Basic Bringup: Cryorefrigerator

# Introduction

This document is an ongoing document detailing the current status of the quick test cryorefrigerator. The intent of this document is to note current problems and attempted solutions as well as providing a history for the project.

# Goals

The goal of this project is to make a cold chamber that can quickly and cost effectively reach a few temperatures. The use for this system would be quick tests of samples prior to placing them in the main cryostats that take ages to reach temperature.

# Progress

A broad strokes design was settled on for the cold chamber. A decommissioned refrigerator tube will make the outside body of the new fridge. Then by simply having a new top plate machined we will have a sealed system.

The top plate will require a hole pattern such that the PT415 by Cryomech can bolt directly to the top plate. In addition to that a series of KF50 and potentially KF25 flanges should be machined into the plate.

Going forward the most time sensitive step is to submit the job to STS. For this reason we will mock up the top plate in a CAD software and hopefully submit the job before fleshing out the details of the assembly and experiments that are intended to be run.

For CAD see the CAD folder.

Cryomech has been emailed requesting a CAD file for the PT415. Cryomech has obliged in giving the cad files under the condition that we don’t plan on taking the PT415 out of the country (a matter of national security as far as I can tell…)

# Stress analysis

Inventor professional has a built in FEM solver for stress. Using this tool it is straightforward to get a rough idea of the deflection which the plate will see under vacuum. A pressure of 15psi was applied to the surface of the plate with the vacuum jacket marked as an immovable object. The result of the calculations is shown in the image below. The takeaway is that for a ¾” austenitic stainless steel plate a maximal deflection of 0.002” is expected.

This is of course just a simulated estimation. Some limitations include gravity not being factored in, using a generic austenitic steel grade for the simulation instead of specifying 316L stainless steel (for example). Also, the weight and the added rigidity of having the flanges populated with equipment was ignored for this test.



A further test with gravity found no difference. Also initial investigations into the natural harmonics of the steel plate show that modifying the orientation of the holes does not have a significant effect on the dominant vibrational mode. You can see that the spherical harmonics for a disk are predominant (as expected) with additional modes due to the corners vibrating.

Talk with Jan checklist

* Bolt pattern for the legs, I’ve allotted four posts each 2”x2”
  + 1.25” legs use some adapter 2”x2” 4 bolt legs
    - I’ve added some mounting holes, instead of 1/4-20 I used the size down (16-28?), you get more threads in at a shallower tap, plus you want a minimum depth to width ratio
  + ¼-20 is what we’re going with b/c you only need a few threads.
* O-ring groove for the PT415
  + Emailed CryoMech for land pattern
    - The recommended O-ring is 2-258, this happens to match the o-ring we settled on. The recommended bellows ID is 5.4”. This dimention becomes tight when we add a second o-ring groove for EMI shielding. However it looks as though we can still fit it.
  + Second O-ring
    - Added a second groove, still needs to be properly dimentioned
    - 25% compression of the Spira product is ideal. The dropoff in effectiveness is significant as you move away from ideal compression. This asks for a 0.25” groove which won’t fit comfortably on the plate. Recommend ordering a more manageable size Spira
    - We hav about 8thou of wiggle room on the height, so if the o-ring is compressed to within 8thou of the plate the depth speced on the website is good, however if the o-ring keeps the PT more than 8thou off the plate then the depth needs to be made more shallow.
  + Choice of bolts?
    - 5/16-18 looking bolt
  + Email cyromech for recommended land pattern.

The vacuum jacket bolt pattern has been measured properly. Test holes drilled in acrylic with the desired spacing. Test hole was fit on every pair of bolts. The center to center dimention which works is 530.5mm. Using a 24” Vernier the bolt to bolt spacing measured by screwing in a pair of M8 bolts in opposite holes and measuring the greatest distance between the heads of each bolt. The distances measured for two sets of holes was 21.381” and 21.385”. The bolt head a nominally 1/2” diameter head. To within small error the center to center spacing is then 21.381-0.5”. Which makes the measured spacing 530.377mm and 530.479mm. A test hole was made with the dimention 530mm and this did not fit nicely (might have been within the clearance hole tolerance). Using 530.5mm had the test piece fit nicely in every bolt pair.

* + Picture of test thing
* A plate of steel might be uneven by up to 40 thou, this means for o-ring surfaces the plate will have to be locally flattened. This is ok right?
* PT415 spira and o-ring groove. Use recommended sizes based on the plate bottoming out and the spira being on the outside of the oring
  + Meet with Andrew on Monday morning to give him the real specs
* We are going to fold our own radiation shields
* 55k stage will be made out of aluminum
  + Tapped holes going around the stage to attach radiation shield
* Braded heat transfer
  + Thermal conductivity is proportional to electrical conductivity
  + Ask grand river welding if they can weld copper
  + Machine and test copper clamping instead of welding.

# Radiation Shield

The purpose of this is to reduce the radiated heat leak into the coldest part of the cryostat. (Pg.10 “Experimental techniques in condensed matter”). The first design question addressed was whether to use some pre-existing shields or to manufacture our own. We have decided to repurpose some shields which were laying around, whether this is the best option has not been fulled explored. Of primary concern is the weight of the shields, with secondary concern that they consume too much of the space in the cryostat.

Of the available pre-existing shields here are dimensions and weights:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Part | ID | OD (in) | Height (in) | Thickness  (Thou) | Weight (lbs) | Material |
| 55K top | 14.5 | 17 | 18.6875 | 186 | 22 | Al |
| 55K bottom | 14.5 | 17 | 25.5 | 186 | 30 | Al |
| 2.8K shield | 11.375 | 12.75 | 32 | ~<140 | 20 | Al |

Also note that the radiation shields available are not the right height for this purpose. As a result they will have to be cut to length, which might be as much work as making custom shields.

For comparison the weights of the radiation shields in the D-wave Cryostat

|  |  |  |
| --- | --- | --- |
| Part | Wall Thickness (thou) | Weight (lbs) |
| 55K Radiation shield (top) |  | 6 |
| 55K Radiation shield (bottom) |  | 15 |
| 2.8K Radiation shield | 66 | 13 |

\*note that the thicknesses were estimated using a micrometer and a drill bit so the accuracy of the measurement isn’t excellent.

Using basic unit analysis to calculate how long it will take to cool a 22lb aluminum radiation shield:

This calculation is a good starting point but ignores the fact that heat capacity is a function of temperature which trends towards zero at low temperatures, meanwhile cooling rate is also temperature dependent, increasing with temperature. Thus this is a gross overestimate of the cooling power.