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The Importance of Quality Control and Integrity Checking*

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During the past five years the major effort in developing the KIWI reactors has been directed toward improved core design, pressure vessels, and nozzles. As a consequence much of the service hardware has been given less attention. A history exists, during reactor runs, of small leaks resulting in superficial damage to some components although no runs have been cancelled because of these leaks.

With the assumption that future reactors will run at higher power levels and pressures, a survey of all cryogenic service piping adjacent to the reactor, for integrity, was instigated. Testing has not been limited solely to cryogenic hardware but instrumentation pass-throughs, gas service piping, hydraulic seals, actuators, etc. have also been checked. In addition to components that have been used or are now in use, cold seals and new hardware are evaluated before they are incorporated into new reactor designs.

Cryogenic pressure checking of these components is just the first phase of complete analysis. Environments including nuclear radiation,

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radiant heating, vibration, acceleration, and temperature gradients need thorough investigation.

Testing is conducted by the Cryogenic Engineering Section of CMF-9 at the Los Alamos Scientific Laboratory. Figures 1, 2 show a typical test setup where budget and personnel involvement are held to a minimum. For initial mechanical testing of seals, connectors, and other cryogenic components the facility is capable of producing 20,000 psi hydraulic pressure or 9000 psi inert gas pressure.

Leak rates are determined by two different methods. First: Two different size vacuum jacketed test vessels that can accommodate flange pairs with a maximum diameter of 24" are used. With this method the actual leak rate of the piece being tested can be calculated from the pressure rise in the vacuum jacket. Theoretically a leak rate as small as 2.7×10^{-9} atm cc/sec can be determined by this method; actually from practical considerations the leak rates determined fall in the range of 1×10^{-7} atm cc/sec. Figure 3 shows a test vessel used with this method and Figure 4 shows the internal vessel with a typical flanged test pair. Second: A gross type of leak checking called a bubble tight leak check is used. This is a go or no go type of check and seems to meet most requirements for checking the integrity of cryogenic seals. An estimate of the leak rate that can be determined by this method is 2.7×10^{-4} atm cc/sec. This amounts to one 1/16" diameter bubble per minute. Figure 5 shows a typical manifolded setup for bubble checking cryogenic connectors. Figure 6 shows the samples after

testing and what pitfalls you can run into following the manufacturers assembly specifications.

Testing for bubble tightness is done in the following manner. After the unit under consideration has been tested to 1.25 to 1.5 times the maximum working pressure it is immersed in a warm water bath at 160-180°F and the internal pressure, usually helium gas, is raised to the required test pressure and the line valve closed. The water bath is watched for bubbles, indicating leaks, and the system pressure gauge is monitored for internal pressure drop. If no leaks are apparent the internal pressure is lowered to approximately 100 psi and the unit is moved to a liquid nitrogen bath for pre-cooling. Here again the internal helium pressure is raised to the required test level and valved off and the pressure is monitored for evidence of leakage. When the unit has cooled to liquid nitrogen temperature the internal pressure is reduced to 100 psi and the unit is moved to the liquid hydrogen bath. There the internal pressure is again raised to the required test level and valved off. The internal pressure is monitored for leakage as in the two previous baths. Again the internal pressure is dropped to 100 psi and the cold unit is taken directly to the 180°F water bath where it is again pressurized to the test pressure. This gives the test unit a 600°R thermal shock in approximately 10 seconds. If no leaks develop this series of tests is repeated for a total of six complete cycles.

The following types of connections have been found leak tight by the bubble method if assembled using the following recommendations:

Female pipe threads 1/8" to 1" NPT lubricated with "Ledplate 250" or vacuum grease mixed with powdered molybdenum disulfide. Other effective pipe thread sealants where heat or radiation are not a consideration are "Loctite" and soft solder. Female pipe threads must be checked for depth by plug gauges and inspected for good thread form according to (ASA B2.1-1945). Good threads and proper depth are especially important where stainless steel fittings are assembled into aluminum units. No torque specifications exist, as far as is known, for making up pipe threads, especially those in aluminum. Male pipe threads must be inspected for proper form and number of threads and those items having torn or smeared threads must be rejected. Pipe threads are often not used, for the previously mentioned quality and assembly reasons, when they would make an effective joint.

Crawford "Swagelok" fittings in sizes 3/16" to 3/4" have been found leak tight by both the bubble check and vacuum check method and are used routinely for high pressure cryogenic work at LASL. There are three things that must be done to use "Swagelok" fittings. Routinely polish the end of the tubing in a radial direction where it enters the fitting. When the tubing is as much as 0.005 inches oversize it is necessary to deburr the conical ring in the fitting or the fitting will leak. Also all parts of the fitting must be clean and free from foreign matter. "Swagelok" fittings are used on copper, aluminum, and stainless tubing. An all aluminum "Swagelok" fitting has even been used successfully on stainless tubing at liquid hydrogen temperatures. "Swagelok"

fittings have been found to be reliable and reusable.

Recently we have tested by the bubble method a "Parker Hannifin" tube fitting in the 1/2 inch tube size. This fitting is unique in that the ferrule is threaded onto the tube with a left hand thread. This fitting was easy to assemble and was found to be bubble tight at liquid hydrogen temperatures with an internal pressure of 1500 psi. Figure 7 shows the unit prior to assembly and Figure 8 shows the unit after assembly and test. Notice that the ferrule is swaged onto the tube at assembly. "Koncentric Unions" in 1/8" to 1" pipe and tube sizes are routinely used for high pressure gas and liquid hydrogen and nitrogen service where radiation is not a consideration. The only precaution necessary in using these connectors is that the "Teflon" gasket must be removed when the fittings are soldered or welded to the tubing. The gaskets are cheap and easily replaced if they are damaged or become impregnated with foreign matter. These unions are leak tight by both the bubble method and the vacuum test vessel method. Figure 9 shows a typical union for use on pipe and Figure 10 shows the unions used in a typical leak test setup.

"Conoseal" manufactured by "Aeroquip" in the stainless steel screwed union type in sizes 1/8" to 2" NPT are easy to use and have been found leak tight by the bubble method and the vacuum vessel method. The union components must be absolutely clean when assembled. The union halves are reuseable but the conical gasket usually is not. Figure 11 shows a typical "Conoseal" union for tubing service.

Two samples of 1/2 inch tube size induction brazed gold alloy flight weight fittings produced by "Aeroquip" were tested and found to be bubble tight at 2200 psi internal pressure and at liquid hydrogen conditions. These joints should be particularly useful in applications where minimum weight and dimension are a requirement and gamma or radiant heating are a problem. The only drawback to this system is the high initial cost of tooling and equipment.

"Harrison K-Seals" have been bubble tested in size #4 to #32 or 1/4" to 2" tube size that fit the AND-10050 series of bosses and counterbores. These seals are leak tight and the gaskets are reusable if the following precautions are taken. The counterbores and chamfers must be free of nicks, scratches, and lumps. Figures 12 through 17 are photographs of the nicks, gouges and general damage found in 6061T6 aluminum test capsules. This damage was found on inspection with a reading glass and rejections run as high as 90 per cent. The threads below the chamfer must be of good quality and gauged for proper depth and size. These threads must be lubricated to prevent galling both with aluminum and stainless steel. Figure 18 shows galling of threads caused by lack of lubrication on anodized aluminum threads. The sealing surface on the mating connector or instrumentation must be well finished and flat. The "K" seal or gasket must be free of nicks, scratches, and lumps. Figure 19 shows a "K" seal as received with a nick on the sealing lip that was discovered with a reading glass. Figure 20 shows a lump on the sealing edge of a "K" seal that

was apparent only after the connection leaked and was torn down.

The "K" seal or gasket must be lubricated with a light coat of "Dow Corning #11" or its equivalent because of the twisting and sliding of the gasket during assembly. Figure 21 shows the scuffed sealing lip caused by a dry gasket. Figure 22 shows scuffing on the heel or spine of the gasket caused by no lubricant. With this assembly all sealing surfaces and the seals themselves must be inspected for nicks, scratches, and surface finish before assembly.

In conclusion I would like to state that very few high pressure cryogenic connectors fail because of design deficiencies. To make most connectors leak tight the following steps are vital:

1. One hundred per cent inspection of all connector components for dimension, flatness, surface finish, cleanliness, and damage.
2. Complete written instructions with check list for use in field assembly, including cleaning techniques, lubricants, handling of gaskets and parts, torque values, and proper use of tools.
3. An integrity or leak check of a representative number of assemblies, simulating actual use conditions, before incorporation into final designs.
4. A field inspection of connector assemblies before, during and after assembly by a competent and authoritative inspector.