Preliminary, (B) Revision of the (A) document.
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SSCL-N-805

# Report on the ASST II Liner Status

Prepared by

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| 16 | Test of liner support heat leak | J. Maddocks, J. Zbasnik |
| 17 | Test of Magnetoresistivity/Parisitic heat/Thermal conductivity at low temp. & high field | Q.S. Shu, Zbasnic, W. Chou, W. Turner |
| 18 | System design package | Q. S. Shu, K. Yu, G. Morales, C. Murray |

* Some name may be unintentionally omitted

# Remarks

This report, Report on the ASST II Liner Status, was prepared under the request of PMO (SSCL Project Management Office) and followed the guideline provided by Dr. Gerry Dugan (SSCL Deputy Project Manager). The report discusses various technical design issues needing resolutions for the ASST liner and reports the status of the liner program.

The Liner System Design Team was organized in July of 1992. The team consists of members from PMO, MSD and ASD. The liner is designed as an option to resolve the concerns due to the synchrotron radiation and accompanying photodesorbed gases. The major responsibility of the design team is to develop a workable liner prototype for the Collider. The liner prototype will be validated in ASST II.

The challenges that this design team is facing can be summarized as follows:

(1) A technical challenge with no previous experiences to be directly drawn from. The SSCL Collider is the first proton superconducting accelerator designed to operate at high enough energy (20 TeV) and beam current (0.072A) that may require a liner. The SSCL Collider will produce a synchrotron power of 0.14W/m (18kW into 4.2K for the two rings). This power may trigger the concerned impact of photodesorbed gases. Many intertwined technical problems must be considered and resolved in the liner design.

(2) A schedule challenge that must catch up with many years of magnet design efforts. When the liner design team was organized, the magnet programs had been well developed for many years. To reduce the cost and schedule impact on the magnet program, the schedule of the liner development must be very aggressive.

The liner design team performed the following tasks in the last four months. Four trade studies were selected to establish the liner design and to minimize the cost & schedule impact on the collider. The physics and engineering tasks were focused on the removal and/or reduction of the risks that a liner design can have on the operation of the collider. Demonstration and verification experiments were planned to validate the concept derived from our studies. The final selection of a conceptual design is well in progress. The detailed engineering design of several items began in November of 1992.

Significant progress has been achieved because of the great team spirit, the extremely hard working members, and extraordinary administrative and technical support from the SSCL divisions. I would also like to devote my personal appreciation to Dr. G. Dugan, Dr. R. Meinke, Dr. W. Turner of PMO and Dr. T. Bush, Dr. R. Coombes, Dr. J. Tompkins of MSD and Dr. T. Kozman, M. McAshan of ASD for their support and guidance. It is my privilege to summarize and to present this excellent work of the Liner System Design Team.

Quan-Sheng Shu
Liner System Design leader
SSCL MSD
November 27, 1992 (revised)

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# I. The Task of Liner System Design

## 1. Why need a Liner?

The SSCL Collider is the first proton superconducting accelerator designed to operate at high enough energy (20 TeV) and beam current (.072A) to produce significant synchrotron power (0.14W/m, critical energy = 284eV, 18kW at 4.2K/two ring). The radiated power and accompanying photodesorbed gases impact the beam vacuum, beam current, cryogenic plant capacity and operational availability of the Collider. A liner configuration is being studied as an option for the Collider vacuum system with the design goal of not requiring more than one machine warm up per year for vacuum maintenance.

### A Comparison of SSC/LHC (CERN) Vacuum Relevant Paremeters

| | SSC | LHC | |
|---|---|---|---|
| Proton energy, TeV | 20 | 7 | (spp(20TeV)=50mb) |
| Beam current, mA | 70 | 850 | |
| Magnetic field, T | 6.6 | 10 | (R=10.2/2.57 km) |
| Magnet temp., K | 4.2 | 1.8 | |
| Photon Flux, photons/m/s | $1x10^{16}$ | $1.8x10^{17}$ | |
| Critical energy, eV | 248 | 64 | |
| Synchrotron power, W/m | 0.140 | 0.562 | (9/9 kW/ring) |
| $H_2$ density corresponding to 150 hr luminosity lifetime | $3x10^8$ $H_2/cm^3$ | | |
| $H_2$ density quech/cryolimit | $4x10^{10}$ $H_2/cm^3$ | | |
| $H_2$ saturated at 4.2K | $2x10^{12}$ $H_2/cm^3$ | | |
| one monolayer desorption | $7.3x10^{15}$ $H_2/cm^3$ | | (0.2 Torr @294K) |

## 2. The Task of SSC Liner Design Development

### (1) A Liner Prototype

A liner prototype is being designed for installation and test in a half cell (five dipoles, one quadrupole, one spool piece) of the ASSTII at the SSCL. The Liner System consists of a 80K perforated tube (the liner) located coaxially inside the 4.2K magnet bore tube, high pressure GHe loops to maintain the liner temperature, cryosorber on the 4.2K bore tube, low thermal conductivity supports, thermal expansion and RF joints and an interface with the beam position monitor

### (2) A techn. transfer packages

A technical transfer packages based on the experiences learned from the prototype for the Collider Liner will be developed for SSCL subcontractors to produce a Collider Liner System, if it is needed.

The ASST is now in the phase I tests. Which magnets and components to be tested in the ASST phase II are not actually assigned yet. With informations from many groups of PMO, MSD and ASD, the Liner System Design Team proposed a preliminary Liner System Layout with the ASST phase II full cell string in Figure 1. From left, there are one SPRA Spool (Meyer), five CDMs, one CQM and another SPRA spool (CVI) in the liner system configuration. The SPRA (CVI) at the right side will be modified to incorporated a BPM that is positioned within the insulation vacuum on the lead end of the spool piece. The 80-K He will enter the Liner system at the Meyer Spool and return to cryo-plant from the CVI Spool. The Return Flow Cooling Loop and End Conductive Cooling will be used respectively for CDMs, CQM and Spools.

## Liner for SSC

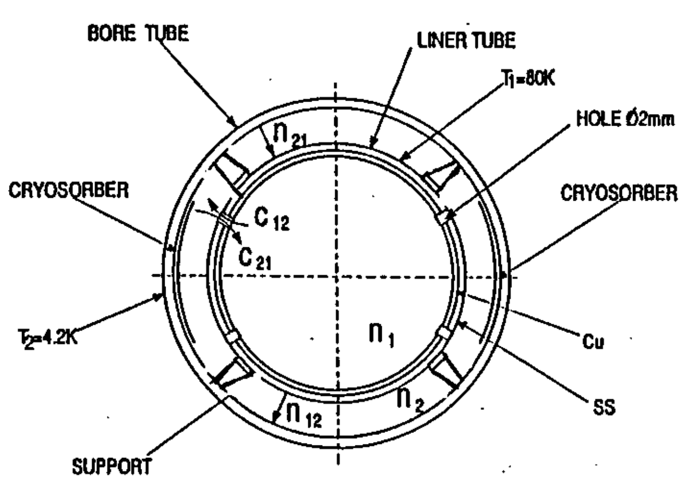
**Primary purpose:** Pump photodesorbed gases.

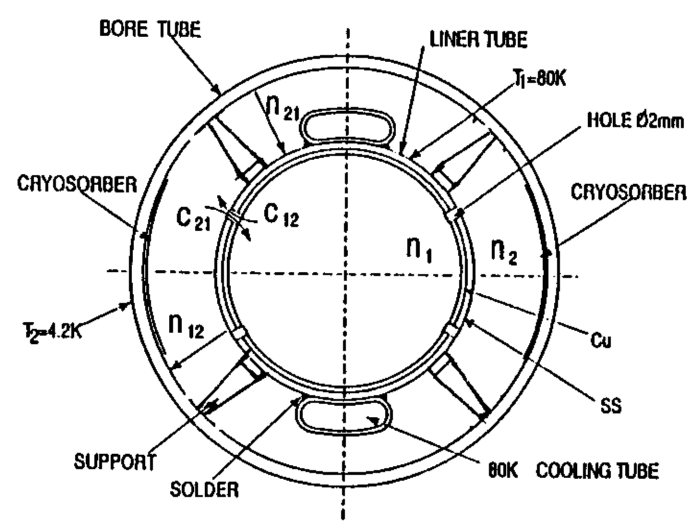
**2nd consideration:** Remove synchrotron heat load if upgraded beam current is needed.

## Liner for CERN LHC

**Primary purpose:** Remove synchrotron radiation heat load at higher temperature than the magnet.

## Cross sections of CDM and CQM Prototype Liner Tubes:



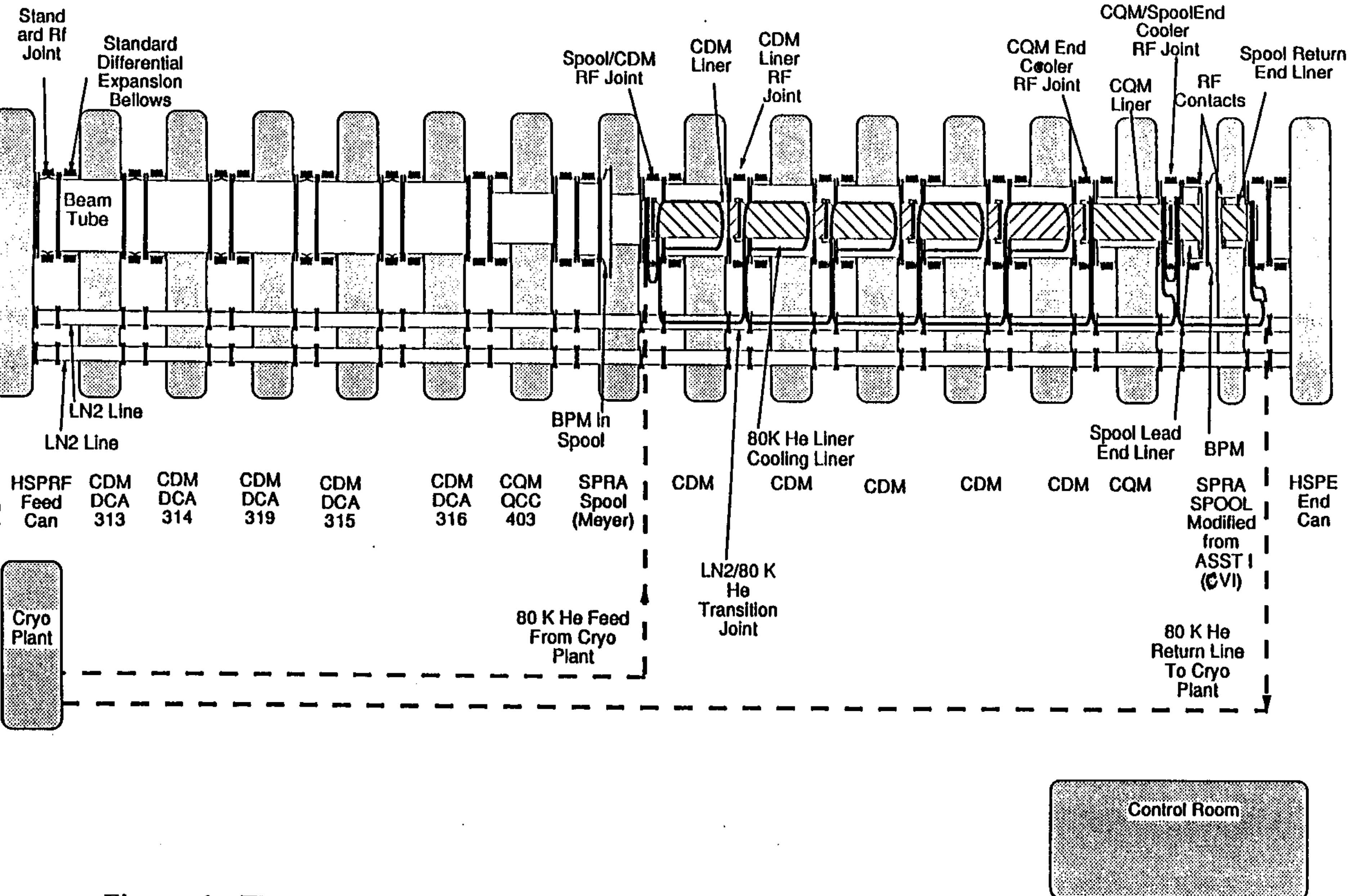



**Figure 1. The proposed Liner System Layout with a full cell string in the ASST II.**

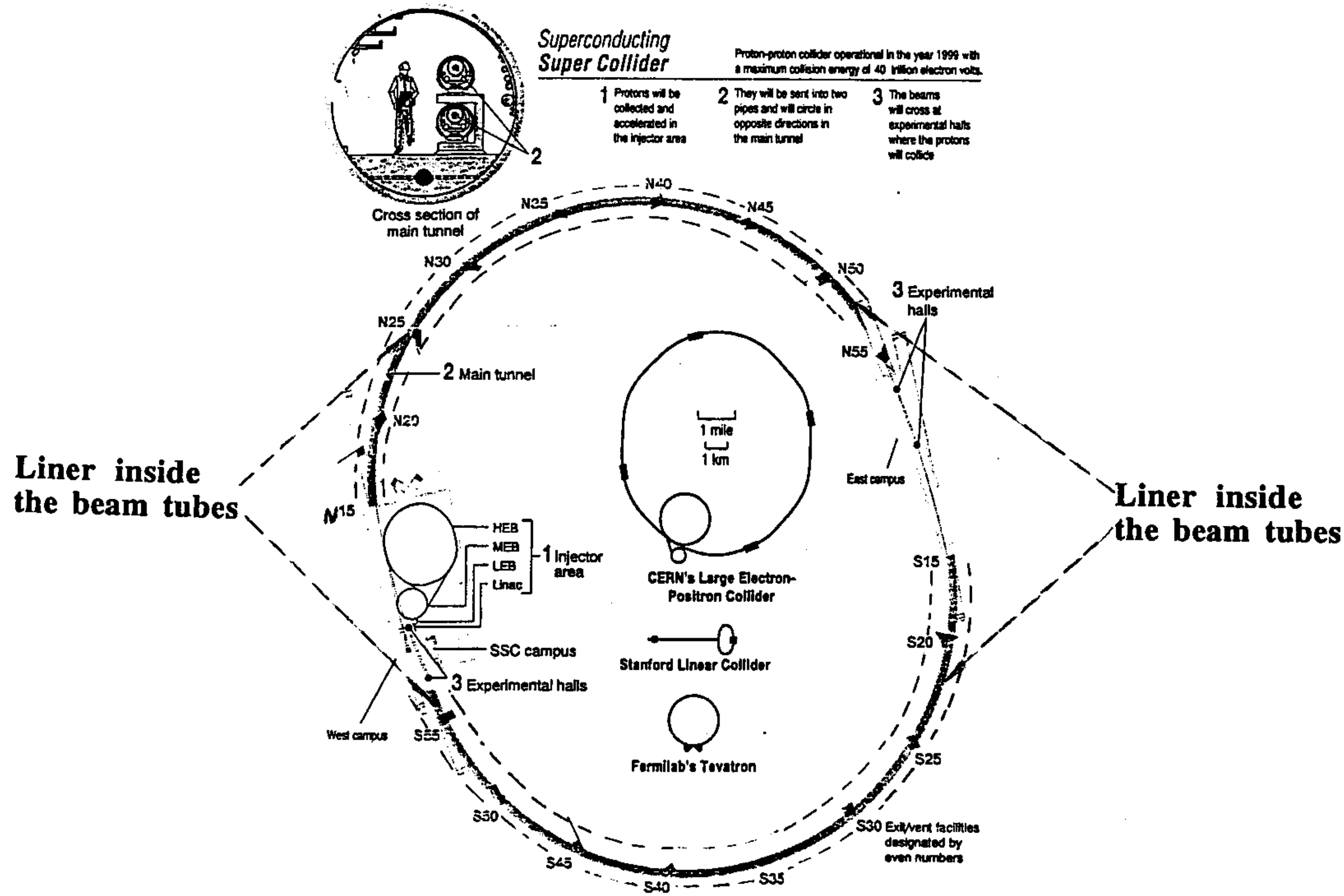



Figure 2. It is proposed that the liner system will be installed into the beam tube of arched areas dashed in the SSC Accelerator Ring if liner is needed. It is still TBD whether a liner system will be used in else place of the ring.

# II. The Status of the Liner System Design

Since the Liner System Design Task Force was formed in July 1992, it has been carrying out the following work:

1. Four trade studies were selected to establish the liner design and to minimize the cost & schedule impact on the collider. These studies were conducted and the major tasks were achieved.

2. The physics and engineering tasks were performed focussing on the removal and reduction of the potential risks that a liner design can impact the operation of the collider. These analysis have been intensively carried out.

3. Demonstration and verification experiments were planned to validate the physics and engineering concepts derived from our studies.

4. The final selection of a conceptual design of the liner system is in progress.

5. The engineering detail design has been conducted recently.

# III The Trade Studies and The Conceptual Design Development

1. End conductive cooling: To make a liner with uniform maximum ID through out magnets with different IDs
2. Options of liner IDs and magnet beam tube IDs
3. Retrofit self-contain liner structure development:

   to reduce the schedule impact on collider program
4. The determination of liner tube materials
5. The effects of liner holes on Evacuation capability and RF impedance
6. Liner cryosorber
7. Liner conceptual structure in collider spool piece
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10. Liner support: To reduce the heat leak from 80 to 4K

# 1. End Conductive Cooling: To make liner with uniform maximum ID through out magnets with different IDs

## The basic idea:

1. The beam tube ID (32.3 mm) of CQM is much smaller than the beam tube ID (42.3mm) of CDM in ASST II.

2. In order to have a unified liner diameter, the liner system design group is interested in an end conductively cooling approach for the Spool Piece and CQM. With this approach the required space between liner and beam tube can be greatly reduced.

3. Quan-Sheng Shu and Kun Yu developed a modified thermal model for the liner in CQM and Spool piece in order to determine the optimum design parameters. The different surface emissivities (0.05 - 0.3) and the copper thickness (0.5 - 2mm) of the liners and the beams tube were used in the calculation.

4. The temperature distribution along the liner as functions of the emissivities were plotted by Shu and Yu. The maximum DT for the Spool could be less than 5 K, and 10 K for CQM. A temperature difference between the pipe ends and the middle of 2 K with copper layer of 2 mm and 10 K with copper layer of 0.5 mm was found for the Spool. A 6 K of DT with copper layer of 2 mm and 26 K with copper of 0.5 mm for the CQM were obtained. The synchrotron radiation heating is 0.14 W/m. The correction of the effect of the magnetic field on copper thermal conductivity is considered in the calculation.

**The minimum radial space needed for a liner with end conductive cooling is 7 mm.**

# To Make End Cooling Work

## The main requirements:

1. The overall resistivity along the liner temperature:

   Inner wall: $\sigma \times t > 2 \times 10^{5}\ \Omega^{-1}$

2. A workable compact heat exchanger to cool the liner end

3. A good thermal conduct joint between both ends of liner

4. Supports with low heat leak between the narrow space of the liner and magnet beam tube.

5. A suitable emissivity of the outer wall surface of liner

# CQM End Cooling Liner Structure

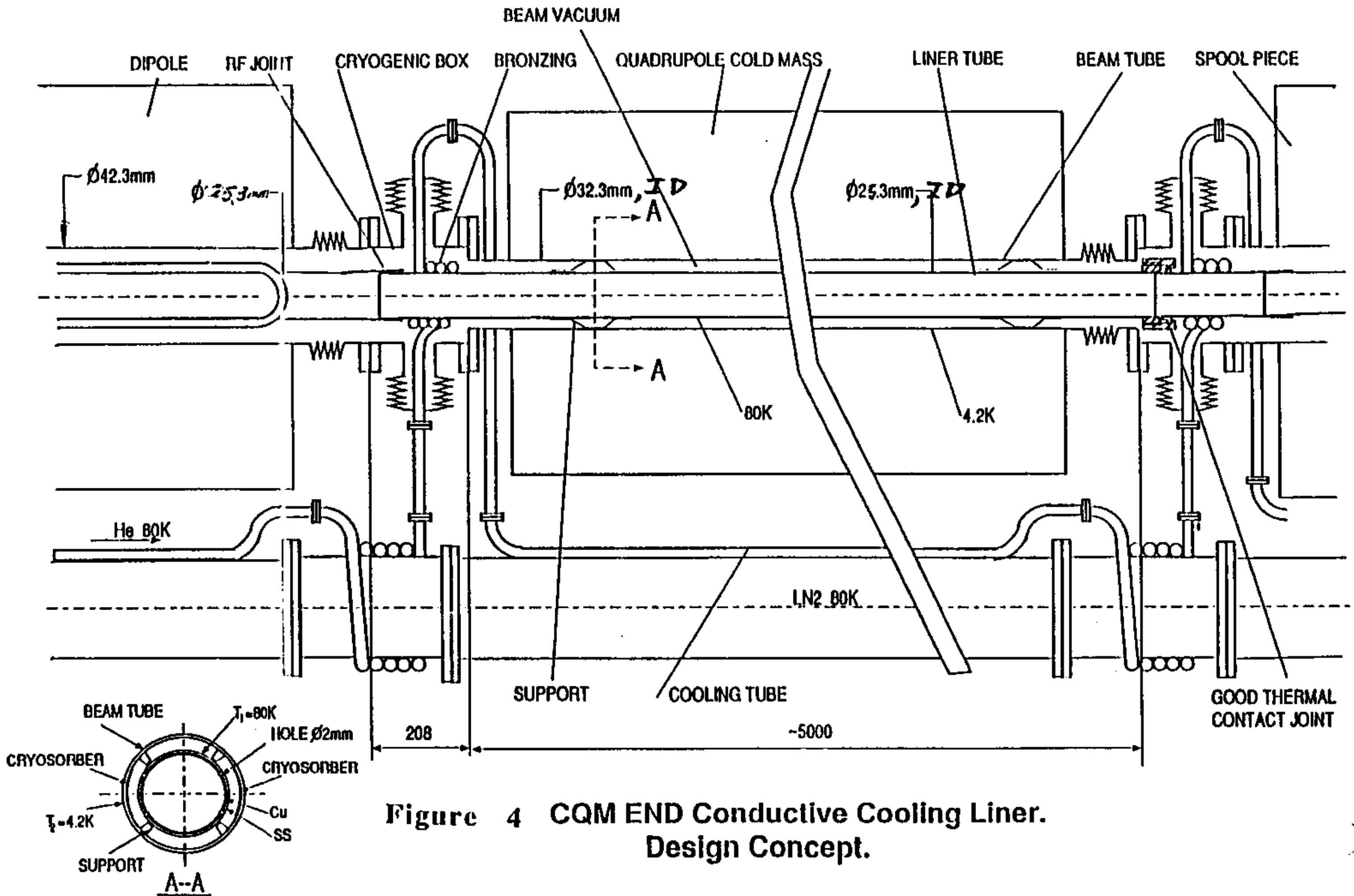
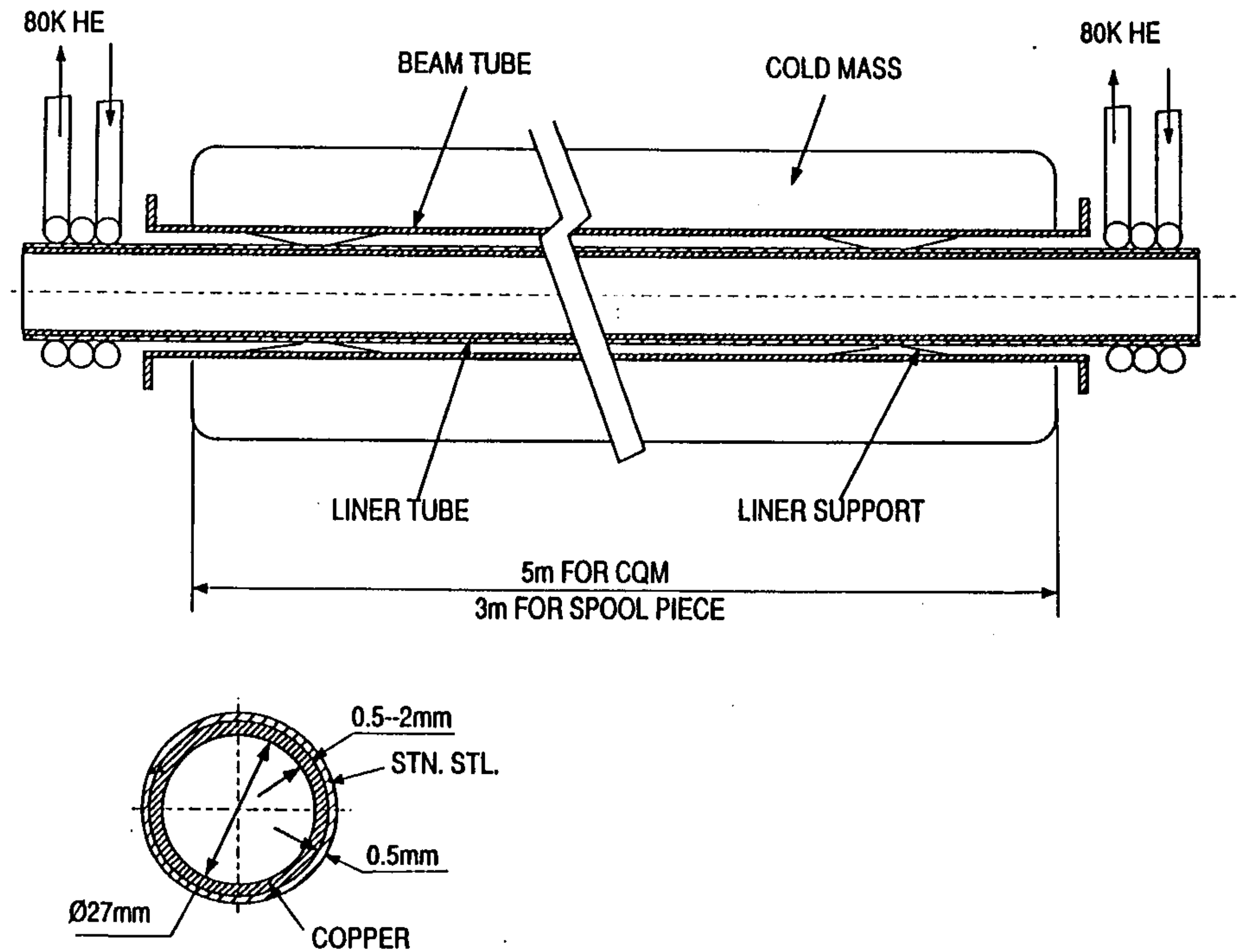



Figure 4 CQM END Conductive Cooling Liner. Design Concept.

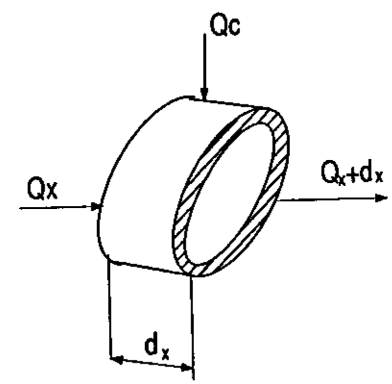
# A 80K Liner with End Conductive Cooling in A CQM or Spool Piece:



# Thermal Model of End Cooling

A thermal model to analyse the end conductive cooling was developed by Q. S. Shu and K. Yu. Assume:

$Q1$ - synchrotron radiation    L x 0.14w / m.
$Q2$ - (heat leak through support + heat leak by radiation)
$L$ - the length of the CQM or Spool piece
$A$ - The area of the cross section of the liner tuber
For each unit of liner cross section



Unit Section of Liner

$$Q_c = \{(Q_1 - Q_2)/2L\}\, dX$$
$$Q_x = -\lambda A\, dT/dX$$
$$Q_{x+dx} = Q_c + Q_x$$

and $Q_{x+dx} = -\lambda A d[T + (dT/dx)dx]$

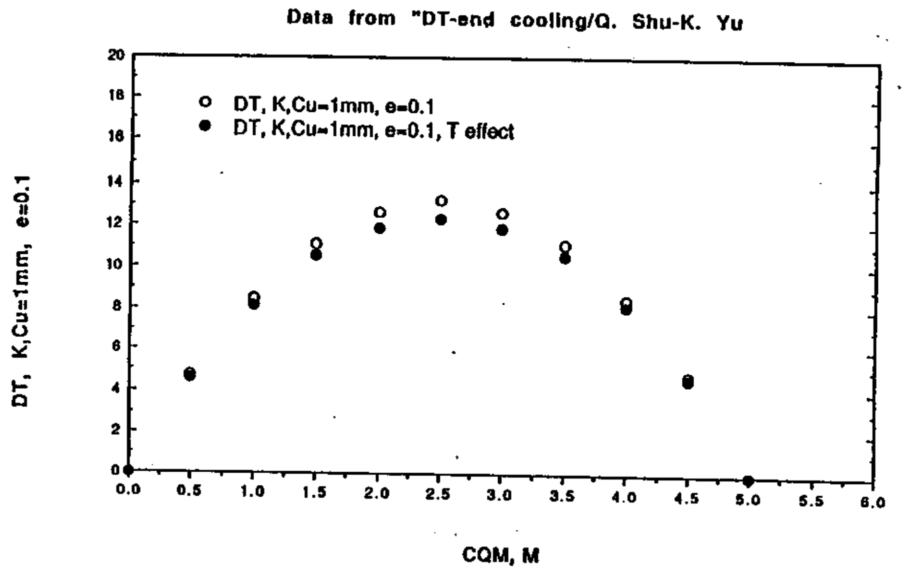
$$-\lambda A(dT/dx) + (Q_1 - Q_2)dx/2L = -\lambda A dT/dx - \lambda A d^2T/dx^2$$
$$(Q_1 - Q_2)/2L = -\lambda A dT^2/dx^2$$

assume $T_{end} = 80k$

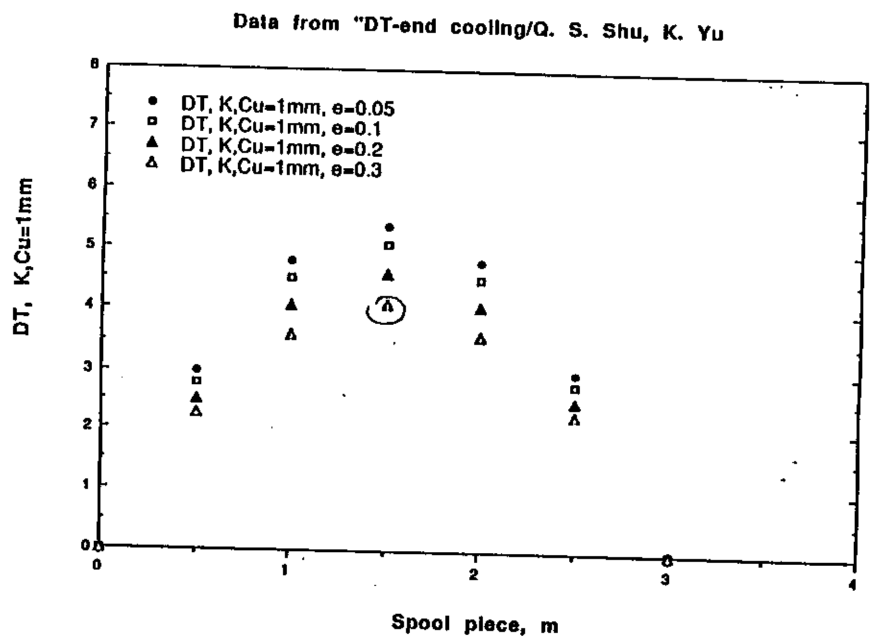
$$T(x) = -(Q_1 - Q_2)x2/4L\lambda A + (Q_1 - Q_2)L/4\lambda A + 80k$$
$$\delta T(x) = T(x) - 80k = -(Q_1 - Q_2)X2/4L\lambda A + (Q_1 - Q_2)L/4\lambda A$$

$$Q_{cond.} = 2A/L \int_4^{80} \lambda(T)\, dT$$
$$Q_{rad.} = \sigma A(T^4_1 - T^4_2)\, \varepsilon_1\varepsilon_2 / (\varepsilon_1 + \varepsilon_2 - \varepsilon_1\varepsilon_2)$$

# Temperature Distribution Along A Liner With End Conductive Cooling

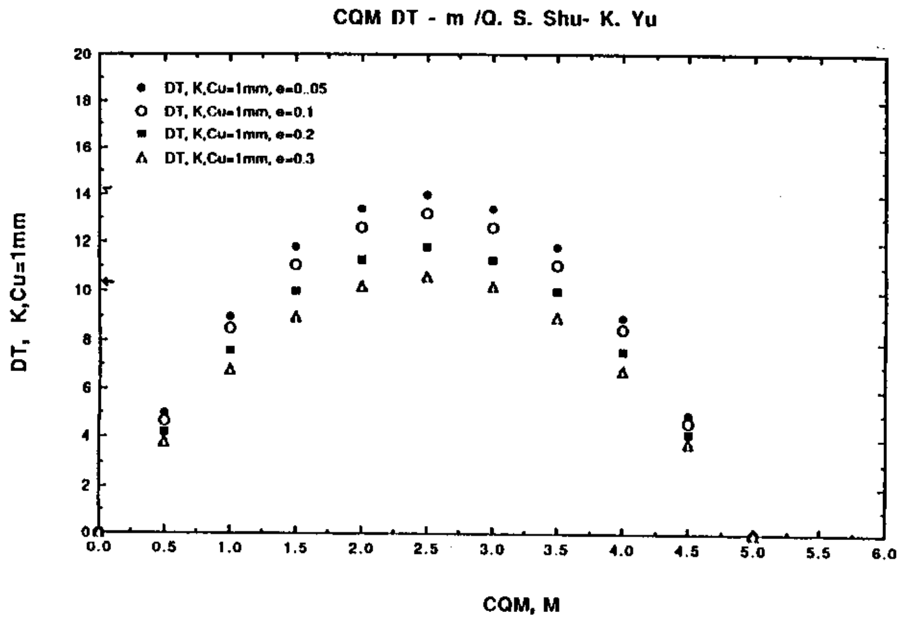



The effect of surface temperature correction on the temperature distribution along CQM by conductively end cooling .

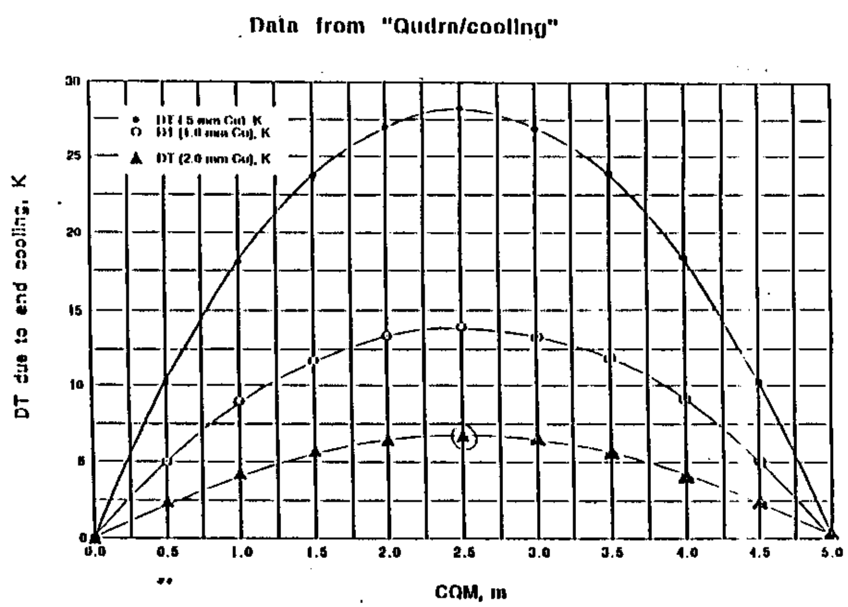



Temperature distribution along Spool piece by conductively end cooling with several emissivities of the Liner outer surfaces.

# Temperature distribution along a liner with end conductive cooling




Temperature distribution along CQM by conductively end cooling with several emissivities of the Liner outer surfaces.

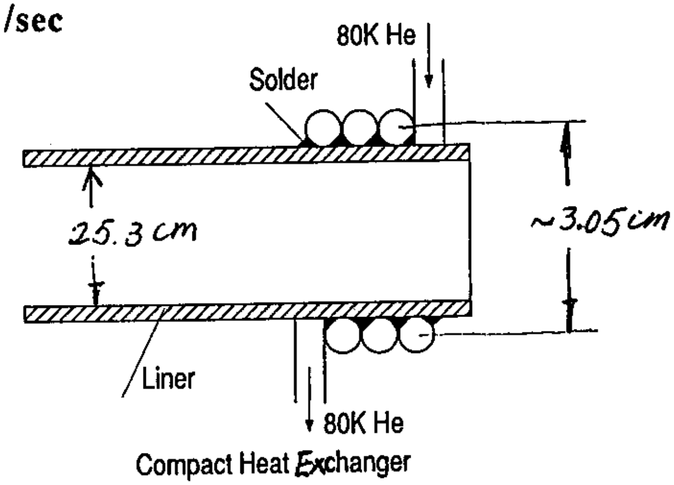



The temperature distribution along the liners with different thickness of the copper layers in the CQM.

# Compact Heat Exchanger for End Cooling

To make end cooling work, a compact heat exchanger with length of less than 5 cm design concept for liner was proposed by Q. S. Shu and K. Yu

If the total heat to be transferred by the heat exchanger Q=2W,
Copper cooling tube ID= 0.25
mass flow rate of the 80-K He, m= 0.25 g /sec
the temperature increase of He, $\delta$ K




Since $Q = Cpm\delta T$

$\delta T = 1.54k$

We have $G = 4m / \pi D2 = 5.09$

$\eta = 40 \times 10^{-6}$ ( P )

$\lambda = 14\ 0 \times 10^{-6}$ ( col / s. K. cm)

$Re = GD/\eta = 1562.5$

$Pr = \eta Cp / \lambda = 0.357$

$h = 0.023\ Cp\ G^{0.8} \eta^{0.2} / ( Pr^{0.6} De^{0.2} ) = 0.0345$

$S = \pi D = 0.785$

$L = ( mCp / hS ) \ln[( T_L - T' ) / ( T_o - T' )]$

If three turns are used,

L = 28.75cm

$\delta T$ = 0.13K

# Good Thermal Contact Joint

To make end cooling more efficient, we need to cool both end of CQM liner with the compact heat exchangers. In order to easily assemble the liner in to the CQM, there should be a joint between two heat exchangers. A joint concept proposed by Q. S. Shu and K. Yu has a good thermal conductivity and also is easy to be assembled

1. Cu-Cu contact area S

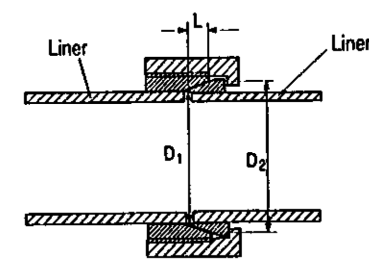
   $S = \pi(R1+R2)L = 4.0134$

2. Synchrotron radiation : 0.14 w /m

   for Quadrupole $Q = 0.14 \times 5 = 0.7$ W

We assume total synchrotron radiation 1 W for Quadrupole.The heat Transferred at each end of the liner is 0.5 W

3. If the pressure of Cu- Cu machined contact is 7 MPa (at temperature range 5 -25 k ) thermal conductance of the contact is



Good Thermal Contact Joint

$$h = 0.13T \quad (w / Cm^2K)$$

as

$$Q = S\, h(T)\, \delta T$$

$$\delta T(25k) = 0.012 \text{ k}$$

$$h(80k)\, \delta T_{80K} = h(25k)\, \delta T_{25K}$$

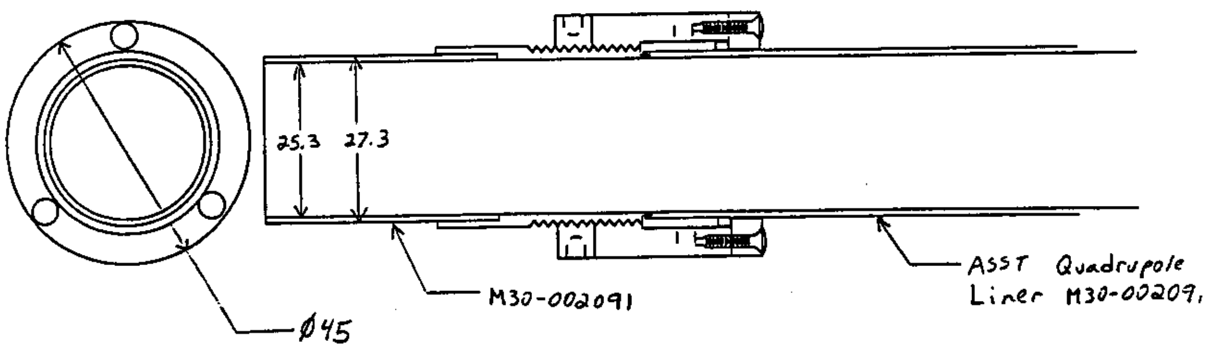
We know $h(80k) > h(25k)$ for same contact and same pressure

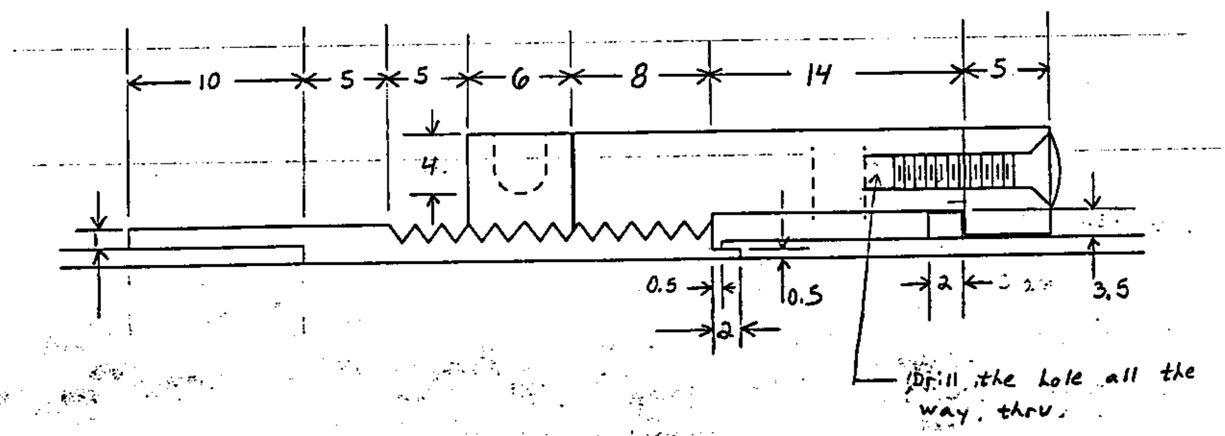
$$\delta T_{80k} < \delta T_{25k}$$

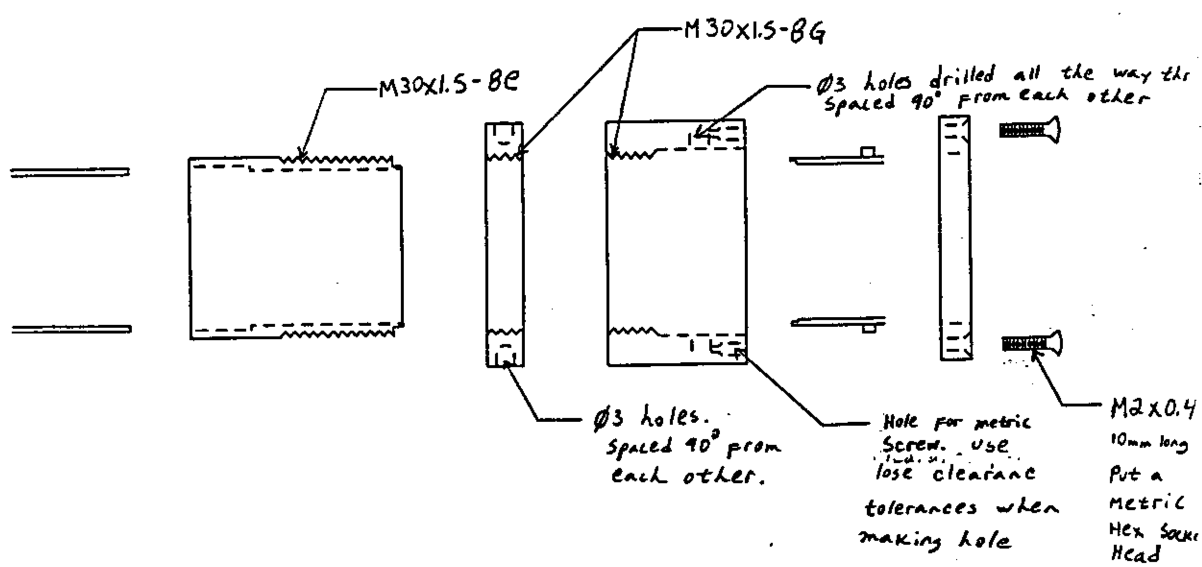
$$\delta T_{80k} < 0.012k$$

So at largest, $\delta T_{80K} \leq 1K$

Good Thermal Contact Joint




G. Morales

# 2 A Simplified Approach to Estimate The Possible Liner ID

Since magnet beam tube ID is ether varied with different magnet category or with the fabrication time in the same magnet category (e. g. ASST dipole and GD dipole). A simplified formula was developed in order to fast estimate the possible Liner ID and the magnet Beam Tube ID required based on the liner ID.

**1. The radial space needed for Liner:**

| | |
|---|---|
| **If regular cooling approach is used:** | Cooling tube 3.8 mm, liner wall 1.25, vacuum gap between cooling tube and magnet beam tube 1mm. |
| **If an end conductive cooling is used:** | Liner wall 1mm, vacuum gap between liner wall and magnet beam tube 1.5mm, cryosorber 1 mm. |

**2. A simplified formula to estimate the Liner ID and the Magnet Beam Tube ID:**

**If regular cooling approach is used:**

(A) <u>Liner ID = Beam Tube ID - 12.1 mm</u>

**If end conductive cooling approach is used:**

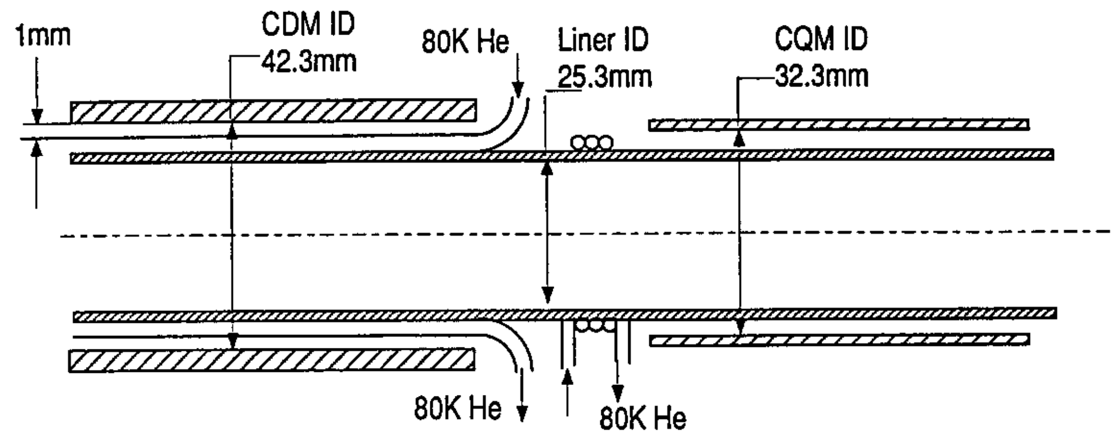
(B) <u>Liner ID = Beam Tube ID - 7 mm</u>

**3. Formula A is used to estimate the max ID of CDM liner, formula B is used to estimate the max ID of CQM liner.**

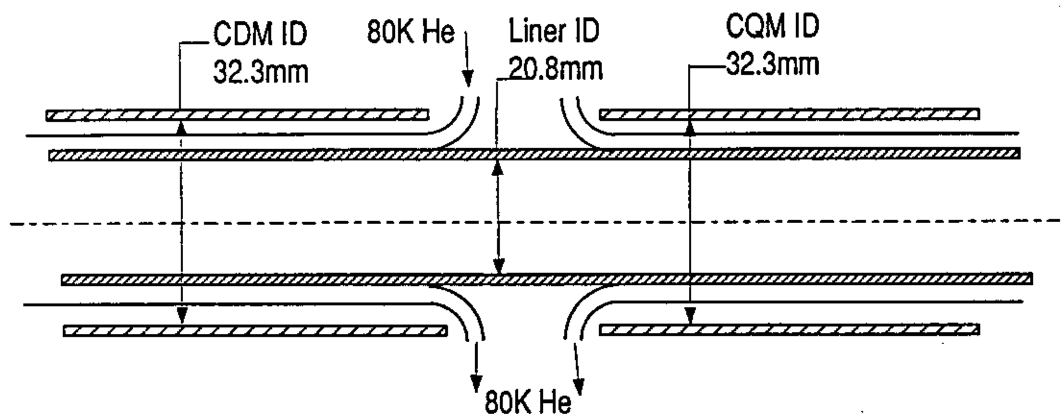
**<u>For ASST II, CQM liner ID = 25.3 mm. To have an uniform liner ID through out all the different magnets, the CDM Liner ID was already determined to be 25.3 mm.</u>**

# Three Options of Magnet
# Beam Tube IDs and Liner IDs

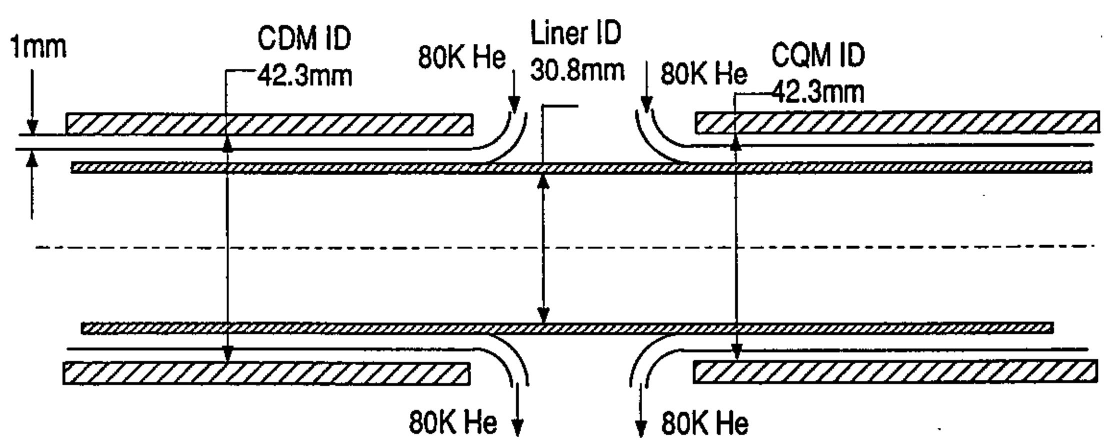
### 1. ASST II Test:




### 2. Exsisted Collider Design:




### 3. Wished Collider Design:



# 3. Retrofit Liner Structure Development

The SSC prototype magnet design and manufacture have already been well developed by SSCL, other national labs (FNAL, BNL and LBL) and vendors (GD, Westinghouse and B & W). A trade study is extensively performed to develop a self-contained liner structure, also called Retrofit Structure, that the liner can be more easily inserted into a magnet. This design can minimize the cost and schedule impact on the magnet manufacturing process. It is our ultimate goal that the liner will be inserted into the magnets after the magnet cryogenic test and prior to the installation in the tunnel. A schematic of the retrofit structure in next page was developed by Shu, Zbasnik etc.

This option includes: A "80-K cryogen flow return loop" was developed to replace the regular "80-K cryogen flow through loop" with a mass flow rate of 0.25 g/sec - 0.5 g/sec of 80-K He. A compact heat exchange with total length of 5 - 7 cm in the interconnect region is used to re-cool the 80-K cryogen rather than passing the liner 80-K He tube through the magnet LN2 tube. The cryosorber is pasted on the inner surface of the magnet beam tube after the magnet fabrication. It is our ultimate goal that a liner can be installed to a magnet after the magnet fabrication and only necessarily minor changes of the magnet is required to accommodate the liner.

# CDM Retrofit Self-Contain Liner Structur

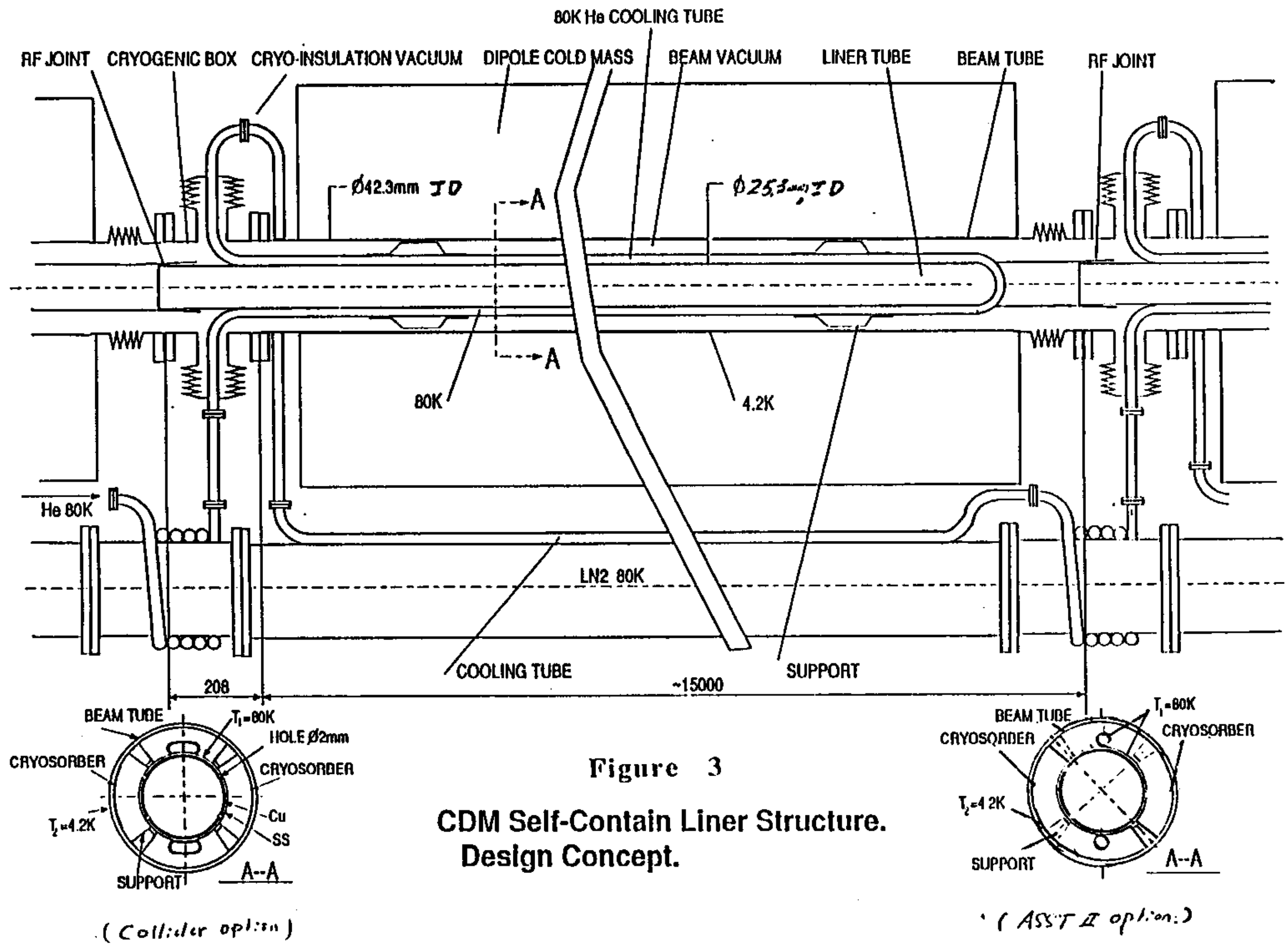
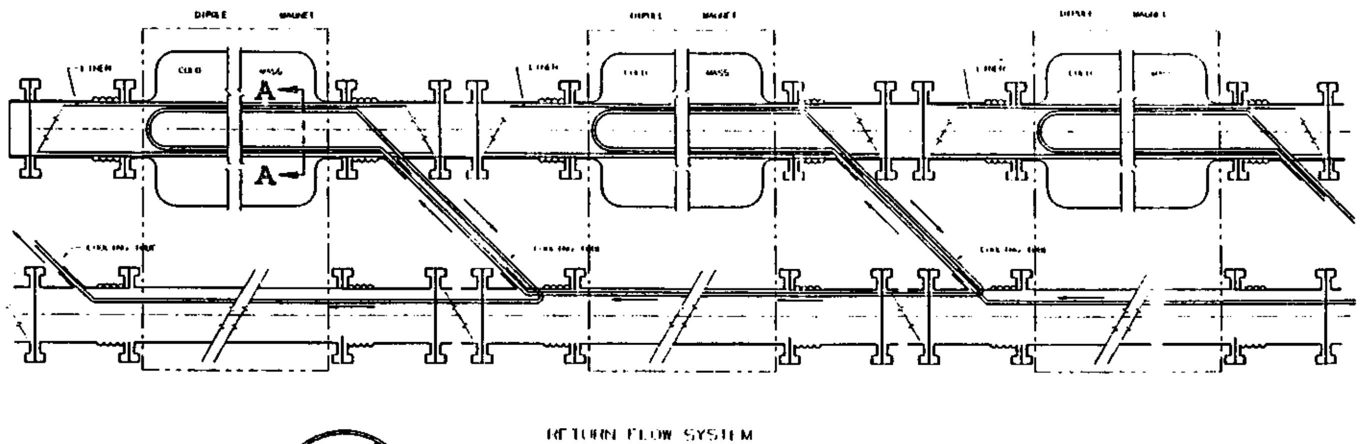
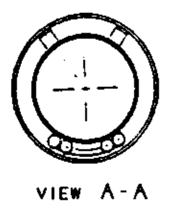



Figure 3

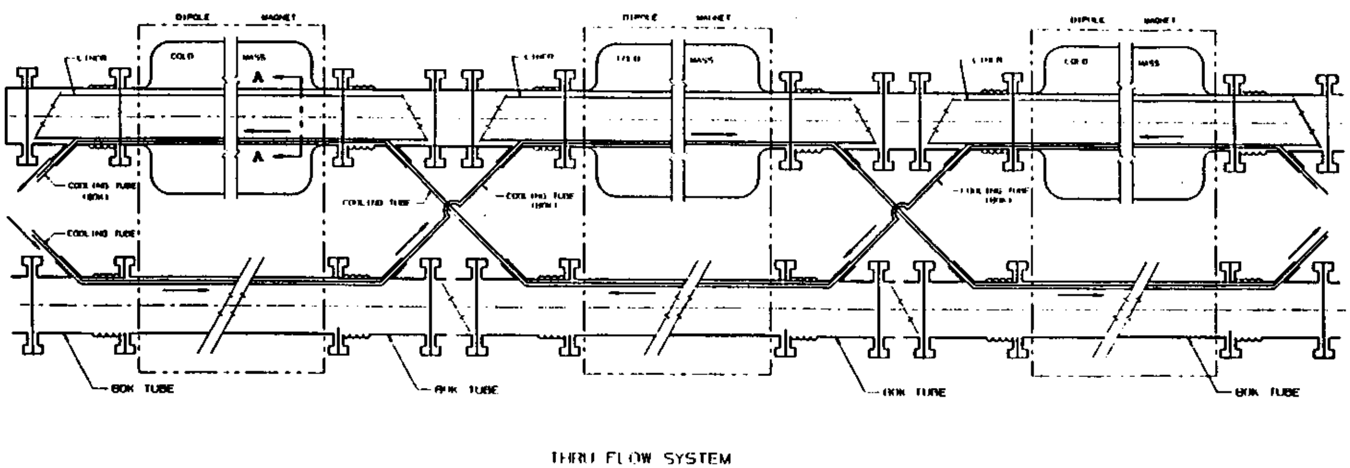
**CDM Self-Contain Liner Structure. Design Concept.**

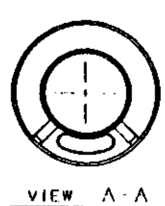
# A Comparison of Return Flow Loop and Through Flow Loop




(A) Return flow loop schmatic.



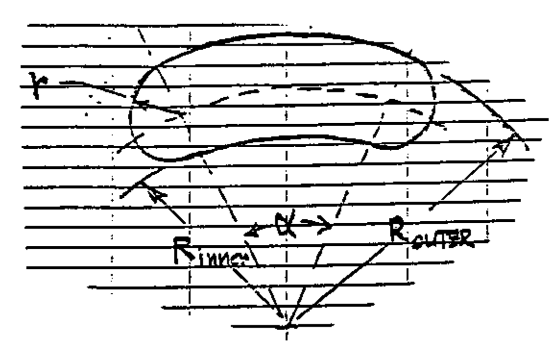

(B) Through flow loop Schematic.

# The Pressure Drop in Cooling Loop if Liner will be used in the SSCL Collider

A summary of analysis on pressure drop versus liner cooling tube size (and shape) was presented by J. Maddocks and J. ZbasniK. It assumed that the cooling tube system had a length equivalent to 48 cells with an additional 6 cells as margin. The conclusions from the data is that a pressure drop of 2.14 MPa (300 psi) with a mass flow rate of .25 g/sec was an optimum design point to size the cooling tube cross section. The cross section of the cooling tube is that of a flattened tube, with 25 degree arc length and 2.5 mm diameter fitting in the 6 mm radial space determined for the liner system. However, the stress analyses from G. Morale showed that it was unabale to achieve an ASME-allowable stress level for the tube with an alpha angle of 20 degree and be within the 6 mm radial space budget. By reducing the angle to 15 degree, the pressure required to feed 54 half cells in series rose to 365 psi, but the acceptable stress of 20.8 ksi were achieved for a wall thickness of o.635 mm. It also meet the liner radial budget. One of the preferred option is to feed the liner of four sections in series (48 half cells) at each of the 10 refrigeration sites at the 1 g/s of the mass flow. (For ASST II, Round tube will be used and pressure drop is not a problem due to limited tube length)

## The Pressure Drop in Different Tube Dimensions

| | | | | | | for mdot = 0.25 g/sec, to supply 54 half cells | |
|---|---|---|---|---|---|---|---|
| Rinner, mm | Router, mm | alpha, deg | Area, mm^2 | Perimeter, mm | Dhyd, mm | Pinlet, psi | Pinlet, MPa |
| 17.15 | 19.65 | 15 | 16.95 | 17.49 | 3.88 | 365 | 2.52 |
| 17.15 | 19.65 | 20 | 20.97 | 20.70 | 4.05 | 330 | 2.27 |
| 17.15 | 19.65 | 25 | 24.98 | 23.91 | 4.18 | 310 | 2.14 |
| 17.15 | 19.65 | 30 | 28.99 | 27.12 | 4.28 | 290 | 2.00 |
| | | | | | | | |
| 17.65 | 19.65 | 25 | 19.42 | 22.56 | 3.44 | 490 | 3.38 |
| 17.65 | 19.65 | 37 | 27.23 | 30.37 | 3.59 | 440 | 3.03 |
| 17.65 | 19.65 | 40 | 29.18 | 32.32 | 3.61 | 430 | 2.96 |
| 17.65 | 19.65 | 60 | 42.20 | 45.34 | 3.72 | 400 | 2.76 |



## The Stress Analyses of the Cooling Tube Attached to Liner

**According to the calculation of Gilberto Morales the cooling tube will require the following geometry to meet ASME B31.3 piping codes.**

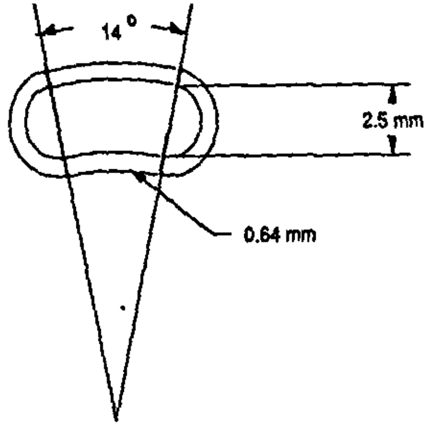


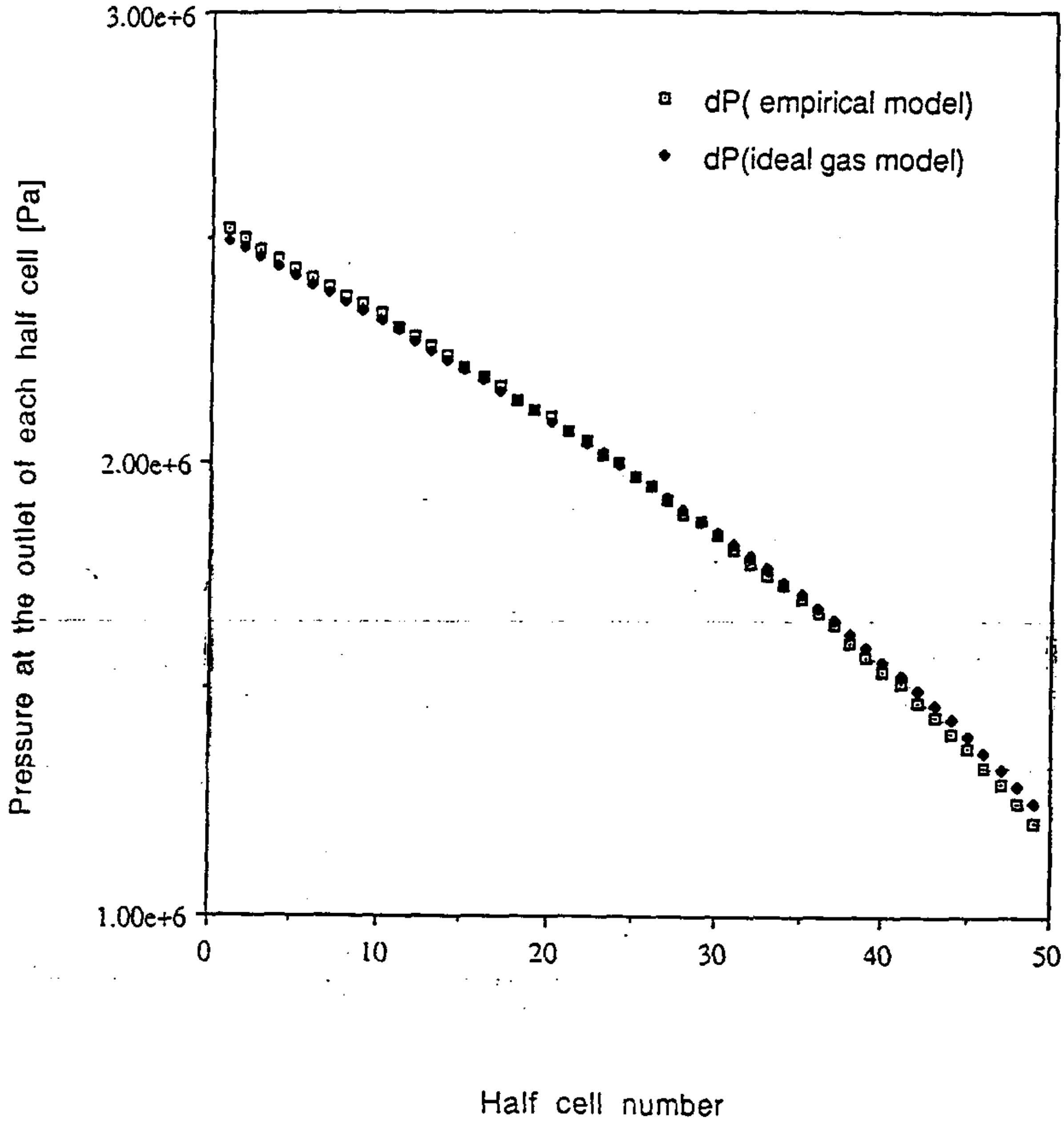

Table 1: Stress Values for Cooling Tube with Different Geometries

| Angle (Degrees) | Wall Thickness (mm) | Pressure (MPa) | Max Van Mises Stress (MPa) |
|---|---|---|---|
| 15 | 0.635 | 2.517 | 157 |
| 15 | 0.64 | 2.517 | 155 |
| 14 | 0.635 | 2.586 | 147 |
| 14 | 0.64 | 2.586 | 143 |

The cooling tube is required to supply forty eight half cells with 0.25 *gm/sec* of helium gas. The smaller the angle the higher the pressure has to be to deliver the required flow rate.

The results show that the stress in a tube with an angle of 14 degrees and a wall thickness of 0.64 mm will meet the ASME pressure codes. ASME B31.3 piping code requires that the stress not exceed a value of 155.13 Mpa. In this tube the maximum Von Mises stress is only 143 which is bellow that required by ASME.

D(hydraulic) = 4 mm.     Mass flow = .25 g/s




Compressible flow Pressure Drop for Supercritical helium with an average Temperature of 82 K.

# 4. The Determination of Liner Tube Dimension & Material

**The Main Criteria of the Choice:**

1. **Quench survivability 100 quenches/25 years**
2. **Inner wall:** $\sigma \times t > 2 \times 10^5\ \Omega^{-1}$
3. **Good thermal conductivity:**
4. **Inner wall photodesorption coefficient:**

   **For Ecrit=284 ev**

   $\eta_{max} = 0.02$

   $\alpha_{max} = 0.3$ for H

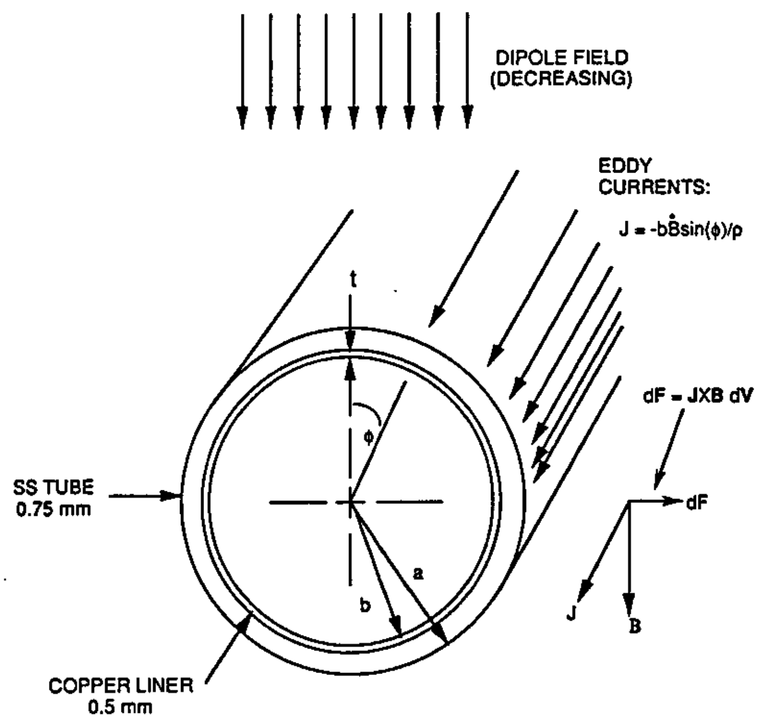
   $\eta(\text{other gases}) < 0.2 \times \eta(H_2)$
5. **Liner impedance:**

   $Z_L/n << 0.34\ \Omega$

   $Z_T << 20\ \mu\Omega/m$
6. **Ultra-high vacuum performance**
7. **Mechanical stability**
8. **Radiation stability**

# (1) Quench survivability: 100 quenches/25 years

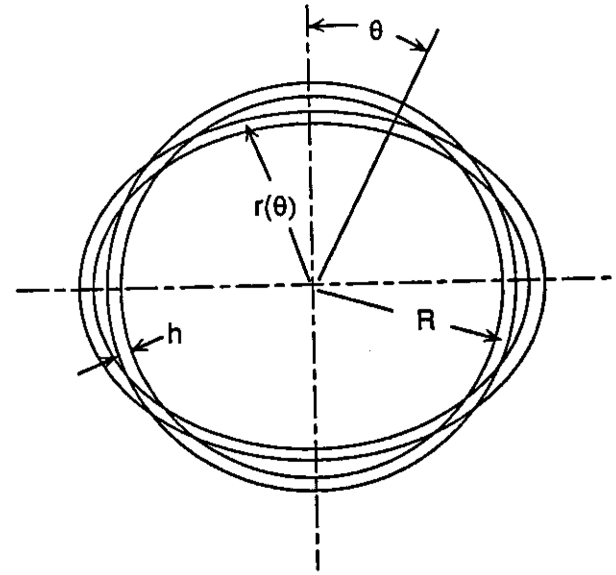
**The Liner material and dimension were chosen to meet the requirements of quench survival and ASME code. Also the structures will be validated under 100 magnet quench tests.**




Maximum equatorial pressure: $P_m = B\dot{B}tb/\rho$

$B\dot{B} \cong 150\ T^2/s$, $b = 14mm$, $t = 0.5mm$, and $\rho = 2.3 \times 10^{-9}$ ohm-m

=> $P_m = 4.9$ atm = 67 psi




Lorentz force: $dF(\theta) = P_m RL\sin(\theta)d\theta$

Total force on each tube half:

$$F_t = 2P_m RL$$

Solution of deformation equation:

$$r = R + u_0\cos(2\theta)\text{ , where}$$

$$u_0 = -\frac{F_t R^3}{24E'I} \quad\text{and}\quad E' = \frac{E}{1-\mu^2}$$

# Materials of CDM and CQM Liner

(1) CDM

Peak B* dB/dt ≈ 175 $T^2/s$ for a quench at 8.1 T (100 $T^2/s$ for 6.7 T)

J. Zbasnic etc. calculated the required material thickness based on $\sigma * t > 2 \times 10^5$ $\Omega^{-1}$ and the Lorentz force at the midplane shown in the following table. K.Leung performed the stress and deflection analyses of the liner at 80K at quench field 6.6 T. For instance, a tube OD is 33.3 mm with stainless steel thickness of 0.75 mm and a copper thickness of 0.5mm. The maximum stress level can be 31 ksi in copper and 33 ksi in S. S., when the Lorentz force is 88 psi. The maximum deflection at vertical position is around -0.0064" and at horizontal position is around 0.0027 mm. The results was used in our conceptual design.

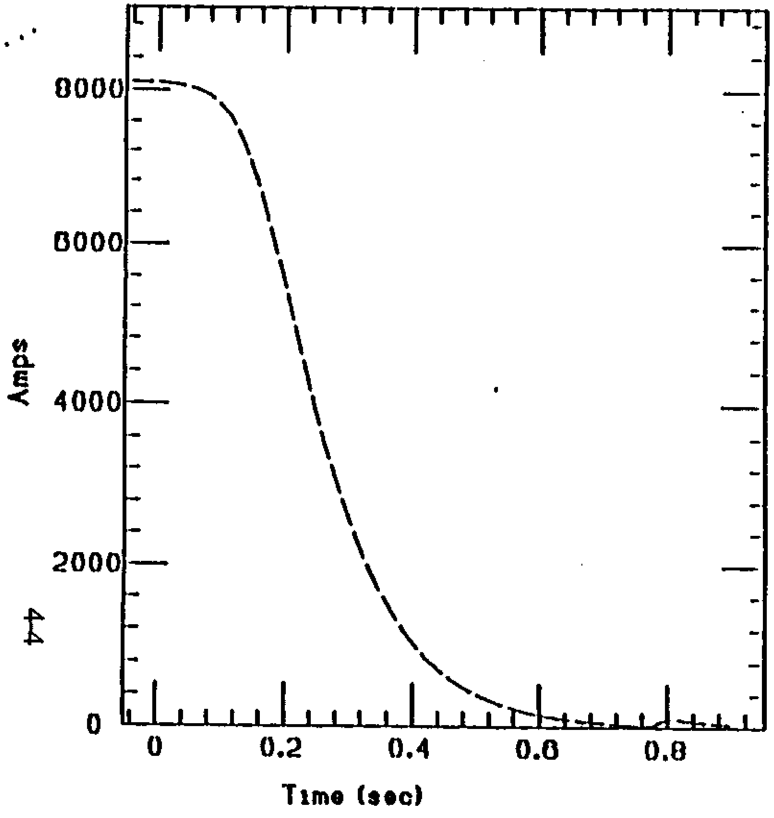
(2) CQM

C. Haddock etc. calculated the Lorentz force in a CQM copper only liner with ID of 24.3 mm and OD of 26.3 mm. The quench data come from a spot heater induced quench at 7054A on LBL long QCC405. The maximum Lorentz force =          and the maximum stress =          . It is determined that the ASST CQM liner will use 1 mm copper tube without a S. S. tube as cover material.

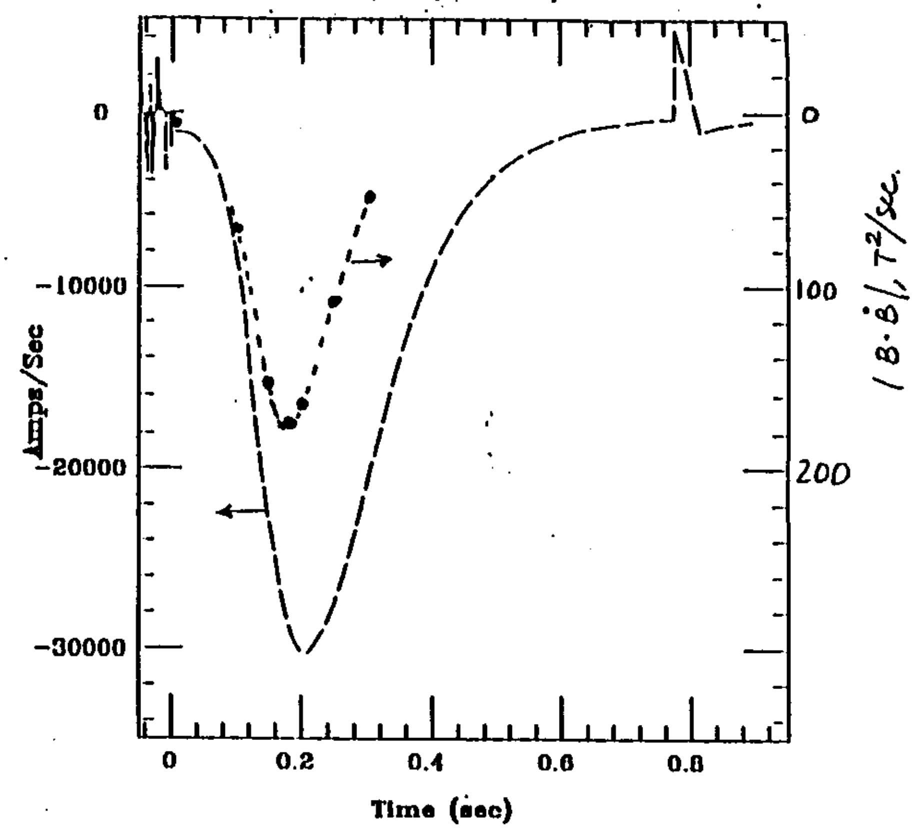
**Liner Thickness and Force in a CDM**

| Material Type | Inner Radius, mm | Electrical Resistivity, nΩm | B Bdot max T**2/sec | Required Thickness, mm | Outer Radius, mm | F on 10 deg Segment, N/m | Equivalent Pressure, psi |
|---|---|---|---|---|---|---|---|
| 4 K Cu RRR = 50 | 16.10 | 0.554 | 155 | 0.11 | 16.21 | 1404.98 | 72.24 |
| 80 K OFHC | 15.40 | 2.00 | 154.30 | 0.40 | 15.90 | 1640.75 | 87.09 |
| 80 K Berylco 25 | 15.40 | 85.00 | 155.00 | 17.00 | 32.40 | 3204.52 | 111.38 |
| 80 K Amzirc | 15.40 | 3.64 | 155.00 | 0.73 | 16.13 | 1337.96 | 70.50 |
| 80 K Glidcop | 15.40 | 3.10 | 155.00 | 0.62 | 16.02 | 1328.74 | 70.26 |
| 80 K Cu/Nb #2 | 15.40 | 5.40 | 155.00 | 1.08 | 16.48 | 1368.28 | 71.30 |
| 80 K Cu/Nb #1 | 15.40 | 7.30 | 155.00 | 1.46 | 16.86 | 1401.51 | 72.18 |
| 80 K Ideallum | 15.40 | 6.00 | 155.00 | 1.20 | 16.60 | 1378.72 | 71.58 |

DCA311: Main Transducor Current




DCA311: dI/dt (Idot coil)



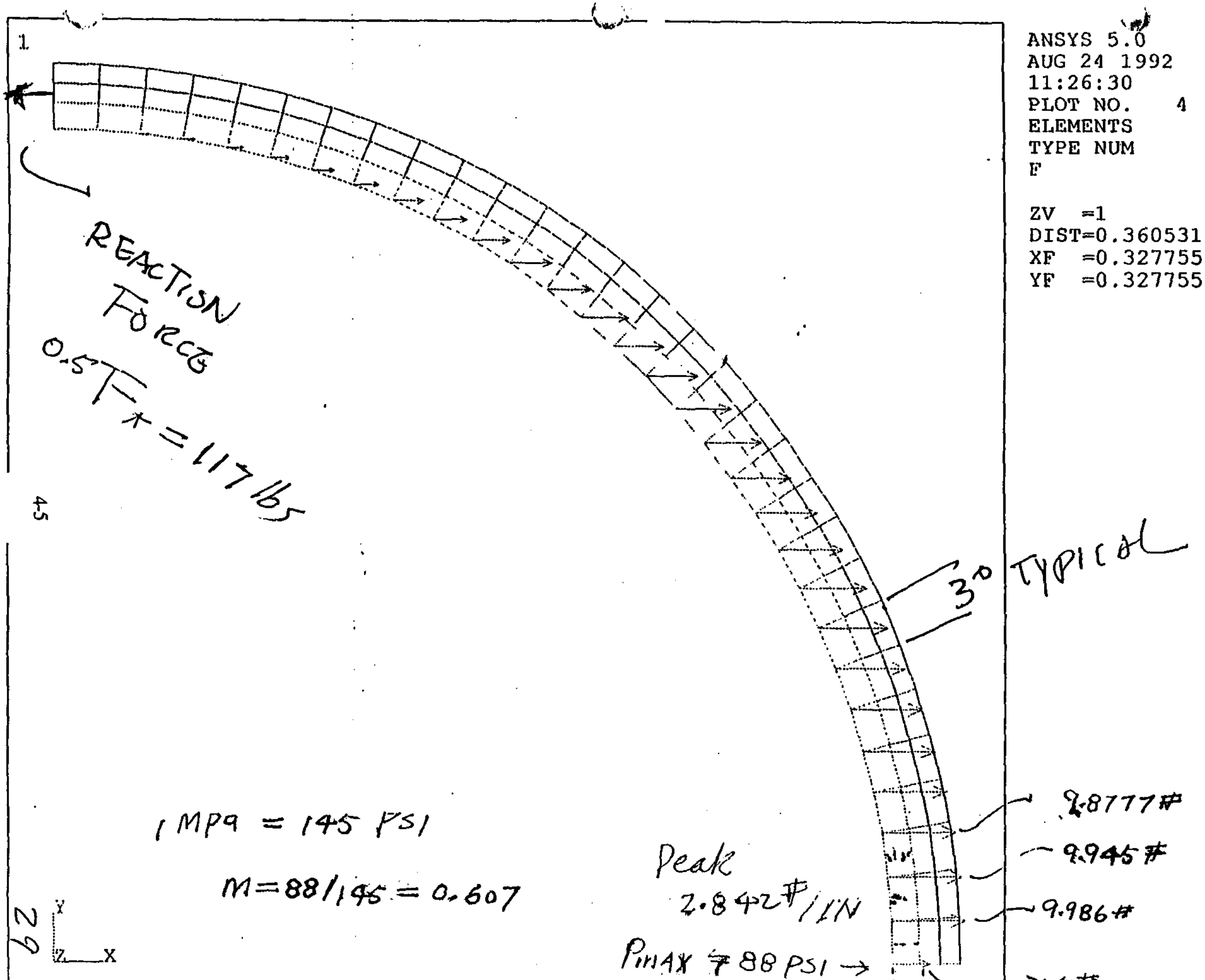

50 mm dipole data : QUENCH AT 8100 A

$|B \cdot \dot{B}|_{MAX} \approx 175\ T^2/sec.$

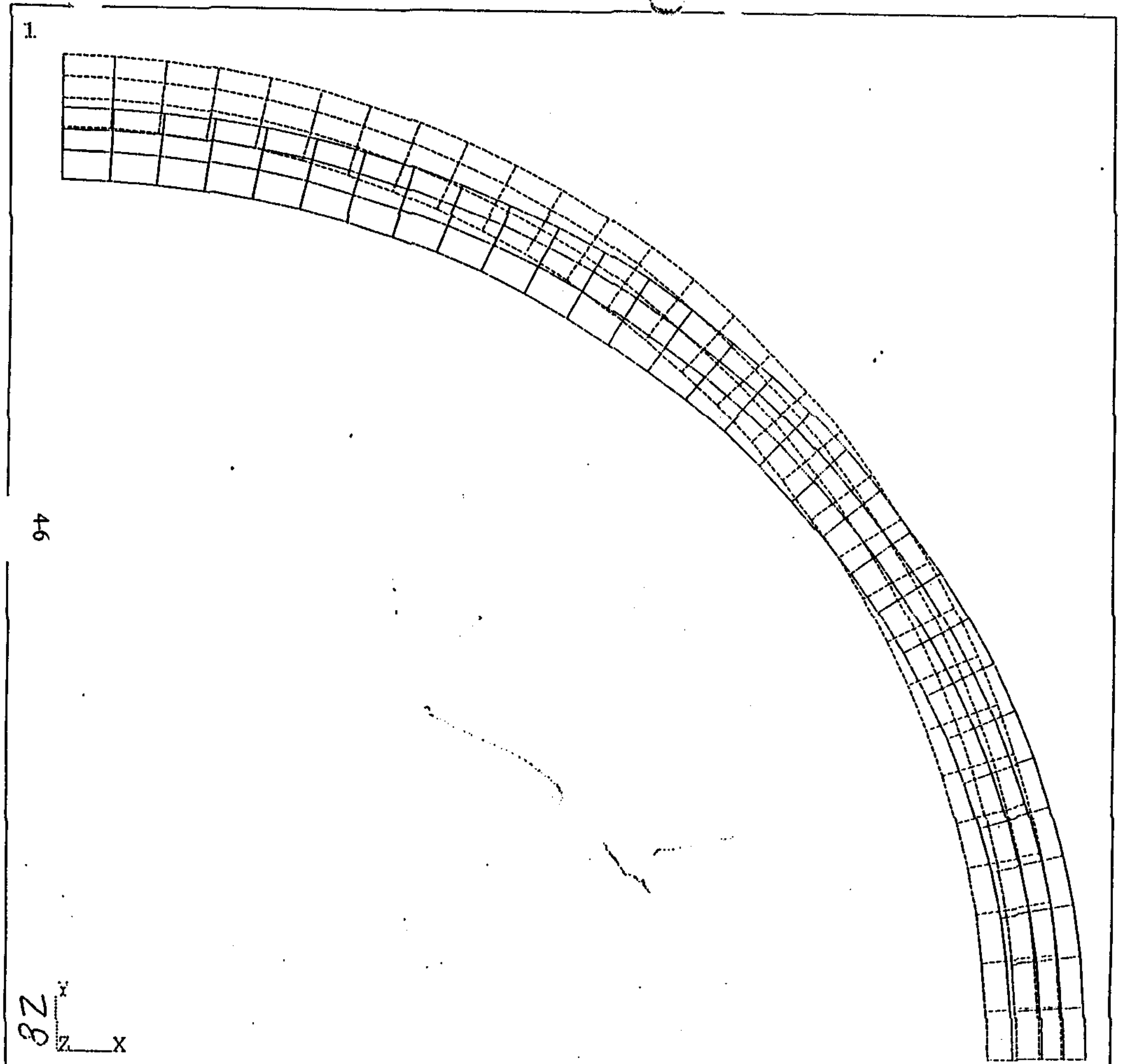
if $\dot{B}$ is independent of quench current level;

$|B \cdot \dot{B}|_{MAX} \approx 147\ T^2/sec$

Magnet: DCA311 File: DCA311.08084 26-NOV-91 09:47:41 Current: 8102.1 (amps) Tq = -.0070 MIITs = 13.43 Ramp rate = 4. (a/sec) QDC # 1 Quench # 0




SS/Cu BeamTube, Lor.Pr=89psi,CoolFrom 300K/80K. (PlaneStress)

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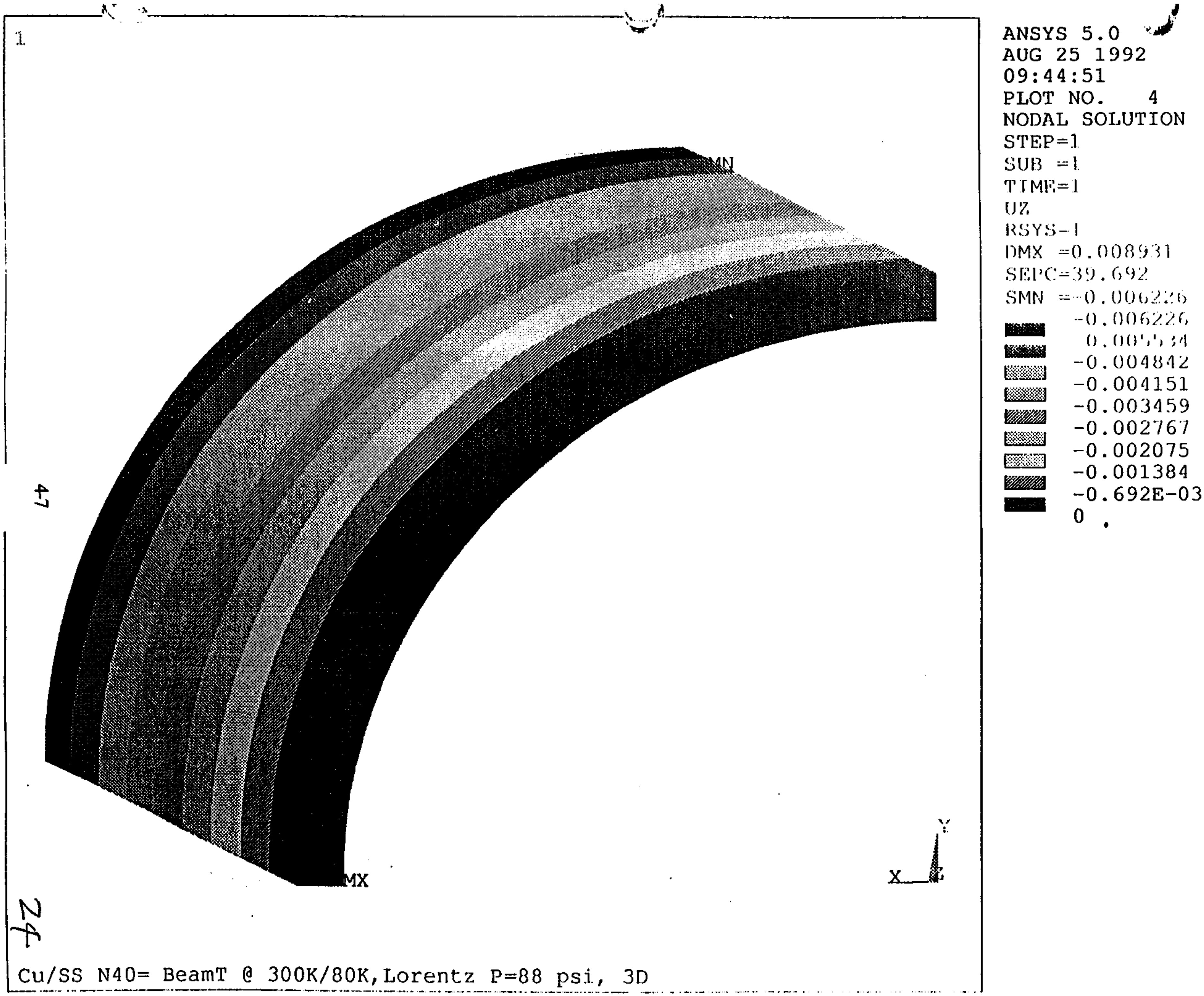
YF =0.327755

SS/Cu BeamTube, Lor.Pr=89psi,CoolFrom 300K/80K (PlaneStress)



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AUG 25 1992
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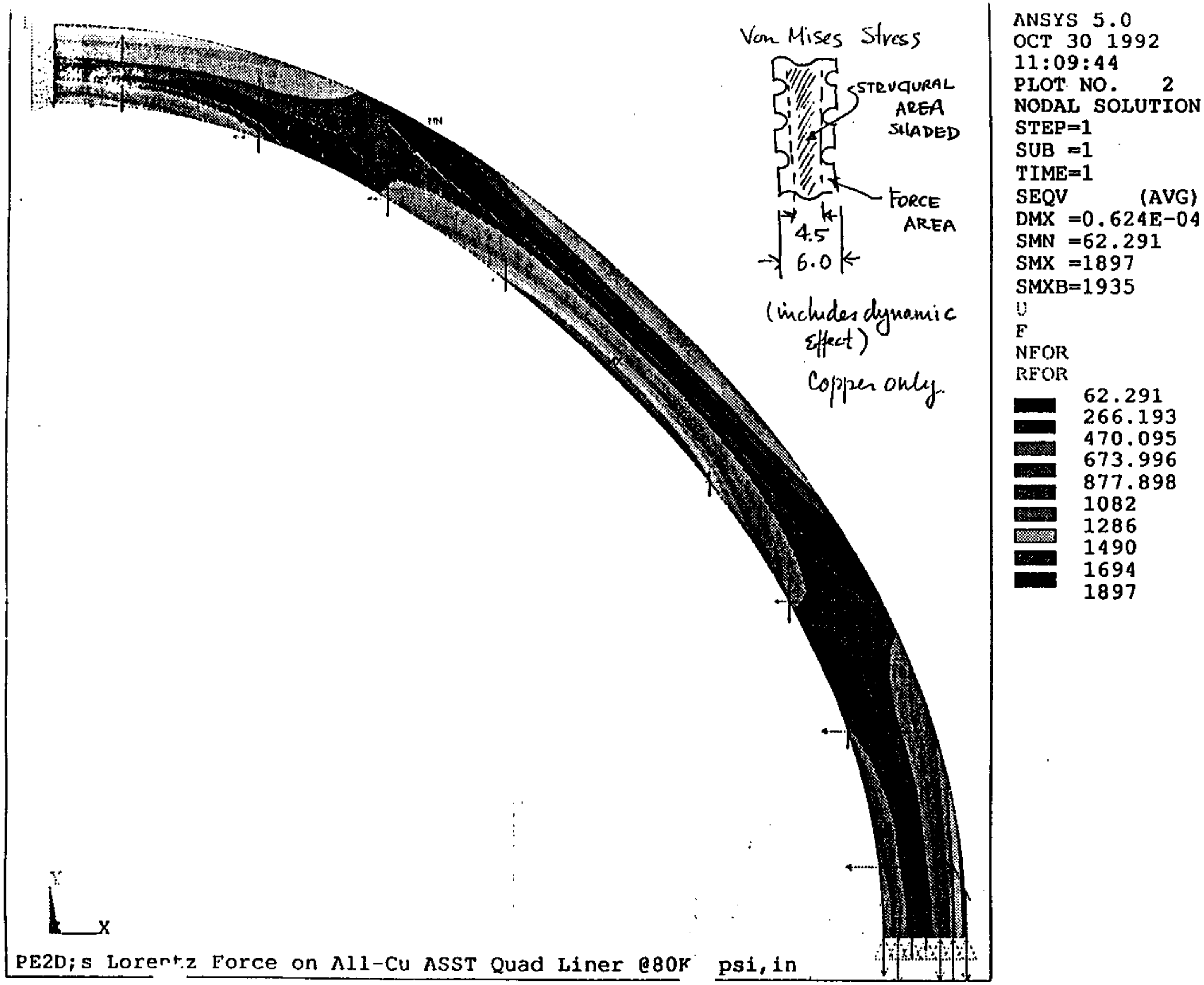
-0.004842
-0.004151
-0.003459
-0.002767
-0.002075
-0.001384
-0.692E-03
0
MN
MX
Y
X
Z
1
Cu/SS N40= BeamT @ 300K/80K,Lorentz P=88 psi, 3D

# A Sample of Stress Analyses for CQM Pure Copper Liner Tube with Evacuating Holes



# Evacuation Capability & RF Impedance

**The design critiria of the liner tube holes:**

1. A southands-holes will fabricated on the liner tube.
   The holes were designed to ensure:

   The liner pumping speed will be 600 l/m/s
   with a cryosorber pump speed of 3000 l/m/s

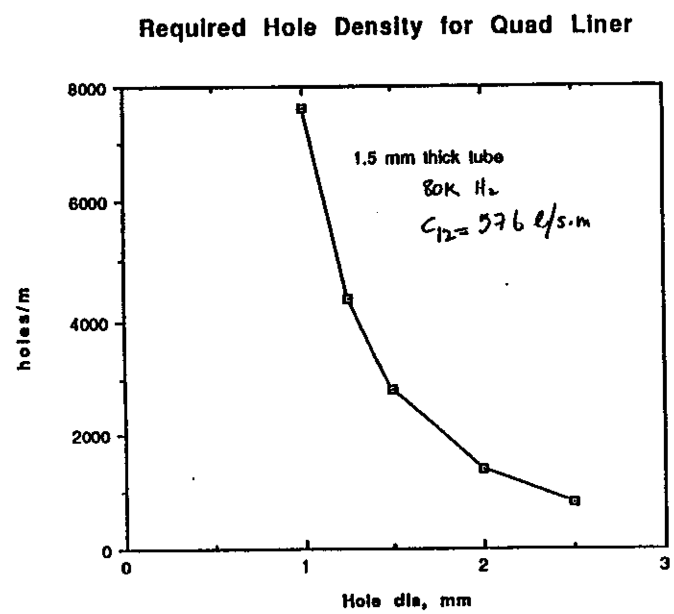
2. Also, the holes must be designed to ensure the Liner RF Impedance:

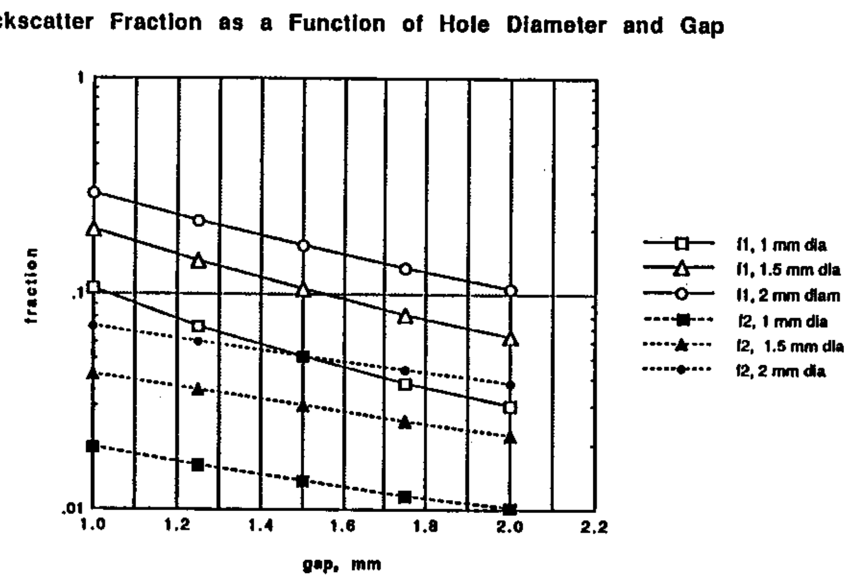
   $Z_L/n << 0.34\ \Omega$

   $Z_T << 20\ \mu\Omega/m$

# The Number and Diameter of the Holes

J. Zbasnic used a Turner-type calculation of holes required for the desired conductance shows that a 1.5 mm Dia. with hole density of 2800/m is a reasonable choice for a CQM liner (magnet bore tube dia. 32.3 mm, liner ID 25.3 mm, radial gap 2 mm). Also, it is find that the backscatter fraction will be less than 10% in the case.




(fig. 4)

# Wakefields & Impedance of a Perforated Liner

According to the calculation of W. Chou and T. Barts , the peaks of the wake potential of the perforated liner are given by:

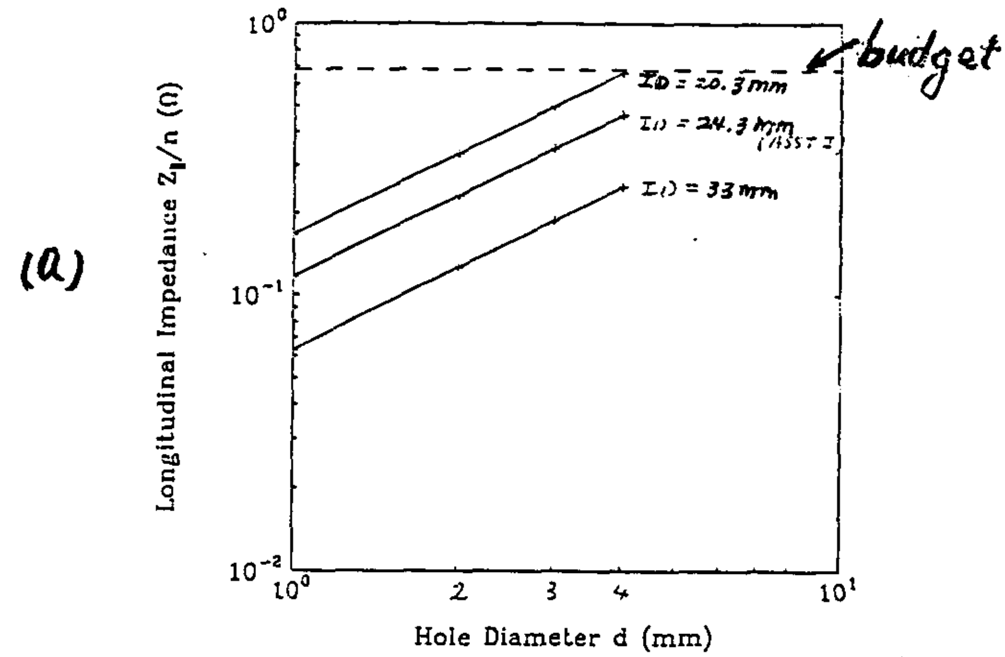
$$\omega_{\parallel}^{max} = Z_0 c r^3/\{6\pi^{5/2}(2e)^{1/2}\sigma^2 b^2$$
$$= 0.0577 \times (d^3/\sigma^2 b^2) \quad \text{V/nC} \quad \text{(per hole)}$$

$$\omega_{\perp}^{max} = Z_0 c r^3/\{6\pi^{5/2}(2)^{1/2}\sigma b^4$$
$$= 1.90 \times 10^{-4} \times (d^3/\sigma b^4) \quad \text{V/nC/mm} \quad \text{(per hole)}$$

d - diameter of the hole (d = 2r), b - the radius of the Liner
$\sigma$ – the rms length of a Gaussian bunch
$Z_0$ –

The low frequency part of the impedance of a perforated liner can be estimated accurately. The plots in next page show that the longitudinal and transverse impedance of the liner with three possible Liner IDs. In the calculation, the area coverage of the holes are kept the same for different hole sizes. When 1000 holes/m and diameter of 2 mm are used, the coverage will be 3%, 4% and 5% for ID = 33 mm, 24.3 mm and 20.3 mm respectively. The impedance budget of of the Collider is also ploted in the figures. When liner ID is 24.3 and hole dia is 2 mm (as the first proposed dimension): longitudinal impedance of the liner is about 34% of the present budget and transverse impedance is about 110%. Since there is a relatively large safety margin (a factor of 6) at the baseline design current of 72 mA, it should not jeopadize the beam dynamics.

# Calculation Results of Liner Impedance




Liner Transverse Impedance

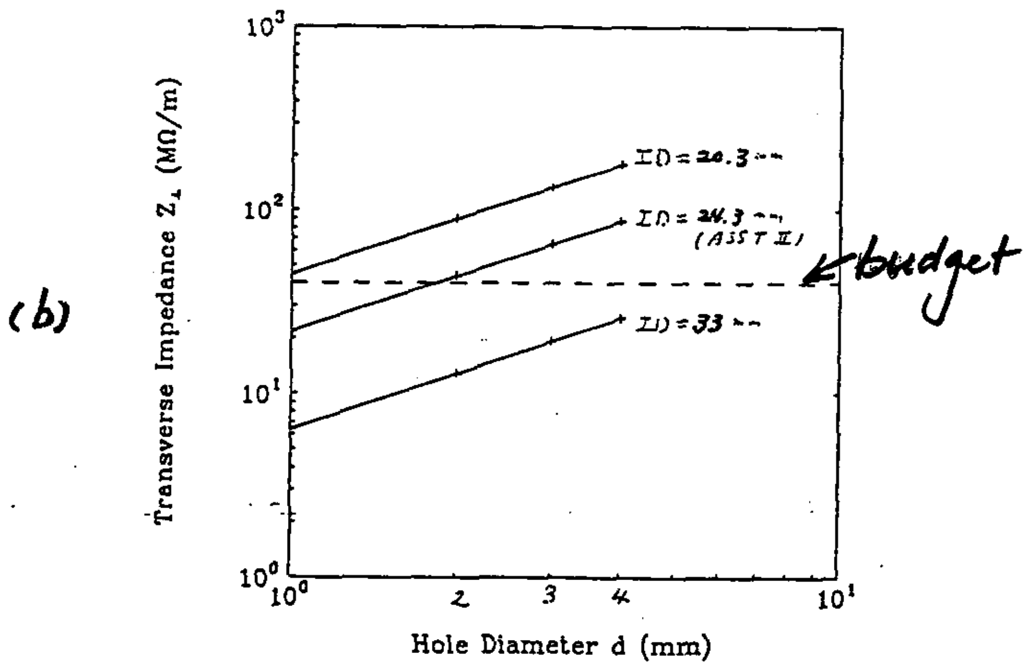



Fig. 6. The total impedances of the liner in the Collider for three possible liner IDs. The dashed lines are the present impedance budget. (a) Longitudinal; (b) Transverse.

# QUAD LINER DESIGN TRADEOFFS

J. Zbasnik 9/30/92

- Assume Quad Liner thickness to be 1.5 mm (1 mm Cu + 0.5 mm SS)

- This may change a little once the stress analysis is done, but we think this assumption has sufficient strength to resist the Lorentz forces

- From Shu's analysis (fig 1), max delta T = 14 K, and $T_{ave} \sim 90$ K

- NBS Cu resistivity value at 90 K is 3 n$\Omega$•m (fig 2)

- At this temperature, $\sigma \cdot t = 3 \times 10^5\ \Omega^{-1}$, thus the spec criterion of $2 \times 10^5\ \Omega^{-1}$ is satisfied

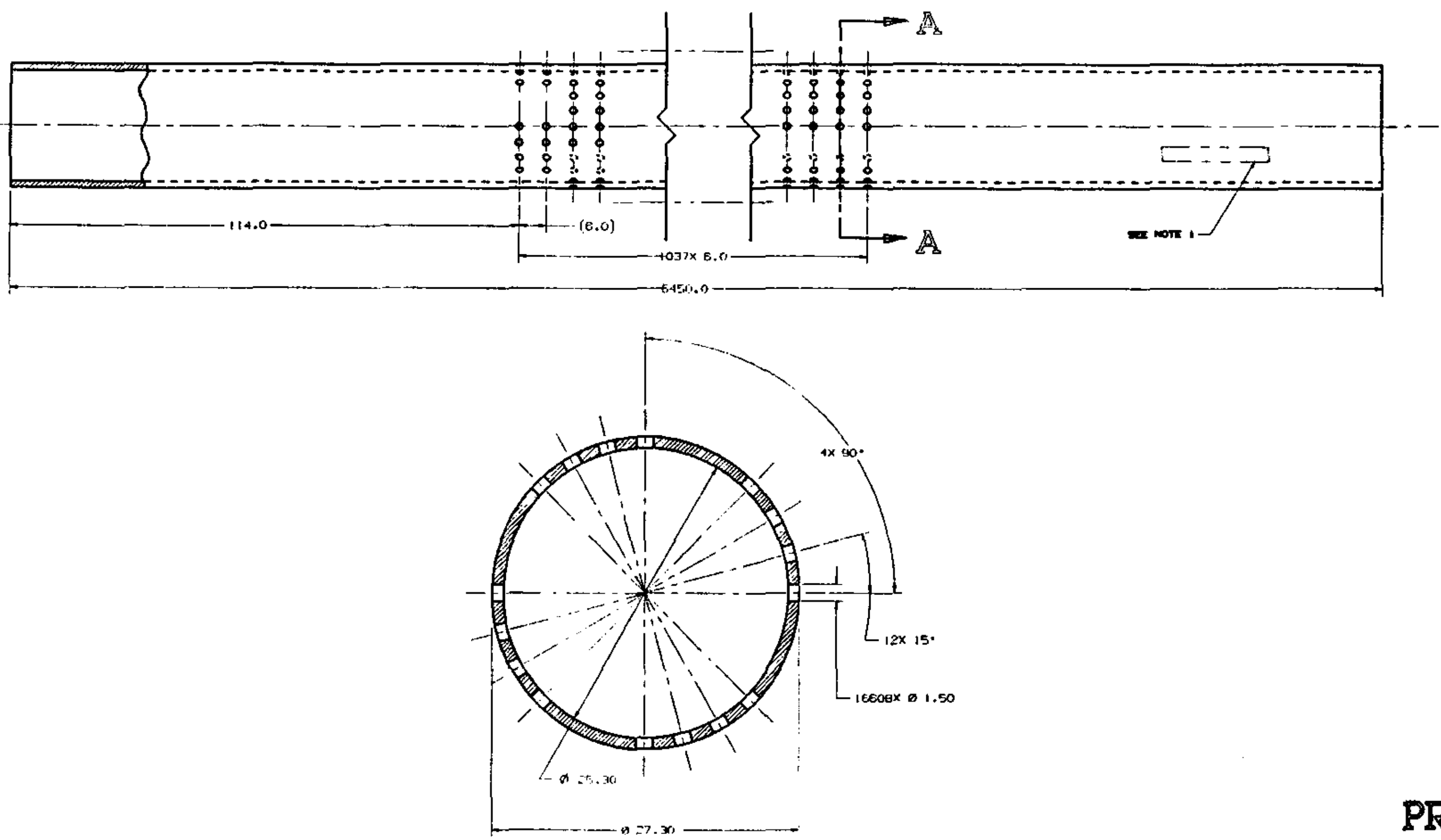
- A Turner-type calculation of holes required for the desired conductance (fig 3) shows that a 1.5 mm dia hole is a reasonable choice ( need 2800 holes/m)

- A radial gap of 1.5 mm between bore tube and liner will achieve a backscatter fraction of less than 10 % (fig 4)

- The proposed support is dimpled Kapton film, epoxied tto the liner. (MSD is testing an adhesive that should satisfy the radiation dose requirement)

- Summary for the ASST quad liner :

| | | |
|---|---|---|
| Bore tube inner dia | 32.2 ±.1 | (from measurements) |
| Liner outer dia | 29.1 | (using 1.5 mm radial gap) |
| Liner inner dia | 26.1 | (assuming a 1.5 mm wall thickness) |
| Pump hole dia | 1.5 | |
| Number of Holes | 2800/m | (14,000 holes total) |




SECTION A-A

SCALE 5:1

REVISIONS

| REV | DESCRIPTION | DATE | ECR NUMBER |
|---|---|---|---|
| - | RECORD RELEASE | | |

NOTES:
1. IDENTIFY PART PER P40-000137 TYPE I. LOCATE IN AREA SHOWN.
2. TUBING TOLERANCES PER AMS 5562 OR EQUIVALENT.

PRELIMINARY

CAD DRAWING
DO NOT MAKE MANUAL
REVISIONS OR ALTERATIONS

SI - METRIC

| QTY | QTY. | QTY. | PART NO. | DESCRIPTION | CAGE CODE | ZONE | ITEM |
|---|---|---|---|---|---|---|---|
| | | 1 | | 1.0 THK, Ø 25.3 ID OFHC (ALLOY101) C | | | 1 |

| -001 | M30-000001 | ASST LINER |
|---|---|---|
| PART NO | NEXT ASSY. | USED ON |
| | APPLICATION | |

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
TOLERANCE OF WHOLE NUMBERS ± 1.0
TOLERANCE OF DECIMALS
.X ± 0.5 .XX ± 0.13 ∠ ± .5°

MURRAY 10/08/92
TROWBRIDGE
ZBASNIK

SSC

LINER,
ASST QUADRAPOLE

D - M30-002091 -

CONTRACT NO. DE-AC02-89ER40486

SCALE 2:1

# 6. Liner Cryosorber

## Cryosorber design criteria (based on W. Turner):

| | | |
|---|---|---|
| 1. | Cryosorber pump speed | 1200 - 3000 l/m/s |
| 2. | Cryosorber pump capacity | 5 - 20 torr l/m |

| | |
|---|---|
| $H_2$ | 45% |
| $CO_2$ | 10% |
| CO | 20% |
| $H_2O$ | 20% |
| $CH_4$ | 5% |

| | | |
|---|---|---|
| 3. | Cryosorber activation temperature | 300K max |
| 4. | Cryosorber regeneration temperature | < 80K for H2<br>< 300K for all gases |
| 5. | Cryosorber recovery fraction | ≥ 98% per generation, 25 cycle |
| 7. | Quench survival | 100 quenches over 25 yrs |
| 8. | Radiation dose tolerance | 1400 MRad over 25 yrs |
| 9. | Up to air accident recovery | > 90% recovery per accident |
| 10. | Thermal cycle (25) | No deterioration of pumping performance or adhesion |

11. The cryosorber is bonded to the inside of the SSC magnet bore tubes upto 15 m length, nominal ID = 32.3 mm and operating temperature = 4.2K
12. The cryosorber is to be applied at ambient temperature after magnet fabrication and measurement.
13. The cryosorber faces the 80K outer surface of the coaxial liner with minimum gap =1 mm at cooling tube and around 4 mm elsewhere.

# Three phase cryosorber development program

- Phase I

  - definition of options
  - short tube (~1m) requirements tests*

- Phase II

  - long tube (~5m) vacuum simulation experiments*
  - long tube ( up to 15m) ASSTII half cell system test*

- Phase III

  - production

* Tubes are to be supplied by the SSCL

# Phase I&II milestones

| | |
|---|---|
| • Agreement between SSCL and contractors on statements of work | Nov. 92 |
| • Complete initial study, identify two or three candidates for cryosorber - eg. charcoal, porous Ag | Dec. 92 |
| • Begin experiments measuring the pumping speed and capacity of cryosorber for $H_2$,$H_2O$,$CH_4$, CO and $CO_2$ and the mixture given in Table 1. | Jan. 93 |
| • Initial measurement of cryosorber pumping speed and capacity in the presence of an $80^{\circ}K$ liner | Feb. 93 |
| • Apply cryosorber to initial 1m long bore tubes (approx. 3ea for each cryosorber to be tested) to be used in photodesorption experiments | Mar. 93 |
| • Measure pumping capacity recovery fraction over 25 cycles for the gas mixture given in Table 1 | Apr. 93 |

# Phase I&II milestones cont'd

| | |
|---|---|
| • Apply cryosorber to initial 5m long bore tubes to be used for vacuum simulation experiments (approx. 3ea for each cryosorber to be tested) | May 93 |
| • Initial test of cryosorber adhesion and pumping characteristics after 25 thermal cycles between $4^{o}K$ and $294^{o}K$ | June 93 |
| • Initial short sample test of cryosorber adhesion and pumping characteristics after 100 quenches in an SSC dipole magnet | July 93 |
| • Apply cryosorber to an ASSTII Collider half cell - 5ea 15m CDM's,1ea 5m CQM and 1ea 3.5m SPR spool piece | Aug. 93 |
| • Initial test of cryosorber adhesion and measurement of the pumping capacity and the pumping speed of cryosorber samples exposed to radiation doses of $1x10^{8}$, $1x10^{9}$ and $1.4x10^{9}$ MRad | Aug. 93 |
| • Program review and definition of future investigations | Sep. 93 |
| • Submit reports on evaluation of cryosorbers | Apr. 94 |

## 7. Liner Conceptual Structure in SPRA (CVI)

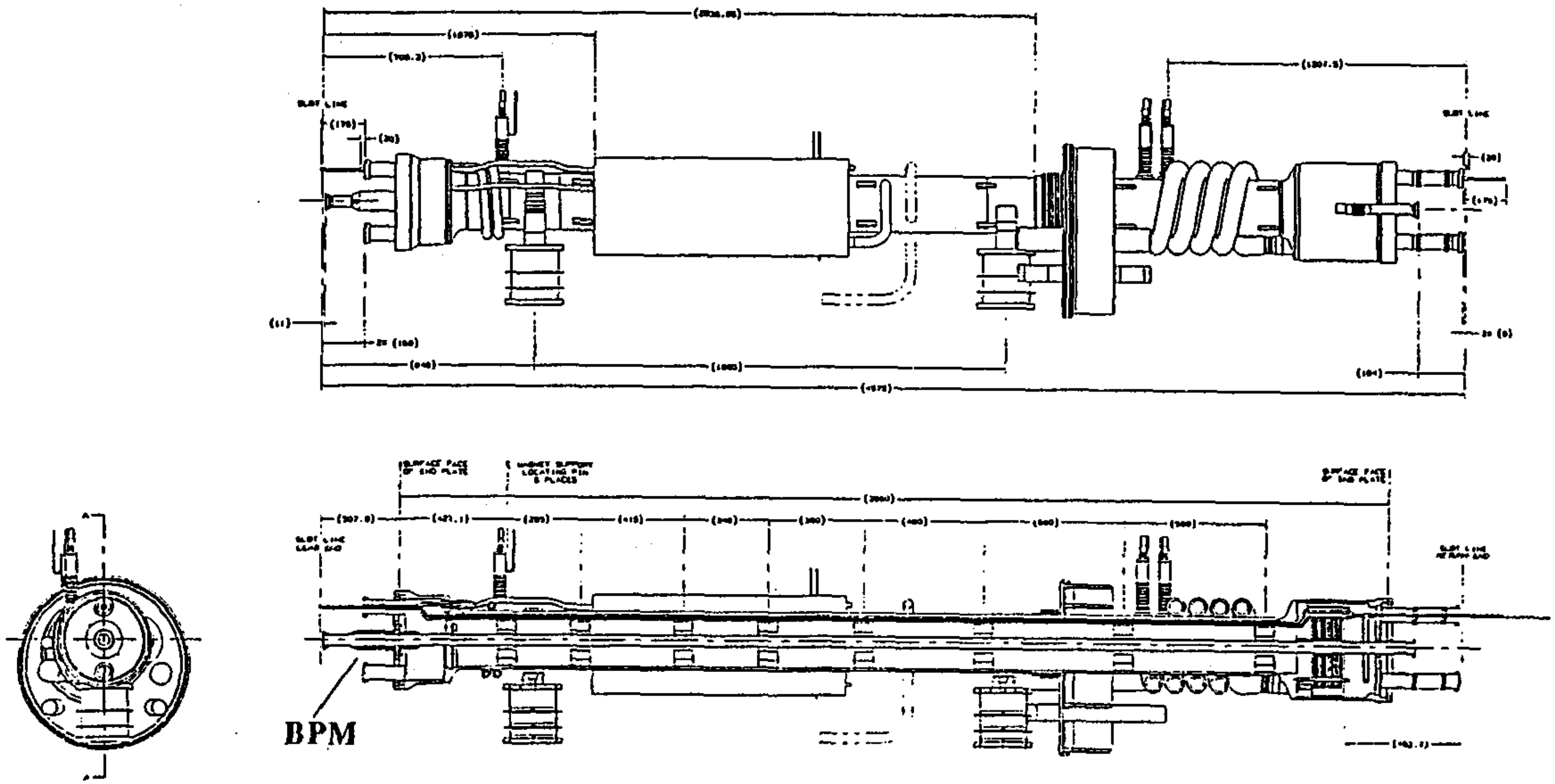
The modified SPRA incorporated with a BPM at the left end is shown in Figure 6. The SPRA liner conceptual design is shown in Figure. The interconnect shall incorporate a dual armed spool designed as an interface that allows the 80-K He cooling tube to wrap around the liner and thus provide the means for end cooling of the liner at the return and location of the CQM and the lead end location of the SPRA.

The liner at this location shall incorporate a thermal contact joint with the CQM liner. the liner is discontinuous as routed through the BPM.

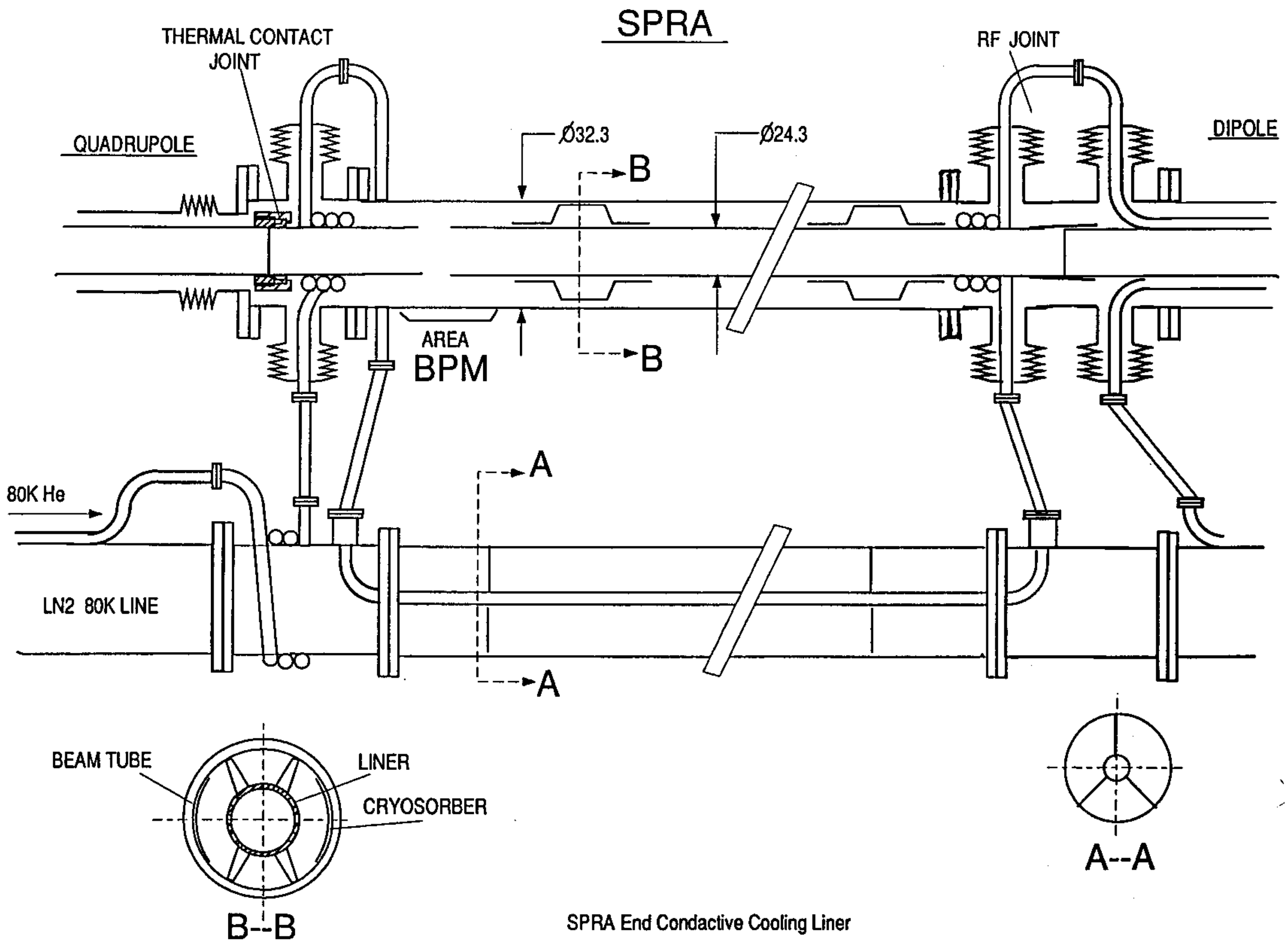
The return end of the SPRA within the interconnect region has room for only one dual armed spool. This unit must be designed to provide the 80 K He cooling access for the CDM liner. The RF joint at the location must be sufficient to allow for thermal expansion and thermal conduction to allow for minimal cooling of the SPRA liner. The liner at a length in excess of 4 meters must depend on the return end for 80-K cooling. The $LN_2$ line shall be modified to incorporate cooling spools at both the lead and return ends of the SPRA. The cooling spools shall be designed to allow for the insertion of the 80-K He cooling tube and also the exiting of the tube as routed through the SPRA.

The liner cooling tube shall be continuous in length through the $LN_2$ 80-K supply line without weld joint exposed to 80-K $LN_2$.

# A Collider SPRA Schematic



# A Schematic of Spool Piece Liner with
# The End Cooling and RF Joint between the CDM and The COM




SPRA End Condactive Cooling Liner

# 8. The Interface between BPM and the Liner

The conceptual design of the interface between the Beam Position Monitor and Liner is in progress. The problem we faced is to maintain the system performance of the BPM while it is incorporating changes in cryogenic design. The BPM system electrical center-line to sextupole magnetic axis must be known to less than 0.1 mm. The BPM detector should have long term mechanical stability and reliability. Additional heat leaks should be maintained below the 200 mW to 4K budget. RF continuity for image currents, good RF transitions, and impedance below 50 micro-ohms should be maintained.

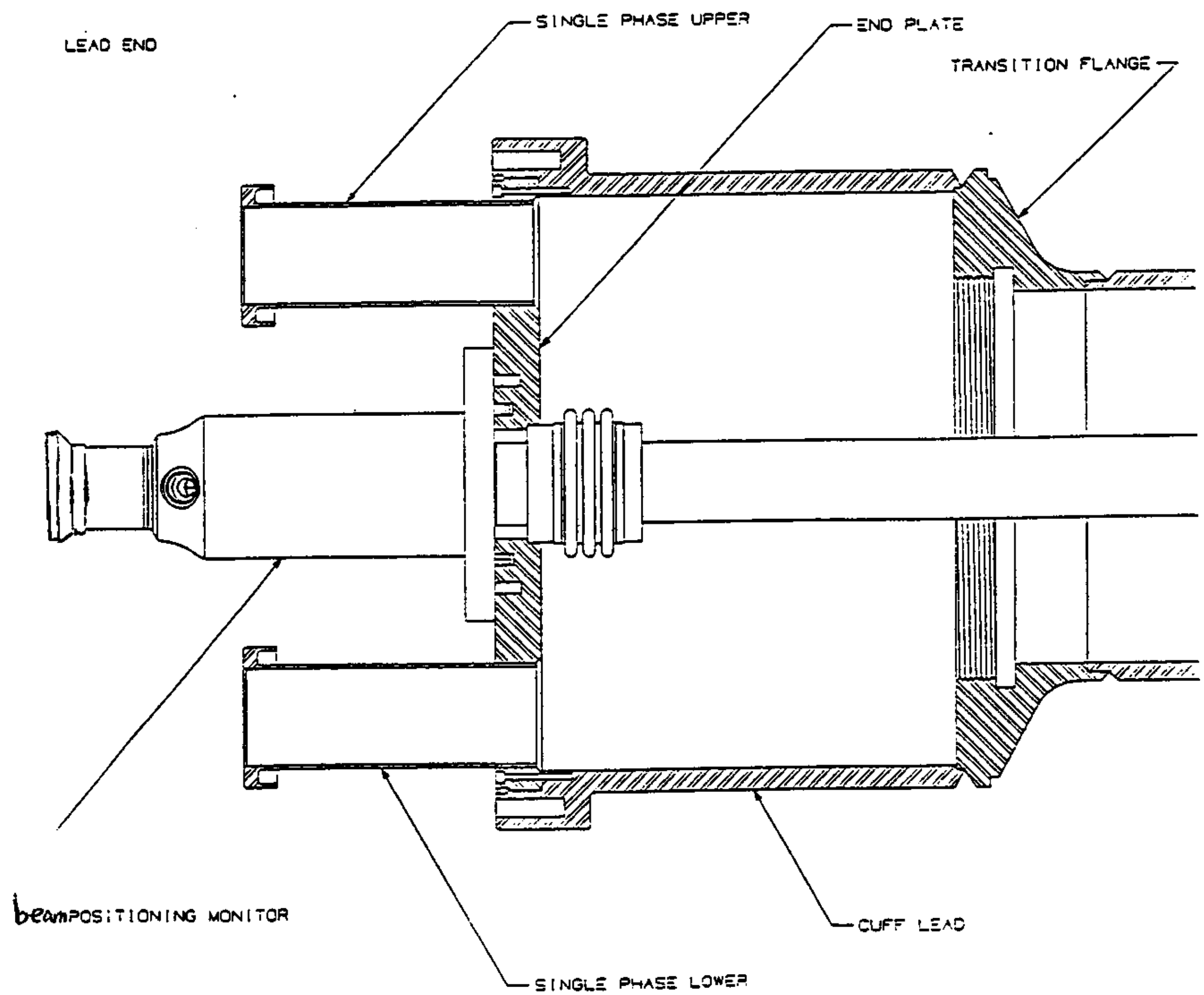
The figure 8 shows two options of the proposed conceptual designs of the interface structure between the BPM and Liner. The upper one is a liner with a 80-K BPM. the advantage is that the liner ID equals the BPM ID, so the RF impedance meets the requirement. But the heat leak through the re-enter tube is large. The lower one is a liner with a 4-K BPM. The structure is simplicity, but the ID of the liner is much less than the ID of the BPM. Therefore, the RF impedance is hardly to meet the requirement. Further study to define a final conceptual design structure is in progress.

D. Martin
D. Meyer

## *BASELINE BPM SYSTEM REQUIREMENTS*

| *Collider Requirements* | *Proposed* |
| --- | --- |
| • X, Y and $I_b$ at niches, X or Y otherwise | • 4 electrode 50Ω Stripline Monitors |
| • Closed Orbit Resolution 25 μm. | • 25 μm @ 72 mA, 4 MHz BW. |
| • Pos. Accuracy wrt sext. 100 μm. rms | • 100 μm. with *in situ* calibration. |
| • $I_b = 2 \times 10^7$ to $1 \times 10^{10}$ ppb (54 dB) | • Log Amp Dynamic Range = 60 dB |
| • 13 MGray radiation field | • 316L S.S. / Alumina / PEEK cable |
| • 200 mW @ 4K Heat Load max. | • <100 mW / Vacuum F.T. proven |
| • BPM not an aperture restriction | • Electrodes shadowed from SR |

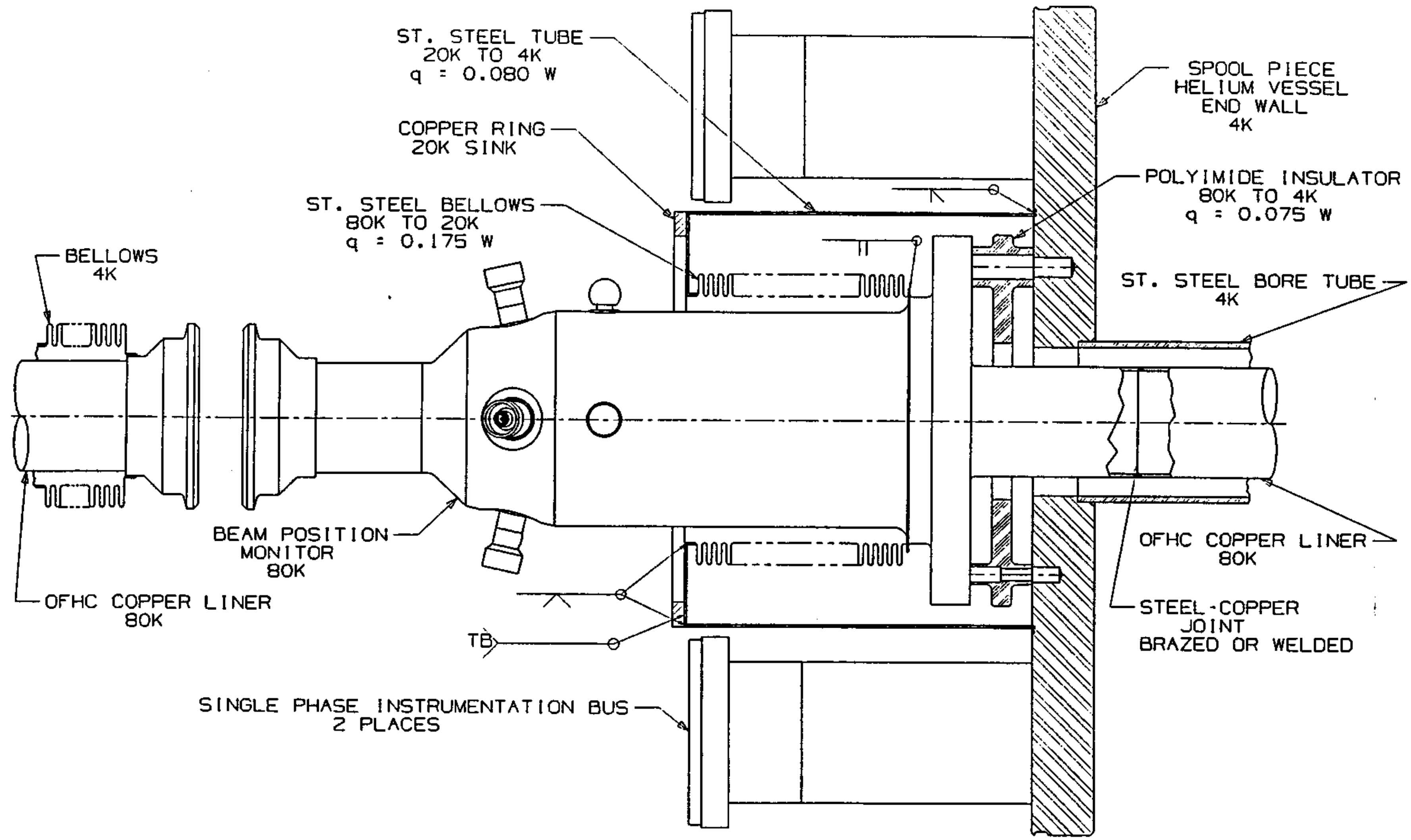
# The Regular Assembly of a 4-K BPM on a Collider SPRA without Liner



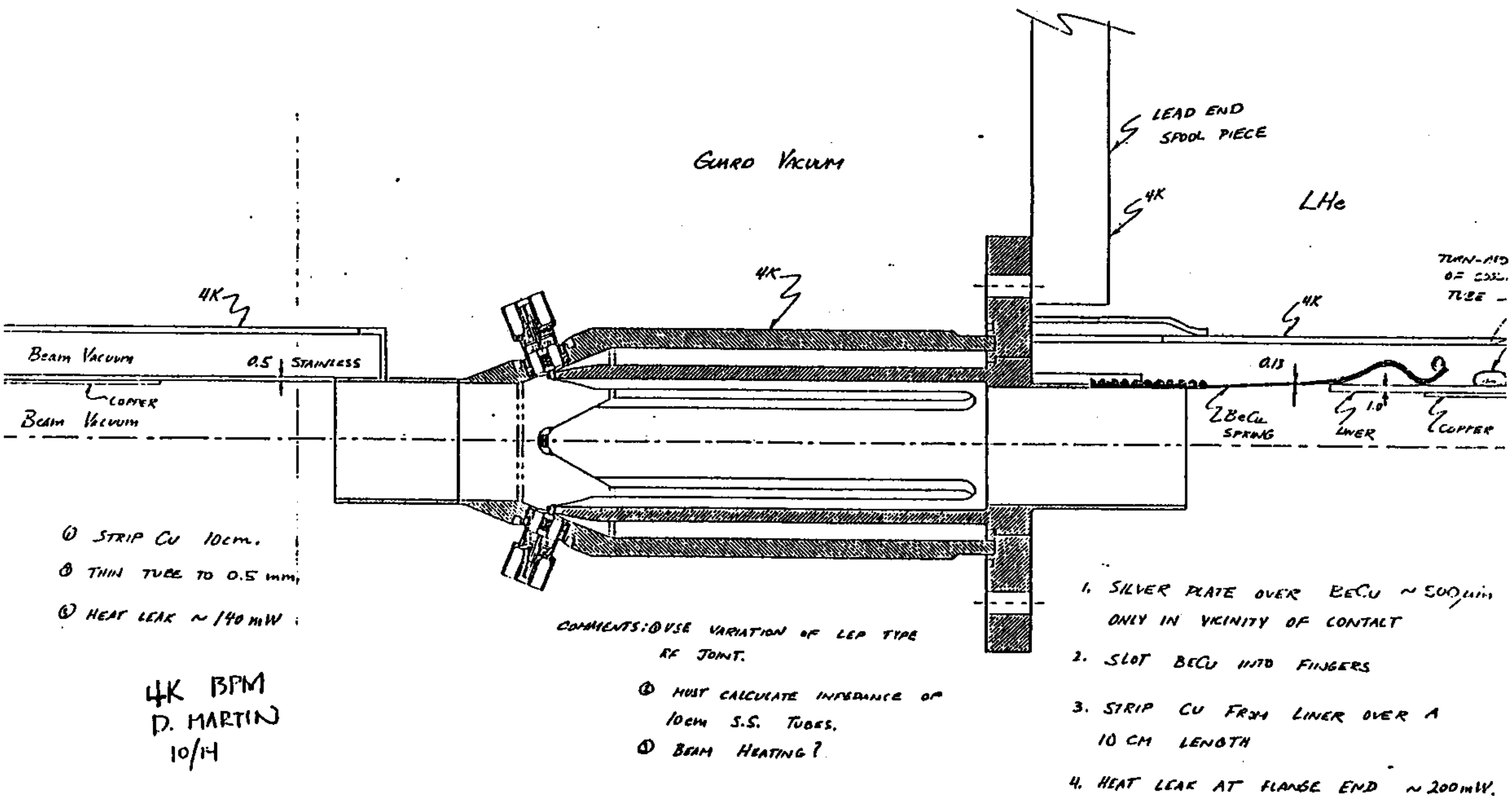
## *4K & 80K CONCEPTS*

| Discipline | • Concept #1 (Preliminary Design) | Concept #2 (Not developed) |
|---|---|---|
| | BPM @ 80 K | BPM @ 4K |
| Heat Leak | Low heat leak. ~235mW/4K | Heat leak may be a problem. |
| Impedance | No impact on machine impedance. | May require copper removal.<br>May impact machine impedance. |
| Vacuum | May require PI insulator in beam vacuum. | No extra organics in beam vacuum. |
| Overpressure | 20 atm. beam tube overpressure concerns. | No impact on pressure rating. |
| Accuracy | Increased location tolerance stack-up. | No impact on location tolerance. |
| Reliability | Small impact. Radiation effects on PI. | Small impact if RF joint required. |
| Cost | <30% cost impact | <30% cost impact |

# A 80-K BPM with A 80-K Liner



# A 4.2-K BPM with A 80-K Liner



# 9. Interconnect Region: Cryogenic & Expansion Joint, RF Joint and Heat Exchanger

There are several unique requirements associated with employing a liner inside the beam tube:

1. There will be a RF joint between liners, but beam tubes.

2. There will be transition joints from 80 K to 4.2K. Therefore, well designed low heat leak cryogenic joints are required.

3. The thermal concentration and thermal expansion must be considered.

4. For end conductive cooling, there will be a small compact heat exchanger.

5. To reduce the schedule impact of a liner on the collider, there may be another small compact heat exchanger tube soldered outside surface of the 80-K $LN_2$ line

6. A good thermal contact joint may be needed to end cool the CQM

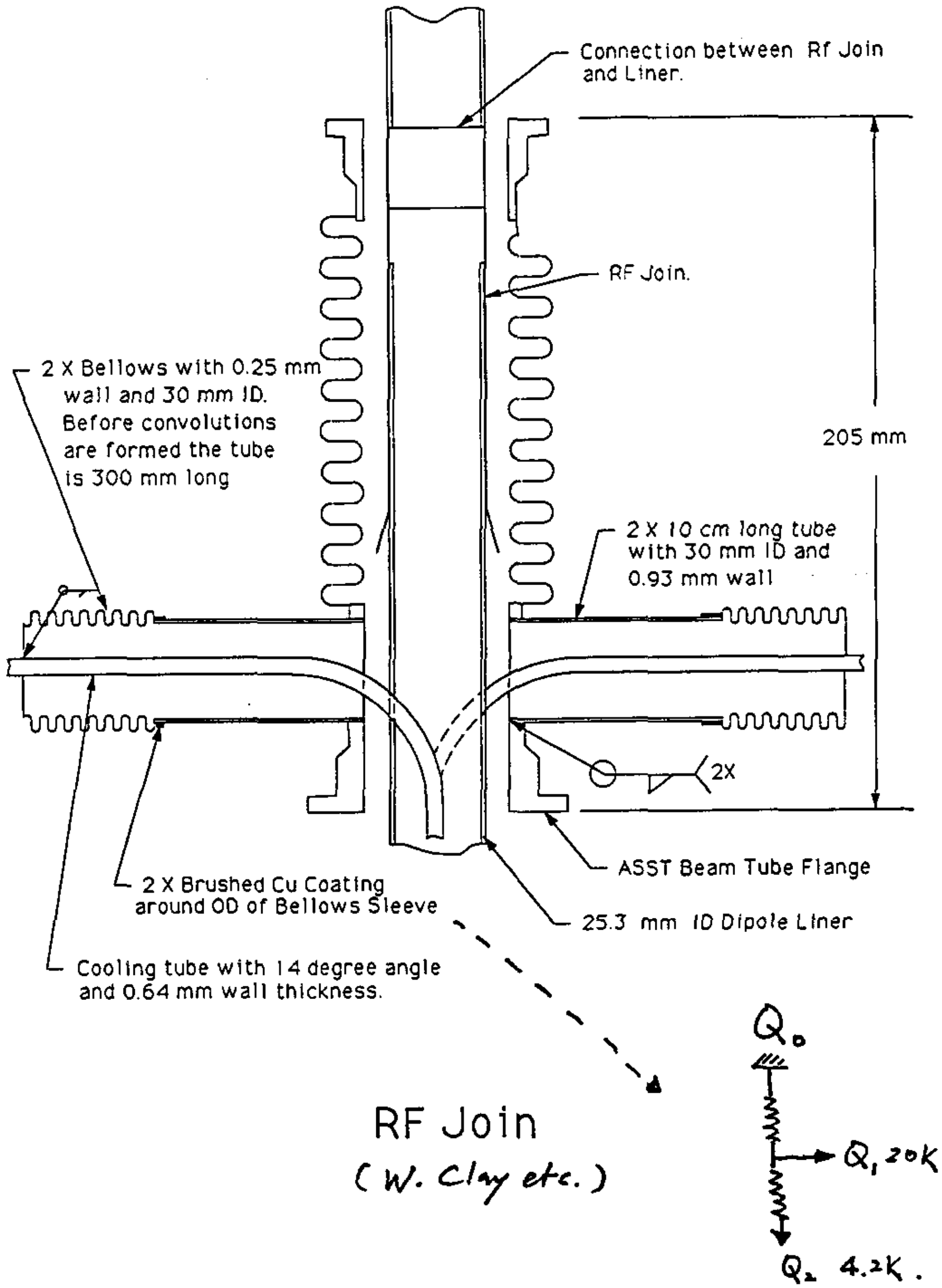
# A Conceptual Design of the Comprehensive RF-Cryogenic Joint:

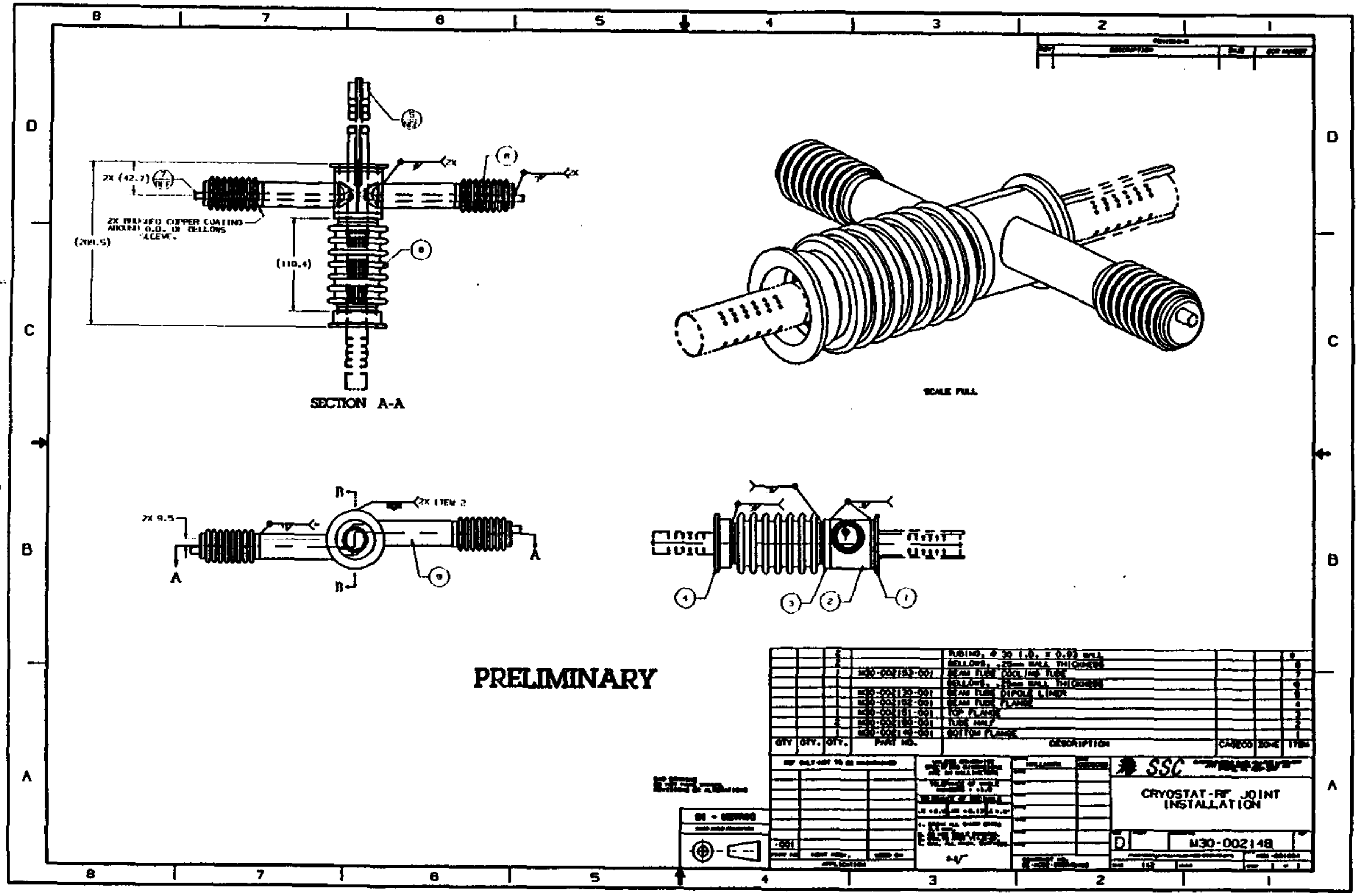
A concepts for the transition of the cooling line through the beam tube was developed by Wayne Clay. The concept introduces an interconnect piece specifically designed to pass the cooling tube out of the beam tube. This piece would be inserted between the Interconnect Bellows and the Beam Tube Flange. The bellows would have to be shortened to accommodate this additional piece. The concept was adapted to the 'flow through' cooling line system (i.e. the cooling line enters at one end of the magnet and exits at the other) and also to the 'return loop' system (the cooling line enters and leaves from the same end of the magnet). The concept uses 100 mW heat leak as a design objective per joint. The flow through system requires a bellows to accommodate differential expansion where as the return loop system constrains only one end of the liner allowing the other to slide within the beam tube. Assembly of the flow through system appears to require liner installation during magnet fabrication, whereas the return loop system feasibly can be installed on a finished magnet. Further details will be developed on these concepts to support analysis.

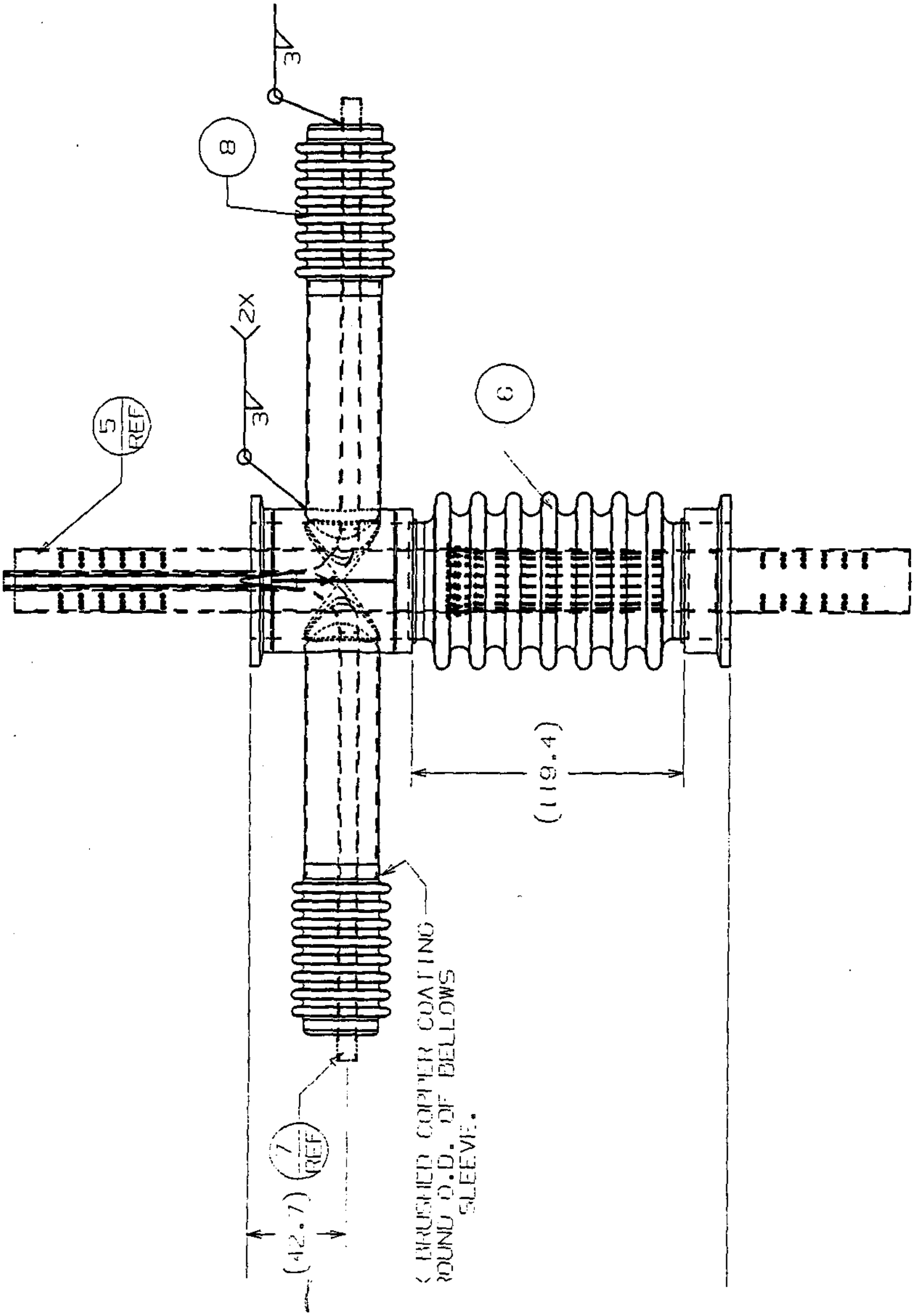
The 20-K thermal bridge is used to reduce the heat leak to 4.2-K region. A detail thermal analyses was conducted by W. Clay, that total heat leak to 4.2 K is 50 mW and to 20 K is 150 mW. The RF joint design is carried out and will be test at the RF group of ASD.

The mechanic design of the compact heat exchanger and the good thermal contact joint will be performed by W. Clay's group based on Q. S. Shu etc's previous calculation.

# A Conceptual Design of the Comprehensive RF-Cryogenic Joint:




SECTION A-A
SCALE FULL
PRELIMINARY
(110.4)
(209.5)
2X (42.7)
2X 9.5
2X PLATED COPPER COATING AROUND O.D. OF BELLOWS SLEEVE.
2X ITEM 2
TUBING, Ø 30 I.D. x 0.93 WALL
BELLOWS, .25mm WALL THICKNESS
BEAM TUBE COOLING TUBE
BEAM TUBE DIPOLE LINER
BEAM TUBE FLANGE
TOP FLANGE
TUBE HALF
BOTTOM FLANGE
QTY
PART NO.
DESCRIPTION
ZONE
ITEM
SSC
CRYOSTAT-RF JOINT INSTALLATION
D
M30-002148



8
6
5 REF
7 REF
3
2X
(119.4)
(42.7)
BRUSHED COPPER COATING
ROUND O.D. OF BELLOWS
SLEEVE.


SECTION A-A

# 10. Liner Support

## Main Consideration:

1. Total heat leak through supports per dipole $\leq 0.5$ W
2. Deflection of support must be meet the requirement
3. Long term stability and quench survivability
4. Good vacuum properties of support materials

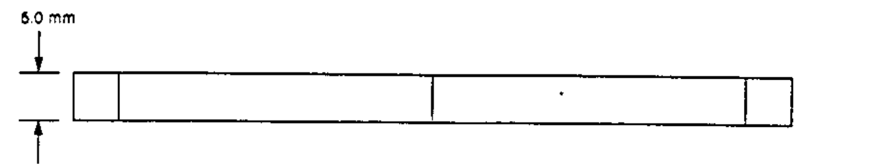
## The support status:

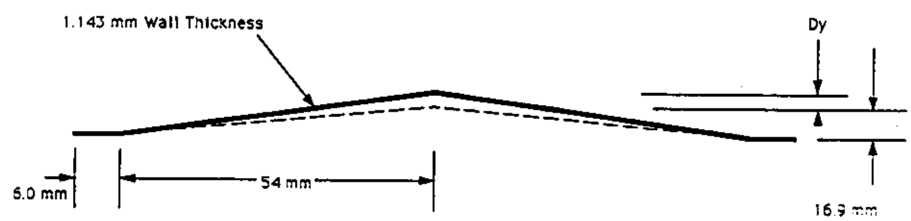
1. A 'bird cage' liner supports were designed by J. Zbasnic as shown in next page. A cryogenic heat leak test facility for the support was developed by J. Meddocks. The first series of runs showed that the heat leak through each support is around 150 mW.

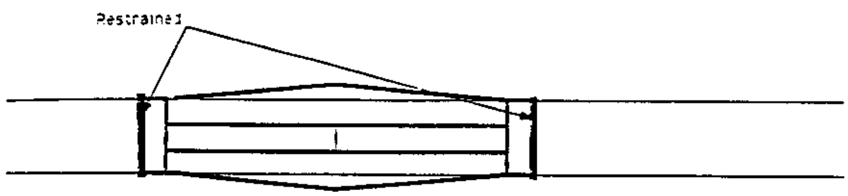
2. G. Morales performed mechanical analysis on the support. The analysis bounds the required spacing of the supports to under 2 m. The design constraint is to limit liner tube deflection to less than 0.5 mm radially. Three constraints were analyzed, one with the 'bird cage' fixed at both ends, one with it fixed at one end only, and one that minimized the thermal contact area.

3. To have three supports spaced at 120° instead of the four currently being modeled was suggested. This would require placing the 80K He cooling lines on the liner horizontal mid-plane instead of the current plan of the vertical mid-plane. Also, high thermal contact resistance materials were considered to be put on the top of the support, where the support contacts the 4.2-K wall.

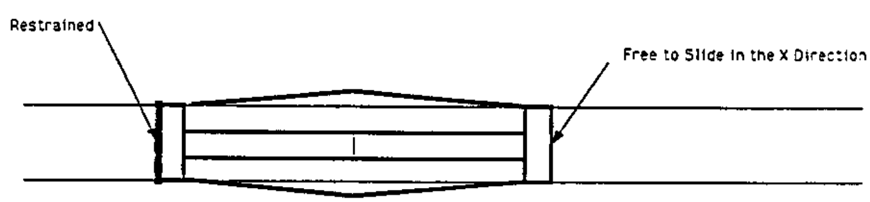
# The Dimension and Shape of the Liner Support



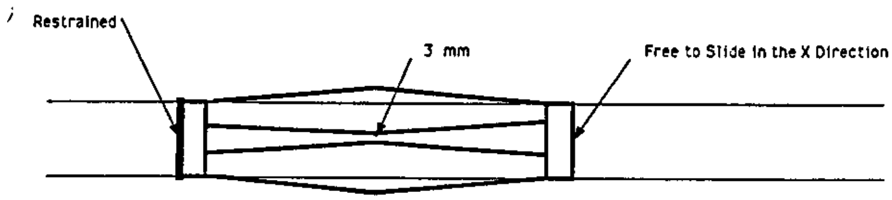



Model A




Model B




Model C

# The Results of Mechanical Analysis

TABLE 1: Stress Values for the Liner Supports

| Model | Displacement (mm) | Maximum Von Mises Stress (MPa) | Factor of Safety (Yield Strength/ Von Mises) |
|---|---|---|---|
| A | 0.25 | 136 | 2.94 |
| A | 0.50 | 284 | 1.38 |
| A | 1.00 | 613 | ---- |
| B | 0.25 | 72 | 5.57 |
| B | 0.50 | 143 | 2.79 |
| B | 1.00 | 288 | 1.38 |

TABLE 2: Stiffness Coefficients for the Liner Supports

| Model | Force (N) | Displacement (m) | K (kN/m) |
|---|---|---|---|
| A | 900 | 0.0398 | 22.6 |
| B | 260 | 0.0124 | 20.9 |
| C | 260 | 0.0168 | 15.5 |

TABLE 3: Deflection of Supports with Various Spring Constants

| Spring Constant (kN/m) | Deflection of Supports (mm) | Total Max Deflection of Liner (mm) | Sag in Pipe (mm) |
|---|---|---|---|
| 10 | 1.00 | 1.70 | 0.70 |
| 20 | 0.50 | 1.20 | 0.70 |
| 27.3 | 0.35 | 1.10 | 0.75 |
| 30 | 0.32 | 1.00 | 0.68 |
| 40 | 0.24 | 0.97 | 0.70 |
| 50 | 0.20 | 0.89 | 0.69 |
| 60 | 0.16 | 0.85 | 0.69 |
| 70 | 0.14 | 0.83 | 0.69 |
| Infinite | 0.00 | 0.69 | 0.69 |

# IV The Physics & Engineering Analysis

The physics and engineering analyses are one of the most important aspects in the liner system design work in order to remove the risks in the Liner design and future operation. These analysis including the mechanics, thermal dynamics, vacuum performance, RF impedance, quench induced Lorentz force, ASME code, hydrodynamics and material performance and cryogenic performance have been carried out. The followings are a list of the items performed or will be conducted.

(1) Liner vacuum analyses. (almost completed-to be modified)
(2) Liner RF impedance analyses. (in progress)
(3) Liner cryogenic and thermal performance analyses. (almost completed for CQM/Spool, but need to consider the thermal conducting joint and make sure the compact heat exchanger works)
(4) Quench induced Lorentz force, stress and ASME code analyses. (almost completed for liner in dipole, but need to consider the liner tube with holes and the effect of the magnetoresistivity)
(5) The liner hydrodynamic performance analyses. (complete several cases)
(6) The liner tube material performance analyses. (complete several cases)
(7) The heat transfer of the liner support analyses. (in progress)

# V The Verification & Demonstration Experiments

Five engineering experiments have been planned to perform the design verification & concept demonstration, including the heat leak of liner support, quench survivability, magnetoresistivity, cryosorber development and The RF surface resistivity of the liner tube. The followings are a list of the items planned and the status of two on going experiments.

(1) The experiment of the heat leak through liner supports. (the experiment has been conducted and some results are produced)

(2) The experiment on quench survivability of a liner tube with supports (test equipment is under construction. The test is scheduled to be performed in December 1992).

(3) The magnetoresistence of the combined liner tubes at 80K will be tested through a contract with NIST. (The SOW was submitted to SSCL from NIST. The SSCL need to go through the procurement procedure to confirm the contract.)

(4) The experiments on Cryosorber will be developed and tested through vendors by contract.

(5) The RF surface resistivity at the 80K of the Liner tube will be tested by other National Laboratory through contract. We are starting negotiation with the Cornell University and will be discuss with Los Alamos National Lab.

# VI The Further Development

A final down selection will be performed based on the results of our studies to develop a mature engineering design. Each sub-project leader already provide at least two design conceptual for further development. A final conceptual design selection meeting will be held as internal review prior to starting detail engineering design.

In order to accomplish the task of Liner System Design, the following work will be conducted:

(1) Continue the supporting analyses and experiments.

(2) Complete the design conceptual selection by 10/30/92.

(3) Perform the engineering design (no later than 10/30/92), procure and fabricate the ASST II prototype liner system.

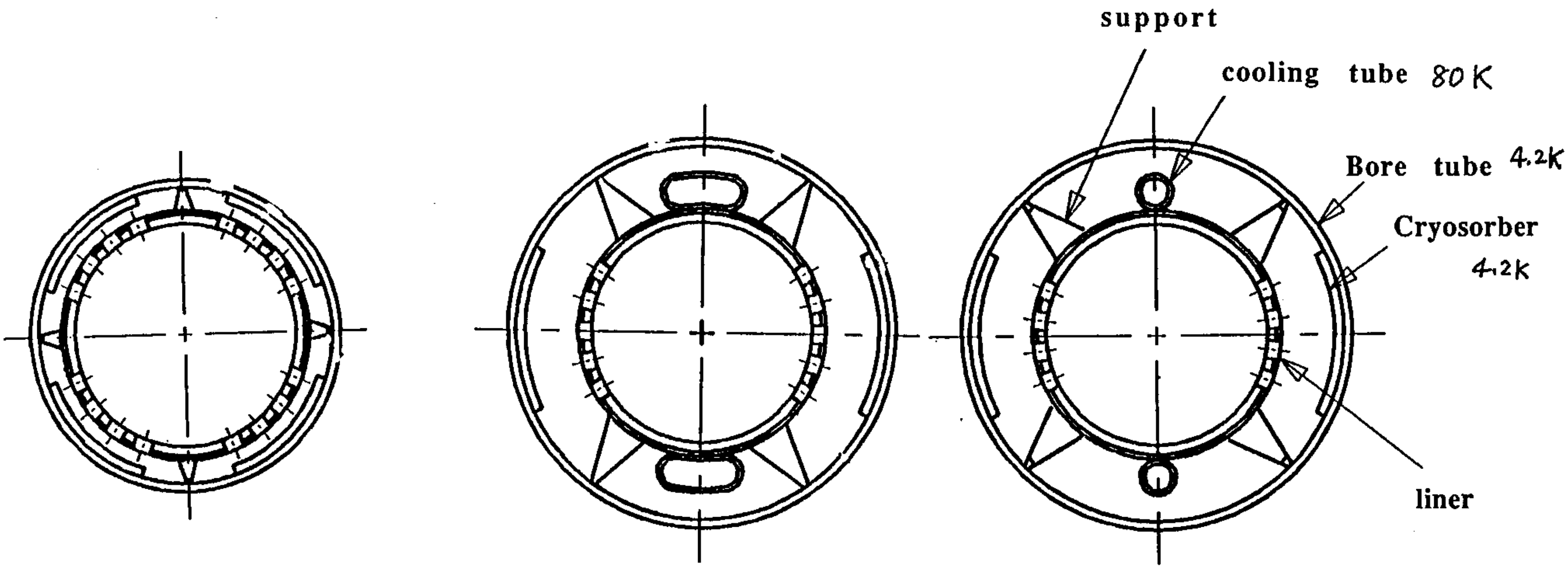
(4) Develop the instruments, install and test the liner System at ASST II. (the personnel for test instruments is still TBD. It is imperative to have a engineer with the expertise on board ASAP)

(5) Prepare to develop a collider liner.

# ASST II Liner Milestones (Based on Dr. W. Turner)

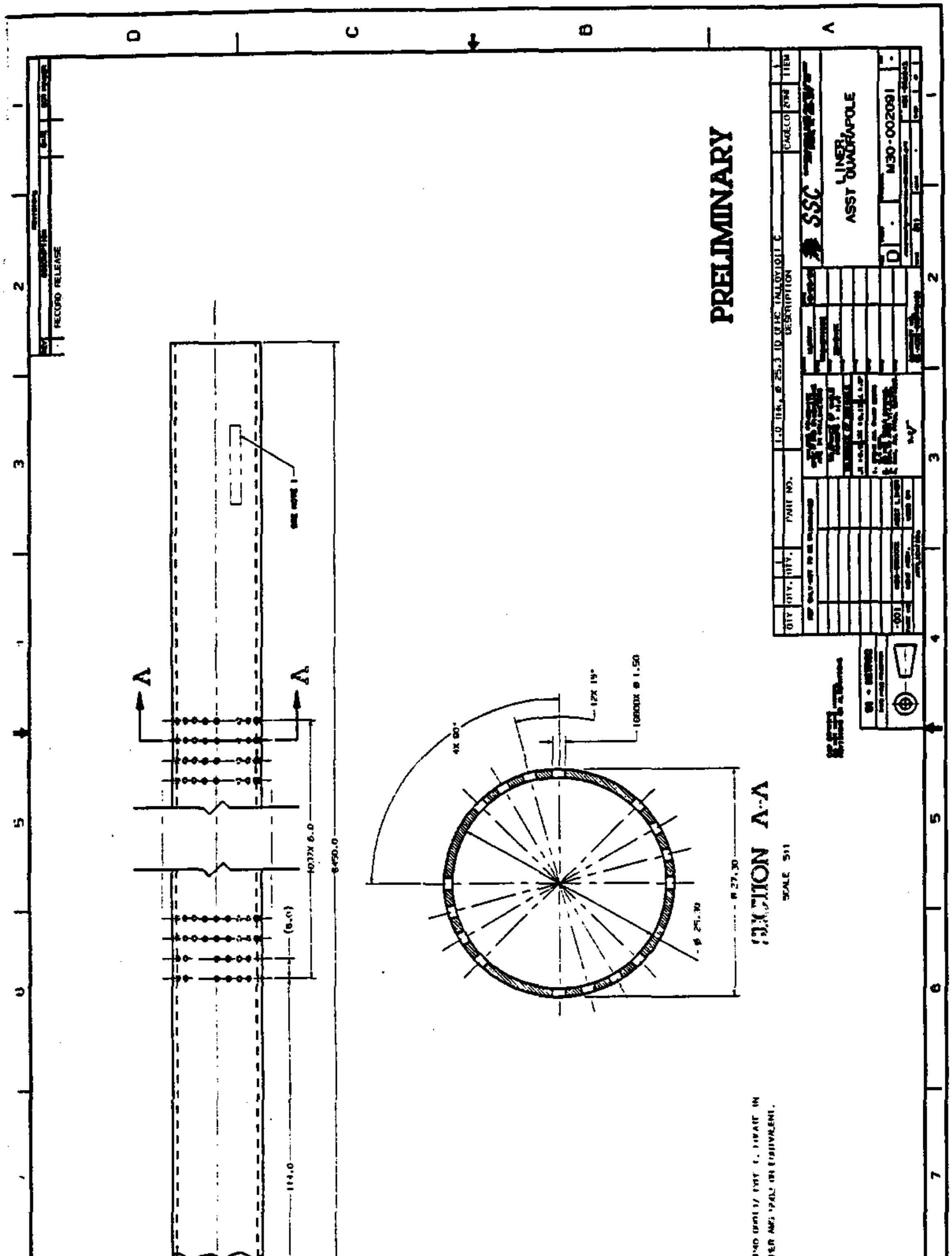
| | Issues | Starting Date |
|---|---|---|
| 1. | Appoint Liner System Design leader | 6/1/92 |
| 2. | Develop a WBS of ASST II liner | 6/15/92 |
| 3. | Organized the Liner Design Team | 7/1/92 |
| 4. | Issued a liner design requirement | 7/15/92 |
| 5. | Started Trade studies | 7/15/92 |
| 6. | Started developing design concept & physics and engineering analysis | 8/1/92 |
| 7. | Started prototype conceptual design | 8/15/92 |
| 8. | Final selection of conceptual design | 11/1/92 |
| 9. | Start engineering design | 11/15/92 |
| 10 | Long lead items procurement | 11/15/92 |
| 11. | Procurement/Fabrication | 1/1/93 |
| 11. | CDR of liner design | 2/93 |
| | Issue Liner Design Repot w/o test results | |
| 12. | Assemble liners: | |
| | CDM liner | 7/5/93 |
| | CQM liner | 7/5/93 |
| | Spool liner | 7/5/93 |
| | Spool Mod's complete | 6/7/93 |
| | BPM Mod's complete | 6/7/93 |
| | Assemble interconnection parts complete | 5/31/93 |
| | Instrumentation available for ASST II | 5/31/93 |
| | Cryo-line available for ASST II | 5/31/93 |
| | Cryosorber available for ASSY II | 8/1/93 |
| 13. | Assemble half cell in ASST II | 8/10/93 |
| 14. | Test half cell Liner in ASST II | 10/5/93 |
| 15. | ASST II liner test complete | 12/28/93 |
| 16. | Issue a complete ASST II Liner Design Report | 2/2/94 |

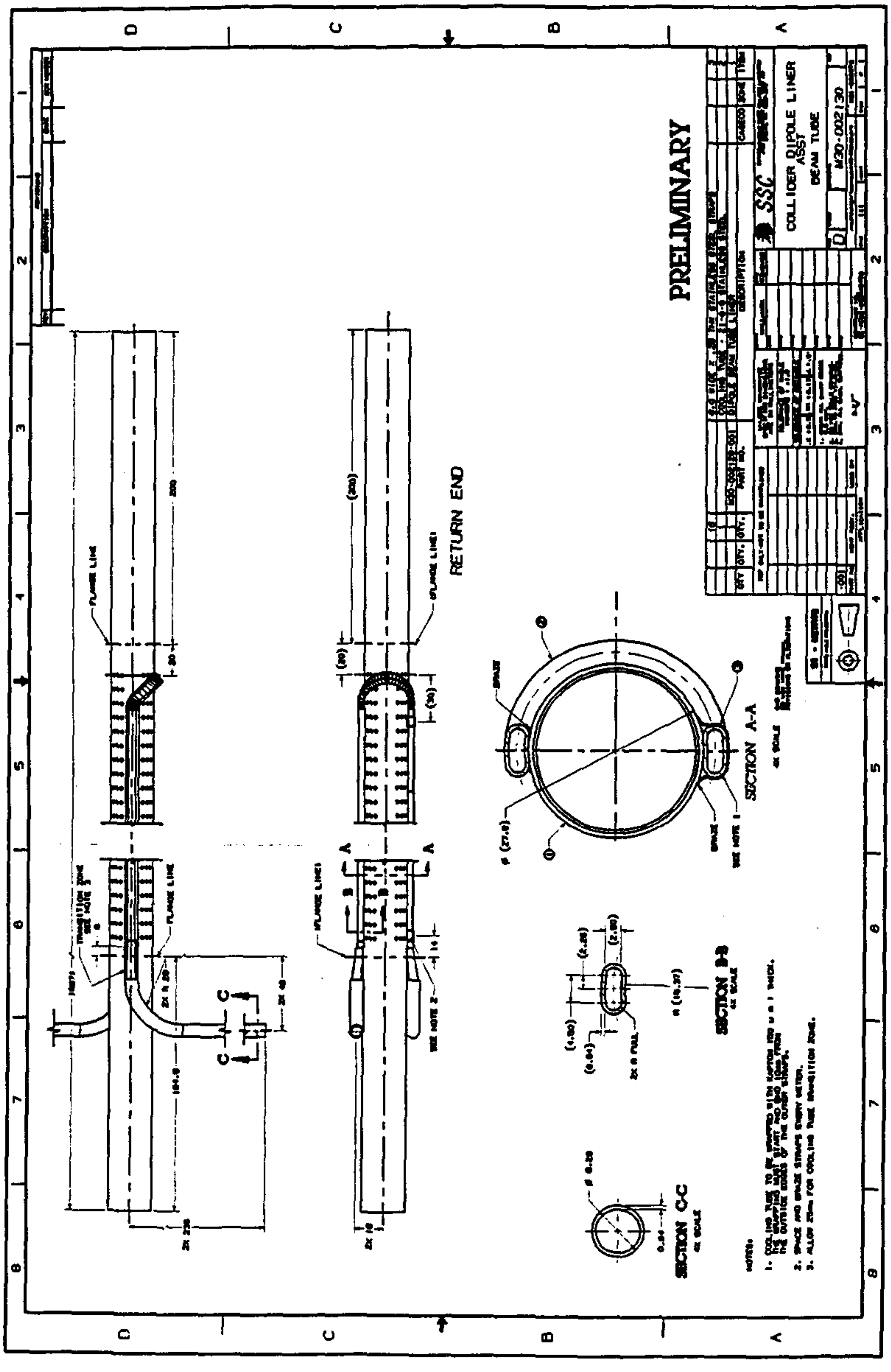
# VII The Selected Drawings of liner Conceptual Design

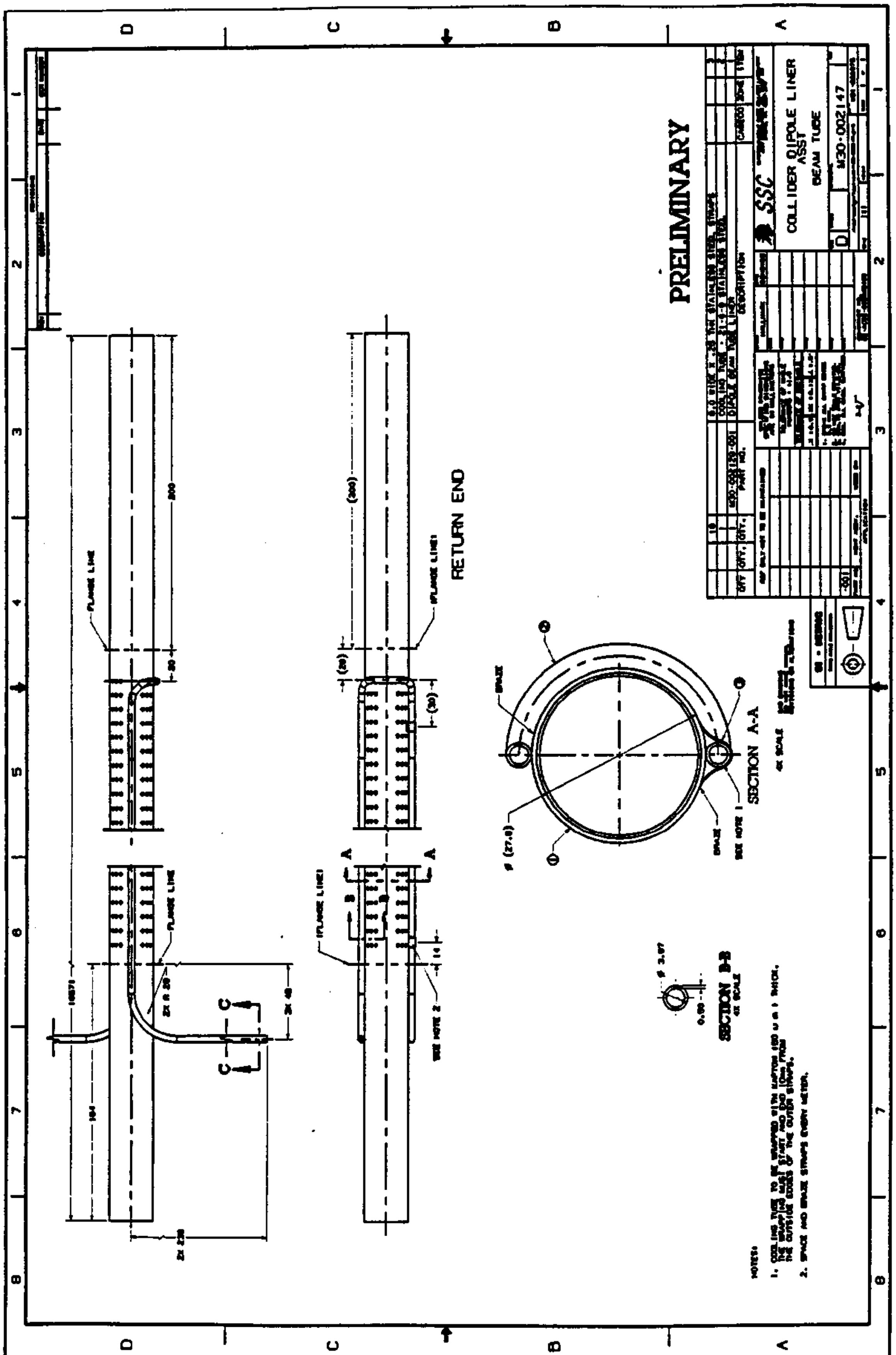



ASST II CQM Liner    Collider CDM Liner    ASST II CDM Liner

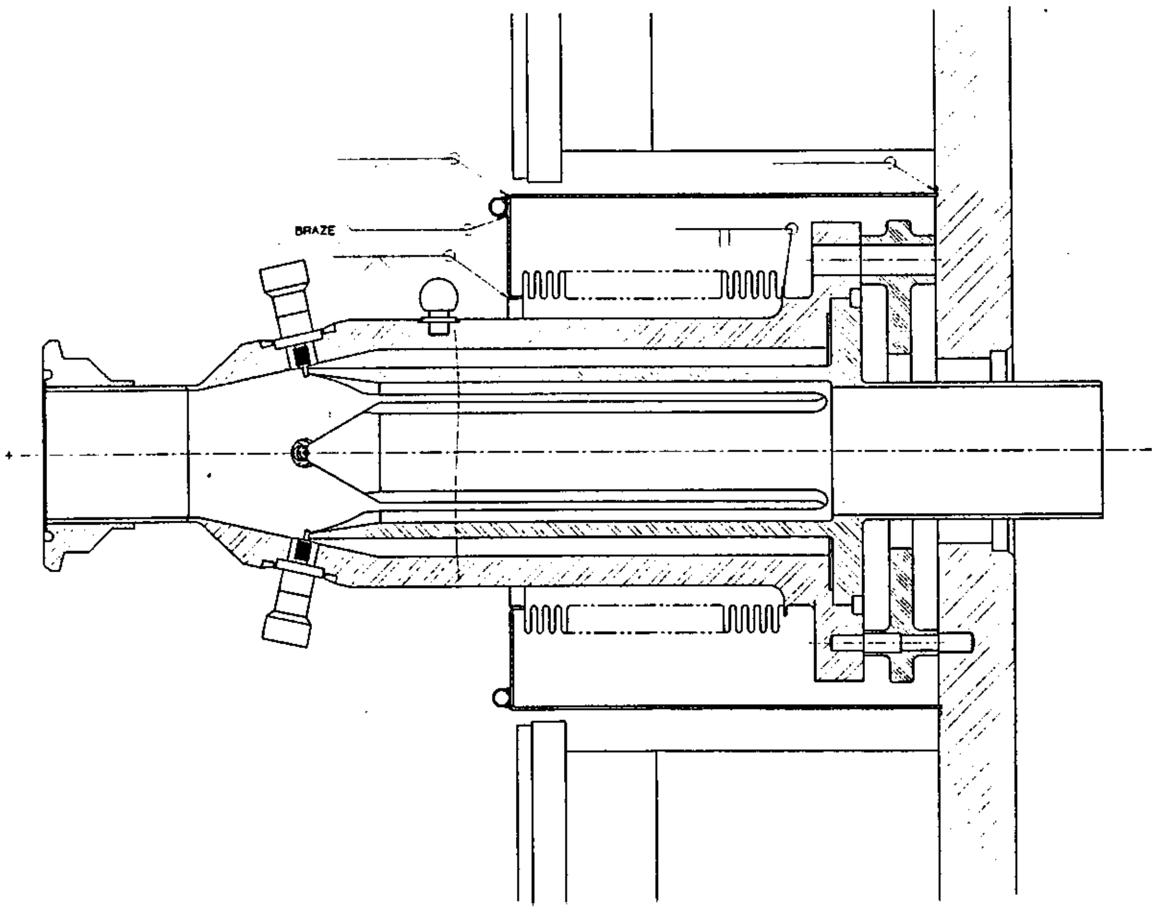
Figure. The Cross section schmatics of the ASST II dipole liner, ASST II Qudrupole liner and Collider dipole liner.


PRELIMINARY
SSC
LINER,
ASST QUADRUPOLE
M30-002091
SECTION A-A
SCALE 5:1
RECORD RELEASE
A
A


PRELIMINARY
SSC
COLLIDER DIPOLE LINER ASSY
BEAM TUBE
RETURN END
SECTION A-A
SECTION B-B
SECTION C-C
FLANGE LINE
BRAZE


PRELIMINARY
RETURN END
SECTION A-A
SECTION B-B
SSC
COLLIDER DIPOLE LINER ASST
BEAM TUBE
M30-002147

# The Structure of an 80-K BPM with A 80-K Liner



# CDM

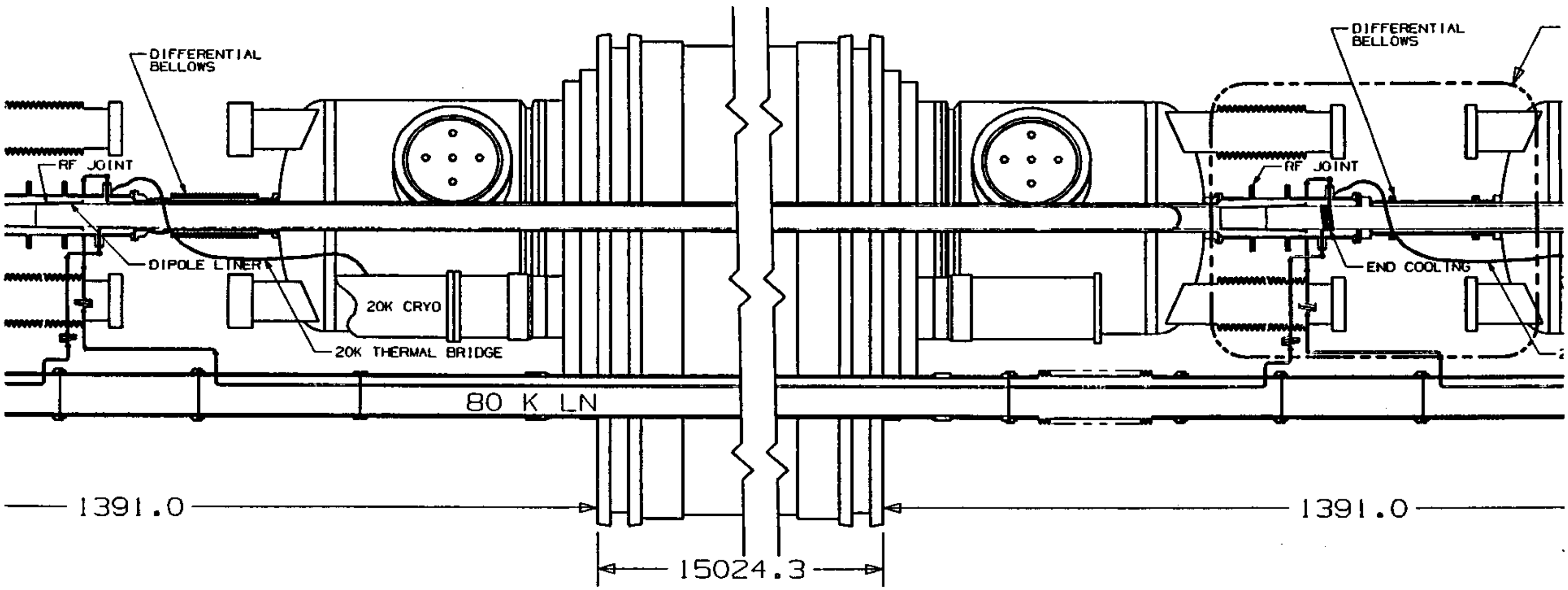



**Figure.** A schematic of CDM retrofit liner assembly with flow return cooling loop and liner interconnet components

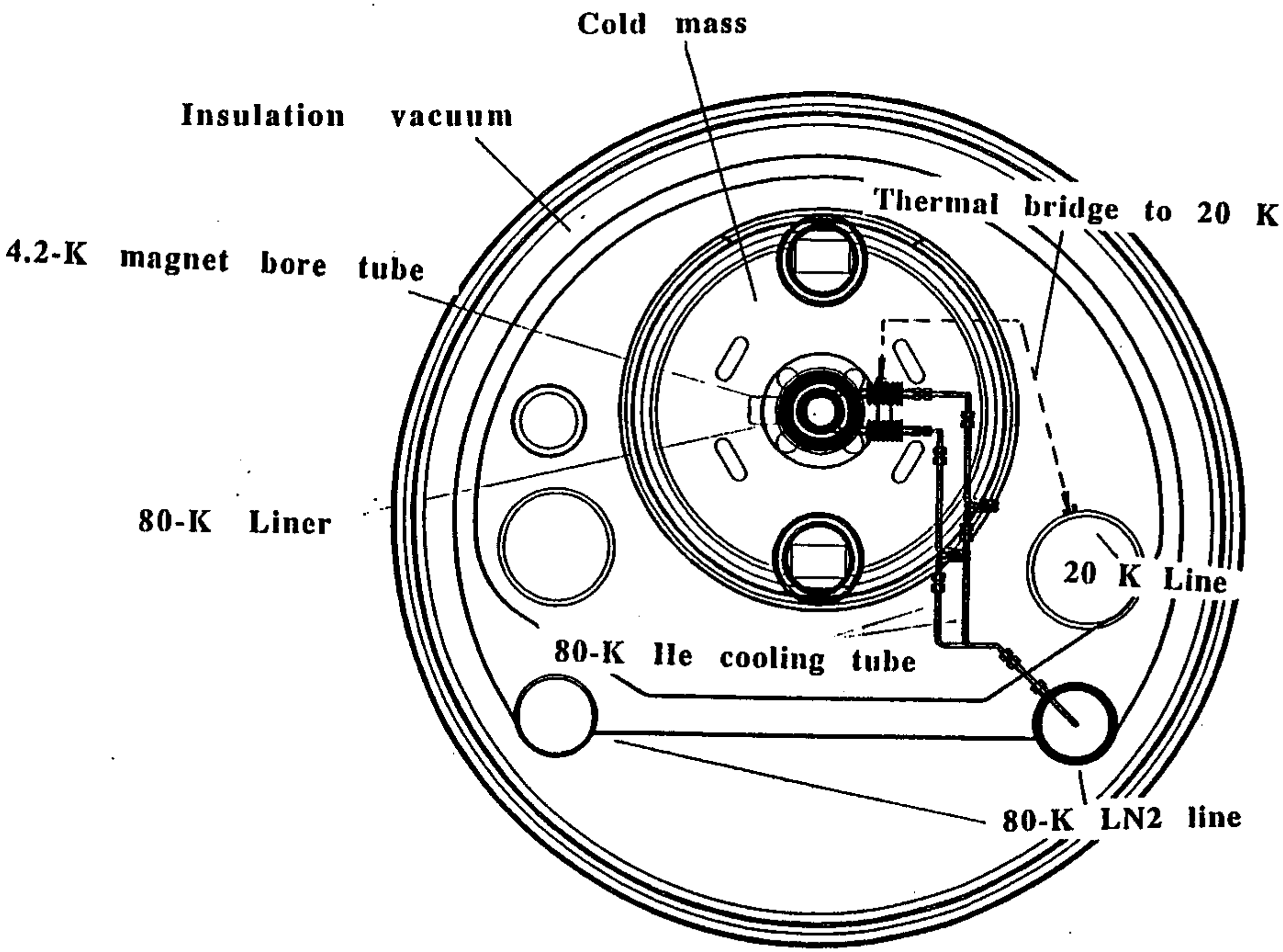



Figure ___. The A-A section of the interconnect region of a collider dipole magnet with a retrofit liner assembly.

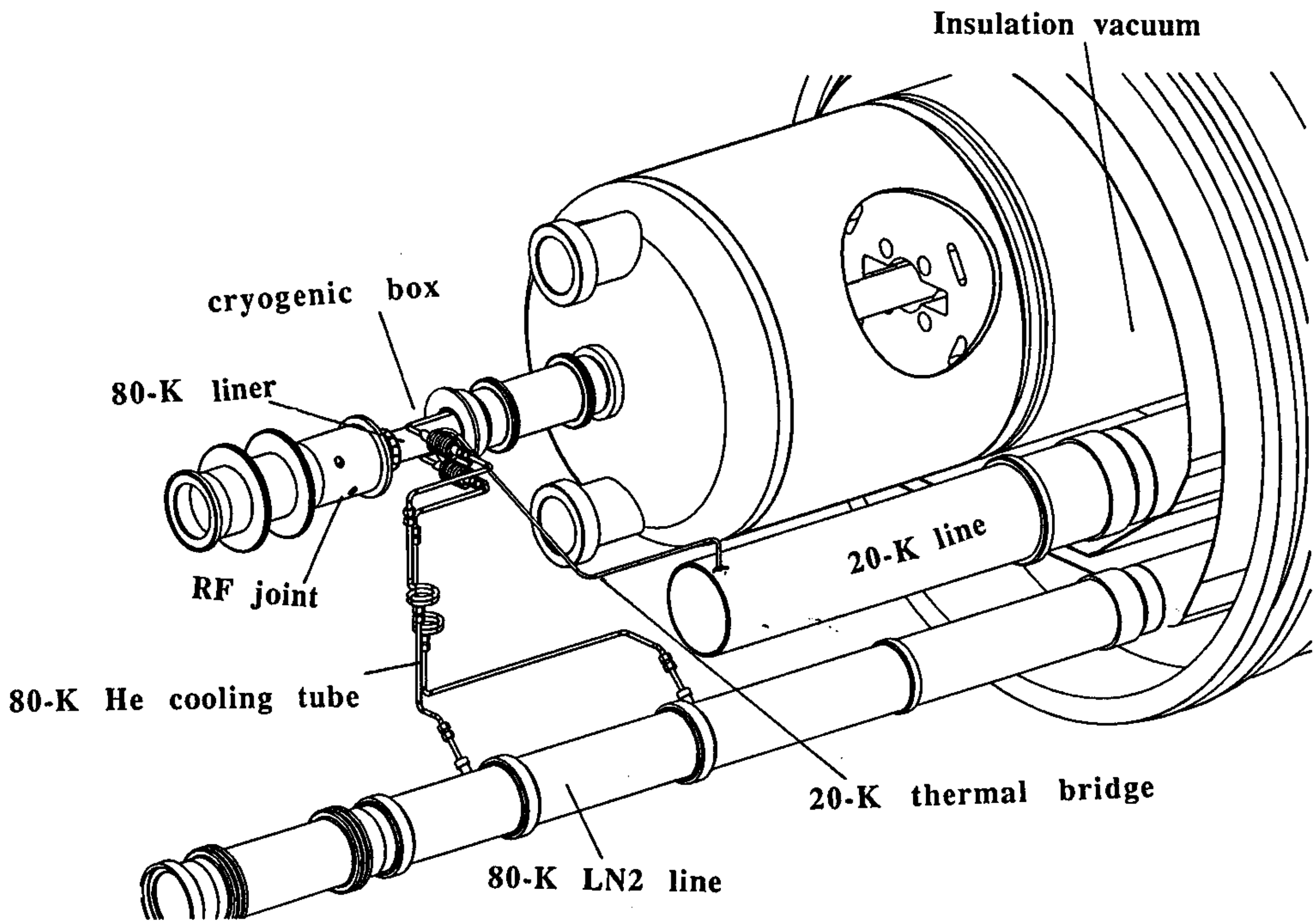



Figure. A three dimension plot of a CDM liner with a flow return cooling loop.

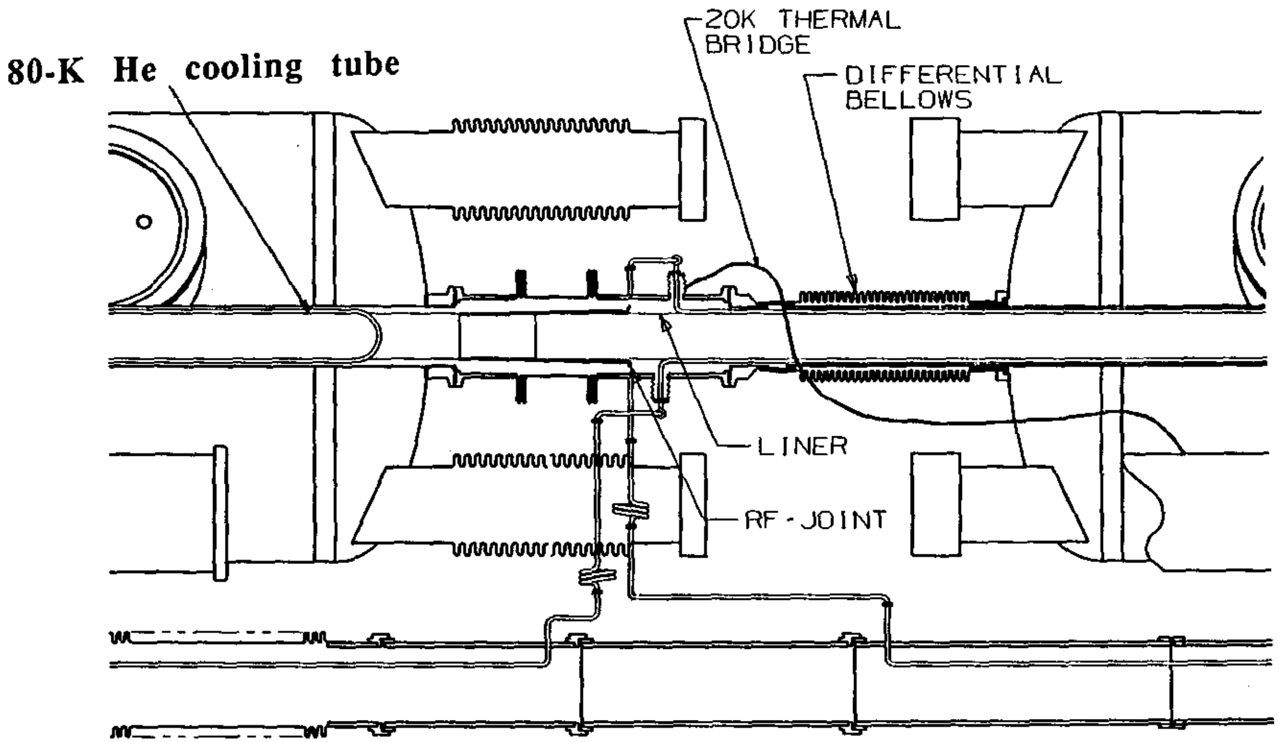



**Figure.** A longitudinal cross section of the interconnect region between collider dipole magnets with a retrofit liner assembly.

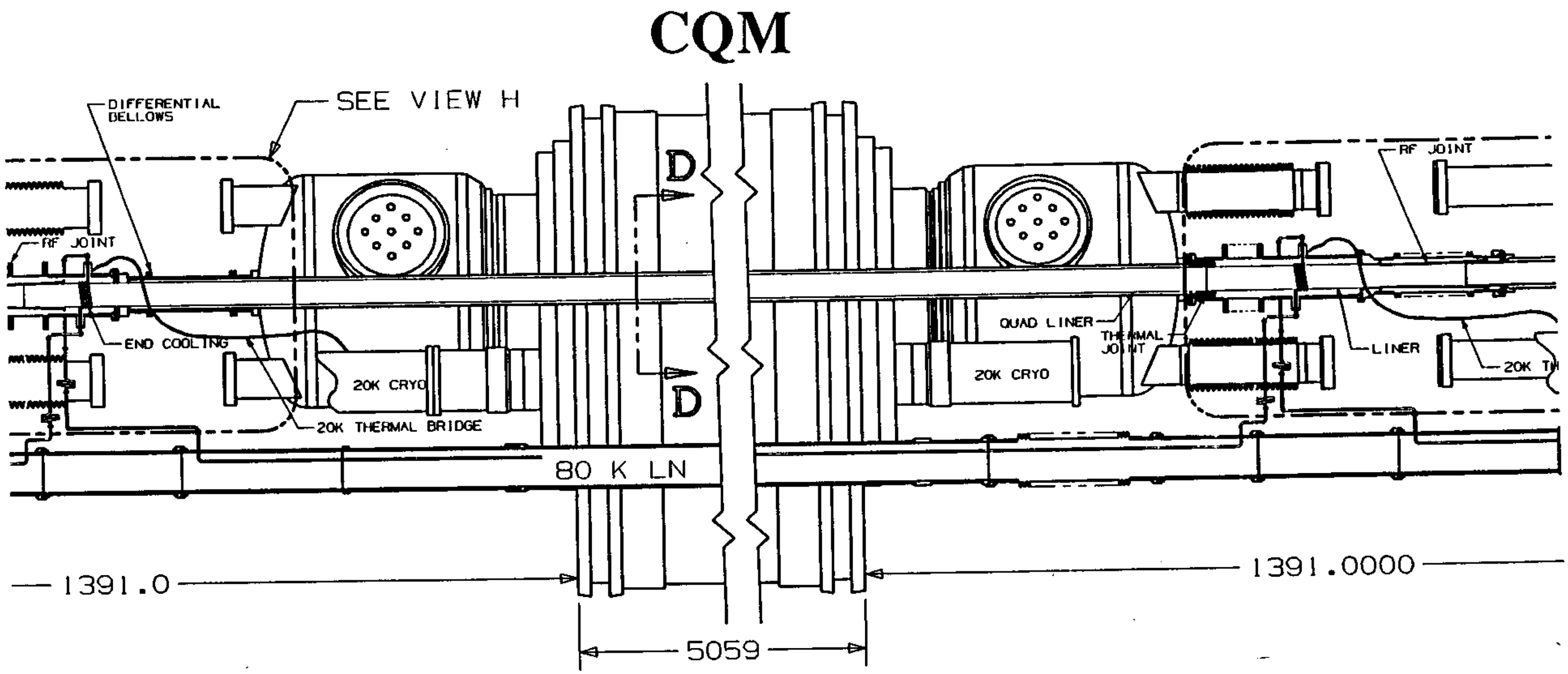



Figure. A schematic of CQM retrofit liner assembly with an end conductive cooling loop and liner interconnet components

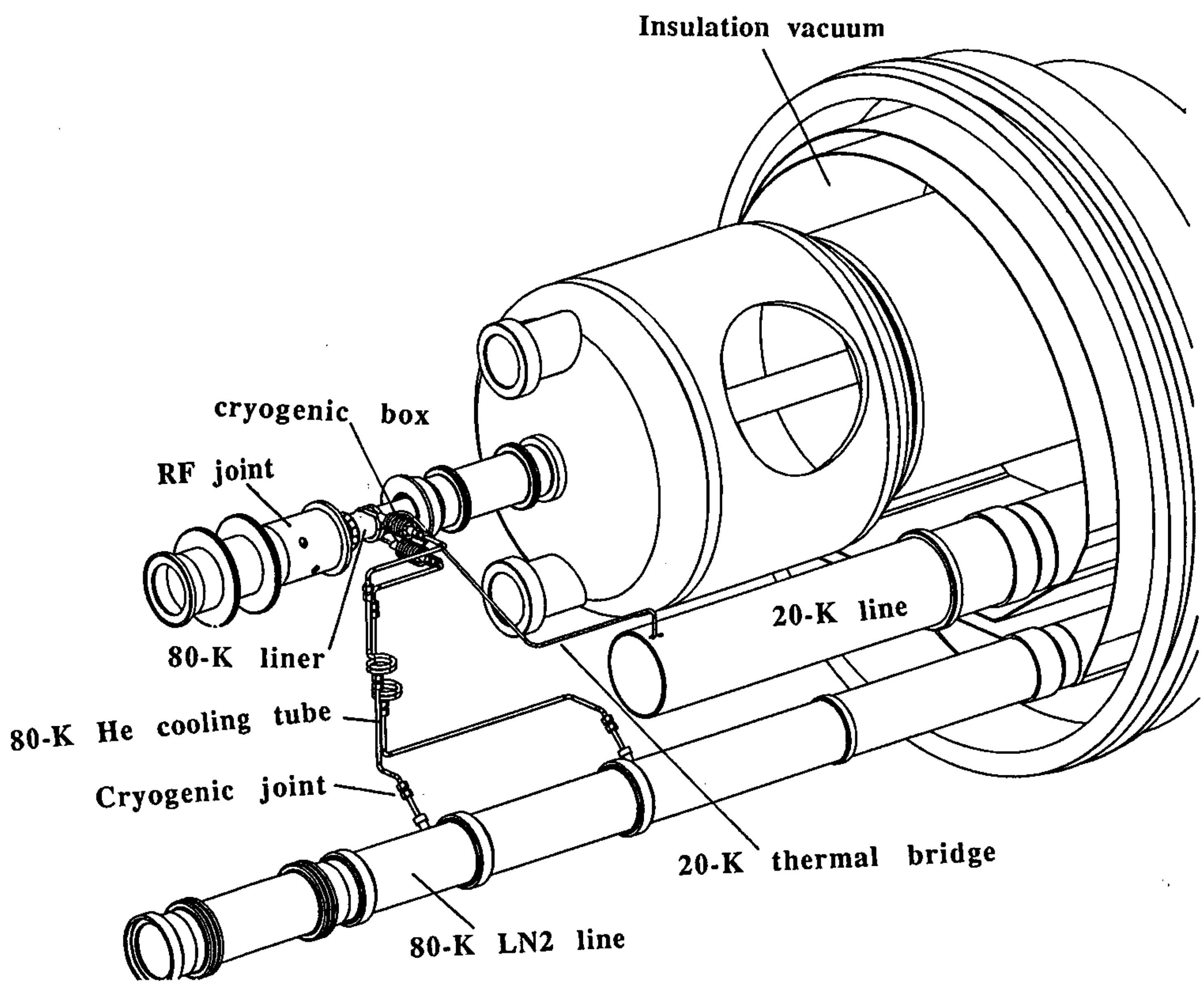



Figure. A three dimension plot of a CQM liner with an end conductive cooling.

SPOOL

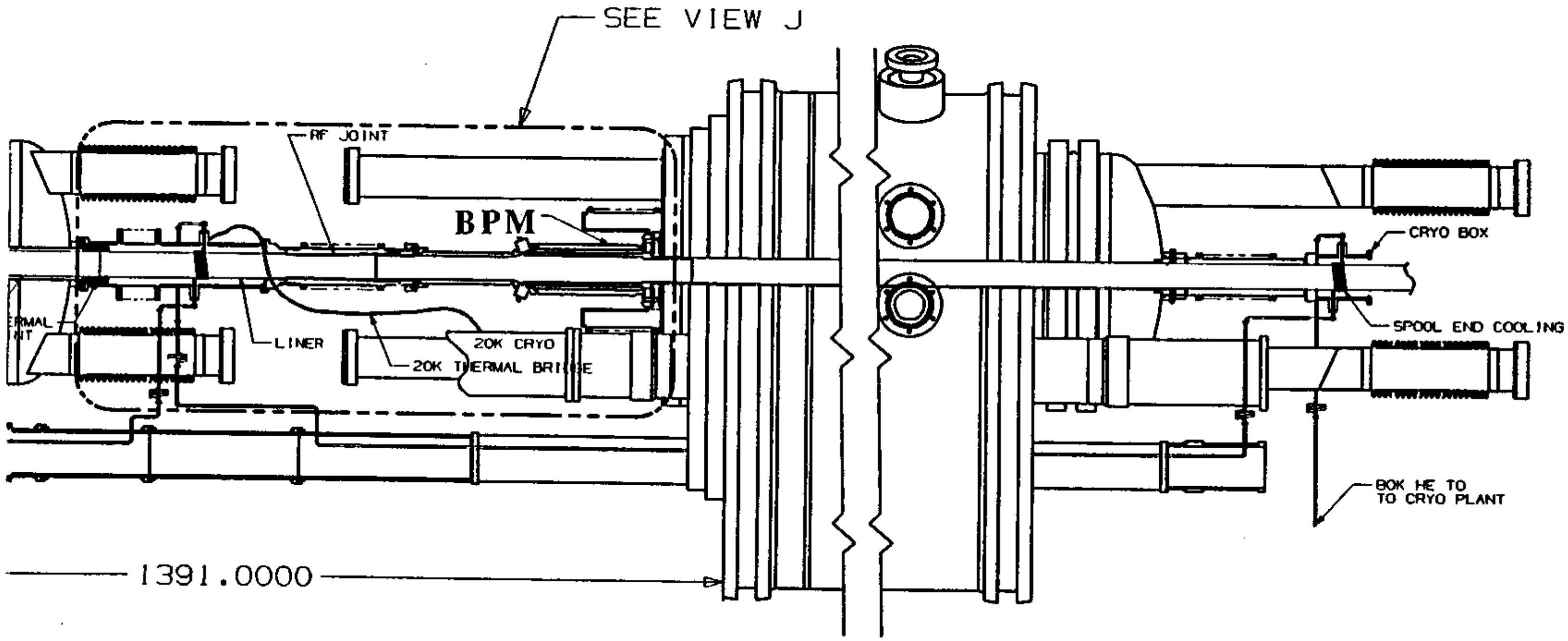



Figure. A schematic of Spool Piece retrofit liner assembly with an end conductive cooling loop and liner interconnet. The cross section of the interfaces of collider spool piece, BPM and CQM are indicated.

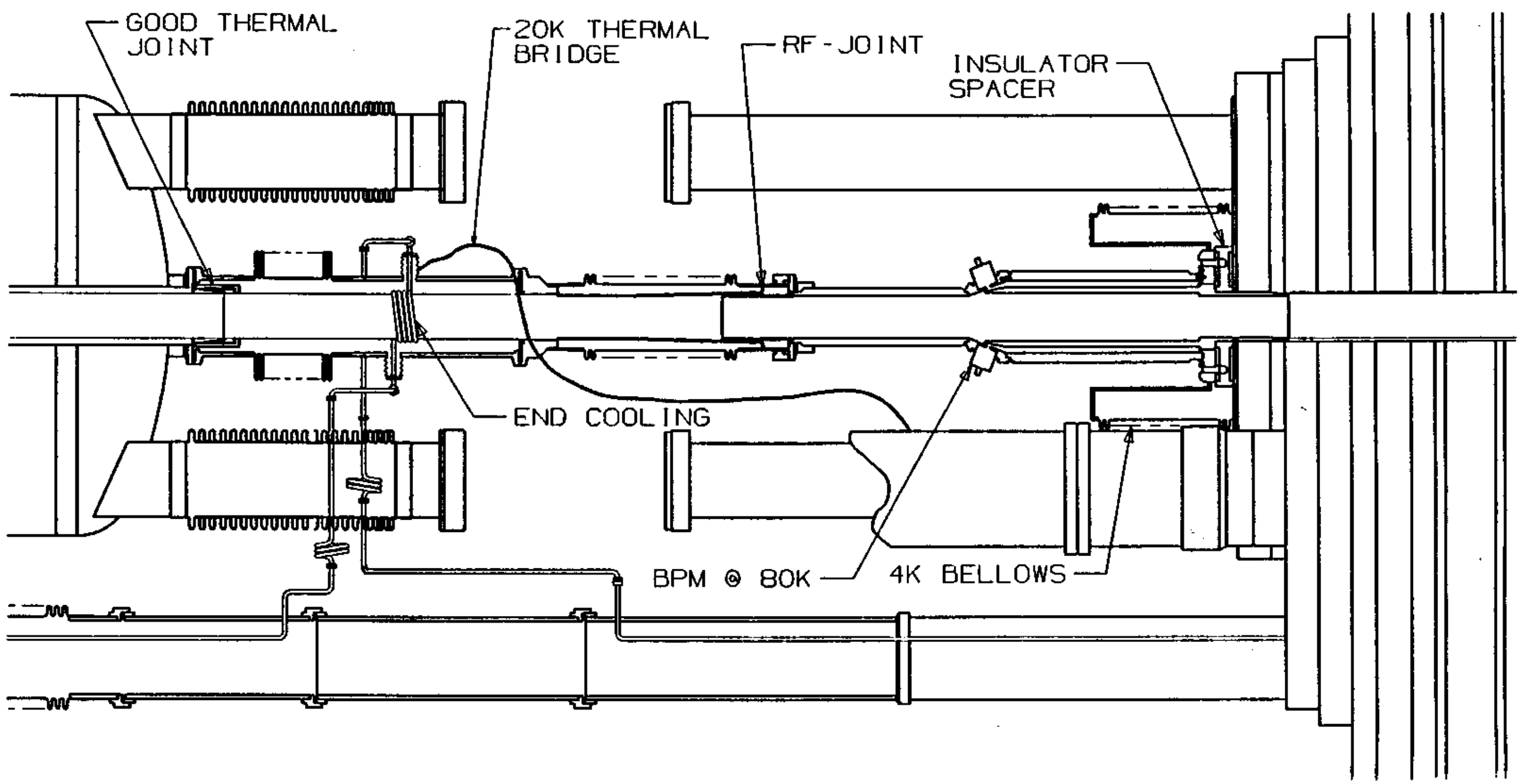



**Figure.** **A longitudinal cross section of the interconnect region between a collider quadrupole magnet and spool piece with BPM.**

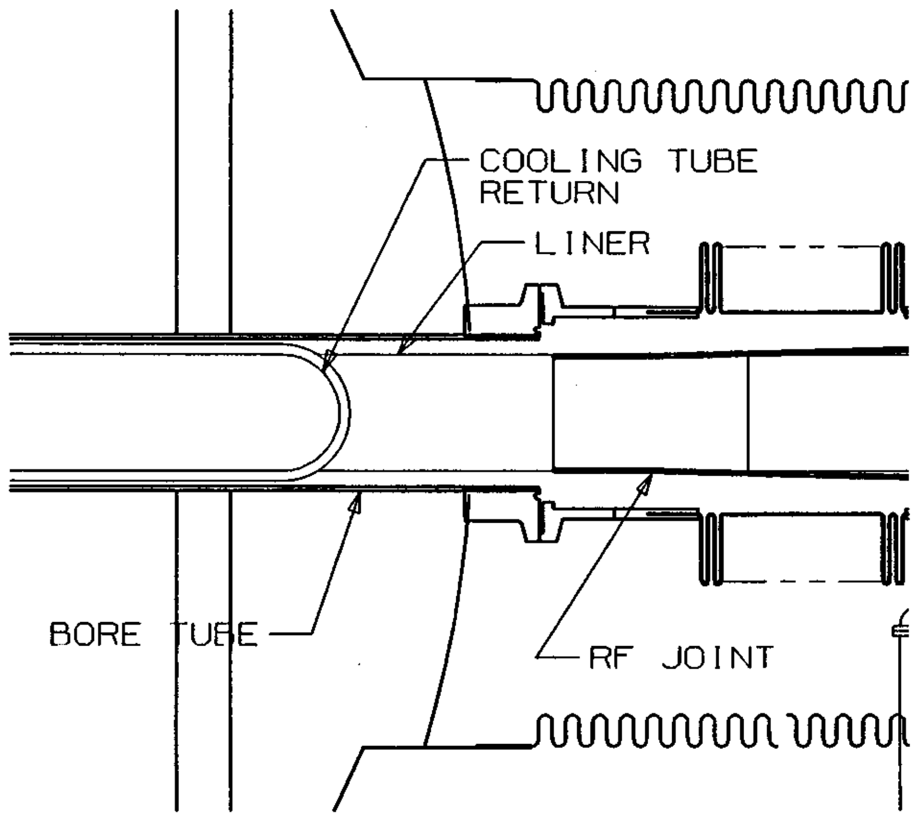



**Figure. The end connection of the dipole liner with the RF joint.**

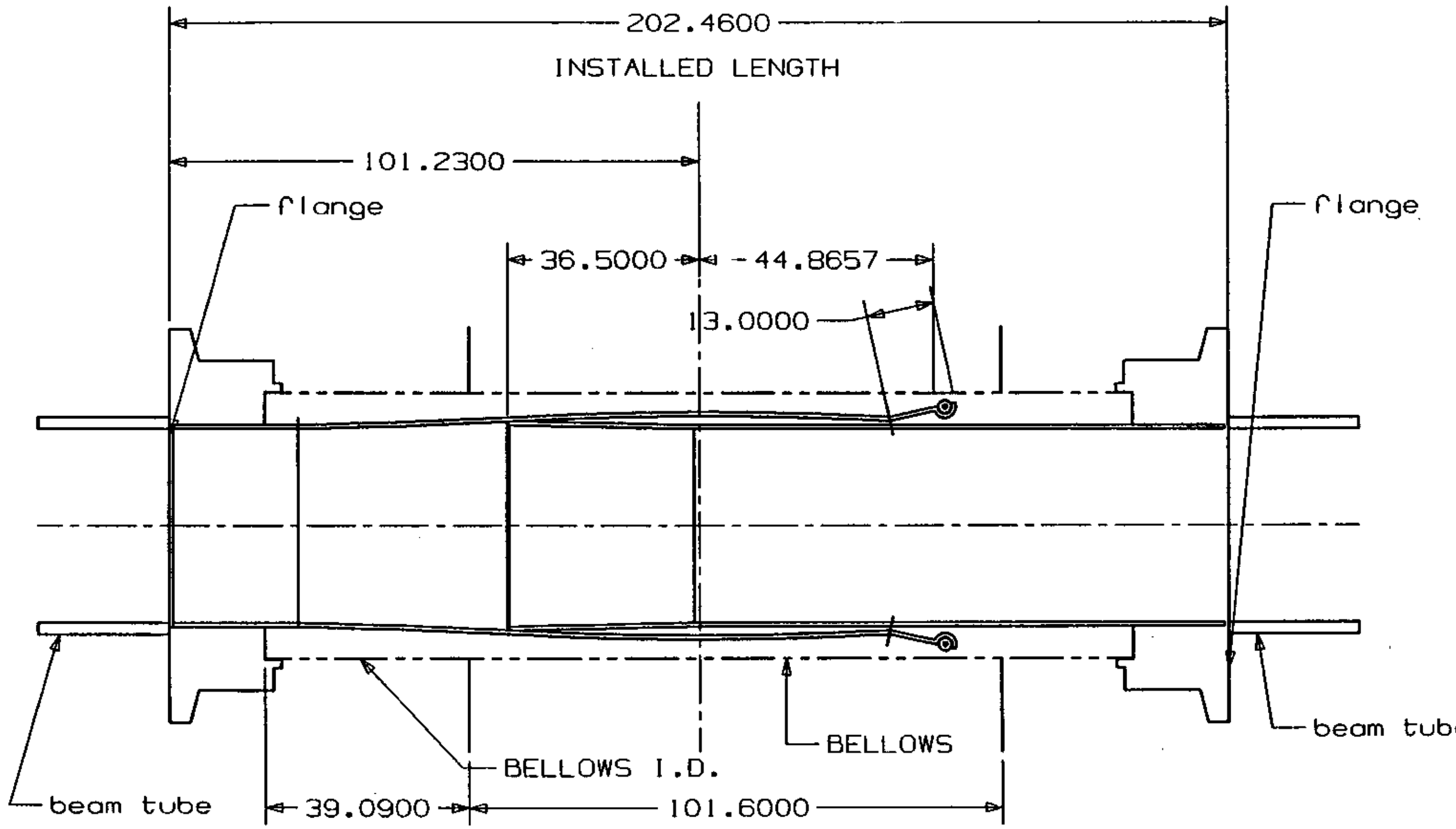



**Figure. A schematic of RF joint to be modified for collider liner.**