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USAF SHIELDED CAB VEHICLES TEST AND EVALUATION

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New Mexico

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HEADQUARTERS
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FOREWORD

This report was prepared by the Mechanical Equipment Branch, Support Equipment Division, Development Directorate, Air Force Special Weapons Center, under AF Project No. 8171, Task No. 817103.

The document presents the results of an in-house test and evaluation program conducted on the "Beetle" shielded remote handling vehicle manufactured by the NMPO Division of General Electric Company for the Air Force under contract AF 33(600)-38062.

The authors gratefully acknowledge the efforts and technical material which have been extended by all concerned in the preparation of this document. We are especially indebted to those organizations listed below whose representatives provided time and technical abilities to make this report possible. Individual acknowledgments have intentionally been omitted because of the great number of people who have assisted in making this report possible.

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ABSTRACT

Three shielded-cab vehicles were tested at the Nuclear Rocket Development Station, Mercury, Nevada, to determine their operational capabilities in radioactive fields. Testing was concentrated on the "Beetle," a shielded-cab vehicle with manipulators, manufactured by General Electric Company. The "Masher," a shielded T-51 Tank Recovery Vehicle, and the "Bat," a shielded Coleman Tow Vehicle, were also tested. All three vehicles were tested for maneuverability, reliability of operation, operational uses, and radiation shielding integrity. The results of the tests, in general, were satisfactory. The complexity of the Beetle requires a continuous preventive maintenance program to ensure its reliability. Much work is left to be done before the Masher and the Bat are completely reconditioned after their long period of dormancy.

PUBLICATION REVIEW

This report has been reviewed and is approved.

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Colonel USAF
Director, Development Directorate

Tyler G. Radford Col USAF
for JOHN J. DISHUCK
Colonel USAF
DCS/Plans & Operations

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1. INTRODUCTION.

There are presently three shielded-cab vehicles in the Air Force inventory, developed under the Aircraft Nuclear Propulsion program. These vehicles, nick-named the "Beetle," the "Masher," and the "Bat," are shown in figures 1, 2, and 3. The vehicles are in use at the Nuclear Rocket Development Station (NRDS), Mercury, Nevada. The Beetle is a track-laying vehicle supported by ten road wheels suspended on torsion bars anchored to the center of the hull. The Beetle tracks were taken from a T-141 US Army Tank. The chassis is a welded fabrication of heavy steel plate which contains the power plant and transmission for driving the vehicle. The Masher, a T-51 tank recovery vehicle to which steel shielding material has been added, is an early prototype of the US Army M-51 tank recovery vehicle. The Bat is a Coleman Tow Vehicle to which shielding has been added.

a. Purpose.

This document presents the results of a test and evaluation program conducted on all three vehicles. The majority of the report deals with the Beetle. The purpose of the Beetle test and evaluation program was to evaluate the vehicle's subsystems and to appraise the vehicle's operational capabilities. More limited evaluations were performed on the Masher and the Bat to ensure operator safety in a radiation area and to develop some operational concepts.

b. Authority.

Authority for this test is contained in Hq USAF 2nd Ind (AFDDC-NS) to a letter Hq AFSWC (SWVSM), 25 May 1961, entitled "Disposition of the Beetle."

2. MOBILE SHIELDED CAB WITH MANIPULATORS (BEETLE).

a. Background.

The Beetle was designed and fabricated by the ANP department of

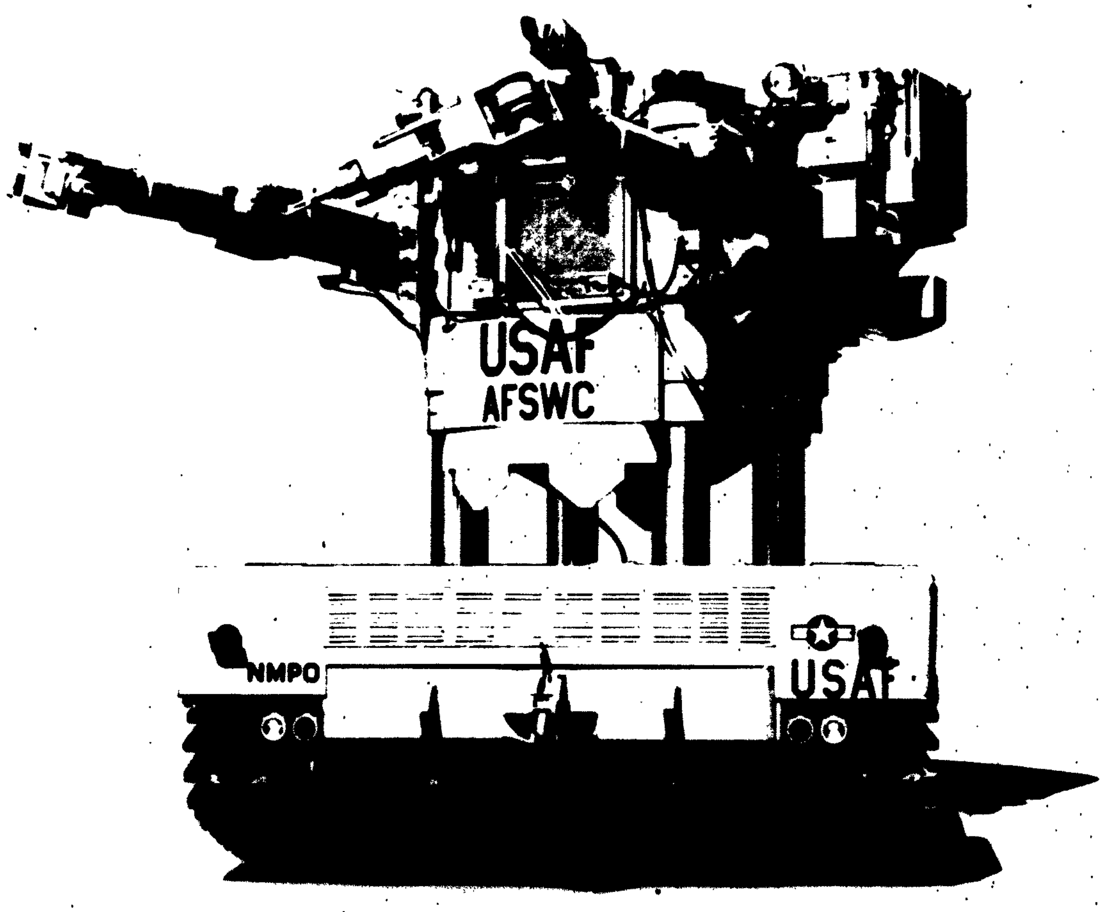

Figure 1. The Beetle

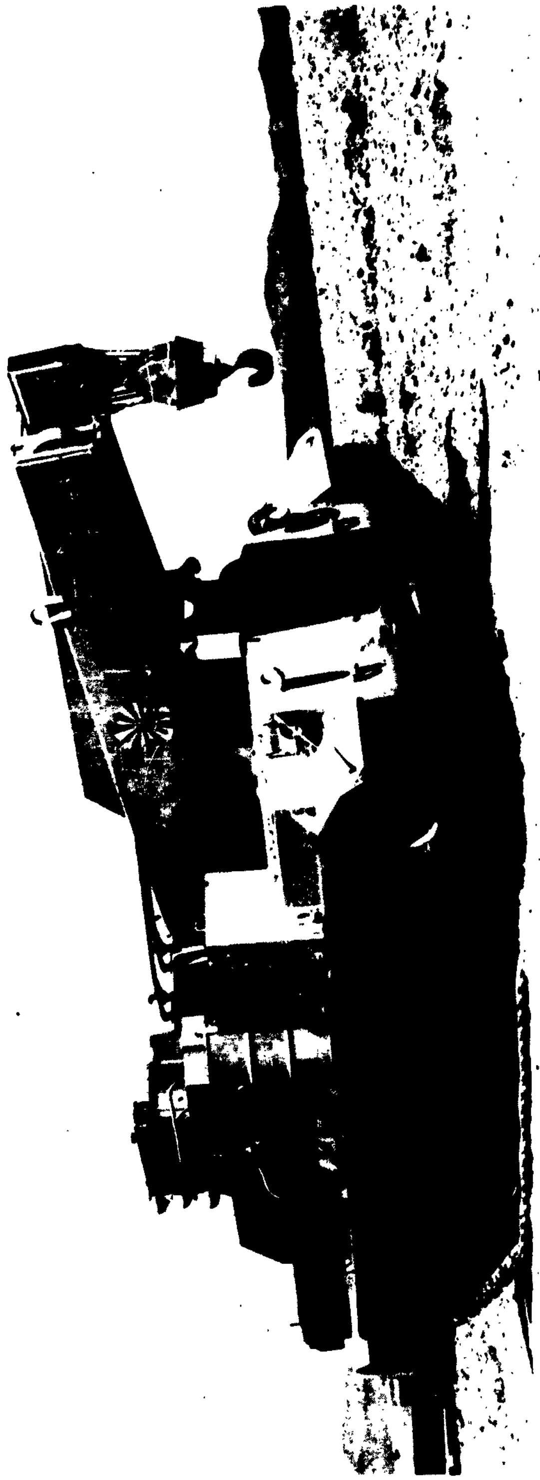

Figure 2. The Masher

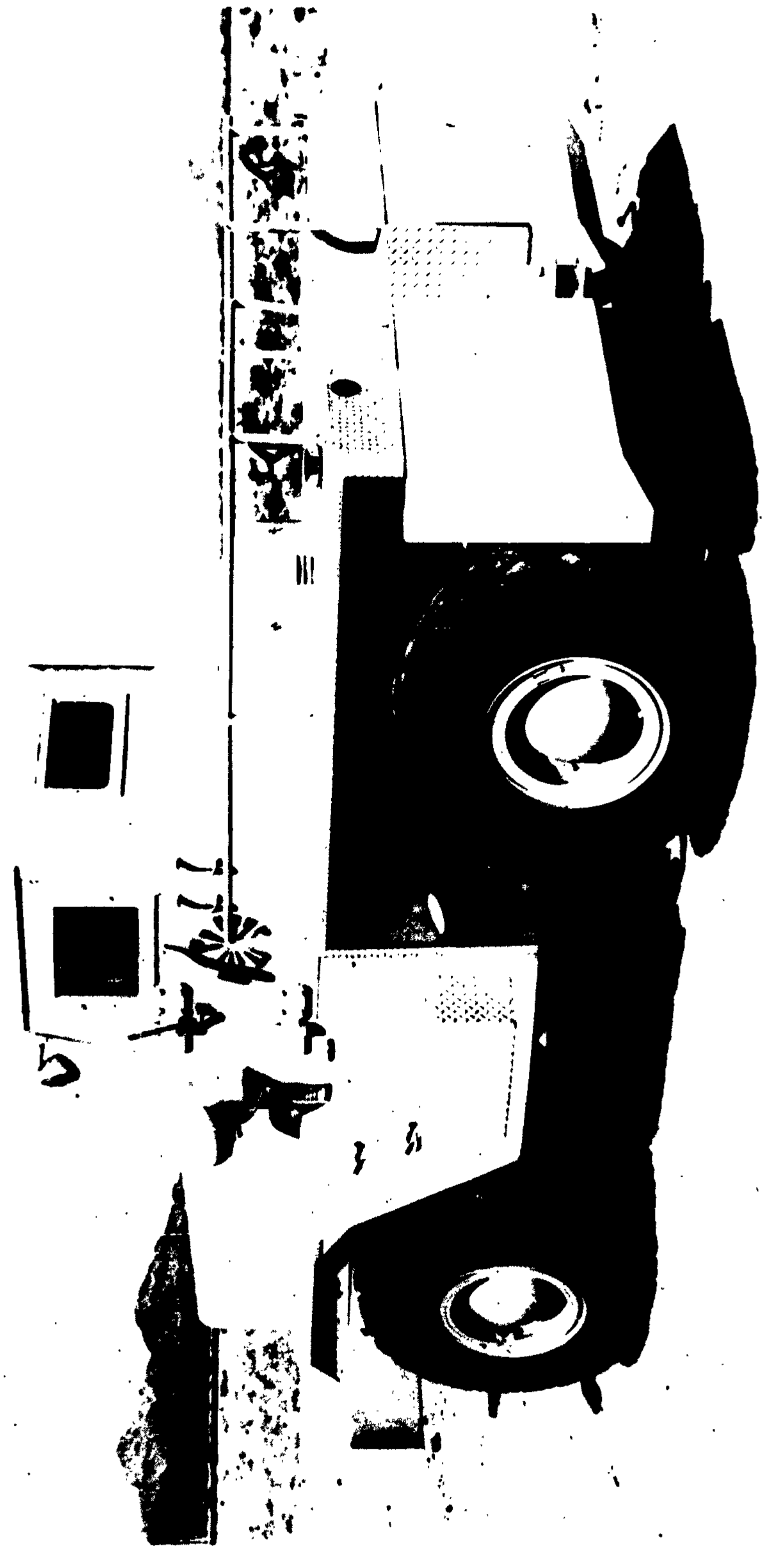

Figure 3. The Bat

the General Electric Company to perform adjustments and repairs as necessary on the aircraft nuclear propulsion engine, which was to be tested under minimum shielding conditions. It was to be mobile, and the cab and manipulators were to be capable of operating at various elevations and angles. Performance specifications and major design requirements were established as follows:

(1) To provide a manned mobile vehicle for operation on a concrete pad with proper comfort and safety and with manipulators of high capacity and reliability.

(2) To provide direct viewing to allow the operator to find the problem area, position the Beetle, and utilize the manipulator and tools to their best advantage.

(3) To be capable of operating inside the engine test facility to position the operator in the most convenient location up to within 3 or 4 feet of the reactor. These movements include cab rotation up to 360° as well as cab elevation of 26 feet 7 inches from the ground.

(4) To provide shielding for protection of the operator from the otherwise fatal radiation environment at close proximity to the reactor. The radiation environment in which the vehicle was to operate was limited to after-shutdown conditions. The vehicle must provide gamma ray protection of 1×10^6 r/hr for short periods and 3,000 r/hr for long-time operation.

(5) To provide, in case of primary power failure, a secondary source of power to allow for removal of the vehicle from the hazard area.

(6) To be capable of operating in a temperature range of -30° to 130°F. This requires complete air conditioning for the operator.

Detailed engineering requirements and specifications were sent by the General Electric Company to interested vendors for final design and fabrication proposals (appendix I). Jered Industries, Inc. of Detroit, Michigan was selected as the subcontractor and work began in 1959 and continued until the Aircraft Nuclear Propulsion program was canceled in April, 1961. Since the Beetle was in final stage of completion, it was decided by USAF that the vehicle should be finished. AFSWC was assigned the technical responsibility for the Beetle completion. The partially finished vehicle was shipped to The General Electric Company, Nuclear Materials Propulsion Operation, Evendale, Ohio, where it was completed.

b. Description of test article.

(1) The Beetle is a track-laying vehicle having a chassis similar in appearance to a conventional army tank. The chassis is a welded fabrication of heavy steel plate which contains the power plant and transmission for driving the vehicle, and is supported by ten road wheels suspended on torsion bars anchored to the center of the hull. The engine and transmission are located in the front part of the chassis, while the operator cab, accessory power pod, and manipulators are mounted on the rear. Figure 4 shows the location of the major components.

(2) The Beetle was designed and fabricated to the following criteria:

Length	19 feet 0 inches
Width	12 feet 7½ inches
Height - Cab down	11 feet 7 inches
Cab up	26 feet 7 inches
Weight	170,000 lbs
Ground pressure	35 lbs/sq. in.
Cab:	
(a) Elevation (max)	15 feet
(b) Rotates	360° at 0.8 rpm
(c) Elevates	4 ft/min. average*
(d) Wall thickness:	
Steel shell ½ inch inside and outside 1 inch	
Lead (minimum)	12 inches
(e) Hatch opens	1 min.*
Window thickness	2¾ inches
Flood light intensity	250 foot-candles @ 15 feet

* As determined in the evaluation program

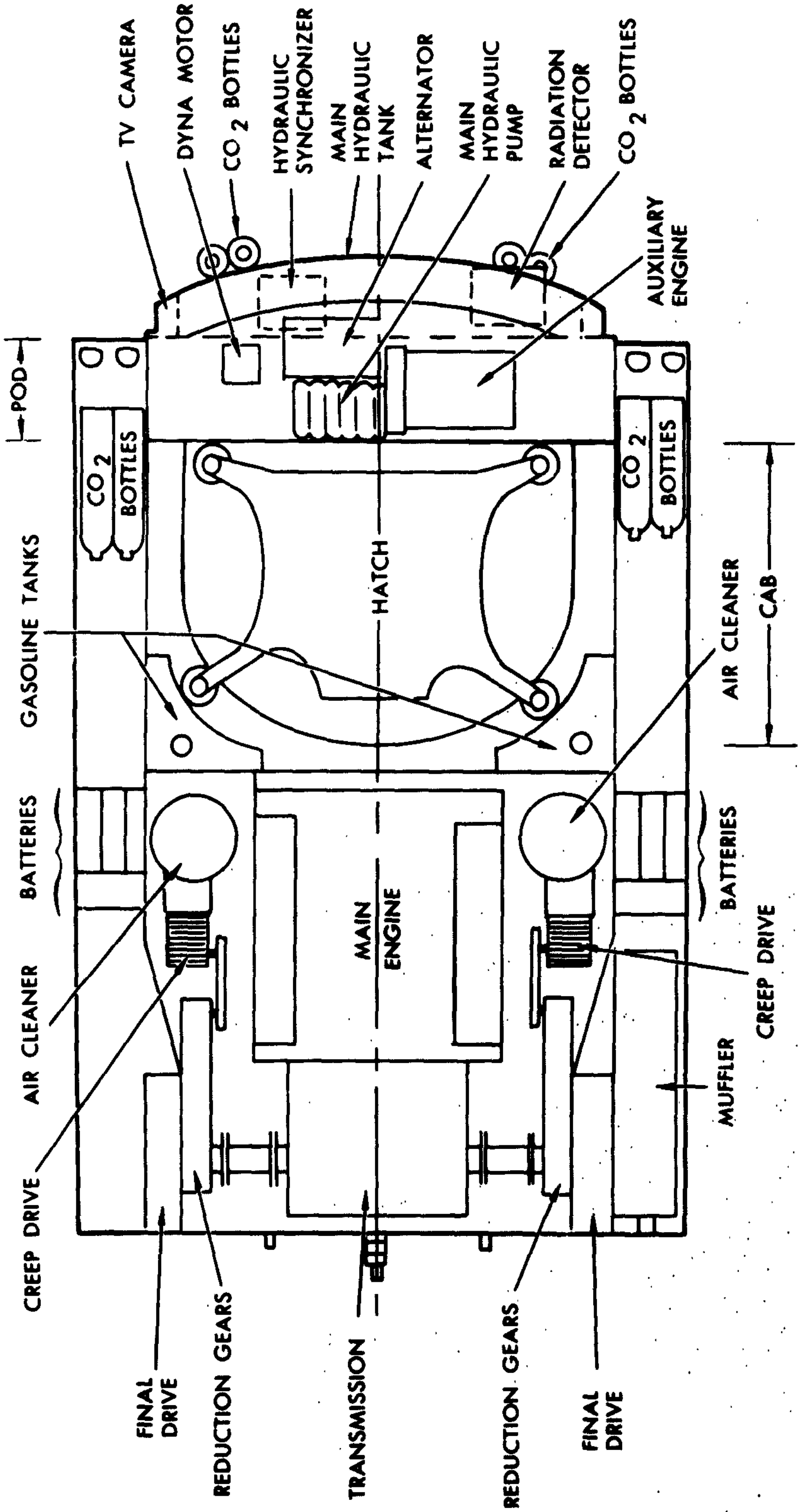

Figure 4. Location of major components

Operating ambient temperature	-30 [illegible]	130°F
Cab interior temperature and humidity	72°F [illegible]	F and 60% RH
Electrical power - generator	120v [illegible]	0-40 kw 3 phases
Battery (emergency)	24v [illegible]	amp hours
Periscope vision - up and down	170° [illegible]	
Circumferentially	180°	
Magnification	1.5 to [illegible]	to 1
Gasoline engines - main propulsion	500 HP	
Auxiliary (generator and hydraulic pump drive)	110 HP	
Radiation meters - outside	1 to 1,00[illegible]	[illegible] hr at 2.5 Mev
inside	1 to 1,00[illegible]	[illegible] at 2.5 Mev

PERFORMANCE CHARACTERISTICS

Speed - 0% grade forward	8 mph*
0% grade reverse	5 mph
10% grade - forward and reverse	5 mph
Drawbar pull	85,000 lbs
Continuous operation	8 hours
Creep drive speed 0% grade	10 ft/min. *
Maximum distance with creep drive	approx. 200 ft. *
Manipulators:	
Maximum reach from operator	17 feet 9 inches
Maximum weight lifted straight down from shoulder	2,000 lbs
Maximum weight lifted with arms extended	100 lbs

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* As determined in the evaluation program

INTERIOR CAB EQUIPMENT

Controls for main power propulsion.

Controls for auxiliary electric-powered creep drive.

Controls for each of two manipulators and manipulator mounts.

Controls for a secondary power supply for two manipulators.

Controls for the shielded cab elevation.

Controls for the shielded cab rotation.

A single TV monitor, controls, and multiple cameras.

Radio, two-way and receiver. (Radio speaker, microphone, and channel controls).

Interior lights.

Controls for exterior lights (including driving, spot, warning, signal, and clearance).

Controls for air conditioning (cooling, heating, pressurizing).

Controls for windshield wipers.

Defrosters.

Controls for entrance hatch, including mechanical safety locks and warning signals.

Seat with five-way adjustment (forward, back, raise, lower, and tilt)

Fire controls -- automatic and manual control with fire warning signals.

Water bottle (insulated bottle for drinking water).

Binoculars.

Emergency air supply and controls (air conditioner, mask, and regulator).

Flash light.

Vehicle and power plant instrumentation.

Controls for audible warning device and powered communications.

An air sampling system for monitoring the entering air.

Writing board and data storage.

(3) The cab is a double-walled steel capsule containing all controls and communications equipment for operating the vehicle and its manipulators. The 12-inch space between the double walls of the cab is filled with lead except for five 23¼-inch-thick windows composed of seven

panes of leaded glass and having a radiation shielding capacity equal to 12 inches of lead. Mounted directly on the rear of the cab, so that the two components move as a unit with respect to the chassis, is the pod assembly. The pod's main function is to provide the power necessary for the operation of all control circuits and cab associated equipment. The pod contains and supports the following equipment:

(a) Auxiliary engine 110 HP and fuel tank,

(b) alternator (120/208 volt a.c. 40 kw 3-phase 60 cycle generator for main power supply) driven by the engine,

(c) main hydraulic pumps and supply tanks, (pumps are driven by the engine and supply 70 gpm at 700 psi max.),

(d) hydraulic synchronizer to control uniform cab assembly elevation,

(e) generator (24-volt d.c. generator to maintain battery charge) driven by the engine,

(f) two 24-volt batteries (one for regular operation, one for emergency),

(g) dynamotor (emergency battery-operated 120/208-volt a.c. power supply),

(h) emergency battery-powered hydraulic pump (hatch elevating),

(i) rear-view television cameras (two),

(j) air conditioner,

(k) radiation monitor and air sampler,

(l) manipulator control circuit assemblies.

(4) The cab and pod assembly is raised and lowered by four telescoping cylinders controlled by the main hydraulic control valves. There are four stages within each cylinder having 45 inches of movement, with a total rise of 15 feet. The height differential of the four telescoping cylinders is controlled by two four-way valves operated mechanically as a function of the relative position of the four cylinders. The position of each cylinder is transmitted to the synchronizer through a cable. One end is attached to the base near its associated cylinder and the other end wrapped around a drum in the synchronizer. Each drum is connected to a differential gear. The cables from diagonally opposite cylinders are connected to differential gears on opposite sides of a common carrier gear. The rotation of the two drums

turns the two differential gears in opposite directions. When the movement of one cylinder exceeds that of the other cylinder, the differential imparts movement to the carrier gear in the direction of the faster moving gear. The carrier gear is coupled to the spool of a four-way valve which channels hydraulic oil in such a manner as to equalize the height of the two cylinders. In this manner the plane of the cab-pod assembly is established in two directions so that it remains within 3/8 inch of reference level at all times. Figure 5 shows a schematic of the cab hydraulic synchronization system.

(5) Control of the Beetle is effected electrically and consists of the following components: two manipulators, the main engine and the transmission of its power to the drive gears, the electric powered creep drive, the auxiliary engine, the d. c. solenoid valves for cab and hatch operation, cab rotation, the air conditioning, lights, windshield wipers, hatch warning signals, audible warning devices, power communication, and fire safety system (manual and automatic). In addition to the controls there is vehicle and power plant instrumentation including radiation monitors, television equipment, tachometers, battery voltmeters, and grip force meters. Figure 6 shows the location of the various electrical junction boxes. The operator has about 160 push buttons in the cab for operation of all equipment controls. With the exception of the lights, periscope, and manipulators, the operator can control all cab-located, pod-located equipment from JB-1 and all chassis-located equipment from JB-10 including cab raise and lower and cab rotate.

(6) The Beetle has two General Mills Co. Model 550 manipulators, mounted one on each side of the cab, facing forward from the operator's position. Appendix II gives the original design specifications for the manipulators. When fully extended, the arms have a reach of 16 feet and will support a 100-pound load with a deflection of approximately 1 inch. Figure 7 shows the various degrees of motion of which the manipulators are capable. The various movements are controlled in speed and direction by lever switches located in separate panels in the cab and are protected against overload by slip-clutches and circuit breakers. Grip-force meters provide the operator with an indication of the force being applied by the manipulator hands.

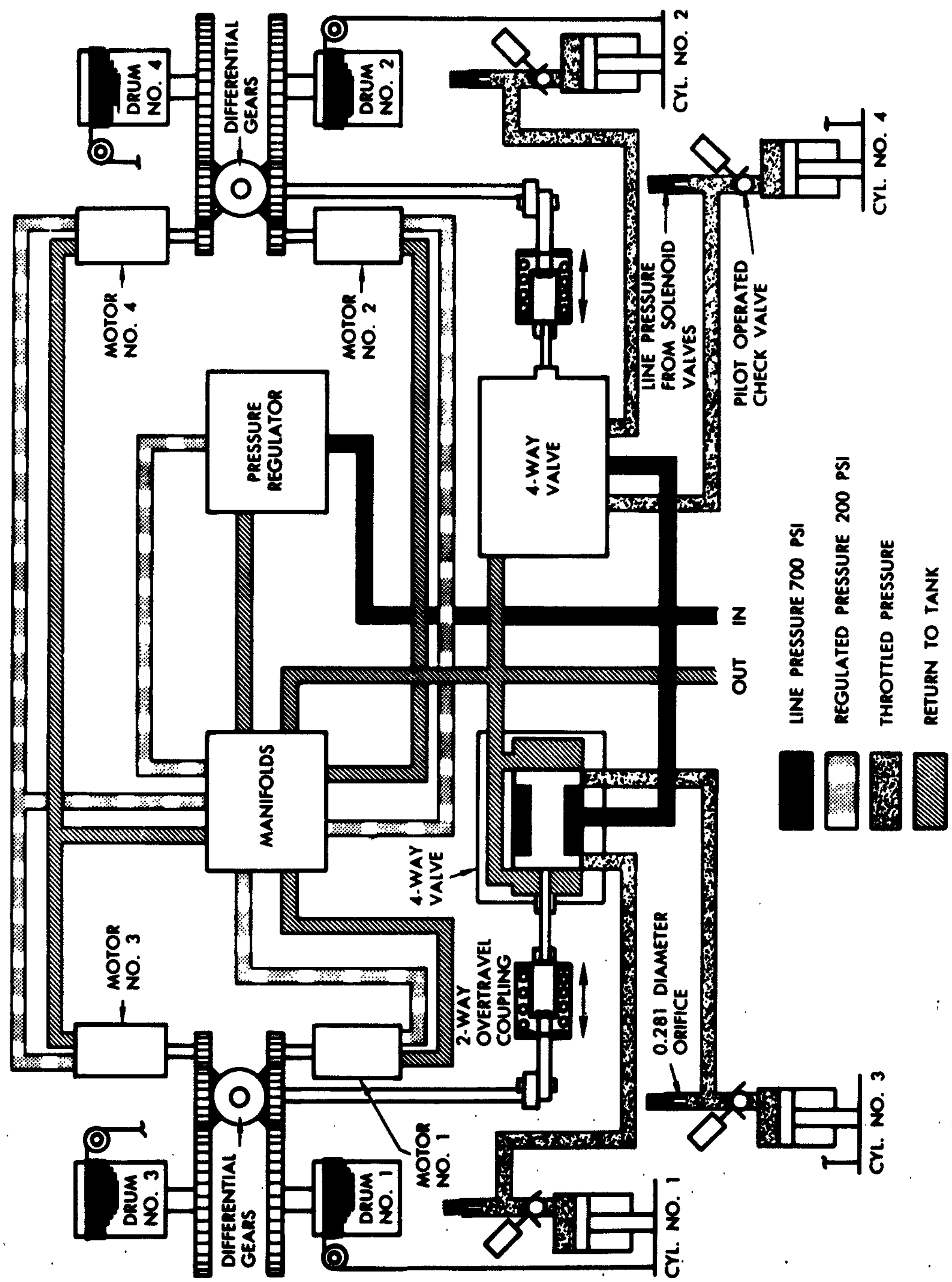


Figure 5. Cab Hydraulic Synchronizer Schematic

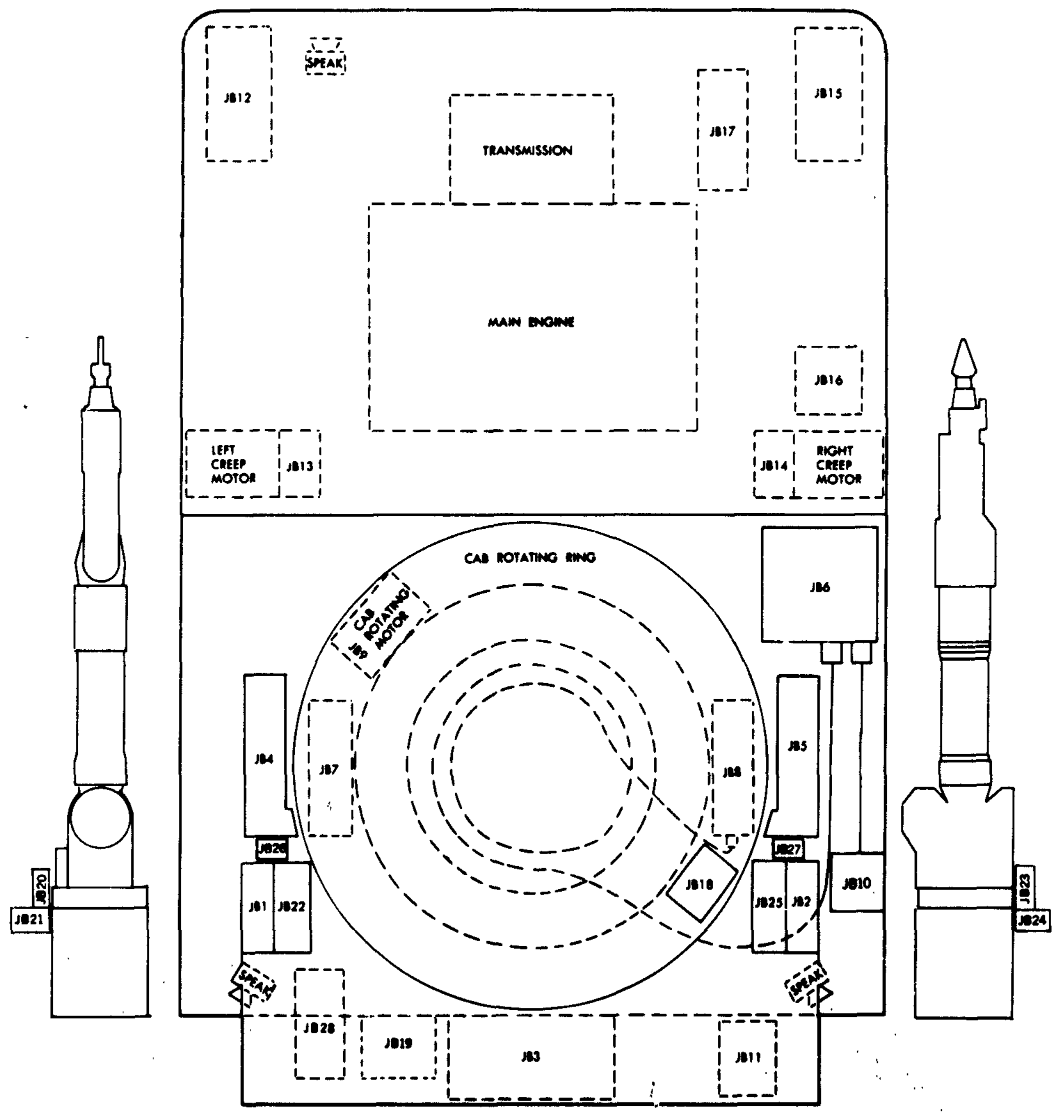


Figure 6. Location of junction boxes

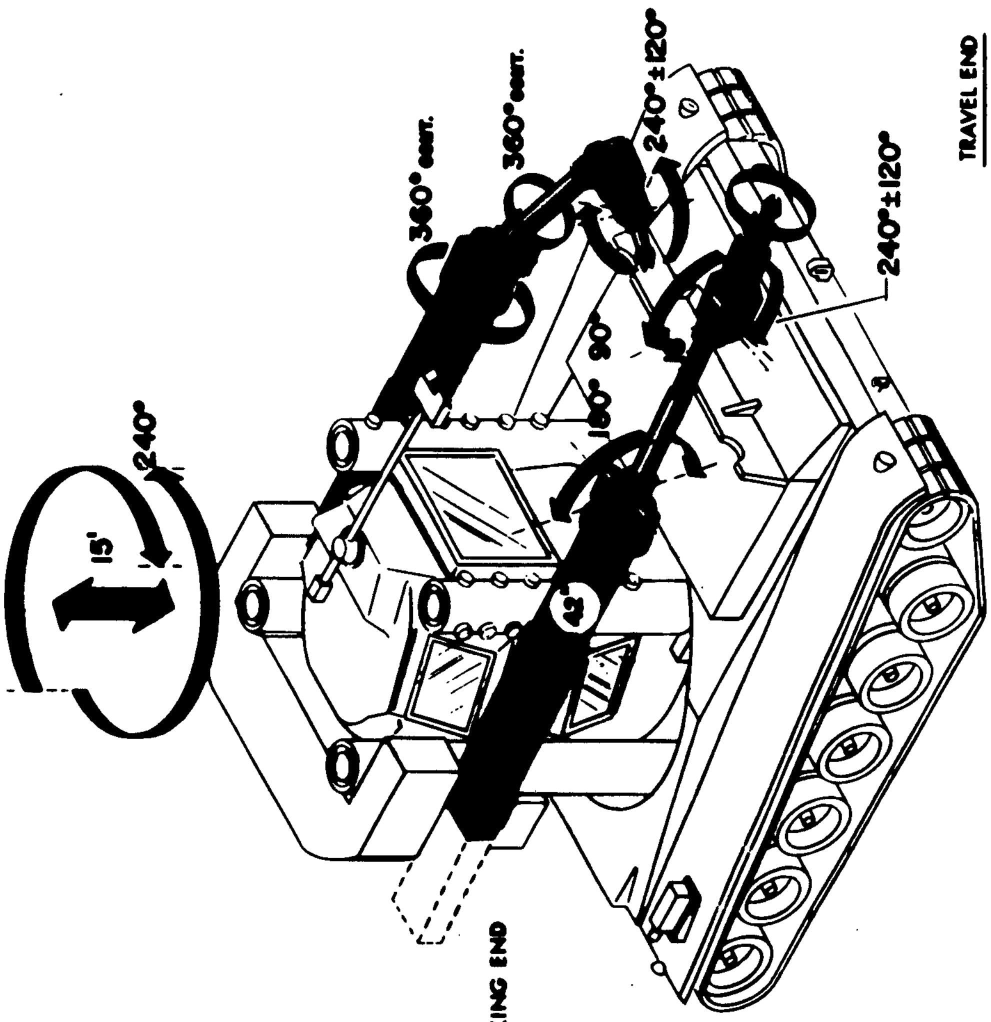


Figure 7. Motions of the manipulator arms

(7) The operator gains entrance to the Beetle cab by raising a 15,000-pound hatch and climbing in through the top of the cab. The hatch is lifted by two hydraulic rams attached to the right front and left rear corners of the hatch. Two guide rods, having the same diameter as the piston rods, are attached to the left front and right rear corners of the hatch. The guide rods have a mechanical locking device which automatically locks the hatch in the up position. The hatch must then be raised and lowered to disengage the locks. A micro-switch indicates to the operator when the cab is in the fully lowered condition. Another light and a buzzer warn the operator when the hatch is not completely closed. Figure 8 shows the Beetle with the hatch open. Since the hatch-raising rams are not synchronized, the hatch tends to wobble or "duck-walk" as it rises. This has led to the striated markings on the guide rods shown in figure 8. To prevent dust collection on the hydraulic pistons, the vehicle should be stored with the hatch down.

(8) The Beetle has 26 iodine-arc flood lights, each rated at 500 watts. Fourteen are mounted in front of the cab to provide high light intensity within the manipulator range of operation. Five flood lights are located at each side of the cab and two are located at the rear. Incandescent spotlights which can be rotated and tilted for better viewing are mounted on each side of the cab. White and red lights on the front and rear of the chassis provide illumination when the Beetle is mobile. Working lights (front iodine-arc lights) are capable of producing 250 foot-candles over an area of 20 square feet at a distance of 20 feet from the light source. Side lights provide an illumination of 50 foot-candles at a distance of 20 feet from the light source. Iodine-arc flood lights provide a yellow light which gives good visibility through leaded-glass windows.

c. Summary of test.

(1) Testing was performed in accordance with the document "Test and Evaluation of the Beetle Vehicle" dated 20 Jan 62. (See appendix III) This document was coordinated with Los Alamos Scientific Laboratories before the program was initiated. Some adjustments to the test plan were required because of a lack of available facilities at NRDS or to obtain

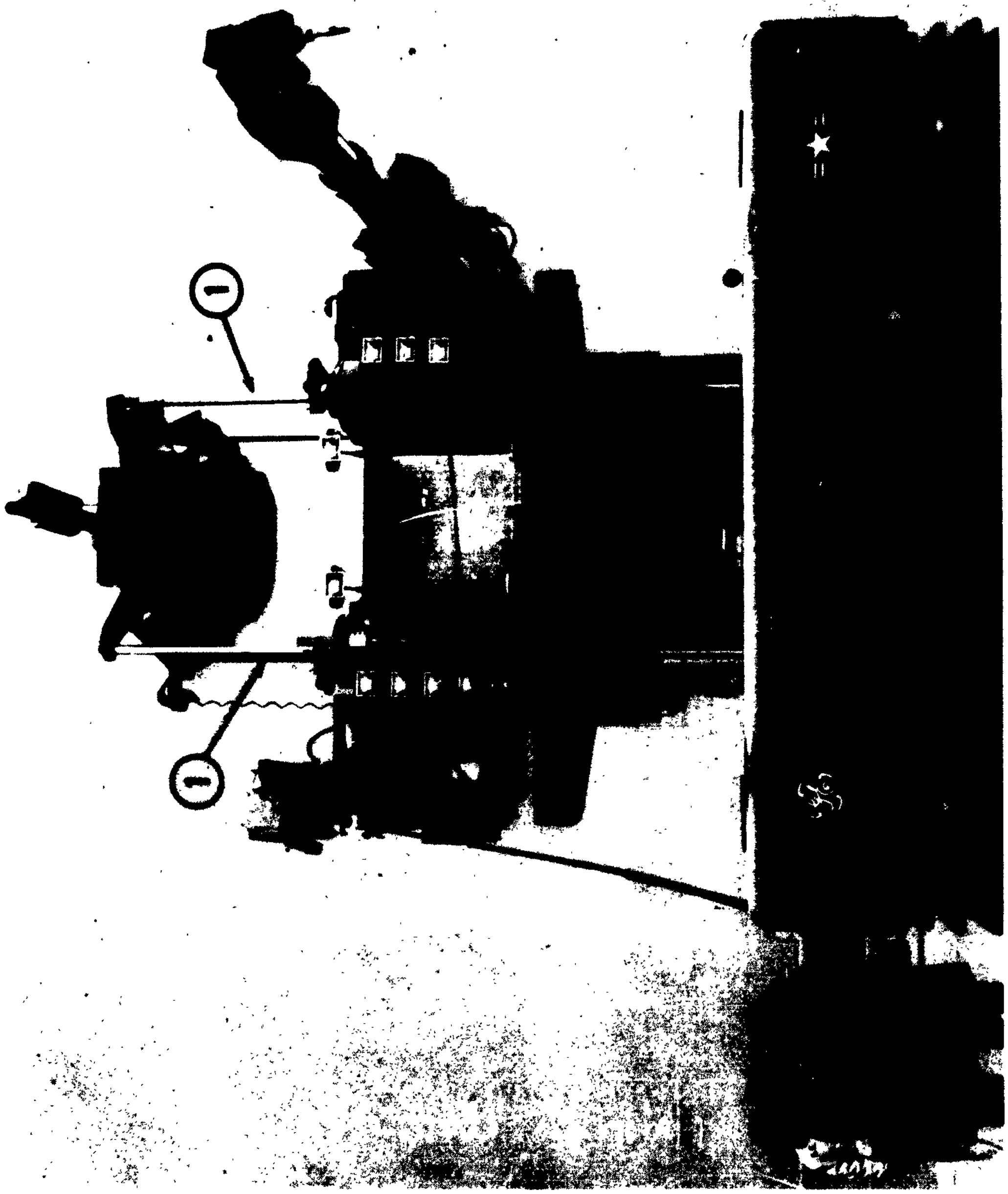


Figure 8. Beetle Hatch UP
1. Guide rods (Note striated markings)

additional data.

(2) Operation checkout.

(a) Chassis (cab controls).

The main engine was started following prescribed procedures. No difficulties were encountered.

After warm-up, the engine speed was increased to approximately 2,800 rpm. No difficulties were encountered.

The vehicle was moved forward in the low-speed range for a distance of approximately 2,000 feet. No difficulties were encountered. Later in the evaluation program (after approximately 2 months of operation) difficulties were encountered in getting the transmission into the low-speed range. It was found that the servo-motors (figure 9) were not moving the range control valve to the proper location. Apparently, vehicle vibration can cause a shift in the relative position of the electrical contacts which determine the angle through which the motor will rotate. The relative position of these contacts is controlled by revolving the disks on top of the motor shown in figure 9. Small clamps, which are tightened by a screw, fix the disks at a given setting. These screws were tight at the time that difficulties were noted. To correct the difficulty, the screws were loosened and the disks moved until the proper setting was obtained. Note the small change in position of the disks as shown by the fact that the painted marks on the disks above the transmission range control motor are not vertical as they were in the malfunctioning condition. This shows that a slight change in the relative position of the disks can make the vehicle inoperative.

The Beetle was moved forward in the high-speed range. This test was performed on asphalt highway which was generally level or slightly downhill. The vehicle performed well up to 2,400 rpm or about 8 mph. Above this speed at about 2,600 rpm an excessive resonant vibration was encountered. It is therefore necessary to limit the maximum speed of the Beetle to 2,400 rpm, or 8 mph.

The Beetle was steered right and left at low speeds.

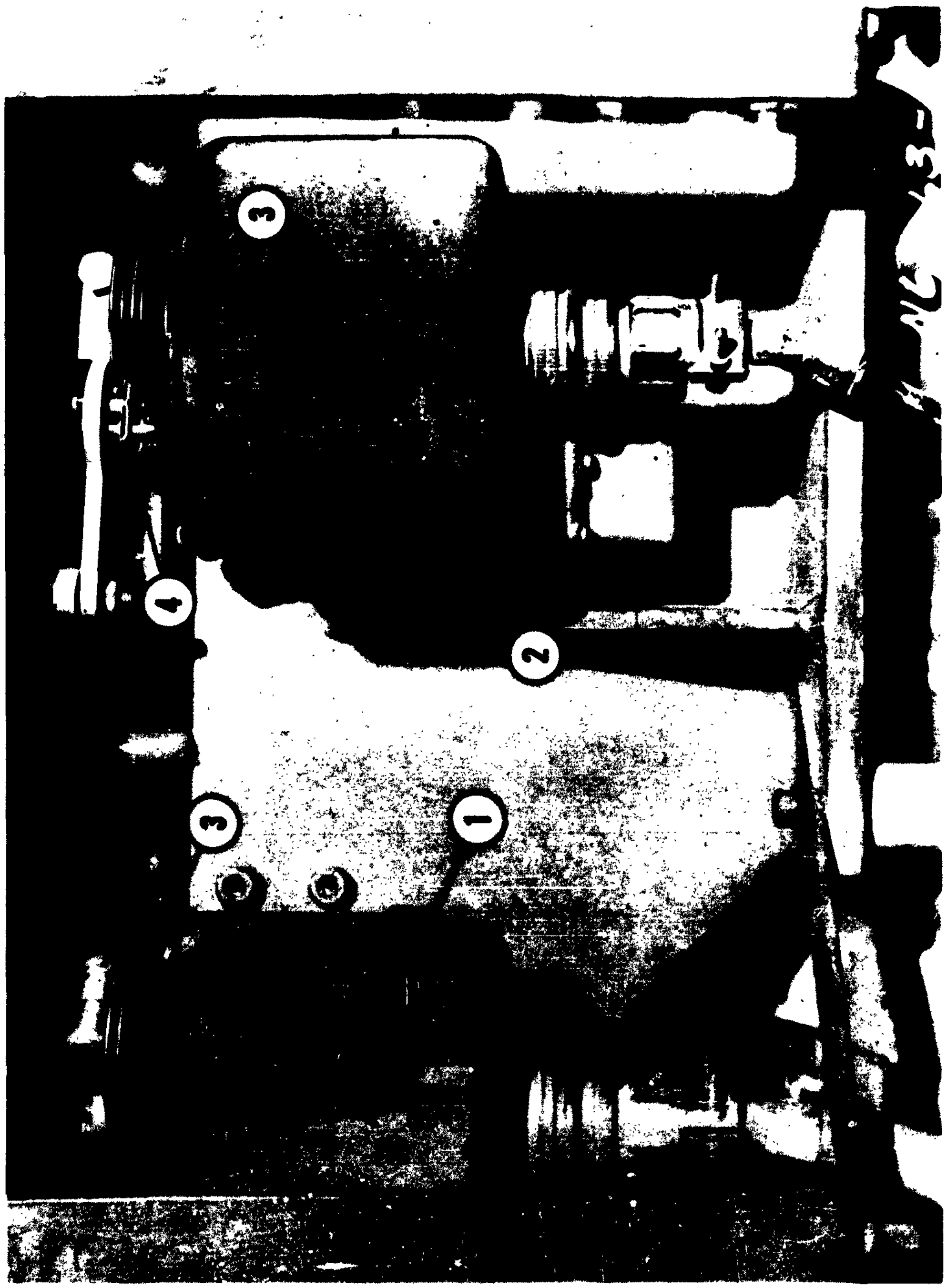


Figure 9. Servo-motors. 1. Transmission servo-motor. 2. Steering servo-motor. 3. Electrical contacts (disks). 4. Clamps

The turning was performed on level, semi-prepared dirt typical of the terrain surrounding the Nuclear Reactor Development Site. Once, during the early phase of the evaluation program, a track was thrown. Figure 10 shows the track dislodged from the rear road wheel. The broken rock found near the track, may have become lodged in the track teeth as shown in figure 11; this would have helped to raise the road wheel above the teeth which normally travel down the center of the wheel. The ground at NRDS is impregnated with rocks. It was raining during this particular run and the resistance of the ground to side loads was thus increased, resulting in an increased side load on the Beetle tracks during turning. Figure 12 shows the design differences between the Beetle's suspension and a tank suspension. Note that there is no possibility of debris falling loose from the track once it starts around the rear wheel. This debris can cause the Beetle to throw a track. The following precautions were taken as a result of this incident:

1. Turns were limited to a 30-foot radius.
2. The maximum allowable turn was limited to 45 degrees.
3. The operator was required to travel at least 20 feet before initiating further turn.

No additional track-throwing incidents occurred.

Trouble occurred periodically when the servo-motor did not move the steering valve to the proper turning position. This is partially due to shifting of the electrical contacts on the servo-motor, as mentioned previously in regard to the transmission range control, and partially due to the fact that the servo-motor had insufficient torque capacity. Tests with a calibrated torque wrench showed that 120 inch-pounds of torque are required to rotate the steering valve to the full steer position. Less torque is required for modulated (partial) steering. The torque rating of the servo-motor is 150 inch-pounds. The servo-motor is usually able to rotate the valve into a full steer. At times, especially following several turns, the servo-motor does not obtain a full steer. While the vehicle can be controlled for a short time through partial steer, extended steering under these conditions will result in burning out the steering clutches. The best solution to the problem appears to be the installation of a servo-motor with

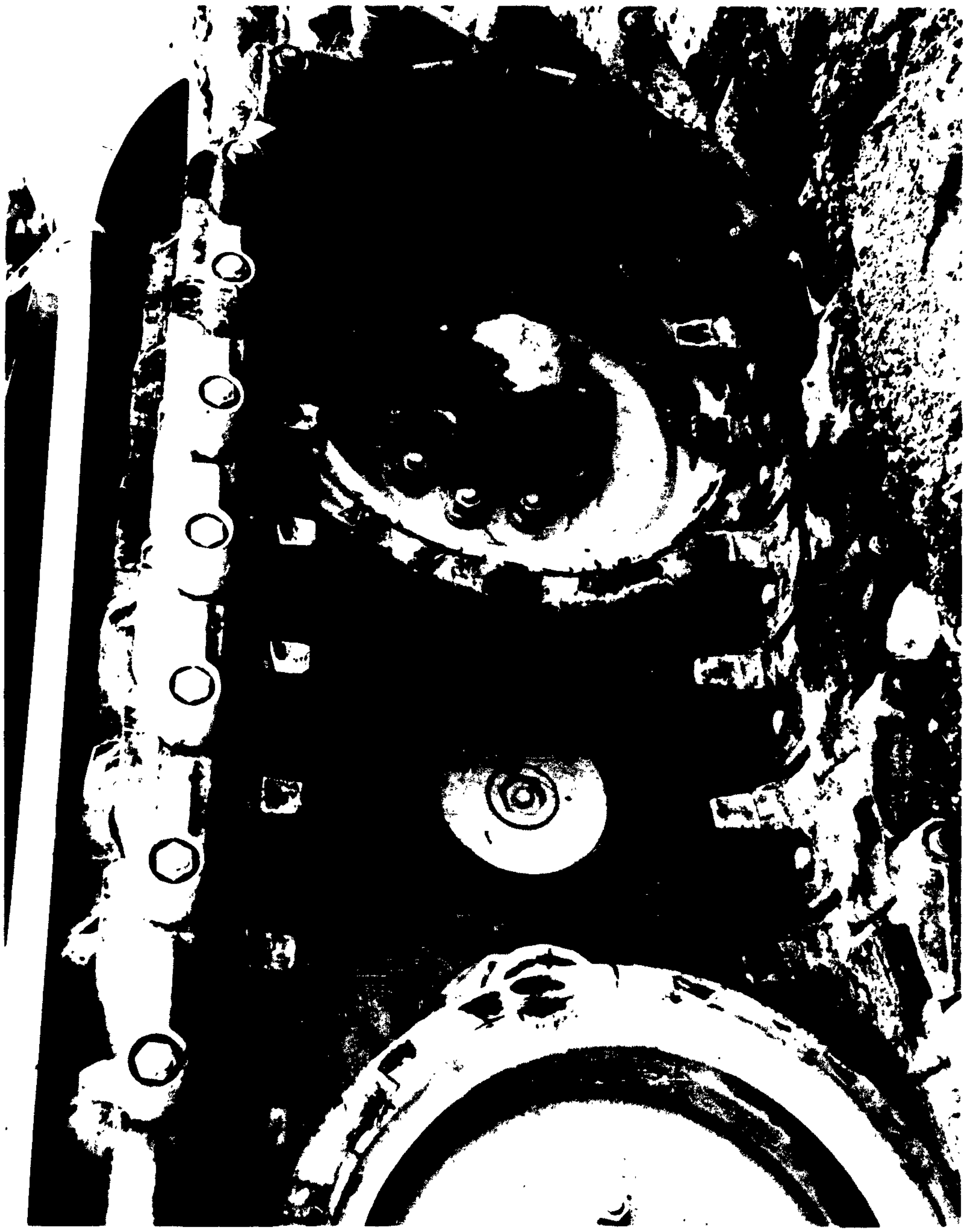


Figure 10. Thrown track on Beetle. Note "V" section in middle of bogy wheel through which track "teeth" normally travel.

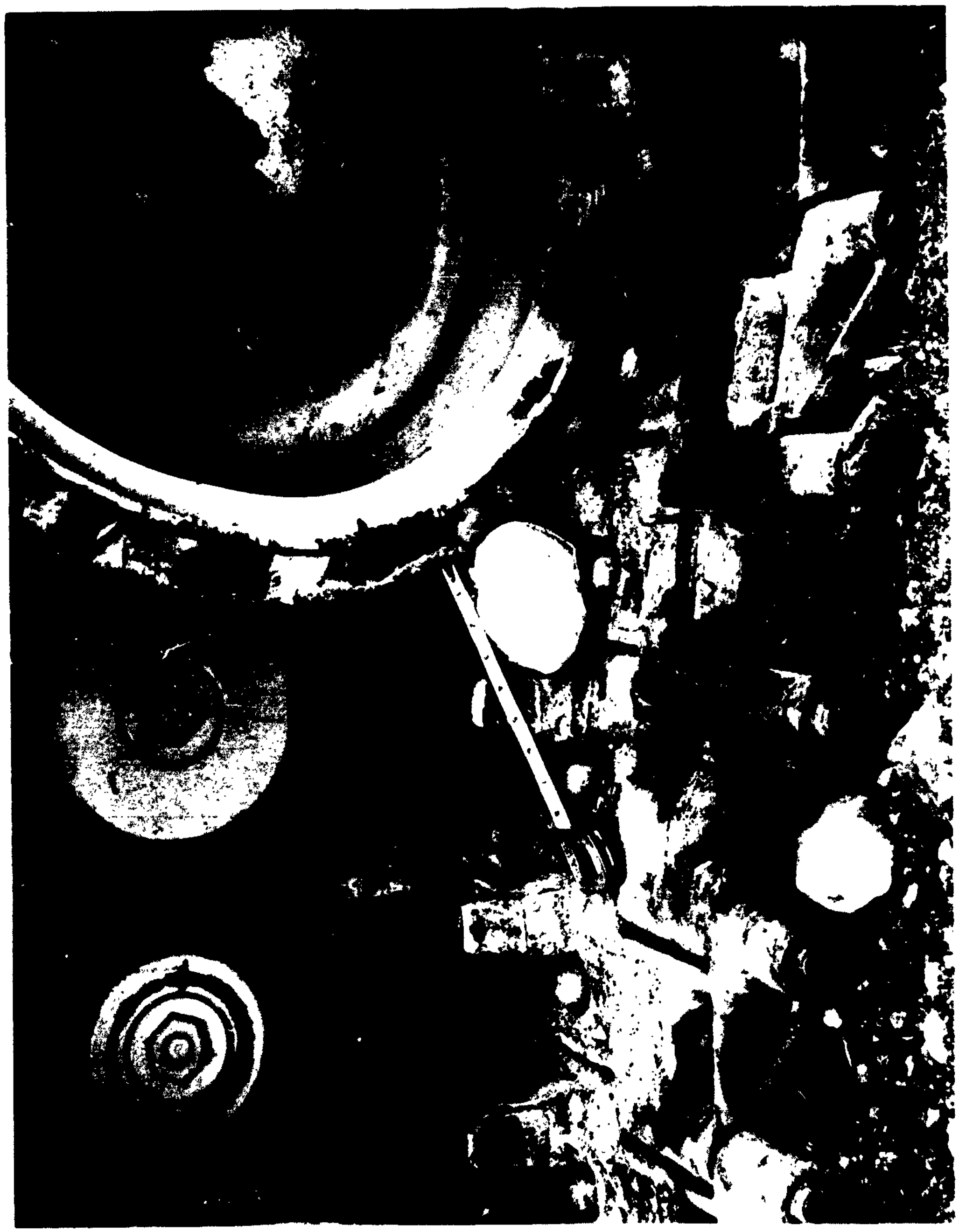


Figure 11. Possible cause of track throwing incident

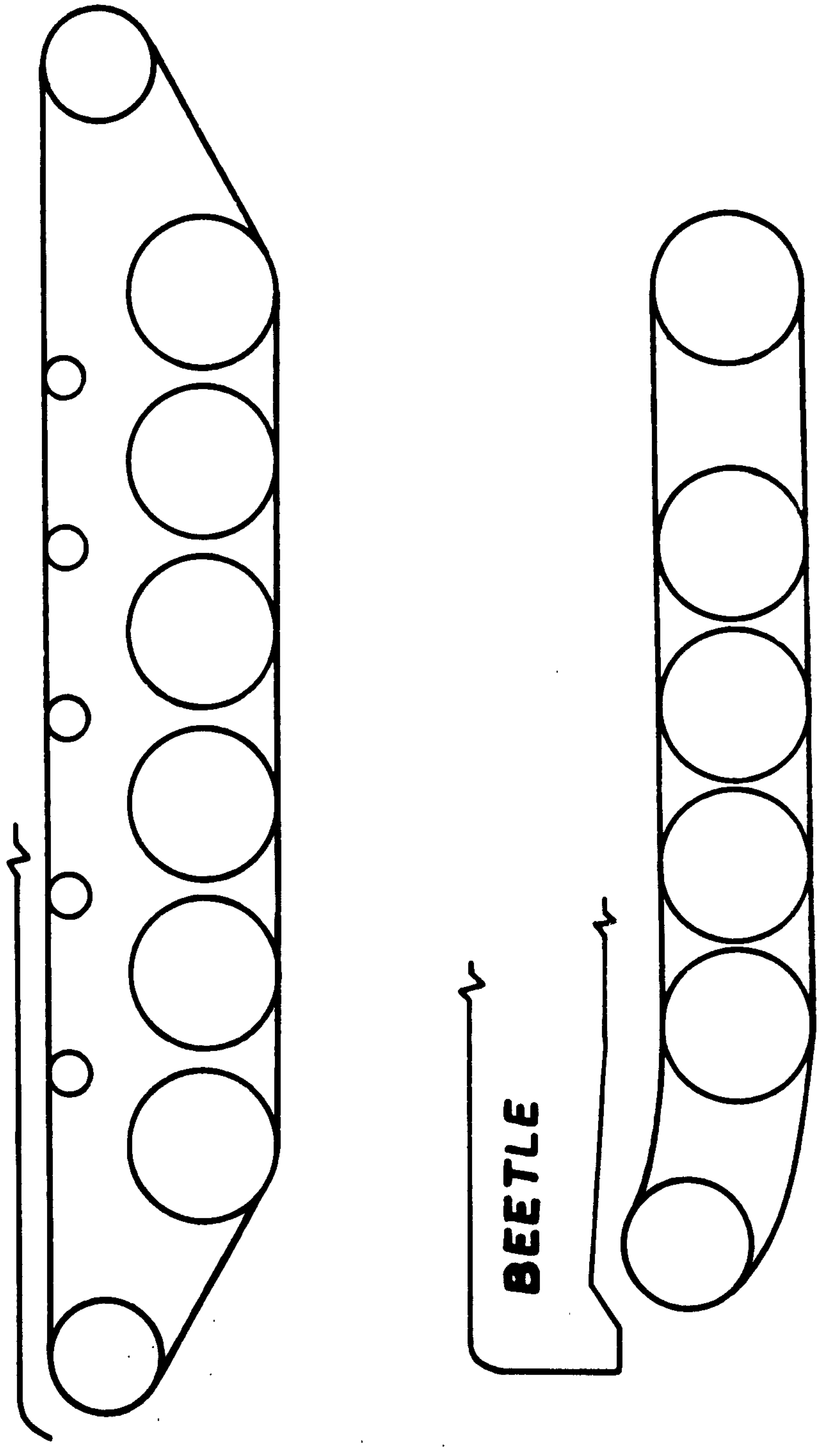


Figure 12. Difference between Beetle track suspension and a normal tank track suspension

a higher torque capacity.

The Beetle was steered to the right and to the left while the vehicle was in the high-speed range. No difficulties were encountered.

The Beetle was operated in the reverse direction. No difficulties were encountered.

Service brakes were engaged whenever necessary throughout the entire evaluation program. No difficulties were encountered.

The parking brakes were engaged with the vehicle on grades not exceeding 10%. No difficulties were encountered.

The vehicle was operated in both pivot right and pivot left. Two difficulties were observed:

1. The vehicle did not always reach a state of full pivot steer because of the insufficient torque capacity of the servo-motor noted earlier.

2. Because of the tremendous weight of the vehicle, there is a tendency for the vehicle to dig into the ground. This tendency varies with the compaction of the earth. Figure 13 shows an attempt to pivot steer the Beetle on noncompacted terrain typical of NRDS. A full pivot was not obtained. Further turning would have risked the throwing of a track.

All creep drive functions were operated. No difficulties were encountered. The creep drive was found capable of negotiating a 10% grade.

The transmission brake was operated on a 10% grade. No difficulties were encountered.

Near the end of the evaluation program, it was noted that the studs in both rear wheels were coming loose from the hub (figure 14). This is due to the excessive weight carried by the rear wheels. To correct for this, the studs were screwed back into the hub and spot-welded in place.

Figure 13. Beetle tracks digging into ground during attempt at right pivot steer

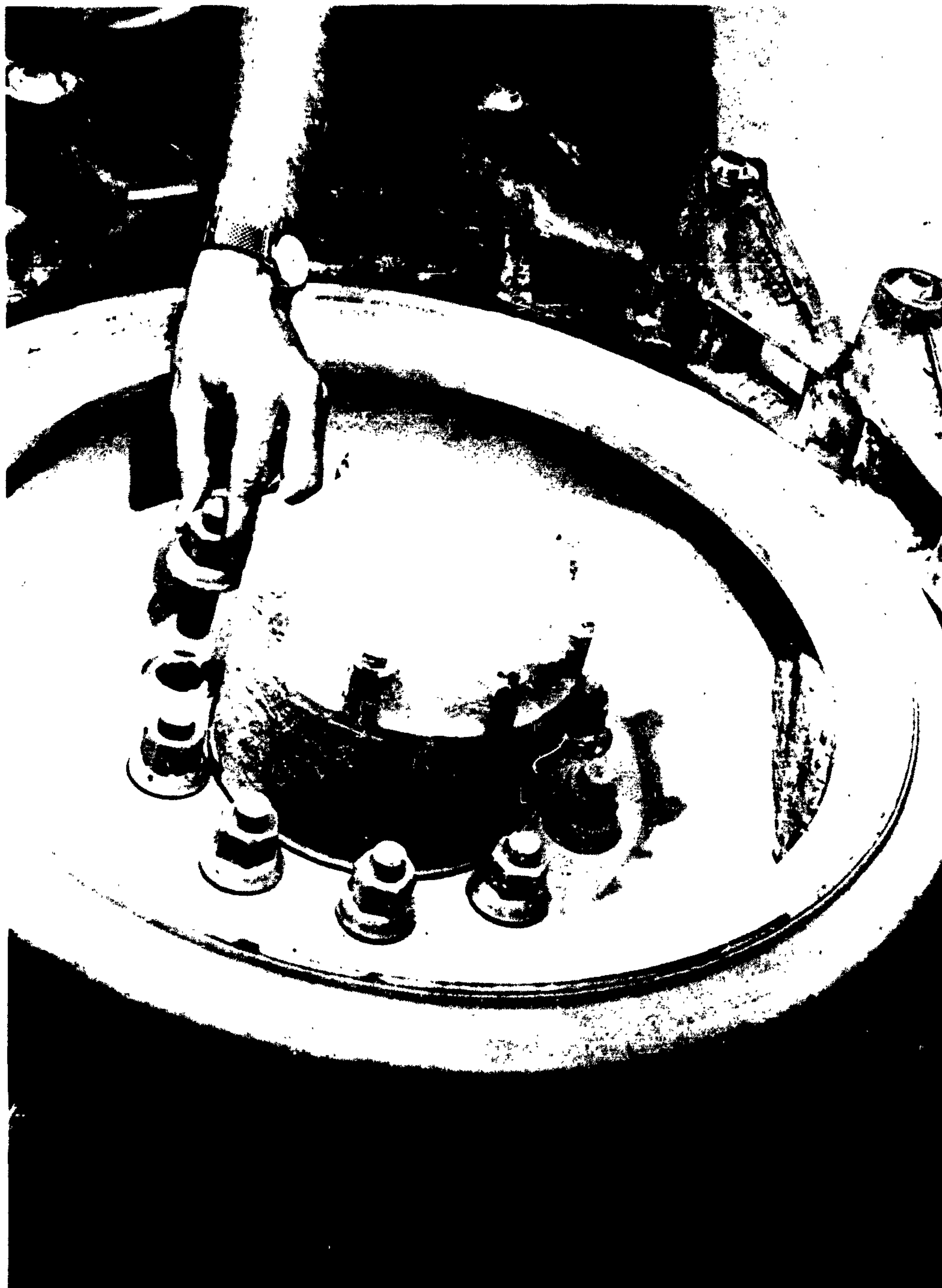


Figure 14. Stud out of rear road wheel

(b) Chassis (outside panel JB-10)

The tests described above were conducted from the outside panel control box as well as from the cab controls. No difficulties were encountered.

(c) Pod (outside panel JB-1)

The auxiliary engine was started according to prescribed procedures. No difficulties were encountered.

The rpm was increased to governor speed. The single-speed governor set the alternator shaft speed at 2,000 rpm as read both in the cab and at JB-1. A check with a stroboscope revealed the true alternator shaft speed to be 1,850 rpm. At this speed, the a.c. generator output was at 62 cps as indicated on the frequency meter in JB-1. This is within the allowable limits of 58 to 62 cps.

The hatch was raised to the open position and then lowered by means of the normal hydraulic pumping system. The hatch safety locks and the hatch warning signal operated. However, the auxiliary engine noise prevents the operator from hearing the buzzer. Fully closed position is noted by the signal light. Following are the observed opening and closing times:

Open -- 63 seconds
Close -- 75 seconds

With the hatch in the closed position, an attempt was made to open the hatch with the outside and inside hand pumps. The outside pump has an 18-inch handle. Measurements showed that a force of 14 pounds is required to pull the handle down, filling the pump with hydraulic oil. A force of 32 pounds is then required to push the handle up, forcing hydraulic oil to the hatch lift cylinders. Because of the small amount of hydraulic oil being forced into the relatively large lift cylinders, it is estimated that it would take 30 minutes of continuous pumping at either pump to raise the hatch to its safety-locked (full open) position. Continuous pumping at these forces is not physically possible for the average person. This is especially true if the pumping is to be performed from inside the cab where the location of the pump is above and to the right rear of the operator. (See figure 15.)

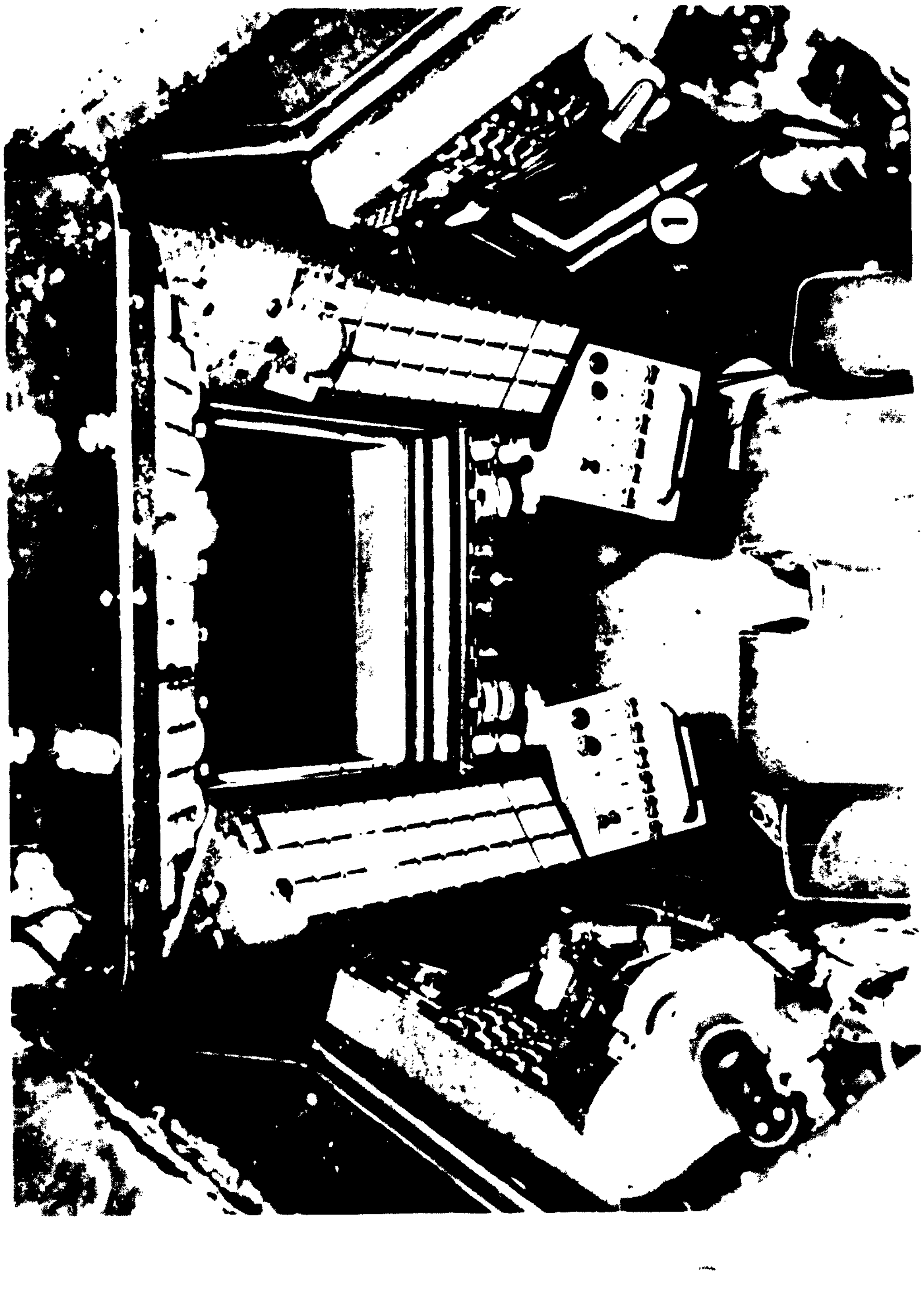


Figure 15. Location of emergency hand pump for raising hatch (handle not attached)

The hatch was raised to the open position by means of the emergency electric hatch pump. The time required to fully raise the hatch was measured and found to be 11½ minutes. The minimum time required for the hatch to raise sufficiently for an operator to escape was measured at 4 minutes.

(d) Normal lift operation of cab.

The auxiliary engine was brought to its operating temperature and the cab was raised and lowered. No difficulties were encountered. The Beetle was on level ground as indicated by a level inside the cab. Average rate of travel was 4 ft/min going up and 5 ft/min going down.

The cab was stopped at 4-foot intervals within the first two stages and rotated through 360°; the over rotation switches stopped the cab at this point. The cab was rotated $\pm 90^\circ$ from the working position when raised to full extension. No difficulties were encountered during any of these rotations. A full 360° rotation from stop to stop takes 68.3 seconds.

No difficulties were encountered in the cab lift synchronization system. After 1 month of operation, however, excessive dust was noted in the gear housing for the synchronizer differential gears. To prevent this condition, dust covers with gasketing were fabricated to cover the gear housings, (figure 16). Also felt wipers were fabricated to help prevent dust from being carried into the synchronizer drums by the height-sensing cables. A check 2 months later showed no evidence of dust in the differential gear housing.

(e) Outside panel.

All of the outside controls on JB-1 were tested to ensure that they were functional. No difficulties were encountered.

(f) Cab accessories.

All electrical lights (spot light, outside lights, interior cab lights, etc.) operated. See section c(4)(b) for more details on visibility using the outside lights.

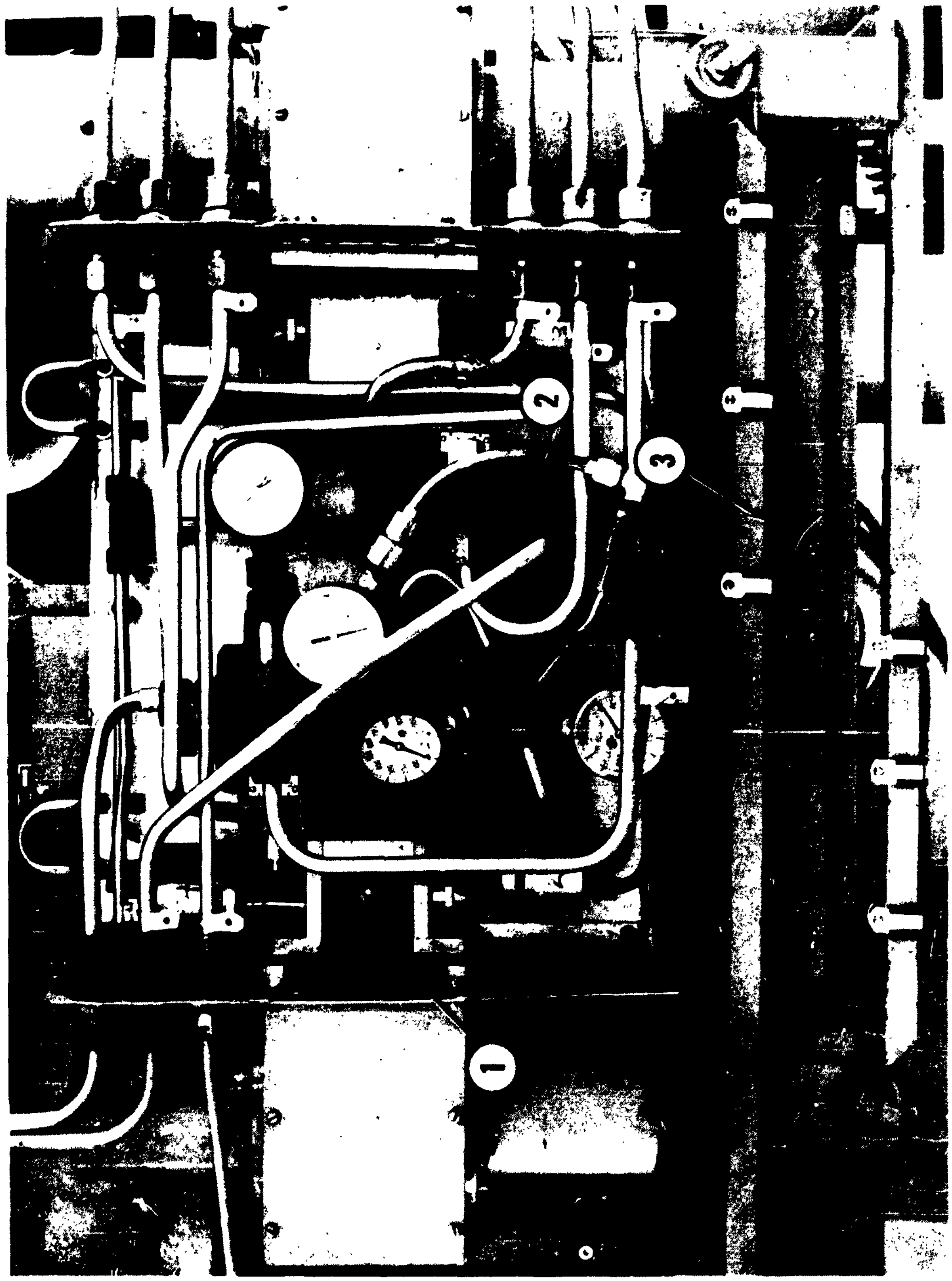


Figure 16. Cab lift synchronizer. 1. Differential gear housing (with dust cover removed). 2. Dust cover. 3. Felt wipers.

The siren was operated with no difficulties. Several times during the evaluation program the PA system shorted out. Fuses have been added to prevent burning out the transistors. However, at the time of this writing, the short had not been located. It will be necessary either to replace the PA system or to locate the intermittent short if reliability is to be ensured.

The periscope was operated. No difficulties were encountered.

The TV equipment and two-way radios were operated. No difficulties were encountered. Extra batteries must be carried for the radio since in continuous operation these batteries run down in a matter of hours.

The windshield wipers and defrosters were operated. No difficulties were encountered.

The seat was operated through its various adjustments. No difficulties were encountered.

Fire controls were not operated. Results of the acceptance test (see appendix V) were accepted and no further tests were conducted.

The emergency air supply and controls were operated. No difficulties were encountered. See section c.(3)(b) for further discussion on the emergency air supply.

The air sampling system operates continuously once pod power is on. No difficulties were encountered in its operation.

Both manipulators were operated through all ten motions. No difficulties were encountered.

(g) Air conditioner.

On first arrival at NRDS the Beetle air conditoner was not cooling satisfactorily. Appendix IV presents a General Electric Company report dealing with improvement of the air conditioning system. This report represents an initial attempt to define the problem and was used as a starting point in analyzing the exact reasons for poor performance. Initially, given an ambient outside temperature of 92°F, the cab air conditioner inlet temperature stabilized at 82°F. This was due to several causes. The steps taken to correct the problem are discussed below.

In going from the air conditioner outlet to the cab inlet the air had to pass through corrugated rubber ducting to the exterior of the cab where it passes through a helical passageway to the cab interior inlet. The ducting was black and had no insulation. Tests showed that a 20°F temperature rise occurred between blower exit and interior cab inlet. Also, it can be assumed that some head loss existed because of friction from the corrugated surface. The passage for recirculating air back to the air conditioner from the cab outlet also contained the corrugated rubber ducting. Accordingly, the corrugated ducting was replaced with insulated aluminum tubing as shown in figure 17.

The air conditioner was removed and the refrigerant checked. Some air was found present in the freon lines which lowered the efficiency of the air conditioner. The unit was then evacuated with a vacuum pump for 16 hours and freon gas #114 was induced into the system with the compressor, condensor fan, and exit blower running. The valve shown in figure 18 was added to enable the introduction of freon to the air conditioner without removing the unit from the Beetle.

Figure 19 shows the air conditioning unit with the side panel pulled away. The blower compartment did not have an air-tight seal and thus allowed ambient air to be mixed in with the cooler air. This not only lowered the efficiency of the unit but it constituted a dust leak. (Figure 20). The seal was improved.

It was felt that the heat exchanger may not operate efficiently since the outlet air from the cab did not seem to be well distributed over the surface of the condenser. (Notice how the dust mark on the condenser in figure 20 is localized to a small portion of the total area). Experiments were conducted with and without the cover plate. At 94°F ambient intake temperature, removing the cover plate decreased the temperature only 2°F at the output side of the exit blower.

Figure 17. Ducting from air conditioner to cab inlet

Figure 18. Rear of Beetle pod showing mounted air conditioner with outside valve for adding freon

Figure 19. Side view of Beetle air conditioner

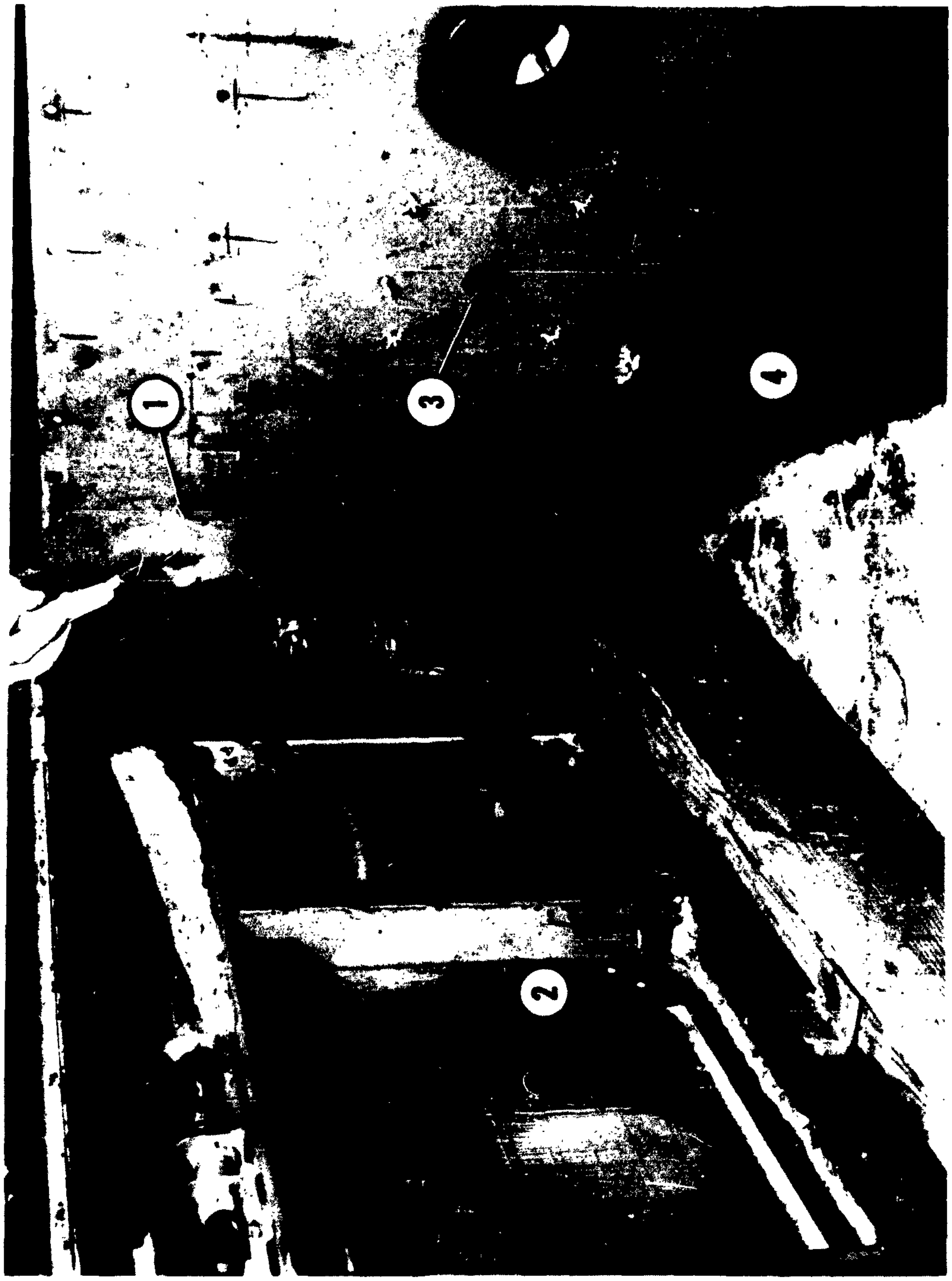


Figure 20. Beetle air conditioner with side panel pulled back. 1. Dust leak. 2. Impact area from cab air return. 3. Outside air inlet. 4. Cover plate.

After repairs, the air conditioner was reinstalled in the Beetle. Tests were run which showed that with an ambient outside temperature of 96°F the cab inlet temperature stabilized at 62°F. However, the upper front of the cab did not get below 82°F. The cab outlet is located near the inlet at the lower rear bottom of the cab, providing poor circulation of the cool air in the cab. Body and instrument panel heat contribute to raising the upper front portion of the cab's temperature. This temperature, however, is not outside the comfort zone for the relative humidities encountered at NRDS. (See section c(3)(b) for a discussion of humidity checks). The operator agreed that the cab was relatively comfortable.

Two additional changes have been made to the air conditioner. The 5/8 inch diameter hole in the middle of the side panel, which is for outside air, was made manually variable up to a 2-inch diameter, allowing the operator more fresh air should he so desire. Also, the air conditioner control relay shown in figure 21 was replaced. Energizing the relay moves a microswitch which closes a circuit providing power to the air conditioner. Severe dust conditions encountered at NRDS led to excessive sticking of this relay. It was replaced with a relay which utilizes contacts rather than moving a microswitch and no further trouble was experienced.

(h) Integrity check.

Appendix VI presents an on-site NTS report of the Beetle integrity check performed by Reynolds Electrical and Engineering Company at NRDS. The test showed that no gross defects in shielding attenuation existed. An attenuation factor of $6x10^{-7}$ existed through the center of the front window. This was the lowest attenuation factor and compares roughly with the design criterion of 10^{-6}. (See appendix I)

The integrity of the Beetle's air conditioner was checked for dust leaks. A small quantity of fluorescein dye was injected into the exterior air filtering intake. This dye had been screened to a minimum particle size of 5 microns which is considered approximately one-half respirable range. The cycling system fan drew the dye concentrated air

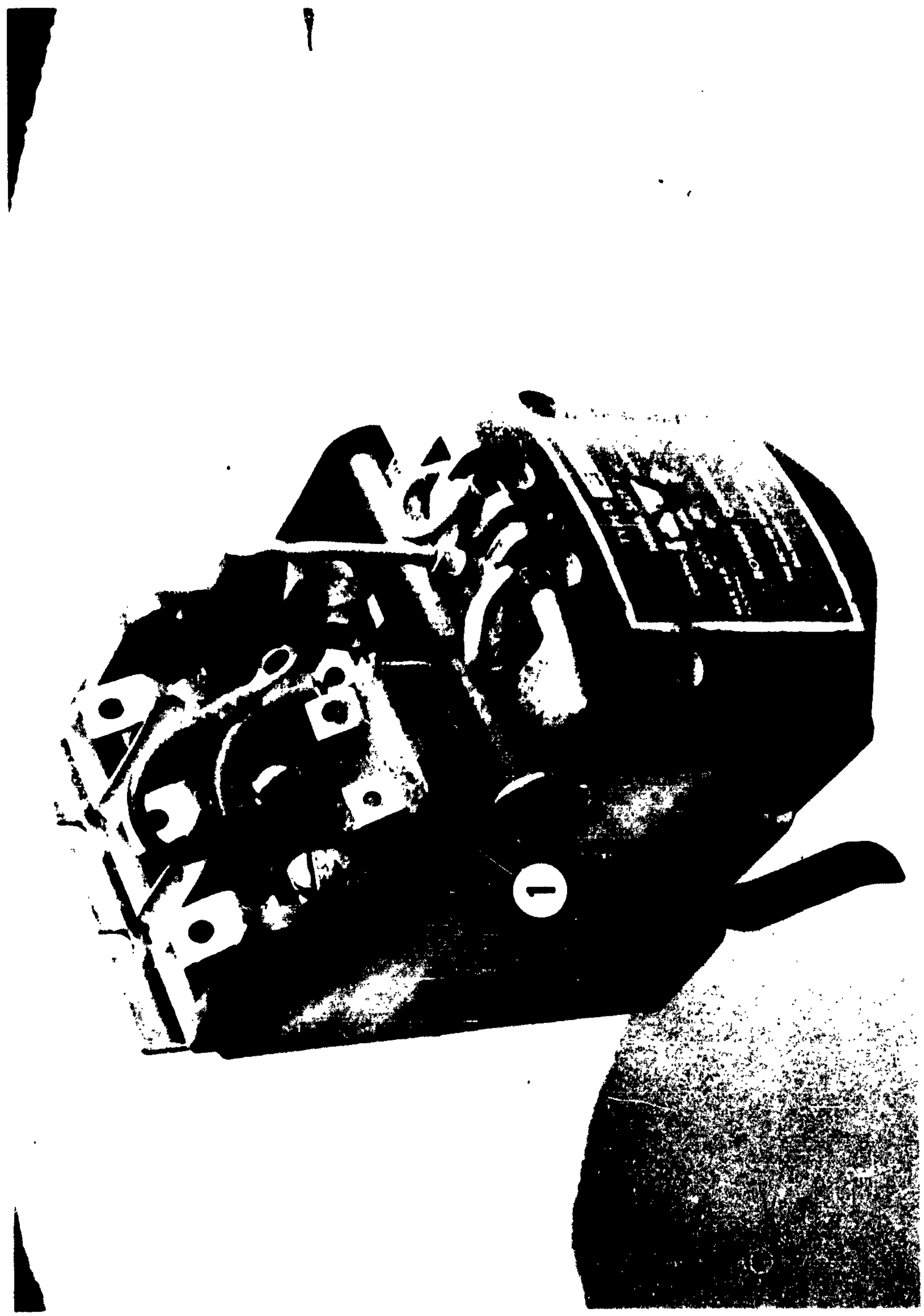


Figure 21. Beetle air conditioner control relay. 1. Microswitch

supply against an absolute filter and into the Beetle cab. Inside the cab near the inlet, a 35 cfm Samplex air sampler drew the injected air through a glass-fibre filter paper with particle retention down to the 0.3 micron range at 99% efficiency. The sampler ran for 5 minutes following the dye injection. The sampler was then removed from the cab and sprayed with a light water mist to accentuate the fluorescence of the dye. Subjecting the glass-fibre filter paper to ultra-violet light revealed an insignificant amount of fluorescence, indicating that there is no gross leakage in the filtering system. No attempt was made to determine the exact quantitative leakage. Since a higher than atmospheric pressure exists within the cab when the air conditioner is operating, there is no possibility for dust to enter the cab.

(3) Operational requirements.

(a) Use requirements.

The exact operating conditions under which the Beetle will be used are difficult to determine until such use is required. The vehicle will be used in support of the Kiwi test series under project ROVER being conducted by Los Alamos Scientific Laboratory. In this project, the reactor is mounted on a test car as shown in figure 22. The test car with reactor mounted can be moved by remotely controlled railroad engines from the maintenance and disassembly (MAD) building to and from the test cell or the radioactive waste dump area. Figure 23 shows the general layout of the various areas. At present, use of the Beetle is contemplated only up to test cell "A." Additional test cells are being built and use of the Beetle may be required at one of these test cells at some later date. The Beetle may be required to work on the reactor anywhere along these tracks. Therefore, a road is being constructed as shown by the dotted line. An additional road to the dump area is contemplated. Possible uses for the Beetle include recovering test equipment from test cell "A" following a powered run of the reactor, making adjustments to the reactor, handling radioactive waste, helping in disassembly of the reactor, and cleaning up should an accident occur during a power run. During the test and evaluation program, an attempt was made to give the operator practice in performing typical operations. Examples of possible operational uses follow.

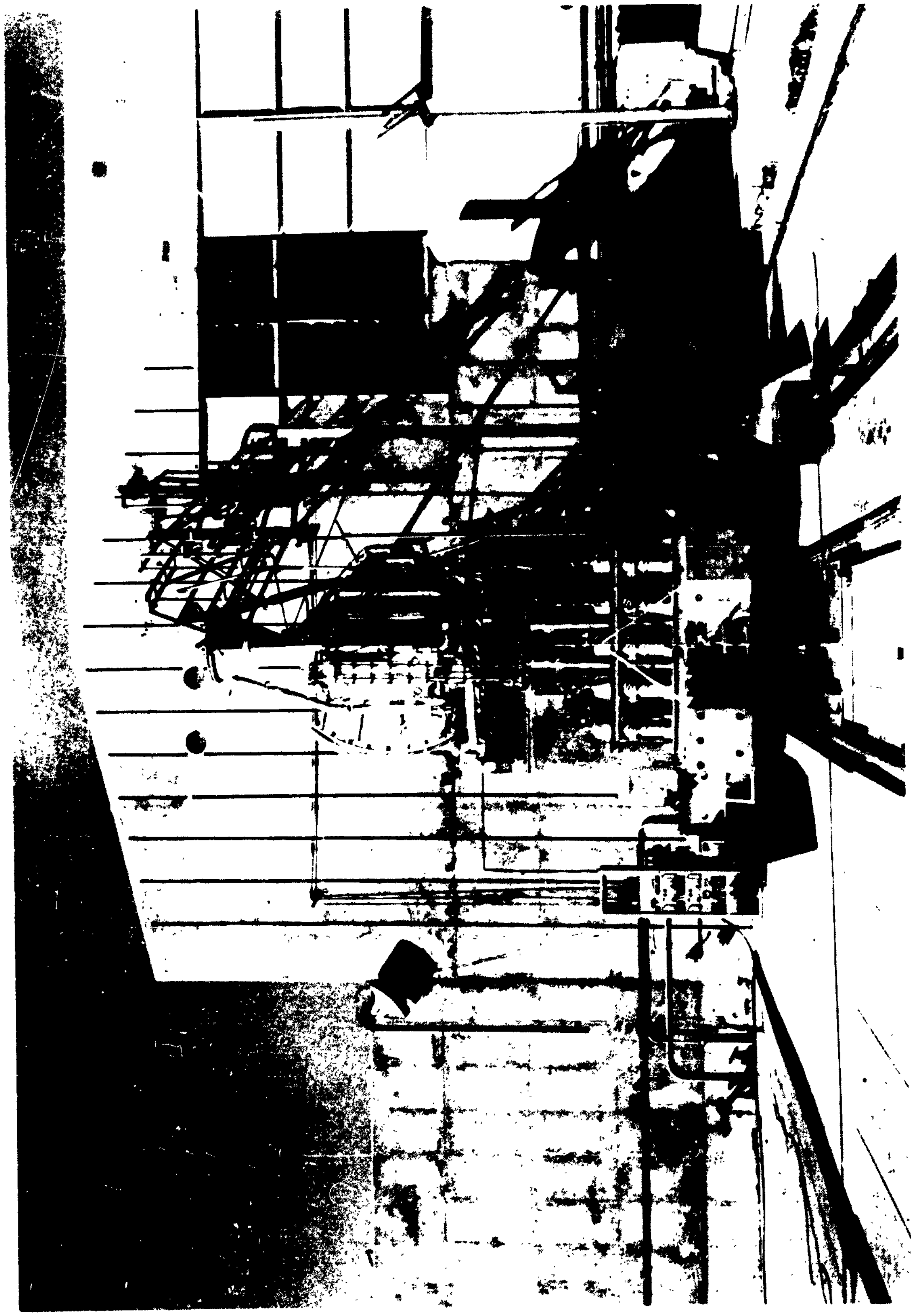


Figure 22. Test car with reactor next to test cell "A"

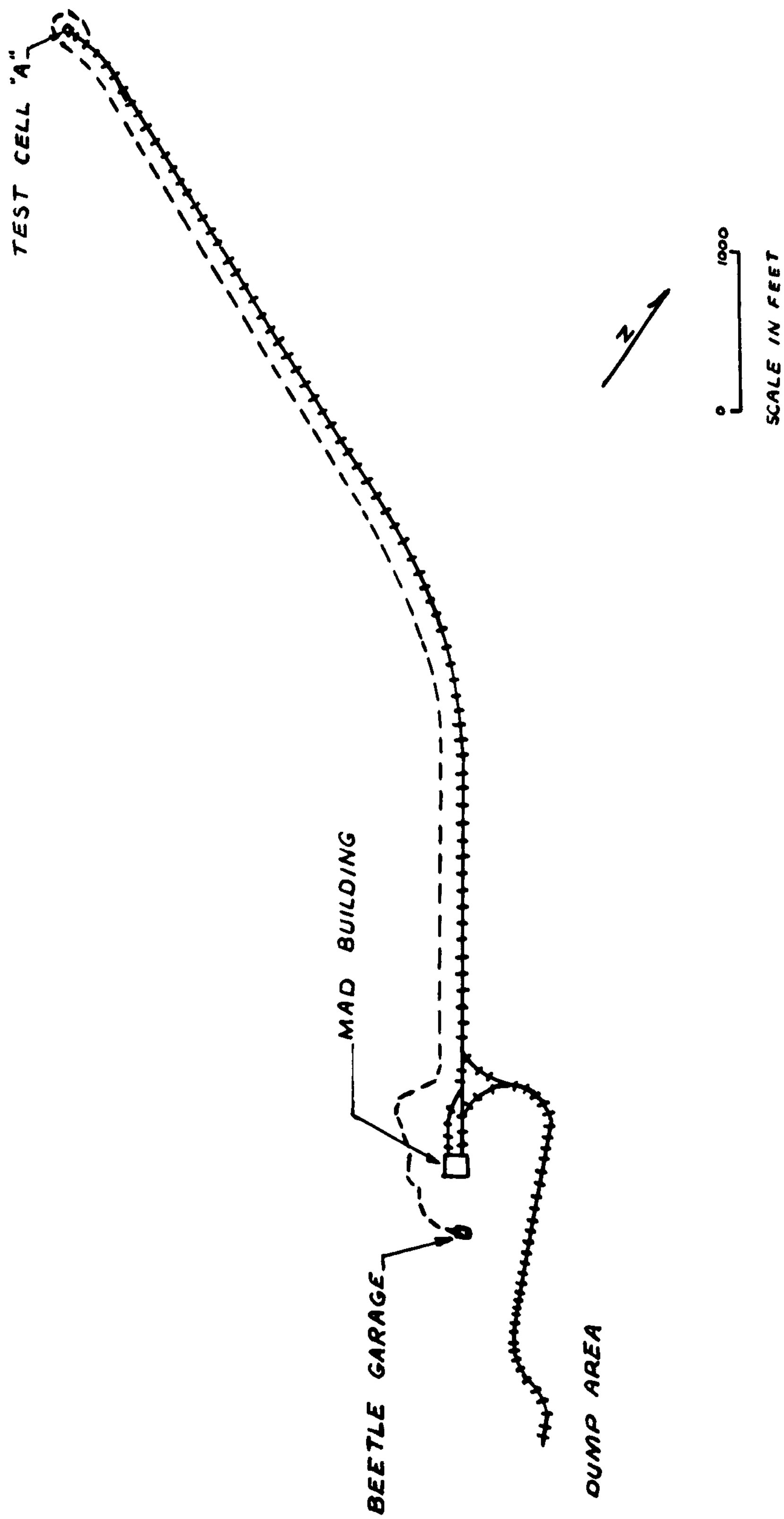


Figure 23. Area 400 at NNRDS

Figure 24 shows the Beetle applying an electrical impact wrench to the top of an instrumentation crypt. It took the operator 2½ minutes to get the impact wrench into the Allen head bolt. Considerably more time is required for bolts in the rear where TV or a mirror must be used to see the bolt head. It is estimated that an hour would be required to remove all 12 bolts on the top of the crypt.

Figure 25 shows the Beetle applying a pneumatic torque wrench to a bolt on the side of the Kiwi-B-1A test car. This example is somewhat hypothetical since the Beetle is not yet equipped with an air supply. However, LASL plans to install the required air supply. An electrically controlled valve on the manipulator arm allows the operator to turn the air to the pneumatic tool on and off from the cab. The other tools shown in the following examples are also pneumatic.

Figure 26 shows the Beetle applying a pneumatic saw to a typical pipe section.

Figure 27 shows the Beetle applying a pneumatic shear to tubing inside the test car.

Figure 28 shows the Beetle turning a control rod on top of the test car. Note the advantage of the vehicle's variable height.

Figures 29 through 32 illustrate the Beetle's ability to reach various components within the test car. Note the use of the TV in observing around corners where the operator could not normally view an object. The Beetle cannot reach components on the far side of the test car. It will, therefore, be necessary to provide a means for the vehicle to travel both sides of the railroad track.

Unfortunately these examples do not provide a concept of the difficulty in performing the illustrated operations or the time involved. Remote operations are typically time-consuming and difficult owing to the nature of the operation. The operator has no kinesthetic sense to feel his way. There is some loss of stereoscopic vision through the thick lead glass windows. The difficulty is further compounded by the fact that, except for fore and aft motion, the Beetle manipulators have no rectilinear motion.

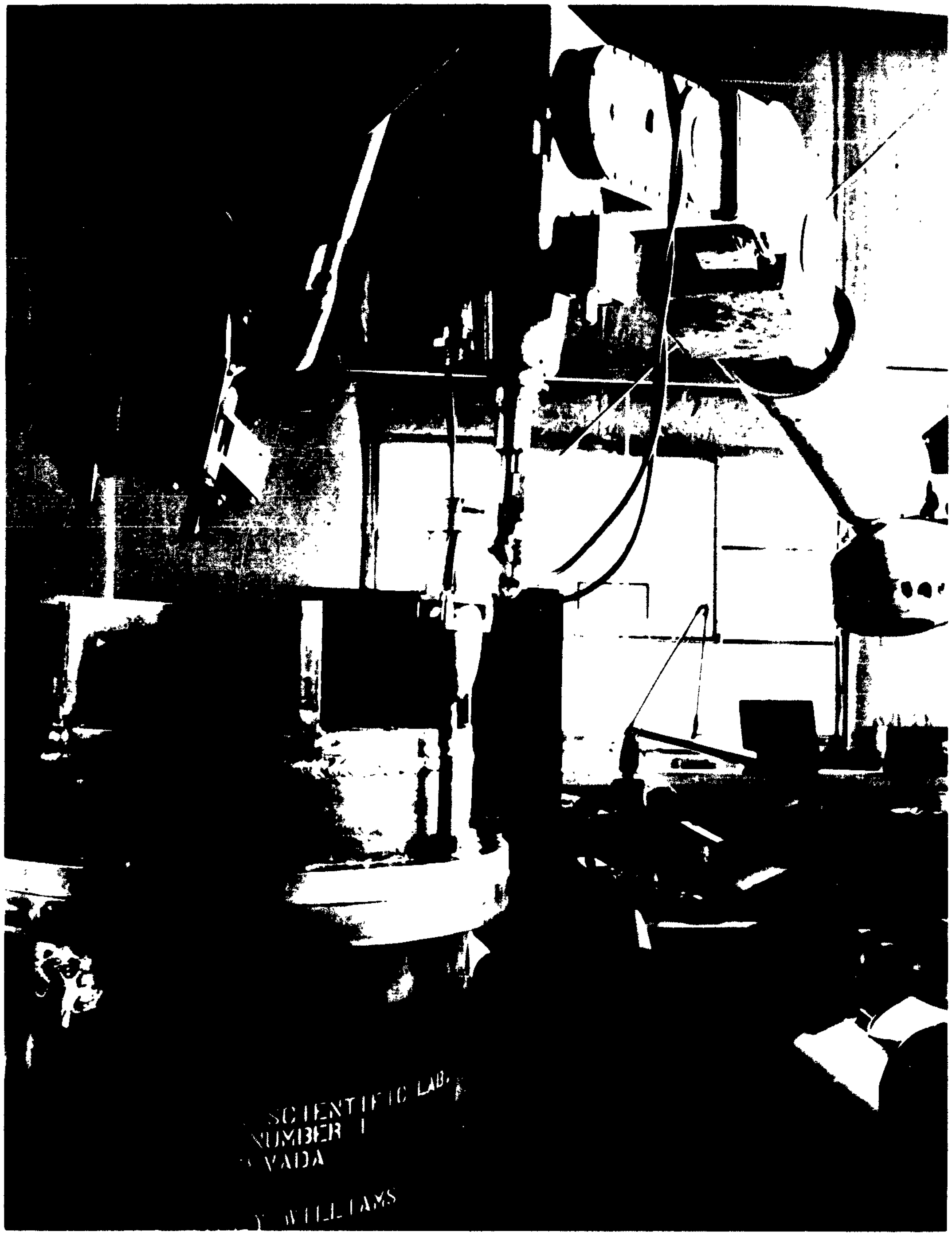


Figure 24. Beetle using electrical impact wrench

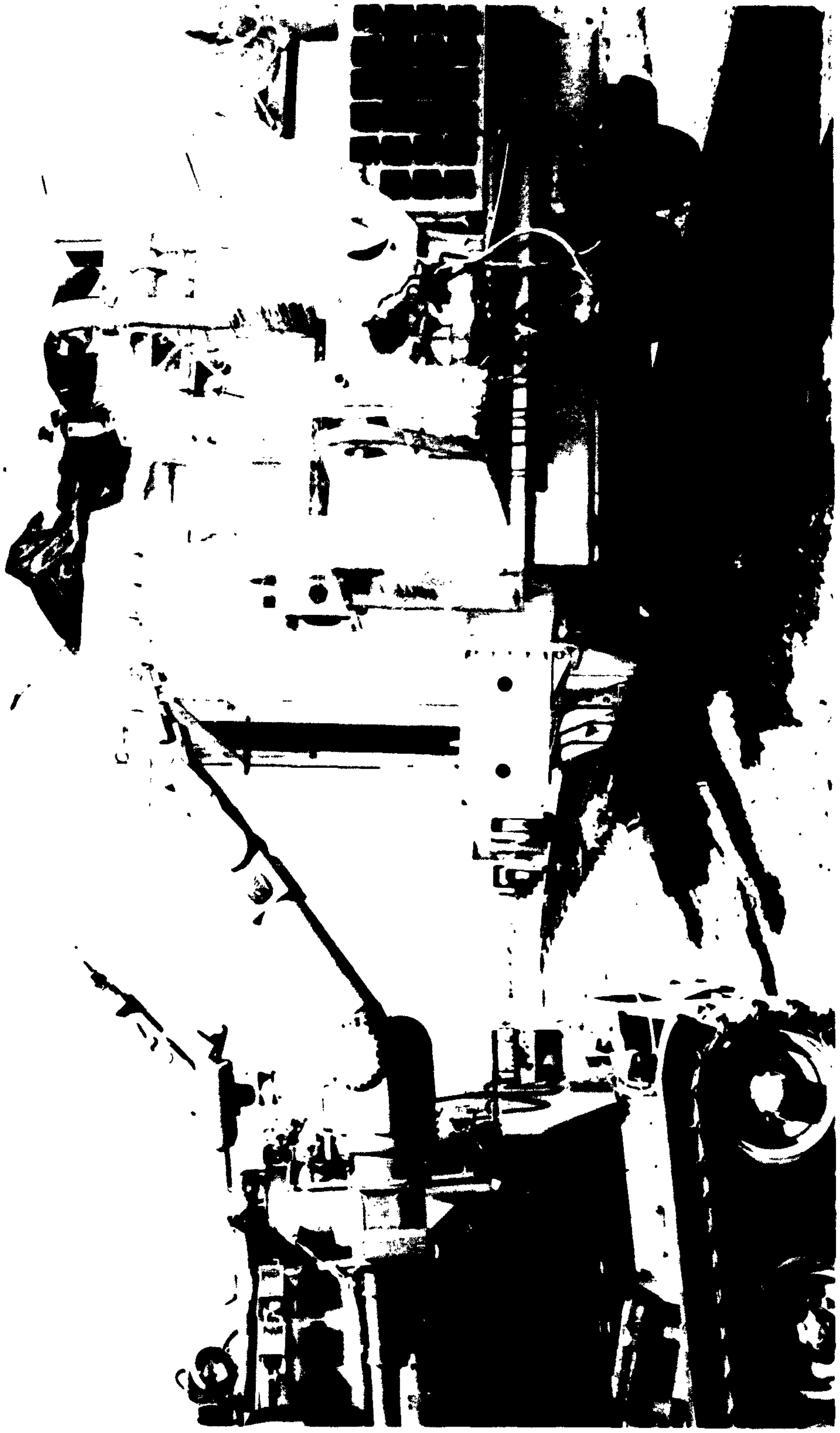


Figure 25. Beetle using pneumatic torque wrench

Figure 26. Beetle using pneumatic saw on typical pipe section

Figure 27. Beetle using pneumatic shear

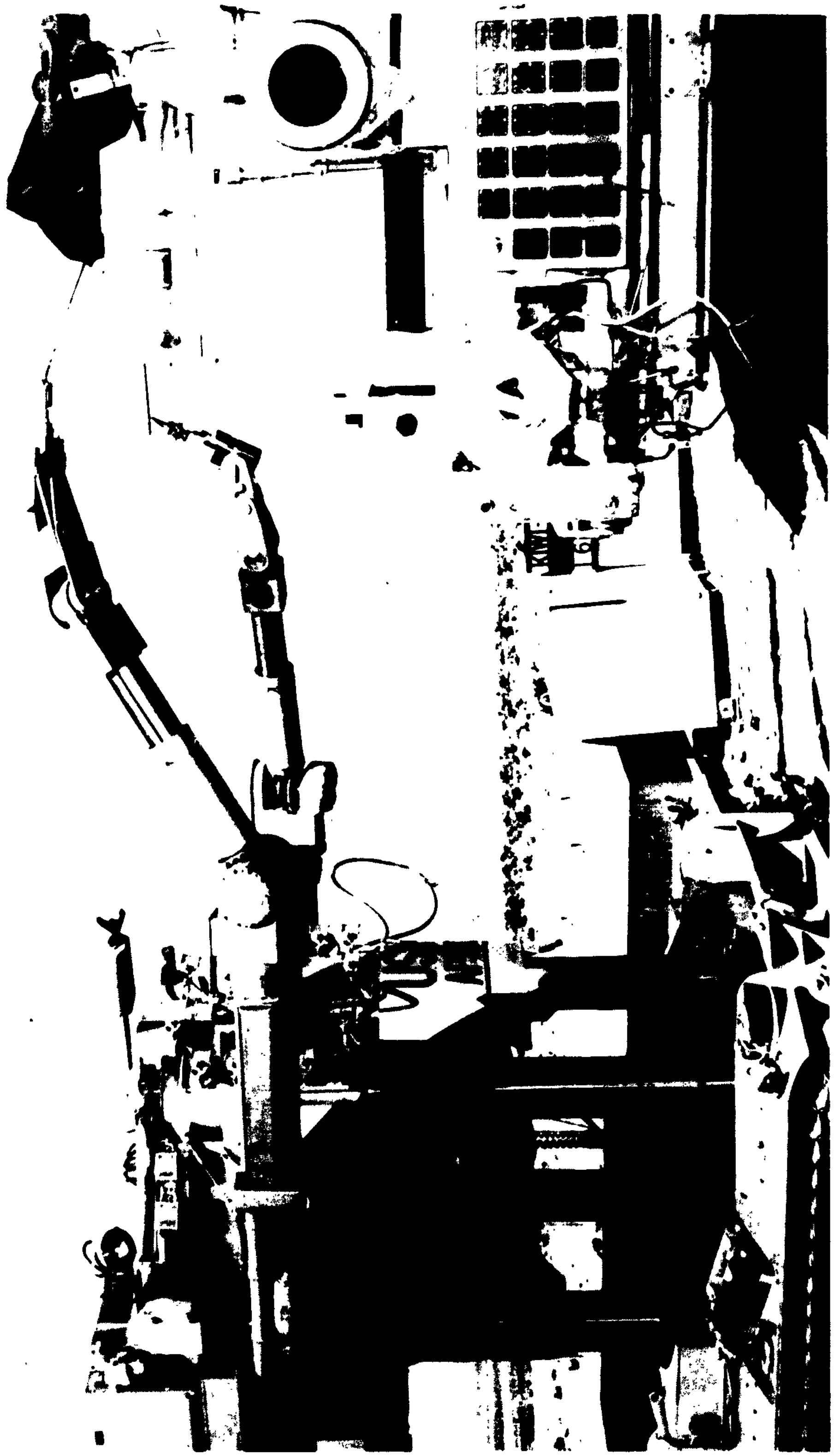


Figure 28. Beetle turning control rod

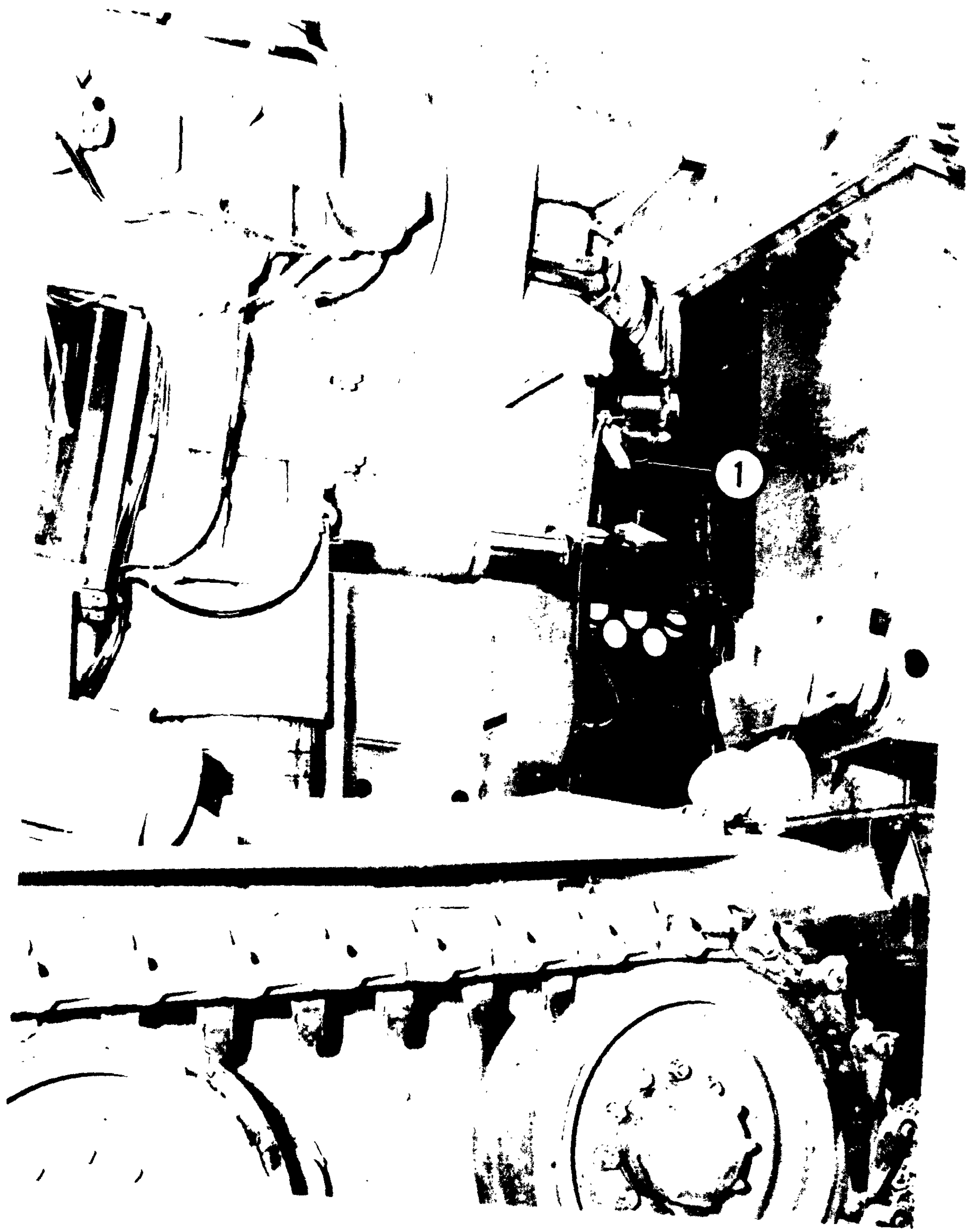


Figure 29. Beetle manipulating within test car
1. Portable television camera

Figure 30. Beetle manipulating within test car

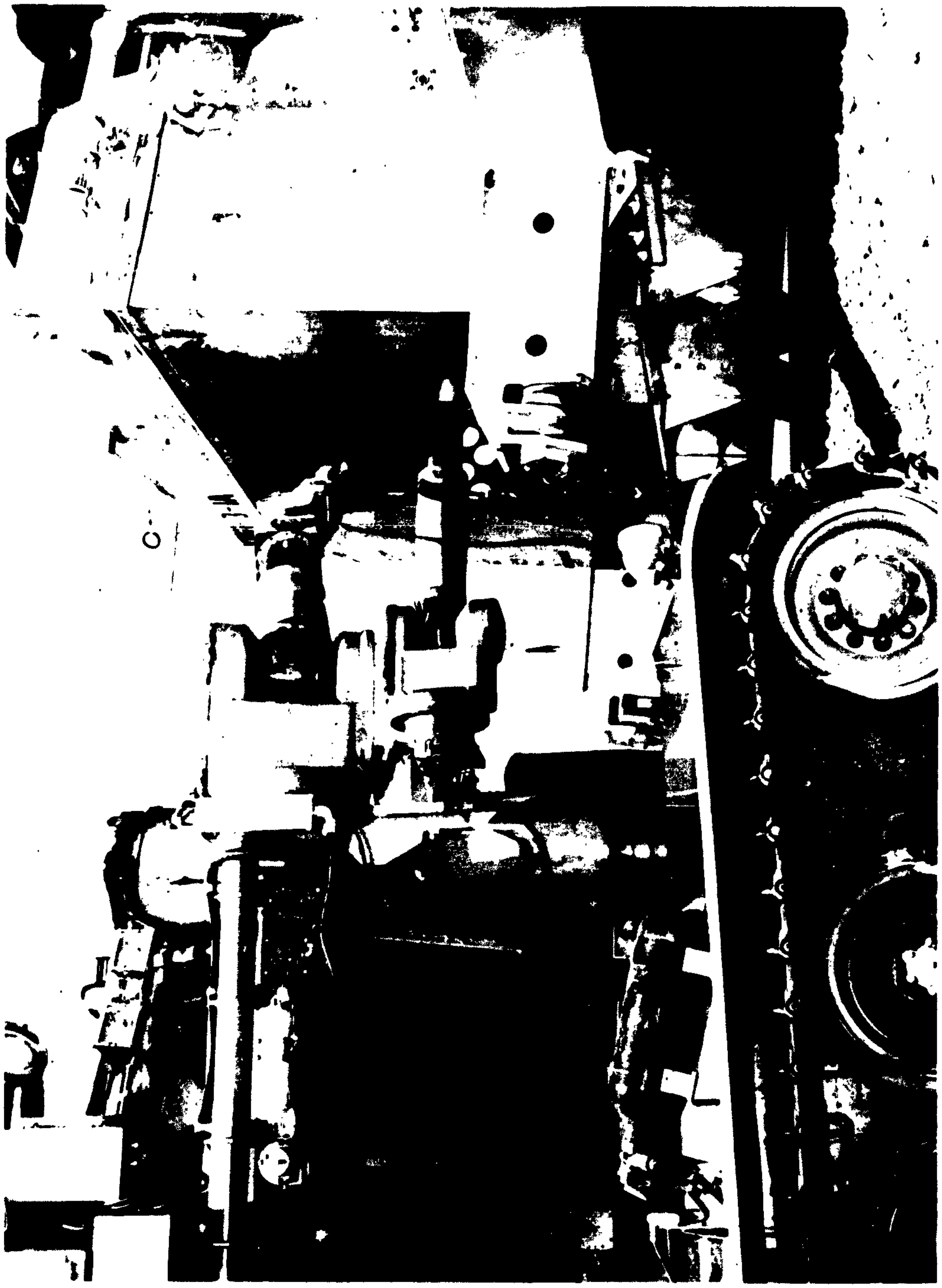


Figure 31. Beetle manipulating within test car

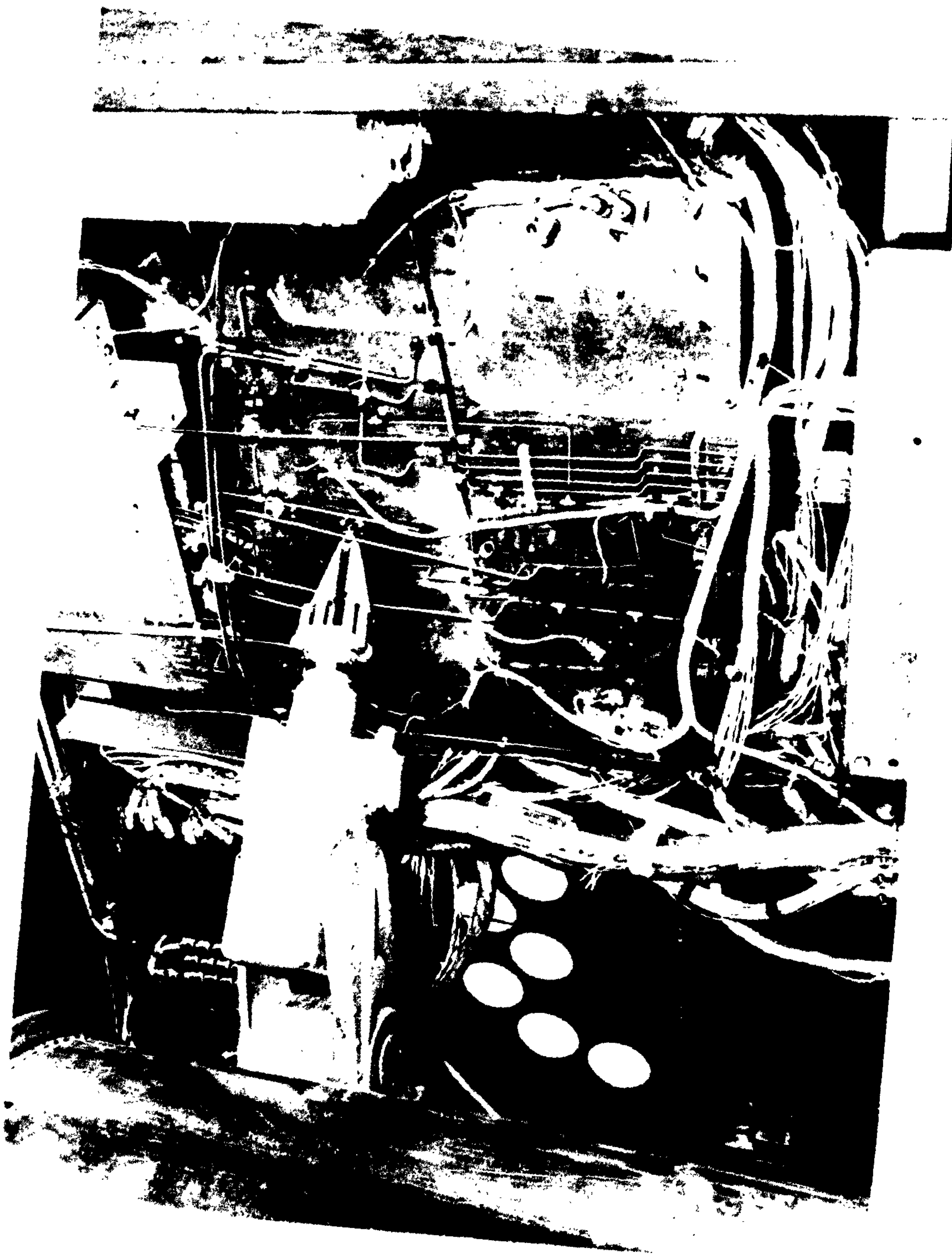


Figure 32. Beetle manipulating within test car

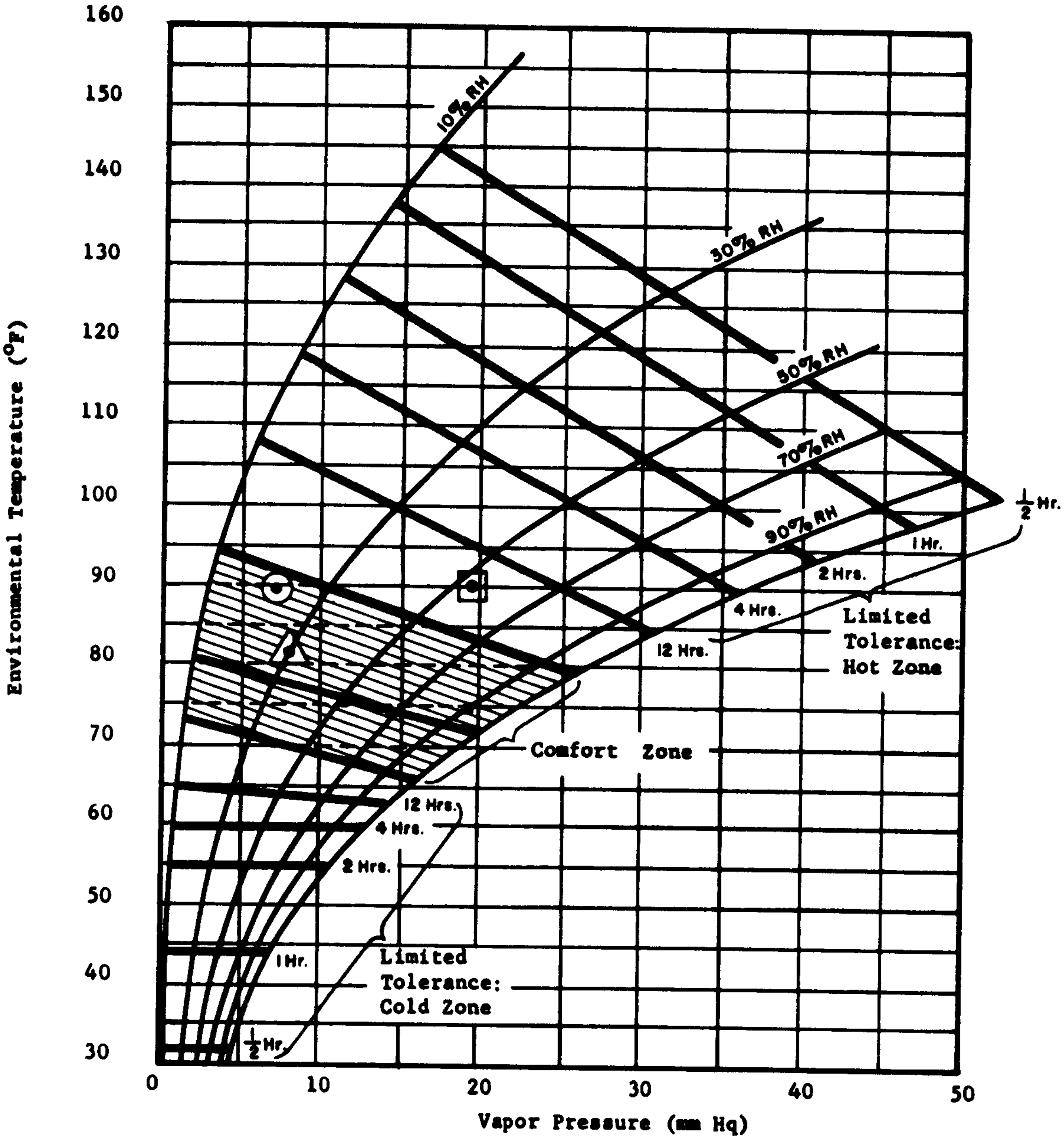
The arms must be moved in segments of an arc. Up and down motion can be obtained by moving the cab but control of the cab movements is not sensitive enough for this type of movement to be considered practical.

(b) Safety requirements.

The transmission was placed in neutral with the main engine turned off, and the creep drive was operated in the forward direction until battery power was lost. This test was run on semi-improved terrain typical of NRDS. Brush and large rocks had been bladed from the area but no attempt had been made to compact the earth. The ground ran level or slightly down hill. The creep drive batteries were at full charge. The Beetle was thus able to run 190 feet at a speed of 10 feet 6 inches per minute before the creep drive batteries lost power.

The air conditoner was turned on and the cab allowed to reach equilibrium temperature. Figure 33 shows temperature and humidity readings for ambient outside air and for inside cab air. The inside cab measurement was taken in the front top portion of the cab. The air conditioner was then turned off and the operator relied on the emergency air supply for a period of 15 minutes. Figure 33 also shows the temperature and humidity measurements at the end of the 15-minute period. Notice that this point falls in the discomfort region. The operator perspired excessively once the air conditioner was turned off. This is primarily due to a buildup in relative humidity once air circulation is lost.

With the auxiliary engine shut down, both the main pod battery and emergency pod battery were fully charged with a battery charger. The right manipulator wrist was then rotated until the dynamotor voltage regulator opened the circuit. This was done for both the main pod battery and the emergency pod battery. The main pod battery was able to provide power for 38 minutes, 57 seconds and the emergency pod battery was able to provide power for 60 minutes, 30 seconds. Figure 34 shows a plot of the a.c. current delivered to the manipulator as a function of time. The transformer for stepping up the voltage from the dynamotor to the manipulator arms is rated at 2.0 KV-a. The dynamotor is rated at 1.0 KV-a. The operation manual recommends that only one manipulator and one manipulator



Sitting man dressed in conventional clothing (1 clo) doing light manual work.
(See MR No. TSEAL - 3-695-56)

Figure 33. Thermal requirements for tolerance and comfort in aircraft cabins

⊙ Ambient outside air condition - 89°F, 21 °/o RH

△ Condition at upper front of cab with air conditioner on and stabilized - 82°F, 30°/o RH

⊡ Condition at upper front of cab with air conditioner turned off after which operator has relied on emergency air supply for 15 minutes - 90°F, 54°/o RH

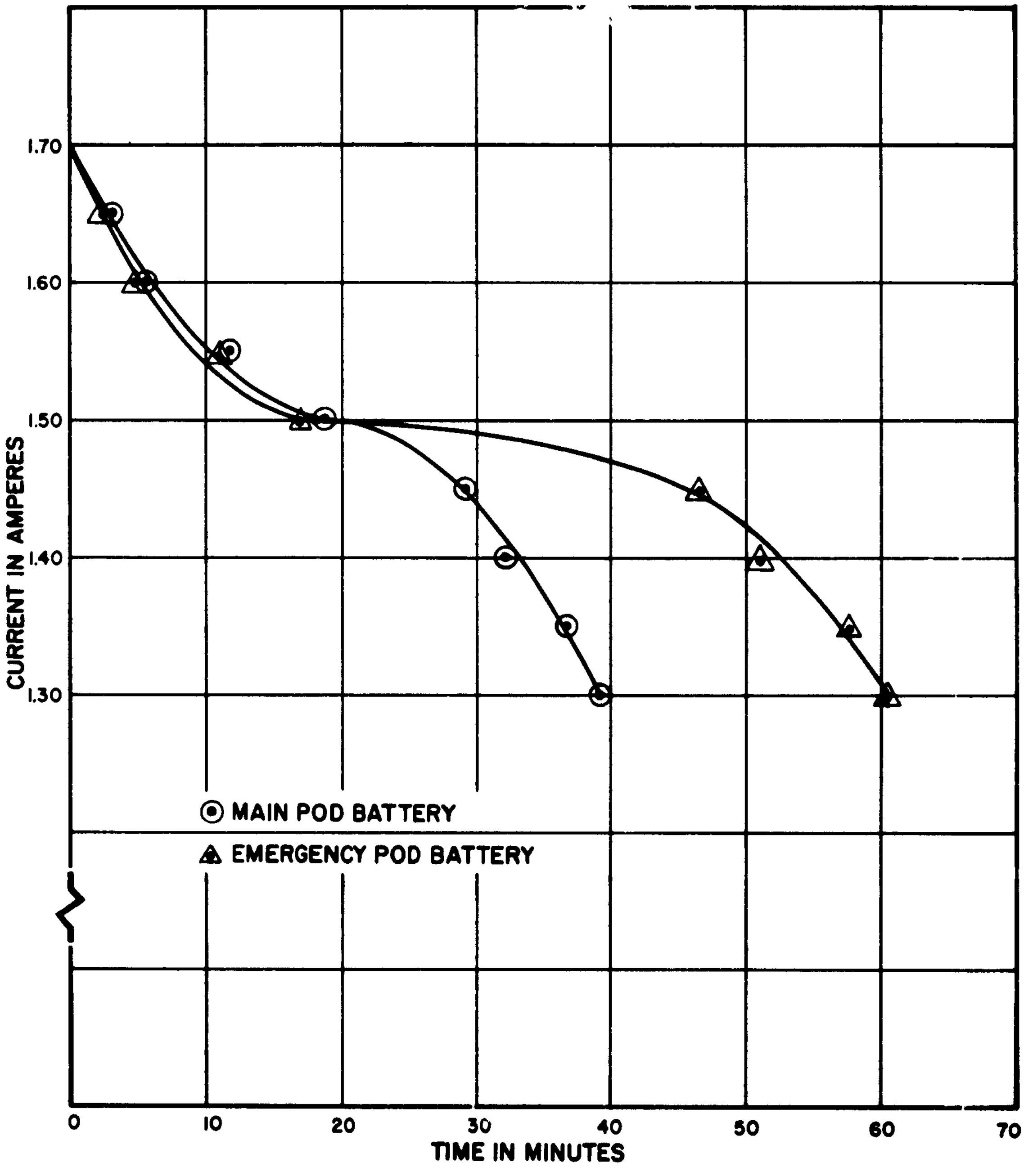


Figure 34. Dynamotor a.c. current output under continuous wrist rotation of right manipulator

function be performed at a time. This function should be limited to hand-open and close and wrist-rotate if possible because power requirements are then within dynamotor and transformer power ratings. Hand-open and close drew the lowest a.c. current of 1.5 amps. However, wrist-rotate was used in this test because the wrist could be set on permanent rotate and the operator could then leave the cab while the test progressed. Additional tests on other manipulator functions showed that the shortest operating time is 7 minutes on shoulder-rotate.

(c) Using exterior controls (JB-10).

The Beetle was moved in the low speed range in both forward and reverse, and was turned both right and left. All creep drive operations were performed from the exterior controls. No difficulties were observed with the exception of those mentioned in section c. (2)(a). Some dust problems were anticipated in the outside control box (JB-10) so the face of the box was covered with a pliable plastic as shown in figure 35.

(4) Capabilities.

This section discusses the capabilities of the vehicle from the standpoint of visibility and manipulative capacity.

(a) TV tests and evaluation.

The Beetle has a 600-line, three-camera, closed-circuit television system. Two cameras, mounted on the pod at each side, provide for general vision to rear of the vehicle. These cameras act in a capacity similar to a rear-view mirror. They cannot be focused from within the cab. A third camera, enclosed in a waterproof case and mounted near the upper right outside corner of the cab, is designed to be handled by the manipulators for close viewing. This TV camera is capable of being focused from within the cab. Controls for camera selection, focusing, and picture quality are located in the cab on the lower control panel, and a 12-inch viewing screen is positioned between the operator's knees.

1. Rear TV cameras.

Figure 36 depicts the cone of visibility outward from the rear TV cameras. A 2¼-inch letter-size printing was moved out from

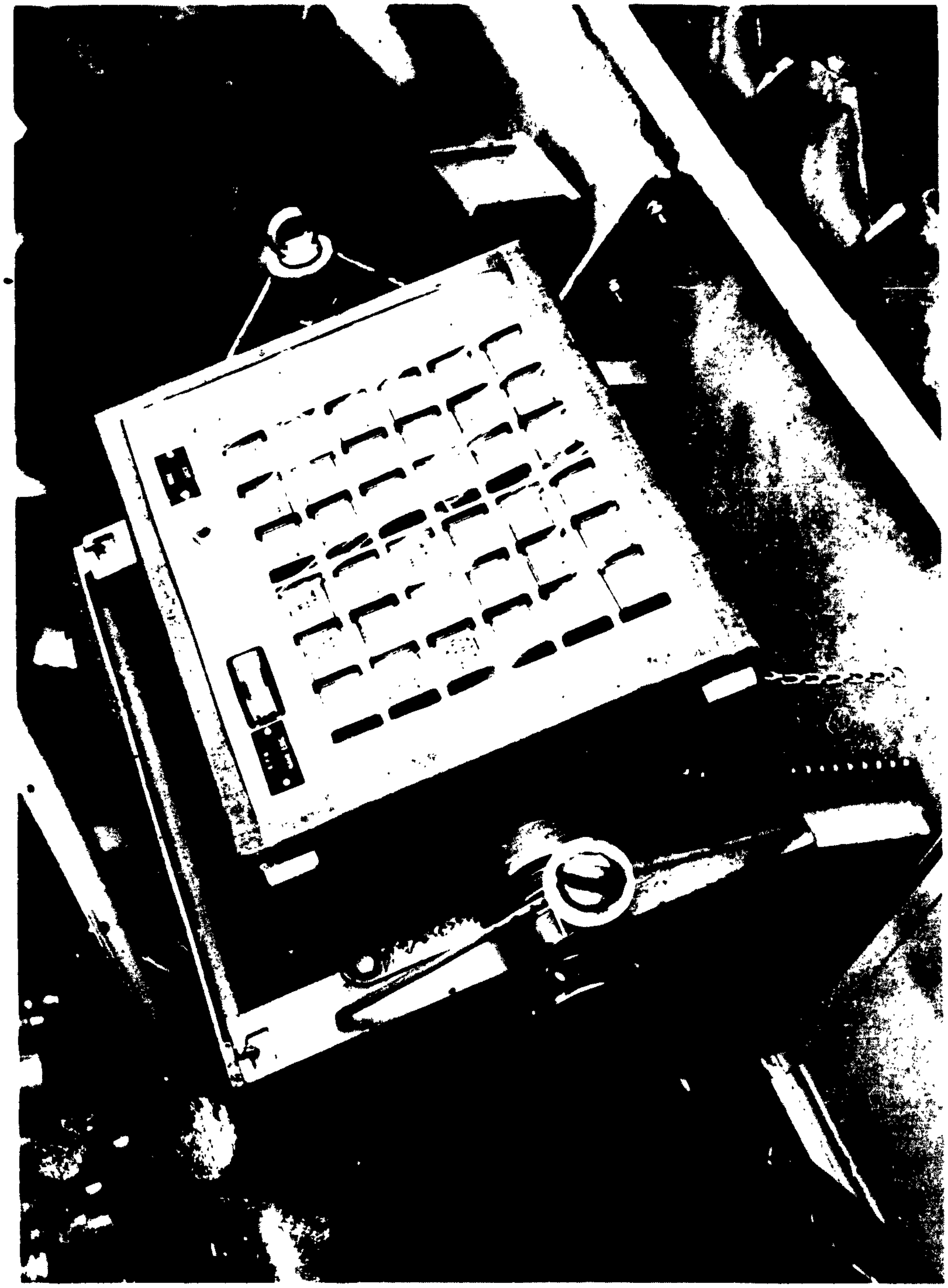


Figure 35. Outside control box with plastic cover

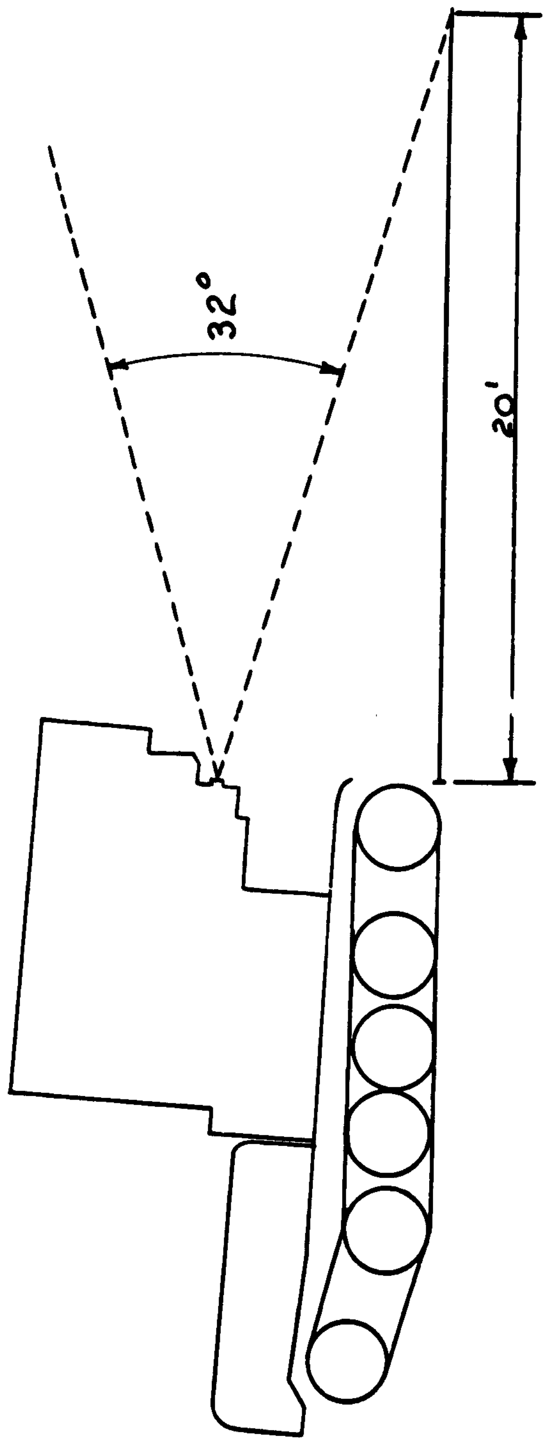


Figure 36. Cone of visibility from rear TV cameras

the rear of the Beetle until the operator could no longer distinguish the letters. For the present focal setting, objects can be clearly distinguished 15 to 20 feet from the camera. A check was made between day and night TV visibility at this setting. There was no perceptible difference between day and night visibility, indicating that the rear lights are sufficiently bright to provide 20-foot resolution at night.

2. Portable TV camera.

The portable TV camera was tested against the 2¼-inch letters under various lighting conditions. While a fuzzy image could be obtained up to 35 feet from the camera during bright daylight, a clear image could be obtained only between 1 inch and 3 feet. The same test was run at night. A clear image was obtained from 1 inch to 15 feet from the camera, indicating that the reduced visibility in daylight is due to glare. Since the portable TV will be used primarily for close-up work, the reduced visibility in bright daylight should not be a hinderance.

(b) Optical tests and evaluation.

The Beetle is equipped with five windows, one large window directly in front of the operator and two smaller windows at each side. All of the windows are 23¼ inches thick and made of multipanel leaded glass with spaces between panes filled with dry nitrogen to prevent condensation. A small nitrogen bottle provides nitrogen for purging the windows should condensation appear. The inner surfaces of each outside pane are covered with a metallic conductive coating to permit electrical defrosting.

Figure 37 shows the relative shape and location of the windows in plain view. The high refraction angle of the leaded glass permits viewing with a minimum of blind areas. The hood prevents viewing the ground directly in front of the Beetle. Figure 38 shows the blind area as determined by test. The operator's ability to see up through the front window is also depicted. Because of a canting of the side windows, a slightly better upward and downward visibility is afforded. For instance, none of the pintle hooks can be seen from the front window. However, use

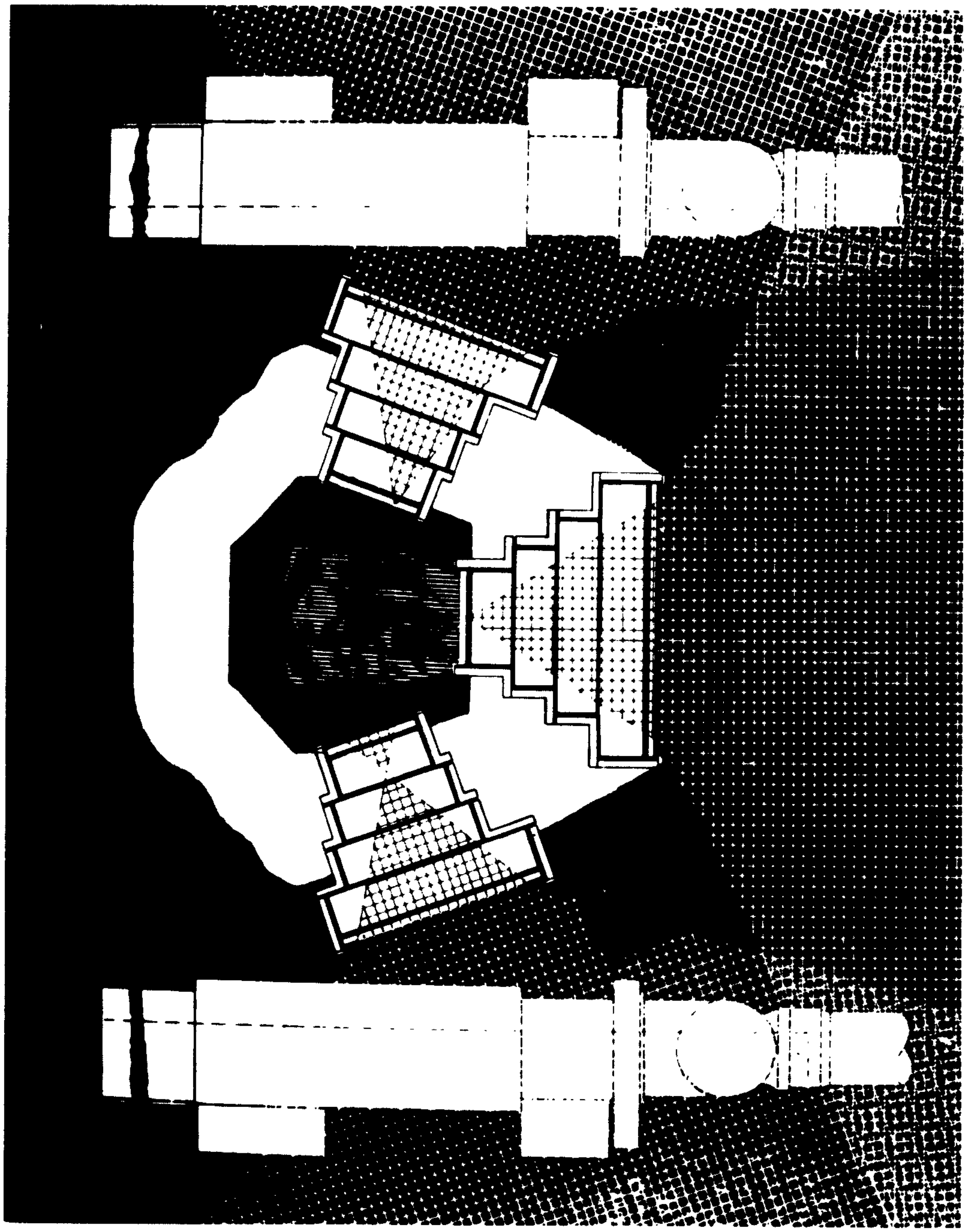


Figure 37. Window viewing area

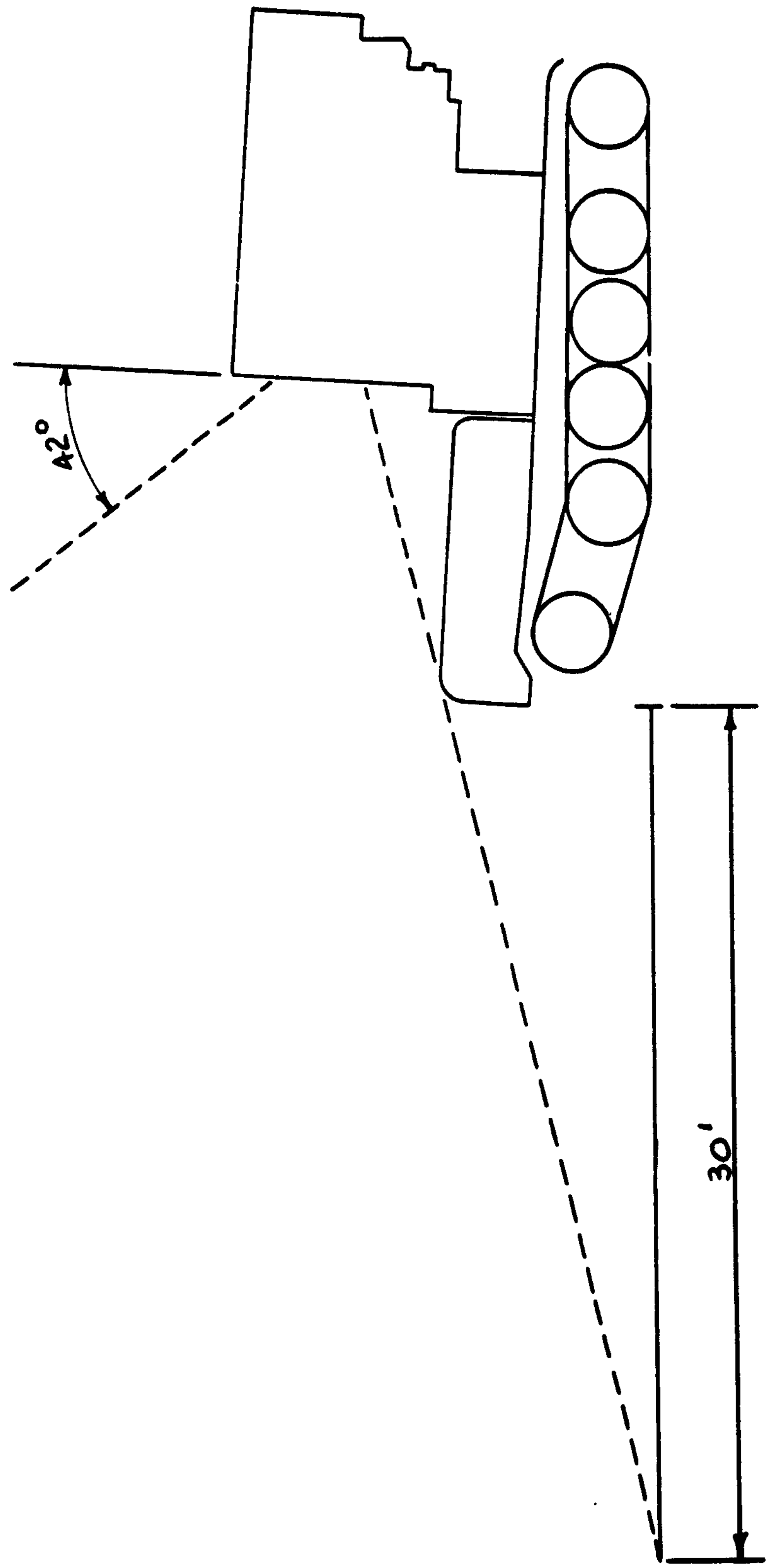


Figure 38. Visibility from front window

of either lower side window allows the operator to view the rear pintle hook if the cab is turned to the side.

During 3 months of use at NRDS, the Beetle windows exhibited no dust pitting.

While no occasion arose to use the defroster, turning it on led to a perceptible increase in temperature of all window panes. This indicates that the electrical defrosters would function properly if required to do so. No difficulties were observed in use of the windshield wipers.

An attempt to purge the windows was unsuccessful. The system would not hold the nitrogen. Leak-Tec was applied to the pressure relief valves, window panes and all other accessible points. The leak could not be found. It is conceivable that the leak is located somewhere within the lead casting of the cab.

Night and daylight visibility checks were made by distinguishing 2¼-inch high letters through both front and side windows. The results of these checks give an idea of the relative efficiency of the Beetle lights as compared to daylight. At night all floodlights were on. The spotlights were not used. The following results were obtained.

Night visibility, front window - 153 feet.
Night visibility, side windows - 60 feet.
Daylight visibility, front and side windows - 450 feet.

(c) Periscope tests and evaluation.

A dual-head periscope (figure 39) is mounted on top of the hatch to permit vertical viewing from 80 degrees above and below horizontal, and horizontal viewing of 180 degrees from stop to stop. It is possible to select two different magnification ranges, 1.5 and 6.0 power. All functions are controlled electrically from within the cab. Appendix VII provides more detailed information on the characteristics of the periscope.

The following periscope functions were checked and found to operate correctly:

Periscope magnification range selection, high and low.
Periscope focus speed control, fast and slow.

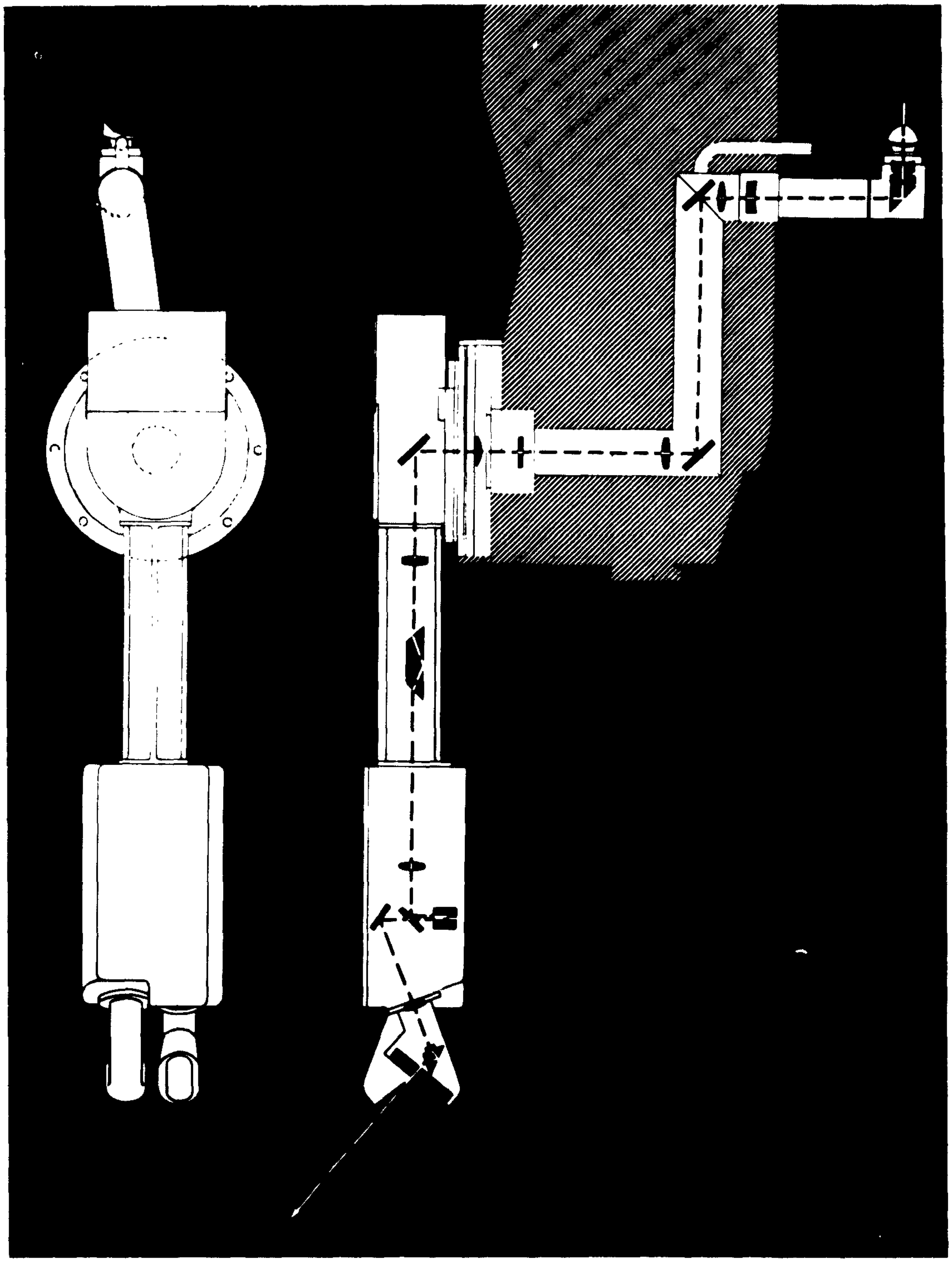


Figure 39. Viewing periscope

Periscope focus controls, close and far.
Periscope directional control, right and left.
Periscope head selector control, top and bottom head.
Periscope vertical scanning controls, elevate and depress.

Night and daylight visibility checks were taken on 2¼-inch-high letters through both powers of the periscope. The cab was facing in the direction of periscope vision so that light from the front floodlights was available at night. The following results were obtained:

Night visibility, low power - 153 feet.
Daylight visibility, low power - 444 feet.
Night visibility, high power - 246 feet.
Daylight visibility, high power - over 2,000 feet.

(d) 550 Manipulator evaluation.

The Beetle is equipped with two General Mills Model 550 manipulators, mounted one on each side of the cab, facing forward from the operator's position. Figure 6 shows the motions that these manipulator arms are capable of undertaking. Figures 40 through 42 illustrate the same manipulator motions with the load capacity for each motion. Appendix II gives the General Electric Company specifications to which the Model 550 manipulators were designed. These manipulators were tested and accepted by the Air Force before incorporation on the Beetle. No attempt was made to duplicate these tests at NRDS. A copy of the results of the original testing is provided in appendix VIII. Some tests were run at NRDS and a discussion of the results follows:

Both manipulators were extended fully forward.

With the axis of all joints vertical (i.e., joints locked in vertical plane) a 100-pound load was applied to the extended manipulator hand to determine the resulting deflection. The observed deflections were:

Right manipulator - 3/8 inch deflection
Left manipulator - ¼ inch deflection

With the axis of all joints horizontal (i.e., joints not locked in vertical plane), the manipulator was moved by hand to determine

Periscope focus controls, close and far.
Periscope directional control, right and left.
Periscope head selector control, top and bottom head.
Periscope vertical scanning controls, elevate and depress.

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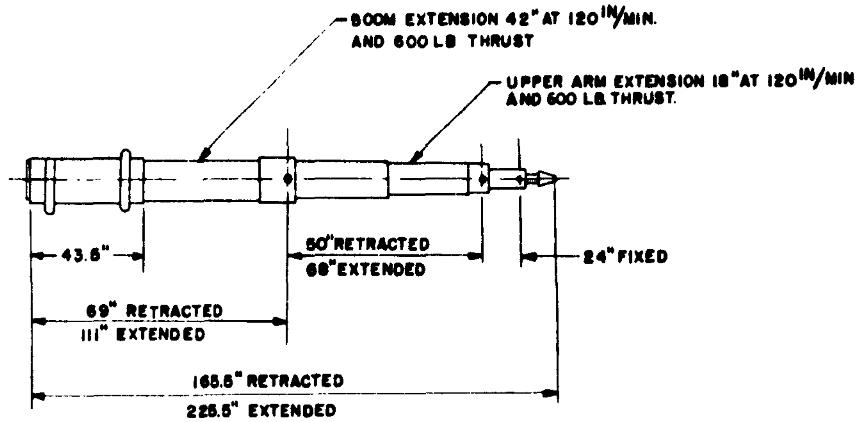

AVAILABLE WITH INTERCHANGEABLE HAND, (200 LB GRIP FORCE, 5" MAX. OPENING AT 20" MIN.) AND HOOK. (750 LB GRIP FORCE, 2 1/2" MAX OPENING AT 8" MIN.)

Figure 40. Manipulator motions

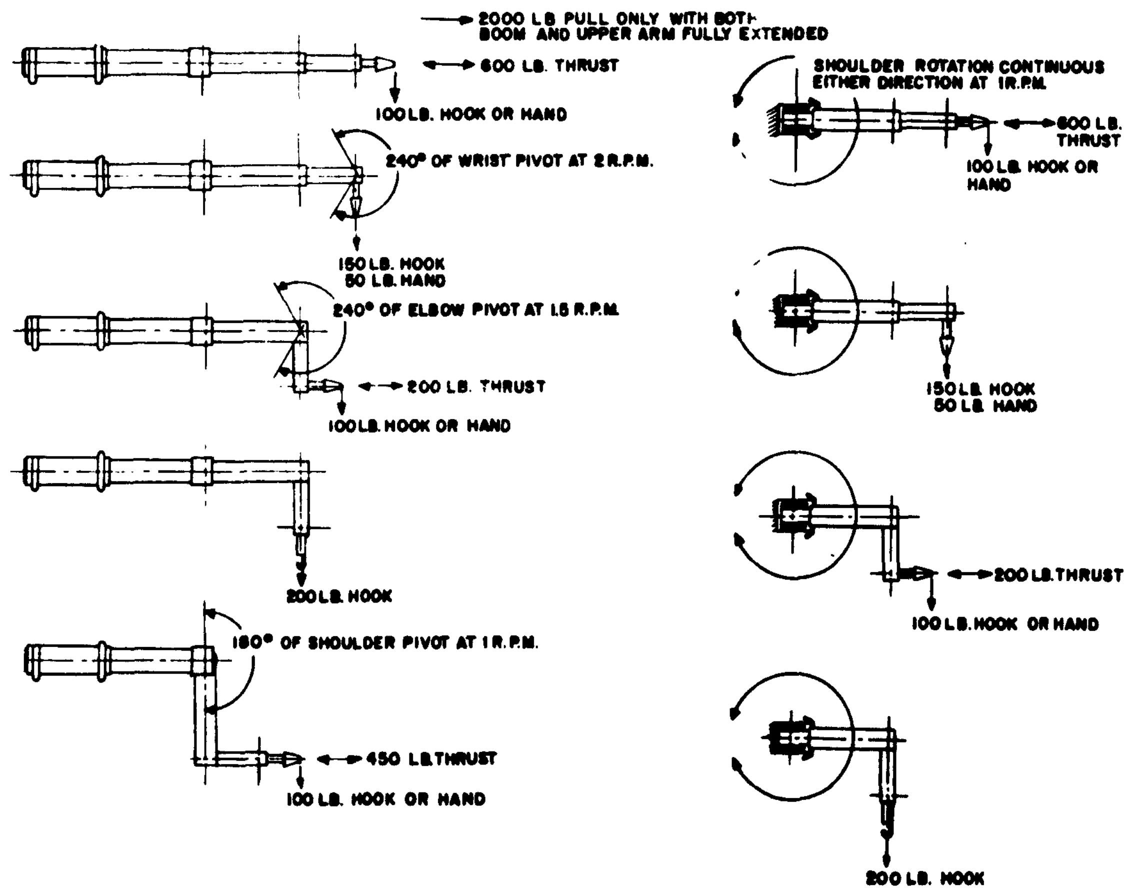

Figure 41. Manipulator motions

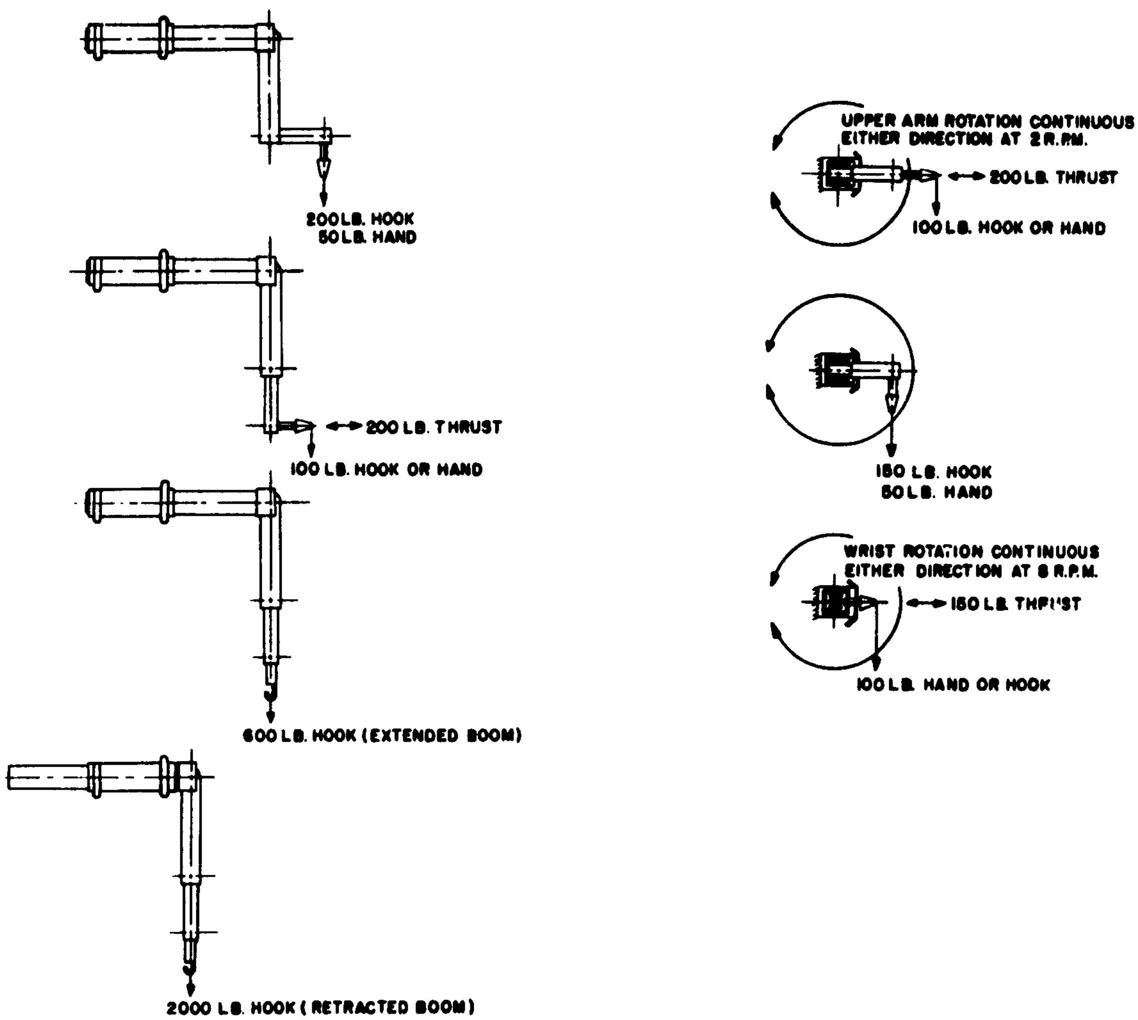

Figure 42. Manipulator motions

the amount of play in the gear trains. The observed plays were:

Right manipulator - 7/8 inch play
Left manipulator - 1¼ inch play

With the axis of the wrist joint horizontal, a 100-pound load was applied to the manipulator hand to determine if the slip clutch was holding as rated. It was found that the slip clutch would not hold 100 pounds. Removal of the cover plate and tightening of the slip clutch remedied this problem. Since the manipulator will carry 100 pounds at full cantilever, it can be shown that the manipulator is capable of handling its rated loads for each joint. It was observed that the gasket on the cover plate was severely deteriorated (see figure 43). This deterioration is due to the effect of the lubricating oil on the neoprene gasket. General Mills Corporation is working on a more suitable gasket material to replace the present gasket.

Both manipulators were operated through a complete spectrum of possible manipulator motions. No difficultes were encountered. The grip force meters operated properly.

The operator practiced removing the portable TV from its stand (see figure 44). While possible only with the left manipulator, the removal can be performed quickly with a little practice.

Several different positions were tried for the hook and hand changing fixtures. Figures 44 and 45 show the optimum positioning. With the hand changing fixtures in the position shown, the operator can obtain a semblance of up and down motion through shoulder rotation and can obtain fore and aft motion through boom extend. Upper arm extension allows the operator to get the hook or hand lined up with the fixture. Figure 45 shows a hand-changing fixture on the operator's right and a hook-changing fixture on the operator's left. These fixtures were procured by General Electric Company along with the manipulators. Although each changing fixture is in an optimum position for the manipulator on the opposite side, it is not possible to use that changing fixture located on the same side of the hood as the manipulator in question. It will therefore be necessary to design new changing fixtures which can change both hand and hook on the same fixture. The fixture should be mounted on a flexible spring base to provide some play should the operator's approach be slightly inaccurate.

Early in the evaluation program, it was noticed that resting the manipulators on the hood arm rests transmitted some unnecessary vibration to the manipulators. This is due to relative motion between the hood and the cab. The relative motion is normally very small but increases at high speeds or during an accident like the track-throwing incident. Following the recommendations of the General Mills Co. technical representative, it was decided to travel with the manipulators extended straight forward and the axis of all joints vertical (i. e., joints locked in the vertical plane.).

Figure 43. Effect of lubricating oil on necprene gasket of right manipulator cover plate. 1. Deterioration

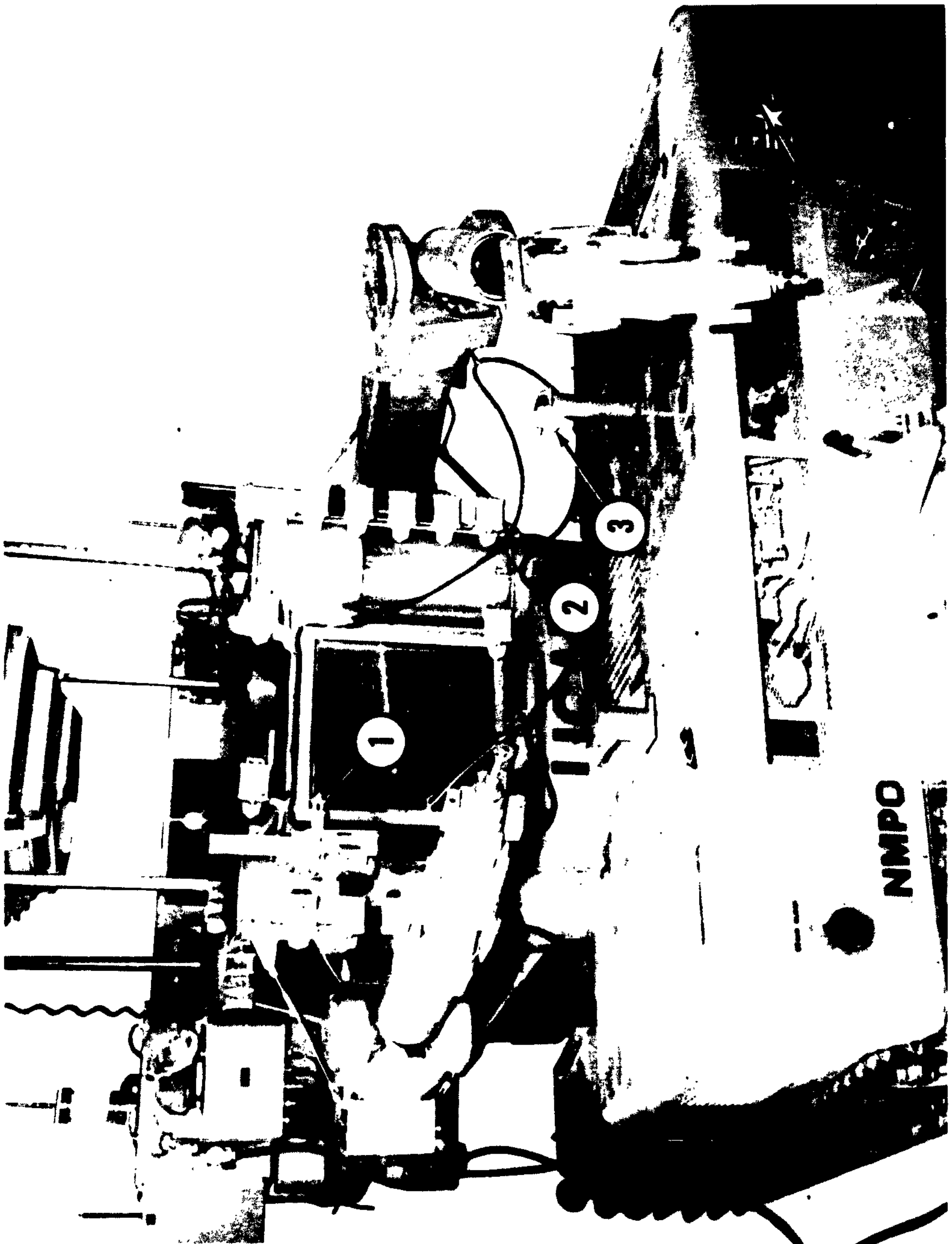

Figure 44. Location of portable TV and hand changing fixtures.
1. Portable TV. 2. Hand changing fixture.
3. Hook changing fixture.

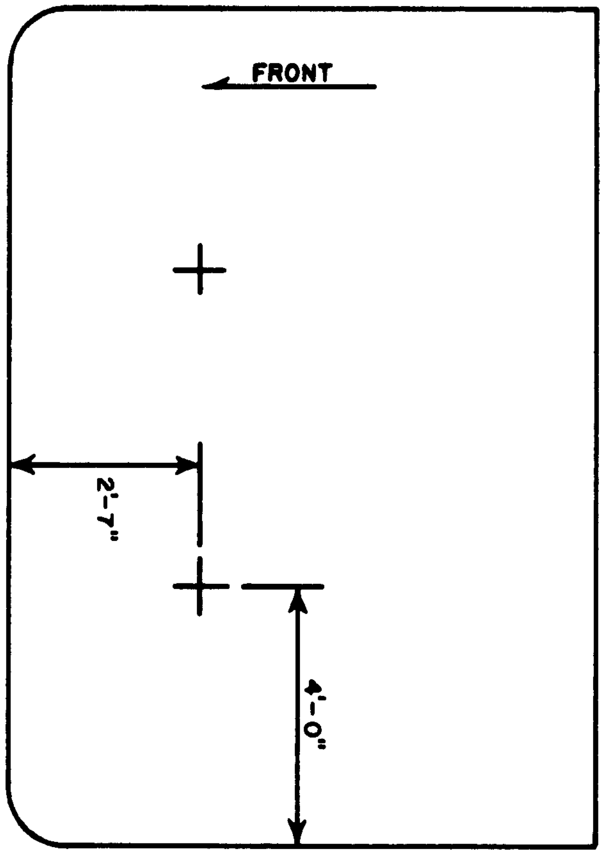

Figure 45. Optimum location of hand changing fixtures

This prevents vibrational wear to the manipulator slip clutches.

(e) Human factors evaluation.

Appendix IX presents a human engineering evaluation conducted on the Beetle by the Maintenance Design Section, Human Engineering Branch, Hq 6570th Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio.

The report makes specific recommendations with regard to the location and types of control switches on the Beetle. The recommendations are good and would reduce operator error. However, cost and space limitations precluded changing the switches during final completion phase. Human engineering was considered in the location of the present switches although space limitation behind the front panel was the principal factor in selecting the type of switch used. The same type of switch is used on the outside control boxes and has not been successful, since in daylight it is very difficult to see the light indications telling the operator which control position he is in.

The report also points out that ease of maintenance does not seem to have been a design requirement. However, because of the extreme complexity of the vehicle, ease of maintenance was difficult to obtain. For instance, it was necessary to add the hydraulic synchronization system in front of the air conditioning system because of space limitations.

d. Conclusions.

(1) Vehicle mobility.

The Beetle was designed to operate on a level concrete surface. The chassis has been strengthened and stronger torsion bars have been added to compensate for the additional weight of the vehicle. The suspension system was not designed for the severe dynamic loads encountered by a combat tank. However, there is no reason to conclude that the Beetle cannot operate on the desert floor once the ground has been cleared of rocks and major obstacles. The Beetle is capable of negotiating and stopping on a 10 percent grade, both in low speed and in creep drive. The high-speed range of the Beetle is limited to 8 mph. Turns must be gradual and a full pivot turn is not possible on uncompacted earth typical of NRDS. Malfunction of the servo-motors controlling both the steering and the transmission range is due to a shifting of the electrical contacts which control the position at which the motor stops rotating. In addition, the servo-motor does not have a sufficient torque capacity to reliably effect a full steer. This is especially true after continuous operation of the steering motor, and indicates that the slip clutch within the motor is becoming ineffective.

(2) Safety systems.

(a) Hatch.

The hatch opens and closes properly with the use of either the normal hydraulic pump or the emergency hydraulic pump. It is not within the average person's physical capability to raise the hatch using the stand-by emergency hand pump system.

(b) Fire control.

The fire control system operates satisfactorily.

(c) Emergency air supply.

The emergency air supply is capable of providing 15 minutes of breathing time should the air conditioner blower fail. Operation under this condition is tolerable but uncomfortable because of rising temperatures and relative humidity.

(d) Creep drive.

The electrical creep drive is capable of moving the vehicle 190 feet over level desert floor typical of NRDS.

(e) Emergency pod battery and dynamotor.

The emergency pod battery and dynamotor both operate properly. There is sufficient power to operate all manipulator functions and to release any object that may be held in the manipulators should pod auxiliary power fail.

(f) System isolation.

A review of the Beetle electrical system reveals that no attempt has been made to isolate electrical wiring for the various safety systems from the overall electrical system. This is especially true in the control circuitry. For example, should an electrical short occur in some one system and lead to the failure of overload relay Number 50 in JB-2, the brakes would apply and controls to put the transmission into neutral or to raise the hatch would be lost. The operator could, however, open the hatch with the electric emergency hydraulic pump. Essentially, the vehicle would be frozen in its position until towed out by another vehicle.

(3) Operational capabilities.

(a) Visibility.

Through the combined use of the portable TV, the windows, and the periscope, the operator has good visibility for all points within reach of the manipulators. The hood blocks the operator's visibility of low silhouette objects for some 30 feet in front of the vehicle. While visibility is reduced at night, lighting is sufficient to distinguish 2¼-inch-high objects up to 153 feet from the front of the vehicle and up to 60 feet from each side.

(b) Radiation integrity.

No gross defects exist in the cab shielding. The lowest attenuation factor is $6x10^{-7}$ through the center of the front window.

(c) Air conditioner.

No gross leaks exist in the air conditioner filter system. The air conditioner is capable of keeping the operator comfortable under temperature ranges anticipated at NRDS. However, the distribution of cool air within the cab is not uniform.

(d) Manipulators.

Both manipulators are capable of lifting up to 100 pounds at a maximum reach of 16 feet. This is the most critical load and thereby indicates the manipulator is capable of handling each of its rated loads.

The present changing fixtures do not allow the operator to change both hand and hook on the same manipulator.

No air supply exists for operating the pneumatic tools.

(4) Reliability.

Throughout the evaluation program, minor difficulties occurred with a variety of components. Considering the immense complexity of the vehicle, continuous difficulties can be expected which may affect operational mission reliability. The problem is further compounded by the fact that the vehicle is being used in a sand and dust environment for which it was not designed. Isolation of the safety systems will help reduce the seriousness of malfunction of an indivual component. However, the Beetle can be expected to require continuous preventive maintenance and should be kept in excellent condition.

(5) Human engineering.

From a human engineering standpoint, the types of control switches being used on the Beetle are not properly suited to the control functions for which each switch is utilized. The location of the switches could be improved. However, space and cost limitations prevent a complete redesign of the control system.

e. Recommendations.

(1) Replace the present steering control servo-motor with a new servo-motor having a torque capacity of at least 200 inch-pounds.

(2) Install viewing ports in the hood of the vehicle to enable inspection of the steering and range control valves. Before each run, inspect the valves to ensure that the servo-motors are moving the range control and steering valves to the proper position.

(3) Perform a thorough analysis of the electrical circuitry and isolate all circuits relating to safety requirements to ensure that failure of some minor circuit will not result in failure of the safety systems. As a minimum precaution, a circuit breaker should be added in the cab in parallel with circuit breaker No. 1 in JB-1. This would allow for resumption of operation should a momentary short trip the manual reset circuit breaker in JB-1.

(4) Design new spring-mounted changing fixtures capable of changing both hook and hand on the same fixture.

(5) Install a portable air supply on the vehicle to enable use of pneumatic tools.

(6) Improve Beetle maintenance facilities at NRDS.

(7) Initiate and follow a strict preventive maintenance program on the Beetle. Records should be kept on any component malfunctions and the inspection period should be shortened for those components indicating weakness.

(8) Replace the switches on the outside control boxes along those lines recommended in appendix IX, figures 5 and 6. The recommended

design for JB-10 (figure 5, appendix IX) does not show switches for cab raise and lower and cab rotate. These should be added.

3. USAF SHIELDED SALVAGE VEHICLE (MASHER).

a. Background.

The Masher was modified from a T51 Tank Recovery Vehicle by the Army Tank Automotive Command, Centerline, Michigan. Its prime function was to support the Nuclear Aircraft Research Facility (NARF) Program, a portion of the now cancelled Aircraft Nuclear Propulsion Program (ANP). The vehicle was located at the NARF facility at General Dynamics, Fort Worth, Texas. At the NARF facility a ground-test reactor was used to perform dynamic testing of small aircraft components in a radiation field and in pressure, temperature, or humidity environments. Numerous sources of radiation as well as an Aircraft Shield Test Reactor were used for radiation testing and shielding experiments. The Nuclear Test Aircraft was a modified B-36 bomber that flew on its own conventional engines but was equipped with a shielded crew compartment, nuclear instrumentation, and a reactor, the Aircraft Shield Test Reactor. The shielded salvage vehicle was on constant standby duty in case of Nuclear Test Aircraft accident, and possible contamination of the area. If such an accident should occur on-base, within the immediate locality or even in the flight test corridor, the Masher would either be transported under its own power or shipped by commercial carrier to the location. In a radioactive environment, two operators are capable of performing cleanup and/or salvage operations on the reactor in complete safety.

It was learned at AFSWC in March 1961 that the Masher was of no further use to General Dynamics. Since cancellation of NARF Program, the vehicle had essentially remained dormant. The possibility of AFSWC controlling the vehicle for support of the Nuclear Rocket Program at the Nevada Test Site was investigated. The controlling agency (ASD) gave permission and the Masher accountability was transferred to AFSWC on a no-cost basis with the stipulation that it would remain Air Force property to help support future Air Force nuclear programs as needed.

b. Description of test articles.

The primary modification performed by the Detroit Tank Arsenal on the T51 Tank Recovery Vehicle was the addition of a shielded cab. The cab has a minimum of 5 inches and a maximum of 10 inches of steel shielding in the rear and front respectively. Five lead glass windows are strategically located around the cab for maximum visibility. Two operators are required to exercise the full capacity of the Masher vehicle, especially in a salvage operation. These operators work in opposite directions. The driver of the vehicle actuates the winch and dozer blade, controls for which are located at his left. At the driver's right, and facing in the opposite direction, is the crane and boom operator's position. This operator controls all crane motions such as raise and lower, traverse, boom retraction and extension, and raise and lower hook. Operator safety and comfort are increased by an outside air filter system and a 1½-ton recirculating air conditioning unit. Eight absolute-cube-shape filters of the 5-micron range compose the outside air filter system for vehicle operation in a fallout area. The cab entrance is a split circular vault type of door which opens outward. The diameter of the entrance decreases in a step fashion from the outside of the cab to the inside. This vault step seal has proved very effective in the protection against gamma radiation.

Characteristics and vehicle specifications are as follows:

GENERAL

Weight - 150,000 pounds
Center of gravity - 53 inches above ground
Maximum speed - 35 mph
Tow speed - 30 mph
Maximum grade - 60%
Range - 130 miles
Bulldozer blade - 8-inch maximum depth of cut
Fire extinguishers: 4 each 16 lb. capacity - main engine
2 each 15 lb. capacity - outside vehicle
1 each 51 lb. capacity - Personnel Cab

Windows (lead glass): Front - 9½" x 34" x 8" thick
Left side - 9½" x 9" x 8" thick
Right side - 7" x 6" x 8" thick
Rear (2 each) - 9½" x 9" x 8" thick

Air conditioner: 1½ Ton capacity

DIMENSIONS

Height - 10 feet 6 inches
Length - 39 feet 5 inches
Width - 12 feet 4 inches

ELECTRICAL SYSTEM

Nominal voltage - 24
Main generator - 28 volts 300 ampere regulated field
Generator - 28 volts 240 amperes shunt field
High tension MAG ignition system with magneto scintilla

RUNNING GEAR

Suspension - Torsion bar
Number of wheels - 14 dual
Wheel size - 26 inches
Track - T-107, Rubber Chevron, double-pin
Pitch - 7 3/32 inches
Tires - 28 solid rubber tires 6 inch x 26 inch

COMMUNICATIONS

Motorola "D"
Series - Industrial dispatcher
Radiophone - Transmitter and receiver

ENGINE PACKAGE

Engine - continental model AVSI-1790-6, 12 cylinder 90° air cooled super charged fuel injection.
Displacement - 1,790 cu. inch; bore 5.75 inches; stroke 5.75 inches

Compression ration - 5.5:1
Governed speed - 2,800
Fuel - 400 gallons of 80 octane
Oil - 64 quarts
Gross horsepower - 1,020 HP at 2,800 rpm
Net horsepower - 850 HP at 2,800 rpm
Gross torque - 1,900 ft/lb at 2,200 rpm
Net torque - 1,620 ft/lb at 2,300 rpm
Engine cooling fans draw air through the oil coolers

POWER TRAIN

Transmission - Model XT 1400-2A cross drive transmission
Hydraulic converter - single-stage polyphase with "lock-up" clutch
Overall usable ratio - Low, 124/1; Intermediate, 58/1; High, 27.2/1; Direct, 6 8/1; Reverse, 135/1
Steering rate - 5.6 rpm turning radius pivot to Inf.
Steering control - manually controlled hydraulic valve
Brakes - mechanical, foot-pedal operated

Crane and hoists:

Crane: Crane has a hoisting capacity of 30 tons at 4 feet distance from rear full plate of vehicle to a hook height of 12 feet. With the crane extended to an 8-foot distance, 15 tons can be lifted to a hook height of 15 feet. Maximum hoisting speed is 14 fpm with full drum. The crane is capable of traversing 30 degrees to both right and left of the longitudinal axis of the vehicle.

Winch: Vehicle has a 50-ton winch consisting of 317 feet of 1¼ inch diameter cable located in front of the vehicle directly over the blade. Winching speed is 29 fpm on the bare drum.

SHIELDING

Front and sides - 10 inches of steel with 8 1/8-inch Penberth "Hi-D" windows.

Rear - 5 inches of steel with 6 1/8 inch-Penberth "Hi-D" windows

Top and bottom - 5 inches of steel

Micron filters: (absolute) - 8 each
5 micron size 6" x 6" x 5 7/8"
with frame 8" x 8" x 5 7/8"

c. Summary of test.

(1) Testing of the Masher vehicle was conducted on a limited scale, since for all practical purposes it can be considered a production vehicle. No specific test document was established as a guideline for testing. Procedures were conducted in a general manner to determine the vehicle's reliability from a safety and mechanical standpoint. The evaluation was conducted in the following phases:

(a) Operational checkout
(b) Shielding integrity
(c) Air conditioning and outside air filter integrity
(d) Operational uses.

(2) Operational checkout

(a) Mobility

Upon arrival at NTS the vehicle was inoperable except for the auxiliary engine. Considerable rust deposits, water, and foreign sediment were found in the fuel system and in the main engine's internal working components. (Figures 46 and 47). The primer system filter was void of an element (figure 48). The oil filter was partially clogged, allowing dirt and rust to enter the engine. (Figure 49.)

All defects mentioned above were corrected as follows:

1. The vehicle's power plant was replaced with a new engine of the same model, Continental Model AVS-1790-6.

2. A new fuel system was installed.

3. The fuel tank was removed, cut into sections and sand blasted free of all rust deposits.

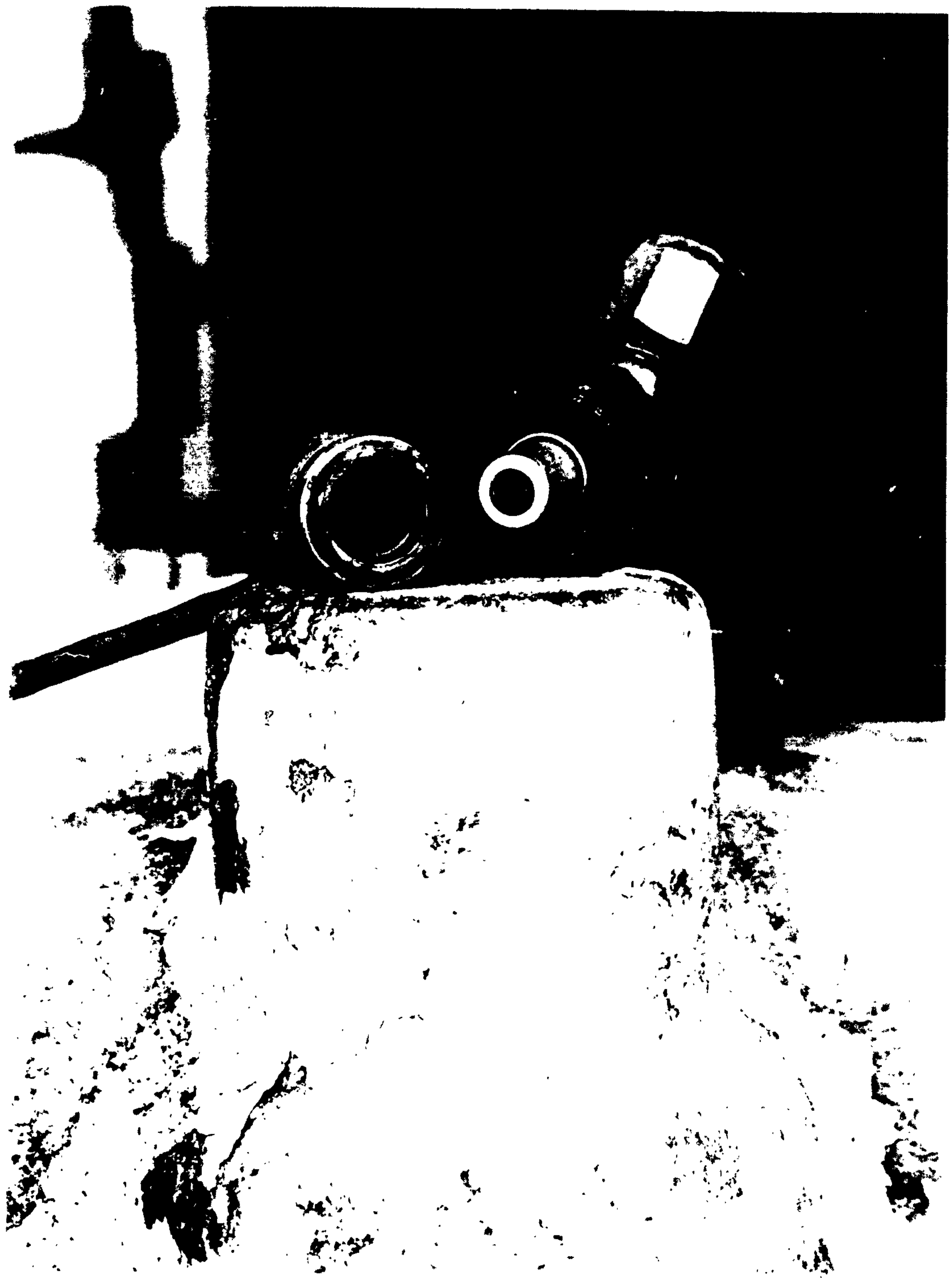

Figure 46. Rusted fuel primer lines

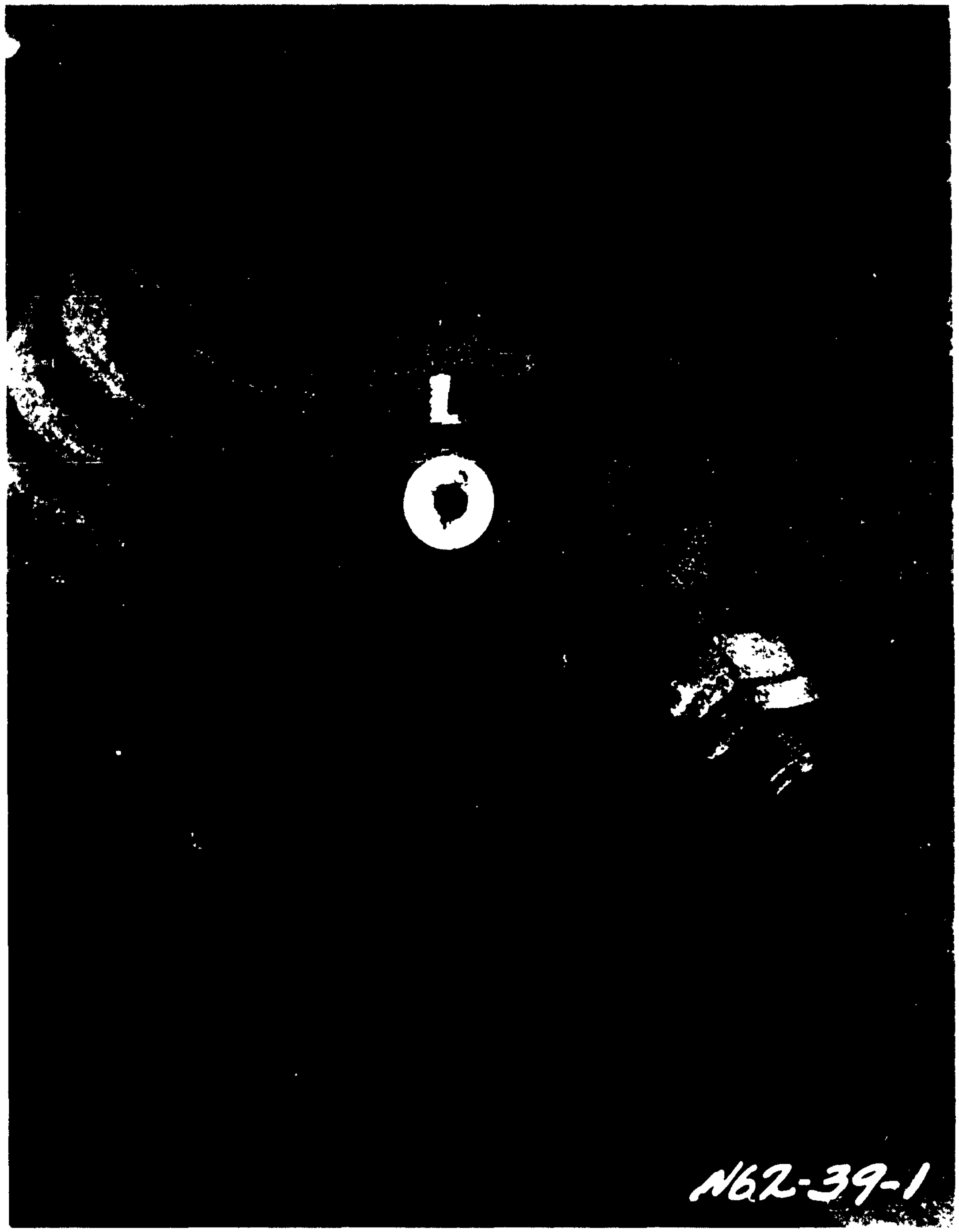

Figure 47. Primer injector nozzle frozen into cast; line broke off in removal attempt

Figure 48. Primer filter system void of element; clogged with rust scales

Figure 49. Note depth of finger impression in grime

The main engine was started following prescribed procedures. No difficulties were encountered.

After a sufficient warm-up period, engine speed was fluctuated between 800 and 2, 800 rpm. No difficulties were encountered.

The vehicle was placed in the low forward drive range and driven in a straight line for approximately 1, 500 feet and then brought to a halt. It was then moved in the reverse direction for the same distance. Performance was smooth in both operations.

In low gear the vehicle performed left and right steering maneuvers on terrain typical of NRDS. No difficulties were encountered. During a later phase of the test a low-speed range turn was attempted and the vehicle's left track dislodged at the sprocket. This can be attributed to several factors. While at General Dynamics, the vehicle's dozer blade was used to make a cavity in the ground large enough for burial of contaminated debris. The soil was turned at too great a blade angle which resulted in steep inclines on either end of the cavity. While the vehicle was maneuvering out of the cavity, its weight was concentrated on the rear road wheels, causing permanent deformation to the suspension arm support housing. The result was the slight inward cant on both sets of rear road wheels shown in figure 50. The angle of cant is such to decrease tension on the track, making the track more susceptible to being thrown. The vehicle's left track hit a large rock partially dislodging the track from the sprocket. It is therefore concluded that semi-prepared rock soil and the overloaded chassis suspension are two causes for throwing a track. Overall damage was slight and did not hamper the vehicle's maneuverability in later operations. (Figure 51.) Turning was limited to the same requirements as the Beetle whenever possible. No additional difficulties were encountered.

Shifting into the high-speed range from the intermediate and low range was accomplished on a normal asphalt highway. A high range speed of 22 mph was attained. Shifting to the intermediate speed range was accomplished on up-grades. All procedures were accomplished without difficulty.

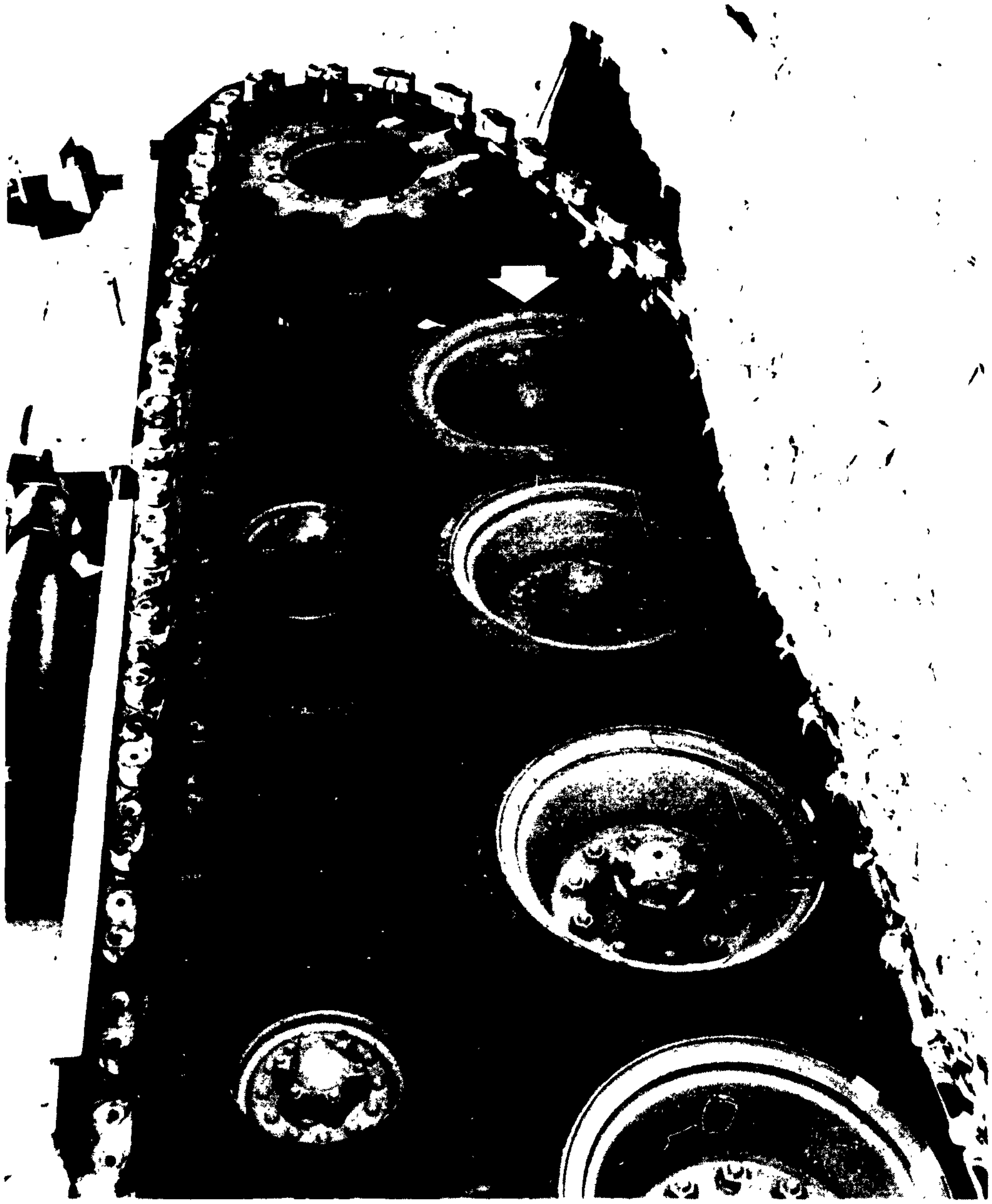

Figure 50. Cant on rear bogy wheel

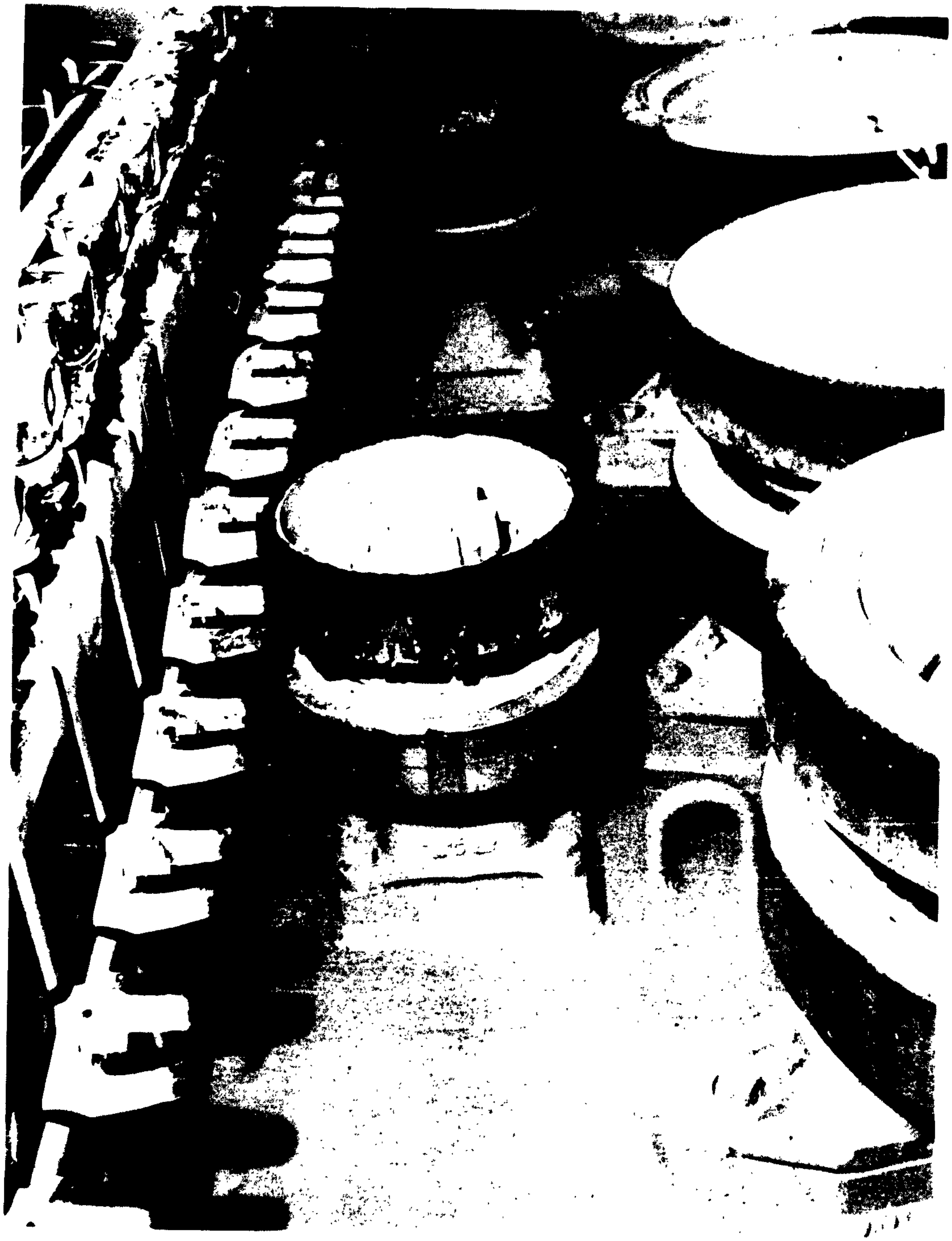

Figure 51. Damage on track idlers

Right and left steering maneuvers were accomplished at high and intermediate speed ranges without difficulty.

The parking brakes and the foot pedal brake were used extensively throughout the test program under ordinary conditions and on an approximate 10% grade without difficulty.

The vehicle negotiated grade elevations up to 15%. No difficulties were encountered.

(b) Visibility.

The Masher's front lead glass window was opaque from oxidation on the exterior surface. Polishing with aluminum oxide and water restored visibility.

The crane operator's visibility is slightly restricted through the 9½ inch x 9 inch rectangular window. The hook cannot be seen when it is lowered below the end of the vehicle because of the limited line of sight. For hook operations on the driver side of the vehicle, monitoring is required by the vehicle operator.

(c) Hydraulics.

Continuous difficulties were encountered on the hydraulic system.

All crane motions were restricted throughout the test program.

Pilot control pressure tests proved that the pressure supplied by the supercharge pump was below the required 100 psi. A new supercharge pump and a direct power takeoff assembly were installed to correct the difficulty. After installation the entire hydraulic system was operable under no-load conditions.

During tests of the lifting capabilities with a 43,000-pound load, the entire system failed after the load had been lifted several inches off of the ground. (Figure 52.) Upon removal of the load the entire system remained inoperable.

Further tests proved that the pilot pressure was again

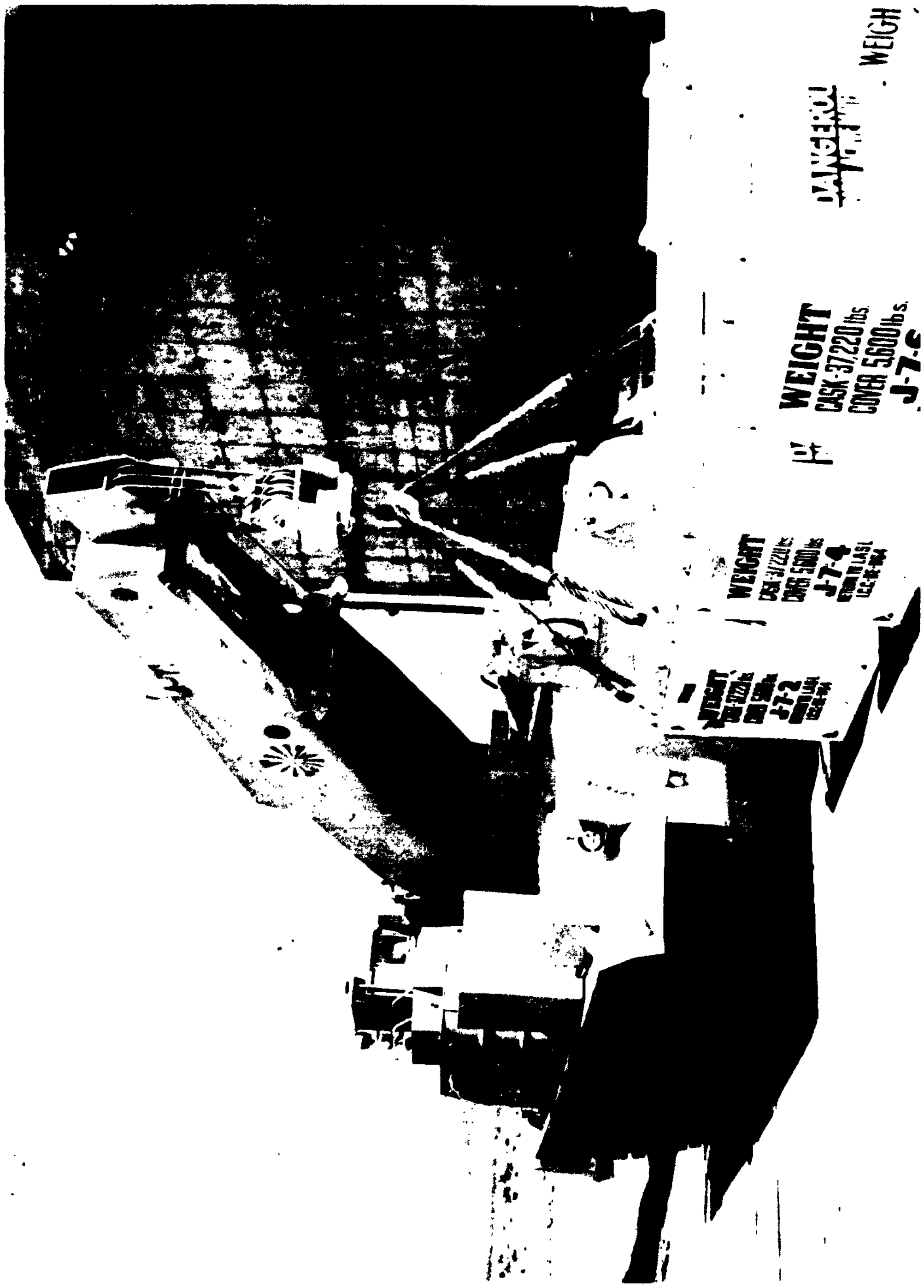

Figure 52. Masher's attempt to lift 43, 000 lb load

below the required 100 psi. Work is in progress to determine the trouble.

(d) Electrical.

Results of a study of the electrical system were satisfactory.

The plates in two of the four 12-volt batteries (two each connected in series for a 24-volt system) were cracked and the batteries were inoperative.

The insulation of a majority of the electrical wiring displayed signs of wear and corrosion making the system susceptible to shortage and reducing overall reliability of the vehicle.

Four new batteries were installed and partial rewiring was accomplished. No difficulties were encountered thereafter.

(3) Shielding integrity.

Appendix X presents an integrity check report performed by Reynolds Electrical and Engineering Company, Radiological Safety Division personnel. Results of the test show that no major defects exist in the Masher shielding. A minimum attenuation factor of 3.3×10^{-2} was found at the top center of the steel cab. The shielding thickness at this location is 5 inches.

(4) Air conditioning and outside air filtering system integrity.

(a) Air conditioner.

The recirculating 1½-ton air conditioning unit was initially inoperable.

The compressor unit was removed and renovated and the system was recharged with freon 12 refigerant to put the unit back into operation. No further difficulties were encountered.

(b) Outside air filtering system.

The Masher's outside air filtering system (which is separate from the air conditioning system) was tested for dust leaks. Procedures of the test were the same as that of the fluorescein dye test performed on the Beetle.

Before the test was begun, the eight individual micron filter boxes were sealed into the supporting frame with a non-hardening putty type of material. Dye particles collected on the air sample filter indicated very poor filtration. Particles up into the 50 micron range had penetrated the filter system.

Tests performed on the individual micron filter elements gave satisfactory results except for two elements which displayed small leaks. This eliminated the possibility that the filter elements were totally defective. The defect is either in the outside air ducting or in the sealing around the filters. All filter elements are scheduled to be replaced for assurance of reliability. Further tests will be performed upon installation to locate the leak.

(5) Operational uses.

Use of the Masher as a recovery vehicle at NRDS on an independent basis is highly improbable. The majority of all recovery operations will require some assistance from the Beetle. (The assumption is made that the recovery operations are in hazardous environments.)

The Masher is capable of accomplishing recoveries of other vehicles or of a test car. The vehicle succeeded in towing a test railroad car several feet but the operation was discontinued because the side angle between the test car and Masher was too great. (Figure 53.) It was possible to derail the test car, since the resultant force vector was at too great an angle from the track direction. In a radiation environment the tow cable would have to be connected to the test car with the Beetle.

The vehicle has the ability to carry nuclear or instrument packages weighing up to 30 tons if secured by a sling for support. Placing the sling in the Masher hook will require the use of the Beetle when in a hazardous area.

Independent operational uses will include reconnaissance work and turning soil. Both of these operations were accomplished in a radiation environment up to 50 r/hr following a nuclear test. The operator and an observer wore self-contained breathing apparatus. The test area was

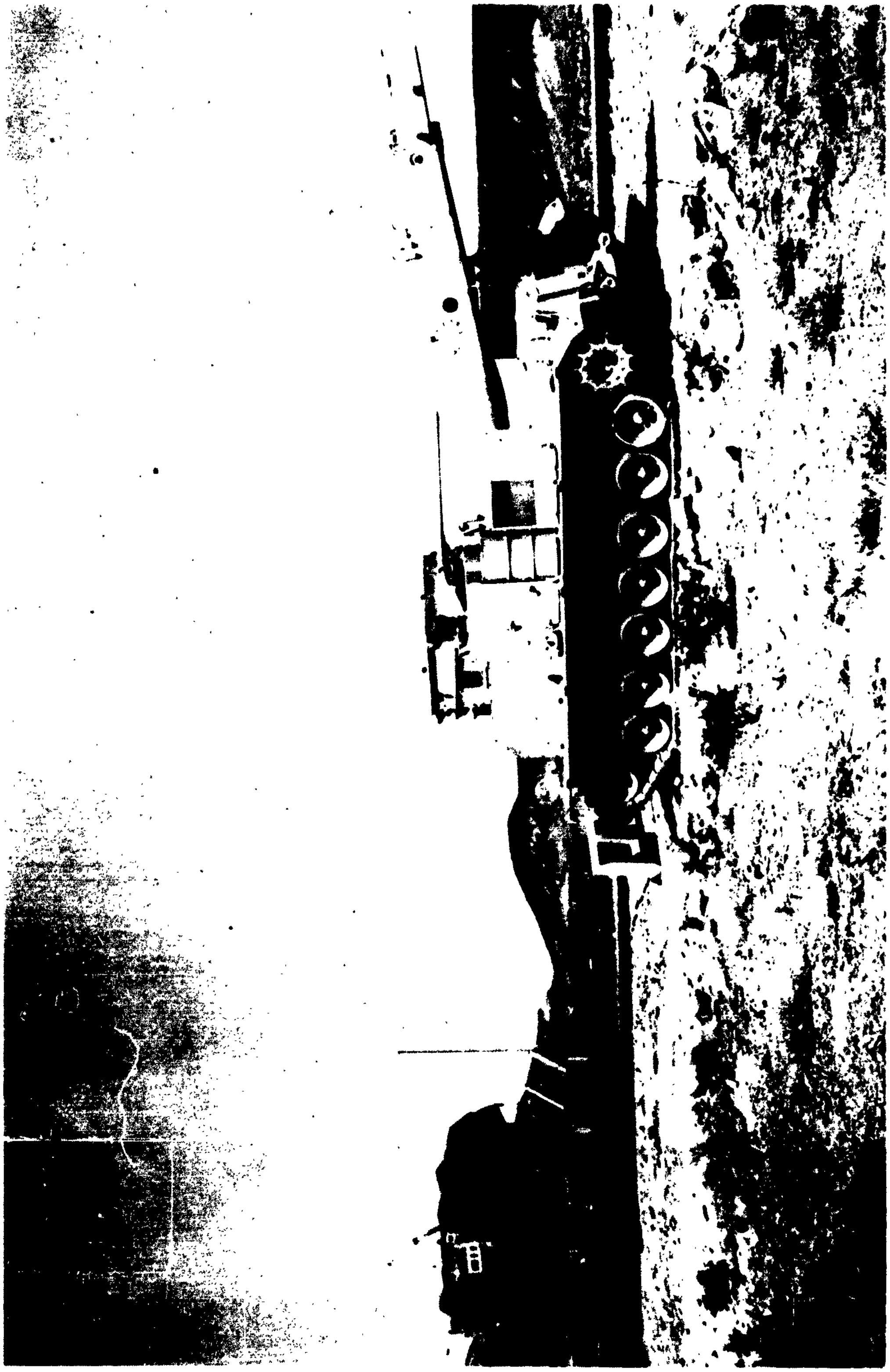

Figure 53. Masher towing test car

penetrated on two separate occasions over a total operating time of approximately 3½ hours. No difficulties were encountered. The operator and observer were comfortable and safe on both occasions. Dosimeter readings for both the operator and an observer showed no significant radiation penetration. Vehicle contact was maintained throughout the recovery operation, via PAC radio sets, with the block house monitoring station.

d. Conclusions.

The Masher is suitable for both recovery and reconnaissance uses in a radioactive environment. Before extensive use is made of the vehicle the following maintenance is necessary to increase vehicle reliability.

(1) The tracks should be replaced. The rubber coating shows considerable wear.

(2) All dust leaks must be located and eliminated in the outside air filter system.

(3) The hydraulic system must be repaired.

(4) The electrical wiring shows wear. Those wires showing insulation deterioration should be replaced.

(5) The rear bogy wheels are canted. Repairs should be made to reduce the possibility of throwing a track.

e. Recommendations.

It is recommended that the vehicle discrepancies mentioned in the conclusions be corrected as soon as possible. Partial arrangements have been made to begin renovations of all discrepancies with the exception of the track replacement.

4. USAF SHIELDED TOW TRACTOR (BAT).

a. Background.

The Bat is a standard USAF Coleman tow tractor modified by the Army Tank Automotive Command, Centerline, Michigan for use as a ground support vehicle at the NARF facility. Its background coincides with that of the Masher. It was used primarily to position the Nuclear Test Aircraft after reactor shutdown. The vehicle also served as an emergency retriever for other shielded vehicles or disabled equipment in a radiation field. The Bat was transported to the Nevada Test Site by rail along with the Masher.

b. Description of test article.

The Bat has a shielded cab to protect the driver from after-shutdown radiation of the Aircraft Shield Test Reactor. The cab top and walls are 2 5/8 inches thick and are composed of steel casing over lead with high-density lead glass windows. The floor has a 1-inch thickness of steel. Front and rear counter-steering differentials minimize the Bat's turning radius. Cab space allows one operator.

Characteristics of the Bat:

GENERAL

Weight - 27,000 pounds
Maximum speed - 20 mph
Range - 100 miles
Wheel size - 140 x 20" - 12 ply
Air conditioner - ½ ton recirculatory and outside air filter system for radiation area.

Personnel recirculatory air heater (hot water system)

DIMENSIONS:

Height - 8 feet 6 inches
Length - 17 feet
Width - 7 feet 6 inches

POWER PLANT

Engine - Chrysler Industrial, Model #56, type 377, Serial #2490, 300 HP, V8, 33 cubic inch displacement.
Electrical - Standard, 12-volt system

Transmission - Five-speed, Model 540, Chrysler Corporation

SHIELDING

Glass - 1 3/8 inches thick 6.2. grams/cc, minimum density
Cab - 2 5/8 inches steel

COMMUNICATIONS

Motorola "D"
Series - Industrial Dispatcher
Radiophone - Transmitter and receiver
Transmitter - No. NLD6050A
Receiver - No. NRD1100
Converter - Carter Motor Co.
Set No. - D 1080CB

c. Summary of test.

(1) Limited testing was conducted on the Bat because of its simplicity in comparison to the Beetle and Masher. The testing engineers devoted their time to minor vehicle rehabilitation for future operational uses of the Bat as a reconnaissance and support vehicle.

(2) Operational checkout.

(a) Mobility.

Driver and mechanical operating characteristics of the Bat are directly comparable to a five-forward-speed standard transmission truck. The main difference is the extremely low gearing system which is typical of a tow tractor.

Starting, stopping and braking procedures were performed. No difficulties were encountered.

The Bat was used as a standby reconnaissance vehicle following a nuclear test. The vehicle was driven some 20 miles to the site at an approximate speed of 20 mph. On several occasions enroute to the location the vehicle had to be stopped since the engine ran extremely hot. The cooling system was flushed thoroughly and operation thereafter was satisfactory. Cooling difficulties arose again at a later date. This time the radiator was removed and flushed with a cleanser, as was the entire system. No further difficulties were encountered.

The vehicle was driven over the desert terrain. It encountered railroad tracks elevated approximate 4 feet above flat terrain and having an approximate grade of 40% on either side. Mobility over this difficult terrain was exceptionally good.

Because of the nature of the transmission, double clutching is necessary to shift from one gear to another.

The transmission power takeoff assembly, the generator, the voltage regulator, and the battery were worn and deteriorated to the extent that vehicle reliability was questionable. All items were replaced.

(b) Visibility.

When the vehicle arrived at the site the left lead glass window was cracked to the point where the operator's safety might be impaired. This window was replaced.

Windows on the Bat are located in the front, on either side, and at the rear of the cab. An operator has good visibility in all directions. (Figure 3.)

(c) Shielding integrity.

Appendix X gives the results of an integrity check performed on the Bat. A minimum attenuation factor of 10^{-1} was determined at the front window (center and top) and at the front right side of the cab. Radiation attenuation is considerably less than that of the Beetle and Masher.

(d) Outside air filtering system integrity.

The outside air filter system contains two micron elements of the 5-micron range. They are identical to the eight individual elements used in the Masher. The two elements were replaced.

(5) Operational uses.

The Bat will function as a reconnaissance vehicle. In event of a nuclear accident it will maintain radio contact in a lesser intensity field (compatible with shielding) than other vehicles (Beetle and Masher) located at the accident site.

It can also be used to survey within low radiation environments, to determine extent of damage, and to monitor radiation fields. LASL has replaced the single seat in the cab with a double seat to permit cab access to an operator and an observer.

d. Conclusion.

The Bat is an extremely reliable vehicle and very mobile in the NTS desert terrain. Its support, as a reconnaissance vehicle in regular testing and in case of accident, will prove invaluable.

e. Recommendations.

Although the Bat is a reliable, mobile, and operational vehicle there is one improvement that, if accomplished, would increase its operational uses.

The gear transmission ratios are so low that a maximum speed of 20 mph can be obtained in the highest gear (forward-fifth). Gear shifting while the vehicle is in motion requires double clutching because of special transmission characteristics. These two factors limit to a great extent the speed and ultimate efficiency of the Bat as a reconnaissance vehicle. This handicap can be eliminated by replacing the transmission with a more flexible and versatile higher-gear model. Since the engine and power converter are standard production types, no special alterations are necessary for replacement. Such a modification would increase vehicle speed for traveling on finished highways and permit smoother shifting operations.

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APPENDIX I

58509-1-152

DETAILED REQUIREMENTS DR-E 1290

Supersedes 8/15/58 Date 6/19/59

SPECIFICATIONS FOR MOBILE SHIELDED CAB WITH MANIPULATORS

1. Applicable Specifications

   1.1 General Electric Company, ANPD Specification DR-E 1002

   1.2 Precedence - If conflict arises between this specification (DR-E 1290) and referenced specification, this specification (DR-E 1290) shall take precedence.

2. Description

   2.1 Mobile shielded cab with manipulators.

3. Detail Requirements

   3.1 Mobile shielded cab ambient operating temperature shall be from -30°F to + 130°F.
   Ambient non-operating temperature may reach + 160°F.

   3.1.1 The relative humidity of the outside atmosphere might range from below 20% to 100%.

   3.2 Purpose of the mobile shielded cab with manipulators.

   3.2.1 Purpose of the mobile shielded cab with manipulators is to allow a person to get within three (3) or four (4) feet of a nuclear power plant or any hot (radiation-wise) object, to make adjustments or to disassemble, assemble and maintain such hot equipment. Another purpose of the shielded cab is to assist in the mating or demating of an aircraft nuclear power plant with an airframe.

   3.3 The shielded cab:

   3.3.1 The walls of the shielded cab shall be 12 inches of lead or equivalent.

   3.3.2 The inside of the shielded cab shall contain the following:

   3.3.2.1 Controls for the vehicle

3.3.2.1.1 Controls for main power propulsion.

3.3.2.1.2 Controls for auxiliary electric powered creep drive.

3.3.2.2. Controls for each of two (2) manipulators and manipulator.

3.3.2.2.1 Controls for a secondary power supply for two (2) manipulators.

3.3.2.3. Controls for the shielded cab elevation

3.3.2.4. Controls for the shielded cab elevation

3.3.2.5. A Single TV monitor, controls and multiple cameras to be determined under 3.5.

3.3.2.6. Radio, 2-way and receiver. (Radio speaker, microphone and channel controls).

3.3.2.7. Interior lights.

3.3.2.8. Controls for exterior lights (including driving, warning signal and clearance).

3.3.2.9. Controls for air-conditioning (cooling, heating, pressurizing).

3.3.2.10 Controls for windshield wipers.

3.3.2.11 Defrosters.

3.3.2.12 Controls for entrance hatch, including mechanical safety locks and warning signals.

3.3.2.13 Radiation level monitor system (radiation counter tube, controls and indicator) with an intensity indication range from 0-1000 mr/hr for inside the cab, including adjustable visual and audible alarm devices and a chart recorder.

3.3.2.13.1 A dosimeter of 500-mr range for inside the cab with visual indication and adjustable visual and audible alarms.

3.3.2.14 Provisions for reading of radiation level outside of cab (counter tube, controls and indicator) from 0-100,000 R/hr, including adjustable visual and audible alarm devices.

3.3.2.15 Seat with 6-way adjustment (forward, back, raise, lower and tilt).

3.3.2.16 Fire controls - automatic and manual control with fire-warning signals.

3.3.2.17 Writing board and data storage. (Space for 8-1/2 x 11 inches instruction manual and provision for reading during operation of vehicle.)

3.3.2.18 Water bottle. (Insulated bottle for drinking water.)

3.3.2.19 Binoculars.

3.3.2.20 Relief container.

3.3.2.21 Emergency air supply and controls (air container, mask and regulator).

3.3.2.22 Flash light.

3.3.2.23 Vehicle and power plant instrumentation.

3.3.2.24 Controls for audible warning device and powered communication.

3.3.2.25 Ash receiver.

3.3.2.26 Automatic cigarette lighter.

3.3.2.27 All of the above (3.3.2.1 through 3.3.2.28) shall be approximate size and location as shown on General Electric Company drawing numbers 629E722, 629E723, 629E724, and 139R488.

3.3.2.28 An air sampling system for monitoring the entering air.

3.3.3 The inside of the shielded cab shall maintain a temperature of between 72°F to 76°F, and a maximum relative humidity of 60% during operation.

3.3.4 All air entering the cab shall be filtered through a high efficiency filter. The filter shall be Flanders Mill, Inc., type 2, or equivalent. The air pressure inside the cab shall be held slightly above atmospheric pressure at all times during operation.

3.3.5 The cab shall contain windows of the appropriate number, size and shape in accordance with Jered Industries, Inc. drawings SK-420 (2 sheets) and SK-452 (3 sheets) and the reported results of DR-E 1290, item 3.5.1. All window specifications, dimensions and arrangements shall be approved by General Electric Company.

3.3.6 Each window of the shielded cab shall be provided with external wipers, de-icers, and defrosters, controls of which shall be operable from the inside of the cab.

3.3.7 The shielded cab shall have mounted upon each of its two (2) sides one (1) General Mills type manipulator and manipulator mount in accordance with General Electric Company specification DR-E 1288. These manipulators shall be located on the sides of the cab between the side windows.

3.3.8 The shielded cab shall contain an entrance hatch not less than 20 inches inside diameter, located on the top surface of the cab.

3.3.9 The shielded cab shall be made in two parts, one part will consist of the main cab with the windows and the other part consisting of the top. Lifting eyes shall be provided for handling each part of the cab.

3.3.10 The shielded cab shall be constructed with steel plates on the ID and OD with lead in between.

3.3.11 The lead in the walls of the shielded cab shall contain no voids.

3.3.12 The vendor shall submit to General Electric Company, ANPD, a written procedure for the pouring of the lead. This procedure must be approved by the General Electric Company, ANPD, in writing, prior to the pouring of the lead. A General Electric

Company-ANPD engineer shall be present during the pouring of the lead for the shielded cab.

3.3.13 Sufficient reinforcing for successful operation shall be provided in or on the shielded cab at points of its support, at lifting eyes and for the mounting of the manipulators.

3.3.14 The cab shall be capable of being elevated fifteen (15) feet at an appropriate rate of six (6) feet per minute, and being rotated 360° at the maximum rate of two (2) rpm and a minimum rate of one (1) rpm by power-operated mechanisms, suitably mounted to the vehicle. The mechanisms shall be capable of being stopped and locked at any elevation or position within the fifteen (15) foot range of vertical movement, and the 360° range of rotation.

3.3.15 All openings into and out of the cab for any purpose shall be stepped construction so that an equivalent of twelve (12) inches of lead shielding is maintained at all points on the cab.

3.3.16 Suitable trouble-free provisions shall be provided for maintaining power and control inside the cab at all positions of the cab within its limits of movement with respect to the vehicle.

3.3.16.1 A secondary power source shall be provided for limited emergency operation of the two (2) manipulators. Secondary power source shall be 208 volt, single-phase, 60-cycle, of not less than 1000 va, independent of primary source under emergency condition and available for a period of not less than thirty (30) minutes.

3.3.17 Working or front lights capable of producing 250-foot candles over an area 20 feet square at a distance of 15 feet from the light source. Remote controlled spot lights, from within the cab, shall be provided capable of producing a minimum 500-foot candles of concentrated light at 15 feet. Side and rear lights on the cab shall provide general illumination of a minimum of 50-foot candles a distance of 15 feet from the light source.

3.3.18 An emergency method shall be provided for opening the entrance hatch from both the inside and outside of the cab.

3.3.19 The entrance hatch shall have an external lifting eye and be capable of being lifted open by a crane.

3.3.20 The operational functions of the vehicle shall be controlled by finger-tip control switches which shall be readily accessible to the operator inside the cab.

3.4 Vehicle

3.4.1 The function of the vehicle is to provide a mobile base for the cab from which the cab and manipulators may be operated.

3.4.2. The vendor shall specify the minimum turning radius of the vehicle.

3.4.3. The vehicle shall contain a power plant suitable for all requirements. Vendor to furnish complete specifications of the power plant and auxiliary accessories.

3.4.4. The vehicle shall be equipped with a braking system capable of holding the vehicle in all positions including a 10% grade, with or without power.

3.4.5 Adequate driving, warning, signal, and clearance lights shall be provided.

3.4.6 Suitable audible warning device shall be provided.

3.4.7 Standard ordnance pintle hooks, each capable of sustaining maximum drawbar pull and modified to operate remotely by the manipulators, shall be provided forward and aft of the vehicle.

3.4.8 The maximum length of the vehicle shall be not more than nineteen (19) feet including pintle hooks.

3.4.9 The maximum width of the vehicle shall be not more than twelve (12) feet six (6) inches.

3.4.10 The maximum height of the vehicle with cab in the lowest position shall not be greater than one hundred and twenty (120) inches. (Antenna may exceed this dimension.)

3.4.11 The vehicle shall be designed for a continuous zero grade road speed of ten (10) mph through stepless acceleration.

3.4.12 The vehicle shall be capable of intermittent maximum speed of five (5) mph upon a 10% grade forward or reverse.

3.4.13 The vehicle, when in any position on a 5% grade, shall remain stable and operable, with the cab in any position and loaded manipulators in any position.

3.4.14 The ground pressure shall not exceed 55 psi with the vehicle on zero grade with the manipulators unloaded.

3.4.15 A suitable method of control outside the vehicle, including power, shall be provided.

3.4.16 An automatic external fire extinguishing system shall be provided.

3.4.17 Space shall be provided for the installation of tool racks.

3.4.18 A minimum of fourteen (14) inches of ground clearance shall be provided.

3.4.19 The vehicle, complete with shielded cab and manipulators, shall have a draw-bar pull of 80,000 lbs. on level, dry pavement.

3.4.20 The manipulators shall be free of vibration at their extremity with the vehicle stationary but providing power for operation.

3.4.21 The vehicle shall be equipped with a creep drive for "close-in" maneuvering and an emergency power source for the event of main power plant failure. Creep drive and emergency power source shall provide for vehicle travel of not less than three hundred (300) feet in one (1) hour on zero grade.

3.5 Auxiliary Viewing

3.5.1 Make study and recommended optimum viewing system for locomotion and positioning of vehicle and cab. Include number, size, specification and location of windows. Consider mirrors, periscopes, including surveillance periscopes.

3.5.2 Make study and recommend viewing for manipulation work area. Field of viewing to include sphere or operation of manipulators. Study to include coarse work location, fine work location, work performed behind obstruction or interfering objects and to include best viewing for manipulator operations under all these conditions.

3.5.2.1 Obtain and evaluate miniature TV camera for viewing small spaces.

3.5.2.2 Design, build, and evaluate an articulated periscope which in effect moves the operator's eye close to the work for viewing of fine work. Field of vision to include the sphere of operation of the manipulators.

3.6 General

3.6.1 All electrical, hydraulic, and air motors for the shielded cab and vehicle shall be of industrial quality and of a type that has been proved acceptable in use and for which spare parts are readily available.

3.6.2 All components and motors shall be protected for operation under adverse conditions.

3.6.3 The vendor shall assemble the manipulators and manipulator mounts to the shielded cab and shall assemble the shielded cab to the vehicle.

3.6.4 All welds shall be to MIL Specs MIL-W-13748 and MIL-E-15599A. Vendor shall indicate weld, weld inspection and stress relief practice on all fabrication drawings and General Electric Company, ANPD, approval shall be obtained prior to manufacture. All welded joints to have full penetration welds where the design stress exceeds 8,000 psi and the weld metal must have at least the strength of the thinnest plate. Those weld joints with design stress below 8,000 psi may receive visual inspection, and those welded joints with a design stress above 8,000 psi must receive radiographic inspection. All welding shall be performed by operators qualified by fulfilling the requirements of the performance qualification tests of Section IX welding qualifications as set forth by the American Society of Mechanical Engineers Boiler Construction Code.

All filler material to be welding electrode A233-E-6010. Substitutions must be approved by General Electric Company, ANPD, prior to use. Separation of parts to be joined by fillet welding shall be 3/16-inch maximum. This is to be verified by inspection at the time of fit up prior to welding. All fillet welds will be visually inspected for size, contour, undercutting, cold lap and cracking. An inspection record of all welds shall be maintained by the vendor. The vendor shall inform General Electric-ANPD prior to welding fabrication and shall provide access of General Electric Company ANPD personnel to the locations of all work for the purpose of inspection at all times during construction and manufacturing. In the event of weld cracking, the General Electric Company, ANPD, is to be notified and no repairs are to be made without prior approval of a G-E representative. Should there be a conflict between the above-referenced specifications and DR-E 1290, this specification (DR-E 1290) shall have precedence.

3.6.5 All designs shall be approved by a General Electric ANPD engineer prior to manufacture.

3.6.6 The vendor shall do all wiring and install all control instrumentation panels.

3.6.7 The vehicle and shielded cab shall be primed and painted with two (2) coats of paint as specified by General Electric Company.

3.6.8 All materials and workmanship of all components of the shielded cab and the vehicle shall be industrial quality or better without regard to radiation damage.

3.6.9 Inspection and test of the vehicle complete with shielded cab and manipulators shall be conducted at the vendor's plant by General Electric Company ANPD engineer prior to acceptance by General Electric Company.

3.6.10 After inspection acceptance of the vehicle the vendor shall provide for the orientation and indoctrination of one (1) or more General Electric Company personnel in the operation and maintenance of the vehicle. This service shall be provided at the vendor's plant for a maximum of two weeks.

3.6.11 After delivery the vendor will supply one (1) qualified employee to assist in field tests for a period of ninety (90) days.

3.6.12 The vendor shall provide fifteen (15) copies of a list of recommended spare parts, components, special tools and special testing equipment which, in his estimation, would normally be required for the support of the equipment.

3.6.13 The vendor shall furnish fifteen (15) copies of an operating and servicing maintenance manual.

3.6.14 The vendor shall furnish one (1) complete set of reproducible drawings of the vehicle, cab, controls, and wiring diagrams.

3.6.15 The vendor shall furnish layout drawings sufficient for the determination of manipulator mountings.

3.6.16 Chemical composition surface finishes (protective coating, etc.) and heat treatment of all materials used in the assembly of the vehicle and shielded cab shall be listed for the purpose of life determination from corrosion and radiation damage.

APPENDIX II

SPECIFICATIONS FOR MECHANICAL MANIPULATORS AND POSITIONING BOOMS FOR SHIELDING CAB

DR-E 1288

Supersedes 6/25/58 Date 9/11/58

1. APPLICABLE SPECIFICATIONS

1.1 The current issues of the following specifications or superseding specifications effective on the date of invitation for bids shall form a part of this detailed requirement except as modified herein.

1.1.1 General Electric Specification DR-E 1002.

2. DESCRIPTION

2.1 Mechanical manipulators and positioning booms for shielded cab.

3. REQUIREMENTS

3.1 The requirements shall be as specified in paragraph 3 of Specification DR-E 1002.

4. GENERAL REQUIREMENTS

4.1 The general requirements shall be as specified in paragraph 4 of Specification DR-E 1002 except as follows:

*4.2 The ambient temperature shall be -30°F to +120°F.

5. DETAIL REQUIREMENTS

*5.1 The nominal operating temperature shall be from -30°F to +120°F.

5.1.1 The relative humidity is normally below 20% but may be as much as 100%.

5.2 Purpose of the mechanical manipulators and positioning booms for shielded cab:

5.2.1 Purpose of the mechanical manipulators and positioning booms for shielded cab is to allow an operator within the cab to get within three (3) or four (4) feet of a nuclear power plant or any hot (radiation-wise) object to make adjustments or to assemble, disassemble and maintain such hot equipment. Another purpose of the manipulators is to assist in the mating and demating of an aircraft nuclear power plant with an airframe.

5.3 The mechanical manipulators

5.3.1 The mechanical manipulators shall consist of two (2) manipulators mounted on positioning booms.

**5.3.2 The manipulator positioning booms shall be mounted on the sides of the shielded cab, one on each side. The method of mounting shall be compatible with the shielded cab hoist mechanisms.

5.3.3 The manipulators are to be interchangeable if possible (not right and left).

5.4 The manipulators to be General Mills, Inc., Model HD 1; Model E-2 mechanical arms modified as required (or equal).

5.4.1 The manipulators shall consist of an interchangeable parallel hand and hook hand.

5.5 Positioning booms

**5.5.1 The manipulator positioning boom shall consist of an outer support structure and an inner traversing section.

**5.5.2 One (1) manipulator positioning boom shall be mounted on the right side of the shielded cab.

**5.5.3 One (1) manipulator positioning boom shall be mounted on the left side of the shielded cab.

**5.5.4 With all members fully extended, the manipulator shall have a reach of sixteen (16) feet measured from the center line of positioning boom outer support structure.

5.5.5 The manipulator positioning mechanism shall provide sufficient power and strength to allow the manipulator mechanisms to be utilized to their full capacities in all directions.

5.5.6 All mechanisms shall contain electrical or mechanical brakes so that they will not drift or creep under load.

5.5.7 All mechanisms shall be "fail safe".

5.5.8 Unitized design shall be used throughout to facilitate ease and speed of maintenance operations.

*5.5.9 All materials shall be selected for resistance to chemical attack and shall be suitably protected against anticipated environmental conditions without regard to radiation damage.

***5.5.10 The controls of all operations of each manipulator and positioning boom shall be in accordance with General Mills, Inc. drawing number 222803 dated May 6, 1958.

***5.5.11

*5.5.12 The manipulator shall be electrically powered.

*5.5.13 The manipulator positioning boom may be either hydraulically or electrically powered.

*5.5.14 The elements of the manipulator and boom system are as follows: (Described sequentially from the cab out.)

5.6 Boom support

**5.6.1 The boom support is the connecting member between the cab and the manipulator system.

5.6.2 Boom

5.6.2.1 The boom mounts within the boom support. The boom traverses in and out relative to the boom support being driven by a boom traverse drive.

5.7 Shoulder

5.7.1 The shoulder mounts to the outer end of the boom. The shoulder rotates relative to the boom, about a horizontal axis parallel to the boom axis, being driven by a shoulder rotate drive. The shoulder provides trunnions for shoulder swing.

5.8 Upper Arm

5.8.1 The upper arm mounts to the shoulder trunnions and swings relative to the shoulder about an axis perpendicular to the shoulder rotate axis being driven by a shoulder swing drive.

5.8.2 The upper arm rotates about its own axis being driven by an upper arm rotate drive.

5.8.3 The upper arm has an extensible member which traverses in and out parallel to the upper arm axis and is driven by the upper arm extension drive.

5.8.4 The extensible member provides trunnions at the outer end for elbow swing.

5.9 Forearm

5.9.1 The forearm mounts to the upper arm trunnions and swings relative to the upper arm about an axis perpendicular to the upper arm axis being driven by an elbow swing drive.

5.9.2 The forearm provides trunnions at its outer end for wrist swing.

5.10 Hand

5.10.1 The hand mounts to the forearm and swings relative to the forearm about the axis perpendicular to the forearm axis being driven by a wrist swing drive.

5.10.2 The hand rotates about its own axis being driven by a wrist rotate drive.

5.10.3 The hand opens and closes being driven by a grip drive.

5.11 A summary of the motions, locations, travels and rates is given in the following table:

	MOTION	LOCATION	TRAVEL	MAXIMUM RATE
**5.11.1	Boom Support	On each side of the cab exact position and method of mounting to be determined.		
*5.11.2	Boom Extension	32" from boom pivot to shoulder rotate; with boom in retracted position.	42 inches	120 inches
5.11.3	Shoulder Rotate	About an axis parallel to boom axis.	360^{o} continuous	1 rpm
5.11.4	Shoulder Swing	About an axis perpendicular to boom axis trunnion centerline 12" from shoulder rotate	180^{o}; $\pm 90^{o}$ from horizontal	1 rpm
5.11.5	Upper Arm Rotate	About an axis parallel to axis of upper arm	360^{o} continuous	2 rpm
5.11.6	Upper Arm Extension	50" from shoulder pivot to upper arm pivot, in retracted position.	18 inches	120 inches per min.

	MOTION	LOCATION	TRAVEL	MAXIMUM RATE
**5.11.7	Elbow Swing	About an axis perpendicular to axis of upper arm.	240°; ± 120° from axis of upper arm	1-1/2 rpm
5.11.8	Forearm		24" fixed length	
**5.11.9	Wrist Swing	About an axis perpendicular to axis of forearm	240°; ±120° from axis of forearm	2 rpm
5.11.10	Wrist Rotate	About an axis parallel to wrist axis	360° continuous	8 rpm
5.11.11	The manipulator shall include provisions for remotely interchanging a parallel jaw hand and a hook.			
5.11.12	Hand	Mounted on outer end of wrist	Maximum opening 5 in.	20 in/min open and close
5.11.13	Hook	Mounted on outer end of wrist	Maximum opening 2-1/2 in.	8 in/min open and close

5.12 Each motion is to have a three-step speed control. The maximum rates are given in the above table. The additional two speeds on each motion will be equally proportioned between zero and the listed maximums.

5.13 Loads

5.13.1 The manipulator will be capable of holding 100 pounds straight out with all linear motions fully extended. The travel rates given will be met under this condition. The rotate rates will be met with a 100-pound load held with pivot elements turned 90° to the axis of rotation.

5.13.2 Load capacities under the various combinations of positions of the manipulator elements will be commensurate with the above maximum conditions. That is, for example, if the manipulator is moved to decrease the horizontal distance from the boom pivot to the supported load, the allowable load will increase proportionally.

5.13.3 The wrist will be capable of exerting a torque of 50 lb. ft.

5.13.4 The hand will be capable of exerting a grip force of 200 pounds.

5.13.5 The hook will be capable of exerting a grip force of 750 pounds.

***5.13.6 The deflection at the tip of the manipulator hand, due to a 100-pound load shall not exceed 8 inches, in any and all combinations of the specified manipulator motions. This deflection is measured relative to the boom support point nearest the hand.

***5.13.7 The maximum width of the boom support housing shall not exceed 16 inches.

5.13.8 The manipulator should be designed to pass through as small a diameter or opening as possible, commensurate with manipulator rigidity, reliability, and serviceability.

5.13.9 Power requirements for all motions should be listed by the vendor.

***5.14 The maximum size of the various components of the positioning boom and manipulator elements shall not exceed the following:
Boom support - 14" x 16" (exclusive of drive mechanisms).
Shoulder Rotating Gear - 19" diameter (exclusive of drive mechanisms).
Shoulder Swing - 13" x 23"
Upper Arm - 10-1/2" diameter
Lower End of Upper Arm - 10" square - a distance of 15" from lower pivot.
Upper End of Forearm - 7" x 12"
Forearm - 7" x 8"
Upper Wrist - 5-1/2" x 7-1/2"
Wrist - 5-1/2" diameter
Lower End of Wrist - 3-1/2" diameter

5.14.1 Inspection and tests of the manipulators shall be conducted at the vendor's plant prior to acceptance by General Electric Company.

5.14.2 Vendor shall provide a list of recommended spare parts, components, special tools, and special testing equipment which, in his estimation, would normally be required for the support of the equipment.

***5.14.3 The vendor shall furnish one set of reproducible drawings of the positioning boom, the manipulator, controls and wiring diagrams necessary for installation, maintenance, and repair.

5.14.4 Chemical composition surface finishes (protective coating, etc.) and heat treatment of all materials used in the assembly of the manipulator and positioning boom shall be listed for the purpose of life determination from corrosion and radiation damage standpoint.

***5.14.5

***5.14.6

*5.14.7 The manipulators shall be wired to provide 1/2 horse power, 110 volts, 60 cycle, single phase, alternating current connection at hands. The connection shall provide for remote connect and disconnect of power tools.

*	Changes incorporated in Revision 1, dated 10/31/57.
**	Changes incorporated in Revision 2, dated 6/25/58.
***	Changes incorporated in Revision 3, dated 9/11/58.

APPENDIX III

TEST AND EVALUATION OF THE BEETLE VEHICLE

1.0 GENERAL

The BEETLE test and evaluation program will be a thorough appraisal of the overall vehicle maneuverability, the operator protective systems, manipulator operational capabilities, the cab's shielding integrity and the effectiveness of the various sub-systems.

1.2 The evaluation program as planned for NTS will include the following three phases:

Phase I - Phase I will be a preliminary checkout of the vehicle by a Tech Rep Team representing General Electric, General Mills, Continental Motors Corp., NTS, and AFSWC to insure that the vehicle is operating correctly after the transfer from G. E. to N. T. S. This phase will also include a Tech Rep orientation program for N. T. S. personnel.

Phase II - Phase II will be the initial testing that can presently be defined as operational requirements for the vehicle. These operational requirements will be those that can be identified to support the requirements as established in Section 3. 0.

1.3 All tests will be made at ambient temperatures and existing environmental conditions unless otherwise noted.

1.4 After the arrivals of the BEETLE at N. T. S. and the completion of Phase II of the Test & Evaluation program it will be necessary to re-evaluate the program in light of the results obtained and the future operational plans for the vehicle.

2.0 PHASE I TEST AND EVALUATION

2.1 Reassembly of Vehicle

2.1.1 With the assistance of N. T. S. & GE personnel the vehicle will be reassembled to its pre-shipment condition, (i. e., manipulators installed and all accessory parts reassembled).

2.1.2 G. E., General Mills, and Continental Motors Corp., will insure that the vehicle's manipulators, and power train operate properly.

2.2 OPERATION CHECK-OUT

2.2.1 Chassis (Cab Controls)

2.2.1.1 Start main engine following prescribed procedures

2.2.1.2 After warm up increase speed to approximately 2000 to 2800 RPM.

2.2.1.3 Move vehicle forward in low speed range for a short distance.

2.2.1.4 Move vehicle forward in high speed range. A speed of 10 MPH on level ground is desirable.

2.2.1.5 Steer right and steer left while the vehicle is in low speed range.

2.2.1.6 Repeat steering right and steering left while vehicle is in high speed range.

2.2.1.7 Operate vehicle in reverse direction. The reverse direction should always be engaged from a stationary vehicle condition.

2.2.1.8 Engage brakes from 2.2.1.1 through 2.2.1.7.

2.2.1.9 Engage the parking brake when the vehicle is standing still.

2.2.1.10 With the vehicle transmission in the neutral position, operate the vehicle in pivot right and pivot left.

2.2.1.11 Operate all creep drive functions with the transmission in the neutral position and the parking brake in the OFF position.

2.2.1.12 The transmission brake should be on when the vehicle is stopped and all power off. The brake should hold the vehicle on a 10% grade with or without power.

2.2.2 Chassis (Outside Panel, JB-10)

2.2.2.1 Repeat 2.2.1.1 to 2.2.1.12 operations that are necessary to verify compatibility of the outside panel control box.

2.2.3 Pod (Outside Panel JB-1)

2.2.3.1 Auxiliary Engine Speed setting at 60 cycle generator output.

2.2.3.2 The single speed governor of the auxiliary engine should automatically set the engine speed at 2400 RPM which will produce 60 cycles through the AC generator. The allowable variance is 58 to 62 cycles.

2.2.3.3 The cycle gage can be read in the JB #1 and the cab.

2.2.3.4 The warning devices, siren, P.A. system, shall be sounded.

2.2.3.5 The hatch shall be raised to the open position. The safety locks and warning signal (Buzzer) should operate.

2.2.3.6 The hatch shall be closed to the vehicle operating position. The final resting position shall be noted by the signal light.

2.2.3.7 The hatch shall be lifted with the inside and outside hand pumps. Note time element and efficiency. The pumps shall be operated with the hatch in the closed position.

2.2.3.8 The electric hatch pump shall be operated to determine the opening capability and time required to perform this operation.

2.2.4 <u>Normal Lift Operation of Cab</u>

2.2.4.1 After the auxiliary engine has reached its operating temperature, the cab shall be raised and lowered. The desired rate of travel is approximately 6 feet per minute average.

2.2.4.2 The cab shall be stopped at various elevations, rotated, (the rotation shall be 360°, stopping the rotation with the over rotation time switches), and alternately moved up and down from the intermediate elevation locations.

2.2.5 <u>Outside Panel</u> - Repeat 2.2.3 to 2.2.4.2 operations that are necessary to verify compatibility of the outside panel control box. (JB-1)

2.2.6 <u>Cab Accessories</u> - Verify by use or operation of the following accessory equipment.

2.2.6.1 Electrical lights (spot light, outside lights, interior cab light).

2.2.6.2 Warning devices, siren and PA system.

2.2.6.3 Air conditioner.

2.2.6.4 Periscope (rotate - change magnification and focus).

2.2.6.5 A single TV monitor, controls and multiple cameras, radio 2-way and receiver.

2.2.6.6 Windshield wipers and defrosters

2.2.6.7 Seat with five-way adjustments

2.2.6.8 Fire controls

2.2.6.9 Emergency air supply and controls

2.2.6.10 Air sampling system for monitoring the entering air.

2.2.6.11 Manipulator - 10 motions

1. Boom out
2. Bend shoulder
3. Extend upper arm
4. Bend elbow joint
5. Rotate wrist
6. Bend wrist
7. Rotate upper arm
8. Rotate shoulder joint
9. Close and open hooked hand
10. Close and open jaw hand

2.2.7 Integrity Check - The following is an effort at listing the main items to be covered in a shielding integrity check of the BEETLE Cab at the MAD Building Compound Area of NTS using a source of 1000 curies and up to 10,000 curies.

2.2.7.1 Prove the shielding capability of the cab in order to insure no shielding violations therein. The source will probably be placed outside the cab of the BEETLE using the BEETLE and MAD building manipulators to move the source around the outside of the cab to give complete coverage and place radiation monitoring equipment inside the cab.

2.2.7.2 Check the operation and calibration of the built-in radiation monitoring system in the BEETLE. This test will be accomplished with the source positioned external to the BEETLE and with an operator in the cab reading the meters of the monitoring system and in dual communication (radio and telephone) with persons outside of the Disassembly Bay at a manipulation operating station.

2.2.7.3 Test the filtering capability of the air handling unit supplying air conditioning for the cab. It is recommended that this test be done outside at a chosen location where dust-bearing fission products could be made airborne and picked up on the filter. The vehicle would not be manned during the test but would be standing still with the air conditioning system in operation. A portable continuous air monitor would be operating within the cab and swipes would be taken within the cab after list.

2.2.7.4 Evaluate the capability of location fixing of radioactive sources around the BEETLE by using the cab as a shield. This test will be accomplished with the source positioned external to the BEETLE and with an operator in the cab reading the meters of the monitoring system and in dual communication (radio and telephone) with persons outside of the Disassembly Bay at a manipulator operating station.

3.0 PHASE II TEST & EVALUATION

3.1 Operational Requirements

3.1.1 A radioactive source will be located in a position similar to what might be expected from explosive scattering. The vehicle's ability to locate the source with existing radiation detecting equipment will be tested. The vehicle's ability to navigate the terrain will be tested. Upon locating the source, the operator will pick up the source and place it in a specially designed container on the vehicle. The container will then be sealed and checked for any radiation leaks.

NOTE: This test will require a specially built container capable of being sealed by the manipulator arms and possibly a moveable radiation detector.

3.1.2 The following special equipment will be designed at NTS for operation from the vehicle's manipulator arms.

a. Decontamination Tool
b. Cutting Tool
c. Power Wrenches

Specific tests will be designed to prove the use of these tools once their application has been determined at NTS.

3.1.3 The vehicle will be equipped with a tow cable. Using manipulators the operator will then attach the cable to the test car and attempt to recover the test car under conditions simulating a prime mover breakdown.

3.1.4 Operator will transfer components from test car in the disassembly bay to an outside flat car.

3.1.5 Operator will remove items in the dump area to an isolated area.

3.1.6 Operations will be performed on the reactor within the disassembly bay in accordance with requirements established at NTS.

3.2 Operational Safety Requirements

3.2.1 Shut down main engine. Place transmission in neutral; and operate creep drive in forward direction for a distance of 300 feet on improved surface roads.

3.2.1.1 Repeat above test in reverse.

3.2.1.2 Repeat test on unimproved roads, both in forward and reverse.

3.2.1.3 Repeat test in forward direction until creep drive batteries run down. Record the maximum distance that can be traveled.

3.2.2 The air conditioner will be turned off for a period of 15 minutes and the emergency air supply will be relied upon. The operator will record any personal discomfort in operating the vehicle under these conditions.

3.2.3 Shut down P.E. 90 engine while manipulator arms are in use. Determine if operator can lower any item he may be handling to the ground on battery power.

3.2.4 Acceptance tests on fire extinguisher system shall serve for demonstration of the vehicle's fire extinguishing safety features.

3.2.5 Using exterior controls, perform the following operations.

a. Move vehicle forward and reverse.

b. Turn vehicle to right and left.

c. Perform all creep drive operations.

3.2.6 Attach a cable of less than 20 foot length between the rear pintle on the vehicle and a D-8 cat. With the transmission in neutral and the parking brakes off, pull the vehicle to the rear.

4.0 PHASE III TEST AND EVALUATION

4.1 Vehicle Operating Characteristics - During the following operations observe engine speed control, steering controls, braking action, vibration, auxiliary equipment operation and the overall operational characteristics.

4.1.1 Operate the vehicle on improved and unimproved roads in low speed range. Steering the vehicle right and left (make one left and right pivot turn).

4.1.1.1 Operating the vehicle in low speed range, determine what terrain is negotiable (i.e., % grade, obstacles, etc.)

4.1.2 Repeat 4.1.1 and 4.1.1.1 using high speed range except delete the pivot turn.

4.1.3 Operate the creep drive (Transmission in the neutral position) forward, reverse, right and left turns. (Make at least one left and right pivot turn). Determine the ability of the vehicle to inch up to and lift or operate intricate parts.

4.2 TV Tests & Evaluation

4.2.1 Check operation of all TV cameras at night to determine if lighting conditions are sufficient for operation.

4.2.2 Check operation of all TV cameras during frosting conditions to determine if frost affects operation of the TV cameras.

4.2.3 Determine advantages and limitations of the portable TV camera.

a. It may be necessary to fabricate a clamp to fix the TV cameras to one of the manipulator arms in order to get full use out of the TV.

4.2.4 Determine the adequacy of vision using the rear POD TV cameras while operating vehicle, and the requirement for focusing rear cameras.

4.2.5 Note any adverse vibration or shock effects on the TV during operation and note troublesome reflections.

4.3 Optical Tests and Evaluation

4.3.1 Windows

4.3.1.1 During a period of adverse weather, check operation of defrosters.

4.3.1.2 At end of evaluation program, check windows for dust pitting.

4.3.1.3 Determine "blind spots" by placing objects in a variety of locations and looking for the object. Note troublesome reflections. The overall evaluation program should determine whether these blind spots are detrimental to operation and where increased visibility is needed. Take photographic coverage of all problem areas.

4.4 Periscope Tests and Evaluation

4.4.1 Operate periscope through complete range and both powers. Determine:

a. Effect of frost on operation

b. Visibility at night

c. Any blind spots adversely affecting operation.

4.5 550 Manipulators Evaluation

4.5.1 Demonstration of various motions unloaded and loaded to maximum. Overloading should be avoided to prevent unnecessary wear of slip clutches. Periodic observations of electrical gages and meters should be made. Operations are to be made at normal ambient conditions.

4.5.1.1 With boom shoulder, upper arm and wrist fully extended.

a. Maximum pull test - 2000# (H)

b. Measure deflection of each arm, loaded and unloaded

c. Maximum vertical load test - 100# (H)

4.5.1.2 Measure angles, rotations and extension lengths of each arm fully loaded and unloaded with both hand and hook attachments. Make note of any deflection that takes place after each motion. All numerical values are maximum. Arms should hold fixed position at any time controls are released.

4.5.1.2.1

a. Wrist

b. Angle - 240°-120° @ 2 RPM

c. Rotate - 360° @ RPM Cont.

4.5.1.2.2 Wrist horizontal (H)

a. Load 100# (U) on hand and hook

b. Thrust 150#

4.5.1.2.3 Wrist vertical (down)

a. Load 150# Hook (U)

b. Load 50# Hand (U)

4.5.1.2.4 Upper arm and elbow

a. Angle - 240°+120° @ 1.5 RPM

b. Rotate - 360° @ 2 RPM Cont

c. Extension - 18" Max

4.5.1.2.5 Upper arm vertical and wrist horizontal

a. Thrust 200# (H)

b. Load 100# (U) Hook or hand

c. Load 200# (U) on Hook

4.5.1.2.6 Shoulder

a. Angle - 180° - 90° @ 1 RPM

b. Rotate - 360° @ 1 RPM Cont.

c. Extension - 42" Max

4.5.1.2.7 Shoulder vertical, wrist and upper arm horizontal

a. Thrust 450# (H)

b. Load 100# (U) on houk and hand

4.5.1.2.8 Shoulder vertical, upper arm horizontal and wrist vertical

a. Load 200# (U) on hook

b. Load 50# (U) on hand

4.5.1.2.9 Shoulder vertical, upper arm and wrist horizontal

a. Thrust 200# (H)

b. Load 100# (U) on hook and hand

4.5.1.2.10 Shoulder, upper arm and wrist vertical (boom extended)

a. Load 600# (U) on hook

4.5.1.2.11 Shoulder, upper arm, and wrist vertical (boom retracted)

a. Load 2000# (U) on hook.

4.5.1.3 All items under 4.5.1.2 should be performed when arms are fully retracted.

4.5.1.4 Observe the working conditions of the cab indication equipment.

4.5.1.4.1 Grip force visual indicator: A center zero meter indicates grip applied by hand or hook.

4.5.1.4.2 FINE position: Full scale deflection with 10# grip force. Suited for fragile items.

4.5.2 Operational capabilities of the manipulators in properly established working positions (on either side and rear of vehicle). Precise maneuvering of the arms will be dependent on the ability of the operator.

4.5.2.1 Intricate, FINE, operations.

4.5.2.1.1 Duplicate intricate work that is required in reactor assembly and disassembly.

4.5.2.1.1.1 Note time element and efficiency.

4.5.2.2 COARSE operations

4.5.2.2.1 Duplicate work would be necessary in cleaning debris after an accident. Handle material that will reach maximum loading requirements.

4.5.2.2.1.1 Note time element and efficiency.

4.5.2.3 Perform manipulator operations with use of the manipulator TV camera.

4.5.2.3.1 Note time element and

efficiency.

4.5.2.4 Observe interchanging of hook and hand attachments.

4.5.2.4.1 Note time element and efficiency.

4.5.3 Manipulator miscellaneous

4.5.3.1 Study manipulator conditions when vehicle is in travel.

4.5.3.1.1 Vibration and shock on arms while in travel mounts.

4.5.3.1.1.1 Predict any damage that might result.

4.5.3.2 Capability of handling fragile items

4.5.3.3 Possible failures

4.5.3.3.1 Lubrication losses

4.5.3.3.2 Motor losses

4.5.3.3.3 Slip clutch failure and setting

APPENDIX IV

RECOMMENDATIONS FOR BEETLE AIR CONDITIONING MODIFICATIONS

May 28, 1962

John W. Tenhundfeld

ABSTRACT: **The results of an analysis of the Beetle air conditioning system are given along with specific recommendations for improving the system.**

TABLE OF CONTENTS

I Introduction

After the Beetle air conditioning unit proved itself inadequate during the initial heat test, an investigation was started to determine what could be done to improve the air conditioning system. This report gives the results of that investigation. The work has not been completed so that this report does not give a complete solution to the problem, but simply states the results of that work and gives recommendations as to what can be done to make the present air conditioning unit satisfactory.

An analysis of the internal and external heat loads, cooling air requirements and pressure drops in the system was made and is reported here.

II Recommendations

1. Obtain complete information on air conditioning unit, especially the capacity of blower. It has been calculated that the pressure drop in the duct will be approximately 4 in. of water at 225 cfm of air flow. Determine if an additional blower working in series with the present blower will provide this flow. If the additional blower will not do the job, a new, high capacity blower will have to be procured. A high capacity blower may be available from the air conditioner manufacturer. The manufacturer of the air conditioning unit was:

   Alpha Electric Refrigeration Co.
   1115 East Seven Mile Road
   Detroit 3, Michigan
   Att: Edwin F. Cope, Service Manager

   The unit was bought on their quotation #2630, dated December 29, 1958.

2. Reduce the pressure drop in the duct by replacing the flexible tubing with smooth tubing and putting radii at all turns. Insulate these tubes to prevent heat gain in them.

3. Improve entry and exhaust characteristics in the ducts wherever possible.

4. Reinstall insulation on inside of cab. Also insulate floor and hatch if possible.

5. Paint outside of cab white to reduce solar load.

6. Do not attempt to keep inside of cab cooler than 90°F when ambient conditions are 130°F. See Figure 1 for comfortable conditions under various temperatures and relative humidities.

III Heat Load

A. Internal Load

Equipment load	700 BTU/hr
One person	300
Make up air (5 cfm)	368
	1368 BTU/hr

B. Wall Transmission

1. Assuming 130° outside temperature and 76°F inside temperature and ignoring solar load

   Wall transmission = 1128 BTU/hr

2. Considering the solar load by assuming a cab skin temperature of 150°F

   Wall transmission = 2620 BTU/hr

C. Total Load

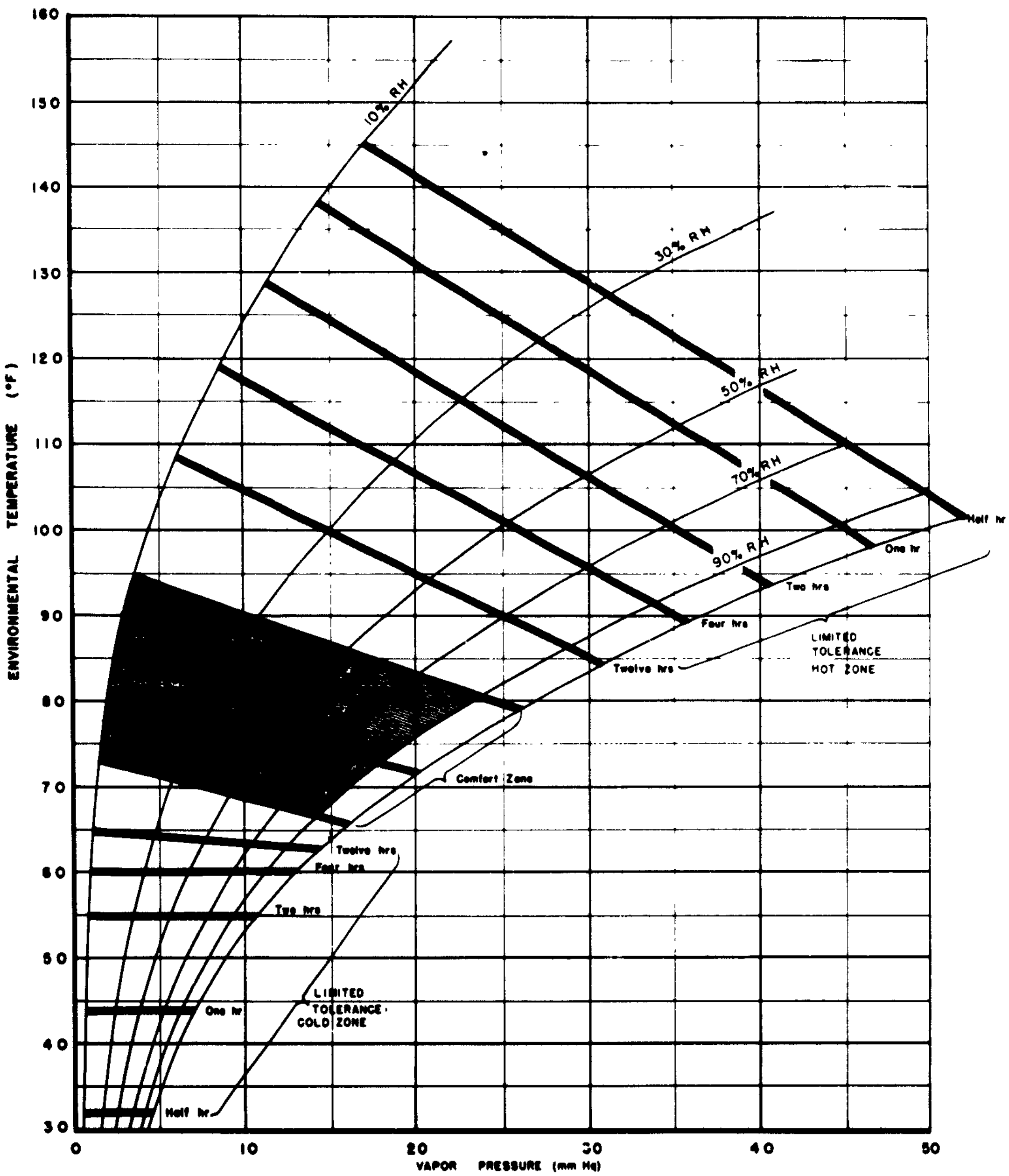
2495 BTU/hr	No solar load
3988 BTU/hr	With solar load

IV Cooling Air Required

Assume ΔT = 16°F thru air conditioning unit
Flow rate = 148 cfm for 2495 BTU/hr
Flow rate = 226 cfm for 3988 BTU/hr

Figure 1

THERMAL REQUIREMENTS FOR TOLERANCE AND COMFORT IN AIRCRAFT CABINS



Sitting men dressed in conventional clothing (1 clo) doing light manual work.
Air motion equals 200 fpm.

(See MR No. TSEAL-3-695-56)

The existing blower is flowing approximately 50 cfm of air into the cab. The cab will require approximately 225 cfm of air to properly cool. A typical blower has a characteristic curve as shown in Figure 2.

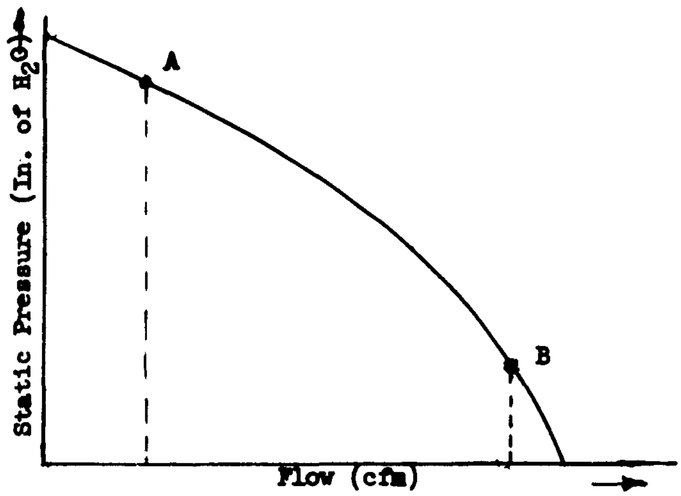


Figure 2

If the present blower is operating near point "A" on the curve it is possible to get sufficient flow out of the blower by placing another identical blower in series with it, thereby decreasing the pressure drop and making each unit operate at point B. This will be possible, however, only if the flow from the blower at 0 static pressure is well above 225 cfm. If the existing blower does not have sufficient capacity, it will be necessary to select a blower with higher flow and higher static pressure capability, i. e., one which will deliver 225 cfm at 4 in. of water.

This increase flow rate will result in air velocities in the order of 2700 ft/min. which, in an ordinary system, would cause objectionable noise levels. However, since the operator will be wearing earphones at all times, this noise level should not be objectionable.

The following company

Air Marine Motors Inc.
2221 Barry Avenue
Los Angeles, California

makes a wide selection of blowers which may fit this application.

V References

1. Marks, Lionel S., "Mechanical Engineer Handbook," McGraw Hill Book Co. Inc., New York, 1951, pp 1618-1625

2. Op. Cit. P 377.

3. Tenhundfeld, John W., Letter to F. C. Linn, GE-NMPO "Report on Trip to WADC, Dayton, Ohio, March 28, 1962 Concerning Refrigerated Suit For Beetle Operator," April 11, 1962

APPENDIX V

BEETLE ACCEPTANCE TEST REPORT

BEETLE ACCEPTANCE TEST REPORT

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BEETLE ACCEPTANCE TEST REPORT

LIST OF TABLES

SECTION I

INTRODUCTION

The objective of the acceptance test program was to ascertain the functional adequacy of each of the Beetle's systems, before it was shipped. The test program was carried out in accordance with specifications of the Air Force Special Weapons Center (SWVSM), and was performed under the direction of personnel of the General Electric Company, Nuclear Materials and Propulsion Operation.

The program consisted of the following specific tests, conducted on the dates shown.

CO_2 Concentration Test, Main Engine Compartment -- 21 December 1961

CO_2 Concentration Test, Pod -- 30 January 1962

A-C Generator Test -- 20 March 1962

Hydraulic Systems Test -- 22, 23 March 1962

High-Temperature Functional Test -- 26 March 1962

Road Test -- 27 March 1962

Dynamotor Operation Test -- 2 April 1962

Steering Clutch Adjustment and Test -- 3 April 1962

The procedures followed in the performance of these tests, and the conclusions derived from them, are found in Section III of this report.

SECTION II

SUMMARY

The results of separate tests, described in Section III, indicated that the vehicle as a whole performed satisfactorily; however, difficulties encountered with some systems and components during Phase I tests required subsequent modification or adjustment of those systems, or replacement of components. Significant deficiencies were found in the original alternator and in the blower of the air conditioning unit. In order to correct the deficiency in the alternator, it was replaced with a new G-E brushless a-c generator, which proved entirely satisfactory in subsequent tests, as indicated in this report. Recommendations for modification of the air conditioning unit have been compiled as a separate report, T.M. 62-6-2, "Recommendations for Beetle Air Conditioning Modifications", by J. W. Tenhundfeld, NM&PO, General Electric Company, and are not duplicated in this publication.

SECTION III

TESTS

3.1 HIGH-TEMPERATURE TEST

3.1.1 CONDITIONS

The high-temperature test was conducted on March 27 in Building GDF-2. In addition to the standard heating facilities of the building, space heaters and electric heaters hung along the walls of the chamber were used to increase heat to the test temperatures shown in Table III-1. A tent of polyethylene sheet was used to contain the heated air, so as to prevent its loss by convection during the test. In order to permit the chamber temperature to stabilize, and to bring the temperature of the Beetle up to the desired point, heating was begun on the evening of 26 March 1962, and was kept on throughout the performance of the test on 27 March 1962. The Beetle was resting on blocks, approximately 4 inches above the floor of the building, during the entire period.

3.1.2 FUNCTIONS TESTED

3.1.2.1 Cab Elevation and Rotation

Starting at 0900 hours, the following functions of the cab were tested:

a. Cab elevated to 6 ft 0 in, and rotated clockwise to limit.
b. Cab rotated counterclockwise to limit, then returned to 180-degree position.
c. Cab elevated to 11-foot height, but not rotated because of

structural interference within building.

d. Cab raised to limit (14 ft, 6 in), and rotated to 45 degrees on each side of 180-degree position.

All functions operated satisfactorily, and all switch indications were normal; however, there was a noticeable lag in the recovery of speed of the PE- 90 engine, that resulted from application of hydraulic load when the cab was raised. This lag was believed due to maladjustment of the governor linkage, and was subsequently corrected.

3.1.2.2 Air Conditioner

Performance of the air conditioning unit is indicated by the time-temperature log shown in Table III-1. The unsatisfactory amount of cooling produced by the unit is thought to be the result of insufficient blower capacity, coupled with too much flow resistance in the intake and exhaust ductwork. Recommendations for correction of this condition are found in TM 62-6-2, "Recommendations for Beetle Air Conditioning Modifications", by J. W. Tenhundfeld, NM & PO, General Electric Company.

TABLE III-1

AIR CONDITIONER TEST LOG

TIME	CAB TEMP. (°F)	CHAMBER TEMP. (°F)	REMARKS
0815	90		Air conditioner started
0850		105	
0855	82		Operator entered cab
0903	83		
0910		109	
0915	84	110	
0924	85		
0930		113	Space heaters shut down because of high CO concentration in chamber
0931	86		

TABLE III-1 (cont'd)

TIME	CAB TEMP. (°F)	CHAMBER TEMP. (°F)	REMARKS
0935		111	
0948	87	110	
0956	88		
1005	89		
1018	90		
1020		106	
1023			Operator forced to leave cab because of exhaust fumes from PE-90

3.1.2.3 Main Engine

The main engine started normally. Dim red light indications were observed at OIL TEMP HIGH and OIL PRESSURE LOW indicators at idling speed. Main engine speed was increased from 1000 rpm to 2400 rpm in 6 seconds, then was returned to idling speed. The engine was held at idling speed during most of the test period, but was run up to 1800 - 2400 rpm for 1½ - 2 minute periods at 10-minute intervals, to prevent carbon build-up. At 1004 hours, the main engine stalled out as a result of carbon build-up during an idling period of about 15 minutes. Restart from JB-10, using flooded-engine starting procedure, was normal; although rough idling was observed at 1000 rpm following restart. The engine speed was increased to 2400 rpm for 1.75 minutes; subsequent return to idling speed found engine running smoothly.

3.1.2.4 Auxiliary Engine

Auxiliary engine starting and operation at idling speed was normal; however, full-speed, no-load operation was erratic, since "hunting" between 1900 and 2000 rpm was observed. Application of hydraulic load during cab-raising operations resulted in engine-speed reduction to about 1500 rpm, with a recovery time of 3 - 4 seconds. The addition of a light electric load to the a-c generator did not stabilize auxiliary engine speed.

3.1.2.5 JB-1 Integrity Check

All operations were performed, and all light indications checked. All functions and indications were normal.

3.1.2.6 JB-10 Integrity Check

All operations were performed, and functions were normal. All light indications were checked, and all found normal except for dim red-light indication at OIL TEMP HIGH and OIL PRESSURE LOW indicators.

3.1.2.7 Visual Inspection

Visual inspection during and immediately following operation, disclosed the following information:

a. CO_2 extinguisher line in contact with muffler housing
b. Cable trough temperatures: 145°F, left side; 155°F, right side
c. Temperature under main engine; 110°F; under left creep-drive gearbox, 115°F
d. Hydraulic fluid leak: right rear. Apparently from main hydraulic tank
e. Excessive vibration in hydraulic synchronizer lines
f. Oil on main engine cooling fan housing. (Subsequent inspection, after shutdown revealed no increase in oil residue; hence, the oil was probably residual oil in main engine compartment, which had been drawn over the engine by air current from the fan)

3.1.3 CONCLUSIONS

Results of the high-temperature test indicated that all systems and components except those listed in Table III-2 operated normally. Table III-2 indicates deficiencies and suggestions for corrective action.

TABLE III-2

TEST DEFICIENCIES

SYSTEM OR COMPONENT	DEFICIENCY	CORRECTIVE ACTION
1. Air Conditioner	Insufficient cooling	Increase capacity of blower. Reduce resistance of duct-work. Replace interior insulation in cab. Paint exterior surface of cab with thermal-reflective paint.
2. Main Engine	Carbon build-up after sustained idling (10 - 15 minutes)	Run-up engine to 1800 - 2400 rpm for 1 - 2 minutes in every 10-minute period.
3. Auxiliary Engine	Speed drop upon application of load, and slow recovery to normal speed	Adjust governor linkage

3.2 AMBIENT TEMPERATURE TEST

3.2.1 CONDITIONS

Ambient temperature range on the date of these tests was from 36°F to 63°F. Since no significant extremes of temperature were encountered, no hourly log of temperatures was made.

3.2.2 FUNCTIONS TESTED

3.2.2.1 Cab Temperature

Temperature in the cab registered 80°F at beginning of test period. Temperature rose to 81°F after the operator had been inside the cab for 2 minutes, and air duct was removed to permit increased flow. Temperature then dropped to 70°F after 8 minutes, and stabilized at 73°F - 75°F for the remainder of the test day.

3.2.2.2 Auxiliary Engine

Because of manual changes on the governor, the auxiliary engine speed was increased to 2400 rpm (indicated), at which time the protective circuit devices dropped the alternator output from the a-c distribution buss.

After changes were completed, operation was normal.

3.2.2.3 Transmission and Steering

Left steer, under main-engine drive, was jerky because of erratic steering clutch engagement during left turn. The pivot steer function also failed to operate properly.

3.2.2.4 Manipulators

Left boom extend and retract functions, and right wrist counter-clockwise rotate function, did not operate at beginning of test. All functions operated normally after operator pressed RESET pushbuttons to re-establish circuits.

3.2.3 CONCLUSIONS

Except for the air conditioner deficiency referred to in Table III-2, and the steering deficiency referred to in paragraph 3.2.2.3, all functions were normal during the ambient temperature tests. The steering deficiencies were subsequently corrected at the Nevada Test Site by a Field Engineer from Allison Division of General Motors Corp.

3.3 ROAD TEST

3.3.1 CONDITIONS

The road test was performed during the late afternoon of 27 March 1962. The ambient temperature at 1600 hours on that date, was 63°F. The vehicle was driven under main engine power from Building GDF-2 to the ramp leading to the lower level of Building 701 -- a distance of approximately 1/2 mile -- on hard surfaced road. The operator was directed by radio from a mobile transmitter/receiver installed in a truck equipped with a 110-volt generator. The ramp on which cab elevation and rotation tests were made has a grade of 13.5 percent.

3.3.2 OPERATION

The vehicle was driven approximately 30 feet down the ramp, to ensure that the entire length of the vehicle was supported on the 13.5-percent grade. The vehicle was stopped at this point, and was held stationary on the grade by application of the parking brake. (See figure 1.) The cab was raised slightly, then rotated 180 degrees to the operating position. While the cab remained at the operating position, the vehicle was driven up the ramp in reverse gear.

The eccentric load of the pod caused the cab-pod assembly to rotate completely around to the 180-degree position after rotational movement had only been initiated by the operator. Neither cab rotation brakes nor the cab rotation motor were sufficiently powerful to overcome the pull of gravity on the eccentric load which was at maximum at this point, because nearly all hydraulic fluid remained in the main hydraulic tank at the rear of the pod. Center of gravity is shown in figure 2.

Tests on the creep-drive function were inconclusive during this test. The vehicle was driven about 30 feet under power of the creep drive, but either the battery charge was insufficient or an open control circuit caused the vehicle to stop after that distance had been covered. Since the main engine was operating, the chassis batteries were recharged automatically before it was possible to check their condition; however, the panels were only temporarily secured to their supports in the cab, and it is presumed that an open circuit caused the failure of creep drive power temporarily.

3.4 SYSTEMS AND COMPONENTS TESTS

3.4.1 HYDRAULIC SYSTEM

3.4.1.1 Procedure

In addition to the test of the cab elevating and rotating functions at high temperatures, described in paragraph 3.1.2.1, a detailed test of hydraulic system operation was performed on 22 and 23 March 1962. This test consisted of two parts: first, checking ascent and descent of the cab while the vehicle remained level, and, second, checking rotation of the cab at various heights while the vehicle was parked on a 2.5-degree slope. Height measurements and pressure readings were made at each of the four individual hydraulic cylinders during the series of tests.

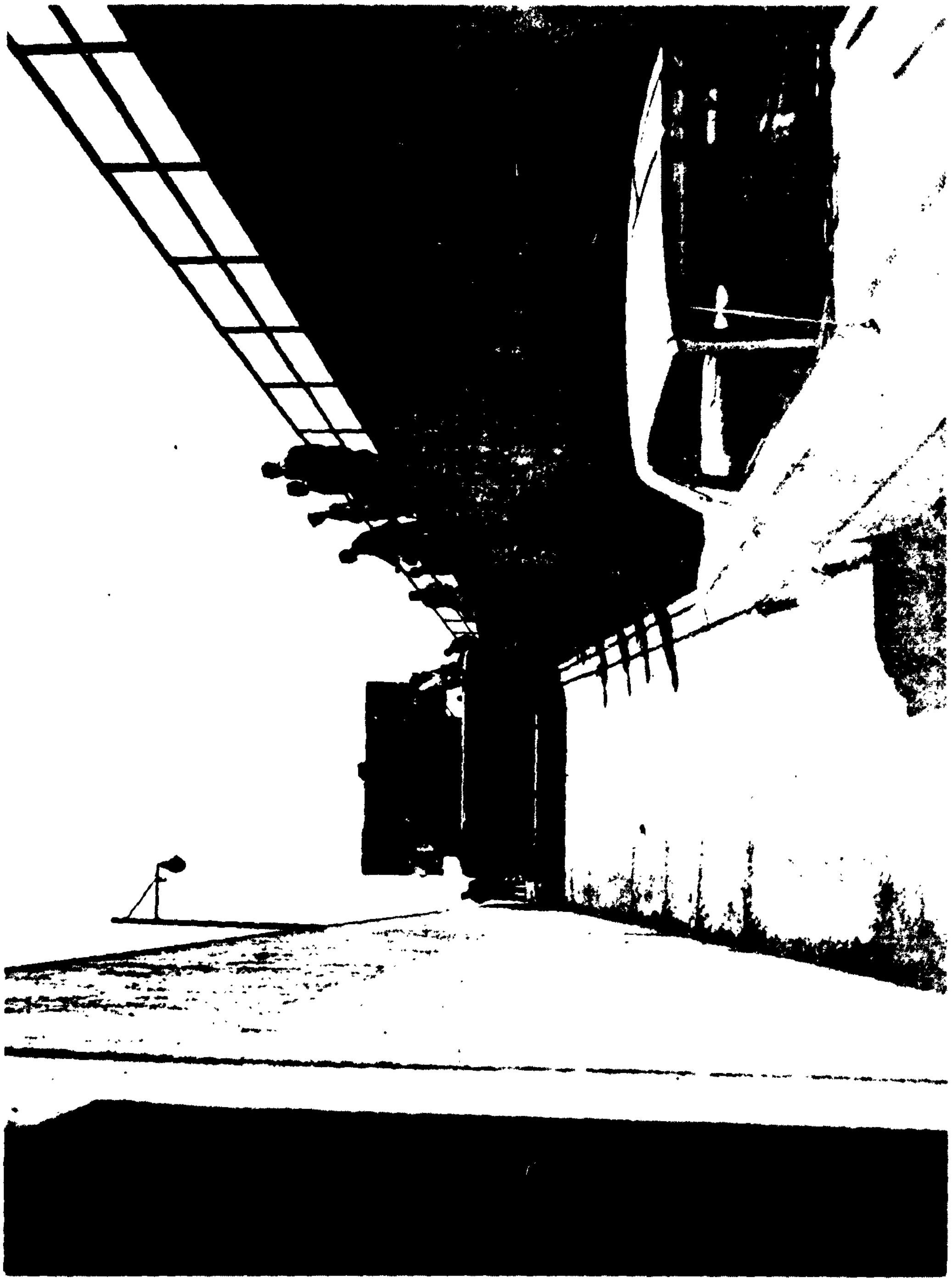


Figure 1 - Photo Number U39331E

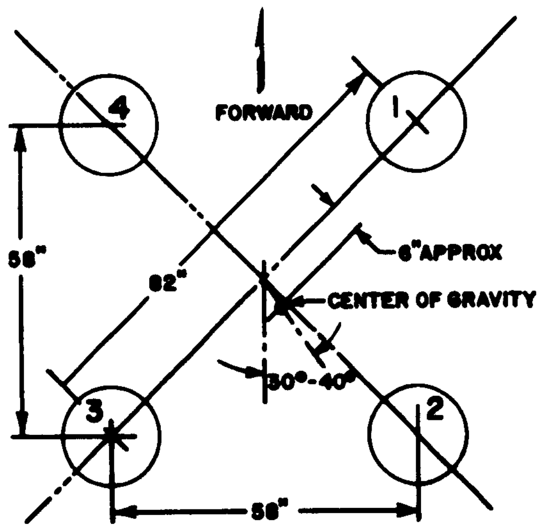


Illustration of Cab-Pod assembly lift cylinders of Beetle showing approximate location of center of gravity of the assembly

Figure 2

During Part One of the test, the vehicle was levelled, and the cab was elevated from rest position, facing forward, to 69-, 111-, and 172-inch heights. Height and pressure at each cylinder were recorded at each position, and pressure readings were taken while the cab was moving from one position to another. (Refer to Table III-3).

During Part Two of the test, the cab was elevated to a height of approximately 35 inches, and was rotated from the zero-degree position to the 45-, 90-, 180-, 270-, and 315-degree positions; height and pressure of each cylinder was measured at each of these points. (Refer to Table III-4, runs 1 through 6.) While at the 315-degree position, the cab was lowered to the mid-point of the first-stage cylinder (23-inch height), then raised to about 70 inches for measurements at the 315-, 270-, 180-, 90-, 45-, and 0-degree positions. (Refer to Table III-4, runs 7 through 12.) Height and pressure of each cylinder were again recorded at the 115-inch elevation for 180- and 90-degree positions (runs 13 and 14), and again at the 155-inch elevation for 180-, 90-, and 0-degree positions. The cab was then lowered 3 inches, and readings were taken at each cylinder. The cab was then rotated 180 degrees, elevated 10 inches, lowered 8 inches, and measurements taken (runs 15 through 20).

In addition to tests of cab elevation and rotation, both normal and emergency hatch raising systems and the cab rotation brake system were checked and found normal.

TABLE III-3

PART I VEHICLE LEVEL - STATIC READINGS

RUN	DEGREES OF ROTATION TO LEFT	DIRECTION OF MOTION PRIOR TO READING	HEIGHT INCHES 1	2	3	4	PRESSURE psi 1	2	3	4
1	0	UP	69-1/4	69-1/8	69-1/8	69-1/4	250	320	260	170
2	0	UP	111-7/8	111-3/4	111-3/4	111-7/8	320	420	370	240
3	0	UP	147-1/4	147-1/8	147-1/8	147-1/4	470	570	420	360
4	0	UP	172-3/4	172-5/8	172-5/8	172-3/4	420	540	535	360

PART I VEHICLE LEVEL - DYNAMIC READINGS

POSITION & DIRECTION OF MOTION	HEIGHT INCHES	PRESSURE - psi 1	2	3	4
1st stage moving up	0 - 45 inches	200	300	190	140
2nd stage moving up	45 - 90 inches	230	330	270	180
2nd stage stop		250	320	260	170
3rd stage moving up	90 - 135 inches	320	420	370	240
3rd stage moving up		350	420	380	250
3rd stage moving down		400	450	340	360
4th stage moving up	135 - 173 inches	420	570	550	390
4th stage moving down		400	620	500	360

TABLE III-4

PART 2 VEHICLE ON 2½° SLOPE - STATIC READINGS

RUN	DEGREES OF ROTATION TO LEFT	DIRECTION OF MOTION PRIOR TO READING	HEIGHT INCHES				PRESSURE psi			
			1	2	3	4	1	2	3	4
1	0	UP	35-1/4	35-	35	35-1/4	180	260	210	110
2	45	UP	35-1/2	35-1/4	35-1/4	35-1/2	180	255	210	110
3	90	UP	35-3/4	35-3/4	35-5/8	35-3/4	180	255	210	110
4	180	UP	No reading available				180	260	160	140
5	270	UP	No reading available				110	360	80	200
6	315	UP	No reading available				150	330	130	160
7	315	UP	No reading available				240	330	270	140
8	270	UP	69-1/2	69-1/4	69-1/4	69-1/2	240	340	250	170
9	180	UP	70-5/8	70-3/4	70-5/8	70-3/4	250	310	260	180
10	90	UP	71-3/4	71-5/8	71-5/8	71-5/8	210	310	290	180
11	45	UP	69-5/8	69-1/2	69-1/2	69-5/8	200	320	290	175
12	0	UP	70-3/4	70-5/8	70-5/8	70-3/4	210	350	290	140
13	180	UP	115-3/4	115-5/8	115-5/8	115-3/4	340	390	350	270
14	90	UP	116-3/8	116-3/8	116-1/4	116-1/4	360	450	345	190
15	180	UP	166	166-1/8	166	166	480	520	480	420
16	90	UP	165-1/4	165-1/8	165	165-1/8	340	575	520	450
17	0	UP	166-5/3	166-1/4	166-1/4	166-3/4	430	600	550	350
18	0	DOWN	162-1/4	162-7/8	162-1/2	162	190	920	530	230
19	180	UP	163-1/2	163-1/4	163-1/4	163-1/2	500	500	440	450
20	180	DOWN	145-1/4	144-7/8	144-7/8	145-1/4	530	460	400	480

3.4.1.2 Conclusions

Operation of the cab when the vehicle was level, was completely satisfactory. Operation when the vehicle was parked on a 2½-degree slope was completely satisfactory for the first two stages of hydraulic cylinders; however, operation in the third stage of elevation was satisfactory only within the range of 90- to 270-degrees from rest position (0-degree). In the fourth stage, cylinders were found to be as much as 7/8-inch out of synchronization when the cab was not rotated. (Refer to Table III-4, run 18.) As a result of these findings, it was recommended that rotation of the cab be restricted to ±90 degrees from the working position in the fourth stage.

There was no sign of leakage from the cylinders during these tests, even when the cylinders were as much as 7/8-inch out of synchronization. Experience gained during previous tests indicates that the cylinders can tolerate a difference in height of as much as 5/8-inch in the first stage, and as much as 1¼-inches in the fourth stage, without leakage from the cylinder seals.

The hatch elevating system was checked for both normal and emergency operation during the test, and all systems worked satisfactorily. In normal operation, the hatch requires approximately 1½ minutes to open completely; on the electric emergency system about 12 minutes is required, and on the manual emergency system about 35 minutes is needed.

The separate cab-rotation brake hydraulic system was checked during the test, and found satisfactory. The system develops 325 psi to release the spring-loaded brakes.

3.4.2 ELECTRICAL COMPONENTS

3.4.2.1 A-c Generator

After preliminary tests, performed in late January and early February, 1962, had indicated that the alternator originally supplied was inadequate, a new G-E brushless a-c generator was installed in the Beetle. Tests performed on 20 March 1962 demonstrated that the new equipment was entirely satisfactory, since it maintained voltage and frequency output over a wide range of loads. Table III-5 contains the data derived from this test.

TABLE III-5

A-C GENERATOR TEST RESULTS

FREQUENCY (Cycles)	PHASE VOLTAGES AB	AC	BC	PHASE CURRENT (Amperes) ϕA	ϕB	ϕC	
61	211	211	211	5.0	5.0	6.5	FACILITY APPLIED LOAD
61	213	213	213	5.0	6.0	12.0	
61	214	214	214	15.0	20.0	20.0	
61	206	206	206	50.0	50.0	40.0	
61	208	208	208	55.0	55.0	45.0	
61	206	206	206	58.0	59.0	48.0	
61	206	206	206	60.0	70.0	49.0	COMBINED FACILITY AND BEETLE APPLIED LOADS
61	203	203	203	75.0	65.0	40.0	
61	204	204	204	80.0	74.0	50.0	
61	203	203	203	105.0	100.0	74.0	
61	206	206	206	105.0	100.0	85.0	
60	205	205	205	120.0	130.0	105.0	

3.4.2.2 Dynamotor

On 2 April 1962, the dynamotor was functionally tested by using it to power the manipulators.

3.4.2.3 Conclusions

Tests indicated that both normal and emergency a-c generating equipment were generally satisfactory. Although the test demonstrated that the dynamotor is adequate to perform its emergency function, it is recommended that it be replaced by a motor-generator set to provide a more stable output voltage. The tests of other electrical components and circuitry were incidental to the performance of other functional tests, and demonstrated their reliability and performance adequately at the time those tests were conducted.

3.4.3 CO_2 FIRE EXTINGUISHING SYSTEMS

3.4.3.1 Conditions

Carbon dioxide concentration tests were conducted separately for the main engine compartment and for the pod. The test on the main engine compartment was carried out on 21 December 1961, and that for the pod on 30 January 1962. Both tests were performed by Mr. A. L. Chudoba, Chief Contact Engineer, Special Hazards Department, The Fyr-Fyter Company, using special equipment and instrumentation furnished by that company. Neither engine was operating at the time concentration tests were made, since it is presumed that the 20-second time delay between activation of the sensors and the firing of the first charge would be sufficient to permit either engine to come to a complete stop. The tests were conducted indoors (Building GDF-2), with engine covers in place. Figure 3 shows the equipment used in making the tests.

3.4.3.2 Procedure

The procedure used for both main engine compartment and pod fire extinguisher tests was identical. Sensor actuating temperature was checked with thermocouples while heat was applied to them with a soldering iron. Both sensors operated normally. The CO_2 concentration tests were performed by incorporating switches in the firing circuits to simplify control set up, to simulate closure of fire detection sensors, and to permit more accurate control of the instant of CO_2 release, for test purposes. In both main engine compartment and pod tests, a single charge was released, and concentrations checked at 10-second intervals. A CO_2 concentration of 28.8 percent is the industry standard for efficient extinguishing action, and, in both cases, this concentration was reached within 30 seconds. Table III-6 contains the time/concentration data obtained in the tests.

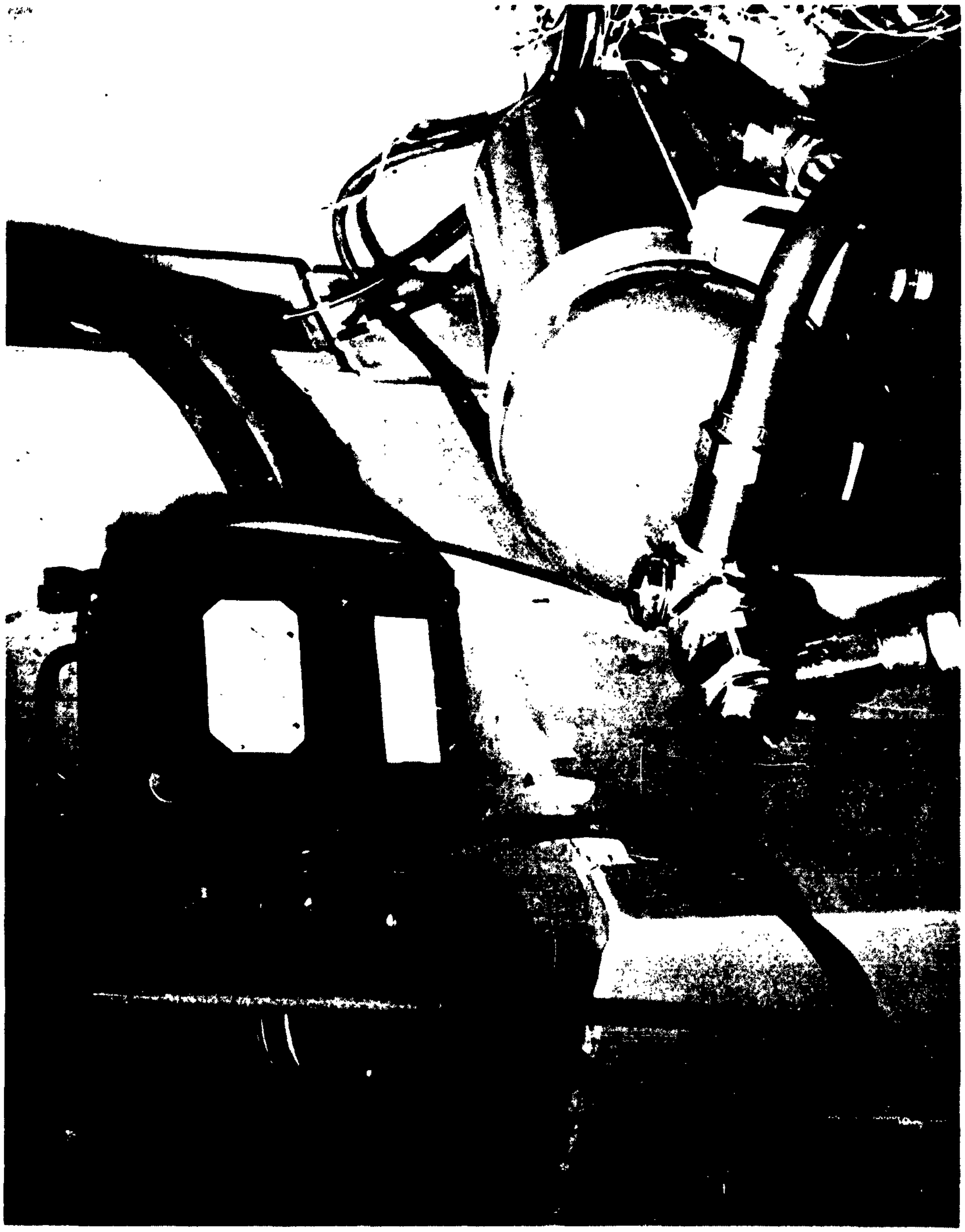


Figure 3 - Photo Number U39312A

TABLE III-6

CO_2 CONCENTRATION vs. TIME

TIME (Sec)	CO_2 CONCENTRATION (Percent) Main Engine	Pod
0	0	0
10	0	0
20	22	10
30	30	32
40	34	18
50	30	9
60	18	--
70	10	--
80	6	--

3.4.3.3 Conclusions

Tests of the CO_2 fire extinguishing systems indicated that they were completely adequate. Minimum acceptable concentrations were attained in less that 30 seconds, and lasted in excess of 20 seconds (main engine compartment) or 5 seconds (pod), using only the No. 1 charge in each case. Longer lasting concentrations at the minimum acceptable level could have been attained by discharging the No. 2 charge after 30 seconds had elapsed.

3.5 MISCELLANEOUS TESTS

3.5.1 GENERAL

While only the tests conducted under specific conditions or those conducted to obtain data on specific systems or components have been described in detail, other systems of the Beetle have demonstrated satisfactory performance. Many of the checks have been made repeatedly during the conduct of other specific tests; for example, various components of the electrical and hydraulic systems demonstrated normal functioning during the performance of road testing, cab elevation and rotation testing, engine starting, etc. Other systems and components to which no reference has been made in the preceding discussion are described and evaluated in the following paragraphs.

3.5.2 LIGHTS

Floodlights, spot-lights, and driving lights were all checked and found satisfactory.

3.5.3 RADIO

Radio transmission and reception was used in communication between the operator and the base station in the performance of other tests. Operation was satisfactory in all cases.

3.5.4 AUDIO AND WARNING SYSTEMS

The public-address system, siren, and engine-monitoring functions were checked during the progress of road tests and demonstrations on several occasions. All functioned satisfactorily.

3.5.5 PERISCOPE

All periscope functions were tested, and all operations were normal.

3.5.6 TELEVISION

Various components of the closed-circuit television system were either bench-checked or operated in place during and after the specific test program. While the equipment proved satisfactory, vibration in shipment to the test site was expected to necessitate re-adjustment when the equipment was re-installed in the Beetle.

3.5.7 RADIATION DETECTION EQUIPMENT

It was not possible at the time these tests were conducted, to check out the radiation detection system; a number of its components had been returned to the vendor for repair.

3.5.8 ACCESSORIES

The following items were checked by use or count, and their condition was determined to be satisfactory.

1. Operator's seat
2. Windshield Wipers
3. Emergency air supply equipment
4. Water bottle
5. Flashlight
6. Writing board
7. Ash receiver
8. Cigarette lighter

APPENDIX VI

THE BEETLE

On-Site Radiological Safety Support Report

TABLE of CONTENTS

THE BEETLE

On-Site Radiological Safety Support Report

I. Introduction

A shielding integrity test of the "Shielded Cab, Remote Handling Vehicle with Manipulators: (Beetle) was conducted May 10, 1962, at the MAD Building in Area 400. The test was conducted at the request of C.D. Montgomery J-6 Division, Los Alamos Scientific Laboratory and was performed as a joint effort of the Reynolds Electrical and Engineering Co., Inc. (REECo), Radiological Safety Division and The American Car and Foundry Industries, Inc. (ACFI). Test results are presented in this report.

II. General Information

The test was divided into two (2) phases. Phase #1 was a test of the cab to determine if it would be safe to place an operator inside the cab for a more detailed test of the cab's shielding integrity. Phase #2 was conducted with an operator in the cab monitoring the cab's interior opposite the location of the outside source. The general approach for conducting the test is listed in Appendix A of this report.

III. Test Equipment

A. Source Description

1. An eighteen hundred ninty-four (1894) curie Barium 140+ Lanthamm 140 source (approximately 2273 r/hr at 1 meter) was utilized as the gamma emitter for the test.

B. Radiation Detection Equipment

1. Two Cobalt 60 gamma calibrated Victoreen Radector Model GB 500B-SR instruments with one hundred foot cable connected probes were utilized during Phase #1.

2. One Eberline E-500B GM type portable instrument mated to an Esterline-Angus strip chart recorder was utilized during Phase #1.

3. A Beckman MX-5 GM type portable instrument was used during Phase #2 of the test.

IV. Test Preparations

A. Background Measurements

1. Radiation measurements obtained prior to the test indicated a background of 0.01 mr/hr inside the cab with the hatch closed.

B. Detector Probe Placement

1. The Beetle cab was instrumented with two detector probes mounted in the center of the cab at heights of two and three feet above the cab floor. Radiation measurements were read-out, outside the Disassembly Bay. The detector-recorder unit was positioned on the floor of the cab to continuously record radiation measurements on a strip chart.

C. Remote Source Positioning

1. During Phase #1 (unmanned phase) the source distance from the outside surface of the vehicle varied from ten (10) to thirteen (13) inches for the forward two-thirds of the cab, due to the necessity to position the source by remote means. The source was positioned at near contact with the bonnet of the cab (a four (4) foot extension attached to the rear of the cab).

2. During Phase #2 (manned phase) the source distance from the exterior of the cab was approximately two (2) feet for the forward two-thirds and near contact with the bonnet.

V. Test Procedure

Procedures for both test phases were as outlined in the "Proposal for the Beetle Shielding Integrity Test Area 400" (Appendix A).

VI. Test Results

A. Shielding Effects

The tabulated data concerning integrity is listed in Appendix B of this report.

1. Radiation measurement locations of interest (windows, window and hatch, seams, etc.) are depicted on diagrams of the Beetle cab. Figures 01 through 05, Appendix C.

B. General Data Interpretation

In general, the shielding integrity test proved the following:

1. There were no gross defects in shielding attenuation.

2. The shielding integrity of the viewing windows were slightly less than the shielding integrity of the wall surrounding the respective windows.

3. Lowering the cab to the normal traveling position will increase the shielding attenuation to the cab's floor by at least a factor of two, due to the additional shielding provided by the vehicles undercarriage.

APPENDIX A

PROPOSAL FOR THE BEETLE SHIELDING TEST - AREA 400

TEST PREPARATIONS

I. Area Control

1. Prior to removal of the source from its shielding container, the following locations will be checked to assure that the areas are clear of personnel.

   a. The Upper and Lower Disassembly Bays.

   b. MAD Building roof.

   c. The Lower West Corridor (Window "A").

   d. Window "N" Area.

   These areas will be locked or barricaded to prevent entry during the test.

II. Safety Considerations

1. Air Sample

   a. A high-volume Staplex Air Sampler with an 8" x 10" fiberglass filter will be in operation for the duration of the test.

2. Swipes will be obtained from the primary source container to determine if the source has ruptured in transit.

3. Swipes will be obtained from the Disassembly Bay floor and walls when the source has been replaced in the shielding Container in order to assure source integrity after the first phase of the test and when the test has been completed.

4. A vacuum cleaner will be connected to a power outlet and will remain in the Dissassembly Bay during the test. The vacuum cleaner will be remotely operated to decontaminate the bay in the event of an accidental source rupture.

5. The Victoreen Remote Area Monitoring System will be operational during the test to assure safety of personnel in the MAD Building.

6. No entry into the bay will be made until the source has been placed in its shielding container and the bay monitored for radiation.

   a. Personnel entering the bay will be provided anti-c clothing and dosimeters and accompanied by a Rad-Safe monitor.

III. Test Procedures

Source Preparations

1. The Source Shielded Container will be pre-positioned in a convenient, visible location in the Lower Bay.

   a. A one hundred (100 sq. ft.) square foot area of the bay floor will be papered and the source container placed in the center of the papered area.

   b. The source container will be prepared so that it can be opened and the source removed remotely.

   c. Source Holding Fixtures and the heat sink will be positioned on the papered area.

Beetle Preparations

1. The Beetle will be brought into the bay and positioned in a location where the Beetle cab can be rotated 360 degrees azimuth. The cab will be raised to allow source access to its underside.

   a. The Beetle cab will be instrumented with two remote detectors mounted in a central location of the cab. Radiation levels detected will be read out outside the Disassembly Bay. In addition, a low-level beta-gamma detector-recorder unit will be placed on the floor of the Beetle cab to continuously record radiation measurements on a strip chart.

Area Control

1. The Disassembly Bays (Upper and Lower) will be cleared of personnel, and the Personnel Doors will be locked.

2. The MAD Building roof will be checked to assure the roof is clear of personnel. Signs and barricades to bar access to the roof will be posted.

3. The entrance to the Lower West Gallery will be locked to prevent access to the Window "A" area.

Test Phase #1

1. The source will be removed by remote means from its shielding container and placed in the Source Handling Fixture.

2. The source will be moved toward the Beetle cab, and radiation levels inside the cab observed by remote detectors.

   a. Radiation levels inside the bay will be monitored by the Victoreen Remote Monitoring System.

3. The source will be moved around the Beetle cab at a distance of one (1) foot until the entire exterior of the cab has been exposed to the source.

   a. Should a significant shielding failure be observed during this phase of the test, the source will be replaced in its shielding container and the Beetle cab re-instrumented with radiation detection equipment to determine the location and magnitude of the shielding failure.

   b. If no shielding failures are detected, Test Phase #2 will commence.

Test Phase #2

1. The source will be placed in its shielding container, and the Lower Disassembly Bay Personnel Door will be unlocked.

2. Rad-Safe monitors will monitor the area for contamination and radiation.

   a. If the area is contaminated, appropriate decontamination and radiation safety measures will be initiated.

   b. If no contamination is detected, the Beetle radiation instrumentation will be removed from the cab in order to allow room for the Beetle operator.

3. The Beetle cab will be manned by an operator familiar with the Beetle Control System and competent to read portable radiation detection instruments.

   a. Communications between the Beetle operator and the Integrity Test personnel will be maintained by means of two-way radios.

   b. The Beetle Operator will have a low range beta-gamma and a high range gamma instrument in his possession. (Tracerlab T1B and a Beckman MX-5).

   c. Radiation detection instruments and communications will be rechecked just prior to removal of the source from its shielding container.

4. The Beetle hatch will be closed, the bay cleared of personnel, and the Personnel Door will be locked.

5. The source will be removed from the shielding container and slowly moved toward the cab.

   a. The Beetle Operator will carefully monitor the cab's interior as the source approaches. The Beetle Operator can, if necessary, rotate the cab to a better shielded position if a shielding failure is observed.

6. The source will be positioned at six (6) horizontal planes during the second phase of the test. A minimum of eight measurements will be obtained at 45 degree intervals in each plane.

   a. Plane #1 will be in the center of the hatch and above the hatch approximately two (2) feet.

   b. Plane #2 above the hatch seam two (2) feet.

   c. Plane #3 will be even with the top of the main viewing window and away from the window approximately two (2) feet.

   d. Plane #4 will be at the same height as the center of the Beetle main viewing window and away from the cab approximately two (2) feet.

   e. Plane #5 will be at the bottom of the lower edge of the main viewing window and away from the cab approximately two (2) feet.

   f. Plane #6 will be under the center of the cab and below the cab approximately one (1) foot.

7. The source will remain at a fixed distance from the cab and the operator will rotate the cab around the source for planes two through five (2 through 5).

   a. The Beetle Operator will obtain radiation measurements at contact with the cab's interior at points opposite the source position outside the cab.

   b. Radiation measurements will be obtained between the eight (8) stationary positions as the cab is rotated past the source to the next position.

   c. Readings obtained will be relayed via radio to personnel plotting radiation intensities.

      1) Plotting personnel will note the source position in relation to the Beetle cab and the radiation measurements obtained on a diagram of the Beetle cab.

8. Upon completion of the Shielding Integrity Test, the source will be returned to its shielding container, and the bay will be monitored for radiation and contamination prior to the Beetle Operator disembarking from the cab.

APPENDIX B

SHIELDING INTEGRITY TEST BEETLE VEHICLE

PHASE #1 (Unmanned)

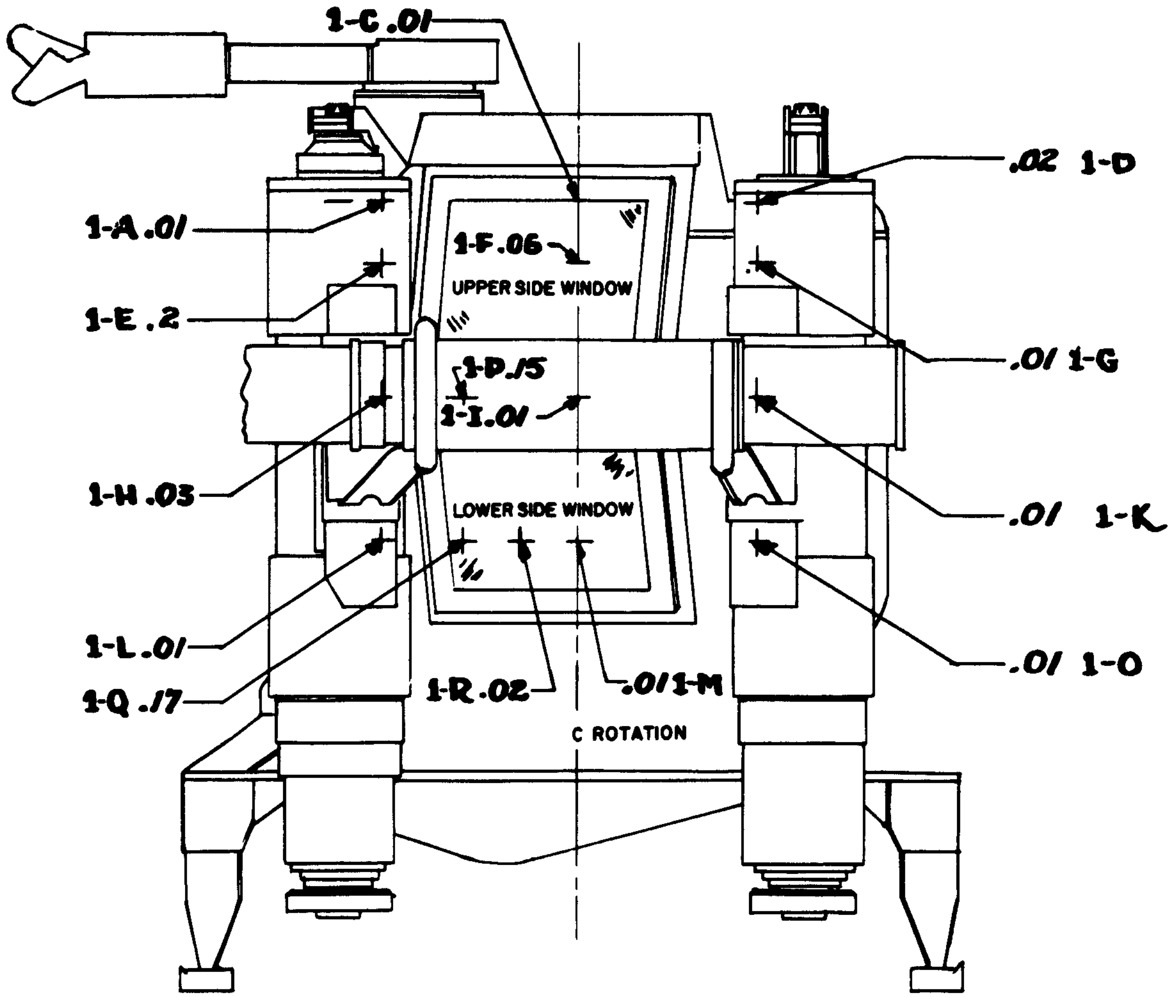
Radiation measurements obtained during Phase #1 were of background intensity. Examination of the detector-recorder strip chart disclosed no intensities above background level within the cab.

PHASE #2 (Manned)

PLANE	Drawing Reference	Radiation Intensity (mr/hr)	Shielding Factor
#1	4-D	0.04	6×10^{-9}
#2	5-B	0.06	6×10^{-8}
	2-B	0.2	2×10^{-7}
	3-V	0.15	2×10^{-8}
	3-W	0.4	6×10^{-8}
	3-B	0.02	3×10^{-9}
	5-C	0.04	4×10^{-8}
#3	5-I	0.04	4×10^{-8}
	5-G	0.02	2×10^{-8}
	5-H	0.5	5×10^{-7}
	3-X	0.02	3×10^{-9}
	5-K	0.06	6×10^{-8}
	5-J	0.2	2×10^{-7}
#4	1-P	0.15	1.5×10^{-7}
	5-O	0.03	3×10^{-8}
	3-Z	0.02	3×10^{-9}
	5-M	0.06	6×10^{-8}
	2-J	0.12	1.2×10^{-7}
	5-N	0.6	6×10^{-7}

PLANE	Drawing Reference	Radiation Intensity (mr/hr)	Shielding Factor
#5	5-S	0.2	2×10^{-7}
	2-N	0.3	3×10^{-7}
	1-R	0.02	2×10^{-8}
	1-Q	0.17	1.7×10^{-7}

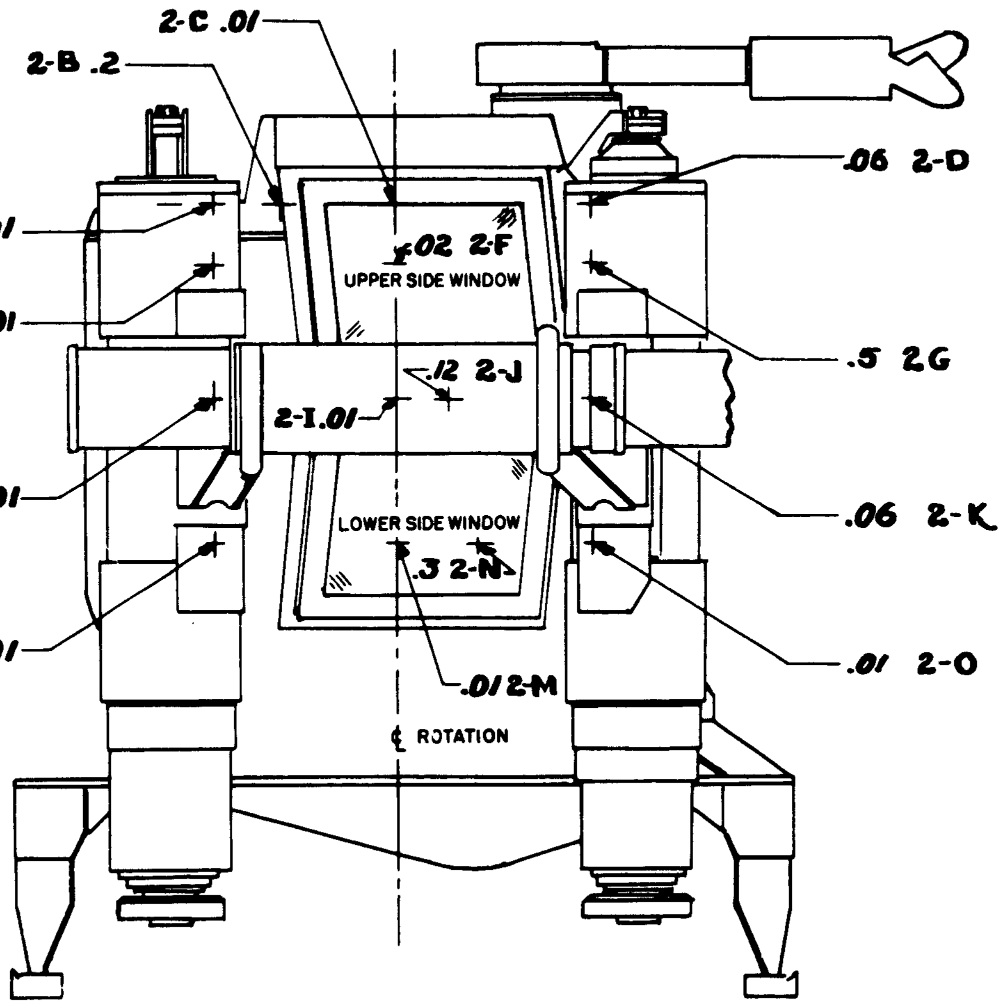
#6	Location of Measurement	Radiation Intensity (mr/hr)	Shielding Factor
	Two ft. from center of cab bottom, left side	0.3	5×10^{-8}
	Two ft. from center of cab bottom, right side	0.3	5×10^{-8}
	Two ft. from center of cab bottom, front	0.2	3×10^{-8}
	Two ft. from center of cab bottom, rear	0.2	3×10^{-8}
	Center of bottom of cab	0.4	6×10^{-8}



LEFT SIDE VIEW

NOTE: SOURCE @ 2"
FROM ALL POSITIONS
ALL READINGS MR/HR

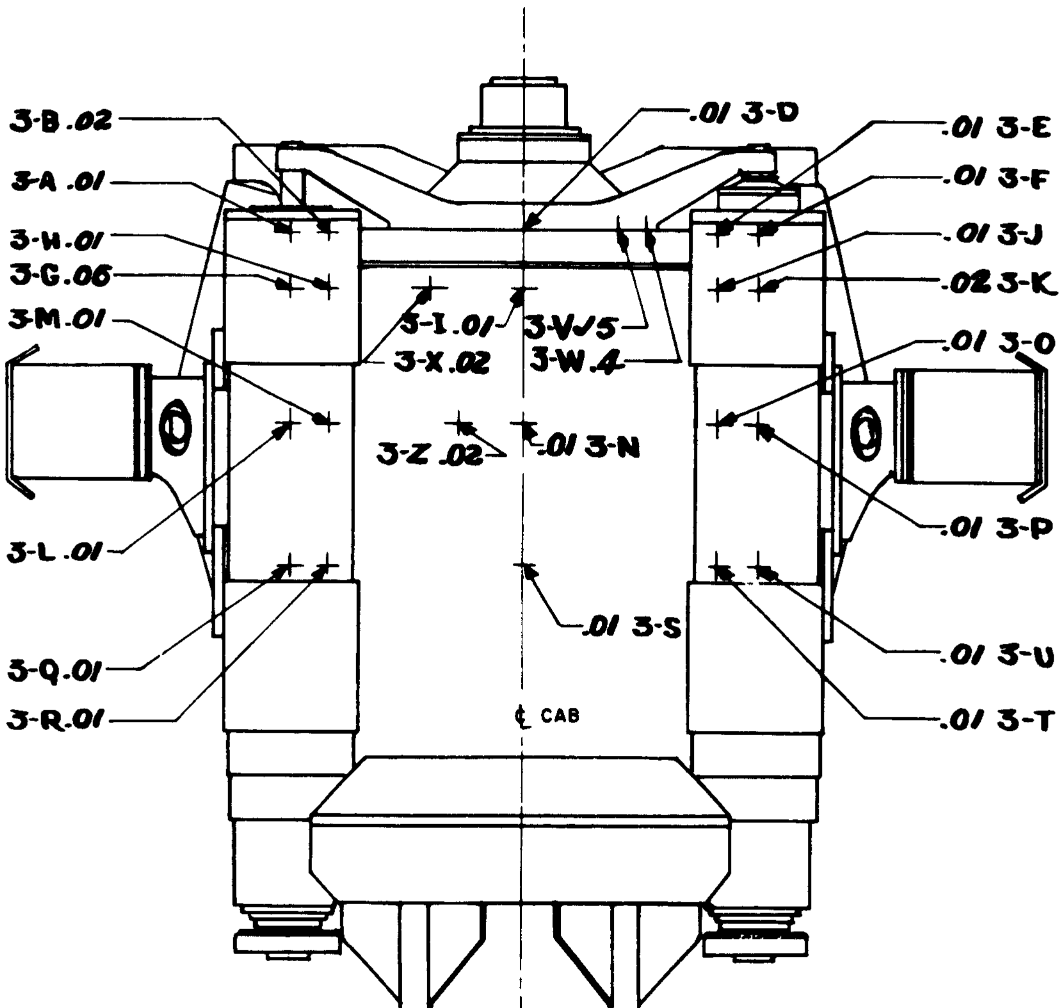
BEETLE	CAB ASSEMBLY	No. 01
DRAWN BY D WILKISON		



RIGHT SIDE VIEW

NOTE: SOURCE @ 2"
FROM ALL POSITIONS
ALL READINGS IN MR/HR

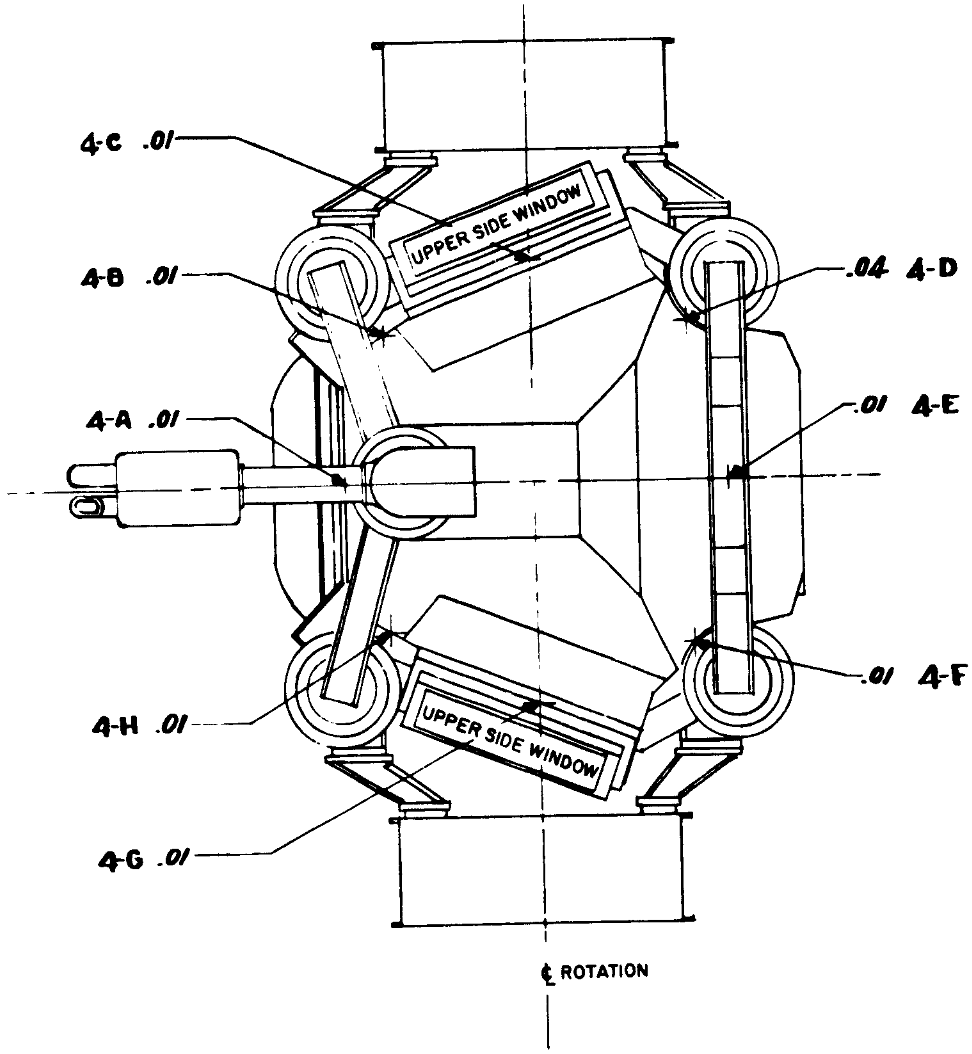
BEETLE	CAB ASSEMBLY	No. 02
DRAWN BY D WILKISON		



REAR VIEW

NOTE SOURCE @ 2"
FROM ALL POSITIONS
ALL READINGS IN MR/HR

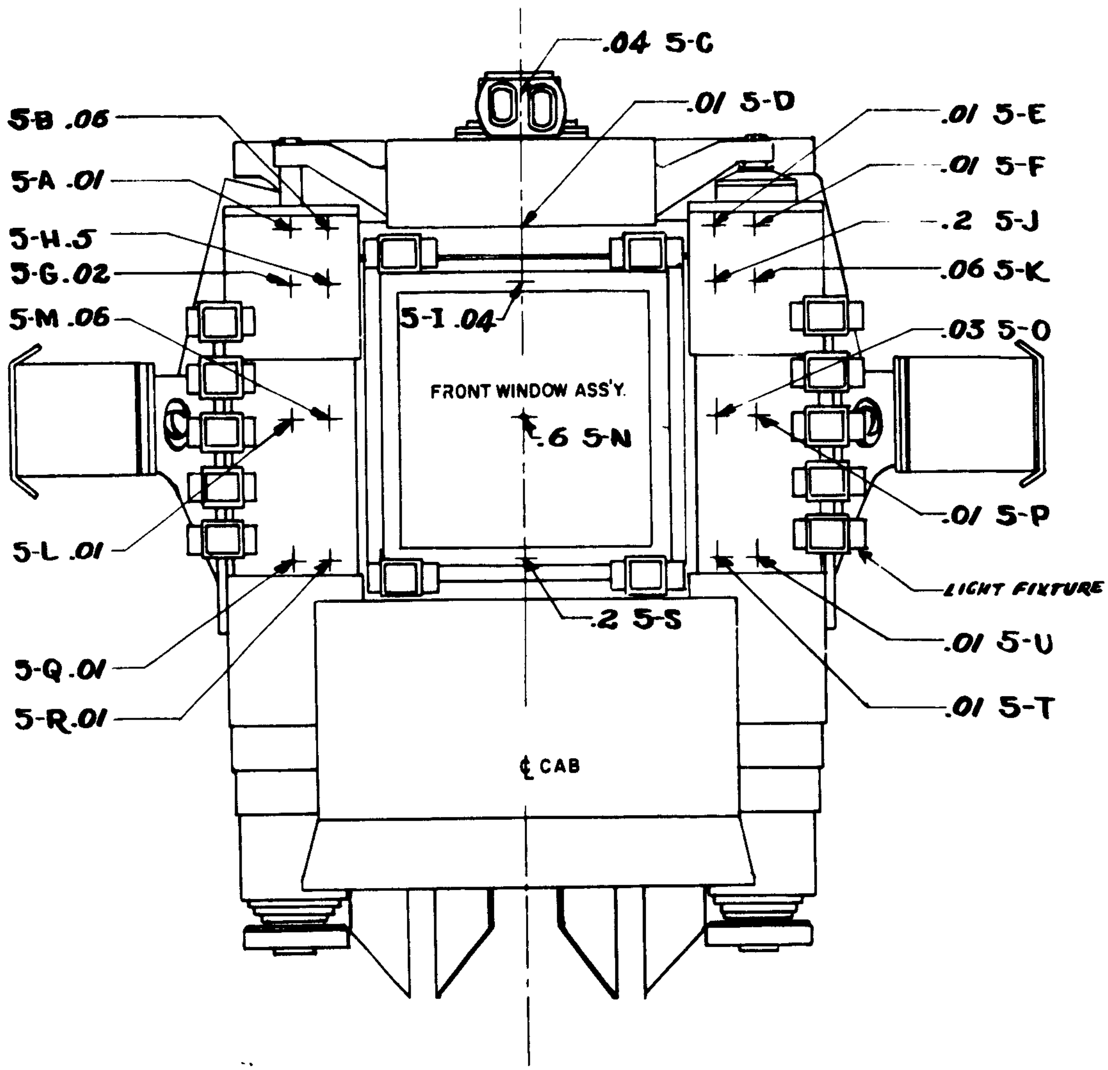
BEETLE	CAB ASSEMBLY	NO. 03
DRAWN BY D WILKISON		



PLAIN VIEW

NOTE: SOURCE WAS 2" ABOVE TOP OF CAB IN EACH POSITION- ALL READINGS IN MR/HR

BEETLE	CAB ASSEMBLY	NO. 04
DRAWN BY D WILKISON		



FRONT VIEW

NOTE: SOURCE @ 2"
FROM ALL POSITIONS
ALL READINGS IN MR/HR

BEETLE	CAB ASSEMBLY	No. 05
DRAWN BY D WILKISON		

APPENDIX VII

CHARACTERISTICS AND POWER REQUIREMENTS OF THE PERISCOPE

General Data

Magnification	Low power	1.5 X
	High power	6.0 X
True field	Low power	32°
	High power	8°
Range of vertical scan	Above horizontal	80°
	Below horizontal	80°
Range of train in azimuth		230° stop to stop
Exit pupil		5 mm
Focusing Range		54" to infinity in both high and low power
Glass		Non-browning in a radiation field
Mirrors		Aluminized first surface mirrors

Power Requirements

115 volts ac	415 watts
24 volts dc	160 watts

APPENDIX VIII

EQUIPMENT TEST REPORT
MODEL 550
MANIP. AND BOOM
RIGHT HAND
JOB 31050

MECHANICAL DIVISION OF
GENERAL MILLS, INC.
NUCLEAR EQUIPMENT DEPT.
419 North 5th St.
MINNEAPOLIS 1, MINN.

JOB NO. 31050

CONTENTS

GENERAL

I. JOB NO. 31050

II. CUSTOMER: General Electric Co.
ANP Department, Bldg. D

III. EQUIPMENT DESCRIPTION:

Mechanical Manipulator and Positioning Boom for Mobile Shielded Cab in accordance with General Electric specification DR-E 1288, 4th Issue, dated 9-11-58, and DR-E 1002 dated 11-12-53. Exceptions to these specifications are covered in Proposal No. 8-4058.

The motions of the Manipulator and Positioning Boom components are shown on General Electric Sketch 295 D 770.

IV. DATE(s) OF TEST: Mar. 21, 1960

V. TEST ENGINEER CERTIFICATION: (S) Oliver R. Rose

(S) Geo. C. Kelly

JOB No. 31050

LOAD TEST ON SLIP CLUTCHES

Motions to be tested	Theoretical load to slip clutch	Theoretical torque wrench setting	Actual torque wrench setting	Actual load req'd to slip clutch
Boom extension	600 lb	600 lb in	800 lb in	800 lbs.
Shoulder rotate	110 lb	22.5 lb in	40 lb in	
Shoulder swing	110 lb	210 lb in	250 lb in	200 lbs.
Upper arm extension	600 lb	16 lb in	17 lb in	950 lbs.
Upper arm rotate	100 lb			125 lbs.
*Elbow bend	100 lb			200 lbs.
*Wrist bend	100 lb			120 lbs.

Wrist rotate -- adjust clutch so wrist exerts a maximum
Check 990 in.-lbs. torque of 600 lb. in. before slipping

Hand grip -- adjust clutch so hand exerts a maximum grip
Check 300 lbs. force of 200 lbs. before slipping

Hook grip -- hook should exert a maximum grip force of
Check 850 lbs. 750 lbs. before slipping

* Set clutch at ass'm. to slip at load given
(These motions, having the clutch between the drive motor and an irreversible speed reducer, require no preadjustment)

COMMENT: These readings were taken at approximately room temperature.

JOB NO. 31050

MANIPULATOR MOTIONS TEST

Motions to be extended	Load at hand	Direction of motion	Speed Min Max	Range Specified	Range Actual
Boom extension	100 lb	Extend and retract	120"/min	42"	42.25
Shoulder rotate	100 lb	CW & CCW	1 rpm	Continuous	Continuous
Shoulder swing	100 lb	Left & right -- up & down	1 rpm	180°	180°
Upper arm extension	100 lb	Extend and retract	120"/min	18"	18"
Upper arm rotate	100 lb	CW & CCW	2 rpm	Continuous	Continuous
Elbow bend	100 lb	Left & right up & down	1½ rpm	240°	223°
Wrist rotate	100 lb	CW & CCW	8 rpm	Continuous	Continuous
Wrist bend	100 lb	Left & right up & down	2 rpm	240°	245°
Hand		Open & close	20"/min	0-5"	0-5"
Hook		Open & close	8"/min	0-2½"	0-2½"

NOTE: All rotate test are made with pivot elements turned 90° to axis of rotation.

COMMENT: From a pre-design study it appeared that the elbow bend range could easily be increased from 180° (the original request range) to 240°. However, this was not the case and 220° proved to be the maximum range attainable.

JOB NO. 31050

ELEMENT TESTED: Boom Extension

			Direction OUT					Direction IN				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No axial	Spd	in/min	144					150				
Load	Iadc	amperes	0.5					0.5				
160 lb. vertical	Vadc	volts	235					250				
Load in hook	Vfdc	volts	225					225				
Load	Spd	in/min						125				
625 lb. axial	Iadc	amperes						2				
Load	Vadc	volts						225				
	Vadc	volts						225				

Limit Switch Check FORWARD OK REVERSE OK

Comments:

JOB NO. 31050

ELEMENT TESTED: Shoulder Rotate

			Direction UP					Direction DOWN				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Spd											
Load	Iadc											
	Vadc											
	Vfdc											
Load	Spd	R. P. M.	1.14					2.08				
100 lbs	Iadc	Amperes	8					0.2				
	Vadc	Volts	200					200				
	Vfdc	Volts	225					200				

Limit Switch Check FORWARD__________ REVERSE__________

Comments:

JOB NO. 31050

ELEMENT TESTED: Shoulder swing

Min Speed		Units	Direction UP 1	2	3	4	5	Direction DOWN 1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Sped											
Load	Iadc											
	Vadc											
	Vfdc											
Load	Spd	R. P. M.	1.39					1.79				
100 lbs	Iadc	Amperes	4					0.2				
	Vadc	Volts	225					375				
	Vfdc	Volts	225					225				

Limit Switch Check FORWARD OK REVERSE OK

Comments:

JOB NO. 31050

ELEMENT TESTED: Upper arm extension

		Units	Direction UP 1	2	3	4	5	Direction DOWN 1	2	3	4	5
Min Speed												
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Sped											
Load	Iadc											
	Vadc											
	Vfdc											
Load	Spd	in/min	124					200				
100 lbs	Iadc	Amperes	2.1					0				
	Vadc	Volts	110					165				
	Vfdc	Volts	110					110				

Limit Switch Check FORWARD none REVERSE none

Comments:

JOB NO. 31050

ELEMENT TESTED: Upper arm rotate

			Direction UP					Direction DOWN				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Spd											
Load	Iadc											
	Vadc											
	Vfdc											
Load	Spd	R. P. M.	1.72					2.08				
100 lbs	Iadc	Amperes	2					0.2				
	Vadc	Volts	120					155				
	Vfdc	Volts	110					110				

Limit Switch Check FORWARD none REVERSE none

Comments:

JOB NO. 31050

ELEMENT TESTED: Elbow bend

			UP 1	UP 2	UP 3	UP 4	UP 5	DOWN 1	DOWN 2	DOWN 3	DOWN 4	DOWN 5
Min Speed		Units										
No Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No Load	Spd											
	Iadc											
	Vadc											
	Vfdc											
Load 100 lbs	Spd	R. P. M	1.79					2.5				
	Iadc	Amperes	2.5					0.2				
	Vadc	Volts	110					155				
	Vfdc	Volts	110					110				

Limit Switch Check FORWARD none REVERSE none

Comments:

JOB NO. 31050

ELEMENT TESTED: Wrist rotate

			Direction UP					Direction DOWN				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Spd											
Load	Iadc											
	Vadc											
	Vfdc											
			C. W.	C. C. W.				C. C. W	C. W.			
Load	Spd	R. P. M.	8. 33	8. 33				over-hauls	over-hauls			
600 in. -lbs.	Iadc	Amperes	0. 75	0. 8				0	0			
Torque	Vadc	Volts	95	93				380	300			
	Vfdc	Volts	110	110				110	110			

Limit Switch Check FORWARD none REVERSE none

Comments: Clutch slips with stalled load at 1. 0 amperes

JOB NO. 31050

ELEMENT TESTED: Wrist bend

			Direction UP					Direction DOWN				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Loac	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Spd											
Load	Iadc											
	Vadc											
	Vfdc											
Load	Spd	R. P. M.	1.67					2				
100 lbs	Iadc	Amperes	1.9					0.4				
	Vadc	Volts	115					135				
	Vfdc	Volts	110					110				

Limit Switch Check FORWARD none REVERSE none

Comments:

JOB NO. 31050

ELEMENT TESTED: Hand

			Direction OPEN					Direction CLOSE				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Spd	in./min.	45.5					47.7				
Load	Iadc	Amperes	0.105					0.11				
	Vadc	Volts	100					100				
	Vfdc	Volts	110					110				
Load	Spd											
	Iadc											
	Vadc											
	Vfdc											

Limit Switch Check FORWARD none REVERSE none

Comments: Clutch slips at 350 lbs. and 1.0 amperes.

JOB NO. 31050

ELEMENT TESTED: Hook

			Direction OPEN					Direction CLOSE				
Min Speed		Units	1	2	3	4	5	1	2	3	4	5
No	Spd											
Load	Iadc											
	Vadc											
	Vadc											
Load	Spd											
	Iadc											
	Vadc											
	Vadc											
Max Speed												
No	Spd	in./min.	9.9					10.4				
Load	Iadc	Amperes	0.21					.22				
	Vadc	Volts	95					90				
	Vfdc	Volts	110					110				
Load	Spd											
	Iadc											
	Vadc											
	Vfdc											

Limit Switch Check FORWARD none REVERSE none

Comments:

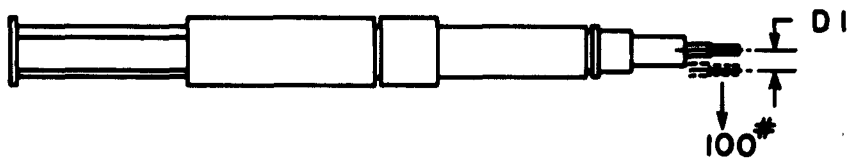
JOB NO. 31050

DEFLECTION TEST

Position 1 - - - Boom and upper arm fully retracted

D1 25/32 in.

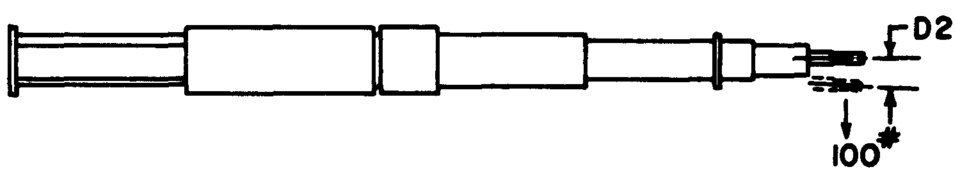
* D1 1/4 in.



Position 2 - - - Boom fully retracted, arm fully extended

D2 3/4 in.

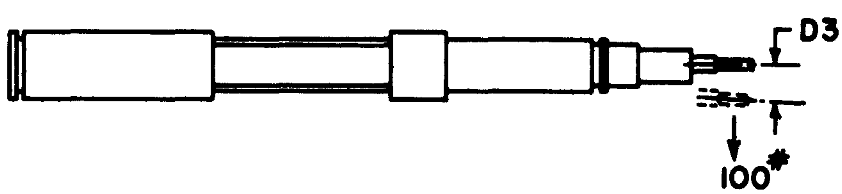
* D2 5/16 in.



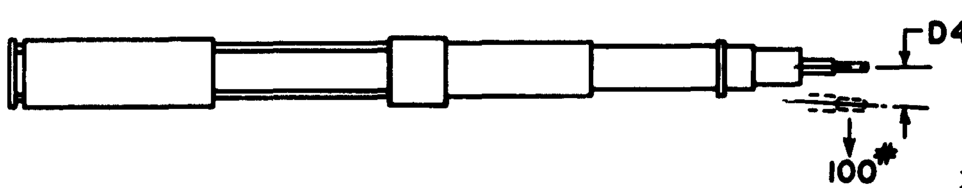
Position 3 - - - Boom fully extended, arm fully retracted

D3 3/4 in.

* D3 5/16 in.



Position 4 - - - Boom and Arm fully extended



D4 7/8 in.

* D4 1/4 in.

NOTE: POSITIONS 1 to 4 are with pivot elements parallel to axis of boom.

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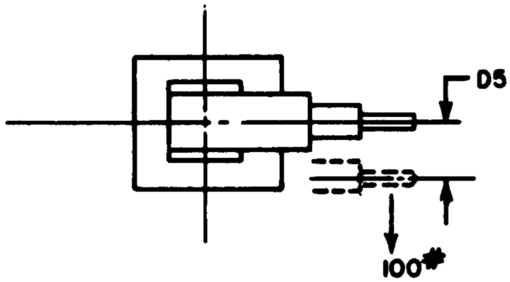
*Shoulder swing axis, elbow bend axis, and wrist bend axis are all in a vertical position.

POSITION 5

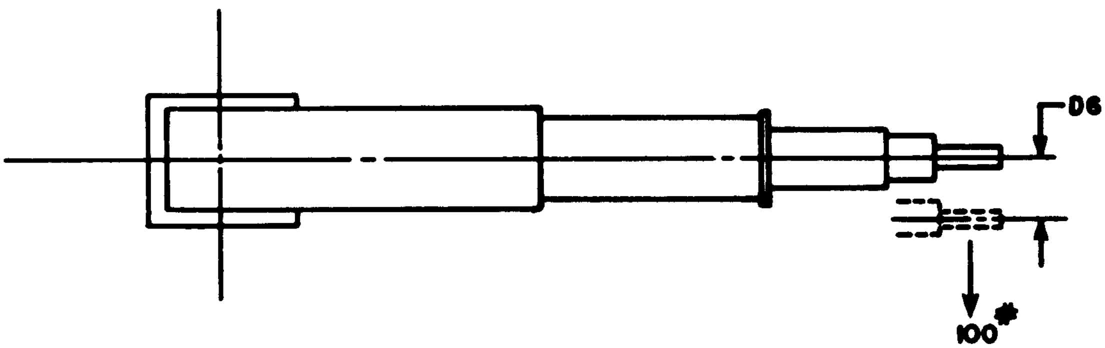
Boom and upper arm fully extended with elbow pivoted 90° to axis of boom



D5	3/8 in.
* D5	5/16 in.

POSITION 6

Boom and upper arm fully extended with shoulder pivoted 90° to axis of boom



D6	2 in.
* D6	1-1/2 in.

POSITION 7

Boom and upper arm fully extended with shoulder, elbow, & wrist each pivoted 90° from their neutral axis

D7	3/8 in.

* Shoulder swing axis, elbow bend axis, wrist bend axis are in a vertical position.

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TEST ON INDICATORS

HAND GRIP	Force - lbs	Scale Reading - ma		
0 - 200 lb	200	Coarse	0.5	*
	100	"	0.45	
	50	"	0.4	
	25	"	0.25	
	12.5	"	0.15	
	8	Fine	0.5	
	6	"	0.25	

WRIST TORQUE	Torque - lb - ft	Scale Reading - Amps	
0 - 50 lb-ft	50	0.8	
			**
	0	0	

COMMENTS:

* These readings were taken with 3400 ohms resistance, RG on drawing 225743C

** These readings were read on 3-0-3 ampere scale. The wrist torque meter should be changed to 1-0-1 ampere scale.

JOB NO. 31050

MISCELLANEOUS TESTS AND CHECKS

ENVIRONMENTAL TEST OF VARIOUS ARM MOTIONS AT -30° F
COMMENTS:

All of the motions were capable of immediate full speed operation with the exception of the wrist bend motion which required a one to two minute warm up period consisting of cycling at a creep or minimum speed.

CHECK TOOL POWER PLUG RECEPTACLE.
COMMENTS:

Functioned OK

CHECK "NO CREEP" SPECIFICATION FOR ALL MOTIONS.
COMMENTS:

No creeping

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COMMENTS

MECHANICAL:

Gear backlash in the shoulder swing joint, elbow bend joint, and wrist bend joint, resulted in the following "free" movement as measured at the finger tips.

Wrist bend joint - - - - -	11/16 in.
Elbow bend joint - - - -	9/16 in.
Shoulder swing joint - - -	2-1/8 in.
TOTAL	3.375 in.

Final test data was taken on maximum load and maximum speed specifications only. A check of the minimum and no load speeds showed them to be the same as that of the left hand manipulator, and therefore it was decided that a repetition of the left hand readings was not necessary.

COMMENTS

ELECTRICAL:

Test Line voltage was 202 volts single phase.

APPENDIX IX

HUMAN ENGINEERING EVALUATION OF SHIELDED-CAB, REMOTE-HANDLING VEHICLE

INTRODUCTION

This report documents a human engineering evaluation conducted on "The Beetle," shielded-cab, remote-handling vehicle, at the Nevada Test Site during the period 18-21 June 1962. Project engineers responsible for this evaluation were Mr. Billy M. Crawford and Lt. D. F. Baker, Maintenance Design Section, Human Engineering Branch, Hq 6570th Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The evaluation was conducted in support of the Advanced Equipment Section, Mechanical Equipment Branch, Support Equipment Division, Development Directorate, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico.

This report is concerned with the extent to which design features of the "Beetle," shielded-cab, remote-handling vehicle, facilitate the efficient utilization of man as a system component. Attention is directed to man's participation in the system as both operator and maintenance man. The primary objective is to provide human engineering information and recommendations with respect to (1) deficiencies identified in the Beetle, (2) possible modification of the Beetle, and (3) design of future equipment for similar purposes.

PROCEDURE

The schedule originally proposed for this investigation and evaluation included the following steps to be accomplished by the human engineering team:

1. Familiarization with operator's role in the system.

2. Observation of the system in operation.

3. Observation of maintenance personnel performing representative maintenance on the vehicle itself.

4. Interviews with project engineers, operator and maintenance personnel.

5. Determination of probable maintenance concept for the system.

6. Limited design modifications for "quick and dirty" evaluation.

7. Evaluation of system design from viewpoint of capabilities and limitations of man and machine.

8. Documentation of findings and recommendations.

However, the complete sequence of steps was not rigorously adhered to. Attenuating circumstances which influenced the decision of the human engineering team to deviate from the original plan involved these considerations:

1. The Beetle was already scheduled for use as back-up support for a nuclear test the following week.

2. Cab air-conditioning and radiation monitoring systems were inoperative. Malfunctioning components had been returned to the manufacturer for repair.

3. The Beetle, although designed for use by the Air Force in its Aircraft Nuclear Propulsion Project, was being released to the Atomic Energy Commission for use in the joint AEC-NASA nuclear rocket program. Therefore, its capabilities and potential role at the Nevada Test Site and the reliability of its subsystems in the desert environment were uncertain.

4. Maintenance personnel assigned to the Beetle had participated in extensive assembly, modification, and "de-bugging" of the vehicle prior to its official acceptance by the Air Force. The vehicle was partially disassembled for shipment to the Nevada Test Site and, upon arrival, re-assembled by the same crew. Additional repair and modification was required as a result of damage to the Beetle incurred during an abortive test of the vehicle at the test site. Moreover, as indicated above, further maintenance was necessary on the malfunctioning air-conditioning and radiation monitoring systems.

Therefore, in the conduct of the human engineering evaluation, activities which might contribute to further complications affecting the maintenance work load and the availability of the remote-handling vehicle were avoided as much as possible. Thus, arrangements for simulation of representative maintenance tasks on the Beetle and modification of equipment to evaluate alternative design features were not considered. Similarly, direct participation in control functions by human engineering team members was restricted to a limited use of the remote manipulator controls.

Opportunities to observe the system in action under the control of a trained operator were also limited. There were brief practice sessions involving the use of the remote manipulators to remove nuts from bolts in a flanged cask cover by means of an impact wrench, a task anticipated in support of the nuclear test scheduled the following week. On another occasion the Beetle was used to tow a modified tank retriever which was being reconditioned for use in the support of nuclear tests. Otherwise, the investigation consisted of interviews with personnel closely associated with the Beetle, study of the instruction manual for vehicle operation and service, and inspection of the vehicle by the human engineering team.

Human engineering recommendations included in this report are based on criteria established by Military Standard 803 (USAF), "Human Engineering Criteria for Aircraft, Missile, and Space Systems Ground Support Equipment (ref. 4). The evaluation is by no means exhaustive and in some instances the recommendations are necessarily tentative. However, it should, at least, suggest the importance of human engineering support during the design and development of support equipment such as this.

Perhaps a word of caution is in order concerning the drawings which are included in this evaluation. Their purpose is to provide a general idea of the effect which changes recommended in this report would have upon the appearance of control panels. They are not intended for use as the sole guide for modifying equipment design. Neither do they in every instance comply with recommendations included in the text of this report. Effective redesign of present equipment or design of new equipment to comply with human engineering standards requires a cooperative effort on the part of design engineers and human factors specialists.

Figure 3 serves to illustrate certain human engineering changes in control and display arrangement which might be incorporated into the current control system using the same controls and displays. Although they are not shown, similar changes would be necessary for control panels JB-1 and JB-10. Figures 4, 5 and 6 show, generally, the effect which major redesign of control panels to comply with human engineering specifications would have upon the system. Figures 7-9 and 10-12 are merely expanded views of panel sections taken from figures 3 and 4 respectively.

RESULTS

CONTROLS

Human engineering considerations related to the design of controls are discussed under three main subheadings: Type and Movement, Coding, and Arrangement.

A. Type and Movement

Criticisms and recommendations referred to in this section are primarily related to the following human engineering principles:

1. When a control or an array of controls is needed for momentary contact or for activating a locking circuit in a high frequency of use situation, push buttons shall be used. The button surface should be concave to fit the finger. When this is impractical, the surface should provide a high degree of frictional resistance to prevent slipping.

2. Toggle switches shall be used for those control functions which require two discrete positions and when space limitations are severe.

3. Rotary selector switches should be used for discrete functions when three or more positions are required. They will normally not be used for a two position function unless ready visual identification of switch position is of primary importance and speed of control operation is not an important requisite.

4. Levers should be used when multi-dimensional movement of the control is required.

5. Control movements should be compatible with those of the controlled display or equipment component.

6. Combined controls, rather than individual controls, should be used for the purposes of: (a) reducing reach movements, (b) aiding sequential or simultaneous movements, and (c) economizing on use of control panel space (ref. 2).

Push-Buttons. The indiscriminate use of approximately 125 push-buttons for the great variety of control functions involved in the operation of the Beetle and its subsystems plus an additional 12-15 indicators, identical to the controls except for function, suggests a lack of consideration for human engineering design principles. The closely spaced buttons are difficult to identify and thus operating time and the likelihood of inadvertent control activation are increased. Of course, positive identification of control status depends upon visual inspection of the indicator light when push-buttons are used whereas toggle switch status can be identified tactually.

These difficulties may be eliminated or reduced, at least, by: (1) using toggle switches or levers when appropriate and, thereby, restricting the use of push-buttons to high frequency of use or "momentary on" situations, and (2) providing adequate space between controls. Beetle control functions for which push-buttons appear to be appropriate are listed below:

Transmission

Pivot Steer, right and left

Park and Service Brakes

Hatch Stop

Emergency Hatch Up

Panel Light Test (Not included in present design)

Prime, Auxiliary and Main Engines

Start, Auxiliary and Main Engines

Magneto Boost, Main Engine

Fire Extinguisher for Pod and Chassis

Gear Box Heater

Heater, Auxiliary Engine

Toggle Switches. Toggle switches are appropriate for a larger number of Beetle control functions which require two discrete control positions and which are not frequently used during the course of vehicle operation. The use of toggle switches, uniformly oriented (preferably in the vertical position with "on" up and "off" down), facilitates identification of control status by tactual as well as visual inspection and conserves panel space. Specific functions for which toggle switches are recommended follow:

Defrosters, Periscope and Windows

Periscope Power

Windshield Wipers

P.A. System

Driving Lights

Panel Lights

Radiation Recorders

Fuel Pump Booster, Main Engine

Magneto Accessory, Main Engine

Magneto Flywheel, Main Engine

Fuel Flow, Auxiliary Engine

Magneto, Auxiliary Engine

AC Power

Emergency AC Power (currently labeled "Dynamotor")

Rotary Selectors. Rotary selectors are recommended for the following control functions which require more than two discrete settings:

Periscope ("off," "top head," "bottom head")

Spotlights ("off," "right," and "left")

Floodlights ("off," "front," "rear")

Air Conditioning ("off," "cool," "heat")

Voltage Regulator ("on," "off," "manual," "auto")

Although the drawings included in this report to illustrate suggested changes show 3-position toggle switches for controlling power to the front and rear floodlights, right and left spotlights, and top and bottom periscope heads; rotary selector switches are preferable from the human engineering viewpoint. Three-position toggles can present difficulties with respect to status identification especially when included in an array of 2-position toggle switches. At the time the drawings were made conservation of space was a prime consideration and rotary switches do require more panel space.

Levers. The characteristics of several Beetle subsystems and associated control functions are such that the use of control levers with multidimensional movement capabilities would be especially advantageous in that it would (1) reduce the number of separate controls, (2) conserve panel space, and (3) provide advantages inherent in compatibility between control movement and the response effected in equipment components. The fact that the Beetle operator may often be required to use two or more relatively complex devices simultaneously during the accomplishment of a remote operation emphasizes the importance of integrating several control functions into an easily identified single control with compatible relationships between control action and the effected response. Subsystems for which this type of control (perhaps toggle-type levers spring-loaded to center) is appropriate are listed below. The proposed changes would reduce the total number of separate controls for these subsystems from 29 to 10.

Spotlights - Tilt up and down, rotate left and right

Cab - Raise and lower, rotate left and right

Hatch - Up and down (open-close)

Creep-drive - Forward and reverse (each track)

Steering - Left and right

RPM, Main Engine - Increase - Decrease

RPM, Auxiliary Engine - Increase - Decrease

Periscope Vertical and Horizontal Scan

Periscope Focus

Perhaps consideration should be given to a joystick control for steering a vehicle like the Beetle. The operator indicated that his fingers were often very busy pushing buttons when putting the vehicle through its paces. Displacement of a stick to left or right is a highly compatible control motion for vehicle steering. Pivot steer could be controlled through stick rotation or twisting with a lock-out device to prevent inadvertent pivoting. Control of main engine rpm might be linked to fore and aft movements of the stick.

Although the remote manipulators are presently controlled by means of levers, the integration of multiple functions into single controls is not used to full advantage. Only reciprocal actions, e.g., clockwise vs. counterclockwise, up vs. down, etc. are incorporated in single control devices. It is suggested that consideration be given to the integration of control functions into one control lever for each logical segment of the arm. For example, manipulator design is such that it appears feasible to divide its control functions into 3 or 4 groups with one rate-control type lever for each group. One lever might control wrist bend and wrist rotation. Jaw-opening and closing by means of a trigger or push-buttons might be included in the same device. A second lever could be used to control both elbow bend and upper-arm rotation. Shoulder bend or swing, upper-arm extension and retraction, and shoulder rotation would be relegated to a third lever. The boom extension control could be retained as is. Thus, the number of separate controls for manipulator movements would be reduced from nine to four for each manipulator arm. A compatible relationship between control movements and corresponding manipulator responses can be readily achieved (See figure 1). This should reduce the probability of directional errors in the operation of these controls. When this is combined with coding of controls for tactual discrimination as recommended in the following section, improved remote task performance and reduced training time should result.

B. Coding

As suggested in the previous discussion, provisions to facilitate identification of controls is rather critical to efficient operation of the Beetle. Good control coding will reduce the amount of time and number of errors involved in locating the correct control. Common methods for control coding are shape, size, location, mode-of-operation, color and labeling. The Beetle controls are presently identifiable by means of labeling and location, although the operator cannot rely too much upon the latter as a cue when going from one control panel to another. Location of controls will be discussed in detail under the section on control arrangement. Of course, provision for coding by mode-of-operation is inherent in the use of different types of controls, i.e., toggle-switches, push-buttons, etc., as recommended above. Therefore, other coding techniques, especially shape-coding, will be emphasized here. This is in keeping with the following human engineering principles:

1. Select controls which are easily identified.
2. Controls should be identifiable both by sight and touch.
3. If blind operation is a requirement, the shapes selected will be tactually discriminable.

An important benefit can be realized from shape-coding of the remote manipulator controls to resemble the manipulator sections which they control as illustrated in figure 1. The capacity of the manipulator arms to rotate continuously creates an additional problem for the operator. This problem is related to the determination of appropriate control movement for wrist bend, elbow bend, and shoulder swing since the relationships can be reversed by a 180° rotation at any one of three arm segments. This problem might be alleviated by coding corresponding sides of the controls and manipulator arms. Knurling portions of controls, which would be tactually discriminable, might be used in conjunction with cross-hatching of corresponding manipulator arm portions for visual discrimination. The manner in which controls might be coded for this purpose is also illustrated by figure 1.

C. Arrangement

The discussion and recommendations which follow are based primarily on the following human engineering principles:

1. All controls having sequential relations or having to do with a particular function or operation, or which are operated together, shall be grouped together, along with the associated displays.

2. Arrangement of functionally similar or identical primary controls shall be consistent from panel to panel.

Factors which influence the location and arrangement of controls include frequency and sequence of use, importance, and function. The most critical controls should be placed so as to be readily accessible. However, trade-offs between importance and frequency of use are often necessary. The determination of the importance of controls must be made by some one closely familiar with the design and operation of the system. Except for controls used to start-up and shut-down the engines, for which the procedures are relatively standard and, hence, involve the use of certain controls in the same order each time, adequate knowledge with respect to sequential relationships between controls and the frequency with which they occur can be obtained only by link analysis. Circumstances did not permit the use of this technique for Beetle control arrangement evaluation; however, information obtained from the instruction manual and vehicle operator suggests that the present control arrangement is not optimum.

When feasible it is desirable to arrange controls which are to be operated or checked sequentially so that the operator moves across the control panel from left to right and/or from top to bottom. Beetle design violates this principle especially with respect to pre-operation checks and control settings. Either the procedure or the control arrangement, or both, should be modified.

The efficiency with which the Beetle is operated also will be detrimentally affected by differences between the arrangement of control groups inside the cab and identical controls in the remote control boxes outside. These control panels should be redesigned for greater similarity between panels which have identical functions to facilitate positive transfer of training.

A third type of criticism related to control arrangement concerns the location of controls and related displays so that they are readily associated. The rpm controls should be located adjacent to the rpm indicators and oriented such that the direction of motion of the indicator needles corresponds to the control motions.

Another recommendation with regard to controls involves the periscope controls which are on the right control panel and obscured from view when the operator is using the periscope eye-piece (which is designed to accommodate the right eye). It is suggested that these controls be redesigned as follows and located on the periscope itself. Controls for vertical and horizontal (rotation) scan should be incorporated into a single lever with multidimensional movement capability. Then this control could be attached on the side of the periscope opposite the eye-piece. Similarly, the bottom of the periscope could be equipped with a lever for controlling focus (near and far) with rate proportional to control displacement. Thus, 7 more push-buttons could be removed from the crowded front panel and placed in a more convenient and accessible location (See figure 2).

The periscope controls which remain on the panel could be moved from the right to the left and redesigned in this manner: The power supply, top head and bottom head controls might be incorporated into a rotary selector or, perhaps, to further conserve space, a 3-position toggle switch with center "off," up "top head" and down "bottom head." A 2-position toggle switch should be substituted for the two buttons which control high power and low power. Similarly, a 2-position toggle switch is probably preferable to the push button for control of the periscope defroster.

Finally, it appears that arrangement of television system controls also might be improved upon considerably. Controls for switching from one to the other of the three cameras are difficult to reach or see since they are located under the front window panel. Picture adjustment controls are on the lower center front panel and the television power switch is on the left front. Although all power switches are sometimes grouped together to facilitate sequential steps in pre-operation procedures, in this instance adherence to the principle of grouping controls for a particular subsystem together appears appropriate. The same recommendation applies to communication system controls which are scattered about the cab as follows: front of left side panel, left front panel, left rear corner of cab, and right front floor (foot-switch).

INFORMATION DISPLAYS

The information upon which the Beetle operator must rely for accomplishment of his purposes is primarily visual and auditory in nature. In addition to the radiation monitor signals and communications, which are apparently adequate (although inoperative at the time of the evaluation) the operator can also monitor noise from the main engine and pod compartments. Consideration should also be given to a sound system for auditory monitoring of remote handling tasks which has proven quite valuable in hot cell operations. This provision also might be used to monitor all external sounds of possible interest in the immediate area of the vehicle.

Time did not permit an objective evaluation of the visual feedback systems. The windows are assumed to be adequate for general viewing requirements. As presently designed, cab space will not accommodate more than one television monitor. However, a single television monitor displaying a two-dimensional picture falls short of visual feedback requirements for efficient accomplishment of most remote handling tasks. Under these circumstances, consideration might be given to advantages afforded by a stereo-television system.

Indicators. A large number of push-buttons in the Beetle control panels include indicator lights of various colors, especially red. In many instances, these provisions violate one or more of the following human engineering principles:

1. Transilluminated indicators will be used primarily to display qualitative information which requires either an immediate reaction on the part of the operator, or which calls his attention to an important system status.

2. Lights shall not be used solely to indicate switch or control position unless the switch position is not, or cannot be made, apparent by proper design and labeling of the control. Lights should be used to display equipment response and not merely switch position.

3. If it is necessary to have many lights on a control panel, a master light test control should be incorporated. If this is not feasible, each indicator shall be designed for "press-to-test" bulb testing. Even more desirable are devices that test the operation of the total indicator circuit.

4. Lights used to denote emergency conditions (personnel or equipment disaster), and only those indicating such conditions, will be coded in flashing red.

5. Use lights and all other indicators sparingly. Be sure that the indicator displays information necessary to effective system operation. (The more lights the less the conspicuity of any single light.)

6. Red shall be used to alert an operator that the system or any portion of the system is <u>inoperative</u> and that a successful mission is not possible until appropriate corrective or override action is taken. Examples of lights which should be coded red are those which display such information as: no-go, error, failure, malfunction, etc.

7. Amber shall be used to advise an operator that a condition exists which is <u>marginal</u> insofar as system effectiveness is concerned, that an unsatisfactory or hazardous condition is being approached or exists but that the system can still operate (battery approaching replacement time, etc.).

8. Green shall be used to indicate that a unit or component is <u>in tolerance</u> or a condition is <u>satisfactory</u> and that it is all right to <u>proceed</u> (go ahead, in tolerance, ready, acceptance, normal, etc.).

9. White shall be used to indicate those system conditions that are not intended to provide a right or wrong implication, such as indications of alternative functions (air burst-ground burst, missile No. 1 selected for launch, etc.), or are indicative of transitory conditions (i.e., action or test in progress), where such indication does not imply success of operations.

It would be desirable to modify the indicator lights presently used in the Beetle so that they are in conformity with the above standards.

GENERAL

<u>Accessibility</u>. Human engineering principles applicable to recommendations which follow are:

1. Construct all emergency doors and exits so that they are readily accessible, unobstructed and quick opening. Design so the door or hatch can be opened by a single motion of hand or foot.

2. Provide handrails on platforms, stairs, and around floor openings or wherever personnel may fall from elevation.

3. Provide skid proof flooring and stair or step treads.

The outside control box, JB-1, which contains controls for the hatch and auxiliary engine is located on the left side of the cab about 10 feet from the ground. Access to these controls and the hatch opening itself requires that the operator either use a step ladder or scale the side of the vehicle haphazardly since no steps or handholds are provided. The JB-1 panel should be relocated somewhere on the frame of the vehicle so that it will be no higher than 5 feet from the ground at any time. Provision for steps and handholds on the cab for use by the operator when ascending to the cab is also in order. This would prevent damage to exposed vehicle components and facilitate emergency escape. Strategically placed handholds and steps should also be provided to aid the operator in entering and egressing from the rather close confines of the cab.

Since the front of the seat is so close to the television monitor and lower front control panel, the operator cannot get his feet and legs into position without considerable difficulty. This problem could be alleviated by designing the seat so that it folds up when not in use.

Safety. The 30 minutes of hand-pumping required to open the hatch in the event of complete power failure reportedly involves the manual application of forces in the range of 30-45 foot-pounds. Cab and hatch design changes to eliminate or lessen the severity of this requirement is highly desirable to say the least. A hatch opening design taking advantage of the force of gravity, rather than opposing it, should be considered for future vehicles of this type.

Other safety provisions not presently included in this system include:

1. Portable fire extinguisher inside the cab
2. Seat Belt
3. Warning device to indicate loss of hydraulic pressure
4. Fuel indicator inside cab

In keeping with paragraph 13.3 of MIL STD 803, appropriate safeguards against the hazard involved in cleaning the windows should be provided. A label beneath each window indicating that direct contact with the window and the ground is to be avoided when cleaning windows may be sufficient.

Comfort. The vehicle operator could not verbalize any specific source of discomfort in terms of cab design features. However, the crowded conditions in the area of the feet and legs are bound to be a source of discomfort during extended periods of operation. For that matter, extended operations are apt to be generally unpleasant for the operator isolated in the necessarily confining conditions of the entire enclosure.

Use of Color. The interior of the cab is almost entirely black. It is recommended that equipment color specifications of Military Standard 803 (ref. 4) be adhered to if possible. However, it should be noted that the revised version of MIL STD 803, which will be adopted in the near future, will specify semi-gloss rather than lusterless paints because of difficulties related to cleaning surface areas.

MAINTAINABILITY

Information concerning the design of the Beetle system for ease of maintenance was obtained from the operator and maintenance crew. The general conclusion is that maintainability could not have been a major consideration in the design of the vehicle. Extreme difficulties had been encountered by maintenance personnel in trouble-shooting and repairing malfunctions already. A major source of difficulty was related to the inaccessibility of malfunctioning subsystems, such as the air-conditioning system, the repair of which necessitated the disassembly and removal of complex intervening equipment.

Acquisition of dust in hydraulic valves is expected to occasion frequent maintenance action. A design shortcoming related to both maintenance and operational reliability is the failure to subdivide the hydraulic fluid reservoir for the separate hydraulic systems. Consequently, a leak anywhere affects all hydraulic subsystems and the entire fluid supply must be drained when any hydraulic unit requires maintenance.

Increases in the complexity of present day systems and the severity of environmental constraints have resulted in a great deal of concern and numerous publications related to design for maintainability. Certainly no less concern should be shown for support equipment required for nuclear systems and tests. Those responsible for the development of such equipment should make every effort to insure that systems are designed to conform to maintenance requirements as well as operational requirements. References 1, 3, and 5 are examples of pertinent guides for maintenance design.

REFERENCES

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4. Human Engineering Criteria for Aircraft, Missile, and Space Systems Ground Support Equipment, MIL-STD-803 (USAF) Department of the Air Force, 5 November 1959.

5. Rigby, L. V., J. I. Cooper and W. A. Spickard, Guide to Integrated System Design for Maintainability, ASD Technical Report 61-424, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, October 1961.

LIST OF FIGURES

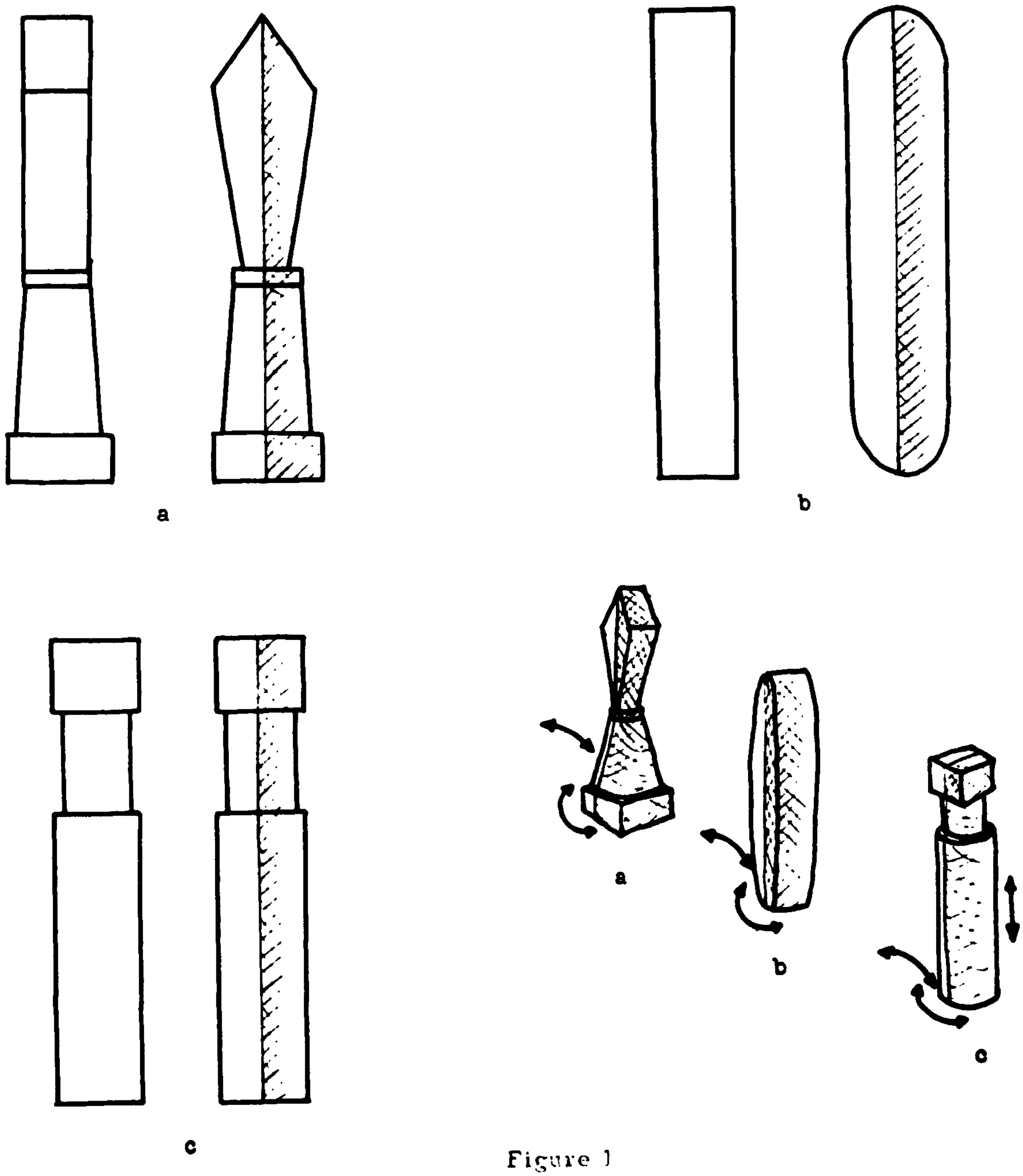

Figure 1

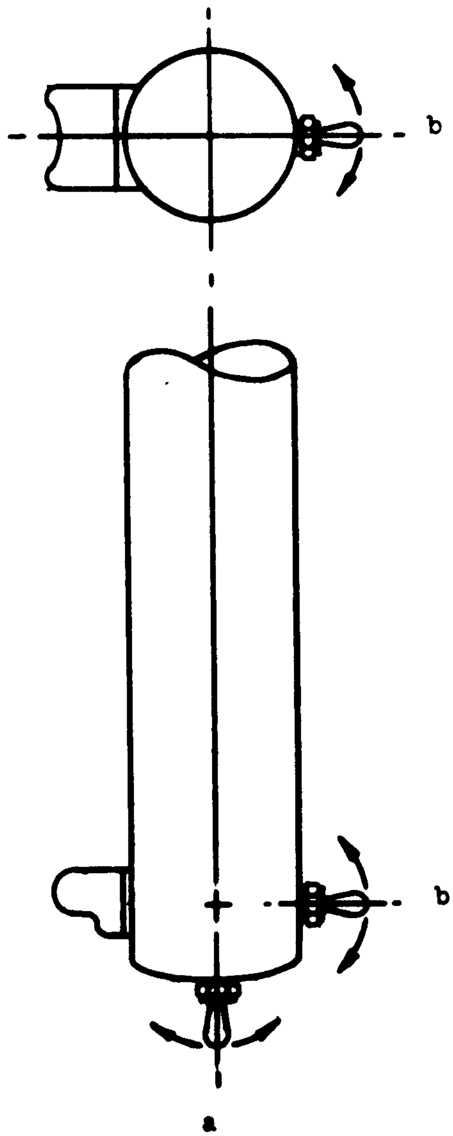

Figure 2

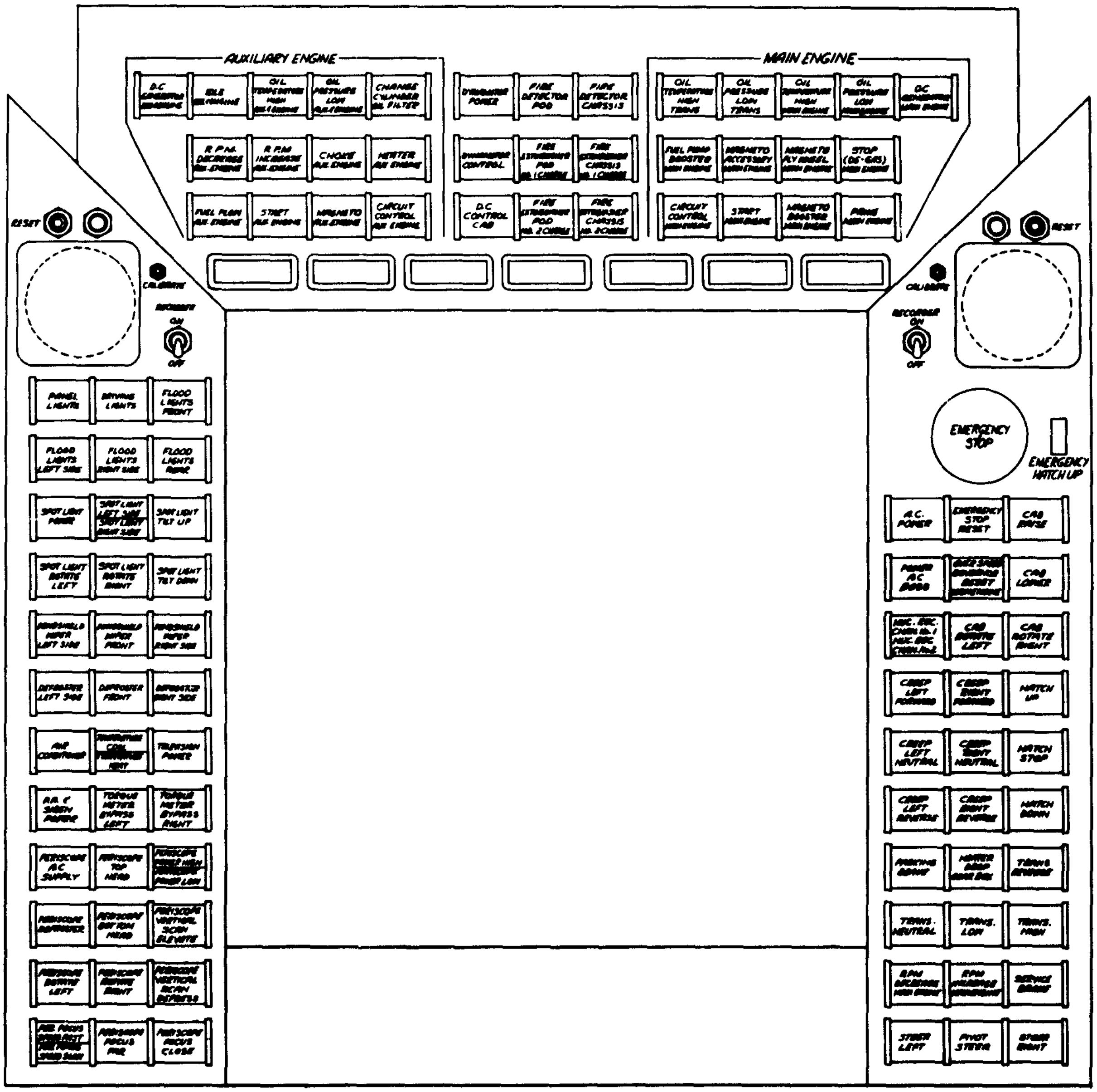
AUXILIARY ENGINE
MAIN ENGINE
RESET
RESET
CALIBRATE
CALIBRATE
RECORDER
ON
OFF
EMERGENCY STOP
EMERGENCY HATCH UP
PANEL LIGHTS
FLOOD LIGHTS FRONT
CHOKE AUX ENGINE
D.C. CONTROL CAB
STOP (DE-GAS)
A.C. POWER
EMERGENCY STOP RESET
CAB RAISE
CAB LOWER
HATCH UP
HATCH STOP
HATCH DOWN
TRANS. NEUTRAL
TRANS. LOW
TRANS. HIGH
STEER LEFT
PIVOT STEER
STEER RIGHT

Figure 3

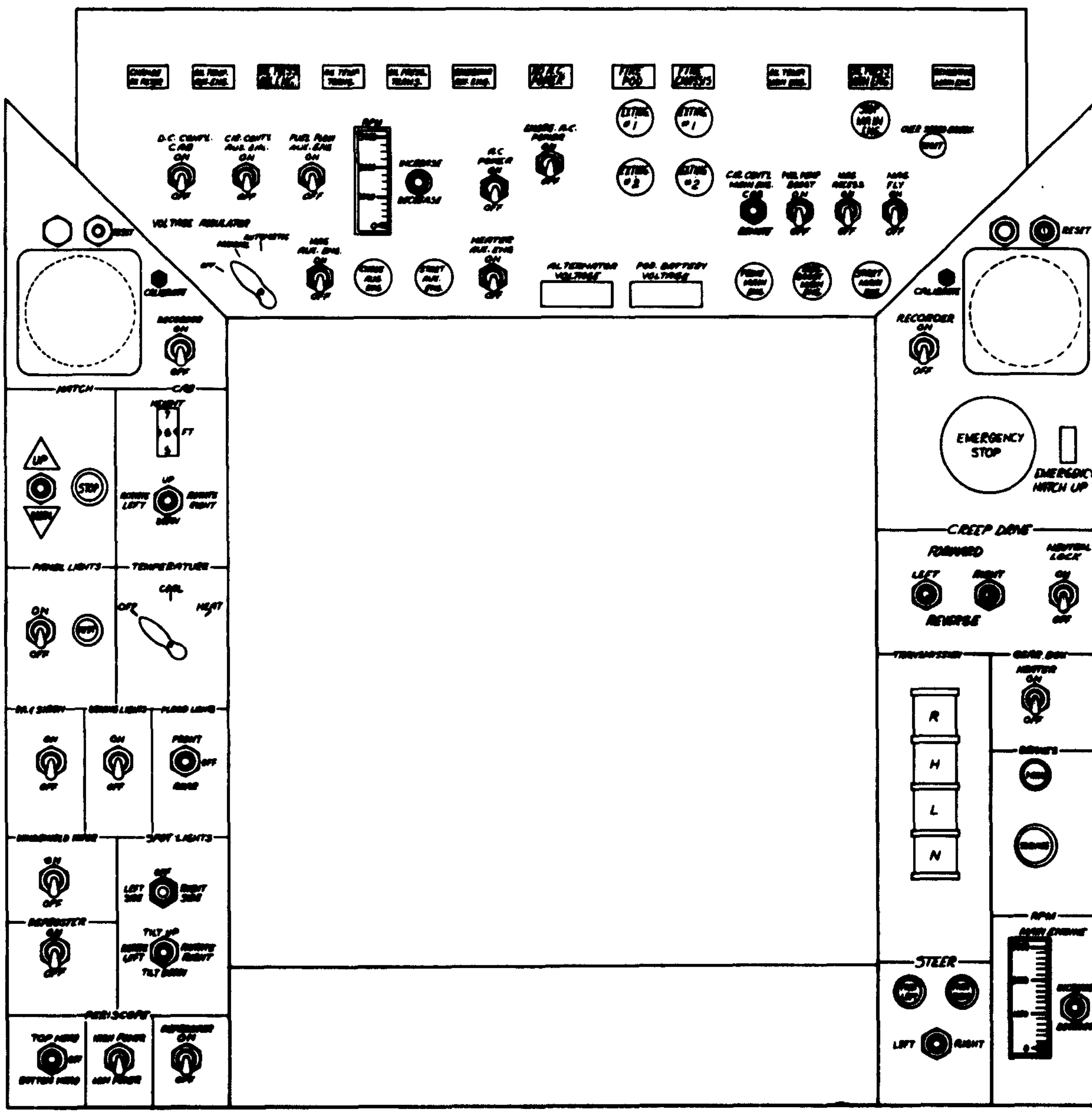
VOLTAGE REGULATOR
RECORDER
ON
OFF
RESET
HATCH
CAB
PANEL LIGHTS
TEMPERATURE
PERISCOPE
EMERGENCY STOP
EMERGENCY HATCH UP
CREEP DRIVE
FORWARD
LEFT
RIGHT
REVERSE
R
H
L
N
STEER
LEFT
RIGHT

Figure 4

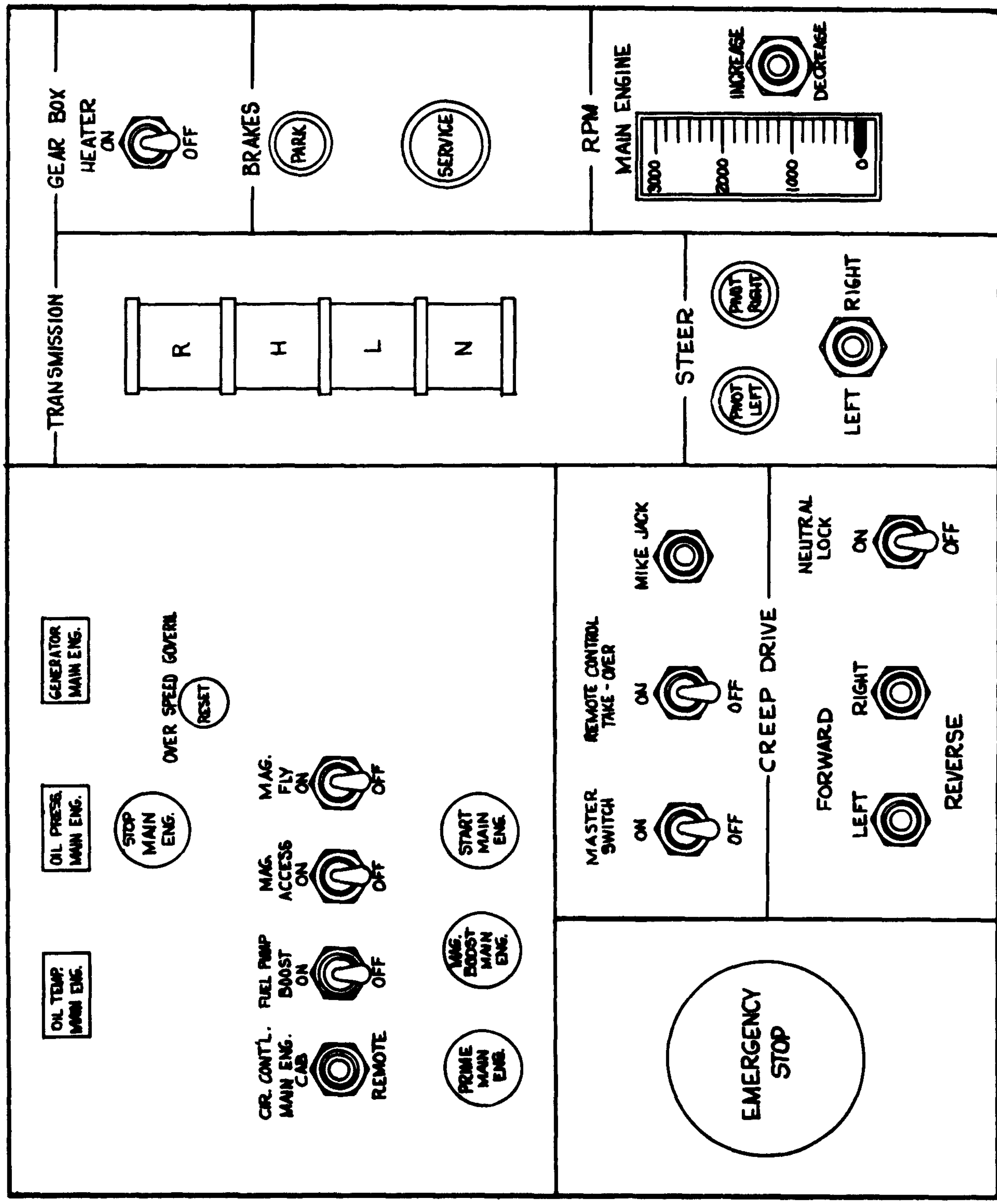
GEAR BOX
HEATER
ON
OFF
BRAKES
PARK
SERVICE
RPM
MAIN ENGINE
3000
2000
1000
0
INCREASE
DECREASE
TRANSMISSION
R
H
L
N
STEER
PIVOT LEFT
PIVOT RIGHT
LEFT
RIGHT
OIL TEMP. MAIN ENG.
OIL PRESS. MAIN ENG.
GENERATOR MAIN ENG.
STOP MAIN ENG.
OVER SPEED GOVERNOR
RESET
CIR. CONT'L. MAIN ENG.
CAB
REMOTE
FUEL PUMP BOOST
ON
OFF
MAG. ACCESS
ON
OFF
MAG. FLY
ON
OFF
PRIME MAIN ENG.
MAG. BOOST MAIN ENG.
START MAIN ENG.
MASTER SWITCH
ON
OFF
REMOTE CONTROL TAKE-OVER
ON
OFF
MIKE JACK
CREEP DRIVE
NEUTRAL LOCK
ON
OFF
FORWARD
LEFT
RIGHT
REVERSE
EMERGENCY STOP

Figure 5

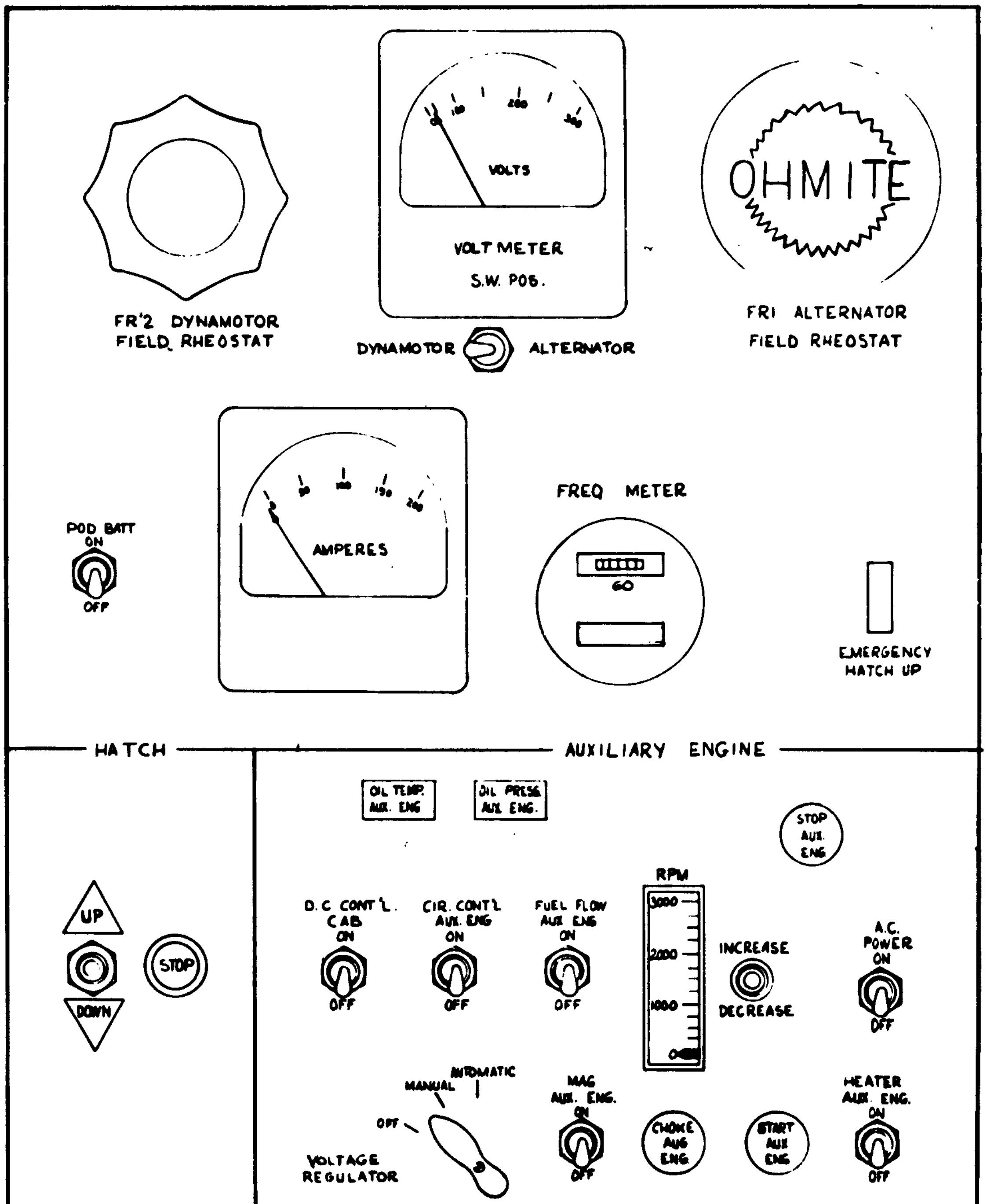
VOLTS
VOLT METER
S.W. POS.
OHMITE
FR'2 DYNAMOTOR
FIELD RHEOSTAT
DYNAMOTOR
ALTERNATOR
FRI ALTERNATOR
FIELD RHEOSTAT
AMPERES
FREQ METER
60
POD BATT
ON
OFF
EMERGENCY
HATCH UP
HATCH
AUXILIARY ENGINE
OIL TEMP. AUX. ENG
OIL PRESS. AUX. ENG.
STOP AUX. ENG
RPM
UP
STOP
DOWN
D.C CONT'L. CAB
ON
OFF
CIR. CONT'L AUX. ENG
ON
OFF
FUEL FLOW AUX ENG
ON
OFF
INCREASE
DECREASE
A.C. POWER
ON
OFF
AUTOMATIC
MANUAL
OFF
VOLTAGE REGULATOR
MAG AUX. ENG.
ON
OFF
CHOKE AUX ENG
START AUX ENG
HEATER AUX. ENG.
ON
OFF

Figure 6

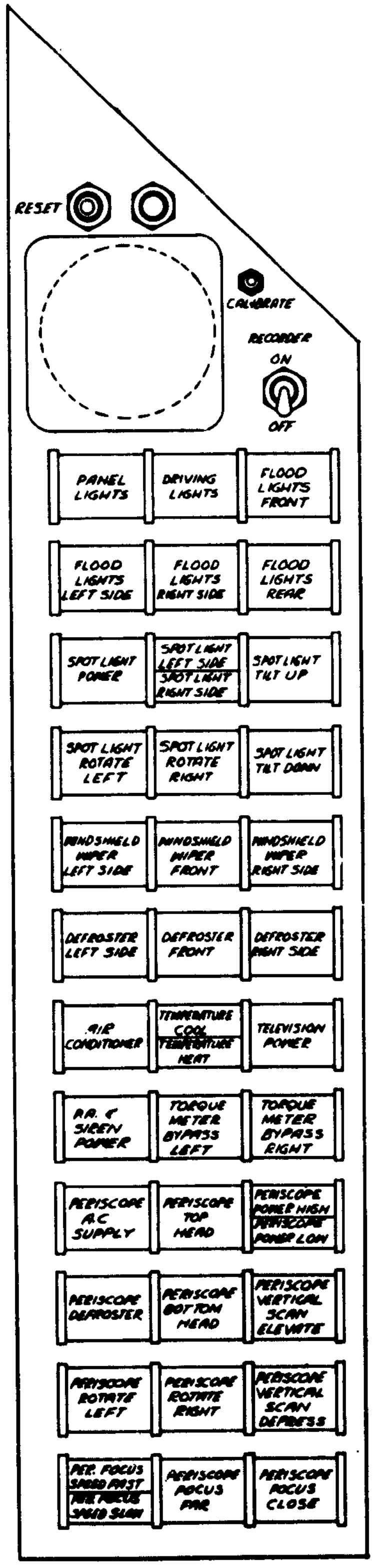
RESET
CALIBRATE
RECORDER
ON
OFF
PANEL LIGHTS
DRIVING LIGHTS
FLOOD LIGHTS FRONT
FLOOD LIGHTS LEFT SIDE
FLOOD LIGHTS RIGHT SIDE
FLOOD LIGHTS REAR
SPOT LIGHT POWER
SPOT LIGHT LEFT SIDE
SPOT LIGHT RIGHT SIDE
SPOT LIGHT TILT UP
SPOT LIGHT ROTATE LEFT
SPOT LIGHT ROTATE RIGHT
SPOT LIGHT TILT DOWN
WINDSHIELD WIPER LEFT SIDE
WINDSHIELD WIPER FRONT
WINDSHIELD WIPER RIGHT SIDE
DEFROSTER LEFT SIDE
DEFROSTER FRONT
DEFROSTER RIGHT SIDE
AIR CONDITIONER
TEMPERATURE COOL
TEMPERATURE HEAT
TELEVISION POWER
P.A. & SIREN POWER
TORQUE METER BYPASS LEFT
TORQUE METER BYPASS RIGHT
PERISCOPE A.C SUPPLY
PERISCOPE TOP HEAD
PERISCOPE POWER HIGH
PERISCOPE POWER LOW
PERISCOPE DEFROSTER
PERISCOPE BOTTOM HEAD
PERISCOPE VERTICAL SCAN ELEVATE
PERISCOPE ROTATE LEFT
PERISCOPE ROTATE RIGHT
PERISCOPE VERTICAL SCAN DEPRESS
PER. FOCUS SPEED FAST
PER. FOCUS SPEED SLOW
PERISCOPE FOCUS FAR
PERISCOPE FOCUS CLOSE

Figure 7

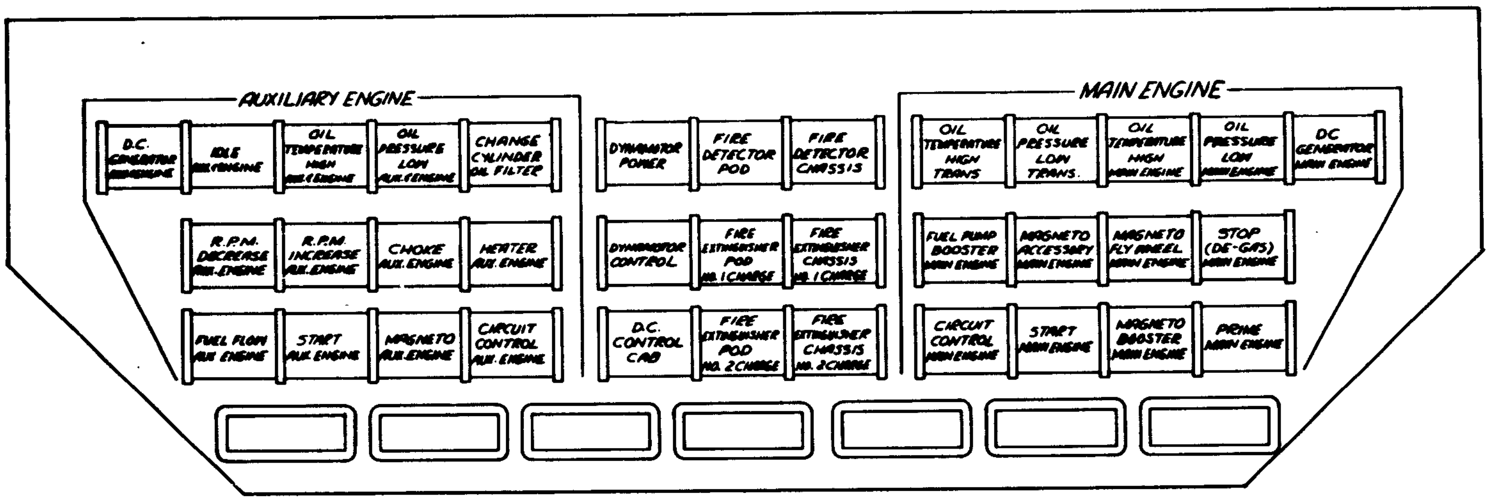
AUXILIARY ENGINE
D.C. GENERATOR AUX.ENGINE
IDLE AUX.ENGINE
OIL TEMPERATURE HIGH AUX.ENGINE
OIL PRESSURE LOW AUX.ENGINE
CHANGE CYLINDER OIL FILTER
R.P.M. DECREASE AUX.ENGINE
R.P.M. INCREASE AUX.ENGINE
CHOKE AUX.ENGINE
HEATER AUX.ENGINE
FUEL FLOW AUX.ENGINE
START AUX.ENGINE
MAGNETO AUX.ENGINE
CIRCUIT CONTROL AUX.ENGINE
DYNAMATOR POWER
FIRE DETECTOR POD
FIRE DETECTOR CHASSIS
DYNAMATOR CONTROL
FIRE EXTINGUISHER POD NO.1 CHARGE
FIRE EXTINGUISHER CHASSIS NO.1 CHARGE
D.C. CONTROL CAB
FIRE EXTINGUISHER POD NO.2 CHARGE
FIRE EXTINGUISHER CHASSIS NO.2 CHARGE
MAIN ENGINE
OIL TEMPERATURE HIGH TRANS
OIL PRESSURE LOW TRANS.
OIL TEMPERATURE HIGH MAIN ENGINE
OIL PRESSURE LOW MAIN ENGINE
DC GENERATOR MAIN ENGINE
FUEL PUMP BOOSTER MAIN ENGINE
MAGNETO ACCESSORY MAIN ENGINE
MAGNETO FLY WHEEL MAIN ENGINE
STOP (DE-GAS) MAIN ENGINE
CIRCUIT CONTROL MAIN ENGINE
START MAIN ENGINE
MAGNETO BOOSTER MAIN ENGINE
PRIME MAIN ENGINE

Figure 8

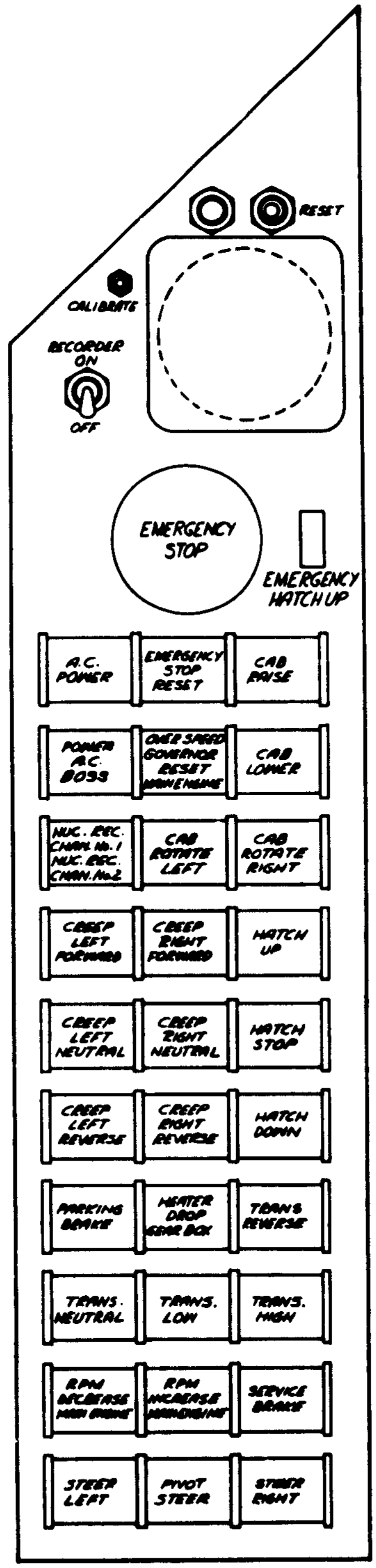
RESET
CALIBRATE
RECORDER
ON
OFF
EMERGENCY STOP
EMERGENCY HATCH UP
A.C. POWER
EMERGENCY STOP RESET
CAB RAISE
POWER A.C. BOSS
OVER SPEED GOVERNOR RESET
CAB LOWER
NUC. REC. CHAN. No. 1
NUC. REC. CHAN. No. 2
CAB ROTATE LEFT
CAB ROTATE RIGHT
CREEP LEFT FORWARD
CREEP RIGHT FORWARD
HATCH UP
CREEP LEFT NEUTRAL
CREEP RIGHT NEUTRAL
HATCH STOP
CREEP LEFT REVERSE
CREEP RIGHT REVERSE
HATCH DOWN
PARKING BRAKE
HEATER DROP GEAR BOX
TRANS REVERSE
TRANS. NEUTRAL
TRANS. LOW
TRANS. HIGH
RPM DECREASE
RPM INCREASE
SERVICE BRAKE
STEER LEFT
PIVOT STEER
STEER RIGHT

Figure 9

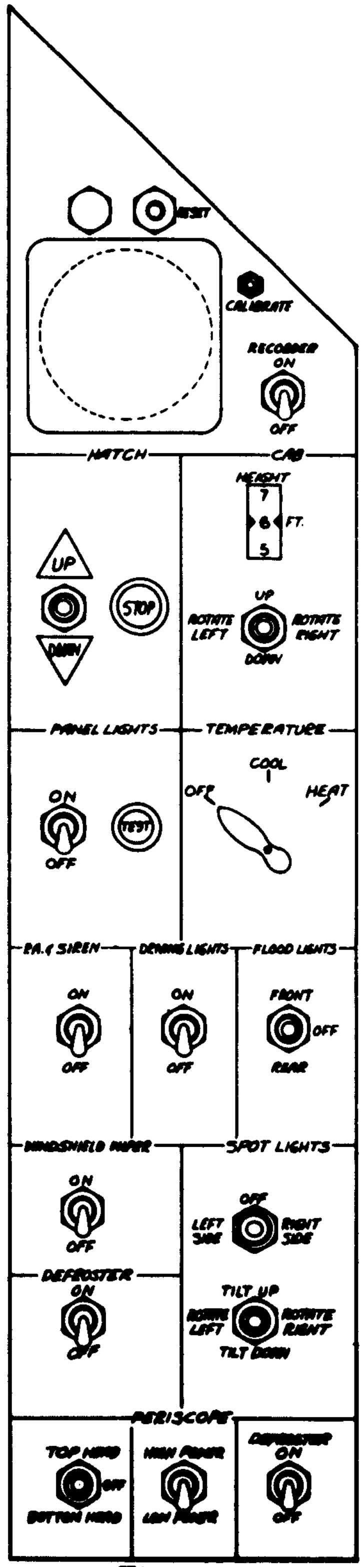
RESET
CALIBRATE
RECORDER
ON
OFF
HATCH
CAB
HEIGHT
7
6
5
FT.
UP
DOWN
STOP
UP
ROTATE LEFT
ROTATE RIGHT
DOWN
PANEL LIGHTS
TEMPERATURE
ON
OFF
TEST
COOL
OFF
HEAT
P.A. & SIREN
DRIVING LIGHTS
FLOOD LIGHTS
ON
OFF
ON
OFF
FRONT
OFF
REAR
WINDSHIELD WIPER
SPOT LIGHTS
ON
OFF
OFF
LEFT SIDE
RIGHT SIDE
DEFROSTER
ON
OFF
TILT UP
ROTATE LEFT
ROTATE RIGHT
TILT DOWN
PERISCOPE
TOP HEAD
OFF
BOTTOM HEAD
HIGH POWER
LOW POWER
DEFROSTER
ON
OFF

Figure 10

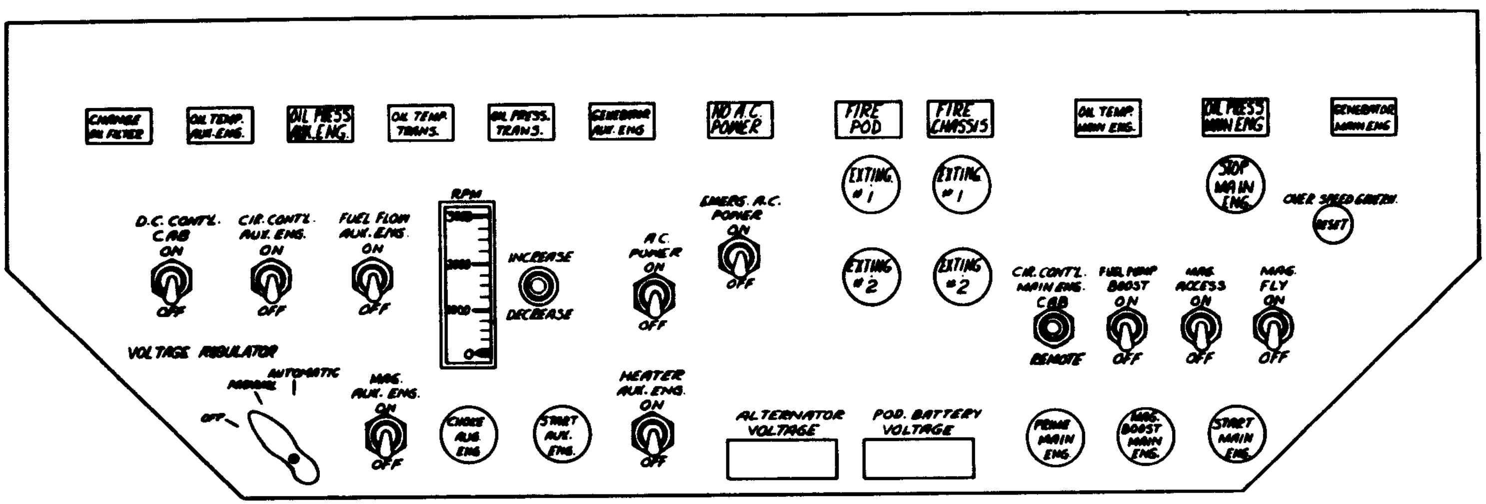
CHANGE OIL FILTER
OIL TEMP. AUX. ENG.
OIL PRESS AUX. ENG.
OIL TEMP. TRANS.
OIL PRESS. TRANS.
GENERATOR AUX. ENG.
NO A.C. POWER
FIRE POD
FIRE CHASSIS
OIL TEMP. MAIN ENG.
OIL PRESS MAIN ENG.
GENERATOR MAIN ENG.
EXTING. #1
EXTING. #1
EXTING. #2
EXTING. #2
STOP MAIN ENG.
OVER SPEED GOVERN.
RESET
D.C. CONT'L. CAB ON OFF
CIR. CONT'L. AUX. ENG. ON OFF
FUEL FLOW AUX. ENG. ON OFF
RPM
INCREASE
DECREASE
A.C. POWER ON OFF
EMERG. A.C. POWER ON OFF
CIR. CONT'L. MAIN ENG. CAB REMOTE
FUEL PUMP BOOST ON OFF
MAG. ACCESS ON OFF
MAG. FLY ON OFF
VOLTAGE REGULATOR
AUTOMATIC
MANUAL
OFF
MAG. AUX. ENG. ON OFF
CHOKE AUX. ENG.
START AUX. ENG.
HEATER AUX. ENG. ON OFF
ALTERNATOR VOLTAGE
POD. BATTERY VOLTAGE
PRIME MAIN ENG.
MAG. BOOST MAIN ENG.
START MAIN ENG.

Figure 11

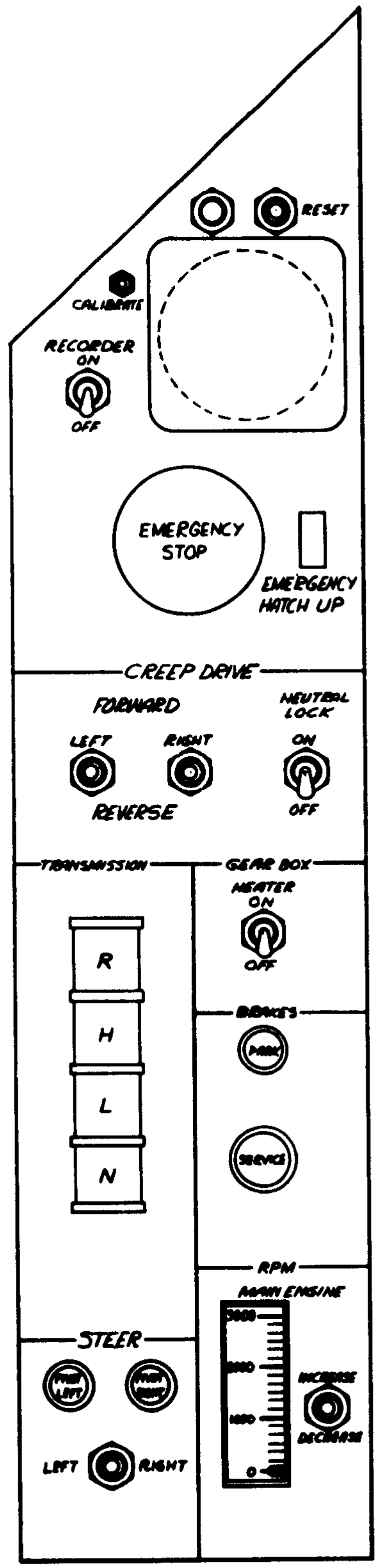
RESET
CALIBRATE
RECORDER
ON
OFF
EMERGENCY
STOP
EMERGENCY
HATCH UP
CREEP DRIVE
FORWARD
NEUTRAL
LOCK
LEFT
RIGHT
ON
REVERSE
OFF
TRANSMISSION
GEAR BOX
HEATER
ON
OFF
R
H
L
N
BRAKES
PARK
SERVICE
RPM
MAIN ENGINE
INCREASE
DECREASE
STEER
LEFT
RIGHT

Figure 12

TDR-62-137

APPENDIX X

THE MASHER
and
THE BAT

On-Site Rad-Safe Report

Radiological Safety Division
Health, Medicine & Safety Department

Reynolds Electrical & Engineering Co., Inc. Mercury, Nevada

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SHIELDING INTEGRITY TEST
MASHER & BAT RECOVERY VEHICLES

I. Introduction

A shielding integrity test of the Masher and Bat recovery vehicles was performed by Reynolds Electrical & Engineering Company, Radiological Safety Division personnel on June 28 and 29, 1962, at the MAD Building in Area 400 of the Nevada Test Site. The integrity test was conducted at the request of C. D. Montgomery, J-6 Division, Los Alamos Scientific Laboratory. The general approach for conducting the test is listed in Appendix A of this report.

II. Test Equipment

A. Source Strength

A one hundred and forty (140) curie Barium 140 + Lanthanum 140 source was utilized as the gamma emitter for the test.

B. Radiation Detection Equipment

Two Cobalt-60 gamma calibrated Victoreen Radector - Model GB500B-SR instruments with one hundred foot cable connected probes were utilized for both phase I and phase II of the test.

III. Test Preparations

A. Intensity Measurements

Prior to the actual test, gamma intensity measurements of the source were made at measured distances from the source. A tape measured range was established and intensities measured at 39", 5 ft., 8 ft., 10 ft., 15 ft., and 25 ft. intervals from the source. These intensities at the respective distances were as follows: 240 R/hr, 100 R/hr, 40 R/hr, 25 R/hr, 12 R/hr, and 4 R/hr.

B. Detector Probe Placement

In both the Masher and Bat vehicles, the detector probes were suspended in the exact center of the cabs for Phase I of the test. During

Phase II, the probes were manually placed in contact with the cab interior directly opposite the exterior source location and read-out in the Disassembly Bay corridor.

C. Remote Source Positioning

Thirty-six (36) inch wooden rules were placed on horizontal and vertical exteriors of the cabs for reference placements of the source during the test. Depth perception fallacies were expected for source placement at distances of greater than 36" from the cab exteriors. For Phase I, these fallacies would be negligible due to the overall distances from the detector probes. For Phase II, the error was calculated to be less than $\pm 2\%$ in the resultant shielding factors.

IV. <u>Test Procedure</u>

The procedures set forth in Appendix A were adhered to except when inconsistancies were noted in gamma measurements. When this occurred, numerous measurements were made to ascertain that no gross flaws existed in the shielding. This primarily occurred during Phase I of the Bat integrity check both during the check of the front viewing window and the shielding integrity of the cab thickness. The vertical slant of the viewing window led to a miscalculation that defects were present in the window frame packing. Phase II completely disproved this. The cab shielding was thought to be only of steel content. This was in turn proved to have a certain amount of lead laminated between steel sheets for an overall thickness of two and five eights inches of shielding material.

V. <u>Test Results</u>

A Shielding Effects

The tabulated data concerning shielding integrity is listed in Appendix B of this report.

B General Data Interpretation

In general, the shielding integrity test proved the following:

1. There were no gross failures in shielding attenuation.
2. Measured shielding factors were in the same magnitude as

the calculated shielding factors for the respective estimated thicknesses of steel and lead.

3. The shielding integrity of the viewing windows in both cases were slightly less than the shielding integrity of the wall surrounding the respective windows.

4. The metallic vehicle parts between the Masher floor and the point source undoubtedly render a shielding approximately one tenth value layer.

APPENDIX A

PROPOSAL FOR THE SHIELDING INTEGRITY TEST FOR MASHER & BAT -- AREA 400

NOTE: The Shielding Integrity Test of the Bat shall be conducted in a similar manner to that of the Masher test, with the exception of Phase II.

Test Preparations

I. Area Control

Prior to removal of the source from its shielding container, the following locations will be checked to assure that the areas are clear of personnel: The Upper and Lower Disassembly Bays. These areas will be locked to prevent entry during the test.

II. Safety Considerations

A. Air Sample

A high-volume Staplex air sampler with an 8" x 10" fiberglas filter will be in operation for the duration of the test.

B. Swipes will be obtained from the Disassembly Bay floor and walls when the source has been replaced in the Shielding Container to assure source integrity after the first phase of the test and when the test has been completed.

C. A vacuum cleaner will be connected to a power outlet and will remain in the Disassembly Bay during the test. The vacuum cleaner will be remotely operated to decontaminate the bay in the event of an accidental source rupture.

D. The Victoreen Remote Area Monitoring System will be operational during the test to assure safety of personnel in the test perimeters.

E. No entry into the bay will be made until the source has been placed in its shielding container and the bay monitored for radiation.

Personnel entering the bay will be provided anti-c clothing and dosimeters and accompanied by a Rad-Safe monitor.

III. Test Procedures

A. Source Preparations

The test source shielded container will be pre-positioned in a convenient, visible location in the Lower Bay.

1. A twenty-five square foot area of the bay floor will be papered and the source container placed in the center of the papered area.

2. The source container will be prepared so that it can be opened and the source removed remotely.

3. Source holding fixtures and the heat sink will be positioned on the papered area.

B. Masher Preparation

The Masher will be brought into the bay and positioned in a location where the side-wall manipulators can reach to any side or above the Masher cab with the source.

The Masher cab will be instrumented with remote readout detectors mounted in a central location in the cab. The radiation levels detected will be read out outside the Disassembly Bay.

C. Area Control

The Disassembly Bays (Upper and Lower) will be cleared of personnel, and the personnel doors will be locked.

D. Test (Phase I)

1. The source will be removed by remote means from its shielding container and placed in the Source Handling Fixture.

2. The source will be moved toward the cab, and the radiation levels inside the cab observed by remote detectors. Radiation levels inside the bay will be monitored by the Victoreen Remote Monitoring System.

3. The source will be moved around the cab at a distance of approximately five (5)* feet from the detectors until the entire cab has been

*One meter for the Bat.

exposed to the source.

a. If a gross shielding failure is observed during this phase of the test, the source will be replaced in its shielding container and the cab re-instrumented with radiation detection equipment to determine the location and magnitude of the shielding failure.

b. If no gross shielding failures are detected, Test Phase Number Two will commence.

E. Test(Phase II)

1. The source will be placed in its shielding container, and the Lower Disassembly Bay personnel door will be unlocked.

2. Rad-Safe monitors will monitor the area for contamination and radiation.

a. If the area is contaminated, appropriate decontamination and safety measures will be initiated.

b. If no contamination is detected, the Masher remote radiation instrumentation will be removed from the central location to allow free movement of the probes during the second phase.

3. The Masher cab will be manned by a person competent to read portable radiation detection instruments.

a. Communications between the operator and the Integrity Test personnel will be maintained by means of two-way radios.

b. The operator will have a low range beta-gamma instrument and two high range gamma instruments in his possession.

c. Radiation detection instruments and communications will be rechecked just prior to removal of the source from its shielding container.

4. The Masher door will be closed, the bay cleared of personnel, and the personnel door will be closed and locked.

5. The source will be removed from the shielding container and slowly moved toward the cab.

6. The source will be positioned eleven (11) times during the second phase of the test.

a. Position #1 will be at the East end of the top of the cab and above the cab approximately fifteen (15) feet.

b. Position #2 will be at the center of the cab top and above the cab approximately fifteen (15) feet.

c. Position #3 will be at the West end of the cab top and above the cab approximately fifteen (15) feet.

d. Position #4 will be midway down the back of the cab at the East side and approximately ten (10) feet away from the cab.

e. Position #5 will be midway down the back of the cab at the center and approximately ten (10) feet away from the cab.

f. Position #6 will be midway down the hatch of the cab at the West side and approximately ten (10) feet away from the cab.

g. Position #7 will be at the center of the East side of the cab and approximately ten (10) feet away from the cab.

h. Position #8 will be midway down the front of the cab at the East side and approximately eight (8) feet away from the cab.

i. Position #9 will be midway down the front of the cab at the center and approximately three (3) feet away from the cab.

j. Position #10 will be midway down the front of the cab at the West side and approximately eight (8) feet away from the cab.

k. Position #11 will be at the West side center of the cab and approximately five (5) feet away from the cab.

7. The operator will obtain radiation measurements at contact with the cab's interior at points opposite the source position outside the cab.

8. Readings obtained will be relayed via radio to personnel plotting radiation intensities.

Plotting personnel will note the source position in relation to the cab and the radiation measurements obtained on a diagram of the Masher cab.

9. Upon completion of the Shielding Integrity Test, the source will be returned to its shielding container, and the bay will be monitored for radiation and contamination prior to the operator disembarking from the cab.

APPENDIX B

SHIELDING INTEGRITY TEST MASHER VEHICLE

PHASE #1

REMOTE READINGS

Source Location	Distance From Detector	Calculated Air r/hr Intensity	Shielding in inches	Actual Intensity r/hr	Shielding Factor
Front-W. Side	~ 6'	70	>9	0.035	1/2000
Front-Center	~ 5'	100*	9	0.10	1/1000
Front-E. Side	~ 6'	70	>9	0.045	1/2000
Top-W. Side	~ 6'	70	>5	1.7	1/40
Top-Center	~ 5'	100*	5	3.2	1/30
Top-E. Side	~ 6'	70	>5	2.0	1/40
Back-W. Side	~ 6'	70	>7 1/2	0.25	1/300
Back-Center	~ 5'	100*	7 1/2	0.5	1/200
Back-E. Side	~ 6'	70	>7 1/2	0.3	1/250
E. Side (Opposite Hatch)	~ 5'	100*	~8	0.2	1/500
W. Side Hatch	~ 5'	100*	8	0.16	1/600
Bottom	~ 5'	100*	~5	0.15	1/650

*Actual Instrument Intensity

SHIELDING INTEGRITY TEST MASHER VEHICLE

PHASE II (MANNED)

Source Location	Distance From Detector	Calculated Air r/hr Intensity	Approx. Shielding in inches	Actual Intensity r/hr	Shielding Factor
Front-W. Side	~8'	40	~9	0.026	1/1500
Front-Center	~3'	280	~9	0.3	1/900
Front-E. Side	~8'	40	~9	0.02	1/2000
Top-W. Side	~15'	12	~5	0.17	1/70
Top-Center	~15'	12	~5	0.17	1/70
Top-E. Side	~15'	12	~5	0.17	1/70
Back-W. Side	~10'	25	~7 1/2*	0.15	1/150
Back-Center	~10'	25	~7 1/2	0.10	1/250
Back-E. Side	~10'	25	~7 1/2*	0.14	1/160
E. Side (Opposite Hatch)	~10'	25	~8	0.045	1/550
W. Side Hatch Line	~5'	100	~8	0.2	1/500
W. Side Wall	~5'	100	~8	0.15	1/650
W. Side Hatch Line	~4.5'	120	~8	0.26	1/460
W. Side Wall	~4.5'	120	~8	0.15	1/800

*Window

SHIELDING INTEGRITY TEST BAT VEHICLE

PHASE #1

REMOTE READINGS

Source Location	Distance From Detector	Calculated Air r/hr Intensity	Shielding in inches	Actual Intensity r/hr	Shielding Factor
Front-W. Side	39"	240	2 5/8	25	1/96
Front-Center	39"	240	2 5/8	17	1/15
Front -E. Side	39"	240	2 5/8	24	1/10
Top-W. Side	39"	240	2 5/8	11	1/20
Top-Center	60"	100	2 5/8	4	1/25
Top-E. Side	60"	100	2 5/8	4	1/25
Back-E. Side	48"	160	2 5/8	8	1/20
Back-Center	39"	240	2 5/8	15	1/16
E. Side-Center	30"	260	2 5/8	12.5	1/20
W. Side-Center	30"	260	2 5/8	13	1/20
Bottom	6"	70	2 5/8	6	1/12
Front Viewing Window		PHASE II (MANNED)			
Center	25'	4	2 5/8	0.4	1/10
Bottom frame Center	25'	4	2 5/8	0.325	1/12
W. Frame-Center	25'	4	2 5/8	0.3	1/13
E. Frame-Center	25'	4	2 5/8	0.375	1/11
Top Frame-Center	25'	4	2 5/8	0.4	1/10
Large Part of Crack	25'	4	2 5/8	0.45	1/9

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Three shielded-cab vehicles were tested at the Nuclear Rocket Development Station, Mercury, Nevada, to determine their operational capabilities in radioactive fields. Testing was concentrated on the "Beetle," a shielded-cab vehicle with manipulators, manufactured by General Electric Company. The "Masher," a shielded T-51 Tank Recovery Vehicle, and the "Bat," a shielded Coleman Tow Vehicle, were also tested. All three vehicles were tested for maneuverability, reliability of operation, operational uses, and radiation shielding integrity. The results of

1. Human engineering
2. Radiation effects
3. Reliability studies
4. Remote handling equipment -- testing
5. Safety studies
6. Shielding

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