

force on the piston would exceed the downward (closing) fluid pressure force on the piston, the net upward fluid pressure force being equal to the annular area of the shoulder and the gauge pressure (absolute fluid pressure less atmospheric or other reference pressure). Because the annular shoulder area could be made less than the area of the lower piston face, the opening force could be tailored to a suit-

ably low value through design choice of the upper and lower piston diameters. (Of course, for a given valve set point, it would be necessary to choose a spring of correspondingly reduced stiffness.) The fluid in the spring cavity would present inertial impedance that would further reduce the opening acceleration of the piston. As an additional benefit, it may be possible to reseal the valve at a greater

fraction (perhaps as much as 100 percent) of the valve set point than that of a conventional relief valve.

This work was done by Bruce R. Farner of Stennis Space Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center, (228) 688-1929. Refer to SSC-00232-1.

Safety Modification of Cam-and-Groove Hose Coupling

Coupling halves cannot be separated while the hose is internally pressurized.

John F. Kennedy Space Center, Florida

A modification has been made in the mating halves of a cam-and-groove hose coupling to prevent rapid separation of the halves in the event that the cam levers are released while the fluid in the hose is pressurized. This modification can be duplicated on almost any commercially available cam-and-groove hose-coupling halves and does not interfere with most vendors' locks that prevent accidental actuation of the cam levers.

The need for this modification arises because commercial off-the-shelf cam-and-groove hose-coupling halves do not incorporate safety features to prevent separation in the pressurized state. Especially when the pressurized fluid is compressible (e.g., steam or compressed air), the separated halves can be propelled with considerable energy, causing personal injury and/or property damage. Therefore, one purpose served by the modification is to provide for venting to release compressive energy in a

contained and safe manner while preventing personal injury and/or property damage. Another purpose served by the modification, during the process of connecting the coupling halves, is to ensure that the coupling halves are properly aligned before the cam levers can be locked into position.

For the purpose of describing the modification, the coupling halves are denoted the receiving and mating halves, respectively. The modification includes the formation of two installation/removal slots and two safety pockets in the receiving coupling half. Each safety pocket is located at an angle of 45° from an installation/removal slot and provides both a "catch" to prevent accidental release and a landing for full installation. The mating coupling half has been modified to receive two shoulder bolts made of A286 stainless steel.

In use, if the mating coupling half is not rotated 1/8 turn relative to the re-

ceiving coupling half, then the cam levers cannot be rotated into position and locked to provide the required seal between the two coupling halves. The head of each shoulder bolt slides in one of the installation/removal slots and provides a stop if release is initiated accidentally while the fluid in the hose is pressurized. The safety pocket prevents rotation of the mating coupling half relative to the receiving coupling half while the fluid is pressurized, thereby also preventing sudden separation of the coupling halves. At the same time, the modifications allow the coupling halves to disengage slightly to allow venting of the pressurized fluid. Once pressure in the hose is sufficiently low, the coupling halves can be safely disconnected from each other.

This work was done by Paul Schwindt and Alan Littlefield of Kennedy Space Center. Further information is contained in a TSP (see page 1), KSC-12713

Using Composite Materials in a Cryogenic Pump

Shaft speed is increased and conductive leakage of heat is reduced.

John F. Kennedy Space Center, Florida

Several modifications have been made to the design and operation of an extended-shaft cryogenic pump to increase the efficiency of pumping. In general, the efficiency of pumping a cryogenic fluid is limited by thermal losses (the thermal energy that the pump adds to the fluid). The sources of the thermal losses are pump inefficiency and leakage (conduction) of heat through the pump structure. Most cryogenic pumping systems are required to operate at maximum efficiency because

the thermal energy added to the fluids by the pumps is removed by expensive downstream refrigeration equipment. It would be beneficial to reduce thermal losses to the point where the downstream refrigeration equipment would not be necessary.

A typical cryogenic pump includes a drive shaft and two main concentric static components (an outer pressure containment tube and an intermediate static support tube) made from stainless steel. In order to reduce the leakage of heat, the

shaft is made longer than would otherwise be needed. The efficiency of the pump could be increased most easily by increasing the speed of rotation of the shaft, but the speed must be kept below the lowest of the rotordynamic critical speeds. (In essence, the rotordynamic critical speeds are resonance frequencies at which the interaction of rotational dynamics and elasticity of the shaft and the rest of the rotor can cause the rotor to vibrate uncontrollably, possibly damaging the pump.)

The modifications include replacement of the stainless-steel drive shaft and the concentric static stainless-steel components with components made of a glass/epoxy composite. The leakage of heat is thus reduced because the thermal conductivity of the composite is an order of magnitude below that of stainless steel. Taking advantage of the margin afforded by the decrease in thermal conductivity, the drive shaft could be shortened to increase its effective stiffness, thereby increasing the rotordynamic critical speeds, thereby further making it possible to operate the pump at a higher speed to increase pumping efficiency.

During the modification effort, an analysis revealed that substitution of the shorter glass/epoxy shaft for the longer stainless-steel shaft was not, by itself, sufficient to satisfy the rotordynamic requirements at the desired increased speed. Hence, it became necessary to increase the stiffness of the composite shaft. This stiffening was accomplished by means of a carbon-fiber-composite overwrap along most of the length of the shaft. Because the thermal conductivity of the carbon-fiber composite exceeds that of the glass-epoxy composite, it was necessary to choose the thickness

of the overwrap as a compromise between adequate stiffening and a need to minimize leakage of heat along the shaft. It was found to be possible to choose a compromise thickness [0.020 in. (≈ 0.5 mm)] to satisfy the heat-leakage requirement while stiffening the shaft by a factor >10 and thereby satisfying the rotordynamic requirements.

Concomitantly with the modifications described thus far, it was necessary to provide for joining the composite-material components with metallic components required by different aspects of the pump design. The metal/composite joints are required to withstand differential thermal contraction and expansion between ambient and cryogenic temperatures and to withstand torque and piping loads while maintaining a vacuum seal throughout the ambient-to-cryogenic temperature range. The joints are also required to have reasonable dimensional tolerances, to be easy to assemble in a repeatable process, and otherwise generally to be manufacturable at a level of effort and cost equivalent to that of the prior stainless-steel design.

An adhesive material formulated specially to bond the composite and metal components was chosen as a means to

satisfy these requirements. The particular adhesive material has a history of excellent performance in cryogenic applications. The joints were designed to put all the loading in shear and reduce stress concentrations. The joint design was optimized with respect to bond thickness, preparation of surfaces to be bonded, and the viscosity of the adhesive itself. A finite-element analysis predicted that the joints would satisfy the load-bearing requirements. Some mechanical tests verified that the joints could withstand the most severe loads imposed. (The loads were chosen, in part, to simulate the temperatures to be encountered in operation.) Other mechanical tests (tensile tests) demonstrated a factor of safety of 6 with respect to anticipated loads. Results of helium testing lent credence to the expectation that joints will not leak during operation.

This work was done by William D. Batton, James E. Dillard, and Matthew E. Rottmund of Barber-Nichols, Inc.; and Michael L. Tupper, Kaushik Mallick, and William H. Francis of Composite Technology Development, Inc. for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Office at (321) 861-7158. KSC-12625/6/7