FERMILAB-POSTER-23-201-STUDENT

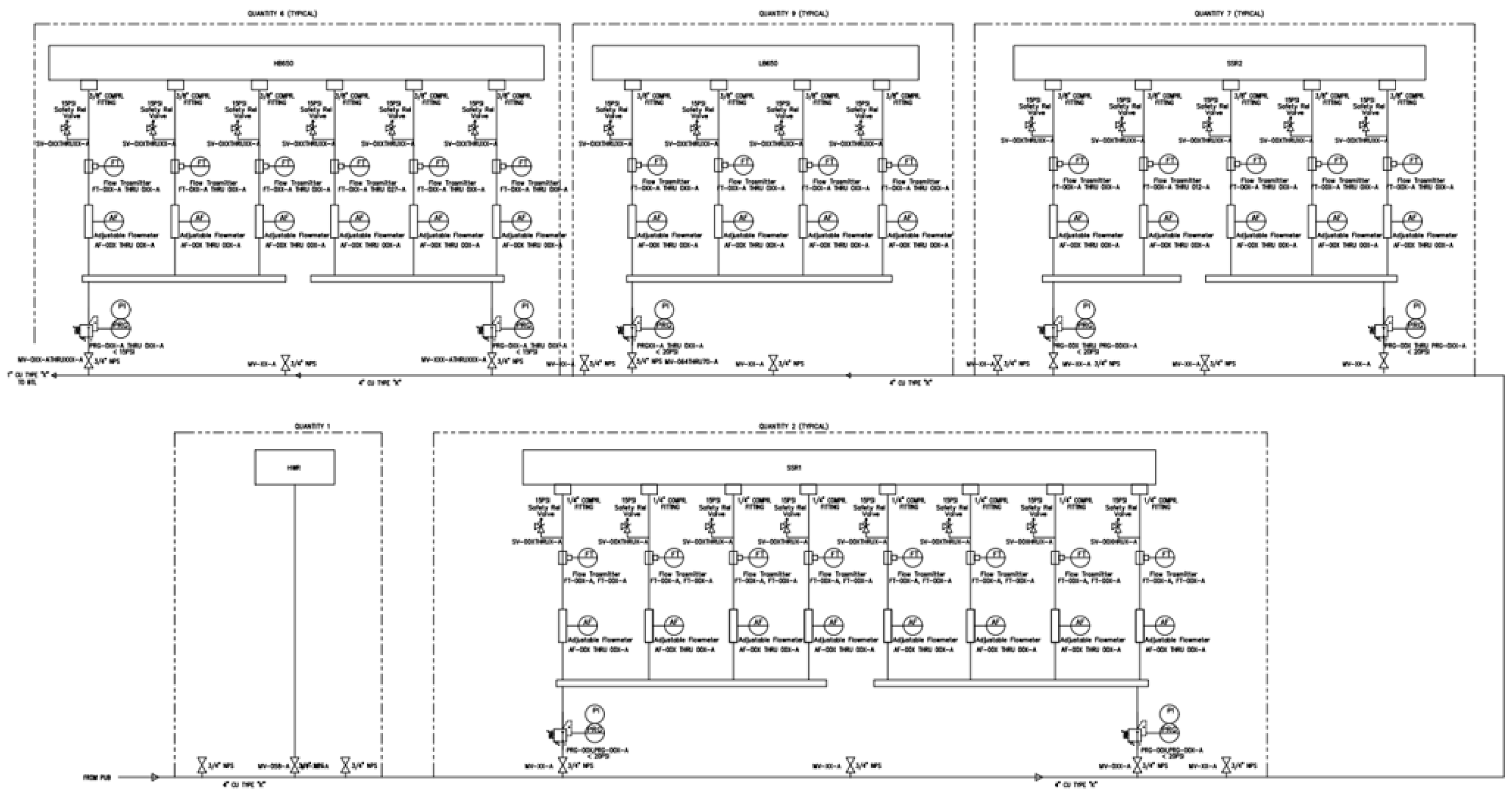
Cryomodule Compressed Air Panels

Lilly Herbst, UW-Milwaukee – SIST Intern | Maurice Ball and Tiffany Price, Fermilab

Background and Purpose

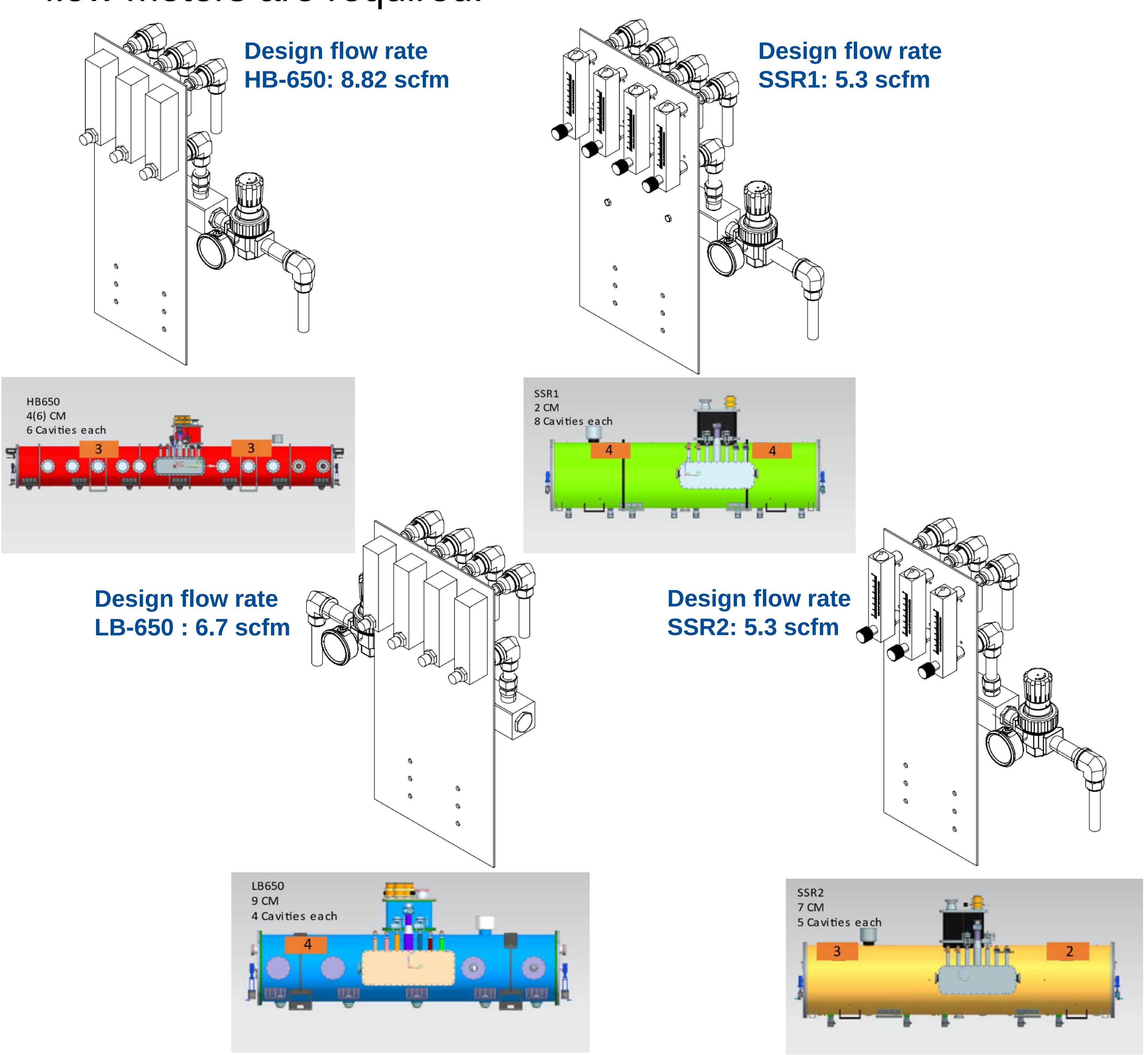
RF couplers require compressed air to maintain operational temperature and performance. Each type of cryomodule has a different configuration dependent on the number of RF cavities and their specifications. Compressed air panels will be mounted on the lifting brackets of the cryomodules to provide support for the hardware.

Specifications and Modeling



PIP-II compressed air P&ID for cryomodule couplers for HB-650, SSR2, SSR1, LB-650

AutoCAD was used to make this P&ID (supply process and instrumentation diagram) which shows the piping and related components. Given the air flow requirements, two different flow meters are required.



Compressed air panel assembly drawings for HB-650, SSR1, LB-650, SSR2

NX was used to create the 3D models and produce fabrication drawings. The flow meters were determined by the airflow requirements and the manifolds reflect the number of cavities or RF couplers. All the components are commercially available off the shelf, but the mounting plates will be fabricated.

Calculations and Analysis

Before FMEA analysis on ANSYS, hand calculations were completed to determine the forces placed on the compressed air panel due to its components. The calculations resulted in a thickness greater than 0.125 inches.

Bending moment formulas

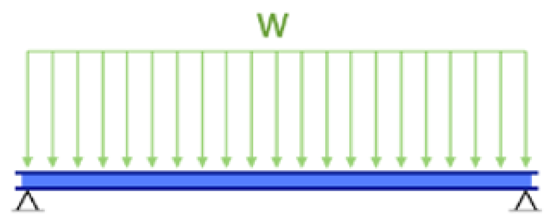
- *Fixed with pins on both ends* $M = \frac{RL^2}{8}$
  - *where* $R = \text{reaction forces}, L = \text{length of plate}$
- *Fixed on both ends* $M = \frac{RL^2}{12}$
- *General* $M = \frac{EI\varepsilon}{d}$
  - *where* $E = \text{elastic modulus},\ I = \text{moment of inertia},\ \varepsilon = \max \text{allowable stress},\ d = \text{distance}$

Relating stress to thickness

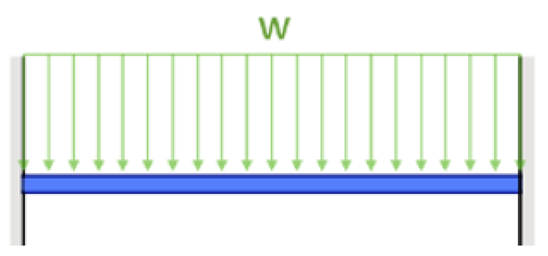
- $t = \frac{EI\varepsilon}{Md}$
  - *where* $I = \frac{Wt^3}{12},\ d = \frac{t}{2},\ w = \text{width},\ t = \text{thickness}$

Substitute

- $t = \frac{\frac{EWt^3\varepsilon}{12}}{\frac{Mt}{2}} \ldots t = \sqrt{\frac{6M}{EW\varepsilon}}$



Fixed with pins on both ends



Fixed on both ends

F (flow meter weight) = 0.74 lbf
E (elbow/top row weight) = 1.1166 lbf
D (distributed load) = 11.818 lbf

Finding the reaction forces R

$\sum R_y = 0, \quad -3F - 3E - D + R = 0$

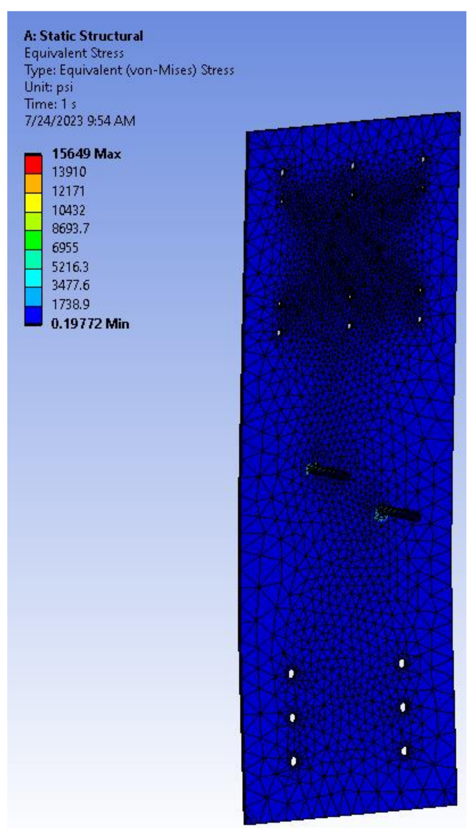
R=17.39 lbf

Assuming we're using Aluminum 6061

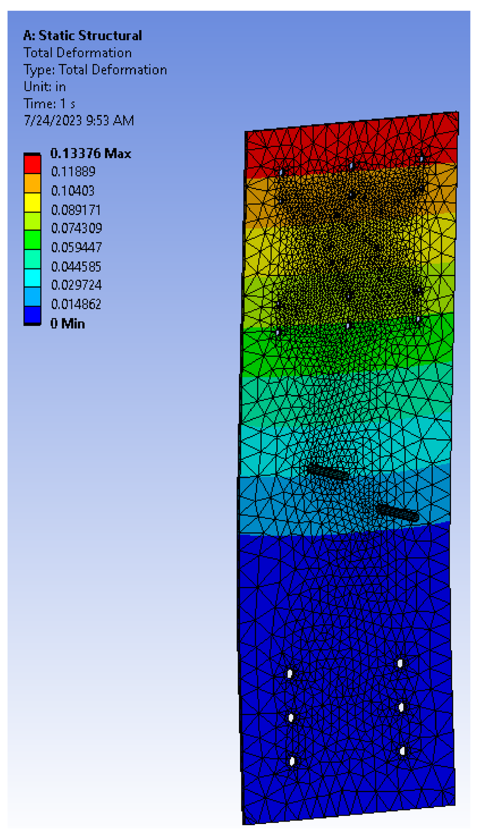
- Elastic modulus: $1.0 * 10^7\ psi$
- Yield strength: $34809.1\ psi$

Calculations for the minimum thickness of the plate

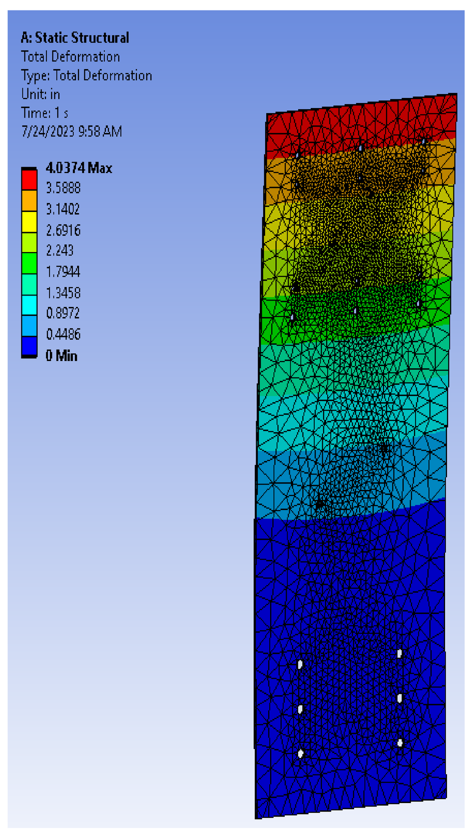
Using 0.125-inch-thick aluminum, a static structural analysis was performed and solved for total deformation and equivalent (von-mises) stress. A pull test of 100 lbs. horizontal force was also studied. The ideal safety factor for this plate is between 2-3. Using the ultimate tensile strength of 6061 aluminum and the equivalent stress, the safety factor came out to 2.68.



Equivalent stress (parts only)

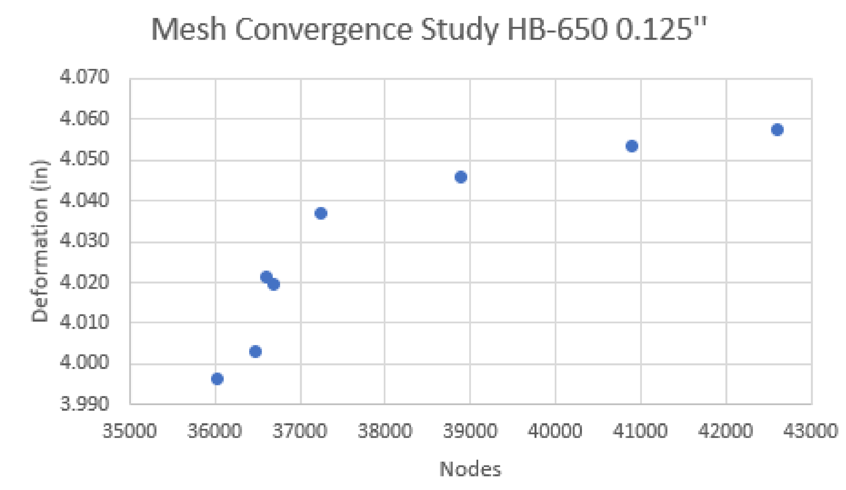


Total deformation (parts only)



Total deformation (pull test)

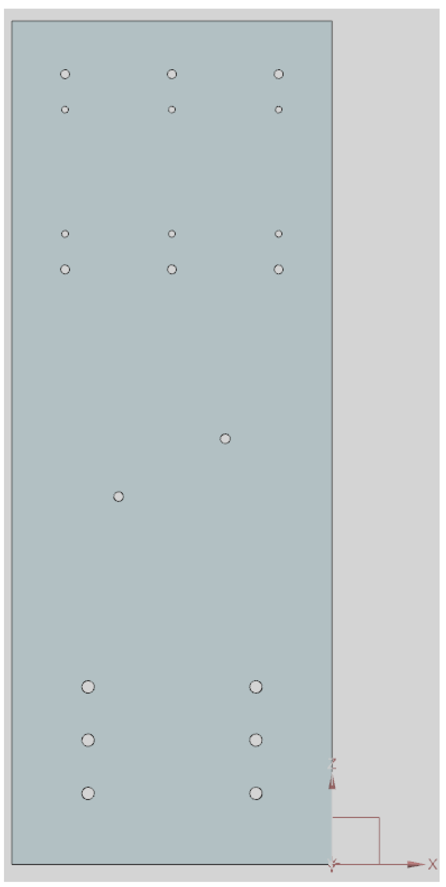
$$\frac{42{,}000\ psi}{15{,}649\ psi} = 2.68$$



Convergence study to confirm max pull deformation

Summary

A 0.125-inch-thick plate provides an inexpensive and stable solution in order to hold all components for the compressed air panel. After fabricating the prototype, components are being purchased to verify the simulations. Future work will include fabricating all panels and assembling them with their components.



HB-650 compressed air plate

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.