

## Development Requirements for Spacesuit Elbow Joint

### Functional Requirements for spacesuit elbow joint:

- 1) The system is a conformal, single-axis spacesuit pressurized joint that encloses the elbow joint of the suited user and uses a defined interface to connect to the suit systems on either side of the joint.
- 2) The system shall be designed to bear the loads incurred from the internal pressure of the system, as well as the expected loads induced by the user while enabling the user move the joint through the required range of motion. The joint torque of the system experienced by the user shall remain at or below the required specification for the entire range of motion.
- 3) The design shall be constructed, at a minimum, as a two-layer system. The internal, air-tight layer shall be referred to as the bladder, and the layer on the unpressurized side of the bladder shall be referred to as the restraint. The design of the system may include additional features or layers, such as axial webbing, to meet the overall requirements of the design.

### Preliminary Performance Requirements:

- 1) The system shall meet all performance requirements within the operating temperature range of: +41 °F- 115° F.  
*Rationale: This is the expected operating temperature range within the insulated area of the spacesuit system, including the pressurized volume within the expected operational cases.*
- 2) The system shall meet all performance requirements within an operating pressure range of 0 to 10.6 psid, relative to a surrounding vacuum environment.  
*Rationale: This is the expected operational pressure range for the spacesuit system.*
- 3) The system shall be designed to withstand an internal pressure of 17.6 psid without structural failure.  
*Rationale: This is a proof test of the system to ensure a 2.0 factor of safety for most normal operating cases.*
- 4) The bladder shall be capable of holding a pressure of 1.0 to 8.3 psid without the restraint layer present.  
*Rationale: The intent is that the bladder can absorb the hoop stress in the case of a tear or rip, but it is not expected to absorb the full plug load. This is to ensure that the system is single fault-tolerance of the pressure garment.*
- 5) The system shall be capable of bearing a 150-lb. force load indefinitely down the long axis of the joint within the operational pressure range of the system.

*Rationale: This requirement simulates the “man-load” or what the wearer of the system can induce while wearing the spacesuit.*

- 6) The system shall meet an ultimate design factor of safety of 2.0, with respect to all expected load cases on the system.

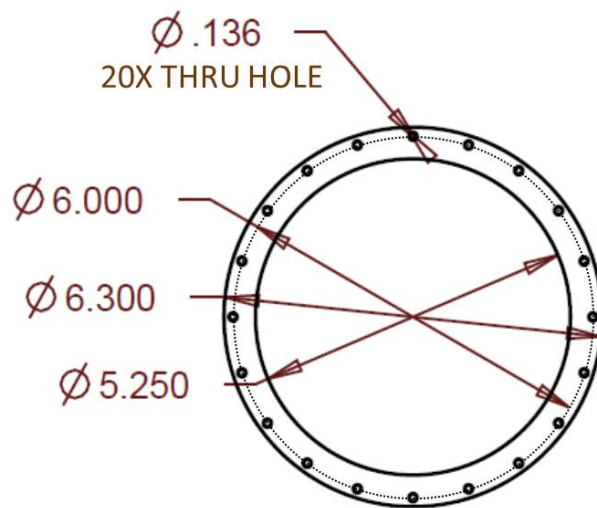
*Rationale: This represents the required minimum safety factor for manned spacesuit designs.*

- 7) The design shall be single-fault tolerant with respect to catastrophic structural failure.

*Rationale: In the case of a credible structural failure mechanisms, the design shall be capable of maintaining the expected pressure loads of the system after the failure.*

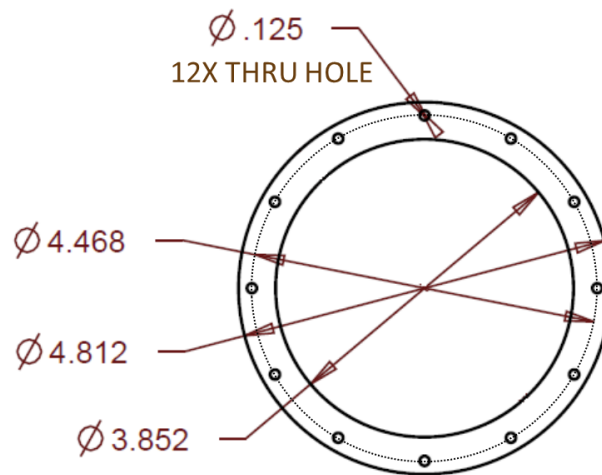
- 8) The system shall be capable of interfacing with the depicted upper-arm flange bolt pattern and sealing surface geometry:

*Rationale: This is the required interface geometry with the bearing design on that end of the system. All dimensions are in inches.*



- 9) The system shall be capable of interfacing with the depicted lower-arm flange bolt pattern and sealing surface geometry:

*Rationale: This is the required interface geometry with the bearing design on that end of the system. All dimensions are in inches.*



- 10) The system shall leak no more than 6.0 SCC/M when pressurized to 8.3 psid and integrated with the arm flanges.
- 11) The system shall not extend beyond the conical volume created by the outer edges of the upper and lower flanges when the joint is fully extended and pressurized within 0 to 8.3 psid.  
*Rationale: The intent is to make the system conformal and not impede on the mobility of the integrated spacesuit system.*
- 12) The system shall have a minimum length of  $8.5 \pm 0.1$  inches while the joint is extended and the pressure of the system is between 1.0 and 8.3 psid.  
*Rationale: The system is required to be dimensionally stable through the pressure range to ensure that the suit fit or functionality does not change with pressure.*
- 13) The system shall provide a method to extend the overall system length in 0.25-inch increments to a maximum of 0.5 inch longer than the minimum system length without the use of tools.  
*Rationale: Ability to size the pressure garment for an individual suited user is critical to ensure optimal performance within a pressure garment. In the past, this has been done typically by providing a method to change the effective length of the joint axial restraint, while allowing the rest of the system to expand in the long axis*
- 14) The system shall have a useful life of 624 hours of manned, pressurized usage.
- 15) The system shall be designed to meet all requirements after 67500 flexion-extension cycles of the elbow joint at greater than 80% of the required range of motion.  
*Rationale: This cycle number is based on the number of joint cycles that the system would see during its entire useable lifetime.*

- 16) The entire system without the flanges shall weigh less than 4 pounds.
- 17) The system shall enable the arm joint to flex from straight-arm (0°) to 125° while pressurized from 1.0 to 8.3 psid.
- 18) The system shall not exceed a joint bending torque of 80 in.-lbs throughout the required range of motion at 8.3 psid.
- 19) All materials chosen shall meet NASA STD-3001 V2 standards for non-toxicity and off-gassing.
- 20) The bladder material shall be compatible with a 100% oxygen environment in the operational pressure ranges.  
*Rationale: The spacesuit will be pressurized with 100% oxygen during an Extravehicular activity (EVA).*
- 21) The system shall be designed such that subcomponents of the system are interchangeable with other components of the same design.
- 22) The system shall be designed such that the system can be serviced and repaired with common tools.

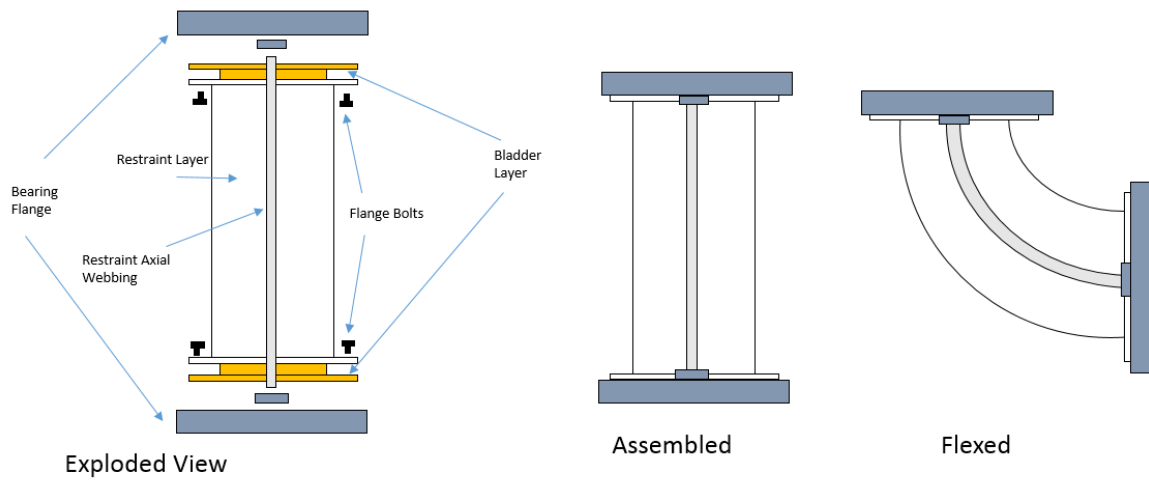
## **Design Considerations**

- 1) Design for constant pressurized joint volume through the required range of motion.  
*Rationale: Constant volume joint designs require less effort for the user and prevent the suit pressure from fluctuating as a result of the motion of the user.*
- 2) Design the bladder to withstand internal abrasion, cut, and puncture resistance.  
*Rationale: EVA, particularly donning and doffing, creates significant wear points that can cause failure of fragile pressure garment systems.*
- 3) The system shall resist cut or tear propagation in all fabrics.  
*Rationale: The system shall be designed to minimize the effects of possible damage to the system.*
- 4) The system shall be designed for comfort, and minimize the occurrence of pressure points, and skin chafing on the user.  
*Rationale: The system should be as comfortable as possible to wear, because an EVA typically lasts greater than 6 hours.*
- 5) The system shall be designed to limit microbial and fungal growth and odors.

*Rationale: This can also be interpreted as being easy to clean in addition to being resistant to the growth of organisms.*

## Example Drawing (Low-Fidelity Representation)

General Representation of Spacesuit Softgood Joint Construction



## Representative Past Design Configuration

