Some Comments about Absorber Integration

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This short document is a guide to Ed Black and others as to how I think the focusing magnet should be integrated with the absorber for the MICE proposal. I have assumed that Ed Black's drawing will be the central drawing describing the experiment. That drawing must present a credible scenario for integrating the absorber with the focusing coil pair. The focusing coils used for this study are the latest used in Bob Palmer's ICOOL simulations. These coils are shorter with a smaller space between them. As a result, they fit into the focusing magnet cryostat better. Figures 1 through 4 at the end of this document illustrate my thoughts on the subject of integration. In order to create the drawings in Figures 1 through 4, I made a number of assumptions that may require collaboration approval.

The assumptions are as follows: 1) The inner window diameter was set at 300 mm with a 20 to 25 mm wide rim around that window (see Fig. 1). 2) The outer window (safety window) was set at 350 mm with a 20 to 25 mm-wide rim around the window (see Fig. 1). For both windows the rim thickness was set at about 12 mm, but the rim could be as thin as 6.4 mm. 3) The inner window temperature is set to be the temperature of the fluid in the absorber. (The fluid temperature is 18 to 20 K at 1 bar when the absorber contains hydrogen. When the absorber contains helium the temperature is set at 4.8 to 5.0 K at 2 bar (30 psia).) 4) The outer window temperature must be greater than 50 K. Having the outer window at a temperature above 50 K means that oxygen in the RF cavity vacuum space will not freeze out on the outer window surface. Because the outer window temperature is higher than the inner window temperature, the space between the windows must be evacuated. A cylinder of 5456 aluminum is between the inner and outer window. The heat used to keep the outer window temperature above 50 K is carried to the window by radiation and by conduction along a thin wall 304 stainless tube that forms the inner cryostat for the magnet. 5) At least one set of absorber windows is removable for the proposal. There are several candidates for the window seal material. Because the space between the windows and outside is pumped and kept under vacuum, the leak rate for the window seals can be as high as 10^{-7} atm cc per second. 6) The vacuum spaces between the pair of inner and outer windows are connected to each other through a 12 by 30-mm slot in the absorber body that connects the two vacuum volumes. The vacuum volume between the windows is connected to the outside world through a pair of 25 mm OD tubes that connect the absorber body to a vacuum tank that is outside of the cryostat (See Fig 2). The tubes leaving the absorber are made from aluminum. A transition from aluminum to stainless steel tube would occur out side of the magnet support structure. Once the transition from aluminum tube to stainless steel tube has been made, the tube can become flexible stainless steel hose. 7) The liquid filled portion of the absorber is connected to the outside through a pair of vertical 25-mm OD tubes that form the neck of the liquid cryogen vessel. These tubes are also made from aluminum. 8) The absorber body is assumed to be supported from the aluminum tubes that come out of the cryogen tank of the absorber. It is assumed that these tubes are in turn supported from magnet coil support structure through a low heat leak NEMA G-10 spider. Other approaches for supporting the absorber are possible. 9) The heat exchanger between the liquid in the absorber body and the helium flowing through the case is an extended surface heat exchanger that goes up each side of the absorber case from a point at an angle of –75 degrees to +75 degrees. (The extended heat transfer surface is shown in Figure 3.) 10) The absorber body diameter is shown as 460 mm. The inner diameter of the inner magnet support structure is shown at 490 mm. Thus the clearance between the absorber body and the inner cold surface of the magnet is 15 mm. 11) The cooling for the superconducting coil is from tubes attached to the outer support shell around the superconducting coils. This support shell is assumed to be made from forged 6061-T6 aluminum. The potted coils are machined and shrunk fit into the two halves of the support structure. The two halves of the support structure are welded together when the magnet is assembled around the absorber body with it pipes coming out of it top and bottom. 12) The pipes that come out of the absorber body run vertical rather than in the radial direction. See the pipes in Figure 4.

Other Issues

Other issues to be considered in the design of the absorber that might affect integration with the focusing coils include the following: Is a bladder installed to shorten the length of the absorber? Is a duct installed in the absorber body to direct the flow of liquid cryogen and reduce the formation of large stagnent eddies that may form high temperature points in the absorber. The extended surface heat exchanger should be discussed a little more.

The bladder is not shown in Figures 1 through 3. It is not clear that a bladder to shorten the cryogen path will be included in the proposal. Two different types of bladders have been proposed. They are the double bladder (a single shaped Mylar or kapton sheet next to each window) or a single bladder that is in the center of the absorber (a ring with two shaped Mylar or kapton sheets). The double bladder has the stated advantage of moving the liquid to the low beta center section of the absorber. The double bladder is more complicated in that helium must be fed to the space between the window and the bladder sheet. The single bladder with two sheets is simpler to build and it can be supported from a couple of points on the absorber inner wall. The single bladder can have a single capillary tube that carries helium to the bladder. This tube can up one of the two necks that go vertically out of the absorber. The stated disadvantage of the single bladder is the fact that all of the liquid cryogen is in the higher beta portion of the absorber.

In my opinion neither bladder solution is completely satisfactory for MICE from a physics standpoint. When one look at the standard case, the beta is 44 cm at the center of the absorber. (Note: the beta number of 44-cm comes from Bob Palmer latest simulation that the focusing coil design shown in Figures 1 through 3 is based on. This number is different from the 42-cm beta previously used.) According to Bob Palmer's simulation the beta at the ends of the focusing coil cryostat is about 56 cm. The beta 175-mm from the center of the absorber (and focusing coil pair) is about 49 cm. For the double bladder case, the average beta in the absorber changes from 47 cm to about 45.5 cm when the bladders are blown up to shorten the absorber path. For the single bladder case, the average beta increases from 47 cm to about 48 cm when the bladder is blown up. One has to ask is there a change in the absorber performance due to the change in average beta. We know that lower beta is better so in a change in performance of the experiment due to a change in average beta or some other factor having to do with a shortened absorber. To make the situation better from an experimental standpoint, I propose an offset single bladder that displaces the cryogen at one end of the absorber. This type of bladder will minimize the change in average beta in the absorber while shortening the absorber length.

The duct is shown in Figures 3 and 4. As an old-fashioned heat transfer person, I would assume by analogy that the use of a duct produces better heat transfer within the absorber. We know that ducting has a dramatic effect on the performance of a helium condenser built for a magnet at LBNL that is cooled using a pair of 1.5 W (at 4.2 K) coolers. There is little if any down side to installing a duct to direct the fluid flow during free convection cooling. The duct may be worth simulating using a free convection heat transfer code to see if it improves performance.

In Figure 3, I show that the heat transfer surface on both sides of the absorber wall is extended. The heat transfer coefficient is highest on the hydrogen side of the absorber, but it is not dramatically higher. Extending the heat transfer surface on both sides by machining grooves on the inside and the outside of the absorber body can't hurt and these grooves should have the effect of increasing the heat transfer area from about 0.22 square meters to about 0.45 square meters. This should increase the effectiveness of the heat exchanger almost a factor of two. The other thing that is assumed in Figure 4 is that helium gas enters the heat exchanger at the bottom on both sides. The helium gas leaves the heat exchanger at the top. This forms a counter-flow heat exchanger that should have a maximum value of the log mean delta T between the cryogen in the absorber and the helium in the body. It should be pointed out to those who want to use a helium in place of the hydrogen in the absorber that the heat exchange from the cryogen to the coolant on the outside of the absorber is a factor of six to eight lower than it is for a hydrogen absorber. The log mean delta T is the driver. That is why it is important that parasitic heat load be taken directly into the absorber body instead of the absorber cryogenic fluid.

Figure 1

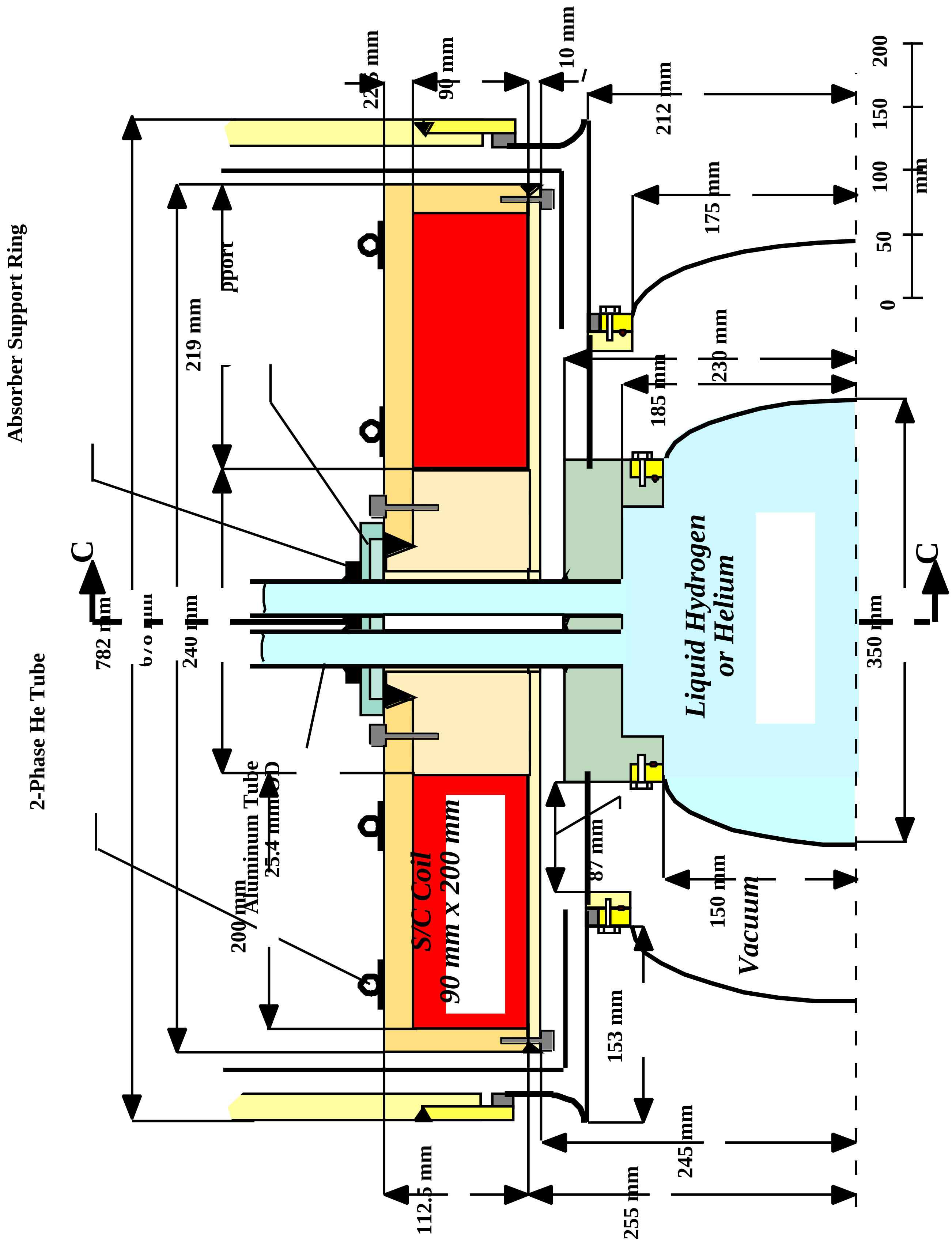
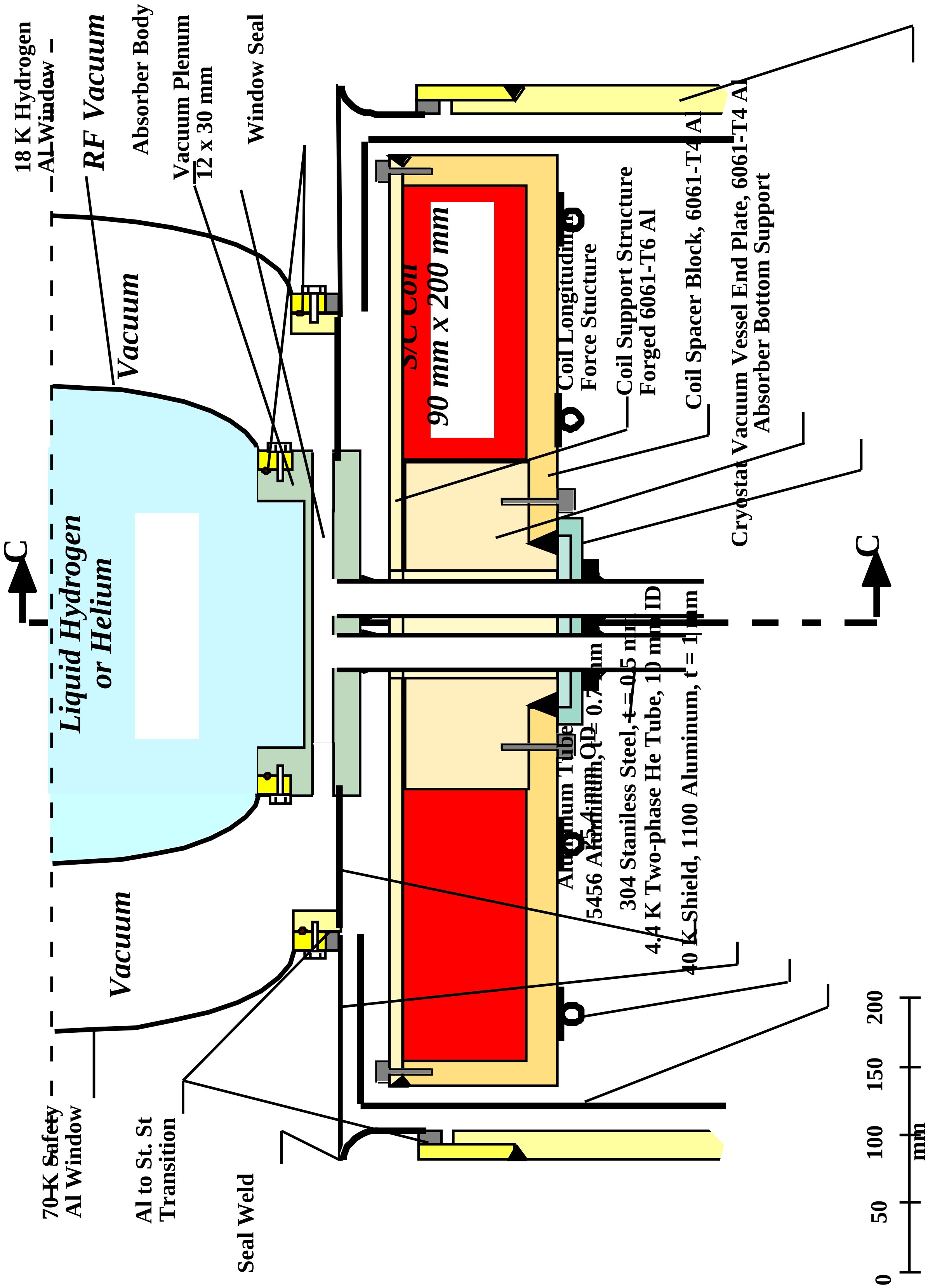

Absorber Support Ring
2-Phase He Tube
Aluminum Tube
25.4 mm OD
S/C Coil
90 mm x 200 mm
Liquid Hydrogen
or Helium
Vacuum
C
C
782 mm
240 mm
219 mm
200 mm
112.5 mm
255 mm
245 mm
153 mm
87 mm
150 mm
350 mm
185 mm
230 mm
175 mm
212 mm
90 mm
10 mm
0
50
100
150
200
mm

Figure 2



18 K Hydrogen
Al Window
RF Vacuum
Absorber Body
Vacuum Plenum
12 x 30 mm
Window Seal
Vacuum
Liquid Hydrogen
or Helium
C
S/C Coil
90 mm x 200 mm
Coil Longitudinal
Force Stucture
Coil Support Structure
Forged 6061-T6 Al
Coil Spacer Block, 6061-T4 Al
Cryostat Vacuum Vessel End Plate, 6061-T4 Al
Absorber Bottom Support
Aluminum Tube
5.4 mm OD
5456 Aluminum, t = 0.7 mm
304 Staniless Steel, t = 0.5 mm
4.4 K Two-phase He Tube, 10 mm ID
40 K Shield, 1100 Aluminum, t = 1 mm
Vacuum
70-K Safety
Al Window
Al to St. St
Transition
Seal Weld
0
50
100
150
200
mm

Figure 3

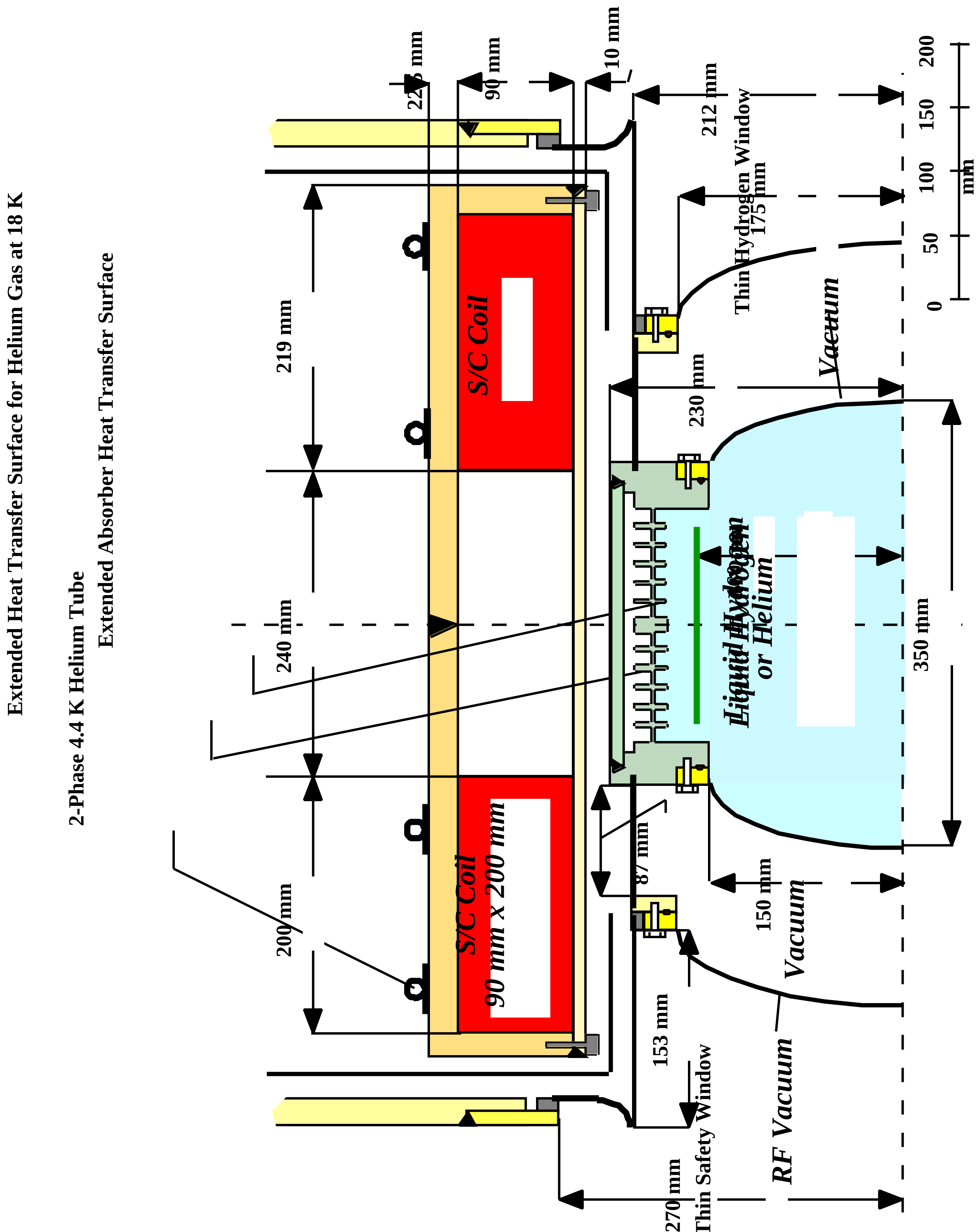
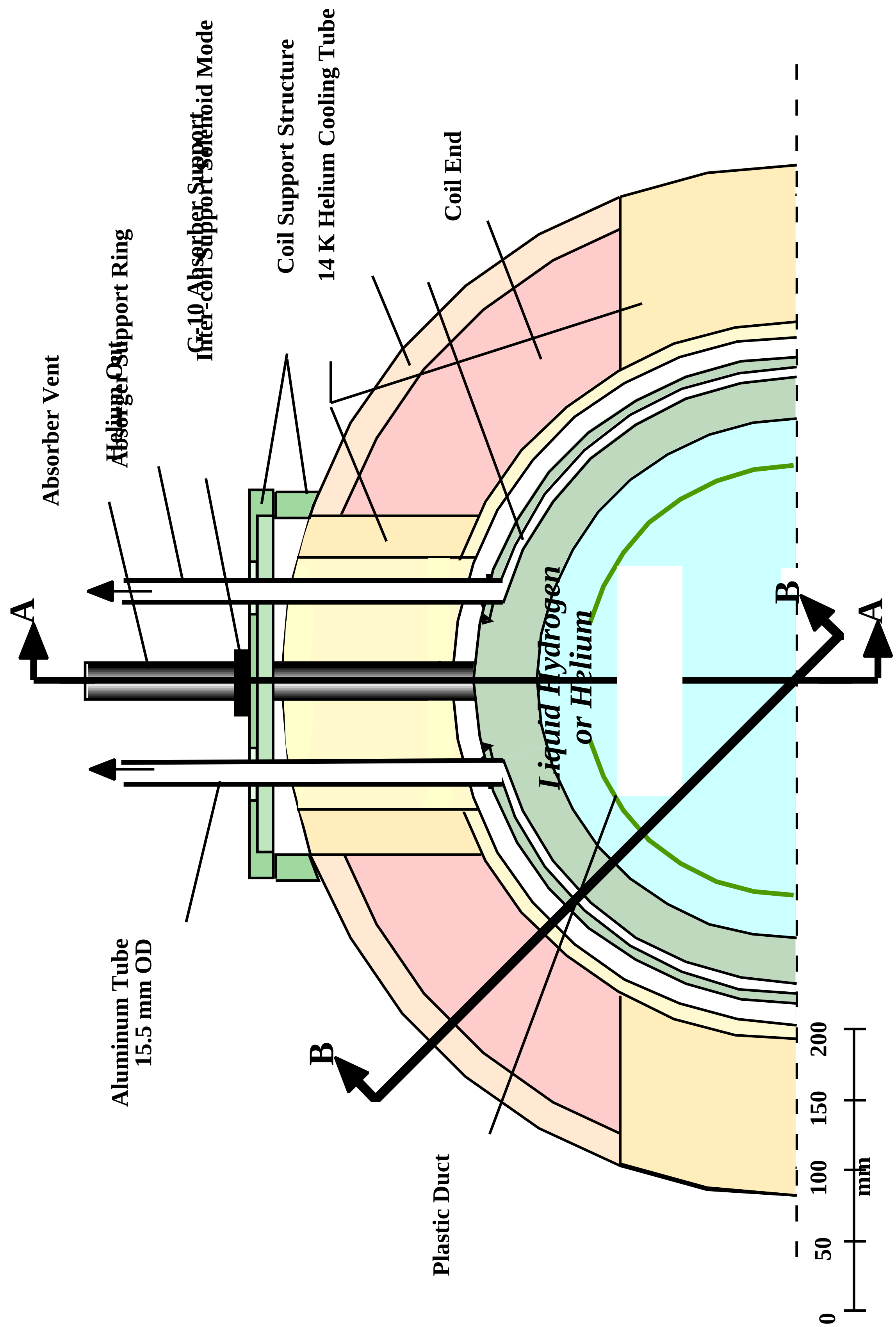

Extended Heat Transfer Surface for Helium Gas at 18 K
2-Phase 4.4 K Helium Tube
Extended Absorber Heat Transfer Surface
90 mm
10 mm
212 mm
175 mm
Thin Hydrogen Window
219 mm
S/C Coil
230 mm
Vacuum
240 mm
Liquid Hydrogen
or Helium
350 mm
87 mm
150 mm
S/C Coil
90 mm x 200 mm
200 mm
Vacuum
153 mm
Thin Safety Window
RF Vacuum
~270 mm
0
50
100
150
200
mm

Figure 4



Absorber Vent
Helium Out
Absorber Support Ring
G-10 Absorber Support
Inter-coil Support Solenoid Mode
Coil Support Structure
14 K Helium Cooling Tube
Coil End
A
A
B
B
Liquid Hydrogen
or Helium
Aluminum Tube
15.5 mm OD
Plastic Duct
0
50
100
150
200
mm