Team 513 Operation Manual

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Project Overview

The objective of this project is to design a connector that will transfer cryogenic fluid to refuel rocket ships on the moon. Developing this system will result in extended space travel missions that will venture further from Earth. When developing a solution, there were two key points involving this connection that determined the direction of development. These points were: the fluid being transferred with respect to how it would affect the connection and the environment’s effects on the system.

The fluid was the first step to consider. The fluid, liquid oxygen, boils at a temperature of roughly 90 Kelvin. Testing was conducted with liquid nitrogen at 77 K, and therefore all components selected can withstand the temperature of liquid oxygen. Undergoing the drastic change in temperature can cause changes in properties, as well as expansion and contraction. Materials selected were chosen to limit the change in properties at that temperature and keep consistent expansion and contraction with temperature changes. To produce a successful connector, the solution withstands thermal cycling while maintaining a secure connection to limit the loss of fluid while refueling.

The environment was the next to consider. The use of this connector interface on the moon can produce varying issues. The moon may have a temperature range of 140 K – 400 K depending on whether it is shaded from direct sunlight. Considering the effects of radiation on the connector while undergoing fluid transfer is out of the scope of the project. There are still safeguards to release pressure build-up if there were to be boil off and over-pressurization of the system. Regolith on the moon would also cause system failure if it was to enter the connector and remain there during fluid transfer.

The following sections will describe all components and how to assemble the parts. It will also describe how to operate the interface along with troubleshooting possible issues. There will also be an inclusion on how to maintain protection against regolith that the connector interface can come into contact with while used on the moon.

Component Description

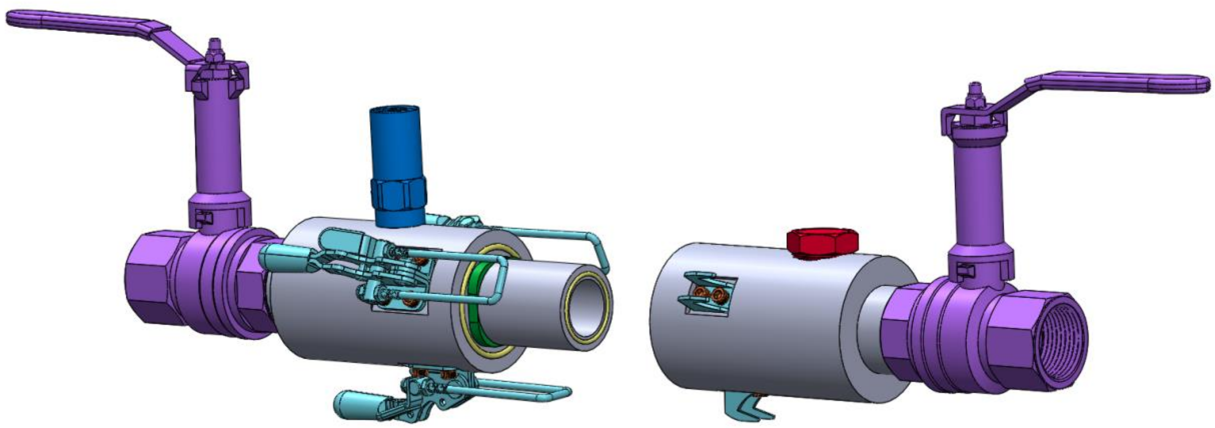

Figure 1: CAD model of the cryogenic connector assembly

The connector design is comprised of two machined parts which consist of a male and female end. The selected material for these was AISI304 stainless steel. These ends were designed to accommodate the rest of the components of the connector. Shown above is an angled view of the design when disconnected. This view displays the O-rings, shown in yellow, and the alignment extrusion, shown in green. The O-rings are made of Viton, which is a fluorocarbon rubber, and are the key to creating the seal of the system. The alignment extrusion was machined to help the user line up the latches in the correct orientation when interlocking the ends together. The latches and hooks that engage the O-rings' compression seal are shown in light blue. They are screwed into the body of the connector with 8-32 x 3/8” screws, shown in orange. To control the flow of the fluid passing through the connector, the handles on the purple AVCO ball valves are rotated 90 degrees. These are attached to the connector with 1” NPT fittings. These ball valves are then connected to the cryogenic storage tank extension hose on one end, and the space shuttle fueling hose on the other end. For safety measures, two pressure relief valves were implemented into the design. The blue automatic pressure relief valve cracks at 50 psi in the case that excess boil-off creates an unwanted increase to the pressure of the system. The red breather vent is removed by the user to depressurize the system and allow the remaining fluid to evaporate before disconnecting the two ends.

Integration

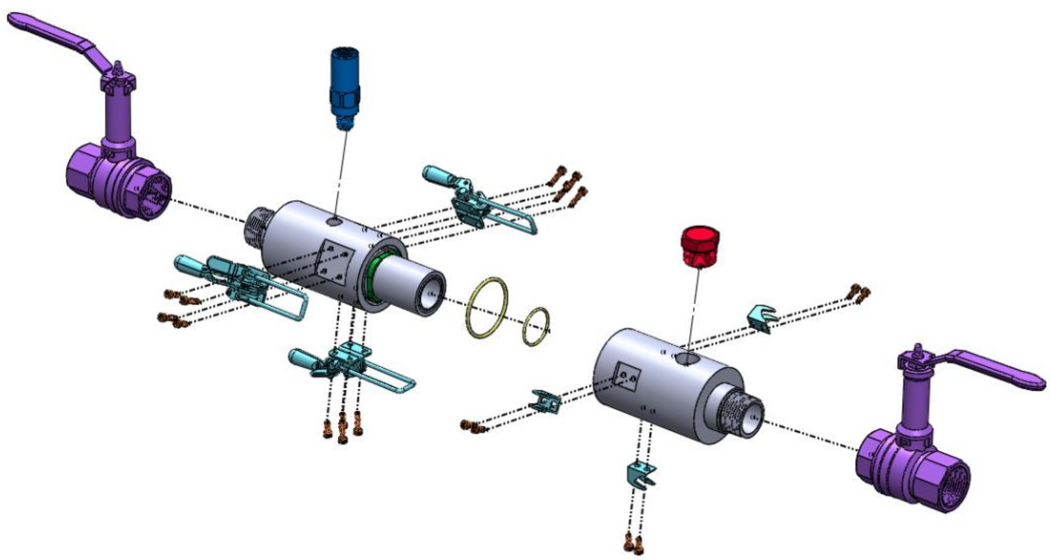

Figure 2: Exploded CAD view of cryogenic connector assembly

To assemble the connector the exploded view shown above should be followed. The dashed lines indicate the location of each component. Each end should be assembled before connecting the interfaces together. The ball valves should be threaded onto both ends and the latches and hooks should be attached with the screws. Both relief valves are threaded in as well. Next, the O-rings are placed in their corresponding grooves. To connect and seal the system, the alignment extrusion is used to help slide the parts together. Finally, the latches are hooked and locked into place.

Operation

We will define the operation of this device as a sequence of events that allows cryogenic fluid to flow through the connector. After proper completion of the assembly, the connector can simply be connected by bringing together the two ends of the connector by matching up the alignment extrusion to the other side and initiating the latches. This will seal the gap between the two faces. To attach the connector to the reservoir containing the cryogenic fuel and the rocket ship, attach the hoses to the connector at either end of the connector to the ball valve using flange to 1" NPT fitting. To operate the AVCO ball valves, there is a small slider that acts as a locking mechanism preventing the handle from rotating. Move the small slider so that it is not in its resting position and then twist the handle 90^{o} which will open the ball valve. At this point, the flow can be opened at the reservoir and flow to the ship. During testing, to flow cryogenic fluid through the connector we used cryogenics lab at the National Magnet Laboratory. To properly connect the ball valves on the connector to the testing equipment 1" NPT (National Piped Thread) to ½" male flange fittings are needed, shown in Figure 3. This can be used the same for the connection of the connector to piping to the reservoir and ship.

After fueling is completed, wait for the temperature of the connector to increase before starting the disconnecting process. To start the disconnecting process, make sure that the reservoir is closed off. Then close both ball valves with the same method of opening. Once ball valves are closed off, disengage the latches, and separate the two ends. Store the two ends in their respective storage locations.

When disconnected, protection is required from the environment. To prevent dirt and dust from entering the system when disconnected, attach caps onto the ends of the connector after disconnection.

Figure 3: 1" NPT (National Piped Thread) to ½" male flange fitting

Troubleshooting

A problem that could arise during use of the connector would be an increase in fluid loss through the connection point of the two sides. There are a couple solutions to this problem if it was to happen. First, one must consider the adjustability of the latch tightness. After O-rings are installed, the user can tighten the nuts on the latch ends to decrease the length of the latch itself and therefore tighten the connection. The latch can be held above the hooks to indicate to the user the placement so that they can adjust to their desired length. If the leak continues, the next option would be to replace the two O-rings used in the connection. There can be added cushions inserted into the O-ring grooves to increase the protrusion of the O-ring from the groove.

The components are also replaceable. If there were to be failures at the latch, ball valve, relief valve, hook, and O-ring, the part can be replaced with a new part. These components must be replaced following the direction for initial assembly but can be replaced as they are not permanent fixtures on the shaft.

Appendix A: CAD Drawings

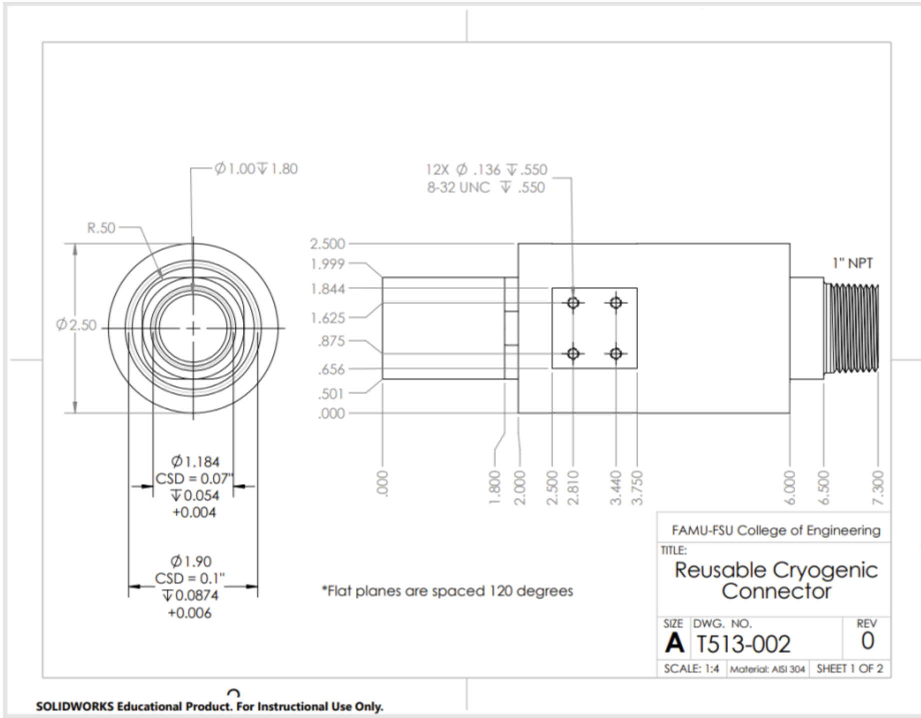

Figure 4: Cryogenic connector male end CAD drawing

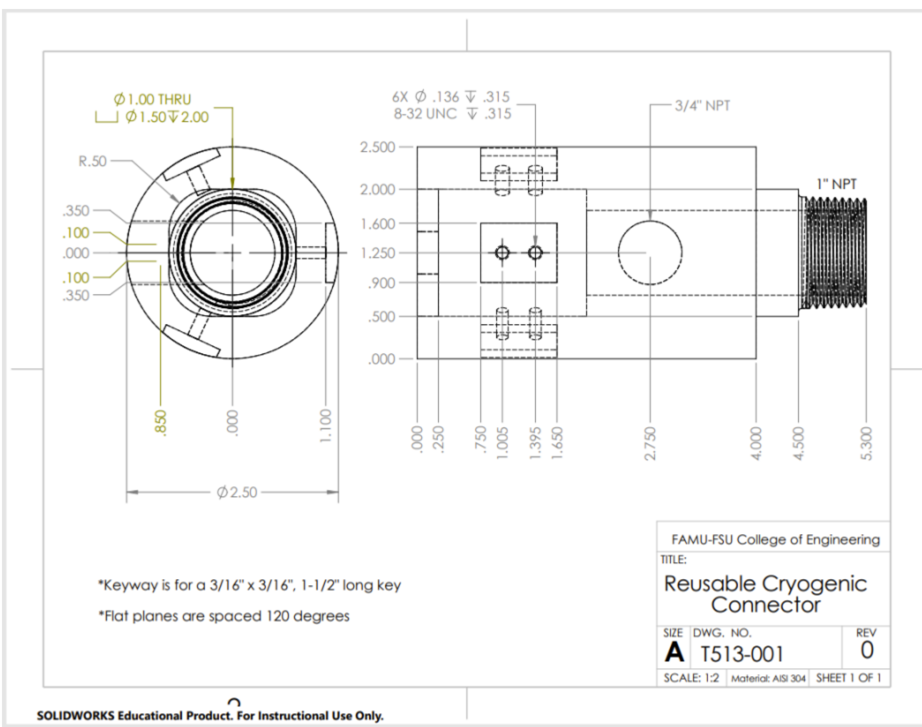

Figure 5: Cryogenic connector female end CAD drawing, page 1

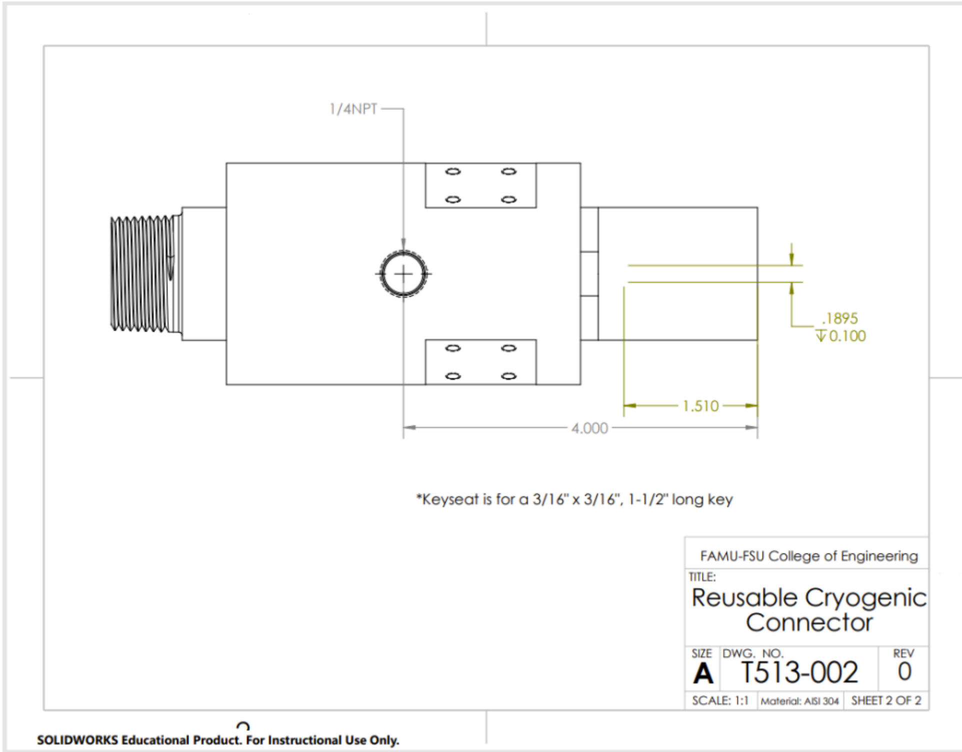

Figure 6: Cryogenic connector female end CAD drawing, page 2