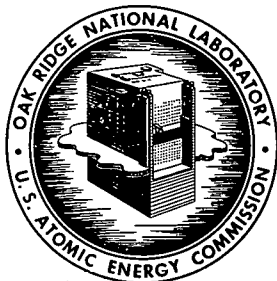


MASTER

X-822



OAK RIDGE NATIONAL LABORATORY

Operated by

UNION CARBIDE NUCLEAR COMPANY

Division of Union Carbide Corporation



Post Office Box X
Oak Ridge, Tennessee

EXTERNAL TRANSMITTAL AUTHORIZED ONLY

ORNL
CENTRAL FILES NUMBER

58-1-20
REVISED

DATE: July 10, 1959
SUBJECT: Notes on Helium Leak Detection
TO: Distribution
FROM: H. J. Metz

COPY NO. 33

Distribution

- 1-50. H. J. Metz
- 51-52. Central Research Library
- 53. Document Reference Section
- 54. Laboratory Records
- 55. ORNL-RC

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report. The information is not to be abstracted, reprinted or otherwise given public dissemination without the approval of the ORNL patent branch, Legal and Information Control Department.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

UNCLASSIFIED

FOREWORD

From time to time engineers and technicians need to use mass-spectrometer-type helium leak-detectors. There is very little data published on the principles, and on the use of such apparatus. These notes are a collection of information that has been put together with the hope that the occasional user of leak detectors will be able to easily use them.

These notes come from letters and phonetalks with Consolidated Electrodynamics engineers, and from their instruction manuals. GENERAL METHODS OF LEAK DETECTION is largely based on Vacuum-Electronic Engineering's operation manual. Some data came from A. Nerken's EXPERIMENTS ON FLOW OF GASES THROUGH LEAKS. Much help was received from - H. E. Banta, R. R. Feezell, N. N. Landay, and J. G. Morgan.

A. Nerken

UNCLASSIFIED

The contents of these notes are divided into ten (10) chapters:

	<u>Page</u>
Units of Measurement	4
Definitions	5
Sensitivity of Leak Detectors	7
Standard Leaks	12
Calibrated Leaks	13
General Methods of Leak Detection	14
Measuring Leakage	26
Operation of the CEC 24-102, 24-110	28
Operation of the Modified GE - see MJP-209, Rev. 1. "Operation of Electronic Leak Detectors", ORGBP Engineering and Methods Department	-
Operation of the Veeco MS-9 - see manufacturers Operation & Maintenance Manual	-

UNITS OF MEASUREMENT

Pressure Units

1 micron = 1×10^{-6} meters of mercury = 1×10^{-3} millimeters of mercury
 1 atmosphere = 14.7 psia = 760 mm of mercury = 7.6×10^5 microns

Volume Units

1 cubic foot = 28,320 cubic centimeters
 1 volume at 60F = $\frac{460 + 60}{460 + 32} \times 1$ volume at 0C

Pressure-Volume Units are usually micron cubic feet or standard cubic centimeters. A micron cubic foot is the quantity of gas that will raise the pressure one micron in a one cubic foot volume when the temperature is 60F. A micron of mercury is one one-millionth of a meter of mercury, or one one-thousandth of a millimeter of mercury. A standard cubic centimeter is the volume in one cc at one atmosphere pressure at 32F.

$$1 \text{ std cc} = \frac{7.6 \times 10^5}{28,320} \times \frac{520}{492} = 28.5 \text{ micron cubic feet}$$

$$1 \text{ micron cubic foot} = \frac{28,320}{7.6 \times 10^5} \times \frac{492}{520} = 0.0351 \text{ std cc}$$

Leak flow-rates are usually measured in standard cc per second, or in micron-cubic feet per hour.

$$1 \text{ std cc per sec} = 3600 \times 28.5 = 102,000 \text{ micron cubic feet per hour}$$

$$1 \text{ micron cu ft per hr} = \frac{0.0351}{3600} = .975 \times 10^{-5} \text{ std cc per sec}$$

$$1 \text{ std cc per sec} = 760 \text{ micron liters per sec}$$

$$1 \text{ micron liter per sec} = 127 \text{ micron cubic feet per hour}$$

$$1 \text{ micron liter per sec} = 0.0013 \text{ std cc per sec}$$

$$1 \text{ micron cu ft per hour} = 0.0079 \text{ micron liter per sec}$$

If weight units are wanted -

$$1 \text{ micron cu ft} = \frac{1}{359 \times 7.6 \times 10^5} = 3.7 \times 10^{-9} \text{ lb mols}$$

$$1 \text{ micron cu ft} = \frac{28,320}{22,400 \times 7.6 \times 10^5} = 1.3 \times 10^{-6} \text{ gram mols}$$

$$1 \text{ std cc} = \frac{1}{28,320 \times 359} = 9.83 \times 10^{-8} \text{ lb mols}$$

$$1 \text{ std cc} = \frac{1}{22,400} = 4.46 \times 10^{-5} \text{ gram mols}$$

DEFINITIONS

These notes are based on Helium leak-detectors such as Consolidated Electrodynamics Corporation Model 24-102, or General Electric, or Veeco MS-9. Calculations for, and the use of other mass-spectrometer-type leak detectors will be similar.

The mass-spectrometer emission unit is called the source in these notes.

The meaning of a division must be spelled-out to permit specification of sensitivity, and to let leak-rate measurements be made on a uniform basis. Different spectrometers have different meter scales. To compare performance and to compare leaks, the same meter scale is assumed for all instruments.

One meter-scale DIVISION is 1/100 of full scale when using the X1 range. At full scale, using the X10, X30, X100 and X300 multipliers, the meter will indicate 1000, 3000, 10,000, and 30,000 X1 range-divisions respectively.

The term PARTIAL PRESSURE of a gas means the pressure caused by a gas, either by itself, or with other gases. When a second gas is not present, the partial pressure is the same as the total pressure. To illustrate Dalton's law of partial pressure - air is 78% nitrogen, 21% oxygen and 1% other gases. The sea level atmospheric-pressure is 760 mm of mercury -

The partial press. of O ₂ is	.21 x 760 = 162
The partial press. of N ₂ is	.78 x 760 = 590
The partial press. of others is	.01 x 760 = 8
The total pressure is -	<u>760</u> mm

At 12,000 feet altitude, the total atmospheric pressure is 483 mm of mercury.

The partial press. of O ₂ is	.21 x 483 = 102
The partial press. of N ₂ is	.78 x 483 = 376
The partial press. of others is	.01 x 493 = 5
The total pressure is -	<u>483</u> mm

These examples show that partial pressure changes directly as total pressure when the composition of the gas mixture stays the same. Now, if the partial pressure of one of the gases in the mixture is to be kept the same while the total pressure is changed, then the composition must change.

The total atmospheric pressure at 46,150 feet altitude is 102 mm of mercury. If a person breathes pure oxygen at 46,150 feet altitude, the oxygen partial pressure is the same as the total pressure. This is equivalent to breathing air at 12,000 feet altitude, where the oxygen partial pressure is 102 mm of mercury.

Another example - Helium partial pressure is 5×10^{-7} microns. If no other gas is present, the system total pressure is also 5×10^{-7} microns. If another gas is present, and the total pressure is 0.2 microns - which

UNCLASSIFIED

is equal to $2,000,000 \times 10^{-7}$ microns, then the partial pressure of the other gas is $2,000,000 \times 10^{-7} - 5 \times 10^{-7} = 1,999,995 \times 10^{-7} = 0.199,995$ microns.

The SOURCE PRESSURE indicator is a meter that measures the electric current through a Phillips ionization gage or through an ionization gage. The meter dial is calibrated to read the pressure when the source and the gage contain dry air, no helium. When the source and the gage contain only helium, the actual pressure in the source is four to six times the meter scale reading. For example - if the source pressure reads 0.2 microns and if air only goes into the leak detector, then the actual pressure is 0.2 microns plus or minus 10%. If the source pressure reads 0.2 microns, and if helium only goes into the source, then the actual pressure is probably 0.8 to 1.2 microns. If a half air and half helium goes into a leak detector, the actual source pressure will probably be 0.4 to 0.6 microns, though the meter reads 0.2 microns. Normally, the meter reading is used as is. No correction is made for gas composition in the source.

Thermocouple vacuum gages, hot-wire vacuum gages, ionization vacuum-gages, all give the true pressure only when measuring the pressure of the gas for which they were calibrated. When other gases are present, they do not measure pressure accurately. McLeod gage do show the true gas pressure if no condensible vapors are present.

UNCLASSIFIED

SENSITIVITY OF LEAK DETECTORS

Leak detector sensitivity is specified in two ways - 1 - the smallest detectable helium concentration in air at a specified source pressure. 2 - The smallest pure helium leak which can be detected at a specified source pressure, and with the specified test conditions.

So far as is known, there is no mathematical correlation between these two specifications. The leak detector manufacturer gives equivalent values based on tests, and on experience.

Actually, mass-spectrometer-type leak detectors measure the partial pressure of helium in the source. The smallest helium partial pressure that will give a readable output is the basic yardstick for indicating the sensitivity of the instrument. This is called the basic sensitivity.

The helium partial-pressure in the source can be changed by changing the total pressure in the source. Halve the total pressure and the partial pressure is halved. This drops the ability to find leaks by one-half. Double the total pressure and thus the helium partial-pressure, and the instruments ability to detect leaks, doubles.

These principles can be explained by using the CEC 24-102 leak detector as an example. The specifications for the 24-102 are -

- A. It will give a five-division indication for one part of helium in 2,000,000 parts of air when the source total pressure is 0.2 microns.
- B. It will give a five-division indication for a pure helium leak of 1×10^{-9} std cc per sec - 1×10^{-4} micron CFH, when no air leaks into the system.

Noise in amplifiers and such like cause a two to two and one-half division meter indication. The smallest readable signal above noise is about two to two and one-half divisions, when the X1 range is used. When the X10 range is used, the smallest readable signal is about $2 \times 10 = 20$ divisions. Other ranges correspond to this.

If the proportion of helium to the air in the source is one to 2,000,000, and the total pressure is 0.2 microns, the partial pressure of helium is $\frac{0.2}{2,000,000} = 1 \times 10^{-7}$ microns. If the source total pressure is cut in half, the proportion of helium to air must double to keep the helium partial-pressure at the same value, $\frac{0.1}{1,000,000} = 1 \times 10^{-7}$ microns. If the source total pressure is doubled, the proportion of helium to air must be cut in half to keep the helium partial - pressure at the same value. $\frac{0.4}{4,000,000} = 1 \times 10^{-7}$ microns. In all these cases, the helium partial-pressure is identical. The leak detector will indicate five divisions even though the ability to detect leaks has changed from

one part helium in 1,000,000 parts of air, to one part in 4,000,000.

The effect of pressure on the leak detector reading is linear only in a perfect instrument with no background noise. Real-life instruments are not linear, nor do they have zero background.

The relationship of basic sensitivity to specification A is a direct relationship. The instrument sensitivity given in specification A depends only on the source, and on the electronics. The rate of flow of the helium-air mixture through the source has no effect on the instrument as long as the source pressure is at the specified value.

Specification B can be obtained by measuring the smallest helium leak rate that will give a readable output when the throttle valve is wide open and when no air leaks in. In this case, the vacuum system, as well as the sensitivity of the source and the electronics must be considered. The helium flow through the source can be large or small, depending on how much gas the internal vacuum pump will pump out. If a high-capacity internal vacuum pump is used to evacuate the source, the smallest readable signal will indicate a large helium flow because the flow through the source is large. If a low-capacity internal vacuum pump is used to evacuate the source, the smallest readable signal will indicate a very small helium flow because the flow through the source is small.

The smallest detectable leak is also affected by the tightness of the system. If air leaks into the system and goes through the source along with the helium from the leak, the helium partial-pressure will be lower because at the specified source pressure indication -

Source total-pressure - air partial-pressure = helium partial pressure.

When the helium partial-pressure is reduced, the leak detector reading is lower.

To sum up - leak detector sensitivity to helium in air depends on the helium partial-pressure in the source, on source sensitivity, and on the electronics. The smallest detectable helium leak depends on the helium partial-pressure, on the source sensitivity, on the electronics, on the internal vacuum pump capacity, and is reproducible only if air does not leak onto the system.

The effect of pressure on the sensitivity of various leak detectors to pure helium can be seen on the curve, Figure 1. The abscissa is the source pressure reading. The ordinate is the sensitivity in cc per sec per division. This comes from dividing the standard leak flow rate by the divisions indicated by the leak detector.

The curve Figure 2 shows the output of the instruments per part per million of helium in air at different source pressures. The abscissa is the source pressure in microns of mercury. The ordinate is the number of scale divisions per part per million of helium added to dry air. The curve symbols are the same as for figure 1.

The fractions beside the point on the curves show the ability of the machines to detect helium in air; $1/3$ means the instrument will give a readable signal for one part of helium in 3,000,000 parts of dry air; $1/6$ - one part helium in 6,000,000 parts of air; $1/1.2$ - 1 part helium in 1,200,000 parts of air. The ability to detect helium in air depends on several things - first the scale multiplier used - the smallest readable signal on the X1 scale is 2 to $2\frac{1}{2}$ divisions, on the X3 scale it is 6 to $7\frac{1}{2}$ divisions, on the X10 scale it is 20 to 25 divisions, and so on. Second, on the noise in the leak detector. The ratio of signal to noise cannot be less than one to one to get a dependable reading.

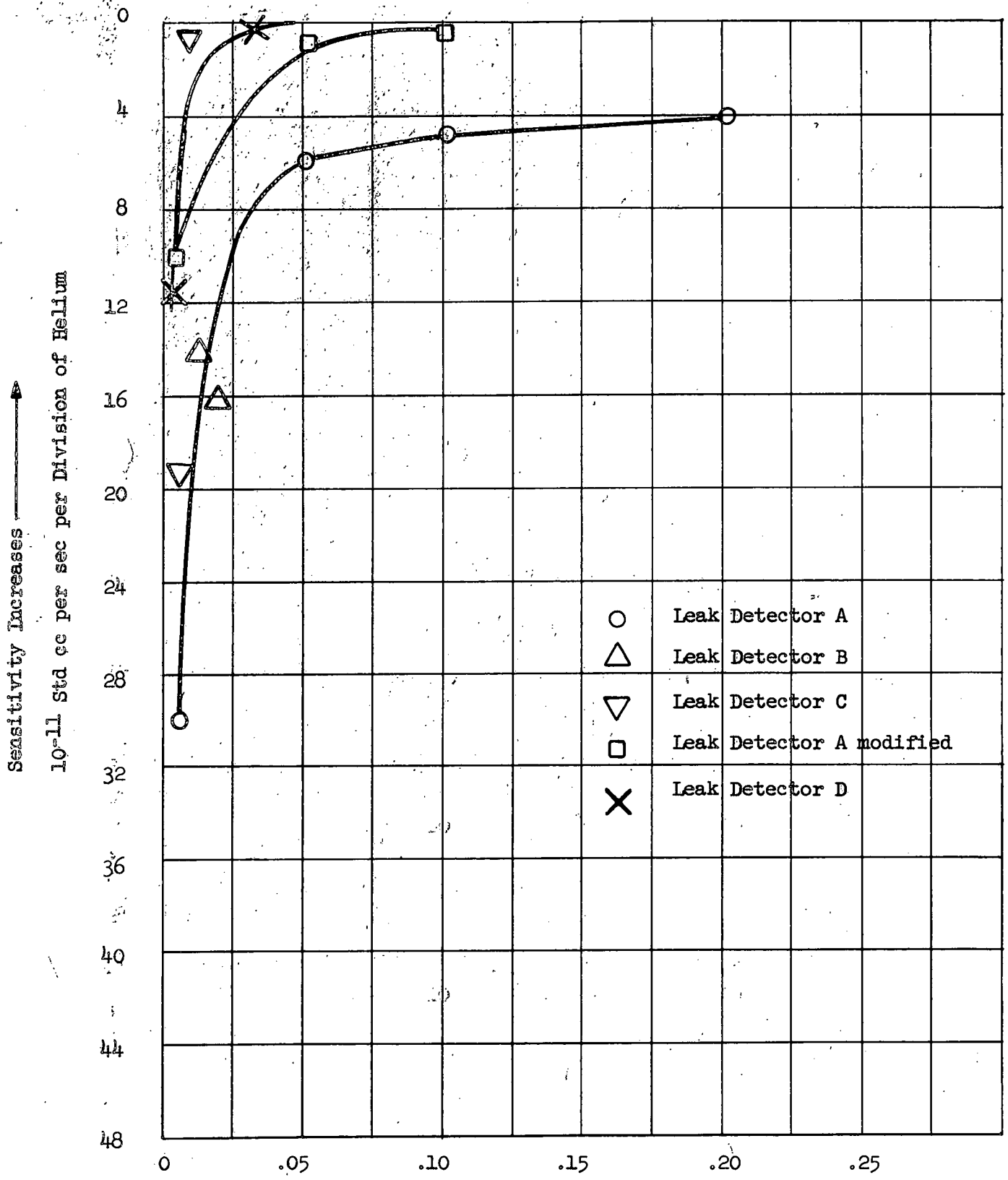
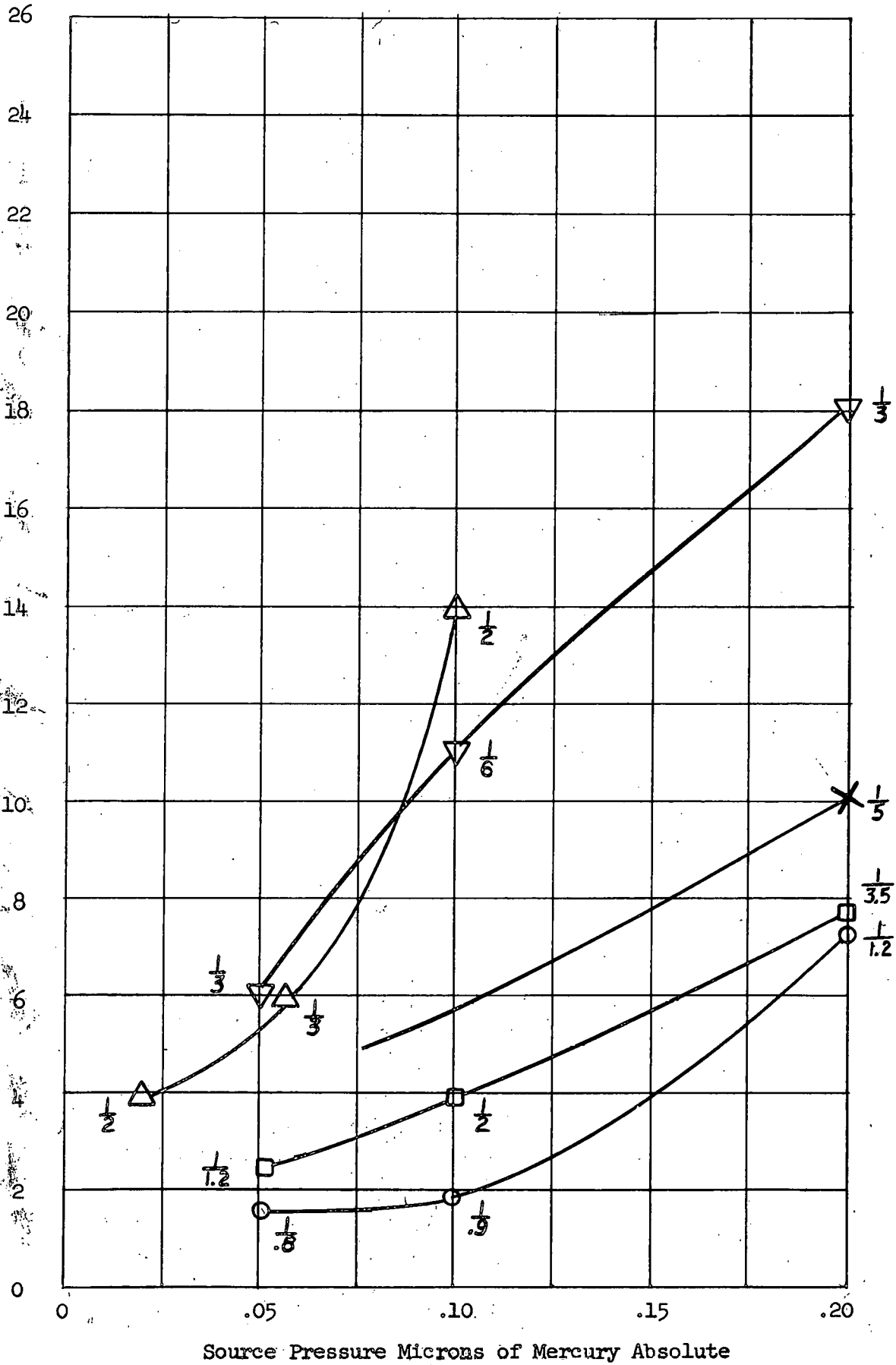


Figure 1

-10-

Ability to Detect Leak Increases \uparrow
 Divisions Output Per Part Per Million of Helium in Air



Source Pressure Microns of Mercury Absolute

Figure 2

UNCLASSIFIED

STANDARD LEAKS

These are small sealed containers of atmospheric-pressure helium with a very small leak built onto the container, usually made of glass. The leak's accuracy is claimed to be within plus or minus 10% of the value shown on the container. The units are standard cc per second. The helium flow from the container is so small that the leak can be connected to a one micron vacuum for many hundreds of hours before the helium pressure in the container goes down appreciably.

The standard leak can be used to check the sensitivity of a leak detector, and within limits, it can be used to find the total air leakage into an evacuated system.

Leak detector sensitivity can be checked with the standard leak if the leak is connected to the leak detector inlet directly, or to an inlet manifold which does not leak. After the leak detector has run until the scale reading is constant, with both throttle and pump valves wide open, the sensitivity can be calculated. The scale is read in the divisions explained in DEFINITIONS.

The calculation is best explained by an example - assume the leak detector scale reads 2200 divisions when connected only to a standard leak. The standard leak used has a flow-rate of 6.47×10^{-7} std cc per sec. The leak detector sensitivity is $\frac{6.47 \times 10^{-7}}{2200} = 2.94 \times 10^{-10}$ std cc per sec per division. The smallest readable output is two and a half times this value, $2.94 \times 10^{-10} \times 2.5 = 7.33 \times 10^{-10}$ std cc per sec. This is the smallest leak that will give a readable output at the time the test was made, and when no air is leaking in.

Leak detector sensitivity calibration with a known helium-in-air mixture is often difficult. A standard leak can be used to check leak detector sensitivity per division for pure helium.

CALIBRATED LEAKS

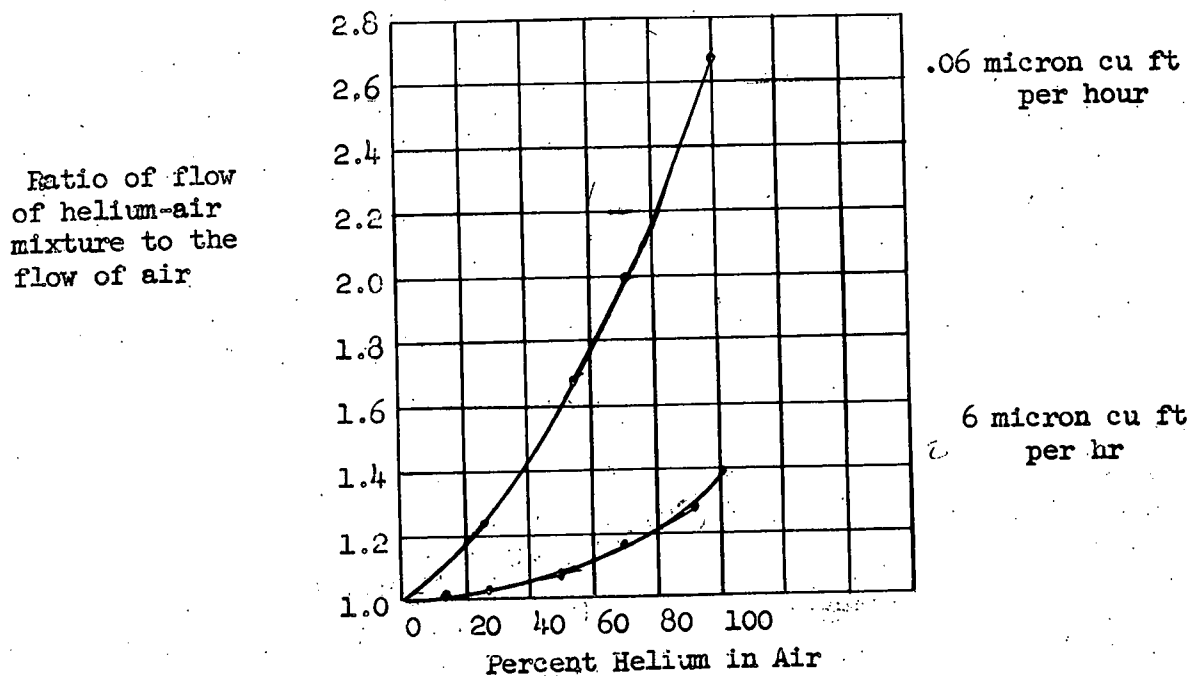
These are usually made by flattening metal capillary tube, and soldering it inside a larger metal tube. Usually these leaks are calibrated with air. Such a leak is generally a series combination of viscous and molecular flows. The overall flow resistance can be considered the sum of two resistances, one due to viscous flow and proportional to viscosity, and the other due to molecular flow and proportional to the square root of the molecular weight.

Flowrates Through Leaks for Different Gases

Gas	Viscosity	Mol-Wt. Air = 1	Large Leak		Small Leak	
			Micron CFH	10^{-4} Std cc per sec.	Micron CFH	10^{-6} Std cc per sec.
Air	1.0	1.0	6.4	6.2	.066	6.4
Hydrogen	.48	0.07	17.4	17.	.240	23.
Freon 12	.67	4.20	6.2	6.1	.041	4.0
CO ₂	.81	1.53	6.7	6.5	.054	5.3
Helium	1.08	0.14	8.9	8.7	.180	18.
Oxygen	1.12	1.11	5.7	5.6	.058	5.7
Argon	1.23	1.39	5.5	5.4	.058	5.7

Helium flow through the small leak was 2.73 times the air flow. Helium flow through the large leak was 1.39 times the air flow. A leak in between these two, 3.8 micron cfh of air, had a helium flow 1.71 times the air flow, 6.5 micron cfh.

Whenever calibrated leaks are used, probably it would be worth while to calibrate them with the same gas that will go through them in use.



-13-
UNCLASSIFIED

GENERAL METHODS OF LEAK DETECTION

All methods of leak detection involve the passage of a "tracer" fluid from one side of a presumed leak to the other, and the subsequent detection of the fluid on the latter side. Helium gas is the "tracer" fluid normally used with the mass-spectrometer leak-detectors.

Leak detectors should be used to find leaks that are too small to find with soap bubbles, or with halogen leak detectors. A large leak might let so much air into a system that other leaks could not be detected. Or so much helium might escape through a large leak that no individual leak could be located because the area would be contaminated with helium.

The leak detector may be used for both vacuum and pressure testing.

In the vacuum method of testing, Figure 3, the equipment under test is evacuated by an auxiliary pump as shown. A sample of the gas in the pumping line is passed to the leak detector, which is continuously being evacuated by its own pumps. To detect leaks, a small stream of helium is played over points of suspected leakage so that, if a leak does exist, the helium enters and is present in the pumping line and in the leak detector. Since helium is present in such small amounts in air, a significant amount of helium will enter the leak detector only when a leak has actually been "probed" with the gas. The detector responds if helium enters it, producing a deflection on a milliammeter ("output" meter). Therefore, a meter deflection indicates a leak. In the absence of detectable leakage, no deflection occurs. The electrical impulse can also actuate an audio leakage indicator.

For pressure testing, Figure 4, helium is introduced within the test object under a pressure greater than atmospheric. The helium will then issue from any existing leaks. A suction line, ("sniffer") which is connected to the leak detector, is passed over suspect points. Any outflowing helium is drawn into the detector, causing a meter deflection and so indicating a leak. Further details on both pressure and vacuum testing follow.

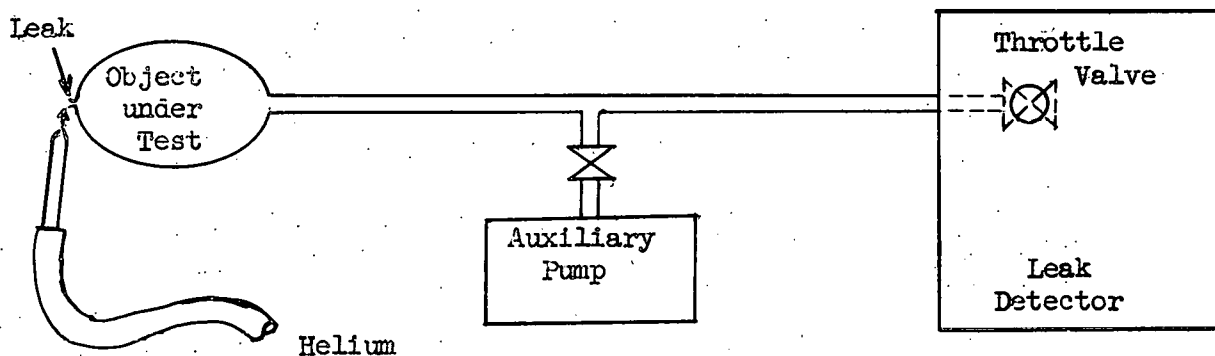


Fig. 3.

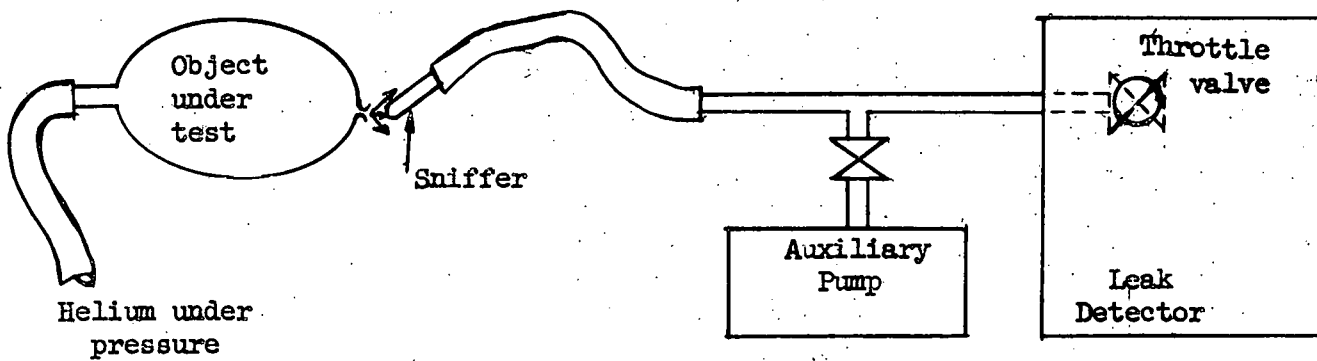


Fig. 4.

LEAK DETECTION

A. Vacuum Testing:

1. General. The procedure is to evacuate the tested object with the auxiliary pump, connect the leak detector to the tested object by opening the throttle valve, then to spray helium at suspected points of leakage and observe the output of the leak detector.

2. Making Vacuum Connections to Tested Object.

a. General Precautions. Poorly designed test connections can be a major source of difficulty in leak testing. Common sources of test connection trouble are leakage, excessive helium contamination and dirt. In order to avoid these time-wasting difficulties, the following points should be observed.

(1) The use of excessive amounts of rubber, neoprene, vinyl, and especially rubber tubing, should be avoided, because these have the property of absorbing helium. Thus, when a large leak is encountered, the elastomers will absorb appreciable quantities of helium which is difficult to remove by pumping. The use of elastomer is necessary in order to make vacuum connections; however, its use should be kept to an absolute minimum. Tubing is particularly bad, not only is it subject to helium contamination but it eventually becomes contaminated with other materials which prevent the attainment of the vacuum required for good leak detection.

(2) Lubricants. When applied to gaskets in moderation, the use of a good low vapor pressure vacuum grease, such as Apiezon, Lubriseal or Silicone, will be of considerable aid in making a vacuum-tight joint. Like elastomers, however, excessive use of vacuum grease will cause helium contamination; furthermore, large quantities of grease will act as a dirt catcher, and the system will soon be so dirty that a good vacuum

~~CONFIDENTIAL~~

will be unattainable. Only a slight film of grease should be applied to the gaskets used, and the excess should be wiped off.

(3) "O" ring Seals. Commercially available "O" rings, which are molded rubber gaskets having a circular cross-section, make very reliable and convenient vacuum seals. About three quarters of the "O" ring is recessed in a groove, and compressed $\frac{1}{4}$ diameter. Engineering data sheets available from manufacturers make recommendations as to the design of the grooves. If these recommendations are followed, it has been found that good vacuum joints result. As mentioned above, when lubricating "O" rings, only a thin film should be applied.

(4) Flat Gaskets. The use of flat gaskets should be avoided whenever it is possible to use "O" rings. However, when it is found necessary to use flat gaskets, their thickness should be held to a minimum so that the vacuum system "sees" the smallest possible amount of rubber.

(5) The need for a clean system cannot be over emphasized. The larger the system, the more important is cleanliness.

3. Step-by-Step Vacuum Testing Procedure.

- a. Put the leak detector in operation with the throttle valve closed. See OPERATION of the various leak detectors.
- b. Connect the object to be tested to the pumping port.
- c. Open the auxiliary pump shut-off valve to begin evacuating.
- d. When a vacuum gauge indicates a pressure in the object being tested, of about 20 microns or when the vacuum no longer improves, open the throttle valve of the leak detector. Be careful not to exceed a leak detector pressure of 0.3 micron. Adjust the throttle valve so as to give the proper leak detector source pressure. If the test object is relatively tight and clean, it should be possible to open the throttle valve wide without exceeding this pressure.
- e. If the throttle valve has been opened wide, and the pressure is too low, try closing the auxiliary pump shut-off valve. If the leak detector pressure does not rise too high, leave the auxiliary pump shut-off valve closed. This will result in maximum sensitivity, because all the helium entering through a possible leak will flow to the leak detector instead of dividing between the leak detector and the auxiliary pump. In no case should the auxiliary pump shut-off valve be closed when the throttle valve is only partly open, since this will result in the accumulation of helium in the test object. If the pressure is lower than it should be, with the auxiliary pump shut-off valve closed, the leak detector pump-valve

can be partly closed. This should raise the pressure to 0.2 microns which will give good sensitivity. Be sure the pressure in the test object is higher than the pressure in the leak detector.

- f. Using the helium control valve, direct a jet of helium at suspected points on the test object. Don't forget to test the temporary vacuum connections. The helium jet should be very small. A flow of about $\frac{1}{5}$ std cc per sec from 0.005 to 0.012 in. inside diameter capillary tube is about right to find the location of small leaks. This is equivalent to one bubble a second when the end of the capillary tube is under water. Do not use large helium flows because a good sized leak may contaminate the system, and the large flows could contaminate the area so that no individual leak could be found.
- g. When the helium jet strikes a leak, the leak detector output will rise. In most cases the deflection will be off-scale, and in order to locate the leak accurately, the amplifier sensitivity should be reduced so as to obtain a readable deflection. The location of the leak may be closely located at that point at which the maximum readable response occurs. If an off-scale deflection occurs even at the minimum amplifier sensitivity, the leak detector sensitivity may be further reduced by first opening the auxiliary pump shut-off valve, and then partially closing the leak detector throttle valve. In this way, the auxiliary pump will carry away some of the helium entering the leak. (For other probing techniques see paragraph 8, below).
- h. When the test is complete, the leak detector should be valved off and shut down according to instructions.
- i. Open the air inlet valve (of the external system, of course) and remove the tested object.

4. Hood Testing

An overall test may be performed by placing the test object in a metal or plastic container and filling the container with helium. In this way, all the test object will be tested at the same time and no leaks will be missed. Total leakage can be measured. See MEASURING LEAKAGE.

5. Bell Jar Testing

Hermetically sealed containers which are filled with helium, or some gas containing a percentage of helium, may be given a rapid sensitive overall leak test by placing them in a bell jar. The bell jar is then evacuated and connected to the leak detector; if a helium indication results, it is due to a leak in the container being tested. The seal between the vacuum plate and the bell jar should be made by means of an "O"-ring. The bell jar should have a minimum volume so as to shorten the pump down time; therefore, specially built metal units are usually preferable to standard glass bell jars. When sealing a bell jar to a vacuum plate, never use vacuum grease to

make the seal - this is an obsolete laboratory technique. Bell jar testing is very good when leaks in small objects and in capillary tubes must be found.

6. Response Time in Vacuum Testing. For fast, accurate leak testing, two requirements are the utmost importance:

- a. The system should react as rapidly as possible when a leak is "probed". That is, it should have a short "response time".
- b. When the tracer gas is removed from the leak, the leakage indication should fall to zero in the shortest possible time. That is, it should have a small "clean-up time".

If these requirements are not met, the leak testing process is delayed to a large and sometimes intolerable extent. To illustrate this, picture a section of weld being probed at a constant rate. If the response time is poor, the leakage indication will appear some time after the probe has moved well beyond the leak, and the probe will then have to back-track slowly until a second signal is obtained. But this second signal cannot be observed distinctly until the first signal has been removed, or "cleaned up". Therefore, the clean-up is of equal importance to the response time.

Please note that response and clean-up times are characteristics of the test system as a whole, including the part being tested and the auxiliary pump. They are not merely functions of the leak detector alone. The leak detector responds almost immediately to any changes in helium concentration that occur at the throttle valve. In a test system, the delay in response is due to the time necessary for the helium concentration to build up at the throttle valve; the delay in clean-up is due to the time necessary for the pump to remove the helium from within the volume of the part being tested.

It can no doubt be seen intuitively that a test object having large volume will cause long delays, while a high speed pump will reduce the delays. Mathematical analysis bears this out, and shows that the important characteristic of the system is the ratio of volume divided by pumping speed ($\frac{V}{S}$).

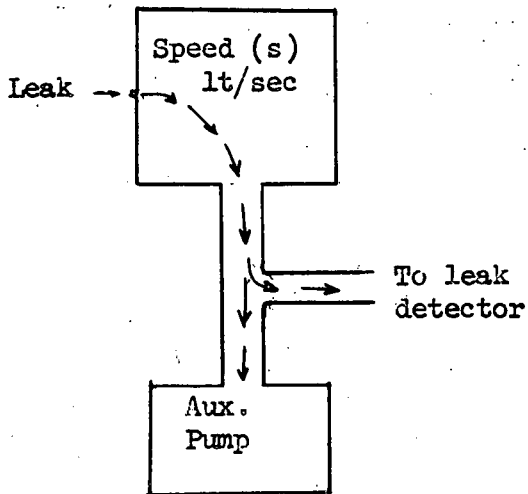


Figure 5 shows a volume of V liters being evacuated at a speed S liters per second. The response and clean-up times are then defined as follows:

T_1 = Response Time = time for a helium indication to build up to 64% of its eventual maximum value

T_2 = Clean-up time = time required after helium is removed from the leak for the helium indication to be reduced to 36% of its initial value.

$$T_1 = T_2 = \frac{V}{S}$$

Fig. 5

NOTE

When V is in liters and S is in liters/second, T is in seconds.

When V is in cubic feet and S is in cubic feet/minute, T is in minutes.

The $\frac{V}{S}$ ratio thus gives a direct measure of the response and clean-up characteristics of the system of Fig. 5, which is basically that which is mostly used. The following example will illustrate:

A part having a volume of 2 liters must be leak tested, and the desired clean-up time is 2 seconds. What pumping speed is required?

Solution: $2 \text{ sec} = \frac{2 \text{ liters}}{S}$

Solving for S , $S = \frac{2 \text{ liters}}{2 \text{ seconds}} = 1 \text{ liter/sec}$

Note that the speed required is the effective speed at the leak, which may be much smaller than the speed of the vacuum pump itself, due to the limiting effect of the connecting lines.

A connecting line has a maximum speed or conductance (S_L) which depends on its diameter (D) and length (L) as follows, in the molecular flow region -

Equation 1. $S_L = 6.6 \frac{D^3}{L}$

where: S_L is the maximum speed of the connecting line in liters per second;
D is the diameter of the connecting line in inches;
L is the length of the connecting line in feet.

The speed given by the above formula is that which would exist at the end of a line if it were connected to a pump with infinite capacity. When connected to a pump with a finite speed (S_P), the speed at the end of the line is reduced to the effective speed (S) as follows:

$$\text{Equation 2. } S = \frac{S_L \times S_P}{S_L + S_P}$$

where: S is the speed at the end of the line
 S_L is the maximum speed of the line;
 S_P is the speed of the pump .

Equation 1 shows the importance of using lines of short length and large diameter (especially the latter), while equation 2 shows how the effectiveness of the vacuum pump is reduced by the connecting tubing, and vice versa. Note that the effective speed is always less than either the pump speed or the line speed, whichever is smaller.

For example, equation 1 shows that tubing whose diameter (D) is $\frac{1}{2}$ inch and length (L) is one foot, will have a limiting speed (S_L) of about 0.83 liters/second. Equation 2 shows that if this same tubing is connected to a pump whose pumping speed (S_P) is 25 liters/second capacity, the effective speed (S) at the end of the line is only 0.80 liters/second, showing the futility of using such a large pump with tubing of this size. On the other hand, if the diameter of the tubing is increased to $2\frac{1}{2}$ inches, the effective speed at the end of the line will be increased to 20.1 liters/second.

When pumping the test object directly into the leak detector, the time response will be determined by the pumping speed of the instrument itself. A Veeco leak detector has a pumping speed of $\frac{1}{2}$ liter per sec with the throttle valve wide open. A CEC leak detector has a pumping speed of 6 liters per second of nitrogen at a pressure of 0.2 microns. Therefore, reasonable time response will result only with volumes up to several liters. However, even on large systems where time is a secondary factor, this method yields maximum sensitivity, since there is no external pump to "rob" the helium.

7. Large Vacuum Systems Testing.

It may be seen from the above discussion that the choice of the size of the vacuum pump will be based on the volume to be tested. For volumes of several hundred liters, adequate time response may be obtained by using very large mechanical pumps. The leak detector is connected to the system near the pump connection, or to the pump line near the system.

However, it is usually better to use an auxiliary high-speed oil-diffusion pump, together with a smaller mechanical pump. In these cases, the location of the leak detector connection depends on the pressure in the system. If the system pressure is below the proper source pressure, the leak detector should be connected to the line between the oil-diffusion pump and the mechanical pump. If the system pressure is above the proper source pressure, the leak detector should be connected to the system near the pump connection; or to the pump line near the system. In both cases, the leak detector throttle valve is used to keep the source pressure at its correct value. If the pressure in the system is as low, or lower, than the leak detector pressure, the auxiliary oil-diffusion pump will get all the helium away from the system. The leak detector will get no helium and leaks cannot be found.

8. Probing Techniques.

a. Probing for a leak in an object under test should proceed from the upper side of objects to the lower. In this way the helium, which rises, will flow back only over areas already tested.

b. When testing individual joints, time may be saved by using a generous flow of helium from a flexible rubber tubing ($\frac{1}{4}$ inch diameter). When a leak is indicated, its exact location can be determined by means of a finer "probe". On the other hand, if there are large leaks in the system, enough helium may enter to saturate the system and the leak detector for a while. If there are many small leaks, diffusion of helium to these small leaks may make leak location difficult. Using a fine probe, the operator can limit narrowly the area covered by helium. The detector output will be a maximum when the probe is directly over the leak.

c. A very large leak will give an indication even when the probe is at some distance from it. To prevent this disturbing occurrence, the leak should be located and then either repaired or temporarily sealed. Vacuum putty may be used for temporary seals.

d. When a point appears to leak, but does not give a consistent response in the detector, a large leak in some other location is to be suspected. The varying leak indication is due to erratic puffs of helium being blown to the large leak.

e. When two possible points of leakage are close to one another, it is sometimes difficult to determine which of them is responsible for a leakage indication. It is then necessary to mask one of them (say, with tape) so as to exclude its possible influence. Using a fine probe and a minimum flow of helium will also help.

f. A number of different types of joints give the same typical leakage indication. The indication is a delayed and slow build-up of the leak signal and then a very slow clean-up. The signal may even stay constant for some time. Such indications are usually due to porosity, flanges

with flat gaskets and rubber tubing joints. This peculiar behavior is due to the great length of the leakage path plus the sotre of helium (at atmospheric pressure) in crevices on the joints. Similar effects are produced by leaks in volumes that are behind constrictions or that are otherwise being pumped slowly.

g. Testing of sub-units before they are incorporated into an assembly or system simplifies testing of the system. Then, only joints between units require investigation.

h. The use of a hood, to determine in one operation the presence or absence of leaks, has already been mentioned.

9. Extreme Importance of Cleanliness.

For best results, the interior of objects to be leak tested should be as clean as possible. In particular, they should be free of water vapor and grease. These materials evaporate in large volume at reduced pressures. This burdens the pumps at the same time that it dilutes the helium that may enter through a leak. This is very important, indeed.

10. Precautions in Vacuum Testing.

a. Before leak testing, be sure that the ion voltage is set at the helium peak, the filament is on, and the throttle valve is open.

b. Don't be fooled into thinking the leak always exists at the spot where the probe is held; the helium deflection may be due to a very large leak some distance away.

c. Never valve off the auxiliary pumps unless the throttle valve is wide open.

d. Be sure to close the throttle valve whenever any change or adjustment is to be made to the test system. This will prevent accidental admission of air to the leak detector. Never open the throttle valve unless the auxiliary pump valve is first opened.

e. Turn FILAMENT switch "OFF" when testing is being suspended for ten minutes or more.

B. Pressure Testing.

1. General. The broad principles of pressure testing have been given in Section I. Variations on the basic method, and some details of procedure require some discussion, however.

2. Probes. A flexible hose, terminating in a nozzle, constitutes the "suction line" required for pressure testing.

The flexible hose is preferably of metal bellows-type construction, but rubber tubing (or better, Neoprene) is frequently used. Whatever the type of flexible hose used, it should be as short as possible.

For some purposes, a specially shaped probe or sniffer may be required. This can be made by appropriately flattening the end of a piece of copper tubing. Needle valves are also of use sometimes, and permit varying the suction through the sniffer. A long needle with slight taper is desirable. The valve must be at the end of the sniffer so that there is no volume between the valve and the point where the sample enters the sniffer.

3. Auxiliary Pump. The leakage through a sniffer is sometimes such that the indrawn air is too large in amount to be handled by the vacuum system of the leak detector. Accordingly, an auxiliary pump is used.

If it is desirable not to use an auxiliary pump, a special sniffer, with smaller leakage, can be used.

A very long rubber connecting hose on the sniffer will necessitate an auxiliary pump, regardless of the use of a special small sniffer. This is the result of the inability of the leak detector pumps to handle the large amount of gas given off the walls of the rubber tubing (outgassing).

The use of a long hose has the further disadvantage of resulting in a long response time, due to the long path which must be traversed before the helium reaches the leak detector. When pressure testing large objects, it is usually preferable to use a short hose and to move the leak detector rather than to use a long hose and a stationary leak detector.

4. Procedure (See Figure 2)

- a. Connect a suitable length of flexible hose to the sniffer.
- b. Connect other end of hose to a tee connection.
- c. Connect second end of tee to the leak detector gas-inlet line.
- d. Connect remaining leg of tee to an auxiliary vacuum pump, preferably through a valve.
- e. Start auxiliary pump. The sniffer will now be sucking a very small amount of air.
- f. Carefully open throttle valve in leak detector until the pressure indication is correct. Turn on filament.

NOTE

Make sure all connections are helium tight.

- g. Proceed to test by passing end of sniffer slowly, over suspected points of leakage.

5. Notes on Probing Technique.

a. As in all leak testing, a non-reproducible indication may be due to a large leak in another location.

b. After "sniffing" in one location, the probe may use up all the helium issuing from a leak there. It will then be necessary to wait until a detectable concentration of helium has built up around the leak.

c. Advantage should be taken of the fact that the tracer gas (helium) will build up in concentration around a leak. In light of this, the test object should be kept out of drafts.

d. The suction through the sniffer is very small. Nevertheless, increased sensitivity is obtained by restricting the slight suction to the neighborhood of the joint under test. This can be done by putting a rubber fitting on the end of the sniffer which will act as a "suction cup" over the leak. In many cases, a small piece of rubber tubing, just long enough to project past the end of the sniffer to form a seal against a test surface, will help considerably.

e. It is essential to have available a known leak to which helium can be applied. With this, the sniffer can be checked for operating efficiency.

6. Sensitivity of Pressure Testing.

Using the "sniffer" method, a helium flow into the atmosphere of about 1×10^{-7} cc/sec. can be readily detected. Such a flow will result in an OUTPUT meter deflection of 2% of full scale at full sensitivity (SENSITIVITY switch at 1). This sensitivity results without resorting to the accumulation techniques mentioned in paragraph 5, above. By using these methods, even greater sensitivity will be obtained.

Fundamentally, however, the sensitivity of pressure testing is not as good as vacuum testing; the ratio being 100 to 1. This is due to the outflowing helium being diluted by the atmospheric air. In vacuum testing, no such dilution occurs.

7. "Pressuring".

The flow through a leak varies roughly as the difference of the squares of the pressures across it. It will be obvious then, that higher pressures of helium within the test object will make possible the detection of smaller leaks.

If it is desired to use several atmospheres pressure of helium, and if the test object is large, considerable helium will be used up in a test. This loss of helium can be avoided by "pressuring up" with some gas such as nitrogen. That is, for instance, one atmosphere of helium might be put in and 10 atmospheres of nitrogen. While this dilutes the helium, the increase in flow rate through the leak more than offsets the dilution.

C. Pressure-Vacuum Testing.

Pressure testing may be combined with vacuum testing in such a way that parts having an internal helium pressure may be tested at the high sensitivity which is inherent to vacuum testing. This may be done by placing the pressurized container inside a bell jar, evacuating the bell jar, and using the leak detector to detect any trace of helium. This has already been discussed in "Bell Jar Testing". Since the helium flowing into the bell jar suffers no dilution, high sensitivity results.

If a leak is indicated during the test, its location may be determined by removing the bell jar, attaching a sniffer connection to the pumping port, and pressure-testing the piece while it is under helium pressure.

The use of the pressure-vacuum method of testing is recommended for leak testing parts having long tubing connections. If such parts were checked by vacuum testing, excessively long response and clean-up times would result, due to the limiting effect of the tubing connection on the effective pumping speed.

Pressure-vacuum testing is also recommended to check pieces which must be back-filled with helium (filled and sealed with helium inside). Since two separate manifolds are used, the back-filling helium does not enter the leak test manifold (except through a leak). In this way, helium contamination of a leak test manifold is avoided.

MEASURING LEAKAGE

In most cases, the size of the smallest detectable leak needs to be known. Otherwise a leakage tests doesn't mean much. Also, it is often necessary to know the total air leakage into system. This knowledge can be obtained only when the vacuum system of leak testing is used.

Two things need to be known to find out the size of the smallest detectable leak, and the system inleakage - the Dynamic Sensitivity of the leak detector system, and the System Sensitivity.

Dynamic Sensitivity of a leak detection set-up is found by connecting a standard leak, or a calibrated leak as shown in Figure 6. Atmospheric pressure helium should be connected to the calibrated leak, if it is used. The leak detector source is held at the same pressure as when connected to the object under test while the system sensitivity is measured. It may take several trials to get the two pressures the same.

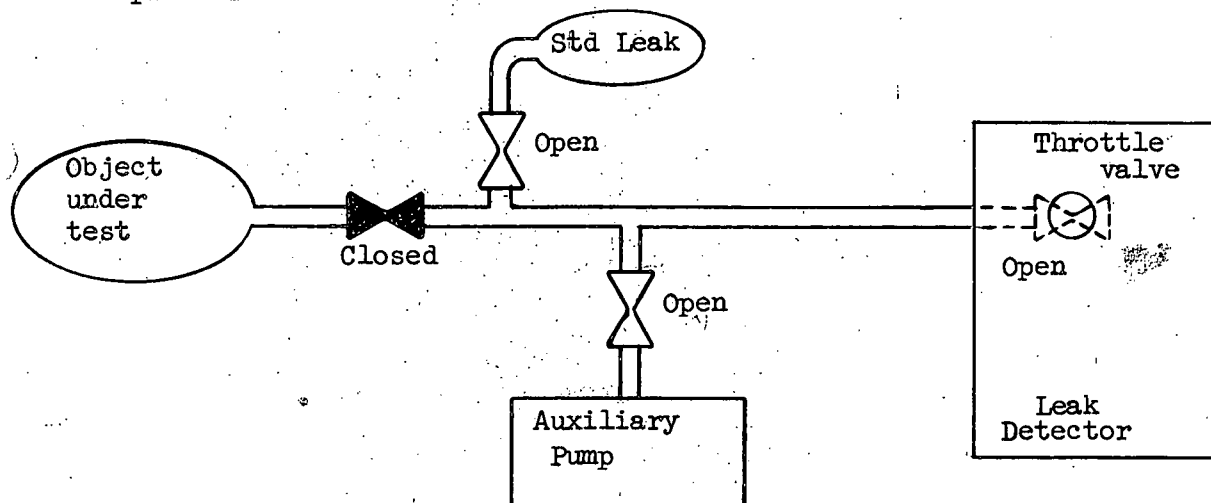


Figure 6.

The leak detector reading divided into the size of the standard, or the calibrated leak, gives the dynamic sensitivity of the leak detection set-up. For example - assume a 1×10^{-5} std cc per sec standard leak is used, and that the leak detector reads 1000 divisions. Then the dynamic sensitivity is $1 \times 10^{-5}/1000 = 1 \times 10^{-8}$ std cc per sec per division. The dynamic sensitivity should not be less than 1×10^{-8} . If it is below this, use a larger standard leak, or a larger calibrated leak, to increase the dynamic sensitivity.

System Sensitivity of a system is found by connecting a standard leak, or a calibrated leak as shown in figure 7, or in figure 8. Atmospheric pressure helium should be connected to the calibrated leak, if it is used. The source pressure is kept at the same value as used to find the dynamic sensitivity by use of the throttle valve or auxiliary pump valve.

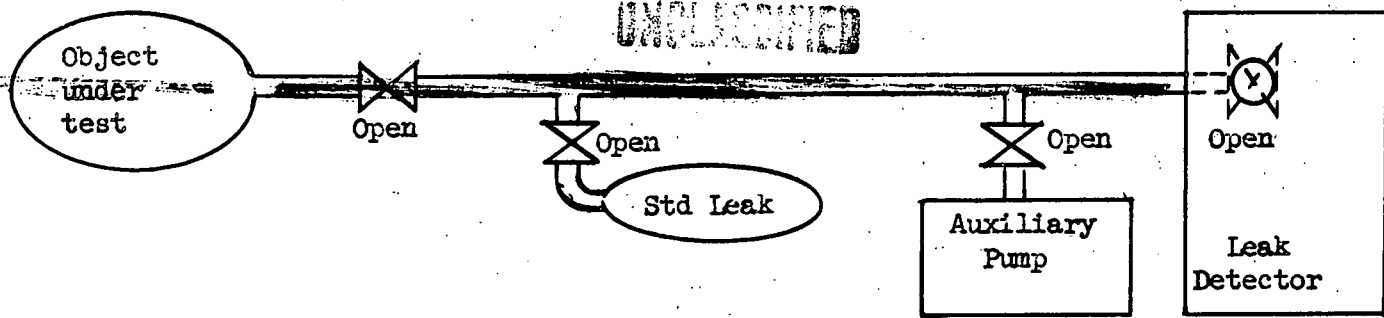


Fig. 7.

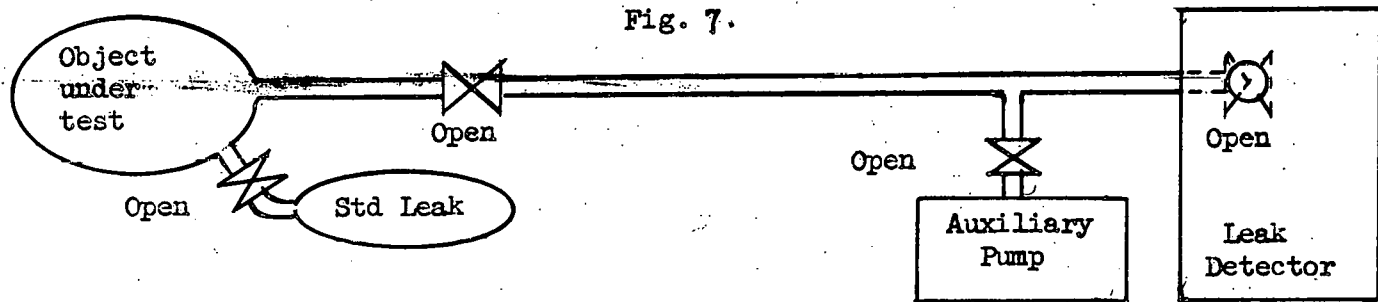


Figure 8.

The leak detector reading divided into the size of the standard leak, or the calibrated leak, gives the system sensitivity of the system under test. For example assume a 1×10^{-5} cc per sec standard leak is used, and that the leak detector reads 100 divisions. Then the system sensitivity is $1 \times 10^{-5}/100 = 1 \times 10^{-7}$ cc per sec per division.

The smallest detectable leak is $2\frac{1}{2}$ times the system sensitivity, or $2.5 \times 1 \times 10^{-7} = 2.5 \times 10^{-7}$ cc per second.

The total leakage into the system is the ratio of system sensitivity to the dynamic sensitivity times the standard leak size, thus $- 1 \times 10^{-7}/1 \times 10^{-8} = 10 \times 1 \times 10^{-5} = 1 \times 10^{-4}$ std cc per sec leakage into the system. This is based on the fact that the only thing that can cause the system sensitivity to be lower than dynamic sensitivity is the air that leaks into the system. If the partial pressure of helium is one-tenth as much when system sensitivity is measured, then there must be 10 times as much air present.

When a leak is flooded with helium from a probe, the output meter will deflect. The size of the leak is directly proportional to the deflection and to the system sensitivity. Assume a reading of 25 divisions when a leak is probed. Then the size of the leak is $25 \times 1 \times 10^{-7} = 2.5 \times 10^{-6}$ std. cc per second.

If leaks are found, and repaired, until the auxiliary pump is no longer needed to hold the pressure in the system down, then the auxiliary-pump valve can be closed. Then the dynamic sensitivity and the system sensitivity can be found under this new condition. The size of the smallest detectable leak is greatly reduced, and a much smaller total inleakage can be measured because all of the helium goes through the source. None is going to the auxiliary pump.

UNCLASSIFIED

OPERATION OF THE CEC 24-102, 24-110 STARTING UP

Close the THROTTLE VALVE and the Hoke ventcock.
Open the PUMP SHUT-OFF-VALVE.
Turn on the FOREPUMP SWITCH.

When the system is pumped down, to 100 microns or less, as indicated by a quiet forepump, turn on the DIFFUSION PUMP SWITCH. Allow 15 minutes for the pump to heat to operating temperature - before the power switch is turned on. Switch the left-hand meter to DIATRON PRESSURE position. Turn on the REGULATED POWER SWITCH. The DIATRON FILAMENT lamp will start flashing after about 30 seconds. The Diatron pressure should drop to less than 0.2 microns within 30 minutes.

If the Diatron pressure is off scale, turn off the REGULATED POWER SWITCH. Operation at high pressure will contaminate the Phillips gage. Check the pressure periodically. The REGULATED POWER SWITCH can be left on when the Diatron pressure is on-scale.

Fill the cold trap about one inch with liquid nitrogen. When the liquid nitrogen has stopped boiling vigorously, fill the cold trap 3/4 full. Do not fill the cold trap full at first. One inch of liquid nitrogen will freeze-out condensibles on the bottom of the trap. This leaves the rest of the trap clean and efficient.

The DIATRON FILAMENT may be turned on when the Diatron pressure is 0.2 microns or less. The Diatron filament lamp should stay on. If it continues to flash, the Diatron is not emitting. See the CEC Operation & Maintenance Manual.

Do not operate the leak detector unless there is plenty of room for air to enter the back. Otherwise the diffusion pump will overheat. Do not let the leak detector touch anything that will cause it to vibrate.

When a leak detector is new, or has not been used for quite some time, it may outgas for several hours. Do not use the leak detector until it is outgassed. The Diatron pressure will be almost zero when outgassed, and with the throttle valve closed.

Do not use the leak detector to rough-out any external apparatus. Use an auxiliary pump. See Figure 7.

UNCLASSIFIED

UNCLASSIFIED

Connect a standard leak as shown in Figure 7. Use a standard leak from 1.5×10^{-8} to 1×10^{-7} std cc per sec in size. Rough out the external piping and tubing with the auxiliary pump.

Slowly open the throttle valve. Slowly close the auxiliary pump valve. Be careful that the Diatron pressure is below 0.2 microns.

With the filament on, and the AMPLIFIER BALANCE knob fully counterclockwise, rotate the ATTENUATOR knob until the meter is just on-scale.

Alternately adjust the ACCELERATOR VOLTAGE and the REPELLOR VOLTAGE for maximum meter deflection.

Adjust the ion current for maximum meter deflection. In no case should the ion current be higher than the red mark on the meter scale.

If the standard leak causes a reading of more than 1000 divisions, decrease the accelerator voltage until the output is 800 to 1000 divisions. Then alternately adjust the AMPLIFIER BALANCE and the PHASE control until the best null is obtained. The null should be less than 30 divisions. Then turn AMPLIFIER BALANCE full counterclockwise. Set voltage for maximum.

Note the output of the leak detector in divisions with throttle and pump valves open, and with auxiliary pump valve closed. Divide this into the size of the standard leak. This gives the sensitivity of the machine. If the sensitivity is less than 4×10^{-10} std cc per sec per division, something is wrong. Expect to get about 1×10^{-10} with a 5886 electrometer tube. These figures do not have any particular correlation with the smallest detectable amount of helium in air. Of course there must be no leaks in the system when this test is made.

LEAK HUNTING

The CEC 24-102 and 24-110 have maximum sensitivity to helium in air when the Diatron pressure is 0.2 microns. The throttle valve, or the pump valves should be used to hold the Diatron at this pressure when leaks are hunted.

Never hunt leaks with the amplifier balance knob at the null point. The machine has no ability to find leaks under this condition. Always rotate the amplifier balance knob counterclockwise from null to give about 50 divisions output with no helium, only air, entering the leak detector, and with the Diatron pressure at 0.2 microns.

SHUTTING DOWN

With the throttle valve closed, and pump valve open, Turn off the Diatron filament, the regulated power switch and the diffusion pump. Let the forepump run until the Diatron flange is cool. Then shut the pump valve. Do not turn off the forepump until the bottom of the diffusion pump is cool enough to touch.

Remove the cold trap flange screws, open the throttle valve, and remove the cold trap. Empty the cold trap and clean the outside with hot water and detergent. Dry the outside thoroughly and put the cold trap in leak detector. If the diffusion pump is cool, shut off the forepump and open the pump valve - the throttle valve is open. Then close both pump and throttle valves.

PRECAUTIONS

Never let the forepump run for any length of time when the pump valve is open, and there is no liquid nitrogen in the cold trap. Oil vapor will contaminate the Diatron and the Phillips gage.

Never let the forepump and the diffusion pump run for any length of time when the pump valve is open, and there is no liquid nitrogen in the cold trap. Oil vapor will back diffuse and contaminate the Diatron and the Phillips gage.

The forepump and the diffusion pump can be left on if the pump valve is kept closed.

Do not let air at a pressure higher than 0.3 microns come in contact with the hot Diatron. Contamination and oxidation result.

Do not let air at a pressure higher than 0.3 microns come in contact with hot diffusion pump oil. The oil will break down.

Do not let the pressure in the diffusion pump get higher than 0.3 microns when the pump is hot. The oil temperature will get too high and the oil will crack.

Use an external cold trap if there is any doubt about the cleanliness of the system under test.

Read instructions for the 24-110 even when using the 24-102. They are more complete.

Modify 24-102's as per CEC Service Bulletin 224.110-16, pages 7A and 8, October 3, 1957.

Substitute a screwdriver adjustment with a locking nut for the accelerator voltage bar knob adjustment.

Modify the peaked amplifier to relocate the gain control. Otherwise the amplifier can become saturated by a large signal and not read full scale. See CEC drawing number D-34047A.