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LABORATORIES DIVISION

CLIMATIC LABORATORY

Project Title: Test of Personnel Heaters, Gasoline Burning Type, for Military Vehicles

Report No. 3431 (Final) Date: 14 February 1956

Laboratory Work Order No. [illegible]
Project No. TT1-642

DETROIT ARSENAL

CENTER LINE, MICHIGAN

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Date: 14 February 1956

Prepared By: Max S. Koga

Initiation Date of Project: 11 Jan 52

Laboratory Work Order No. 6048

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DETROIT ARSENAL
Laboratories Division

Report No. 3431 (Final)

Date: 14 February 1956

PROJECT TITLE: TEST OF PERSONNEL HEATERS, GASOLINE BURNING TYPE, FOR MILITARY VEHICLES

OBJECT:

To determine performance, endurance, and efficiency of the personnel heaters, Code A, B, C, D, E, and F; check their operational characteristics and obtain information for future comparison and qualification tests.

SUMMARY:

This heater test consisted of five 24-volt heaters (Code B, C, D, E, and F) of which Code C and D were identical except for the igniter resistor. The sixth heater, Code A, was a 12-volt system.

1. Electrical test

The 24-volt heaters for running required from 2.1 to 6.2 amperes and the 12-volt heater required 15 amperes. For starting, the heaters required from 8 to 10 additional amperes. The minimum starting voltage at minus 65 F ambient temperature varied from 19 to 21 volts for the 24-volt heaters and was 11 volts for the 12-volt heater.

2. Tilt and Rotation test

At an ambient temperature of minus 65 F, Code A, B, C, and D heaters started at 90° tilt with blower up and blower down and at 90° angles of rotation. Code E and F heaters failed to start at 90° tilt with blower down but started on the other 90° test positions.

3. Efficiency test

Under the test conditions, at high heat, Code C and F heaters attained the highest efficiency while Code A heater was lowest. At low heat, Code F heater was the most efficient and Code E heater was the least efficient. However, Code A and B heaters did not perform consistently at low heat setting. The efficiency of the heaters varied from 52.4 to 62.7 percent.

4. Cycling test

The 100-cycle test indicated, at an ambient temperature of minus 65 F, that the average time to "run" varied from 32.7 to 101.1 seconds. The starting current varied from 8.8 to 16.3 amperes at 24 volts. Code A heater used 23.1 amperes at 12 volts. The starting energy, in watt minutes, extended from 2.54 to 9.75 and the average time to purge required 33 to 214 seconds. Code B, C, and E heaters started 100 times without a failure; Code A heater failed 5 times and Code F heater failed 13 times in the 100 trials.

5. 200-hour Cold Room test

The heaters operated at ambient temperature of minus 65 F but none of the heaters would operate without repairs, adjustment, and troubles. The maximum length of time without any failure was 84 hours.

6. Vibration test

At 20 cycles and total displacement of 0.125", there was no indication of major failure after 24 hours of vibrating. This period consisted of 16 hours of heater operation and 8 hours not in operation.

CONCLUSIONS:

1. Electrical test

The electrical test did not consist of sufficient variables to determine the range of current requirements for each heater. The low voltage test indicates that the heaters will start at voltages below the battery capacity at temperatures of minus 65 F.

2. Tilt and Rotation test

Heaters can be designed to operate with the heater in the vertical position or be rotated with the control components turned 90° from the vertical.

3. Efficiency test

The efficiency of the heaters cannot be evaluated fully unless other variables are introduced to the tests; however, the heater efficiency can be as high as 60 percent at ambient room temperature.

4. Cycling test

The results indicate that wide variation of starting characteristics exist among the heaters. The Code A and B heaters showed much better characteristics than the Code C, E, and F heaters.

5. 200-hour Cold Room test

The heaters will not operate for 200 hours continuously without maintenance and repairs.

6. Vibration test

All the heaters withstood the vibration forces; however, the test should introduce other frequencies and amplitudes than those used for the test.

RECOMMENDATIONS:

For further heater tests, the following additions should be included:

1. The electrical power requirement should include the variables which affect the power requirement such as vehicle operating voltage of 28.5 volts, several ambient temperatures, various combinations of fresh air and exhaust back pressure, high and low heat setting.

2. The efficiency tests should include the same factors as in the electrical test.

3. The tilt and rotation test should be conducted at 10° increments of the maximum angle of operation.

4. At least six heaters of one model should be obtained for testing.

5. A 1000-hour endurance test should be included in the test procedure.

6. The vibration test should be extended to include acceleration forces to approximately 20 G's.

INTRODUCTION:

Arctic operation of military vehicles at sub-zero temperatures may be accomplished with the use of heating equipment. The objective of obtaining heating equipment which is reliable, effective, and simple introduces many problems in design and development.

In addition to these objectives, ease of maintenance must be considered so that personnel wearing arctic clothing will not be hindered in the maintenance operation. Compactness of the heater is another important consideration because many of the present day military vehicles, especially those intended for combat, have been equipped to the extent that space is at a premium.

To approach the objective, the gasoline burning, fresh air heater seems to be, at the present time, the most practical solution for heating personnel. However, the specifications MIL-H-3199, for this type of heater, are totally inadequate for the establishment of performance, endurance, minimum starting requirements, angle of operation, vibration, power requirement, etc. Consequently, heater designers have been handicapped in that design objectives are not known. Prior to this test, one fresh air heater was accepted for Ordnance use. To promote development of this type of heater, other heater manufacturers were induced to submit heaters for tests. Two of the heaters submitted for test were the same capacity (20,000 Btu/hr) as that of the accepted model. Two were of a larger capacity; one 30,000 and the other 60,000 Btu/hr.

This test was initiated to obtain information on performance, endurance, efficiency, and operating characteristics of these heaters to serve as a basis for future qualification and acceptance specifications.

TEST MATERIAL:

All the heaters for this test were the forced warm air, gasoline burning type of heater, using the vehicle electrical system as a source of power. The heater produces heat by burning gasoline mixed with air inside a combustion chamber, after which the combustion gases flow through the heat exchanger passages and to the exhaust outlet. As exhaust gases pass through the exhaust chamber, the ventilating air is forced across the exchanger surfaces by an electrically powered blower to absorb the heat.

The operation of the heater can be separated into three systems: fuel and combustion air, ventilating air, and electrical components. The fuel and combustion system consists of fuel filter, electrically operated pump, a regulation and metering valve, combustion air blower and combustion chamber. The ventilating system consists of blower motor, fan, and air passage through and around the heat exchanger. The electrical system includes a control box, flame switch and igniter.

The differences between the heaters are the method of combining the components and the type of burner. Table I lists the components for each heater and Table II summarizes the data submitted by the manufacturers.

	Heater, Code					
	A	B	C	D	E	F
Motor, ventilating blower			X	X	X	X
Motor, combustion blower			X	X		X
Motor, combination ventilation and combustion blower	X	X			X	
Fuel pressure regulator, solenoid valves, meter separate					X	
Fuel pressure regulator and shut off valve combined	X	X				
Fuel pressure regulator, shut off and metering set	X	X	X	X	X	X
Overheat switch			X	X	X	X
Thermal relay	X	X				
Flame detector switch	X	X	X	X	X	X
Relay and resistor				X		
Igniter resistor		X	X	X	X	X
Terminal strip	X	X	X	X		X
Manual igniter provision					X	
Circuit breaker in control box	X	X	X	X	X	X
Recirculating exhaust for combustion air			X	X		
Type of vaporizer	Generator	Pot	Pad	Pad	Pot	Ceramic brick

MAJOR HEATER COMPONENTS

Table I

	Code Heater				
	A	B	C	E	F
Output (Btu/hr)					
Fresh Air					
High	60,000	30,000	20,000	20,000	20,000
Low	30,000	18,000	10,000		9,000
Air Temperature Rise					
High rise	226 F	230 F			170 F
CFM	250	130		80	120
Fuel Consumption (Gal. per hour)					
High	.8	.4	.25	.25	.22
Low	.4	.24	.125	.125	.11
Rated Voltage	12	24	24	24	24
Power Consumption (Watts)					
Start	304	432	264		300
Running	160	144	60		60
Physical Characteristics					
Length	24"	18 3/4"	18 1/2"		18"
Height	11 5/8"	9"	9 3/4"		10"
Width	8"	6"	8 1/4"		8"
Weight	28 lbs.	23 lbs.	23 lbs.		24 lbs.

HEATER SPECIFICATIONS FROM MANUFACTURER

Table II

Figures 1 - 12 show each of the completely assembled heaters and break down of the components.

Figures 13 - 17 show the wiring diagram of each heater since slight variations were noted.

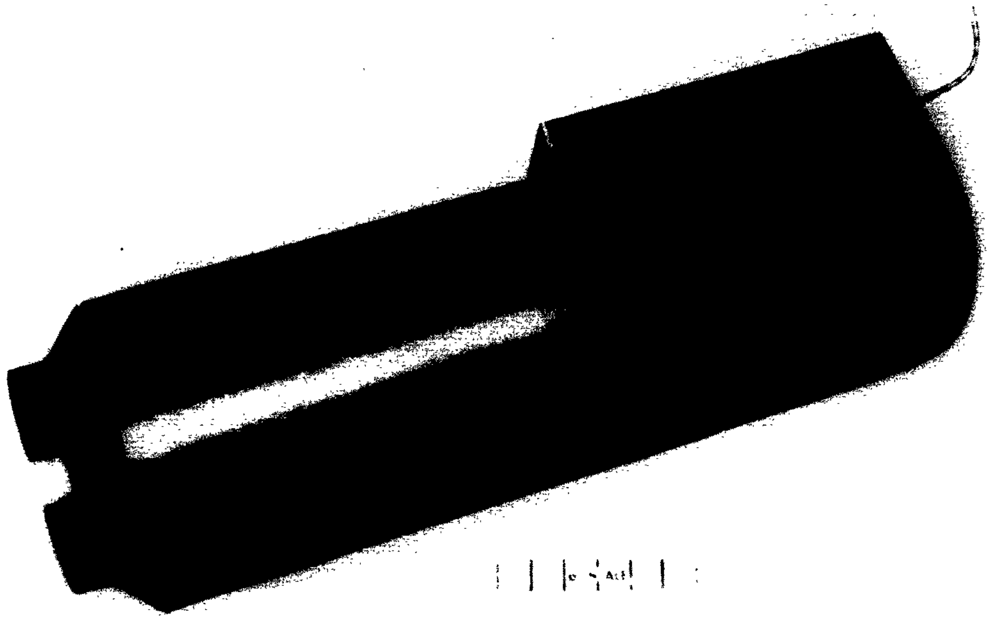


Figure 1

Code A heater, assembled

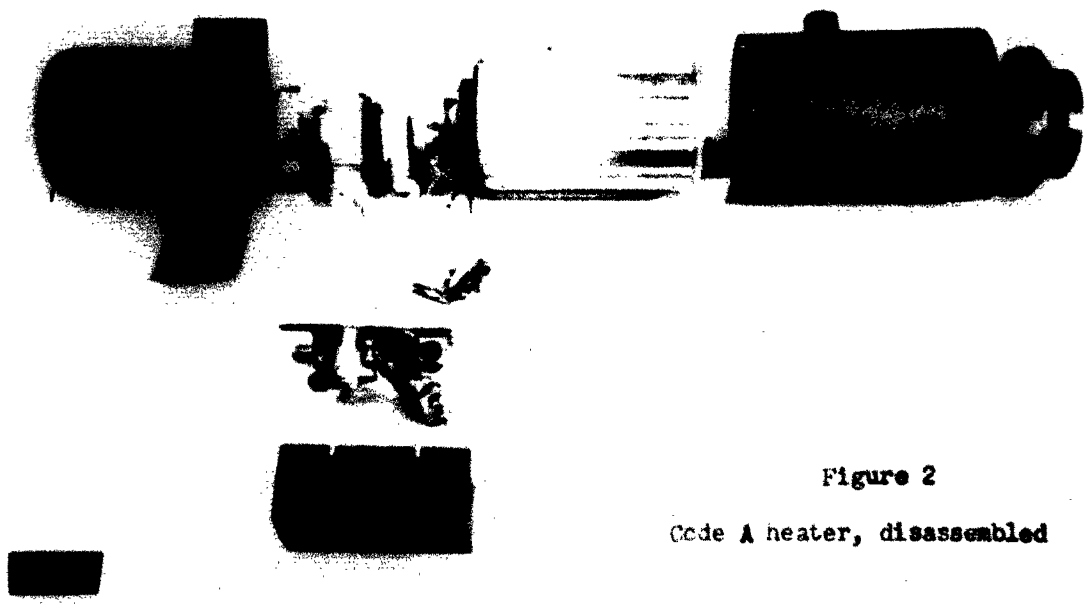


Figure 2

Code A heater, disassembled

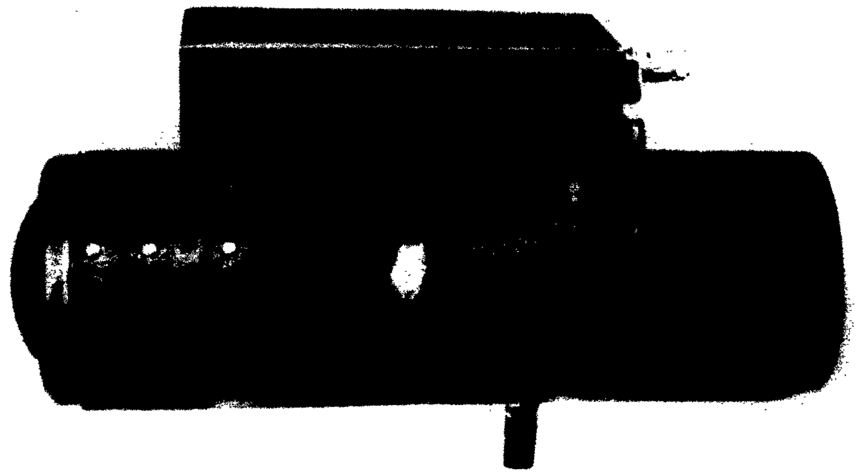
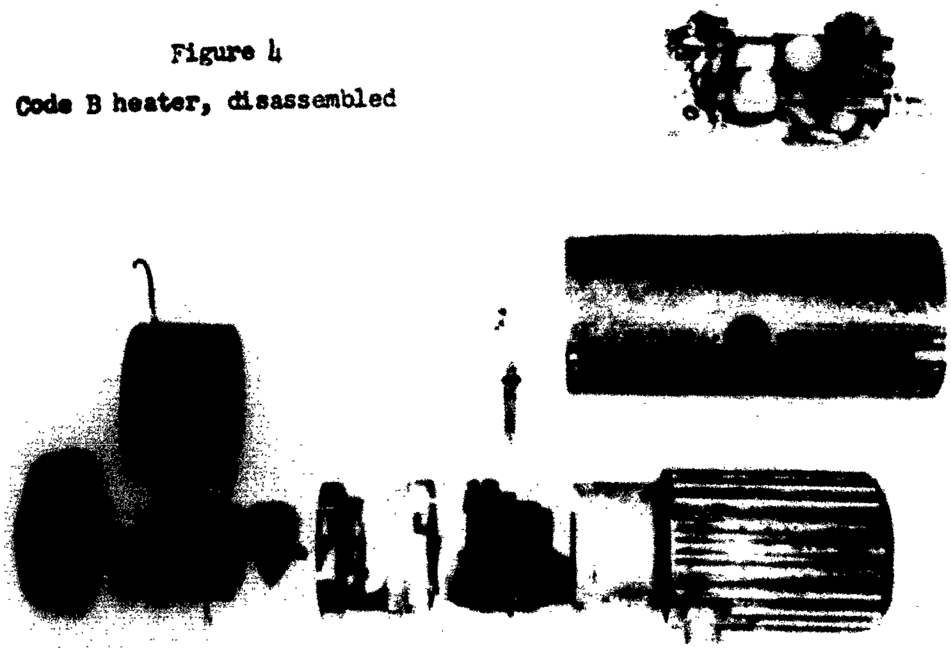


Figure 3

Code B heater, assembled

Figure 4

Code B heater, disassembled



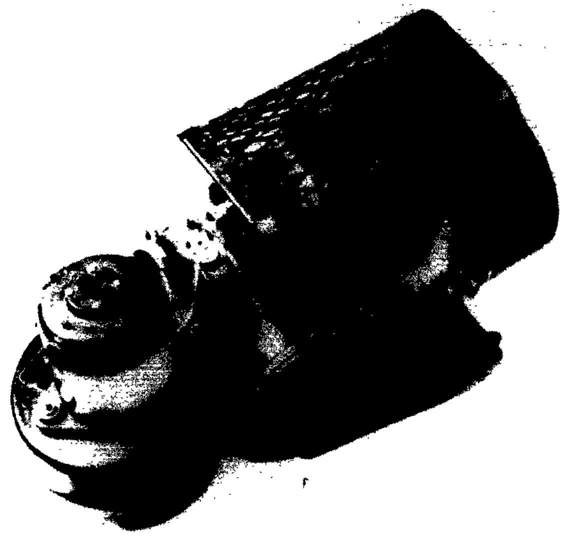


Figure 5

Code C heater, assembled

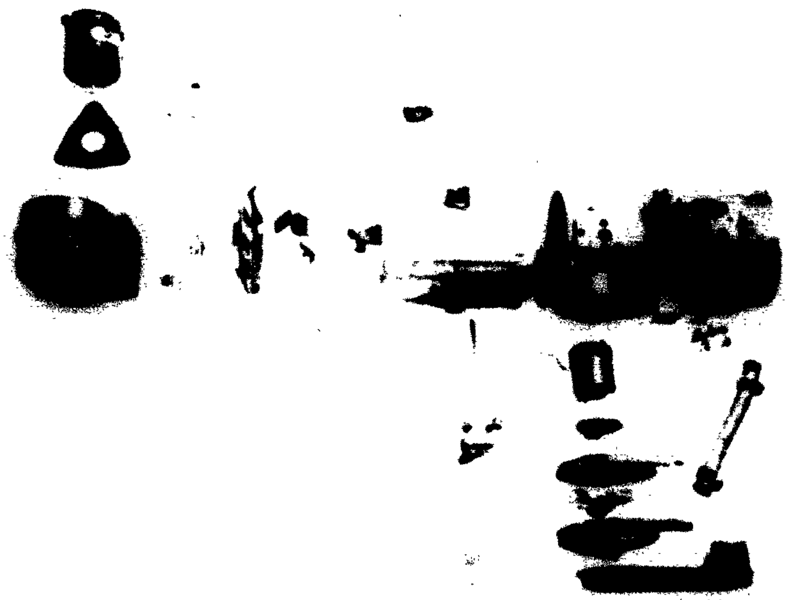


Figure 6

Code C heater, disassembled

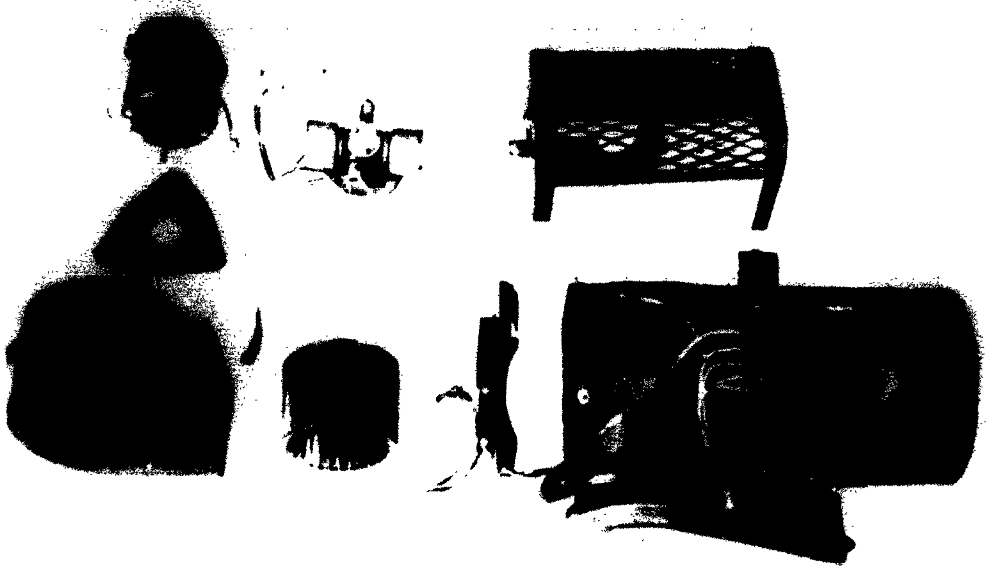


Figure 7

Code D heater, disassembled

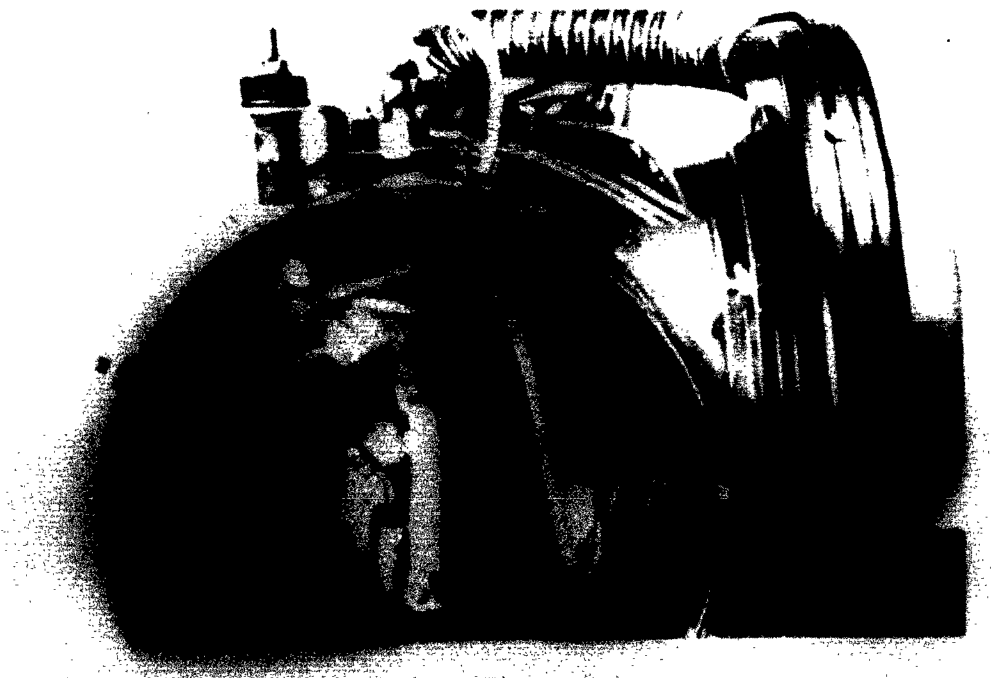


Figure 8

Code D heater igniter and igniter resistor

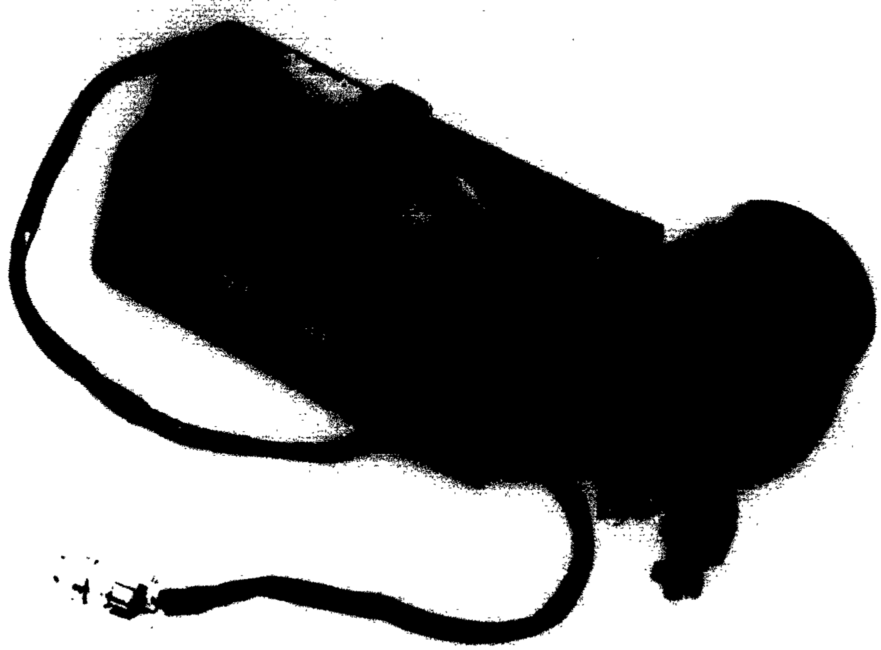


Figure 9

Code E heater, assembled

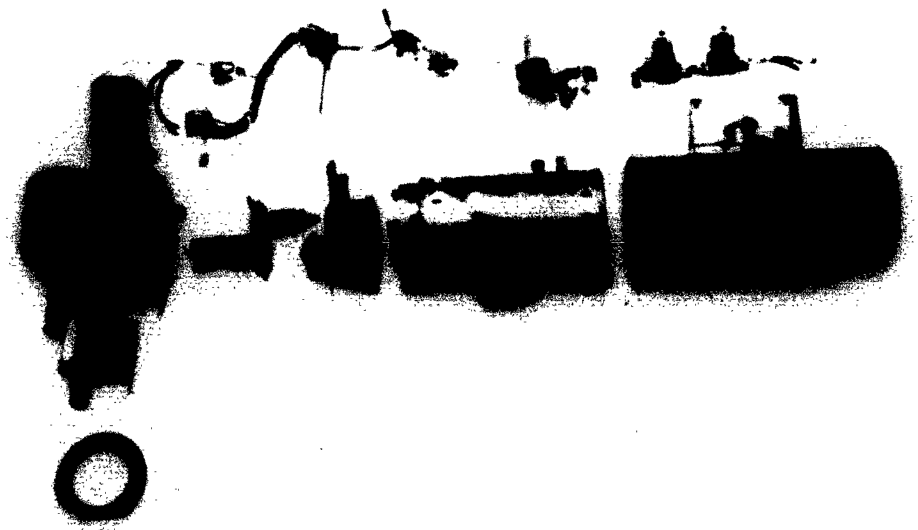


Figure 10

Code E heater, disassembled

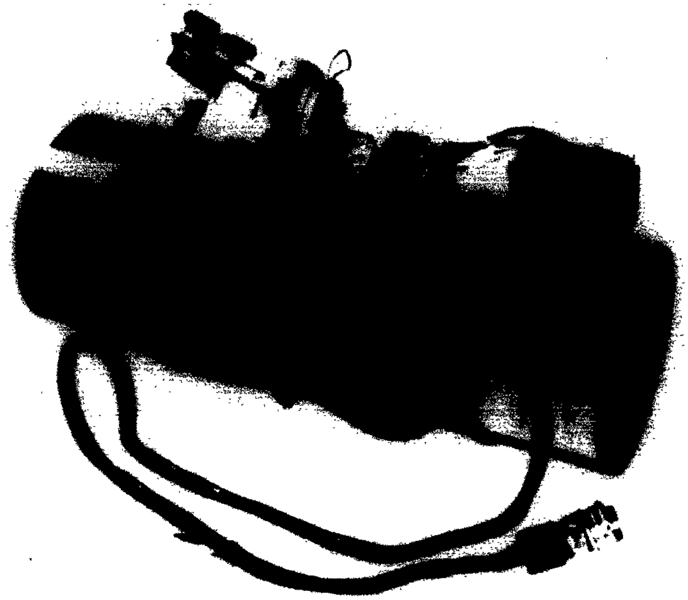


Figure 11

Code F heater, assembled

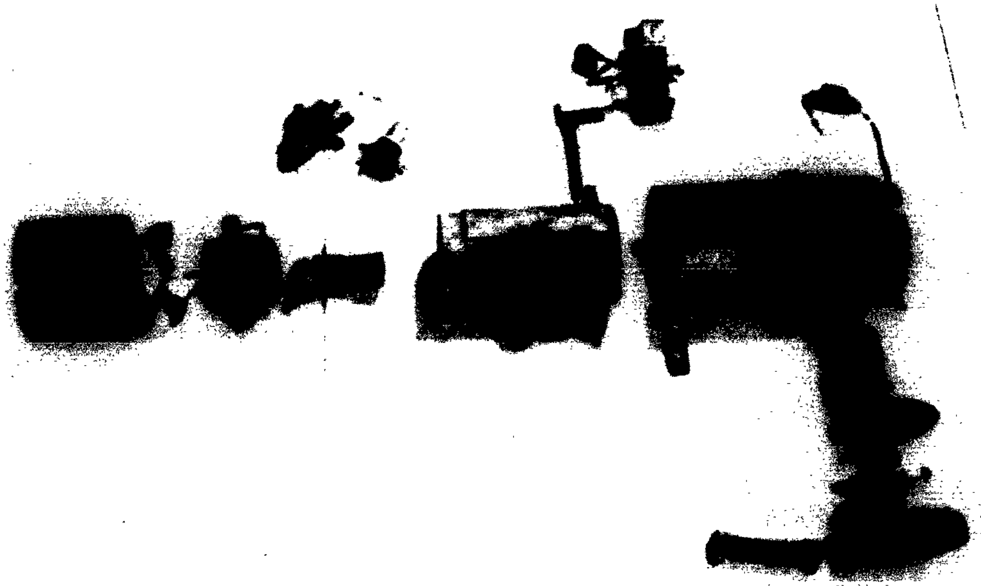
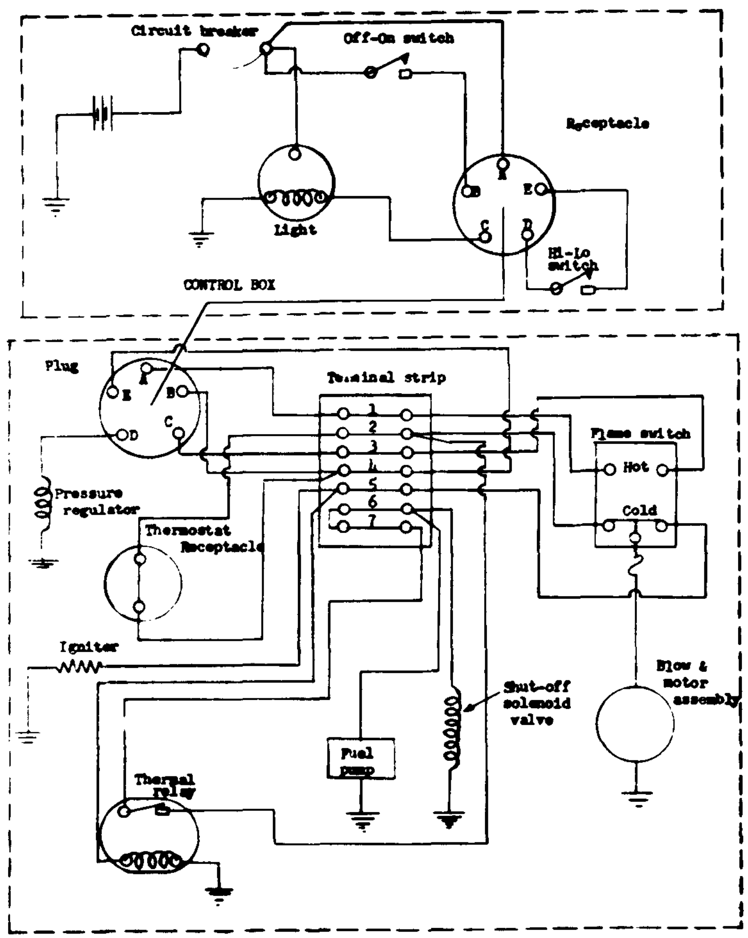


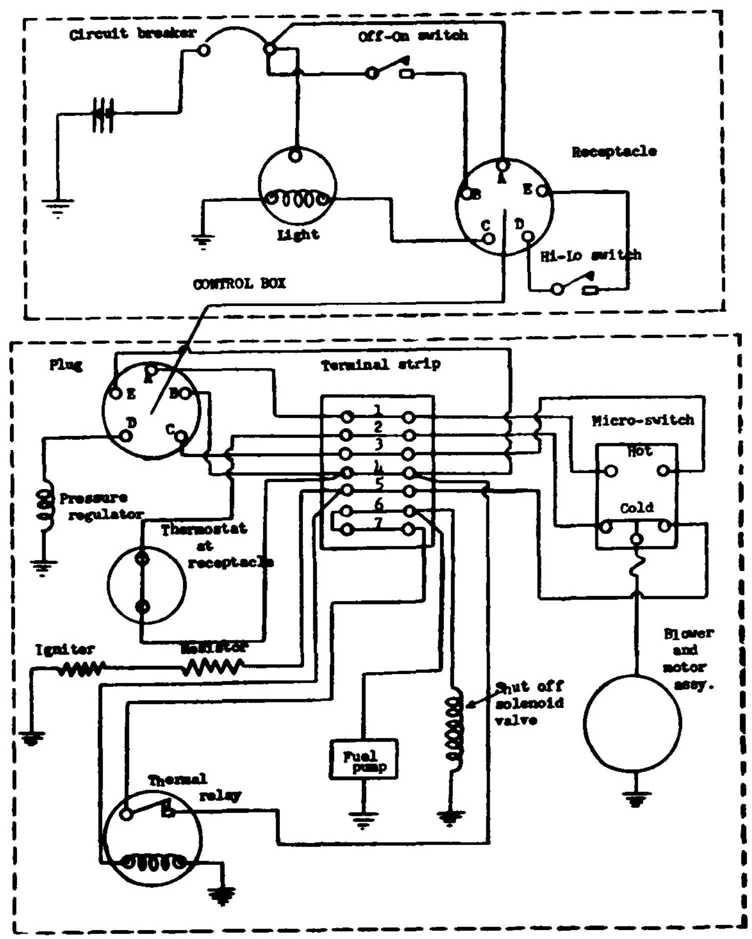
Figure 12

Code F heater, disassembled



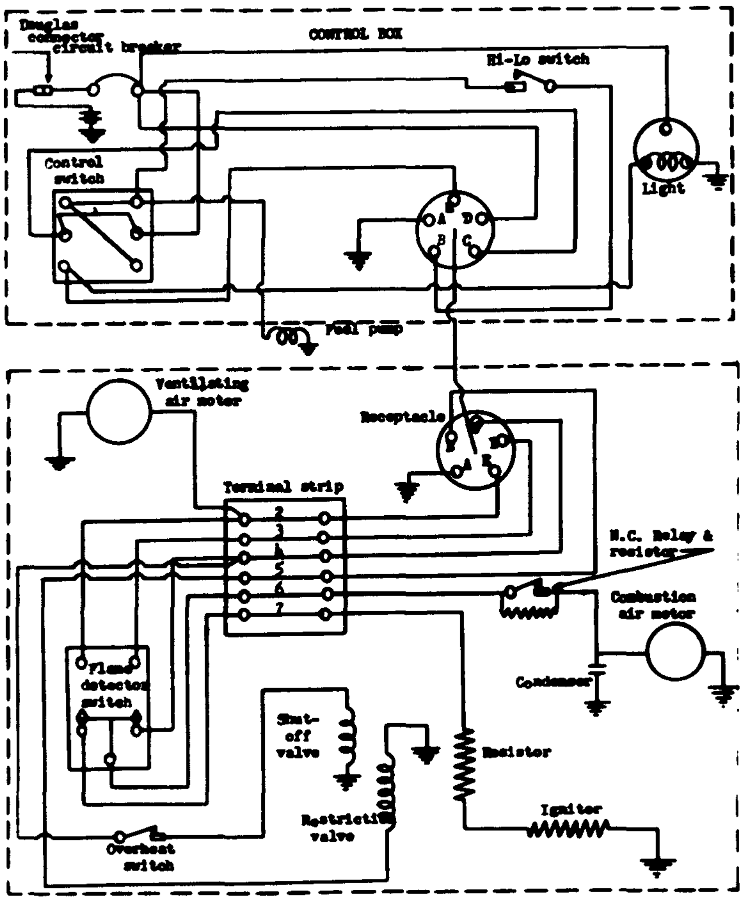
WIRING DIAGRAM OF CODE A

Figure 13



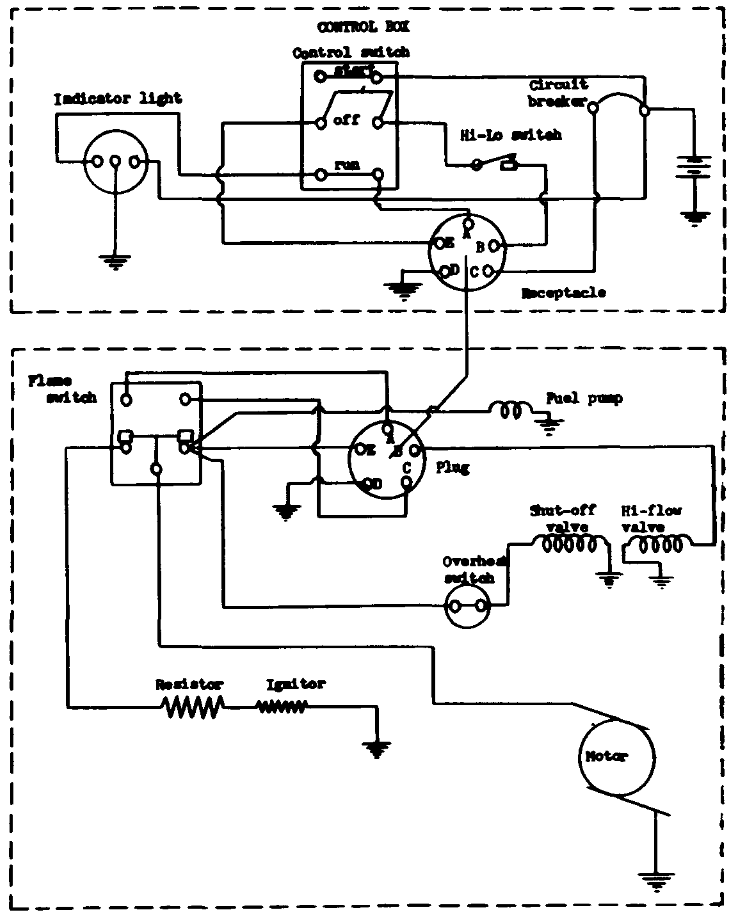
WIRING DIAGRAM OF CODE B

Figure 14



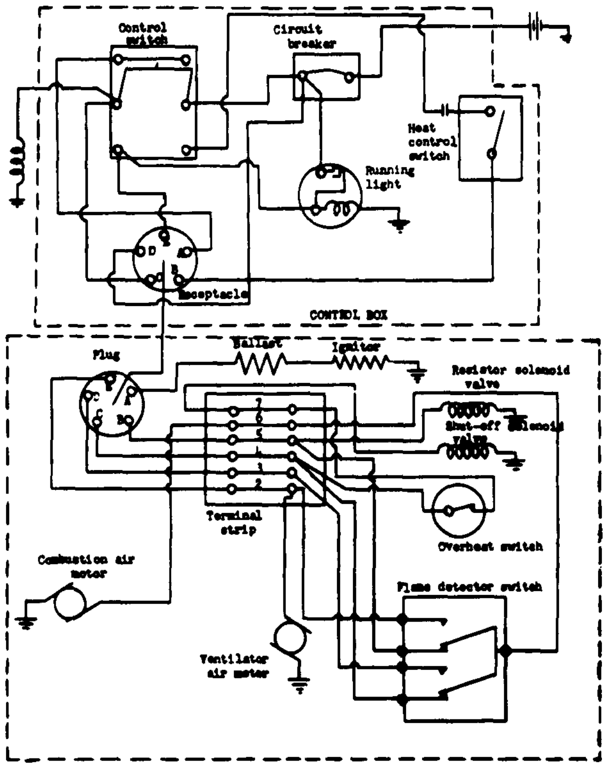
WIRING DIAGRAM OF CODE C

Figure 15



WIRING DIAGRAM OF CODE E

Figure 16



WIRING DIAGRAM OF CODE F

Figure 17

TEST APPARATUS:

The equipment used for the test is listed in the test program (see Appendix A).

TEST PROCEDURE:

The test procedure outlined in the test program was followed with these exceptions:

a. Two additional heaters from different manufacturers were included in the tests.

b. The sequence of the tests was changed to the following: The heater efficiency test was conducted after the tilt test.

c. The high voltage phase of the electrical test was omitted.

RESULTS AND DISCUSSION:

1. Electrical test

The electrical test was introduced to determine the electrical power requirements and the minimum starting voltage at which the heaters would start. The use of storage batteries when the vehicle engine is not in operation dictates that at low temperatures the heaters consume the least power possible. The discharge characteristics of storage batteries are such that the higher the discharge current the lower the terminal potential. Therefore, the heater which requires more current to start should be able to start at a lower voltage.

The electrical power consumption test was not completed because of inadequate d-c regulated power supply. However, Table III shows the current requirements for the heater at room ambient temperatures and without any restriction at the fresh air outlet.

	12 volt	24 volts				
	Code A* (amps)	Code B* (amps)	Code C (amps)	Code D (amps)	Code E (amps)	Code F (amps)
Start	26.5	16.2	10.4	10.0	13.7	11.5
Run	15	6.2	2.1	2.1	2.1	2.1
			28.5 volts			
Start			12.5	12.2	16	13.6
Run			2.5	2.8		2.8

*Both heaters had trouble with the igniters. The test was run later at 12 volts for the Code A and 24 volts for the Code B heater.

CURRENT REQUIREMENTS

Table III

The major item requiring current during running is the ventilating blower motor. The amount of electrical current which is needed is determined primarily by the type of blower. Code B heater which required approximately three times more than Code D, E, and F heaters has a backward tip type of fan. However, this heater is capable of producing a higher back pressure than the other three 24-volt heaters. This is shown in Appendix C (Efficiency test) in which Code B heater produced a maximum static pressure of 3.32 inches of water. The Code C heater with the blower identical to that of the Code D heater, developed 37.0%, the Code E developed 44.5%, and the Code F developed 25.6% of the Code B static pressure capacity.

The results of the low voltage start test at minus 65 F is shown in Table IV.

	Code A	Code B	Code C	Code D	Code E	Code F
Minimum start voltage	11	21	20	20	19	19
Time to run at minimum voltage in seconds	25	101	100	55	62	85

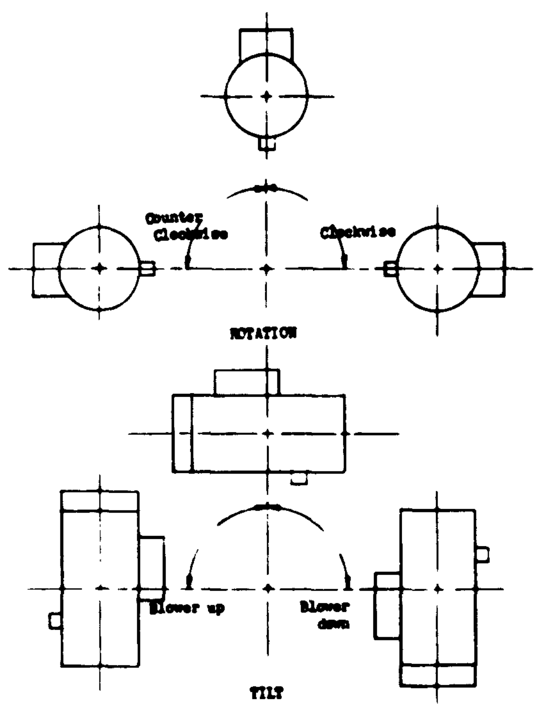
LOW VOLTAGE START TEST

Table IV

2. Tilt and Rotation test

Tilt and rotation tests were conducted to determine the angles at which the heaters could be installed in vehicles, and to determine if cross country inclines were within the operating range of the heaters.

The positions at which the heaters were tested were the maximum angles from the level position. Figure 18 shows the tilt and rotation angles at which the tests were conducted.



HEATER OPERATIONAL POSITIONS

Figure 18

Table V shows the average of 5 runs at ambient temperature of minus 65 F which was divided into starting and purging. Heaters, Code A, B, C and D started at all the angles; Code E and F failed to operate at the 90° blower down position.

		Time in Seconds					
	Heater:	A	B	C	D	E	F
Tilt 90° Blower down	Avg. time to fire	21	25	50	45	*	*
	Avg. time to run	27	31	64	73	*	*
	Purge	138	73	215	338		
Tilt 90° Blower up	Avg. time to fire	18	30	82	52	30	68
	Avg. time to run	23	40	96	63	39	85
	Purge	129	84	103	93	59	243
Rotation 90° Left	Avg. time to fire	13	13	85	42	43	69
	Avg. time to run	19	17	99	57	58	85
	Purge	45	73	118	93	45	241
Rotation 90° Right	Avg. time to fire	18	13	186	50	34	63
	Avg. time to run	25	21	203	66	46	78
	Purge	41	73	104	91	56	236

* Gasoline leaked past the igniter because no seal was provided.

SUMMARY OF STARTS AND PURGE FOR TILT AND ROTATION TEST

Table V

These two heaters were considered as failures at that position because of gasoline leakage. Code E heater would start at the angle of 60°, but the maximum angle at which no leakage was observed was 20°. The maximum angle at which the Code F heater would start was 45° and the angle at which no leakage was observed was 5°.

The variations in the time to run was small for the Code A, B, and D heaters at the four positions, but the Code C heater required approximately twice the time when the heater was rotated 90° to the right. Since the purge time indicates the amount of unburned fuel at the burner, the purge time is also tabulated in the table.

The variation of purge time at each angle was negligible only for the Code B heater; the other heaters varied much more at other positions, especially with the heater tilted to the blower down position.

The difference in purge time between the heaters can be attributed to the type of burner which the heater utilized. The Code F heater required much more time to purge because of the ceramic cone which the other heaters did not use.

3. Efficiency test

The limitation imposed to keep the size of the heater to a minimum affects the heat exchanger efficiency. Therefore, the efficiency test was conducted to determine the efficiency of the heaters to determine which heater was able to extract the most heat at only one condition which will be described later. The efficiency of the heater is defined as the heat absorbed by the ventilating air divided by the heat available from the fuel.

Since the heat exchanger was the primary consideration, the electrical power required was not included in the efficiency measurements. The conditions of the test were as follows:

> The outlet pressure of the ventilating air was maintained by the atmospheric pressure. The exhaust gas restriction was the eight feet of 1½" diameter tubing for the 20,000 and 30,000 Btu/hr heaters. The 60,000 Btu/hr heater required a 2" diameter tubing.
>
> Voltage at the control box was maintained at 24 volts.
>
> The ambient temperatures were between 70 - 80 F.

A summary of the results is shown in Table VI. The results of the test only indicate the relationship of one heater to another. It is believed that any change of the above conditions will change the efficiency of the heater.

Heater	Heat Position	Heat Output Btu/hr	Efficiency (Percent)
A	High	53,350	52.4
B	High	28,100	56.6
C	High	20,725	62.9
C	Low	9,180	60.8
E	High	18,075	53.7
E	Low	10,220	55.2
F	High	20,300	62.7
F	Low	8,980	61.7

SUMMARY OF EFFICIENCY TEST

Table VI

In addition to the efficiency test, the maximum static pressure which the ventilating blower could produce was also determined. This was conducted to determine the possibility and the limitation on the amount and size of duct work which could be connected to the heaters.

4. Cycle test

The starting factors of these heaters at sub-zero temperatures, using electrical resistance wire type of igniter, are the minimum time required to run, consistency in starting, and minimum electrical energy requirement. To evaluate these factors, the data from the 100-cycle test for each heater was used. The time to run was measured from the time the switch was turned on to the time the igniter circuit was de-energized by the flame switch. Consistency in starting was evaluated by computing the average starting time, the standard deviation and the dispersion of starting times. The electrical energy in starting was determined by multiplying the average starting current, the voltage, and the average time to run. Table VII shows these factors including the number of failures to start, average running current and average purge time.

	Heater, Code				
	A	B	C	E	F
Average time to run in seconds	32.7	34.0	101.1	70.9	87.8
Standard deviation of time to run in seconds*	10.1	4.2	31.1	14.2	15.3
Average starting current in amperes	23.1	16.3	8.8	11.8	10
Average running current in amperes	15.8	6.3	2.2	2.2	2.2
Starting energy in watt-min.	2.54	3.7	5.92	9.75	5.83
Average purge time in seconds	59	33	142	99	214
Number of failures to start	5	None	None	None	13

*See Appendix B for sample calculation.

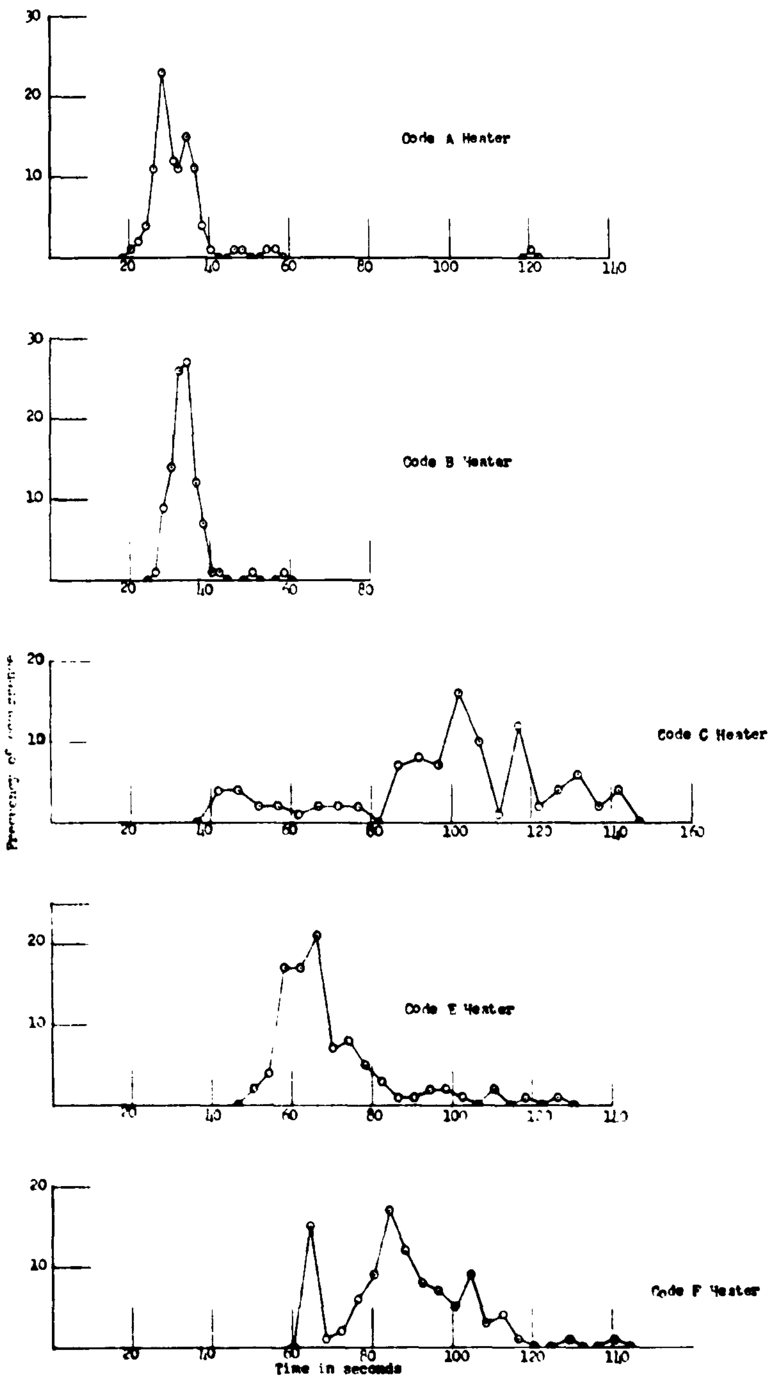
SUMMARY OF 100 CYCLE TEST

Table VII

The minimum time to run for the five heaters was 37.7 seconds for the Code A heater. The minimum standard deviation, range of starting time or the consistency in the time of starting was 4.2 seconds for the Code B heater. The distribution of the starting times is shown in Figure 19.

The least amount of energy required for starting the 24-volt heaters was 3.7 watt-min. for the Code B heater. The Code A heater, a 12 volt system, did not require a resistor for the igniter which accounts for the energy being less than the other heaters.

Three of the heaters, Code B, C, and E started 100 times without failure, but the Code A heater failed to start five times; Code E failed 13 times. The number of failures was not included in the computation of the average time to run and the standard deviation, since no penalty factor was involved.



DISTRIBUTION OF STARTING TIME FOR 100 CYCLE TEST

Figure 19

5. <u>200-hour Cold Room test</u>

The heaters operated at ambient temperature of minus 65 F to determine the operational stability and reliability. Not one of the heaters operated for the 200 hours without a failure. The following table summarizes the difficulties encountered during the test:

Number of Run Hours		Remarks
		CODE A HEATER
15	1.	Exhaust temperatures were too low, therefore another type of jet was installed. In addition, the flame detector switch required adjustment and the igniter was replaced.
	2.	Heater would not operate with changes in part (1), then the flame detector switch and fuel filter were replaced.
	3.	After the second attempt to operate the heater for the test, the quartz rod was found to be broken and one of the control harness leads was found to be disconnected.
	4.	After the control valve was checked and found to be all right, the seal for the filter was found to be defective.
	5.	Discovered that an exhaust restriction was necessary for normal operation.
	6.	The above work was recommended by the company representative.
62.5		The control valve was tapped to eliminate an air pocket.
67		Discovered gasoline leaking from the burner head; it was removed and silver soldered. In addition, the thermal relay and igniter were found to be defective. The mixing plate was replaced with one made of a corrosion resistant alloy (Inconel) but the first one was not yet defective. It was noted that a large piece of carbon formation was on the flame detector tube.
105	1.	Gasoline was leaking from burner head.

Number of Run Hours		Remarks
	2.	Removed carbon formation from flame detector switch.
108		Tapped control valve
149		Tapped control valve and bled fuel line at control valve.
168		Discovered hole in burner head combustion air inlet tube.
180.5		Replaced quartz rod of flame detector switch, igniter, and repaired gasoline leakage at burner head.
		CODE B
58		Tapped control valve
68.5		Flame out - reason unknown
82.5	1.	Flame out - reason unknown
	2.	Thermal relay was faulty. Heater was turned off because the exhaust temperature was too high; worn motor brushes were the cause.
110.5		Flame out - reason unknown
116		Exhaust was restricted
136		Blower screen was frosted causing high fresh air outlet temperature
168.5		Tapped control valve
179.5		Fuel line bled
180.5		Fuel line bled
		CODE C
28.5		Low exhaust temperature was caused by control valve
112		Replaced combustion blower motor
183		With the combustion air adapter, the heater would not operate. The heat exchanger was replaced.

Number of Run Hours		Remarks
		CODE E
63	1.	The flame out which occurred was probably caused by the hole in the heat exchanger, which was replaced.
	2.	The flame detector switch required an adjustment.
82.5		The fuel pump was not operating properly.
106.5		Heater would not restart in cold room; reason unknown.
		CODE F
66		Replaced combustion blower motor
94	1.	Vaporizer brick was heavily carboned
	2.	Flame detector switch tube baffle was burned
124	1.	Flame out because of control valve leak
	2.	The overheat switch was faulty
126	1.	Combustion blower tubing was ruptured.
	2.	Control valve required adjustment
	3.	Igniter was defective
144		Flame out occurred
153.5	1.	Replaced igniter, vaporizer brick, and igniter replaced.
	2.	Inside of heat exchanger was carboned heavily. Air was used to remove as much as possible.
172.5		Vaporizer brick was carboned heavily.

SUMMARY OF HEATER FAILURES AND STOPPAGES DURING 200 HOUR COLD ROOM TEST

Table VIII

6. Vibration test

The vibration test was conducted at 20 cps and .125 inch total displacement (peak to peak) to determine the ability of the heaters to withstand the forces. The heaters were vibrated at the above condition for eight (8) hours and then for sixteen (16) hours while the heater was in operation. There was no indication of major damage to any of the heaters tested. Code A, C, and F heaters operated without any maintenance or failure. Code B heater required one flame switch adjustment because the lock nut became loose. Code E heater had three wire failures and loosening of the pressure regulator adjustment screw.

No indication of carbon monoxide was found in the fresh air from any of the heaters.

Written By:

MAX S. KOGA

Signed By:

FRANKLYN BERGSMAN

Reviewed By:

CLARENCE W. BANTON, JR.
Acting Chief,
Climatic Laboratory

APPROVED BY:

GEORGE A. TUTTLE
Major, Ordnance Corps
OIC, Laboratories Division

DETROIT ARSENAL
Laboratories Division

TECHNICAL REPORT DISTRIBUTION

Date: Report No. 3431 (Final)

PROJECT TITLE: TEST OF PERSONNEL HEATERS, GASOLINE BURNING TYPE, FOR MILITARY VEHICLES

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APPENDIX

Report 3431 (Final)

APPENDIX A

Test Program

TEST PROGRAM

TITLE: TEST OF PERSONNEL HEATERS, GASOLINE-BURNING TYPE, FOR MILITARY VEHICLES

OBJECT:

To determine performance, endurance, and efficiency of four Personnel Heaters; check their operational characteristics; and obtain data for future comparison and qualification.

OUTLINE OF PROBLEM:

The present specification for Gasoline-Burning Personnel Heaters, MIL-H-3199, Type I, is inadequate. The requirement section does not specify minimum performance under such conditions as low temperature operation, corrosion resistance, operational endurance, water-proofness of electrical components, angle of operation, etc. The testing section does not specify test methods and detailed procedures covering each requirement in order to determine conformance with the specification.

With more manufacturers becoming interested in supplying the Ordnance Corps with heaters, it is urgent that all presently available heaters be tested to provide information which will serve as a basis for future qualification and acceptance specifications.

EQUIPMENT:

1. Cold room facilities with temperature range to -70 F
2. Personnel Heaters (Code A, B, C, and D, three manufacturers)
3. Test stands, fuel supply containers, and variable voltage D-C electric power
4. Air flow equipment
5. Tilting table
6. Vibration machine
7. Balance scale
8. Voltmeter and ammeter
9. Thermocouples and potentiometer
10. Vibration pickup and meter
11. Velometer

PRELIMINARY INSPECTION:

Conduct a preliminary inspection of heater to determine the following:

PRELIMINARY INSPECTION (CONT'D):

1. Weight
2. Length
3. Width
4. Height
5. Rated voltage
6. Rated Btu/hr
7. Rated starting and operating current
8. Blower motor type and horsepower
9. Rated fuel consumption
10. Rated heat output
11. Rated C.F.M. Combustion and ventilating blower

TEST REQUIREMENTS:

1. Tests on the heaters are to be conducted in the following order:

   a. Electrical
   b. Heating efficiency
   c. Tilting (maximum angle)
   d. Cycling (OFF and ON operation)
   e. Continuous operation
   f. Vibration

2. Temperature

   The above tests are to be conducted at room temperature of 80 F, ±15 F unless otherwise specified. Tests conducted in the cold room will permit sufficient cold soaking time before starting test.

3. Use Gasoline, Automotive, (Combat) MIL-G-3056, Type 80C, for fuel.

4. Position the heaters with the longitudinal axis level with the horizontal and without any rotation around this axis unless otherwise specified.

5. Use a constant voltage source with the rated voltage at the heater and leads of 72 inches, unless otherwise specified.

6. Prior to each test the heaters are to be completely disassembled and inspected visually. All accessories such as the pump, control valve, flame detector switch, ignitor, etc. are to be checked according to manufacturer's specifications.

7. All electrical and fuel leads to the source are to be separate for each unit.

8. Maintain a chronological log for duration of each test.

9. Note any design or operational deficiencies and photograph if possible.

TEST PROCEDURE:

Phase I, Electrical Test

1. At room temperature, determine the voltage drop and current requirement of each electrical component at all the variable electrical conditions, such as high and low heat, starting and running.

2. At room temperature, determine the effects of 28.5 volts on the electrical components for 24 volt heaters and 14.25 volts for 12 volt heaters.

3. At -65 F to -70 F determine lowest voltage at which the heaters will start and operate.

Phase II, Heater Efficiency Test

Determine the heater efficiency by obtaining fuel consumption, air flow, and air temperature.

Obtain and record the following data:

1. Fuel

   a. Weight fuel consumed during the run
   b. Length of time
   c. Temperature of fuel at source
   d. Heating value of fuel

2. Air and Exhaust

   a. Inlet and outlet ventilating air temperature
   b. Inlet combustion air temperature
   c. Exhaust temperature and pressure
   d. Ventilating air blower speed
   e. Air flow from heater outlet
   f. CO content of ventilating air

Phase III, Tilt Test

Conduct this test at ambient temperature of -65 F to -70 F with the heater on a tilting table.

1. Determine the maximum starting angle when the heater is rotated around its longitudinal axis clockwise and counter-clockwise.

2. Determine maximum running angle when the heater is rotated around its longitudinal axis clockwise and counter-clockwise.

TEST PROCEDURE (CONT'D):

3. Determine maximum starting angle when the longitudinal axis of the heater is tilted above and below the horizontal.

4. Determine maximum running angle when longitudinal axis of the heater is tilted above and below the horizontal.

Record the following data:

1. Temperatures

   a. Ventilating air inlet and outlet
   b. Combustion air inlet
   c. Exhaust
   d. Case temperature

2. Electrical

   a. Voltage
   b. Starting current
   c. Running current
   d. Purging current

3. Time

   a. Starting time
   b. Ignitor time
   c. Purging time

Five successful, consecutive starts or trials will be considered as satisfactory at the maximum angle of rotation or tilt of the heater for starting and running.

Phase IV, Cycling Tests

Conduct this test at ambient temperature of -65 F to -70 F for 100 cycles. Each cycle shall consist of starting the heater, running the heater for 15 minutes, purging the heater and cooling it for 1 hour and 5 minutes. Record the same data for each cycle as specified in Phase III.

TEST PROCEDURE (CONT'D):

Phase V, Continuous Operation Test

Conduct this test at ambient temperature of -65 F to -70 F for 200 hours of continuous operation. Record the same data as specified in Phase III, and in addition, weigh the combustion chamber before and after the test. If possible record the outlet velocity of the ventilating air.

Phase VI, Vibration Test

Vibrate the heater at 20 cps and with a total excursion (below and above the mean axis) of one-eighth inch for 24 hours in 8 hour periods. The first 8 hour period shall be conducted without operating the heater. The last 16 hours shall be conducted with the heater in operation. The heater will be inspected after each 8 hour period. For the last 16 hour period record data as specified in Phase III, and also record CO content of ventilating air.

CONCURRED BY:

Robert W. Koo

Robert W. Kos

Written By:

Max Koga

Max Koga

APPROVED BY

Fred B. Hunt

for REX H. WHITE, JR.
Major, Ord Corps
Director, Comp Lab Div

Reviewed By:

Raymond F. Brozek

Raymond F. Brozek
Chief, Low Temperature Lab

APPENDIX B

Example of Standard Deviation Calculation

EXAMPLE OF STANDARD DEVIATION: CALCULATION

$$s = c\sqrt{\frac{\Sigma fd^2}{n} - m_d^2} \qquad m_d = \frac{\Sigma fd}{n}$$

s = standard deviation
c = common difference
f = frequency
d = deviation from reference point of each item in multiple of c
n = number of items
m_d = mean of all deviation
x_o = reference point

x	f	d	fd	fd^2
26.5	1	-3	-3	9
28.5	9	-2	-18	36
30.5	14	-1	-14	14
32.5	26	0	0	0
34.5	27	1	27	27
36.5	12	2	24	48
38.5	7	3	21	63
40.5	1	4	4	16
42.5	1	5	5	25
50.5	1	9	9	81
58.5	1	13	13	169
Σ	100		68	488
Σ/n			.68	4.88

n = 100
c = 2
x_o = 32.5

$s = 2\sqrt{4.88 - .4624}$

$s = 2\sqrt{4.4176}$

$s = 2 \times 2.102 = 4.20$

Appendix B

APPENDIX C

Performance Tests of Five Personnel Heater Assemblies

LABORATORIES DIVISION
Development and Engineering Department
DETROIT ARSENAL

FORM B

Date: 26 May 1952

SUBJECT: Report of Performance Tests for Five Personnel Heater Assemblies

TO: Low Temperature Laboratory - Attention: Mr. Ray Brozek

Material received on Job Order No. 6048 was tested as described in the Test Procedure, with results as follows:

A. Purpose:

1. To determine the heater performance (air temperature rise, air delivery, fuel flow, heat output, efficiency, and power consumption) of heater assemblies A, B, C, E, and F.

2. To determine the static pressure developed by the heater ventilating air blower at zero air delivery for each heater assembly tested.

B. Results and Conclusions:

The test results obtained are summarized as follows:

1. Heater Performance:

Heater	Heat Range	Temp. Rise °F	Air Flow cfm	Fuel Flow cc/min	Heat Output btu/hr	Eff. %	Power Consumption watts
A	high	263	285.5	48.8	53,350	52.4	198
B	high	273	146	23.5	28,100	56.6	144
C	high	217	126	15.9	20,725	62.9	48
C	low	88	116.5	7.33	9,180	60.8	48
E	high	221	108	16.6	18,075	53.7	60
E	low	116	101.5	8.61	10,220	55.2	60
F	high	172	146	15.4	20,300	62.7	60
F	low	70	138	6.92	8,980	61.7	60

For more detailed results, reference may be made to Table I.

Appendix C

2. Static pressure developed by the heater ventilating air blower at zero air delivery:

Heater	Static Pressure (in. H_2O)
A	4.07
B	3.32
C	1.25
E	1.48
F	0.85

Approved by:

Robert E. Thibodeau

Robert E. Thibodeau
Chief, Power Plant Laboratory

Reported by:

Albert W. Carion

Albert W. Carion

TEST APPARATUS:

1. Plenum chamber, 2 feet x 2 feet x 4 feet, covered with 2 inches of fiber glass insulation (Figure 1c)

2. 2 inch diameter Bureau of Standards type nozzle

3. 3-inch diameter Bureau of Standards type nozzle (Figure 1c)

4. 9 inch diameter outlet duct, 94 inches long (Figure 2c)

5. Auxiliary exhauster installation, consisting of ventilating fan assembly, Ordnance Number 7722221 (Figure 2c) with control damper

6. Fuel tank, 2 gallon capacity (Figure 3c)

7. Skinner purifier filter, Model No. 473441, Skinner Company (Figure 3c)

8. Fuel pump, 12 volt, Ordnance No. 7354018

9. Fuel pump, 24 volt, Ordnance No. 7354014 (Figure 3c)

10. Glass flask - capacity approximately one quart (Figure 3c)

11. Miscellaneous copper tubing, valves, and neoprene hose (Figure 3c)

12. Scale, Toledo Scale Company, Model No. 860999, range 0 - 5 kilograms, 1 gram sensitivity (Figure 3c)

13. Stop watch (Figure 3c)

14. Brown Potentiometer, Serial No. 541153, forty-eight stations, range -100 to 600 F (Figure 4c)

15. Pyrometer, Hoskins Thermo-Electric, Serial No. 25028, range 0 - 2000 F (Figure 4c)

16. Air temperature, seventeen thermocouples (eight with, and nine without radiation shields)

    Fuel temperature, one thermocouple

    Exhaust gas temperature, one thermocouple

17. Two piezometer rings with .040 inch diameter static pressure holes spaced 6 inches apart

18. Piezometer ring with four 0.040 inch diameter static pressure holes equally spaced

19. 8 feet of 1 1/2 inch diameter flexible exhaust tubing

20. 8 feet of 2 inch diameter flexible exhaust tubing

21. Two inclinometers, range 0 to 6 inches H_2O (Figure 4c)

22. Inclined draft tube (Figure 4c)

23. Variable resistor, carbon pile, Laboratory No. CL-7264 (Figure 4c)

24. Voltmeter, Laboratory No. CL-7094, range 0 - 30 volts (Figure 4c)

25. Voltmeter, Laboratory No. CL-7580, range 0 - 50 volts (Figure 4c)

26. Ammeter, Laboratory No. CL-7114, range 0 - 100 amperes, with shunt (Figure 4c)

27. Converter, a-c to d-c, Laboratory No. CL-199950 (Figure 4c)

28. Storage batteries, 6 and 12 volts

29. 24-volt power supply

30. Psychrometer and barometer

TEST PROCEDURE:

The test apparatus was set up as shown in Figure 5c. It consisted essentially of equipment to regulate and measure air flow through the heater, to obtain air temperature rise through the heater, and to determine the fuel flow.

Air Flow - Measurement and Regulation:

The heater assembly was mounted to the front plate of the plenum chamber (Figure 6c). The air was forced into the plenum chamber by the ventilating air blower of the heater assembly, passed through the plenum chamber, nozzle, and the outlet duct, and was discharged into the atmosphere by the auxiliary exhauster (Fig. 5c).

With the heater operating, the air flow of the auxiliary blower was adjusted by means of the damper assembly to obtain atmospheric pressure at the heater outlet inside the plenum chamber (as indicated by the inclined draft tube shown in Figure 5c). This condition simulated heater operation at "free delivery"; that is, the heater discharged directly into the atmosphere without overcoming the restriction imposed by any external duct system. Any such external duct system would decrease the air delivery of the heater.

The air delivery of the heater was obtained by measuring the pressure drop across a Bureau of Standards type nozzle (as indicated by inclinometer No. A, Figure 5c). A sixteen mesh screen was placed twelve inches upstream from the nozzle in order to diffuse the air discharged by the heater, and obtain a more suitable air flow pattern ahead of the nozzle.

A two inch diameter nozzle was used for all the heaters tested with the exception of Heater A. The increased air delivery (288 cfm versus average 130 cfm) necessitated the use of a three inch diameter nozzle.

The method used to calculate the air flow from the observed pressure drop across the nozzle is described in Appendix C-1.

Determination of Air Temperature Rise through the Heater:

The inlet air temperature of the heater was obtained as the average reading of two thermocouples placed approximately one inch upstream of the heater ventilating air blower.

The heater outlet temperature was obtained by a series of three grids of four thermocouples each (Figure 5c). Two of these grids (each equipped with four shielded thermocouples) were placed 6 inches and 12 inches, respectively, downstream from the heater outlet. On each grid, the thermocouples were placed directly in the air stream discharged from the heater. The third grid (with four unshielded thermocouples) was installed approximately three inches downstream of the Bureau of Standards type nozzle.

The average air temperature, obtained with the grid located 12 inches downstream from the heater, was used as the heater outlet air temperature for all tests with the exception of those conducted with Heater A. For Heater A, the average air temperature obtained for the grid downstream from the Bureau of Standards type nozzle was used as the heater outlet air temperature.

Determination of Heat Output:

The heat output of the heater was determined as follows:

Heat output = air delivery x air specific heat x air temperature rise
(btu/hr) (lb/hr) (btu/lb ^{o}F) (^{o}F)

The air delivery (lbs/hr) was obtained as the product of the air flow (cfm), calculated from the pressure drop across a Bureau of Standards type nozzle, and the air density (lbs/cu.ft). The air specific heat at constant pressure was calculated, making allowance for the water vapor present. The air temperature rise was obtained as the difference of the observed inlet and outlet air temperatures. For the detailed calculations of the heater output, reference may be made to Appendix C-1.

Measurement of Fuel Consumption:

A schematic sketch of the fuel measuring system is shown in Figure 7c. Fuel was supplied to the heater by one of two sources, a fuel tank or a glass flask; either source could be connected to the heater fuel line by means of a stop cock and needle valve.

To measure the fuel consumption, fuel was supplied to the heater from a glass flask placed on a scale. The fuel consumption was calculated from the recorded time required to burn a definite weight of fuel.

The fuel temperature was observed by means of a thermocouple located at the junction of the fuel supply line to the heater.

Determination of Heater Efficiency:

The efficiency of the heater assembly was obtained as the ratio of the heat output (page 5) to the heat input supplied to the heater by the fuel.

The heat input by the fuel (btu/hr) was obtained as the product of the fuel consumption (lbs/hr) and the heating value of the fuel (btu/lb); the latter was obtained by an adiabatic calorimeter (Appendix C-2).

Measurement of Exhaust Condition:

All heater tests were conducted with eight feet of 1 1/2 inch diameter flexible hose connected to the heater exhaust with the exception of Heater A. The large exhaust of the latter necessitated the use of eight feet of 2 inch diameter flexible hose.

The exhaust back pressure at the heater outlet was observed by inclinometer B (Figure 5c). The exhaust gas temperature was measured by a thermocouple placed two inches below the pressure tap in the flexible hose.

Measurement of Heater Power Consumption:

The power supply circuit is shown in Figure 1c. The power consumption of the heater assembly was determined as the product of the observed voltage and current.

Tests Performed:

A. Heater Performance

The performance at "high heat" and "low heat" was obtained for five heaters (Code Numbers A, B, C, E, and F), following the procedure as described above. A sample of the readings taken and the calculations of the heater performance is given in Appendix C-1.

B. Static Pressure of Heater Ventilating Air Blower at Zero Delivery

Tests were performed to determine the maximum static pressure developed at zero delivery by the heater ventilating air blower.

Zero delivery was obtained by removing the air outlet duct (Figure 1c) and sealing the outlet of the Bureau of Standards type nozzle. With the heater ventilating air blower operating, but without supplying fuel to the heater, the maximum static pressure produced in the plenum chamber was observed. The observed static pressure values were corrected to "standard air" (0.075 lbs/cu. ft. air density) as follows:

$$\text{Corrected Static Pressure (In. } H_2O) = \text{Observed Static Pressure (In. } H_2O) \times \frac{0.075}{\text{Observed Air Density (lbs/cu ft)}}$$

RESULTS AND DISCUSSION:

A. Heater Performance

The results of the performance tests conducted with Heater A, B, C, E, and F are summarized in Table I.

Heater C:

A condensed summary of the performance test is given below:

Date	Heat Range	Inlet Air °F	Temp. Rise °F	Air Flow cfm	Fuel Flow cc/min	Heat Output btu/hr	Eff. %
26 Mar	high	76	217	125	16.0	20,600	62.4
9 Apr	high	81	217	127	15.8	20,850	63.4
25 Mar	low	86	94	116	7.10	9,680	66.2
9 Apr	low	87	82	117	7.56	8,680	55.5

The test accuracy of the various items, listed in the above table is estimated to be as follows:

Temperature difference variation	± .5%
Air flow	± 1%
Fuel flow	± 1%
Heat output	± 2.5%
Efficiency	± 3.5%

These test accuracies are also applicable to the performance tests conducted with Heaters A, B, E, and F.

The condensed summary indicates that the two values obtained for heat output (20,600 and 20,850 btu/hr) and the corresponding efficiency (62.4 and 63.4% at "high" heat are well within the estimated test accuracy. However, the variation of heat output (9680 and 8680 btu/hr) and the corresponding efficiency (66.2 and 55.5%) obtained for the two tests conducted at "low" heat are not within the estimated test accuracy. It is believed that the observed change in the heat output and the efficiency is due to the variation in fuel flow (7.10 and 7.56 cc/min).

Heater F:

A condensed summary of the performance test is given below:

Date	Heat Range	Inlet Air °F	Temp. Rise °F	Air Flow cfm	Fuel Flow cc/min	Heat Output btu/hr	Eff. %
27 Mar	high	80	172	146	15.4	20,300	62.7
27 Mar	low	78	70	138	6.92	8,980	61.7

Prior to conducting tests on this heater, a new firing head was installed, because the one furnished with the heater assembly failed to support combustion.

Heater B:

A condensed summary of the performance test with "high" heat is given below:

Date	Heat Range	Inlet Air °F	Temp. Rise °F	Air Flow cfm	Fuel Flow cc/min	Heat Output btu/hr	Eff. %
10 Apr	high	74	273	146	23.5	28,100	56.6

The fuel regulator originally furnished with the heater assembly did not function properly, thus causing irregular fuel flow at both "high" and "low" heat. A new regulator was installed prior to conducting the performance test listed in the above table. The new fuel regulator eliminated the fuel flow irregularities at "high" heat; however, variations in fuel consumption as high as 24% were still observed at "low" heat. It was, therefore, impossible to conduct satisfactory performance tests at "low" heat.

Heater E:

A condensed summary of the performance test is given in the table below:

Date	Heat Range	Inlet Air °F	Temp. Rise °F	Air Flow cfm	Fuel Flow cc/min	Heat Output btu/hr	Eff. %
2 Apr	high	82	229	108	17.8	16,500	50.9
4 Apr	high	74	212	108	15.3	17,650	56.5
1 Apr	low	80	118	102	8.53	10,340	53.6
4 Apr	low	75	114	101	8.68	10,100	56.8

In order to determine the cause of the observed variation in fuel consumption (16%) at "high" heat, the fuel regulator assembly was removed from the heater case and connected to the 24-volt supply circuit. After a one hour test run the fuel regulator housing reached a temperature of 150 F. This indicated that the fuel flow variation at "high" heat may have been due to vapor lock.

Heater A:

The condensed summary of the "high" heat performance test is given below:

Date	Heat Range	Inlet Air °F	Temp. Rise °F	Air Flow cfm	Fuel Flow cc/min	Heat Output btu/hr	Eff. %
12 Apr	high	75	249	288	48.2	52,200	51.9
14 Apr	high	74	277	283	49.4	54,500	52.9

After the test conducted on 12 April, it was necessary to install a new ventilating air blower motor; the bearing located on the combustion air fan side failed (Figure 9c).

"Low" heat operation could not be obtained with the fuel regulator originally furnished with the heater. A new fuel regulator was installed; however, "low" heat operation was still impossible.

B. Static Pressure of Heater Ventilating Air Blower at Zero Delivery:

The table below summarizes, for each heater tested, the static pressure developed by the ventilating air blower at zero delivery. The pressure values are corrected to "standard air" (0.075 lbs/cu.ft air density):

Heater	Static Pressure (in. H_2O)
A	4.07
B	3.32
C	1.25
E	1.48
F	0.85

INCLOSURES:

1. Table I - Summary of Test Results
2. Figure 1c - Personnel Heaters, Gasoline Burning Type. Test Set-up, Plenum Chamber and Nozzle Installation (Neg. No. 30588)
3. Figure 2c - Personnel Heaters, Gasoline Burning Type. Test Set-up, Plenum Chamber, Outlet Duct, and Auxiliary Exhauster (Neg. No. 30587)
4. Figure 3c - Personnel Heaters, Gasoline Burning Type. Test Set-up, Equipment for Measuring Fuel Consumption (Neg. No. 30585)
5. Figure 4c - Personnel Heaters, Gasoline Burning Type. Test Set-up, Instrumentation (Neg. No. 30584)
6. Figure 5c - Schematic View of Test Set-up
7. Figure 6c - Personnel Heaters, Gasoline Burning Type. Test set-up, Heater Installation (Neg. No. 30586)
8. Figure 7c - Schematic View of Fuel Measuring System
9. Figure 8c - Diagram of Power Supply Circuit
10. Figure 9c - Personnel Heater. Gasoline Burning Type. Code A. Heater Combination Ventilating and Combustion Blower Motor, showing Failed Bearing, during Efficiency Test (Neg. No. 30437)

Appendices:

C-1 - Sample Calculations for Heater Performance Test

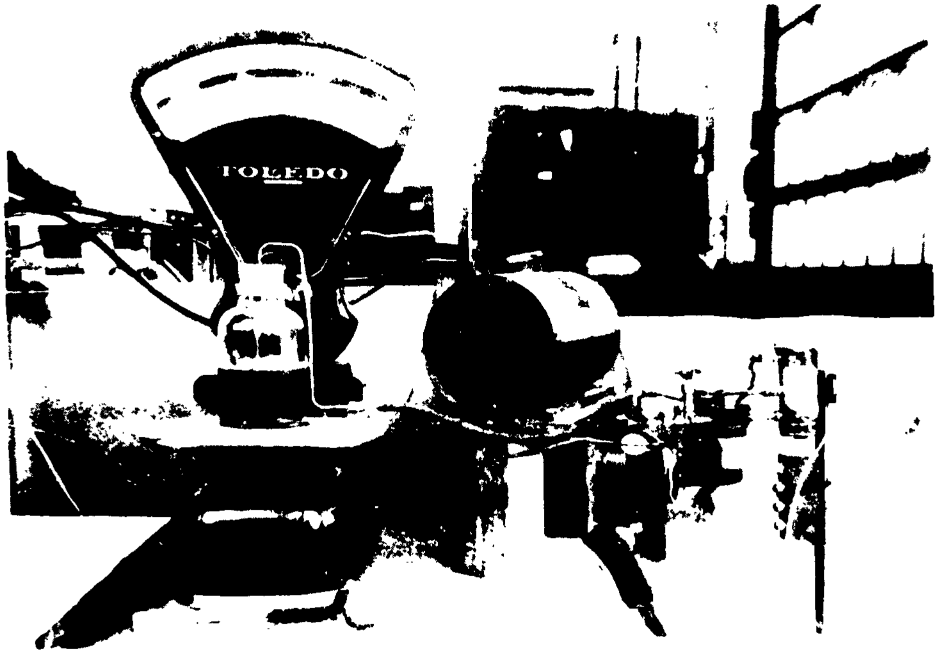
C-2 - Fuel Analysis Report

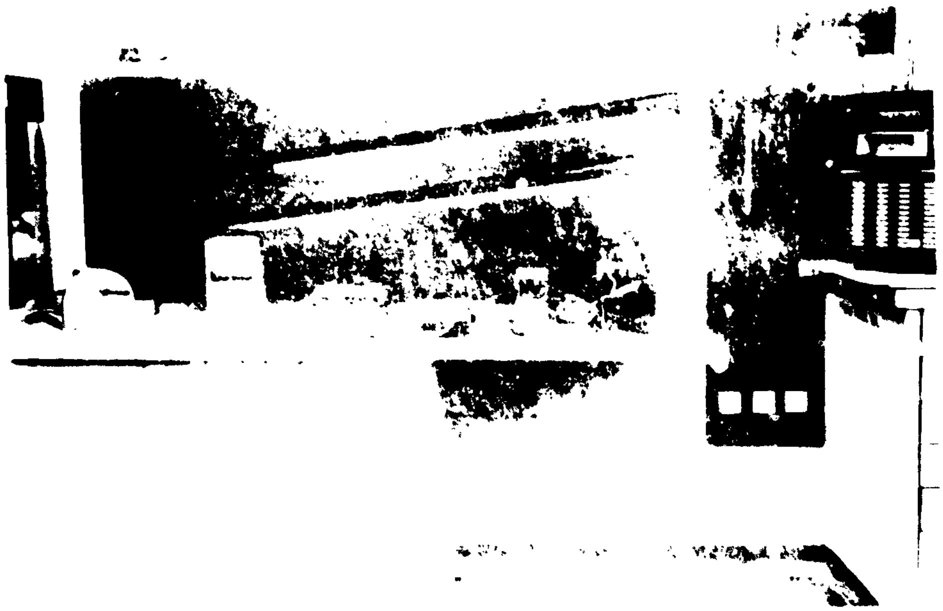
Heater	Heat Range	Inlet Air	Air Temp. Rise	Nozzle Mixture Density	Nozzle Pressure Drop	Air Flow Volume	Air Flow Weight	Air Specific Heat	Heat Output	Fuel Temp.	Fuel Specific Gravity	Fuel Heating Value	Fuel Flow Volume	Fuel Flow Weight	Heater Eff.	Exhaust Back Pressure	Exhaust Temp.	Power	Static Pressure at Zero Delivery	Date of Test
		(F)	(F)	$\frac{lb}{cu.ft}$	(in. H_2O)	(cfm)	(lb/hr)		(BTU/hr)	(F)	(at 60°/60°)	(BTU/lb)	(cc/min)	(lbs/hr)	(%)	(in. H_2O)	(F)	(watts)	(in. H_2O)	(1952)
A	High	75	249	.0498	1.46*	288	861	.2438	52200	80	.724	21850	48.2	4.61	51.9	.28	820	198		12 April
A	High	74	277	.0475	1.39*	283	806	.2441	54500	78	.724	21850	49.4	4.72	52.9	.35	950	198	4.07	14 April
B	High	74	273	.0482	1.83	146	421	.2441	28100	89	.724	22000	23.5	2.255	56.6	.36	1060	144	3.32	10 April
C	High	76	217	.0520	1.46	125	390	.2436	20600	85	.721	21630	16.0	1.525	62.4	.12	612	48		26 March
C	High	81	217	.0516	1.49	127	394	.2437	20850	86	.721	21630	15.8	1.510	63.4	.61	730	48	1.25	9 April
C	Low	86	94	.0607	1.46	116	423	.2437	9680	86	.721	21630	7.10	.677	66.2	.14	386	48		25 March
C	Low	87	82	.0619	1.52	117	435	.2432	8680	95	.721	21630	7.56	.723	55.5	.52	440	48		9 April
E	High	82	229	.0508	1.07	108	331	.2438	18500	83	.728	21620	17.8	1.71	50.9	.28	800	60		2 April
E	High	74	212	.0530	1.10	108	342	.2435	17650	82	.728	21620	15.3	1.62	56.5	.25	790	60	1.48	4 April
E	Low	80	118	.0584	1.09	102	358	.2445	10840	82	.728	21620	8.53	.892	53.6	.26	510	60		1 April
E	Low	75	114	.0601	1.10	101	364	.2433	10100	82	.728	21620	8.68	.836	56.8	.25	540	60		4 April
F	High	80	172	.0553	2.11	146	484	.2432	20300	86	.719	22100	15.4	1.465	62.7	.13	628	60	0.85	27 March
F	Low	78	70	.0642	2.17	138	527	.2428	8980	80	.719	22100	6.92	.658	61.7	.15	366	60		27 March

* Pressure drop was measured using a 3-inch diameter Bureau of Standards type nozzle instead of the 2-inch diameter nozzle used for all other tests.

SUMMARY OF TEST RESULTS

TABLE I


TOLEDO



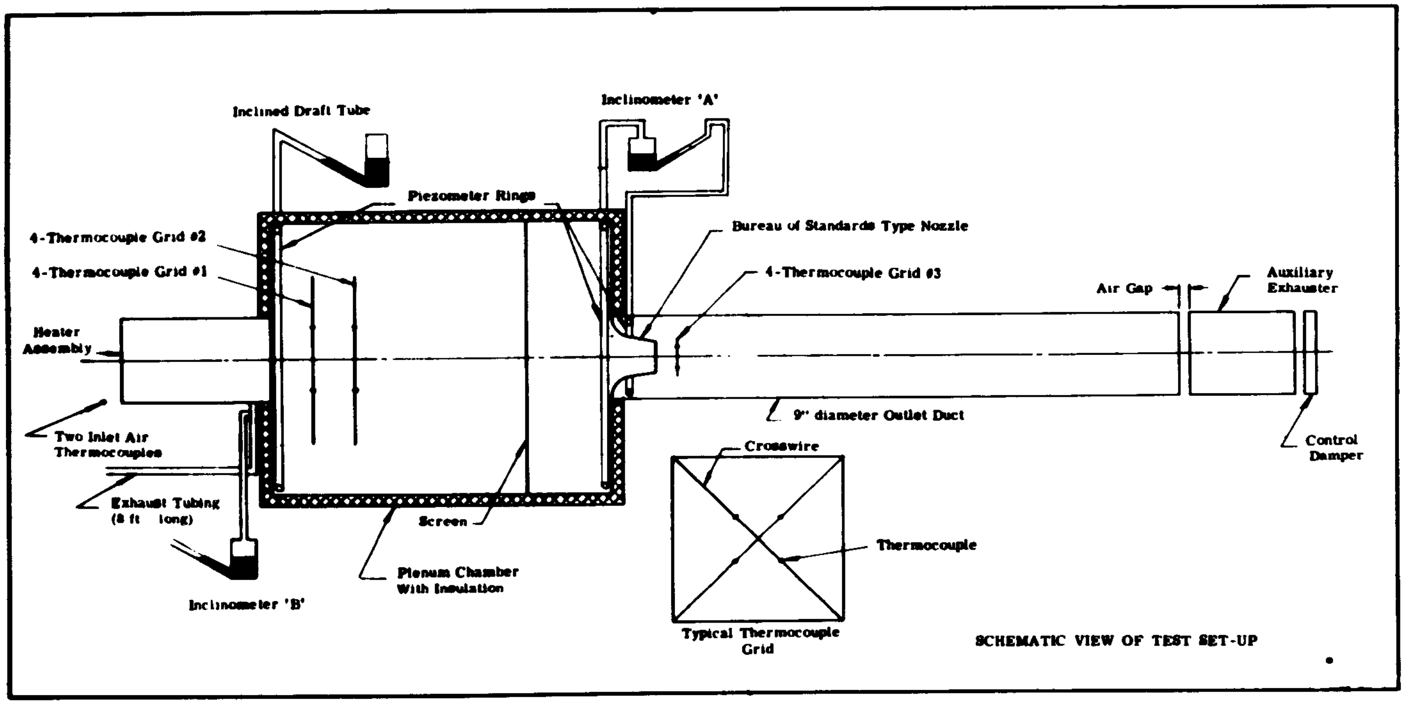


Figure 5c - Schematic view of fuel measuring system

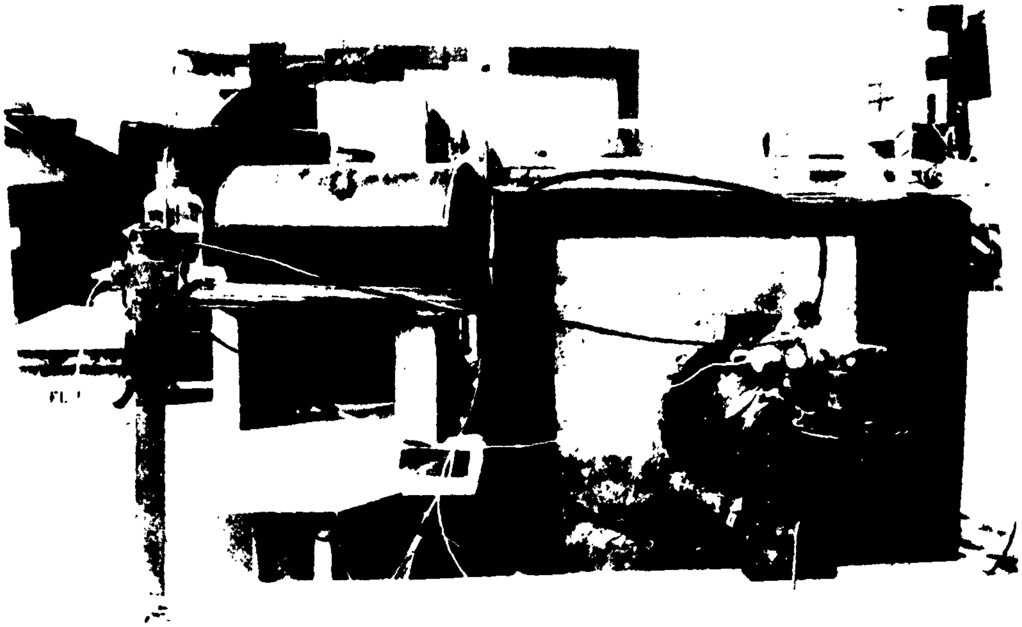


Figure 6c

Test set-up; heater installation

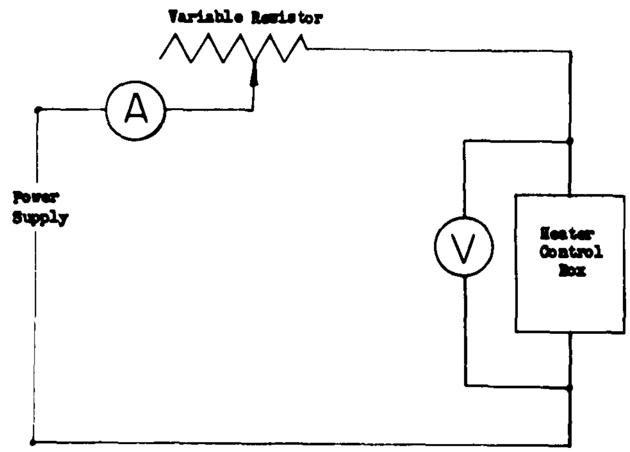


DIAGRAM OF POWER SUPPLY CIRCUIT

Figure 8c

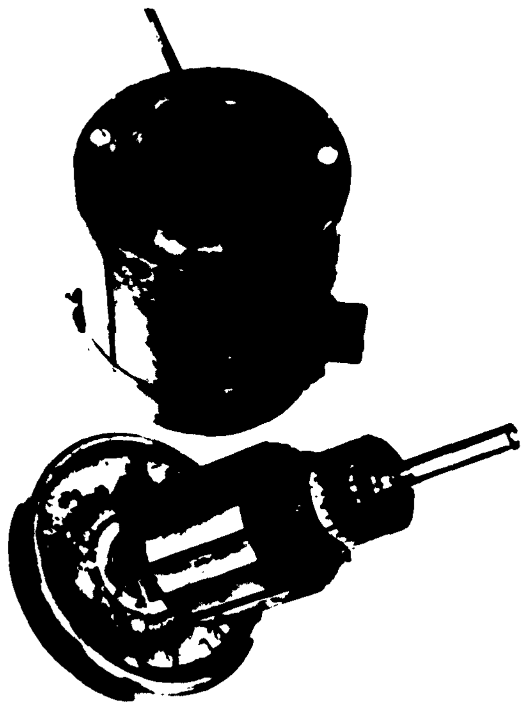


Figure 9c

Code A heater; combination ventilating and combustion blower motor showing failed bearing during efficiency test

APPENDIX C-1

Sample calculations for heater performance test

SAMPLE CALCULATIONS
FOR HEATER PERFORMANCE TESTS

HEATER A "HIGH HEAT"

For the complete set of observed data, reference may be made to the sample data sheets, pages 6, 7, and 8 of this Appendix (C-1)

Determination of Air Flow:

1. Mixture density at the nozzle

$$p_s = p_w - \frac{(p_b - p_w)(t_d - t_w)}{2800 - 1.3\, t_w}$$

p_s = water vapor pressure at inlet conditions (In. hg.)

p_w = water pressure at wet bulb temperature (In. Hg.)

p_b = corrected barometric pressure (In. Hg.)

t_d = dry bulb temperature (F)

t_w = wet bulb temperature (F)

$$p_s = 0.4052 - \frac{(29.11 - 0.4052)(68.5 - 53)}{2800 - 1.3\,(53)} = .2422 \text{ In. Hg.}$$

$$W_s = 0.622 \frac{p_s}{p_b - p_s}$$

W_s = weight of water vapor per lb. of dry air

$$W_s = 0.622 \frac{0.2422}{29.11 - 0.2422} = 0.00520 \ \frac{\text{lbs water vapor}}{\text{lb. dry air}}$$

$$D_m = \frac{1.326\,(p_b - 0.378\, p_s}{460 + t_n}$$

D_m = mixture density at the nozzle (lbs/cu. ft.)

t_n = temperature at the nozzle (F)

$$D_m = \frac{1.326\,(29.11 - 0.378 \times 0.2422)}{460 + 351} = 0.0475 \text{ lbs/cu. ft}$$

2. Volume of air flow

$$Q = 1082\ A \sqrt{\frac{p_d}{D_a}}$$

Q = volume of air flow (cfm)

1082 = nozzle coefficient

A = area of Bureau of Standards type (sq. ft)

p_d = pressure drop across the nozzle (In. H_2O)

$$Q = 1082 \times \frac{\pi (3)^2}{4 \times 144} \sqrt{\frac{1.35}{0.0475}} = 283 \text{ cfm}$$

3. Weight of air flow

$$W_a = Q \times D_a$$

W_a = weight of air flow (lbs/hr)

$W_a = 283 \times 60 \times 0.0475 = 806$ lbs/hr

<u>Determination of Heat Output:</u>

1. Specific heat of dry air

$$(c_p)_a = 0.24112 + 0.000009t$$

$(c_p)_a$ = specific heat of dry air at constant pressure (btu/lb. F)

t = mean temperature of inlet and outlet air (F)

$$(c_p)_a = 0.24112 + 0.000009\ (213) = 0.24304 \text{ btu/lb.F.}$$

2. Specific heat of water vapor

$$(c_p)_{wv} = 0.4423 + 0.000018t$$

$(c_p)_{wv}$ = specific heat of water vapor at constant pressure (btu/lb. F.)

$$(c_p)_{wv} = 0.4423 + 0.000018\ (213) = 0.446134 \text{ btu/lb. F.}$$

3. Specific heat of air-water vapor mixture

$$c_p = \frac{(c_p)_a + W_s\ (c_p)_{wv}}{1 + W_s}$$

c_p = specific heat of air-water vapor mixture at constant pressure (btu/lb. F.)

W_s = weight of water vapor per lb. dry air

$$c_p = \frac{0.24304 + (.0052)\ (.446134)}{1 + 0.00520} = .2441 \text{ btu/lb. F.}$$

4. Heat output

$$H = W_a \times c_p \times (t_o - t_i)$$

H = heat output (btu/hr)

W_a = weight of air flow (lbs/hr)

t_o = outlet air temperature (F)

t_i = inlet air temperature (F)

$$H = 806 \times 0.2441 \times (351 - 74) = 54{,}500 \text{ btu/hr}$$

<u>Determination of Fuel Flow:</u>

1. Weight of fuel flow

$$W_f = \frac{w}{t} \times \frac{3600 \text{ sec}}{1 \text{ hr}} \times \frac{0.002205 \text{ lbs}}{1 \text{ gram}}$$

W_f = weight of fuel flow (lbs/hr)

w = weight of fuel flow (grams)

t = time to burn weight of fuel flow (sec)

$$W_f = \frac{50}{84} \times 3600 \times 0.002205 = 4.72 \text{ lbs/hr}$$

2. Volume of fuel flow

$$V = \frac{W}{t} \times \frac{60 \text{ sec}}{1 \text{ min}} \times \frac{1}{s.g.}$$

V = volume of fuel flow (cc/min)

s.g. = specific gravity of the fuel (grams/cc)

The specific gravity of the fuel (0.724 with respect to water at 60 F) was obtained with a hydrometer for a fuel temperature of 60 F. However, the actual fuel temperature observed during the test was 83 F. The correction of specific gravity for the temperature change (60 F to 80 F) would decrease the specific gravity approximately 1%. This change was considered insignificant and therefore neglected.

$$V = \frac{50}{84} \times 60 \times \frac{1}{.724} = 49.4 \text{ cc/min}$$

Determination of Heater Efficiency:

$$\text{Efficiency} = \frac{\text{heat output}}{\text{heat input}} = \frac{\text{Heat output}}{W_f \times H.V.}$$

W_f = weight of fuel flow (lbs/hr)

H.V. = heating value of the fuel (btu/lb) (Appendix C-2)

$$\text{Efficiency} = \frac{54,500}{4.72\ (21,850)} = 52.9\%$$

Determination of Power Consumption:

Power (watts) = voltage (volts) x current (amps)

Power = 12 x 16.5 = 198 watts

HEATER A - EFFICIENCY TEST

HIGH HEAT

Date: 14 April 1952

	Start	Finish
Time	1500	1900
Barometric Pressure	29.09	29.13
Wet bulb temp.	53	53
Dry bulb temp.	70	68

*1st Grid - TC #4,5,6,7
2nd Grid - TC #8,9, 10, 11
3rd Grid - TC #12,13,14,15

TIME	VENT AIR INLET		COMB. AIR TEMP.	AIR OUTLET TEMPERATURES											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1600	71	71	-	314	319	310	404	335	330	330	361	346	347	347	346
1610	71	71	-	314	316	308	396	337	330	330	359	345	344	344	344
1620	72	72	-	313	319	310	399	336	330	329	358	345	344	344	344
1630	72	72	-	313	323	310	400	336	331	331	357	346	347	346	345
1645	72	72	-	314	321	308	402	336	331	329	360	347	348	348	348
1700	73	73	-	314	320	309	400	336	330	328	359	348	347	348	348
1715	74	74	-	310	322	308	401	332	328	328	358	346	345	345	345
1730	74	74	-	312	326	309	404	334	332	330	355	347	346	346	347
1745	74	74	-	316	328	313	407	337	335	334	363	350	351	351	351
1800	74	74	-	319	328	312	408	338	336	335	364	352	352	352	352
1815	74	74	-	319	327	312	408	340	336	334	366	352	353	353	353
1830	74	74	-	319	326	312	408	340	336	334	364	351	351	351	351
1845	74	74	-	319	326	312	407	341	336	334	365	351	351	351	351
1900	74	74	-	318	325	311	407	340	336	334	364	351	351	350	351

*See Figure 5c

HEATER A - EFFICIENCY TEST

HIGH HEAT

NOTE:
Temp. in degrees F
Pressure in inches of water

FUEL			EXHAUST GAS		AIR DISCHARGE	VENT BLOWER			NOZZLE PRESS.	FAN SPEED	AUX. BLOWER VOLTAGE
Temp. 16	Time Sec.	Weight Grams	Temp. 17	Pressure	Temp. 18	Press.	Volt	Amp			
74			940	.37	132	0	12	16.5	1.30	-	27
73			930	.37	132	0	12	16.5	1.33	-	27
74			940	.37	134	0	12	16.5	1.32	-	26
74	85	50	950	.37	134	0	12	16.5	1.32	-	26
76	85	50	950	.38	137	0	12	16.5	1.36	-	26
76	86	50	940	.37	137	0	12	16.5	1.36	-	26
76	88	50	940	.37	136	0	12	16.5	1.36	-	26
76	85	50	940	.35	137	0	12	16.5	1.36	-	26
77	83	50	950	.36	141	0	12	16.5	1.35	-	26
77	84	50	940	.35	141	0	12	16.5	1.35	-	26
78			940	.35	142	0	12	16.5	1.35	-	26
78	85	50	940	.35	142	0	12	16.5	1.35	-	26
78	85	50	930	.35	142	0	12	16.5	1.35	-	26
78	84	50	930	.35	141	0	12	16.5	1.35	-	26

TIME	INLET °F	OUTLET AIR 1st GRID °F	2nd GRID °F	3rd GRID °F	TEMPERATURE RISE At 1st GRID °F	At 2nd GRID °F	At 3rd GRID °F
1600	71	337	339	346.5	266	268	275.5
1610	71	333.5	339	344	262.5	268	273
1620	72	335	338	344	263	266	272
1630	72	336.5	339	346	264.5	267	274
1645	72	336	339	348	264	267	276
1700	73	336	338	348	263	265	275
1715	74	335	336.5	345	261	262.5	271
1730	74	338	339	346.5	264	265	272.5
1745	74	341	342	351	267	268	277
1800	74	342	343	352	268	269	278
1815	74	341.5	344	353	267.5	270	279
1830	74	341	343.5	351	267	269.5	277
1845	74	341	344	351	267	270	277
1900	74	340	343.5	351	266	269.5	277

AVERAGE TEMPERATURE SUMMARY SHEET

HEATER A - HIGH HEAT

APPENDIX C-2

Fuel Analysis Report

LABORATORIES DIVISION
Development and Engineering Department
Detroit Arsenal

FORM B.

Date: 17 April 1952

SUBJECT: Report of Test

TO: Power Plant - Engine Laboratory

Material received on Job Order No. 6048 was tested in accordance with instructions thereon with results as follows:

A. Purpose:

To determine the heat of combustion and the specific gravity of several gasoline samples.

B. Sample Data:

Five samples of gasoline, Automotive Combat, MIL-G-3056, Type A, were submitted by the Power Plant-Engine Laboratory.

C. Results:

Test results appear in Table I.

D. Conclusions:

None.

Inclosure C 2

TABLE I

Sample	Total Heat of Combustion B.T.U./lb*	Specific Gravity 60/60°F
Heater A	21,850	0.724
Heater B	22,000	0.724
Heater C	21,630	0.721
Heater E	21,620	0.728
Heater F	22,100	0.719

* Total heat of combustion at constant volume per unit quantity of gasoline. Final products: Ash, Gaseous CO_2, SO_2, and Liquid, H_2O.

Reported by:

Roger J. Pasqual, Jr.
Chemical Engineer

Reviewed by:

Francis S. Lemmer,
Chemical Engineer

Approved by:

C. W. Banton, Jr.
Chief, Chemical Section
Materials Laboratory

Form ORDMX-EA 3988
1 Feb 50

ORDNANCE DEPARTMENT
DETROIT ARSENAL

LABORATORY WORK ORDER
(For Use by Dev. & Eng. Dept. Only)

TO: Chief, ~~Components~~ Laboratories Division

DESCRIPTION OF WORK IN DETAIL:

12 October 1951

Project Engineer: Robert W. Koe   Ext. 3-1222

SUBJECT: Heater, Personnel,

1. Tests are to be conducted to determine the durability and practicability of subject heater.

2. The following tests are to be made as per inclosed test program.

   a. Vibration test.
   b. Tilting test.
   c. Cycling test, 100 cycles.
   d. Continuous operation test, 200 hours at -65°F.

3. Formal report is required and necessary photographs.

NOTE: Inclosed wiring diagram.

Estimate submitted by Mr. Raymond Brosez, Chief of Low Temperature Br.
Components Laboratory Div.

COPY

SERIAL NO. 6048

COMPLETION NOTICE	ESTIMATE MUST NOT BE EXCEEDED. QUOTE FULL W.O. AND PART NOS. ON ALL PROCUREMENTS AND JOB CARDS.		PROJ. NO. TT1-642
COMPLETION DATE	COMP. LAB. LABOR ONLY	EST.	EX. ORDER 800 F75
	MATERIAL AND WORK OF OTHER DEPARTMENTS	EST.	EX. ORDER 790 F4
LAB. BR. CHIEF	APPROVED		
LAB. DIV. CHIEF			
	BRANCH CHIEF OF Components	DIVISION CHIEF OF Res & Dev	CHIEF, DEV. & ENG. DEPT.

Form ORDMX-EA 3988
.1 Feb 50

LABORATORY WORK ORDER
(For Use by Dev. & Eng. Dept. Only)

ORDNANCE DEPARTMENT
DETROIT ARSENAL

TO: Chief, Laboratories Division 6 November 1951

DESCRIPTION OF WORK IN DETAIL:

Project Engineer: Robert W. Kos, Ext. 3-1222

SUBJECT: Heater Tests

1. Tests are to be conducted to determine the durability and practicability of the following heaters using heater (a) as a control heater.

a. Heater, Personnel (24 volt)

b. Heater, Personnel

c. Heater, Personnel & Engine Preheater (24 volt) 30,000 B.T.U.

d. Heater, Personnel & Engine Preheater (24 volt) 60,000 B.T.U.

2. The following tests are to be made as per inclosed test program.

a. Vibration test.

b. Tilting test.

c. Cycling test, 100 cycles.

d. Continuous operation test, 200 hours at -65° F.

NOTE: Inclosed wiring diagram

Estimate submitted by Mr. Raymond Brozek, Chief of Low Temperature Branch
Components Laboratory Division

SERIAL NO. 60481

COMPLETION NOTICE	ESTIMATE MUST NOT BE EXCEEDED. QUOTE FULL X.O. AND PART NOS. ON ALL PROCUREMENTS AND JOB CARDS.		PROJ. NO. TT1-642
COMPLETION DATE	LAB. LABOR ONLY	EST.	EX. ORDER 800 P75
LAB. BR. CHIEF	MATERIAL AND WORK OF OTHER DEPARTMENTS	EST.	EX. ORDER 790-4
	APPROVED		
LAB. DIV. CHIEF	BRANCH CHIEF OF Components	DIVISION CHIEF OF Res & Dev	CHIEF, DEV. & ENG. DEPT.

Form ORDMY-LA 3988
1 Feb 50

LABORATORY WORK ORDER
(For Use by Dev. & Eng. Dept. Only)

ORDNANCE DEPARTMENT
DETROIT ARSENAL

TO: Chief, Laboratories Division 8 January 1952

DESCRIPTION OF WORK IN DETAIL:

N Johnson 1-8-52

Project Engineer: Norwood Johnson Ext. 3-3242

SUBJECT: Test of Personnel Heaters, Gasoline Burning Type for Military Vehicles.

Since the release of Lab Work Order No. 6048, two more heaters have become available for test. One is termed Code E. It is desired to test Code E heater under the same conditions as Code A, B, C and D. The second heater is modified with preheater and is designed to operate at any angle of tilt. This heater should be run on the electrical and tilting phases of subject Lab Work Order only. The Model is to be termed Code F.

Estimate cost furnished by H. Wright.

Low Temp

RECEIVED
JAN 11 '52
COMP. LAB.

SERIAL NO. 6048-S-2

COMPLETION NOTICE	ESTIMATE MUST NOT BE EXCEEDED. QUOTE FULL X.O. AND PART NOS. ON ALL PROCUREMENTS AND JOB CARDS.		PROJ. NO. 711-642
COMPLETION DATE	LAB. LABOR ONLY	EST	EX. ORDER 800P75
LAB. BR. CHIEF	MATERIAL AND WORK OF OTHER DEPARTMENTS	EST.	EX. ORDER
	APPROVED		
LAB. DIV. CHIEF	[signature] BRANCH CHIEF OF	[signature] DIVISION CHIEF OF	[signature] CHIEF, DEV. & ENG. DEPT.