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VEHICLE WINTERIZATION HEATING KITS WITH INTERMITTENT COMBUSTION HEATERS

FINAL REPORT

By

Robert P. McGowan
Mobility Branch

February 1974

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U. S. ARMY LAND WARFARE LABORATORY

Aberdeen Proving Ground, Maryland 21005

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Winterization heating kits were developed for three military tactical wheeled vehicles. The heater used is commercially available from a foreign manufacturer. The heater is an intermittent combustion type, while current standard U.S. Army heating kits utilize continuous combustion heaters. One basic heater is used with several different heat exchangers for all vehicle heating requirements. The heater is also capable of portable self-contained operation. The heater requires no electric power when operating. Tests were conducted in a cold chamber, and in Alaska. The tests showed that the heater (OVER)

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ABSTRACT (CONT'D)

and heating kits are capable of satisfying arctic vehicle heating requirements, including quick preheating, and standby heating. The heaters proved to be more reliable in operation than heaters in current use, and required less maintenance.

PREFACE

This development task was conducted by the Mobility Branch of the U.S. Army Land Warfare Laboratory during the period July 1970 to September 1972.

Mr. R. P. McGowan was the Project Engineer. Engineering design and drafting support was provided by the Technical Support Division, Design Branch, under the supervision of Mr. C. K. Ramsdell, by Messrs J. J. Mike, G. Merrill, and B. J. Andrews.

Cold chamber and over-the-road tests were conducted by the USATECOM Materiel Testing Directorate, Automotive Division, Wheeled Vehicle Branch, under the supervision of L. S. Weaver. Mr. G. J. Norquay was the Test Engineer.

Arctic testing was conducted by the U.S. Army Arctic Test Center, Fort Greely, Alaska, during the FY72 and FY73 winter seasons. CPT W. T. Moorer was the Test Officer; SP5 A. W. Yoder and SP4 N. P. Springer were Test Engineers.

Upon initiation of the development, vehicle heating problems and requirements were discussed in detail with personnel of the Alaskan Army Command Headquarters - primarily with Mr. William Pitts of the Combat Development Office, and Mr. Richard Gunther of the Maintenance Division. Both provided needed guidance. These requirements were also discussed with the heater manufacturer, the Eberspacher Co. of Esslingen, West Germany, who provided information and suggestions for application of the heaters.

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INTRODUCTION

The current standard vehicular winterization kits use heaters which have not fully met the requirements for quick preheating, standby heating, and reliability. The practice has been to purchase heaters from a Qualified Products List under Federal Specifications for personnel and powerplant (coolant) heaters. Thus, heaters of several different types, sizes, and manufacture are in the system. These heaters are continuous combustion type heaters, and typically require 190 to 240 watts of electric power during operation. This prevents their use for standby heating for extended pweriods of time because of vehicle battery drain. Also, these heaters are attached to the vehicle and cannot be used for portable operation, e.g., for thawing frozen vehicle drive-line components. In addition, users have reported unsatisfactory reliability.

Because of this background, a task was initiated and vehicle winterization kits were developed and tested for three military vehicles. The approach taken in this development was to incorporate a heater which has a different operating principal and different characteristics than current standard heaters. The vehicles were selected as being typical of military vehicle heating requirements. The heater was selected because of the following characteristics:

a. One standard heater can be used in any of several heat exchangers for all vehicular heating requirements. Therefore, only one model heater is required in the supply system.

b. Once started, the heater operates without any electric power requirements. The exhaust gas-stream has sufficient mechanical energy to form heating units which possess their own thermic flow without any outside energy. Therefore, the vehicles may be kept warm for extended periods -- ready for instant starting -- because there is no vehicle battery drain.

c. The heater detaches from the heat exchangers by means of a quick-acting clamp. This permits the heater to be operated as a portable hot-air blower. No electric power is required, and the heater has an integral gasoline tank. In the portable mode, the heater is used to thaw frozen vehicular drive-line components, pipes, valves, etc., and to preheat portable equipment such as generators and air compressors.

d. The heaters had been reported to be reliable in operation and easy to maintain.

DESCRIPTION

HEATER

The heater is commercially available and is manufactured in West Germany. The heater is fully self-contained for operation, including a fuel tank for 3 to 4 hours operation. The basic heater unit is shown in Figure 1. External battery power is required only for starting -- 150 watts for 15 to 180 seconds, depending on the ambient temperature. The combustion is intermittent, occurring approximately 90 times per second. Succeeding ignitions are caused by residual hot particles remaining in the combustion chamber. Fuel flow is maintained by pressure bleed from the combustion chamber over-pressure. The heater may be used alone; or, by means of a quick-acting clamp, connected to any of several heat exchangers for various heating requirements. The heater is noisy (but not deafening) when operated alone, but is effectively muffled when connected to the heat exchangers. For continuous operation, a special fuel cap is furnished for connection to the vehicle fuel tank or an auxiliary fuel tank. Fuel flow may be either by gravity or electric pump, as required. A safety valve is available which will shut off fuel flow in the event of a broken fuel line. Other characteristics are as follows:

Weight, empty	25 lbs.
Length	36 inches
Output	20-40,000 BTU/hr
Fuel	Gasoline
Fuel Tank	1.05 Gallon
Fuel Consumption	0.18-0.42 Gallon/hr
Voltage	24 V DC
Electric Power Requirement (Starting)	150 Watts (1/4 to 3 minutes)
Electric Power Requirement (Running)	None

HEAT EXCHANGERS

Turboheater - The Turboheater is a warm-air blower. The heated fresh air is conveyed by a blower which is driven by the exhaust gas-stream of the heater unit. The heater exhaust pipe is inserted into the Turboheater and fastened by means of a coupling ring and clamp as shown in Figure 2. No electric power is required. A complete separation of exhaust gas and fresh heated air is maintained within the unit.

WATERBOX

The waterbox consists of a double mantle pipe with a coupling ring for the heater unit, and connections for liquid to circulate through the mantle by thermosyphon action (see Figure 3). The exhaust gas escapes through an exhaust line, and can be further used for heating, e.g., the vehicle crankcase.

IMMERSION EXCHANGER

The Immersion Exchanger is a single-wall mantle with a coupling ring for the heater unit, and a flange for mounting to a counter-flange of a liquid container. The exhaust gas

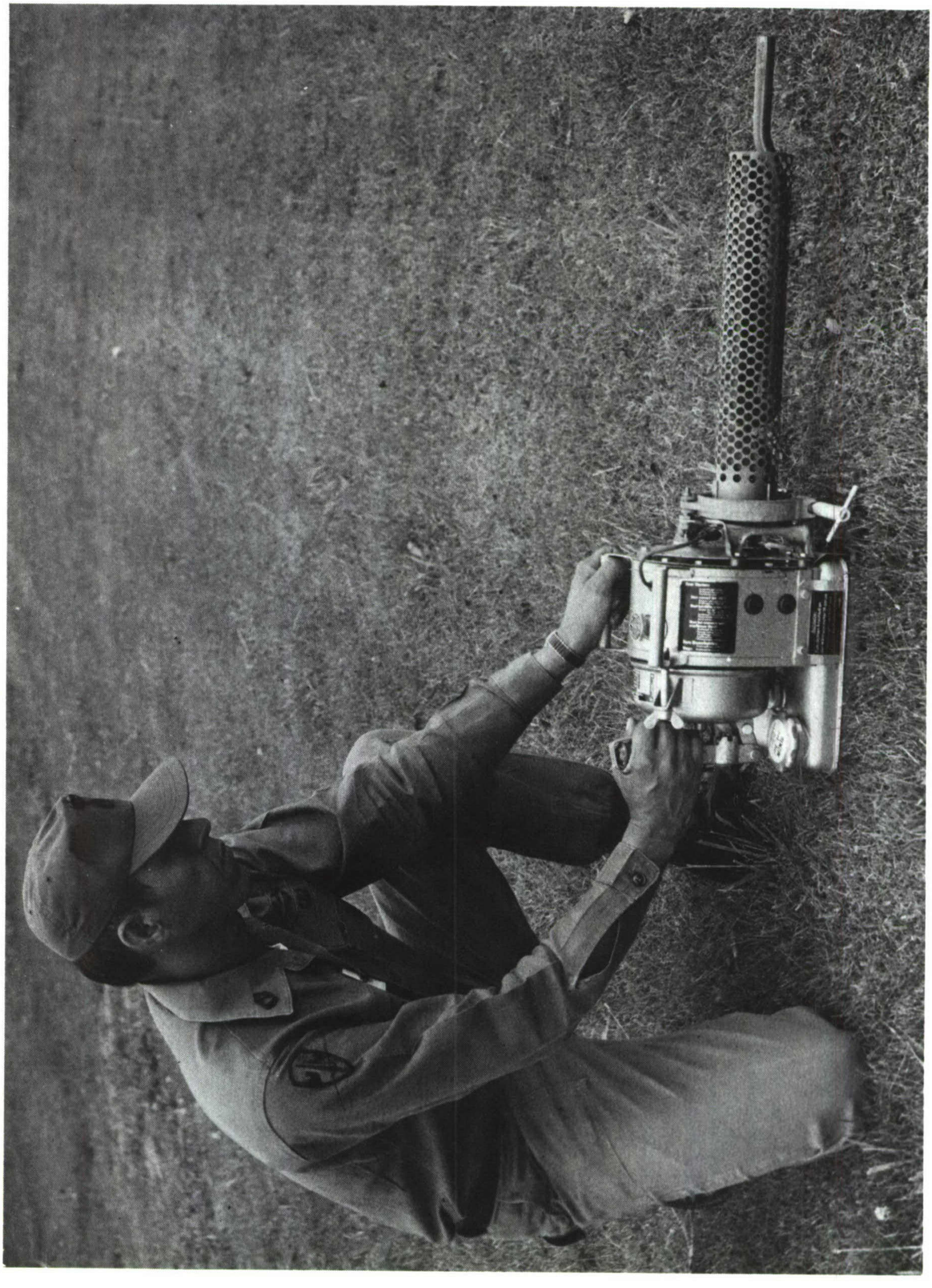

FIGURE NO. 1: Basic Self-Contained Heater Unit

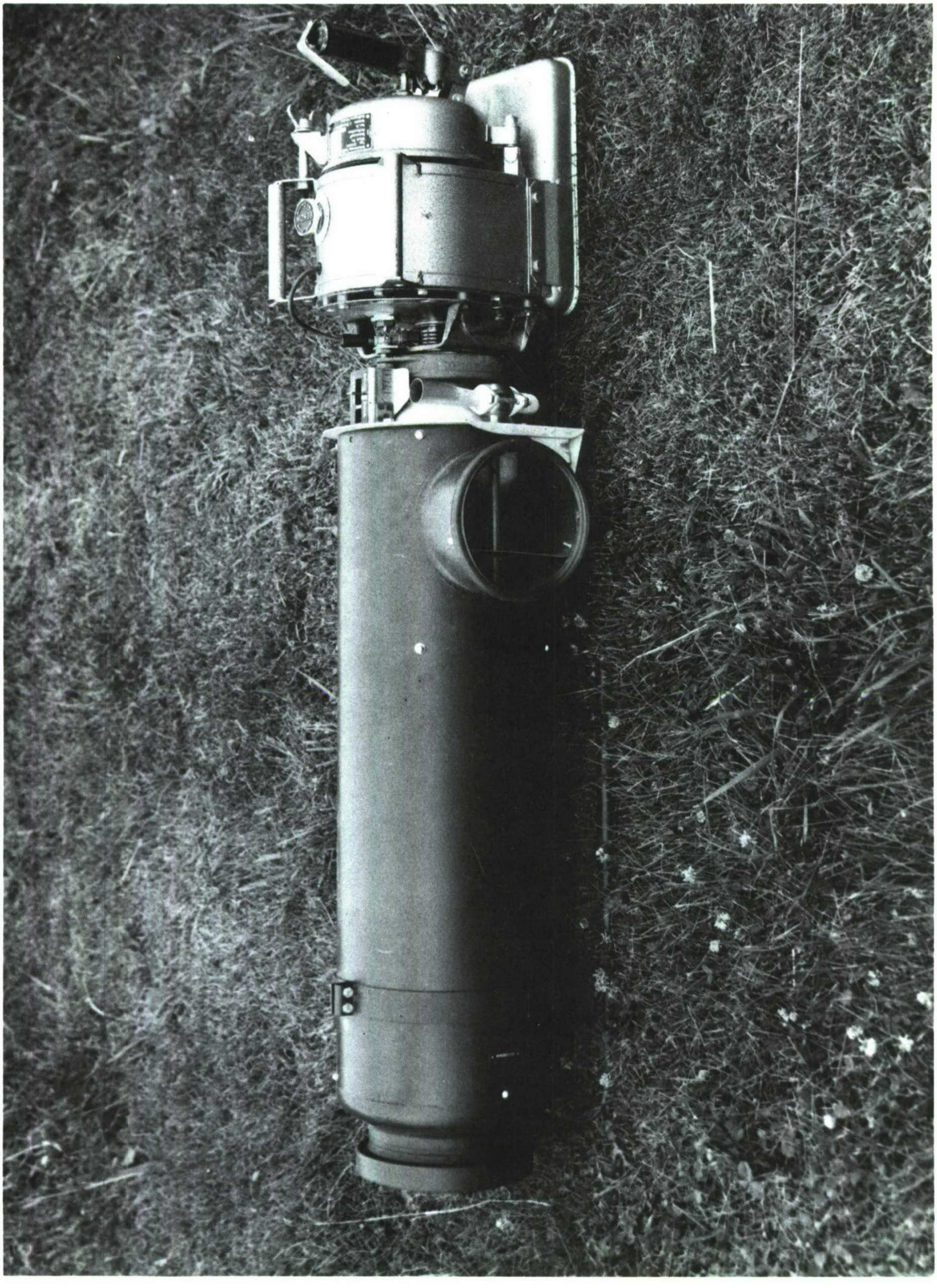

FIGURE NO. 2: Basic Heater Attached to Turboheater

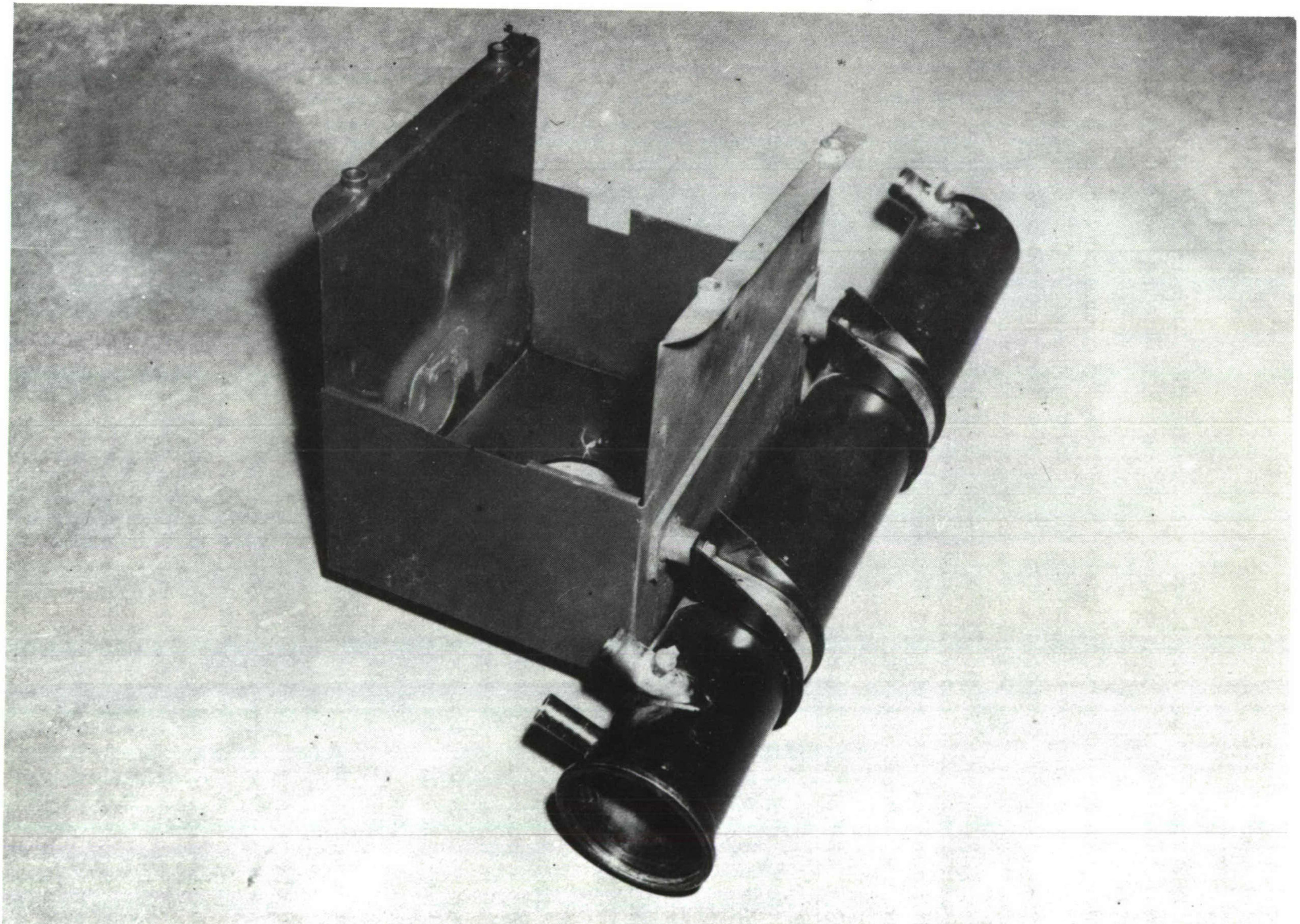

FIGURE NO. 3: Waterbox Installed on M35A2 Oilpan Shroud escapes through an exhaust line and can be further used to heat valves, pipes, etc.

MIXING PIPE

The Mixing Pipe is a lightweight sheetmetal casing with a coupling ring for the heater unit as shown in Figure 4. It is designed to efficiently utilize the heat output of the heater unit when it is used as a portable hot-air blower. Fresh air is drawn into the casing through an annular injection nozzle, flows along the combustion chamber and exhaust pipe, then mixes with and is expelled with the exhaust gas at 300-350°C. It is used to heat frozen vehicular components, e.g., brake shoes and clutch, and to preheat engine compartments and portable equipment such as generators or compressors. Preferably, the machinery to be heated should be enclosed in a compartment or covered with a tarpaulin. The heater can be used in a similar fashion without the Mixing Pipe, but the Mixing Pipe recovers more heat from the heater, increases the volume of air-flow, and reduces the temperature of the exhaust gas.

VEHICLE WINTERIZATION HEATING KITS

The winterization kits are designed for use in areas where the normal temperatures during the coldest part of the year are -25°F or lower.

M35A2, 2-1/2 Ton Cargo Truck

This kit performs in three modes of operation: Quick-preheating, standby heating, and heating during operation of the vehicle.

In the quick-preheating mode, two heaters are used. See Figure 5. One is installed in a waterbox mounted next to the engine oil pan and heats the engine coolant by convective circulation through the Waterbox as shown in Figure 3. The vehicle is never mobile with the heater installed in this location. The exhaust gas is piped to the oil pan shroud to heat the engine oil. The second heater for quick preheating is installed in a warm-air turboheater located on the vehicle fender. The warm-air is circulated into the battery box and thence to the vehicle cab. The exhaust gas of this heater is also piped to the oil pan shroud by means of the flexible metal hose shown in Figure 5.

For standby heating (maintaining the heat with the engine not running) one heater is used. It is installed in the warm-air turboheater on the vehicle left fender. See Figure 6. Warm air is circulated to the vehicle cab, battery box, and to the engine compartment, as shown in Figures 7, 8, and 9. The exhaust gas is piped to the oil pan shroud (the metal hose is not shown connected in Figure 6).

For heating during vehicle operation, one heater is also used, installed in the warm-air turboheater on the vehicle left fender. See Figure 6. The air is ducted to the vehicle cab, to the battery box, and to the windshield defrosters. See Figures 7, 8, and 9. If the vehicle is equipped with an arctic truck-body enclosure, a second turboheater is installed to heat this area. See Figures 10 and 11. This also provides a stowage location for the second heater used for quick-preheating. A hot-air Mixing Pipe is furnished, and

FIGURE NO. 4: Heater with Mixing Pipe

FIGURE NO. 5: Heating Kit, M35A2 Truck. Quick Preheating Operation

FIGURE NO. 6: Heating Kit, M35A2 Truck. Standby or Mobile Operation

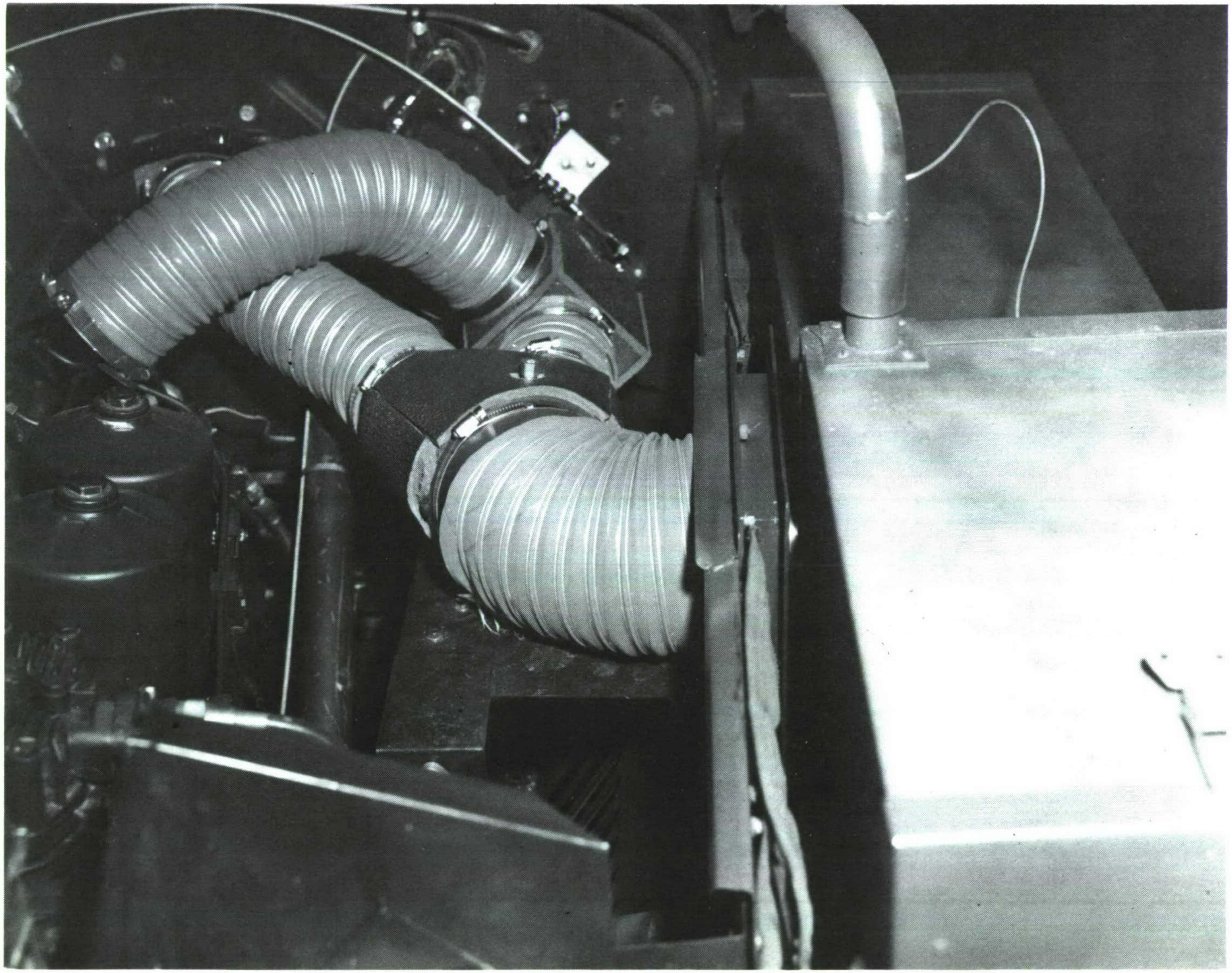

FIGURE NO. 7: M35A2 Truck. Air Distribution Ducts

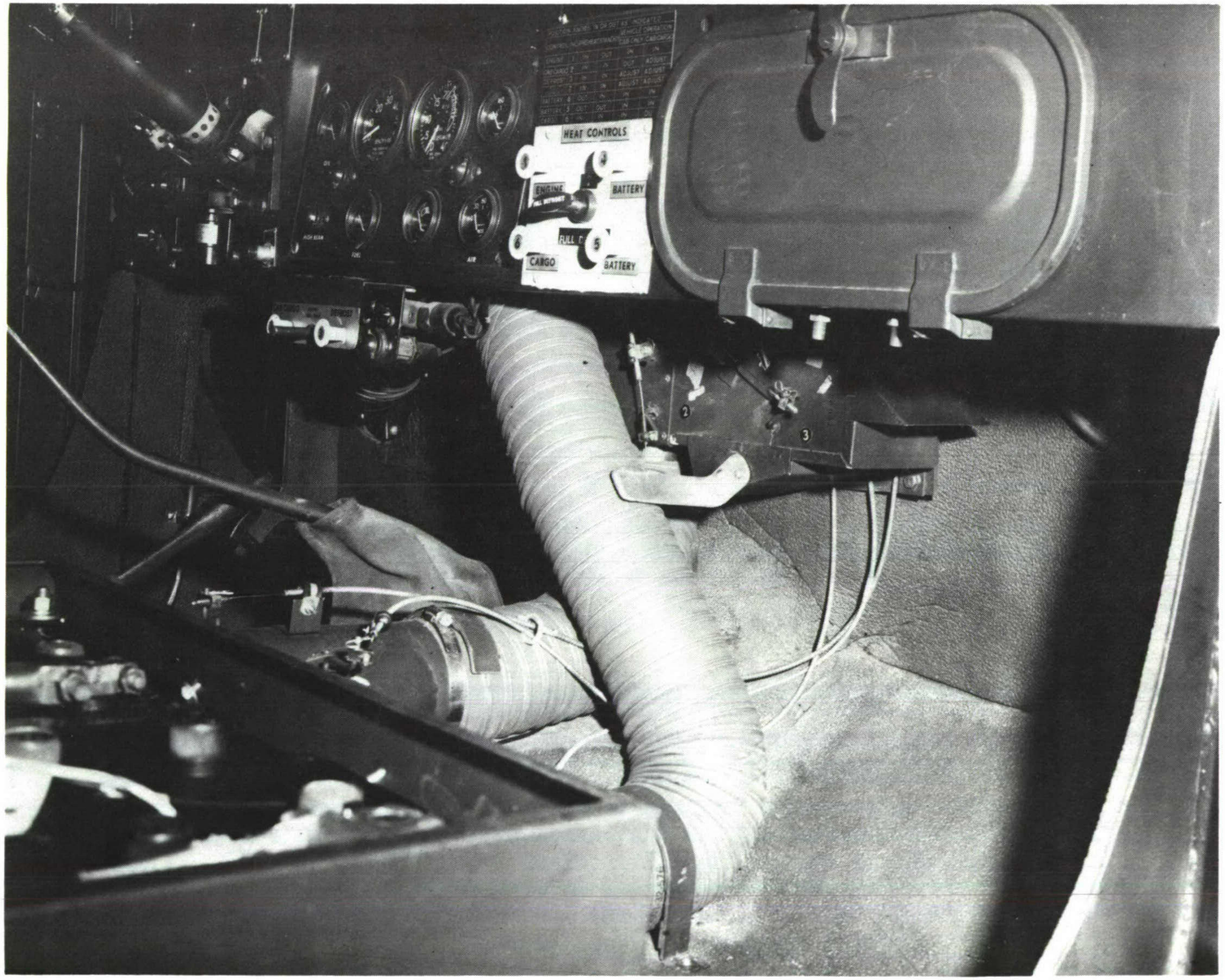

FIGURE NO. 8: M35A2 Truck. Air Distribution Ducts

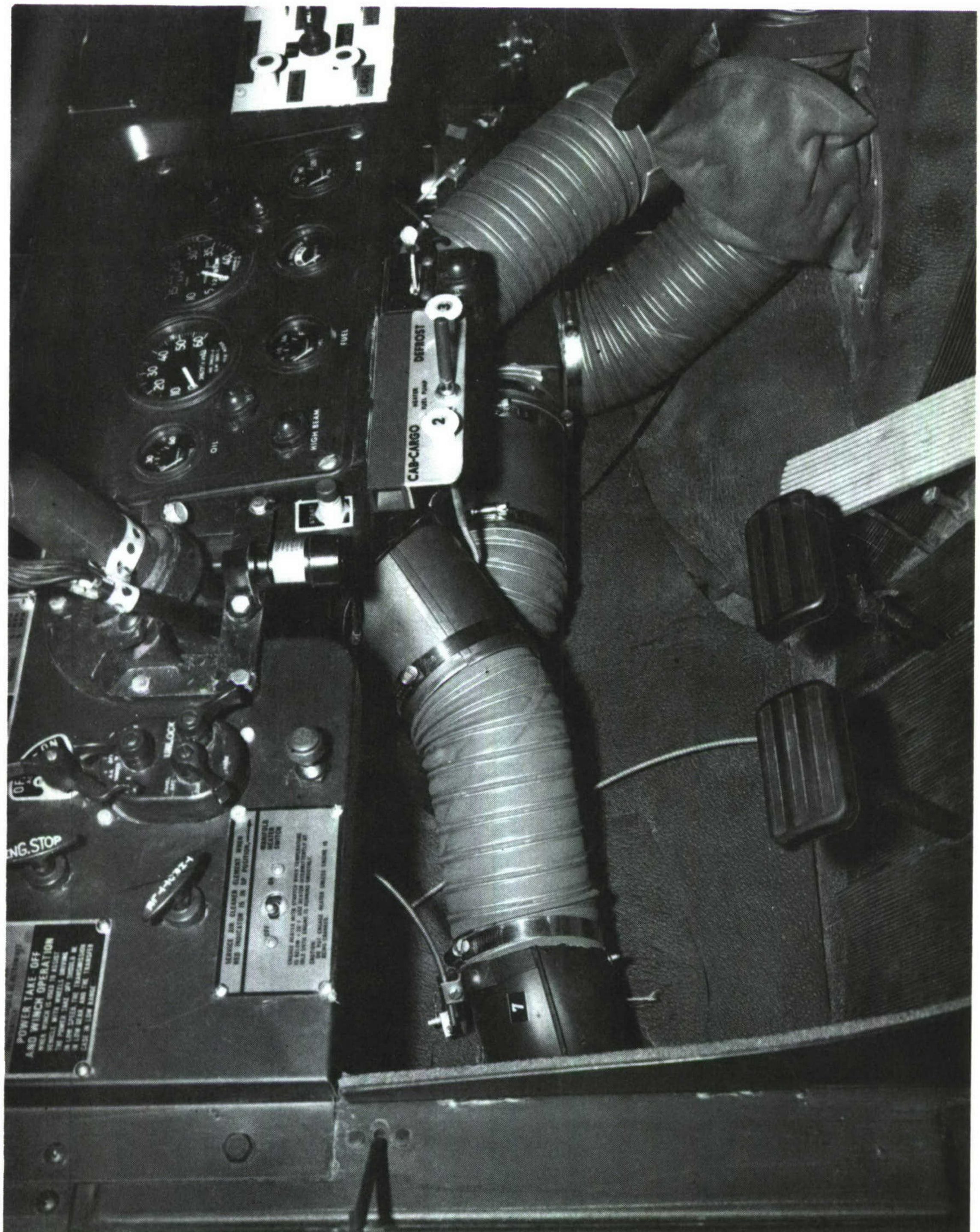

FIGURE NO. 9: M35A2 Truck. Air Distribution Ducts

FIGURE NO. 10: Heater Installation for Arctic Truck Body Enclosure

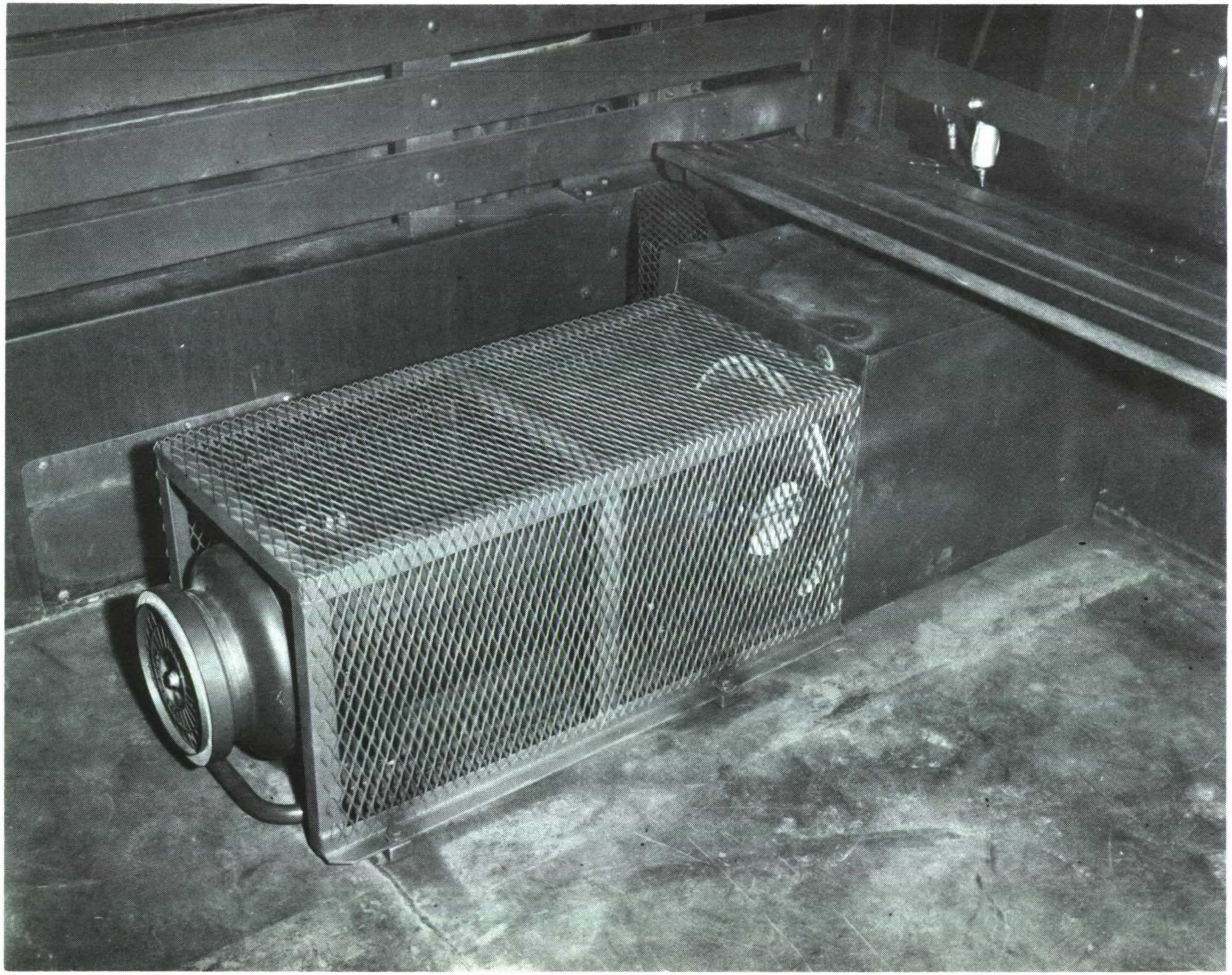

FIGURE NO. 11: Heater Installation for Arctic Truck Body Enclosure is stowed on the right side of the vehicle in the battery compartment underneath the cab. See Figure 12. This permits the heater to be used as a portable utility hot-air blower. See Figure 4. For quick-preheating or portable operation, the heater is operated with fuel from its integral fuel tank. For standby or over-the-road operation, a fuel line connects to an electric pump and an auxiliary 5-gallon fuel tank.

Warm-air is distributed and controlled by ducts and manual controls. See Figures 7, 8, and 9. After initial testing in the arctic, an electric booster fan was provided to improve defrosting and heat distribution when the vehicle is operating over-the-road, as shown in Figure 13.

M151A2, 1/4-Ton Utility Truck (Jeep)

This kit performs in three modes of operation: Quick-preheating, standby heating, and heating during operation of the vehicle. One heater installed in a turboheater is used for all modes of operation. See Figure 14. Warm-air is distributed and controlled by ducts and manual controls to the personnel cab, defrosters, battery box and engine compartment. See Figures 15 and 16. For preheating, the exhaust gas is ducted to an oil pan shroud, as shown in Figure 17. The fuel line is connected to the vehicle gas tank, and an electric pump provides continuous operation, but may be quickly disconnected for portable operation of the heater. After initial arctic testing, an electric booster fan was provided to improve defrosting. The fan is located within the Inside-Outside Air Control Box, shown in Figure 18.

M149A1 400-Gallon Water Trailer (Fiberglass)

The kit is for use in areas where the temperatures are consistently below freezing. One heater and Immersion Exchanger are used. A hole is cut into the forward end of the trailer and a flange installed for mounting the Immersion Exchanger, which extends into the interior of the tank. The exhaust gas from the Immersion Exchanger is used to thaw the shut-off valve, external pipes, and the faucets on one side of the trailer. See Figures 19 and 20. For starting power, the heater starting cable is wired into the trailer lighting circuit; also, a jumper cable may be used. Since heater operation is only required for an hour or two each day, the integral fuel tank of the heater is adequate, and an auxiliary fuel tank is not needed. The heater may also be used to maintain hot water or hot drinks, or to melt ice or snow added to the trailer tank.

DESIGN REQUIREMENTS

M35 and M151 Vehicles

The principal design requirements were stated by the Alaskan Command and are summarizes as follows:

a. Provide preheating for starting from a $-65^{\circ}F$ cold-soaked condition after 45 minutes of heat application.

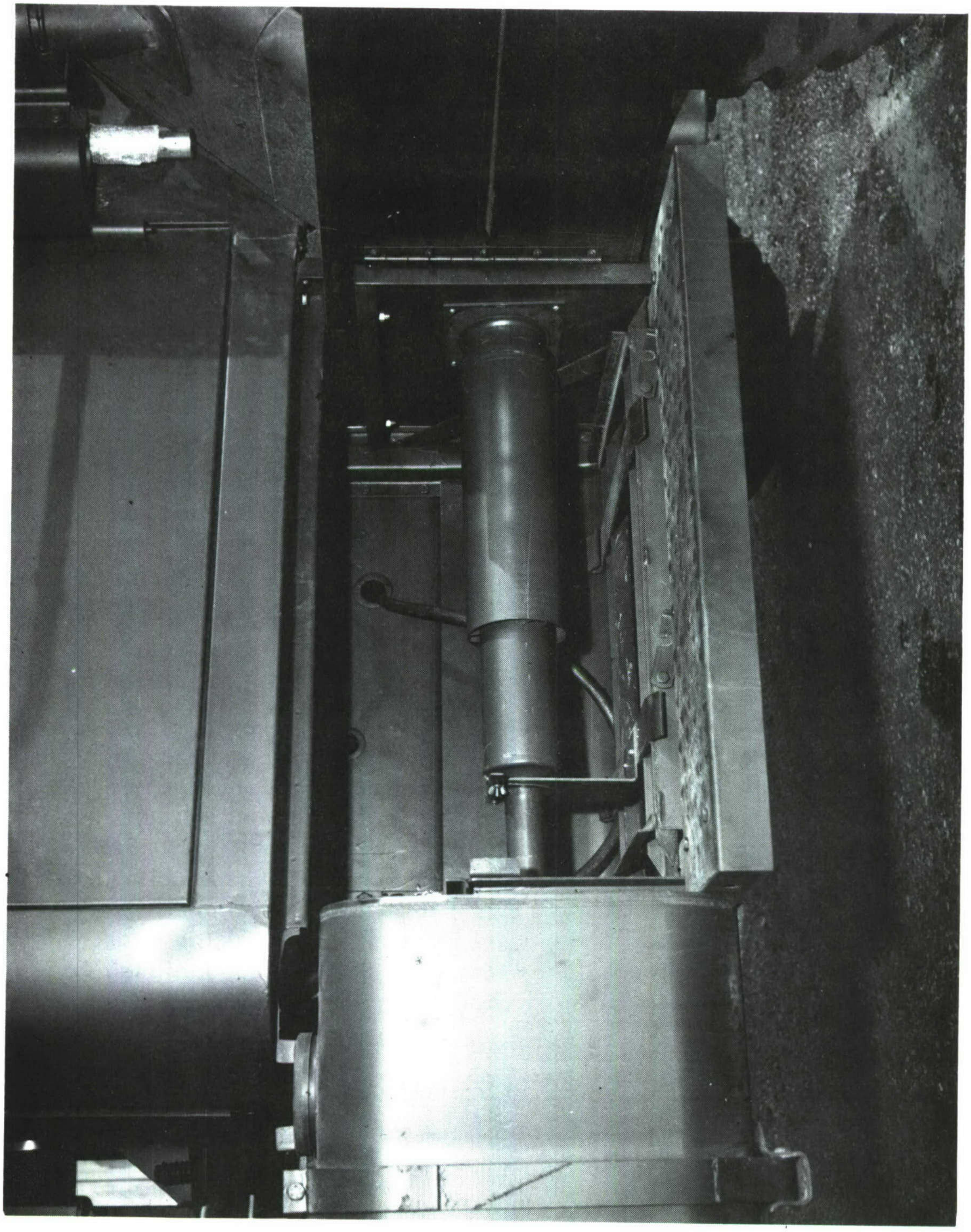

FIGURE NO. 12: M35A2 Truck. Mixing Pipe Stowage

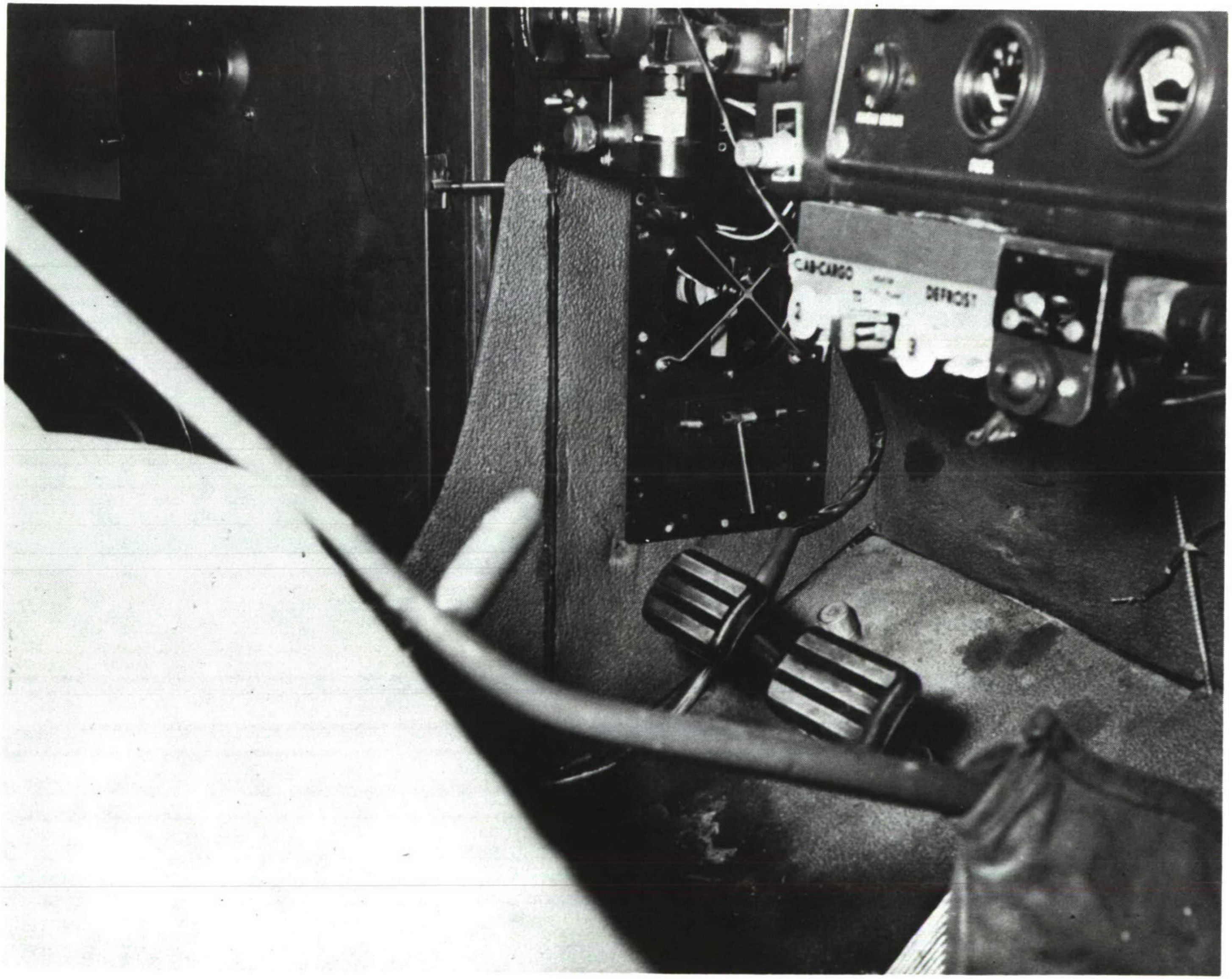

FIGURE NO. 13: M35A2 Truck. Booster Fan, Air Return

FIGURE NO. 14: Heating Kit, M151A2 Jeep

FIGURE NO. 15: M151A2 Jeep, Air Distribution Ducts and Controls

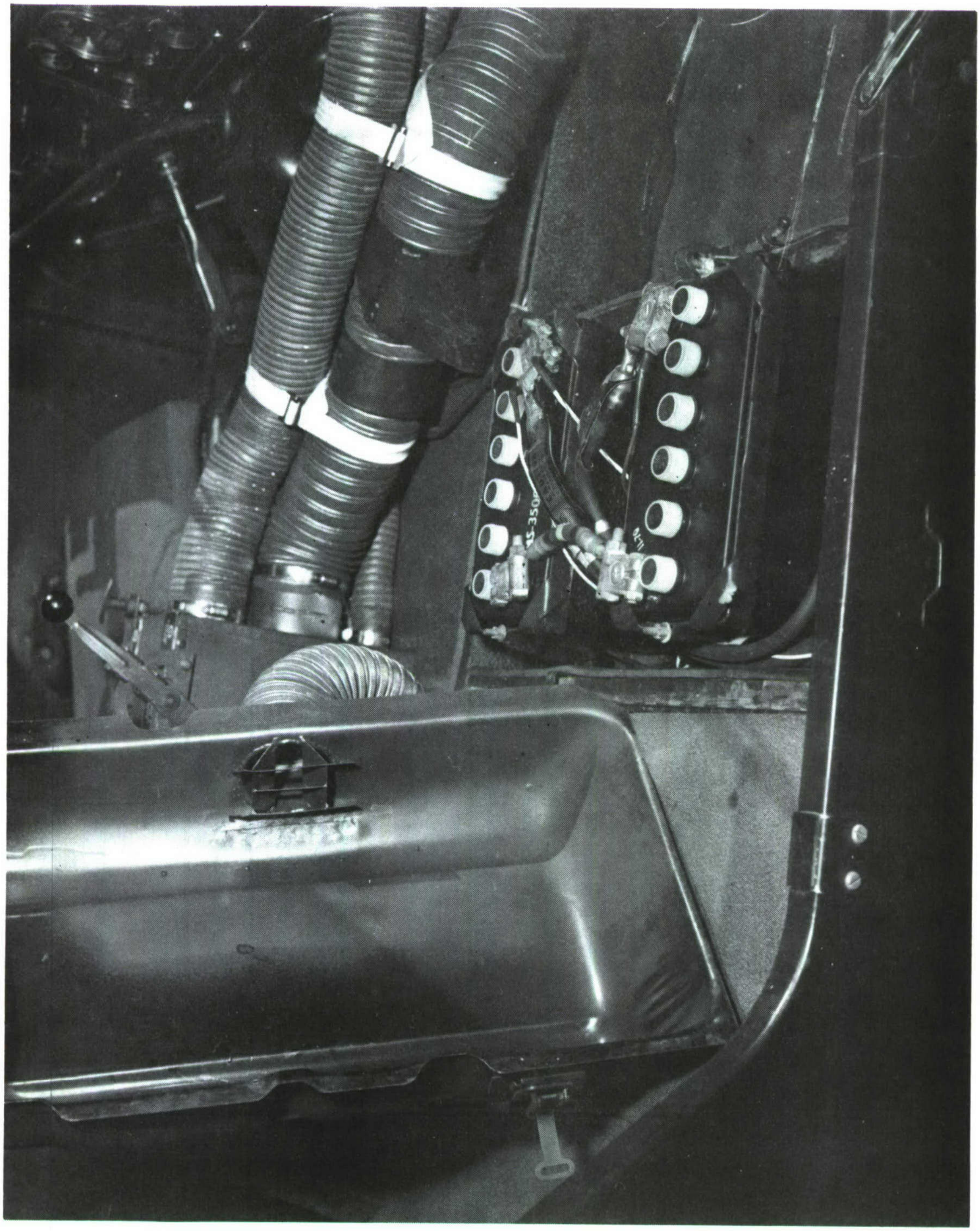

FIGURE NO. 16: M151A2 Jeep, Air Distribution Ducts and Battery Box

FIGURE NO. 17: Heating Kit, M151A2 Jeep, Quick-Preheating or Standby Heating

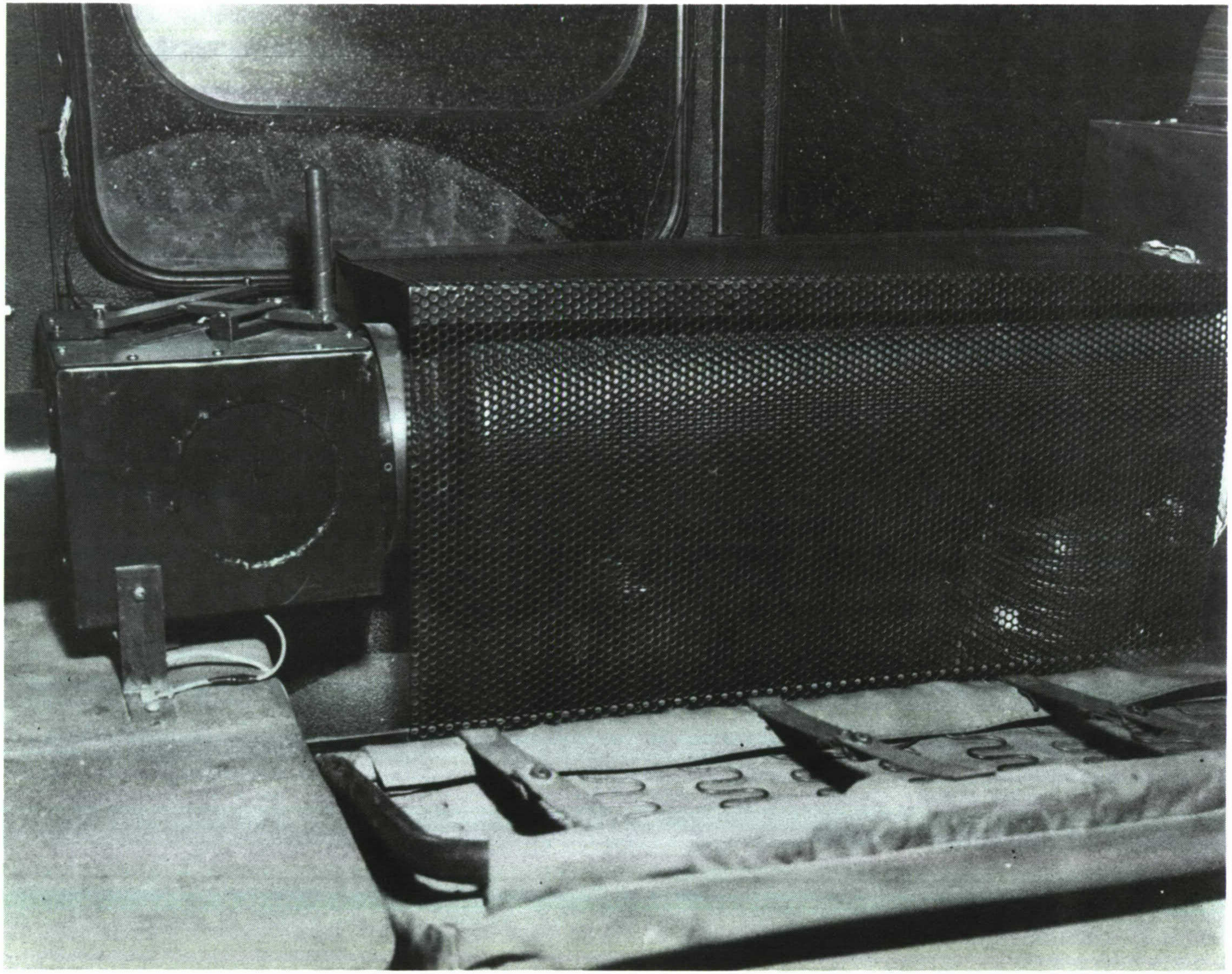

FIGURE NO. 18: M151A2 Jeep, Turboheater and Inside-Outside Air Control Box

FIGURE NO. 19: Heating Kit, M149A1 Water Trailer

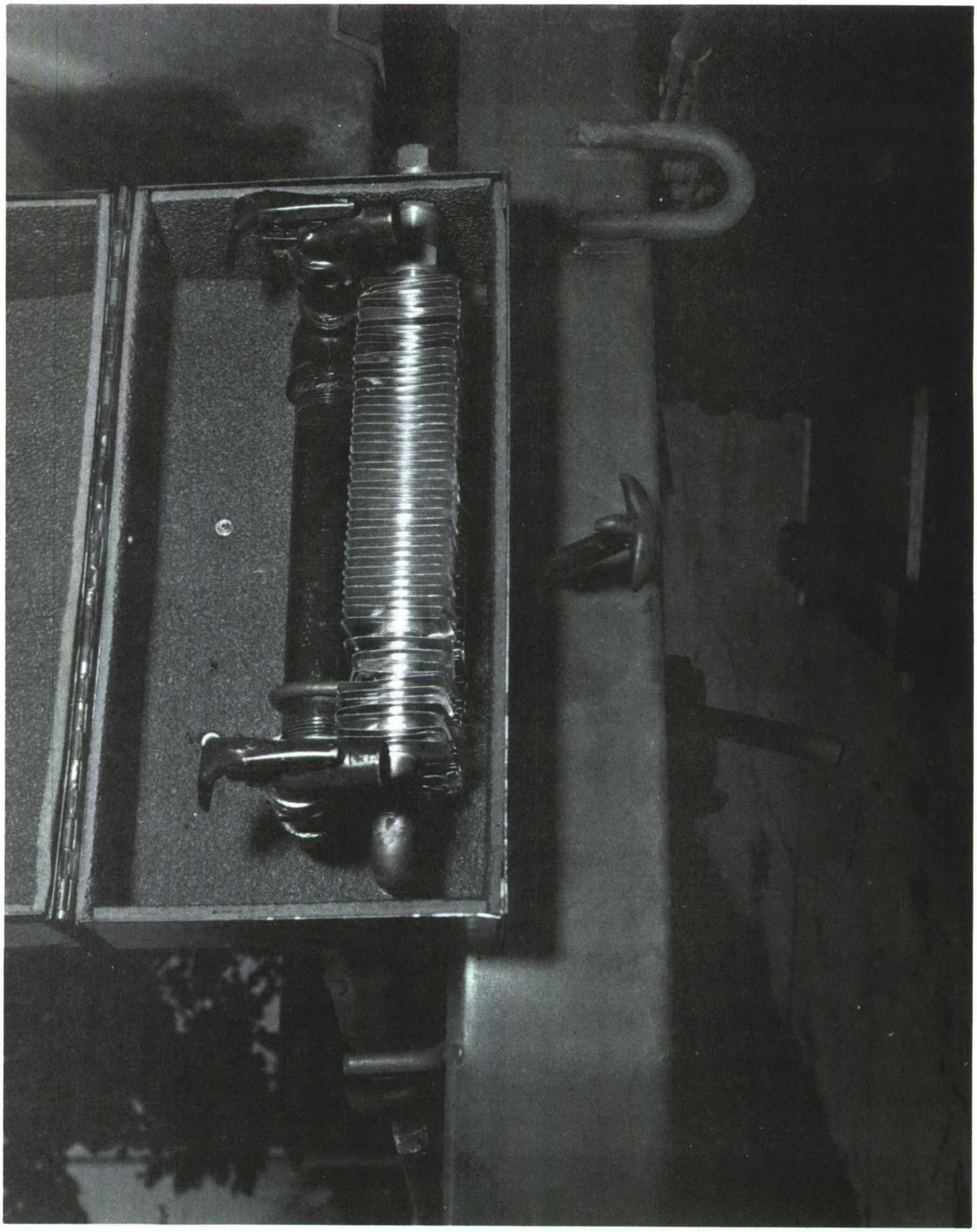

FIGURE NO. 20: M149A1 Water Trailer, Exhaust Gas Heating of Faucets

b. Provide standby heating (maintaining the vehicle heated for instant starting) at -65°F for a 24-hour period without battery drain.

c. Maintain a temperature of 45°F in the crew and passenger/cargo compartments (with winterized enclosures) at -65°F.

d. Clear and maintain the windshields 75 to 100 percent free of frost.

e. The heater must be quickly detachable from the vehicle, and operate as a portable, hand-held, self-contained hot-air blower without external fuel or electrical connectors.

f. Operate for 500 hours without unscheduled maintenance above the organizational level.

Water Trailer

The Water Trailer heating kit requirement is to maintain the water above the freezing point, and to thaw the external valves, pipes, and faucets when ambient temperatures are down to -65°F. Secondary requirements are to heat and maintain hot water, and to melt ice or snow.

DEVELOPMENT AND TEST

As a first step in the development, a visit was made to the Alaskan Army Command Headquarters to discuss vehicle heating problems and requirements. A requirements statement was drafted, and later formally submitted by the Alaskan Command.

Heater kit installations were designed for the M151A2 and M35A2 trucks and for the M149A1 Water Trailer. These kits are described in the Description section of this report.

For the trucks, the standard winterization hard-top enclosures were installed on the vehicles. The test heater kit installation required no modification to the M35A2 hard-top enclosure. The enclosure for the M151A2 was modified to install the heater enclosure as shown in Figure 14. These standard enclosures are not tight fitting, and the air leaks make uniform heating and defrosting difficult. This is especially true for the 2 1/2-ton M35A2 truck. In this vehicle the windows are not contained in a channel around the sides and top, such that lateral looseness of the glass results in as much as a 1/2-inch crack along the top edge of the glass.

Battery preheating was recognized as being critically important for self-contained starting capability under arctic cold conditions. The cranking capability of lead-acid batteries is reduced by 75 percent at -40°F, and is negligible at -65°F[1].

[1] TM 9-6140-200-15, Storage Batteries, Lead-Acid Type.

The standard heating kit for the M35A2 heats the vehicle batteries (which are placed in the vehicle cab underneath the assistant driver's seat) by means of a pad placed underneath the batteries. Engine coolant is circulated through the pad by convection. This produces no measurable battery temperature rise during one-hour preheating with the engine coolant heater, and is intended only to warm the batteries during vehicle operation so that they will accept a charge. Consequently, the practice has been to slave the battery for starting in cold conditions, or to heat the batteries by removing them from the vehicle. The standard heating kit for the M151A2 vehicle had been designed to distribute heated air into an enclosed battery compartment, and this was more successful in preheating the battery.

In order to achieve self-contained starting capability, the kit developed for the M35A2 was designed to duct the entire hot-air output from one heater through the battery compartment during preheating. Also, the battery box was designed so that the heated air would flow over all six sides of the battery. The kit developed for the M151A2 was similarly designed, except some of the heat was also ducted to the engine compartment during preheating.

It was recognized that the battery terminals provided the best heat path into the battery. To increase this flow, copper fins were braised to the battery terminal connectors. Later, after completion of the testing, a design was made for cast finned connectors, and a sample quantity was cast as prototypes for future production, as shown in Figure 21.

Inlet and outlets, for convective flow of coolant through the M35A2 engine block, were selected at the highest and lowest locations respectively as possible. Developmental tests were conducted with two different outlets. The inlet selected is an existing threaded (normally plugged) hole on top of the water pump housing, as shown in Figure 22. The outlets selected are on the same side of the block, near the bottom and to the rear of the engine pressure regulator. Two holes (one existing and one added to an existing boss) were manifolded together to minimize flow resistance, also as shown in Figure 22. The alternate outlet tested was on the opposite side of the engine block. A hole and fitting were added to the bottom of the oil cooler housing. Slightly higher block temperatures were obtained with the flow path selected, as shown in Figure 23, and also required less modification to the vehicle.

The three vehicles with heater kits installed were operated over paved, secondary and cross-country roads at Aberdeen Proving Ground as a shakedown test. The only failure was a four-inch crack, starting from one of the forward mounting holes of the heater enclosure on the M35A2 truck. This was remedied by placing a strap across both mounting holes to distribute the load. This proved satisfactory during 3000 miles of subsequent operation at the Arctic Test Center.

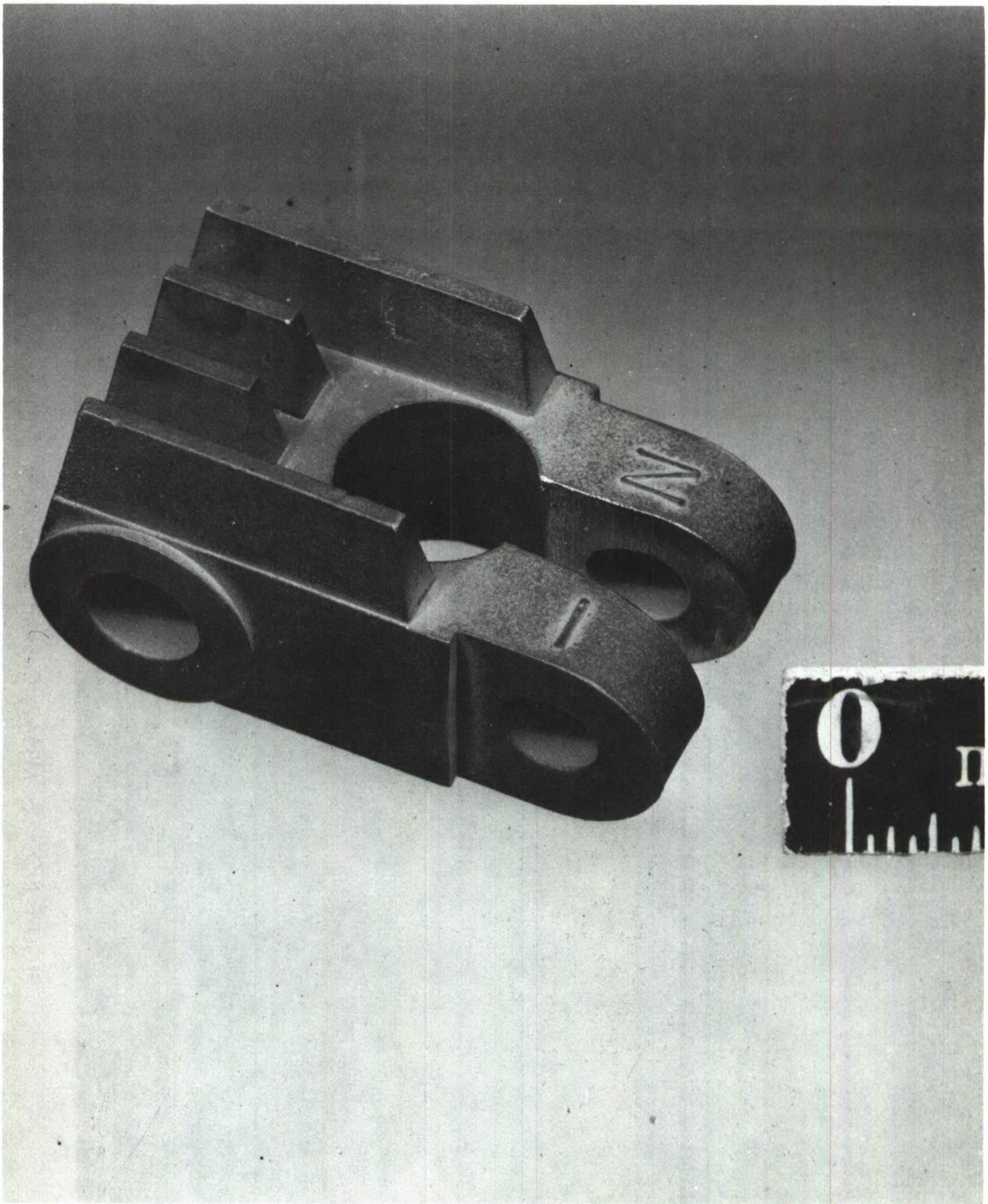

FIGURE NO. 21: Finned Copper Battery Terminal Connectors

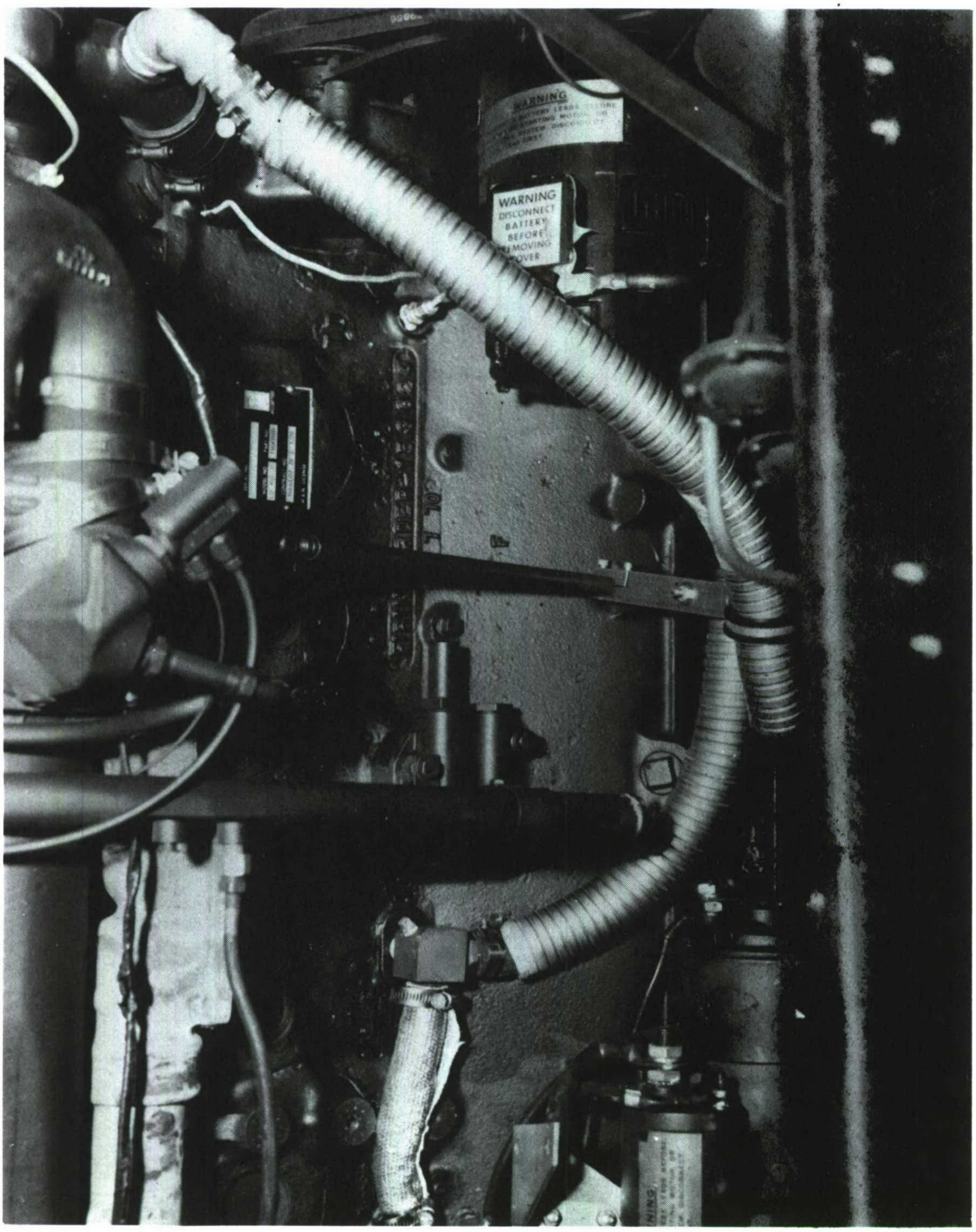

FIGURE NO. 22: M35A2, Coolant Connections for Preheating

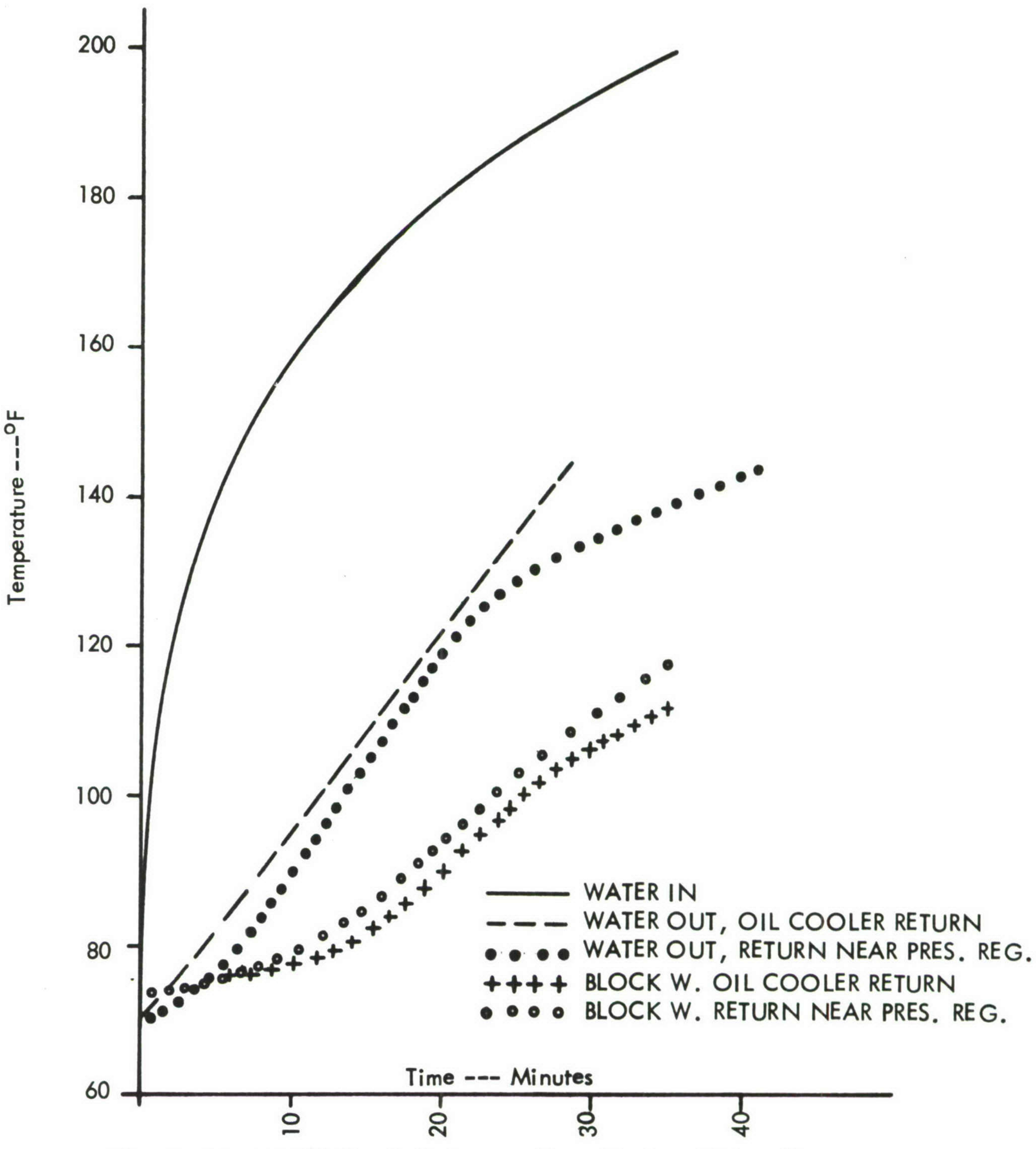

FIGURE NO. 23: M35A2 Quick-Preheating Test, Block and Water Temperatures

Cold Chamber Tests were conducted at Aberdeen Proving Ground at -65°F ambient temperature[2]. As a result of these tests, design changes were made to improve heat distribution and to correct deficiencies.

Tests were conducted at the Arctic Test Center during the FY72 and FY73 winters[3,4]. These results are summarized as follows:

Starting After Preheat

Successful cold starts were made after one-hour preheating at ambient temperatures down to -57°F. Cold starts were made after 45 minutes preheating at ambient temperatures down to -49°F. (These temperatures were not lower limits, but were the lowest ambient temperatures which occurred during tests.) The temperature changes recorded at the end of the preheating period are shown in Table 1.

TABLE 1 - Summary of Temperature Rise After Preheating

Vehicle	M151A2		M35A2	
Time of Preheat, Hrs.	3/4	1	3/4	1
Number of Tests	7	11	10	4
	Average Temperature Rise, °F			
Battery Electrolyte	46	49	23	39
Engine Oil Sump	80	-	135	-
Engine Oil Gallery	31	44	57	91

NOTE: Battery temperature is average of two cells.
Ambient temperature range, -22 to -57°F.
Average ambient temperature, -41°F.

Successful cold starts were made in every test where the batteries were 60% or more charged. Cranking times for the M151A2 varied from 11 to 122 seconds, averaging 43 seconds. These cranking times do not correlate with the temperature, but were apparently related to the condition of the vehicle. The cranking times for the M35 varied from 0.9 to 16.8 seconds, averaging 3.2 seconds.

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[2] G. J. Norquay, Vehicle Heaters, Military Potential Test, USA Test and Evaluation Command, Aberdeen Proving Ground, Oct 71.

[3] W. T. Moorer, Vehicle Heaters, Military Potential Test Under Arctic Winter Conditions, USA Test and Evaluation Command, Arctic Test Center, 24 May 72.

[4] Military Potential Test of Improved Vehicle Heaters, Letter Report, USA Test and Evaluation Command, Arctic Test Center, 11 Apr 73.

Battery electrolyte temperature rise varied considerably from test to test, apparently due to the positioning of the thermocouple in the electrolyte, or other test variables. The values shown in Table 1 are averages of all tests, including tests with finned and with standard battery connectors. A series of 3 preheating tests on the M151 with finned connectors in comparison with 8 tests with standard connectors, both test series conducted during the FY72 season, resulted in temperature rises of 67°F and 43°F respectively -- a clear advantage for the finned connectors. However, a similar comparison of M35 test series conducted in succeeding seasons - the only comparison possible from the data - shows approximately the same temperature rise. Therefore, the data does not clearly establish that the finned connectors increase the rate of heat transfer into the batteries.

Standby Heating

Five standby heating tests were conducted for each vehicle for periods of 16 to 24 hours. The M35 truck uses only one of its heaters for standby heating. The ambient temperatures ranged from -30°F to -42°F. At the end of these preheating periods, all starting attempts were successful. The data recorded during these tests is reproduced in Tables 2 and 3. The absence of battery drain during standby heating was a distinct advantage in favor of the test heater; e.g., standby tests conducted at the Arctic Test Center during the FY72 season, using a 15,000 BTU fuel-fired standard ordnance type coolant heater, and a coolant pump, on the M792 1 1/4-ton Ambulance, resulted in a 4% charge depletion rate per hour for the two 2HN batteries. Assuming a 75 percent initial charge, the vehicle could not be expected to start after 18 hours of standby operation. On the other hand, a vehicle equipped with the test heater could be maintained in standby for an indefinite period[3].

Personnel Heating and Defrosting

Personnel heating and defrosting tests were conducted in both stationary and mobile modes of operation. There were some shortcomings in heat distribution and regulation. While this can be partially attributed to the poor fit of the arctic hardtop enclosures, careful design of the warm-air ducting and controls could undoubtedly provide some improvement.

After the FY72 testing season, the air distribution systems were modified by the addition of an electric booster fan - primarily to improve defrosting, but also to improve air distribution for personnel heating. The Turboheater will only operate at peak airflow output against 1/4-inch of water or less system back-pressure. The electric fan compensated for system back-pressure, and increased airflow by approximately 50%. The fans were only used when the vehicles were running, not for standby heating operation when the battery drain would be detrimental.

Summary data is reproduced in Tables 4, 5, and 6. The electric fan did result in higher temperatures in the personnel spaces (Tables 4 & 5), but did not improve defrosting (Table 6). However, the distribution of heat still produced unconfortable differences in temperatures. The drivers' feet areas were too cold, especially for mobile operation. Also, since the M35 did not have a "Fresh Air - Recirculate" control, the assistant driver's head area was uncomfortably warm.

Why the increased airflow did not improve defrosting is not clear.

TABLE 2 - M151A2 Truck Standby Engineering Cold Starts

Average Ambient Air Temp For Standby Period (°F)	Ambient Air Temp Prior to Engine Start (°F)	Length of Heating (hrs)	Engine Oil Gallery Temp (°F) Before Heating*	Engine Oil Gallery Temp (°F) After Heating	Battery Temp (°F) Before L	Battery Temp (°F) Before R	Battery Temp (°F) After L	Battery Temp (°F) After R	Battery Percent Charge Before Heating L	Battery Percent Charge Before Heating R	Did Vehicle Start With Batteries?	Number of Attempts Cranking Time (sec)
-39	-38	16	115	77	82	86	74	71	100	90	Yes	1/1.1
-42	-45	18	126	77	91	89	57	54	100	100	Yes	1/2.8
-30	-19	20	122	57	68	66	54	51	100	100	Yes	1/1.5
-38	-36	22	55	86	84	91	68	67	75	85	Yes	1/4.1
-38	-37	24	NR	66	NR	NR	68	68	50	65	Yes	1/16.1

NR - Not Recorded.

*Standby tests were started immediately after preheating; hence, the high initial temperatures.

TABLE 3 - M35A2 Truck Standby Engineering Cold Starts

Average Ambient Air Temp For Standby Period (°F)	Ambient Air Temp Prior to Engine Start (°F)	Length of Heating (hrs)	Engine Oil Gallery Temp (°F) Before Heating*	Engine Oil Gallery Temp (°F) After Heating	Battery Temp (°F) Before L	Battery Temp (°F) Before R	Battery Temp (°F) After L	Battery Temp (°F) After R	Battery % Charge Before Heat L	Battery % Charge Before Heat R	Vehicle Start	Number of Attempts Cranking Time (sec)
-39	-38	16	157	68	33	30	24	26	70	100	Yes	1/0.9
-42	-45	18	166	79	42	31	18	19	80	75	Yes	1/0.8
-30	-19	20	166	89	27	19	19	20	90	90	Yes	1/1.0
-38	-36	22	157	75	48	47	19	22	90	90	Yes	1/1.3
-38	-37	24	160	67	24	22	19	19	80	80	Yes	1/1.1

*Standby tests were started immediately after preheating; hence, the high initial temperatures.

TABLE 4 - Summary of M151A2 Truck Personnel Heating with Air Booster Fan (FY73) and without Air Booster Fan (FY72)

STATIONARY TESTS

Average Temperatures After 1 Hour (^{o}F)

Thermocouple/ Temperature Locations	FY73, w/Fan				FY72, w/o Fan	
	Fresh Air		Recirculated Air		Recirculated Air	
	Driver's	Asst Driver's	Driver's	Asst Driver's	Driver's	Asst Driver's
Head Level	66	69	96	95	82	82
Hand Level	61	75	84	94	59	79
Foot Level	56	69	71	88	48	94
Defrost Outlet	92	95	163	167	127	124
Heater Outlet	147		263		317	
Ambient Temp	-21		-36		-38	
No. of Trials	5		7		6	

MOBILE TESTS

Average Temperatures After 1 Hour (^{o}F)

Thermocouple/ Temperature Locations	FY73, w/Fan				FY72, w/o Fan	
	Fresh Air		Recirculated Air		Recirculated Air	
	Driver's	Asst Driver's	Driver's	Asst Driver's	Driver's	Asst Driver's
Head Level	60	65	69	75	67	66
Hand Level	56	64	56	69	46	56
Foot Level	35	68	46	86	30	55
Defrost Outlet	95	111	109	129	77	84
Heater Outlet	172		217		270	
Ambient Temp	-22		-29		-41	
No. of Trials	3		7		6	

TABLE 5 - Summary of M35A2 Truck Personnel Cab Heating with Air Booster Fan (FY73) and without Air Booster Fan (FY72)

STATIONARY TESTS

Average Temperatures After 1 Hour (^{o}F)

	FY73, w/Fan Recirculated Air		FY72, w/o Fan Recirculated Air	
	Driver's	Asst Driver's	Driver's	Asst Driver's
Head Level	70	99	57	75
Hand Level	80	98	65	76
Foot Level	40	67	25	46
Defrost Outlet	101	113	105	125
Heater Outlet	220		218	
Ambient Temp	-27		-39	
No. of Trials	11		6	

MOBILE TESTS

Average Temperatures After 1 Hour (^{o}F)

	FY73, w/Fan Recirculated Air		FY72, w/o Fan Recirculated Air	
	Driver's	Asst Driver's	Driver's	Asst Driver's
Head Level	54	73	34	56
Hand Level	57	71	41	57
Foot Level	34	56	15	40
Defrost Outlet	89	107	76	98
Heater Outlet	183		198	
Ambient Temp	-27		-39	
No. of Trials	11		6	

TABLE 6 - Summary of Defroster Tests with Air Booster Fan (FY73) and without Air Booster Fan (FY72). Heat Controls Set for Maximum Defrost

M151A2 TRUCK

	Averaged Data FY73	FY72
Time Required to Clear 75% of Windshield (Minutes)	27	27
Time Required to Clear 100% of Windshield (Minutes)	45	43
Ambient Temperature (^{o}F)	-20	-23
No. of Trials	6	3

M35A2 TRUCK

	Averaged Data FY73	FY72
Time Required to Clear 75% of Windshield (Minutes)	29	23
Time Required to Clear 100% of Windshield (Minutes)	49	41
Ambient Temperature (^{o}F)	-27	-24
No. of Trials	10	3

Note: During all tests, the assistant driver's windshield area was clear of frost 7 to 10 minutes earlier than the driver's windshield area.

FY72 tests without booster fan; FY73 tests with booster fan.

The results of the heating tests - operating over-the-road - for the M35A2 Arctic Truck-Body Enclosure (Figures 8 & 9) are shown in Table 7.

Noise Level - Radio Interference

The heaters were not audible at the driver's or assistant driver's position when the vehicles were operating. The heaters did not produce any audible or electronic interference during radio transmissions or receptions. The sound level of the heater at the driver's and assistant driver's head level - engine off and vehicle stationary - averaged 74 decibels. The average noise level with the vehicles operating over-the-road, and with the heaters not operating, was 91.4 decibels.

Water Trailer

The filled water trailer remained outdoors for a 113-day period during the FY72 winter season. Ambient temperatures ranged from 38°F to -58°F, and averaged -20°F. The heater was operated once each 24-hour period. The average water temperature rise per hour of heater operation was 6°F. The average cooling rate per 24-hour period was 8°F. At temperatures ranging from -51°F to +18°F (average ambient of -28°F) the cut-off valve and spigots were thawed after 30 and 15 minutes respectively of heater operation. The results of developmental tests at APG, MD are shown in Figure 24.

Carbon Monoxide - Fumes

No disagreeable odors were reported by operators during the test. No significant levels of CO were detected during periods of vehicle operation. During engine preheating tests - when heater exhaust gases are used to heat the engine oil pans - levels from 18 to 41 ppm were detected in the personnel cabs. While below the safe level of 50 ppm (for an 8-hour period), this condition only lasts for the 45-minute preheating period. The manuals and decals provided warning against occupying the personnel cabs during engine preheating without ventilation.

Reliability and Maintenance

Six heaters were tested for a total operating time of 3084 hours during the FY72 winter season. A total of six failures occurred, all of which permitted continued operation of the heater. Four failures were of the push-button starter switch. Shorting the wires permitted starting of the heater. Two of the failures were hairline cracks in one of the leaf springs in the ignition vibrator coils. This appeared to affect functioning, but the vibrators worked upon test, and continued to function after excess carbon build-up was cleaned from the spark plug. (Note: The vibrator coil and spark plug function only during starting of the heater.)

32 Scheduled and 17 unscheduled maintenance actions were performed, requiring 12.2 and 19.1 man-hours, respectively. A total of 25 spare parts were utilized, consisting of 10 line items.

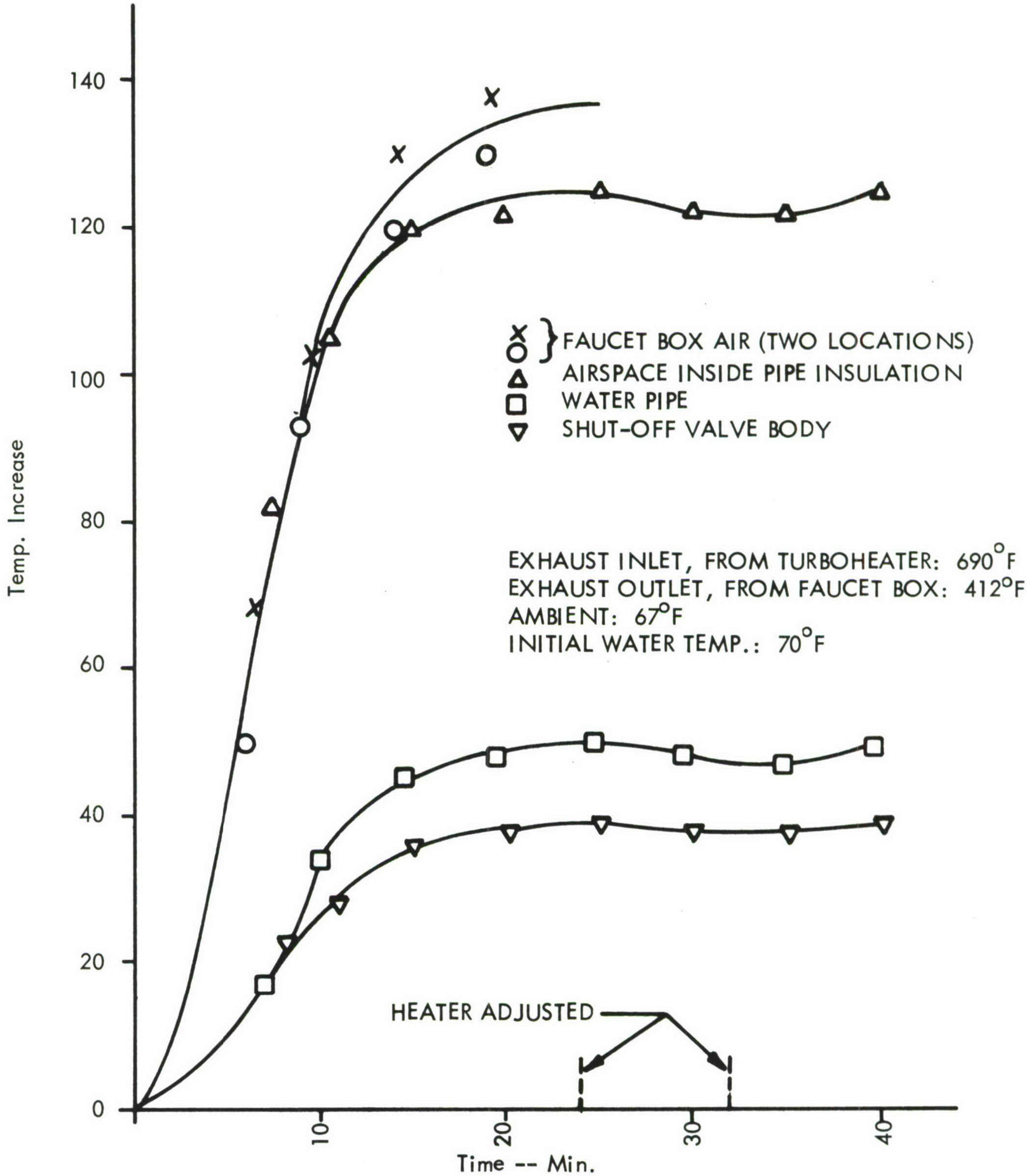

FIGURE NO. 24: Water Trailer. Test of Exhaust Heating of Pipes and Valves

TABLE 7 - M35A2 Truck, Truck Body Enclosure Heating Tests - Mobile

Thermocouple Position	16 Feb 72	17 Feb 72	18 Feb 72	19 Feb 72 0005	19 Feb 72 1030	20 Feb 72
Turbo Heater						
Inlet	39	38	51	48	73	50
Outlet	225	236	249	248	282	245
Head L. F.	51	44	58	37	71	45
Hand L. F.	34	41	41	43	70	48
Foot L. F.	23	34	29	24	58	41
Head R. F.	57	47	60	44	83	62
Hand R. F.	50	83	64	79	78	56
Foot R. F.	103	90	104	74	112	91
Head L. R.	50	60	57	63	85	67
Hand L. R.	47	50	54	59	82	63
Foot L. R.	27	26	27	37	59	42
Head R. R.	50	58	57	66	89	71
Hand R. R.	43	45	48	56	76	58
Foot R. R.	24	30	27	34	54	38
Center of Compartment	50	51	56	56	79	61
Ambient: Start	-48	-49	-39	-43	-33	-34
Aft 1 Hr	-48	-49	-39	-43	-18	-34

Note: The temperatures throughout the enclosure had not stabilized at the end of the 1-hour periods.

Portability

Use of the heater in a portable mode of heating was not part of the Test Plan. However, in the course of the testing, expedient use of the heaters for portable heating was made on nine occasions - for heating frozen transmissions, brakes, and fuel systems. When required for this purpose, a heater was simply removed from a vehicle-installed heat exchanger, and replaced when the portable heating requirement was satisfied.

In addition, in the few instances when a failure had occurred, or when maintenance was required, the heater could be removed for maintenance and/or replaced with another. Removal or replacement of a heater could be accomplished by personnel in arctic apparel in one-half minute.

DISCUSSION

Incomplete information has been received on the development and test of a multi-fuel version of the test heater by the manufacturer. Reportedly, the heater performed satisfactorily with both fuels (gasoline and winter diesel oil) at temperatures below freezing, but only on diesel oil at temperatures above freezing. At temperatures above freezing, vapor lock occurred due to the high combustion chamber temperature required to burn the diesel fuel.

Subsequent to the development and tests reported herein, project responsibility was transferred to the U.S. Army Tank Automotive Command. In response to requests by the U.S. Army Alaskan Command for an operational capability with the heaters and heating kits, TACOM tasked the vehicle production contractors to develop designs for production of the winterization heating kits. Information received from the M35A2 and M151A2 production contractors indicates that substantial improvements have been made in the producibility and performance of the kits.

CONCLUSIONS

The test heaters and winterization heating kits for the M151A2 and M35A2 vehicles meet the arctic requirements for:

- preheating and engine starting after cold soaked exposure and 45 minutes of heat application.

- standby heating of engine and personnel spaces without battery drain.

- portable operation.

The test heater, and winterization heating kit for the M149A1 400-Gallon Water Trailer, meet the arctic requirements for maintaining the trailer contents unfrozen, and for thawing the trailer's pipes and valves with 1 to 1 1/2 hours of heater operation per day. The heating kit may also be used to maintain the trailer contents hot, and to thaw ice and snow when added to the tank.

The test heater operated under arctic conditions with 500 hours mean time between failures; and a maintenance ratio (maintenance hours divided by operating hours) of 0.0101.

While personnel heating requirements were generally met, heat distribution for personnel heating and defrosting can be improved in a production design of the heating kits. However, optimum distribution of heat in personnel spaces cannot be achieved without improvements in the current standard vehicle hardtop enclosures to reduce air leakage.

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