Fabrication of niobium superconducting accelerator cavity by electron beam welded joints

T.K.Saha[1], J. Mondal[2], K.C.Mittal[2], K.G.Bhushan[3] and A.V.Bapat[1]

Bhabha Atomic Research Centre,
Mumbai-400085, India

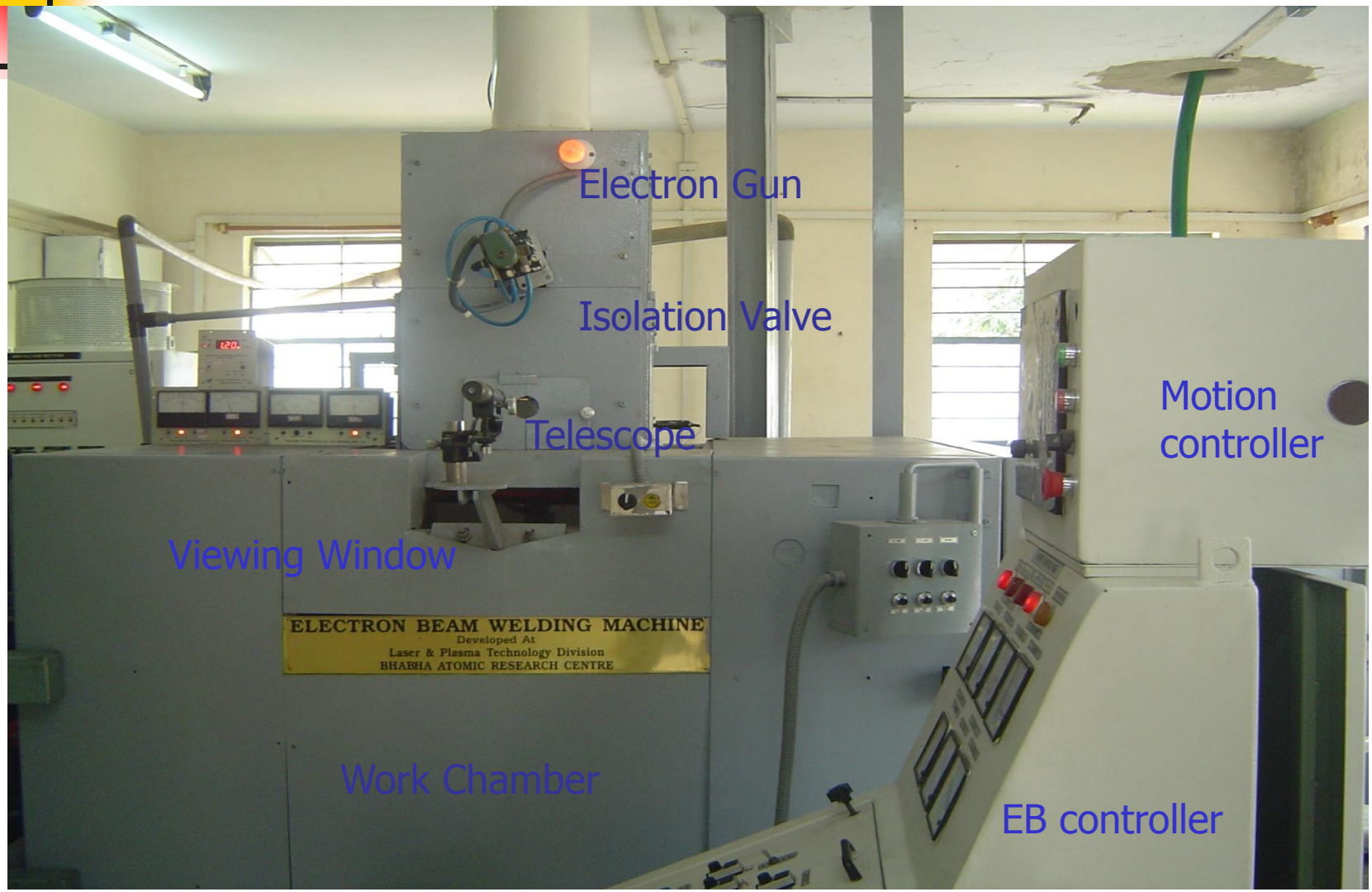
Why electron beam welding?

- Low gas contamination
- Low heat input resulting low deformation or buckling
- No machining requirement
- Lowest HAZ
- Lowest metallurgical damage
- Autogenous welding process

Vacuum: the purest welding environment

Welding Environment	% Oxygen	% Nitrogen
Argon Commercial Gr.	0.0079	0.02
Argon (IOLER) grade-I	0.0002	0.00005
Vacuum: 10^{-1} m bar	0.003	0.01
Vacuum 10^{-3}m bar	0.00003	0.0001
Vacuum 10^{-5} m bar	0.0000003	0.000001

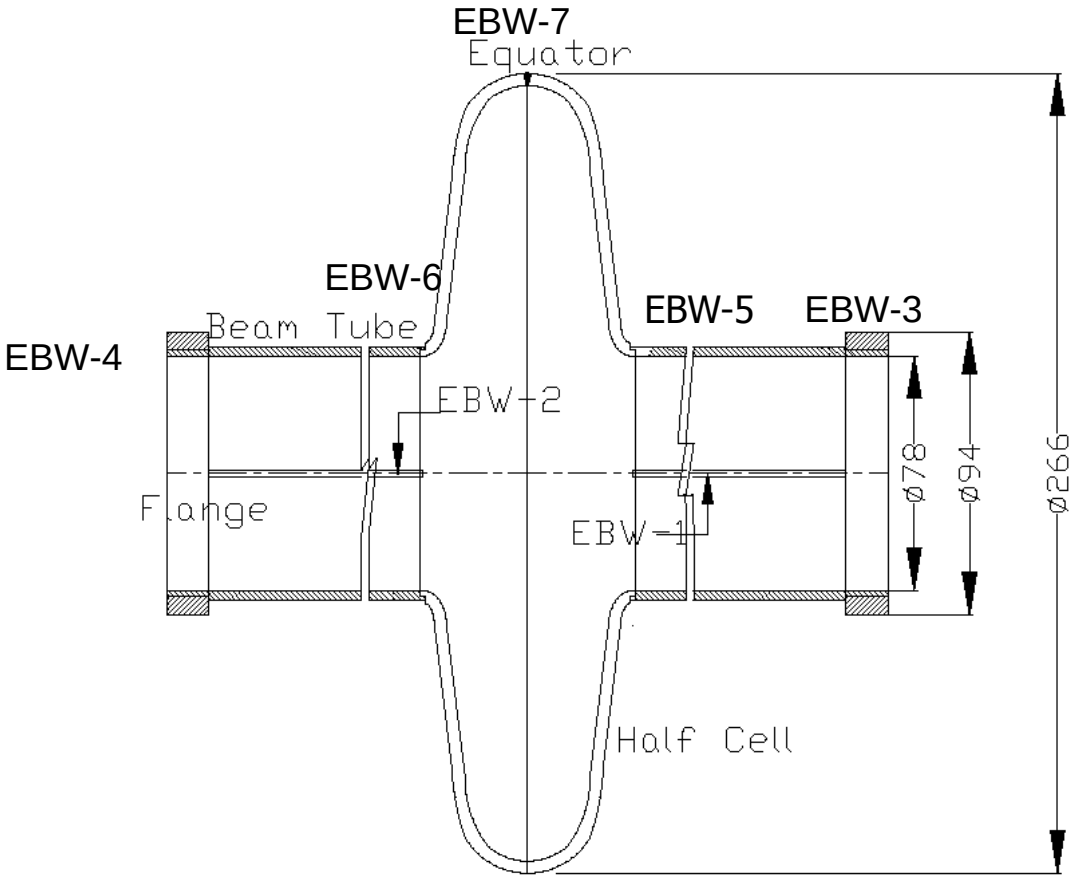
Description of welding equipment



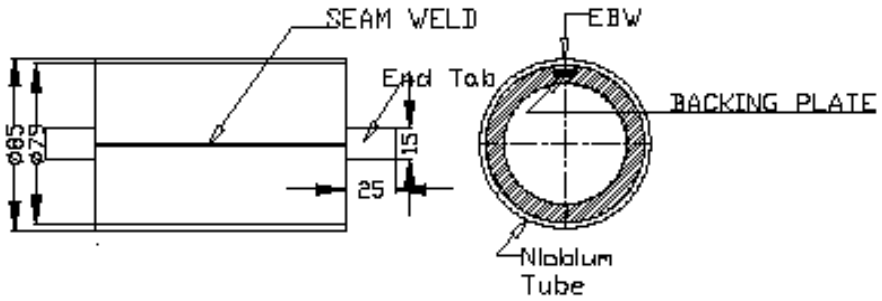
Specification of the EB welder

- Make: Bhabha Atomic Research Centre, India
- Accelerating energy: 100 kV max
- Beam Current: 0-40 mA
- Chamber Size: 1500X1000X1000 mm
- Work table size: 700mm (l) X 500mm (w) X 200mm (h)
- Table movement: 700mm in X and 400mm in Y dir
- Table speed: 20– 2000mm/min in X and Y directions
- Speed Rotary table: 0-20 RPM clock and anti clock wise
- Gun vacuum: $2X10^{-6}$ mbar
- Chamber vacuum: $5X10^{-5}$ mbar

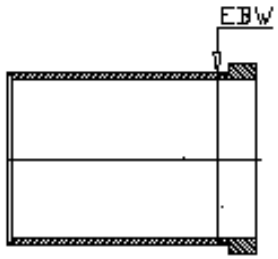
Schematic of proposed 1050MHz, β=0.49, Niobium single cell cavity



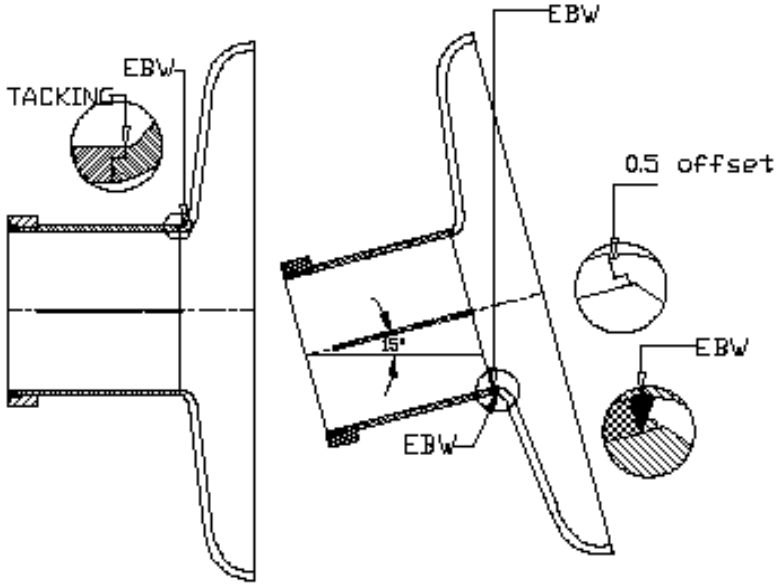
SCHEMATIC VIEW OF NIOBIUM CAVITY



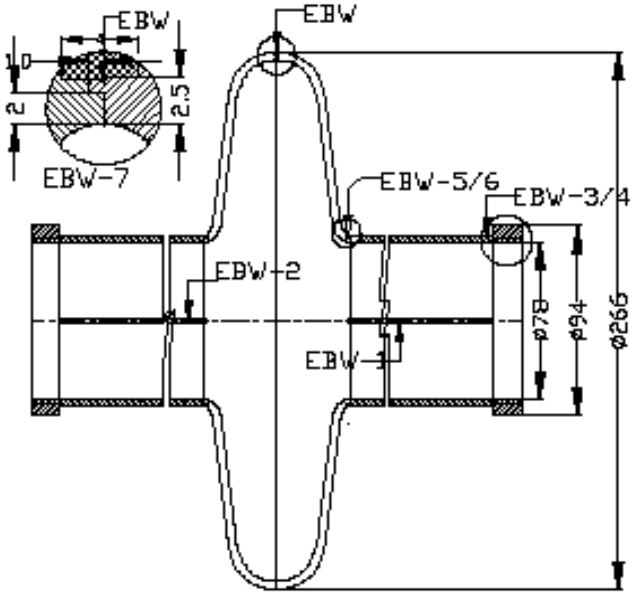
WELD SET UPBEAM TUBE (1,2)



WELD SET UP FOR BEAM TUBE
TO FLANGE: WELD NO: 3,4.

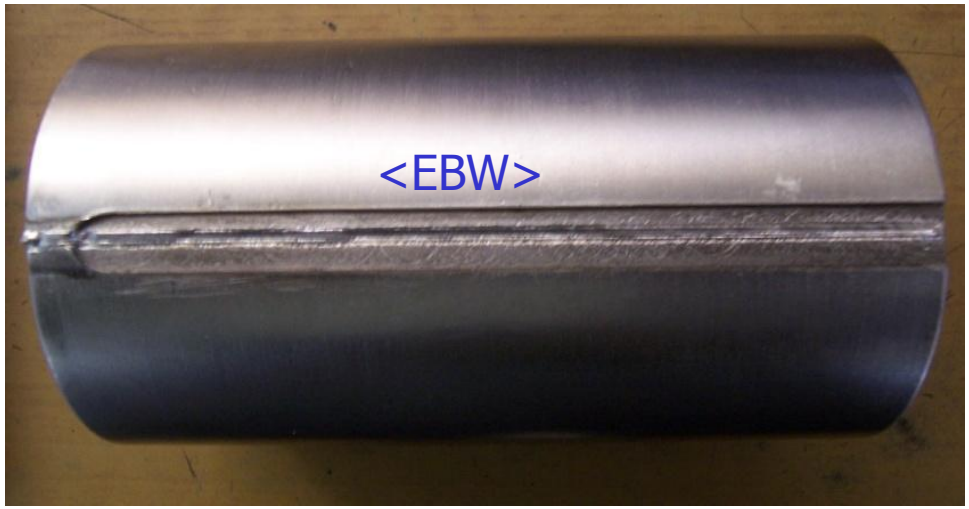


WELD SET UP FOR IRIS-HALF CELL (5,6)



EQUATOR WELDING :7
ALSO SHOWN ALL WELDS

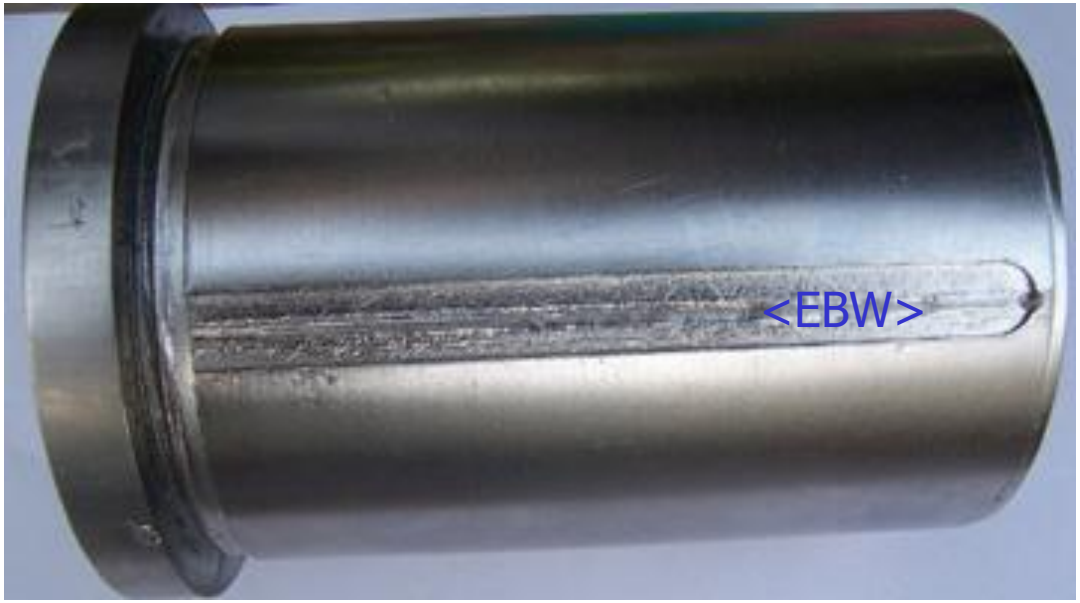
Welding of beam tube



Seam welded beam tube

- Acc Energy: 100kV
- Beam Current: 22mA
- Weld speed: 600mm/min
- Chamber Vacuum: 5×10^{-5}mbar

Welding of Beam tube to Flange

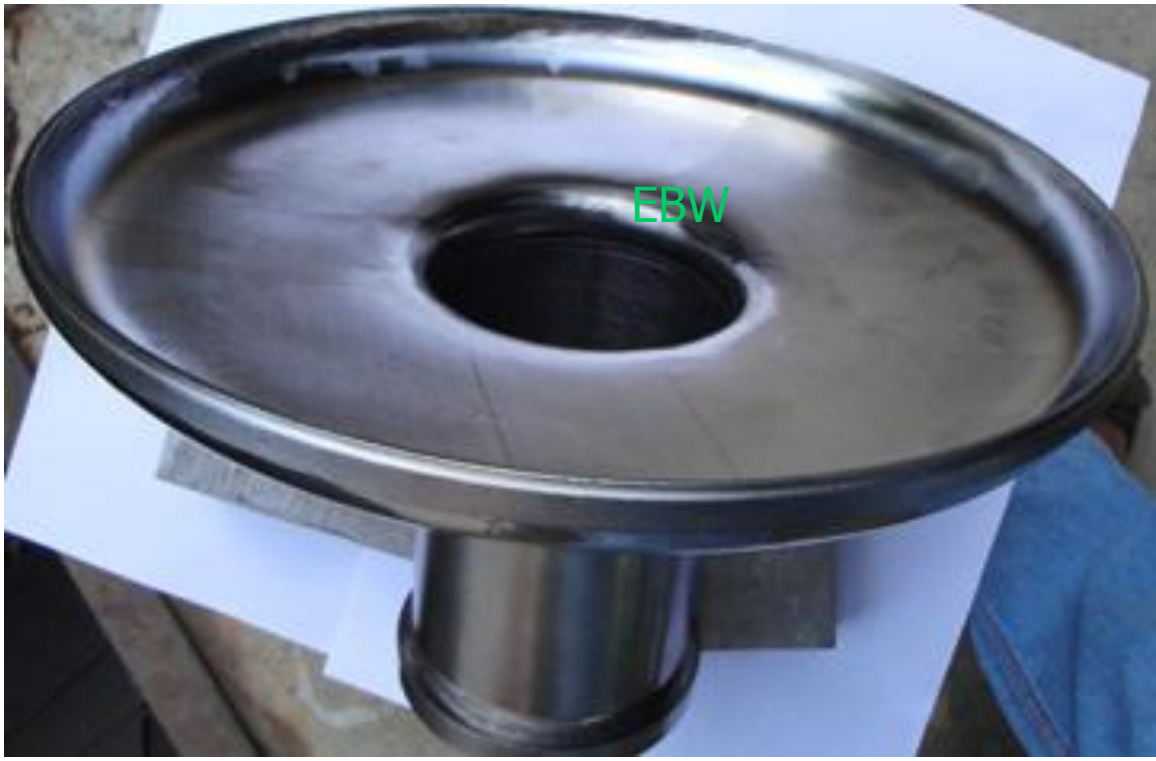


Joining of beam tube to flange by EBW

- Acc Energy: 100kV
- Beam Current: 18mA
- Weld speed: 600mm/min
- Chamber Vacuum: 5 X 10^{-5}mbar

Welding of beam tube to half cell (Iris)

- Acc Energy: 100 kV
- Beam Current: 20 mA
- Weld speed: 600 mm/ min
- Welding was performed at inner joint at angle of 15º
- Tacking was made at outer joint prior to weld with 10mA beam and was given cosmetic run after welding.



Welded Beam tube to half cell (IRIS)

Welding of equator

Electron beam welded single cell niobium superconductor cavity

Weld Parameter:

Acc energy: 100 kV

Beam current:32 mA

Weld speed:

600mm/min

Tack Current:10mA

Cosmetic pass: 22mA defocused beam

Mass Spectrometer Leak Detection results

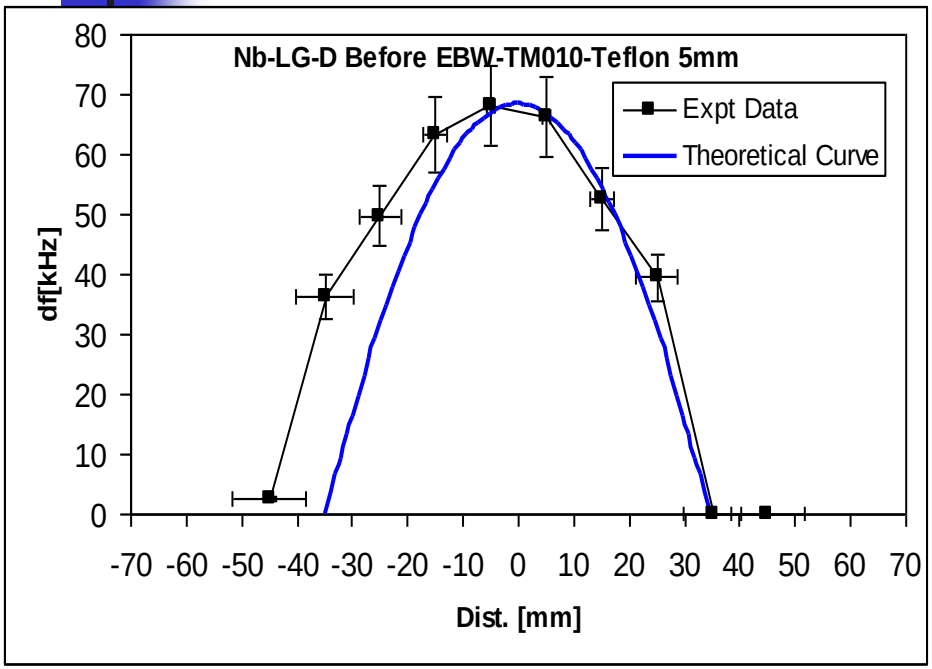
Name of the components	Leak rate (mbar-litre/sec)
Beam tube after seam welding (left)	$< 1x10^{-9}$
Beam tube after seam welding (right)	$< 1x10^{-9}$
Beam tube to flange welded (left)	$< 1x10^{-9}$
Welded beam tube to flange (right)	$< 1x10^{-9}$
Beam tube assembly to half cell welded (left)	$< 1x10^{-9}$
Beam tube assembly to half cell welded (right)	$< 1x10^{-9}$
Equator assembly after welding	$< 1x10^{-9}$

RF Values measured before and after EB weld

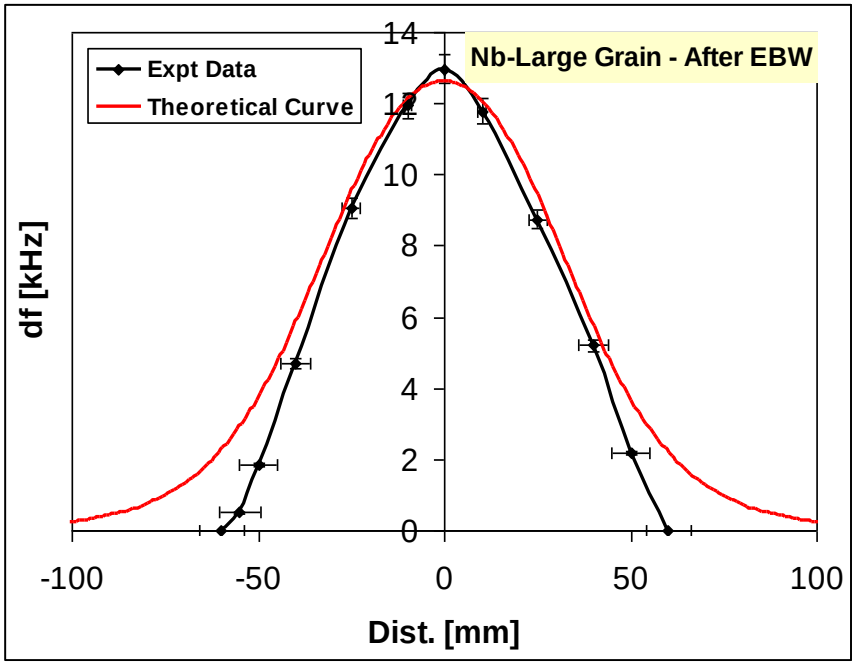
Parameters	Simulated value without Beam tube	Measured value before EBW without beam tube	Simulated value with Beam tube	Measured value after EBW with Beam tube
Frequency [MHz]	1050	1048	1036.856	1036.507
Q Value	17000	459	17032	8076 (not cleaned after EBW)
Effective Shunt Impedance [MΩ/m]	4.469	0.175	4.711	3.61 (not cleaned)
R/Q [Ω]	9.225	8.59	9.675	9

Electric field distribution before and after welding

Pre and post weld axial field distribution



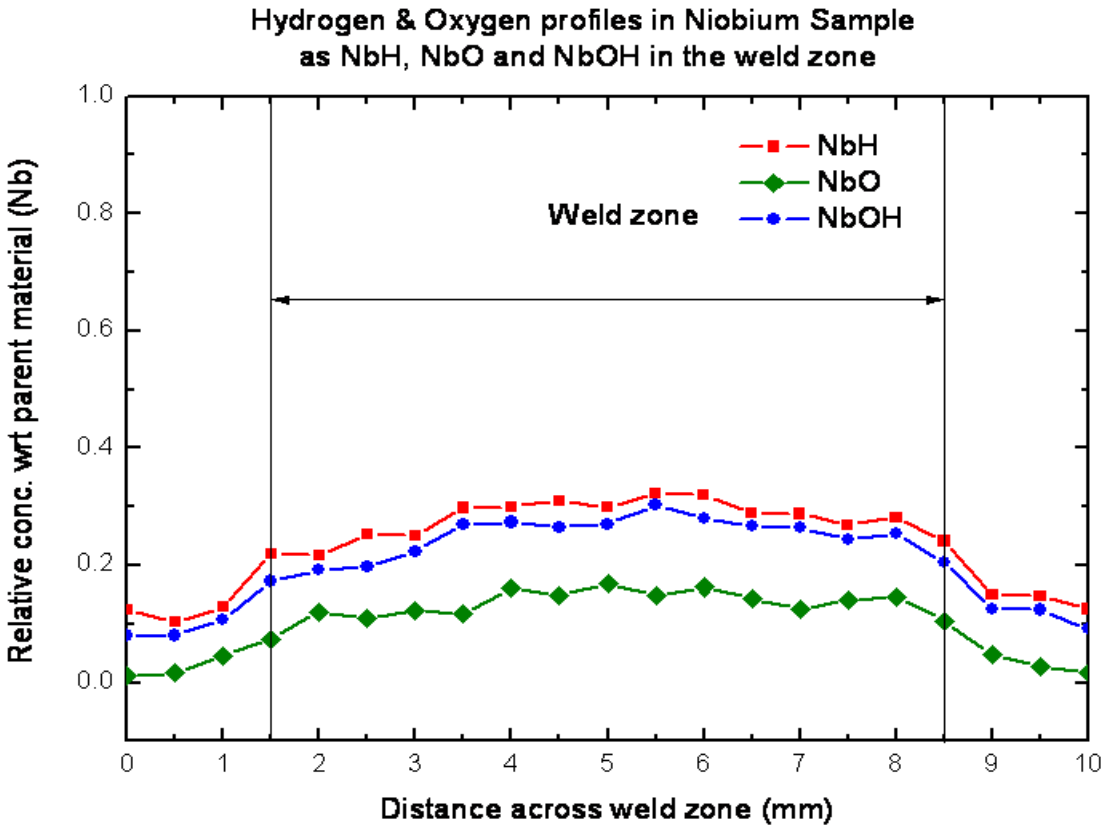
Axial field distributor before EBW



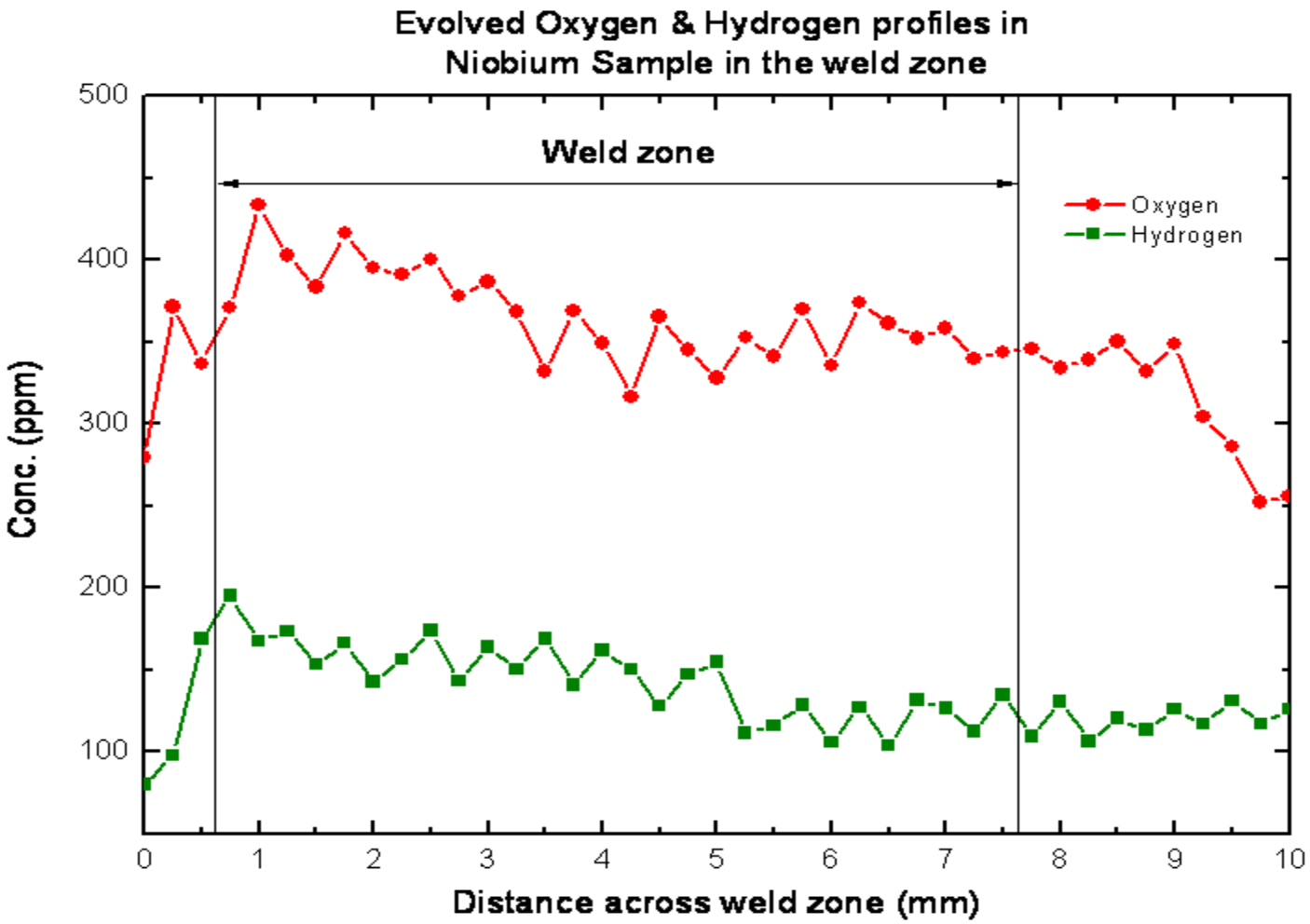
Axial field distriubution- after EBW

SIMS analysis of weld profile

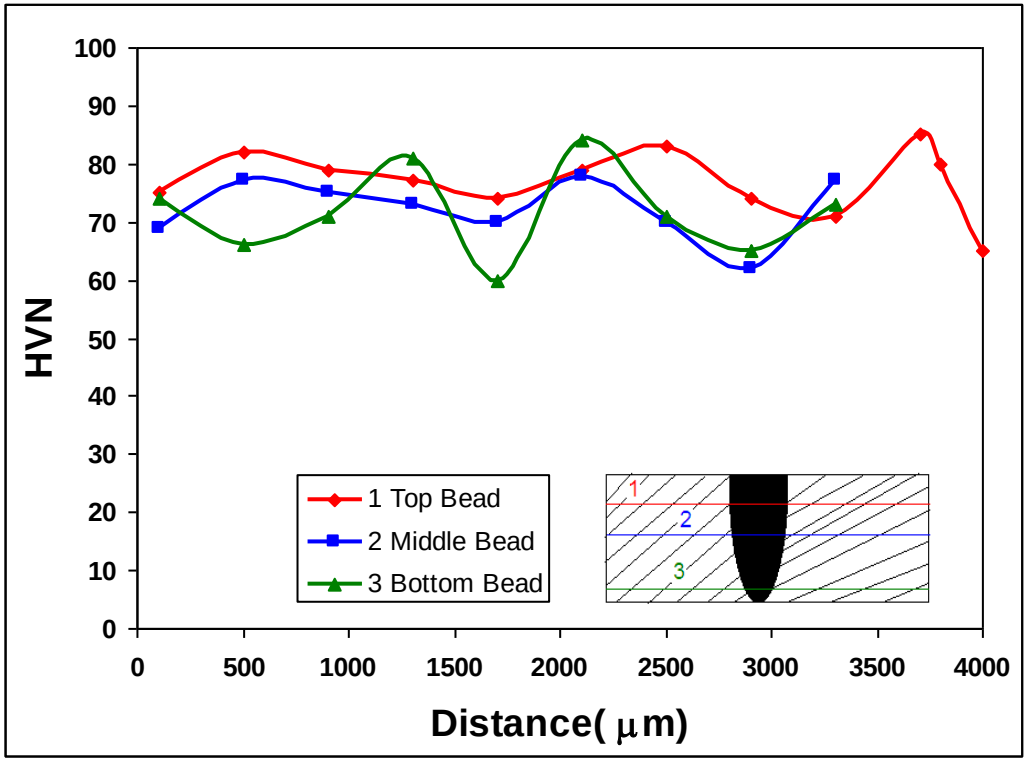
TOF – SIMS Profiles of Oxygen & Hydrogen in Niobium sample as NbH, NbO and NbH



TOF – SIMS Profiles of evolved Oxygen & Hydrogen in Niobium Sample



Micro hardness profile across weld



Conclusion

- Fabrication of 1st Niobium cavity in BARC is completed
- MSLD leak testing revealed leak proof welds.
- electric field distribution and RF measurements at room temperature shows encouraging result.
- Analysis of the welded specimen showed an alarming level of oxygen and hydrogen pick up in weld pool.
- Necessary modification in fabrication will be carried out depending upon further tests