SURFACE VEHICLE RECOMMENDED PRACTICE

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Laboratory Testing of Vehicle and Industrial Heat Exchangers for Durability Under Vibration-Induced Loading

RATIONALE

In accordance with the SAE Five-Year Review process, this document includes both technical and editorial revisions, with several sections reworded for clarity.

1. SCOPE

This SAE Recommended Practice is applicable to all liquid-to-gas, liquid-to-liquid, gas-to-gas, and gas-to-liquid heat exchangers used in vehicle and industrial cooling systems. This document outlines the test to determine durability characteristics of the heat exchanger from vibration-induced loading.

1.1 Purpose

This document provides a test guideline for determining the durability of a heat exchanger under specified vibration loading.

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.

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 J1542 Laboratory Testing of Vehicle and Industrial Heat Exchangers for Thermal Cycle Durability

SAE J1597 Laboratory Testing of Vehicle and Industrial Heat Exchangers for Pressure Cycle Durability

SAE J1726 Charge Air Cooler Internal Cleanliness, Leakage, and Nomenclature

3. OBJECTIVE

To verify compliance with established criteria that ensures durability in a specific application. This document describes a system to induce stresses in a heat exchanger resulting from vibration loading. The process is accomplished by vibrating the unit at specified frequencies and amplitudes, or at specified frequencies and acceleration.

4. FACILITY REQUIREMENT

The facility should provide the following as required:

4.1 Equipment

Vibration equipment with controls on frequency, amplitude, and acceleration (for 50 Hz and below, electrohydraulic is suggested; higher frequencies may require electrodynamic). It should be verified that the test equipment will meet the parameters of the agreed upon test plan. Examples of test equipment include multi-axis shaker, sequential axis random shaker, etc.

4.2 Test Fixture

4.2.1 Best practice is using customer-provided vehicle/machine structural members to create a test fixture which represents actual installation.

4.2.2 If actual installation is not available, a fixture should support the heat exchanger with orientation as in service or as specified. The fixture must be rigid so as not to induce any additional dynamic inputs.

4.3 Means of checking heat exchanger integrity.

4.4 Equipment to monitor motion of unit during test.

4.5 Source for pressurizing and heating test unit as required.

4.6 Additional equipment may include but not be limited to the following:

a. Accelerometers

b. Automatic data logging equipment

c. Automatic emergency shutdown

d. Cycle counters

e. Digital signal analyzer

f. Function generator (sine wave, random noise, square wave, ramp function, etc.)

g. Load transducers

h. Pressure gauges

i. Pressure regulators

j. Data recording equipment

k. Safety features as specified by regulatory codes and common practices

l. Strain measurement equipment

m. Temperature monitoring and control equipment

5. TESTING

5.1 Initial Leak Testing

Test heat exchanger(s) for fluid integrity prior to starting vibration test.

5.2 Installation

Install test unit on vibration test fixture as in 4.2, fill with specified test fluid(s), and include all mounting hardware: isolators, tie rods, mounting brackets, etc. All heat exchanger mounted masses will affect the response characteristics of the test unit and should be attached. Examples of mounted masses for a radiator are: charge air cooler, condenser, oil cooler, air dryer, shrouds, shutters, hoses, etc. All fan systems must have a defined control strategy in the customer specification, and, if deemed applicable, components included in the setup.

5.3 Fixture Frequency Response Test

A frequency response sweep of the vibration test fixture may be performed to determine the frequency response curve of the vibration test fixture in each of the three axes. The recommended input for the sweep is a sinusoidal 1 G input, with time to sweep of approximately 1 minute per 100 Hz. The first order frequency should not conflict with the working frequencies of the test. If they do, the first change should be to stiffen the fixture. If after that the first order frequency moved away from a discrete working frequency, but is still within the working frequency range, then a truncation of the input frequency profile (5.5) may be appropriate.

5.4 Isolator Selection and Verification

Isolators should be tested to confirm proper selection and compatibility with the test fixture. Isolator fatigue damage may occur more rapidly with accelerated input profiles, warranting spot cooling and/or isolator replacement before profile completion. The following methods may be used to evaluate isolator suitability with a test fixture and/or replacement criteria unless otherwise specified.

5.4.1 Impulse Test

a. Place a tri-axial accelerometer on the test fixture, e.g., on the middle of the upper radiator core cover.

b. At ambient temperature, input 25 G fixed input, half-sine, 10 ms duration pulse.

c. Filter the output with a low pass filter at a frequency of 200 Hz. Record four channels of data (Z input, X output, Y output, and Z output). Plot the data with acceleration (G) versus time (ms).

   i. The ratio of the absolute values of the positive and negative peak values should be between 0.8 and 1.2.

   ii. The absolute value of the positive and negative peak values should be lower than 50 G.

When an isolator is deemed to be replaced this test should be run again. Criteria should be established with the customer for both the positive/negative ratio and absolute peak magnitude results for isolator replacement.

5.4.2 Frequency Response Test

Perform a first order frequency sweep from a minimum value to a maximum of 125 Hz with an input of 0.25 G and 1.0 G. Plot four channels with acceleration (G) versus frequency (Hz). Also plot four channels with acceleration (G) versus time (ms). As with 5.4.1, when an isolator is deemed to be replaced, the test should be repeated and the energy shift compared to customer criteria established for isolator replacement.

5.5 Test Mode

The control system can be set up to obtain the specified vibration cycle (input frequency profile) under one or more of the following modes:

5.5.1 Road or Duty Cycle (Simulation or Replication)

It may be desirable to filter road cycle data to remove non-damaging portions of the drive event (smooth road for example) to reduce overall test time. From a test time perspective, it is ideal to utilize test equipment capable of providing vibration input in the X, Y, and Z axes simultaneously (tri-axial). If that is not possible, then each axis should be run independently (sequential axis) for the prescribed test time.

5.5.2 Failure mode simulation.

5.5.3 Sine sweep at specified acceleration or amplitude.

5.5.4 Resonant frequency at specified energy input.

5.5.5 Random noise at specified acceleration levels.

5.5.6 Other customer established specification.

5.6 Pressurize and heat the test unit as required.

5.6.1 Pressures exceeding specified maximum value can cause significant structural damage which will invalidate the test results. The system shall be capable of maintaining test pressure within 5% absolute pressure unless otherwise specified and should be measured within or as near the test unit as possible.

5.6.2 Monitoring pressure during vibration testing can be beneficial in identifying or verifying when leaks occur.

5.7 Run test to specified duration or component failure. Inspection may also be required at specified intervals.

5.8 Remove and test heat exchanger(s) for leaks and structural damage. Methods described in SAE J1726, Charge Air Cooler Cleanliness, Leakage and Nomenclature, should be used for air-to-air charge air coolers to determine if post-test leakage is acceptable. Qualitative inspection methods can also be used to evaluate post-test condition of heat exchanger.

6. TEST DOCUMENTATION

6.1 During and after test, document leakage rate(s), location(s), and structural failures for comparison to acceptance criteria. Methods described in SAE J1726 should be used for air-to-air charge coolers to determine if post-test leakage is acceptable.

6.2 Document the following:

a. Condition of unit prior to test (new or previous history)

b. Unit orientation (see 5.2)

c. Test mode (see 5.5)

d. Pressure and temperature (see 5.6)

e. Duration of test (see 5.7)

f. Location of leaks and structural damage (see 5.8)

6.3 Testing should be adequately documented to allow test reproduction. Documentation to include a test log of the complete test, recording any changes in the heat exchanger and fixture. Test log to include cycles or hours, time of day for all test starts and stops with reasons for stops.