Innovations in self-sealing under cryogenic conditions

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Ordinary tube fittings can always maintain a tight seal when they are assembled under room temperature conditions. If the temperature of the fluid through the tubes is high, the thermal expansion of the parts tends to tighten the seal. However, when a piping system is handling liquid hydrogen such as that for the space shuttle, contraction of material due to the low temperature invariably causes leakage. An explosive and dangerous environment can be created.

The concept of self-sealing tube fittings was inspired by persistent leakage of liquid hydrogen through the ordinary fittings in the space shuttle program at Kennedy Space Centre. Researchers at Florida Atlantic University's Cryogenic Laboratory have developed a unique sealing device for this type of application. The Contracting Self-Sealing Cryogenic tube fitting performs leak-free from room temperatures to cryogenic temperatures as low as liquid helium.

Testing the concept

Although the idea was simple, its feasibility needed to be verified in a representative environment. A cryogenic laboratory was established in the grounds of Florida Atlantic University, in which liquid helium was used to achieve the low temperatures required.

The cryogenic testing system consisted of a cryostat providing a sample space of 90 mm diameter and 228 mm length which could be maintained at 5.5 K while the system pressure was rated at 500 psig (Figure 1). These conditions were created with liquid helium as the coolant, and gaseous helium from the high-pressure tank as the pressurising agent.

Test sequences showed researchers that the basic consideration for designing self sealing fittings should be based on the selection of material with a small expansion-contraction coefficient as the body of the fitting, and the material with a relatively larger coefficient as the sealing spacer and housing.

Zero gap design

Simplified analysis based on the

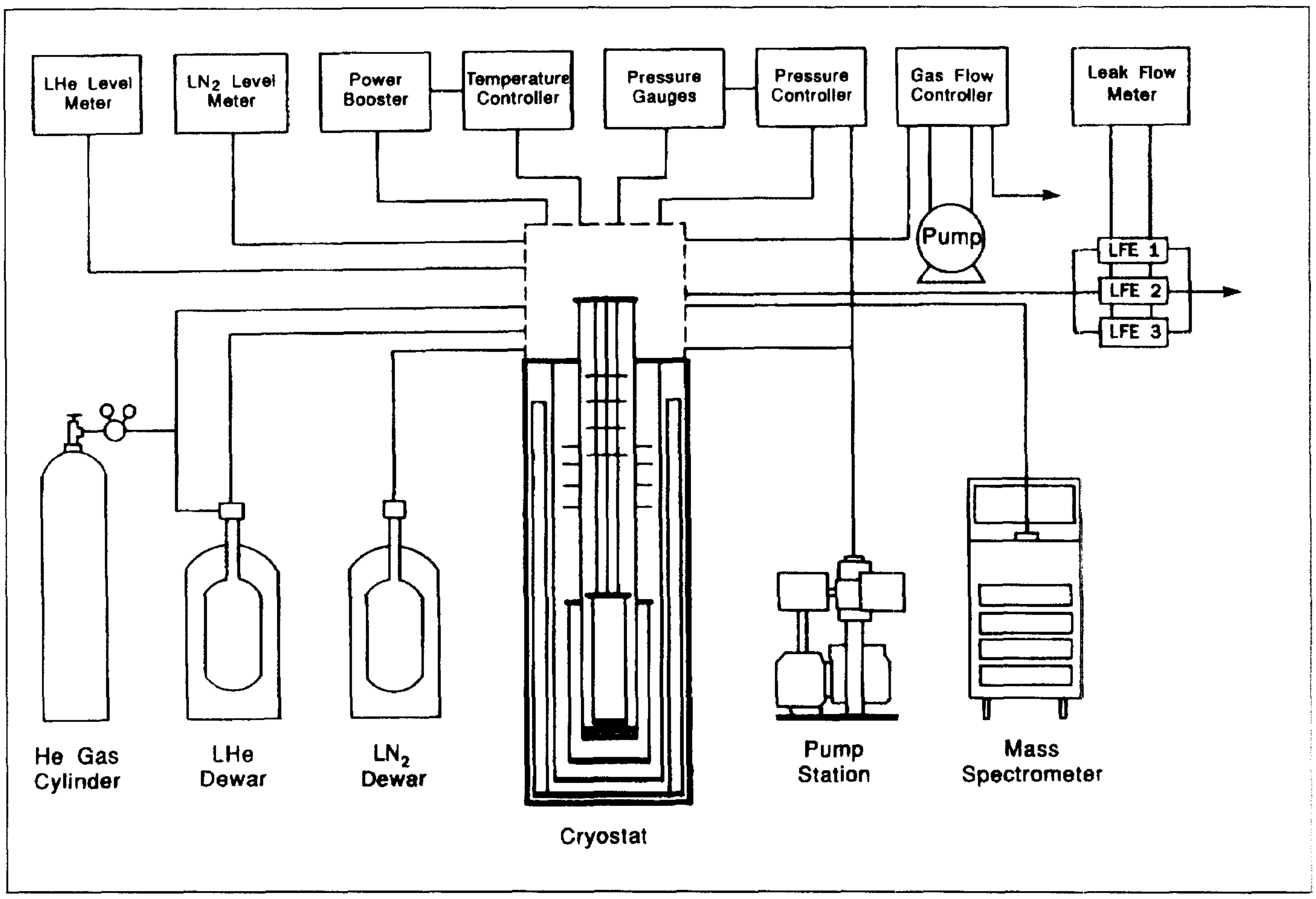

Figure 1. Schematic diagram of the cryogenic test system layout.

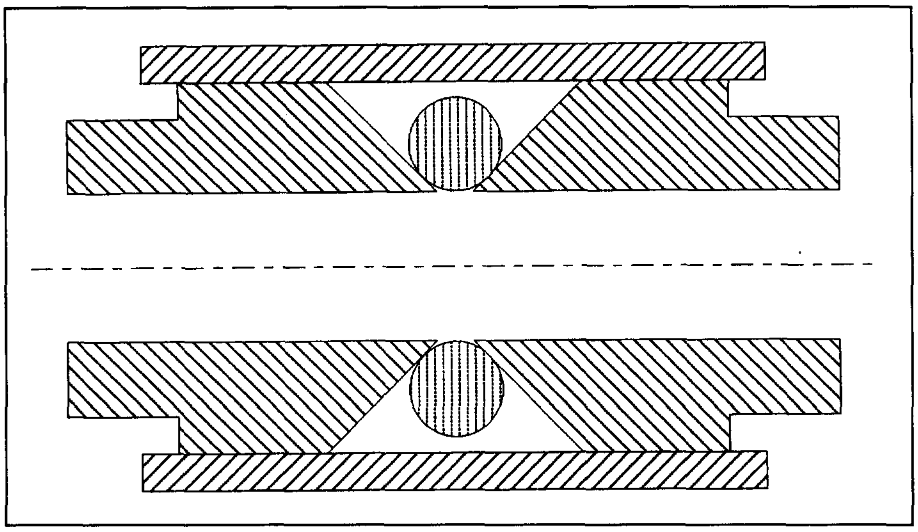

Figure 2. The contracting self sealing tube fitting.

linear contraction approximation was developed to show the relationship that must be satisfied for self-sealing. This was based on the assumption that a gap between the sealing O-ring and the outer conical body of the fitting exists at the low temperature as a result of the different expansion-contraction coefficients of the materials. The sealing condition assumes that the gap should be zero or negative, and fittings designed according to this criterion did not leak during testing.

FAU's CSSC tube fitting uses the different properties of selected dissimilar materials along with specific geometries in accordance with certain design criteria. The design consists of four basic components: two metal couplings, an O-ring spacer and a housing nut (Figure 2).

In operation, as cryogenic fluid begins to flow through the tube, the various parts of the tube seal shrink in size, ensuring a leak-free seal. The cooling process also forces the contraction of the sealing spacer to further tighten the seal.

Initial tests on some self-sealing test fittings indicated no sign of leakage at the temperature of liquid nitrogen (77 K) and a pressure of 400 psig. Leakage was not detected even at 6 K under the same pressure conditions.

The benefits of this development are a self adjusting seal, that is easy to assemble and is reusable. No spare parts are required. The device works in vacuum as well as low or high pressures, and is adaptable to a wide variety of cryogenic applications.

The tube fitting could be used for cryogenic systems in electron microscopy, electron spectroscopy, atomic and molecular physics, and nuclear physics. The seal could be extended to applications where a wide range and high rate of temperature cycling is required.

Sealing under contraction and expansion

The original study of contracting self sealing cryogenic fittings led to the development of fittings which could seal at both cryogenic and elevated temperatures. A typical fitting of this kind is presented in Figure 3.

While sealing at the cryogenic temperatures relies on the outer contact surface of the spacer, the inner contact surface serves at elevated temperatures. Certainly the tolerance must be tightly controlled and specified in the process of fabrication. Tests on this style of seal demonstrated no leakage at 12 K and 400 psig.

FAU seeks to enter into a technology transfer license agreement. Contact: Dr Jerry Merckel, Research Corporation, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431, USA. Tel: +1 561 367 2140; Fax:+1 561 367 2141.

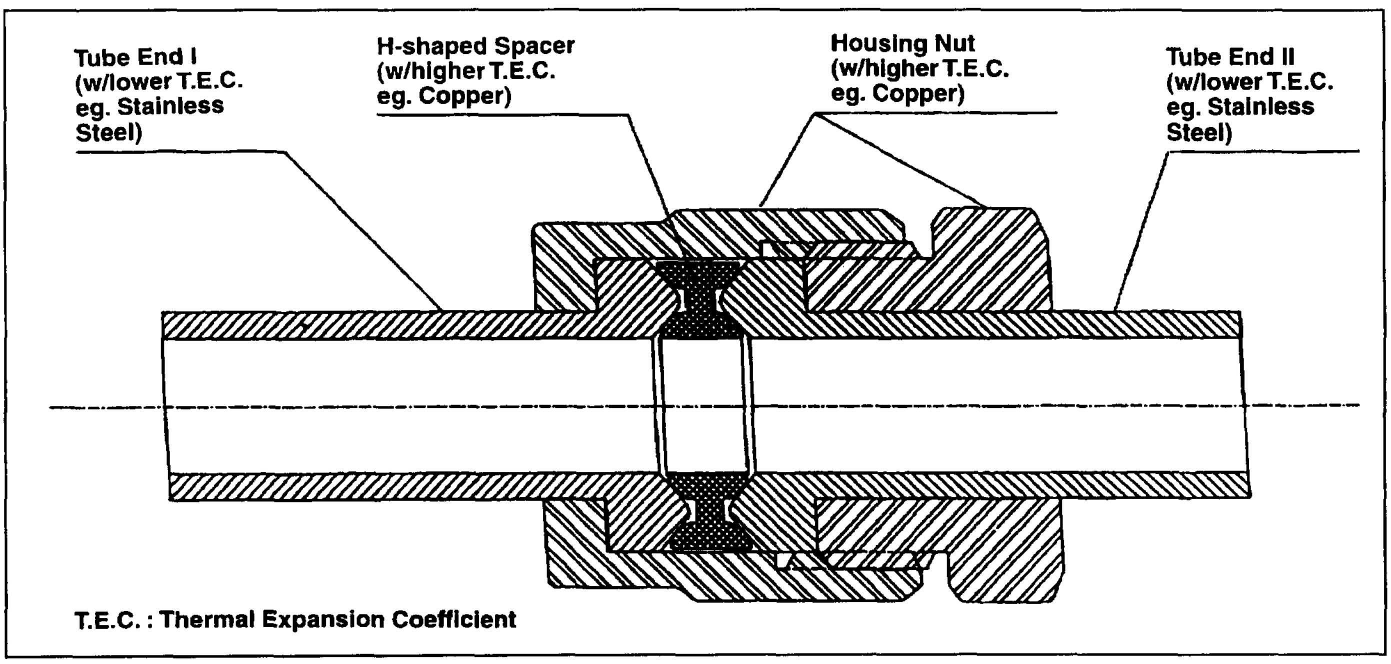

Figure 3. Contracting expansion self-sealing cryogenic fitting.