SAE Aerospace
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AEROSPACE RECOMMENDED PRACTICE

SAE ARP900	REV. B
Issued 1975-07 Reaffirmed 2002-01 Revised 2011-12 Superseding ARP900A	

(R) Methods for Evaluating Cryogenic Filters

RATIONALE

This document is revised to clarify the limitations of the test methodology for cryogenic filters with respect to the detectable particle size limit. Additionally, equipment system accuracy requirements have been clarified, unit conversions provided and external references have been updated to current releases and practices.

1. SCOPE

The purpose of this document 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 for particle sizes equal to or greater than 5.0 μm and flows up to and including 60 gpm (230 L/min) 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 from those recommended in this document.

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

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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 724-776-4970 (outside USA), www.sae.org.

ARP598 Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems

ARP901 Bubble Point Test Method

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/ARP900B

2.1.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

2.1.2.1 Military Standards

MIL-STD-810 Environmental Test Methods and Engineering Guidelines

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 (230 L/min), or a flow rate equal to the test filter's rated flow if less than 60 gpm (230 L/min), at a gage pressure of 200 psi (1379 kPa) for a minimum period of 3 minutes.

3.2 Membrane Filter Holder

Holders designed for 47 mm diameter membrane filters shall be used downstream of the test filter. 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 in accordance with ARP598. It may be necessary to modify the filter holders by installing a polytetrafluoroethylene seal to eliminate external leakage at cryogenic temperatures. Membrane filters defined in ARP598 shall be used in the holders for taking effluent samples.

3.3 Desiccator

A desiccator 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 ARP598.

3.5 Pressure Gages

All pressure gages shall have an accuracy equal to or better than ±0.5% at the point of measurement and shall be attached to the system utilizing a minimum length of 18 in (46 cm) of 0.25 in (6.4 mm) diameter 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. The overall error, inclusive of the recording system, shall not exceed ±1% at the point of measurement. The pressure lines to the differential gage shall have a minimum length of 18 in (46 cm) of 0.25 in (6.4 mm) diameter 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 ±10 °F (±5.5 °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 °F (9 °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 National Institute of Standards and Technology (NIST), shall be utilized to determine the system flow rate. The overall error of the flow meter and recording system combined shall not exceed a root/ mean square of ±4% at the point of measurement.

3.9 Manometer

A manometer calibrated in 0.1 in (2.5 mm) subdivisions shall be utilized for pressure measurements below 2 psig (14 kPa).

3.10 Mass Spectrometer Leak Detector

Detectable minimum leakage of 1 x 10^{-5} std cc/s.

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 in^3 (5 L) 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 ARP901. 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 °F (104 °C) for a period of 1 h to eliminate the possibility of residual liquid freezing and causing detrimental effects during subsequent testing.

4.2 Low Temperature External Leakage Test

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

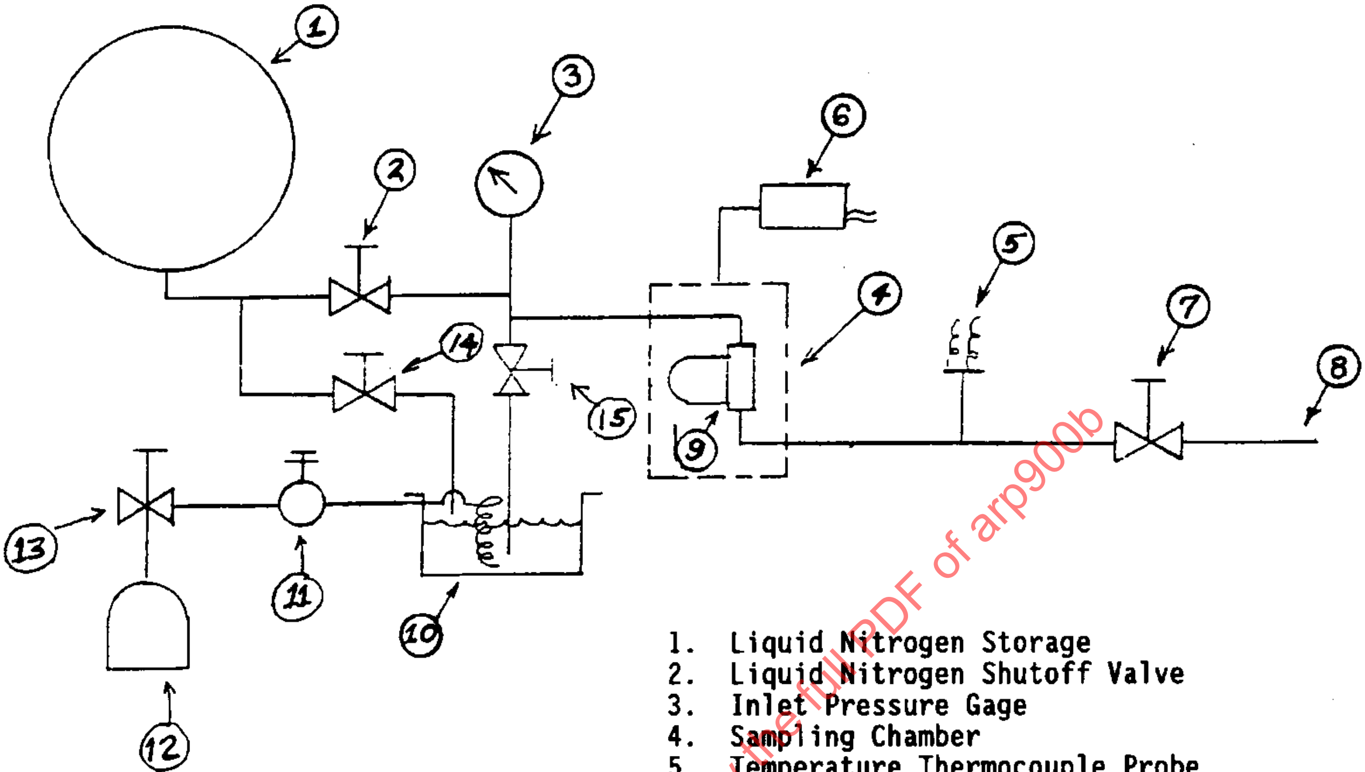
The heat exchanger utilized to reduce the temperature of the gaseous helium shall be filled and maintained at the full level by the adjustment of the liquid nitrogen shutoff valve #14. The heat exchanger shall have the capacity of reducing the temperature of the gaseous helium to -320 °F ± 20 °F (-196 °C ± 11 °C) at the outlet. The flow control valve #7 shall be opened and the system purged with liquid nitrogen until a temperature of -320 °F ± 20 °F (-196 °C ± 11 °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 °F ± 20 °F (-196 °C ± 11 °C) for a 1 min period.

The liquid nitrogen shutoff valve #2 shall then be closed and the liquid nitrogen within the system drained, by opening valve #7. Once drained the flow control valve #7 shall be closed. With the pressure regulator #11 closed, open shutoff valve #15 and gaseous helium shutoff valve #13. Adjust pressure regulator #11 to the desired test filter proof pressure .

The pressure shall be maintained for a 20 min period. Indication from the mass spectrometer leak detector #6 should show a leakage rate of less than 1 cc/min.

After the 20 min pressurization period, the gaseous helium shutoff valve #13 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.

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



1. Liquid Nitrogen Storage
2. Liquid Nitrogen Shutoff Valve
3. Inlet Pressure Gage
4. Sampling Chamber
5. Temperature Thermocouple Probe
6. Mass Spectrometer
7. Flow Control Valve
8. Vent Tube
9. Test Filter
10. Low Temperature Heat Exchanger
11. Pressure Regulator
12. Gaseous Helium Storage Bottle
13. Gaseous Helium Shutoff Valve
14. Liquid Nitrogen Shutoff Valve
15. Shutoff Valve

FIGURE 1 – LOW TEMPERATURE EXTERNAL LEAKAGE TEST SYSTEM

4.3 Maximum Particle Test

A bubble test as described in 4.1 shall be performed on the filter element at room temperature.

A system as shown in Figure 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 utilized 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 be in accordance with ARP598. One membrane filter shall be utilized to obtain effluent samples at flow rates from 0 to 20 gpm (80 L/min). Two membrane filters shall be installed in parallel to obtain the effluent samples at flow rates from 20 to 40 gpm (80 to 150 L/min). At flow rates from 40 to 60 gpm (150 to 230 L/min), three 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 °F (52 °C) for a 1 h period prior to installing in the test system to remove all signs of moisture.

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 °F ± 20 °F (-196 °C ± 11 °C) at the inlet temperature thermocouple probe #5. Valve #10 shall be adjusted to maintain the flow rate through the system for a 1 min period. Upon conclusion of the 1 min 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 Section 3.4 to determine whether any glass beads are present. If signs of glass beads are observed, the complete system will be recleaned, and the test described 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 °F ± 20 °F (-196 °C ± 11 °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 1 min 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 utilizing the optical equipment described in Section 3.4. 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.

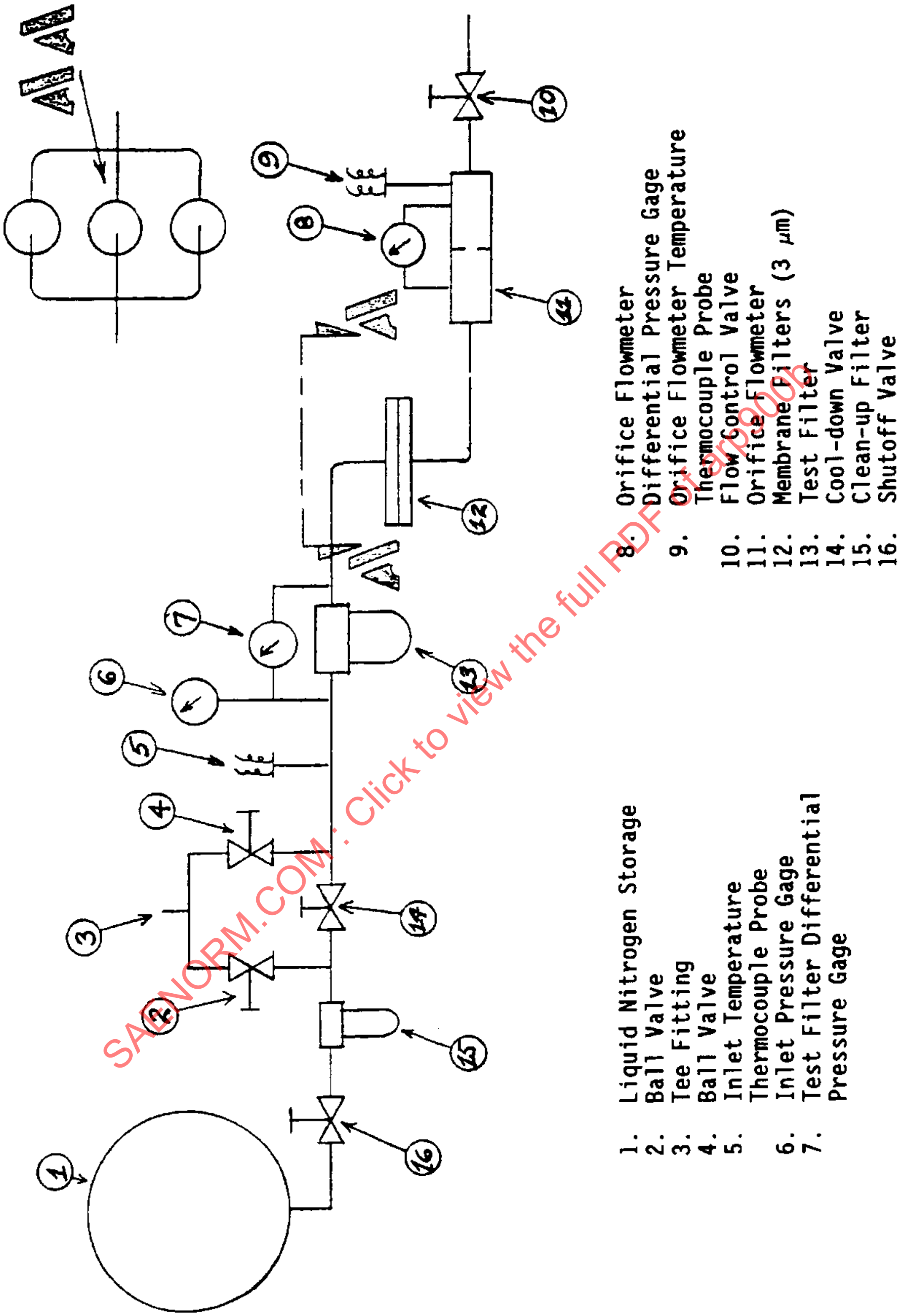


FIGURE 2 – MAXIMUM PARTICLE TEST SYSTEM

4.4 Thermal Shock Test

The test filter shall be subjected to a bubble point test as described in Section 4.1 and ARP901. 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.

The test filter shall then be installed in a system, as shown in Figure 3, and subjected to an ambient temperature of 160 °F (71 °C) for a period of 1 h, or until complete temperature stabilization has occurred; whichever is greater. Temperature stabilization shall be determined as having occurred when a temperature of 160 °F ± 10 °F (71 °C ± 5.5 °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 (-184 °C) in a 30 s period, or less. The test filter shall then be resubjected to an ambient temperature of 160 °F (71 °C) until temperature stabilization as occurred. The temperature cycle described shall be repeated ten times. Upon conclusion of the ten cycles, the filter shall be removed from the test system and disassembled.

The element shall then be subjected to a bubble point test as described in Section 4.1. The bubble point obtained 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 Heat Influx Determination Test

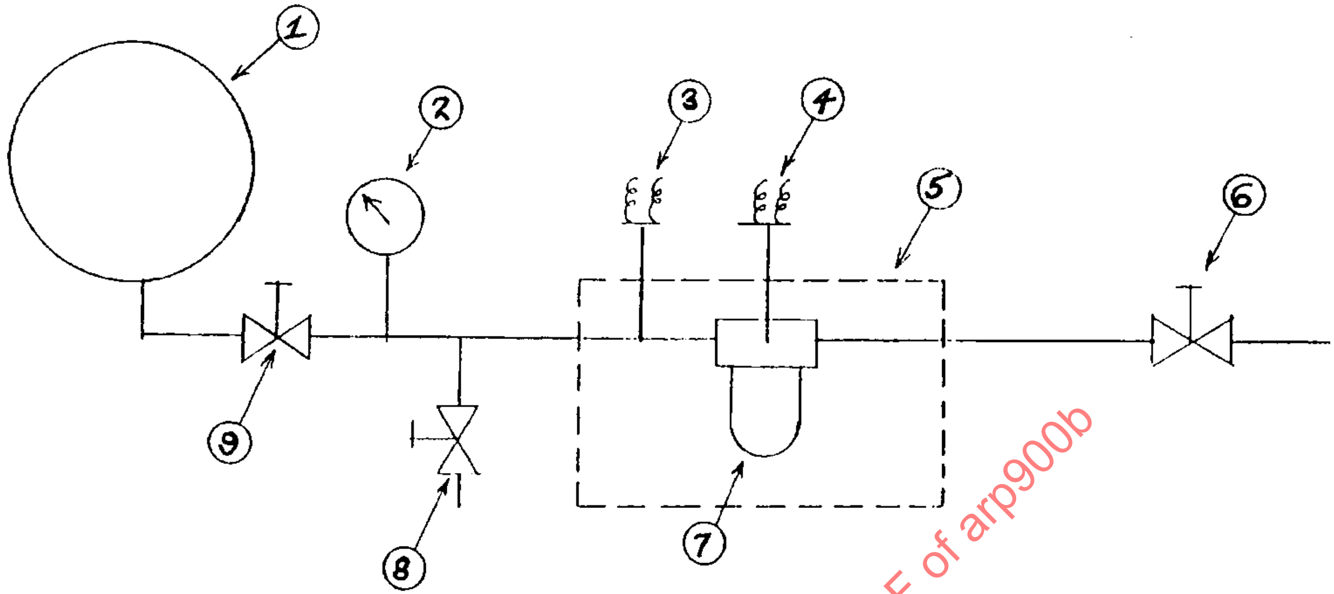
Prior to conducting the heat influx determination test, the sunshine test, as described in MIL-STD- 810, Method 505.5 Procedure II, shall be performed on the test filter. The surface temperature of the test filter, recorded during the sunshine test, shall be the surface temperature of the filter during the heat influx determination test.

The test filter shall be installed in a system as shown in Figure 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/h (370 kJ/h). 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.

The shutoff 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 #1. 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 ±1 s. 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 4.5.1 herein. The test described 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 ±5 Btu/h (±5 kJ/h). The mean value between the three runs shall be utilized as the gross heat influx.

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 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/h (±5 kJ/h). The mean value shall be utilized to calculate the net heat influx.



1. Liquid Nitrogen Storage
2. Pressure Gage
3. Inlet Temperature Thermocouple Probe
4. Skin Temperature Thermocouple Probe
5. Temperature Chamber (160 °F)
6. Flow Control Valve
7. Test Filter
8. Cool-down Valve
9. Shutoff Valve

FIGURE 3 – THERMAL SHOCK TEST SYSTEM