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60,000-BTU/H, MILITARY DESIGN, MULTIFUEL SPACE HEATER.(U)
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Report 2184

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June 1976

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U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND
MERADCOM

U.S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 2184	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 60,000-BTU/H, MILITARY DESIGN, MULTIFUEL SPACE HEATER.		5. TYPE OF REPORT & PERIOD COVERED Final Report, June 1972 – through December 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Bernard W. Flynn, Jr		8. CONTRACT OR GRANT NUMBER(s) DAAK02-73-C-0454
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Mobility Equipment Research and Development Command ATTN: DRXFB-EN Fort Belvoir, Virginia 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project 1G764717DL3911
11. CONTROLLING OFFICE NAME AND ADDRESS Commander, U.S. Army Mobility Equipment Research and Development Command Fort Belvoir, Virginia 22060		12. REPORT DATE June 1976
		13. NUMBER OF PAGES 54
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 50p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

14 USAMERDC-2184

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Combustion-Type Heater
Military Design Heater
Multifuel Heater
Space Heater

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers engineering development and testing of a 60,000-Btu/h, Military Design, Multifuel Space Heater. Heaters are required to accept two types of standard, Army electrical power: 120-volt a.c., 60-Hz, 1-phase; and 208-volt a.c., 400-Hz, 3-phase. The heaters will replace performance specification heaters presently produced for use in mobile van and shelter applications. Testing was done by the contractor, the subcontractor, and MERADCOM to determine design weaknesses or to verify critical performance prior to

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entering the Development Test II (DTII) phase. The report concludes that the contract for DT II heaters will require further design effort to effect improvement of the vent blower performance and configuration, the EMI suppression, the noise level attenuation, the low-temperature performance, and the combustion blower motor brush durability. The development should proceed to contract for DTII heaters, followed by DTII tests at the U.S. Army Test and Evaluation Command.

SUMMARY

This report covers development and test of the 60,000-Btu/h, Military Design, Multifuel Space Heater. The heater was developed under Contract DAAK02-73-C-0454 with Hunter Manufacturing Company, Solon, Ohio. Tests reported herein were conducted by the contractor, two subcontractors, and/or MERADCOM.

The report concludes that:

a. The testing and evaluation during Engineer Development was effective in determining weaknesses in the heater design and inadequacies of subcontractor EMI tests.

b. Redesign effort is required to effect improvement in the vent-, or circulation-, air blower, EMI suppression, noise level, low-temperature performance, and combustion blower motor brushes.

c. The heater design was found acceptable in capacity, airflow, high-temperature operation, altitude operation, vibration, and reliability.

d. The design also is judged to be compatible with other environmental and performance requirements based on experience with other heaters and previous testing.

e. The contract for DTII test models will require redesign to improve the vent blower performance and configuration, the EMI suppression, the noise level attenuation, the low-temperature performance, and the combustion blower motor brush durability. Also, the recommendations of the P-TEAR will be included in the redesign.

f. Use of a separate 60-Hz to 400-Hz converter for operating a 60-Hz heater on 400-Hz input power was demonstrated as feasible.

g. Development of the 60,000-Btu/h, Military Design, Multifuel Space Heater may proceed to contract for DTII test models, followed by DTII testing at TECOM.

PREFACE

Authority for conducting the development and tests covered by this report is contained in "Department of the Army Approved Small Development Requirement (SDR) for a Family of Multifuel Space Heaters (CDOG paragraph 149f(6)," 9 September 1970, now superseded by "Materiel Need (Engineering Development) (MN(ED)) for 60,000 BTUH Heater, Multifuel, CARDS Reference Number1648," 22 February 1974. The work has been performed under Project 1G764717DL3911: "Heating, Van Type."

Development and tests were the responsibility of Bernard W. Flynn, Jr., Project Engineer, under the supervision of Darald C. Frink, Chief, Environmental Equipment Division, Laboratory 3000.

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60,000-BTU/H, MILITARY DESIGN, MULTIFUEL SPACE HEATER

I. INTRODUCTION

1. Subject. This report covers development and engineering design tests of the 60,000-Btu/h, Military Design, Multifuel Space Heater by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM). The heater is one of a family of multifuel heaters being developed for mobile shelters, electronic equipment, critical operation shelters, and special-purpose climatic conditioning use where heating is essential to satisfactory operations or maintenance. The objective of this task is the development of military design heaters for standardization and replacement of inadequate models presently in use. The design of this heater is depicted on detail drawings and is free of components which are proprietary to the heater manufacturers.

2. Background. Efforts to develop a military, 60,000-Btu/h heater have been delayed by difficulties in obtaining approved requirements documents, by unavailability of funds, and by technical problems with prototype hardware. Following approval of a Small Development Requirement (SDR) for a family of multifuel space heaters in September 1970, the development was reinitiated during the Coordinated Test Program In-Process Review (CTP-IPR) in 1972.

II. INVESTIGATION

3. Approach. The development reported herein represents continuation of an in-house program aborted earlier for the lack of funds. Contract DAAK02-73-C-0454 was awarded to Hunter Manufacturing Company, Solon, Ohio, on 6 June 1972. The contract was a three-phase effort summarized as follows:

a. Phase I. Analyze a Hunter UH68D, 120/60 Type I Heater and data to determine design changes necessary to provide a heater capable of satisfying specified heater requirements. The analysis considered, but was not limited to, the following unproven areas of the design: reliability, electromagnetic interference, noise level, and environmental characteristics. Provide a preliminary Design and Visualization Plan outlining data to support the proposed design.

b. Phase II. Design, fabricate, test, and deliver four models of the proposed heater for preliminary government testing to indicate design acceptability.

c. Phase III. Redesign (if dictated by testing), fabricate, test, and deliver four Engineer Design Test (EDT) model heaters. Provide detailed drawings of the final design and reports of contractor testing.

It was initially planned to develop two versions of the 60,000-Btu/h, Military Design, Multifuel Space Heater per the approved requirements document. Funding limitations precluded developing the 400-Hz model under the contract, so plans were changed; MERADCOM was to purchase necessary parts and modify the 60-Hz heater for operation on 400 Hz. However, further investigation of heater requirements revealed that the 400-Hz quantity was too low to warrant development of a separate 400-Hz heater. The development program was then redirected to developing only a 60-Hz heater and locating or, if necessary, developing a separate military quality 400-Hz to 60-Hz power converter for operation of the 60-Hz heater from a 400-Hz power supply.

Government testing under the EDT category then was required to determine the degree to which technical performance, reliability, and durability requirements were satisfied. The test results will expose weaknesses in the design and enable design changes prior to fabrication of test models for Development Testing II (DTII) by the Army's Test and Evaluation Command (TECOM).

The SDR was converted to Materiel Need (MN) format during the CTP-IPR in March 1972. Approval of the Materiel Need (Engineering Development) (MN(ED)) and the CTP-IPR was withheld by the Department of the Army (DA) pending completion of Tentative Basis of Issue Plans (TBOIP). DA further directed that all effort on this development be suspended until the TBOIP and MN(ED) were approved. Permission was later granted to permit continuation of the contract and in-house effort (acceptance testing) as required to fulfill the government's obligations under the contract.

The TBOIP issue was finally resolved and the MN(ED) was approved by DA in February 1974. Although formal EDT was deferred until approval of the MN, most of the essential subtests were conducted as a part of contract acceptance tests. EDT continued into November 1974.

In November 1975, a 400-Hz to 60-Hz power converter was obtained, and a very limited compatibility demonstration was conducted.

4. **Description.** The 60,000-Btu/h, Military Design, Multifuel Space Heater is self-contained in a sheet-metal enclosure measuring 11 by 21.2 by 29 inches (27.94 by 53.85 by 73.66 centimeters) and weighs approximately 120 pounds (54.43 kilograms). (See Figure 1.) The heater is an uncontaminated, forced-air type with automatic thermostat control. The heater may be operated in an upright, inverted, or horizontal position by maintaining the float assembly in a horizontal position. Mounting provisions are built into the cabinet, and brackets are included with the heater for floor, bench, or wall installation. The fuel inlet and electrical power connections are located

Figure 1. View of 60,000-Btu/h, military design, multifuel space heater.

on the front surface of the heater. The control box, which can be installed remote from the heater with the addition of an interconnecting cable, is also mounted on the front of the heater. Exhaust-gas discharge is located on the rear surface of the heater. Two panels – right side and left side – are removable to provide ease of maintenance for the circulating-air blower and the combustion-air blower. Service doors on the right side and left side provide access to the burner head, ignitor, and nozzle assemblies. Combustion air is drawn through a louver on the front surface of the heater. Circulating air is drawn into the heater either through a damper assembly located on either side of the heater or through the top of the heater by removing the top panel. A damper cover is provided for closing the side damper when the top panel is removed. The air is forced around the exterior surface of the combustion chamber, where it is heated and distributed through the bottom of the heater.

The 60,000-Btu/h, Military Design, Multifuel Space Heater is physically and functionally interchangeable with the 60,000-Btu/h heater produced in accordance with Performance Specification Document MIL-H-11511E to fulfill current and past supply requirements. Several features of the military design heater will provide improved performance in the areas of electromagnetic interference, noise level, and reliability. Also, the selection of off-the-shelf components and the location of components has been improved to preclude unnecessary removal of other components. The achievement of this goal provides a considerable improvement in the ease of maintenance.

Major components of the heater subassemblies are described as follows:

a. **Heat Exchanger.** A continuously welded, sealed, stainless steel heat exchanger provides a chamber for combustion, which transfers the heat of combustion to clean circulating air and conveys the exhaust gases to an exhaust pipe for discharge external to the heated space.

b. **Burner.** The burner contains provisions for mounting the fuel nozzle, ignitor, and the combustion-air hose to enable uniting the fuel, air, and the ignition for proper mixing and initiation of combustion. The burner interfaces with the heat exchanger for completion of the combustion process.

c. **Fuel System.** Basic components of the fuel system include: the fuel filter; an electric, low-pressure military standard fuel pump; a constant level fuel control; a solenoid valve; a fuel-metering needle assembly; and a fuel nozzle. An electric preheater is attached to the nozzle assembly to keep fuel at operating temperatures during extra-cold ambients.

d. **Atomizing-Air Systems.** An electrically driven, turbine-type blower provides low-pressure air through a hose into the burner head to provide combustion air and to aspirate fuel.

e. Circulating-Air System. An electric motor provides power for a double-shafted-motor centrifugal blower arrangement. The circulating-air blower draws air through the return-air opening (side or top location) and discharges the air over the heat exchanger, where the air is heated. The air is then discharged into the area to be heated.

f. Ignition System. Energy for ignition is provided by a step up, high-voltage transformer to the ignitor plug on the burner head assembly. The complete unit is shielded electrically to suppress electromagnetic interference.

g. Electrical System. In addition to the motors and fuel pump discussed above, the electrical system included a power conversion unit (transformer/rectifier) to convert alternating current input to a nominal 24-volt d.c. output.

h. Control System. Components of the control system include the room thermostat; the manual fan/off/on switch; the flame-sensing switch; the switching relay; and safety controls for protection against flame failure, excessive outlet-air temperature, and excessive electrical current draw because of defective wiring or components.

5. Operating Cycle. The operating cycle includes distinct steps when the heater is operating an automatic control. During startup, all components are energized except the switching relay. If ignition and proper combustion are assumed, then the flame-sensing switch is actuated by the heat of combustion and closes to activate the switching relay, which deenergizes the flame-failure timing circuit. The cycle is then in the normal-run mode, and operation continues until enough heat is delivered to satisfy the room thermostat. The room thermostat will open when the desired temperature is reached, causing the fuel circuit (fuel pump and solenoid valve) to be deenergized. Without fuel, the operation will then move to the purge cycle, where operation of the fan motor, combustion-air blower motor, and ignition continues until the heat exchanger dissipates any residual heat. When cool, the flame switch opens to deenergize the switching relay, and operation of all components ceases. The heater then remains in a standby mode until the space temperature requires heat, at which time the thermostat is activated and the next cycle is started.

If combustion is not established during the start cycle, the flame-sensing switch will not activate causing the flame-failure timing circuit to remain energized for approximately 45 to 60 seconds; then, the flame-failure control will open to interrupt all operation. The flame-failure control must be manually reset to restore operation.

Malfunctions which cause overheating will open the high-limit temperature control to deenergize the solenoid valve and fuel pump. When fuel flow stops, the overheating condition will cool until the high-limit control is automatically reset, allowing normal operation to resume. The manual fan/off/on switch is used to deactivate the automatic operation whenever it is desired to remove the heater from service. Also, the third position of the fan/off/on switch is used when the circulation of unheated air is desired. This feature can be used during periods when temperatures deem that cooling or heating is not required but that fresh or circulated air is desired.

6. **Requirements.** The essential development requirements of the SDR and MN(ED) were expanded, interpreted, and converted into a specification-type format. The performance and physical requirements are provided in Appendix A as extracted from "Development Specification for: Heater, Space, Multifuel, With Blower, 60,000 BTU/H," dated 12 February 1971.

7. **Engineer Design Tests.** The procedures for individual tests in the EDT category were established in preparation of the Development Specification. These procedures were provided both as a directive to the contractor for his testing and as information to indicate how DA would conduct tests. Although tests were prescribed for assessing capability to satisfy each development requirement, not all tests were conducted. Testing was limited to critical requirement areas where weaknesses would jeopardize the probability of success during the DTII to be conducted by TECOM. Considerable testing by MERADCOM on similar heaters provides a good background for assessing the probability of successfully completing tests during both EDT and DTII. Those tests judged to be of little or no risk were passed over during the EDT in order to minimize needless duplication of tests which eventually would be conducted by TECOM. The tests that were not run because of the negligible risk include the following:

Thermostat Operation (same thermostat as existing heaters)
Inclined Operation
Low-Temperature Storage
High-Temperature Storage
Humidity
Salt Fog
Fungus
Shock
Chemical/Biological (CB) Compatibility
Voltage and Frequency Variation

The tests which were conducted during EDT are listed below, and the procedures are discussed in Appendix B.

Physical Inspection
Heat Exchanger Pressure Test
Controls
Operational
Capacity/Airflow
High-Temperature Operation
Run-In
Noise
Electromagnetic Interference
Voltage and Frequency Variation
Altitude Operation
Low-Temperature Operation
Vibration
Reliability

8. **Test Results.** Results of tests are discussed for both the preliminary heaters and the final, EDT-model heaters. Some tests were conducted on both heaters, and other tests were limited to only the preliminary model heaters. The results are discussed individually in paragraphs 8a through 8n, following, for each test conducted.

a. **Physical Inspection.** Each heater was inspected at the contractor's plant prior to delivery to DA. Initially, the nameplates, instruction plates, and wiring diagram plates were missing. The contractor installed the missing plates prior to shipping the heaters. More detailed examinations of the Phase II heaters (D517) revealed that movement of the return-air dampers interfered with the combustion-air blower and power connectors. Design changes were incorporated during Phase III of the contract to correct this interference. The heaters were judged to have passed the physical inspection successfully.

b. **Heat Exchanger Pressure Tests.** A pressure test of each heat exchanger was conducted by the contractor prior to assembly of the heaters. These tests were witnessed by MERADCOM personnel. Additional heat exchanger pressure tests were conducted at 500-hour intervals during durability-reliability tests and following the vibration test. All tests indicated the heat exchangers to be free of leaks; therefore, all heaters successfully passed the heat exchanger pressure test.

c. **Controls Tests.** The operation of each control on each heater was checked to verify that the control properly performed its function. Some initial adjustments of the flame-sensing controls were necessary to guard against nuisance flame-failure shutdowns and excessive cycling of the blowers during the purge cycle. The flame-failure circuits all responded within the time range of 50 to 60 seconds to provide shutdown during simulated flame-failure conditions. The temperature high-limit control opened to stop fuel flow to the burner at an outlet-air temperature considerably under the 250° F (121° C) limit. All controls performed their required function during the controls tests and during subsequent heater operation.

d. **Operational Tests.** The heaters performed satisfactorily during all operational testing. The data indicated acceptable performance relative to output capacity, efficiency, and exhaust-gas content of carbon monoxide and smoke. The combustion efficiency ranged from 75 to 77 percent, and the CO did not exceed the 0.02-percent limit during the operation of properly adjusted heaters.

Table 1 provides a summary of calculated results and data on selected operational test runs. The data summary provides the same information as the capacity/airflow tests; however, the operational test is shorter, and its accuracy may be questioned because of the unvalidated temperature stability.

e. **Capacity/Airflow Tests.** Two heaters were subjected to capacity/airflow testing. Results and data from these tests are summarized in Table 2. All tests were conducted at MERADCOM using a 120-volt a.c., 60-Hz power input and with an external static pressure of about 0.35 inch (0.89 centimeter) water gage. Both heaters delivered adequate airflow ranging from 42.9 to 44.7 lb/min (19.46 to 20.28 kg/min) and acceptable capacity ranging from 60,464 to 62,832 Btu/h. The measured efficiency range was 70.8 to 73.4 percent and the combustion efficiency range was 74.4 to 78.3 percent. The heaters operated satisfactorily during all capacity testing with the highest recorded CO level of 0.001 percent and the highest smoke measured at No. 1 on the Bacharach Scale.

Appendix C contains the data sheet and a two-page printout of the airflow and capacity calculations for one of the capacity/airflow test runs. These are provided as an example of the data and calculations required for each capacity/airflow test.

f. **High-Temperature Operational Test.** The high-temperature operational test was conducted by the contractor at his facility and witnessed by the MERADCOM project engineer. The data in column 6 of Table 1 were collected under conditions of high-temperature operation. No adverse performance was observed while operating on gasoline with the elevated inlet temperature of 75.7° F (24.28° C). Heaters D521 and D522 were also subjected to these same operational test conditions without any adverse performance.

g. **Run-In Tests.** The run-in tests were conducted at MERADCOM on heaters D521, D522, and D523 at the start of durability/reliability tests. The only malfunction during the 100-hour run-in was reported on heater D521. After 29 hours,

Table 1. Summary of Results and Data, Operational Tests

Characteristic	Heater					
	D522	D522	D523	D515	D523*	D523*
Fuel Type	Gas	DF2	Gas	DF2	Gas	DF2
Input Power (Hz)	60	60	60	60	50	50
Airflow:						
lb/min	43.2	45.0	43.6	45.2	42.7	41.1
kg/min	19.59	20.41	19.77	20.50	19.37	18.64
Air Temp (In):						
° F	58.0	61.2	61.0	65.0	75.7	73.0
° C	14.5	16.21	16.1	18.33	24.27	22.77
Air Temp (Out):						
° F	157.0	156.1	158.3	159.3	177.5	179.5
° C	69.44	68.94	70.17	70.72	80.83	81.94
Fuel Rate:						
lb/h	4.17	4.47	4.23	4.59	4.28	4.26
kg/h	1.89	2.03	1.92	2.08	1.94	1.93
Capacity (Btu/h):						
Input	83,817	87,612	85,023	89,964	86,000	83,400
Output	61,563	61,568	61,055	61,420	62,000	62,200
Measured Efficiency (%)	73.5	70.3	71.8	63.8	72.1	74.6
Exhaust Smoke (Bacharach No.)	0	0	1.3	0	0	0
Exhaust CO (%)	0	0	0	0	0	0
Exhaust CO_2 (%)	13.0	12.5	13.3	12.3	12.6	12.8
Exhaust Temp						
° F	670	670	707	632	785	780
° C	355	355	375	334	418	416
Combustion Efficiency (%)	77.2	76.8	76.5	77.4	75.4	76.8
Supply Voltage	120.7	120	120	120	120	120
Current (A)	8.9	8.7	8.9	9.1	NR	NR
Power Consumption (W)	960	918	937	960	903	940
Fan Speed (r/min)	2,100	2,200	2,200	2,127	2,263	2,197

* *Data taken at manufacturer's plant*

NR – not recorded

Table 2. Summary of Results and Data, Capacity/Airflow Tests

Characteristic	Heater D510	Heater D510	Heater D522	Heater D521
Fuel Type	Gas	DF2	Gas	DF2
Input Power (Hz)	60	60	60	60
Airflow:				
lb/min	44.7	44.5	42.9	43.3
kg/min	20.28	20.19	19.46	19.64
Air Temp (In)				
°F	69.0	68.0	63.4	61.0
°C	20.56	20.0	17.44	16.11
Air Temp (Out)				
°F	164.4	166.0	161.8	158.0
°C	73.56	74.4	72.1	70.0
Fuel Rate				
lb/h	4.28	4.37	4.27	4.29
kg/h	1.94	1.98	1.94	1.95
Capacity (Btu/h)				
Input	86,028	85,652	86,028	84,084
Output	61,487	62,832	60,803	60,464
Measured Efficiency (%)	71.5	73.4	70.7	71.9
Exhaust Smoke (Bacharach No.)	0	1.0	1.0	0
Exhaust CO (%)	0	0.001	0	0
Exhaust CO_2 (%)	12.8	13.5	11.4	11.5
Exhaust Temp				
°F	616	643	708	737
°C	324	339	375	391
Combustion Efficiency (%)	78.3	78.1	74.8	74.4
Supply Voltage	120	120	120	120
Current (A)	9.7	8.8	9.1	9.3
Power Consumption (W)	970	958	954	958
Fan Speed (r/min)	2,100	2,138	2,142	2,136

it was determined that the control box was defective. Both indicating lights were lit simultaneously. The control box had been subjected to previous disassembly/ reassembly during a Physical Teardown Evaluation and Allocation Review (P-TEAR). The control panel was replaced with one from heater D523, which had endured 2,000 hours of previous testing. Investigation revealed an error in reassembly wiring after completion of the P-TEAR. No other malfunction was observed on any of the three heaters.

The contractor conducted a run-in test on the preliminary model heater, D508, and reported no malfunctions. Some carbon buildup was present in the main burner tube at the end of 100 hours, but it did not alter the heater performance.

h. **Noise Tests.** Investigative noise tests were conducted during preliminary design of the 60,000-Btu/h military design heater. The tests were conducted by Riverbank Acoustical Laboratories under subcontract. The contractor utilized results of the early tests to aid in the selection of a circulating-air fan and of the type and location of insulation for sound attenuation within the heater case.

A retest of noise was made on the final configuration of heater D508 by the same subcontractor. The results of the final sound test are presented in Table 3 along with identification of the desired and maximum noise level limits from the heater development specification.

Table 3. Noise Test Results, Preliminary Model Heater D508

Octave-Band Center Frequency (Hz)	Desired Sound Power (dB)	Maximum Sound Power (dB)	Measured Sound Power (dB)
125	77	85	73.1
250	73	81	78.5
500	69	80	80.2
1,000	67	77	77.3
2,000	66	75	71.6
4,000	65	74	67.6
8,000	64	73	64.6

NOTE: All values are sound power re 10^{-12} W.

The noise level barely exceeded allowable limits in the 500- and 1,000-Hz octave bands and was less than those limits in all other bands. The desired level was exceeded in all octave bands except the 125-Hz band.

i. **Electromagnetic Interference Tests.** Electromagnetic interference

(EMI) tests were conducted on the preliminary model heater D508 under subcontract by Captor Corporation. EMI tests on the final model heater D520 were conducted at MERADCOM. The Captor tests were conducted using rather antiquated instruments which were manually operated, and EMI noise levels were determined by the operator's physically listening to an output signal. The MERADCOM test was conducted in a relatively new facility using modern, automatic scanning and recording instruments. Both of these instrumentation systems are permitted by the EMI test specification.

Initial tests by Captor Corporation indicated the heater EMI levels exceeded specification limits of MIL-STD-461A in both the conducted (CE03) subtest and the radiated (RE02) subtest. A Captor filter (model A-2199) on the input power leads and a capacitor across the flame switch brought the conducted EMI within limits. Shielding of the thermostat leads was necessary to reduce radiated EMI below specification limits. Captor Corporation then reported that the heater EMI levels satisfied the requirements of MIL-STD-461A. The design, as approved by Captor Corporation, included considerable shielding of internal wiring harnesses in addition to improvements discussed above.

Tests of the final model heater D520 sought to verify that all of the suppression devices – filter, capacitor, and shielding – were necessary. The MERADCOM tests indicated the heater to be unacceptable with and without the included suppression devices. Numerous suppression techniques were attempted but none were successful in providing an adequately suppressed EMI design. The flame-sensing switch was determined to be the major source of EMI. The Captor-designed suppression devices were effective in reducing the conducted emissions, but no solution was found for the excessive radiated emissions.

j. **Voltage and Frequency Variation Tests.** An operational test was conducted on each of three heaters with 50-Hz input power. These tests were performed by the contractor. The data indicated no significant deviation from similar data recorded with 60-Hz input power. See Table 1, columns 6 and 7, for a data comparison on heater D523. The results were nearly identical for heaters D521 and D522. Tests for high-frequency variation and voltage variation were not conducted.

k. **Altitude Operation Tests.** The altitude operation test was conducted on heater D521. Starting and operation during the 1-hour test were quite satisfactory. The fuel rate was expectedly reduced to compensate for the less dense air at 10,000 feet simulated altitude. Recorded data included the fuel rate at 2.8 lb/h (1.03 kg/h), the air temperature rise through the heater at 68.9° F (20.5° C), the exhaust temperature at 380° F (193° C), the carbon monoxide in exhaust at 0, and the smoke in exhaust at 0.

l. Low-Temperature Operation Tests. Heater D521 was subjected to low-temperature start and operation tests after an overnight soak at -50° F (-45° C). The heater would not start, and the trouble was traced to the military standard fuel pump. Tapping the fuel pump housing with a wrench resulted in fuel flow, and the heater would start but, then, would cease when the tapping was stopped. Heat was applied to the fuel pump from a heat lamp for 10 minutes, after which another restart attempt was made. The heater started, and performance was satisfactory until the heat lamp was removed. Removal of the fuel pump's microbond filter did not improve the low-temperature operation, nor did substituting a similar military standard pump improve performance.

Finally, the low-temperature operation test was performed with heat constantly applied to the external fuel pump. Data recorded while operating on DFA fuel oil included: the fuel rate – 4.26 lb/h (1.93 kg/h), temperature rise – 75.4° F (24.1° C), exhaust temperature – 500° F (260° C), carbon monoxide in exhaust – 0 percent, and smoke in exhaust – No. 2 Bacharach. The heater performance was satisfactory as long as heat was being applied to the fuel pump.

m. Vibration Test. The vibration test was conducted with early prototype heater D510. The resonant search indicated significant vibration of the heat exchanger tube relative to the front bulkhead at nearly all selected resonant points. In the first plane of vibration, horizontal front-to-back, resonant points for the heat exchanger tube were selected at 58, 78, and 127 Hz, and the fourth resonant point was 106 Hz for the control box. Visual inspection after the first plane of vibration revealed no damage.

The second plane of vibration was the horizontal side-to-side. Three resonant points were selected with the heat exchanger tube prominent in all three points. Also in resonance were: at 56 Hz, the side panels and louvers, the flexible fuel lines, and the filter bowl; at 86 Hz, the side panels and louvers. No damage was detected by visual examination following the second plane of vibratin.

The vertical vibration plane resulted in four resonant point determinations with the heat exchanger tube and the vent fan motors and scrolls in resonance at each point – 45, 77, 123, and 168 Hz. Other components in resonance included the side panels and the fuel filter assembly at 45 Hz and the control box and fuel float bowl assemblies at 77 Hz. The post-test inspection revealed no visible damage. The heater was capacity tested following the vibration test. No degradation of performance was evident. Results of the capacity test were included in paragraph 8e and Table 2.

n. Reliability Tests. Heaters D521, D522, and D523 were subjected to durability testing for assessment of their reliability and life-to-overhaul characteristics.

Testing of D522 and D523 was continued until 1,017 and 2,050 hours, respectively, had been accumulated on each heater. Heater D521 was operated for 1,033 hours. Appendices D, E, and F provide a listing of incidents which were recorded in the log during the durability tests. Figure 2 provides a summary of durability test incidents and actions for each heater relative to its accumulated operating time.

Heater D521 incurred two unscheduled stops in 1,033 hours. The cause of the first is unknown since the heater was restarted merely by pushing the "Reset" button. The second stop, at 1,033 hours, was caused by carbon deposits on the ignitor and the fuel nozzle. The unscheduled stop could have been avoided with scheduled cleaning of the ignitor and nozzle at 500-hour intervals. Replacement of the control panel after 29 hours was not done as a result of heater malfunction but because of false indication from the indicating lights. This replacement occurred during the first 100 hours, or during the run-in portion of the durability test; therefore, the malfunction should be assigned to the infant mortality category. Further investigation revealed a wiring error in reassembling the control panel following the P-TEAR disassembly. Another incident occurred which did not affect heater operation and was not shown on Figure 2. Noise from the heat exchanger at 209 hours was attributed to expansion and contraction of internal baffles. No corrective action was taken, and no heater problems related to the heat exchanger were experienced in 1,033 hours.

Heater D522 incurred three unscheduled stops in 2,017 hours. All three stops occurred within a 100-hour period, leading to the presumption that if proper corrective action had been taken there would have been only one unscheduled stop. The cause of all three stops is believed to be a dirty fuel nozzle, and no further problem was encountered after cleaning the nozzle. Again, these unscheduled stops could be avoided by scheduled cleaning of the nozzle and ignitor at 500-hour intervals. A plastic fuel overflow tube was replaced at 1,040 hours. During the 1,000-hour performance check, test personnel had rotated the burner head, which requires rerouting of the fuel supply and overflow tubes. Carelessness on the part of test personnel resulted in the overflow tube resting against the burner head, where heat deformed the tubing sidewall. Incorporation of clamps to secure the tubing would prevent recurrence of this problem. The fuel rate was readjusted at 863 hours after a decline in output temperatures was noted. Two incidents not recorded in Figure 2 were reported; noises involving the vent blower motor bearings and the heat exchanger baffles. Noise in the heat exchanger was noted at 162 hours, and the vent blower motor bearing noise was reported at 1,040 hours. No corrective action was taken for either incident, and the heater continued to function without any related problems for the remainder of the durability test.

Heater D523 experienced one unscheduled stop at 1,913 hours. The cause was worn out brushes on the combustion blower motor. The vent blower wheel

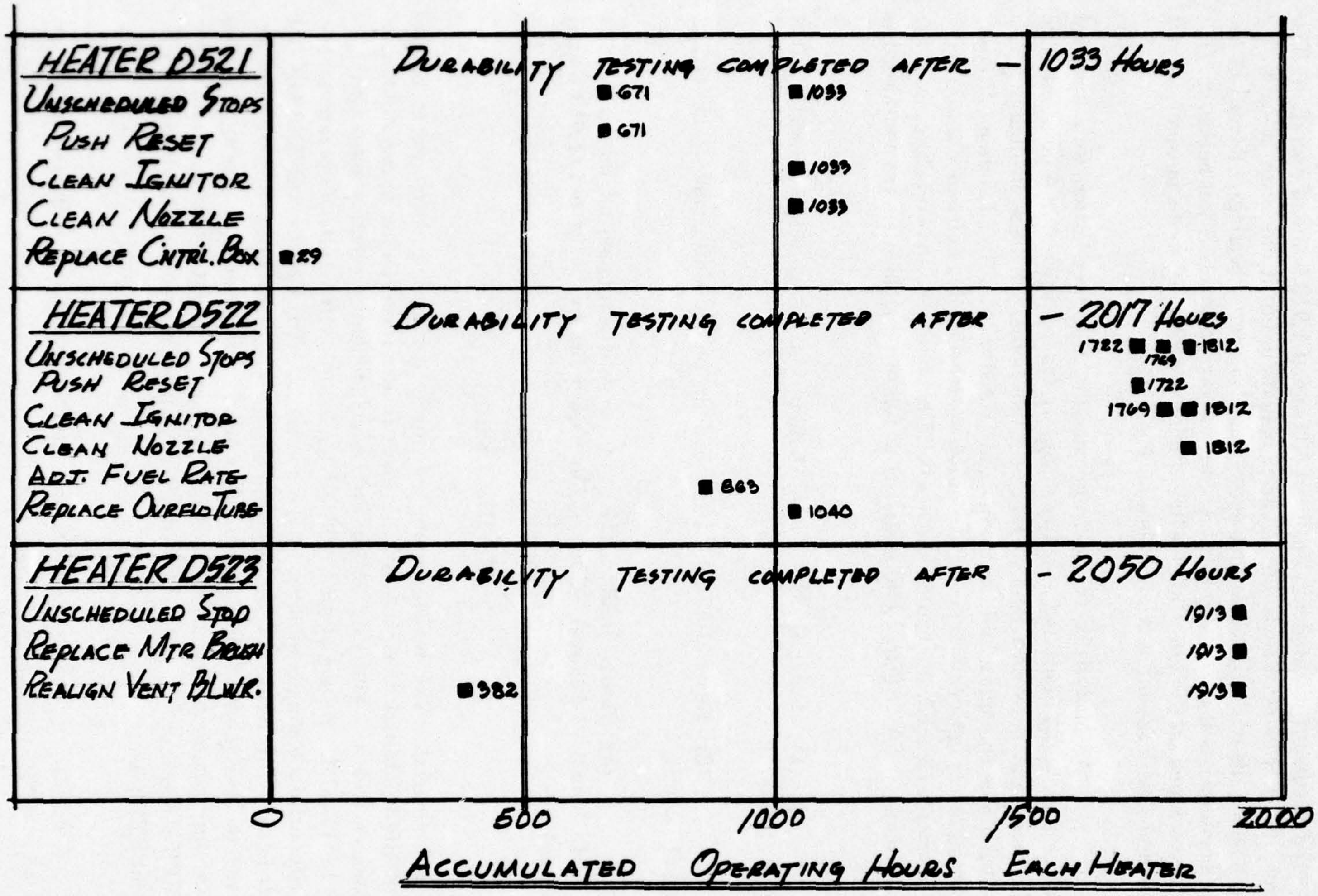

Figure 2. Summary of incidents and actions during durability tests.

and scroll alignment required adjustment at 382 and at 1,913 hours of operation. This incident did not cause a cessation of heater operation, but it did occur twice on the same heater. Heater D523 also had noisy vent fan motor bearings. Record of the noisy bearings was made at 1,690 hours, but no corrective action was necessary. The heater continued on for 2,050 hours without relative problems, so the incident was not considered significant and was not shown on Figure 2.

An analysis of Figure 2 indicates that the three heaters were operated for more than 5,033 hours and only five reliability failures occurred. A point estimate of the mean time between failure (MTBF) is 1,006 hours. Of these five failures, two are attributable to carbon buildup on the ignitor and nozzle. This failure mode could be eliminated or drastically reduced by requiring a scheduled maintenance action every 500 hours for cleaning the ignitor and nozzle. Eliminating these two failures from the data increases the MTBF to 1,680 hours. The following incidents were considered as failures:

(1) **Heater D521.** Carbon buildup on the ignitor and nozzle (1,033 hours) (1 failure).

(2) **Heater D522.** Carbon buildup on the ignitor and nozzle (1,722 hours) (1 failure).

(3) **Heater D523.** The vent fan wheel rubbing on the scroll (382 and 1,913 hours) (2 failures). Combustion blower brushes worn out (1,913 hours) (1 failure).

III. DISCUSSION

9. **General.** The testing conducted during engineering development of the 60,000-Btu/h, Military Design, Multifuel Space Heater was effective in determining its weaknesses and in identifying design areas which require corrective action prior to DTII by TECOM. Testing at MERADCOM tended to verify results of operational and capacity/airflow testing conducted by the contractor. The EMI tests at MERADCOM contradicted EMI results of the subcontractor. The MERADCOM EMI tests are believed to have more validity because they used more modern, automatic scanning and measuring equipment. When feasible, future development contracts should utilize the MERADCOM or TECOM EMI facilities to obtain maximum repeatability for subsequent EMI tests.

Results of the development and EDT indicated design improvements are required in the following areas:

a. Vent- or Circulation-Air Blower
b. Electromagnetic Interference
c. Noise Level
d. Low-Temperature Performance
e. Combustion Blower Motor Brushes

The vent blower structure and configuration needs redesign to eliminate alignment problems of the blower wheel and scroll. It is also desirable to reduce susceptibility to vibration resonance and to improve airflow distribution over the heat exchanger. The present vent blower design produces a high noise level and the motor has a high electric current draw due to its high slip speed.

The MERADCOM EMI tests indicated inadequate suppression of the EMI. Presently incorporated EMI suppression devices are complex and expensive. Further investigations and consultations are required to obtain acceptable suppression and to provide producible, economical design.

The heater noise level is slightly higher than the maximum levels of the development specification and considerably above the desired levels. The vent-air blowers circulate airflow in excess of the airflow requirement and are known to be a significant contributor to the overall noise level. Redesign of the vent blower as discussed above will assist in reducing the noise level; however, other noise producing sources also need to be investigated.

The heater itself performed satisfactorily at -50° F (45.5° C), but operation of the government recommended fuel pump was not satisfactory. Testing of previous heaters with an alternate brand of the MS pump has consistently provided acceptable performance at low temperature. Low-temperature performance of future heaters will be accomplished by insuring that the chosen fuel pump actually meets its own performance specification requirements. If attempts to requalify the defective brand are unsuccessful, then the heater data package will be revised to specify a fuel pump known to be satisfactory.

In addition to the combustion motor brush failure at 1,913 hours (heater D523), heater D522 was inspected at the conclusion of tests; the combustion blower motor brushes were found to have only a few hundred hours of serviceable life left. Since the replacement of motor brushes is not a desired preventive maintenance task, it appears that a design change of these brushes is necessary to improve this durability limitation.

The heater was found to be acceptable in the areas of capacity, airflow, high-temperature operation, altitude operation, vibration, and reliability. Sufficient testing was not performed to indicate performance at various voltages and frequencies, but results on 50-Hz input power were satisfactory. Previous testing of similar equipment has not resulted in performance problems at these various power extremes.

An almost negligible amount of testing was conducted to demonstrate the chosen concept for accomplishing a 400-Hz capability for the 60,000-Btu/h military design heater. That concept will utilize a separate, packaged 400-Hz to 60-Hz power converter to enable operation of the 60-Hz heater on a 400-Hz supply. There is not sufficient demand for 400-Hz heaters to warrant development of a separate heater. Testing under this development program consisted of location and purchase of an "off-the-shelf" military quality power converter and a very brief operating period to determine compatibility between the converter and the heater. The limited operation was acceptable, and the chosen 400-Hz approach is judged feasible.

The development of the 60,000-Btu/h, Military Design, Multifuel Space Heater is currently in the suspended state due to inadequate funding and higher priority programs. When the program is reactivated, now scheduled for FY79, the design improvements dictated by the results of Engineering Development and EDT tests will be incorporated into the contract for fabrication of DTII test items. Design changes recommended by the P-TEAR also will be incorporated in the contract. These improvements will be tested during Contractor Acceptance Tests and by DTII at TECOM.

IV. CONCLUSIONS

10. ***Conclusions.*** *It is concluded that:*

a. The testing and evaluation during Engineer Development was effective in determining weaknesses in the heater design and inadequacies of subcontractor EMI tests.

b. Redesign effort is required to effect improvement in the vent-, or circulation-, air blower, EMI suppression, noise level, low-temperature performance, and combustion blower motor brushes.

c. The heater design was found acceptable in capacity, airflow, high-temperature operation, altitude operation, vibration, and reliability.

d. The design also is judged to be compatible with other environmental and performance requirements based on experience with other heaters and previous testing.

e. The contract for DTII test models will require redesign to improve the vent blower performance and configuration, the EMI suppression, the noise level attenuation, the low-temperature performance, and the combustion blower motor brush durability. Also, the recommendations of the P-TEAR will be included in the redesign.

f. Use of a separate 60-Hz to 400-Hz converter for operating a 60-Hz heater on 400-Hz power was demonstrated as feasible.

g. Development of the 60,000-Btu/h, Military Design, Multifuel Space Heater may proceed to contract for DTII test models, followed by DTII testing at TECOM.

APPENDIX A

PERFORMANCE AND PHYSICAL REQUIREMENTS FOR

60,000-BTU/H, MILITARY DESIGN, MULTIFUEL SPACE HEATER[1]

3.0 Requirements.

3.1 Item Identification. An automatic, 60,000-Btu/h-capacity, multifuel space heater is required for standardization and replacement of inadequate models presently in use. *The heater will be compact, lightweight, safe, rugged, reliable, simple, and economical* to operate. The heater will be capable of operation in ambient air temperatures from 75° F to -50° F, of storage in ambients from 160° F to -70° F, and of enduring exposure to shock, vibration, salt fog, fungus, and humidity. The heater shall be of a self-contained, single package unit containing a combustion chamber and heat exchanger, burner, combustion-air supply device, air circulating blower, ignition system, fuel system, electrical system, safety controls, and a thermostat control. The heater is compatible with a variety of applications due to its multifuel capabilities (3.2.1.4) and its availability in two electrical types (3.2.1.5).

3.2 Characteristics.

3.2.1 Performance.

3.2.1.1 Airflow. The heater shall deliver a minimum of 32 lb/min of air against 0.35 inch water gage (WG) external static pressure in an ambient temperature of 65° F at sea level (0 to 500 feet). The heater shall produce the above stipulated airflow at rated power input (3.2.1.5), except a 15-percent reduction in airflow shall be allowed when operating the Type I heater on 50-Hz power.

3.2.1.2 Heating Capacity. The heater shall produce a minimum capacity of 60,000 Btu/h when operated in an ambient temperature of 65° F at sea level (0 to 500 feet). *The heater shall produce the above stipulated capacity at rated power input* (3.2.1.5), except a 15-percent reduction in capacity shall be allowed when operating the Type I heater on 50-Hz power.

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[1] Extracted From: *Development Specification For: Heater, Space, Multifuel, With Blower, 60,000 BTU/H,* 12 February 1971.

3.2.1.3 Efficiency. Under the conditions stated in paragraph 3.2.1.2, the heater shall have a minimum combustion efficiency of 70 percent as determined by subtracting stack loss percentage from 100 percent. Also, under these conditions the heater shall have a minimum measured efficiency of 65 percent.

3.2.1.4 Fuel. The heater shall require no more than a fuel-rate adjustment to operate using any of the following liquid fuels: combat gasoline conforming to MIL-G-3056 or VV-G-76 or with any other gasoline (leaded or aromatic) up to 100-octane grade, DITE, JP-4, JP-5, and with diesel fuel conforming to VV-F-800 (class DF-1, DF-2, or DF-A) having a cloud point not lower than -55° F. The heater shall meet all the criteria of paragraphs 3.2.1, 3.2.3, and 3.2.5 using any of the above referenced fuels (within the design temperature limits of the fuel). Operation on any of these fuels shall not produce carbon monoxide in excess of 0.01 percent of flue gases and/or smoke in excess of Bacharach No. 4 in flue gases. Also, the burner shall not become clogged from operation on any of these fuels.

3.2.1.5 Electrical System. The heater shall be available in the following two electrical types:

Type I: 120-volt a.c., 50/60-Hz, single-phase
Type II: 208-volt a.c., 400-Hz, three-phase

3.2.1.5.1 Voltage and Frequency Variation. Each type shall meet the requirements of paragraph 3.2.5.1.1 when operated as follows:

a. ± 10 percent rated voltage and rated frequency (all types)
b. ± 5 percent rated voltage and ± 5 percent rated frequency (Type II units)
c. ± 5 percent rated voltage and 50 Hz (Type I unit)
d. ± 5 percent rated voltage and 63 Hz (Type I unit)

3.2.1.6 Operating Positions. The heater shall be able to operate when positioned at 90° increments about an axis parallel to the long dimension of its base. The heater shall be able to operate with its vertical axis up to 10° from vertical in any direction.

3.2.1.7 CB Compatibility. The heater shall be able to operate without malfunction when supplied with return air frim self-powered, external Chemical Biological (CB) protective devices and when operating in a space pressurized to 1½ inches of water above ambient by such CB devices. In addition, the quantity of combustion air shall not exceed 2 lb/min when the heater is operating within the 1½-inch-WG pressurized space.

3.2.1.8 Air Filter Compatibility. The heater shall meet the airflow and heating capacity specified in paragraphs 3.2.1.1 and 3.2.1.2 when operated with an external pressure drop of 0.35 inch WG resulting from an external air filter and ducting.

3.2.1.9 **Noise.** Heater design shall stress noise reduction. The design objective and the maximum allowable sound power levels (re 10^{-12} W), determined by testing in a reverberant test chamber per ASHRAE Standard 36-62, are listed below:

Frequency (Hz)	Maximum Allowable (dB)	Design Objective (dB)
125	84	77
250	81	73
500	80	69
1,000	77	67
2,000	75	66
4,000	74	65
8,000	73	64

3.2.1.10 **Controls.**

3.2.1.10.1 **High-Temperature Safety.** The heater shall include a nonadjustable, automatic control to interrupt combustion chamber fuel flow to prevent the outlet conditioned air temperature from exceeding 250° F.

3.2.1.10.2 **Flame-Failure Safety.** The heater shall include an automatic control to interrupt combustion chamber fuel flow and stop all heater operation in the event of ignition failure or flame failure. The fuel shutoff shall be accomplished within 60 seconds after failure. A manual reset shall be provided.

3.2.1.10.3 **Overcurrent.** Electrical protective devices shall be included to protect the heater from overcurrent damage caused by maladjustment of the controls, short or open circuits, or failure of circuit parts. The electrical protective devices shall be accessible from the control panel. If a fuse is used, a replacement shall be located on the control panel.

3.2.1.10.4 **Motor Overload Protectors.** The motor(s) shall be equipped with automatic resetting, thermal-overload protectors sized to prevent motor operation above the safe operating temperature for which the motor is rated.

3.2.1.10.5 **Thermostat.** The heater shall have a remote thermostatic control to automatically cycle the heater on and off for the purpose of maintaining a desired space temperature. The thermostat shall be adjustable between 50° F and 70° F with no more than a 5° F differential or continuous modulation when set at 60° F. This item shall be furnished with all heaters.

3.2.1.10.6 Control Switch. A three-position toggle switch shall be provided for Heat-Off-Vent control of the heater. The switch shall conform to the requirements of paragraph 3.3.1.11.5.

3.2.1.11 Restart Capability. The unit shall be capable of being stopped (by any means other than an internal protective device) and, then, immediately restarted under any condition or mode of operation.

3.3.1.11.5 Toggle Switches. Toggle switches shall be of the sealed toggle bushing type conforming to Specification MIL-S-3950 with terminals permanently marked. Toggle switches shall be mounted so that the "ON" position is up.

3.2.1.12 Sealed Heat Exchanger. The combustion chamber-heat exchanger shall be of a sealed construction to prevent the escape of combustion gases into the conditioned-air circuit. The combustion chamber-heat exchanger shall be capable of withstanding 5 psig of internal air pressure without leakage.

3.2.2 Physical Characteristics.

3.2.2.1 Weight. Heater design shall stress weight reduction. The design objective shall be 120 pounds, and the maximum weight shall be not more than 140 pounds.

3.2.2.2 Dimensions. Nominal outside dimensions of the heater shall be: width, 24 inches; height, 21 inches; depth, 11 inches. Mounting brackets, exhaust outlet fittings, fuel fittings, screw heads, and air intake screens may extend not more than 4.375 inches beyond these dimensions.

3.2.3 Reliability. The heater shall have a reliability of 95 percent. The unit shall meet this requirement when operated at rated power input (3.2.1.5) including both 50-Hz and 60-Hz input for the Type I heater.

3.2.3.1 MTBF. Mean time between failures shall be not less than 480 hours of operation. The unit shall meet this requirement when operated at rated power input (3.2.1.5) including both 50 Hz and 60 Hz for the Type I heater.

3.2.3.2 Failure Definition. A "failure" for the purposes of determining MTBF shall be:

a. Any malfunction causing the automatic heater operation to cease

b. Any malfunction that aborts the mission, would damage the system by continued operation, would create a personnel safety hazard, or reduce heater output to below 90 percent of rated capacity

c. Simultaneous occurrence of related malfunctions are considered as one failure

NOTE: Any malfunction that does not affect mission performance (e.g., loose housing bolts, cracks in unit casing, missing knobs, and similar minor defects) shall not be classed as a failure.

3.2.4 **Maintainability.** The heater shall be designed to require a minimum of operational and in-storage maintenance. Repair by replacement and maintenance-free components shall be used to the maximum practicable extent. Only standard military tools and test equipment shall be needed for organizational and direct support maintenance. All moving parts shall incorporate permanently or self-lubricated bearings.

3.2.4.2 **Scheduled Maintenance.** The minimum allowable time between scheduled organizational maintenance shall be 125 hours.

3.2.4.3 **MTBO.** The minimum service life prior to overhaul shall be 2,000 hours.

3.2.4.4 **MTTR.** The mean time to repair shall be:

Organizational – 2 hours
Direct Support – 8 hours
General Support – 24 hours

3.2.4.5 **Percent Maintenance at Support Level.** Corrective maintenance and occurrences at direct and general support level shall not exceed 10 percent of total actions.

3.2.5 **Environmental Conditions.** Heater design and construction shall be such that the equipment shall be capable of withstanding the extremely hard usage encountered in military service. Hard usage shall be such as the following: cross-country transportation by truck or trailer; operation at extreme environments and at high altitudes; and operation and storage in the open air, exposed to the elements for extended periods of time. To the maximum extent, materials and special treatments shall be utilized to provide effective resistance to wear, abuse, rust, decay, erosion, and corrosion.

3.2.5.1 **Climatic Conditions.**

3.2.5.1.1 **Operation.** The heater shall be capable of continuous, safe operation without malfunction in environments ranging between +75° F and -50° F and at an altitude of 10,000 feet. Électrical input conditions shall be as stated in paragraph 3.2.1.5.1.

3.2.5.1.2 Storage. The heater shall be capable of safe storage and transportation under the conditions prescribed by climatic categories 3 and 8 of AR 70-38.

3.2.5.2 Vibration. The heater shall be able to withstand exposure to vibration as specified in MIL-STD-810B, Method 514, Category (f), Procedure VIII, Table 514-II, Schedule III, mileage schedule group c (4,000 miles), 5-minute sweep, 5 Hz through 200 Hz at input of 1.5 g, without failure.

3.2.5.3 Shock. The heater shall be able to withstand exposure to shock as described in MIL-STD-810B, Method 516, Procedure I, Figure 516-2. Peak pulse value shall be 10g and pulse duration 11 milliseconds, without failure.

3.2.5.4 Humidity. The heater shall be able to withstand exposure to high humidity as specified in MIL-STD-810B, Method 507, Procedure I, without degradation of performance or excessive corrosion.

3.2.5.5 Salt Fog. The heater shall be able to withstand exposure to salt fog as specified in MIL-STD-810B, Method 509, Procedure I. Exposure time shall be 50 hours without degradation of performance or excessive corrosion.

3.2.5.6 Fungus. The heater shall be able to withstand exposure to fungus as described in MIL-STD-810B, Method 508, Procedure I, for a period of 90 days without degradation of performance or excessive corrosion.

3.3.2 Electromagnetic Interference Suppression. The heater shall be fully equipped for suppression of electromagnetic interference and for operation in an environment in accordance with MIL-STD-461A, Type II-B equipment.

APPENDIX B

TEST PROCEDURES FOR ENGINEER DESIGN TESTS ON 60,000-BTU/H, MILITARY DESIGN, MULTIFUEL SPACE HEATER[2]

4.1.2 **Special Tests.** Tests shall be conducted as described utilizing all components and accessories in place during all tests. The operational test (4.1.2.1) shall be performed at least once for both 50 Hz and 60 Hz electrical input power on the Type I heater (3.2.1.5) and for both DF-2 and gasoline fuels on each heater type.

4.1.2.1 **Operational Test.** This test shall be conducted to provide data for comparison purposes on a repeatable basis. The purpose of this test is to determine if the heater is operating satisfactorily and/or extent of degradation (if any) of performance as a result of various tests conducted throughout the test program. Results of this test and the capacity test data (4.2.1.2) shall be utilized to establish an acceptable performance baseline consisting of differential air temperatures, flue-gas analysis and temperature, electrical power input characteristics (volts, amps, watts, and frequency), fuel rate and type, and circulation-air blower rpm. This test shall be conducted at an ambient temperature and return-air temperature of 60° F ± 5° F (sea level). Except for air temperature measuring apparatus, the instruments and test apparatus for this test shall be the same as required for the capacity test (4.2.1.2.1). The air temperatures for this test shall be determined by multipoint thermocouple grids consisting of at least four thermocouples equally spaced over the entire opening. The thermocouples shall be connected in parallel to obtain an average temperature. The scale division on the potentiometer shall not exceed 1° F. The heater shall be operated until temperature stabilization (see 4.2.1.2 for definition) has been accomplished and then operate the heater for 20 minutes, recording data at 10-minute intervals, until three complete sets of data have been recorded. Test results shall be based on the average of the three sets of data. Each set of data shall consist of the following:

a. Return-air temperature (° F)
b. Discharge-air temperature (° F)
c. Fuel weight, pounds.
d. Flue-gas analysis (CO_2 and CO percent by volume; smoke)
e. Flue-gas temperature

[2] Extracted From: *Development Specification For: Heater, Space, Multifuel, with Blower, 60,000 BTUH,* Dated 12 February 1971.

f. Electrical power characteristics (watts, amps, volts, and frequency)
g. Circulation-air blower rpm.

The combustion efficiency shall be determined (see 4.2.1.3) from these data. Nonconformance to 3.2.1.4 (CO and smoke) or 3.2.1.3 (combustion efficiency) shall constitute failure of this test. Also, observation of any data varying more than 5 percent from like data of previous Operational Tests (4.1.2.1) or observation of any malfunction, leak, rough or erratic operation, excessive vibration or noise, or any irregular characteristics shall constitute failure of this test.

4.1.2.2 **Run-In Test.** The heater(s) shall be "run in" for at least 100 hours. Running time accumulated during other tests that satisfy the requirements of this paragraph may be counted as "run-in" time. No major components (fans, motors, burner, heat exchanger, etc.) shall be replaced during "run-in." "Run-in" time shall be restarted after replacement of any of these items. The logbooks required by 4.1.1.3 shall be used for time accumulation and repair actions. The purpose of this test is to locate possible reliability problem areas. The heater(s) shall be operated in an ambient of 55° F (± 10° F) and cycled (by use of an electrical timer in the thermostat circuit) twice each hour (25 minutes on, 5 minutes off). The test shall be conducted using DF-2 diesel fuel. The heater operation shall be continuously monitored utilizing recording-type potentiometers for the return-air and discharge-air temperatures. The air temperature instrumentation shall be as detailed for the operational test (see 4.1.2.1). An operational test (4.1.2.1) shall be conducted prior to and following the 100-hour "run-in" test. After completion of the post-operational test, the burner(s) shall be disassembled and inspected for defects and/or carbon buildup in the burner or heat exchanger. Nonconformance under 4.1.2.1, nonconformance to 3.2.1.4, or any malfunctions during the 100-hour "run-in" test shall constitute failure of this test. Logbooks not in accordance with 4.1.1.3 shall constitute failure of this test.

4.1.2.3 **High-Temperature Operation Test.** This test shall be conducted on each heater type (3.2.1.5), including both 50-Hz and 60-Hz input power for Type I with gasoline fuel, to indicate the heater's capability to operate satisfactorily at high return-air temperatures. This test shall be conducted using instruments, methods, procedures, data recording, etc. conforming to 4.1.2.1 except that the return-air temperature shall be 75° F ± 2.5° F and the return-air opening shall have an additional static pressure loss of 0.20 inch WG to simulate a return-air filter (3.2.1.8). Nonconformance under 4.1.2.1 or nonconformance to 3.2.1.8 and/or 3.2.5.1.1 shall constitute failure of this test.

4.2 Quality Conformance Tests and Inspections.

4.2.1 **Performance Tests.** Tests shall be conducted at prevailing room ambient temperatures. All operating tests shall be repeated on each type of heater with input power for Type I heaters at 60 Hz unless otherwise specified herein. All components and accessories shall be utilized in all tests unless otherwise specified. All operating tests shall be conducted using one or more of the fuels specified in 3.2.1.4. All instruments shall be calibrated prior to tests.

4.2.1.1 Airflow. The heater circulation airflow shall be determined by test methods and test apparatus in accordance with Air Moving and Conditioning Association (AMCA) Standard No. 210-67 or American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard No. 37-69 or 16-69. The airflow test shall be performed in conjunction with the capacity test (4.2.1.2) and shall comply with the requirements of 4.2.1.2. The test data (five data points per 4.2.1.2) recorded shall be no less than that required by the above referenced standards. Airflow calculations and test results shall be in accordance with the above standards and shall be stated in lb/min and cfm (at return-air conditions) based on an average of the five data points. Nonconformance to 3.2.1.1 shall constitute failure of this test.

4.2.1.2 Capacity. Prior to any capacity and airflow tests, the heater shall be satisfactorily tested per 4.2.1.10 and 4.1.2.1. All capacity and airflow tests shall be conducted using combat gasoline and repeated utilizing DF-2 diesel fuel. Capacity and airflow tests shall be conducted on each heater type (3.2.1.5), including both 50-Hz and 60-Hz input power for the Type I heater, and utilizing both gasoline and diesel fuel for each of the test conditions. The test unit ambient- and return-air conditions for all capacity and airflow tests shall be 62.5° F ± 2.5° F. For temperature stabilization, the return-air temperature shall not vary more than ± 1° F from any other recorded return-air temperature, and the discharge-air temperature shall not vary more than ± 2° F from any other recorded discharge-air temperature. All capacity and airflow tests shall be conducted with all grilles and panels in the proper position and location on the heater.

For the capacity test, connect all instrumentation and test apparatus to the heater and establish test conditions. The heater shall be operated for at least 1 hour at stabilized temperature conditions before starting the capacity test run. For the capacity test, data shall be recorded at the start of and at 15-minute intervals thereafter until a 1-hour test run has been completed with five complete sets of data recorded. Test results shall be based on the average of the five sets of data. Each set of data shall consist of the following:

a. Return-air temperature (°F dry bulb and °F wet bulb), determined at 4 to 6 inches from the return-air inlet using a sampling device per Figure 2 of ASHRAE Standard 41-66, Part 1

b. Discharge-air temperature (°F dry bulb), determined by a sampling device (per Figure 2 of ASHRAE Standard 41-66, Part 1) located downstream from air mixers (per Figure 1 and paragraph 4.3 of ASHRAE Standard 41-66, Part 1)

c. Fuel weight, pounds

d. Flue-gas analysis (percent CO_2 and CO by volume; smoke) samples taken from heater exhaust stack at a point 18 inches from the heater

e. Flue-gas temperature (°F), read within 1 inch of where flue-gas sample is taken

f. External static pressure (inches WG) read at conditioned-air outlet

g. Electrical power input characteristics (volts, amps, watts, and frequency)

h. Barometric pressure (inches of mercury)

i. Circulation-air blower rpm

j. Airflow data in accordance with 4.2.1.1

k. Higher heating value of fuel (Btu/lb)

l. Discharge-air temperature (°F dry bulb) determined by multipoint thermocouple grids consisting of at least four thermocouples equally spaced over the entire discharge-air opening on the heater. The thermocouples shall be connected in parallel to obtain an average temperature. The scale division on the potentiometer shall not exceed 1° F

4.2.1.2.1 Instrumentation. All instrumentation used for the capacity and airflow tests shall conform to the requirements of this paragraph.

4.2.1.2.1.1 Electrical Instruments. All instruments used for electrical measurements shall have an accuracy equal to or better than 1 percent of the reading. All readings shall be greater than one third of the maximum scale reading. All instruments shall be calibrated prior to each test.

4.2.1.2.1.2 Speed Measuring Instruments. Fan speeds shall be measured with instruments conforming to paragraph 10.7 of ASHRAE 37-69. The instrument shall be calibrated prior to each test.

4.2.1.2.1.3 **Weight.** Fuel weight used shall be measured using a balance-type scale or apparatus conforming to paragraph 10.8 of ASHRAE Standard 37-69. The maximum range of the indicating dial shall be 5 pounds and the dial markings shall be a maximum of 0.01-pound intervals. The instrument shall be calibrated prior to each test.

4.2.1.2.1.4 **Barometric Pressure.** Barometric pressure shall be measured with a mercury barometer and shall be corrected for temperatures of the scale and the mercury and for the location of the barometer with regard to altitude and latitude.

4.2.1.2.1.5 **Air Pressures.** Air pressures shall be measured using instruments and methods conforming to paragraph 10.3 of ASHRAE Standard 37-69.

4.2.1.2.1.6 **Temperatures.** Air temperatures shall be measured using instruments and methods conforming to paragraph 10.1 of ASHRAE Standard 37-69.

4.2.1.2.1.7 **Flue-Gas Analysis.** Flue-gas analysis shall be made with an Orsat as prescribed in ASME Power Test Code, Supplement on Instruments and Apparatus, Part 10 – Flue Exhaust Gas Analysis or any electronic analyzer capable of producing readings of at least 100 parts per million of the various gases (CO_2 and CO). Electronic analyzers when used shall be calibrated and checked with a known value of gas prior to the test. A smoke content tester equivalent to the Bacharach True Spot Smoke Test set (Code 21-1000) shall be used to measure the smoke content of the flue gases.

4.2.1.2.2 **Test Results.** The test data from the capacity test shall be used to determine the following results:

a. Circulation airflow in lb/min and cfm (@ return-air conditions)

b. Capacity in Btu/h determined from the product of the airflow (lb/min) x 0.24 x 60 x temperature difference of discharge and return air (item b minus item a of 4.2.1.2)

c. Combustion efficiency (percent) determined in accordance with 4.2.1.3

d. Heater efficiency (percent) determined from the product of 100 percent x heating capacity (Btu/h) divided by the product of the fuel consumption (lb/h) x higher heating value of fuel (Btu/lb)

e. Flue-gas contents of carbon monoxide (percent) and smoke (Bacharach No.)

4.2.1.2.3 Basis of Failure. Nonconformance with 3.2.1.2 shall constitute failure of the capacity test.

4.2.1.3 Efficiency. Flue-gas losses for liquid fuels may be determined with sufficient precision from standard curves if the CO_2 content and temperature of the flue gases are known. The standard curves shown as Figure 1, page 206, of the ASHRAE Handbook of Fundamentals, 1967 edition, shall be used in conjunction with the test data recorded during the capacity test (4.2.1.2, subparagraphs d and e) to determine the stack loss percentage for any of the fuels referenced in paragraph 3.2.1.4 (Appendix A). The combustion efficiency will be determined by subtracting the stack loss percentage from 100 percent. The measured heater efficiency shall be determined from capacity test data as the ratio of measured input (fuel only) to measured output. Nonconformance to 3.2.1.3 shall constitute failure of this test.

4.2.1.4 Fuel. Satisfactory operation of the heater will be determined during all Operational, Capacity, High-Temperature Operation, and Environmental Operation Tests. Satisfactory completion of these tests with the lightest fuel, gasoline, and the heaviest fuel, DF-2 (arctic grades at low temperature), will determine compliance with 3.2.1.4.

4.2.1.5 Electrical. Satisfactory operation of the heater will be determined during all Special, Performance, Reliability, and Environmental Tests. Also, an operational test shall be conducted on the heater per 4.1.2.1 except that the input electrical power shall be varied as described in 3.2.1.5.1. Nonconformance to 3.2.1.5.1 shall constitute failure of this test.

4.2.1.6 Inclined Operation. The heater shall be operated, tested, and data recorded the same as required by 4.1.2.1 except that the heater shall be operated for 1 hour with one base edge inclined 10° from normal. The test shall be repeated until the edges have tilted in all four major directions. Nonconformance to 3.2.1.6 shall constitute failure of this test.

4.2.1.7 CB Compatibility. The heater shall be operated, tested, and data recorded the same as required by 4.1.2.1 except that the heater environment shall be pressurized to 1 inch WG. The combustion gases shall be exhausted external of the pressurized environment. The heater shall be operated for 1 hour at this test condition. Nonconformance to 3.2.1.7 shall constitute failure of this test.

4.2.1.8 Filter Compatibility. The data determined during the High Temperature Operation Test (4.1.2.3) shall be used to establish compatibility of the heater with an external air filter device. Nonconformance with 3.2.1.8 shall constitute failure of this test.

4.2.1.9 Noise. The heater shall be operated in a reverberant test chamber (exhaust piped outdoors) at 60° F (± 5° F) ambient and the thermostat requiring heat. Conduct a sound power test in accordance with ASHRAE Standard 36-62, paragraph 4.2.1, while the heater is operating on DF-2 or gasoline fuel. This test shall be repeated on each heater type (see 3.2.1.5) (60-Hz only for Type I). Nonconformance with 3.2.1.9 shall constitute failure of this test.

4.2.1.10 Controls. Place the unit in a properly ventilated area and check visually the electrical system, fuel system, airflow system, and cabinet for loose or missing parts, loose or improper connections, and electrical overcurrent protection and thermostat in place. Perform the preoperational check in accordance with operating instructions. After correction of any problem area discovered above, adjust the thermostat to 70° F and immerse the thermostat sensing element in water at a temperature of 55° F ± 5° F. Turn switch to "heat" for approximately 5 minutes and quickly check the following:

a. Check and adjust (as required) fuel rate for proper operation

b. Evidence of fuel leaks

c. Fuel pump and solenoid valve are operating, and fuel is delivered to the burner

d. Ignitor is on and operating properly

e. Air compressor, combustion-air blower, and circulation-air fan are on and operating properly

f. Visually observe flue-gas smoke content

Turn switch to "off" and observe the heater for proper operation of the purge cycle. After correction of any problem areas, turn the heater on again and check the above items again. If no additional problems are discovered, operate the unit for approximately 15 minutes. Next, adjust the thermostat setting to 50° F and place the thermostat sensing element in water at a temperature of 65° F ± 5° F. Visually observe that the fuel flow stops, the heater is purged, and, then, the heater stops operating. Next, adjust the thermostat setting to 70° F and immerse the sensing element in water at 55° F ± 5° F. Turn switch to "heat" and allow the unit to run and, then, to "heat" again. Repeat this action three times. Finally, after turning switch to "off" and waiting for completion of purge cycle, turn switch to "vent" and visually observe that the circulating fan operates independently. Nonconformance to 3.2.1.10.5, 3.2.1.10.6, 3.2.1.11, 3.3.1.2, or 3.3.1.7 shall constitute failure of this test.

4.2.1.10.1 High-Temperature Safety. The heater discharge airflow shall be partially blocked during heater operation until the high-temperature safety control stops the flow of fuel to the combustion chamber. After the air temperature reaches 210° F, the rate of blocking shall be adjusted to limit the rate of average temperature change to 1° F per minute. The temperature of the discharge air shall be determined as required by item b of 4.2.1.2. Nonconformance to 3.2.1.10.1 shall constitute failure of this test.

4.2.1.10.2 Flame Failure. Start the heater with the ignition wires disconnected. Record the elapsed time until the flame failure safety device stops fuel flow to the combustion chamber. After the device stops fuel flow, attempt to restart the heater by manual reset. Nonconformance to 3.2.1.10.2 shall constitute failure of this test.

4.2.1.10.3 Overcurrent. Adequacy of overcurrent protection shall be determined by visual inspection. Failure of any electrical components during other tests caused by inadequate overcurrent protection or nonconformance to 3.2.1.10.3 shall constitute failure of this test.

4.2.1.10.4 Motor Protectors. Conduct a motor locked-rotor test on all electrical type motors in accordance with MERDC Test Procedure No. 103C. Nonconformance to 3.2.1.10.4 shall constitute failure of this test.

4.2.1.10.5 Thermostat. Connect an indicating electrical circuit, such as a light or buzzer, on the thermostat control leads. By immersing the sensing element in water and adjusting the thermostat setting, determine that the thermostat has an adjustable range of at least 50° F to 70° F. Next, adjust the thermostat to 60° F and immerse the sensing element in water at 50° F. Determine that the thermostat control circuit is closed. Increase the water temperature at approximately 2° F per minute, but not more than 4° F per minute, and record the temperature when the thermostat control circuit opens. Next, cool the water at a rate of approximately 2° F per minute, but not more than 4° F per minute, and record the temperature when the thermostat control circuit closes. Nonconformance to 3.2.1.10.5 shall constitute failure of this test.

4.2.1.10.6 Control Switch. Operation of the heater during each control test 4.2.1.10 or other operating test will verify function of the on-off switch. Nonconformance with 3.2.1.10.6 shall constitute failure of this test.

4.2.1.11 Restart Capability. Conduct of tests under 4.2.1.10 will provide evidence of satisfactory restart capability. Nonconformance with 3.2.1.11 shall constitute failure of this test.

4.2.1.12 Pressure. Seal all external openings of the heat exchanger except one, which shall be fitted with an air valve. Subject the heat exchanger to an internal air pressure of 5 psig and submerge the heat exchanger in water. Any evidence of air leakage (3.2.1.12) shall constitute failure of this test.

4.2.2 Physical Inspection.

4.2.2.1 Weight. The heater weight, complete with all components, panels, and grilles shall be determined to the nearest pound. Nonconformance with 3.2.2.1 shall constitute failure of this test.

4.2.2.2 Dimensions. The heater width, height, and depth shall be determined to the nearest 1/16 inch. All panels, brackets, screws, fittings, and screens shall be in mounted position for this test. Nonconformance with 3.2.2.2 shall constitute failure of this test.

4.2.3 Reliability. Reliability data shall be confirmed by endurance testing. Not less than 3,500 aggregate operating hours shall be accumulated on not less than three units. Not less than 2,000 of these hours shall be accumulated on one individual unit. During the 3,500 hours, not more than three failures (see 3.2.3.2) shall occur. Time accumulated during other tests may be credited to this paragraph. Units shall be cycled twice each hour during the credited time and shall be in full heating operation not less than 65 percent of the credited time. All electrical type heaters shall be included in the test. An operational test (4.1.2.1) shall be performed at least once during each 168 hours. Gasoline and diesel fuel shall be used, with total operating time approximately equal on each type of fuel. Records shall be maintained to permit determinations of minimum time between scheduled maintenance, minimum service life to overhaul, and mean time to repair. Nonconformance to 3.2.3 shall constitute failure of this test.

4.2.5 Environmental Tests.

4.2.5.1 Climatic Conditions.

4.2.5.1.1 Operation.

4.2.5.1.1.1 Altitude Operation. The heater shall be operated in an ambient simulating 10,000 feet altitude. The ambient temperature shall not exceed +75° F. An operational check (4.1.2.1) shall be performed while the heater is in the altitude environment. Nonconformance under 4.1.2.1 or 3.2.5.1.1 shall constitute failure of this test.

4.2.5.1.1.2 Low-Temperature Operation. Conduct the low-temperature operational test on the heater(s) using DF-A diesel fuel and repeat using arctic gasoline per 3.2.1.4. This test shall be conducted at -50° F (± 2.5° F). The unit shall be soaked in the

-50° F ambient for 2 hours prior to operation. The unit shall then be operated per 4.1.2.1 for a period of not less than 1 hour for each fuel tested. After completion of this test, the ambient temperature shall be raised, and an operational test per 4.1.2.1 shall be conducted. Nonconformance under 4.1.2.1 or 3.2.5.1.1 shall constitute failure of this test.

4.3.2 Electromagnetic Interference. The heater shall be tested for electromagnetic interference in accordance with MIL-STD-461A, Type II-B equipment, subtests CE03 and RE02, for each type of electrical input (3.2.1.5). Nonconformance to 3.3.2 shall constitute failure of this test.

APPENDIX C

SAMPLE DATA AND CALCULATIONS FOR CAPACITY/AIRFLOW TESTS ON 60,000-BTU/H, MILITARY DESIGN, MULTIFUEL SPACE HEATER

DATA SHEET
PERFORMANCE TEST - HEATERS

TEST UNIT: 60,000 BTUH, MH-MF-60C4-208 HEATER, MERDC NO: D-521

DATE 12 AUG 74 TEST BY: L. TATE

TIME: MINUTES	0	15	30	45	60	AVG.
TEMPERATURES						
AIR IN °F db	62.5	62.5	62.5	64.5	65.0	63.4
AIR IN °F wb	57	57	57	61.	62	58.8
AIR OUT °F db	161	161	160	163	163	
AIR OUT °F db	161	161	160	163	163	161.8
AIR OUT °F db	162	161	161	163	164	
AIR OUT °F db						
EXHAUST GAS °F db	705	715	710	705	705	708
ICE BATH °F	31	31	31	31	31	
AIR FLOW DATA						
NOZZLE FACTOR 4.5" DIA	←		119.95	→		119.95
BAROMETRIC PR @ SL,"Hg	30.13	(–) MINUS	LAB ELEVATION 0.14			29.99
STATIC @ UNIT, " WG	0.37	0.37	0.37	0.37	0.38	0.372
STATIC AFTER NOZZLE,"WG	-2.77	-2.78	-2.78	-2.76	-2.76	-2.77
NOZZLE DELTA P, "WG	2.02	2.01	2.02	2.01	2.02	2.016
FUEL FACTOR						
FUEL WEIGHT - LBS						
START	0	4.59	3.50	2.42	1.36	
END	4.59	3.50	2.42	1.36	0.31	
NET	0	1.09	1.08	1.06	1.05	4.28
EXHAUST GAS ANALYSIS						
% O_2	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
% CO_2	11.5%	11.0%	11.5%	11.5%	11.5%	11.4%
% CO	0.001%	0.0%	0.0%	0.0%	0.0%	0.0%
SMOKE RATE	0-1	1	1	1	1	1
VENT BLOWER RPM	2,140	2,140	2,140	2,140	2,150	2,150
ELECTRICAL DATA						
FREQUENCY, HZ	60	60	60	60	60	60
VOLTS	120	120	120	120	120	120
AMPS	4.54	4.54	4.53	4.53	4.53	4.534
WATTS	478	478	476	477	477	477.2
C T RATIO	10/5	10/5	10/5	10/5	10/5	10/5

PAGE I

AIRFLOW CALCULATIONS
METHOD: ASHRAE STD 37-69, SECTION 7.

AT EACH (*) ENTER THE NEEDED DATA, THEN KEY GO.

```
TEST ITEM:(*)              MH-MF-60C4-208
TEST NO:(*)                    521.10        DATE:(*)                81274
OPERATOR:(*)               LITTLE

  AT POINT OF WET BULB MEASUREMENT:
  DRY BULB TEMP (*)                     63.400°F
   WET BULB TEMP (*)                     58.800°F

  NOZZLE DELTA P (*)                     2.016 INCHES WATER
  STATIC AFTER NOZZLE (*)               -2.770 INCHES WATER
  EXTERNAL STATIC (*)                     .372 INCHES WATER
  BAROMETRIC PRESSURE (*)               29.990 INCHES HG

[ IF NOZZLE FACTOR KNOWN. KEY 04
 IF NOT. KEY 05]

NUMBER OF NOZZLE FACTORS USED(*)                  1
FACTOR NO   1 (*)              119.950

[ IF DATA OK KEY 03 ]


  DRY BULB TEMP ENT NOZZLE (*)                    161.800°F

FOR DATA ABOVE:

NOZZLE VELOCITY:          6176 FPM [WITHIN LIMITS OF PAR 7.3.1 ]
AIRFLOW: POUNDS PER MINUTE               42.910
       SCFM                             572.146

HEATING CAPACITY

TEMP IN (*)                   63.400°F
TEMP OUT (*)                 161.800°F

    60803.16 BTUH HEATING.

END.              CHANGE PAPER. LOAD BLK2.
```

PAGE II TEST NO: 521.10 DATE: 81274

AT EACH (*) ENTER THE NEEDED DATA, THEN KEY GO.

FUEL RATE, LB PER HR (*) 4.28

HIGHER HEATING VALUE.
FOR DF2 KEY 05
FOR GASOLINE KEY 06
FOR OTHER KEY 07

GASOLINE 20100.00 BTU PER LB

HEAT INPUT 86028.00 BTU PER HR

MEASURED EFFICIENCY 70.68 PCT

STACK TEMP, DEG F(*) 708.00

CARBON DIOXIDE, PCT (*) 11.40

COMBUSTION EFFICIENCY 74.8 PCT

SMOKE RATE (BACHARACH SCALE) (*) 1.00

CARBON MONOXIDE, PCT (*) 0.000

ELECTRICAL CALCULATIONS
CT RATIO (*) 2

VOLTS	L1-L2(*)	120.00	L2-L3(*)	0.00	L3-L1(*)	0.00	AVG	120.0
AMPS	L1(*)	4.53	L2(*)	0.00	L3(*)	0.00		
xCT		9.0		0.0		0.0	AVG	9.1
WATTS	L1(*)	477	L2(*)	0	L3(*)	0		
xCT		954		0		0	TOT	954

POWER FACTOR = 87.4 PCT

END.

APPENDIX D

SIGNIFICANT INCIDENTS, DURABILITY TESTING OF 60,000-BTU/H HEATER D521, POWER INPUT – 120 V/60 Hz

Date	Hours Accumulated	Incidents
14 Aug 74	20	Started endurance testing on gasoline, 120 V/60 Hz, at a 23-minute "on" and 7-minute "off" cycle.
14 Aug 74	29	Found faulty control box – both indicating lights on. One should be off when operating properly. Replaced control box and restarted test.
23 Aug 74	209	Observed noise in heat exchanger when heater starts up and while operating; appears to be baffles inside of the heat exchanger moving due to expansion of the metal.
4 Sep 74	503	Ran out of gasoline. Stopped to run operational and capacity tests at the end of 500 hours.
5 Sep 74	503	Completed performance check. Data OK. Tested heat exchanger – no leaks.
6 Sep 74	506	Resumed endurance testing on DF-2.
13 Sep 74	671	Found heater off – pushed "Reset" to start.
27 Sep 74	1,000	1,000 hours completed on this heater.
30 Sep 74	1,033	Spark plug loaded with carbon buildup; nozzle face also had a buildup. Stopped test since heater is to be used for climatic tests – low-temperature and altitude.

APPENDIX E

SIGNIFICANT INCIDENTS, DURABILITY TESTING OF 60,000-BTU/H HEATER D522, POWER INPUT – 120 V/60 Hz

Date	Hours Accumulated	Incidents
17 Apr 74	0	Started endurance testing on gasoline, 120 V/60 Hz, at a 23-minute "on" and 7-minute "off" cycle.
24 Apr 74	162	Noticed noise which appeared to be coming from inside of heat exchanger. Possible expanding and contracting of baffle or deflector plates in return bench of heat exchanger. No effect on operation.
9 May 74	524	Stopped test to run capacity and heat exchanger tests. Tests OK. Had to raise fuel setting to get capacity.
13 May 74	536	Started back on endurance test on gasoline.
21 May 74	706	Changed fuel to DF-2.
28 May 74	863	Adjusted fuel flow – exhaust temperature had dropped down.
4 Jun 74	1,034	Stopped heater to make durability checks.
5 Jun 74	1,040	Completed checks – capacity OK, and heat exchanger did not leak. Observed noise coming from motor bearings, and plastic (NYFLEX) fuel line appeared to touch heat exchanger bulkhead. This was probably done at the first durability check during reassembly; a more careful assembly or routing of fuel lines must be observed. Started recycling on gasoline.
2 Jul 74	1,610	Stopped to make durability checks.

3 Jul 74	1,610	Completed pressure test and capacity test on gasoline. Restarted heater on DF-2.
8 Jul 74	1,722	Heater failed to start. Pushed "Reset" button, heater started.
10 Jul 74	1,769	Heater failed to start. Pushed "Reset" button, heater still failed to start. Investigation showed ignitor fouled with carbon buildup. Cleaned and heater restarted.
12 Jul 74	1,812	Heater failed to start. Investigation showed ignitor fouled with carbon; appears to get a spray of fuel from nozzle. Cleaned nozzle and ignitor and restarted.
18 Jul 74	2,017	Completed durability test.
1 Aug 74	2,017	Disassembled fan motor to check noise – found bearing dry, regreased with Dow 33 grease. Found brushes on combustion-air blower to be of adequate length but should be replaced. Heater capacity OK, and heat exchanger does not leak.

APPENDIX F

SIGNIFICANT INCIDENTS, DURABILITY TESTING OF

60,000-BTU/H HEATER D523, POWER INPUT – 120 V/60 Hz

Date	Hours Accumulated	Incidents
1 Apr 74	0	Started endurance testing on DF-2, 120 V/60 Hz, on a 23-minute "on" and 7-minute "off" cycle. Day operation only.
2 Apr 74	10	Unit operating OK.
4 Apr 74	22	Started unit on 24-hour-cycle operation.
19 Apr 74	382	Upon stopping unit, noticed fan noise in front scroll.
24 Apr 74	501	Turned off heater to perform 500-hour check.
29 Apr 74	517	Completed capacity test and pressure tested heat exchanger – test OK.
1 May 74	517	Checked system, adjusted front blower and scroll.
2 May 74	517	Started heater on second 500 hours of cycling. This 500 hours on gasoline.
23 May 74	1,016	Heater off due to empty fuel tank.
28 May 74	1,141	Heater removed for capacity and pressure tests.
29 May 74	1,141	Completed capacity and heat exchanger pressure test. Test results indicate no problem.
30 May 74	1,146	Restarted on durability test on DF-2.
31 May 74	1,168	Adjusted fuel rate after 24 hours of operation. Heater operating OK.

22 Jun 74	1,690	Heater stopped due to empty fuel tank.
24 Jun 74	1,690	Restarted heater. Received new fuel supply. Upon restart, noted that ventilation fan motor bearings make noise. No maintenance will be done to see if heater will make the 2,000-hour operational period.
28 Jun 74	1,790	Stopped heater and performed capacity and heat exchanger pressure tests.
1 Jul 74	1,790	Completed all tests and started final durability tests on gasoline.
6 Jul 74	1,913	Heater stopped. Attempted to restart manually – pushed "Reset" button. Would not restart. Found ignitor shorting out inside of shield – wet ceramic, burnt off. Combustion blower would not operate. Found brushes to be worn – no new brushes available, so replaced with complete combustion blower. Had to readjust vent blower scroll; wheel hitting inlet ring again.
9 Jul 74	1,913	Started heater cycling.
10 Jul 74	1,930	Heater off. Electrical power plug came out of receptacle on wall.
10 Jul 74	1,930	Restarted heater.
15 Jul 74	2,050	Heater shut down for final check of durability tests.
22 Jul 74	2,050	Completed testing of heater capacity and pressure tests; inspection OK.

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