AEROSPACE RECOMMENDED PRACTICE

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

ARP900

Issued July 1975
Revised

METHODS FOR EVALUATING CRYOGENIC FILTERS

1. SCOPE

1.1 The purpose of this test procedure is to present test methods that can be utilized to evaluate the filtration and operating characteristics of filters that will be utilized in a cryogenic system. The methods presented herein are intended to supplement standard filter testing specifications to allow evaluation of filter performance characteristics in areas that could be affected by extreme low temperatures. The test methods can be utilized to evaluate filters up to and including 60 GPM (330 liters per minute) capacity. If higher flow rate filters are to be evaluated in accordance with the test methods presented herein, it will be necessary to increase the system flow capacity and the size of effluent sampling system.

1.2 The test methods presented herein do not encompass testing of cryogenic bypass relief valves, Δ P indicators, gages, or components other than a basic filter housing and element.

1.3 This procedure utilizes SI metrication. Units more familiar to some are added in parenthesis for convenience. For the intent of this procedure, the two figures shall be considered equivalent.

2. REFERENCES

2.1 MIL-STD-810 Environmental Test Methods for Aerospace and Ground Equipment

2.2 Fluid Controls Institute, Inc.

Recommended Standard FCI 58-2, Recommended Voluntary Standard for Measurement Procedure for Determing Control Valve Flow Capacity, November 25, 1958

2.3 SAE Aerospace Recommended Practices

ARP 598A The Determination of Particulate Contamination in Liquids by the Particle Count Method

ARP 901 Bubble-Point Test Method

3. TEST EQUIPMENT

3.1 Liquid Nitrogen Source: The liquid nitrogen source shall be capable of maintaining a constant single phase flow rate of 60 GPM (330 liters/minute), or a flow rate equal to the test filter's rated flow if less than 60 GPM (330 liters/minute), at a pressure of 200 PSIG (1.38 Newtons/cm^2 gauge) for a minimum period of 3 minutes.

3.2 Membrane Filter Holder: Holders designed for membrane filters shall be used down stream of the test filters. Such holders shall have suitable backing to support the membrane without rupture for the pressure drops involved. The effective filtering area of the holders shall be measured by the method of paragraph 4.1.1 of ARP 598. It may be necessary to modify the filter holders by installing a Teflon seal to eliminate external leakage at cryogenic temperatures. Membrane filters of 3.0 micrometre (micron) mean pore size shall be used in the holders for taking effluent samples.

3.3 Desiccator: A Fruehling and Shultz desiccator or equivalent shall be utilized to remove moisture from the membrane filters prior to test.

3.4 Effluent Optical Inspection Equipment: The effluent samples obtained during the Maximum Particle Test, specified herein, shall be examined and sized utilizing the microscopic equipment described in the apparatus section of ARP 598, Reference 1.3.

3.5 Pressure Gages: All pressure gages shall have an accuracy of $\pm 0.5\%$ or better and shall be attached to the system utilizing a minimum of 18 in. (46 cm) of 1/4 in. (0.635 cm) tubing to insure an ambient temperature at the pressure gage.

3.6 Differential Pressure Instruments: All differential pressures shall be observed utilizing a differential pressure gage or transducer with an overall accuracy of better than $\pm 1\%$. The pressure lines to the differential indicator shall have a minimum length of 18 in. (45.7 cm) of 1/4 in., (0.635 cm) tubing between the gage and the system to insure temperature stabilization at the gage.

3.7 Temperature Measuring Instruments: A temperature measuring device having an accuracy of $\pm 10^{\circ}F$ ($\pm 6^{\circ}C$) at the point of indication shall be utilized to record temperatures. The response time of the temperature indicator shall not be less than $16^{\circ}F$ ($9.6^{\circ}C$) per second.

3.8 Flow Meters: A turbine flow meter, or any other type flow meter compatible with cryogenic fluids and having traceability to NBS, shall be utilized to determine the system flow rate. The overall error of the flow meter and recording system combined shall not exceed an RMS value of $\pm 4\%$.

3.9 Manometer: A manometer, calibrated in 2 mm (or 0.1 in.) subdivisions shall be utilized for pressure measurements below 0.014 N/cm^2 (or 2.0 PSIG).

3.10 Leakage Detector, Helium: Detectable range of 1×10^{-5} Std. CC/Sec.

3.11 Sampling Chamber: The sampling chamber utilized in the low temperature leakage test system shown in Figure 1 shall have an internal volume of no more than 300 cubic inches (5 liters) after deducting the volume of the test filter. The complete chamber shall be sealed prior to testing. The sampling port shall be located at the top of the helium sampling box.

4. TEST PROCEDURES

4.1 Bubble Test: The test filter shall be subjected to a bubble point test as described in Paragraph 4 of ARP 901. The initial bubble point observed shall be recorded and utilized as a reference to determine damage and deformation to the filter element during subsequent testing.

Upon completion of the bubble point test, the filter element shall be dried at a temperature of $220^{\circ}F$ ($105^{\circ}C$) for a period of 1 hour to eliminate the possibility of residual liquid freezing and causing detrimental effects during subsequent testing.

4.2 Low Temperature External Leakage Test:

4.2.1 The test filter shall be installed in a low temperature pressurization system, as shown in Fig. 1, in a position that will allow the majority of liquid nitrogen to drain from the filter when flow control valve #7 is opened.

The heat exchanger utilized to reduce the temperature of the gaseous helium shall be filled and maintained at the full level by the adjustment of the liquid nitrogen shut-off valve #15. The heat exchanger shall have the capacity of reducing the temperature of the gaseous helium to $-320^{o}F \pm 20^{o}F$ ($-196^{o}C \pm 10^{o}C$) at the outlet. The flow control valve #7 shall be opened and the system purged with liquid nitrogen until a temperature of $-320^{o}F \pm 20^{o}F$ ($-196^{o}C \pm 10^{o}C$) is obtained at the thermocouple, located downstream of the test filter. The temperature at the thermocouple probe shall be maintained at a temperature of $-320^{o}F \pm 20^{o}F$ ($196^{o}C \pm 10^{o}C$) for a one minute period.

The liquid nitrogen shut-off valve #2 shall then be closed and the liquid nitrogen within the system drained, by opeing valve #7. The flow control valve #7 shall be closed and the desired proof pressure applied to the inlet port of the test filter, by adjustment of pressure regulator #12.

The pressure shall be maintained for a 20 minute period. There shall be no indication from the helium detector that the helium content within the sampling box has exceeded 10% of the lower explosive limit. The resultant leakage rate under time, volume, and helium content conditions specified are equal to less than 1 cm^3/min.

After the 20 minute pressurization period, the gaseous helium shut-off valve #14 shall be closed and the system pressure reduced to zero by opening valve #7. The system vent line #8 shall be long enough to exclude the possibility of contaminating the atmosphere within the sampling chamber #4.

4.2.2 The cool-down and pressurization cycle, described above, shall be repeated three times. There shall be no indication of the helium contamination level within the sampling chamber exceeding the specified limit.

4.3 Maximum Particle Test:

4.3.1 A bubble test as described in Paragraph 4.1 and ARP 901 shall be performed on the filter element at room temperature.

A system as shown in Fig. 2 shall be utilized to determine the maximum size particle that will pass through the test filter's element. The test system will be designed to minimize all traps or cavities that would entrain the glass beads utilixed as a contaminant during testing. A pressurization source or a cryogenic pump can be utilized to establish the required flow rate. Prior to conducting a test program, the system should be thoroughly cleaned and dried.

The membrane filters utilized to obtain the effluent samples shall have a 3.0 micron (micrometre) pore size, with a 47 mm diameter. One membrane filter shall be utilized to obtain effluent samples at flow rates from 0 to 20 GPM (110 liters per minute). Two membrane filters shall be installed in parallel to obtain the effluent samples at flow rates from 20 to 40 GPM (110 to 220 liters/minute). At flow rates from 40 to 60 GPM (220 to 330 liters/minute), three 47-mm-diameter membrane filter holders shall be utilized in parallel to collect the effluent sample. The membrane filters shall be dried in a desiccator at a temperature of $125^{o}F$ ($50^{o}C$) for a one hour period prior to installing in the test system to remove all signs of moisture.

4.3.1 (Continued)

Prior to installing the test filter in the system, a blank run will be performed to insure that residual glass beads have not remained in the test system from previous tests. A fitting shall be installed in the system to duplicate the filter. The contaminant induction valves #2 and #4 shall be placed in the closed position with valve #14 in the open position. A membrane filter, or filters, depending upon flow rate, shall be installed downstream of the test filter.

Valves #10, #14, and #16 shall then be placed in the open position and the system cooled down. Flow control valve #10 shall be slowly adjusted to obtain the test filter's rated flow through the system, after single-phase liquid flow has been obtained, as indicated by a continuous reading of $-320^{o}F \pm 20^{o}F$ ($-196^{o}C \pm 10^{o}C$) at the inlet temperature thermocouple probe #5. Valve #10 shall be adjusted to maintain the flow rate through the system for a one minute period. Upon conclusion of the one minute flow period, valve #16 shall be placed in the closed position and the pressure within the system allowed to decay to zero.

Flow control valve #10 shall then be closed and the system allowed to return to ambient temperature. The pressure within the system, after returning to ambient temperature, shall be bled through valve #10 to atmosphere and the membrane filter removed.

The entire effective membrane filter area should then be examined, utilizing the optical equipment described in Reference 2.4 to determine whether any glass beads are present. If signs of glass beads are observed, the complete system will be re-cleaned, and the test described above repeated until there is no evidence of glass beads.

The test filter shall be installed in the system and a membrane filter installed in the filter holders, Item #12. Valve #2 and #4 shall be placed in the closed condition and valves #10, #14, and #16 placed in the open position to allow the system to cool down.

The tee fitting cap #3 shall be removed; the glass beads introduced into the system; and the cap replaced. The quantity and size distribution of glass beads should be equal to the quantity and size required by the basic specification to which this specification is a supplement.

After single-phase flow is obtained through the test filter, as indicated by a constant differential pressure across the filter, and an inlet temperature of $-320^{o}F \pm 20^{o}F$ ($-196^{o}C \pm 10^{o}C$) at the inlet temperature thermocouple probe, the flow control valve #10 shall be adjusted to maintain rated flow. Valves #2 and #4 shall be opened and valve #14 placed in the closed position. The flow rate through the system shall be maintained for a one minute period. Valve #16 shall then be placed in the closed position and the system pressure allowed to decay to zero; at that time valve #10 shall be closed and the system allowed to return to ambient temperature. The pressure built up within the system due to thermal expansion, should be periodically vented to atmosphere so as not to exceed the working pressure of the system. The membrane filters utilized to obtain the effluent sample shall then be removed from the system. The entire surface area will then be scanned for the maximum particle. If disintegration of the membrane filter is observed at any point on the surface, the test results will be considered invalid and the test repeated.

4.4 Thermal Shock Test:

4.4.1 The test filter shall be subjected to a bubble point test as described in Paragraph 4.1 and ARP 901. The initial bubble point observed shall be recorded and utilized as a reference to determine damage and deformation to the filter element during thermal shock.

4.4.1 (Continued)

The test filter shall then be installed in a system, as shown in Fig. 3, and subjected to an ambient temperature of 160°F (70°C) for a period of one hour, or until complete temperature stabilization has occurred; whichever is greater. Temperature stabilization shall be determined as having occurred when a temperature of 160°F $\pm$ 10°F (70°C $\pm$ 5°C) is recorded on both the internal and external thermocouple probes.

Flow control valves #8 and #9, located upstream of the test filter shall then be opened and a single phase of liquid flow obtained. Flow control valve #8 shall then be closed and flow control valve #6 opened, allowing the temperature at the outlet port of the filter to be reduced to -300°F (-150°C) in a 30 second period, or less. The test filter shall then be resubjected to an ambient temperature of 160°F (70°C) until temperature stabilization has occurred. The temperature cycle described above shall be repeated 10 times. Upon conclusion of the ten cycles, the filter shall be removed from the test system and disassembled.

4.4.2 The element shall then be subjected to a bubble point test. The initial bubble shall compare with the initial bubble point obtained prior to conducting the thermal shock test.

There shall be no evidence of damage or distortion.

4.5 <u>Heat Influx Determination Test:</u>

4.5.1 Prior to conducting the Heat Influx Determination Test, the Sunshine Test, as described in MIL-STD-810, Method 505, shall be performed on the test filter. The surface temperature of the test filter, recorded during the Sunshine Test, shall be the surface temperature of the filter during the Heat Influz Determination Test.

The test filter shall be installed in a system as shown in Fig. 4. The installation shall duplicate the final installation intended. Any exposed portions of the lines or connections should be insulated after installation of the test filter, to maintain the system heat leak tare below 350 BTU/hr (370kJ/hr). It is essential that the system be clean and moisture-free to eliminate the possibility of floats freezing to the wall of the ullage chamber.

4.5.2 The shut-off valves #1 and #11 shall be opened and the system purged with liquid nitrogen until temperature stabilization has occurred in the system, as indicated by a continuous single phase flow of liquid nitrogen out of valve #11. Valves #1 and #11 shall be placed in a closed position and the system allowed to stabilize as indicated by a steady reading on the ullage indicators. The position of the indicator in each ullage shall be observed and recorded. The time required for the indicators and floats within the ullage chambers to fall a minimum of 8 in. (20 cm), due to boil-off of liquid nitrogen, shall be observed and recorded to within $\pm$ 1.0 second. The reading of each indicator should be taken simultaneously. The surface temperature of the test filter and the fluid temperature within the test system shall be continuously recorded during the boil-off period, to insure system temperature stability. The atmospheric pressure will be recorded to allow correction of the heat of vaporization and specific volume of liquid nitrogen as described in 4.5.4 herein. The test described above shall be repeated a total of three times, and the data accumulated during each cycle, recorded.

The heat influx of the system recorded during the three separate tests shall agree within $\pm$5 BTU/hr ($\pm$5 kJ/hr). The mean value between the three runs shall be utilized as the gross heat influx.

4.5.3 The test filter shall be removed from the test system and the two fittings utilized to connect the test filter to the test system joined together. The test described above shall be repeated with the ambient temperature maintained at the previously prescribed temperature. The test shall be performed a total of three times to determine system tare. The test results obtained during each test shall have a repeatability of ±5 BTU/hr (±5 kJ/hr). The mean value shall be utilized to calculate the net heat influx.

4.5.4 The total heat influx into the test filter shall be determined, utilizing the calculations presented below:

LIST OF SYMBOLS

Q_G = Total heat influx of system and test filter - BTU/hr (kJ/hr)

Q_T = Heat influx of test system

Q_F = Heat influx of test filter

H_V = Heat of vaporization at saturated pressure - BTU/LB (kJ/hr)

S_V = Specific volume at saturated pressure - FT^3/LB (m^3/kg)

L_1 = Indicator stroke of ullage chamber #1 - inches (centimetres).

L_2 = Indicator stroke of ullage chamber #2 - inches (centimetres).

t = Vaporization time of liquid between indicator readings - min.

D = Internal diameter of ullage chambers - centimeters.

The gross heat influx into the test system and test filter shall be calculated using the following equations:

$$Q_G = \frac{.0273\ Hv \quad (L1 \quad + \quad L2) \quad D^2 \quad BTU \ (kJ)}{(t) \qquad (Sv) \qquad Hr.}$$

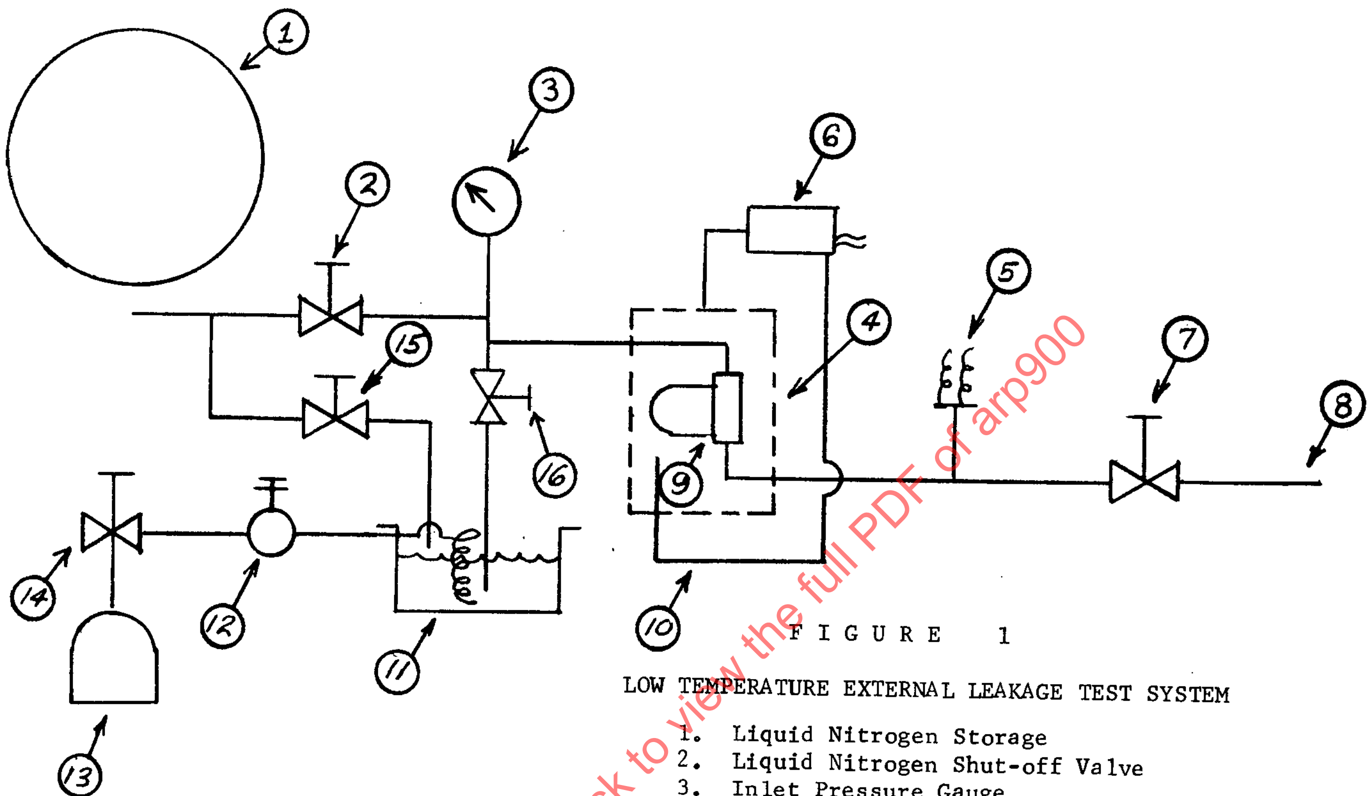
The tare heat influx of the system alone shall be calculated in the same manner as the gross heat influx.

$$Q_T = \frac{.0237\ Hv \quad (L_1 \quad + \quad L_2) \quad D^2}{(t) \qquad (Sv)}$$

The heat influx of the test filter will be equal to the total heat influx of the system and test filter, minus the tare heat influx of the system.

$$Q_F = Q_G = Q_T$$

PREPARED BY
CONTAMINATION & FILTRATION PANEL of
SUBCOMMITTEE A-6C, FLUID POWER DISTRIBUTION ELEMENTS of
SAE COMMITTEE A-6, AEROSPACE FLUID POWER & CONTROL TECHNOLOGIES



F I G U R E 1

LOW TEMPERATURE EXTERNAL LEAKAGE TEST SYSTEM

1. Liquid Nitrogen Storage
2. Liquid Nitrogen Shut-off Valve
3. Inlet Pressure Gauge
4. Sampling Chamber
5. Temperature Thermocouple Probe
6. Helium Detector
7. Flow Control Valve
8. Vent Tube
9. Test Filter
10. Helium Detector Return Line
11. Low Temperature Heat Exchanger
12. Pressure Regulator
13. Gaseous Helium Storage Bottle
14. Gaseous Helium Shut-off Valve
15. Liquid Nitrogen Shut-off Valve
16. Check Valve

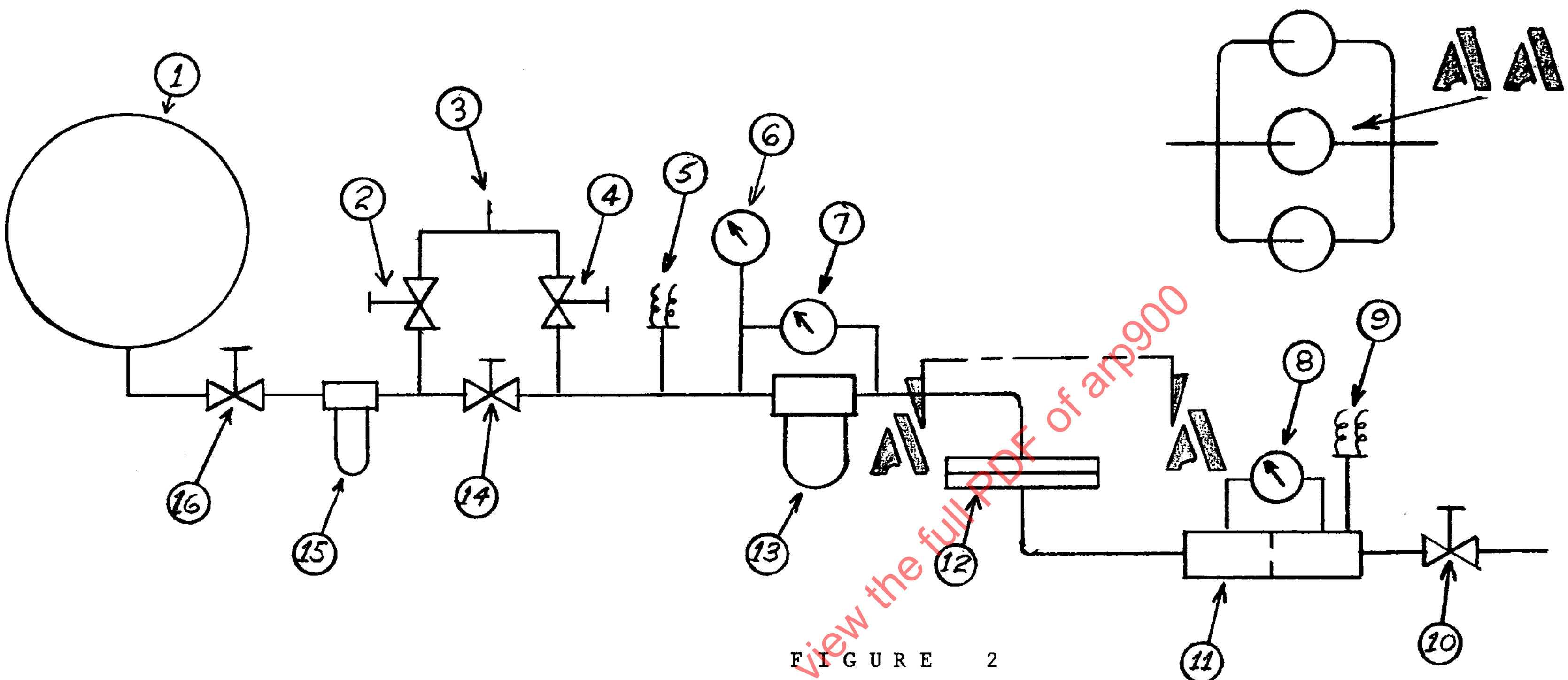


FIGURE 2

MAXIMUM PARTICLE TEST SYSTEM

1. Liquid Nitrogen Storage
2. Ball Valve
3. Tee Fitting
4. Ball Valve
5. Inlet Temperature Thermocouple Probe
6. Inlet Pressure Gauge
7. Test Filter Differential Pressure Gauge

8. Orifice Flowmeter Differential Pressure Gauge
9. Orifice Flowmeter Temperature Thermocouple Probe
10. Flow Control Valve
11. Orifice Flowmeter
12. Membrane Filters (3.0 Micron)
13. Test Filter
14. Cool-down Valve
15. Clean-up Filter
16. Shut-off Valve