As military spending increases, and commercial electronics product quality becomes more and more competitive, the demands of proof of quality is not just a contractual way of life. There have been many tests developed over the past few decades for the purpose of providing the credibility of a device. One of the major weaknesses of a device is the "Hermeticity" of the package. There are endless causes for package leakage, many of which are poorly understood by the engineers who create the tests to isolate them. The authors have studied seal leakage problems for many years, and found the primary cause to be handling damage. Not just people handling, but handling devices, or automatic manipulation systems. Due to this damage problem, both manufacturers and users are required to test for leakage, generally as close to the last handling step as possible.

The above knowledge, plus considerable data showing system failures to be the result of leaking devices, there seem to be more and more developments of leak test methods to check for hermeticity. As a result, the Military Standards have offered us an oversupply of leak test methods, many of which have been expanded and subdivided over the past few years, based upon a minimum of research and engineering study. Most of the methods have a very specific area of application, and must be looked at carefully by the component purchaser, (who usually defines the test he wants under contract)

The bell distribution curve presented in Figure 1 was developed based upon data from several million devices which were leak tested for gross and fine leaks using radioactive Krypton 85 gas, and then, in most cases, subjected to engineering analyses to characterize the leakage mechanism. When looking at various test methods available to us, we must note that the studies used to plot Figure 1 identified certain characteristics of a leaking part which make it undetectable by the bubble or helium method. The shaded area identifies leakage known as "Molecular Flow". This generally includes fine porosity leakage, with holes too small to produce a bubble in times short of several hours or days, but with total leakage so large the helium is lost before the mass spectrometer can make a reading. The data has also shown that most of the leakers are leaking at leak rates greater than $1 \times 10^{-7}$ atm cm$^3$/s. This paper will cover the theory and application of leak testing devices using the Kr$^{85}$ method with the Radiflo system.
Radiflo Pressurization

The devices are pressurized using the Radiflo pressurization system, as shown in Figure 2. The devices are placed in the test tank and air is evacuated out of the tank to prevent dilution of the Kr$^{85}$/N$_2$ mixture of working gas. The devices are then pressurized with Kr$^{85}$/N$_2$ mixture for a few minutes to allow some of the mixture to enter the leaking devices. The working gas is then returned to storage and the tank vented to air. The devices are removed and scanned for any Kr$^{85}$ which was left within a part (The scanning techniques will be covered later). The touch screen control panel in Figure 3 directly displays amount and concentration of the working gas in the machine, which, in the equipment shown is automatically sampled and displayed every cycle. These values are used to program the pressurization parameters in accordance with the Mil-Stds. The test conditions are based upon the amount of time required to allow a detectable quantity of Kr$^{85}$ to enter through a leak.

Sensitivity

A great misnomer in the leak test game is the "sensitivity" of a leak detector. More correctly put, it is the "Detectability" of the tracer gas which is important. For example, a device filled with N$_2$ in manufacture will be pressurized with helium to introduce 10 percent He into the device if it is leaking, so that it may be detectable at the mass spectrometer. That will take from a few hours to many days if properly done, and will introduce some $10^{18}$ to $10^{19}$ molecules of helium into the part. To contrast this with Kr$^{85}$ the detectability is generally for $10^{11}$ molecules of Kr$^{85}$ gas within the part, or one ten millionth of the standard helium requirement. Thus, the bombing time with Kr$^{85}$ is tremendously reduced to times of ten to fifteen minutes for a $1 \times 10^{-8}$ atm cm$^3$/s test, (even with concentrations of only 0.01 percent Kr$^{85}$). This short bombing requirement has been the key to performing leak tests to sensitivities of $10^{-10}$ or $10^{-11}$ atm-cm$^3$/s in production applications. The actual measurement for Kr$^{85}$ is a reading of the number of molecules trapped within the device. In addition, the isotope represents one part in ten million parts of the parent gas within the device, and therefore is little effected by leakage back out of the part. In the helium case, The mass spectrometer readout assumes 10% helium for accurate measurement. Any less than 10% helium inside the devices will result in an erroneous reading of the leak rate resulting in an order of magnitude error.

Reading Devices

Devices which have been through the Radiflo are taken to a Counting Station for sorting of the rejects which contain a measurable quantity of Kr$^{85}$ gas. In manual testing, the devices are pressurized in baskets for bulk testing or individual fixtures. The devices are then removed from the basket or fixtures and placed in a 2 inch diameter static free tube which is then inserted into a "Well" counter, as shown in Figure 5. Devices can be tested individually or in groups. The Kr$^{85}$ gas gives off gamma rays which pass through the wall of the part, and are detected by the crystal. A photomultiplier tube reads
the crystal ionization and transmits a signal to a Ratemeter. Normally, an operator would hand count 7,000 to 8,000 units per hour with a good quality lot. Figure 6 shows a manual or "Bulk" testing station with a Well crystal, and a square "Flat Top" crystal used to test some of the more recently developed larger packages (Fig. 7).

When devices are being tested in automatic counting stations, they are passed through a detector crystal on a conveyor belt. The detection of the Kr$^{85}$ is easily accomplished in a tenth of a second. The speed of measurement which has been developed, allows the devices to read individually at a rate of 2 devices per second. thus making the large or gross leakers easily detected. Figure 4 shows an automatic counting station. Typically this type of parts handling counting station tests 5 million devices per month. This test is performing both gross and fine leak test.

Gross leak testing with radioactive gas requires very fast cycling of the Radiflo to return the gas to storage. Many studies have been performed to demonstrate that a gross leak, whether viscous or molecular flow, is very reliably detected by the radioisotope method, as long as the gas recovery is quick, and counting is within 5-10 minutes. The gross / fine test combination requires nothing different in the way of equipment. Only the bombing time is extended to allow the Kr$^{85}$ entry through a smaller or fine leak. Studies have shown less than a tenth of an order of magnitude deviation on hundreds of data points taken at numerous facilities, when Radiflo leak testing the same gross and fine leakers. For such data to be of value, the non-leakers must be tested by whatever method is necessary to confirm no escapes were allowed. In the studies conducted by IsoVac Engineering, the devices were all destructively checked using Red Dye. All devices were bombed at 90 PSI for one hour while immersed in the dye, then removed, acetone washed, and the lids removed to examine for dye in the chip cavity. No nondestructive tests are available to provide absolute proof.

Another major advantage of the Kr$^{85}$ method is the ability to avoid the false rejections so common to other methods. Kr$^{85}$ gives off two types of radiation, gamma rays, which pass through the walls of the devices Figure 8, and beta particles (which are completely stopped by the walls of the device.) The Beta particles provide a method of detecting gas which is trapped on the surface of a part. False rejects from helium testing are a very common problem, especially when the devices have been stripped and re-plated. The stripping etches the glass seal line and produces a very porous surface which stores excessive amounts of the tracer gas. This is a problem since the helium test requires 100% pure helium bombing for long periods. In contrast, the Kr$^{85}$ is usually 0.01 percent Kr$^{85}$ /N$_2$ concentration, and the bomb times are very short. Problems from labeling inks and finger oils are minimal with Kr$^{85}$ testing.
Safety

It is well realized that the tracer gas is radioactive, and thus must be handled with care. The Radiflo includes: closed loop plumbing, special detectors, and lead shielding of the tanks to protect the operators. Safety considerations with the Kr$_{85}$ process involves the licensing of the equipment to handle an isotope, the control of the area where the equipment is used, the training of the people to operate the machine, and the control of reject devices. There are proven advantages to come from these requirements:

♦ The licensing requires that only trained people to perform the process.

♦ The control of the area certainly helps keep the equipment under better management.

♦ The training of the people to operate the equipment assures that the process is properly applied, with extensive training by the equipment manufacturers. It further prevents untrained and unqualified people from performing the leak test.

Absolute Confirmation

The only way that a leaking device may be nondestructively confirmed for fine leak rate, is through the use of an isotope as a "tracer". With Kr$_{85}$ gas this is quite easily performed, and thus used in engineering efforts to resolve correlation disputes, or to establish the true leak rate for leakers. Following the Kr$_{85}$ leak test, a leaking device is read quantitatively for the Kr$_{85}$ content. The device is then placed in vacuum overnight, removed and measured for Kr$_{85}$ content. The number of molecules of Kr$_{85}$ within the part is an absolute confirmation of the gas which entered the part. The 24 hour measurement is valid for the amount of gas which has leaked out of the part. The actual reading is proportional to the partial pressure of the Kr$_{85}$ within the part. Reading the part as many times as desired will provide a "Decay" curve for the gas loss, which may be plotted using the following equation:

$$P_t = P_o e^{-kt}$$

Where: $P_t$ = partial pressure of Kr$_{85}$ at time t.  
$P_o$ = original Kr$_{85}$ partial pressure  
$k$ = leak rate / vol. of cavity  
$t$ = time

A plot of this data on semi-log paper provides very accurate readouts for future devices to be quickly compared to, and provide projections of time to lose Kr$_{85}$. Figure 9 shows a plot of such a decay curve. Using these absolute leak rates also provides a method to correlate with the helium fine leak test. The helium leakage from a fine leaker is 4.7 times that of the Kr$_{85}$ leak rate due to the lesser helium "Mass". Therefore, using the absolute Kr$_{85}$ leak rates, and multiplying by 4.7, the proper helium leak rate is found which should then be put into the helium equation in the MIL STD, and the correct bombing conditions will be established. This method is commonly performed in correlation work. Note that it is not possible to perform this technique starting with the helium indicated leak rate, since the true helium content of the package cannot be known without a destructive analysis.

Cost Savings

Substantial cost savings have been achieved with the use of the radioisotope process in production, due to:

⇒ The Radiflo process typically tests 8,000 UPH and much higher for gross and fine leak; while the helium process typically tests 300 to 900 UPH for fine only.

⇒ The bomb times are very short for several thousand devices per cycle, and, since the readout is so quick, there is no need to keep the devices under an atmosphere of tracer gas until tested.

⇒ The equipment doesn’t require a wait time to come back on line after a failed device is read.

⇒ The helium costs are recurring while Kr$_{85}$ is reused for many years.

⇒ Labor reduction is substantial, especially when it is realized that one radioisotope system often replaces 4 to 8 helium systems and usually an equal number of gross leak systems.