no home for the three-barrel, 400,000-pound-thrust booster it has developed for the SM-64 production *Navaho*. The powerplant has been described as extremely reliable in static tests. NAA may propose that the engine be used in the first stage of a souped-up *Titan*, replacing the 300,000-pound motor Aerojet is developing for that purpose.

•

On its first flight in June, the *Atlas* ICBM test vehicle reportedly maintained structural integrity under stresses ranging up to 22 g's. The stresses occurred during the two loops the rocket performed after fuel starvation shut off one of the two motors. The Air Force is understandably pleased by the performance because the structure of the bird has been pared to the limit to insure maximum mass ratio. Example: it must be pressurized during transport to prevent distortion of the fuel tanks.

•

The Navy's decision to settle on a solid-propellant motor for its air-to-surface *Corvus* missile reportedly dealt the death blow to USAF interest in the project. The airmen aren't satisfied with the range of the Navy version, and they see no growth capability in the solid-propellant configuration.

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missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

m/r exclusive:

Solid Fuel Industry Round-up

By the Editors of m/r

IN 1936 AN INFORMAL group, headed by Dr. Theodore von Karman, was formed at the California Institute of Technology (GALCIT Project) for research on rockets. Modest solid propellant work was undertaken. Two years later, in December 1938, General H. H. Arnold, Commanding General of the then Army Air Corps, asked Cal Tech to come up with a program to develop rockets for boosting aircraft.

It was not until July, 1939, however, that the program got underway at Cal Tech under National Academy of Science sponsorship. The Army Air Corps assumed sponsorship in July, 1940. By 1941, a successful solid RATO (rocket assisted takeoff) was demonstrated and the Aerojet Corp. (under Andrew Haley) was formed to produce the solid rockets. In 1943, the ORDCIT Project was launched to develop long-range rocket missiles. Also in 1943, the US Naval Ordnance Test Station at China Lake, Calif. was established (at a cost of over $100 million).

Under OSRD some $100 million was spent on various rocket projects during World War II. These projects developed such solid rockets as the Bazooka, a full line of aircraft and artillery rockets, the *Privates A* and *F*, and the large *Tiny Tim* 11.75-in. aircraft rocket. In 1946, the Jet Propulsion Laboratory was established at Pasadena at a cost of about $3 million.

From these humble beginnings has grown a vast solid propellant framework of governmental agencies (Table 1) and an industrial and research team (Table 8). From the original Aerojet group there are now over a dozen private companies engaged in various phases of solid propellant rocket activity. Most are under ten years old—and the average is nearer five years. A run-down on the latest activities of the industry-research team follows.

Solid Rundown

AEROJET-GENERAL: Now a subsidiary of General Tire & Rubber, Aerojet now accounts for 40-50% of revenue. Latest developments: A static firing of Polaris; lowering of RATO cost to under $200 each for a one thousand pound thrust, 15 sec unit; also, development of a low-cost ammonium nitrate solid propellant using oil-extended synthetic rubber fuel-binder. Present standard binders are believed to be polyester (Aeroplex) base. President is Dan C. Kimball, former Navy Secretary.

AMERICAN ROCKET: Formed in 1954, this group is active in all types of composite solids. Has specialized in gas generators and auxiliary power units but now said to be working on primary sustainer. Operated under Alfred J. Zaehringer with extensive experience in solids.

ATLANTIC RESEARCH: Since Korea, Atlantic has continued to expand its Navy-built rocket facility. Engaged in development of *Iris* and *Arcon* sounding rockets. Basis of propellants may be polymer-type (viz., epoxy, polyurethane, or vinyl). Headed by Arch C. Scurlock, strong in combustion field and V. P. Arthur W. Sloan, organic chemist.

ARMOUR RESEARCH: Has one group devoted to solid propellant research. Armour has played an active role in the development of rocket artillery—particularly the rocket gun.

EXPERIMENT, INC.: Also a research group, Experiment's work has been concentrated in problems involving the combustion of solids.

GRAND CENTRAL: Originating around Korea, GC has been divorced from its parent Grand Central Aircraft. Activities include production of *Dart*, *Wasp*, and *Asp* solid propellant rockets. Seems to be centered in composites. Working on third-stage Vanguard rocket using composite propellant plus conventional metal hardware. Headed by former JPL man, Charles E. Bartley, a staunch low-cost solid propellant advocate.

HERCULES POWDER CO.: Hercules Powder has operated the Allegany Ballistics Laboratory since World War II. Operations seem to be built around double-base solids. It is also now working on a third-stage *Vanguard* rocket but using a high-energy homogeneous propellant and plastic hardware. Also produces *Honest John* propellant and a RATO unit.

JET PROPULSION LABORATORY: Still a strong research and development influence in the solid field, JPL has advanced the concepts of large solid propellant rockets through its *Sergeant* design.

OLIN MATHIESON: Prior to present

*

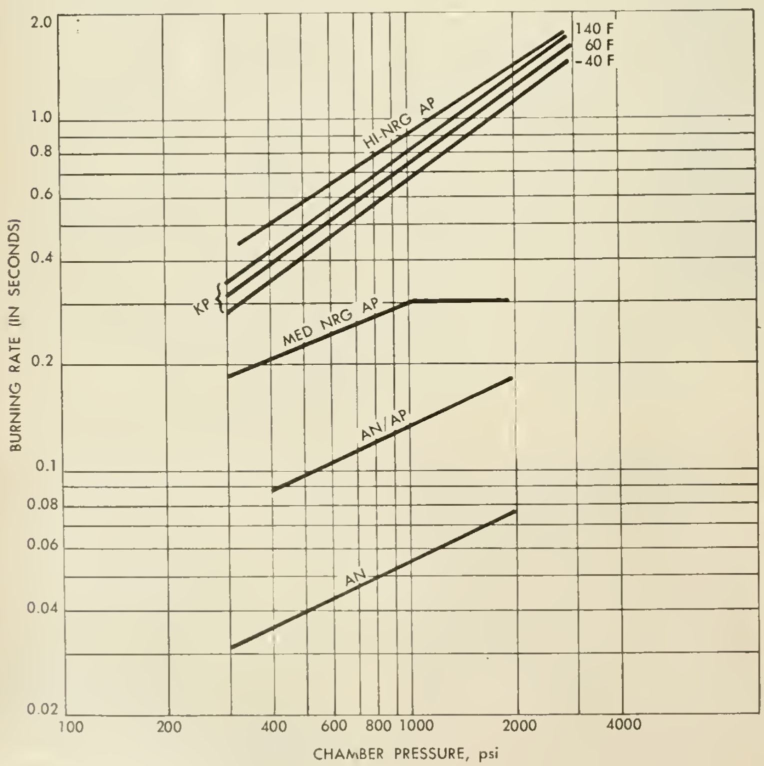
During the past ten years solid propellants have come up fast performance-wise. A great deal of expansion, scale-up, and consolidation is now taking place. In this issue, m/r presents for the first time an exclusive and complete roundup of the US solid propellant picture. This is another in a series of m/r special services to industry.

*

Table 1

Governmental Solid Propellant Activities

AGENCY	LOCATION	ACTIVITY
Air Force		
Armament Center	Eglin AFB, Fla.	Aircraft Rockets
Flight Test Center	Edwards AFB, Calif.	Testing (w/aircraft)
Holloman ADC	Alamogordo, N. M.	Testing
Missile Test Center	Cocoa, Fla.	Testing
Wright ADC	Dayton, Ohio	Propellant evaluation
Army		
Ballistics Research Lab.	Aberdeen, Md.	Prop. evaluation & testing
Chemical Center	Edgewood, Md.	Gas generators
Frankford Arsenal	Philadelphia, Pa.	Gas generators
Ordnance Ammunition Cmd.	Joliet, Ill.	Rocket guns
Picatinny Arsenal	Dover, N. J.	R&D, production & testing
Redstone Arsenal	Huntsville, Ala.	R&D
Rock Island Arsenal	Rock Island, Ill.	Testing
White Sands Proving Ground	White Sands, N. M.	Testing
NACA		
Lewis Flight Propulsion Lab.	Cleveland, Ohio	Propellant evaluation
Pilotless Aircraft Res. Sta.	Wallops Island, Va.	Booster testing
Navy		
Missile Test Center	Point Mugu, Calif.	Testing
Ordnance Test Station	Inyokern, Calif.	R&D, production & testing
Powder Factory	Indian Head, Md.	R&D, production & testing
Proving Ground	Dahlgren, Va.	Testing



Graph illustrates the performance characteristics of some better known solid oxidants.

merged firm, Olin industries under John Olin had developed considerable experience in homogeneous propellants for guns. After World War II, this experience was put to work in rocket field. Largest unclassified solid propellant activity is devoted to turbojet starters and cartridge actuated devices.

Phillips Petroleum Co.: Entering the ammonium nitrate propellant field around Korea, Phillips now operates the large Air Force Plant No. 66 and is engaged in production of the M15 RATO and large booster rockets.

Propellex Chemical: Newest entry into the solid propellant field is headed by Dr. Robert A. Cooley who formerly headed double base rocket propellant operations for Olin Mathieson after World War II. Formed last year, Propellex will produce double base and composite propellants.

Rohm & Haas: The Redstone Division is devoted to research and development of high-energy double base propellants.

Reaction Motors: Formerly all-liquid, RMI has recently turned to research and development of solid systems.

Southwest Research Institute: The SWRI solid propellant work has been headed toward research and development of industrial uses of solids.

Standard Oil Co. (Ind.): Entered the ammonium nitrate solid field around Korea, this operation is headed by Wayne A. Proell. Now in production of S12 cartridge starters and other solid rockets.

Thiokol Chemical Corp.: Entered the rocket field around 1948. Rocket groups are headed by Harry Ferguson with technical head Harold W. Ritchey—cogent believer of large solid rockets. Thiokol's far-flung rocket empire now accounts for ¼-½ of company revenue. Employs composites using own polysulfide fuel-binder. Rockets: *Lacrosse, Loki, Falcon, Nike-Hercules,* RV-A-10, and *Sergeant.* Boosters: T-40, T-50, and T-55.

University of Detroit: Formed last year for research, the Missile and Rocket Section is headed by Dr. Donald J. Kenny. Projects solid fuels for ramjets, new high-energy fuels and oxidants.

In addition, there are the offshoots of the rocket field (Table 3) whose services are required for solid propellants—viz., squibs, igniters, and rocket pyrotechnics.

Today and Tomorrow

During all of World War II, nearly $0.75 billion was spent on research, development, and production of solid propellant rockets. Since that time a conservative estimate is that at least that much has been spent during the ten years following the war. Of this latter amount, about 75% was spent during the Korean affair. At the present time nearly $100 million per year is going into raw materials for solids, research and development, hardware, and production. At the present rate of expansion, the solid propellant industry will be worth about $250 million per year within the next five years.

It is hard to derive an employment figure for the solid rocket industry. Much smaller forces are employed than the talent being poured into the liquid business. Estimates place the employment at between 50,000 and 100,000 total if one includes all hardware, engineering, administrative, and supporting personnel. One thing is certain, however. The solid propellant industry, despite the hazards, is far safer than virtually any other industry. Figures just published by the Bureau of Labor Statistics give the overall industrial injury frequency rate as 11.1 per million man-hours. The figure for the explosives field (which takes in solids) is 2.4. Only synthetic fibers had a lower rate (2.3).

With an environment like this, the solid propellant industry cannot help growing into a new influence in this rocket age.

Solids Selling

During the past ten years solid propellants have made a great deal of progress from the specific impulse of gunpowder at about 50 seconds to near 250 seconds with the new high-energy composite solids. This progress has been made without much fanfare or ballyhoo. Indeed, so quiet has been the transition that only a few are aware of the great strides solids have made. Only now is the great operational shift to solids being realized. Probably the most cogent factor in this shift is one of the most outstanding properties of a solid propellant rocket-simplicity. Out of this extreme simplicity has come the reliability which has not yet and may never be achieved by the liquid propellant rocket. In addition, there is now obtainable a performance equal to or better than present liquid rockets. Other important factors are ease in handling and long shelf life.

All of these factors are responsible for solids selling. It is evident in our growing arsenal of missile weapons. In almost every weapons category, solids are occupying a more prominent position.

Solids first invaded the artillery field and have been strong there for about ten years—particularly for short range ballistic weapons. During World War II and the Korean operations, solid rockets were handled by the average GI under the most adverse environmental conditions. Under such battlefield environments, solid rockets gained the reliability of conventional artillery—viz., failures on the order of one in ten to a hundred thousand. The range of such artillery rockets has been constantly expanding so that *Dart, Little John, Lacrosse,* and *Honest John* have given the battlefield commander a depth of operation of about 20 miles by these simple weapons. Now, the solid *Sergeant* is about to replace the operationally complex and awkward liquid *Corporal* to give a span of about 50 miles. This, however, is not the stopping point. Already the solid *Polaris* its beginning to have its effect on the

Table 2

Hardware on the Shelf: RATO's, Boosters, and Sustainers

Name	Time (Sec)	Thrust (lb.)	Impulse (lb. sec)	Overall Length (in)	Diam. (in)	Loaded wt. (lb)	Ford (lb)	Mfr.	Prop.	Notes
1.0KS-10,000	1	10,000	10.000					A	KPC	Firebee Booster
1.8KS-7,800	1-8	7,800						A	C	Booster
2.KS-36,250	2	36,250						A	C	Booster
2.2KS-33,000	2.2	33.000						A	C	Regulus I Booster Canted Nozzle
2.5KS-18,000	2.5	18,000						A	C	Cost $515 ea.
3.5DS-5,700	3.5	5,700		110		155	55	H	DB	"Deacon" I sp = 196 Cost = $2,500 ea.
4KS-8,000	4	8,000						A		Booster
5KS-4,500	5	4,500	22,500	54.6	9.38	236	111	A	APC	Canted Nozzle
12KS-250B	12	250		20	7	55	35	A	APC	"Junior JATO"
14AS-1,000	14	1,000	14,000	35.4	10.25	194	115	A	AKPC	Asphalt propellant
14DS-1,000	14	1,000	14,000					H	DB	Black Smoke
15KS-1,000	15	1,000	15,000	33.4	10.1	144	72	A	APC	Cost $155 ea. CAA certified
M-15	16	1,000						P	ANC	Formerly T-60 Operation = 65th 160F
Pusher				175	24			P	ANC	Smart Sled prop. Possible Bomarc booster
RV-A-10				180-192	15-20			T	PSC	Hermes motor
T-40				54				T	PSC	Artillery rocket
T-50	2.36-2.50	53.000						T	PSC	Matador Booster
T-55				37.5		61.5	26	T	PSC	Booster
T-56	14	1.000						H	DB	Glass-reinf plastic bottle by Fairchild
T-131								?	?	Spin stab. 2.75" Mighty Mouse gun launched
X-90	90							AR	ANC	Sustainer
X-300								AR	ANC	Sustainer
S-12								SOI	ANC	Cartridge Starter for B-57

A =Aerojet-General
H = Hercules Powder
P = Phillips Petroleum
T = Thiokol
AR = American Rocket

SOI = Standard Oil (Ind.)
KP = Potassium Perchlorate
AP = Ammonium Perchlorate
A = Asphalt
PS = Polysulfide

AN = Ammonium Nitrate
C = Composite
DB = Double Base

Table 3

Squibs, Igniters and Rocket Pyrotechnics

COMPANY	LOCATION	PRODUCT
Atlas Powder Co.	Wilmington, Del.	Squibs
Bermite Powder Co.	Saugus, Calif.	Igniters, Black Powder
E. I. duPont deNemours & Co.	Wilmington, Del.	Squibs, Black Powder
McCormick Selph Assoc.	Hollister, Calif.	Squibs, Igniters
Hercules Powder Co.	Wilmington, Del.	Squibs
Metal & Thermit Co.	E. Chicago, Ind.	Pryotechnics
National Northern Co.	W. Hanover, Mass.	Squibs, Pyrotechnics

Table 4

Solid Propellant Ballistics

Propellant	Burning Rate (@ 1000 psi (70 F)	n	Temperature Sensitivity	Combustion Temp. (°F)	Density 9/cc	JSP (Sec.)
Cordite (SU/K)	0.50	0.71	High	3800 (@ 350 psi)	1.6	14J @ 350 psi 195 @ 2000 psi
Ballistite (JPN)	0.65	0.69	High	5300	1.7	200-205
Black Powder	....	....	Low	4000	1.2-1.9	40-80
Galcit (Asphalt)	1.4	0.75	Medium	4000-4500	1.8	176
KCL04-Aeroplex	0.74	0.71	Medium	....	......	180-190
NH4CL04-Aeroplex	0.3-0.9	0.5-0.6	Low	4000-4500	......	210
NH4N03-Aeroplex	0.055	0.5	Low	....	......	......

long range rockets, *Redstone, Jupiter,* and *Thor*. Next will come a solid propellant ICBM!

Even as reliable as solids are today, the reliability picture is constantly improving. This improvement comes as a result of using well established ordnance techniques plus bringing in the latest in quality control and inspection. Solids in the RATO field have achieved an enviable reliability record: a failure of about five in one million! The reason is simple—what can go wrong in a system unburdened by plumbing, valves, controls, and containing no moving mechanical parts? For all the bugs have been ironed out in a research and development program aided by constant firings in static and dynamic tests. Obviously this results in costly development (probably no more costly than a liquid program) but the payoff comes in a superior operational product whose characteristics are well defined. For one shot operation, solids, despite their higher apparent cost, are actually cheaper. And, interestingly, the liquid people only hope to have achieved a reliability of 98% in the next ten years. Compare this to the reliability of 99.995% already attained by the average solid propellant artillery rocket or the 99.9995% attained by solid RATO.

Of course, solids have long been selling for aircraft rockets. The solid *Mighty Mouse* has done for rockets what bullets have done for guns. The larger *Falcon* is now further increasing the punch of the interceptor as is the *Sidewinder* and the *Sparrow*. The solid *Nike-Hercules* and the *Hawk* are beginning to invade the ground-to-air field. It is interesting to note that a solid propellant booster is being considered for the *Bomarc* and that an advanced solid propellant ramjet for long-range AA is in the works.

Now that unexcelled reliability and performance comparable to liquids have been achieved, three barriers (now largely mental blocks in the minds of engineers) are systematically being dis-

solved by the solid propellant industry. These so-called barriers are control, repeated operation, and cost.

The matter of control is believed to be receiving major attention. By control is meant on-off operation or throttability. Solid rockets can now be built in almost any size—even to the ICBM or larger. However, ways and means must be sought to make corrections to the pre-programmed systems of present solid propellant rockets. This is now thought to be capable of solution by design of a pre-program which will take care of most flight situations and then using smaller auxiliary rockets for corrections. Such systems are already well advanced concepts in the *Honest John*, the X-17, and the forthcoming *Vanguard*. On-off solid propellant operations for a number of cycles has already been accomplished. Efforts toward throttling solid motors have been directed toward the lines of a solid-liquid motor. However, what has been gained in throttling appears to be lost in reliability.

It is true that most solid propellant motors have been designed for one-shot operation and for most situations this has been perfectly satisfactory. However, there are many situations where recovery and repeat operation are desirable. Here solids are making an inroad through cartridge actuated devices. It is now perfectly feasible to design a large solid propellant rocket motor which can be fired, reloaded and refired for a number of times much as a gun. Such repeat operation is the key, too, for many commercial and industrial applications of solid propellant power. Within ten years, cartridge devices will have advanced to the point where large power outputs—comparable to internal combustion engines—will be possible.

In the field of costs, two factors are at play. One, as production increases, costs have been coming down. The most significant whack at solid propellant prices have been made by the cast composites—particularly ammonium nitrate types. However, the entire matter of cost is becoming less important as it is realized that solids are doing their good jobs. Despite the fact that you may buy flour, milk, eggs, and yeast cheaper than the final product, few housewives bake their own bread. Thus, a pre-packaged food industry has grown up. Solid propellants will do the same thing for the rocket industry. Here, a completely unitized rocket product, ready to use, a so-called "instant" rocket will be turned out. We are simply equating total cost and the ability to do a given job. Thus, the old engineer's forte that liquid propellants' cost is lower than

Table 5

Solid Oxidants

Material	Available Oxygen, %	Performance (1)	Cost, $/lb	Availability (2)	Exhaust
Ammonium nitrate	19.5	M	0.05-0.10	H	N
Ammonium perchlorate	34.2	H	0.50-0.75	L	N,HCl
Nitrocellulose ...	...	M	0.73-1.00	M	C,H,O,N
Nitrogylcerin	...	H	......	M	C,H,O,N
Potassium perchlorate	46.2	M	0.15	M	KCl

(1): High, over 200 sec
Medium, under 200 sec

(2): High: > 1,000,000 tons/yr
Medium: < 1,000,000 tons/yr
Low: < 1,000,000 lb/yr

One of the outstanding uses of plastics in the missile business is their application as solid fuel-binders. The number of materials available is extensive. Processing system is either thermoplastic or thermosetting although in the case of polyamide both are used. Generally, the fuel value of the plastic is good. Due to great plastic demand for many applications throughout the industry availability is high with costs not excessive. Although costs for plastics are much higher than with metals an increasing demand for the material is expected in the future. New fabrications are constantly being explored.

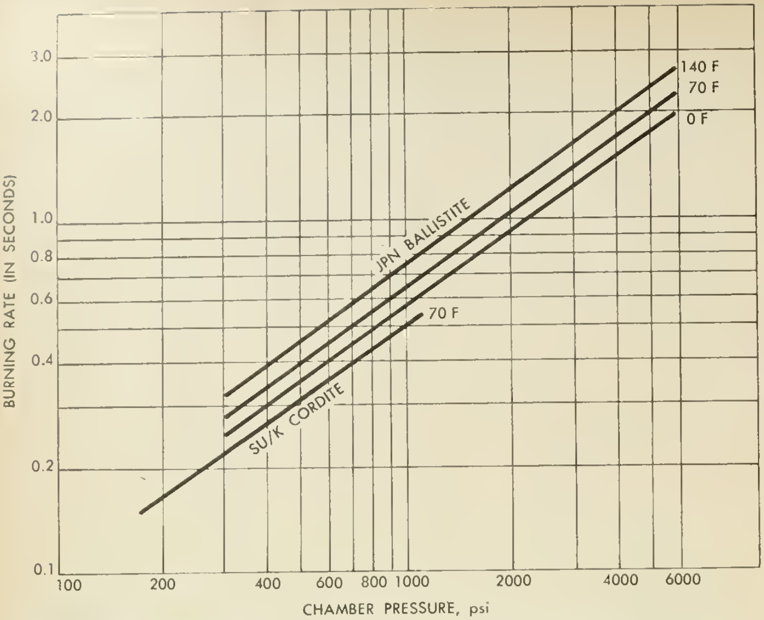
Table 6

Plastics for Fuel-Binders

Material	System	Physicals	Binding Efficiency	Fuel Value	Processing	Cost	Availability	Exhaust Products Contribution
Acrylic	TP	B	G	G	C	H	M	C,H,O
Cellulosic	TS	F	G	H	C-EX	L	H	C,H,O
Epoxy	TS	B-F	H	F	C	H	L	C,H,O
Phenolic	TS	B-F	H	F	C-EX	L	H	C,H,O,N
Polyamide	TS-TP	F	H	F	C-EX	M	H	C,H,O,N
Polyester	TS	B-F	H	F	C	L	H	C,H,O,
Polyethylene	TP	F	G	G	C-EX	L	H	C,H,O,
Polysulfide	TS	F	H	G	C	H	L	C,H,O,S
Polyurethane	TS	F	H	G	C	H	L-M	C,H,O
Polyvinyl	TP	F	G	F	C	L	H	C,H,Q
Synthetic Rubber	TS	F	G	P	EX-M	L	H	C.H.O (N,O,S)

TP: Thermoplastic *TS: Thermosetting* *B: Brittle* *F: Flexible* *L: Low* *G: Good* *H: High* *P: Poor* *M: Medium* *C: Casting* *Ex: Extrusion* *M: Milling*

Major role played by ammonium nitrate for the past ten years has been based on low cost, high availability. Performance of less than 200 sec I_{sp} is pushing it into the background. Ammonium perchlorate, with high oxygen content and I_{sp} over 200 sec, could be replaced by lithium perchlorate. U.S. production of oxidants currently exceeds the demand. Red China disclosed interest in the solid propellant field by ordering the following chemicals from Britain and Norway: ammonium nitrate, cellulose nitrate, lithium compounds, potassium chlorate, potassium dichromate, potassium nitrate, sodium nitrate, and sodium perchlorate.



Performance comparison between two well known solid grains, JPN Ballistite and SU/K Cordite. High operating pressure and burning rate of Ballistite illustrate favorable performance characteristics. Ballistite is a performance-proven propellant for air-to-air missiles.

solid propellants' cost is fast falling by the wayside. And it has been demonstrated that the propellant cost of a modern missile is only a fraction—2 to 5%—of the total cost. The reasons for a lower delivery cost with solids is, again, due to simplicity. Solid rockets are generally much cheaper to build than a liquid rocket—as much as 50 or 100% cheaper in many cases. Because of the usual higher density of solids (despite somewhat lower specific impulse), solid rockets are much better in performance on a volumetric basis. In field operations, the advantages of a simple, ready-to-go solid rocket are obvious. If your rocket is difficult to service, set-up, and fire, all delivered factory price advantage disappears. And, strategically, all missiles, solid and liquid, are as vulnerable as the factory producing them.

For these reasons, solid rockets will continue to sell. They are, in effect, selling themselves.

The Propellants

Despite the wide range of ballistic performance in the various available propellants, the actual raw materials going into solids is quite limited (Table 7—Production of Solid Propellant Materials and Table 5 Solid Oxidants and Table 6 Plastics for Fuel-Binders).

Although there is a great deal of propellant activity, there is very little available information on modern solids—either composite or double base. Table 4, however, does present ballistic properties for some recent propellant formulations.

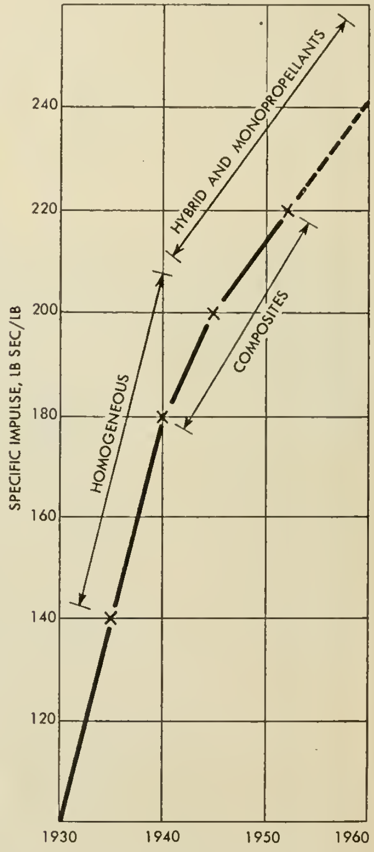
It has been a general axiom in the solid field to keep technology either in the classified or "trade secret" domain. Because of this attitude many applications have fallen by the wayside or have been passed over to the more open liquid propellant rocket industry. In addition to this potential sales loss, the very meager information has caused young engineers coming up the ladder to look to the glamour of liquids. An industry cannot continue healthy growth in such a stifling environment.

Historically, the first break away from old black powder came with the discovery of molecules which contained both oxidant and reductant (fuel) in the same compound. Such materials are nitrocellulose, nitroglycerin, and the newer diethylene glycol dinitrate. Although these and similar materials give high energy releases (performances on the order of 200 sec and to 250 sec in 5 years), stability has been a big problem. Aerojet, Hercules, and Rohm & Haas are working on new solid monopropellant molecules such as the nitropolymers, and nitrated plastics. And, it now appears fairly well certain that only the stability problem will be licked and that getting an I_{sp} of over 250 sec is a long way off.

Therefore, it seemed a matter of expediency to try mixtures of oxidant and fuel to get the desired performance and stability. These composites have achieved a great deal of stability, though perhaps at the cost of specific impulse. Only now is work being directed toward jacking up performance to 250 sec or greater. Under classification, this may already have been achieved, though outwardly composites appear to be hung up at 210-225 levels. with known compounds, getting over the 250 hump may be impossible to achieve in practical systems. Yet basic work is reported on the "weird" or "impossible" compounds which might make new oxidants or fuels. The solid people will have to seriously look at these new developments if they are to compete with the new fluorine or ozone liquid systems.

During the past ten years, ammonium nitrate has played an immense role in lower solid costs and maintaining good performance. It now looks like ammonium perchlorate which has formed the mainstay of our high energy composites may eventually lose ground to lithium perchlorate which is now being advocated. In addition, potassium perchlorate's role as an oxidant will continue on the down-grade.

Another alternative is visualized as the solid-liquid system. Only two such systems have been tried (GE with their



Tremendous rise in specific impulse for solid propellants since 1930 is seen as an outstanding engineering achievement. Composites are currently raising energy release.

hydrogen peroxide-polyethylene and the Pacific Rocket Society with LOX and polysulfide rubber). Netiher of these systems probably reached over 225 and the additional complexity was a definite disadvantage. It is even doubtful if gels, pastes, slurries and the "gunk" combinations can break through the solid impulse plateau.

The Hardware

Since the develoment of the first successful solid RATO there has been a constantly increasing buildup of hardware on the shelf in the form of RATO's, boosters, and sustainers. The accompanying table lists some of the major types now known to exist. In addition, there are available many classified units and rockets which are yet on the design boards.

In addition to better construction methods and improved reliability, the unit costs of such hardware has steadily been coming down. In a recent contract to Aerojet (an order of over twenty thousand ammonium perchloride-Aeroplex units), the familiar 1000-lb RATO dropped in cost to slightly over \$160. However, lowering propellant cost on a similar unit (as evidenced from Phillips' ammonium nitrate propellant) has only dropped that figure by about \$30. One can thus conclude: that unless solid propellants can be made on a continuous rather than a batch basis or unless an automated propellant plant is possible, labor costs will be the determining cost rather than low materials cost. It is also evident that a large portion of the total rocket cost will be vested in hardware rather than propellant by virtue of labor costs.

As yet the glass-reinforced plastics hardware has yet to make significant inroads into solid motors. Although some rather startling advances can be made (viz., in strength-to-weight ratios), it is also true that costs are much higher than with metals because of more hand operations. Even where machine techniques have been introduced in plastics hardware, there still appears to be too much variation for engineers to contend with. Plastics, though, are definitely here to stay, in the fabrication of solid propellant rocket hardware.

A considerable amount of scale-up has taken place since the "large" *Tiny-Tim* rocket of World War II. The scale-up barrier was first broken by development of the cast composite grains and then was closely followed by solventless cast double base grains. A conservative estimate places the impulse level of today's single grains at about the ½-1 million lb-sec mark. Indeed, it seems likely that several million lb-sec are now possible; this is borne out by the fact that Aerojet is working on a solid IRBM, the *Polaris*. It is not known if this fleet ballistic weapon will be single or multiple-staged. Now, both the double base and the composite manufacturers seem confident enough in possible scale up to say that they have not yet reached an upper size limit. Then, it seems likely that large solid propellant powerplants will first invade the IRBM class and will then follow up with a truly strategic or tactical ICBM. Application of solid propellant power to these weapons will mean that virtually any spot on earth can be used for a base.

Aside from the use of existing solid rockets as boosters or auxiliary power plants for space operations, it is certain that truly solid space rockets will have to wait until the solid IRBM and ICBM has become a reality. It also means that solids are still trailing liquids in the large-scale applications but the gap between the two is constantly drawing closer. When the gap is closed and if solids can overtake and exceed liquids remains for the solid propellant industry to accomplish by hard work.★

Table 7

Production of Solid Propellant Materials

Material	Total US Production 1956 (Short Tons)	Estimate Rocket Use 1956 (Short Tons)
Ammonium nitrate (solid only)	1,000,000	5,000
Ammonium perchlorate	3,600	3,000
Lithium nitrate	5	0.25
Lithium perchlorate	1	0.75
Nitrocellulose	10,000	1,000
Nitroglycerin	2,000	900
Potassium perchlorate	1,000	500

Table 8

The Industry-Research Team

Firm	HQ	R&D	P	T
Aerojet-General Corp.				
Azusa, Calif.	X	X	X	X
Sacramento, Calif.		X	X	X
American Rocket Co.				
Wyandotte, Mich.	X	X	X	
Ypsilanti, Mich				X
Armour Research Foundation				
Chicago, Ill.	X	X		
Joliet, Ill.				X
Atlantic Research Corp.				
Alexandria, Va.	X	X		
Gainesville, Va.			X	X
Experiment, Inc.				
Richmond, Va.	X	X		
Grand Central Rocket Co.				
Redlands, Calif.	X			
Mentone, Calif.	X	X	X	X
Pomona, Calif.				X
Hercules Powder Co. (Allegany Ballistics Lab.)				
Cumberland, Md.	X	X	X	X
Jet Propulsion Laboratory				
Pasadena, Calif.	X	X	X	X
Olin Mathieson Chemical Corp.				
E. Alton, Ill.	X	X	X	X
Phillips Petroleum Co.				
Bartlesville, Okla.	X	X		X
McGregor, Tex.			X	
Propellex Chemical Corp.				
Edwardsville, Ill.	X	X	X	X
Rohm & Haas Co., Redstone Div.	X	X		X
Reaction Motors, Inc.				
Denville, N. J.	X			
Dover, N. J.		X		X
Southwest Research Institute				
San Antonio, Tex.	X	X		X
Standard Oil Co. (Ind.)				
Whiting, Ind.	X	X		
Seymour, Ind.			X	X
Thiokol Chemical Corp.				
Trenton, N. J.	X			
Elkton, Md.		X	X	X
Huntsville, Ala.		X	X	X
Marshall, Tex.		X	X	X
Ogden, Utah			X	X
University of Detroit (Missile & Rocket Section)				
Detroit, Mich.	X	X		
Ann Arbor, Mich.				X

HQ: Headquarters; R&D: Research & Development; P: Production; T: Testing.

MISSILES & MYTHS

The bibliography of missiles, rockets and atomic power embraces the entire known history of mankind. Even the record of primordial man, when we examine what remain of his cave-drawings, indicates the use of some form of missile.

The Talmud and the Christian Bible have innumerable references to missiles and rockets; (Psalms, Proverbs, Epistles etc.) In the Bible we read: that one Ussiah (808-756 BC), ". . . made in Jerusalem, engines invented by cunning men, to be on the towers and upon the bulwarks, to shoot flaming arrows and great stones withal." We may classify these "engines" in two main groups, namely, catapults and ballista, which today are represented by howitzers and guns. (It is interesting to note that our modern word "howitzer" derives from the old Bohemian: "houfnice," a sling.)

We are told that in the 3rd Century BC a certain Dionysius invented the first recorded machine-gun, called "polybolos" or "repeater-thrower," which fired a succession of arrows from a magazine. At about the same time, an Alexandrian engineer, Ctesibius, geared pistons to a catapults arms, "working in carefully wrought cylinders, filled with compressed air."

Plutarch wrote of Archimedes in his Life of Marcellus at the siege of Syracuse, (214-212 BC): "Archimedes soon began to play his engines upon the Romans and their ships, and shot stones of such an enormous size (about 100 pounds), and with so incredible a noise and velocity that nothing could stand before them. The stones overturned and crushed whatever came in their way, and spread terrible disorder through the Roman ranks—at length the Romans were so terrified that if they saw a rope or a beam projecting over the walls they cried out that Archimedes was levelling some missile engine at them, and turned their backs and fled."

The "Atomists" of Democritus (460 BC) developed the theory that all matter is made up of exceedingly small parts, and it is significant that they called such parts "atoms," whence the word found its way into Latin and so down to us.

There exist in many museums in the world, specimens of missile type weapons of the Egyptian Neolithic Age, (circa 3200 BC). Many are in Cairo, Athens, Rome, Berlin, London and some in America. The most interesting are of flint, knapped and chipped with extraordinary care, and some with serrated edges so minute as to be hardly visible to the naked eye. They are believed to have been propelled by bows, throw-sticks, or blow-pipes, and some scientists have theorized that they were given the force of projection by tightly twisting a skein of hair or sinew, prepared in a manner unknown. The missile had a guide stick, often feathered.

What is historically called "Greek-fire" was used as early as the 4th Century BC. It is represented in Assyrian bas-reliefs and graphically described in a record of a siege of Delium (424 BC). Here cauldrons of pitch, sulphur and burning charcoal are shown being hurled against an enemy's position. One Vegetius (350 AD) gives an interesting formula for mixtures of sulphur, naphtha, pitch, incense and tow, all packed in wooden tubes and hurled upon the decks of enemy ships where they ignited.

The Greek-fire idea transformed by modern chemistry, was seen in the two World Wars.

The rocket of the 20th Century is certainly a missile; but it had its genesis in an era before the use of gun-powder. Gun powder had been known to the Chinese long before the 13th Century and had been used both for its fusive and explosive properties. The Chinese first made use of it in a military way by setting off bombs that terrified more by noise and stench than by real destructive power. However, they discovered that rockets could be made that would provide a propellant "going by itself"; instead of advancing from an original position by a sudden force which would decrease to zero, it would increase its speed by self-contained, timed propulsion charges.

A most interesting book by an Arab, Hassan-el-Rammah Nedchureddin, (AD 1280) called "The Book of Fighting," describes a large missile to be used on water. He describes it as two pans containing a pear shaped body filled with naptha, saltpetre and two poles to serve as guides or rudders, and propelled by a series of fuses.

The closest translation from his Arabic text given by an expert is: "a flying egg." If you have ever tossed a flat object over a body of still water and watched it skid in hops, that would seem to partially describe one of the ideas of the Arabian Hassan's missile.

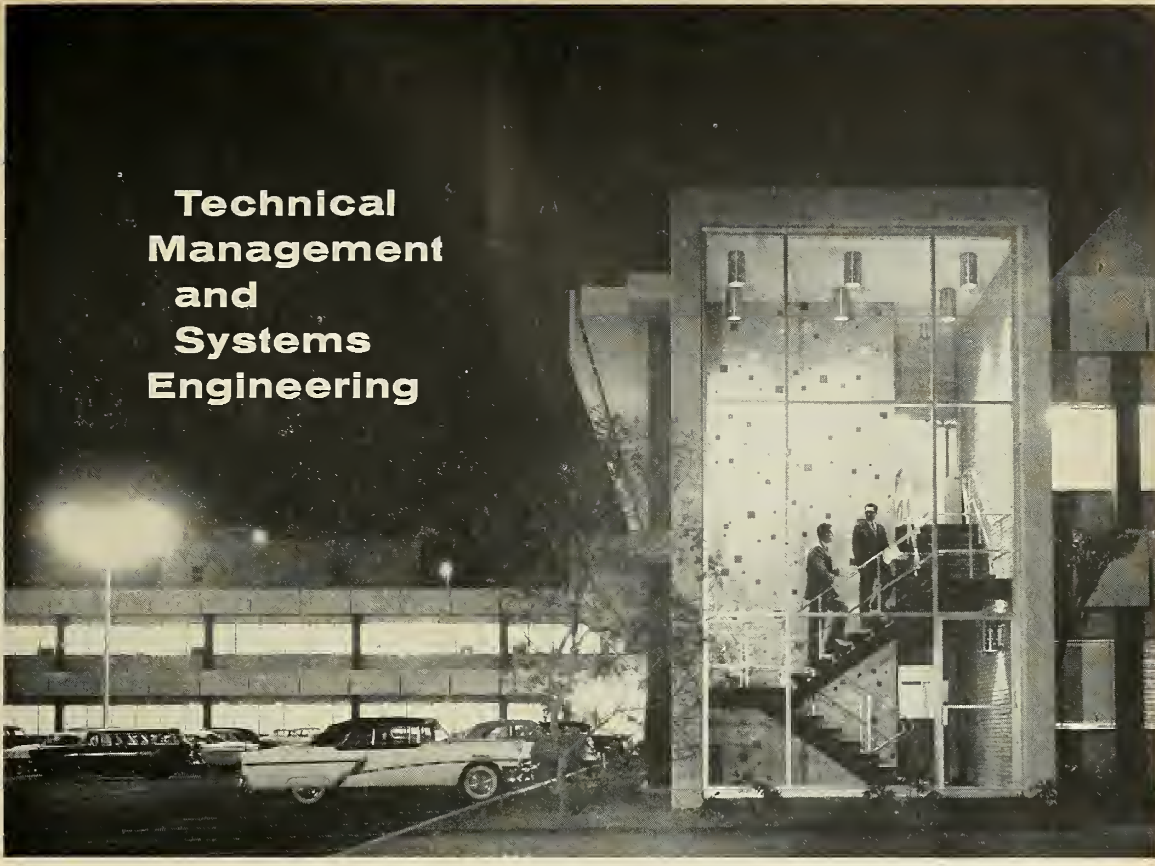
In 54 BC the Britons used hot clay balls as missiles to set fire to Ceasar's camp; (De Bello Gallico, Bk V); in AD 69 igneous missiles were employed in an attack on Placentia; (Tacitus, History Bk II).

During the 12th Century an engine for hurling missiles called a "trebuchet" is recorded as having a projectile force supplied by the gravitation of a heavy weight, rather than twisted cordage as in the catapult and ballista. It is reliably reported that these trebuchets threw other missiles besides stones or flaming arrows; they threw putrid corpses and sometimes live men. A dead horse in the last stages of decomposition, bundled up and shot by a trebuchet into a town in which the defenders were half dead from starvation, started a pestilence. Froissart tells us that John, Duke of Normandy, infected a town this way. Manure, offal and the dead bodies of slain soldiers were used the same way. William of Malmsebury described the Turks at Antioch throwing the heads of slaughtered townsmen into the Frankish Camp. An envoy or messenger was sometimes tied up alive and cast back into the town. (Cowper's Art of Attack.)

The idea of starting a pestilence by use of missiles for such purposes in the 12th Century, seems to have produced an echo in the 20th; until the use of poison and mustard gases, bacteriological warfare and kindred barbaric methods were internationally outlawed. We might ask ourselves if we are any more civilized than the 12th Century generals.

Certainly, our 20th Century has vastly extended the horizons of science and is continuing to fully explore, the illimitable potential science offers for humanity's benefit. Scientists of the world today have justifiable pride in their achievements. Indeed, any study of the history of missiles, rockets and atomic energy by non-scientific people will enhance the respect and appreciation our scientists merit.

Even a cursory reading of the history of missiles and rockets will convince us that there is "Nothing New Under The Sun."



In systems engineering work, it is necessary to bring together a team that includes scientists and engineers of a wide range of technical specialties. In major weapons-systems projects, such teams will include hundreds of scientists and engineers.

But the assembly of a large group of scientists and engineers, no matter how capable they may be individually, does not of itself ensure good systems-engineering performance. The caliber of the project management has a major effect upon its technical accomplishment. It is not easy to coordinate the activities of large numbers of scientists and engineers so as not to stifle their creativeness on the one hand, nor to permit the various development sub-efforts to head toward mutually incompatible objectives on the other.

Of primary importance for good systems management is the philosophy underlying the selection of the supervisory personnel. The head of a technical activity should, first of all, be a competent scientist or engineer. A common mistake — nearly always fatal in systems work — is to fill such positions by non-technical men who have been trained only in management techniques. In the highly complex activities of major systems work, what is required is *technical management*, and of the two words, the word *technical* must never be overlooked.

In the selection of scientists and engineers for technical management, it is essential that the men chosen be broad in their training and approach. Each principal department head, for example, must have a good basic understanding of the technical facts of life of the other departments. When these people get together they need to speak a common language and understand each other's fields, so that proper decisions can be made on the many interrelated problems that come up. The higher the organizational responsibility of a technical manager, the more important this factor becomes.

The Ramo-Wooldridge Corporation is engaged almost entirely in systems work. Because of this, the company has assigned to scientists and engineers more dominant roles in the management and control of the business than is customary or necessary in most industrial organizations.

Scientists and engineers who are experienced in systems engineering work, or who have specialized in certain technical fields but have a broad interest in the interactions between their own specialties and other fields, are invited to explore openings at The Ramo-Wooldridge Corporation in:

Guided Missile Research and Development
Aerodynamics and Propulsion Systems
Communications Systems
Automation and Data Processing
Digital Computers and Control Systems
Airborne Electronic and Control Systems
Basic Electronic and Aeronautical Research

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5730 ARBOR VITAE ST. • LOS ANGELES 45, CALIF.

Rocket-maker Dan Kimball

Big Future, More Uses for Solid Propellants Liquids to be Limited to Specialty Roles

Former Navy Secretary Dan A. Kimball is one of the top business executives in America's incipient rocket industry. As President of Aerojet-General Corp. he has helped to pioneer many rocket firsts. Here, he outlines a glowing future for solid propellants.

Q. Mr. Kimball, will you tell us a little about Aerojet's role in solid propellants?

A. Actually we're in both the solid and liquid propellants. Aerojet was an outgrowth of the work that Cal Tech did during the war. At that time the only solid propellant we had was the old Smokey JATO unit. We built something like 200,000 of these. We made the first JATO used and the first composite propellant.

Q. Can you say anything about how much of an effort you are putting on solid propellants now compared to liquids?

A. At the present time our dollar sales in liquids engines are much ahead of the solid because of work on the ICBM, *Vanguard* engines and *Bomarc* engines. Also on the number of auxiliary powerplants. On the other hand our development work is more on solids. We've got roughly 10,000 people. We've got almost 5000 working on liquids. We've got about 3000 on solids altogether and the balance is covered with our underwater, avionics, architect and engineering divisions.

Q. What do you think the ratio of solid to liquid uses may be five years from now?

A. I think you'll have many more applications for solids. Liquids are going to lend themselves to specialized applications like ICBMs and possibly IRBMs.

Q. Why wouldn't the solid work so well for the ICBM?

A. So far we don't get the specific impulse from solids we get from liquids, but we're catching up. We're getting about 230 on solids and better than 250 on liquids. I would think in the liquid field you'd have the biggest chance for advancements in specific impulse. But when you get into the very high energy liquids you're going to have some compounds that are very difficult to handle. But I think your real growth potential in the liquid field will be for specialized applications. However, we've made some big advances in solids in the last three years.

Q. Are we at a point in solids now where we can start working with additives like borons?

A. Well, I'm no technical man but I don't think you can put zip fuel additives into solids yet.

Q. Do you think the chemical industry, generally speaking, is backing the rocket industry the way they should?

A. Well, I don't think they know what we want. In our case we've got a pretty large chemical department—as large as any group in the western United States. We've got to tell the chemical people what they should be working on although there are a number of chemical companies that are showing increasing interest. A number of people from different chemical companies come to see us at least once a week and I'd say that we visit them once a week in different fields.

Q. Does fluorine get into solid propellants?

A. Fluorine does nothing. We don't know how to put it in yet. We don't even know the uses in liquids, but we do a lot of talking about it.

Q. Do you think future solid propellant missiles can be stored for from five to ten years?

A. I would think that we'd be pretty sure if we stored them for ten years under reasonably controlled conditions. I don't think that you could let the thing cycle from 140° to —100°F. and do that four or five times a year, however.

Q. Going back to the chemical industry again—on the volume of business. In a solid propellant missile, like Honest John how much, in terms of percent of total cost do the propellant raw materials represent?

A. In the JATO unit you've got 180 pounds of which about 100 pounds is raw propellant. On top of that you have the metal parts of the propellant to process. So I'd say about 35%.

Q. Is it true that 60% of money in the missile business goes for electronics gear?

A. I don't know what the overall figures are on electronics costs. I think it depends on how complicated your missile is. I would think it would be about 1/3 powerplants, 1/3 electronics, and 1/3 fabrication and design. That's without the cost of the warhead.

Q. Would you say that a solid propellant Polaris would be less expensive than a liquid propellant Polaris?

A. In production I would think your solid propellant *Polaris* would be a little cheaper.

Q. Would you say that solid propellant missiles, on an overall basis, would be less expensive than liquids?

A. No, I don't think you could put on an overall basis. It all depends on the particular missile. The liquid engine on the *Nike* we built pretty cheaply when we build a lot of them.

Q. Is there a limiting size to solid propellant missiles where the weight of the casing would be fantastic?

A. You have a problem of handling those bigger sizes, of course. They get to weigh quite a lot. Liquids you don't have to load until your missile is on the launching site. With the solids you have to transport them. None of them yet are of a magnitude that would bother you.

Q. What about work on plastic casings?

A. We've done a lot of work on casings in several different fields of plastics and different kinds of steels.

Q. How are we coming on development of a disposal booster for the Nike?

A. I don't know that they have it yet. We haven't got one, I know. But I think more important than a disposable booster is a disposable case. It's theoretically possible to build one of those cases that will burn themselves up at the end of the run. It's not an easy job. But there are a lot of things you can do if you want to put enough money into it.

Q. Thiokol has mentioned thrust on the order of 300,000 lbs. Is this tops?

A. You've got to realize a rocket's size is a function of impulse, not thrust. We think we've fired the biggest solid propellant rocket yet, but, with the security restrictions we can't be sure.

Q. Would you care to make a size prediction for the next five to ten years?

A. Just tell us what size you want.

Q. Where is the limiting size of a single unit?

A. Well, every time we think we're near a limit then somebody builds a bigger one. This is a function of the specific impulse of the propellant and it keeps going up all the time. You see it isn't only the increase in thrust you want. You've got to have an increase in specific impulse. I think we could build a 2-or-3 or 400,000 lb. thrust solid engine, but without high impulse propellants it wouldn't be efficient. I remember 10 or 12 years ago the Army wanted a 100,000 lb. unit. We produced it in a few days and it blew up in about 1 minute.

Q. Which propellant materials show the greatest promise for the future?

A. You're going to have to find additives to raise specific impulse.

Q. Tomorrow's solid propellant engine, then, will be a truly composite unit?

A. Oh, yes. They're composite now.

Q. Can you say anything about how you're advancing on the Polaris *project?*

A. Well, we've test fired engines about the size that are to be used. You've got to work out your metal techniques and your weights and control your burning so you can stop it when you want to, however.

Q. On that subject, are you working then on powerplants that you can shut off and start again?

A. We don't know how to start them again.

Q. Is there any possibility of combination engines? I was thinking in terms of two things. One where you might have a solid propellant and afterburn with liquids so to speak, or bypass your solid propellant and add ram air.

A. Yes. If you can find a way to use some of the oxygen from the air for certain applications we could cut out the amount of oxidizer we carry in the case and so increase specific impulse. One of the hard things to get is money to invest in the state of the art. Mostly you have to tie your funds to a specific job. Some of the biggest advances we've made is where we've put our own money into the state of the art work and where the services have also seen fit to put some money in with us.

Q. I'd like to talk about production costs. Does your process engineering group—production engineering group—have more or less equal status with your design people when you get to production missiles?

A. Oh sure. One reason that we moved our whole solid production business up to Sacramento is that we have our production people up there, our research and development people, the whole works. When you start to do the development on a new job, the production people are right in there to start, so that the hardware the development people turn out is something we can use later on. If you don't do it that way, then you have a terrific transition period from the development stage to the production stage.

Q. Is extruding of solid propellants more efficient than casting?

A. Well, it all depends on what you want. If you're going to have high volume, and you don't have to have too high a performance you can extrude the thing cheaper than you can cast it. But the cost of extrusion equipment is very high, and when you want to change the size of your unit, then you've got to change your whole set-up. We think the casting is going to be the best overall, particularly if continuous casting can be perfected.

Q. Can we go underwater—your 155 knot torpedo, for example?

A. We're doing a lot of underwater work. We think there's a real future.

Q. In the case of a hydroduct or solid propellant isn't there a noise problem where the self noise would interfere with the sonar gear in the missile?

A. Well, it all depends on how you're going to use the solid propellant. If you're using the propellant for a direct drive you'll have one noise level. If you're using it to run through a turbine, to run a propeller you have another. One advantage solid propellants would have for torpedoes you'd have a longer storage life. Of course with torpedoes you have to have a number of them ready to go anytime you need them.

Q. Do you see any room for liquid propellant underwater?

A. Yes, sure. We've done considerable work on it.

Q. Do you think that the solid propellant underwater engine has more of a future?

A. We think so. Maybe we're wrong, but we think so. We've done some work on hydrogen peroxide; we've done a lot of work on solids; but we think there's a real future for solid propellants in torpedoes.

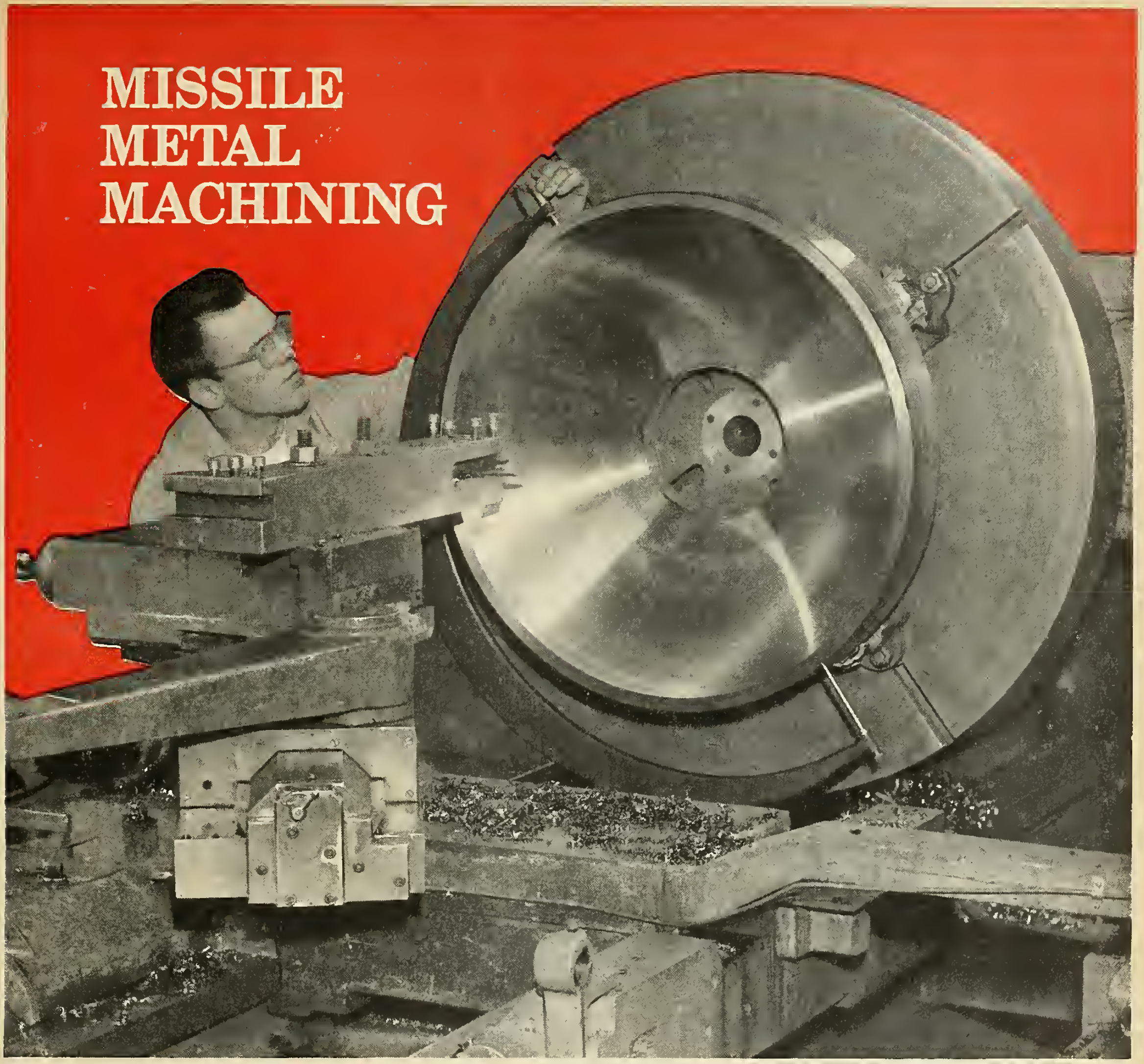
Q. How fast will tomorrow's underwater missile be?

A. We think we can top 300 knots in operational underwater missiles.★

No limit to solid rocket size . . .

We think we've fired the biggest yet.

. . . can build 300-knot underwater missile.



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SMALL SOLID ROCKETS for Commercial Use

By G. E. Rice
Manager of Commercial JATO Sales
Aerojet-General Corporation

SMALL ROCKET engines for emergency standby use are being installed at a constantly increasing rate in business and airline aircraft. Aerojet-General's pioneering efforts in this field have been instrumental in providing power units with operational performance capabilities. Commercial application appears to offer the greatest immediate civil market.

Business aircraft use of rocket engine standby units has far surpassed use by airlines. The airlines made the first civilian standby application for high altitude operations. The emergency performance margin of solid rocket engines is recognized increasingly by owners of DC-3's *Lodestars, Convairs,* and converted B-25, B-26, PV-1 and PBY aircraft. These engines have been installed in DC-4 and DC-7 aircraft operated by some airlines. Installations for other types of aircraft are being developed.

Aside from very minor modifications required by standby use, the rocket engine currently used is the same 15KS-1000 smokeless JATO which has been widely used by the military as an assist takeoff unit. After satisfactorily passing through exhaustive vibration, temperature and pressure cycling and drop tests, it has received a CAA Engine Type Certificate.

This 15 second duration 1000-lb thrust solid rocket is the only rocket engine that has received certification. However, Aerojet has a smaller 15NS-250 solid rocket engine currently undergoing CAA certification tests. This smaller unit is designed for use on the lighter aircraft, and may be installed singly or in multiples on airplanes from cub-size through the light twin engine class. It is understood that some other manufacturers are giving consideration to CAA certification of solid rocket engines but this far nothing has been announced.

Standby rocket engines are used on civilian aircraft to meet the requirements of takeoff and approach climb with one engine inoperative and landing climb with all engines. Where takeoff runway limitations occur, they may also be used to shorten the required runway by increasing the acceleration and the rate of climb for earlier clearance of runway obstacles.

They will also provide full thrust within a few tenths of a second to greatly increase the aircraft performance margins to meet any other short duration emergency requirement. Analysis has shown that they offer a potential for application to over 40 per cent of the situations which lead to takeoff, landing or in-flight accidents.

The 15KS-1000 AI rocket engine weighs 144 lbs. and the 15NS-250 unit will weigh about 42 lbs. The rocket engine weights reduce to 72 lbs. and 21 lbs. respectively when expended. Installed weights are about 175 lbs. for the larger engine and 50 lbs. for the smaller one.

An existing CAA interim policy permits an increase in the gross weight of transport category aircraft equal to the weight of the installed rocket engines in all cases where such weight increase will not exceed the structural gross weight limitation.

As an example, a typical DC-3 installation of two 15KS-1000-AI rocket engines weighs 350 lbs. In DC-3s licensed under transport category performance limitations, the gross weight may be increased by 350 lbs. with the rocket engines installed whenever the weight is limited only by CAB takeoff climb requirements.

A proposal for a new Special Civil Air Regulation is now under consideration by the CAB which would provide much greater weight credits and still result in higher emergency acceleration and climb margins. This proposal covers aircraft certificated under CAR 3, 4B, 4a(T), SR406, SR407, and the new turbine powered aircraft regulation. Early action is expected on this regulation and it should serve to greatly stimulate standby rocket engine installations in both airline and business aircraft.

The gross weights of multi-engine aircraft are generally limited by CAR requirements for climb with one engine

Convair 240 equipped with 15KS-1000-A1 standby motors mounted externally and internally.

inoperative. Under this condition, the maximum available thrust is required to maintain level flight.

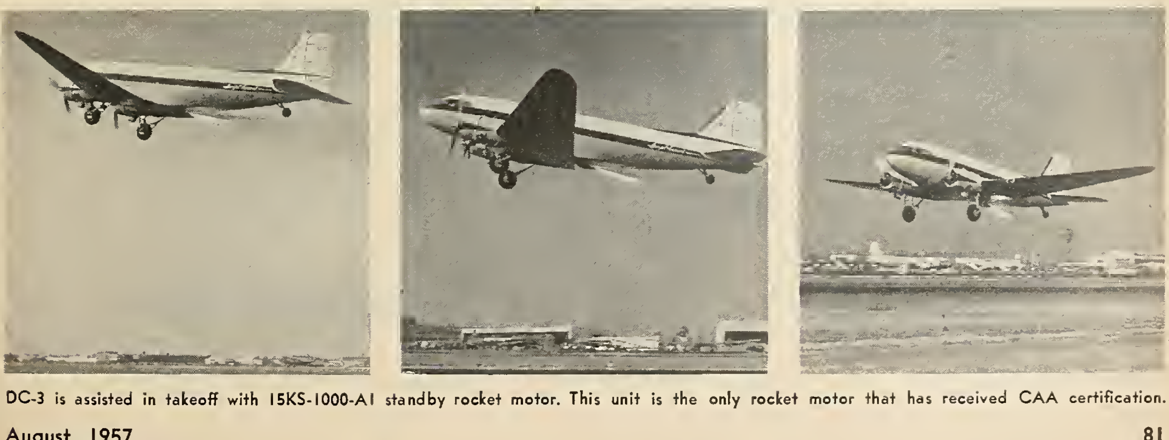
The small remainder available for acceleration and climb is known as the "excess thrust." Since the thrust of one standby rocket engine may be equal to several times the normal "excess thrust" with one engine inoperative, the introduction of the rocket engine thrust will result in phenomenal increases in rates of climb or acceleration.

Limitations in the proposed CAR on the amount of standby thrust for which credit may be obtained preclude the possibility of creating a critical performance situation in an airplane equipped with standby rocket engines. Under the philosophy of the proposal, multiple sequenced units will be required to gain the highest weight increase. These units may be ignited simultaneously to produce very high rates of climb or acceleration to meet severe emergencies.

Standby rocket engines may be either submerged in the airframe or mounted externally. In high speed aircraft the submerged installation is generally preferred. However, measurable drag effect has not been found in multiple 15KS-1000-AI standby engines mounted under the center section of several types of low wing airplanes with speeds up to 365 mph. Design criteria for engineering new installations have been prepared and are CAA approved.

Indicative of standby rocket engine value are three otherwise marginal instances in South American high altitude airline operations. In each case a passenger-laden, four engine aircraft was in critical speed range with no opportunity to accelerate with normally available power. Standby thrust accelerated all three airplanes into speed ranges with comfortable safety margins.

Several manufacturers are now contemplating optional factory installations of standby rocket engines. It is believed that in the not too distant future it will be considered quite normal to incorporate such systems in the basic airframe concept, both as a safety factor and to broaden the operating flexibility of the airplane. ★



DC-3 is assisted in takeoff with 15KS-1000-A1 standby rocket motor. This unit is the only rocket motor that has received CAA certification.

"AURORA," a recent expression from the brushes of Simpson-Middleman, a team of artists who find their subjects in the world of the natural sciences. "Aurora," they explain, "is a visual statement with equivocal overtones of dawn, the Aurora itself and a hint of a Chimera." Painting courtesy of John Heller Gallery, Inc.

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Propulsion Engineering

By Alfred J. Zaehringer

MORE LOX FOR MISSILES: Air Products is working on two oxygen plants for the government. One is a 20 ton/day unit (cost is $1½ million), the other is a 5 ton/day unit ($100,000). ARDC has a new 150 ton/day unit installed at Edwards AFB, Calif. Tonnage LOX can now be produced for $5-15/ton.

MORE HELIUM, TOO, will be going into missiles for propellant pressurization, high pressure controls and actuators. By 1960, the missile industry will gulp down some 300 million cubic feet of the gas per year. In 1950, helium output was about 63 million cubic feet a year.

INDICATIVE OF AMERICAN POTASH & CHEMICAL CO.'s role in the missile market: formation of a chemical fuels section. The section will manage sales of boron and lithium chemicals for exotic fuels and ammonium and potassium perchlorate for solid propellants.

CHEAPER EXOTICS ARE ON THE WAY: Price of sodium borohydride—an intermediate for producing Olin Mathieson alkyl borane fuel—is to go down. Cost of OM's HEF-2 fuel was running $5,000/lb. but is expected to drop to about $4-10/lb. in full-scale production. The high energy fuel would enable the B-58, for example, to fly around the world without a refuel.

LATEST EXOTICS: the diammoniate of tetraborane, a stable $B_4H_{10} \cdot 2NH_3$, reported by the University of Michigan; this compound reacts with water to liberate hydrogen and looks interesting for underwater propulsion systems. Meanwhile at Iowa State College, a nitrile has been reacted with a boron hydride to give $B_{10}H_{12} \cdot 2MeCN$.

STATE OF THE ART of propulsion devices for space flight is "highly speculative" at the present time according to Rocketdyne's George Sutton. Liquid propellant rockets now seem our best bet. Atomic rockets might offer two to three times the specific impulse and other performance increases might come from successful storage of free radicals.

BIG BUGABOO IN ETHYLENE OXIDE systems—large amounts of coke in combustors and carbon in the exhaust. Aerojet, for example, gives ETO exhaust products as (all per cent by volume): hydrogen, 9.1; carbon monoxide, 46.6; methane, 38.4; ethane, 2.0; carbon, 3.9. ETO gives a $C^* = 3474$ ft/sec (chamber pressure of 750 psi and $L^* = 1000$-2000).

ON THE HORIZON: potential replacements for ammonium nitrate oxidants in solid propellants. Present AN catalysts do not give completely smokeless exhausts. Newer oxidants, soon to be attractively priced, will not require messy catalysts and promise greater stability and lower operating pressures.

THE SOLID PROPELLANT PEOPLE have a waste disposal problem, too. All spillage, waste and residue have to be carefully isolated and carried out to a dump for burning or detonation. As a result serious study is being given to "recycling" scrap propellant for use in a new batch.

THE SEPR FIRM has compared the use of hydrogen peroxide and nitric acid oxidant systems with kerosene fuel for use on manned aircraft. Nitric acid won on counts of high density, low cost and ease in handling. With the same fuel, peroxide systems were found to cost about ten times that of an acid system. The French rocket group ran acid in some 14,000 static tests and handled about 3000 metric tons without major trouble. At the same time, six severe accidents occurred in handling only 200 tons of peroxide.

ATOMIC COLEOPTER has been proposed by Helmut Zborowski, of the French BTZ firm. A nuclear rocket motor is suggested for boost while ramjets take over for sustaining cruise. A cylindrical rocket motor is used.

stepped-up interest:

Solid Fuel Missiles for the Army

By **John I. Shafer**
Jet Propulsion Laboratory
Huntsville, Alabama

THE ARMY has become increasingly interested in solid propellants in recent years because of the significant technical improvements and the distinct logistic advantages they offer for most of the Army's specific needs.

Early in 1945 research on solid propellants was focused on extending the operable temperature range. In time, substitution of a special elastomer or rubber for the asphalt fuel matrix revealed that cartridge charges would perform reliably even at —50° and 160°F. Furthermore, burning was reproducible at very low chamber pressures, so that the combustion chamber could be lightened and overall performance improved.

Ammonium perchlorate, too, had been substituted for potassium perchlorate in certain formulations. Thus, propellant flame temperature was decreased and propellant performance increased. Thrust and pressure were much less sensitive to changes in burning surface or nozzle throat area. Exhaust gases contained no smoke; however, in very humid atmospheres a fog was created in a rocket's wake.

The Ordnance Department, recognizing the need to extend development of the class of propellants and adapt them to production techniques and specific missile applications contracted with Thiokol Chemical Corp. late in 1946 for a broad development program. Facilities for this work were eventually set up at Redstone Arsenal; later a separate production facility with substantial capacity was also established at Longhorn Ordnance Works under Thiokol's management.

About this time, March 1947, JPL experiments were also made using a radically new charge geometry, the internal burning star.

With this design combustion chambers were so well insulated from the flame by the unburned propellant that chilled motors retained their surface frost, even after relatively long static test firings and despite flame temperatures in excess of 4000°F. As a result, rocket motor designs could be based on the room temperature strength of heat-treated alloys. Performance of solid propellant motors again increased significantly.

In separate tests they had also noted that their new rubber-base propellant could be cast into and the charge bonded to the combustion chamber itself. Adhesion occurred automatically during the charge solidification operation following casting.

With the adoption of the internal burning, case-bonded charge, additional benefits were realized:

1) Processing costs were reduced.

2) The charge was fully supported by the motor against pressure and acceleration forces throughout flight.

3) Performance was further improved by eliminating supplemental charge supports and through higher propellant loading density.

4) The relatively rigid propellant charge materially supported the chamber during transport and handling in the field.

Fundamental research was paying off with significant technical gains.

During November 1947 and April 1948, flight tests were made with a small research vehicle to evaluate the rubber-base propellant for large boosters. Accelerations in excess of 100 g demonstrated their applicability; despite a relatively heavy air frame, velocities were greater than 3500 feet per second. This motor, in a slightly shorter length, was pressed into service as the interim propulsion system for the Air Force guided missile *Falcon* through the cooperative efforts of Hughes Aircraft Co., JPL, Thiokol Chemical Corp. and the interested Armed Services.

Significant improvements in propellant and motor performance continue to materialize as a result of the collective, coordinated effort of all agencies working on solid propellants. Today there are alternate propellant formulations, both composite and double-base (nitrocellulose-nitroglycerin), that exhibit competitive performance in large and small motors, so that the country is not dependent on the rubber-perchlorate type exclusively.

As a result of the Army's long and active endeavor in the solid propellants field, many of its missiles are based on this form of propulsion.

Some of the newer systems acknowledge the increasing interest in solid propellants, like the *Nike Hercules,* which will in time replace *Nike Ajax* and will have a solid propellant sustainer as well as booster. Both *Lacrosse* and *Hawk* will have this type propulsion. Even the somewhat larger *Corporal* will eventually be replaced by the *Sergeant* which will be powered by a solid propellant motor.

In view of the fact that solid propellant missiles at the end of the war were unable to compete performance-wise with liquid systems such as the V-2, one might ask how they have succeeded in such a short time in closing the large gap. Many factors shortened the time schedule; the following undoubtedly contributed:

1) The solid propellant motor is inherently very simple. Once basic research had established fundamentally desirable propellant properties and motor design criteria as a firm foundation on which to build, progress was rapid. It might be said as a corollary that the motor's simplicity also permitted fundamental solutions to problems rather than temporary or patch-up solutions.

2) Interchange of information on problems and developments has been quite free in the entire solid propellant field and all agencies have profited enormously. Unfortunately, the

problem of "proprietary rights" has entered the field so that the interchange is now somewhat restrained, but it is hoped that this problem can be resolved soon. As early as 1946 the Solid Propellant Information Agency (SPIA), jointly sponsored by all services, was created to further this objective. Important annual symposia and a strong reliance on SPIA by all solid propellant personnel are tributes to its success.

3) Very close liaison by U.S. Army user agencies and the Ordnance Corps has repeatedly guided and reoriented the research and development agency with respect to Armed Forces problems and requirements.

4) The solid propellant industry appreciated its early performance deficiencies with respect to liquid propellant systems and therefore concentrated on first things first. It minimized any duplication of effort and avoided in most cases an examination of areas that might offer fringe benefits only.

In periodically evaluating solid and liquid propellant systems for new applications, the Army's special requirements must be kept in mind constantly. Basically it is concerned with tactical rather than strategic weapon systems. It therefore demands high flexibility and unusual mobility consistent with the PENTANA concept of tactics in which units disperse to avoid detection and destruction but converge to fight.

Tactical units must be small, independent battle groups capable of operating for extended periods at long distances from higher echelons. They must no longer be roadbound and tied to a ponderous logistic tail but must have improved cross-country mobility through the increased use of cargo carriers and air vehicles. Much of the supplies to and within the field army must be delivered by aircraft of the assault cargo and convertiplane type.

Unlike the Navy which carries its home with it, or the Air Force which returns home each night, the Army and its equipment must be able to survive and function miles from civilization in an environment of extreme heat, cold, humidity, salt spray, fungus, sand or mud. In the chain of supply from factory to depot to launcher, experience had shown that even before PENTANA, the closer one came to the launcher, the more important it became to minimize manpower, equipment and problems of handling and maintenance. PENTANA now merely serves to emphasize this.

The fundamental objective of the missile system itself is to detonate a warhead on a given target at a designated time with a specified accuracy. Delays in launching can frequently be as serious as inadequate accuracy or range. The threat of counter-fire, too, prompts one to "shoot and scoot" when possible.

Missile ruggedness and reliability will also be of prime importance. Units must be capable of withstanding "humping" loads from railroads, vibration from aircraft, the jolting from trucks on rough terrain, as well as frequent loadings and unloadings, yet maintain a high degree of reliability.

The simpler the system, and the less it demands manpower having special skills or non-standard equipment requiring special maintenance, the more desirable it will be.

Solid propellant proponents are quick to point out that their inherently simple propulsion system meets most of these requirements quite well. With a pre-packaged motor, operations in support of the propulsion system are negligible. The need for a large number of nonstandard trucks, equipment and personnel with special skills, normally required for fueling in the field, is obviated. In addition, missiles stored with pre-packaged propellants are available on a moment's notice, a factor particularly important for anti-aircraft missions.

They point out, too, that the reliability of their propulsion systems is particularly noteworthy. Motors now in production, that have firing failures, ignition malfunctions, improper thrust program and motor failures constitute a very small fraction of the total number of high performance booster or guided missile propulsion systems used. The failure rate is less than one-quarter that of comparable liquid systems. Alternately, the amount of development time and money needed to achieve a given degree of reliability would be less for the simpler solid system.

Motor ruggedness in the field and transportability are enhanced materially by the stiffening action of the relatively rigid solid propellant charge, particularly when case-bonded. With the trend toward higher-performance missiles and lighter motor structure, this factor assumes more importance.

Of interest to programs developing large motors is the fact that solid propellant designs may be evaluated in small inexpensive motors and then scaled directly to large motors, which will have identical performance (except, of course, for those characteristics that should change with scale). Motors differing in weight by a factor of more than one hundred have confirmed this early proposition. Of interest, too, is the fact that no one has yet built a solid propellant motor too large to work successfully.

In large ballistic missiles the substitution of solid propellants for liquids in the tanks would eliminate the guidance complexity normally associated with fuel sloshing in flight. So, too, problems normally associated with control of liquid propellant mixture ratio are non-existent; in solid propellants the ratio is "frozen" at the factory. Finally, excessive axial accelerations that could penalize guidance accuracy can, in most cases, be avoided automatically by selecting an appropriate charge design; no separate mechanical devices would be necessary.

The report that the cost of solid propellants after loading in a motor exceeds that for liquid propellants is, in most cases, true. However, the cost of the complete propulsion system when metal parts are taken into account appears to be lower for solids because of their extreme simplicity. In the ultimate comparison, however, the relative propulsion costs will probably be determined by the extent that each influences the complexity and cost of their guidance systems.

It is important to maintain a proper perspective and recognize that solid propellant systems also have their problems and disadvantages. Most of these are concerned primarily with surface-to-surface ballistic missiles and the effects of propulsion characteristics on guidance.

The thrust level of most solid propellant motors changes much more with a change in temperature than liquid systems. This large temperature sensitivity increases complexity in guidance parameter setting (to admit temperature data) and increases variability or complexity of the flight computer markedly. These complications in guidance can be eliminated by temperature-conditioning the motor prior to its use.

A satisfactory method of varying the missile range precisely has yet to be established for solid propellant motors. Methods of cancelling or terminating thrust, comparable to propellant valve closure on a liquid system, appear to be very promising.

In some instances solid propellant motors exhibit irregular pressure fluctuations and motor vibrations typical of combustion instability. Guidance components then become damaged or degraded in accuracy. Fortunately, several promising cures have been devised to eliminate instability if encountered.

Finally, in the event that liquid rocket investigators succeeded in overcoming the problems in pre-packaged liquid systems without a serious penalty in weight and size, much of the logistic advantage that solid propellants now possess would be nullified. A second look would then be warranted. ★

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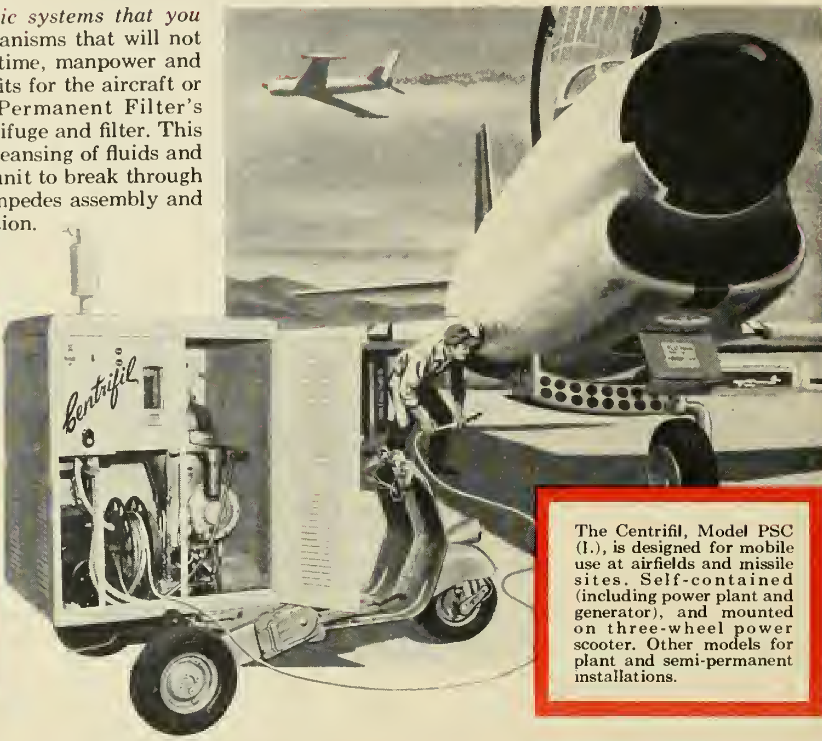

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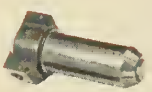

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Solid Propellant Rocket Testing

Accuracy is a must . . . so is quality . . . because the goal is perfection . . .

By H. E. Westgate

Grand Central Rocket Co.

ALL OF GRAND CENTRAL'S activities on solid propellants are vital and interesting but the testing phase is by far the most dramatic.

The scurry of activity by the various rocket technicians at a test site, their final withdrawal to the shelter of the operations bunker, the expectant silence of the final pre-firing phase culminated by the countdown: "5-4-3-2-1 fire"—these are the prelude to the roar and shaft of flame as the rocket responds to the signal from the firing bunker.

Technical organization for the test involves the Chief Test Engineer, his staff and three subdivisions or groups: the test mechanics group, the electronics instrumentation group and the data reduction group.

The rocket engines to be tested are of three basic kinds: the small research units supplied by the research department in order to determine the feasibility of certain rocket propellants or fuels; the larger experimental rockets designed by the Engineering Division for full-scale testing, and finally the well-established production units fired as part of the continuing check on the quality of production rockets.

Temperature Conditioning

If the rocket is of a type that will eventually be fired in the low temperatures of high altitudes or arctic conditions, the test firing may require a pre-firing conditioning or "soaking" at the extremely low temperatures to be encountered. Or, if the rocket is to be fired later under conditions of extreme aerodynamic heating or after being stored under conditions of tropical heat, a pre-firing conditioning at elevated temperatures may be in order.

In either case the mechanics will follow the test request and place the rocket in the proper hot or cold box or pit for the required number of hours prior to firing. At present Grand Central has 19 such conditioning chambers ranging in size from 2 to 20 feet in length.

Instrument Calibration

Coincidental with the final phases of the temperature conditioning of the engine, the preparation of the proper instrumentation for determining the rocket chamber pressure and gross thrust are readied.

Electrical calibrations alone suffice for some of the routine tests and are made with special electrical checking units. However, for many of the more precise tests the pressure pickups, which are installed directly on taps in the engine head and nozzle, are also hydraulically calibrated. This calibration involves the filling of each pickup with oil and pumping it up to exact pressure levels in a series of incremental steps.

When a rocket is expected to have a peak chamber pressure of three thousand pounds per square inch, the pressure pickup or transducer may be pumped up to one, two, three, four and five thousand pounds per square inch. Its electrical output is recorded at each one of these levels.

Later when the engine is fired these calibration points serve to fix with extreme exactitude the various points on the resulting pressure-time and thrust-time data. For even more critical testing, the same procedure is also repeated immediately following the test firing.

This later calibration serves to confirm the earlier calibration and to show with certainty whether or not any small change has occurred in the calibration of the entire system during the firing phase. Such double-checking is expensive and time consuming, however, and is reserved for the more critical tests.

Mechanical Preparations

While the electronic group is busy with the pre-firing calibrations, the

mechanical group is busy, preparing all the mechanical items necessary for a successful test. Among these are the nozzle, the head cap and the handling and mounting fixtures. The nozzles and head caps are generally not attached to the rocket until after engine conditioning since it is safer, especially at elevated temperatures, to perform the conditioning with the nozzles and head caps removed. In this state any accidental ignition would produce only a static fire since the engine could not develop appreciable thrust with both ends open.

When the allotted time for conditioning has elapsed the engine is removed from the conditioning box and readied for firing. At this point exact timing of the work counts and advance preparation and smooth teamwork pay off. The nozzle and head cap are first attached to the engine case and then the final attachment hardware are clamped on. The rocket is then transported quickly to the proper firing bay.

Installation of Engine in Firing Bay

To expedite this series of steps, the conditioning areas, assembly area and the firing bays are located as close together as permitted by safety considerations. Six large firing bays are currently available at Grand Central's Redlands test site. All bays are of the type which secure the rocket engines in a horizontal position. This type has been found to be most convenient and minimizes the requirement for overhead handling equipment. All of the bays are equipped with heavy structural rails imbedded in thick reinforced concrete floors. These rails provide a strong anchor for the engine test stands.

The test stands are cradle-like structures which serve primarily to support and anchor down the rockets during the test firings. Some are merely used to support and hold down the motors. Others allow the motor to shift slightly forward when firing and so exert the firing thrust on measuring instruments. These in turn relay this information electronically to the instrument bunker.

Engines to be operated under specific high or low temperatures have to be capable of properly igniting under those conditions. As soon as a rocket is removed from a conditioning box its temperature naturally starts to return to the temperature of the existing surroundings. It is therefore necessary that the engine be fired as quickly as possible after its removal from the conditioning box if the required high or low temperature firing is to be a valid test.

The mechanical operations of properly installing a rocket in a complex firing stand may, by virtue of the existence of special mechanical features, require upwards of a hundred or more bolts in this final assembly. Likewise, a complete complement of electrical instrumentation to adequately determine chamber pressures, case temperatures and strains along with the thrust, may involve the last minute installation and electrical hook-up of as many as thirty or more electrical pickups and gages. These last-minute electrical and mechanical operations must therefore be performed under stringent time limitations which necessitate precise and efficient operation.

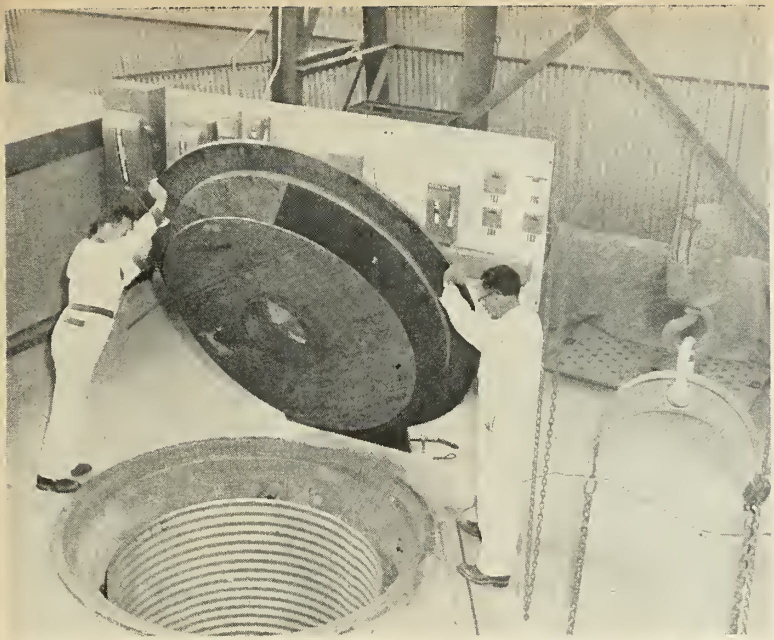
In some cases the speed element can be successfully slowed down by constructing a hot or cold conditioning box right in the firing bay surrounding the engine itself. This saves last-minute time but in general adds so much complexity to the test that this method is not as widely employed as might be expected.

Firing Instrumentation

Solid propellant engines may, depending on their size and grain configuration, burn anywhere from a fraction of a second to several minutes. In either case precise recording of the electric signals coming into the instrument room from the various instruments on the rocket is essential. These signals, when interpreted later, give the detailed technical picture of the firing. Hence there is a need for the fastest and most accurate recording devices.

Firing test data at Grand Central is generally recorded on long rolls of light-sensitive paper, the data being traced on the paper during the firing by banks of accurate, light-beam galvanometers. An eight to ten foot strip of paper 5 to 12 inches wide, all filled with a seemingly meaningless series of curved, wiggled, interrupted and otherwise deflected galvanometer traces may constitute the entire data from a firing which may last less than a second but, which may cost hundreds or thousands of dollars in materials and man-

Latest addition to Grand Central's facilities—three test bays for static firing small and medium-sized solid-propellant rocket motors.



Attendants remove the lid from a large vertical pit-oven preparatory to curing operation.

hours of testing time.

For tests of longer duration, the results of a single test may cover several hundred feet of this same paper. From the complexity of the lines and the length of the paper the subsequent job of data reduction can be readily appreciated. In most cases the roll or rolls, known as "the record" generally represent about 80 per cent of the data from a typical test firing.

Additional data is obtained visually by direct viewing, regular movies, high-speed movies or closed-circuit television. Additional audio information may be obtained directly by listening or by a more accurate microphone-tape recorder combination.

Grand Central has just finished installing at the Redlands test area a completely new automatic fire control console and associated racks of the necessary power supplies, amplifiers, monitors, and recorders. A wide variety of both D.C. and carrier amplifier recording channels are provided. By utilizing a system of switchboard plugs any combination of amplifiers and recorders may be plugged into lines extending to any of the six firing bays.

Firing

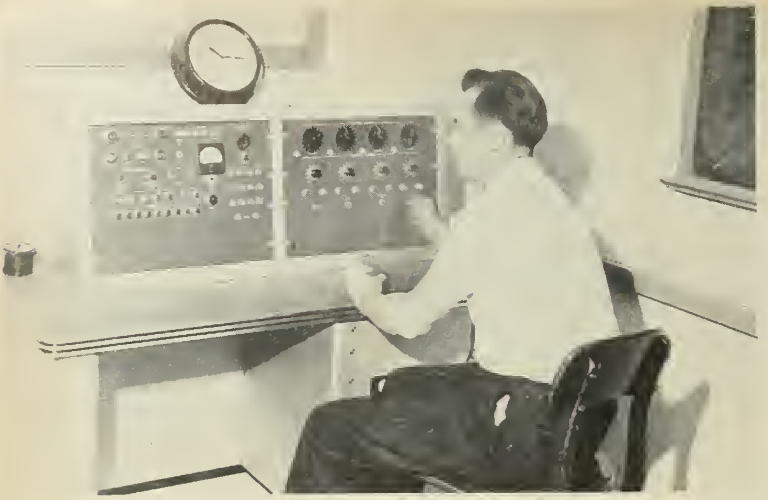
When the engine has been finally installed in the firing bay and all the instruments have been calibrated and attached to the motor, the engineers make their final checks and the time comes for the last minute operations. The test safety man checks the firing area and withdraws, progressively arming various key points of the firing lines as he leaves.

The safety man also brings the connecting safety "jumper" which is the final electrical link to complete the current flow between the firing console and the igniter. This jumper, which he carries at all times when working with a rocket in the bays, is his assurance that no one can fire the rocket before he and his men are safely in the observation bunker.

This jumper is now inserted in its proper socket in the firing console. When the instrumentation technicians are sure that all their recording gear is ready, they switch on the firing system, thus arming the firing console.

The firing operator then pushes the firing button. From here on the operation is entirely automatic and thus eliminates the possibility of any last minute errors of the test personnel. The firing console starts the electronic five minute countdown. Safety gate locks are monitored, and if any are left open or are later opened, the console will "kill" the firing. When the

LEFT—Test mechanics lowering a motor into a conditioning box. RIGHT—Final checking of nozzle fit before clamping motor to stand.



A portion of the instrumentation room which houses the power supplies, monitors, amplifiers., recorders, and switchboard panels for instantaneous channeling and recording data.

unit reaches the X-minus-thirty-second point the count-down delays begin to turn on cameras, recorders and other testing devices.

The electronic voice recorder drones out the verbal portion of the countdown in perfect synchronism with the timing unit. When it calls "Fire!" the rocket engine igniter is fired and the rocket engine surges to life. After the firing is over there is a brief wait which is terminated by the familiar all clear signal.

Post-Firing Procedure

Following the all-clear signal the test mechanics start to dismantle the mechanical set-up and the electronics group unloads all the recorders and cameras and process the film and paper. The engine itself then comes in for some further study.

Auto accident analysts and air crash investigators have nothing on rocket development engineers when it comes to the analysis of charred engine parts, or in cases where there is an engine malfunction during testing.

The spent shell of a burned-out or fractured rocket engine may seem a worthless item. Actually the reverse is true. A normally spent rocket test engine is always carefully handled and precisely weighed to determine the degree of completeness with which the propellant grains burned. The nozzle is inspected for flame erosion, residues and high temperature effects. The final nozzle orifice size is recorded by micrometer readings or micro-projector diagrams.

In the case of a malfunction. the analysis is even more thorough. This is generally true for two reasons. If the engine's performance was unique, unusual or just plain undesirable it is vital that the results be sifted to determine the exact causes of the particular malfunction.

Depending on the violence of the malfunction, it is possible that important instruments may have separated from the engine at the moment when the most enlightening data was being obtained. In the case of total failure the fragments of the rocket chamber and nozzle are methodically collected and fitted together to try to determine whether the failure was due to heat, pressure, imperfect parts or other causes. Often a sharp or dull-edged fragment, a tiny scorched piece of the case or a battered nozzle will give the clue as to what corrective engineering has to be undertaken.

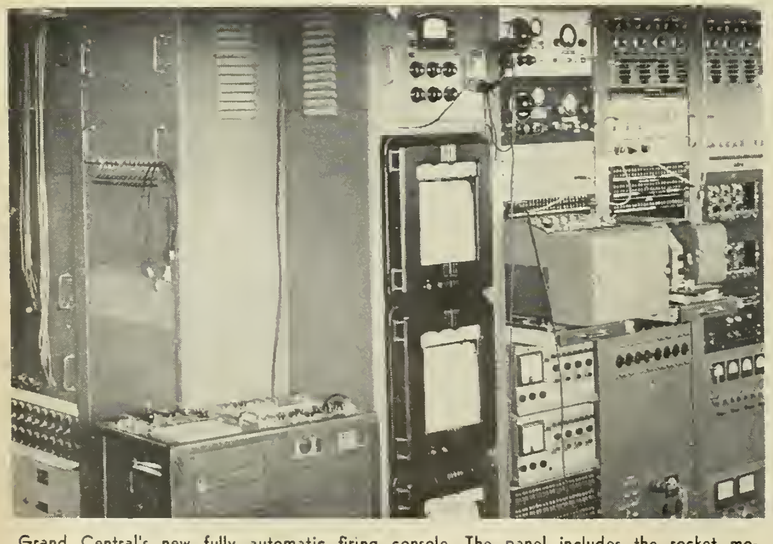
When all the data from the recorders, cameras, observers and inspectors has been collected and the initial photo-processing, logging, marking and other basic operations have been completed, the combined and somewhat heterogeneous collection of information is ready to leave the test site and forwarded to the data reduction group.

Data Reduction

The tools employed by data reduction computers are primarily translucent "light-tables" (for properly inspecting the test records), scales, planimeters, sliderules and conventional calculating machines. The test data is thoroughly analyzed with these tools by converting the traces on the record rolls to typed data and charts which give engine burning time and thrust, combustion chamber pressure and wall stresses, nozzle temperatures, propellant specific impulse and other useful engineering information.

The New Remote Test Site

To meet the continual need for testing very large solid propellant rocket engines. Grand Central has set up a large motor test facility in an 1800 acre portion of an 8000 acre isolated mountainous area near Beaumont, Calif. Instrumentation vans have been obtained and are being equipped to provide mobile instrumentation facilities for this new Beaumont area. One large firing bay is already in use in the new test area and other bays are under construction in line with the need for continued and expanded work in the field of solid propellant missile development. ★



Grand Central's new fully automatic firing console. The panel includes the rocket motor operating controls, count-down lights, and camera and recorder time-setting controls.

Swing to Solid Propellants

gaining momentum in missile planning

By John Wilson

Atlantic Research Corp.

CONTROVERSY BETWEEN liquid and solid propellant engineers over the relative merits of their propulsion system seldom leads to an impartial analysis of exactly where the two types stand in the current state of the art. A comparison of the present status and possible future status of the two systems is needed. It is needed not only by military planners, but by rocket and missile engineers who need to know the probabilities and the possibilities of development. The missile propulsion systems now in the dream-and-scheme stage can then take shape around the anticipated propellant developments.

Transportation planners are also interested in future propulsion possibilities for missiles. The big question mark here—how soon may we start using missiles for passengers, mail and freight deliveries? Nonmilitary uses of rocket power in the past have been limited largely to aircraft-assisted-take-off units—JATO bottles.

Planners now count on rocket power for routine transportation possibly within the next quarter of a century. In order that this go beyond the Buck Rogers day dreaming stage, costs must be drastically reduced to compete with air rates. Big technical problem to be solved is bringing the missile down safely, and exactly where you want it.

Current Status

Evaluation of the liquid versus solid propellant systems currently in operation must consider other types of propulsion now being used.

Turbojet applications, although limited because of altitude and subsonic speeds, power the *Petrol, Matador, Regulus,* and *Snark* missiles. Ramjets, operating from subsonic to Mach 5 or better at altitudes up to 100,000 feet, propel the *Bomarc, Talos, Navaho,* and *Triton*. The turbojet *Snark* and ramjet *Navaho* both have 5,000-mile range, but certainly neither should be compared to the liquid-propelled ICBM *Titan* and *Atlas.*

Ramjet and turbojet powerplants will continue to be used for manned and low-speed, low-altitude missiles, filling both military and civilian needs. It is in the long-range, high-speed missile field that liquid-propellant or solid-propellant systems will be called to supply the needed power for the immediate future.

The liquid propelled missiles are the most glamorous and consume the major part of missile funds. In contrast, there are a greater number of solid propellant missiles. Most are of small size for tactical missions.

This decided movement toward using solid propellants for a greater number of missile systems stems primarily from the difficulties involved in handling liquid propellants.

Advantages and disadvantages of liquid propellants are familiar to all missile men, and are quickly recited. Specific impulse is now up to 25% greater than for solid propellants. The operation pressure can be low, heat transfer can be regulated, and the rate and richness of the fuel oxidizer ratio can be regulated. However, it is in this separate handling of fuel and oxidizer that liquid propellants cause the most grief.

In the liquid propelled rocket plumbing becomes an outstanding and overwhelming engineering problem.

Solid propellants, with a lower specific impulse and presently lacking the control features which liquid propellants possess, has, in its ease of handling, a big lever with which to topple liquid propellants from their historically predominent position.

Missile work gets its big impetus from the military planners, and what the military decides is by and large the direction missile development is going to take. Defense appropriations pay for present missile research and development and any peaceful applications must involve as few modifications as possible. Aside from defense allocations there isn't enough available money for fruitful peaceful missile development.

Liquid Propellant Missiles

First consideration will be given to the liquid propellant missiles, which, in addition to their glamour value, have involved multi-billion dollar expenditures. The known missiles in this category are: *Rascal, Corporal, Nike Ajax, Titan, Bomarc, Jupiter, Redstone, Thor* and *Atlas.*

The Air Force intercontinental ballistic missiles, *Atlas* and *Titan* and the intermediate range ballistic missile, *Thor,* are liquid propelled. The Army has *Redstone* and *Jupiter,* although prospects of the *Jupiter* is clouded since Secretary of Defense Wilson gave the longer-range ballistic missiles to the Air Force. It is felt that the story is not yet completely told; and although the *Jupiter* missile is within the range stipulated, work continues. The mass-produced *Nike-Ajax* is the missile that the Army has deployed for defense all over the world. It is, by far, the most operational missile today.

Liquid propellant missiles owe much to the success achieved by the German scientists of Peenemunde during World War II. Many refinements have been made since and a lot of perplexing problems have been answered. Essentially the advances made in American liquid propulsion systems are not far removed from the German technology. Many engineers feel these same German missile men have been allowed to dominate the liquid propellant thinking.

As is repeatedly pointed out, it was solid propellants that got a head start, beginning with the Chinese rockets of the 13th century. Liquid propellants have had the longest record of concentrated development activity. Goddard's first experiments with liquid propellants began in 1921; his first liquid-propellant vehicle was launched in 1926.

Before World War II, major rocket development effort was concentrated in Germany, predominately in the liquid propellant field. Thus, liquid propellants have a continuous 35-year development history. Solid propellants had their first serious start during the last war but major effort has come only since the war. At most, solid propellants have a 15-year history of concentrated development.

In the meantime liquid propellant men are striving for plumbing simplicity. A benefit of this simplification would be the successful design of a small diameter liquid propellant missile. The best prospect today is the Naval Ordnance Test Station's 5-inch liquid-bipropellant aircraft rocket (LAR). Although this missile is unguided, the propulsion system, if successful in operation, could be applied to smaller tactical guided missiles.

Development of a monopropellant that could be handled as safely as aircraft fuel would give ease of handling both in servicing the weapon and in design of the missile system. Development of a liquid monopropellant presents many of the problems of a solid propellant, which is also a "monopropellant".

Swing Toward Solids

The listing of solid propellant missiles is more extensive and diversified. It includes the most outstanding operational or near operational: *Gimlet, Mighty Mouse, Zuni, Falcon, Sidewinder, Sparrow, Bull Pup, Hawk, Tartar, Terrier, Dart, Honest John, Little John, Sergeant, Lacrosse,* and *Polaris.*

The greater number of missiles, when compared with the liquid propellant list is immediately evident; not that either list claims to be exhaustive. Evident also, of course, is the size range, from the 2-inch *Gimlet* and 2.75-inch *Mighty Mouse* to the 30-inch *Honest John.*

Key entry among the solid propellants is the navy's intermediate range missile *Polaris.* Until it was decided to develop *Polaris* as a solid propellant missile, the down-to-earth thinking on large missiles was in liquid propellants. The barrier to large solid propellant missiles has apparently been breached.

In view of other shipboard missiles, either solid propellant or jet propelled, such as *Terrier, Regulus, Sidewinder,* the Navy's decision on *Polaris* was to be expected. Considering the difficulties present in carrying aircraft fuels aboard ship, there is little chance the Navy will involve itself with difficult-to-handle liquid propellants.

H. S. Seifert in an article on the development of missile propulsion for the last 25 years in "Jet Propulsion," November 1955, forecast the *Polaris* decision.

"Liquid rockets have held the lead as motive power for large-scale, long-range applications, but even here new developments in solid rockets indicate that this supremacy may be challenged."

It would be premature to say that the supremacy of liquid propellant propulsion systems is challenged. It is evident that for large-scale, long-range, high-speed applications, movement is under way to break the monopoly of liquid propellants. Messrs. Stehling and Foster (m/r, Oct. 56, p. 58) proposed a rocket vehicle for a flight to the moon utilizing a solid propellant propulsion system. Considering the practically religious adherence to liquid propellants for this chore in the past, this would almost constitute a major breakthrough.

An outstanding example of solid propellants leading over liquid propellants is research rockets. Ease of development and handling are mandatory for research rockets. The only liquid propellant research rocket is the *Aerobee,* and *Aerobee-Hi.* The solid propellant research rockets now in use are: *Arcon, Asp, Deacon, Cajun, Dan, Iris, Rockaire, Rockoon, Terrapin,* and *Wasp.*

Synthesizing of the composite solid propellants has spearheaded the drive into the longer-range high-speed field. A new development in solid propellants was needed if they were to keep pace with modern needs.

The prevailing philosophy of World War II and immediately thereafter was to use large quantities of relatively short-range missiles to insure a reasonable kill probability. This is the barrage or saturation approach. Today, however, reliance is more and more being placed on a very few units of long range and high accuracy. We might call this the pin-point approach.

Solid propellant internal-burning grains were ideally suited for saturation tactics but they find considerable difficulty in meeting the new demands made upon them. There is an urgent demand for an end-burning grain which will answer the strategic and tactical need, including those of ballistic missiles. This need is being met by composite propellants.

In contrast, liquid propellant technology has shown no similar breakthrough. To make this breakthrough composite propellants must be considered. It is the development of composite propellants which has made possible such propellant systems as the *Polaris*. It is possibly a polymer-based composite propellant, since Aerojet has done extensive work in this field.

These composite solid propellants are drawing great interest as the propellants that will speed tomorrow's rockets—such as rubberbase-polymers at Thiokol, as well as Aerojet's polyurethane-base.

Despite this advance afforded by composite propellants, solid propellant systems suffer a serious impediment. Traditionally, a solid propellant system is a constant energy device which cannot be metered for operation. This obstacle can and is being overcome, although the details are still classified.

If development of solid propellant military and research missiles is moving into the large-diameter long-range field that liquid propellant has had staked out for itself, then it is indicated that solid propellants are going to be next to impossible to stop.

Ion-Atomic Propulsion

The challenge, of course, to both liquid propellant and solid propellant systems is ionic or nuclear propulsion. Latest in the ionic propulsion category is the plasma jet with high temperature and low thrust. Solve the metallurgical problem of high temperature and boost the missile out to where the low ionic thrust is all you need and you're in business. It has been proposed that a rocket boosted to the ionosphere could pick up enough energy with solar batteries to continue on its way.

Barring an unexpected breakthrough, missiles of the immediate future will be propelled by liquid or solid propellants.

The propellant systems may, however, be hybrid. A system utilizing liquid oxidizer for a solid fuel has been designed. Systems such as *Vanguard* with the first two stages liquid and the last solid might be considered hybrid. But so then must all the liquid propellant missiles with solid propellant boosters and gas generators.

It is certainly possible that such hybrids will win out over "pure systems" of strictly one propellant. What will happen and has happened is that each system will be used, alone or in combination, as conditions dictate.

It is current operational conditions which are dictating the pronounced swing toward easily handled, increased performance, composite propellants. Startling new developments in solid propellants should be expected in the near future.★

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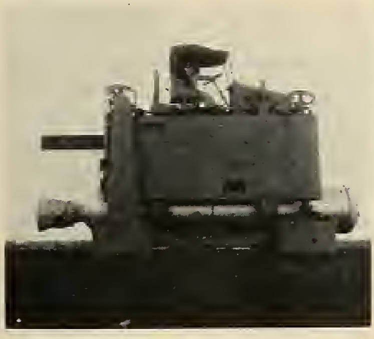
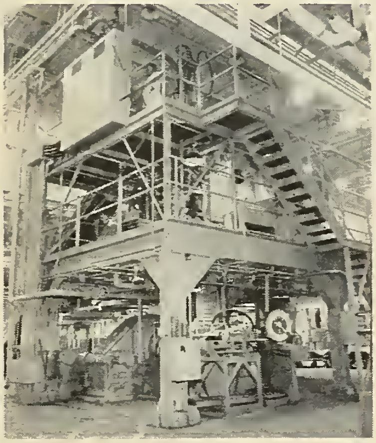
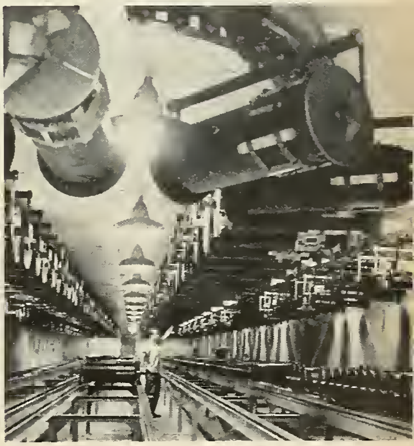
Phillips Petroleum Co., a major factor in solid propellant development and production since 1952, is contractor-operator of Air Force Plant 66 at McGregor, Texas. Phillips' Rocket Fuels Division's first major development was the M15 JATO. Phillips also lists three large off-the-shelf booster units for military missile and sled applications. Units are: Pusher, Producer and Megaboom. RIGHT—Temperature-conditioned booster unit is systematically checked before test firing.

Air Force Pushing Big Pushers

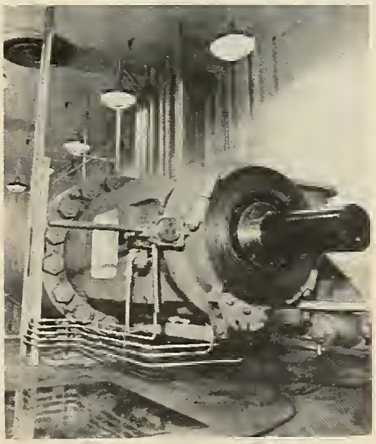
RIGHT—Solid propellant mixing machinery. FAR RIGHT—Propellant grains moving along conveyor belts in cooling room. BELOW—Lift truck used by Plant 66 for transporting complete solid propellant motors in the plant.

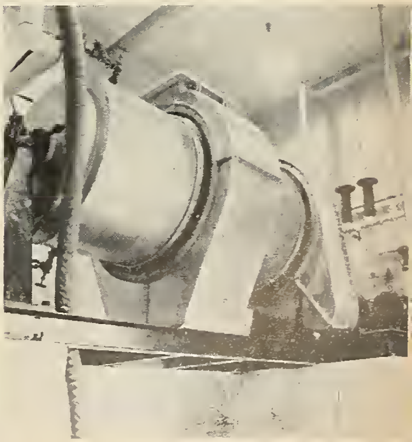






RIGHT—A batch of propellant emerges from an extruder. An attendant, through remote control closed-circuit TV, operates the processing machinery. FAR RIGHT—Rotary vacuum reduces moisture content of a solid ingredient used in rocket fuel development.





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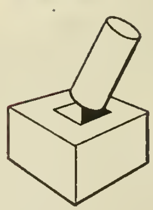

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New High-Heat, Low Cost Fuel Reported

MISSILES AND ROCKETS has learned that preliminary work has been completed on a new concept in high energy fuels. The new fuel is said to combine ultra heat of combustion, good handling properties, and after a low molecular weight. all gaseous, smokeless exhaust. The compound and its combustion products are non-toxic. Further, the fuel is apparently stable when pure. Though not named, the fuel can be burned in air, or with any conventional oxidant. Reports state that higher heats of combustion (BTU/gal) over conventional hydrocarbons or metal hydrides are in evidence.

Perchloryl Floride Now on Market

Perchloryl fluoride, C103F, is being introduced by Pennsalt Chemicals. Available in pilot plant quantities, PF is a gas (bp-52 F) which can be safely stored in liquid form (critical temperature 203°F, critical pressure 53 atm, specific gravity 1.4). High reactivity is a feature of the colorless, non-corrosive material with a characteristic sweet odor. PF is said to be thermally stable to 500°C and stable to mechanical shock but reacts on contact with most organic materials. Acute vapor toxicity is placed at 2000-4000 rpm (4 hrs. exposure).

Oxygen Generating Plant Nearing Completion

New $5.5 million liquid oxygen generating plant now nearing completion at the Experimental Rocket Engine Test Laboratory at the Air Force Flight Test Center, Edwards AFB, will produce 150 tons of liquid oxygen daily, with 15 tons of liquid nitrogen per day as a byproduct. Latter is used for prechilling liquid oxygen missile tanks and pressurization of component missile equipment.

Solid Motor Cases Made of New Plastics

Polcarbonates-condensation products of phosgene and bis-phenyl-A are now appearing as high-impact and tensile strength plastics which may soon wind up as motor laminates or possibly as a fuel-binder for solids. GE has come out with its "Lexan" polycarbonate while Bayer of Germany and Eastman Kodak are also doing work with this material.

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Extreme environmental conditions are simulated in the laborat or encountered in actual field tests on the firing range at West H over or the 1900-acre test range at Halifax, Mass. Here, too, AP& will extend its facilities for the investigation and development TRONA* boron, lithium and perchlorate chemicals in high energy fu

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3030 WEST SIXTH STREET, LOS ANGELES 54, CALIFORNIA
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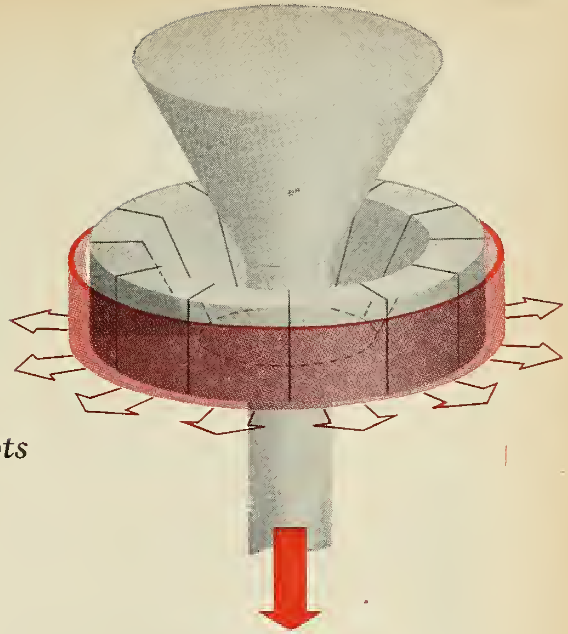
Evolution of a Method

By George Shaw



Grotnes Machine Method Adapts to Production of Power-Plant and Missile Components

WHEN CHARLES C. GROTNES launched his business in 1898, building machines to produce tapered steel barrel hoops, his product was geared to that age. Today, more than 50 years later, they are doing essentially the same job of forming metals, but in a more complex manner and on a vastly larger scale; as much at home in the age of the atom as in the barrel shop.

Die casting, drop forging and stamping processes have been in general use almost as long as metals have been formed by machinery, but the method of altering the shape of cold metal by expansion and shrinking started with Grotnes. The basic principle involved is fairly simple and very adaptable. In fact, the magnitude of the jobs it can perform is only limited by the size of the equipment available, and this explains the enormous size and power of some of the Grotnes machines in use throughout the world.

The name plate on a piece of Grotnes equipment bears the legend, "equipment for expanding—shrinking—rolling of metals." The legend suggests a line of exceptional machines which will form a piece of cold plate to almost any shape required at low cost and at a high rate of production.

It does not, however, suggest the wide application of these machines to an age that creates new and complex problems in metalworking almost daily. The wooden barrels have given way to guided missile parts and freezer cabinets; to washers and dryers and irrigation pipes, and the machines have kept pace. The method remains the same but the machines have grown in magnitude and in utility until today there is a Grotnes machine that will shrink or expand a piece of metal into a cylinder, a square or a polygon.

Demand for Auto Rims

Shortly after the turn of the century the automotive age began its slow roll into the realm of heavy industry. The new carriages, if they were to be really efficient, had to have steel rims for their rubber tires. Grotnes was called upon to develop a method to form and mass-produce the rims.

The hoop expanding machines were turned to production of steel rims, and Grotnes became associated with the tremendous surge of mass production in the automobile industry. Today practically all of the automobiles, trucks and agricultural machinery in the world roll on rims produced by Grotnes machines, or on machines using the Grotnes method.

Of the three basic operations comprising the Grotnes method the rolling operation is the least adaptable. While the rolling operation can only be performed on a cylinder or "coil," the expanding and shrinking operations range from, and to, any shape desired.

The cylindrical stock is formed on a weld roller, an operation that rolls the weld into the metal comprising the sheet stock and the weld is smoothed out on a Grotnes weld roller. This coil, as it is called, can then be rolled, shrunk or expanded to any shape required, without heating. Some of the more complicated operations may call for annealing between steps, but generally the forming is done without the need for treatment of the metal as in other methods.

In the production of a jet engine ring, the coil first goes to an expander where a channel or bead is expanded into the center section of the cylinder. This first operation facilitates the last one, where the coil is slit to form two rings identical in size and configuration. When the bead is expanded the coil is placed between two rings, one an expander ring and the other a hold-back ring. Corresponding dies in the two rings allow for consistent control of very close tolerances.

The coil then goes to the rim rollers for profiling. Two hydraulically operated spindles, mounting suitable tooling for the profile desired, form the rim in a continuous operation. The upper spindle is fixed, while the lower one is moved upward against the rim by hydraulically operated toggle linkage. Thus a differential can be provided in the gear train of one spindle and thereby reduce slippage between the roll and the part.

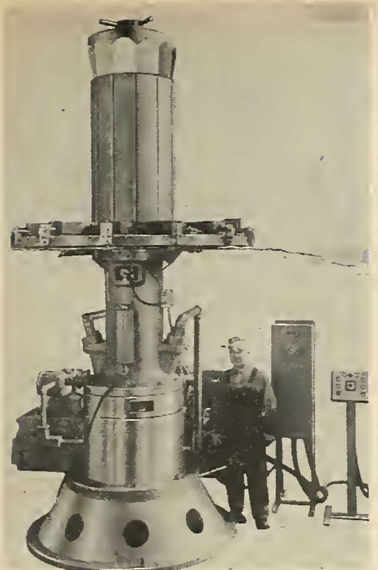
Rates of feed can be varied so that in any given operation the desired number of turns will be provided to form the desired contour. Cold forming of metals this way is said to materially improve the mechanical properties of the metal and uniform thickness is maintained throughout the part.

View looking into the 'maw' of a shrinker. Simplicity of operation can be seen in the control box arrangement at left. This shrinker sizes heavy ring sections of stainless steel, aluminum, alloy steel and titanium.

More ecnomical production is claimed for Grotnes machines than with processes which, in principle, can produce the same results. The reasons cited are, simpler manufacturing processes, versatility and adaptability. Quick changeover of forming rolls permits handling of a wide range of shapes and sizes of materials. As noted earlier the rim roller can only handle circular material; however with the expander and shrinker the dies on the machines can be adjusted to handle any shape.

The Grotnes expander is probably one of the most fascinating pieces of machinery ever devised for general application. No quality or characteristic of metal is overlooked in the design of expander principle and operation and surely there is no more versatile a mechanical apparatus in the metalworking field. To borrow a simile from the machine—any improvement in the expander is an expansion of the principle itself.

Such metals as mild steel, alloy steel, stainless, titanium and aluminum can be formed on the expander and the process is called the most economical means of forming and/or sizing any part having a continuous cross section—round, square, oval or polygonal. Subassemblies can be joined by the



Capable of bar pull force of up to 680 tons, the machine pictured above is one of the largest expanders in general use. This machine sizes and forms jet engine parts such as cones, rings and cylinders.

process without resultant distortion such as with welding or bolting.

In another application such heavy sections as jet engine rings, hydraulic cylinders and motor frames can be expanded to rough size, considerably reducing machining time and material waste. Expanding is also widely used in testing weld strength and in improving welds and the adjacent metals. Though expanders are designed for use in forming a specific part they are generally adaptable to a certain degree.

The expansion process is simpler and more accurate than any other method known. For instance, in the case of a ring that must be joined permanently with another ring, one within the other, the expander usually does the job in one operation. The outer or larger ring is enclosed by a hold-back ring. The expander presses the smaller ring into the larger one in a permanent bond and the hold-back ring retains the shape and outside diameter of the whole. The inside diameter is established by the expanding dies.

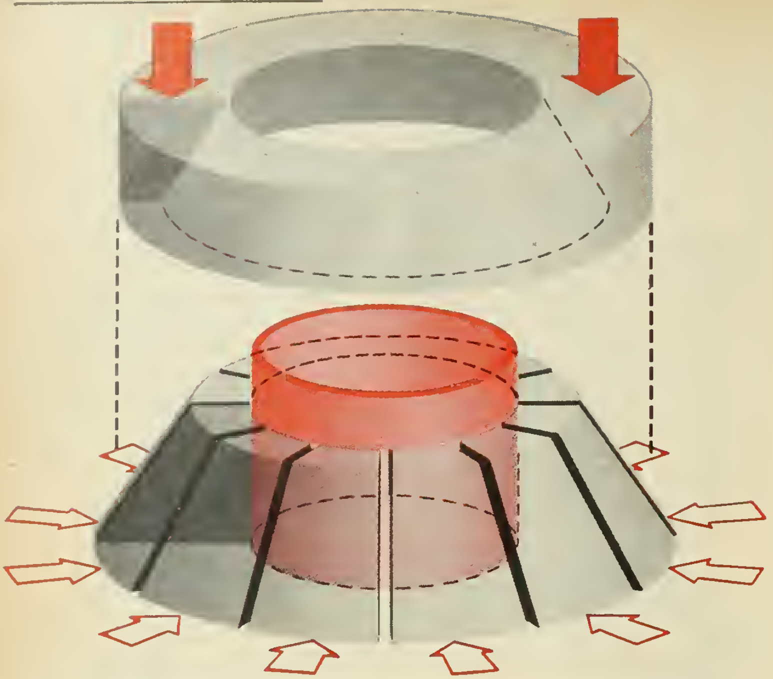
Although the bulk of expander production is concerned with circular or cylindrical parts, it can and does handle a variety of odd and unusual configurations. A wide choice of dies and die arrangements permits an almost unlimited choice of single and multiple operations to produce a desired shape. Once the machine has been set up and a couple of control tests are run, the machine can be run on a production basis, capable of extremely high production rates. A good example is a machine used in the container industry which will turn out 2000 curled, beaded, offset and flanged pails per hour.

As noted before, the basic principle of the expander is fairly simple. However, in the modern versions of the machines a number of inter-related variables tends to complicate the process considerably. The basic principle is that of the inclined plane or wedge, actually a polysided cone resembling a modified frustum of a pyramid. In addition to the cone the basic elements of the expander are the drawbar, jaws, table and power system. The cone is attached to the drawbar which may be hydraulically or mechanically operated.

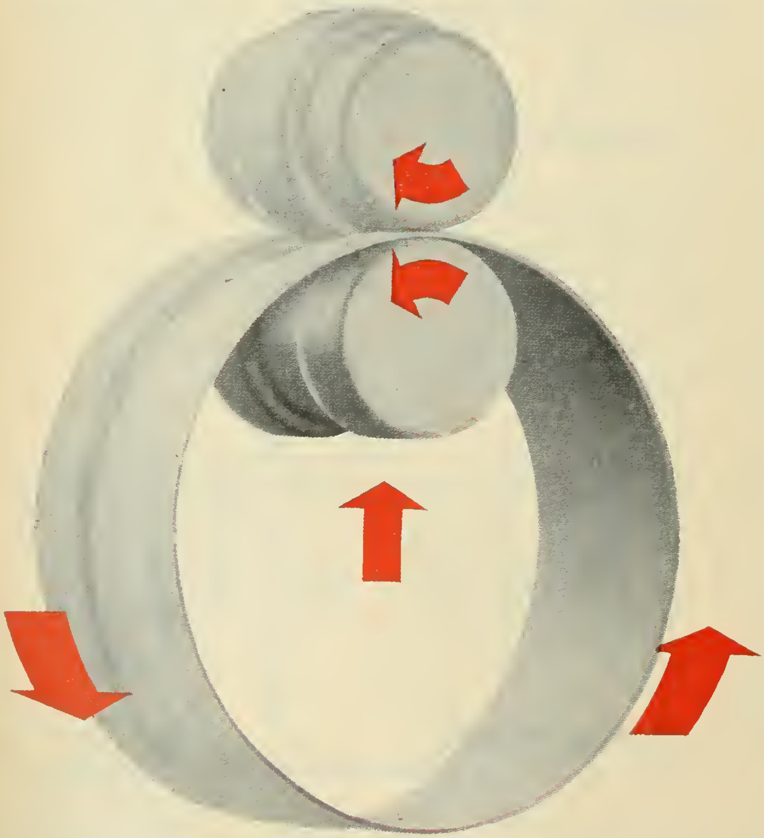
The movement of the cone being drawn down between the jaws forces the jaws outward at right angles to the cone travel. The jaws move through slots in the table provided for this purpose. The dies for a particular operation are placed on the jaws and as they are forced outward they move against the part to be molded or expanded. The part is placed over the jaws and as the cone is drawn down the metal is stretched until the cycle of the cone travel is completed.

Wide Range, High Production Rate

The hold-back mechanism can be fitted with dies or it can be used as a simple retaining surface. When forming beads, or when a combination operation is desired—shrinking and expand-



Shrinking is directly opposite to expansion, the jaws being forced against the part by the descending ring, and is used where tolerances are critical.



Arrows show direction of rollers in forming a rim. Upper roller is fixed while lower one is actuated by hydraulically operated toggle linkage.

ing—corresponding dies can be fitted. An unusual feature of the expansion process is the tendency of stretched metal to spring back to its original shape. Though this action is minute it must be taken into account when setting the jaw travel. After the spring-back is calculated for a given metal and the jaws are set accordingly, all items processed with that setting are formed with identical OD and ID measurements, thus permitting mass production standards to be established.

By fitting the jaws and hold-back ring as noted earlier, a cylinder can be expanded to a square or a cone can be given a polygonic base. In fact, some of the combinations of shapes possible with expansion and shrinking are either impossible or impracticable using any other method. Because of the fact that the metal is processed cold, and that in most cases no machining is required, processing metal parts with the Grotnes Method and Grotnes machines is generally the most economical production standard available.

The question invariably asked is: "Where does the metal come from to allow for displacement in shrinking and expanding metal parts?" The answer supplied by the Grotnes Chicago office is sufficient of itself. It seems that the cold flow over the face of the dies in cold-forming allows the metal to be drawn from the entire body of the part, thus avoiding any local thinning or weakening. Amazingly, in such operations tolerances of no more than ±.002″ are maintained, a degree of accuracy which eliminates much costly additional processing.

The principle of shrinking is exactly opposite to that of expanding. In shrinking the jaws are forced inward by the action of a tapered ring or by toggle links. Shrinking is used where the amount of reduction in diameter is relatively small and where a higher degree of dimensional accuracy is demanded. Shrinking is often employed in conjunction with expansion, and as with expansion, shrinking is done with or without dies. A clear picture of this operation can be adduced by imagining the metal part being compressed by the action of a ring or mandrel being drawn over it.

Typical of the shrinker application is the reduction in diameter and sizing of the domed heads for compressed air tanks. Sizing is effected automatically to insure an inside diameter consistent with the cylindrical shell. Like the expanders the shrinkers lend themselves to a high rate of production.

The Grotnes principle, the company claims, can supply at least part of the answer to any problem of metalworking that might arise.★

Machining for Solid Propellant Rockets

cooperation between product engineer and hardware source can crack missile price barrier

By Joachim H. Kauffmann
President, Diversey Engineering Co.

THE MISSILE is a costly bird, particularly when you figure that despite all the love, labor and money that goes into it, just push the button once and . . . scrap! It's a throw-away item.

The taxpaying public has tolerated the high cost of researching and developing missiles with patience and understanding. The results, on the whole, have justified both patience and cost. However, whether either public or the economy will long stand for production missiles with research and development price tags is doubtful. The recent top-level AF missile cost symposium for major contractors is an example of the coming price consciousness. The desire for more missiles in less time for less money is becoming a national necessity.

In the case of certain vital components, such as rocket nozzles, forward domes, aft closures, adapter rings, accumulators and sometimes even nose cones, machining is often the only known practical means of obtaining the desired end product. Also, it's one of the costliest missile production processes. But costs have been cut in the past and, with proper cooperation between component supplier and end-product engineer, the missile price barrier will also be cracked.

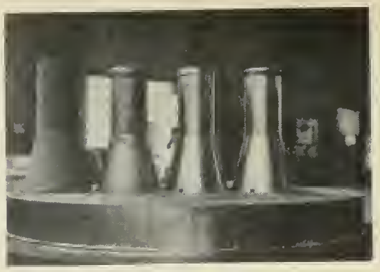
Missile metal machining has progressed a long way since World War II. Technological advances in metalworking, machine tools and metallurgy have all played their part. But better methods breed more rigorous demands. Just as a manufacturer figures he's got a new and complex process down to a routine, along comes a rocket design requirement that demands closer

tolerances, more rigid specifications, more complex contours and a yet more awkward material to be machined.

Diversey Engineering Company now has contracts for machining parts for over fifteen major missiles including *Hawk, Titan, Sparrow, Falcon, Talos, Nike Ajax, Nike Hercules, Recruit, Lacrosse, Polaris, Deacon* and others. The missile materials the company works with include aluminum, magnesium, titanium, aircraft quality steels, nickel-cobalt alloys and molybdenum.

As with any component supplier, it is the responsibility of an engineering company specializing in complex machining to keep its processes and techniques not only up to the job, but on as low a cost basis as possible. It is also its responsibility to keep its market constantly aware of latest developments. Just as missile system research and development teams must propose and test, so must a missile machine shop experiment with and try to develop new and promising processes.

It was just such an effort that proved the full worth of the air tracer lathe—today's mainstay of missile metal machining. And it is just such a similar effort with hydro-spinning and hydroforming that will result in new design flexibility and production economy. Diversey has pioneered in both these



Above: Four stages in the production of a solid propellant rocket nozzle—rough casting; rough machining; finish machining; threading. To the right, a solid aluminum billet begins to take shape as the core mold for fixing shape of solid propellant burning surface.

fields and now has the largest single contract supply of Monarch air tracer lathes in the U.S.

In the last eight years development of this equipment has put three dimensional contour tracing on a mass production basis, enabling the rapid repetitive machining of complex missile parts that would otherwise require costly, time-consuming hand work. Hydro-spinning shows particular promise in the production of rocket cones, nozzles and tubes.

To get an idea of the complexity of process and rigidity of specifications in rocket machining takes only a quick

look at the quality control requirements imposed in a missile contract.

Each machined part has its own serial number coded to files containing as much inspection and process data as the health record of a VIP at a modern hospital. These cover material analysis, heat treatment of components, subassembling, magnafluxing, radiological and fluorescent dye penetrant inspection processes, hydrostatic testing and finally the bug-a-boo of all missile hardware: strict reliability.

These demands cause a veritable blizzard of metallurgical, quality control reports and certifications to accompany each component to the final assembly point. Precision inspection equipment for examining finish surfaces, contours and dimensions alone in such a plant as Diversey may represent a capital investment of $100,000.

The machining, for example, of one solid propellant rocket nozzle calls for a three dimensionally contoured wall of tapered thickness to be machined to an internal dimensional tolerance of ±0.001 inch and a surface finish of at least 32 microinch. In another case an accumulator's internal dimensions must be held to within +0.0005 inch, —0.0000 by machines designed for normal tolerances of ±0.001. And these machine tools are the best available.

The problems in machining rocket parts are varied. The major one is that standard straight line machining is not acceptable. Items of solid propellant motor hardware generally have one similarity—thin-walled contoured sections. This necessitates the employment of contouring machinery on a greater scale than in any other industry. Thiokol, Allegany Ballistics Laboratory, Aerojet-General, as well as other designers have this common requirement. Diversey specializes in satisfying these needs.

Solid propellant rocket hardware is not as varied as in the liquid engine field but has specific problems all its own. The major hardware items are: a cylindrical case, forward domes, aft closures, adapters and nozzles.

Nozzles are either bolted or screwed to the aft section of the motor case to facilitate the loading of the motors. The case assembly is either rolled and welded, deep drawn or of laminated construction.

The most commonly used alloy steel in this fabrication is electric furnace, aircraft quality 4130 (MIL-S-6758). This hardware with exception of nozzles is generally welded to the case. The whole weldment is heat treated to specifications which spell out yield and tensile properties or they merely specify a hydrostatic pressure test for specific time periods.

After heat treatment of the motor assembly, several surfaces must be remachined to assure alignment of the nozzle. Concentricity and squareness of these surfaces are critical and tight tolerances are spelled out. For example, concentricity and squareness of a typical solid propellant motor assembly might be as close as ±.005 on concentricity over a 12 foot length and squareness and parallelism of .003 inches on all trued up surfaces. This is to be attained on a weldment.

The problem is not so much doing these things, once or twice. It is the development of production methods that enable them to be done on a nearly automatic, repetitive, low cost basis.

Utilizing contour turning techniques permits the design engineer to cut his lead time from prototype to pre-production or production of a solid propellant hardware item. He has the time saving advantage of being able to specify all complex details on a single template, instead of being forced to delay machining until special form tooling, cams and checking fixtures are constructed.

The details are simply machined on a thin plate of good quality steel and can be checked in any modern inspection department, either by standard vernier and radius gages or by comparator. If the template is properly machined, the job is ready to run.

A typical example of this problem is a large, solid propellant motor adapter. The contours are complex, tolerances and surface finishes critical. To fabricate the part properly, it requires a forging designed to give optimum strength. The units are rough machined, using a roughing template in a tracer lathe, to a ±.010 inch tolerance to control heat treating results. Finish machining is done in the hardened state to surface finishes as fine as 16 microinches and dimensional tolerances as close as ±0.0005.

With proper utilization of new

turning principles and cutting tools, such as ceramic "throw-aways" and the harder carbides, superior finishes can be attained on modern, rigid lathes which are tracer controlled and can repeatedly duplicate difficult contours and sweeping radii to close tolerances.

In machining hardened missile components, exceptional results have been obtained on air-gage tracer lathes using ceramic tool bits, M-95 and K7H carbides. High velocity turning up to 1000 surface feet per minute—three times what steel is normally turned at—imparts excellent surface finishes ranging between 32 and 63 microinch, thereby eliminating costly grinding and polishing.

Manufacture of core molds for casting the solid propellant is a constantly expanding field. Long contoured tapers are milled on aluminum bars or extrusions in a variety of shapes such as star or cruciform configurations. Extreme care is needed to maintain concentricity along each of the tapered planes in order to ease the extraction of the core from the solid propellant. Generally, all cores are coated with Teflon or a similar substance.

The welding of solid propellant components must be rigidly controlled due to the fact that after welding and heat treating, the only machining that is possible on motor case assemblies and subassemblies are light finishing cuts to true up the axis of the case to the nozzle and to the adapter. Jigs for holding components during welding must insure the end product being as concentric as possible. Since all assemblies are subject to hydrostatic test and/or radiological inspection, welding specifications must be strictly followed.

Care must be taken in heat treating that a minimum of distortion takes place. Here again, due to the thin wall, uneven sections of solid propellant components, a thorough analysis must be made of each component prior to heat treating.

When considering production items from a cost point of view, design and engineering groups should work closely together to ascertain whether an investment casting out of the proper alloy steel can be used by simply machining out the area matching the external dimensions in the components and welding same in place. This can result in great savings in manhours, scrap and lead time.

In most instances this 5000-year-old "lost wax" casting process provides physical properties that meet design standards. It is entirely possible that it may prove as economical and useful in rocket motors as it has in turbine engines and other ordnance gear.

Actually, when a missile or rocket

motor is scheduled to go into production, all specifications and tolerances should be given a close second look. For example, is it necessary to pay the heavy premium of machining a rocket motor adapter to thousandths of an inch when it's going to be given a plastic liner accurate to hundredths?

When a missile is in the research and development stage, designers are worried primarily about making the *system* work. There may be a tendency to over-specify materials and tolerances in order to preclude failures due to simple mechanical failures. However, once the system is proved it may well be possible to ease specifications, particularly of individual components. Easing the preparations for machining and the material to be machined, minimizing tolerance—all tend to reduce machining costs. Molybdenum costs more to machine than titanium; titanium, more than steel; steel, more than aluminum, etc.

By machining one component, now in full production, out of an investment casting rather solid stock, per unit costs may be reduced from $800 a copy down to around $200. When the order entails thousands, this is a major cost factor. Considerable cost savings may also result when, say, the external tolerances and finish on an accumulator are eased. Wherever closer tolerances are called for, cost goes up exponentially.

This is the job of the production or process engineer. Its his task to design producibility into production missiles—to check every specification the design engineer calls for; to point out to him differences in costs of various materials, various production methods, tolerances, etc., vs. the difference in performance (if any). This is a vital phase of anything scheduled to go into production, missiles and rocket motors included.

Low Cost Hydrospinning

In this connection, hydrospinning may prove as useful over the next decade as the air tracer lathe is now. Hydrospinning is a cold process in which the work piece is forced to take the shape of a hardened rotating mandrel. Its great usefulness is in the manufacture of hollow symmetrical parts of tubular or conical shape, and is particularly advantageous where walls of varying thickness are required.

In some missile operations now requiring careful contour machining, hydro spinning will save 80 per cent in machining time and 50 per cent in machine costs.

The big plus, however, is in savings in material and time, increase in tensile strength and fatigue resistance and, in some cases, reduction in weight as a result of cold working. In addition, an excellent finish is obtained on the inside surfaces. Outside diameter finishes are frequently satisfactory in the "as spun" condition.

During hydrospinning, the metal being formed undergoes shear deformation. Work hardening accounts for an appreciable increase in tensile and yield strength. Elongation is decreased proportionately. The process has many advantages in the case of cost cutting and mass production.

At present, cones with an included angle of 30° can be spun from a flat blank. This is a blank reduction of 75%. Lower degree angles can be obtained if the part is preformed. For cones of varying wall thickness, a premachined blank is required.

In the event contours other than those of parallel or angular size are desired, a contour attachment can be used to obtain the necessary shape. This combination of contour hydrospinning lends itself admirably to most solid propellant rocket motor parts.

For tube spinning, hydrospinning basically amounts to cold extrusion. Raw materials can be in the form of cold drawn tubing, hot rolled tubing, rolled or welded blanks or, in some instances, preforms machined from forgings. Because of the tremendous pressure applied, welding defects in welded blanks will show up as a defect in the surfaces of the tubing, thus providing excellent welding inspection. Maximum recommended wall thickness for the tubular blanks is ¾ inch. Some tubes have been spun with a reduction as high as 90%.

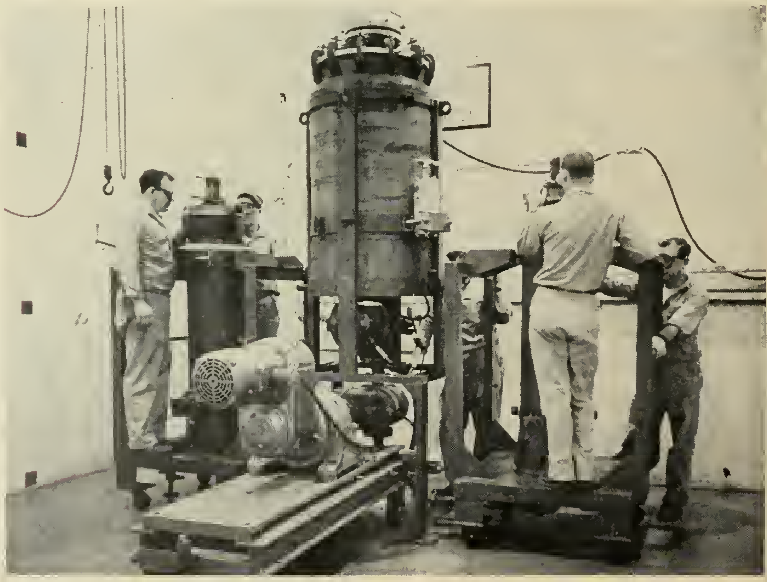
In regard to reliability, the missile hardware machining source must exercise strict reins on quality control. Top management must instill a feeling of absolute responsibility in all branches of the facility. Supervisory personnel, as well as machinists, welders, assemblers, testers and quality control personnel must be thoroughly briefed on problems to be solved, processes involved, high quality of workmanship, etc. The whole missile hardware plant must take the deepest interest in all operations. "The end items can only be as good as are the capabilities of the men that manufacture them. A feeling of pride and intense interest must prevail throughout."

As the solid propellant field widens, more unusual demands will be made on the hardware source. It is imperative that this source stays abreast of the newest developments in machine tools. Design, project and process engineers must be informed of these developments and urged to adapt their designs insofar as possible to manufacturing processes with optimum producibility.★

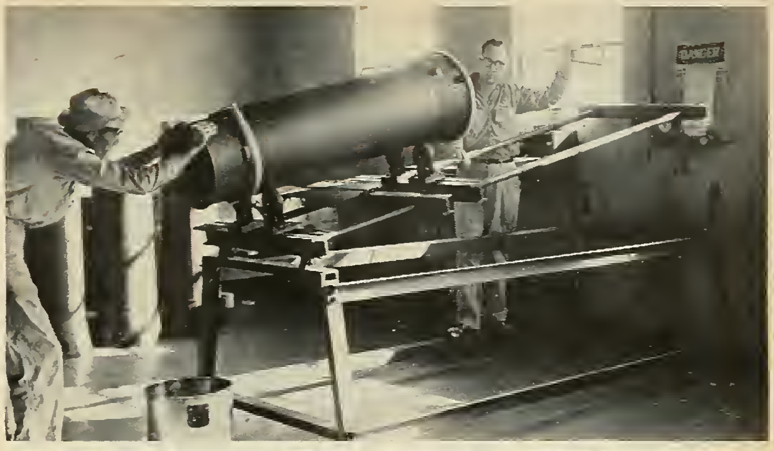
Processing for Solids at Thiokol

Vertical rocket motor test. The complete rocket motor is subjected to test firing during development (over a very wide rocket motor temperature range). Selective sampling of production motors is a major effort of the testing team. A vertical test pit and allied instrumentation surrounds the motor in this scene and only hot exhaust gases are shown.

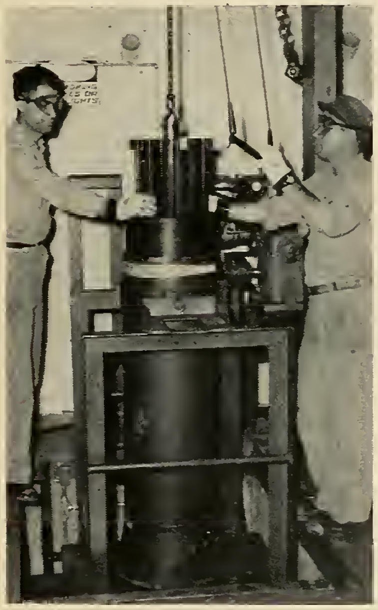
LEFT—Remote operation scene. A technician operates a machine from behind a revetment while viewing the operation through a port-and-mirror. RIGHT—Composite propellant mixer in a tilted position as used during discharge of the propellant from the mixer to the transfer can. The Baker-Perkins mixer accommodates about 1,400 lbs. of propellant. The mixer is jacketed and a heating fluid is used to control the temperature of the propellant during mixing.



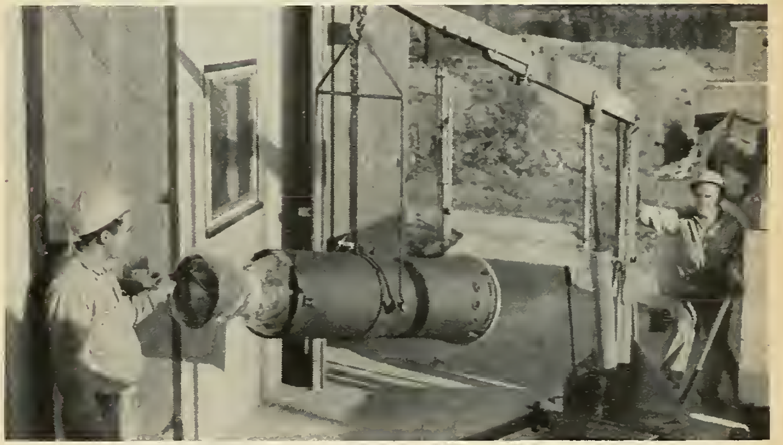
Propellant (polysulfide, composite type) in the raw state is pumped from the large transfer can into two rocket motors. At this stage the propellant is a very viscous fluid which flows into the lined rocket motor case. The loaded case will be placed in an oven to cure the raw propellant to a hard rubber solid that bonds to the lined case.



Rocket motor case being prepared for lining operation. Each case is first tested, inspected and cleaned. Liquid rubber made by Thiokol is then applied to the entire inside surface of the case and a thin layer of this lining rubber is cured. This thin layer bonds to the case and provides an excellent surface for later bonding of the propellant.



Removal of the core. A core is placed in the raw propellant prior to cure of the propellant. The core is subsequently removed leaving the desired internal cavity in the case bonded propellant. During burning the flame front progresses radially outward from the internal cavity thus the case is protected by the propellant from the hot gases.



Transfer of a rocket motor from a temperature conditioning chamber to a test cell. Each rocket motor is conditioned to a known temperature prior to test firing thus eliminating one variable from the evaluation of motors during development. This procedure is also used to demonstrate the wide operating temperature range of which these motors are capable.

The Army's most sophisticated tactical surface-to-surface missile, LACROSSE, leaves a searing flame in its wake during launch from White Sands Proving Ground. Flame is produced by one of the largest production solid propellant motors—an achievement of the Thiokol Corp. The motor's propellant has a synthetic rubber base, containing an oxidizer.

electronics briefs

AC Spark Plug Developing *Regulus* Guidance System

A new type of guidance system for the Navy's *Regulus* missile is under development by the AC Spark Plug Division of General Motors, as well as a guidance system for the Martin *Matador*. Chance Vought Aircraft, builder of the *Regulus*, reports that the missile has already been checked out at altitudes in excess of 50,000 feet and at speeds of Mach 1.5 and above. The *Regulus* system is being handled by AC's Milwaukee plants.

Servo Corp. Builds *Sidewinder* System Tester

Testing and calibration of the *Sidewinder's* infrared detection system is done with an infrared radiation standard developed by the Servo Corp. of America. The Government and Industrial Division of Philco Corp. used the IR device to test the sensitivity of the lead sulfide cell, the heart of the *Sidewinder*.

Sidewinder, the Philco-Navy developed AAM for Navy fighters, is the first missile to successfully use the infrared homing system.

Radioplane Receives Army Target Contract

Radioplane Co. has been awarded a $4.5-million contract by Army Ordnance for providing target flight service to the Army's surface-to-air missile training program at Fort Bliss, Tex. One of the first of its kind to be awarded, the contract requires that Radioplane Company provide not only aerial targets and ground support equipment, but operational, training, and maintenance personnel as well. Field headquarters for the program will be at the Radioplane plant in El Paso, Tex.

Missile Master System Will Support *Hawk*

Missile Master, an electronic system for controlling and coordinating fire of *Nike* anti-aircraft batteries, will also be used to coordinate the *Hawk*, the low-altitude air defense missile, according to a recent Army announcement.

Missile Master is manufactured by the Martin Co. at interim facilities in Orlando, pending completion of the company's Orlando Division plant.

Astrionics

By Henry P. Steier

"Our kingdom for a transistor," could be the next utterance of IGY scientists. Serious delays in obtaining enough camera tracking equipment for the satellite program are raising questions as to what it would mean if a satellite were launched without them.

Dr. John P. Hagen, Project *Vanguard* director said recently that we can go ahead safely with Minitrack alone. There must be something lost if the cameras don't materialize on time: It is the degree of accuracy with which data on the earth's shape, gravitational field, atmospheric density, etc., will be obtained.

Use of the cameras would add a whole order of accuracy to such data and new orders of accuracy are a prime goal of IGY work. If only a 1000 megacycle transistor were available the cameras might not be needed.

Minitrack's tracking accuracy limitations will be set by refraction of the satellite's 108 mc signals as they pass through the ionosphere. The angles from which the signals come will be "apparent" not real. Minitrack's designers say raising the signal frequency to 1000 mc would enable Minitrack to compete with camera tracking accuracy.

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Results of six years surveillance of military electronics in the field have been published by Aeronautical Radio Inc.'s Reliability Research Department. The work should go down in history as a definitive study of unreliability and what causes it. If ever a study was conducted to highest scientific standards of observation and classification of facts this one was. In the face of much talk about unreliability and superficial treatment of it by many segments of industry, this work should, after a close study of its conclusions, be very convincing as a guide post to do something about unreliability, in all electronics work.

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New rallying point for strolling satellite enthusiasts ought to be International Business Machine Corp.'s new *Vanguard* computer center at 615 Pennsylvania Ave., N.W., Washington, D.C. On one side the new building houses a most colorful display of gold-plated satellite, rocket engine, optical and radio tracking gear, and guidance devices. On the other is equally colorful IBM 704 computer that will keep scientists and the public posted on "how goes it." Not open to the public, the building was designed for sidewalk viewing. It's the newest addition to the "sights" in Washington.

•

Navy will soon give radio astronomy a field tryout on board the U.S.N. Compas Island to determine usefulness for navigation of missile ships and submarines. All weather position-fixing capability is needed. Pioneering work in the field of radio astronomy by Dr. John P. Hagen to codify radio signals from various stellar bodies may soon pay off as a new means of navigation. Navy says the large-antenna problem has been overcome and now antennas suitable for shipboard can be used.

•

If you see a *Moccasin, Rattlesnake,* or *Copperhead* missile name don't be surprised. It'll belong to the *Sidewinder* family of infra-red tracking missiles. We just learned from Dr. Alvin Novick of Harvard University that nature was way ahead of us on use of this tracking method. These snakes belong to a species known as Pit Vipers. On each side of the head between the nostril and the eye is a sensory pit. It houses a heat radiation detector that enables these cold-blooded creatures to track warm-blooded creatures at night. *Sidewinder* snake is one of this species.

Space Medicine

by Hubertus Strughold, MD., PhD.

The following is a report covering the symposium on "Problems Common to Astronomy and Biology" held in Flagstaff, Ariz., June 18. The occasion was a joint meeting of the Astronomical Society of the Pacific and the International Mars Committee.

A paper by Lt. John A. Kooistra, Jr., Dr. Roland B. Mitchell, and the writer, dealt with the behavior of microorganisms under conditions simulating those of Mars. It attracted much interest among astronomers. In these experiments soil samples obtained from the Painted Desert in Arizona, and samples of lava, etc., with their inherent microflora, were exposed to a combination of lowered barometric pressure, altered atmospheric chemical composition, reduced moisture and low temperature as these conditions are found on Mars.

Preliminary results show that there has been a trend of the dominant micropopulation originally in the soil samples to change into a different type of population capable of surviving and multiplying under these conditions. Some of the microorganisms gradually disappeared from the original sample. The experiments represent a completely new approach to the question of life on other planets and to astrobiology generally.

At the same meeting Dr. Ingeborg Schmidt of the University of Indiana at Bloomington, a specialist in color vision, discussed the applicability of recent advances in physiological optics to astronomical observation. She included new data on color vision, night vision, contrast vision, etc.

After the Symposium, color vision examinations were given by Dr. Schmidt. It is well known that about 4 per cent of the male population as a whole and only 0.3 per cent of the female population, are defective in color vision. These examinations attracted special interest because of the controversies extending over many years about the various colorations found on the planets. Of the 30 persons examined, six were color defective to a greater or lesseor degree. Information on these cases were, of course, kept confidential by Dr. Schmidt.

In another interesting paper, Maj. David G. Simons, USAF (MC) from the Aeromedical Field Laboratory at Holloman AFB, N. M., discussed the possible use of sealed gondolas in high-altitude balloons as astronomical observatories.

The International Mars Committee, with headquarters at the Lowell Observatory on Mars Hill in Flagstaff, will continue its work. Dr. E. C. Slipher, Director of the Observatory, is the Committee's Chairman. Dr. Slipher conducted studies of Mars during its oppositions in 1954 and 1956, at Bloemfontein, South Africa. (See his report in the National Geographic Magazine of September 1955.) Dr. Gerard De Vaucouleurs, noted French astronomer and author of the book "Physics of the Planet Mars," is secretary of the Mars Committee. He is now in Flagstaff.

The educational television series on Space Medicine has been completed. (As I have reported, the script is by Mr. Green Peyton, Chief of Information Services at the School of Aviation Medicine; the films are produced by the University of Houston; the series is sponsored by the Ford Foundation). In one of the last two films Dr. Albert G. Wilson, Deputy Director of the Lowell Observatory, is seen discussing conditions on other planets with regard to their ability to support life. In the final one, Major General Bernard A. Schriever, Commander of the Air Force Ballistic Missile Division, Air Research and Development Command, appears in a discussion of the human problems raised by satellites and missiles.

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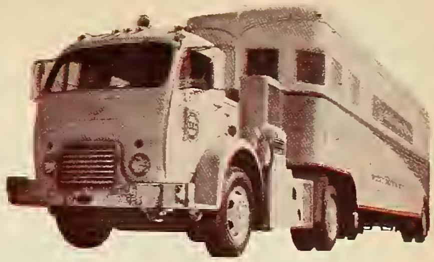

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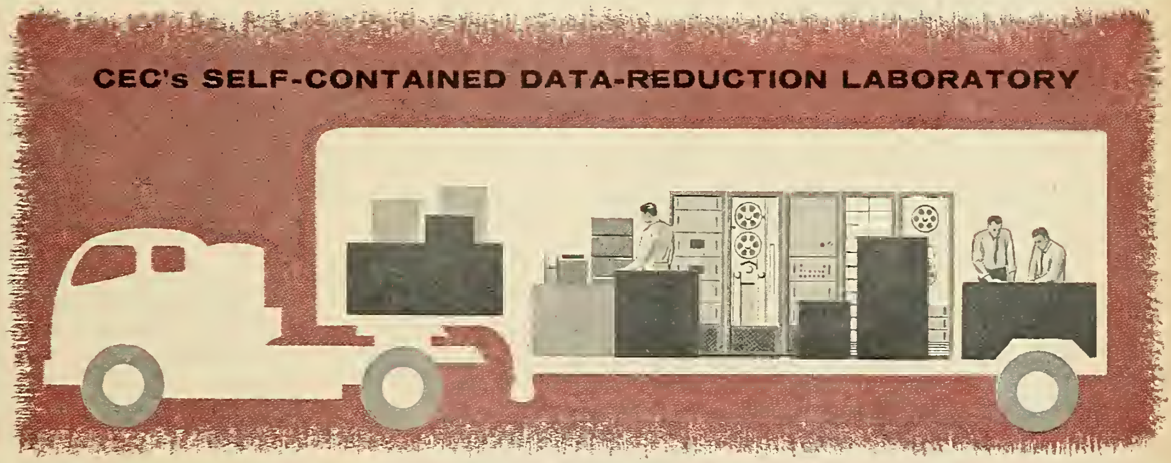

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Missile Miscellany

By 1/1/58, this page hears, solid propellants will be able to do anything liquids can (and more) with greater safety, readiness and reliability--all at less cost. This includes city-killer missile ranges up to 12,000 miles and large satellite vehicles. In fact, from propulsion viewpoint, new SPR mass ratios may obsolete Titan, Atlas, Thor, Jupiter overnight.

But then, National Bureau of Standards has produced atomic nitrogen and oxygen; possibly atomic hydrogen and the hydroxyl ion. Made at 2450 megacycles, they are stored at 4.2°K by molten helium. So goes the see-saw.

Add the Navaho demise, White House missile ire, etc., and signs are many that the young, precocious, expensive missile industry is heading for a jolting shake-out. While some companies will fall, stunned and flattened or wholly shattered, others will rebound vigorously from reality's hard floor. And the missile business, emerging from the remains of the aircraft industry, will headline new names among the old. This page figures the future's for those who stick to facts; that for those who would cite fact and fiction as one, tomorrow will be rough; end early. And speaking of facts, like dates, those who have reason to fear the first shake should beware the ides of October.

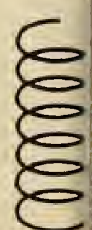
All of which goes to a bit of morning coffee philosophy: Namely, that the missile industry cannot long survive based on the premise that (apologies to P. T. Barnum) "a taxpayer is born every minute!"

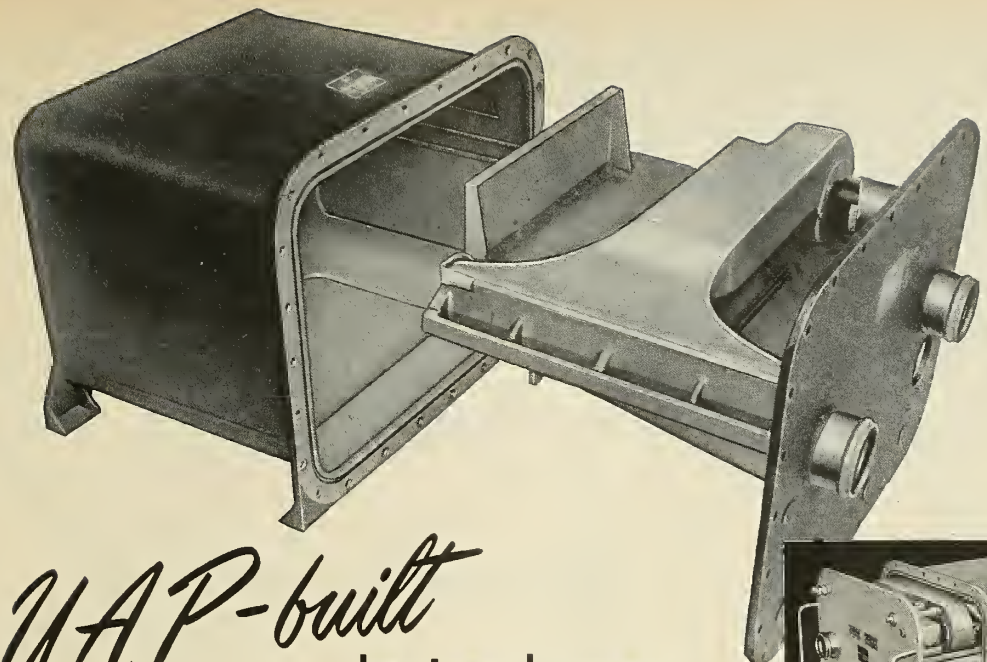
And as a further sign of the times, other groups similar to Omar (Olin-Mathieson, Marquardt, Reaction Motors) are forming. Their avowed goals: Take missile business away from the aircraft industry; develop civil uses for rockets. Their means: Production knowhow. Watch their stocks.

In contrast to $269 million in reentry nose cone development contracts to GE and AVCO, this page recently heard a Wilmington company claim it can meet the need with ease and inexpense of a potter spinning soup bowls. An NACA-tested 1/2-inch thick disc of its material failed to disintegrate or crack under 20-second blast of 12,000°F plasma jet.

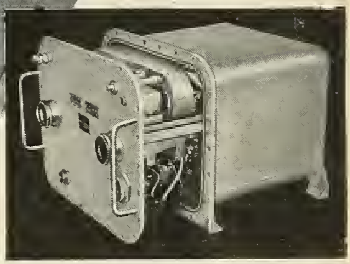
And back to a favorite subject: What happens to a sub-critical mass of plutonium that's accelerated to relativistic velocities? And another: Why won't heat flow faster when the potential difference is greater?

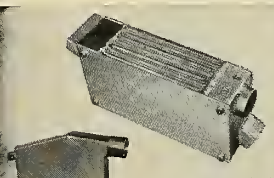
Lest we forget, missiles are a tough business as witness accelerations of plus or minus 40 G's at frequencies up to 600 cycles imposed on missile body by Snark boosters . . . And from the University of Dayton word of work on a reentry test vehicle . . . A rumor that AF may do operational testing of big missiles with nuclear warheads from Pacific coast because of danger of clobbering South Atlantic friends and possible fact Soviets have Florida range better instrumented than AF . . . Suggestion that wherever they're tested, some insurance company might do well to sell anti-missile insurance to those in line of fire . . . Plans for inertial guidance in airliners and FBM-launching submarines contrast with German use of inertial systems in WW I submarines . . . Russia's studying compatabilities of isolated pairs of men and women in arctic experiments--Adamsky ee Evesky on Mars maybe? Dr. H. C. Urey wants to chip study chunks off the moon with nuclear war-headed missiles . . . Smithsonian Astrophysical's Dr. T. E. Sterne figures life of 200-800-mile high satellite at nine years . . . If he gets job here, Dr. Hermann Oberth may cancel his return to Germany . . . Add Danes and Norwegians (but not m/r's exec-ed.) to those taking missile courses at Huntsville . . . Residents of San Fernando valley have timed Rocketdyne engine tests up to two minutes . . . To the right: One way to get ultra-long burning times for solid propellants in minimum length . . .



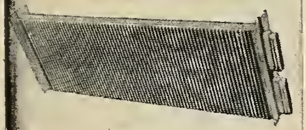


UAP-built heat exchanger, chassis-case assembly for compact pressurized airborne electronics*

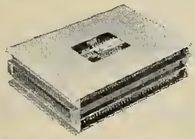




AIR TO AIR HEAT EXCHANGER, ELECTRONIC EQUIPMENT APPLICATIONS.



COLD PLATE FOR MOUNTING IN "BLACK BOX" WHICH HOUSES PRINTED CIRCUIT ASSEMBLIES; 1 AIR PASSAGE.



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**Unit shown designed by Ohio State University Research Foundation —Air Force Cooling Study Project, W. Robinson, Supervisor.*

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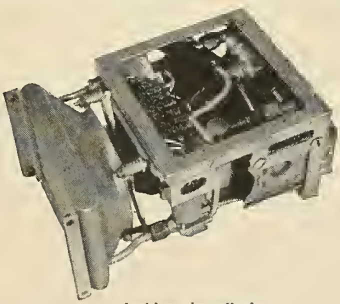

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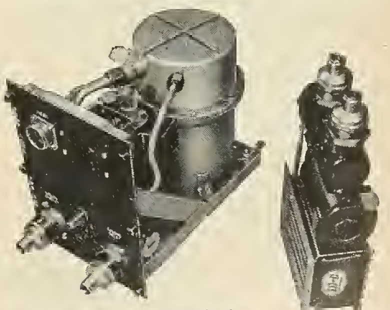

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INDUSTRY SPOTLIGHT

By Norman L. Baker

Thiokol Geared for Solid Propellant Business Boom

ELKTON, MD.—The Thiokol Chemical Corp. may well play the lead role in the military planners increasing emphasis on solid propellants for missile propulsion units of the future. The list of the nation's operational missiles gives Thiokol an impressive lead as supplier of solid power plants.

Lockheed apparently has released a contract to Thiokol for the initial testing of the powerplant for the Navy's Fleet Ballistic Missile, *Polaris*. Largest solid propellant missile officially revealed the *Polaris* will have a thrust of about 300,000 lbs. Reportedly Thiokol was selected for the testing phase of the *Polaris* motor development because of its advanced state of the art in developing large high-thrust solid propellants. This further indicates that Thiokol has been pioneering work in the high-thrust field for some time.

Significant is the fact that this work may have stemmed from the *Big "B"* ballistic missile program (m/r July 57, p. 48). Reported to be a 2000-mile Army missile powered by a Thiokol solid propellant motor its thrust rating would be comparable to the *Polaris* propulsion unit. A companion project, *Little "B"*, 750-mile ballistic missile, also will rely on Thiokol for powerplant development.

First flights under the Air Force Office of Scientific Research space program. Project *Far Side,* scheduled to begin this fall, will utilize a multistage solid-propellant rocket configuration. The motors, classed as off-the-shelf units, will be provided by Thiokol and Grand Central. *Recruits* will form the four-barreled first stage. A single *Recruit* will make up the second stage. Third and fourth stages will be modified *Loki* rockets. The fourth stage rocket will be nestled within the package of the four-rocket third stage. *Recruit* power plants are produced by Thiokol while the *Loki* is a development of Grand Central.

Thiokol's solid propellant development history can best be summed up in a list of existing operational missiles. The diversified program required to provide propulsion units for these varied weapon and research vehicles is quickly apparent. The motors range from boosters for the *Matador* and *Goose* to sustainer motors for *Falcon, Nike Hercules, Lacrosse, Terrapin, RV-A-10, Cajun, Recruit, Sergeant, Polaris, Big "B", Little "B"*, and the rocket motor for the new RESCU *Mark I* rocket ejection seat catapult.

Continuing research at Thiokol is conducted in the fields of propellant processing, manufacturing techniques, case-liner-propellant bonding, new material research for case fabrication and new propellant applications. Propulsion units developed at Thiokol range from "thimble-size to those limited only by practical mass-ratio values." Usually, as the size of the motors increase, the weight of the casing also increases until the mass-ratio value makes the design impractical. The search for new materials such as titanium and plastics is a continuing effort of the research team.

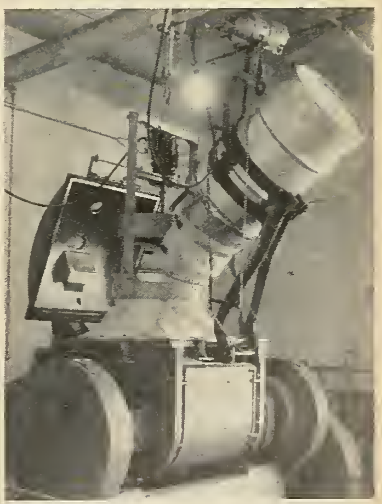
To the question of possible solid-propellant ICBMs, a company spokesman answered, "The development of a missile of the magnitude required for an ICBM is well within the realm of feasibility at the present time." This indicates a major reduction in the weight of the casing, a technical breakthrough which could very well mean the elimination of the size-limitation of solid rockets.

A major contribution to the field of solid propellants is the "case-lined cast-in-place" composite fuel mixture, a pioneering effort by the Thiokol Chemical Corp. With this system the composite fuel mixture is cast into place as a liquid and allowed to solidify. This permits bonding of the fuel charge directly to the internal walls of the pressure chamber. Insulation or cooling of the chamber casing and weight of supports is eliminated. Since the burning progresses from the interior toward the chamber wall, the chamber is protected from the heat of combustion by the propellant itself.

The elimination of the weight of inert components and utilization of a lighter, thinner engine chamber resulting in higher mass ratio values, makes the case-lined cast-in-place solid propellant adaptable to high performance systems. Thiokol's case-bonded composite-type propellants are readily adaptable for such an application. This is the determining factor for their apparent lead in the present emphasis on solid propellants for missile weapon systems.

The composite propellants produced by Thiokol are formulated principally of a polymer manufactured by Thiokol, an oxidizer salt, and a small percentage of chemical additives. The dry oxidizer and the polymer are dumped into a mixer by remote control. In the meantime a liquid layer of rubber is applied to the inner surface of the rocket casing and cured. This rubber acts as a bonding agent between the case and the propellant.

When the propellant has been thoroughly mixed it is discharged to a transfer can for the casting operation. The mixture is pressure-pumped from the transfer can into the rocket casings. The mixture is very viscous during this phase of the processing. A core, designed to form the internal configuration of the burning surface, is inserted in the raw propellant. The package is then cured in an oven until the mixture



Dry oxidizer salt is mixed with a Thiokol polymer. Mixing operation is by remote control.

reaches the solid rubber state. The propellant is ready for trimming for the attachment of the rocket nozzle after removal of the core.

The discovery and development of Thiokol synthetic rubber by Dr. J. C. Patrick during the 20s led to the formation of the Thiokol Corp. in 1929. In 1941 a plant was installed at Trenton, N. J. for production of a solid polysulfide synthetic rubber and by 1945 this plant was marketing the basic component of Thiokol propellants, a polysulfide liquid polymer.

Thiokol currently operates six plants and laboratories: Main Offices, Trenton, N. J.; Redstone Division, Huntsville, Ala.; Elkton Division, Elkton, Md.; Longhorn Division, Marshall, Texas; Chemical Plant, Moss Point, Miss.; the Utah Division, Brigham City, Utah.

The Elkton Division was the first to undertake research and development on solid propellants and JATOs under contract with Army Ordnance. Main rocket activities were transferred to the Redstone Division in 1949. Research and development on industrial products are carried out at the main plant in Trenton. The facilities at Redstone and Elkton concentrate on rocket research for the Armed Forces. Although some production work is handled by Redstone and Elkton, the major production effort is at Longhorn.

The Utah Division, latest expansion achievement, recently began test operations. The new test stand at Utah will accommodate motors up to 12 feet in diameter and resist a two million pound load. The testing section is the first major portion of the facility while rocket motor mnaufacturing will commence this fall.

Thiokol employs over 2500 people, over 300 of whom are chemists, chemical engineers, mechanical engineers, mathematicians and physicists.

RMI Expands For Solid Propellants

Reaction Motors, Inc. has announced creation of a separate department for handling solid propellant fuels. Designated the Applications Engineering Department for Solid Propellant Rocket Power Plants, the new department will be headed by William M. Davidson and will be responsible for the development of new business in the field of solid propellants.

RMI's reorganization points out the growing trend in the industry toward the solid propellant fuels. This is the first time in RMI's history that a separate department for solid fuels has been set up, and it reflects the company's interest in this phase of rocket fuel development.

In the six months since the Institute of Aeronautical Sciences meeting heard speakers deplore the lack of exploitation in the solid propellant fuel field, there has been a distinct trend toward utilizing the fuels to a greater extent. Previous reluctance was laid to reliance on performance figures based on black gunpowder rockets. Judging by RMI's move and those of other producers of fuels, this is no longer true.

Mathieson Plans Propellant Expansion

Olin Mathieson Chemical Corp. has announced a four year expansion program to increase their facilities for developing and producing high energy, solid propellants. New R&D laboratories, pilot plants, and test and production facilities will be constructed at the company's Ordill works, near Marion, Ill.

The program at Ordill will involve the development of new propellants and new processes for the production of propellant grains for rocket engines. The company also plans to expand its development and production of gas generators for auxiliary power units on jet engines and missiles. In addition, it will cast double-base propellants which involve Mathieson's "ball powder" techniques and composite propellants for rocket engines in missiles.

These expansion programs are part of Mathieson's general plan to increase all their research, development and production in the broad field of fuels and propellants, including the new high energy chemical fuels. Two plants for the production of "zip" fuels are already under construction in Niagara Falls. The current program marks the company's first major effort in the field of solid fuels for rocket engines.

Rocketdyne Operates Vacuum Wind Tunnel

Rocketdyne engineers are now using a wind tunnel that pulls high speed air through a vacuum to simulate conditions at extremely high altitudes. The vacuum wind tunnel will be used in probing the performance of rocket engines and testing their components at these altitudes. The tunnel, located at the company's Los Angeles plant, is one of the first designed for high altitude rocket study.

In the tests, compressed air will be released in a supersonic rush through scale models of rocket engine thrust chambers resembling the narrow waist and flare of a hoop skirt. To duplicate the upper atmosphere, the two-foot-wide testing chamber of the tunnel will be maintained under a partial vacuum adjusted to varying altitudes.

Final instrumentation check-out is made on rocket engine thrust chamber in test section.

Aerojet Sets Up Astronautics Lab

Aerojet-General Corp. has set up an Astronautics Research Laboratory to study advanced propulsion systems, astrophysical chemistry and materials. The laboratory's propulsion section expects to work on research involving ultra-high-energy chemical propellants, ion propulsion systems, gaseous free radical propulsion and nuclear plasma propulsion systems. In addition the lab will study all systems capable of high velocity extra-terrestrial flight. Director of the lab will be Y. C. Lee, Aerojet Director of Research, and Milton Farmer, Associate Director of Research.

Convair Occupies *Atlas* Production Plant

Convair-Astronautics has begun moving into its $40 million plant for the production of the *Atlas* ICBM. The plant, located on the northeastern outskirts of San Diego, is expected to be completely occupied by January. Moving plans and final construction plans were coordinated to afford a minimum of work interference on the missile, which is now in pilot production.

More than 7000 persons will be shifted to the plant. The million-square-foot plant will replace Convair's San Diego facilities as the headquarters of Convair's *Atlas* program.

The engineering lab will be the first section to be occupied, followed by the office and reception center buildings. The factory building is scheduled for full use by mid-January. Total cost of the plant and its equipment will exceed $40 million, divided almost evenly between Convair and the Air Force. Convair is paying for the land, buildings and some of the equipment, with the AF providing most of the heavy equipment, including machine tools.

Chrysler Lists 1300 *Redstone* Subcontractors

The Army's prime contractor in the *Redstone* Ballistic Missile system, Chrysler corp. has compiled a list of vendors from whom purchases have been made during the program. The list is said to name over 1300 firms in the U.S. from whom purchases were made for the production and research and development phases only. There are a total of 1675 vendors in 34 states and the District of Columbia.

Chrysler's breakdown of the figures show that: 811 of the firms, or 48.4% employ less than 100 persons; 519, or 31% employ from 100 to 500; 121, or 7.2%, employ from 500 to 1000; and 224, or 13.4%, employ over 1000 persons. Since "small business" is usually defined as those employing under 500 persons, the actual number of such vendors is 1330 or 79.4%.

AC Spark Plug Receives *Thor* Guidance Contract

AC Spark Plug Division of General Motors has been awarded a $38-million contract from the Air Force for research, development and production of the inertial guidance system for the IRBM, *Thor*. Authority to begin work under the contract was given some months ago by the Ballistic Missiles Office, Air Materiel Command, which awarded the contract.

GE Gets Contract For Reentry Nose Cones

General Electric's Missile and Ordnance Systems Department in Philadelphia has been awarded a $158-million contract to develop nose cones for the *Atlas* ICBM and the *Thor* IRBM. The company's Nose Cone Section, under R. W. McFall, is staffed by 2000 people engaged in research, systems engineering, design engineering and development manufacturing of the nose cone.

West Coast Industry

By Fred S. Hunter

"First *Atlas* Ends in Failure" is the way the headline read in a widely-circulated national magazine. Well now, let's see! What, actually, constitutes "failure" in the test firing of the prototype of a new missile? How do you define it? Matter of fact, if you learn anything at all from the test firing of an experimental missile, can you call it a failure?

If something starts to go wrong on the first flight—or any test flight—of a manned aircraft, there's a pilot aboard to bring the airplane back to the hangar. Occasionally, a test pilot has to bail out, but normally he's able to return to base and continue the test program with the same airplane after fixes are accomplished. By contrast, if a missile starts to wobble, there's no alternative but to blow it up. You don't get to bring it back and use it again.

Where do you draw the line of "failure." We're reminded of the news writer who coined the phrase "*Snark*-infested waters" in describing Northrop's troubles with early XSM-62s in Florida. Northrop lost 13 experimental *Snarks* in these early tests. Now, successful *Snark* flights have become commonplace over a 2000-mile range in the Atlantic. The missile's reliability is one of its stronger points. How did Northrop accomplish this? Through the things it learned from the 13 losers. Would you say they were failures?

•

With the Air Force dropping North American's *Navaho*, what happens now to Wright Aero's ramjet engines? The *Navaho* was the only vehicle for which these particular engines were scheduled. But not many ramjets are in the works and the Air Force might consider an R&D contract for continued development advisable. Moreover, the Wright engines are big ones—48 inches as compared to 28 inches for the engine developed by Marquardt for the *Bomarc*. The Wright ramjets never reached flight test in the *Navaho*. It is understood that in one XSM-64 test, they were ignited momentarily at about Mach 1.5, but this wasn't fast enough to keep them going.

•

North American's new general office building in El Segundo is on the route over which Northrop trucks *Snarks* from Hawthorne to the Los Angeles International Airport for loading on Air Force C-124s, and all Lee Atwood and Larry Waite have to do is look out the windows to count their competitor's deliveries.

•

Air Force's announcement that General Electric's $158-Million nose cone contract covers both the *Atlas* and *Thor* missiles would seem to be fair evidence that the Douglas IRBM is still in business and should set at rest rumors that it's shaky. Avco's contract for the nose cone of the *Titan* came to $111 million. It doesn't necessarily follow that the same dollar amount of GE's contract applies to the *Atlas*—it might even be less—but it isn't unreasonable to use it as a measurement and this would leave $57 million of the GE order for the *Thor*. Whatever else may be said of the *Thor*, it certainly is the "quickie" of all the ballistic missiles. Douglas had the first article on the pad within one year's time.

•

Rocketdyne estimates two-way radio systems installed in eight trucks operating out of the Canoga Park plant enable present equipment and personnel to accomplish about a third again as much work.

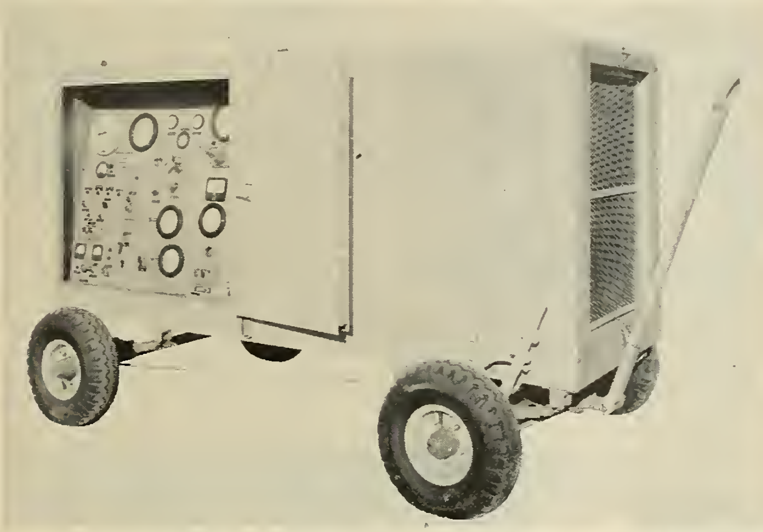
NEW MISSILE PRODUCTS

MISSILE CHECK-OUT UNIT

A portable hydraulic power supply unit, designed by Haskel Engineering and Supply Company, serves as a source of high pressure hydraulic power for guided missiles requiring precise circuit check-out prior to launching. Designed for use with OS-45 high-temperature synthetic hydraulic fluid, the power supply contains two independent hydraulic circuits with a capacity of 20 gpm and providing pressures up to 5000 psi.

source of trouble has been corrected. Indicator lights are provided to locate the trouble.

The system features automatic pre-fill and bleed of the hydraulic circuits and is provided with a nitrogen purge pressurization system to preclude the possibility of contaminating the fluid. An automatic control is provided for the air type heat exchanger to maintain proper fluid temperature. Flow indication,



The unit is designed for remote control for personnel safety and its two circuits are both overheat and back-pressure controlled to shut off pressure and return in either circuit in case of excessive heat or back pressure. These controls also provide for dumping the pump output back into the tank and it is not possible to re-energize either circuit until the

system selection, on and off operation and emergency shutdown can all be achieved remotely. The unit is mounted on roadable running gear using light-weight Air Force Arctic tires. The cooling system, electrical system and piping can be serviced from separate access doors.

Circle No. 220 on Subscriber Service Cord.

COUNT RATEMETER

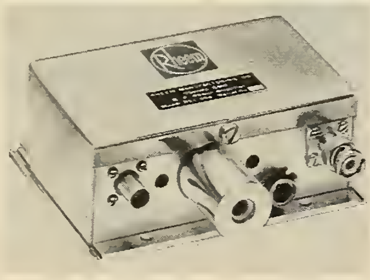
Nuclear Measurements Corp. has introduced its manual range changing linear

count ratemeter, model CRM-11. The instrument detects radioactivity sensed by GM, scintillation and proportional counting detectors. It is equipped with six linear scales, ranging from 0-300 C/M to 0-300,-000 C/M. Dimensions are 22 x 15 x 10½ inches.

Circle No. 212 on Subscriber Service Cord.

POWER AMPLIFIER

Rheem Electronics Division has introduced a new power amplifier for use



in airborne telemetering systems which is available in 17 configurations. Designated the REL-09 RF Power Amplifier, the unit is a single package containing volume, connectors, filament voltage and cathode bias, varied to extend the range of application. The product weighs 16 ounces.

Circle No. 214 on Subscriber Service Cord.

INSULATING VARNISH

Lynn Engineering Co. is distributing an insulating varnish capable of withstanding temperatures from —55°C to 250°C, and which is unaffected by gasoline, oils (including ester oils), alcohol, jet fuels, moisture and fungus. Known as Ulti-Meg 110, the varnish is suited for use on high speed rotating machinery and to all types of equipment subject to severe vibration. The chemical reaction of the product is completed during the baking cycle, producing a molecule which is physically and chemically stable and retaining its insulating qualities indefinitely.

Circle No. 206 on Subscriber Service Cord.

SMALL POWER UNIT

Rheem Electronics Division has developed a special miniature power supply for missile telemetry applications.. It provides one unregulated high voltage output, one regulated HV output and a 6.3 volt heater supply. The unit is constructed for maximum reliability under environmental extremes.

Circle No. 204 on Subscriber Service Cord.

CERAMOPLASTIC RADOME

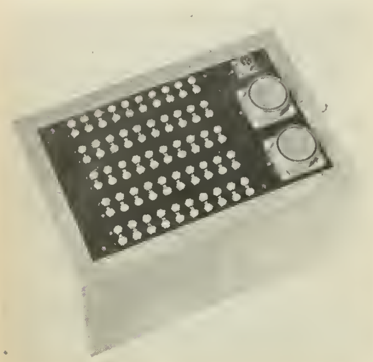
A new molding material for radome manufacture is being produced by Mycalex Corporation. Called "Supramica 555", the material withstands temperatures as high as 950°F. The ceramoplastic contains platelets of synthetic mica to act as "crack stoppers" holding the

material together even when cracked. Molding tolerance in wall thickness of ±.005 "can be achieved, as well as machining tolerances of ±.001". The manufacturer anticipates that the thermal endurance of the material will be satisfactory at speeds as high as Mach 3.5.

Circle No. 203 on Subscriber Service Cord.

THERMOCOUPLE JUNCTION

Pace Engineering Company is manufacturing its BRJ Series of bridge stabilized thermocouple reference junctions providing controlled temperature reference for multi-channel thermocouple measurements. The unit has precision beyond the capabilities of ice baths and cold junction compensators now in use. Up to 48 channels are available in cabinet or rack



mounted models, as well as three-wire junctions allowing a choice of thermocouple materials in each channel.

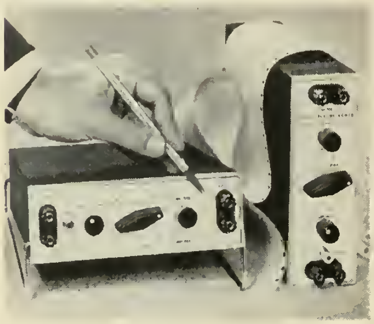
Long term temperature stability within 1/5°F is achieved with an integral resistance bridge temperature sensing system and magnetic-amplifier controlled heater. The reference temperature may be set to any specified level from 25° above ambient to 250°F and thermocouple tables are available for the standard reference temperature of 150°F.

Several models are offered with a variety of input arrangements and output coupling, thermocouple types and number of circuits. The reference junction is also furnished as part of an integrated control and calibration system for oscillograph recording. The unit's weight is 25 lbs., and it measures 10 x 10 x 15 inches.

Circle No. 218 on Subscriber Service Card.

TRANSISTOR AMPLIFIER

A completely transistorized electronically modulated DC amplifier for use with milliammeter recorders has been introduced by Texas Instruments Inc. The amplifier has a sensitivity range from 10



millivolts DC to 100 volts DC full scale in 12 ranges. Frequency response is up to 50 cps. Specifications on the model 301 are: 7½ x 10 x 2½ inches; 4¾ lbs.; input impedance is 2.5 megohms per volt; output impedance is 39 ohms and absolute accuracy is 2% of full scale.

Circle No. 200 on Subscriber Service Card.

BISTABLE DIODE

Shockley Semiconductor Laboratory has produced a new type diode. It is a low-power four-layer switching diode. The

two-terminal silicon device is capable of existing in either an open or high impedance state (1 to 100 megohms) or a closed or low impedance state (1 to 10 megohms). The diode is switched from one state to the other by controlling voltage and current values.

Typical value ranges are: firing voltage ranges from 20 to 60 volts; holding currents of 25 ma or somewhat less, at

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about one volt; switched current capacity of 100 ma; maximum power dissipation of about 100 milliwatts; and switching rates of about 1 mc.

Circle No. 211 on Subscriber Service Card.

REDESIGNED PREAMPLIFIER

A new weatherproofed and pressurized preamplifier design is announced

by Nems-Clarke, Inc., for use with telemetering receivers. The company says line losses as high as 6 db will not decrease the sensitivity of the receiving system by more than a few tenths of a db. The pass band has a uniform response of 3 db over a frequency range of 215-245 mc. The unit has a self contained power supply controlled from a 1¾" power control panel mountable in a relay rack with other receiving equipment. Similar units are available in the frequency range 225-260 mc.

Circle No. 210 on Subscriber Service Card.

WAVEGUIDE PRESSURE WINDOW

A new waveguide pressure window for half-X waveguide applications has

been developed by Microwave Associates. The window (MA-1339) covers the frequency range 9.5 to 10.1 kmc with maximum VSWR of 1.10 at the band edges. Resonant frequency is 9800 mc. It is used in .2 x .9 ID waveguide applications. Maximum power rating is 20 kw. Maximum pressure handling capability is 45 lbs. on the glassed side of the window and 30 psi on the opposite side. Window construction is of kovar and glass.

Circle No. 201 on Subscriber Service Card.

people

Dr. Joachim W. Muehlner has been appointed a consulting scientist in Lockheed Missile Systems Div.'s research and development branch at Palo Alto. **Dr. Muehlner** was technical director of the range instrumentation development division, Army Ordnance, at White Sands Proving Ground for more than five years before joining Lockheed.

J. Y. Cunningham will head the new Missile Development Division organization at North American Aviation, which has just been separated from the Los Angeles Division. Other appointments in the new division are **R. M. Stronks,** manufacturing supt.; **Fred Burry,** general supv. of manufacturing services; **Harry Armour,** general supv. of missile planning; **D. F. Ziegler,** general supv. of missile tooling.

The new development planning staff at Fairchild Guided Missiles Division will be headed by **Harry Iddings** who was formerly associated with Cornell Aeronautical Laboratory.

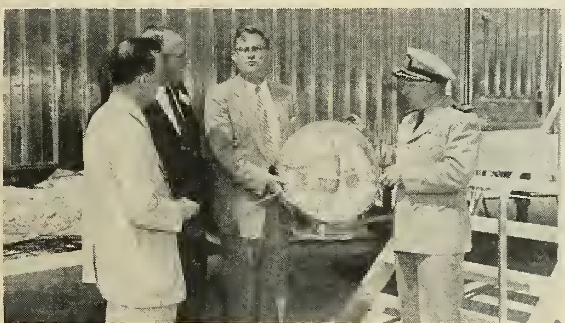
Albert E. Schwerin, manager of Flight Test Engineering for General Electric's missile and ordnance systems department, has been assigned to the Air Force's Missile Test Center. He will head up his department's test activity at Patrick Air Force Base.

Lt. General Laurence C. Craigie (USAF, ret) has been elected to the Board of Directors of the Associated Missile Products Corp. **T. Rogers McNamara,** of Hughes Aircraft Co., has been appointed accounting manager of the corporation.

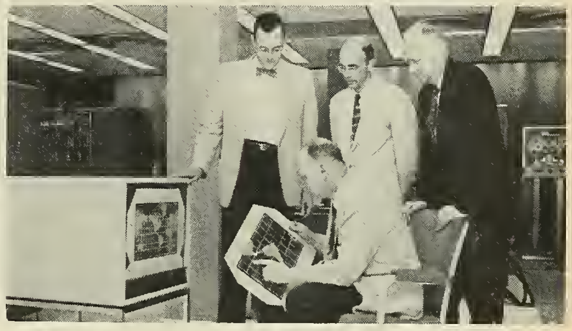
Dr. Michael Markels, Jr., formerly manager of heat transfer operations, Columbia University Heat Transfer Research facility, has been appointed to head Atlantic Research Corp.'s nuclear activities.

Willem Schaafsma has been named director of projects for the Grand Central Rocket Co. **Stanley Waxman,** former director of R & D, succeeds Schaafsma as director of engineering and research.

Wilfred E. Walton, formerly with General Electric, has been appointed director of engineering at American Machine & Foundry Co.'s Rochester Division.



Minitrack equipment for station No. 1 and a VANGUARD model are inspected by (left to right): Dr. J. P. Hagen, Project VANGUARD Dir.; A. E. Abel, Gen. Mgr. Bendix Radio Div.; J. T. Mengel, Chief, Tracking and Guidance, NRL.; Capt. P. H. Horn, Dir. NRL. Vans equipped by Bendix are heading for S. American Minitrack station sites.



Naval Research Lab. scientists examining a map overlay on which the IBM 780 cathode ray tube output display will trace earth satellite's path. Left to right: Dr. J. W. Siry; Dr. Paul Herget; H. Chrisman; J. J. Fleming. Herget is in charge of computation at VANGUARD Computing Center installed by IBM in Washington, D. C.

Above, Robert Edwards, newly appointed Bus. Mgr., Cook Research Lab., Cook Electric Co. Below is D. A. Bair, Mgr., Reliability Test Section, Cook's Inland Testing Lab., a multi-million facility to include world's largest (100,000 curies) gamma radiation source.

people

Adm. John H. Sides, deputy to the special asst. to the Secretary of Defense for guided missiles, will assume the rank of vice admiral and report as director, weapons system evaluation group, Department of Defense, on August 1.

Edward C. Wagner has been appointed to the post of assistant to the vice president for engineering, Ford Instrument Co., Division of Sperry Rand Corp.

Max Moore has been appointed chief engineer for the Precision Potentiometer Division of General Controls Co.

E. Douglas Reddan and Norman C. Anderson have been elected president and vice president respectively of Infrared Industies, Inc.

George S. Schairer has been appointed director of research for Boeing Airplane Company. He was formerly chief engineer of the Seattle division.

Jack E. Shuck, formerly a colonel in the Air Force's Air Materiel command, has been appointed a staff scientist on the Product Planning Staff of Lockheed Missile Systems Div.

Charles L. Backus, Jr., has been appointed manager of the Dayton office of Autonetics, a division of North American Aviation, Inc.

S. G. Gregory has been named for the newly created position of director of personnel services for Borg-Warner Corp.

Willis M. Hawkins, asst. gen. mgr. of Lockheed's Missile Systems Div., has been appointed a member of the U.S. Army Scientific Advisory panel.

Dr. Jacob L. Zar, the Guided Missiles Div. of Republic Aviation Corp., has been appointed director of engineering by Airborne Accessories Corp.

Robert J. Mill has been named manufacturing mgr. of Aerojet-General Corp.'s Liquid Rocket Plant at Sacramento. **Y. C. Lee** has been appointed director of research and planning for Aerojet's Liquid Engine Div.

Convair Division of General Dynamics Corp. has announced the following new assignments: **William C. Dietz,** chief of B-58 project; **Norm H. Simpson,** senior project engineer; **Don R. Kirk,** senior project engineer; **Robert W. Moller,** asst. mgr. of B-58 flight test program; **J. F. Robinson,** chief of engineering test laboratories; **R. P. Scott,** chief of engineering flight test; **William H. Crow** and **J. C. Thurmond,** asst. chief design engineers.

Reginald R. Kearton, formerly director of nuclear projects for Lockheed's Georgia Div., has been named director of the new sales branch of company's Missile Systems Div. at Sunnyvale.

James R. Merrill has been named mgr. of Raytheon Manufacturing Co.'s Santa Barbara (Calif.) laboratory, succeeding Harold E. Beveridge, resigned.

John E. Ranks, who served as a missile test officer at sea and as officer-in-charge of the Officers Electronic School, Treasure Island, Calif. during the Korean war, has been appointed mgr. of the Small Systems Dept.'s product engineering section at ElectroData Div. of Burroughs Corp.

Dr. John W. Bond, Jr., has been appointed chief of the physics group at Convair-San Diego.

Edward E. Slowter has been elected vice president of Battelle Memorial Institute, Columbus, O.

Rheem Manufacturing Co.'s new Aircraft Div. has announced three key appointments: **Glen S. Gipson**, western district sales mgr. with hq. at Downey, Calif.; **P. J. Raferty**, district representaitve in Chicago; **V. E. Selvig**, legal advisor.

The following management changes are announced by Olin Mathieson Chemical Corp.: **John M. Olin**, chm. of financial and operating policy committee as well as chm. of the exec. committee; **Thomas S. Nichols**, chm. of board of directors; **Stanley de J. Osborne**, president of the corporation.

Robert Lee Baddorf has been appointed chief engineer of Topp Manufacturing Co.

Wade Wolfe, Jr., has been named technical liaison mgr. in the construction engineering dept. of Olin Mathieson Chemical Corp.'s high energy fuels organization.

Richard E. Welch, vice president and treasurer of W. M. Welch Mfg. Co., Chicago, was elected president of the Scientific Apparatus Makers Assn.

Ralph Carlisle Smith, asst. director of Los Alamos Scientific Laboratory, has been appointed assistant to the president of the Nuclear Products-Erco Div., ACF Industries, Inc.

Edmund B. Parke has been named director of Production Div. at Reaction Motors, Inc.

Baboo Ram Teree has been elected vice president—engineering and manufacturing of Greer Hydraulics, Inc.

John Carter, a vice president of Corning Glass Works, has been elected president of Fairchild Camera and Instrument Corp.

J. M. Miller has been placed in charge of all design activity on equipment for the Talos missile and **E. F. Lapman**, now chief electronics engineer, has the responsibility for design for all electronic systems, Products Div., Bendix Aviation Corp.

J. E. Schaefer of Wichita has been elected vice chairman of Boeing Airplane Co.

Dr. Seymour B. Cohn has been appointed mgr. of Stanford Research Institute's Antenna Systems Laboratory.

Dr. John P. Nash has been appointed mgr. of the information processing division, Lockheed Missile Systems Div.'s research and development branch.

David E. Shonerd has been named president of Era Engineering, Inc.; **Harold D. Hutchinson**, vice president; **Mary F. Cramer**, treasurer; and **Glendon Tremaine**, secretary.

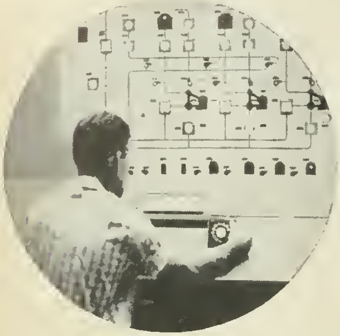
Gladyln H. Putt has been named executive assistant to L. Eugene Root, vice president and gen. mgr. of Lockheed's Missile Systems Division. Putt was formerly with RAND Corp. as executive assistant to the president.

Sterling C. Spielman is the new director of engineering at Philco Corp.'s Government and Industrial Division. He was previously director of electronic engineering.

I. J. Hammill has been appointed as executive vice president and managing director of Walter Kidde & Co. of Canada Ltd. He succeeds C. K. McLeod who becomes chairman of the board.

ENGINEERS

Honeywell's "balanced" diversity brings you more opportunities



This Supervisory DataCenter, which enables one man in one location to control an entire air conditioning system for a large building, is just one of Honeywell's advanced automatic control products for civilian use. Honeywell also develops and produces advanced control devices and systems for the home, farm, industrial processing and factory automation.

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Sperry Rand Corp. Enlarges Salt Lake Lab

Sperry Rand Corporation will add a 100,000 square foot unit to its Salt Lake City Engineering Laboratory, thus tripling the size of its Utah facility. The new unit will add 90,000 square feet of manufacturing space, 5000 square feet of environmental testing space, and 5000 square feet of utility space to the north side of Sperry's present lab.

It is reliably reported that Sperry will manufacture the Thiokol solid-propellant-powered *Sergeant* missile at the facility.

Honeywell Gets Missiles Repair Contract

New military emphasis on maintenance of missile electronic equipment has resulted in the instigation of a contract repairs program by the Aeronautical Division of Minneapolis-Honeywell Regulator Co. Named to head the new program is George P. Smith, with John S. Wagner administering the integration of production facilities and possibly reorganizing plant operations.

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Lockheed Builds New R&D Center

Lockheed's Missile Systems Division has begun construction on a new lab at its Palo Alto R&D Center, increasing the center's facilities to 218,000 square feet. The new lab is the fourth 51,000 square foot lab to be built at the Palo Alto activity. This latest addition brings the division's Bay area facilities to a total of 583,000 square feet now in use or under construction. Its Van Nuys plant, with 475,000 square feet, raises the Missile Division's total plant space to more than a million square feet.

The new lab, which will be begun at about the time the third lab in the series is occupied, is next to the last in the building program of the division's 22-acre Stanford Park industrial site. Construction will be of the concrete tilt-up type reinforced with steel.

Ryan Opens New R&D Center

Ryan Aeronautical Co. is centering all its engineering, research and development work under one roof at its new half-million dollar Engineering and Research Center in San Diego. The new center includes an environmental test laboratory, a self-contained research machine shop and the main engineering laboratory.

The new center will be used for ground testing components of high-speed aircraft and missiles. While finishing touches are being put on the two-story building, installation of special equipment is commencing. The equipment in the center includes devices to simulate extreme shock, vibration, acceleration, temperature, altitude, humidity and radio interference.

RIAS Awarded Satellite Contract

RIAS, Inc., has been awarded an earth satellite contract by the National Science Foundation, in collaboration with the Franklin Institute, to carry out measurement of the heavy cosmic ray flux. The experiment requires light-weight, shock-resistant, high performance equipment that RIAS is developing with the Martin Co.

The two companies have succeeded in developing a transistorized pre-amplifier to amplify the impulses of an ionization chamber that will detect the cosmic rays in outer space.

Navy Opens *Vanguard* Computing Center

High-speed electronic calculations at the *Vanguard* Computing Center, which the Navy opened on July 2, will predict future orbits of U.S. scientific satellites. The center will be operated for the Navy by IBM, which will use their 704 electronic data processing system. In conjunction with the 704, which will be magnetic-tape operated, IBM plans to utilize an IBM 780 Cathode Ray Tube Display Unit. This visual display unit will picture the 704's computations in the form of graphs, geometric figures, engineering symbols or words and numbers. The display unit will actually picture a satellite's orbit.

W. R. Grace Co., Pechiney To Produce Silicon

The formation of a new U.S. company for the production of high-purity elemental silicon and other semi-conductors was announced in July by the W. R. Grace Co., of New York, and the French chemical and metallurgical firm of Pechiney. The two companies will combine their efforts in silicon production as they did in 1952 for the production of ammonia and urea in Memphis.

Cooper Development Will Enlarge Facilities

Cooper Development Corp. is doubling its plant facilities due to increased activity in the design and production of high-altitude research rocket devices, meteorological rockets, infrared equipment and special missile assemblies. The three way expansion program involves a new plant in Baldwin Park, Calif., a facility at Fontana, Calif., and a new addition at the main plant in Monrovia, Calif.

Engineers:
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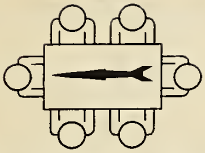

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Composed of key personnel drawn from the major departments of the Engineering Division, a Project Team must see its project through, from conception to completion. Each engineer represents his department and carries equal responsibility for the success of the operation.

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NEW PRODUCT BRIEFS

'ION MOTOR. Three phase, 200 , 400 cycle motor for intermit- ry. Unit is of internal planetary onstruction with output shaft of 200, 800, 4000, or 20,000 rpm. tios alterable to suit needs. Re- 1/4 hp, rotor shaft on anti-fric- earings. Operates at ambient tures of —100°F to 200°F. n Bosch Arma Corp.
o. 223 on Subscriber Service Card.

SAL CUTTER. Tape-controlled tool cutting head can twist or ny degree during cutting. Stop- e cut or relocating the part is sary. Northrop Aircraft Co.
o. 224 on Subscriber Service Card.

BAND ABSORBER. Broadband ve absorbent material with a n reflection of 0.1% above 8400 ws accurate testing of systems Other absorbers available with characteristics at lower frequen- F. Goodrich Co.
o. 225 on Subscriber Service Card.

OVERTER SWITCH. Precision, nant inverter, available in 75 ed variations for low-power and cuit uses. Wide variations in ratings, vibration and shock re- , and frequency ranges avail- e Bristol Co.
o. 226 on Subscriber Service Card.

ATE INDICATOR. Provides ac- instantaneous readings for set- f hydraulic feeds on machine Jnit gives feed-rate changes of d 0-50 ipm, with accuracy within Other scales available. Overall 3/4 x 9 5/8 x 4 3/4". National Auto- ool Co.
o. 227 on Subscriber Service Card.

OL ALLOY AVAILABLE. Soft ic alloy coupling high permeabil- n high wear-resistance; contains egic elements. Available in strip as .025"; maximum permeability 0 to 120,000; coercive force is sted and Rockwell hardness is). Hamilton Watch Co.
o. 228 on Subscriber Service Card.

CAL COOLANT. A chemical dielectric for airborne elec- equipment which remains pump- om —65°F to 400°F is available with "black-boxed" electronic Coolant is a silicate ester-based afe to handle and compatible most all structural and electronic ls. Monsanto Chemical Co.
o. 237 on Subscriber Service Card.

PNEUMATIC PRESSURE REDUCER. Miniature reducer with 1/4" ports conforms to MIL-R-8572A; weighs 0.17 to 0.25 lbs. depending on spring. Available with or without relief valve and adaptable to hydraulic uses. Operating temperature range from —65°F to 225°F may be altered with internal design change. Pneu-Hydro Valve Coro.
Circle No. 230 on Subscriber Service Card.

EPOXY GLASS LAMINATES. Micaply epoxy glass laminates for printed circuitry are available in black material for uses requiring this type. Standard thicknesses include from 0.032" to 0.5". The laminates are available clad in copper or unclad. Units are also available with circuits flushed to surface of the material. Mica Corp.
Circle No. 231 on Subscriber Service Card.

STANDARD DATA ANALYZER. Developed by Control Instrument Co., this unit simulates and projects machine operations, using precision potentiometers to control programming. Each of three dial-potentiometers represents a different factor in selecting optimum machining conditions. Control Instrument Co.
Circle No. 232 on Subscriber Service Card.

BLAST GAGE. Microphones linear to a 200 db level vs. 0.0002 microbars for accurate reproduction of transient pressure waves without distortion are being produced which are capable of operating continuously at 160°F. Rise times on the order of 100 microseconds are measured, showing steepness of a wave front. Overall dimensions are 2 3/8" x 5/8". Massa Laboratories.
Circle No. 233 on Subscriber Service Card.

TRANSISTORIZED CONVERTER. Power conversion unit weighing 1.06 lbs. and having a conversion ratio of 85%, with only about 2% drop in ratio at 185°F. and a ground support unit with 5 DC and 3 AC outputs and weighing 3700 lbs. are both being manufactured by Wincharger Corp.
Circle No. 235 on Subscriber Service Card.

FERRITE CIRCULATOR. A miniature ferrite phase differential circulator provides service as a duplexer and load isolator, functioning as a switching device between magnetron, receiver and antenna. The device gives sufficient insulation between the magnetron and RF energy reflected from line mismatches. Units are available in almost all waveguide sizes. Airtron, Inc.
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MISSILE LITERATURE

DESIGN RELIABILITY HANDBOOK. New materials, processes, techniques, design aids and reliability concepts are treated in this handbook by the Navy Electronics Laboratory. Also deals with preferred circuits, construction techniques, design procedures, application design data, components applications notes, machanical considerations, et al. OTS, Department of Commerce.

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DIRECT RECORDING OSCILLOGRAPHS. Illustrated bulletin describing two new models of recording oscillographs raquiring no developing or processing of the record. Midwestern Instruments.

Circle No. 102 on Subscriber Service Card.

CONVERSION FACTORS. Wall reference table for engineers and other executives that contains numarous conversions not easily located elsewhere. Precision Equipment Co.

Circle No. 103 on Subscriber Service Card.

CRYSTAL LATTICE MODELS. Chemical element, compound, mineral and alloy models are listed and illustrated in a 6-page bulletin. Models available for advanced study. Arthur S. LaPine & Co.

Circle No. 104 on Subscriber Service Card.

FLAME EXTINGUISHING AGENTS. Results of a survey on current knowledga of physico-chemical means of extinguishing flames. Topics discussed include methods of flame extinguishment, uninhibited and inhibited gaseous flame, actions of inhibitors and the burning of rocket-propellant chemicals. Special emphasis placed on future planning of flame-extinguishing mechanisms. Title is Survey of Fundamental Knowledge of Mechanisms of Action of Flame Extinguishing Agents. Department of Commerce.

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FUME HOODS. Closed type fume hoods for use in industrial laboratories are described in two peges of data. Accessories also described. Arthur S. LaPine & Company.

Circle No. 106 on Subscriber Service Card.

LINEAR ACCELEROMETERS. Bulletin illustrating and describing redesigned line of linear accelerometers, including models specifically designed for recording missile launching accelerations. Overall dimension chart included with bullatin. B & F Instruments, Inc.

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TUBE BENDING. A 24 page catalog showing products available, a list of bending dies and data on minimum banding radii. American Tube Bending Company.

Circle No. 108 on Subscriber Service Card.

REYERS BALANCES. Illustrated two pege folder describing the Reyers-Progress balance for laboratory weighing to 1/100,000 of capacity and the Reyers-Rapid balance for bulk weighing and dispensing to 1 kilogram capacity. Arthur S. LaPine & Co.

Circle No. 105 on Subscriber Service Card.

ATOMIC RADIATION EFFECTS. Biologicel effects of radiation, shielding methods, monitoring instruments, permissible radiation doses and medical evaluation and treatment of injuries are discussed in simplified terms in this 120 page book. RCA Service Co.

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MISSILE DYNAMOTOR. Data shaet on new 1500 Serias units designed specifically for missiles use. Induction Motors Corp.

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AIRCRAFT STRUCTURAL MATERIALS. Results of tests contained in two reports, one on aluminum alloys 2024 and 7075 and another on cylindrical and tubular specimens of structural alloy show causes and effects of stress, metal fatigue, torsion and reduction of strength. Department of Commerce.

Circle No. 112 on Subscriber Service Card

MINIATURIZED AUTOMATIC CONTROL. Complete circuitry information available in a 12 page bulletin describing automatic control with miniaturized non-indicating meter-relays. San Gorcini Division, Assembly Products, Inc.

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MAGNETIC TAPE. The effects of heat, humidity, and tension on magnetic tape are discussed in a three page bulletin dealing with recording of instrumentation data under extreme conditions. Minnasota Mining and Manufacturing Co.

Circle No. 114 on Subscriber Service Card

SURFACE FINISH. Booklet shows how to reduce machining costs and control surface finish, defines geometric irregularities, gives symbols for drawings, specifications and reports, gives roughness comparison specimens and classifies surface charecteristics. Brush Electronics Co.

Circle No. 115 on Subscriber Service Card

TIME, FREQUENCY CALIBRATION. Four paga illustrated folder details number of methods for using transmissions from stations WWV and WWVH for time and frequency calibration. Discusses calibration of low RF sources, upward extension of standard frequencies, AF comparisons, use of 10 cycle time pulses. Covers program schedules, code symbol notices of propagation disturbances and conditions necessary for obtaining various levels of signal accuracy. Specific Products.

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MISSILE FACTS. A sixteen paga booklet covering in general form the construction of a missile, major types of missiles, functions in a weapons system, research on missiles and peeceful uses of missiles. Generel Electric.

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VALVES. Four paga illustrated brochure dealing with check valves, ralief valves, shuttle valves and shutoff valves for missiles applications. Includes "O" ring recommendations; model, material and connection designations; and flow and seal characteristics. James, Pond & Clark, Inc.

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TIMING DEVICES. Electric timing motors, devices and clock movements described in a 30-page catalog covering hysteresis, inductors, clutch, reversible, direct-current, miniature and heavy-duty electric timing motors; time delay, interval end cycle timers and clock movements. Haydon Mfg. Co.

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