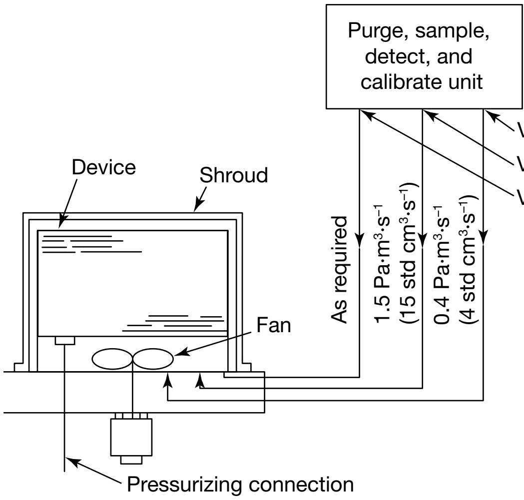

Figure 23. Method E halogen accumulation leak testing arrangement with purge sample, detect, and calibrate (PSDC) unit (ASTM E 427).

by Equation 2:

(Eq. 2)
$$A_s = \frac{Q - F}{V}$$

where A_s is the rate of halogen tracer partial pressure increase in the accumulation volume (Pa/s); Q is the rate of leakage into the volume (m^3/s); F is the flow rate in the detector probe ($Pa \cdot m^3 \cdot s^{-1}$); and V is the net volume of the accumulation system (cubic meter).

For practical operating considerations, the minimum value of the rate of halogen pressure accumulation A_s that should be used is about 2×10^{-12} Pa/s (2×10^{-11} std cm^3/s). This will give a leak detector readout of $50 \times 2 \times 10^{-12}$ or 10^{-10} $Pa \cdot m^3 \cdot s^{-1}$ ($50 \times 2 \times 10^{-11}$ or 10^{-9} std cm^3/s) after 50 s accumulation period. Thus, based on a probe flow rate $F = 0.4$ $Pa \cdot m^3 \cdot s^{-1}$ (4 std cm^3/s), a 5×10^{-11} $Pa \cdot m^3 \cdot s^{-1}$ (5×10^{-10} std cm^3/s) leak may be detected in a system of 100 cm^3 (6 $in.^3$) net volume, or a 5×10^{-6} $Pa \cdot m^3 \cdot s^{-1}$ (5×10^{-5} std cm^3/s) leak in a 10 m^3 (350 ft^3) system. Where variables of time, volume, and leakage rate permit, values of readout should be set in the 10^{-8} to 10^{-9} $Pa \cdot m^3 \cdot s^{-1}$ (10^{-7} to 10^{-8} std cm^3/s) range for less critical operations.

INTERFERENCE BY ATMOSPHERIC HALOGEN CONTAMINATION

When Method A or B direct probing is used to locate leaks, the halogen leak detector probe is drawing in air from the atmosphere. If the atmosphere is contaminated with halogen to a degree that produces a noticeable indication on the detector, the detection of halogen from leaks becomes much more difficult. Significant atmospheric contamination with halogen is defined as the level where the detector response, when the probe is moved from zero halogen air to test area atmosphere, exceeds that expected from the smallest leak to be detected. For reliable testing, atmospheric halogen concentration must be kept well below this level.

Halogens Outgassed from Absorbent Materials

When leak testing is done in enclosures that prevent atmospheric contamination from interfering with the test (Methods A, B, and C), halogen absorbed in various nonmetallic materials (such as rubber or plastics) may be released in the enclosure. If the amount of halogen compounds released by outgassing starts to approach the amount of input from the leak in the same period of time, it becomes more difficult to conduct a reliable leak test. The amount of such halogen absorbing materials in the enclosure, or their exposure to halogen, must then be reduced to obtain a meaningful leak test.

PRESSURIZING WITH TEST GAS

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 before 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 less than 1 kPa (10 torr), and then filling with the test gas. If it is not 100 percent tracer, the test gas must be premixed before it is added to a system.

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REQUIREMENTS FOR HALOGEN LEAK DETECTOR APPARATUS

To perform leak tests as specified in *ASTM E 427*, the leak detector should meet the following requirements.

1. An alkali ion diode sensor should be used.
2. The readout may be digital or analog.
3. The linear range is 3×10^{-7} to 3×10^{-10} Pa·m^3·s^{-1} (3×10^{-6} to 3×10^{-9} std cm^3/s) full scale or arbitrary equitable scales.
4. The response time should be <3 s.
5. The stability of zero and sensitivity values should meet applicable leak testing specifications. Normally for refrigeration, a maximum variation of ±15 percent of full scale is allowable on the most sensitive range, while the detector probe is in pure air. The maximum allowable variation is ±5 percent of full scale on other ranges for a period of 60 s.
6. The range control should be adjustable.
7. An automatic zeroing option is desirable.

REQUIREMENTS FOR HALOGEN REFERENCE LEAKAGE STANDARDS

To perform leak tests as specified in *ASTM E 427*, the reference leak standard should meet the following requirements.

1. Ranges are 10^{-6} to 10^{-10} Pa·m^3·s^{-1} (10^{-5} to 10^{-9} std cm^3/s) full scale.
2. Adjustable leak standards are convenient but not mandatory.
3. Accuracy should be ±25 percent of full scale value or better.
4. Temperature coefficient shall be stated by the manufacturer.
5. The halogen content of the specification leak should remain compatible with the expected level of atmospheric halogen and the test method as outlined earlier. Fixtures or other equipment specific to one test method are listed under that method later in this discussion.

REQUIREMENTS FOR HALOGEN TRACER GASES

To be satisfactory, the test gas should be nontoxic, nonflammable, inexpensive, not detrimental to common materials, and have a response factor of one. Refrigerant-22 provides a pressure of 900 kPa gauge (130 lb_f/in. gauge) at 21 °C (70 °F). If the test specification allows leakage of 1×10^{-6} Pa·m^3·s^{-1} (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 nonhalogen gas such as dry air or nitrogen. This will avoid operating in the nonlinear portion of the sensor output, or, in the case of large vessels, save tracer gas expense. When a vessel is not evacuated before adding test gas, the test gas is automatically diluted by 100 kPa (750 torr) of air at atmospheric pressure already contained in the vessel under test.

Producing Premixed Halogen Test Gas

If the volume of the device or the quantity to be tested is small, premixed gases can be conveniently obtained in cylinders. The user can also mix gases by batch in the same way. Continuous mixing using calibrated orifices is another simple and convenient method when the test pressure does not exceed 50 percent of the tracer gas pressure available. (Caution: The liquid tracer gas supply should not be heated above ambient temperature.) Another method is to pass the nonhalogen gas through the liquid tracer, which produces test gas containing the maximum amount of tracer gas.

Requirements for Halogen Free Gas Used in Pressurizing Test Volumes

Pure air, air from which halogens have been removed to a concentration of 1 nL/L (or other suitable nonhalogen gas, such as nitrogen) should meet the following requirements: (1) less than 1 nL/L of halogen; (2) less than 10 µL/L of gases reactive with oxygen, such as petroleum based solvent vapors; (3) dew point 10 °C (50 °F) or more below ambient temperature; and (4) reasonable freedom from rust, dirt, or oil. Air or gas of suitable purity may be produced by first passing it through a conventional filter dryer (if necessary) and then through activated charcoal.

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CALIBRATION OF HALOGEN LEAK DETECTOR

The leak detectors used in making halogen vapor leak tests 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 (part of the instrumentation set to the specified leak size) 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 reading not off the meter scale. More specific details are given later under procedures for each method. To verify detection, reference to the leak standard should be made before and after a prolonged test. When rapid repetitive testing of many items is required, the leak standard should be referred to often enough to ensure that desired test sensitivity is maintained.

TEST SPECIFICATIONS FOR USING HALOGEN LEAK DETECTOR

Operators should have a halogen leak testing specification that includes the following test information: (1) gas pressure on the high side of the device to be tested and on the low side if different from atmospheric; (2) test gas composition, if there is need to specify it; (3) maximum allowable leakage rate in $Pa{\cdot}m^3{\cdot}s^{-1}$ (or std cm^3/s); (4) whether the leakage rate is for each leak or for total leakage of the device; and (5) if, according to leak specification, areas other than seams, joints, and fittings need to be tested.

LEAKAGE RATE SAFETY FACTOR FOR HALOGEN LEAK TESTING

Where feasible, the test operator should ascertain that a reasonable safety factor has been allowed between the actual operational requirements of the device and the maximum leakage rate specified for testing. Experience indicates that a safety factor of at least ten in leakage rate should be used when possible. For example, if a maximum total leakage rate for satisfactory operation of a device is 5×10^{-7} $Pa{\cdot}m^3{\cdot}s^{-1}$ (5×10^{-6} std cm^3/s), then the test requirement should be 5×10^{-8} $Pa{\cdot}m^3{\cdot}s^{-1}$ (5×10^{-7} std cm^3/s) or less.

Selecting Test Pressure for Halogen Leak Testing

It is desirable to pressurize a device to be leak tested at or above its operating pressure and with the pressure drop in the normal direction across the pressure boundary, where practical. Precautions should be taken so that the device will not fail during pressurization and so that the operator is protected from the consequences of a failure.

Disposition or Recovery of Halogen Tracer Gas

Test gas should not be dumped into the test area if further testing is planned. Halogen tracer gas should be recovered for reuse to avoid atmospheric contamination, both indoors and out.

DETRIMENTAL EFFECTS OF REFRIGERANT-12 AND REFRIGERANT-22 TRACER GASES

The refrigerant-22 and refrigerant-134a tracer gases are inert and seldom cause any problem with most materials, particularly when used in gaseous form for leak testing and then removed. Refrigerant-12 may no longer be legally made in or imported to the United States. Test gas should not be left in the device unless it is dry and sealed, as most halogens in the presence of moisture accelerate corrosion over a period of time.

When there is a question as to the compatibility of the tracer with a particular material, authorities on corrosion and the specific materials should be consulted. This is particularly true when the material may be subject to inservice chloride stress corrosion. Halogen contamination must not be permitted when the enclosure contains hot or sparking components, or when arc welding or similar high temperature operations may occur. The chlorides are generally banned from austenitic materials in nuclear applications.

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CORRELATION OF TEST GAS LEAKAGE RATES WITH LEAKAGE RATES OF OTHER GASES OR LIQUIDS AT DIFFERENT PRESSURES

Given the normal variation in leak geometry, accurate correlation of leakage rates with halogen vapors and with other fluids is impossible. However, if a safety factor of ten or more is allowed, adequate correlation for gas leakage within these limits can usually be obtained by assuming viscous flow and using the relation of Equation 3:

$$Q_t = Q_0 \frac{n_1}{n_2} \frac{P_2^2 - P_1^2}{P_4^2 - P_3^2} \qquad \text{(Eq. 3)}$$

where Q_t is test leakage rate, Pa·m³·s⁻¹ (or std cm³/s); Q_o is operational leakage rate, Pa·m³·s⁻¹ (or std cm³/s); n_2 is viscosity of test gas (m/s); n_1 is viscosity of operational gas (m/s); P_2,P_1 are absolute pressures on high and low sides during leak testing (pascal); and P_4,P_3 are absolute pressures on high and low sides in operation (pascal).

Experience has shown that, at the same pressures, gas leaks smaller than 10^{-6} Pa·m³·s⁻¹ (10^{-5} std cm³/s) will not show visible leakage of a liquid such as water that evaporates fairly rapidly. For slowly evaporating liquids such as lubricating oil, the gas leak should be another order of magnitude smaller, namely 10^{-7} Pa·m³·s⁻¹ (10^{-6} std cm³/s). (Note that viscosity differences between gases is a relatively minor effect and can be ignored if desired.)

METHOD A — DIRECT HALOGEN LEAK TESTING IN ATMOSPHERE

Apparatus

Equipment and facilities required for Method A, direct halogen leak testing, include the following: (1) test specification; (2) halogen leak detector of standard detector probe type; (3) halogen leak standard, upper 90 percent of scale to include halogen content of maximum leak allowable in accordance with the specification, with response factor correction; (4) test gas, at or above specification pressure; (5) pressure gauges, valves, and piping for introducing test gas and, if required, vacuum pump for evacuating device; (6) pure air supply, if not part of halogen leak detector; and (7) test booth or other atmospheric contamination control, if shown to be necessary.

Procedure

Procedural steps in direct leak detector probe tests by Method A include the following.

1. Set the halogen reference standard at the maximum halogen content of the specification leak.
2. Start the pure air supply and adjust its flow in excess of that of the leak detector probe. Couple the detector probe loosely to the supply so that air is not forced into the detector.
3. Start the detector, warm it up, and adjust it in accordance with the manufacturer's instructions for detection of leaks of size cited in Step 1 above, using the manual zero mode.
4. Remove the detector probe from the pure air supply to the test area. Note the new reading and also minimum and maximum readings for a period of 1 min.
5. Rezero the instrument, place the detector probe at the port of the leak standard, and note the reading. (If necessary to obtain a reasonable instrument deflection in the last two steps, return the detector probe to the pure air supply, adjust the range control, and rezero if necessary.)
6. If the instrument reading in the test area atmosphere is larger than that attained on the leak standard, or if the 1 min variation is more than 30 percent of the leakage rate of the standard leak, take steps to reduce the atmospheric halogen content of the test area before proceeding with the leak test.
7. If the automatic zero mode is to be used, increase the sensitivity by a factor of three.
8. Evacuate (if required) and apply test gas to the device at the specified pressure.
9. For probe areas suspected of leaking, hold the probe on or not more than 5 mm (0.2 in.) from the surface of the device and move it not faster than 30 mm/s (1.2 in./s). If leaks are located that cause a reject indication when the detector probe is held 5 mm (0.2 in.) from the apparent leak source, repair all such leaks

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HALOGEN LEAK TEST REPORT

Tester ____________________ Date of Test __________
Test witnessed by ______________________________
Tested per ASTM std. __________ Method __________
Device tested ________ No. pieces ________________
No. accepted ________ No. rejected ______________
Max leakage accepted pieces ___ x 10___ std $cm^3 \cdot s^{-1}$ or $Pa \cdot m^3 \cdot s^{-1}$
Total ______ or per point ______ leakage
Device evacuated before charging ________
If evacuated, pressure ________ Pa or torr
Test pressure _____ $lb_f \cdot in.^{-1}$ or kPa gage
Test gas: ____% ___Tracer: ___% ____ gas
Atmospheric halogen equivalent _____ x 10 ____
Leak detector serial No. ______________________
Leak standard serial No. ______________________

Figure 24. Sample halogen leak test report form (ASTM E 427).

before performing final acceptance test. If a marginal indication is observed while detecting automatic zero mode, reduce the sensitivity by a factor of three, switch to the manual zero mode, and compare the leakage reading on the leak standard with that on the device.

10. Maintain an orderly procedure in detector probing the required areas, preferably identifying them as tested and plainly indicating points of leakage. Start the probing operation at the top of the test object, because halogen tracer gas is denser than air and tends to flow downward from leak exits.
11. At the completion of the test, evacuate or purge, or both, the test gas from the device.
12. Write the test report, or otherwise indicate test results as required (Figure 24).

METHOD B — DIRECT HALOGEN LEAK TESTING WITH PROPORTIONAL DETECTOR

Equipment used for Method B is the same as for Method A except that the halogen leak detector is of the proportioning detector probe type. The testing procedure is the same as for Method A except that a self-contained pure air supply activated by closing the detector probe tip valve tightly sends 100 percent pure air to the sensor. Some halogen detector models have a fixed proportioning detector probe instead of a valve.

In Procedure Step 2 of Method A, the detector probe valve is open wide (above two turns), which sends 100 percent atmospheric sample to the sensor. If the conditions of Step 6 are met, proceed with the test. If not, partially close the probe valve until they are met. However, do not reduce the valve opening below the point at which the response to the leak standard is reduced by 30 percent.

METHOD C — SHROUD TEST WITH HALOGEN LEAK DETECTOR

Apparatus

Equipment required for Method C shroud testing with halogen tracer gas includes (1) test specification; (2) test gas, at or above specification pressure, if the device is not already pressurized; and (3) purge sample, detect, and calibrate (PSDC) unit (Figure 20) plus shroud as in Figure 21 to fit device.

The upper 90 percent of the halogen leak standard scale shall include halogen leakage rate of maximum leak in accordance with the specification, with response factor correction.

Procedure

Steps involved in halogen leak testing by the shroud Method C, using the purge sample, detect, and calibrate (PSDC) unit shown in Figure 20, include the following.

1. Set the halogen leak standard at the maximum halogen content of the specification leak.
2. Adjust the air pressure, air flows (except purge valve 2), and valves 4 and 7 as indicated in the diagram for this method (Figure 20). (The addition of flow meters and pressure gauges at appropriate places in the circuit to facilitate these adjustments is recommended.)
3. Start the detector, warm it up, and adjust it in accordance with the manufacturer's instructions for detection of leaks of specified size, using the manual zero mode.
4. Place a dummy device not containing halogen in the shroud and open valve 2 for as long as is required to purge the shroud of atmospheric halogens.

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5. Turn valve 7 to calibrate and valve 4 to the sample position. Note detector indication and adjust the sensitivity if required. Return the valves to the original (standby) positions. Remove the dummy device from the shroud.
6. Insert the device to be tested inside the shroud and connect the evacuating line, pressurizing line, or both, if device is not already pressurized with tracer gas.
7. Open valve 2 for as long as is required to purge the shroud of atmospheric halogens.
8. Turn valve 4 to the sample position.
9. If the device is already pressurized, read the leakage, if any, on the detector.
10. If the device is not pressurized, check the leak detector for indication of incomplete purging, then pressurize, and read the leakage, if any. A leak detector indication greater than that obtained during calibration shows leakage greater than allowed by the specification.
11. If the device has been pressurized with halogen tracer for the leak test only, exhaust the test gas outside the test area or recover for reuse.
12. Remove the device from the shroud and write the test report, or otherwise indicate the results of test as required.

METHOD D — AIR CURTAIN SHROUD HALOGEN LEAK TESTING

Steps involved in the air curtain shroud Method D of halogen leak testing with the purge sample, detect, and calibrate (PSDC) unit shown in Figure 22 include the following.

1. Set the halogen leak standard at the maximum halogen content of the specification leak.
2. Adjust the air pressure and flows as indicated in Figure 22 for this method. Valve 2 is open and valve 4 is set at the sample position continuously.
3. Start, warm up, and adjust the detector in accordance with the manufacturer's instructions for detection of leaks of size 1, using the manual zero mode.
4. Place a (dummy) device not containing halogen in the shroud. Turn valve 7 to the calibrate position, note detector indication, adjust the sensitivity if required, and return the valve to the original (standby) position. Remove the dummy device.
5. Insert the device to be leak tested (and which has previously been bombed or which is pressurized with halogen tracer) in the shroud. (Any part of the device that is to be leak tested must be below the purge air opening.)
6. Read the leakage, if any. An indication on the leak detector greater than that obtained during calibration shows leakage greater than that allowed by the specification.
7. Remove the device and record the test results as desired.
8. If a large leak is detected, the clean up of the shroud and sensor can be expedited by turning valve 7 to standby for a few seconds. This will purge shroud, lines, and sensors with pure air.

METHOD E — HALOGEN ACCUMULATION LEAK TESTING

Apparatus

Equipment required for Method E halogen accumulation leak testing includes the following: (1) test specification; (2) test gas, at or above specification pressure, if the device is not already pressurized; and (3) purge sample, detect, and calibrate unit plus shroud as in Figure 23.

The upper 90 percent of halogen leak standard scale shall include halogen content of maximum leak per specification, with response factor correction.

Procedure

Steps required in accumulation leak testing by Method E using the purge sample, detect, and calibrate unit in Figure 23 include the following.

1. Set the halogen leak standard at maximum halogen content of the specification leak.
2. Adjust the air pressure and flows (except purge valve 2) as indicated on the diagram of Figure 23 for this method.
3. Start, warm up, and adjust the detector in accordance with the manufacturer's instructions for detecting leaks of specified size using the manual zero mode.
4. Place a (dummy) device not containing halogen under the shroud.

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5. Open valve 2 for as long as is required to purge the shroud of atmospheric halogen.
6. Turn valve 7 to the calibrate position, allow an appropriate accumulation period (with fan running), turn valve 4 to the sample position, and note detector indication. If necessary, adjust the sensitivity and repeat Steps 5 and 6. Remove the dummy device.
7. Insert the device to be tested inside the shroud and connect the evacuate or pressure line, or both, if device is not already pressurized with tracer gas.
8. Open valve 2 for as long as is required to purge the shroud of atmospheric halogens.
9. Turn valve 4 to the sample position.
10. If the device is already pressurized, note whether the detector reading increases (in the allotted accumulation period) beyond that obtained during calibration. If so, reject the device.
11. If the device is not pressurized, check the leak detector for indication of incomplete purging, then pressurize and proceed as in Step 10.
12. Alternatively, sampling for leakage (valve 4) may be delayed until the end of the accumulation period. However, if this is done, time is lost and the sensor will be subjected to a more concentrated halogen sample if the device has a large leak.
13. If the device has been pressurized with halogen tracer for leak test only, exhaust the test gas outside the test area or recover for reuse.
14. Remove the device from the shroud and write the test report (Figure 24) or otherwise indicate the results of the test as required.

COMBINATION PRESSURE VACUUM BOX LEAK TESTING OF HALOGEN PRESSURIZED SYSTEMS

By means of a flexible combination pressure vacuum box, a temporary closed system capable of being pressurized is locally produced over a section of weld in the test boundary to be tested with the halogen detector probe. Figure 25 shows a cross section sketch of a typical combination pressure vacuum leech box for halogen leak testing. Figure 26 shows fabrication details, including valves and dial gauges.

Both compartments of the combination pressure vacuum leech box shown in Figure 25 are first evacuated using an air ejector or vacuum pump. The resulting greater external atmospheric pressure physically seals the box against that weld test section. The center compartment over the weld section can then be internally pressurized with refrigerant for halogen detector probe test. With the

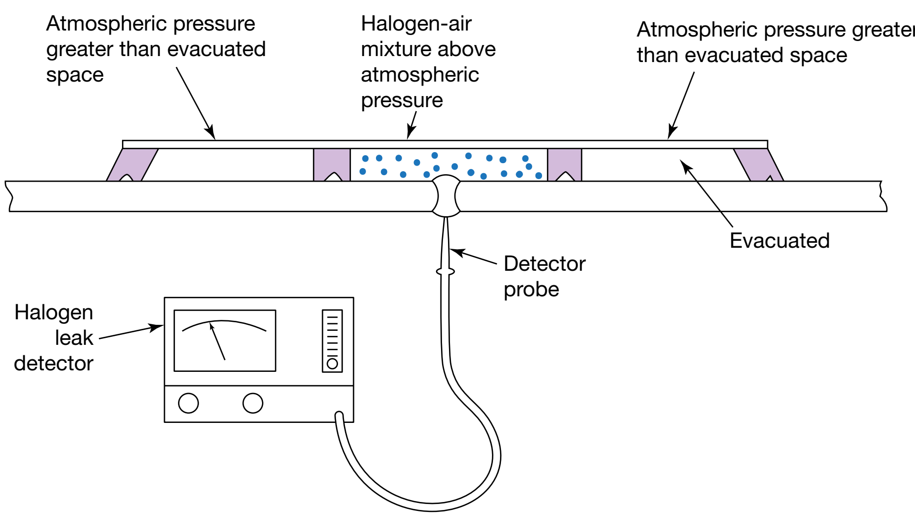

Figure 25. Cross section of combination pressure vacuum leech box used for halogen leak testing by the detector probe technique.

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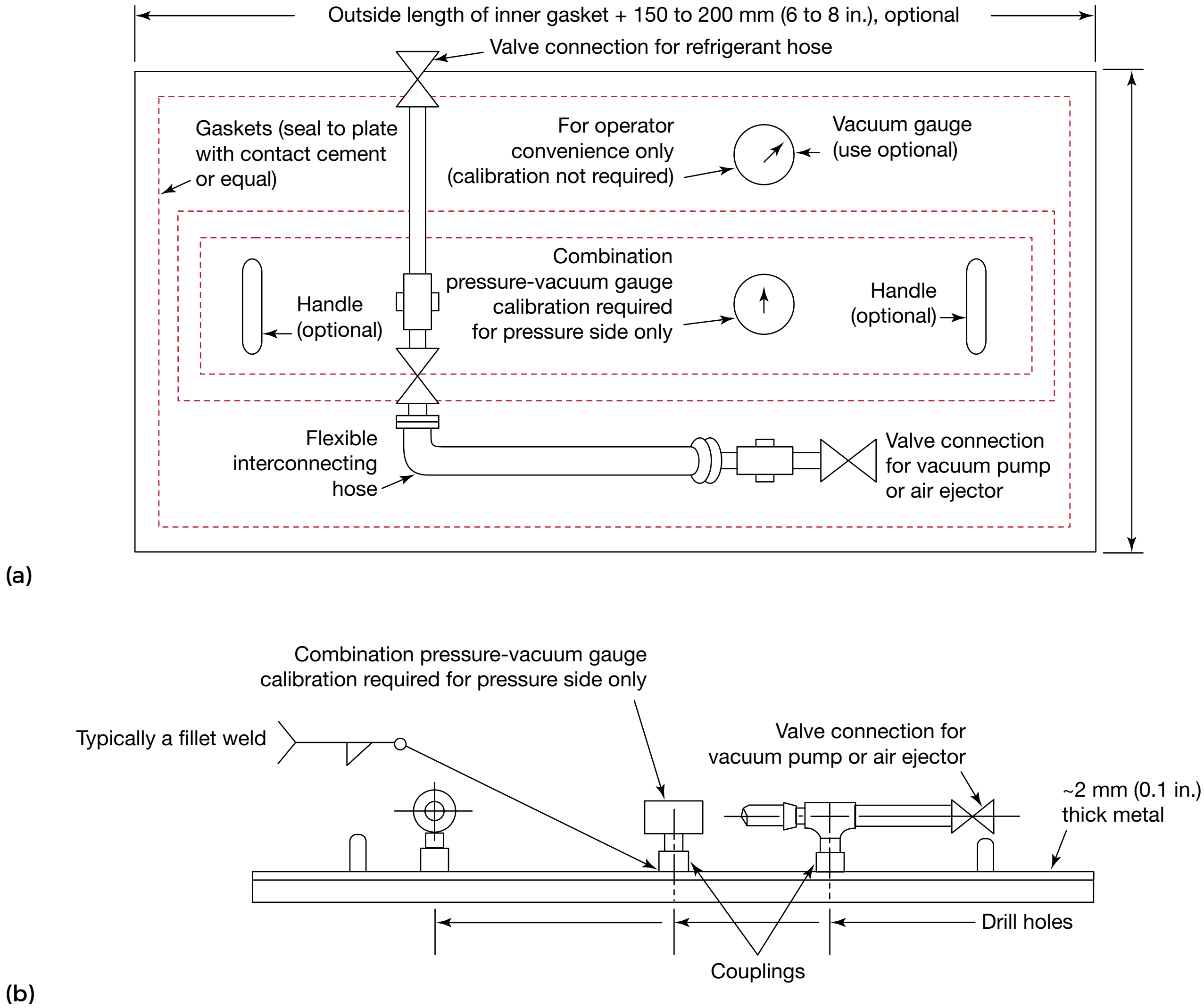

Figure 26. Fabrication details for design and construction of combination pressure vacuum leech box shown in Figure 25: (a) plan view; (b) side view.

detector probe, the operator then scans the opposite side of the boundary, such as a weld, pressurized by the halogen tracer filled internal chamber of the leech box.

An example of use of this type of pressure vacuum box is the leak testing of bottom head welds of a nuclear containment vessel, which are to be embedded in concrete before completion of the vessel. These welds must be halogen detector probe tested before embedding because of their inaccessibility during final test of the vessel.

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PART 4
Industrial Applications of Halogen Leak Detection

APPLICATION OF HALOGEN LEAK TESTS TO PRESSURIZED ENCLOSURES

Pressurized enclosures and piping can be easily tested for leaks by using heated anode halogen leak detectors. Leaks are located by pressurizing these enclosures with a halogen tracer gas and manually probing seams, joints, and welds with the detector probe of the detector. If a leak exists in the enclosure, some of the halogen gas will pass through the leak and be detected by the leak detector.

Some examples of equipment that have been leak tested with halogen leak detectors are automobile air suspension systems, automobile radiators, air conditioning and refrigeration equipment, pressurized radar systems, nuclear power system structures and components, heat exchangers, dairy equipment, air compressors, steam boilers and piping, valves and pipe fittings, lengths of pipes and tubes, missile fuel tanks and fuel lines, aircraft fuel tanks, aircraft hydraulic systems, chemical and petroleum systems, underground pipe lines, transformers, and hermetically sealed instruments and components. These heated anode halogen vapor detectors are suitable for use in any atmosphere that does not contain combustible or explosive gases.

COMPARISON OF HALOGEN VAPOR TESTS WITH OTHER LEAK TESTS

In most cases halogen leak detectors are much more sensitive, faster, more reliable, and in general a cleaner and easier means of leak testing than the ordinary methods such as bubble, hydrostatic, pressure drop, or halide torch testing. However, there are some applications where one of these alternative methods may be more suitable or more sensitive. For example, bubble testing is better for locating leaks in a tank filled with natural gas than is heated anode leak detection, which presents the hazard of an explosion. Safer alternative methods would be to use an electron capture type of halogen leak detector or ultrasound detector. With leak testing equipment such as boilers that are given a high pressure hydrostatic test as required by law, it may be that the hydrostatic test is actually more sensitive than the halogen leak detector. This follows because it is possible to use much higher pressures with the hydrostatic test than with tracer gas and compressed air, for safety reasons. The extremely high pressures possible during hydrostatic testing sometimes cause leaks to open up that do not exist at lower pressures.

There are a few cases such as those cited above where the halogen vapor leak detector may not be as suitable or as sensitive as another method of leak testing. However, on most applications, the halogen test is among the most sensitive, most positive, easiest, and cleanest of all methods of leak detection for leakage to the atmosphere.

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DETERMINING PERCENT TRACER GAS AND TEST PRESSURE FOR LEAK TESTS

The percent tracer gas and the pressure required within the enclosures depend on the size leak to be detected and the normal operating pressure of the equipment being tested. A relatively low positive pressure within the enclosure is sufficient to permit leak testing. However, if the piece of equipment being tested normally operates at some positive pressure or if a leakage rate is specified at some pressure, it is recommended that the halogen leak test of the enclosure be performed at its normal operating pressure or at the pressure at which the leakage rate was specified. (For leak testing of some refrigeration or air conditioning systems, for example, a maximum allowable leakage rate of 0.3 g/yr (0.01 oz/yr) of refrigerant-134a refrigerant gas may be specified.)

A safety factor of four or five is used in determining the test leakage rate to compensate for normal factory conditions, operator carelessness, or loss in sensitivity of the sensitive element. This safety factor of 4.5 has been factored into Table 8, based on a nominal sensitivity setting of near 10^{-6} Pa·m^3·s^{-1} (10^{-5} std cm^3/s).

Table 8. Example of relation of percent refrigerant-22 halogen tracer gas at 200 kPa (15 $lb_f/in.^2$ gauge) to detectable leakage rate.[a]

Tracer Gas Percent	Leakage Rates Pa·m^3·s^{-1}	(std cm^3/s)	g/yr	(oz/yr)
100	9.0×10^{-7}	(9.0×10^{-6})	1.5	(0.05)
50	1.8×10^{-6}	(1.8×10^{-5})	3	(0.1)
25	3.6×10^{-6}	(3.6×10^{-5})	6	(0.2)
10	9.0×10^{-6}	(9.0×10^{-5})	15	(0.5)
5	1.8×10^{-5}	(1.8×10^{-5})	30	(1.0)
1	9.0×10^{-5}	(9.0×10^{-4})	150	(5.0)
0.5	1.8×10^{-4}	(1.8×10^{-3})	300	(10.0)

a. Safety factor of 4.5 is included in these tracer gas concentrations. The assumed halogen leak detector sensitivity setting is 2×10^{-7} Pa·m^3·s^{-1} (2×10^{-6} std cm^3/s).

Determining Partial Pressure of Tracer Gas Required

To determine the partial pressure of refrigerant-12 gas needed in the enclosure to get a certain percent mixture, use Equation 4:

$$p = \frac{\%T \times P}{100} \qquad \text{(Eq. 4)}$$

where p is partial pressure of refrigerant gas; $\%T$ is percent of tracer gas by volume; and P is total absolute pressure in the tank, in kilopascal ($lb_f/in.^2$ absolute).

Figure 1 indicates the maximum pressures possible with halogen tracer gases refrigerant-22 and refrigerant-134a in equilibrium with their liquid forms at various ambient temperatures. To attain 100 percent halogen tracer gas within test systems at these pressures, the system must be evacuated before filling it with the halogen tracer gas. Dilution of the halogen tracer with a neutral pressurizing gas such as air or nitrogen is necessary to attain test pressures in excess of limits.

Determining Partial Pressure of Tracer Gas from Pressurizing Conditions

The partial pressure of refrigerant is that portion of the total absolute pressure in an enclosure due to the refrigerant gas content (Figure 15). In other words, if a tank that contains air at atmospheric pressure (about 100 kPa or 15 $lb_f/in.^2$ absolute) and refrigerant gas is added to raise the pressure to about 140 kPa (20 $lb_f/in.^2$ absolute), then the partial pressure of refrigerant is about 40 kPa (5 $lb_f/in.^2$) and the percentage tracer gas is 28 percent. The pressure of refrigerant gas can be added at any air pressure below the vapor pressure above the liquid refrigerant. In this case it was added when the tank was at atmospheric pressure of 100 kPa (15 $lb_f/in.^2$ absolute), raising the pressure to 140 kPa (20 $lb_f/in.^2$ absolute). If the final test pressure was 280 kPa (40 $lb_f/in.^2$ absolute), more air could have been added after the refrigerant gas, thus raising the pressure to 280 kPa (40 $lb_f/in.^2$ absolute). Alternatively, the air could have been added before the refrigerant gas by raising the air pressure to 240 kPa (35 $lb_f/in.^2$ absolute) and then adding the 40 kPa (5 $lb_f/in.^2$) of refrigerant gas. Either sequence

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can be used unless the final test pressure is to be greater than the vapor pressure of the refrigerant, in which case the refrigerant should be added first.

However, it is advisable to initially pressurize with the refrigerant in order to reduce the described effects of cylinder cooling and cold weather, if applicable. This also aids in the dispersion and mixing of the refrigerant throughout the test system.

PREPARING THE PRESSURIZED SYSTEMS FOR HALOGEN LEAK TESTING

If the enclosure already contains a halogen tracer gas, as do refrigerators or air conditioners that contain one of the refrigerant gases, it is ready for leak testing. Refrigerant gases are relatively inert to metals, rubber, plastic, or other types of materials when in the dry vapor state. Other enclosures must have a halogen tracer gas introduced into them under pressure. Before charging an enclosure with tracer gas, it should first be emptied of all liquids. Refrigerant-134a is recommended as a tracer gas because it is odorless, relatively nontoxic, chemically inert, and available at any refrigerant supply company. It may be purchased in small cans or in large tanks depending on the most economical arrangement for a particular application. The actual mixing of the desired percentage of tracer gas and the filling can be accomplished in several ways. Usually one way will be simplest and most satisfactory for a particular setup.

Programmed Fill Method of Charging Test Enclosure with Refrigerant-22 Tracer Gas

In the programmed fill method of providing air mixed with tracer gas, the enclosure being tested is filled with tracer gas (refrigerant-22) to a predetermined pressure (Table 8), then completely filled with air to the final test pressure. This method is simple and is suitable for compact shapes such as tanks where turbulence produced by filling ensures good mixing of the gases. If tubular coils, complete refrigeration systems, or long restricted devices are filled by this technique, large variations in mixture percentage may result and premixing of gases is recommended.

Simultaneous Fill Method of Pressurizing Test Enclosure

In the simultaneous fill method of providing air mixed with tracer gas, air and halogen tracer gas are admitted simultaneously in the proper proportions by means of metering restrictions of valves. This method will produce good mixing in any pressurized device. The test pressure will be limited to about one half that of the halogen gas tank pressure in order to have adequate pressure drop across the metering orifices.

Premixed Fill Method of Pressurizing Test Enclosure

In the premixed fill method, the enclosure under test is filled directly from a line containing the proper mixture of halogen tracer gas and air. This is the best method for high pressure leak testing of devices having an internal shape not suitable for internal mixing, as outlined in the program fill method. It is also convenient where a large number of leak testing stations are to be serviced with the mixture. The mix can be produced in two ways.

1. In the program fill method, the test gas storage tank is filled with a certain ratio of tracer gas and air by using the ratio of partial pressures.
2. When mixing before compression, the proper amounts of halogen tracer gas and air are metered into the compressor intake. Care should be taken that the partial pressure of tracer gas in the tank does not exceed its vapor pressure.

For either method, it is suggested that the unit under test be evacuated and backfilled to eliminate trapped air and moisture in capillaries and blind ducts.

LEAK SEARCHING PROCEDURES

After the enclosure has been prepared for testing by charging it with a halogen tracer gas, it is ready for leak testing. Leaks are located by manually probing seams, joints, welds, and other areas suspected of leaks with the gun or pencil shaped detector probe, depending on which leak detector is being used. When probing along seams and welds, the operator should place the tip of the probe on the test object surface and move it along the seam at a rate of about 2 cm/s (0.8 in./s). If a leak is encountered, the

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