72-1014

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BY OVERNIGHT MAIL

January 10, 2000

Ms. Marissa Bailey
Project Manager
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Subject: USNRC Docket No. 72-1014, TAC No. 22221
HI-STORM 100 Dry Storage System

References:
1. Holtec Project No. 5014
2. Phone Conversation Between NRC and Holtec International Held January 10, 2000

Dear Ms. Bailey:

As agreed in our telephone conference today, enclosed please find the following documents submitted to assist in the resolution of certain comments regarding helium leak testing of the HI-STORM Multi-Purpose Canister welds.

1. *Introduction to Helium Mass Spectrometer Leak Detection,* Varian Vacuum Products, September, 1995.

2. Varian Vacuum Products Bulletin, Solutions #95-3, *High Sensitivity Helium Sniffing for Production Applications.*

3. Excerpts from the Non-Destructive Testing Handbook, Second Edition, Volume 1, Leak Testing, American Society for Nondestructive Testing.

If you have any questions or require additional information, please contact us.

Sincerely,

Brian Gutherman. P.E.
Licensing Manager

Approval

K.P. Singh, Ph.D., PE
President and CEO

NMSS01 Public

PDR ADOCK 07201014

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PRODUCTS Solutions #95-3

High Sensitivity Helium Sniffing for Production Applications

Introduction

Helium sniffing with mass spectrometer-based leak detectors can be used for detection of small leaks (to 10^{-8} atm cc/sec range) in parts that are pressurized with a mixture of, or pure helium. The reasons for using sniff testing instead of evacuation-type testing are among the following:

- The part under test might be normally pressurized under operation. It would then be desirable to leak-test under pressurized conditions.
- The part may not mechanically withstand evacuation of its inside, or be too large to perform practical evacuation tests.

Relating Sniffing Test Results to Product Leak Rates

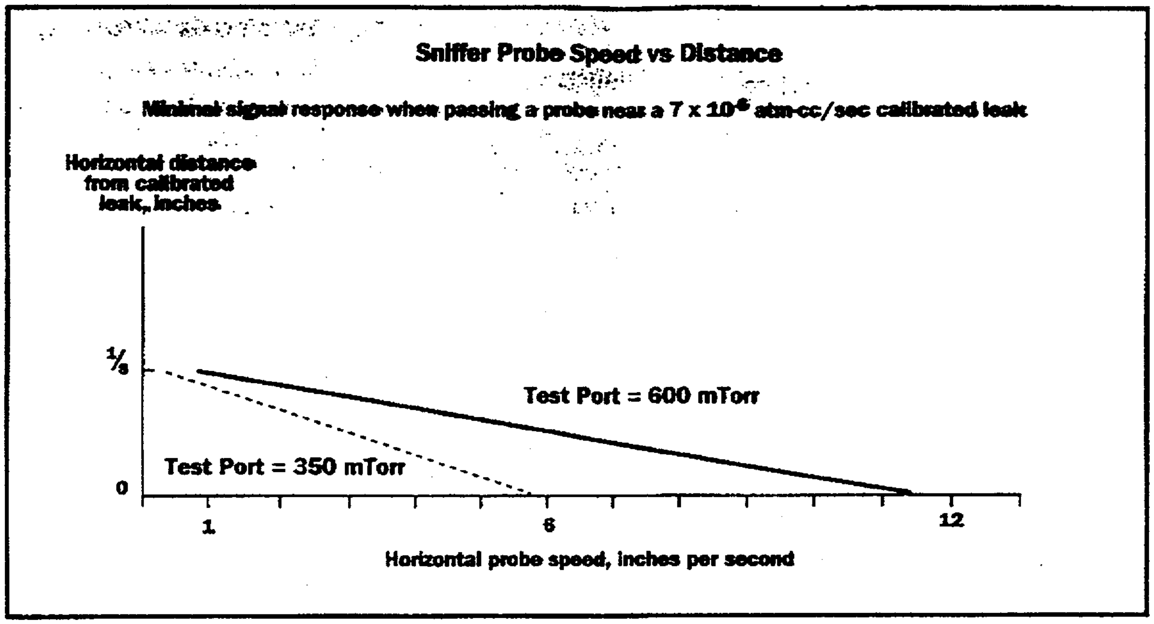
Determining the procedures and specifications of a sniffing leak testing process requires knowlege of the following: 1. The product's total leak rate specification under operating conditions, 2. How this relates to a helium leak rate under the testing conditions, and 3. The relationship between the product's helium leak rate, and how this relates to sniffing mode test measurements.

Since the sniffing process samples the air in the vicinity of a potential leak, several factors influence what size of signal is displayed by the instrument. These include:

- The distance from the probe head inlet to the suspected leak
- The sniffing gas flow rate and hose length
- Probing speed
- Use of leak accumulation techniques
- Testing orientation and shape of the sniffing probe head
- The leak detector's configuration and sensitivity setting
- Amount of background helium in the testing area
- The pressure and helium ratio of the part's fill gas

Once the product's leak rate specification for helium has been determined, only actual testing under the anticipated production conditions can determine the ability of the process to detect leaks of a minimum specified size. The incorporation of leaks of a known size into the product can be done by adding small orifice-type leak tubes into the product. These leaking products should be "randomly" added into the pilot and production runs to be certain that they will be spotted during the leak testing process.

The graph below shows the effect of linear probing speed on the ability to sense a calibrated leak of 7×10^{-6} atm cc/sec. Two different probe gas flow rates were used, indicated by the 350 and 600 mTorr leak detector test port pressures. The distance between the probe inlet and the leak source is critical. When located more than ⅛" (horizontally) from the leak source, this size of helium leak was not sensed even if the probe was held static. The measurements were performed with a Varian 959 Power-Sniff leak detector.



Sniffing Technique Guidelines

When performing helium sniff testing, the following should be considered:

- Determine the product leak rate specification under typical operating conditions. From that, derive and verify the helium leak test procedure under production conditions.
- Test the leak detection process by inserting known leaks into sample parts that will be tested in the same way that production parts are tested.
- Make sure the leak testing system is calibrated, well maintained, and operated at the correct probe sampling pressure.
- Check that the operator is not moving the sniffer probe at a speed faster than that required to register the leak.
- Control the helium background in the testing area to ensure sensitivity of the testing process.
- To achieve higher sensitivity, accumulate helium in the vicinity of the area to be sniff tested by clamping the part with an accumulation device for at least 10 seconds prior to the sniff test.

Product Solutions

A major innovation in sniffing leak testing was made when Varian incorporated the new MacroTorr high vacuum spectrometer pump in the 959 portable leak detectors. This pump provides a higher compression ratio than standard turbo pumps. As a result, it can keep the spectrometer under the required high vacuum conditions with a foreline pressure as high as several Torr, instead of the 0.1 to 0.5 Torr limit that is typical of diffusion and standard turbo pumps. As a result, the maximum testing pressures (both for evacuation and for sniffing) in Contra-Flow™ leak detectors has been greatly increased.

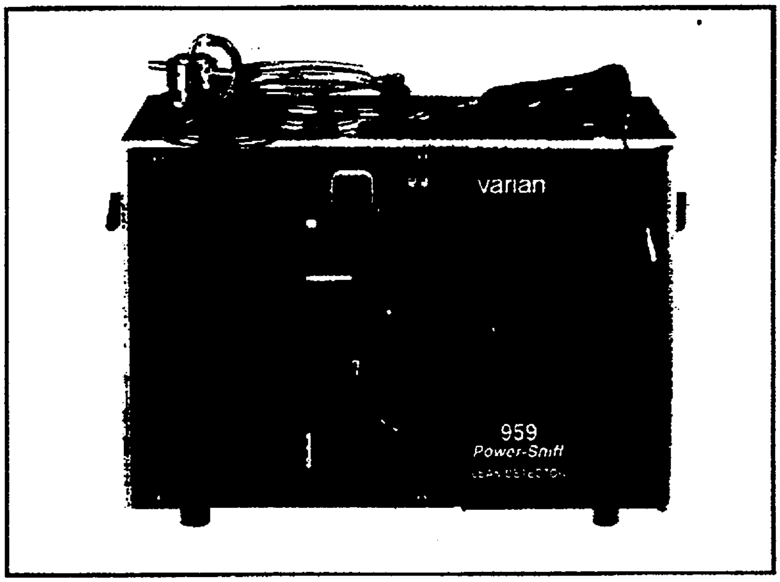
The 959 Power-Sniff leak detector is based on the 959 MacroTorr leak detector with a specially designed sniffing probe. Its advantages over other mass spectrometer based sniffing leak detectors are:

1. It does not require the use of dedicated sampling pumps and membranes, which reduces machine cost and enhances reliability.
2. The MacroTorr pump provides the ability to sniff at test port pressures of 300 to 600 mTorr and has an inherently high helium pumping speed. As a result, the helium signal

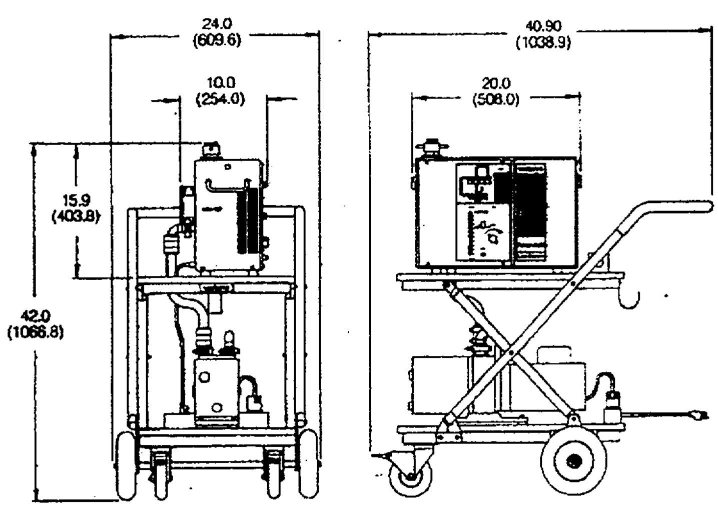
response time is less than one second, and cleanup times after exposures to large leaks are very short.

3. The helium signal is not diluted since all of the sampled gas flow reaches the foreline of the high vacuum spectrometer pump. As a result, the machine can be routinely operated with stable sniffing sensitivities in the 10^{-7} atm cc/sec range.
4. The machine is optimized for production leak testing. It can operate in environments exceeding 120°F, has maintenance-free high-vacuum pumping, automatic startups, easy spectrometer servicing, and a lockable control adjustment panel. In addition, the machine can be instantly converted for use in the evacuation leak detection mode.

959 Power Sniff Leak Detector



959 Power Sniff Leak Detector
Shown with Universal Cart



Dimensions inches (mm)

NONDESTRUCTIVE TESTING HANDBOOK

Second Edition

VOLUME 1
LEAK TESTING

ROBERT C. McMASTER
EDITOR

AMERICAN SOCIETY FOR
NONDESTRUCTIVE TESTING

AMERICAN SOCIETY FOR METALS

ATT 3

PART 6

STANDARD METHOD FOR DETECTOR PROBE HELIUM LEAK DETECTION

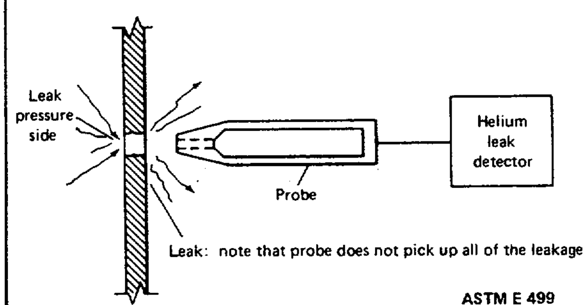
Capabilities of Detector Probe Leak Detection with Helium Mass Spectrometer

The methods of detector probe helium leak detection described in this discussion have been accepted and recommended by the American Society for Testing and Materials through its ASTM Committee E-7 on Nondestructive Testing. This discussion is based on ASTM Standard E 499, "Standard Methods of Testing for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode", copyrighted by ASTM and used with their permission.

This discussion covers procedures for testing and locating the sources of gas leaking at the rate of 1×10^{-9} Pa·m³/s (1×10^{-8} std cm³/s) or larger. The test may be conducted on any device or component across which a pressure differential of helium or other suitable tracer gas may be created, and on which the effluent side of the leak to be tested is accessible for probing with the mass spectrometer sampling probe. The two methods described are (1) Method A, direct probing and (2) Method B, accumulation.

Both methods require a helium leak detector equipped with an atmospheric detector probe (or sniffer). The instrument should have a full-scale readout of at least 1×10^{-8} Pa·m³/s (1×10^{-7} std cm³/s) on the most sensitive range, no detectable drift over a period of 1 min, and sensitivity of ±5% of full scale on this range, and ±2% or less on others. These sensitivities are those theoretically attainable by probing a standard reference leak under ideal laboratory conditions. They are not typical of the test sensitivities attainable when leak tests are performed in the shop or in the field.

FIGURE 29. ASTM Method A, direct probing with sampling probe or sniffer on test objects leaking to air at atmospheric pressure.



ASTM Method A, Direct Probing of Leaks to Atmosphere

The direct probing method (see Fig. 29) is the simplest test, and may be used on parts of any size. It requires only that a tracer gas pressure be created across the area to be tested and the searching of the atmospheric side of the area with the detector probe. This method detects leakage and its source or sources. Experience has shown that probe testing in factory environments will usually be satisfactory to 1×10^{-6} Pa·m³/s (1×10^{-5} std cm³/s), if reasonable precautions against releasing gas like the tracer gas in the test area are observed, and the effects of other interferences (discussed later in this section) are considered.

Apparatus and Materials Required for ASTM Method A

The following items constitute the equipment and materials required for testing of helium-pressurized test objects leaking to air at atmospheric pressure (see Fig. 29).

1. Test specification
2. Helium leak detector, with atmospheric detector or sampling probe
3. Helium leak standard, discharge to atmosphere—size equal to or as near as possible to helium content of maximum leakage rate per specification
4. Helium leak standard, discharge to vacuum—size: anywhere between 1×10^{-7} and 1×10^{-10} Pa·m^3/s (1×10^{-6} and 1×10^{-9} std cm^3/s), unless otherwise specified by maker of leak detector.
5. Test gas, at or above specification pressure
6. Pressure gauges, valves, and piping for introducing test gas and, if required, vacuum pump for evacuating device
7. Liquid nitrogen, if required.

Procedure for ASTM Method A, Direct Probing in Atmosphere

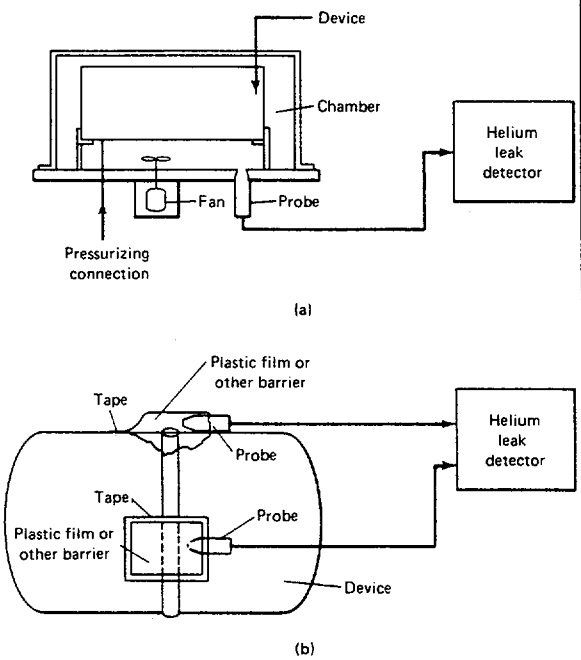
The following steps constitute the leak testing procedure with helium-pressurized test objects leaking to air at atmospheric pressure (see Fig. 29).

1. Set helium leak standard at maximum helium content of specification leakage. Example: Maximum leak rate: 1×10^{-5} Pa·m^3/s (1×10^{-4} std cm^3/s). Test gas: 1% helium in air. Set standard at $1 \times 10^{-5} \times 0.01 = 1 \times 10^{-7}$ Pa·m^3/s (1×10^{-6} std cm^3/s).
2. Start detector and adjust in accordance with manufacturer's instructions.
3. Attach atmospheric detector probe to detector sample port in place of leak standard and open valve of detector probe, if adjustable type is being used, to maximum flow rate under which detector will operate properly.
4. Re-zero detector to compensate for atmospheric helium.
5. With orifice of leak standard in a horizontal position, hold the tip of the detector probe directly in line with and 1.5 ± 0.5 mm (0.06 ± 0.02 in.) away from the end of the orifice, and observe reading while scanning past the orifice at a normal rate of about 2 cm/s (4 ft/min). If necessary to obtain a reasonable instrument deflection, adjust range, re-zero if necessary, and again apply sampling probe to leak standard.
6. Remove probe from standard leak and note minimum and maximum readings due to atmospheric helium variations or other instabilities.
7. If atmospheric helium variation is larger than 30% of standard leak indicator, take steps to reduce the helium added to the atmosphere, or to eliminate other causes of instability. If this cannot be done, testing at this level of sensitivity may not be practical.
8. Evacuate (if required) and apply test gas to device at specified pressure.
9. Probe areas suspected of leaking. Probe should be held on or not more than 1mm (0.04) from the surface of the device, and moved not faster than 20 mm/s (0.8 in./s). If leaks are located that cause a reject leakage indication when the probe is held over 1 mm (0.04 in.) from the apparent leak source, repair all such leaks before making final acceptance test.
10. Maintain an orderly, bottom to top, procedure in probing the required areas, preferably identifying them as tested, and plainly indicating points of leakage.
11. At completion of the test evacuate or purge test gas from the device, if required.
12. Write a test report or otherwise indicate test results as required.

ASTM Method B, Accumulation Leak Testing

The accumulation test (see Fig. 30) provides for

FIGURE 30. ASTM Method B, accumulation testing with sampling probe or sniffer.



ASTM E 499

(a) Accumulation leak test, complete device in chamber. (b) Accumulation leak test, flexible shroud over a small portion of device.

the testing of parts up to several cubic meters in volume as in Fig. 30(a) or in portions of larger objects as in Fig. 30(b). This is accomplished by allowing the leakage to accumulate in the chamber for a fixed period, while keeping it well mixed with a fan, and then testing the internal atmosphere for an increase in tracer gas content with the detector probe. The practical leak sensitivity attainable with this method depends primarily on (1) the volume between the chamber and the object, (2) time available for testing, and (3) the amount of outgassing of tracer gas produced by the object. Thus, a part having considerable exposed rubber, plastic, blind cavities or threads cannot be tested with the sensitivity of a smooth metallic part. The time in which a leak can be detected is directly proportional to the leakage rate and inversely proportional to the volume between the chamber and the part. In theory, extremely small leaks can be detected by the accumulation method. However, the time required and the effects of other interferences limit the practical sensitivity of this method to about 1×10^{-9} Pa·m^3/s (1×10^{-8} std cm^3/s) for small parts, but only 10^{-3} std cm^3/s for volumes of several cubic meters.

Procedure for ASTM Method B, Accumulation Test with Chamber or Shroud

The accumulation test procedure is the same for Steps 1 through 7 of Method A. However, somewhat larger variations in atmospheric helium can be tolerated due to the isolation of the part during test. In general, it will be advantageous to use the maximum stable sensitivity attainable with leak detector, in order to reduce the accumulation time to a minimum. Steps in the accumulation test procedure are

1. Insert the part to be tested (unpressurized), the leak standard for discharge to atmosphere, and the detector probe in the enclosing chamber or shroud.
2. Note the rate of increase of detector indication.
3. Remove the leak standard, pressurize the part with test gas, and again note rate of rise, if any. If Step 3 exceeds Step 2, reject part.
4. Remove the part from the enclosure and purge out any accumulated helium.
5. Evacuate or purge test gas from the part, if required.
6. Write a test report or otherwise indicate test results as required.

Interfering Effects

The atmosphere contains about 5 µL/L (5 ppm) of helium, which is being continuously drawn in by the detector probe. This helium background must be zeroed-out before leak testing using helium tracer gas can proceed. Successful leak testing is contingent on the ability of the detector to discriminate between normal atmospheric helium, which is very constant, and an increase in helium due to a leak. If the normally stable atmospheric helium level is increased by release of helium in the test area, the reference level becomes unstable, making leak testing more difficult.

Helium absorbed in various nonmetallic materials (such as rubber or plastics) may be released during the test. If the rate and magnitude of the amount released approaches the amount released from the leak, the reliability of the test is decreased. The amount of such materials or their exposure to helium must then be reduced to obtain a meaningful test.

In order to evaluate leakage accurately, the test gas in all parts of the device must contain substantially the same amount of tracer gas. When the device contains air prior to the introduction of test gas, or when an inert gas and a tracer gas are added separately, this may not be true. Devices in which the effective diameter and length are not greatly different (such as tanks) may be tested satisfactorily by simply adding tracer gas. However, when long or restricted systems are to be tested, more uniform tracer distribution will be obtained by first evacuating to ~1 kPa (a few torr), and then filling with the test gas. The test gas must be premixed if not 100% tracer.

As the orifice in the detector probe is very small, the parts being tested should be clean and dry to avoid plugging of the detector probe orifice. Reference should be frequently made to a standard leak to ascertain that this has not happened. However, plugging causes the pressure in the sensing element of the helium leak detector to decrease significantly, which should alert test operators to the possibility of plugging.

Test Apparatus Required for Helium Leak Testing in Detector Probe Mode

Test apparatus for helium leak testing in the detector probe mode includes a helium mass spectrometer analyzer, calibrated leaks, and test fixtures. To perform tests as specified in this standard, the helium leak detector should be equipped with an atmospheric detector probe and be adjusted for testing with helium. The helium leak detector should meet the following minimum requirements.

The sensor mass analyzer should have a panel instrument or digital readout and a sensitivity of most sensitive range of 1×10^{-8} Pa·m^3/s (1×10^{-7} std cm^3/s) full scale. The response time should be 3 s or less. The required instrument stability and sensitivity should result in maximum variation not exceeding ±5% of full scale on most sensitive range while the probe is active but no helium leaks are being sensed. A maximum variation of ±2% of full scale on other ranges should be attained for a period of 1 min. The instrument should provide a range control preferably in steps of about 3X, and a zero control having sufficient range to null out atmospheric helium background signals.

Requirements for Leak Standards for Helium Leak Testing

To perform leak tests as specified in this standard, use is made of two helium leak standards which should meet the following minimum requirements:

1. The helium leak standard calibrated for discharge to atmosphere should have ranges of 1×10^{-3} to 1×10^{-8} Pa·m^3/s (1×10^{-2} to 1×10^{-7} std cm^3/s).
2. The helium leak standard calibrated for discharge to vacuum should have ranges from 1×10^{-5} to 1×10^{-7} Pa·m^3/s (1×10^{-4} to 1×10^{-6} std cm^3/s.
3. Accuracies of helium leak standards should be ±25% of full-scale value or better.
4. Adjustable leak standards are a convenience, but are not mandatory.
5. The temperature coefficient of leak standards shall be stated by manufacturer.

Requirements for Test (Tracer) Gas and Gas Mixtures

To be satisfactory, the test gas should be nontoxic, nonflammable, not detrimental to common materials, and inexpensive. Helium, or helium mixed with air or nitrogen, or helium mixed with some other suitable inert gas, meets the requirements. If the test specification allowable leakage is 1×10^{-6} Pa·m^3/s (1×10^{-5} std cm^3/s) or more, or if large vessels are to be tested, consideration should be given to diluting the tracer gas with another gas such as dry air or nitrogen. This will avoid excessive helium input to the sensor and save tracer gas expense in the case of large vessels. When a vessel is not evacuated prior to adding test gas, the gas mixture is automatically diluted by 1 atm (100 kPa) of air.

Producing Premixed Test Gas

If the volume of the device or the quantity to be tested is small, premixed gases in cylinders can be obtained conveniently. The user can also mix gases by batch in the same way. Continuous gas mixing using calibrated orifices is another simple and convenient method when the test pressure does not exceed 50% of the tracer gas source pressure available.

Calibration During Helium Leak Testing

The leak detectors used in leak testing with helium tracer gas are not calibrated in the sense that they are taken to the standards laboratory, calibrated, and then returned to the job. Rather, the leak detector is used as a comparator between a leak standard (set to the specified leak size), which is part of the instrumentation, and the unknown leak. However, the sensitivity of the leak detector is checked and adjusted on the job so that a leak of specified size will give a readily observable, but not off-scale reading. More specific details are given next under the test method being used. To verify sensitivity, leak test equipment should be checked with a standard leak before and after a prolonged leak test. When rapid repetitive testing of many items is required, the leak standard is referred to often enough to ensure that desired test sensitivity is maintained.

Specifications for Helium Leak Testing

A testing specification should be in hand. This specification should include:

1. The gas pressure on the high side of the device to be tested, also on the low side if it need differ from atmospheric pressure.
2. The test gas composition, if there is need to specify it.
3. The maximum allowable leakage rate in $Pa \cdot m^3/s$ (std cm^3/s).
4. Whether the leakage rate is for each leak or for total leakage of the device.
5. If an "each leak" specification, whether or not surface areas other than seams, joints, and fittings need to be tested.

Safety Factor in Specified Leakage Rates

Where feasible, it should be ascertained that a reasonable safety factor has been allowed between the actual operational requirements of the device and the maximum specified for testing. Experience indicates that a safety factor of at least 10 should be used when possible. For example, if a maximum total leakage rate for satisfactory operation of a device is 5×10^{-7} $Pa \cdot m^3/s$ (5×10^{-6} std cm^3/s), the leak test requirement should be 5×10^{-8} $Pa \cdot m^3/s$ (5×10^{-7} std cm^3/s) or less if feasible or practical.

Selection and Control of Leak Test Pressure

The device should be tested at its design operating pressure and with the pressure drop in the normal direction, where practical. Precautions should be taken so that the device will not fail during pressurization, or that the operator is protected from the consequences of a failure; see Section 4.

Disposition or Recovery of Test Gas

Test gas should never be dumped into the test area if further testing is planned. It should be vented outdoors or recovered for reuse if the volume to be used makes this worthwhile.

Detrimental Effects of Helium Tracer Gas

Helium tracer gas is quite inert and seldom causes any problems with most materials, particularly when used in gaseous form for leak testing and then removed. When there is a question as to the compatibility of the tracer with a particular material, an authority on the latter should be consulted. This is particularly true when helium is sealed in contact with glass or other barriers that it may permeate.

Correlation of Test Gas Leakage with Leakage of Other Gases or Liquids at Different Operating Pressures

Given the normal variation in leak geometry, accurate correlation between a measured leakage rate and that for other gases or pressures is an impossibility. However, if a safety factor of 10 or more is allowed, adequate correlation for gas leakage within these limits can usually be obtained by assuming viscous flow of gas and using the relation:

$$Q_2 = Q_1(n_1/n_2)\,[(P_2^2 - P_1^2)/(P_4^2 - P_3^2)] \qquad \text{(Eq. 23)}$$

where Q_2 is test leakage rate, $Pa \cdot m^3/s$ (or std cm^3/s); Q_1 is operational leakage rate, $Pa \cdot m^3/s$ (or std cm^3/s); n_2 is viscosity of test gas; n_1 is viscosity of operational gas; P_2, P_1 are absolute pressures on high and low sides at test; P_4, P_3 are absolute pressures on high and low sides in operation.

Viscosity differences between gases are a relatively minor effect and can be ignored if desired. Leakage increases at a rate considerably greater than that of the pressure increase. For this reason, it is often desirable to increase the sensitivity of the test by testing at the maximum safe pressure for the part. Increased sensitivity may even be obtained with the same amount of helium by increasing the pressure with another less expensive gas, as when pressurizing with air.

Experience has shown that, at the same pressures, gas leaks smaller than 1×10^{-6} $Pa \cdot m^3/s$ (1×10^{-5} std cm^3/s) will not show visible leakage of a liquid, such as water, which evaporates fairly rapidly. For slowly evaporating liquids, such as lubricating oil, the gas leakage should be another order of magnitude smaller, 1×10^{-7} $Pa \cdot m^3/s$ (1×10^{-6} std cm^3/s).

INTRODUCTION TO HELIUM MASS SPECTROMETER LEAK DETECTION

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ATT 1

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