Zeolite Membrane Module

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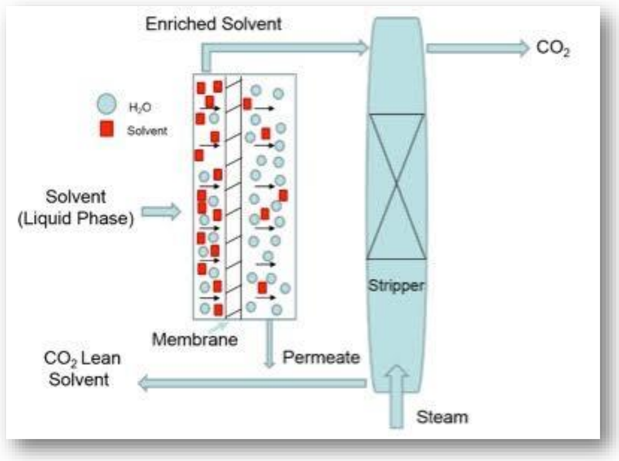
Module Process

The zeolite membrane module is a membrane distillation column that extracts excess water from a concentrated amine solution. Less water in the solvent stream leads to reduced energy costs downstream in the CO2 capture process. The solution flows perpendicular to the tubular zeolite membranes at approximately 100 psi and 120 °C.



Schematic display of the module's contribution to the process

The issue with the current design of the module is the seals between the zeolite membranes and the end caps. The issue with the current design is the O-rings that seal the tubular membranes to the frame are failing to block the amine solution from contaminating the extracted water. This could be due to various reasons such as:

- Imperfect sealing between the O-rings and porous zeolite surface
- The membrane cross section not being perfectly circular
- Unknown chemical reactions between the O-ring material and the amine

Original module with epoxy connections

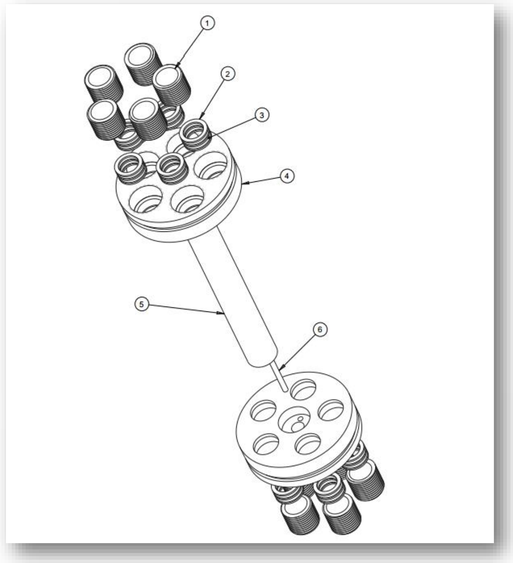
The objective of this project is the completely seal off the concentrated amine solution from the extracted water stream. It is important to complete the overall objective while maximizing membrane surface area exposure and avoid using epoxy due to unknown chemical reactions with the solution.

Design Constraints

Items mentioned below are to remain the same throughout the design process. These are requirements that were established by UK CAER:

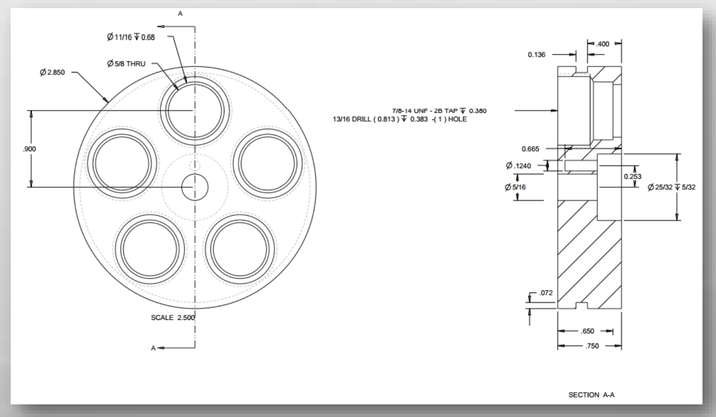
- Pressurized vessel shell is to remain unchanged. - Unit is made from stainless steel.
  - Location of solvent input and output valves
  - Two thermocouples, one at the top and bottom.
  - Hollowed shell with welded flanges on the top and bottom.
- Membrane design is to remain the same.
  - Tubular zeolite membrane.
  - 1.2 cm. outside diameter.
  - 18 cm. in length.
- Machining will take place at the UK CAER's machine shop facility with the assistance of the skilled machinist.
- Design concepts will be reviewed and approved by the necessary project leaders of UK CAER.
- Stainless steel bar stock and all-thread, washers and O-rings orders will be placed through UK CAER.

Prototype Design



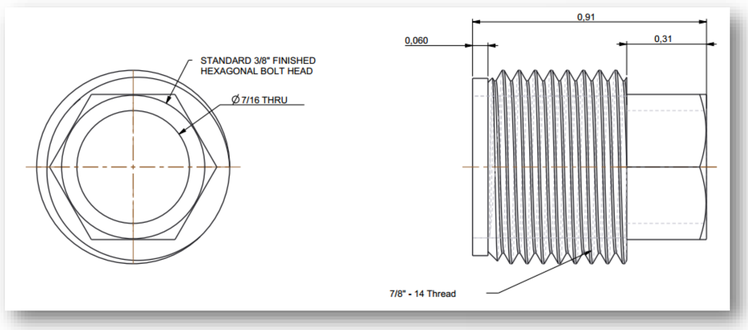
Exploded drawing of prototype design

The complete prototype will be a fully functional pressurized membrane module with attributes of the new seal design incorporated. The re-designed end plate will feature only five holes for the zeolite membranes as opposed to six in the previous model to provide the extra space necessary for the threaded fasteners. Also each end plate hole will have a machined step to stop the fasteners once the desired compression ratio of the O-rings is reached, as well as a threaded mating surface for the fasteners.



Prototype End Cap drawing

The O-ring and washer combination will feature two ethylene-propylene O-rings and three steel washers around each membrane. The material for the O-rings was carefully selected to be chemically resistant to the amine solution and also withstand the high temperature and pressure inside the vessel during operation. Ethylene-propylene was chosen because it is a softer elastomer, which is more desirable for rough surface applications.

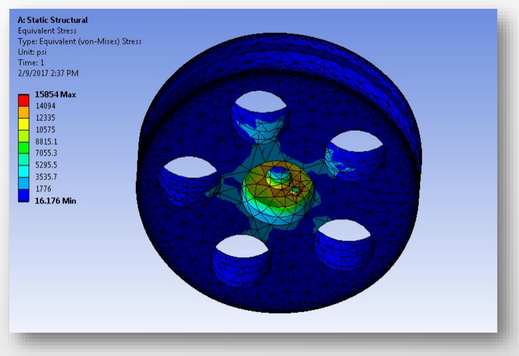


Prototype Threaded Fastener drawing

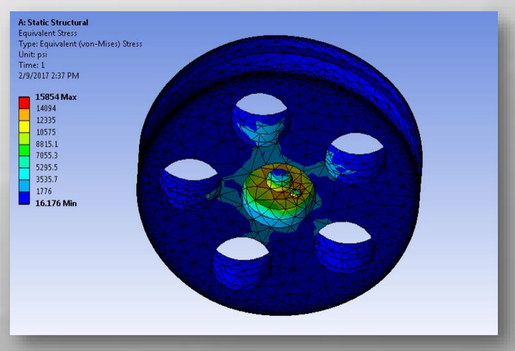
The threaded fastener concept is completely new to any previous design that UKCAER has attempted for sealing around the membranes. This is the key feature to the design and will be critical in creating a uniform, liquid tight seal around the circumference of the membranes. The tolerances of all these individual parts are of high importance to ensure they fit together and make contact with both the membranes and the end plate wall.

Prototype Testing

The team will follow the same procedure that UK CAER has previously performed to test if the membrane module is working. The main area of concern is the seals between the ID of the O-rings and the OD of the Zeolite membranes. UK CAER has been able to determine membrane failure through visual inspection, permeate analysis, and pressure surveys. Finally, A computer program was used to test the module under operating conditions to ensure no mechanical failures.



ANSYS Stress Simulation



ANSYS Safety Factor Simulation