A Rapid Cycle Method for Gross Leak Testing with the Helium Leak Detector

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Abstract—A new noncontaminating dry gas, quantitative test method has been developed that permits gross leak measurements on hermetic packages. It provides rapid testing with a helium leak detector over the leak size range of less than $1 \times 10^{-5}$ to more than 1 atm*cm$^3$/s with a test gas of ~1 percent helium. The present limitation on dry gas procedures results from the rapid depletion of the test gas from the package interior which prevents detection of the larger leaks. The rapid cycle method attacks this limitation by employing either a rapid transfer of the test package or a rapid gas cycling technique for extending the upper range of the helium leak detector procedure. Theoretical relationships have been derived based on viscous flow to correlate the leak detector reading to leak size. Experimental apparatus is described, and test results are given for a test time of about 8 s, a measurement precision of 15-35 percent, and a correlation coefficient between theory and test of better than 0.99. The rapid transfer mode of operation can be implemented readily with any helium leak detector equipped for fast pump-down and high helium flow rate.

1. INTRODUCTION

LEAKAGE in semiconductor device packages is presently detected by a number of methods which employ pressurization with a tracer gas, or fluid, followed by a measurement of the amount of tracer either captured within the packages or flowing out per unit time, or which employ temperature changes to cause internal vapor to expand into an outer fluid bath for bubble production. Testing is generally divided into fine and gross ranges as determined by the capabilities of available instrumentation and by the nature of the gas transport regime. Because of the nature of test equipment, fine leaks can be detected quantitatively with a firm theoretical basis for relating measured leakage rate to real leak size [1], yet the correlation between fine leak size and device failure rate is not definitive [2]. In contrast, the correlation between the gross leak size $>1 \times 10^{-5}$ atm * cm$^3$/s and failure rate is definitive, but the hermetic test methods currently in use for this range are far from satisfactory.1 These gross leak test methods suffer one or more disadvantages such as narrow test range, which leads to undetected leaks between the fine and gross ranges, low detection efficiency, nondetection of very large leaks and porosities, use of potentially contaminating fluids that accelerate failure of leaky devices missed in the tests, subjective rather than quantitative interpretation, rejection of good packages, and lack of precise mathematical relationship between measured leak rate and true leak size [3]. A new, noncontaminating dry gas, quantitative test method has been formulated to obviate these problems and is intended for rapid testing over the leak size range of $<1 \times 10^{-5}$ atm * cm$^3$/s to $>1$ atm * cm$^3$/s.

The major factor which has limited the use of dry gas procedures for the gross leak range is the relatively long time that it takes to transfer the test part from the pressurization chamber to the tracer gas detector, during which dwell time the gas is lost from the package interior with consequent non-detection of large leaks. The method described below attacks this problem directly by employing either a rapid transfer of the test specimen or a rapid gas cycling technique for extending the upper range of the helium leak detector procedure (and presumably the radioisotope procedure) by effectively reducing the delay between the back pressurization and detection phases. There are several additional objectives for the process.

1 Although the SI system of metric units is now preferred, present engineering practice uses units of atm * cm$^3$/s for leak rate and lb/in$^2$ for pressures near or greater than 1 atm. Conversion factors are $1 \text{Pa} = 1.01325 \times 10^5 \text{Pa}$, $1 \text{lb/in}^2 = 9.869 \text{atm} * \text{cm}^3/\text{s}$, and $1 \text{std atm} = 1.01325 \times 10^5 \text{Pa}$.

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dure. One is to tailor the environmental conditions during the test so that a quantitative relationship holds between true and measured leak value, the second is to achieve a high rate of testing, and the third is for a method suitable for automation.

II. THEORY

Two modes of operation have been employed. One mode copies the normal procedure of separating the pressurization and detection phases, but utilizes a small pressurization chamber in close proximity to the test chamber along with a rapid transfer of the test specimen between the chambers. The second mode of operation utilizes a single test chamber for both pressurization and detection along with rapid gas handling procedures for appropriate conditioning.

A. Two-Chamber Procedure

For the two-chamber mode of operation, the specimen (singly or in batches) is pressurized in a small chamber, such as I in Fig. 1, with a test gas mixture containing a fraction of helium, e.g., 1 percent, for a period of time of the order of 1–2 s. The chamber is vented and simultaneously flushed with dry air or nitrogen for ~0.2 s. The chamber is opened and the specimen(s) quickly transferred within a fraction of a second to the second small detection chamber which is ancillary to the helium leak detector. This second chamber is evacuated as rapidly as possible and then ported into the leak detector.

To relate the consequent leak detector reading $R$ to the leak size $L$ of the test package, one must know the gas pressure within the package at the time of measurement, the gas flow mechanism, and the helium partial pressure in order to determine the flow rate back through the leak channel into the leak detector. Since the test is concerned with the measurement of gross leaks, the assumption is made that the passage of gas through the leak channel is essentially described by laminar viscous flow. This is surely the case during pressurization [4], is probably the case for leakage to atmosphere during the transfer provided the interval is short, and is surely appropriate during a short pump-down and detection phase. The flow rate through a leak channel is then determined by the square of the pressure, the cross sectional shape and dimension, the channel length, and the viscosity of the gas [5].

At any instant the interior pressure $P$ is given by

$$\frac{dP}{dt} = \frac{K}{V} (p^2 - P^2),$$

where $V$ is the interior volume open to gas collection, $K$ is the factor dependent on geometry and gas viscosity, and $P$ is the exterior pressure. Since the leak size $L$ is defined as the flow rate through a channel with one standard atmosphere of air upstream and zero pressure downstream,

$$K = \frac{L}{P_0^2},$$

where $P_0$ represents one std atm pressure [6]. Equation (1) is then applied and integrated for each step in the process in order to determine the interior pressure at the end of each step. The partial pressure of helium is determined at the end of each step from the pressure changes. As a result, the flow rate $R$ of helium from the specimen to the leak detector system is

$$R = \frac{n}{V} \left( \frac{\alpha \gamma - 1}{\alpha \gamma} \right) \left( \frac{\delta}{\gamma} \right)^2 \frac{P_0}{2\tau},$$

which is expressed in terms of a time constant $\tau = V P_0 / 2 L$, rather than just $L$, in order to derive a single expression for each set of pressurization and time parameters for all volumes. In (3), $n$ is the fractional pressure of helium in the test gas mixture, $\alpha = P_1 / P_0$, $P_1$ is the test gas pressurization value,

$$\gamma = \frac{P_1}{P_t} = \frac{1 - \frac{\alpha - 1}{\alpha + 1} \exp \left( -\frac{\alpha T}{\tau} \right)}{1 - \frac{\alpha - 1}{\alpha + 1} \exp \left( -\frac{\alpha T}{\tau} \right)},$$

$P_1$ is the peak interior pressure following pressurization, $T$ is the duration of pressurization,

$$\xi = \frac{P_2}{P_0} = \frac{1 - \frac{1 - \alpha \gamma}{1 + \alpha \gamma} \exp \left( -\frac{t - \tau}{\tau} \right)}{1 + \frac{1 - \alpha \gamma}{1 + \alpha \gamma} \exp \left( -\frac{t - \tau}{\tau} \right)},$$

where $P_2$ is the interior pressure at the end of the transfer period, $t$ is the time required to vent and transfer the specimen, and

$$\frac{P_3}{P_2} = \frac{1}{1 + \frac{\xi}{\tau} t'},$$

where $t'$ is that time interval from beginning of exhaust to leak detector reading, and $P_3$ is the interior pressure when the leak detector reading is made. The actual leak detector output signal would be conditioned further by inlet constrictions and bypasses, which effect would be measured by calibration procedures.

Numerical values can be derived readily from (3) with a programmable calculator or computer. Expected results for $R/V$ are illustrated by the curves in Fig. 2 which are drawn for two conditions relevant to the test results given later in Section IV. For these characteristics the fractional helium con-
Fig. 2. Two-chamber mode. Predicted helium leakage rate per unit interior volume versus reciprocal time constant, $1/\tau = 2L/P_{0}V$. $a = 3$, $T = 3$ s, $n = 1$, $t = 2.2$ s. (a) $t' = 4.3$ s. (b) $t' = 20$ s. Data points are average values uncorrected for variations in $V$, $\alpha$, $t'$. mdv: minimum detectable value. 12 specimens with directly measured leak sizes are represented.

The interval $n$ was set to 1. Each value of $R/V$ corresponds to two possible values of $1/\tau$ and hence two possible values of $L$. The correct choice can be determined from the falloff in the leak detector signal which is proportionately more rapid for the larger value of $L$. The expected decrease in signal can be determined by solving (3) for the two possible values of $1/\tau$ for longer values of $t'$ and hence values of $\delta$ from (6) to be inserted into (3).

B. One-Chamber Procedure

Where both the pressurization and detection functions are carried out in a single chamber, e.g., chamber II of Fig. 1, the primary task is to reduce the helium concentration in the ambient around the specimen to a low enough value that the helium leaking from the package itself is not masked by the background. A simple evacuation of the chamber is not sufficient, so a dilution phase has been incorporated to accomplish this. Processing takes place in four rapid steps. The test gas mixture is introduced into the chamber to the desired pressure for the 1-2-s period. The chamber is then vented and evacuated in a continuous sequence of about 0.75-s duration to reduce the ambient gas pressure. Dry air (or nitrogen) is then introduced under pressure to dilute the residual helium within about 0.2 s. The chamber is once again vented, evacuated, and finally ported into the leak detector, all within a few seconds.

Again, the intervals are kept short and the exterior pressures are so controlled that laminar viscous flow is applicable. Equation (1) is applied sequentially to the four phases of pressurization, evacuation, dilution, and final evacuation. The resultant relationship for the helium flow rate $R$ is

$$\frac{R}{\nu} = n(\alpha_1\gamma_1 - 1)(\alpha_2\gamma_2\delta_1\delta_2^2)\frac{P_0}{2\tau},$$

where $\alpha_1 = P_t/P_0$, $\alpha_2 = P_n/P_0$, $P_n$ is the dilution pressurization value, $\gamma_1$ is defined by (4),

$$\delta_1 = \frac{P_2}{P_1} = \frac{1}{1 + \frac{\alpha_1\gamma_1}{t_1}},$$

$t_1$ is the time required for venting and evacuation following the first pressurization phase,

$$\gamma_2 = \frac{P_3}{P_n} = \frac{1 - \frac{\alpha_1\gamma_1\delta_1}{\alpha_2}}{1 + \frac{\alpha_1\gamma_1\delta_1}{\alpha_2}} \exp\left(-\alpha_2 T_2/\tau\right).$$

$P_3$ is the resultant interior pressure following pressurization with air to an amount $P_n$, and $T_2$ is the recharging time,

$$\delta_2 = \frac{P_4}{P_3} = \frac{1}{1 + \frac{\alpha_2\gamma_2}{t_2}},$$

where $P_4$ is the interior pressure when the leak detector is read, and $t_2$ is the time required for the last evacuation and readout. Illustrative results for $R/V$ are shown in Fig. 3 for conditions similar to those used to derive the curves in Fig. 2.

III. EXPERIMENTAL

A. Apparatus

The vacuum-gas handling system that was used to test the feasibility of both modes of operation is shown schematically in Fig. 4; standard symbols [7] are used to indicate the components.

All valves were electrically or pneumatically driven and commercially available. Most were packing sealed; some were bellows sealed. Those valves directly connected to chamber II were so oriented that only the area of the seals faced into the chamber in order to minimize exposure of elastomers and to reduce added volume. Valves 5 and 7 as larger bore bellows-sealed vacuum valves required simple modification of the sealing disk to remain vacuum tight under the pressurization phases of the single-chamber mode. Valve FL was a simple metering device. Valve operation was under automatic control. Following the signal for start of test, timing circuits stepped a multiplexer which activated optocoupled relays for operation of each valve in the appropriate sequence and combination.

Chambers I and II were of nominal 100-cm$^3$ volume, while ballast tanks $B_1$ and $B_2$ were of 10-l volume. The mechanical pump had a rated free air displacement of 160 l/min (5.6
Fig. 3. One-chamber mode. Predicted helium leakage rate per unit interior volume versus reciprocal time constant, $1/r = 2L/P_0 V$. $\alpha_1 = \alpha_2 = 3$, $T = 2$ s, $n = 1$, $t_1 = 0.8$ s, $T_2 = 0.2$ s. (a) $r_2 = 6.2$ s. (b) $r_2 = 20$ s. Data points are average values uncorrected for variations in $V$, $\alpha$, $t_2$, $mdv$: minimum detectable value. 12 specimens with directly measured leak sizes are presented.

Fig. 4. Rapid cycle apparatus—schematic. Two-chamber mode: I for pressurization and flush, II for fast evacuation and detection, valves 1 and 2 inoperative. One-chamber mode: all functions in chamber II.

During the interval that chamber I was vented and flushed, an alarm sounded. A 2-s period was then allowed for the first chamber to be opened, the specimen to be taken from that chamber, the specimen to be deposited in the second chamber, and the second chamber to be closed. At the end of the 2-s interval, the sequence was automatically continued. Evacuation was then accomplished quickly by a cascaded expansion into the ballast tanks followed by continued pump-down from that resultant low pressure. For this, the chamber II atmosphere was first expanded into $B_1$ through valve 6 for an immediate reduction in pressure by a factor of 100 to ~8 torr within 0.75 s. Valve 6 was closed and valve 8 was opened for a second sequential pressure reduction by a factor of 100 from ~8 torr to ~80 mtorr within an additional 1.5 s. After closure of valve 8, valve 7 was opened for a continued pump-down of about two more seconds, until the ambient pressure was ~25 mtorr. Then valve 4 opened to provide a path directly to the leak detector spectrometer section through FL. In this last step, FL and the pump-out line through V7 served as a flow divider to reduce the helium input to the leak detector. The total time for this entire procedure was only ~6 s with an evacuation phase of ~4 s. In contrast, the normal pump-down time for the particular leak detector with a small chamber directly on the inlet port was ~18 s.

In the single-chamber mode of operation, the pressurization phase was simply carried out in chamber II for 1-2 s. The chamber was then vented to atmosphere and sequentially expanded into $B_1$ within ~0.75 s to a pressure of ~8 torr. The chamber was then pressurized with nitrogen (or air) which reduced the helium concentration to one part per 100 $\cdot$ $\alpha$ of its initial value, where $\alpha$ is the nitrogen pressure in atmospheres. Venting to atmosphere, expansion into $B_2$, and continued pump-down for ~5 s to <30 mtorr then resulted in a total reduction from the original helium pressure by a factor of ~$10^7$ within some 7 s.

B. Test Specimens

The ends of short sections of clean, 3-mm bore, heavywalled glass tubing were flamed and drawn down to form ca-
pillary channels. These channels were snapped in the center and roughly graded for leak size by microscopic examination. Any debris in or at the interior throat of the channel was cause for rejection. The remaining leaks were measured by a rate-of-rise (and fall) procedure which utilized a precision volume, capacitance diaphragm manometer, and controlled pressure upstream [8]. These calibrated leaks were then coded. Their leak sizes ranged from \(5 \times 10^{-6} \text{ atm \cdot cm}^3/\text{s}\) to more than \(1.5 \text{ atm \cdot cm}^3/\text{s}\), the upper limit of the calibration equipment. Two had values larger than the equipment measurement capability. Repeatability of measurement with a number of samples was of the order of one percent and uncertainty of measurement for the specimens was estimated as less than three percent. Four of the leak structures were set aside as reference leaks, and the remainder were sealed off to form capsules with a nominal interior volume of \(0.2 \text{ cm}^3\). Some 14 specimens then survived a repeated microscopic examination of capillary channels for debris. Individual interior volumes were estimated from the average bore diameter of the original tubing and from the measurement of interior cavity length. Fig. 6 is a photograph of the test specimens.

C. Operational Characteristics

There are two constraints on the amount of gas allowed into the leak detector. The first is that the total flow must be small enough to keep the high vacuum of the spectrometer section within its operational range. The second is that the flow of tracer gas must be so regulated that the leak detector signal remains on scale, provided numerical values are desired. These adjustments are made during operation with the regulating valve FL (see Fig. 4) first with the chambers empty and then with a few leaky packages. Once adjusted, FL may be locked in position.

When the system is initially activated on empty chambers and in the single-chamber mode with no tracer gas, the leak detector signal may not change significantly when valve 4 in Fig. 4 opens to tie chamber II to the leak detector. As specimens are examined with the two-chamber mode, or when tracer gas is admitted in the single-chamber mode, the leak detector signal will show a baseline behavior due to residual helium in the mechanical pump and lines as well as from additional desorption from the elastomer seals in the single-chamber mode. Typical baseline behavior as derived from recorded output is as shown in part (a) of Fig. 7 and 8 for both modes.

The leak detector signal with a leaky package is determined by the leak detector response time, the flow rate from the package, falloff of flow rate, and the length of time valve 4 is open. Typical signals are shown in Figs. 7(b) and 8(b). It is to be noted, for example in Fig. 8, that the peak signal was obtained 18 s after initiation of the test, whereas the actual test sequence from start to the time voltage was applied to valve 4 was set at 9.2 s (8.5 s for two-chamber mode). The response time for the particular leak detector itself was \(\approx 2 \text{ s}\) [9]; therefore, the time expected to reach \(\approx 99\) percent of signal amplitude for a constant input would be some 10 time constants.

Following a test sequence, the apparatus has to be conditioned for the next test. This comprises pump-down of the ballast tanks. For the single-chamber mode of operation, this required evacuation from \(\approx 8 \text{ torr}\) to the preset value established. If the pump-down was to 0.1 torr, 20 s were required for each tank. If the pump-down was limited to 1 torr in the ballast tank, which does not affect the expansion ratio significantly, pump-down for each tank was then reduced to 8 s. Thus conditioning required 16 s for the single-chamber mode with the apparatus used. In the two-chamber mode, the pump-down sequence was first for \(B_2\) from \(\approx 0.1 \text{ torr}\) to 20 mtorr in 16 s, followed by \(B_1\) from \(\approx 9 \text{ torr}\) to 1 torr in 8 s for 24 s total.

D. Calibration

Calibration of the system comprised periodic tuning of the leak detector with a permeation type standard leak [9] and calibration of the whole system with the measured reference capillary leaks at each test run.

For calibration of the test apparatus, a reference capillary leak was mounted on chamber II and flooded with the test gas mixture. A normal test sequence was applied, and the system was held at the detection step until the signal came to steady state. At least two reference leaks of different value were used for each calibration. A "gauge factor" was then deter-
mined as the ratio of the reference leak size to the leak detector output; the exact helium concentration in the test gas mixture is not a factor in the measurements as long as the same supply is used for both test and calibration. The flow rate from the test specimen is then

$$R = GF \times (S - S_h),$$

where $S$ is the leak detector signal, $S_h$ is the baseline value, and $GF$ is the gauge factor.

Gauge factors with a test gas mixture of five percent helium were $2.5 - 3.8 \times 10^2$ atm $\cdot$ cm$^3$/s for the two-chamber mode depending on FL setting, and $2.5 - 4.5 \times 10^4$ atm $\cdot$ cm$^3$/s for the single-chamber mode; i.e., FL was set for smaller flow with the single-chamber mode in order to reduce the larger baseline signal due to residual helium and desorption.

**IV. RESULTS**

The 14 specimens were subjected to nine measurement runs for the two-chamber mode and to ten runs for the single-chamber mode. Each run consisted of a calibration of the system against the reference capillary leaks, measurement of all samples randomly selected, empty chamber measurements before, during, and at the end, and a post-conditioning of specimens for 1 h under vacuum, followed by exposure to dry nitrogen for 1 h. The leak detector itself was also tuned occasionally to a reference permeation leak. The gauge factor was derived for each run. The measured value for each specimen was taken as the leak detector peak signal less the base height as derived from the empty chamber measurements. During any one run, the base height remained constant to $\pm 10$ percent.

Average values and calculated standard deviations indicated precisions for both modes of operation to have a two estimated standard deviation (95 percent confidence level) variation of $\pm 15$ percent for the two-chamber mode and $\pm 35$ percent for the single-chamber mode. These imprecisions include all variations in both reference and specimen leaks, test dynamic pressures, valve operational times, etc.

The $R$ values were calculated from (11). Results are displayed as data points in Figs. 2 and 3 where the $R/V$ values represent the ratios of the average $R$ value measured for each specimen to the nominal $V$ value of 0.2 cm$^3$. The time constant values were derived from the leak sizes originally measured for each specimen and the nominal $V$ value of 0.2 cm$^3$.

Although 14 specimens were represented in the determination of precision, only the 12 for which the original leak sizes could be measured are represented here. The minimum detectable value represented for each mode was derived from the product of the average baseline value and the gauge factor as in (11) with values of $1.1 \times 10^{-4}$ atm $\cdot$ s$^{-1}$ for the single-chamber mode and $1.3 \times 10^{-6}$ atm $\cdot$ s$^{-1}$ for the two-chamber mode. The narrower test range of the single-chamber mode reflects the increased baseline level due to sorption and residual helium, as well as the effect of multiple pressurizations and expansions.

When values for $R/V$ calculated according to (3) were corrected for actual dwell times as affected by leak detector response, the estimated volume for each specimen, and the measured static pressures off the gas sources, the comparison of theory to experiment gave the result as indicated in Fig. 9 for the two-chamber mode. For this comparison, the estimated rather than the nominal volume for each specimen was used in determining the experimental $R/V$ values. Each point, again, is the average value for nine measurements. A regression line fit for

$$\log R/V (\text{theory}) = a + b \log R/V (\text{experiment})$$

resulted in values of $a = 0.068$, $b = 0.986$, and $r = 0.998$, where $r$ is the correlation coefficient for those points on the main sequence for leak sizes originally measured as $10^{-4} - 10^{-1}$ atm $\cdot$ cm$^3$/s. For both modes, the signals (and corresponding $R/V$ values for the specimens at the extremes) were larger than expected from theory. The results are shown as rectangular data points in Figs. 2, 3, and 9. The specimens have the same relative positions in each figure. In the case of the larger leaks, originally measured as $\sim 1$ atm $\cdot$ cm$^3$/s ($1/r \sim 10$ s$^{-1}$), microscopic examination of the capillary channels evidenced some irregularities. Presumably, such irregularities
would cause the actual leak size to be smaller than originally measured. The smaller leaks, originally measured as \( \sim 10^{-5} \text{ atm} \cdot \text{cm}^3/\text{s} \), would have to be larger than originally measured to fit the theoretical curve. Further experimentation is required for the extreme values to resolve these discrepancies.

V. TEST APPLICATION

As described above, these methods were evaluated as measurement procedures in order to derive precision and to test the validity of the theoretical model. For this evaluation, the detection interval of the test sequence had to be prolonged until a peak reading was obtained from the leak detector. When used as a screening procedure, however, this delay would be eliminated, and the test sequence could be held to the programmed intervals, for the leak detector signal would rise to a preset rejection level within a fraction of its response time for any leak well above the minimum detectable value.

The effect of package volume on the leak size test range can be seen directly in the characteristics of Figs. 2 and 3. As the package volume increases, the test range is moved to larger leak sizes. For example, with the present exploratory apparatus, a minimum detectable value for \( R/V \) of \( \sim 1 \times 10^{-6} \text{ atm} \cdot \text{s} \) for the two-chamber mode predicts a test range for the 0.2-cm\(^2\) volume of \( 5 \times 10^{-5} \text{ atm} \cdot \text{cm}^3/\text{s} \) to \( > 10 \text{ atm} \cdot \text{cm}^3/\text{s} \), whereas a volume of 0.01 cm\(^3\) would shift the predicted range to a span of \( 2.5 \times 10^{-5} \text{ atm} \cdot \text{cm}^3/\text{s} \) to \( > 0.5 \text{ atm} \cdot \text{cm}^3/\text{s} \). The characteristics for the single-chamber mode predict a range in leak size about two decades less than the two-chamber mode because of the larger background signal (\( \sim 1 \times 10^{-4} \text{ atm/s} \)). If this background were lower by reducing sorption effects and residual helium, the results would be comparable.

The shift in test range with volume is in the same direction as in the fine leak tests, and, therefore, there is a natural complement. That is, as volume increases, the fine leak test range shifts to larger leak size so that the overlap in test ranges would be maintained [10]. The characteristics in Figs. 2 and 3 were derived on the basis of \( \sim 30 \text{ psig} \) (\( \sim 3 \text{ atm abs.} \)) pressurization. The small leak size range can be extended to smaller values by increasing the test pressures. The larger leak size test range can be extended to larger values by decreasing dwell time.

A further advantage of a dry gas test is that the gross and fine leak tests may be done in a natural order. Since present gross leak tests, e.g., those in MIL STD 883B, require exposure to liquids which can plug fine leaks, the fine leak test must be carried out first [10]. With a dry gas procedure, the gross leak test may be carried out first, and with extension to a lower limit by increased pressurization time and/or pressure, this may be sufficient for hybrid packages.

Test times could be reduced further over those obtained with the experimental apparatus by increasing the capacity of the mechanical pump and by increasing the conductance of the lines to the expansion tanks through valves 6 and 8 in Fig. 4. At present, these valves are small, pneumatically operated units with \( \frac{1}{8} \)-in diameter orifices.

The apparatus as described produces an evacuation interval in chamber II for the two-mode procedure of \( \sim 4.3 \text{ s} \) which could be reduced further. However, helium leak detectors are now available with 6-s pump-down times and with facility to range to high helium input rates so that the two-chamber mode could be employed with the simple addition of chamber I to off-the-shelf instrumentation. Fig. 2 indicates that the small increase in dwell time would not cause any severe degradation in test range.

The single-chamber mode of operation is attractive for the simplicity of handling, but to be feasible it requires further modification to reduce the effect of sorbed and residual helium.

Present confirmation of this test method has been derived with capillary leaks. Some further testing is needed with leak sizes at the extremes and with the types of leakage found in real packages, e.g., porosities, cracks, etc.

VI. CONCLUSION

The range of the dry gas, back pressurization method of hermetic testing can be extended to cover the gross leak range by a systematic reduction in the dwell time required between the pressurization phase and the leak detection phase. A gas transport model based upon laminar viscous flow is appropriate for deriving the numerical relationship between the measured helium flow rate and the leak size for short test times and large pressure differentials. Implementation of the test method for optimum results requires ancillary apparatus to the leak detector. The apparatus can be constructed from commercially available components. Implementation of the method with some decrease in test range can be made readily with minor addition to off-the-shelf commercially available leak detectors equipped for fast pump-down and high helium input rates.

REFERENCES


