SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Laboratory Testing of Vehicle and Industrial Heat Exchangers for Pressure-Cycle Durability

RATIONALE

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-air, liquid-to-liquid, air-to-air, and air-to-liquid heat exchangers used in vehicle and industrial cooling systems.

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 J1598 Laboratory Testing of Vehicle and Industrial Heat Exchangers for Durability Under Vibration-Induced Loading

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

2.1.2 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 10771 Hydraulic fluid power – Fatigue pressure testing of metal pressure-containing envelopes

3. OBJECTIVE

The objective of this document is to establish a guideline for the pressure cycle durability testing of heat exchangers. The pressure cycle durability test is intended to simulate pressure variations that occur during the typical duty cycle of a heat exchanger and is accomplished by alternating high and low pressures in the heat exchanger. The cycling is designed to induce a high but reasonable level of pressure strain damage to the heat exchanger, and the target number of cycles may be historically or empirically correlated back to a vehicle level durability target. Pressure cycling can result in fatigue fractures in the fluid-carrying components (tube, plates, tanks, headers, etc.) of the heat exchanger, resulting in leaks. The likelihood of fatigue fractures resulting in leaks is affected by material thickness, material strength, high pressure, high temperature, magnitude of pressure differentials, and number of cycles. The pass/fail criteria should be "no leaks," but may also include other undesirable damage associated with the testing. The test pressures, temperatures, flow rates, number of cycles, and pass/fail criteria may be different for each type of heat exchanger and application; therefore, the test specification should be determined and agreed between the heat exchanger manufacturer and their customer.

4. FACILITY REQUIREMENT

The test facility should provide a system that provides a source of high-pressure process fluids that are:

4.1 Of the type used in the application or fluid with similar properties

4.2 Supplied at the specified temperature(s) and pressure(s)

The system may include:

4.3 Safety features as specified by regulatory codes and common practices, such as pressure relief, automatic shutdown in case of fluid leaks, and an enclosure to contain fluids

4.4 Automated data logging and cycle counting

4.5 Filters to maintain fluid quality

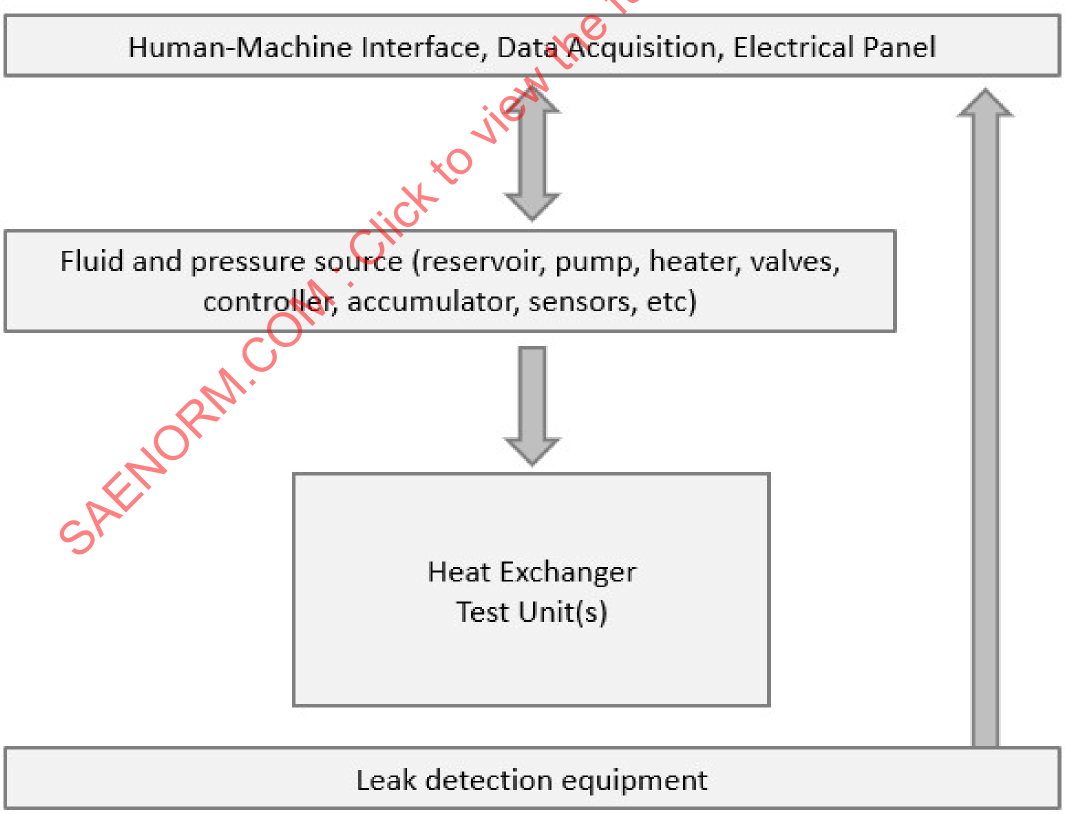

Figure 1 - Typical pressure cycle test system

5. TESTING

5.1 Prior to starting test, check heat exchanger for integrity. This is generally a leak test. For charge air coolers, use the methods described in SAE J1726 to verify that leakage does not exceed acceptable levels.

5.2 Fill test unit(s) with the desired/specified fluid making sure to remove all air pockets. Leaving air pockets trapped in test unit(s) can yield inaccurate test results.

5.3 Unlike other types of tests (thermal cycle, vibration), replicating installation in vehicle position is typically not as critical for pressure cycle testing. Heat exchanger mounting constraints which influence stress/strain, however, should be considered and emulated in test fixturing.

5.4 Set up control system to obtain desired or specified cycle (see Figure 2 for reference).

5.4.1 High pressure is based on specific application, should be equal to or greater than normal operating conditions, is expressed in ranges in Table 1 to include the various applications and Original Equipment Manufacturer (OEM) specifications, is typically agreed to in accordance with the customer's reliability targets, and should be maintained to a mutually agreeable tolerance. Low pressure, if not defined by the customer application, should be as close to 0 kPa (gauge) as possible.

5.4.2 Test temperature should be based on the specific application. Typical temperatures in Table 1 are expressed in ranges to include the various applications and OEM specifications, are typically agreed to in accordance with the customer's reliability targets, and should be maintained to a mutually agreeable tolerance. Test temperature is especially important when it is approaching the material temperature limits. Testing at ambient temperature can be accomplished with historical correlation or other methods of parameter adjustment.

Table 1 - Typical pressure cycle test pressures

Type of Heat Exchanger	Typical High Pressure (Gauge)	Typical Test Temperature
Radiator (Liquid-to-Air)	100 to 200 kPa	90 to 115 °C
Oil Cooler (Oil-to-Air or Oil-to-Liquid)	1000 to 3000 kPa	50 to 150 °C
Charge Air Cooler (Air-to-Air or Air-to-Liquid)	200 to 400 kPa	120 to 280 °C
Exhaust Gas Recirculation Cooler (Gas-to-Liquid)	100 to 800 kPa	50 to 850 °C

5.4.3 The test cycle and its segments are based on specific application and are typically measured in milliseconds. One cycle should consist of a high-pressure segment and a low-pressure segment. Each segment includes the ramp time to reach a specified pressure and the hold time at that pressure and should be approximately 50% of the total cycle; reference Figure 2. Ramp rates will vary depending on test media, test equipment, and test method. The ramp up rate should be reviewed with the OEM to make sure it does not ramp up too fast to damage the part outside of normal requirements or ramp up too slow to relax the input such that the cycling impact is defeated. Cycle frequency can be optimized to accelerate testing, but care should be taken to verify stress is representative of the application and heat exchanger materials (polymers, elastomers, metals) are given the opportunity to elongate. An abnormally high cycle frequency can yield false cycle counts. An abnormally low cycle frequency can make the test duration unnecessarily long. Test specifications should include tolerances allowed for hold times, hold pressures, temperatures, and ramp rates.

5.5 Test duration cycle count varies widely, depending on application and heat exchanger type. At minimum, the pressure cycle test should be run to a target number of cycles based either on a pre-determined specification or the life of an existing, comparable heat exchanger. Testing to failure beyond the target cycle count can add value to the results by providing data to estimate life of the heat exchanger in the application, correlate to Finite Element Analysis (FEA), and identify potential design improvements to further extend life. Instrumenting and measuring temperatures, pressures, flows, etc. of heat exchangers in application during a typical duty cycle combined with expected product life in the vehicle/machine can provide the means to determine test duration cycle count. The typical duty cycle should incorporate vehicle/machine loading and operating conditions in both hot summer and cold winter operating environments. Typical on-highway vehicle duty cycle can include cold startup, city traffic, highway, hill climb, rolling hills, idling, hot soak, and cool down. Typical off-highway machine duty cycle incorporating conditions for a typical workday covering all primary working modes can include traveling, digging, plowing, grading, truck loading, etc. Test duration cycle count can be determined by extrapolating out the resulting cycle peak amplitudes and frequency over the expected product life, applying safety factors as desired.

5.6 After test completion, remove and check heat exchanger(s) for leaks and structural damage.

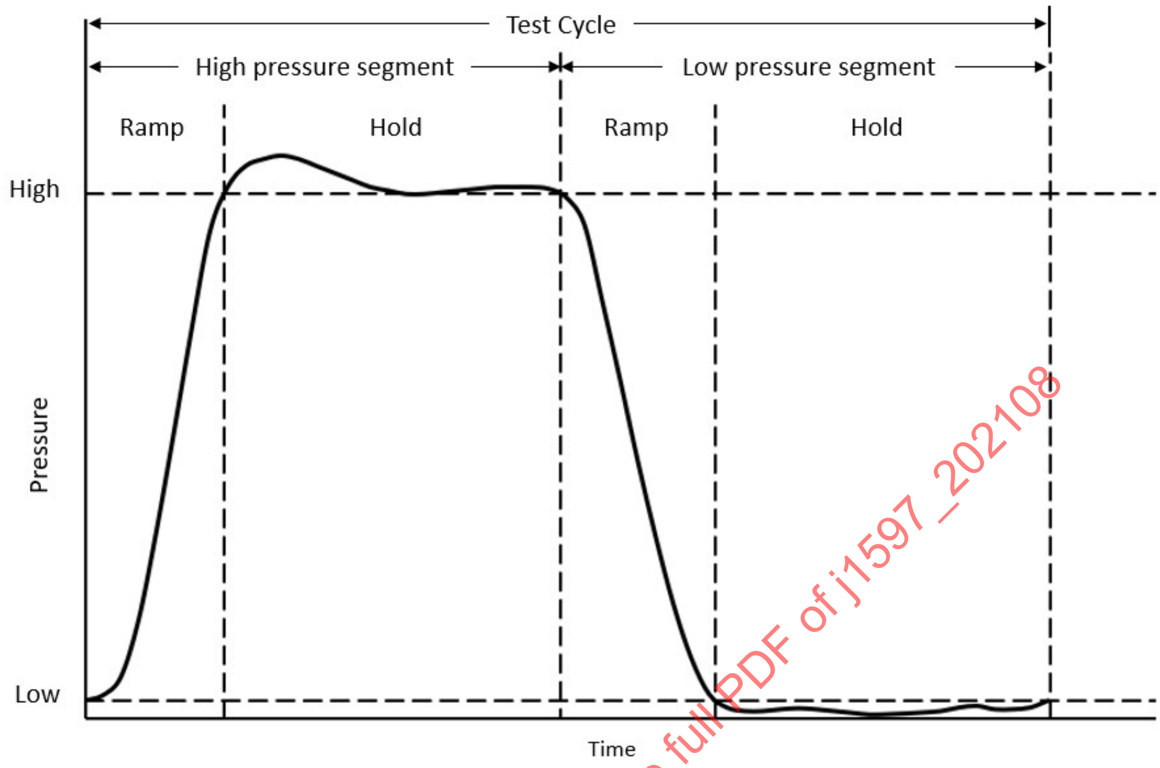

Figure 2 - Typical pressure cycle

6. TEST DOCUMENTATION

6.1 During and after the test, document leakage rate and location(s) at specified pressure (gage or absolute) and compare to acceptance criteria.

6.2 Document the following variables:

1. Condition of unit prior to test (new or previous history)
2. Unit orientation
3. Test equipment calibration and tracking information
4. Pressure range
5. High pressure
6. Frequency, high pressure dwell, low pressure dwell, ramp rates
7. Fluid temp
8. Number of cycles to completion
9. Location of leaks and structural damage
10. If testing is continuous or in interrupted blocks of time