SURFACE VEHICLE RECOMMENDED PRACTICE

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

RATIONALE

In accordance with SAE's Five-Year Review Policy.

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 of heat exchangers 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. It also describes and recommends the instrumentation for testing. The procedure presented for documenting the results 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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2.1.1 SAE Publications

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

SAE J1393 Heavy-Duty Vehicle Cooling Test Procedures

SAE J1468 Oil Cooler Application Testing and Nomenclature

SAE J2414 Application Testing of Oil-to-Water Oil Coolers for Heat Transfer Performance

Cheong, A., "Prediction of Heat Transfer Performance of a Heat Exchanger Based on Test of a Small Sample," SAE Technical Paper 890227, 1989, https://doi.org/10.4271/890227.

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. Airflow 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 Calibration protocol for the facility.

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.

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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. Run pumps and/or fans as required to prevent heater over-temperature.

4.3 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. Airflow rates and pressure drop (see Equation 1 for standard air pressure drop correction) 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 one-third of the pipe diameter as illustrated in Figure 1. Record the readings and obtain the mathematical average to be used for heat transfer calculations.

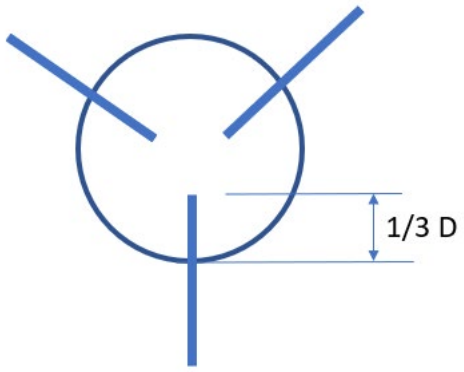


Figure 1 - Probe position in inlet and outlet pipes

$$\Delta p_{Std.} = \Delta p_{Test} \frac{\rho_{Test}}{\rho_{Std.}}$$

$$\rho_{Test} = \frac{p}{RT}\left(\frac{1+\omega}{1+1.6078\omega}\right) = \frac{p_{i,HEX};Pa}{(286.9\ J/kg-K)T_{i,HEX};K}\left(\frac{1+\omega}{1+1.6078\omega}\right)\frac{kg}{m^3}$$

$$\omega = \frac{0.622 p_{Sat.}}{p_{i,HEX} - p_{Sat.}}$$

where:

$p_{Sat.}$ = saturation vapor pressure of the humidity in the air

$$\rho_{Std.Pressure} = \frac{p_{Atm.}}{RT_{Test\ Requested}} = \frac{101{,}325\ Pa}{(286.9\ J/kg-K)\ T_{Test\ Requested};K} \quad \text{(Eq. 1)}$$

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Table 1 - List of symbols

Symbol	Name	Definition	Units
ρ	rho	Density of air	Kg/m^3
p		Absolute pressure	Pa
R		Specific gas constant	286.9 J/kg-K
T		Temperature	K
ω	omega	Specific humidity	Dimensionless

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 ten times the connecting hose or pipe hydraulic diameter on both inlet and exit sides to allow for flow recovery prior to and after the heat exchanger. In particular for fluids, 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.

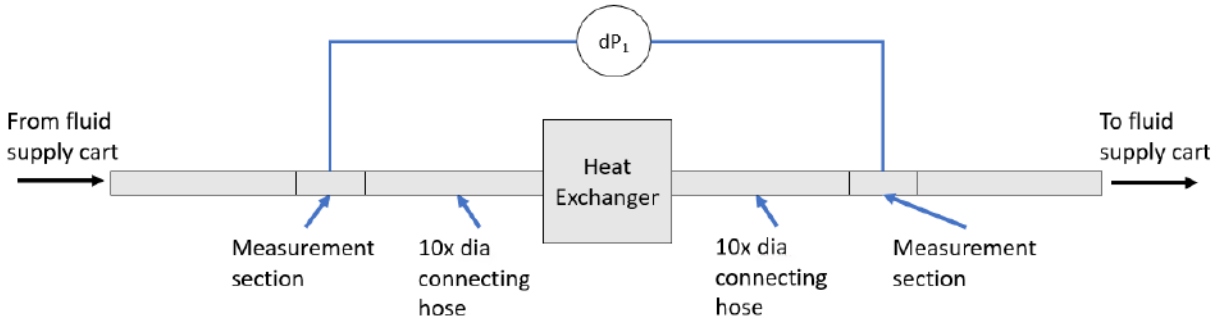


Figure 2 - Pressure drop bench test setup with heat exchanger

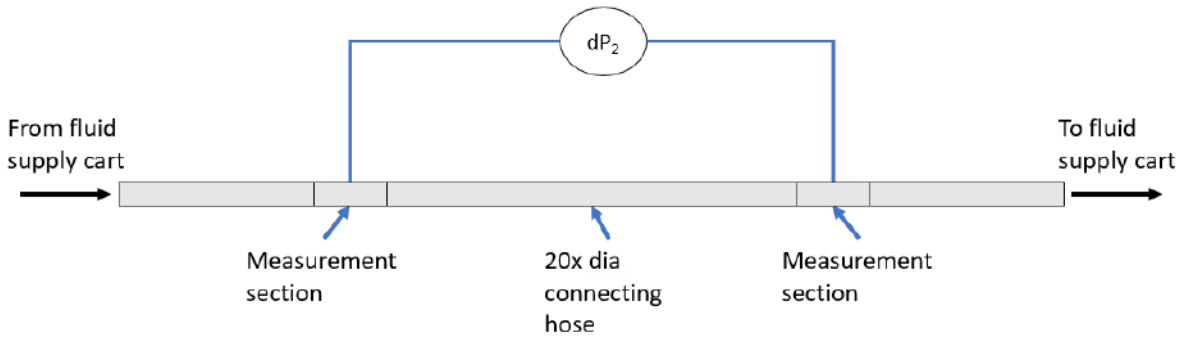


Figure 3 - Pressure drop bench test without the heat exchanger to eliminate test setup effect on pressure drop measurements

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