

*The attached three page document is an excerpt of  
the “Annex on Seal Testing Technology”*

*It was included in the AIAA S-113 Specification for:*

**AIAA S-113-2005**

**Standard**

**“Criteria for Explosive Systems and Devices  
on Space and Launch Vehicles”**

*This Annex was added to the specification due to the concerns that the seal testing of small cavity ordnance devices using the conventional helium mass spectrometer test procedures could allow non-hermetic escapes. It was intended to clarify the technology involved and assist the users in understanding the options that exist.*

*It is provided here for reference only. The specification may be obtained from the AIAA ISBN 1-56347-772-6*

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## Annex E Seal Effectiveness

The technology involved in the evaluation of a hermetic seal requires careful review before choosing a seal effectiveness method and test procedure. The most difficult seal defects to detect are on small ordnance devices with very small internal voids or cavities. Specific device design characteristics, degree of hermeticity, sensitivity, and life expectancy all must be carefully reviewed before choosing the test method to be applied. Too often these requirements are not clearly defined, and the choice is left to the technician applying the test, or, more commonly, the “same test that has always been used” is continuously applied. As a result of this complacency, test methodology has not advanced with the advancement of the designs currently being encountered.

Ordnance device designs have changed over the past thirty years. Devices have become more compact, and commonly use compressed ordnance materials, with newly developed methods of sealing the devices. Unfortunately the leak testing methods have continued to be used without advancement to accommodate these design changes. This common misapplication of test methods is known to allow ‘non-hermetic’ devices to escape through the seal evaluation phases of a manufacturing program.

The degree of allowable leakage, or leak test sensitivity for ordnance devices is looser than that of the electronics industry where very high sensitivities are required, i.e.  $10^{-8}$  std cc/sec, or less, which was based on research that has shown that electronic micro-circuits will degrade and fail if they are not maintained free of environmental contaminants. The ordnance industry faces a different environmental consideration associated with primarily the chemical stability of the ordnance materials used in the device, the corrosion resistance of the bridge element, the criticality of the application, and the desired life. Ordnance devices are usually required to pass a leak test from visible leaks to a sensitivity of  $5 \times 10^{-6}$  std  $\text{cm}^3/\text{s}$ . The literature commonly classifies this range of hermeticity as the gross leak-rate range.

Although most military standards and company specifications call for a bubble test as the commonly applied leak test for the gross leak rate range, the ordnance industry has a strong resistance to subject ordnance devices to an elevated temperature liquid bubble test. That forces the consideration of alternate methods to detect a device that may have a very large leak. Also, the text books only consider bubble testing to be practical for  $10^{-1}$  to  $10^{-4}$  std cc/sec leaks, which does not cover the entire gross leak range required for ordnance devices. Visual inspection can assist to remove some devices with badly defective seals, but is not capable of detecting devices with leaks in the gross leakage range, ( $< 10^{-1}$  std cc/sec), especially devices with ‘multiple’ or ‘porosity’ leaks, each of which may be less than, ‘say’  $10^{-4}$  std cc/sec.

There is mixed interpretation of the characteristics of ‘Gas-Flow’ through a leak. The range of leak rates that are found in most ordnance devices is of a leak size and leak rate where the gas flow is usually of a “viscous-flow” or perhaps a “transitional-flow” mechanism. The ASNT Textbook on “Leak Testing” considers leaks from  $10^{-2}$  std  $\text{cm}^3 \cdot \text{s}^{-1}$  into  $10^{-6}$  std  $\text{cm}^3 \cdot \text{s}^{-1}$  to be: “turbulent flow/laminar flow/transitional flow,” (in that order), and “molecular flow to start at  $10^{-6}$  std  $\text{cm}^3 \cdot \text{s}^{-1}$  and continue in leaks below that point. The term “Viscous Flow” is commonly used to cover both turbulent and laminar flow of gases in leak detection, and, since transitional flow occurs as the mean free path of the tracer gas is almost equal to the diameter of the hole, it is at the threshold of molecular flow. It must also be remembered that most ordnance specifications call for detection of leaks larger than  $5 \times 10^{-6}$  std  $\text{cm}^3 \cdot \text{s}^{-1}$ . That means that the majority of leak rate measurements are going to encounter ‘viscous-flow’ characteristics. A quick review of the viscosities of the commonly used tracer gases will show that the viscous flow of each of these gases in leak detection of ordnance devices will behave similarly, not requiring conversions for comparisons of different tracer gas leak measurements based on molecular weights. The transition into molecular flow is enhanced by reducing the pressure or creating a vacuum. However, in the devices being tested in helium mass spectrometry, the gas within the device can be considered to be at ambient pressure, (or higher), following external helium pressurization. The flow of the tracer gas from the inside of the device will begin at ambient pressure and the transition in flow from viscous to molecular will be effected by the size of the leak, the length of the leak path and the resultant pressure drop through that passage as the gas is drawn out of the device through the leak and into the evacuated mass

spectrometer. This transition of flow changes is one of the most difficult to accurately predict mathematically, primarily due to the unknown configuration of the leak path. When very large gross leaks are encountered, that transition point will instantly move from the outside to the inside of the leak path, and due to primarily viscous flow of the tracer gas, it can result in the tracer gas supply being instantly depleted before it can be accurately measured to verify a leak. This is especially common in very small or zero cavity devices.

The most recently addressed issue in leak detection is the difficulty, or more often inability, to detect gross leaks in devices which have very small or no internal cavities in which to store or hold the tracer gases. The assumption that the helium tracer gas will be stored within the energetic material must be very carefully considered. If the energetic material is highly compressed into the device, as in many initiator designs, there may be no significant interstitial or interparticulate cavities where the tracer gas can be stored. However, if the device is subjected to helium pressurization for lengthy periods of time, some helium will dissolve into the compressed ordnance material. This is usually into the organic binders used to assist in the compression of the ordnance material. A very large gross leak will allow the helium to be evacuated instantly from a small cavity device, leaving only the dissolved helium to be drawn into the mass spectrometer. Research shows that the release of such dissolved helium from very small surface areas of compressed ordnance material is extremely slow, and rarely will provide sufficient tracer gas release to indicate gross leakage greater than the  $5 \times 10^{-6}$  std  $\text{cm}^3 \cdot \text{s}^{-1}$  level, (as required in the specification). It can often be detected on a high sensitivity mass spectrometer, but with an indicated leak rate usually orders of magnitude below the leak rate threshold, thus passing a leaking device. If the device contains loose powder, there may be sufficient interstitial cavity to trap tracer gases. However, the evacuation into the mass spectrometer must be performed quickly to detect sufficient helium to reject the device. To assist in this detection, it is most important to use a mass spectrometer test chamber that is small in size, leaving a very small chamber volume to be evacuated before the device is sampled into the detector. This assists in avoiding the loss of the helium tracer gas from within the device cavity during the mass spectrometer pump down. This is a commonly overlooked problem.

A very different technology is encountered in the radioisotope leak detection method. The tracer gas is krypton85, an inert gas that emits two types of radiation: beta particles and gamma rays. The beta particles are of weak energy and rarely will penetrate the walls of the device being tested. The gamma rays are photons that will penetrate the walls of most devices, thus allowing the Kr85 tracer gas to be detected while it is entrapped within the device, measured through the walls of the device, and not requiring the gas to be sucked back out of the device, as in mass spectrometry. The gamma radiation emitted by the Kr85 tracer gas that leaked into the device has many orders of magnitude greater detectability than mass spec detection of helium gas. This allows the pressurization cycle to be very short. The short pressurization cycle with Kr85 makes it easy to test the devices to a sensitivity of  $1 \times 10^{-6}$  std  $\text{cm}^3/\text{s}$  (Kr). This overcomes the concern for the 5:1 ratio of molecular flow rate between He and Kr, if the leakage should happen to be at the molecular flow transition point in the leakage characteristics encountered. Since marginal leak rates are rarely found, it is not likely that good devices might be rejected using this increased sensitivity. The final measurement of the Kr85 within a leaking part will indicate the number of molecules of Kr85 gas that have entered the part during pressurization, which is a direct measurement of the leak size. Devices that have external organic materials can also be tested with Kr85 tracer gas, as any externally trapped Kr85 will emit beta particles, indicating that the radiation is emitted from the outer surface of the part. The devices can be measured at time intervals until the beta radiation has dissipated, indicating the surface Kr85 is gone. Then any gamma radiation measurement will be from Kr85 gas trapped within the device, indicating it is a reject. The detection of Kr85 trapped within a part requires that the part have an internal cavity to trap and hold the tracer gas, the same requirement as in the mass spectrometer test. If there is no internal cavity in the device being tested, a leak can not be detected unless a "gettering medium" is provided within the device that will adsorb and hold the Kr85 tracer gas as if there were a cavity. A current technology is available which utilizes steam activated coconut-shell charcoal as a gettering medium that has great physio-chemical affinity for Kr85 gas. The charcoal will adsorb large quantities of Kr85 and hold it for lengthy periods of time, allowing the device to be detected as a reject. The charcoal provides very large surface areas, (500-1,000  $\text{m}^2/\text{gm}$ ),

thus creating an extremely large surface area which, in effect, acts as a large cavity. The Kr85 gas is then adsorbed and held by Van der Waals forces, even in a part with wide open gross leaks. This technology is applied to ordnance devices by blending a few milligrams of charcoal with the ordnance material prior to introduction into the hardware. High force compression of the ordnance material has no deleterious effects on the charcoal. Explosive materials are normally compressed onto the device header, encasing the bridge wire in a zone without any cavity thus eliminating the cavity required for the entrapment of any tracer gas. The presence of a few milligrams of charcoal in the compressed ordnance material provides an artificial cavity in the form of a large surface area as high as a few thousand  $\text{cm}^2$ . The charcoal is also known to adsorb up to 27% by wt. of water that might enter the device during its life.