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Technical Report

No. 13504

M915 Radiator Reverse Engineering Effort

SEPTEMBER 1990

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By _____

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Performance tests were conducted on two new M915 radiators to develop requirements needed for solicitation of new materiel sources. These requirements were not previously available to TACOM and due to the lack of M915 radiators in the Army Supply System, a need was warranted for requirement testing and development.

Testing was conducted in-house at TACOM's air flow lab facility, in a joint effort between AMSTA-RGD and AMSTA-TBM, during the months of April and May 1990.

Results were reviewed, adopted and provided to the sponsoring organization, SFAE-CS-TVH.

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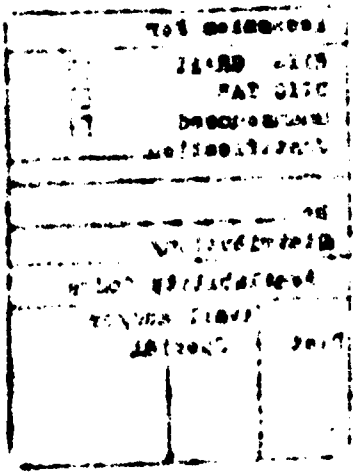

1.0. INTRODUCTION

This report describes the cooling test program of the M915 tractor truck radiator which was conducted to develop the performance requirements needed for competitive procurement. The test requirements and report were developed by the Transmissions and Integration Branch of the Propulsion Systems Division, U.S. Army Tank-Automotive Command (TACOM).

2.0. OBJECTIVE

The primary objective of this program was to conduct cooling performance testing of two new radiators to develop performance requirements for inclusion onto a level-3 drawing to be used for competitive procurement.

3.0. CONCLUSIONS

3.1. The heat rejection for the power pack is approximately 10,650 BTU/min (10,250 BTU/min for engine, 400 BTU/min for transmission and other components) (see Appendix A). This radiator was able to meet the cooling requirement for each test run, based on test derivation from MIL-R-45306C.

4.0. RECOMMENDATIONS

4.1. Use the test data as performance criteria and combine with other standard radiator requirements for incorporation into a M915 radiator level-3 drawing (see Appendix B).

4.2. Perform similar testing on all other military radiators without government-owned TDPs to develop individual radiator performance requirements. This would preclude shortage problems arising from sole-source acquisition.

4.3. Establish an improved quality inspection procedure for the radiators either at the manufacturer's facilities or upon arrival at Army depots.

5.0. DISCUSSION

5.1. Background

The lack of radiators in the Army Supply System and the delays in delivery from the sole-source supplier created a need to investigate additional sources. In order to solicit additional sources, radiator performance requirements were needed. The absence of a government-owned Technical Data Package (TDP) brought about this investigation to develop performance requirements for the subject radiator.

The performance testing was conducted at TACOM's Air Flow Laboratory from April 1990 through May 1990.

5.2. Scope and Limitations

The unavailability of radiators in the Army Supply System limited the amount of samples to be used for testing. The two test radiators were received from the depot's latest shipment of newly produced radiators delivered by the manufacturer. The scope of this report will cover the testing that was performed and the development of performance requirements for the M915 radiator.

5.3. Outline of Test

The test program consisted of the following operations:

Determination of cooling requirements.

Development of check-out procedures and performance tests.

Installation and instrumentation of radiator.

Collection of test data.

Cleaning and preparation of radiator for return shipment.

Evaluation and reporting of test results.

5.4. Test Material and Equipment

Two (2) M915 radiators, NSN 2930-01-092-7922, were obtained from the manufacturer and were used in this test program.

TACOM's Air Flow Laboratory and associated equipment and instrumentation were used to perform the testing. During heat-rejection testing, 18 thermocouples were gridded and placed on each side of the radiator core to measure the average inlet and outlet air temperatures. Quartz thermometers were used to measure the inlet and outlet water temperatures.

5.5. Test Procedures

As no test procedure was available for this radiator, MIL-R-45306C, "Radiators, Engine Cooling, Industrial" (see Appendix A) was used to derive test points for the heat-rejection data. Additional tests such as the fill-rate test, maximum free-flow rate test, and pressure-cap test were included in the test plan and were performed to provide additional radiator performance data. These tests were obtained from the TACOM Cooling System Design Guide. Testing of the radiators was conducted in various steps to insure proper accuracy and to determine radiator characteristics. The details of these steps are described below:

5.5.1. Visual Inspection of Radiators. Visual inspection was performed to document any noticeable external defects.

5.5.2. Preliminary Water-Pressure Test. With all ports blocked, the radiator was completely filled with water and pressurized to 20 psig. The radiator was then checked for leakage, and results were recorded.

5.5.3. Air-Pressure Test. An air hose was connected to the radiator and with all ports blocked, was pressurized to 20 psig. The radiator was then submerged in a reservoir of water and was inspected for air leaks. Results were recorded.

5.5.4. Flushing of Radiators. The radiators were thoroughly flushed with water until a clean fluid was seen exiting the radiator. This was done to ensure that no deposits would be present during testing of the cooling system.

5.5.5. Fill-Rate Test. With the outlet port blocked, the radiator was filled to 90 percent capacity, and the fill time was recorded. This procedure was conducted to ensure that a five-minute time limit was met.

5.5.6. Maximum Free-Flow Rate Test. The radiator was suspended below a receiving drum and connected to a water flow system. The water was adjusted so that a constant water level of one-half inch above inlet port of the radiator was maintained. Flow measurements were recorded to determine the maximum free-flow rate of the radiator (see figure 5-1).

5.5.7. Pressure-Cap Test. A standard pressure-cap testing device was used to measure the relief valve setting of the cap.

5.5.8. Heat-Transfer and Core-Resistance Tests. The radiator was mounted in a wind tunnel and was tested at 100, 105, and 125 percent of the rated coolant flow specified in MIL-R-45306C. At each coolant-flow rate, the heat rejection was determined at the following air velocities:

COOLANT FLOW RATE (GPM)	AIR VELOCITY (FPM)
110	1600
	1800
	2100
116	1600
	1800
	2100
138	1600
	1800
	2100

TABLE 5.1 HEAT-TRANSFER TEST CONDITIONS

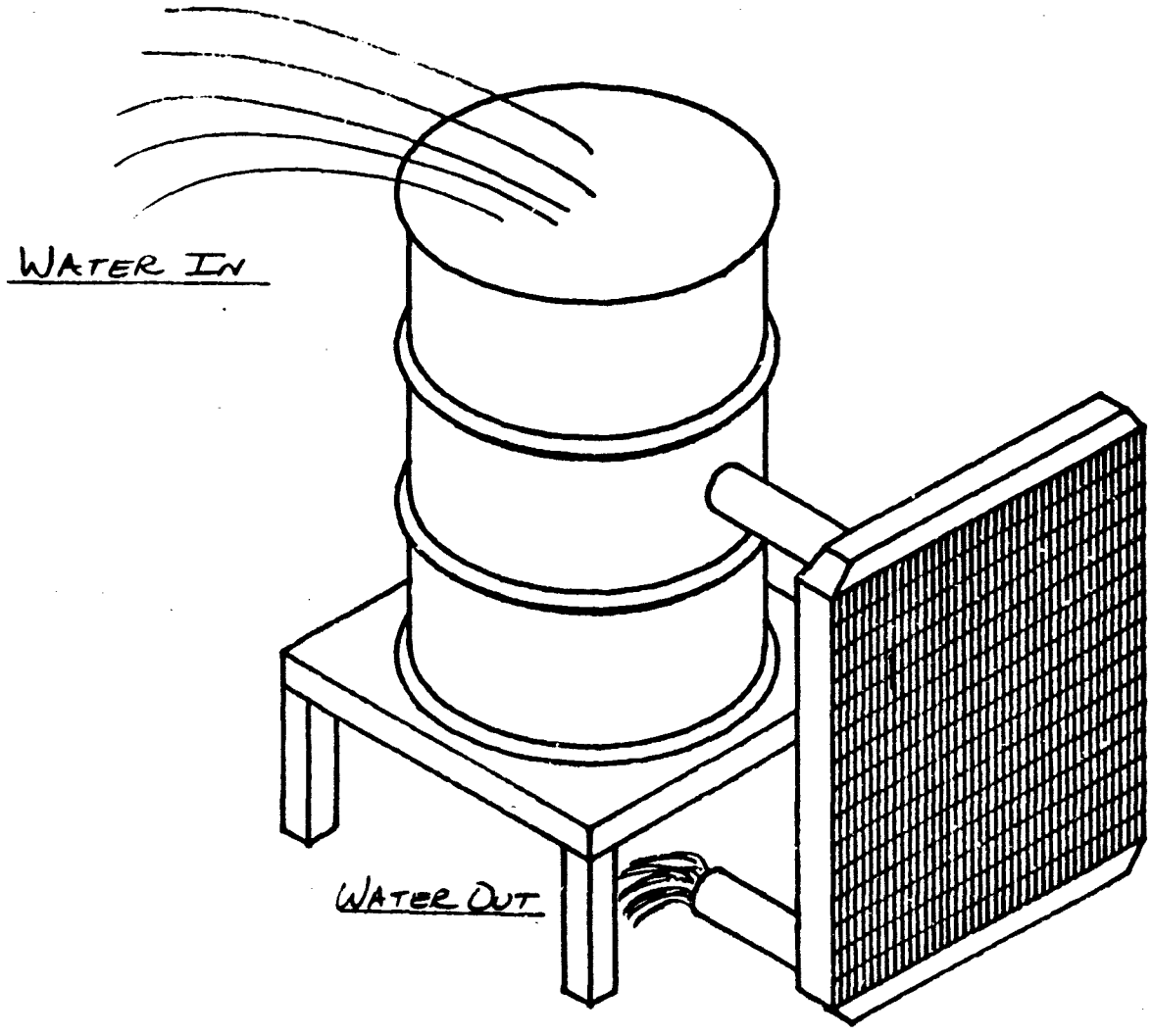

Figure 5-1. Maximum Free-Flow Rate Test Set-Up

Heat rejection was calculated according to the following equations:

A. Heat Transfer - Heat energy absorbed by air flow:

$$\dot{Q} = \dot{m} C_p \Delta T$$

Where $\dot{m}$ = Air flow rate (lb_m/minute)
C_p = Specific heat of air (Btu/lb_m/°F)
ΔT = Air Temperature Difference (°F)

B. Heat Transfer - Heat rejection from coolant flow:

$$\dot{Q} = \dot{m} C_p \Delta T$$

Where $\dot{m}$ = Coolant flow rate (lb_m/minute)
C_p = Specific heat of coolant (BTU/lb_m/°F)
ΔT = Coolant Temperature Difference (°F)

5.5.9. Final Air-Pressure Test. The Preliminary Air-Pressure Test was repeated to ensure that no damage was made to the radiators during testing.

5.6. Radiator Configuration

The current configuration of the M915 radiators are crossflow heat exchangers with uninterrupted plain-fin surfaces (see figure 5-2). The core area is approximately 1200 square inches, and the coolant capacity is 17.25 gallons.

5.7. Test Results

The following paragraphs summarize the results of each test that was performed. For more detailed tabulated results, see Appendix B.

5.7.1. Visual Inspection of Radiators. Portions of the core were missing near both the top and bottom tanks on both radiators. Figures 5-3 and 5-4 show these deficiencies. Prior to start of the Preliminary Water-Pressure Test, a thick yellow fluid was found inside sample #1. When the radiator was filled with water, this fluid floated to the top of the water. In sample #2, before filling the radiator with water, a yellowish brown fluid was found. Chemical analysis revealed that the characteristics appeared to be similar to those of a transmission oil fluid. A detailed test report of this analysis can be found in Appendix B. No military specifications call for a preservative oil to be placed inside the radiator, however, the manufacturer could have placed the fluid on his own accord. These fluids were removed, and the radiators were flushed clean before proceeding with the test.

5.7.2. Preliminary Water-Pressure Test. No leakage occurred in either of the two radiator test samples.

5.7.3. Air-Pressure Test. A small leak was noticed on radiator sample #1 from a bolt located below the radiator outlet on the lower tank. After the radiator was submerged for 30 minutes, the leak stopped.

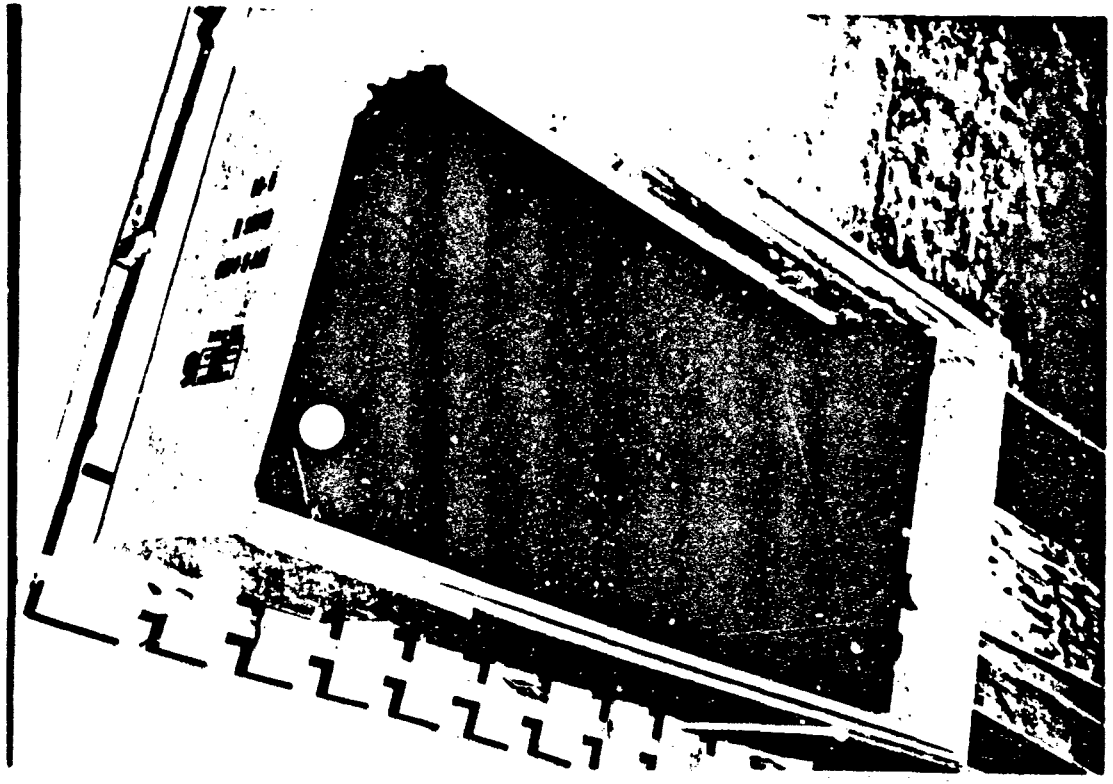

Figure 5-2. M915 Radiator Configuration

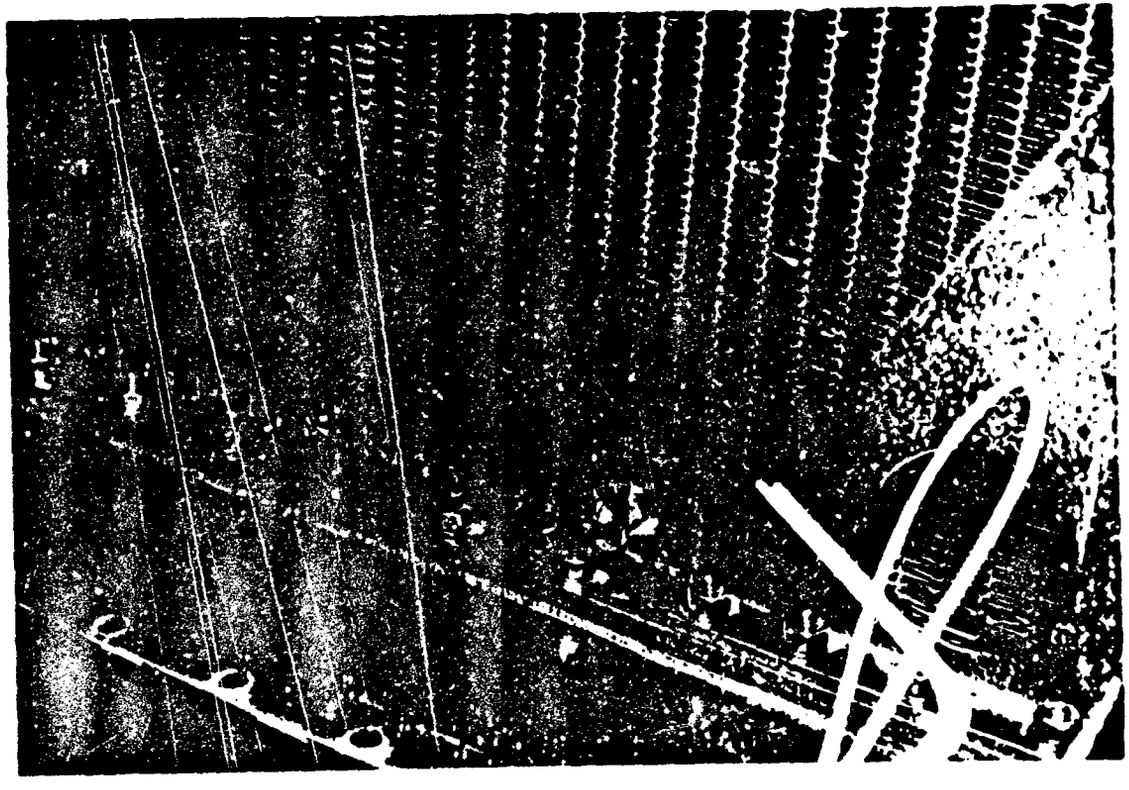

Figure 5-3. Radiator Quality Deficiencies, Test Sample #1

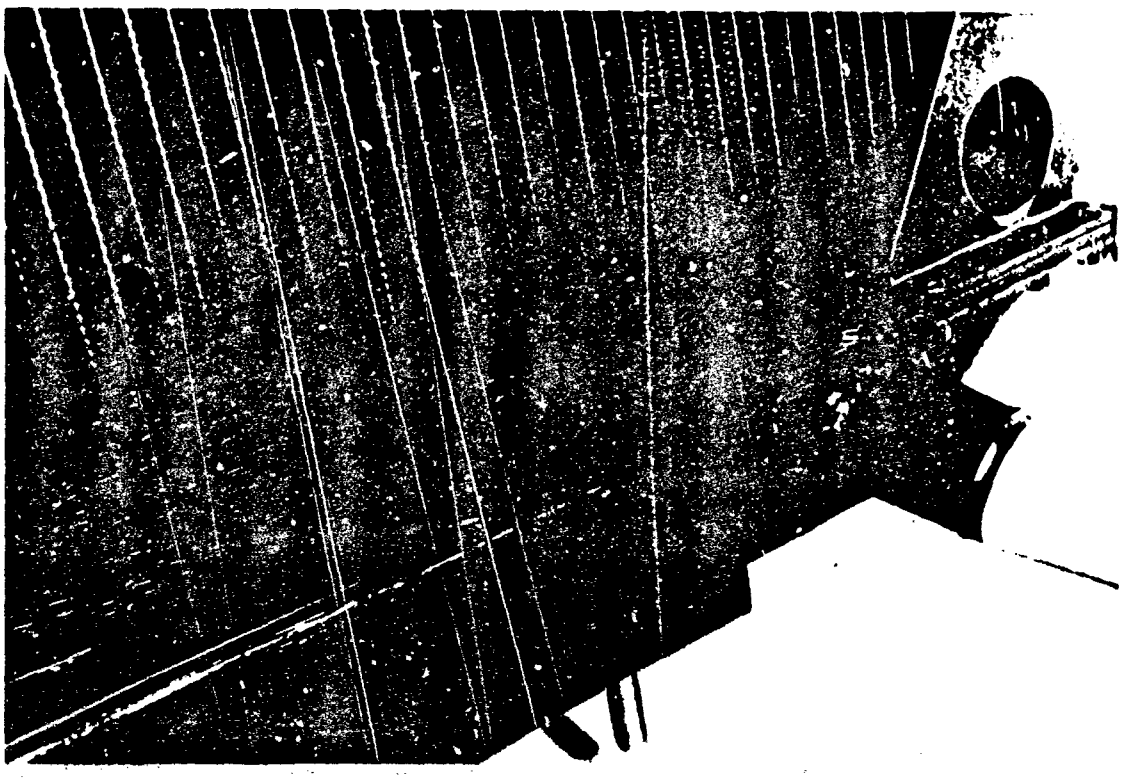

Figure 5-4. Radiator Quality Deficiencies, Test Sample #2

On radiator sample #2, a small leak was initially cited at the soldering joint between the fillerneck and the top tank. This leak gradually became worse and, upon stabilization, was measured at 21,660 ml/min (5.722 GPM).

5.7.4. Flushing of Radiators. Both test radiators were flushed out with water to ensure that clean cooling systems would be used during the heat transfer test. During flushing, clean water was observed leaving both radiators.

5.7.5. Fill Rate Test. In order to fill the radiator to 90 percent capacity, an average fill rate of 0.29 minutes was recorded by both radiators.

5.7.6. Maximum Free-Flow Rate Test. After coolant flow was stabilized, an average measurement of 52.8 GPM was recorded for radiator sample #1 and 57.7 GPM was recorded for radiator sample #2. Combining test runs from both radiators produced an average maximum free-flow rate of 55.3 GPM.

5.7.7. Pressure-Cap Test. The pressure caps of both radiator samples were tested and measured 9.9 psi and 10 psi, respectively.

5.7.8. Heat-Transfer and Core-Resistance Tests. Four test runs, out of a total of 18, were removed from the final analysis. These four runs did not meet the 5 percent-difference specification between air heat rejection and coolant heat rejection. Test data showed that the radiator met the cooling requirements of the vehicle's powerpack.

5.7.9. Final Pressure Test. Radiator sample #1 did not show any signs of leakage. Radiator sample #2 had repairs on the fillerneck but still maintained a small leak. This leak was measured to be approximately 997 ml/min (0.263 GPM).

5.8. Discussion of Results

The resulting core-resistance data may look suspicious, as it does not agree with those values found in MIL-R-45306C. It therefore must be reiterated that this specification was used solely as a test parameter design guide, and not as a performance guide. The resulting core-resistance data derived from this testing did provide adequate cooling. If restriction on the radiators were too great, then the cooling requirements of this radiator's cooling system would most likely not have been met. The results of the heat-transfer testing proved that this vehicle's cooling requirements were met by this radiator design.

5.9. Other

Vibration and pressure-cycle tests were not included in this test plan. These tests are destructive tests, and the radiator samples that were used during testing were on loan to TACOM. These tests are also known as structural tests, not performance tests, and the purpose of the testing was to determine performance requirements.

APPENDIX A

M915 RADIATOR TEST REQUIREMENTS DATA

Performance Data

All data is based on the engine operating with fuel system, water pump, lubricating oil pump, compressor (unloaded) and air cleaner; not included are alternator, fan, optional equipment and driven components. Data is based on operation under SAE standard J816b conditions of 500 feet (150 m) altitude (29.00 in. (736 mm) Hg dry barometer), 85°F (29° C) intake air temperature and 0.38 in. (9.6 mm) Hg water vapor pressure, using No. 2 diesel or a fuel corresponding to ASTM D2.

Brake Mean Effective Pressure @ Rated Power—PSI (kPa)	176 (1 213)
@ Peak Torque —PSI (kPa)	203 (1 399)
Piston Speed @ 2100 RPM—ft./min. (m/s)	2100 (10.7)
Friction Horsepower @ 2100 RPM—hp. (kW)	71 (53)
@ 1500 RPM—hp. (kW)	40 (30)
Idle Speed—RPM	600
Maximum No Load Governed Speed—RPM	2400
Maximum Overspeed Capability—RPM—(15 Second Maximum)	2700
Torque Available at Clutch Engagement—(800 RPM)—lb.-ft. (N-m)	534 (719)
Thrust Bearing Load Limit—Maximum Intermittent—lb. (N)	1400 (6 000
—Maximum Continuous—lb. (N)	700 (3 000

Engine Delivers Rated Performance up to Altitude—

Maximum approved altitude when operated in a transient mode- ft. (m)	12,000 (3 600)*
Maximum approved altitude when operated continually at altitude- ft. (m)	6,000 (1 800)*

Ambient Air Temperature Above Which Output Should be Limited—°F (°C) 120 (49) *

Chart Below Reflects Data Based on the Following Variables at Conditions of Rated Power:

Coolant Temperature—°F (°C)	185 (85)	Air Intake Restriction—in. H_2O (mm H_2O)	10 (250)
Water Inlet Pressure—PSI (kPa)	7 (50)	Air Intake Temperature—°F (°C)	85 (29)
Block Pressure—PSI (kPa)	35 (240)	Exhaust Restriction—in. Hg (mm Hg)	2.0 (50)

Maximum Rating

RATING	PERF. CURVE	OUTPUT BHP (kW)	SPEED RPM	TORQUE LB.—FT. (N-m)	AIR FLOW† CFM (liter/s)	EXHAUST CFM (liter/s)	GAS(DRY)† TEMP.°F (°C)	WATER FLOW† U.S. GPM** (liter/s)	HEAT REJ.† BTU/MIN. (kW)
'400'	C-3733-B								
Full Power		400 (298)	2100	1000 (1356)	1050 (496)	2365 (1116)	900 (482)	140 (8.8)	10,250 (180)
Peak Torque (15% Torque Rise)		328 (246)	1500	1150 (1559)	820 (283)	1700 (802)	1100 (593)	100 (6.3)	7,780 (137)
Cooling Check Point									

Optional Ratings

ENGINE RATINGS	PERF. CURVE	OUTPUT BHP (kW)	SPEED RPM	TORQUE LB.—FT. (N-m)
'370' Rating	CO-3733-B1			
Full Power		370 (276)	2100	925 (1254)
Peak Torque (24% Torque Rise)		328 (246)	1500	1150 (1559)

ENGINE RATINGS	PERF. CURVE	OUTPUT BHP (kW)	SPEED RPM	TORQUE LB.—FT. (N-m)

MIL-R-45306C
3 May 1983
SUPERSEDING
MIL-R-45306B
3 July 1973

MILITARY SPECIFICATION

RADIATORS, ENGINE COOLING, INDUSTRIAL

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers coolant radiators for liquid-cooled, industrial, internal-combustion engines of 10 horsepower and above.

1.2 Classification. The radiators shall be of the following types, as specified (see 6.2):

Type I - Soldered-tank radiator.
Type II - Bolted-tank radiator with replaceable core.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified (see 6.2), the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation, form a part of this specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

VV-L-800 - Lubrication Oil, General Purpose, Preservative (Water-Displacing, Low Temperature).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Mobility Equipment Research and Development Command, ATTN: DRDME-DS, Fort Belvoir, VA 22060 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 2930

PPP-B-601 - Boxes, Wood, Cleated-Plywood.
PPP-B-636 - Boxes, Shipping, Fiberboard.

MILITARY

MIL-P-116 - Preservation, Methods of.
MIL-C-5501 - Cap and Plug, Protective, Dust and Moisture Seal.
MIL-G-12803 - Gasket Material, Nonmetallic.
MIL-T-22085 - Tape, Pressure-Sensitive, Adhesive, Preservation and Sealing

STANDARDS

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-129 - Marking for Shipment and Storage.
MIL-STD-130 - Identification Marking of US Military Property.
MIL-STD-889 - Dissimilar Metals.
MIL-STD-1188 - Commercial Packaging of Supplies and Equipment.
MS35773 - Radiators, Engine Cooling, Industrial.
MS35884 - Cores, Radiators, Engine Cooling, Industrial.

(Copies of specifications, and standards required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following document(s) form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, if applicable.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/ASTM B-36 - Brass Plate, Sheet, Strip, and Rolled Bar.
ANSI/ASTM B-152 - Copper Sheet, Strip, Plate, and Rolled Bar.

(Application for copies should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A308 - Twine Plates.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3. REQUIREMENTS

3.1 Description. The radiators and cores shall be as shown on MS35773, MS35884, and as specified herein.

3.2 First article (first-produced radiator and core). The contractor shall furnish one or more radiators and cores as specified (see 6.2), for examination and tests within the time frame specified (see 6.2), to prove prior to starting production, that his production methods will produce radiators and cores that comply with the requirements of this specification. Examination and tests shall be as specified in Section 4 and unless otherwise specified herein, all examination and tests shall be conducted by the contractor subject to surveillance and approval by the Government (see 6.3). When specified (see 6.2), the Government will conduct any or all of the preproduction examination and tests.

3.3 Materials. Materials shall be as specified herein and as shown on applicable standards. Materials not specified shall be selected by the contractor and shall be subject to all provisions of this specification (see 6.5).

3.3.1 Copper tubing. Tubes shall be copper, red brass, or naval brass with 85 percent copper and 15 percent zinc. Tubing shall not be subject to dezincification and resultant corrosion.

3.3.2 Sheet copper. Sheet copper for fins shall conform to ANSI/ASTM B152.

3.3.3 Sheet brass. Sheet brass for tanks and header plates shall conform to ANSI/ASTM B36.

3.3.4 Terne plate. Terne plate for side members for type I radiators shall conform to ASTM A308 Terne Plate, with LT-35 coating thickness as a minimum.

3.3.5 Gasket. Gasket material shall conform to MIL-G-12803, Type I, identification number P1161A.

3.3.6 Dissimilar Metals. Dissimilar metals as defined in MIL-STD-889 shall not be used in intimate contact without suitable protection in order to prevent or minimize galvanic corrosion.

3.3.7 Identification of materials and finishes. The contractor shall identify the specific material, material finish, or treatment for use with components and subcomponents. This information shall be available, upon request, to the contacting officer or his or her designated representative.

3.3.8 Material deterioration and control. The radiators shall be fabricated from compatible materials, inherently corrosion resistant or treated to provide protection against the various forms of corrosion and deterioration that may be encountered in any of the applicable storage and operating environments to which the item may be exposed.

3.4 Fins and tubes. The core assembly shall be of the tube and plate-fin construction with the fins perpendicular to and in close contact with the tubes.

3.5 Performance.

3.5.1 Heat rejection and core resistance. The heat rejection and core resistance curves of the test core shall be compared with the corresponding heat rejection and core resistance curves of the standard core. A fan curve at standard air density (0.075 lbs/cu. ft.) shall be drawn through the standard core resistance points at the 1500, 1800 and 2100 feet per minute air velocity points. The point at which the fan curve intersects the test core resistance curve shall be projected onto its respective heat rejection curve. When compared to the standard core values, the projected core values shall conform to the values stated on sheet A of MS35773.

3.5.2 Heat rejection comparison. The comparison between heat rejection (air gain) and heat rejection (water loss) shall not exceed 5 percent.

3.5.3 Distortion. When tested as specified in 4.5.2.3, the radiator and core shall show no leakage or permanent distortion exceeding 1/8 inch.

3.5.4 Vibration and leakage. The radiator or core when vibrated as specified in 4.5.2.4 at the most critical resonant frequency shall show no evidence of structural damage, seepage, or leakage.

3.6 Identification marking. Radiators and type II cores shall be identified in accordance with MIL-STD-130. A metal identification plate shall be permanently affixed to the side of the top tank of each radiator near the water inlet. In addition, a metal identification plate shall be permanently attached to the side of the type II core. Marking shall include the following information

Military standard radiator
MS part number
Manufacturer's name or trademark

3.7 Finishing and painting. Unless otherwise specified (see 6.2), the radiator and core shall be finished and painted in accordance with the contractor's standard practice.

3.8 Type I. The type I soldered-tank radiator shall be as shown on MS35773, part numbers -1, -2, -3, -9 or -10, as specified (see 6.2).

3.9 Type II. Bolted-tank radiator with replaceable core, type II, shall be as shown on MS 35773, part numbers -4, -5, -6, -7, or -8, as specified (see 6.2).

3.10 Workmanship.

3.10.1 Cleaning. The completed radiator and cores shall be cleaned and free from defects such as dirt, sand, metal chips, rust, cracks, and other foreign materials or defects that could impair their serviceability. Water from the cleaned radiator or cores shall not show a "pH" change of greater than 1, the chloride content shall not exceed 75 parts per million, nor shall there be a change in chlorine content no greater than 75 parts per million when compared with water before rinsing.

3.10.2 Soldering. Soldering of the overflow tube to the filler neck and the filler neck to the radiator top tank shall not interfere with the proper operation of the pressure cap. In the event any soldering is done to parts after the radiator or core has been cleaned, the radiator or core shall be cleaned again after the soldering operation.

3.10.3 Header plates. The gasket area, the corresponding boltholes, and the bolthead area of the header plates used on type II radiators shall be free of solder lumps and a water resistant nonhardening cement shall be used on the gaskets when the core is assembled to the tanks.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Component and material inspection. The contractor is responsible for insuring that components and materials used are manufactured, examined, and tested in accordance with referenced specifications and standards.

4.1.2 Disassembly inspection. Failure of any test by the first-produced model shall be cause for disassembly, in the presence of a Government representative, of the first-produced model to the extent necessary to determine the cause of the failure. Each disassembled part shall be examined in detail for compliance with this specification in regard to materials, dimensions, tolerances, and workmanship. Parts not complying with such requirements shall be rejected.

4.2 Classification of inspection. Inspection shall be classified as follows:

a. First-produced radiator inspection (see 4.3).
b. Quality conformance inspection (see 4.4).
c. Inspection of packaging (see 4.6).

4.3 First-produced radiator inspection.

4.3.1 Examination. The first-produced radiator(s) shall be examined as specified in 4.5.1. Presence of one or more defects shall be cause for rejection of all first-produced radiator(s).

4.3.2 Tests. The first-produced radiator(s) shall be tested as specified in 4.5.2.1 through 4.5.2.5. Failure of any test shall be cause for performing the inspection specified in 4.1.2.

4.4 Quality conformance inspection.

4.4.1 Sampling. Sampling for examination and tests shall be in accordance with MIL-STD-105, Inspection Level II.

4.4.2 Examination.

4.4.2.1 Samples. Samples selected in accordance with 4.4.1 shall be examined as specified in 4.5.1. AQL shall be 2.5 percent defective for major defects and 4 percent defective for minor defects.

4.4.3 Tests.

4.4.3.1 Samples. Samples selected in accordance with 4.4.1 shall be tested as specified in 4.5.2.1 through 4.5.2.5. AQL shall be 2.5 percent defective for major defects and 4 percent defective for minor defects.

4.5 Inspection procedure.

4.5.1 Examination. The radiators or cores shall be examined for the following defects:

Major

101. Dimensions not as specified.
102. Material not as specified.
103. Soldering not as specified.
104. Materials are not corrosion resistant or treated to be made corrosion resistant for the applicable storage and operating environments.
105. Dissimilar metals as defined in MIL-STD-889 are not effectively insulated from each other.
106. Contractor does not have documentation available for identification of material, material finishes, or treatments.

Minor

201. Identification marking incorrect or illegible.
202. Cleaning not as specified.
203. Workmanship not as specified.

4.5.2 Tests.

4.5.2.1 Conditions. The following conditions shall apply during the tests performed in accordance with this specification on complete radiators and on radiator cores when they are furnished separately. Radiator cores furnished separately shall be tested in fixtures which simulate, for test purposes, the top and bottom radiator tanks.

4.5.2.1.1 Supports. The radiator or core shall be supported on its normal points of support and shall not be supported on a cradle or bracket which in any way restrains the possible distortion of the radiator or core when under pressure.

4.5.2.1.2 Equipment. The test radiator or core, as applicable, shall be mounted on a test stand. A circulating pump shall be used to maintain an even temperature in the water reservoir. A flow pump and piping shall be used to provide water to the test radiator or core and a throttling valve shall be used to regulate the flow to the desired rate. A variable speed fan or adjustable dampeners or louvers shall regulate the airflow to the test radiator or core.

4.5.2.1.3 Instrumentation. Instrumentation shall be provided to perform the following functions:

a. To measure the temperature in the waterline at inlet and outlet to test radiator or core.
b. To measure airflow in the airduct. (When an orifice is used to measure the airflow, a manometer shall be connected upstream from the orifice to indicate the static pressure in the duct.)
c. To measure the pressure drop or the resistance to airflow across the core.
d. To measure the temperature of the airflow on each side of the core.

4.5.2.1.4 Control limits and data observations. The observed data shall be recorded. All points for each test shall be recorded only after all variables have been stabilized. The degree of stabilization and accuracy of observations shall be acceptable if the heat-rejection comparison conforms to 3.5.2.

4.5.2.1.5 Coolant. The coolant shall be water.

4.5.2.1.5.1 Coolant temperatures. The temperature of the water entering the test section shall be between 170° F and 210° F.

4.5.2.1.6 Heat rejection. The heat rejection test shall be made using one of the following test methods.

4.5.2.1.6.1 Heat rejection, test method (a). The core section shall be tested in the wind tunnel at the 100 percent waterflow rate and at 125 percent of the rated waterflow. If these selected values are not possible the core shall be tested at not less than three waterflow rates which bracket the 100 and 125 percent rate for each radiator size. At each waterflow rate, the heat rejection shall be determined at not less than four air velocities overlapping the range of 1,500 to 2,100 feet per minute as indicated on sheet 7 of MS35773. The heat

rejected by the water and the heat gained by the air shall be separately calculated at each test condition. A performance curve shall be plotted as shown on MS35773, Figure 1 or 2, as applicable. The heat rejection and core resistance values at 1,500, 1,800, and 2,100 feet per minute air velocity shall be taken from the performance curve and recorded. The difference between the test data and standard core data shall be checked for conformance to 3.5.1.

4.5.2.1.6.2 Heat rejection, alternate test method (b). When the same core section is used for more than one radiator type and size, waterflow rates and air-velocity rates which overlap the entire range of required conditions shall be chosen for test points on the sample core. All the air velocities shall be tested at each chosen waterflow rate. These results shall be plotted as shown on MS35773, figure 1 or 2, as applicable. The varying waterflow rates in gallons per minute can be plotted as a parameter on these curves. From these curves, a cross plot can be made with heat rejection in Btu/minute as the ordinate, waterflow rates as the abscissa, and air velocity lines of 1,500, 1,800, and 2,100 feet per minute as the parameter. From this cross plot, the required values can be obtained and recorded. The data thus obtained shall be compared to the standard core values of MS35773, Figures 1 and 2, as applicable. The difference between the test data and standard core data shall be checked for conformance to 3.5.1.

4.5.2.1.7 Air flow. Air flow through the test core section shall be from either side.

4.5.2.1.8 Air-pressure-drop-corrections. The air-pressure-drop measurements shall be corrected to standard conditions by use of the following formulas:

$$\Delta P_c = \frac{(\Delta p)\rho}{\rho_o}$$

ΔP_c = Corrected drop, in H_2O.

Δp = Measured drop, in H_2O.

ρ = Inlet air density, lbm/cu. ft.

ρ_o = Standard air density, 0.075 Lbm/cu. ft.

4.5.2.1.9 Vibration. The radiator shall be filled with tapwater for the test specified in 4.5.2.4. The radiator shall be supported as specified in 4.5.2.1.1 and securely fastened to a rigid mounting bracket which shall be bolted to the vibration table to insure that the motion of the radiator shall be essentially the same as the motion of the platform. Means shall be provided for controlling the direction of vibration of the test machine and for adjusting and measuring frequencies and amplitudes of vibration to keep them within prescribed limits.

4.5.2.2 Heat rejection and core resistance. The radiator or core, as applicable, shall be tested as specified in 4.5.2.1.6 based on rated heat rejection as defined in 6.4.12. These values may be determined on a square-foot basis. These values shall then be corrected to the area in square feet. Nonconformance to 3.5.1 shall constitute failure of this test.

4.5.2.3 Pressure cycling. The complete radiator shall be tested with all outlets closed. Pressure, variable from atmospheric to 150 percent of cap pressure not exceeding 18 psig, shall be applied at the inlet using air, steam or glycol and shall be maintained at a temperature of at least 212° F during the test. When steam is used, means shall be provided to prevent the accumulation of water. The pressure cycling shall take place in 3 to 4 seconds and at a rate of 6 pressure cycles plus or minus 1 cycle per minute. The radiator shall be cycled to a minimum of 50,000 pressure cycles. The radiator shall be examined periodically for evidence of leakage or distortion. Only tube leaks and tube-to-header leaks, not to exceed three, shall be repaired or plugged before continuing the test. Any evidence of leakage or maximum permanent distortion of more than 1/8 inch shall constitute failure of this test.

4.5.2.4 Vibration.

4.5.2.4.1 Resonance survey. The radiator which has been tested in accordance with 4.5.2.3 may be rebuilt or another radiator may be used for this test. The radiator shall be tested for leakage prior to start of this test. The radiator shall be prepared in accordance with 4.5.2.1.9 and vibrated at frequencies from 10 cps to 33 cps at the table displacements specified in table I. The change in frequency shall be made at intervals of 1 cps and maintained at each frequency for 1 minute. If resonance occurs at any point in the specified range, the frequency of vibration at that point shall become the test condition for 4.5.2.4.2.

4.5.2.4.2 Procedure. This test shall be run after completion of 4.5.2.4.1 if no leaks are observed. The radiator shall be vibrated for not less than 24 hours at the most critical resonant frequency. If no resonance was observed, this test shall be performed at 33 cps at the displacement referenced in table I. The radiator shall be periodically examined during the test for evidence of seepage and leakage. Nonconformance to 3.5.4 shall constitute failure of this test.

Table I. Table Displacements.

Frequency range	Total table displacement
cps	inches
10 to 15	0.060 ± 0.006
16 to 25	0.050 ± 0.005
26 to 33	0.040 ± 0.005

4.5.2.5 Washing operation. The radiator or core shall be filled with distilled water or tapwater of known pH index (see 6.4.13), at a temperature of 80° F to 100° F. The radiator shall then be shaken to assure thorough mixing and then allowed to stand for 1 hour. At the end of the 1-hour period, 1/2 gallon of the contents shall be drained into a clean container and tested for pH change and chloride content. Nonconformance to 3.10.1 shall constitute failure of this test.

4.6 Inspection of packaging.

4.6.1 Quality conformance inspection of pack.

4.6.1.1 Unit of product. For the purpose of inspection, a completed pack prepared for shipment shall be considered a unit of product.

4.6.1.2 Sampling. Sampling for examination shall be in accordance with MIL-STD-105.

4.6.1.3 Examination. Samples selected in accordance with 4.6.1.2 shall be examined for the following defects. AQL shall be 2.5 percent defective.

104.	Materials, methods, or containers not as specified for level A or B. Each incorrect material, method or container shall constitute one defect.
105.	Openings into radiators or replacement core assemblies not sealed as specified for level A.
106.	Gaskets not preserved as specified for level A.
107.	Contents not immobilized within box as specified for level A.
108.	Box closure and sealing not as specified for level A.
109.	Radiators or replacement core-assemblies of unlike description packed together for level A or B.
110.	Quantities packed together exceed the weight limitation of the box for level A or B.
111.	Preservation or packing not in accordance with the referenced documents as specified for commercial.
112.	Marking missing, illegible, incorrect, or incomplete for level A, B or commercial.

5. PACKAGING

5.1 Preservation. Preservation shall be level A or commercial as specified (see 6.2).

5.1.1 Level A. Unless otherwise specified (see 6.2) radiators or replacement core-assemblies shall not require application of a contact preservative. When specified (see 6.2), slush or flush interior of radiators replacement core-assemblies with VV-L-800 to insure complete coverage and thoroughly drain excess. Openings into radiators or replacement core-assemblies shall be sealed with tape conforming to MIL-T-22085, Type II or with caps or plugs of the appropriate size conforming to MIL-C-5501. The filler neck cap shall be secured in place to prevent loss. Gaskets for each replaceable core assembly shall be protected with fiberboard stiffeners and shall be preserved in accordance with MIL-P-116, Method IC-1 or IC-3. Each radiator or each replaceable core-assembly with gaskets, shall then be placed in a close-fitting box conforming to PPP-B-636, class weather resistant, grade as applicable, style optional. The contents shall be blocked, braced or cushioned as applicable within the box to prevent movement or damage. Box closure and sealing shall be as specified for method V in the appendix to the box specification.

5.1.2 Commercial. Each radiator or replacement core-assembly with gaskets, shall be preserved in accordance with MIL-STD-1188.

5.2 Packing. Packing shall be level A, level B or commercial as specified (see 6.2).

5.2.1 Level A. Radiators of like description or replacement core-assemblies of like description, preserved as specified in 5.1, shall be packed together in a close-fitting box conforming to PPP-B-601, overseas type, style optional, in quantities not to exceed the weight limitation of the box. Box closure and strapping shall be in accordance with the appendix to the box specification.

5.2.2 Level B. Radiators or replacement core-assemblies with gaskets shall be packed as specified in 5.2.1 for level A except that boxes shall be domestic type.

5.2.3 Commercial. Radiators or replacement core-assemblies with gaskets, preserved as specified in 5.1, shall be packed in accordance with MIL-STD-1188.

5.3 Marking.

5.3.1 Military. Marking for military levels of protection (level A or B) shall be in accordance with MIL-STD-129.

5.3.2 Commercial. Marking for commercial packaging shall be in accordance with MIL-STD-1188.

6. NOTES

6.1 Intended use. The radiators covered by this specification are intended for use with liquid-cooled internal combustion engines to dissipate the heat from the coolant.

6.2 Ordering data. Procurement documents should specify the following:

a. Title, number, and date of this specification.
b. Date of issue of DoDISS applicable and exceptions thereto (see 2.1.1).
c. Type of radiator or core, when applicable, required (see 1.2).
d. Time frame required for submission of first-produced radiator(s) and number of radiators required (see 3.2).
e. When the Government will conduct any or all of the preproduction model examination and tests. When the Government will conduct some but not all of the preproduction examination and tests, the contracting officer should specify which examination and tests will be conducted by the Government and which examination and tests shall be conducted by the contractor (see 3.2).
f. Finishing and painting when other than as specified (see 3.7).
g. Applicable MS part number required (see 3.8).
h. Applicable MS part number required (see 3.9).
i. Degree of preservation and degree of packing required (see 5.1 and 5.2).
j. When interior of radiator or replacement core-assemblies are to be preserved (see 5.1.1).

6.3 First-produced radiator. Any changes or deviations of production radiators and cores as applicable, from the approved first-produced radiator during production will be subject to the approval of the contracting officer. Approval of the first-produced radiator will not relieve the contractor of his obligation to furnish radiators and cores as applicable, conforming to this specification.

6.4 Definitions. For the purpose of this specification, the following definitions shall apply.

6.4.1 Rated internal pressure. The rated internal pressure shall be 7 psig for radiators conforming to MS35773-1 through -10.

6.4.2 Standard air. Standard air shall be air at a temperature of 70° F, a barometric pressure of 29.92 inches of mercury, and a density of 0.075 pound per cubic foot.

6.4.3 Rated air velocity. The rated air velocities shall be those listed on sheet 7 of MS35773.

6.4.4 Rated coolant flow. The rated coolant flow shall be the flow listed on sheet 7 of MS35773, and shall be based on approximately a 10° F drop in coolant temperature in the radiator.

6.4.5 Heat transfer - heat energy absorbed by air flow. The heat energy absorbed by air flow is the product of the air flow, specific heat of air, and air temperature rise.

Heat energy absorbed by air flow = $WC_p \Delta T$

W = air flow rate, Lbm/Min.

C_p = 0.24 Btu/Lbm/°F

ΔT = air temp rise, °F

6.4.6 Heat transfer - the heat rejection from water flow. The heat rejection from water flow is the product of the coolant flow, specific heat of coolant and coolant temperature drop.

Heat transfer (heat rejection from water flow) = $WC_p \Delta T$

W = water flow rate, Lbm/Min.

C_p = 1 Btu/Lbm/°F

ΔT = water temp drop, °F

6.4.7 Specific heat at constant pressure of water. The specific heat at constant pressure of water shall be based on the average water temperature. The

specific heat at constant pressure shall have the value of 1 Btu/lb./° F for water temperatures up to 215° F.

6.4.8 Specific heat at constant pressure of air. The specific heat at constant pressure of air shall have the value of 0.24 Btu/lb./° F for air temperatures up to 215° F and pressure around 1 (atm.).

6.4.9 Average water temperature. The average water temperature of the radiator is the sum of the water inlet and outlet temperatures divided by 2.

6.4.10 Rated potential. Rated potential shall be defined as the average water temperature minus the entering air temperature and shall have a value of 80° F.

6.4.11 Observed potential. Observed potential shall be defined as the observed average water temperature minus the observed entering air temperature during heat-rejection and core-resistance test.

6.4.12 Rated heat rejection. The rated heat rejection shall be total observed heat rejection in Btu's per minute multiplied by the rated potential and divided by the observed potential.

6.4.13 Index of acid intensity. The pH index shall be defined as the negative logarithm of the hydrogen ion concentration per liter. A pH index of 7 is a neutral solution. A pH index of less than 7 is an acidic solution. A pH index of greater than 7 is a basic solution.

6.4.14 Resonance. Resonance is a condition of maximum magnification of an applied vibration. It is usually manifested by visibly increased vibration of the radiator under test.

6.5 Recycled material. It is encouraged that recycled material be used when practical as long as it meets the requirements of the specification (see 3.3).

Custodians:
Army - ME
Air Force - 99

Review activity:
Army - AT
Air Force: 82
DLA - CS

Preparing activity:
Army - ME

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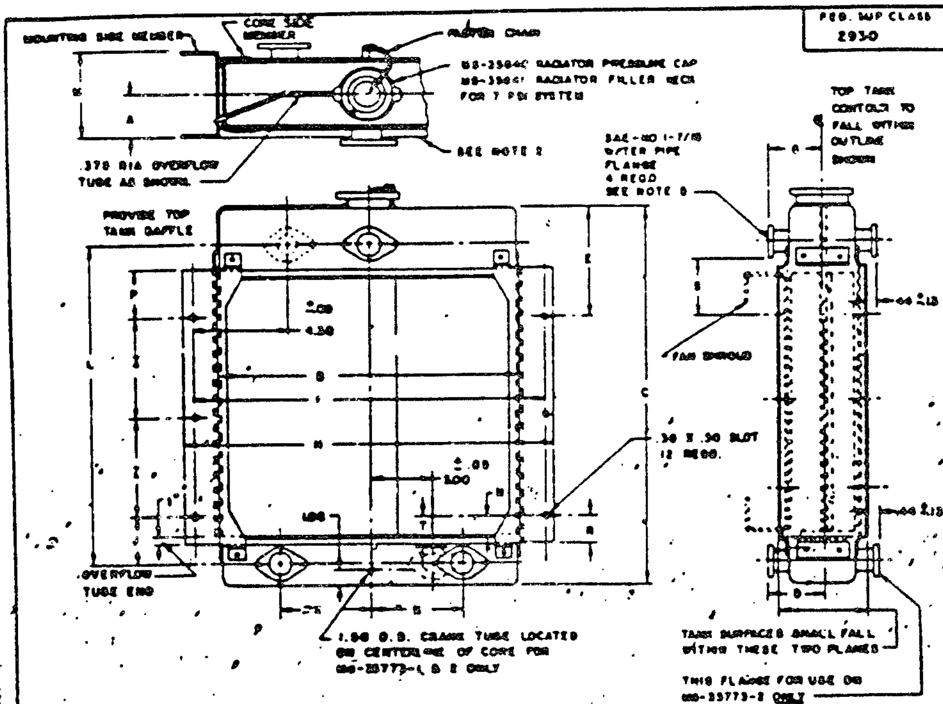
FED. SUP CLASS 2930



MS PART NO.	A ±.13	B MAX	C ±.13	D ±.13	E ±.13	F ±.13	G ±.13	H ±.13	I
MS-35773-1	2.22	16.32	20.13	2.18	4.63	15.75	2.81	18.00	6.00
MS-35773-2	1.81	18.32	23.00	2.81	4.75	19.25	2.81	20.50	7.38
MS-35773-3	1.81	22.32	30.00	2.81	5.50	23.38	2.81	24.63	10.50

J ±.09	K ±.13	L ±.13	M ±.06	N ±.13	P MAX	R MAX	FAN SHROUD S MAX	FAN SHROUD T MAX	U ±.13
2.25	5.00	16.81	4.44	0.88	1.38	1.38	1.47	1.16	13.94
2.38	5.13	20.13	4.44	0.88	2.30	1.63	1.91	1.28	17.00
2.38	7.00	26.38	4.44	1.00	2.13	1.50	1.91	1.28	23.88

NOTES: (APPLY TO SHEET 1 ONLY - SEE SHEET 10 FOR GENERAL NOTES):

1. THIS SHEET FOR TYPE I RADIATORS.
2. PROVIDE AIR SEAL STRIP ACROSS TOP AND BOTTOM OF CORE WHERE APPLICABLE TO PROVIDE FOR FLUSH SHROUD MOUNTINGS IN ACCORDANCE WITH "U" IF DISTANCE BETWEEN SEALING SURFACES EXCEEDS 0.13.
3. PROVIDE HORIZONTAL AIR SEAL FILLER STRIP IF "U" EXCEEDS CORE HEIGHT TOLERANCE LIMITS.
4. PROVIDE 1/4 PLATE FLANGE COVER WITH 1/16 GASKET, 2 HEX HD. CAP SCREWS, 3/8-16 UNC-2 X 3/4 LG, 2 LOCKWASHERS FOR EACH UNUSED FLANGE.
5. FOR MS 35773-2 FLANGE, 5 REQUIRED

(B) ENTIRE STANDARD REVISED AND REDRAWN

APPROVED 9 JUNE 1958 REVISED (B) 8 APR 1966

P.A.	ARMY MO (ERDL)	TITLE	MILITARY STANDARD
Other Cust.	TD 82	RADIATORS, ENGINE COOLING, INDUSTRIAL	MS 35773
PROCUREMENT SPECIFICATION	SUPERSEDES		SHEET 1 OF 10

DD FORM 672-1

THIS DOCUMENT CONTAINS 10 PAGES

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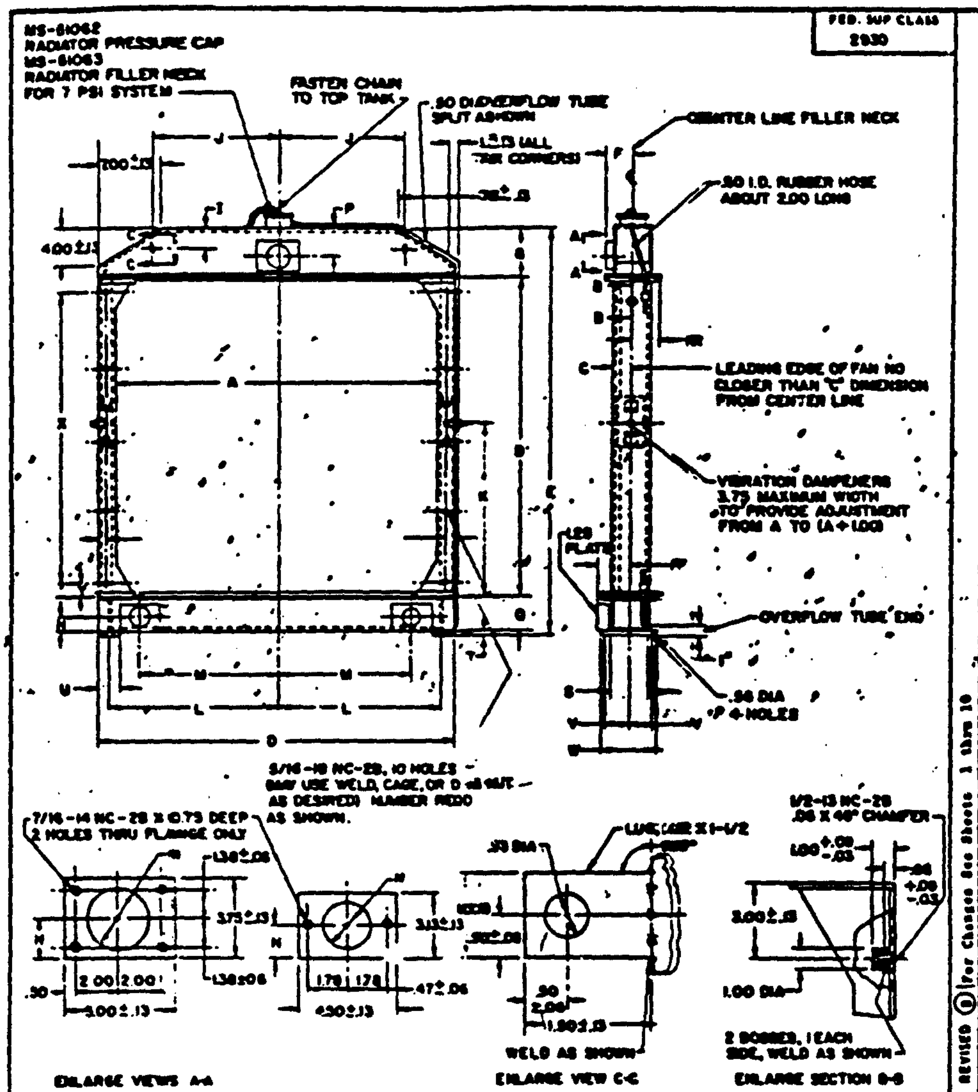

NOTES (APPLY TO SHEET 2 ONLY)

6. THIS SHEET FOR TYPE II RADIATORS.
7. FOR A THRU Y DIMENSIONS, SEE SHEET 3, FOR DETAIL OF CORE SEE SHEET 5.
8. PROVIDE 1/4 PLATE FLANGE COVER WITH 1/16 GASKET AND HEX. HD. CAP SCREWS, 7/16-14 UNC-2 X 3/4 LONG, AND OR 4 LOCKWASHERS, AS APPLICABLE, FOR ONE OF THE BOTTOM OUTLETS.
9. PROVIDE TOP TANK BAFFLE.

APPROVED 9 JUNE 1950 REVISED (B) For Changes See Sheets 1 thru 10

P.A. ARMY MO (EPOLI) Other Cust YD 02	TITLE RADIATOR, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
PROCUREMENT SPECIFICATION MIL-R-45306	SUPERSEDES	SHEET 2 OF

DD FORM 672-1

Review Activity: MO, 02
User Activity: YD, MC

This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for all new engineering and design applications and for repetitive use shall be made from this document.

0783

FED. SUP CLASS 2930

Review Activity: MO 82
User Activity: YD, ME

MS PART NO.	A ±.13	B ±.06	C ±.13	D ±.13	E ±.18	F ±.13	G ±.13	H ±.06	I ±.13	J ±.13	K ±.13 SEE NOTE 13	L ±.13
MS-35773-4	23.50	27.00	2.38	27.00	36.38 SEE NOTE 11	3.63	5.00	1.56	2.50	8.00	13.50	12.75
MS-35773-5	27.00	30.00	2.38	30.50	39.38 SEE NOTE 11	3.63	5.00	1.56	2.50	10.00	15.00	14.50
MS-35773-6	33.50	36.00	2.38	38.00	47.00 SEE NOTE 12	3.63	6.00	1.88	3.00	12.00	18.00	17.50
MS-35773-7	39.50	40.00	2.38	44.00	51.00 SEE NOTE 12	3.63	6.00	1.88	3.00	15.00	20.00	20.50
MS-35773-8	43.50	44.00	2.38	48.00	55.00 SEE NOTE 12	3.63	6.00	1.88	3.00	17.00	22.00	22.50

M ±.13	N ±.06	P ±.06	Q ±.13	R ±.13	S ±.13	T ±.06	U ±.25	V ±.13	W ±.13	X	Z ±.06	CORE MS PART NO.
9.50	2.38	2.50	4.00	3.50	4.75	0.38	1.50	3.00	7.00	4-HOLES @ 6" O.C. × 24"	1.50	MS-35884-1
11.25	2.38	2.50	4.00	3.50	4.75	0.38	1.50	3.00	7.00	4-HOLES @ 9" O.C. × 27"	1.50	MS-35884-2
13.50	3.00	3.38	4.50	3.50	4.75	0.50	3.00	3.00	7.00	5-HOLES @ 8" O.C. × 32"	2.00	MS-35884-3
16.50	3.00	3.38	4.50	3.50	4.75	0.50	3.00	3.00	7.00	5-HOLES @ 9" O.C. × 36"	2.00	MS-35884-4
18.50	3.00	3.38	4.50	3.50	4.75	0.50	3.00	3.00	7.00	5-HOLES @ 10" O.C. × 40"	2.00	MS-35884-5

NOTES: (APPLY TO SHEET 3 ONLY)
10. THIS SHEET FOR TYPE II RADIATORS.
11. INCLUDES .38" THICK MOUNTING FOOT.
12. INCLUDES .50" THICK MOUNTING FOOT.
13. BOTTOM OF SIDE SUPPORT TO CENTER LINE OF VIBRATION DAMPENER

APPROVED 9 JUNE 1958 REVISED (8) For Changes see Sheets 1 thru 11

This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for this new engineering and design applications and for repetitive use shall be made from this document.

P.A. ARMY MO (EROL) Office Cust YD 82	TITLE RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
PROCUREMENT SPECIFICATION MIL-R-45309	SUPERSEDES	SHEET 3 OF

DD FORM 672-1

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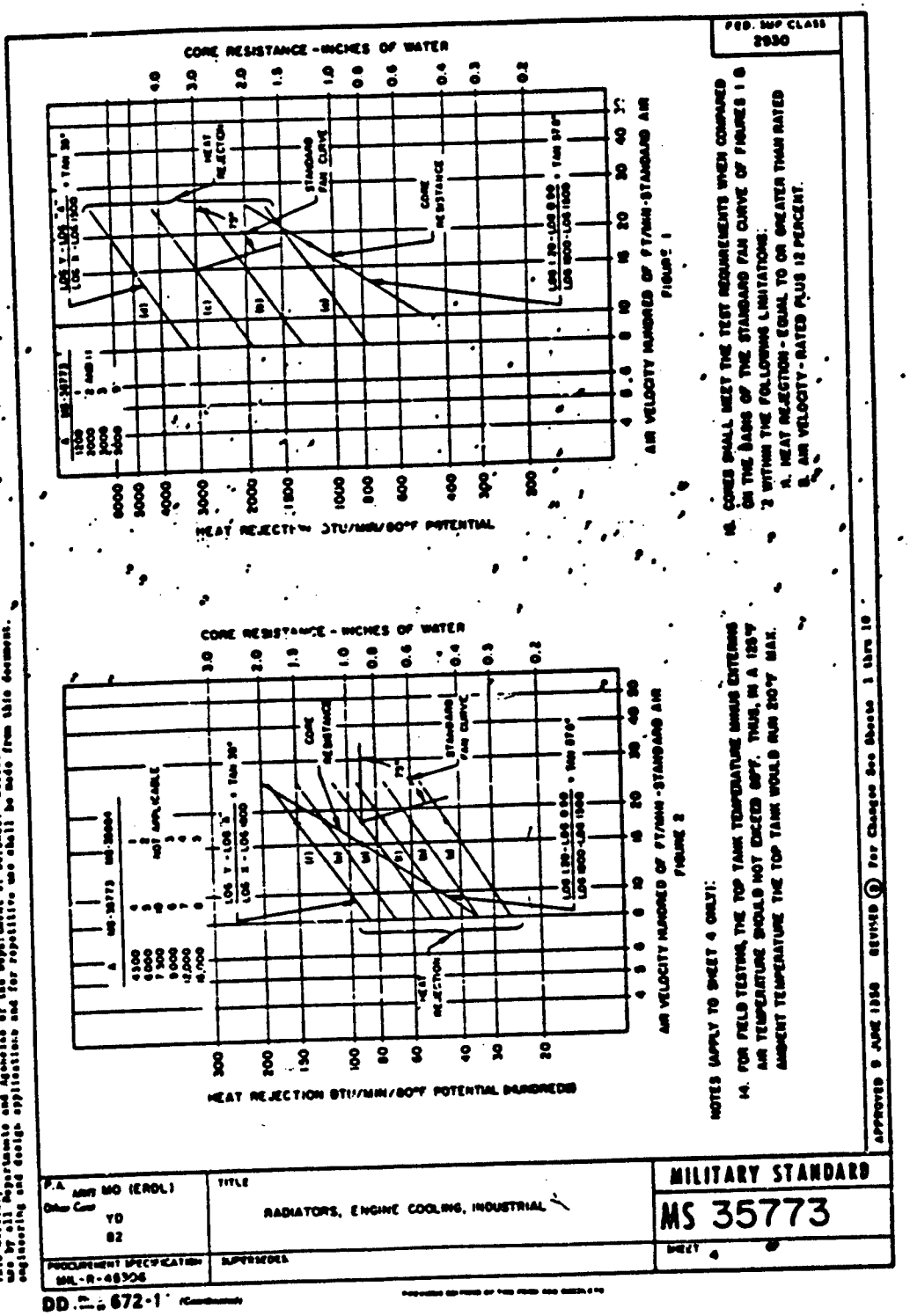
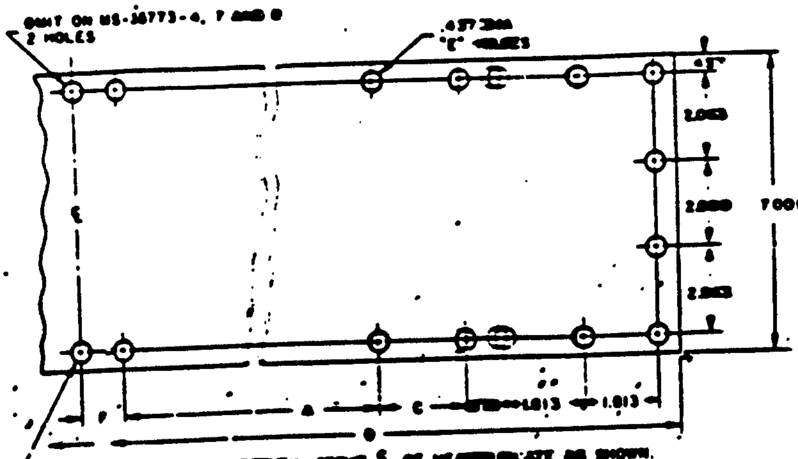


This Military Standard has been approved by the Departments of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for all new engineering and design applications and for repetitive use shall be made from this document.

Review Activities: MD 82
User Activities: YD, 82

0785

FSCM SUP CLASS
2930



BOLT HOLES ARE SYMMETRICAL ABOUT ℄ OF HEADER PLATE AS SHOWN. PROVIDE FOR SCREW, CAP HEX HD, 3/8-16 NC X [illegible] LG, CAD. PL STL, AND NUT, PLAIN, HEX, 3/8, WITH LOCKWASHER.

RADIATOR MS PART NO	A	C	[illegible]	E	F	CORE MS PART NO.
MS-35773-4	4 HOLES @ 2" OC = 6"	1.[illegible]	[illegible]	36	1.000	MS-[illegible]-1
MS-35773-5	4 HOLES @ 2" OC = 6"	2.2[illegible]	350.50	[illegible]	2.000	MS-[illegible]-2
MS-35773-6	6 HOLES @ 2" OC = 10"	2.0[illegible]	388.00	46	2.000	MS-[illegible]-3
MS-35773-7	8 HOLES @ 2" OC = 14"	2.0[illegible]	444.00	52	1.000	MS-[illegible]-4
MS-35773-8	9 HOLES @ 2" OC = 16"	2.0[illegible]	446.00	56	1.000	MS-[illegible]-5

NOTES (APPLY TO SHEET 3 ONLY)

16 THIS SHEET FOR TYPE IX RADIATORS

17 UNLESS OTHERWISE SPECIFIED ALL DECIMALS ARE ±.03 FOR TWO PLACE AND ±.010 FOR THREE PLACE.

APPROVED 8 JUNE 1960 REVISED Ⓑ For Changes See Sheets 1 thru 10

P.A. AMY / Other Cust: MO (EROL) YD 82	TITLE: RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
PROCUREMENT SPECIFICATION MIL-R-45306	SUPERSEDES	SHEET 3 OF

DD FORM 672-1 (Continued)

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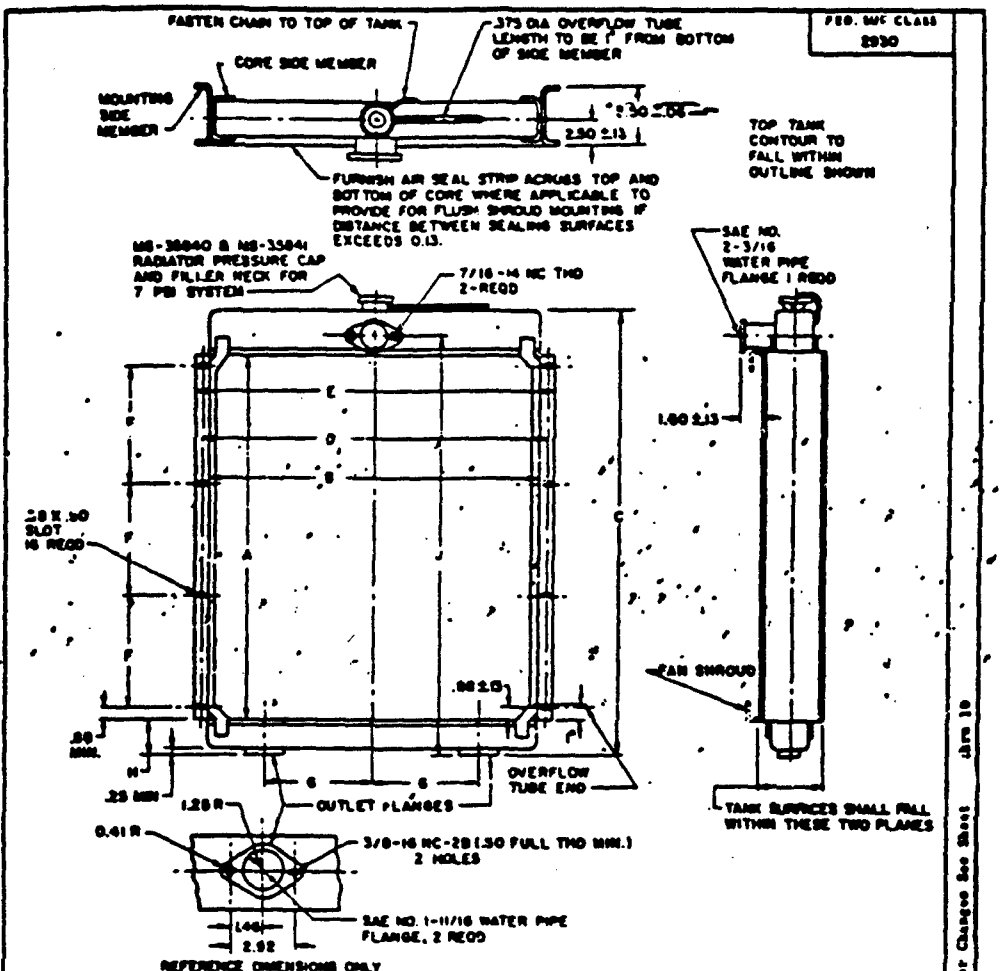


MS PART NO.	A ±.13	B MAX	C ±.13	D ±.13	E ±.13	F	G ±.13	H ±.09	J ±.13
MS-35773-9	28.00	29.00	38.06	30.75	32.00	8.75	9.00	3.84	32.81
MS-35773-10	34.00	34.90	44.56	32.75	34.00	10.75	10.90	4.44	39.31

NOTES: (APPLY TO SHEET 6 ONLY)
10. THIS SHEET FOR TYPE I RADIATORS.
18. PROVIDE 1/4 PLATE FLANGE COVER WITH 1/16 GASKET, 2 HEX. HD. CAP SCREWS, 3/8-16 UNC-2 X 3/4 LONG, 2 LOCKWASHERS FOR ONE OF THE BOTTOM OUTLETS.
20. PROVIDE TOP TANK BAFFLE.

P.A. ARMY MD (ERDL) Other Cust YD 82	TITLE: RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS35773
PROCUREMENT SPECIFICATION MIL-R-46306	SUPERSEDING	SHEET 6 OF

FED. MIC CLASS 2930

APPROVED 9 JUNE 1958 REVISED (B) for Change See Sheet 1 dtm 10

Review Activities: MD 82 User Activities: 19, MC

This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Suggestions for improvement of engineering and design specifications and for repetitive use shall be made from this document.

DD FORM 672-1

0787

FED. SUP CLASS
2930

HEAT REJECTION AND CORE RESISTANCE REQUIREMENTS FOR MILITARY STANDARD RADIATORS

LEGEND SEE NOTE 21	MS PART NUMBER	HEAT REJECTION BTU/MIN ("A") •MIN REQ ALLOWABLE	AIR VELOCITY FT/MIN ••RATED VALUE	MAX RESISTANCE INCHES WATER •••MAX REQ ALLOWABLE	WATER FLOW GALS/MIN (RATED VALUE)
1(a)	MS-35773-1	• 1200 1363 1619	••1800 1800 2100	•••0.9 1.2 1.8	18
1(b)	MS-35773-2 MS-35773-11	• 2000 2272 2531	••1800 1800 2100	•••0.9 1.2 1.8	25
1(c)	MS-35773-3	• 3000 3408 3797	••1800 1800 2100	•••0.9 1.2 1.8	36
1(d)	MS-35773-9	• 5000 5682 6328	••1800 1800 2100	•••0.9 1.2 1.8	62
2(a)	MS-35773-4 MS-35884-1	3960 • 4500 5012	1800 ••1800 2108	0.9 •••1.20 1.8	56
2(b)	MS-35773-5 MS-35884-2	5281 • 6000 6684	1800 ••1800 2100	0.9 •••1.20 1.8	75
2(c)	MS-35773-10	8400 • 7500 8358	1800 ••1800 2100	0.9 •••1.20 1.8	92
2(d)	MS-35773-6 MS-35884-3	7921 • 9000 10080	1800 ••1800 2100	0.9 •••1.20 1.8	110
2(e)	MS-35773-7 MS-35884-4	10560 • 12000 13270	1800 ••1800 2100	0.9 •••1.20 1.8	160
2(f)	MS-35773-8 MS-35884-5	13200 • 15000 16710	1800 ••1800 2100	0.9 •••1.20 1.8	185

NOTES (APPLY TO SHEET 7 ONLY):

21. REFER TO FIGURES AND CURVES - SHEET 4.
22. ABOVE REQUIREMENTS ARE BASED ON 60°F POTENTIAL.

60°F POTENTIAL = AVERAGE WATER - ENTERING AIR

$$\text{AVERAGE WATER} = \frac{T_1 + T_2}{2}; \quad T_1 = \text{TOP TANK TEMPERATURE}, \; T_2 = \text{BOTTOM TANK TEMPERATURE}$$

$$\text{HEAT REJECTION CURVE} = \frac{\text{LOG } Y - \text{LOG "A"}}{\text{LOG } X - \text{LOG 1800}} = \text{TAN } 38°$$

$$\text{RESISTANCE CURVE} = \frac{\text{LOG } 1.20 - \text{LOG } 0.90}{\text{LOG 1800} - \text{LOG 1500}} = \text{TAN } 57.6°$$

APPROVED 9 JUNE 1958 REVISED (6) For Changed See Sheet 1 thru 30

This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for all use engineering and design applications and for repetitive use shall be made from this document.

Review Activities: MD, AF, Navy Activities: YD, SC

P.A. Army MD (ERDL) Other Govt YD 82	TITLE: RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
Procurement Spec. MIL-R-45308	SUPERSEDES	SHEET 7

DD Form 672-1 (Continued)

0788

FED. SUP CLASS
2930

MATERIAL REQUIREMENTS

RADIATOR TYPE	MS PART NO.	TANKS (SEE NOTE 23)	SIDES	HEADER PLATES		HEADER BARS (SEE NOTE 23)	NOMINAL TUBE WALL THK	NOMINAL END LIVE TUBE WALL THK
				TOP	BOTTOM			
I	MS 35773-1	*20 GA (.032) BRASS	*18 GA. (.047) TERNE WITH *14 GA. (.080) SAE 1010 WIRE	*20 GA (.032) BRASS	*20 GA (.032) BRASS	-----	.006	.008
I	MS 35773-2 MS 35773-11					-----	.006	.008
I	MS 35773-3					-----	.006	.008
I	MS 35773-9					-----	.006	.008
I	MS 35773-10	*18 GA (.040) BRASS		*18 GA (.040) BRASS		-----	.006	.008
II	MS 35773-4 MS 35884-1	*10 GA (.135) SAE 1010	*10 GA (.135) SAE 1010			SAE 1010	.006	.008
II	MS 35773-5 MS 35884-2			*18 GA (.040) BRASS		SAE 1010	.008	.010
II	MS 35773-6 MS 35884-3	*7 GA (.177) SAE 1010	*7 GA (.177) SAE 1010		*11 GA (.091) BRASS	SAE 1010	.008	.010
II	MS 35773-7 MS 35884-4					SAE 1010	.008	.010
II	MS 35773-8 MS 35884-5					SAE 1010	.008	.010

NOTES (APPLY TO SHEET 8 ONLY)

23 NOT APPLICABLE TO STANDARD MS 35884

24 THE USE OF COPPER BEARING STEEL OR INGOT IRON IS ALLOWED IN PLACE OF SAE 1010

25 INTERNAL SURFACES OF PARTS CONSTRUCTED FROM SAE 1010 SHALL BE PROTECTIVE COATED.

26 GAGE SIZES SHOWN ARE MINIMUM

APPROVED 9 JUNE 1950 REVISED (8) For Changes See Sheets 1 thru 10

Review activities: WG, 82
User activities: TD, MC

This Military standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for all new engineering and design applications and for competitive use should be made from this document.

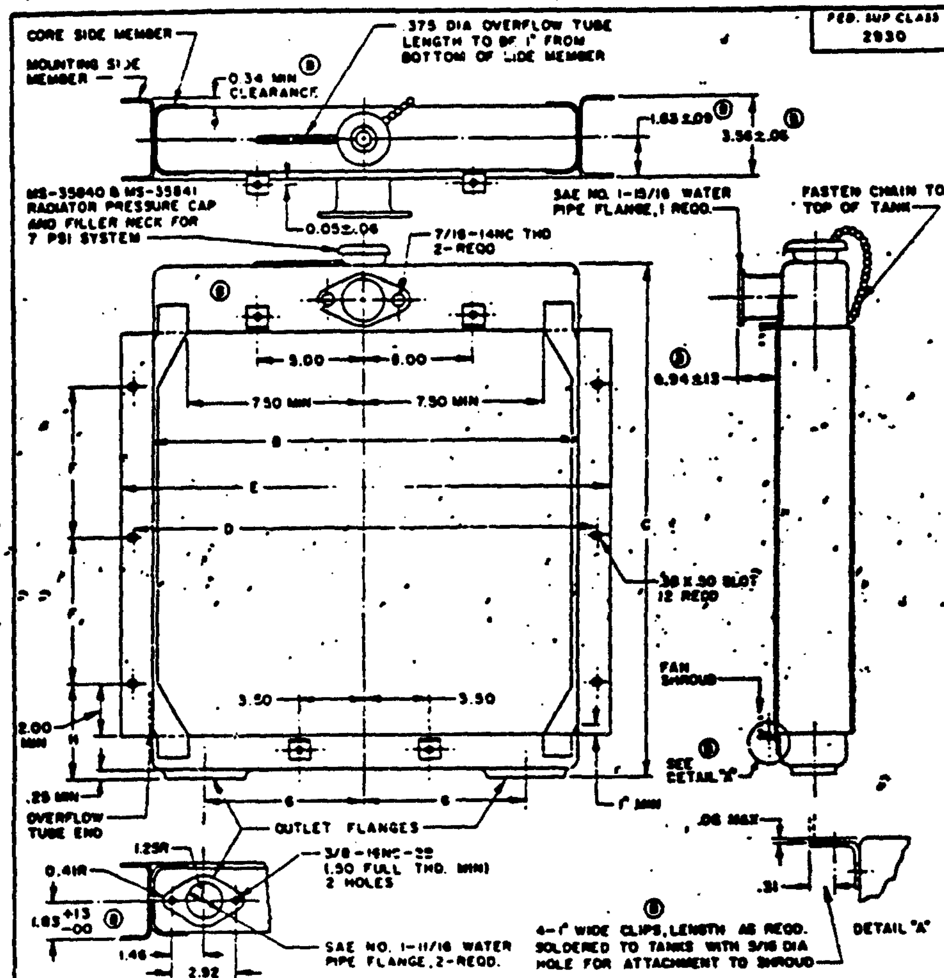
P.A. ARMY MD (ERDL) Other Cust YC 82	TITLE RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
PROCUREMENT SPECIFICATION MIL-R-45306	SUPERSEDES	SHEET 8 OF

DD FORM 672-1 (Reverse)

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

0789

FED. SUP CLASS
2930



REFERENCE DIMENSIONS ONLY

MS PART NO.	A ±.13	B MAX	C ±.13	D ±.13	E ±.13	F	G ±.13	H ±.09	J ±.13
MS-35773-11	19.00	20.25	23.86	22.00	23.00	7.00	7.50	4.38	22.50

NOTES (APPLY TO SHEET 9 ONLY)

26. THIS SHEET FOR TYPE I RADIATORS.
27. PROVIDE 1/4 PLATE FLANGE COVER WITH 1/16 GASKET, 2 HEX. HD. CAP SCREWS, 3/8-16 UNC-2 X 3/4 LONG, 2 LOCKWASHERS FOR ONE OF THE BOTTOM OUTLETS.
28 PROVIDE FOR TOP TANK BAFFLE.
29. PROVIDE HORIZONTAL AIR SEAL FILLER STRIP IF "A" EXCEEDS CORE HEIGHT TOLERANCE LIMITS.

APPROVED 9 JUNE 1958 REVISED (B) For Changes See Sheets 1 thru 10

P.A. ARMY MO (ENG.) Other Cust YD 82	TITLE RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
PROCUREMENT SPECIFICATION MIL-R-45306	SUPERSEDES	SHEET 9 OF

This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for all new engineering and design applications shall be made from this document.

0790 DD FORM 672-1 (Continued)

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

FED. SUP CLASS
2930

Review activity: MO 82
User Activity: YD, ME

GENERAL NOTES (APPLY TO SHEETS 1 THRU 9):

30. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMAL DIMENSIONS ± .03 INCHES.
31. RADIATORS MS 35773-1 THRU MS 35773-41 WILL BE TESTED IN WATER WITH AIR PRESSURE AT 5 LBS. MINIMUM TO 10 LBS. MAXIMUM PRESSURE.
32. ALL DIMENSIONS ARE IN INCHES.
33. FOR DESIGN FEATURE PURPOSES, THIS DOCUMENT TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
34. REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON THE DATE OF INVITATION FOR BIDS.

(B) SHEET ADDED

APPROVED 9 JUNE 1958 REVISED (B) For Changes See Sheets 1 thru 10

This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense. Selection for all new engineering and design applications and for repetitive use shall be made from this document.

P.A. ARMY MO (EROL) Other Cust YD 82	TITLE RADIATORS, ENGINE COOLING, INDUSTRIAL	MILITARY STANDARD MS 35773
PROCUREMENT SPECIFICATION MIL-R-45306	SUPERSEDES	SHEET 10 OF

DD FORM 672-1

0791

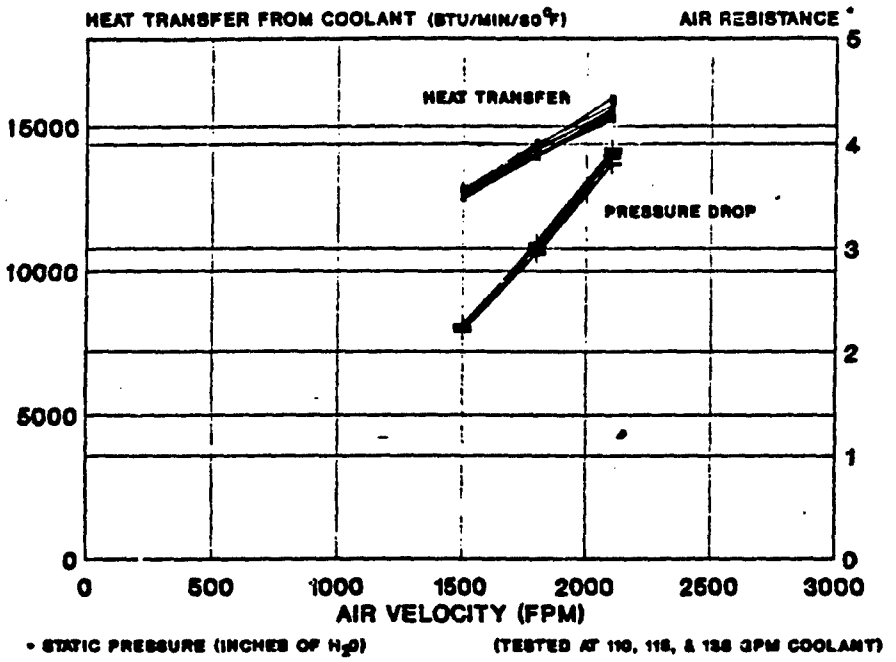
APPENDIX B

M915 RADIATOR TEST RESULTS DATA

NOTES:

1. LEAKAGE:
   THE RADIATOR, WITH ALL OPENINGS CLOSED, SHALL NOT LEAK IN EXCESS OF 5 CUBIC CENTIMETERS PER MINUTE, NOR FROM MORE THAN ONE LOCATION, WHEN SUBJECTED TO 18 + 1 PSIG AIR PRESSURE.

2. COOLING:
   RADIATOR COOLING PERFORMANCE SHALL MEET REQUIREMENTS AS SHOWN IN GRAPH, WITH INLET WATER TEMPERATURE 180 ± 5 °F.



3. FILL RATE TEST:
   WITH RADIATOR OUTLET PLUGGED, THE TIME TO FILL THE RADIATOR TO 90% COOLING SYSTEM CAPACITY SHALL BE ACCOMPLISHED IN A 5 MINUTE PERIOD.

4. MAXIMUM FREE FLOW RATE TEST:
   WITH THE RADIATOR SUSPENDED BELOW A RECEIVING DRUM AND CONNECTED TO A COOLANT FLOW SYSTEM, THE MAXIMUM FREE FLOW RATE SHALL MEASURE 55 ± 5 GPM.

6. PRESSURE CAP:
   THE PRESSURE CAP SHALL MEASURE 10 PSIG.

7. FAILURE:
FAILURE TO MEET NOTES 1 THROUGH 4 WILL RESULT IN FAILURE OF THE RADIATOR.

8. FINISH:
PRIME TO BEST COMMERCIAL PRACTICE AND BE COMPATIBLE WITH MIL-E-52853A AND MIL-E-52798A. COLOR BLACK.

9. INTERNAL CLEANLINESS:
THE RADIATOR ASSEMBLY SHALL BE CLEANED AND BE FREE OF DEFECTS AND FOREIGH MATERIAL. AFTER CLEANING, WATER FROM THE CLEANED RADIATOR SHALL NOT SHOW A "pH" CHANGE OF GREATER THAN 1, AND A CHLORIDE CONTENT INCREASE OF GREATER THAN 75 PARTS PER MILLION WHEN COMPARED TO THE INDUCED WATER.

10. REMOVE ALL BURRS AND SHARP EDGES.

NOTES 1,8,9, & 10 TAKEN FROM 5-TON TRUCK RADIATOR

Fill-Rate Test Results
Time to Fill to 90% Capacity (in minutes)

Test Run	Radiator #1	Radiator #2
1	0:30	0:30
2	0:29	0:28
3	0:28	0:30
Average	0:29	0:29

Table B-1.

Maximum Free-Flow Rate Test
(Gallons per Minute)

Test Run	Radiator #1	Radiator #2
1	50.1	58.9
2	71.7	59.1
3	42.2	47.5
4	65.3	63.1
5	41.7	58.9
6	45.8	58.7
Average	52.8	57.7

Table B-2.

TEST DATA: SAMPLE #1
WATER TEMP IN: 180°F +10°
AIR TEMP IN: 100°F +10°
DENSITY WATER (180°F): 8.0986 LB /GAL

NOTES:
ALL TEMPERTURES IN DEGREES FAHRENHEIT
CORE RESISTANCE CORRECTED TO STD ATM CONDITIONS
*DATA POINTS OMITTED(GREATER THAN 5%)

TEST RUN	WATER FLOW (GPM)	AIR FLOW (CFM)	WATER TEMP IN	WATER TEMP OUT	AVE AIR TEMP IN	AVE AIR TEMP OUT	HEAT REJ WATER (BTU/MIN)	HEAT REJ AIR (BTU/MIN)	HEAT REJ WATER (BTU/MIN/80°F)	HEAT REJ AIR (BTU/MIN/80°F)	PERCENT DIFF.	CORE RESIST " H2O
1	118	12375.0	180.0	166.2	89.1	150.0	13337.9	13377.2	12642.6	12679.8	0.29	2.24
2	118.2	12375.0	180.5	166.5	90.7	151.2	12813.0	13117.8	12379.7	12673.4	2.32	2.25
3	118	12375.0	180.1	166.5	93	151.7	12424.4	12726.7	12377.9	12679.2	2.38	2.23
1	118	14860.0	180.4	165	91.9	146.6	14068.8	14241.8	13929.5	14100.0	1.21	3.02
2	109.8	14860.0	180.9	165.7	93.7	146.9	13860.8	13850.5	13930.4	13920.1	0.07	3.01
3	109.6	14860.0	180.4	165.1	93	147.7	13926.6	14241.8	13970.2	14285.6	2.21	3.02
1	109.4	17307.0	180.3	164	94.5	144.3	14809.7	15180.3	15257.9	15557.3	1.92	3.89
2	110	17307.0	180.4	163.8	93	143.8	15165.0	15403.5	15337.6	15578.8	1.55	3.91
3	110	17307.0	180.7	163.9	93.7	144.1	15347.7	15282.2	15621.1	15554.4	0.43	3.90
1	115	12375.0	180.1	166.5	86.8	149.5	12989.1	13594.0	12913.0	12572.5	4.45	2.26
2	115.5	12375.0	179.9	166.2	85.8	149.3	13141.5	13767.4	12949.5	12623.4	4.55	2.26
* 3	115	12375.0	180	166.3	85.6	149.9	13684.6	13940.9	11956.2	12738.7	6.14	2.26
1	115	14839.0	180.2	164.2	85.5	145	15281.3	15460.0	14100.4	14273.4	1.21	3.84
2	115	14839.0	180.4	164.6	86.1	144.8	15281.3	15260.0	14165.7	14146.7	0.13	3.85
3	115	14839.0	180	164.9	87.1	145.3	14421.7	15130.0	13517.7	14182.3	4.69	3.85
1	115	17343.0	180	163.8	90	142.6	15472.3	15982.5	15113.4	15611.7	3.19	3.92
2	115	17343.0	180	163.7	88.8	141.8	15567.0	16104.0	14996.1	15512.6	3.33	3.93
3	115	17343.0	180.3	163.8	88.4	141.6	15758.0	16164.8	15071.2	15459.4	2.51	3.95
1	137.6	12375.0	180.5	168.9	94	153.8	13256.2	12965.2	13141.2	12852.0	2.19	2.22
2	137.8	12375.0	181.6	170.1	95	154.7	13161.0	12943.6	13022.6	12807.5	1.65	2.21
* 3	134.8	12375.0	180.2	169.5	95.1	154.6	11978.9	12980.2	12016.4	12940.6	7.14	2.20
1	138.4	14839.0	180	167.5	91.9	148.8	14367.7	14792.0	14043.0	14458.5	2.87	3.81
2	137.6	14839.0	180.3	167.9	93	149.4	14170.4	14662.8	13970.2	14464.0	3.36	3.82
3	138	14839.0	180.4	167.9	94	149.6	14326.2	14454.8	14299.4	14427.8	0.89	3.80
1	138	17325.0	180.6	166.2	89	143.6	16583.0	16573.0	15643.4	15709.0	0.42	3.93
2	138	17325.0	180.5	166.3	88.2	143.6	16274.6	16815.0	15281.3	15789.5	3.22	3.96
3	137.8	17325.0	180.5	166	89.8	144.7	16594.3	16664.0	15908.3	15975.1	0.42	3.94

Table B-3. Heat-Rejection Data, Radiator Sample #1

TEST DATA: SAMPLE #2
WATER TEMP IN: 180°F +10°
AIR TEMP IN: 100°F +10°
DENSITY WATER (180°F): 8.8986 LB /GAL

NOTES:
ALL TEMPERATURES IN DEGREES FAHRENHEIT
CORE RESISTANCE CORRECTED TO STD ATM CONDITIONS
*DATA POINTS OMITTED(GREATER THAN 5%)

TEST RUN	WATER FLOW (GPM)	AIR FLOW (CFM)	WATER TEMP IN	WATER TEMP OUT	AVE AIR TEMP IN	AVE AIR TEMP OUT	HEAT REJ WATER (BTU/MIN)	HEAT REJ AIR (BTU/MIN)	HEAT REJ WATER (BTU/MIN/80°F)	HEAT REJ AIR (BTU/MIN/80°F)	PERCENT DIFF.	CORE RESIST " H2O
1	109.6	12375.0	180.9	166.5	94	151.4	12781.5	12444.9	12829.6	12491.7	2.63	2.19
2	119.2	12375.0	180.0	167.4	94	151.0	11959.0	12531.6	13777.7	14437.3	4.57	2.19
3	110	12375.0	180.4	166.9	95	151.9	12026.4	12336.5	14082.5	14445.5	2.51	2.19
1	110.2	14850.0	181.1	166	95	147.6	13019.0	13685.0	14074.9	13937.7	0.97	2.95
2	110	14850.0	180.9	165.7	96	148.1	13086.0	13555.0	14371.1	14028.4	2.38	2.94
3	110.2	14850.0	180.5	166	96.1	148	13270.6	13502.9	13760.9	14001.7	1.72	2.94
1	109.6	17325.0	180.3	164.6	96.0	144.7	14290.7	14539.3	15112.4	15375.3	1.71	3.81
2	109.6	17325.0	180.7	165.3	97.1	144.9	14017.6	14588.9	14774.0	15292.7	3.39	3.81
3	110	17325.0	180.0	165.2	98	145.4	14251.5	14387.5	15201.6	15346.7	0.95	3.80
1	114.0	12375.0	180.6	166.0	90	150.4	13157.2	13095.3	12575.6	12516.4	0.47	2.20
2	115.1	12375.0	180.3	167	91	150.7	12713.6	12943.6	12306.0	12528.5	1.78	2.20
3	114.6	12375.0	180.2	166.4	91	150.0	13134.3	12965.2	12767.2	12602.9	1.29	2.20
1	115.1	14850.0	180.7	165.9	93	147.1	14147.5	14075.3	14094.6	14022.7	0.51	2.96
2	115	14850.0	180.6	166.3	94	147.5	13657.7	13919.2	13752.2	14015.6	1.88	2.95
3	114.6	14850.0	180.4	166	94.3	147.6	13705.3	13867.2	13896.4	14060.5	1.17	2.95
1	115.1	17325.0	180.6	165.7	96.7	144.9	14243.1	14630.3	14904.5	15309.7	2.65	3.82
2	115.1	17325.0	181	164.9	92.2	143.1	15398.2	15449.9	15247.2	15306.4	0.39	3.86
3	114.8	17325.0	181	164.5	92	142.6	15731.4	15358.8	15585.3	15216.2	2.37	3.86
* 1	138.4	12375.0	179.8	178	94.1	153.4	11264.3	12856.8	11152.8	12729.5	12.39	2.20
2	138	12375.0	180.3	169.2	93	152.9	12721.7	12986.9	12449.3	12708.9	2.04	2.19
* 3	137.6	12375.0	179.6	169.3	93	152.9	11778.6	12986.9	11561.0	12755.7	9.37	2.19
1	137.8	14850.0	180.4	167.8	94	148.7	14419.9	14231.4	14401.9	14213.6	1.31	2.96
2	138.2	14850.0	180	167.9	94	148.5	13887.9	14179.4	13896.6	14188.2	2.06	2.96
3	138	14850.0	180.2	167.5	92.9	147.5	14555.4	14205.4	14384.6	14038.7	2.48	2.97
1	137.8	17325.0	180.3	166.3	90.4	143.4	16022.1	16087.3	15461.6	15524.5	0.41	3.88
2	138.2	17325.0	180	166.2	90.1	143.3	15039.1	16148.0	15266.6	15564.3	1.91	3.89
3	138.2	17325.0	180.3	166.5	92.3	144.1	15039.1	15723.1	15624.2	15509.8	0.73	3.87

Table B-4. Heat-Rejection Data, Radiator Sample #2

BELVOIR FUELS AND LUBRICANTS RESEARCH FACILITY (SwRI)
6220 CULEBRA ROAD – P.O.DRAWER 28510 PH:512-684-5111 SAN ANTONIO,TEXAS 78284

BFLRF

File: 02-1955-180
21 August 1990

Commander
U.S. Army Tank-Automotive Command
Attn: AMSTA-RGT (Ms. Christine Radlein)
Warren, Michigan 48397-5000

Subject: **Analysis of Fluids Drained From Radiators**

Dear Sir:

Two fluid samples were received from TACOM for analysis. BFLRF was asked to identify the fluids if possible. The samples received were:

AL-19294-X	Sample A, From Radiator No. 1
AL-19295-X	Sample B, From Radiator No. 2

Since the two samples were expected to be the same with the exception of water in AL-19294-X, only AL-19295-X was analyzed. The sample was analyzed by gas chromatography and infrared spectroscopy.

A simulated distillation, using gas chromatography, was conducted on Sample AL-19295-X along with two known samples for comparison. The two known samples were a transmission fluid and a light machine oil (Singer Sewing Machine Oil). The chromatograms are given in Figures 1 through 3. Sample AL-19295-X is nearly identical in boiling point distribution to the two known samples, indicating that it is most likely a light weight (approximately 10 weight) oil such as a transmission fluid.

Figure 4 is the infrared (IR) spectra for Sample AL-19295-X. The peaks at 2920 cm^{-1}, 1460 cm^{-1}, and 1380 cm^{-1} are consistent with the peaks from C-H groups. The other minor peaks are most likely due to trace contaminants or additives. The peak at approximately 3420 cm^{-1} is due to water in the sample.

In conclusion, the data indicate that the fluids received from TACOM are some type of light weight oil. If there are any questions concerning the analyses, please contact Steve Westbrook at (512) 522-3185.

Very truly yours,

S.J. Lestz, Director

S.R. Westbrook
Senior Research Scientist

SJL/SRW/lap
(SRW.BB)

cf: U.S. Army Belvoir Research, Development and Engineering Center, Attn: STRBE-VF, Messrs. M.E. LePera and T.C. Bowen
Belvoir Fuels and Lubricants Research Facility (SwRI), Attn: Mr. L.L. Stavinoha

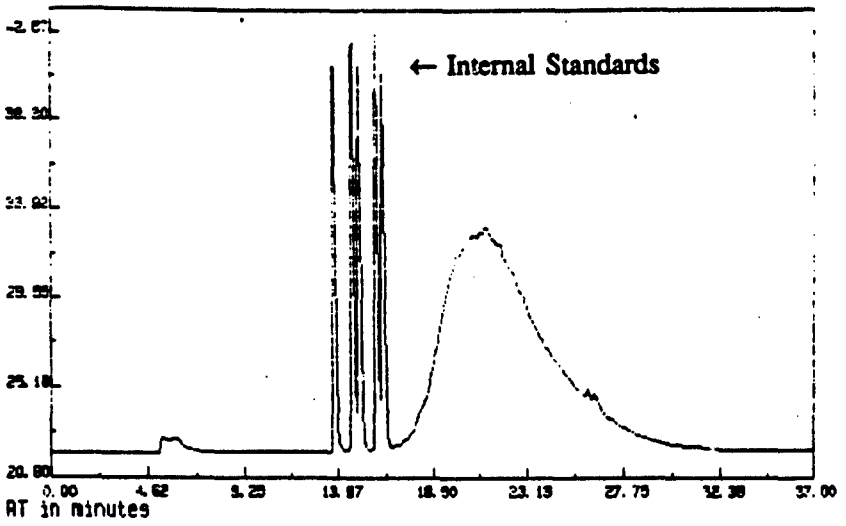


Figure 1. GC Simulated Distillation of Sample AL-19295-X

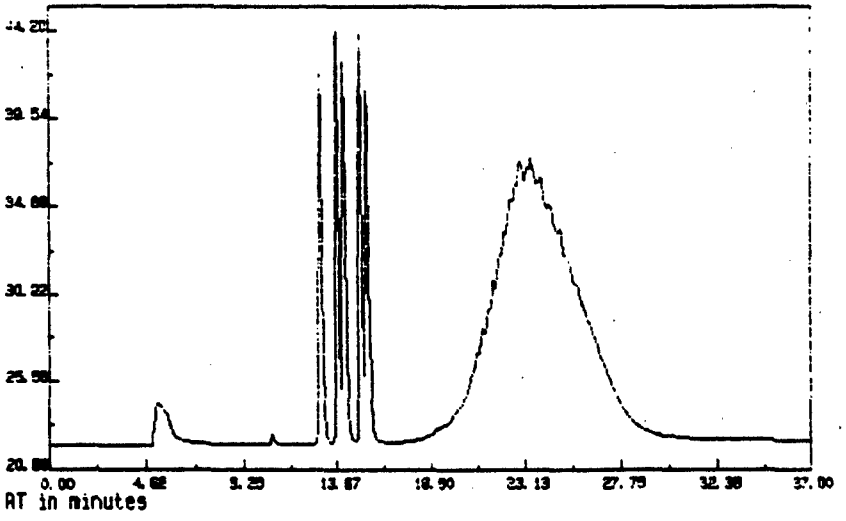


Figure 2. GC Simulated Distillation of Automatic Transmission Fluid

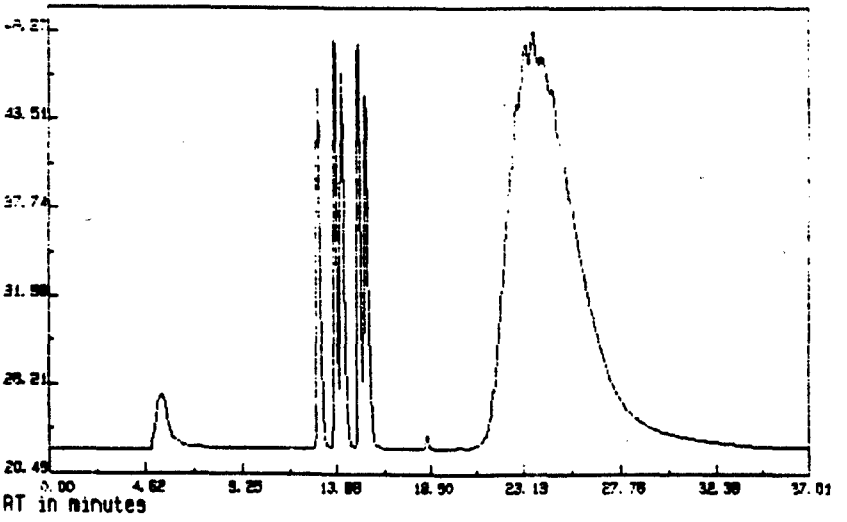


Figure 3. GC Simulated Distillation of Light Machine Oil

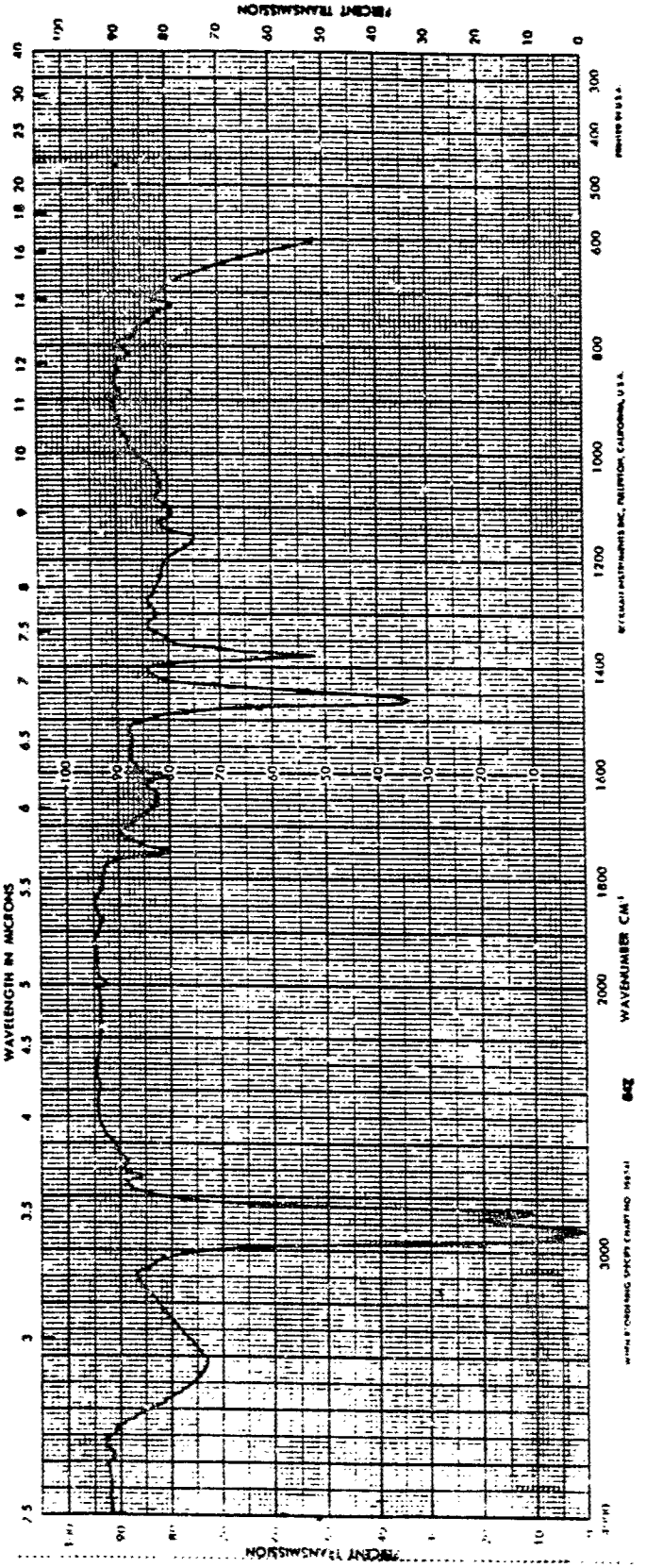


Figure 4. IR Spectra for Sample AL-19295-X

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Manager Defense Logistics Studies Information Exchange ATTN: AMXMC-D Fort Lee, VA 23801-6044	2
Director U.S. Army Materiel Systems Analysis Activity ATTN: AMSXY-MP (Mr. Cohen) Aberdeen Proving Ground, MD 21005-5071	1