



SURFACE VEHICLE RECOMMENDED PRACTICE

J1994™

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(R) Laboratory Testing of Vehicle and Industrial Heat Exchangers
for Heat Transfer and Pressure Drop Performance

RATIONALE

This document has been reviewed for its Five-Year Review with changes in heat transfer and pressure drop recommended practices and other minor changes.

1. SCOPE

This SAE Recommended Practice is applicable to all heat exchangers used in vehicle and industrial cooling systems. This document outlines the tests to determine the heat transfer and pressure drop performance under specified conditions. This document has been reviewed and revised by adding several clarifying statements to Section 4.

1.1 Purpose

This document is to provide a test guideline for determining the heat transfer and pressure drop performance of a heat exchanger under specified testing conditions.

1.2 Objective

To determine and document the heat transfer and pressure drop characteristics of a heat exchanger. This document describes a system to flow fluids through the heat exchanger at specified rates and temperatures, and describes and recommends the instrumentation and the procedure for documenting the results. The procedure may be varied to match existing equipment and methods.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

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Documents

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2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1393 Heavy Duty Vehicle Cooling Test Code

SAE J1468 Oil Cooler Application Testing and Nomenclature

Cheong, A., "Prediction of Heat Transfer Performance of a Heat Exchanger Based on Test of a Small Sample," SAE Technical Paper 890227.

3. FACILITY REQUIREMENTS

The facility should provide the following as required:

- 3.1 Source capable of delivering the fluids to the test unit at a specified temperature, pressure, and flow.
- 3.2 Means of moving these fluids to and from the test unit in a specified manner.
- 3.3 A test system adequate to contain the test unit and control the flow and temperatures of the fluids as specified. In addition to the proposed instrumentation, the instrument accuracy for specific flow domain and operating temperature should be specified. Instrumentation and equipment may include, but not be limited to, the following:
 - a. Air flow rate instrumentation
 - b. Automatic data logging equipment
 - c. Fluid flow rate meters
 - d. Heater and controls
 - e. Humidity measuring equipment
 - f. Pressure measuring instrumentation
 - g. Pump and motor with controls
 - h. Reservoir
 - i. Safety features as specified by regulatory codes and common practices
 - j. Temperature indicators
 - k. Thermocouples
 - l. Valves as required
 - m. Various ducting, piping, hoses, and fittings
- 3.4 Each facility will have a calibration protocol.
- 3.5 Each facility will have a test start-up protocol that ensures, among other things, that the facility temperature profiles are stable in advance of data collection.

4. TESTING (NOT NECESSARILY IN THE FOLLOWING ORDER)

- 4.1 Install test unit as specified.
- 4.2 Start heaters and heat fluids to specified temperature.
- 4.3 Start pumps and adjust flows and pressures as specified.
- 4.4 Ensure conditions are stable before recording data.
- 4.5 Read and record inlet and outlet temperatures and mass flow rates for fluids. Calculate the differences in temperature, multiply the differences by the mass flow rates (taking into account corrections for relative humidity if necessary), and specific heats of each to obtain heat transfer capacity. Air flow rates should be calculated or corrected using air density at standard conditions. It is recommended to measure fluid temperatures at three concentric locations with temperature probe inserted $1/3$ of the pipe diameter as illustrated in Figure 1. Record the readings and obtain the mathematical average to be used for heat transfer calculations.

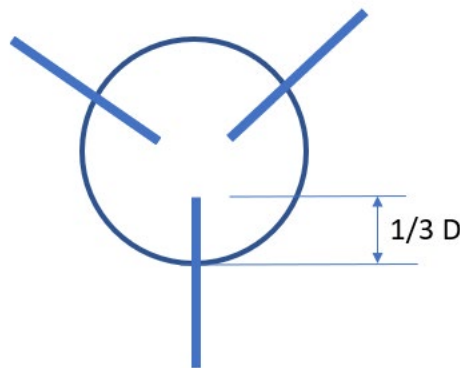


Figure 1 - Probe position in inlet and outlet pipes

- 4.6 If the heat transfer capacity of the fluids are within 3% of each other, record the data and continue. (This may be difficult to obtain when one fluid has a small temperature change.)
- 4.7 Read and record pressure drop of each fluid. It is recommended to measure pressure at a distance that is at least 10X the connecting hose or pipe diameter on both inlet and exit sides to allow for flow recovery prior to and after the heat exchanger. A correction is recommended by running the same flow condition, mass transfer, and temperature, through the same testing setup without the heat exchanger. By subtracting the second set of measurements from the first set, a pressure drop through the heat exchanger alone is isolated. Figures 2 and 3 illustrate the test bench setups. You will note that Figures 2 and 3 are not shown in the figures of Appendix A.

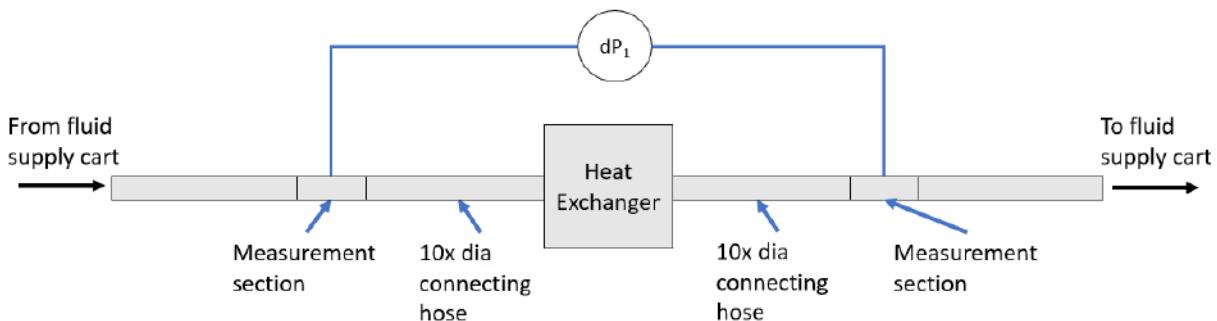


Figure 2 - Pressure drop bench test setup with heat exchanger



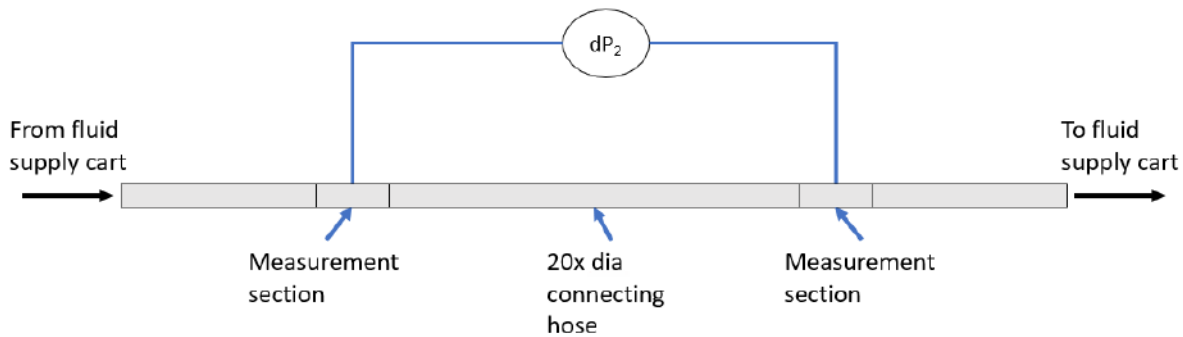


Figure 3 - Pressure drop bench test without the heat exchanger to eliminate test setup effect on pressure drop measurements

Heat exchanger pressure drop is calculated using Equation 1:

$$dP_{\text{Heat Exchanger}} = dP_1 - dP_2 \quad (\text{Eq. 1})$$

In most heat exchangers, inlet and outlet fittings are of the same size. In the case where inlet and outlet fittings are not of similar size, correction for Bernoulli's effect is recommended.

4.8 Change test parameters and repeat steps 4.4, 4.5, 4.6, and 4.7 as specified.

5. TEST PROCEDURES (SEE APPENDIX A FOR SPECIFIC PROCEDURES)

5.1 Liquid-to-gas (e.g., radiator) (see Figures A1A and A1B).

5.2 Liquid-to-liquid (e.g., shell/tube) (see Figures A2A and A2B).

5.3 Gas-to-liquid (e.g., jacket water, aftercooler) (see Figures A3A and A3B).

5.4 Gas-to-gas (e.g., air-to-air aftercooler) (see Figures A4A and A4B).

6. THIS DOCUMENT IS VALID FOR LABORATORY PERFORMANCE TESTING AND COMPARISON

It is recommended that a full-size heat exchanger be tested, if possible. If this is not possible, then it is recommended that the test results from the test heat exchanger be extrapolated to the full-size heat exchanger as recommended in SAE Paper 890227 and the results be reported for the full size.

Any correlation to field results must be developed on an individual basis (refer to SAE J1393, SAE J1468, and SAE J2414 for details of field and application testing).

7. NOTES

7.1 Revision Indicator

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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