Design, Installation and Commissioning of new Vacuum chamber for Analysing Magnet of K-130 Cyclotron

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1) **Introduction**

2) **Requirements**

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4) **Fabrication and Installation**

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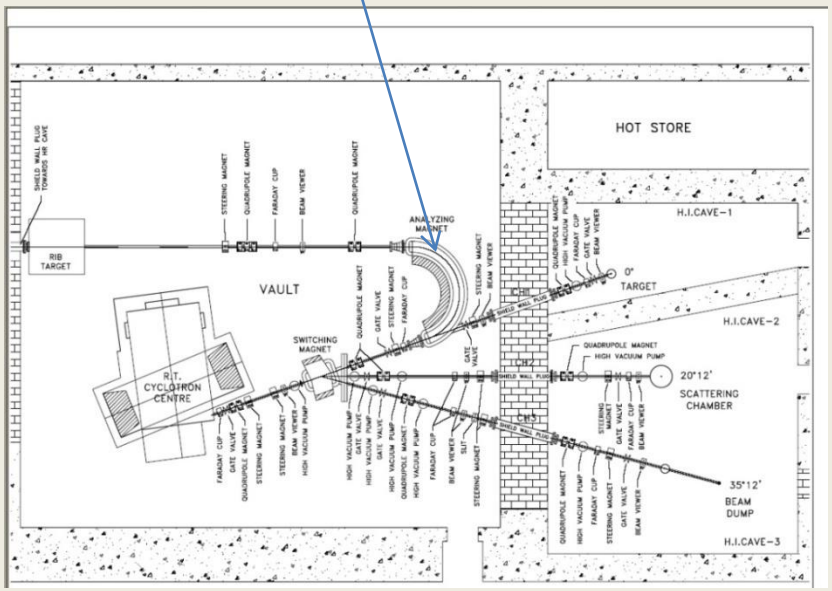
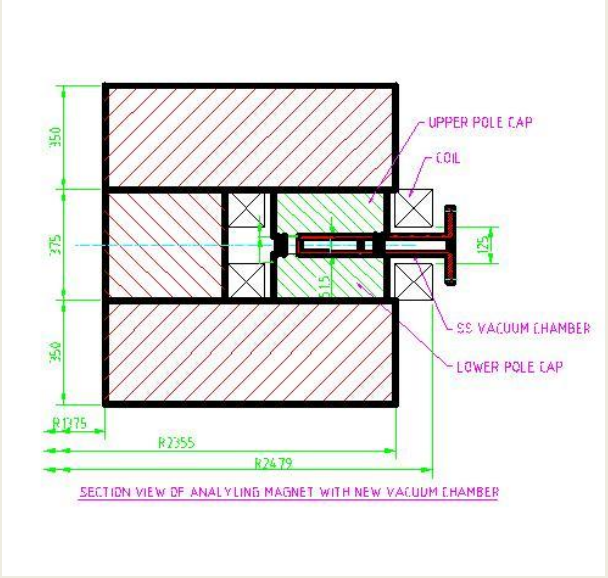
1) Introduction:

Beam line (Ch-IV) for RIB experiments having a C-shaped, 1T, Dipole type 159^0 Analysing Magnet weighing ~ 38 ton at the vault of K-130 Cyclotron. The beam chamber is just a vacuum chamber inside this magnet. The magnet x-section is having an inner arc of diameter 2750 mm. The vacuum inside the chamber is in the order of 2 x 10^{-6} mbar.





The previous chamber made of Al-alloy gives frequent trouble in vacuum leak due to the lengthy (~9 m) “O” ring interface – that leads to a huge cyclotron down-time as well as lot of maintenance work.

The newly chamber made of SS-304 , a welded structure without “O” ring is the solution to come-out of teething problem. The effective gap in the beam chamber reduced by 10 mm due to chamber walls.

Previous Chamber

New Chamber

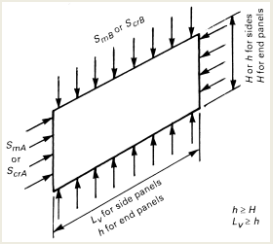
2. Requirements:

The x-section of the chamber is trapezoidal to enhance maximum space for beam spread inside tapered poles.

- **Beam space gap ~as high as possible (~50 mm).**
- **X-section typically 4447 OD x 63 ht_1 x 4057 ID x 59.94 ht_2 x 210 wide (mm) i.e. an average mid-gap of 51.5 mm.**
- **Two nos. of evacuation ports**
- **One protruded beam line for Ch-I towards HI cave, is required between extreme ends**
- **Material: non magnetic**

3, Design: The semicircular and trapezoidal x-section chamber's structural design under external pressure is not straight forward like cylindrical or rectangular straight chamber.

•Equivalent rectangular straight vacuum chamber under external pressure may be done as per ASME –Section-VIII, Div-1 appendix -13.



•Each side plates are checked for compression and buckling criteria

$S_{mA} = P_e hH/2(t1H + t2h)$, $S_{mB} = P_e h/2t1$

$S'_{crA} = \pi^2 E_2 (t1/H)^2 K_A/(12(1 - v^2))$

$S'_{crB} = \pi^2 E_2 (t1/L_v)^2 K_B/(12(1 - v^2))$

$S''_{crA} = S_y - S_y^2/4S'_{crA}$; $S_{crA} = S'_{crA}$ for $S'_{crA} \leq S_y/2$; $S_{crB} = S'_{crB}$ for $S'_{crB} \leq S_y/2$

$S''_{crB} = S_y - S_y^2/4S'_{crB}$ $= S''_{crA}$ for $S'_{crA} > S_y/2$; $S_{crB} = S''_{crB}$ for $S'_{crB} > S_y/2$

•$2S_{mA}/S_{crA} + 2S_{mB}/S_{crB} \leq 1.0$

•Column stability of the entire cross section is also done

$\{Sa/Fa + Sb/(1 - Sa/F''e)S\} \leq 1.0$, where $Sa = P_e hoHo/2(t1Ho + t2\,ho)$

For $2Lv/R1 \leq Cc$, S = Allowable stress as per ASME Section II, Part-D

$Fa = [1 - (2L_v/R1)^2/2Cc^2]^2/[5/3 + 3(2L_v/R1)/8Cc - (2L_v/R1)3/8Cc^3]$

else, $Fa = 12\pi^2 E_2/23(2L_v/R1)^2$, $Cc = \sqrt{(2\pi^2 E_2/Sy)}$, $Sb = Mc1/Ie$,

$M = P_e hoHo\, y$, $F'e = 12\pi^2 E_2/23(2L_v/R1)^2$,

Plate thickness 6.5 mm justify the stability as pe r ASME for equivalent chamber.

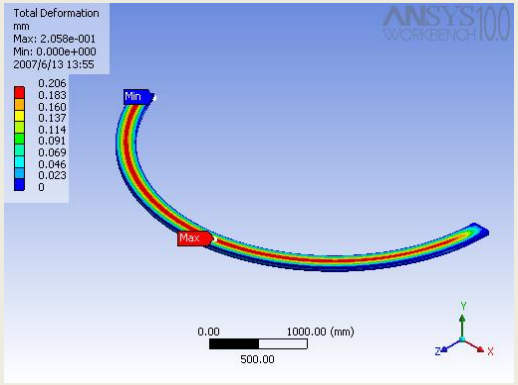
3. Design:

•Structural design over **FEM tools** is the feasible option. ANSYS-Muti-physics results are as below

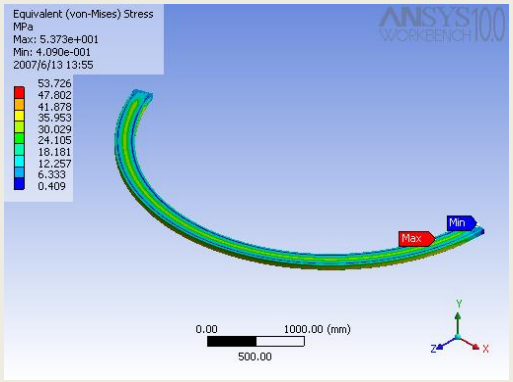
Structural calculation results of vacuum chamber for various thickness

Sl. No.	Thickness (mm)	Maximum Deformation(mm)	Maximum Stress (Mpa)	F.O.S
a)	4	0.73	181.5	0.95
b)	5	0.38	64.43	2.67
c)	6	0.21	53.73	3.20
d)	7	0.13	52.01	3.31

Tensile Yield Strength for SS-304 is 172.4 Mpa: **Designed thickness of chamber wall : 5 mm**



Total Deformation



Von-Mises Stress

4. Fabrication and Installation:

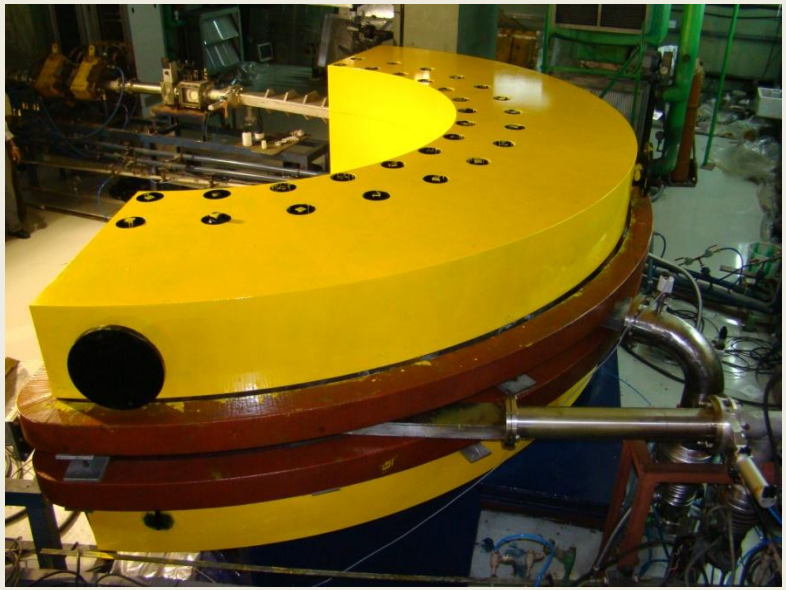
- **Materials tested to 6 KGauss to confirm non-magnetism,**
- **Flatness maintained over entire surface to 500µ,**
- **Surface finish maintained to 1.6µ,**
- **He leak rate ensured to < 2.0 x 10^{-9}mbar l/s.**
- **Installation done on removal and reassembly of 10 nos. of shielding plank of 27 ton each complying all the check points for coil, LCW flow rate, evacuation system, beam lines components etc.**

5. Results:

On installation of SS vacuum chamber with two DN160 , 700 l/s DP, system vacuum was achieved to 3.0 x 10^{-5} mbar after 24 hrs and 1.0 x10^{-6} mbar after 60 hrs smoothly.

The Analysing magnet (achromatic mode) is re-commissioned with the new vacuum chamber with 40 MeV alpha beam in the test run.

Ch-IV i.e. RIB feeder line of K-130 Cyclotron is ready with re-commissioned 159.5 ^{0} Analysing Magnet.



THANKS