**AMERICAN VACUUM SOCIETY STANDARD**
**(Tentative)**

**AVS 2.1 Rev.—1973**

# Calibration of Leak Detectors of the Mass Spectrometer Type

(Received 11 April 1973)

## FOREWORD

This foreword is not part of AVS 2.1.

This publication specifies practices tentatively approved as standard by the American Vacuum Society for the calibration of leak detectors of the mass spectrometer type and is one of a series published by the American Vacuum Society. It contains data secured from many sources and represents the best thinking of a number of experts in the field. It is the first issuance of a standard for this topic. After several years of use, this standard will be forwarded to the American National Standards Institute with the request that it be used as a basis for an ANSI Standard. Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the American Vacuum Society, 335 East 45th Street, New York, N. Y. 10017.

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## 1. SCOPE

This Standard prescribes procedures to be used for calibrating leak detectors of the mass spectrometer type; that is, for determining a sensitivity figure for such leak detectors. The procedures require the use of a calibrated leak and a standard gas mixture; the preparation and standardization of these is outside the scope of this proposal. Hereafter, the designation "leak detector" will be used to refer to a detector of the mass spectrometer type.

A leak detector permits detection of leakage due to mechanical openings, such as pinholes, and of leakage due to permeation, such as occurs through many polymeric materials. Virtual leaks, such as those due to surface desorption, vaporization, and gas pockets cannot, in general, be detected by a leak detector.

Various gases may be used in conjunction with leak detectors. The present document concerns the use of helium–4. Nevertheless, the procedures described may be used for other search gases such as Argon –4,0 subject to appropriate precautions.

The present standard deals only with leak detectors which have an integral high vacuum system to maintain the sensing element (mass spectrometer tube) at a low pressure. Specifically excepted from treatment are sensing elements without such a vacuum system. It is also to be understood that the procedures are not intended to constitute a complete acceptance test; such tests will be the subject of a further document.

The application of this proposal is restricted to leak detectors not capable of detecting leaks smaller than $10^{-11}$ Torr liters/sec ($10^{-12}$ Pa $m^3$/sec). Factors that are unimportant for larger leaks may become significant for leak rates that are substantially smaller than 10 Torr liters/sec ($10^{-12}$ Pa $m^3$/sec).

Objects being tested by a leak detector may be under high vacuum, or, at the other extreme, under pressure greater than atmospheric. The leak detection techniques will, in general, differ in the two situations. In the first case, the leak detector usually will be operating near its ultimate low pressure; in the second case, the detector is frequently used at or near its maximum operating pressure. Corresponding to these two conditions of operation, two sensitivity terms are defined, minimum detectable leak rate and minimum detectable concentration ratio (see Sec. 3, Definitions). The two quantities thus defined are related, but in practice it is not feasible to obtain either figure from the other by calculation. Methods are therefore specified for determining both.

## 2. DESCRIPTION OF LEAK DETECTOR

The helium leak detector considered here is essentially a gas analyzer employing the mass-spectrometer principle. In the mass-spectrometer tube, a mixture of gases from the object under test is first ionized, then separated into a series of ion beams or groups, each beam or group ideally representing a single species of gas. (Actually, the ions in each beam have the same mass-to-charge ratio.) In the helium leak detector, means are provided for "tuning" the instrument so that only the beam due to helium hits an ion collector. (The detector can be retuned, generally, to respond to other gases.) The current produced by the beam is amplified, and its magnitude is a measure of the partial pressure of the helium gas in the incoming sample. It will be assumed that the gas ionization is produced by electrons from a hot filament.

Leak detectors consist of a mass-spectrometer tube, a high-vacuum system for maintaining the tube under vacuum with a flow of gas sample through or into the tube, voltage supplies, and an ion-current amplifier. The output of the amplifier can be displayed in a number of ways, and almost invariably an indicating electrical meter is one of the means chosen. For the purposes of the present procedures, however, it will be assumed that the output is shown on a chart recorder. Means are provided for reducing the output so that a large range of leak sizes can be detected and measured. In other words, the leak detector can be set at one of a number of different detection levels, hereafter referred to as sensitivity settings.

Since the spectrometer tube is required to receive a gas sample from the system under test and also to be kept under vacuum, an inlet line is provided for leading gas from the outside into the spectrometer tube, and this line must have an isolation valve ("inlet valve") in it (see Fig. 1.0). Likewise, a pressure-indicating device is also included; the pressure in the spectrometer tube may thus be observed and prevented from exceeding the maximum specified operating pressure.

## 3. DEFINITIONS

Note: Where a word may be either a noun or a verb, the letters "n" or "v", in parentheses, indicate which usage is involved.

### 3.1 Background (or Residual Signal)

*3.1.1 General*

In general, background is the total spurious indication given by the leak detector without injected search gas. Background can origin ate in either the mass spectrometer tube (see below) or the associated electric and electronic circuitry, or both. (Frequently, the term is used to refer specifically to the indication due to ions other than those produced from injected search gas.)

*3.1.2. Drift*

The relatively slow change in the background. The significant parameter is the maximum drift measured in a specified period of time.

*3.1.3 Noise*

The relatively rapid changes in the background. The significant parameter is the noise measured in a specified period of time.

*3.1.4 Helium Background*

Background due to helium released from the walls of the leak detector or leak detection system.

### 3.2 Components

*3.2.1 Inlet Line (or Sample Inlet Line)*

The line through which the search gas passes from the object under test to the leak detector.

*3.2.2 Valve, Inlet*

A valve which is placed at the end of the sample inlet line and adjacent to the leak detector. See Fig. 1.0. Almost invariably the inlet valve is an integral part of the leak detector.

*3.2.3 Valve, Leak Isolation*

A valve placed between a leak which is to be used for testing the leak detector and the sample inlet line (see Fig. 1.0)

*3.2.4 Valve, Pump*

A valve placed between the auxiliary pump used for evacuating the sample inlet line and that line (see Fig. 1.0).

*3.2.5 Valve, Vent*

A valve used to admit air or other gas into an evacuated space so as to increase the pressure therein to atmospheric pressure.

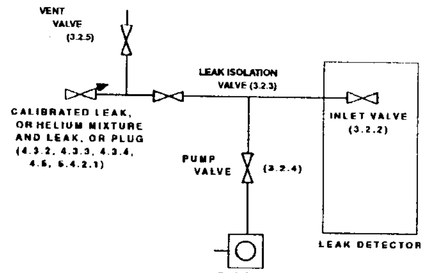


**Figure 1.0. Test arrangement.**

*3.2.6 Backing-off Control (or Zero Control)*

An electrical control, present on most leak detectors, which may be used to shift the output indication of the device. Frequently, the backing-off control is used to return the output indication to zero of the scale, whence the alternative name.

*3.2.7 Filament*

The source of the (thermal) electrons which ionize the gases in the mass-spectrometer tube; the filament is located in this tube.

*3.2.8 Mass-Spectrometer Tube*

That element of a leak detector in which the search gas is ionized and detected.

### 3.3 Search Gas

A gas applied to the outer surface of equipment under leak test and detected, after entry into the equipment through the leak, in a vacuum test; or introduced into the equipment under test and detected after it is emitted from the leak in a pressure test.

## 3.4 Leaks

*3.4.1 Leak (n)*

In vacuum technology a hole, porosity, permeable element, or other structure in the wall of an enclosure capable of passing gas from one side of the wall to the other under action of a pressure or concentration difference existing across the wall.

Also, a device which can be used to introduce gas into an evacuated system.

*3.4.1.1 Channel leak.* A leak which consists of one or more discrete passages that may be ideally treated as long capillaries.

*3.4.1.2 Membrane leak.* A leak which permits gas flow by permeation of the gas through a nonporous wall. For helium, this wall may be of glass, quartz, or other suitable material.

*3.4.1.3 Molecular leak.* A leak through which the mass rate of flow is substantially proportional to the reciprocal of the square root of the molecular weight of the flowing gas.

*3.4.1.4 Viscous leak.* A leak through which the mass rate of flow is substantially proportional to the reciprocal of the viscosity of the flowing gas.

*3.4.2 Calibrated Leak*

A leak device which provides a known mass rate of flow for a specific gas under specific conditions.

*3.4.3 Standard Leak*

A calibrated leak for which the rate of leakage is known under standard conditions, namely, 23 ± 3 °C, a pressure of 760 Torr ± 5% at one end of the leak, and a pressure at the other end so low as to have a negligible effect on the leak rate.

*3.4.4 Virtual Leak*

The semblance of a leak due to evolution of gas or vapor within a system.

## 3.5 Leak Rates

*3..5.1 Leak Rate*

The mass rate (also called "throughput"; differentiated from volume rate of flow (liters/sec) also called "pumping speed"), in Torr liters/sec (or Pa $m^3$/sec) at which a specific gas passes through a leak under specific conditions.

*3.5.2 Standard Air Leak Rate*

The mass rate of flow, through a leak, of atmospheric air of dew point less than −25°C under standard conditions specified as follows: the inlet pressure shall be 760 Torr ± 5%, the outlet pressure shall be less than 10 Torr and the temperature shall be 23 ±3°C.

*3.5.3 Equivalent Standard Air Leak Rate*

Short-path leaks having standard air leak rates less than $10^{-6}$ – $10^{-7}$ Torr liters/sec ($10^{-7}$ – $10^{-8}$ Pa $m^3$/sec) are of the molecular type (see Sec 3.4.1.3). Consequently, helium (mol. wt 4) passes through such leaks more rapidly than air (mol. wt 29) and a given flow rate of helium corresponds to a smaller flow rate of air. In this recommendation, helium flow is measured and the "equivalent standard air leak rate" is taken as $(4/29)^{1/2}$ = 0.37 times the helium leak rate under standard conditions (see Sec 3.5.2).

## 3.6 Operation of the Leak Detector

*3.6.1 Peak (n)*

The trace showing a maximum on the chart recorder when a leak detector is scanned (see below) with gas present, usually the search gas, to which the detector is sensitive.

*3.6.2 Peak (v)*

To so set the scanning control (see Scan below) of a leak detector that the output due to a given search gas input is maximized. This is a form of tuning.

*3.6.3 Scan (v)*

To vary the accelerating voltage (or other equivalent operating parameter) of a leak detector, particularly across that range of voltage which includes the voltage necessary to produce a search gas peak.

*3.6.4 Tune (v)*

In leak-detection technology, to adjust one or more of the controls of a leak detector so that its response to a search gas is maximized. Tuning by means of the scanning control only is called "peaking."

*3.6.5 Zero (v)*

To adjust the zero or backing-off control so that the output indication of the leak detector is at the zero of the indicating scale or at some other reference point.

## 3.7 Relative Gas Concentration

*3.7.1 Concentration Ratio*

Same as Mole Fraction (below).

*3.7.2 Mole Fraction*

The ratio of the number of atoms (or molecules) of a given constituent of a mixture to the total number of atoms (or molecules) in the mixture. For ideal gases, the mole fraction has the same value as the fraction based on volume; in general, leak detectors are operated in the pressure range where gases behave ideally. (This is the same as concentration ratio.)

*3.7.3 Partial Pressure*

In a mixture of gases, the partial pressure of a constituent is the product of the total pressure of the mixture and the mole fraction or concentration ratio of the given constituent.

## 3.8 Sensitivity Terms

*3.8.1 Sensitivity*

The sensitivity of a device is the change in output of the device divided by the change in input which caused the response.

*3.8.2 Minimum Detectable Signal*

An output signal due to incoming search gas which is equal in magnitude to the sum of the noise and the drift.

*3.8.3 Minimum Detectable Leak (or Minimum Detectable Leak Rate)*

The smallest leak, as specified by its standard air leak rate, that can be detected unambiguously by a given leak detector (see Sec. 1). The minimum detectable leak rate depends on a number of factors. One of the purposes of this Standard is to describe practical procedures for determining minimum detectable leak rate, taking into account background, volume rate of flow (pumping speed), and time factor.

*3.8.4 Minimum Detectable Concentration Ratio*

The smallest concentration ratio of a given search gas in an air mixture that can be detected unambiguously by a given leak detector when the mixture is fed to the detector at such a rate as to raise the pressure in the instrument to some optimum high value. In this Standard, the minimum detectable leak rate is calculated—by a somewhat arbitrary procedure—from observations of the response of the leak detector to a helium-air mixture of known helium concentration ratio (see Sec. 1).

### 3.9 Time Factors

*3.9.1 Time Constant*

The time interval required for the output of an instrument or system to change by $1-1/e$ or 63% of the ultimate (steady-state) output change produced by an abrupt change in input.

*3.9.2 Response Time T*

The time constant corresponding to a change from a zero or small leak-rate indication, to a positive or large leak-rate indication.

*3.9.3 Cleanup Time (or Clearing Time)*

The time constant corresponding to a change from a positive leak rate indication, of limited magnitude, to a small or zero leak-rate indication.

N.b. In this standard, response time and cleanup time are assumed to be equal.

## 4. TEST CONDITIONS AND APPARATUS

### 4.1 Ambient Temperature

Ambient temperature should be 23 ± 3°C.

### 4.2 Ambient Pressure

Ambient pressure should be 760 Torr ±5%. When deviation from 760 Torr exceeds 5%, appropriate correction shall be made, with 5% tolerable inaccuracy.

### 4.3 Leaks

*4.3.1 General*

Two leaks may be required: one with a relatively small leak rate and the other with a relatively large leak rate. The small leak is used for determining minimum detectable leak, the large leak for minimum detectable concentration ratio. The small leak should be calibrated and may be of the channel type or of the membrane type; preferably, the large leak should be capable of being adjusted to vary its leak rate, but this is not essential. The leaks are specified in the following.

*4.3.2 Small Channel Leak*

This should have a leak rate such that when helium, at 760 Torr pressure and 23 ± 3°C, is fed to the leak and thence to the leak detector under test, a deflection is produced on the recorder chart which is not less than 50 times the minimum detectable signal (see Sec. 5.3 below). The leak detector should have been adjusted as in 4.6 below. A temperature correction should be specified for the leak and this correction applied for the difference between the temperature of the leak at the time of use and the temperature at which the leak was calibrated.

*4.3.3 Small Membrane Leak*

This should have its own integral, sealed source of helium at not less than 760 Torr pressure. It should leak the helium at a rate which will produce a deflection as specified under Small Channel Leak, Sec. 4.3.2, above. A temperature correction should be specified for the leak, and this correction applied for the difference between the temperature of the leak at the time of use and the temperature at which the leak was calibrated.

*4.3.4 Large (Adjustable) Leak*

This should be a viscous leak, either fixed or so adjusted that when connected to the leak detector with ambient air at the inlet side of the leak, the pressure in the leak detector rises to the optimum high operating pressure (±50%) specified by the manufacturer.

### 4.4 Helium

This should be at least 99.9% helium (available from commercial dealers in bottled gases).

### 4.5 Helium Mixture

This should be helium and air mixture of a known helium concentration ratio such that it produces a deflection of at least 10 times the minimum detectable signal (see Sec. 6.4) when fed at a pressure of 760 Torr ± 5% and at a temperature of 23 ± 3 °C to the large (adjustable) leak (4.3.4 above) and thence into the leak detector under test. Where applicable, atmospheric air may be used as the helium mixture. In either case, the air for the mixture should be obtained from a point at least 2 m outside the walls of the building housing the test equipment. Helium concentration ratio shall be represented by the symbol $C_M$ and should be expressed as a fraction with numerator reduced to unity. Alternatively, the concentration ratio may be expressed in parts of helium per million parts of mixture (parts per million by volume). The concentration ratio of helium in air should be taken arbitrarily as 1/200 000 or 5 parts per million, and this figure should be taken into account when preparing mixtures containing more helium. (Note: The latest data indicate 5.24 parts per million of helium in air by volume—E. Glueckauf, *Compendium of Meteorology*, edited by T. F. Malone (American Meteorological Soc., Boston, 1951), pp. 3-10.)

## 4.6 Leak Detector

*4.6.1*

The leak detector should have been connected to a power source conforming in voltage, frequency, and regulation to the manufacturer's specifications.

*4.6.2*

The leak detector should have been "warmed up", as specified by the manufacturer, prior to all test procedures.

*4.6.3*

The leak detector under test should have been adjusted for optimum detection of helium in the manner specified by the manufacturer.

*4.6.4*

If the vacuum system of the leak detector is such as to permit adjustment of volume rate of flow (pumping speed), the selected rate should not be varied during the test.

## 4.7 Chart Recorder

This should be an instrument of at least 1-h recording time suitable for recording the output of the leak detector under test.

The time constant of the recorder should be small enough to introduce no error in the response time of the leak detector.

There should be negligible interaction between the recorder and the output indicating meter, i.e., the velocity of the pointer of either should not generate sufficient electrical signal to affect the indication of the other. If the recorder is connected in parallel with the meter, this interaction will be negligible if each has an input resistance 200 times that of their common voltage source.

*4.7.2*

The recorder should be adjusted so that full scale on the recorder corresponds to full scale of the leak detector output meter when the leak detector is at its most sensitive detection setting and so that zero of the recorder corresponds to zero of the output meter.

## 4.8 Apparatus

This is illustrated diagrammatically in Fig. 1.0.

# 5. TEST PROCEDURE – MINIMUM DETECTABLE LEAK

## 5.1 Drift and Noise Observation

*5.1.1*

The output of the leak detector is connected to the recorder, the leak detector being at its maximum sensitivity setting and the inlet valve closed. See also Sec. 4.6.

*5.1.2*

The leak detector backing-off (or zero) control is adjusted so that the recorder reading is approximately 50% of full scale, the filament being on.

*5.1.3*

The output is recorded for 20 min or until the output has reached full scale, for positive drift, or zero, for negative drift.

*5.1.4*

Draw a series of line segments intersecting the curve recorded in Sec. 5.1.3, the lines to be drawn at 1-min intervals at right angles to the time axis (abscissa) of the chart, and to commence at the point where the procedure of Sec. 5.1.3 is started. The lines so drawn will be called the "1-min lines". Draw straight-line approximations for each segment of the curve between adjacent 1-min lines.

## 5.2 Drift and Noise Determination

*5.2.1*

Examine the straight line approximations of Sec. 5.1.4 to determine that 1-min segment of the output curve having the greatest slope. This greatest slope is measured in scale divisions per minute and is called the *drift*. If the greatest slope is less than the scale divisions corresponding to 2% of full scale of the recorder, the total (absolute) change in output over the 20-min period is determined. The total change divided by 20 is then called the drift.

*5.2.2*

For each 1-min segment of the curve, determine the maximum (absolute) deviation of the recorded curve from the straight-line approximation.

*5.2.3*

The average of these maximum deviations, multiplied by 2, is called the noise (scale divisions).

Note: In determining the noise, neglect any large deviation (spike) which occurs less frequently than once in any 5-min interval.

## 5.3 Minimum Detectable Signal

The minimum detectable signal is taken to be equal to the sum of the absolute values of the drift and of the noise. It should be measured in scale divisions. If the sum is less than the scale divisions corresponding to 2% of full scale, then the scale divisions corresponding to 2% of full scale is called the minimum detectable signal.

## 5.4 Sensitivity Determination

*5.4.1 Arrangement of Apparatus*

The leak detector is connected to an auxiliary system as shown in Fig. 1.0. (Frequently, the auxiliary system is included with the leak detector as an integral part thereof.)

The system should contain a minimum of rubber or other polymeric surfaces. Preferably, such surfaces should consist only of the exposed surfaces of an O-ring or O-rings. Accordingly, the "Leak Isolation Valve" shown in Fig. 1.0 should preferably be of all-metal construction, but in any case should not act as a significant source of adsorbed or absorbed helium.

*5.4.2 Spurious Signal Correction*

Note: This determination requires the use of the small calibrated leak. If the calibrated leak has its own integral valve, and the leak and valve are of all-metal construction (except perhaps for the membrane in a membrane-type leak), Sec. 5.4.2 may be omitted from the procedure.

*5.4.2.1.* A metal plug is connected to the leak detector as indicated on the left side of Fig. 1.0.

*5.4.2.2.* The output is zeroed, with the filament on.

*5.4.2.3.* The leak isolation valve is opened.

*5.4.2.4.* The pump valve is opened.

(Note: For its safety, the filament of the mass spectrometer tube may be turned off at this point.)

*5.4.2.5.* When the atmospheric air present between the plug and the inlet valve has been evacuated, the pump valve is closed.

*5.4.2.6.* The inlet valve is opened promptly, but gradually. The pressure in the leak detector is allowed to reach a steady value, showing no observable change in a 1-min period.

*5.4.2.7.* Turn on filament of mass spectrometer tube if it is not on.

*5.4.2.8.* When the output has reached a steady value, but in any case not longer than 3 min after Sec. 5.4.2.6, the output reading is noted. If the leak detector has been set at reduced sensitivity, the reading should be converted to equivalent scale divisions for full-sensitivity setting.

*5.4.2.9.* Close the leak isolation valve as rapidly as feasible.

*5.4.2.10.* Note the output reading 10 sec after closing the isolation valve. As in 5.4.2.8, convert the reading if necessary.

*5.4.2.11.* Subtract the reading noted in 5.4.2.10 from that noted in 5.4.2.8. If the difference is negative, it is to be considered equal to zero. The difference will be called the "spurious-signal correction" and will be applied in Sec. 5.4.3.14.

*5.4.2.12.* Close the inlet valve.

*5.4.2.13.* Open the vent valve.

*5.4.2.14.* Remove only the plug from the inlet line; all connections are to remain in place.

*5.4.2.15.* Close the vent valve.

*5.4.3 Sensitivity*

*5.4.3.1.* Connect the all-metal leak to the leak detector. However, if the procedure of 5.4.2 was necessary, the small calibrated leak is put in place of the plug removed in 5.4.2.14 above, the leak being inserted the same distance into the connection as the plug had been.

*5.4.3.2.* The output is zeroed with the filament on.

*5.4.3.3.* The leak isolation valve is opened.

*5.4.3.4.* The pump valve is opened.

*5.4.3.5.* Helium at 760 Torr ±5% pressure is applied to the leak. If the leak has its own supply of helium, this step is omitted.

(Note: The filament of the mass spectrometer tube may be turned off before Sec. 5.4.3.6.)

*5.4.3.6.* When the atmospheric air present between the calibrated leak and the leak detector has been evacuated, the pump valve is closed.

*5.4.3.7.* The inlet valve is opened promptly after Sec. 5.4.3.6. The pressure in the leak detector is allowed to reach a steady value, showing no observable change in 1 min.

*5.4.3.8.* Turn on filament of mass spectrometer tube if it is not on.

*5.4.3.9.* At this point it may be necessary to change the sensitivity setting. When the output signal has reached a steady value, showing a change in 1 min which is not greater than the drift (as corrected for the sensitivity setting), the output reading in scale divisions is noted. If the leak detector has been set at reduced sensitivity, the reading should be converted to the equivalent scale divisions for full-sensitivity setting.

*5.4.3.10.* Immediately after the preceding step, the stopwatch is started and simultaneously the leak isolation valve is closed *as rapidly as practical.* Alternatively, the recorder chart may be marked to indicate the beginning of the timed period and the leak isolation valve then closed rapidly.

*5.4.3.11.* The output is observed continuously and the stopwatch is stopped when the reading has decreased to 37% of the reading observed in Sec. 5.4.3.9 above. The reading of the stopwatch is noted ($T$ sec). Alternatively, the recorder chart is examined to determine the time $T$ required for the specified decrease in output. $T$ is the response time (Sec. 3.9.2).

Note: Should response time be a function of sensitivity setting, $T$ as observed should be corrected to response time at full sensitivity setting, if any other setting was used.

*5.4.3.12.* One minute after closing the leak valve (see Sec. 5.4.3.10), the output is read and noted. Correct for sensitivity setting as in 5.4.3.9.

*5.4.3.13.* The uncorrected signal due to the calibrated leak shall be taken as the difference between the reading noted in 5.4.3.9, and that noted in 5.4.3.12, the required conversion of these readings to equivalent scale divisions at full-sensitivity setting having been made.

*5.4.3.14.* The corrected signal due to the calibrated leak is taken as the difference between the uncorrected signal, Sec. 5.4.3.13, and the spurious signal correction in 5.4.2.11. The sensitivity is calculated by the formula below and should always be stated together with the response time, $T$:

$$\text{Sensitivity, with Response Time } T = \frac{\text{Signal due to Calibrated Leak}}{\text{Standard or Equivalent Standard Air Leak Rate of Calibrated Leak}}$$

The units are scale divisions (on full sensitivity setting) per unit leak rate (Secs. 3.5 and 3.8).

### 5.5 Minimum Detectable Leak

Referring to Secs. 5.3 and 5.4.3.14, this is calculated from the formula

Minimum Detectable Leak, with Response Time $T$

$$= \frac{\text{Minimum Detectable Signal}}{\text{Sensitivity}}$$

The units are those of leak rate.

## 6. TEST PROCEDURE – MINIMUM DETECTABLE CONCENTRATION RATIO

### 6.1 General

The determination of minimum detectable concentration ratio requires means within the leak detector under test for scanning the helium peak. This means is generally an adjustment of the accelerating voltage, and it will be assumed that this is the case (see Sec. 3.6.3). When leak-detector output (scale divisions) is plotted against accelerating voltage, a curve is obtained, whose general features are illustrated by the solid line in Fig. 2.0. The rise in the curve to a peak at B is due to the presence of helium. The faired curve indicated by a broken line is due to a varying background signal contributed by other ions in the absence of helium. With helium present, and in the absence of background, the curve obtained would be symmetrical, falling off asymptotically to zero on either side of the peak voltage. The curve shown in Fig. 2.0 is very nearly a direct superposition of the background curve and the symmetrical pure-helium curve.

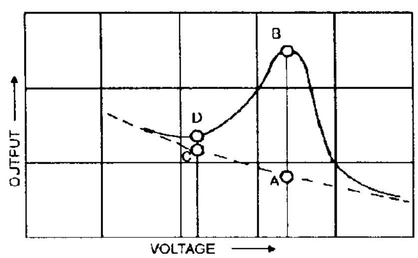


Figure 2.0. Typical helium scan.

It should be noted that as the voltage is varied from the left side of the graph to the right, the output first decreases, then increases, and finally decreases again. This reversal in direction, indicating the presence of helium, is very easily detected when the scan is being observed visually on a meter. As the helium input is progressively reduced in absence of helium background, the reversal becomes smaller until eventually a curve, such as is shown by the solid line in Fig. 2.1, is obtained. Under these conditions the output never reverses; it remains constant for a very short voltage interval. Such a condition will barely be detected by the usual visual observations. In the absence of noise and drift, the concentration ratio of helium which produces this condition determines the Minimum Detectable Concentration Ratio.

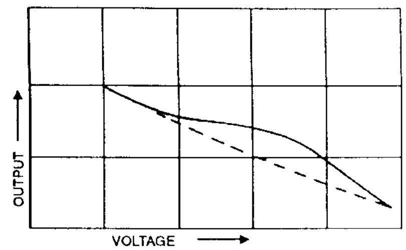


Figure 2.1. Scan in absence of helium.

Helium background gives rise to a trace similar to that of Figure 2.0. The total situation is illustrated by Fig. 2.2. The first (lowest) solid-line curve represents the minimum detectable concentration ratio. The next curve represents the helium output due to background in the absence of injected helium. The third curve represents the output due to incoming helium plus helium background.

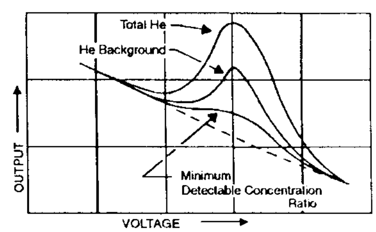


Figure 2.2. Total effects scan.

In the following determination the helium background is called the spurious signal.

Under practical conditions it is not possible to make a rigidly correct determination of the minimum detectable concentration ratio as defined above. In the following, somewhat arbitrary determinations are used for calculating a sensitivity figure. The minimum detectable concentration ratio so obtained is one that is reasonable in light of practical experience.

### 6.2 Drift and Noise Observation

*6.2.1*

The output of the leak detector is connected to the recorder, the leak detector being at its maximum sensitivity setting, the inlet valve closed, and the filament off. See Sec. 4.6.

*6.2.2*

The leak detector is connected to an auxiliary system as shown in Fig. 1.0 and further specified in Sec. 5.4.1.

*6.2.3*

The large leak (calibrated or adjustable) is connected to the leak detector. See Fig. 1.0.

*6.2.4*

Atmospheric air or a helium mixture (see Sec. 4.5) is fed, at 760 Torr ± 5 %, to the leak. In case atmospheric air is used, the feed line should not of itself act as a Source of helium and preferably should be of all metal construction.

*6.2.5*

The leak isolation valve is opened.

*6.2.6*

The pump valve is opened.

*6.2.7*

When the atmospheric air present between the leak and the inlet valve has been evacuated, open the inlet valve.

*6.2.8*

Close the pump valve.

*6.2.9*

If an adjustable leak is being used, adjust it to bring the pressure in the leak detector to its optimum value as specified in Sec. 4.3.4.

*6.2.10*

Turn on the filament and adjust the sensitivity control, if necessary, to the highest sensitivity setting that will result in an on-scale recorder indication.

*6.2.11*

Adjust the zero control (backing-off control) so that the recorder reading is as near to 50% of full scale as possible.

*6.2.12*

The output is recorded for 20 min or until the output has reached full scale, for positive drift, or zero for negative drift. This record is called the *drift curve.*

*6.2.13*

Set the sensitivity control on full-sensitivity setting. If the indication is off-scale bring it to midscale by means of the zero (backing-off) control. If this is not possible, set the sensitivity control to the highest sensitivity setting that will produce an on-scale indication; then bring the indication to midscale by means of the backing-off (zero) control.

*6.2.14*

The output is recorded for 20 min or until the output is off-scale. This record is called the *noise curve.*

*6.2.15*

Treat the drift and noise curves as in Sec. 5.1.4.

### 6.3 Drift and Noise Determination

*6.3.1*

Determine the drift from the drift curve as in 5.2.1, correcting for any reduced sensitivity setting.

Determine the noise from the noise curve as in Secs. 5.2.2 and 5.2.3.

### 6.4 Minimum Detectable Signal

*6.4.1*

This should be calculated as in Sec. 5.3.

### 6.5 Spurious Signal Determination

*6.5.1*

With the equipment as it was at the end of Sec. 6.2.13, close the leak isolation valve and turn on the filament if it is not already on.

*6.5.1.1.* Set the leak detector for the greatest sensitivity that will give on-scale readings. (If necessary, readjust scanning control for helium peak.)

*6.5.1.2.* When the output signal has reached a steady value, showing no observable change in 1 min, scan the helium peak as specified for the instrument. The output will, in general, produce a curve of the form shown in Fig. 2.0. The curve is faired, as is also shown in the figure by the dashed line.

The ordinate AB is to be taken as a measure of the helium background, B being located at the maximum of the curve and A directly below B.

*6.5.1.3.* If AB is not zero, the scanning is to be repeated at 15-min intervals until AB has become zero or has not changed over a $^1/_2$-h period.

*6.5.1.4.* If AB is ultimately different from zero, its magnitude is determined and is referred to as the spurious signal (s.s.) (scale divisions). If the leak detector is at reduced sensitivity setting, the s.s. should be converted to equivalent scale divisions at full-sensitivity setting.

### 6.6 Minimum Detectable Concentration Ratio

*6.6.1*

Close the inlet valve.

*6.6.2*

Open the leak isolation valve.

*6.6.3*

Open the pump valve.

(Note: The filament may be turned off at this point.)

*6.6.4*

When the air present between the leak and the inlet valve has been evacuated, open the inlet valve.

*6.6.5*

Close the pump valve.

*6.6.6*

When the pressure in the leak detector has reached a steady value, showing no change in 1 min, turn on the filament if it is not on.

*6.6.7*

When the output signal has reached a steady value, showing no change in 1 min which is greater than the drift (Sec. 6.3.1), scan the helium peak as specified for the instrument. The output will, in general, produce a curve of the form shown in Fig. 2.0. The curve is faired, as is also shown in Fig. 2.0 by the dashed line.

*6.6.8*

Mark on the curves the point B (scan maximum), point A (directly below B), point D (scan minimum), and point C (directly below D). Measure the distances of points B, A, and C from the abscissa (voltage axis) of the chart (scale divisions) and denote these ordinates, respectively, by *b*, *a*, and *c*. If the leak detector is at reduced sensitivity setting, the ordinate should be converted into equivalent scale divisions at full-sensitivity setting.

***6.6.9 Minimum Detectable Concentration Ratio***

The minimum detectable concentration ratio should be calculated by the following formula:

Minimum Detectable Concentration Ratio

$$= \frac{C_M (c - a)}{b - a - \text{s.s.}}$$

where CM is the concentration ratio of helium mixture (see Sec. 4.5) and s.s is the spurious signal (see 6.5.1.4). Or, if $c-a$ is less than the minimum detectable signal (M.D.S., see Sec. 6.4), use the formula

Minimum Detectable Concentration Ratio

$$= \frac{C_M \text{(M.D.S.)}}{b - a - \text{s.s.}}$$