

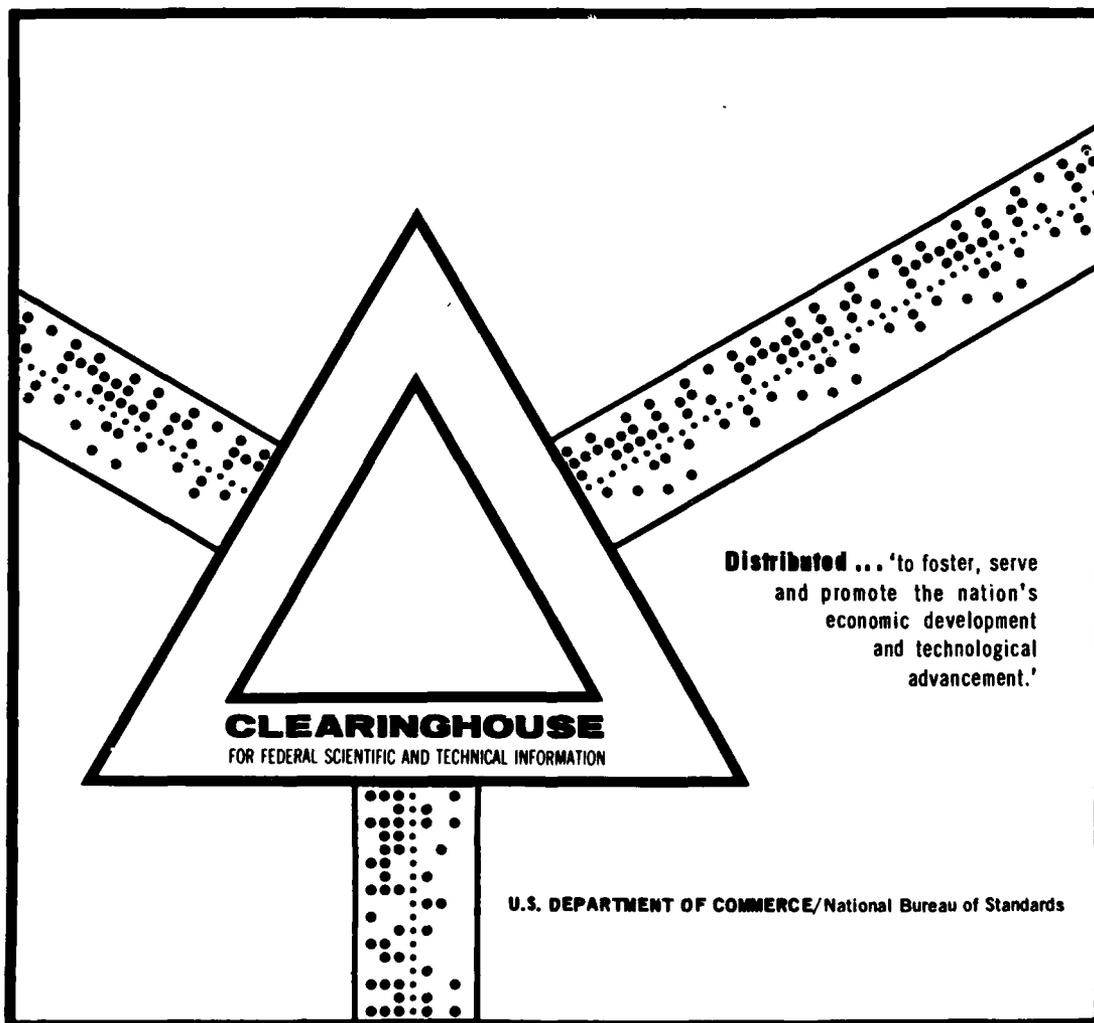
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HUMAN FACTORS STUDY OF QMC CLOTHING AND
EQUIPMENT DURING COLD WEATHER TESTS OF
THE PERSHING MISSILE SYSTEM

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Quartermaster Research and Engineering Center
Natick, Massachusetts

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PIONEERING RESEARCH DIVISION

Engineering Psychology Research Study Report

EPR-1

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TESTS OF THE PERSHING MISSILE SYSTEM

Prepared by

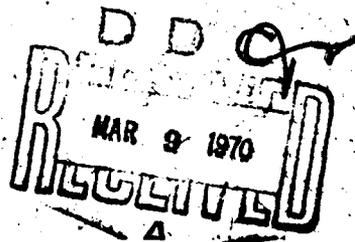
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**HUMAN FACTORS STUDY OF QMC CLOTHING AND EQUIPMENT DURING COLD WEATHER
TESTS OF THE PERSHING MISSILE SYSTEM**

1. Introduction

The primary purpose of ~~QMR&EC Engineering~~ ^{Psychology} Laboratory participation in this test was to detect human factors problems associated with QMC standard clothing and equipment in the operation of the PERSHING Missile System and to report these problems to the responsible design and development groups. Secondary goals were to make preliminary studies (1) concerning the new experimental QMC Integrated Clothing System, and (2) concerning the feasibility of using electrically heated handwear for performing critical tasks during operation of the PERSHING equipment.

Quartermaster participation in the test was at the request of the Army Ordnance Missile Command. The cold weather phases of the test were conducted in the Climatic Hangar of the Air Proving Ground Center Climatic Laboratories at Eglin AFB, Florida between 22 January and 2 March 1962, at temperatures of 0, -25, -45 and -65° F. The Artillery Test Team which participated in operation of the system consisted of a Commanding Officer and 15 enlisted men, all from the Army Ordnance Missile Command, Redstone Arsenal, Alabama. The test was conducted by the Martin Company, Orlando, Florida, under the technical supervision of the Test and Evaluation Laboratory, Army Ordnance Missile Command.

Members of the test team and a few additional men were furnished complete Army cold-dry clothing ensembles, with the exception that most team members furnished their own wool cushion sole socks and winter underwear. Helmet liners were furnished members of the team who did not work in shelters. Also, helmets were issued and were worn as needed to study their compatibility with other items of clothing and personal equipment and with the system equipment.

During the -45 and -65° F. portions of the test the Erector Launcher (EL) operator used the new Integrated Clothing System, including Glove-Shells, Leather, Lightweight, Insulated, T61-3 with Glove-Inserts, Wool, OG 108, and Arctic Mitten Set, Lightweight, T61-3.

2. Method

The report is based on observations made by two QMC Engineering Psychology Laboratory representatives, one a psychologist and the other a mechanical engineer. The number of observations, and their effectiveness were limited by the following circumstances: (a) system

operating procedures had not been completely standardized for cold weather conditions; (b) operating schedules were extremely inconsistent because equipment was sometimes inoperable for relatively long periods; (c) Martin Company employees, who were wearing Air Force rather than Army clothing, played a major role in operating the equipment and in the necessary trouble shooting, maintenance and repairs; (d) operations were sometimes conducted during the night shift, without sufficient prior notice concerning their exact nature to enable QMC representatives to plan to be present;* (e) easy accessibility of a heated hut for rewarming made it possible for men to work in the cold for short periods of time while wearing relatively light clothing. This would have occurred much less frequently under true field conditions.

3. Observations

a. General observations and comments regarding the clothing worn

(1) Standard clothing

In general the crew members who wore the standard QMC cold-dry clothing commented favorably concerning its warmth. There was an apparent exception when four men complained that their feet became cold. However, investigation disclosed that the men had opened the pressure adjusting valves and forced out part of the air trapped in the insulating layer of the boots. These four pairs of boots were baked for 24 hours at 200° F. with the air valves open. The air valves were then closed and the boots returned to the original wearers, who made no further complaints of cold feet.

Unfavorable general comments concerning the clothing related to its bulkiness, cumbersomeness, time required to don and doff it, and to incompatibilities between headgear and communications equipment. Also, several crew members expressed the opinion that commercially available thermal underwear is warmer and more comfortable than the Army winter underwear.

The anti-contact gloves proved to be somewhat lacking in durability

* It was not considered worth-while to have QMC representatives regularly assigned on the night shift. On one occasion a QMC representative observed during the night shift after observing during the day shift and made no new observations during the entire 8-hour period at night.

for the work done. Four pairs had to be salvaged because of ripped seams at the thumb of the gloves. It is believed that this damage resulted largely from the fastening and unfastening of electrical cables which connect system components.

Some members of the PERSHING crew complained that the standard Army arctic clothing was too heavy and cumbersome for wear while performing prolonged manual tasks. In this connection it was noted that crew members seldom wore arctic mittens for their work. When questioned concerning this, they said the mittens were too bulky and slowed the work too much.

It was found that the steel helmet and helmet liner were not completely compatible with the standard dry-cold ensemble. This finding is in agreement with similar observations made earlier by a number of observers in a variety of situations. The helmet and liner could not be worn properly under the winter hood even when the protection of the hood against cold was needed. When the helmet liner and helmet were worn in the proper position for maximum ballistic protection, the visor of the pile cap was forced down in front of the eyes where it interfered materially with the field of vision. Also, the Erector Launcher (EL)

operator could not wear the standard communications head set with the pile cap, winter hood, helmet, and helmet liner.



Fig. 1. Standard Arctic head-gear: hood, pile cap, helmet and helmet liner

However, it should be emphasized that the new standard helmet liner has a nape strap which is a definite improvement. The nape strap helps hold the helmet and liner in position on the head and helps materially to keep the helmet and liner from falling off when the helmet chin strap is not fastened and the wearer is very active. In spite of the improvements in the helmet liner, members of the crew objected to wearing the helmet inside the system shelters for the following reasons: (1) the metal of the helmet might come into contact with line terminals and result in serious electrical shock to the wearer, and (2) if the helmet should fall off, it might damage panel equipment in falling.

(2) Integrated clothing system

The only set of integrated clothing available to the crew members was worn by the EL operator. He also had some difficulty in wearing the communications equipment. However, he was able to wear the head set under the new integrated hood without a pile cap, and was able to keep satisfactorily warm at -65° F.



Fig. 2. New experimental integrated clothing system

The integrated clothing was very well liked by the EL operator who used the ensemble constantly for two weeks at -45° F. and for two weeks at -65° F. He considered it to be lighter in weight, less cumbersome, and somewhat warmer than the standard clothing. He commented very favorably on the new handwear which he used constantly. In addition, the dry-cold white rubber insulated boots kept his feet warm for continuous working periods as long as $4\frac{1}{2}$ hours. This was true in spite of his history of severe frostbite of both feet.

A QMC engineering psychologist who wore the integrated clothing for approximately $3\frac{1}{2}$ weeks at -45 and -65° F. was of the opinion that when the hood of the integrated clothing is thrown back, it is a little more difficult to pull it forward into position to protect the head and face and to adjust it than was the case with the standard winter hood with fur ruff. On the other hand, the new Velcro fastenings were a definite improvement. The same observer, who in the past had run the mitten harness through the shoulder straps

on the standard field jacket and parka, found the lack of the shoulder straps a definite disadvantage. He found the lightweight arctic mittens to be warm and compatible with the remainder of the ensemble. However, they were wider than the standard arctic mitten, and this was a disadvantage when working in confined spaces. All of his other comments concerning the clothing were favorable.

At -45 and -65° F. the cloth surgical face masks provided by the Air Force to protect men working in the Climatic Hangar became uncomfortably damp. As no M17 Masks, Protective, Field were available for wear, one QMC observer wore a foam plastic face mask to secure more comfort and

greater protection than the surgical masks provided.* (It should be noted that under windy conditions the air-permeable surgical masks may not protect against frostbite).

b. Compatibility of the standard arctic clothing ensemble with the PERSHING System

(1) Ground mobile mode

(a) The missile containers

No important human factors problems were observed during the removal of the missile sections from their containers.

(b) The missile

The task of connecting cables between the first and second stage motors was difficult because the shortness of the cables limited the working space between missile stages to approximately six inches, for work done approximately nine inches inside the missile. Connecting the cables between the guidance section and second stage and between the warhead and the guidance section involved the same problem to a lesser degree. In contrast, the actual splicing of the stages did not involve any dexterity or other human factors problems.

(c) The missile blanket

No serious dexterity problems were encountered in handling the missile blanket. Extensive use of Velcro tape fastenings in place of straps and buckles, which have been used traditionally on weapon and missile covers and blankets, appears to have greatly reduced the dexterity problems and time required to install and remove the heating blankets.

At the time of the test, no decision had been reached concerning the location where the missile blankets would be stored. However, this should not be a difficult problem because large storage areas are available in the bed of each of the XM474 vehicles except the one which

* The mask used was originally designed by Sir Hubert Wilkins, and was modified and manufactured under the direction of Mr. Abraham Lastnik of this Command. It had been worn in a number of field and chamber studies conducted at low temperatures.

transports the EL. However, these storage areas do not afford complete protection against the environment.

(d) The Erector Launcher (EL)

The EL is mounted on an XM474 tracked vehicle. As the doctrine concerning the stowage of equipment on the various vehicles during tactical operations has not been finalized at this time, the next statement applies only to the equipment configuration as tested. The following items are stowed on this vehicle: three launcher pads, two front support pads, three stabilizing fins, two ramps, the missile blankets (when they are not in use), one 5KW generator which supplies power for the blankets, and a container for stowing tools. One operator, who is usually stationed at the control panel, does most of the work on the EL during preparations for launching. However, it is necessary to have one man on each side of the EL to quickly remove the azimuth ring tie-bars which must remain in place until after the missile has been erected and must then be removed before the erector can be lowered to the horizontal position preparatory to firing.

Decks and other footing on the EL furnish satisfactory footing for the operator's arctic boots. Also, the main control panel and launcher leveling controls are suitably designed for use with arctic mittens. However, when arctic mittens were worn, limited space hampered the connection of tie-bars between the erector and the launcher and the placing of chassis jacks in their front rest supports. Both of these tasks are easily accomplished with gloves.

Connecting the cable mast to the missile proved to be very difficult and time-consuming at temperatures of -45 and -65° F. The rear pin of the mast was difficult to align with arctic mittens. However, the basis of this difficulty appears to be mainly an engineering rather than a dexterity problem.

The EL operator reported that he was able to do all of his work satisfactorily while wearing anti-contact gloves and standard arctic mittens. However, when wearing Glove-Shells, Leather, Lightweight, Insulated, T61-3 with Glove-Inserts, Wool and occasionally using Arctic Mitten Set Lightweight T61-3 for rewarming, he was able to do the work more rapidly and more efficiently, and his hands remained warmer than when he was wearing standard handwear. With the lightweight insulated gloves he was able to work continuously without a break for as long as 4½ hours by donning the lightweight arctic mittens over the

gloves when his hands became uncomfortably cold, or when the work being done did not require a high level of dexterity.

(e) The Programmer Test Station (PTS) and the Power Station (PS)

The PTS and the PS are mounted on another XM474 Tracked Vehicle, facing the road side with the PTS at the bow and the PS control panel at the stern of the vehicle. The five-inch space between the PS and the PTS is too small for a man in full arctic clothing to efficiently connect the three cables which attach to the PTS at a distance of one foot from the corner of the PTS.

There is only just sufficient space in the PTS shelter for the operator and assistant operator. The shelter door is ordinarily kept



Fig. 3. Programmer Test Station Interior

closed in order to keep the equipment and instruments at suitable operating temperature. After a relatively short time in the shelter, it becomes necessary for the operators to remove their outer garments, and there is no suitable space in the shelter for stowing them "out of the way." The relatively large number (15-25) of closely spaced cable connections on the front of the PTS would create a difficult dexterity problem if it should become necessary to disconnect one or a small number of the more centrally located cables.

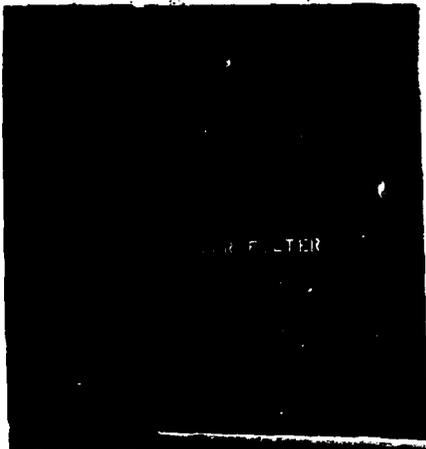


Fig. 4. The latches are hard to operate with arctic handwear

The access door latches on the Power Station are very difficult to grasp with arctic mittens. In addition, each latch requires three full turns for fastening or unfastening. Latches which are more compatible with arctic handgear are available and should be substituted for the ones now used. Also, the number of different replacement parts required would be reduced if the fewest possible types of latches were used with the system.

(f) Communications Central

In marked contrast with the PTS, the communications central affords ample room for the operator with sufficient space for the stowage of removed outer garments. However, no special facilities are available for protecting the clothing. The panel latches (round, push type) used with this pack can be operated quite easily with arctic mittens.

A large inflatable radio antenna is mounted on the roof of the communications central. Access to the roof is by means of a ladder. Clearance is adequate for arctic boots and the ladder rungs are knurled to reduce the possibility of slipping. The 10KW generator fits into the communications shelter when it is being transported and a door closes over it for protection. A container is to be provided for spare parts and tools. However, it was not available during the test.

(g) Warhead Carrier

An XM474 vehicle transports the warhead in a container whose top half serves as the warhead sling. The lower half serves as the pallet for the warhead unit. The buckles on the warhead sling straps were difficult to operate with arctic mittens. The davit kit (hoist mechanism) is also mounted on the warhead carrier, and the azimuth laying equipment is stowed on this carrier in a container secured by catches which are easily operated with arctic mittens.

(h) The XM474 Tracked Vehicle

The XM474 Tracked Vehicle is equipped with a winterization kit which protects the driver from the wind and cold. The driver's station, although limited in size, is adequate for a large man wearing arctic clothing. No serious incompatibilities involving the man dressed in arctic clothing were observed in the operation of the vehicle. All the controls were operable with arctic mittens and arctic

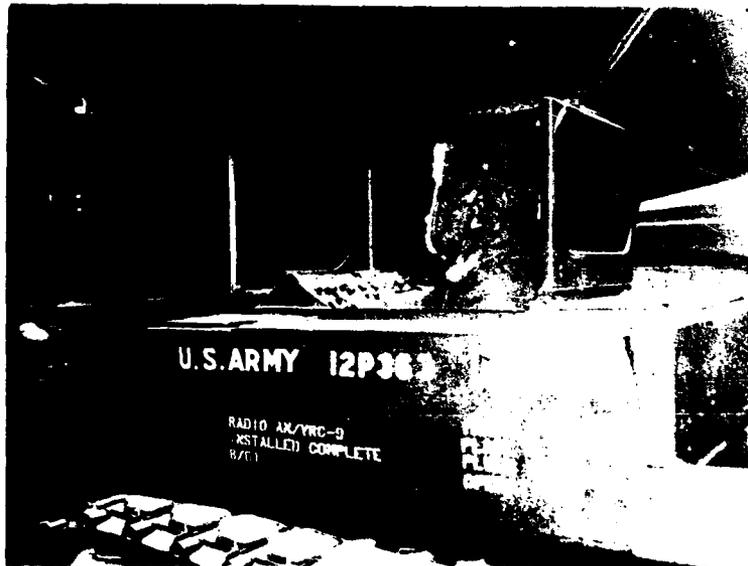


Fig. 5. Driver's station in the XM474 Tracked Vehicle

headgear did not interfere with observation of the displays. However, it is possible that the winter hood with fur ruff may interfere somewhat with the driver's view to either side when the vehicle is in motion. As the XM474 vehicles were stationary during nearly all the test there was little opportunity to evaluate this point. For this reason, it should be carefully checked during cold weather field tests of the system.



Fig. 6. Gas tank cap is difficult to grasp with arctic handgear

A minor incompatibility was observed between the bail on the vehicle gas tank cap and the arctic mittens. When the bail is down in contact with the cap, it is difficult to grasp with arctic mittens. Even though the bail can be grasped by gloves, it would appear desirable to modify it so that the middle of the bail will extend beyond the edge of the cap sufficiently to be lifted up for grasping with arctic mittens. No other incompatibilities were observed between the arctic clothed man and this vehicle.

(i) Azimuth Laying Equipment

Earlier studies at -25° F. by Martin Company engineers had demonstrated that the fine leveling screws and focusing sleeve of the theodolite froze up and became inoperable after approximately 30 minutes, and that contraction of the tripod and theodolite made it impossible to keep the latter level during this period of time. In order to eliminate these difficulties and others involving the theodolite, theodolite control box, theodolite operator, encoder, north-seeking gyro, and related gear, the azimuth laying equipment was placed in a heated air supported maintenance tent. Use of the heated tent avoided the incompatibility problems involving the arctic clothing of the operator.

The latches of the storage containers for the azimuth laying equipment can be operated easily even when arctic mittens are worn.

(j) Air supported maintenance tent

The Tent, Maintenance, Multipurpose, Air Supported,

Sectionalized T61-1, developed by the U. S. Army QMR&E Command, was erected next to the EL. During the test it was kept inflated by the blower and ducting supplied with it, and was warmed by a Corps of Engineers 150,000 BTU per hour heater. The tent, which proved to be a very satisfactory addition to the PERSHING system, was erected quickly and easily at -25° F. and remained up during the -45° F. period, except for being deflated and re-erected once when the blower power supply was interrupted. It remained up during 10 days of the -65° F. period, was then deflated, rolled up, moved, unrolled, returned to its original position, and re-inflated, all at -65° F. Except for one broken zipper, it was undamaged.



Fig. 7. Air Supported Maintenance Tent

The only human factors problems were the lack of a definite set of written instructions for erecting and striking the tent and the lack of a definite decision concerning provisions for stowing and transporting it with the system equipment. Although Martin Company personnel at Orlando, Florida had been instructed in the proper erecting procedures under arctic conditions, and had been forwarded printed instructional material, neither the instructions nor the personnel who had received the training were present when the tent was first erected at the Eglin AFB Climatic Laboratory.

Lack of knowledge of the correct erecting procedure easily could have resulted in the "breaking of the tent's back." If erected without the three cables which hold the opposite ends of the arch at the proper distance from each other the strain on the fabric will not be distributed properly during inflation. Provisions should be made to insure that the cables remain with the tent, and that clear instructions for erecting be packed with it in a location where they will be found without difficulty and available for use when needed. Otherwise, it is possible that serious damage may result from faulty erection techniques.

(2) Helicopter mode

(a) Missile and missile container

Comments are the same as for the ground mobile mode.

(b) Erector Launcher

In the helicopter mode the EL has its own set of rubber-tired wheels for mobility. The EL is removed from the XM474 vehicle by means of two ramps which are stored on the XM474. A cable winch controls the descent of the EL as it is lowered down the ramps. Once the EL is removed from the XM474 it must be towed to any new location. No new or additional human factors problems were observed during the helicopter mode.

(c) Programmer Test Station

Four rack bar jacks are used to raise the PTS above the XM474 and then to lower it after the XM474 has been removed. This is a slow procedure which requires close synchronization of activities by the four jack operators. If any one of the operators works faster or more slowly than the others, his jack will bind and prevent lowering of the PTS until the latter is again leveled. After the PTS has been lowered part way, the mobilizers (small wheels) are attached, and then lowering is continued until the entire weight is supported on the mobilizers. No difficulties with handgear were observed during these operations.

There were no incompatibilities with either the Standard or Integrated clothing and no human factors problems were noted other than the one mentioned in the preceding paragraph.

The remote firing panel, which is stowed in the PTS, presented no human factors problems.

(d) Power Station

The PS is removed from the XM474 vehicle in the same manner as the PTS by means of the same equipment.

(e) Communication Central

The communication central is removed from its vehicle in the same way that the PTS and the PS are removed from theirs.

(f) Missile dollies

Missile sections are supported on dollies while the

sections are being spliced together. No comment can be made concerning human factors problems as there was no opportunity to observe the splicing of sections of the missile in the helicopter mode because this operation was performed at night without prior scheduling.

(g) Warhead unit dolly with sling and pallet

This equipment was not observed in use.

(h) Horizontal Laying Equipment and container

The theodolite and control box and north-seeking gyro and control box are stowed in one container, which can be opened easily with arctic mittens. If the air supported shelter is used with the helicopter mode no problems of compatibility with the QMC-clothed arctic soldier are to be expected. If the tent is not available, it is believed that horizontal laying equipment will not operate successfully at low temperatures.

(3) Auxiliary equipment

(a) Distribution van

Latches on the distribution van air filter, purification pack and other doors were similar to those on the access doors of the power station (Fig. 4) and were equally difficult to operate with arctic mittens. As the air filter door is the access door to the dip stick of the compressor, which must be checked each time before the compressor is started, and as the air purification door must be opened periodically (after 5 hours of operation) to change air filters, it is desirable that these latches be readily opened by the mittened hand. These problems were identical for ground mobile and helicopter modes of operation.

(b) Diesel power units

The only human factors problem observed was the poor location of a gas cap chain which hung in the way when the cap was being removed or replaced.

(c) Truck M-53 and davit kit

Only one human factors problem was observed in connection with this item. Adjustment screws for chassis leveling were too close to the fenders for efficient operation, even with bare hands.

The problem increased when bulkier handgear was worn.

(d) Crane

An Air Force crane was substituted for an Army crane to load the missile sections on the EL. Since the crane was not a standard part of the equipment, no comments concerning its operation are included in this report.

c. Possible utility of electrically heated gloves with the PERSHING System

During observations of the PERSHING system, no regular operations were observed which could not be performed with standard Army handgear, and probably performed somewhat more easily with the Lightweight Insulated Gloves. Nevertheless, system personnel were of the opinion that one or two pairs of electrically heated gloves would be useful for and would materially cut down on the time required to do "trouble shooting" and maintenance work on system equipment. The value of such gloves would be particularly large if continuous work requiring a high level of dexterity should be necessary over a period of several hours.*

4. Conclusions

a. There are relatively few serious incompatibilities between the operator who is wearing standard arctic clothing and the equipment of the system. However, the incompatibilities mentioned here should be remedied if the engineering costs are not prohibitive.

b. Limited use of the new Integrated Clothing suggests that it is lighter, less bulky, less encumbering, permits somewhat greater mobility, is at least equally warm, is more comfortable, and furnishes greater dexterity and hand protection against cold over long periods of relatively continuous use than does the Standard Cold-Dry Ensemble.

c. The air supported maintenance tent contributed materially to the effectiveness of the system under dry-cold conditions.

* New experimental two-circuit electrically heated glove liners are now available which furnish twice the heat furnished by those previously used. This is accomplished without increasing the temperature of the individual wire heating elements which are woven into the liners. Several pairs of these new glove liners are being procured for use during future cold weather tests of missile systems.

d. One or two sets of electrically heated handwear for use during field maintenance and repairs should be a valuable addition to the equipment of the system.