# Vacuum Brazing of Accelerator Components

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# Introduction

- **Common materials** *for accelerator components are vacuum compatible and thermally conductive*.
- **SS, Al and Cu** are common materials.
- **SS a Poor Heat Conductor** and not used where good thermal conductivity is required.
- **Al and Cu** and their alloys are frequently used for the above purpose. The accelerator components made of Aluminium are developed using welding process
- **OFE Cu** frequently used in RF devices for accelerators and Front-End components of beam lines and are *fabricated using process of brazing in vacuum and inert atmosphere*.

# Introduction

- **Main Purpose/Requirement**

  **Removal of heat or to check/contain radiation produced by SR.**

- **These components have SS-Copper and Copper-Copper joints. In most of the cases vacuum brazing carried out using Cusil BVAg-8 brazing alloy in vacuum ~ $5x10^{-5}$ mbar at temperatures ranging from $830^{O}C$ to $860^{O}C$.**

# Working Principle of Brazing Process

- Filler alloy is placed in the **gap** provided in between the two components.
- The components are then **heated below 50 to 100 deg C** to the melting points of the components and some **50 deg C above** the melting point of filler alloy in controlled atmosphere.
- **On heating the filler alloy, it melts, flows between the gaps by capillary action, wets the joining surfaces and forms the joint on cooling of the parts**. Brazing creates an extremely strong & good leak tight joints.

# Working Principle of Brazing Process

- Flow, wetting and spreading of liquid filler is affected by the presence of oxides and dirt at the surfaces to be brazed.
- Special Cleaning methods are used to remove the oxides. Most of the dirt and the remains are generally of volatile nature detrimental to joining. These are cleaned by physical, chemical methods and/or by vacuum degassing.

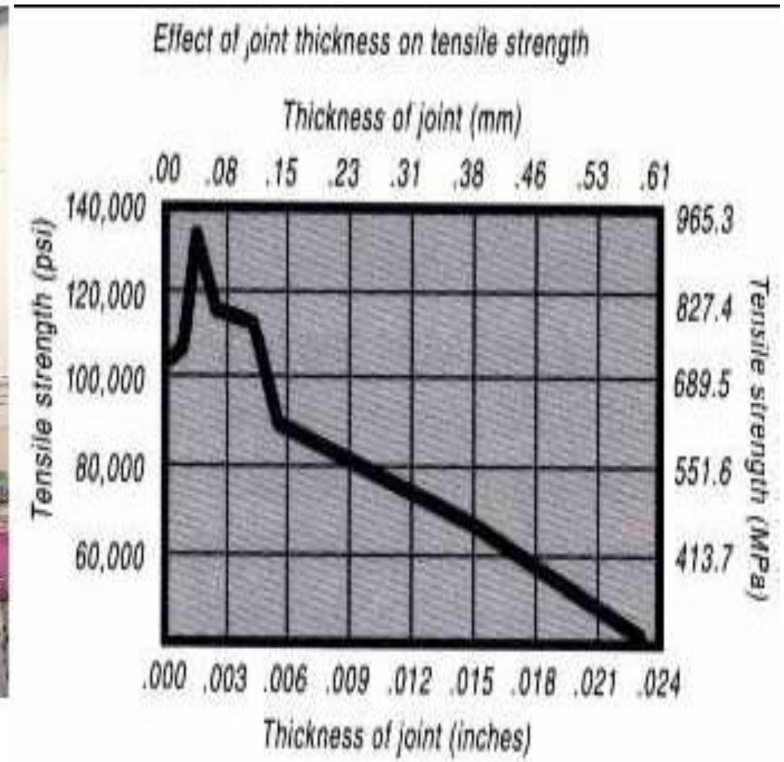
# Working Principle of Brazing Process

- Some oxides of metals also dissociates during heating of the job in the furnace. This results into self- cleaning of the components.
- Gases are desorbed (Vacuum Degassing) from the components during heating and these are also removed to great extent. Jobs are uniformly heated with no uneven distortion.
- ***In this way in vacuum brazing an ideal conditions created for carrying out joining of the components.***

# Vacuum Brazing Furnace

- **Specifications –**
- **Type – Water cooled double walled vertical , bottom loading, both doors demountable type**
- **Heating Elements – Moly. Ribbon type**
- **No. of Radiation Shields – 6 ( 3Moly. + 3SS)**
- **Vacuum – $5x10^{-5}$ mbar**
- **Operating Temperature – $1000^{o}C$**
- **Hot Zone Size – 2200mmx700mm dia.**

# Vacuum Brazing Furnace



# Main Steps in Vacuum Brazing

- *Clean and Compatible Vacuum Furnace*
- *Cleaning of the components/Assemblies*
- *Joint Design and Types of Joints*
- *Good Fit and Proper Clearance*
- *Assembly and Loading of the Job*
- *Heating Cycle of Furnace/Job*

# Brazing of Accelerator Components

Following are some of the important vacuum brazed components–

## PWT Linac Structures of 8-cell & 12-cell

For high electric field gradients ≥ 20 MV/m, linac structures are operated under high vacuum ≤ 1x10-7 mbar. All joints should have very good electrical/rf conductivity to minimize losses.

A 12-cell PWT linac structure that is capable of accelerating electron beam to > 10 MeV energy consuming ~ 8 MW of RF power.

- **These involved brazing of copper-copper and copper-SS joints with minimum distortion and good electrical conductivity.**

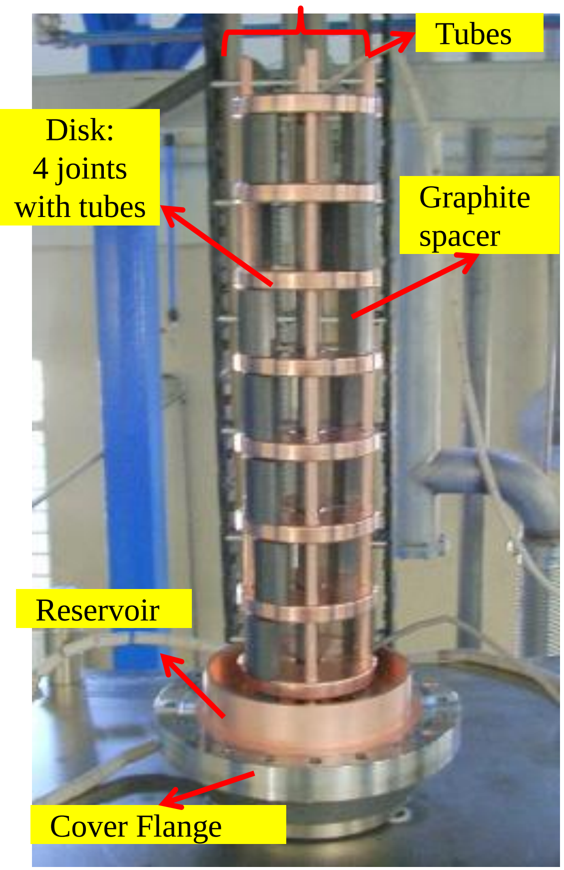
- **Eight-cell and twelve-cell PWT linac structures have been successfully developed indigenously using Vacuum Brazing process.**

- **These have been successfully vacuum brazed and He leak-tested to a leak rate better than 5 x $10^{-10}$ mbar l/s.**

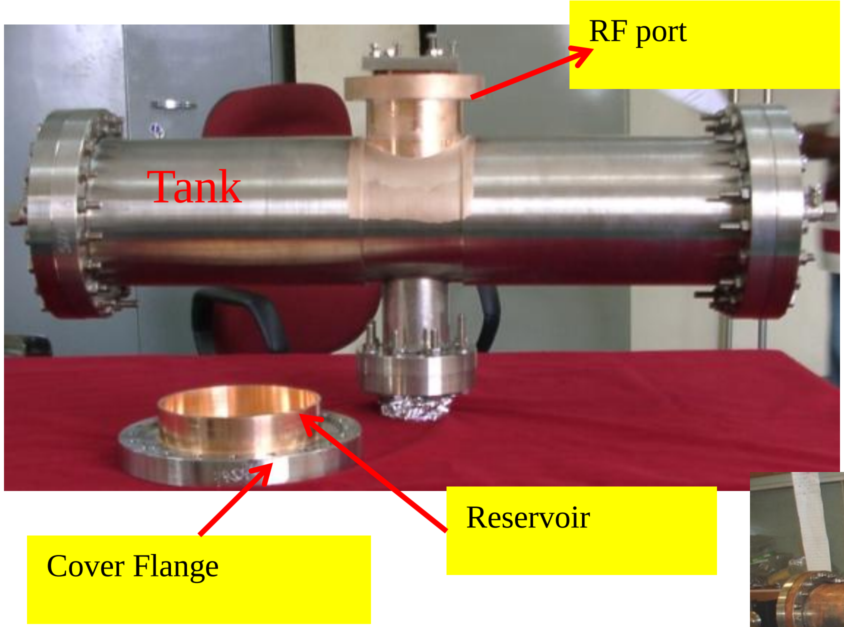
# 8 Cell PWT Linac for CUTE-FEL

**Disk array**
- 8 disk with 4 support cum cooling tube: 32 SS- Cu joints
- Reservoir to cover flange: 1 SS to Cu joint
- Reservoir to support cum cooling tubes: 4 Cu-Cu joints

**Tank and Reservoir**
1. RF port with Tank: 2 SS-Cu+1 Cu-Cu joint
2. Reservoir to cover flange: 1 SS to Cu joint




Disk array assembly

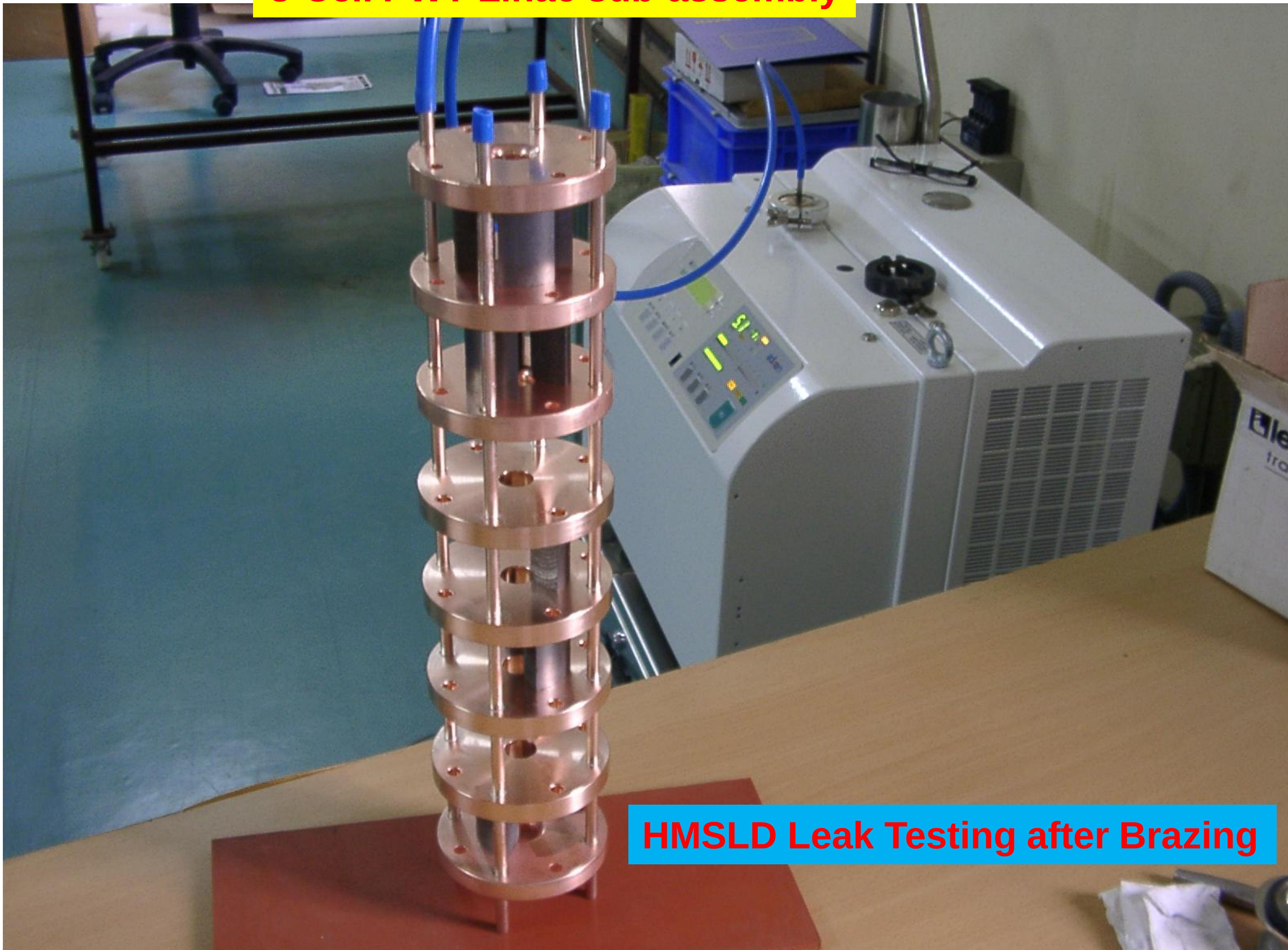



Tank and Reservoir

8 Cell PWT on low power RF test stand

All Joints are leak tight for $5 \times 10^{-10}$ mbar-l/s

# 8-Cell PWT Linac sub-assembly



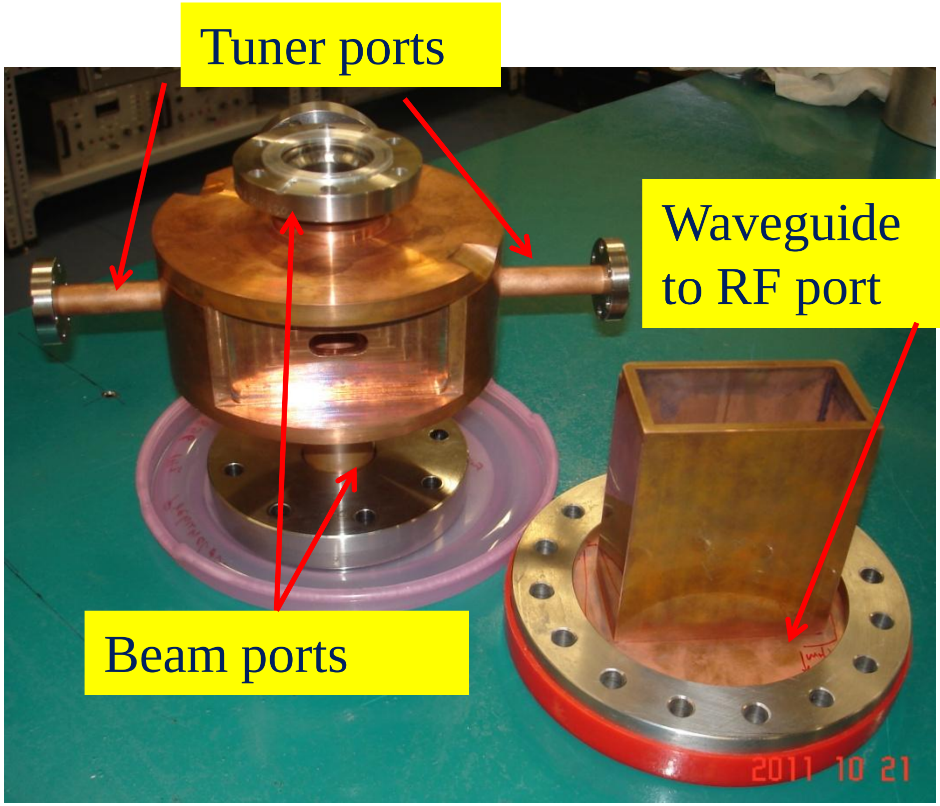
# Vacuum Brazing of S-band pre-buncher

- **S-band pre-buncher - It is to bunch an electron beam from a sub-harmonic pre-buncher before injection into the PWT linac structure for acceleration to rated energy.**
- **The structure has two beam ports, two tuner ports, one vacuum pumping port and one RF port with a rectangular wave-guide section. Except the RF port, all ports are made of AISI SS 316L and electroplated with copper before brazing of the assembly using eutectic copper- silver/Cusil (72-28) filler/brazing alloy.**

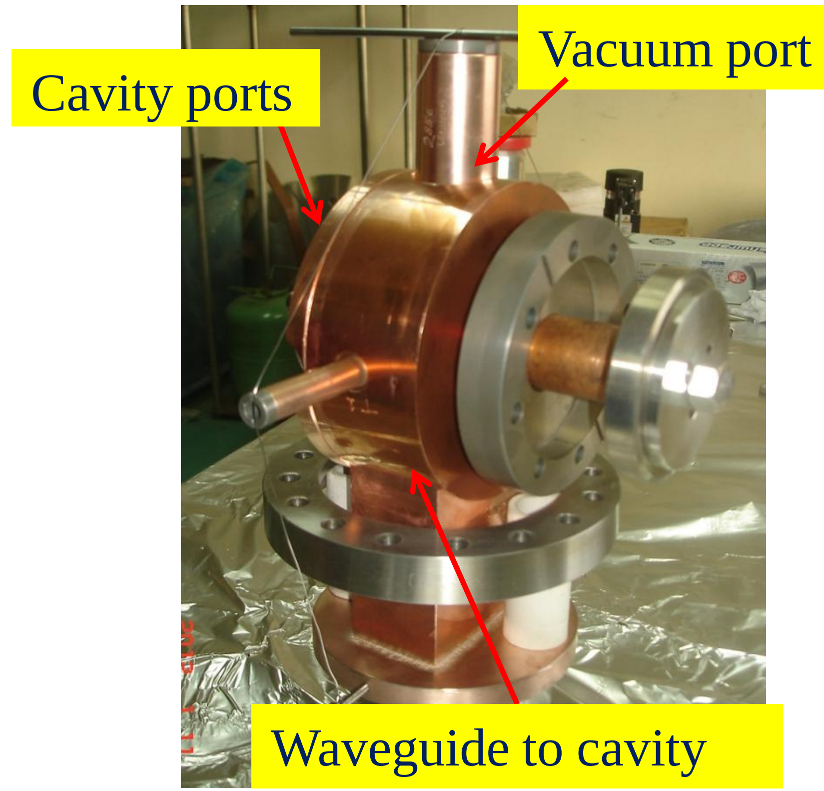
# S- Band pre-buncher for CUTE-FEL

First brazing cycles: 5 joint
- Beam entry and exit ports with cavity
- 2 Tuner ports with cavity
- Waveguide to RF port flange

Second brazing cycles: 3 joint
- Two parts of cavity
- Vacuum port with Cavity
- Waveguide with cavity



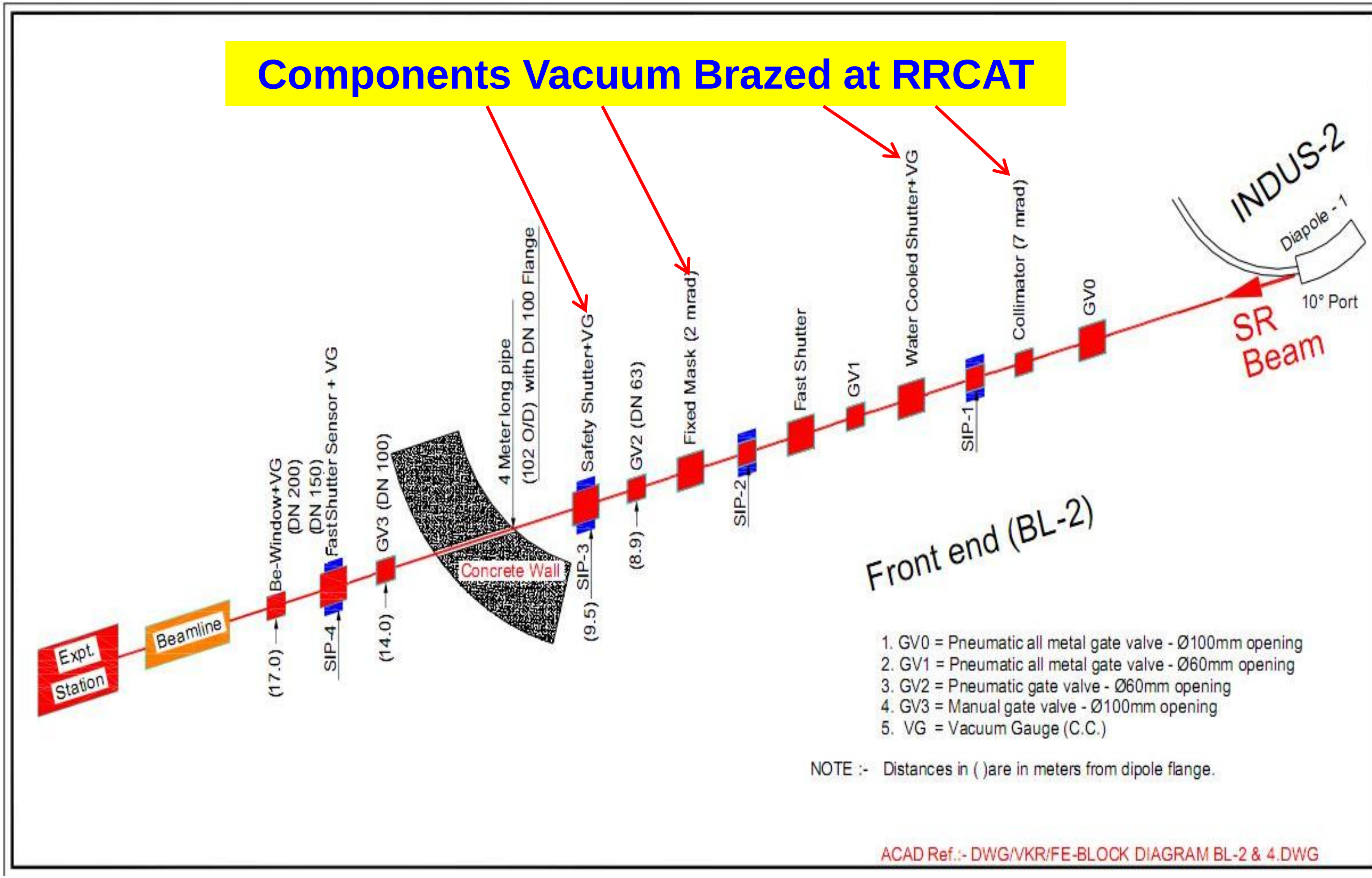
Components after first brazing cycle



Cavity after second brazing cycle

**All Joints are leak tight for $4 \times 10^{-11}$ mbar l/s**

# Front End Components

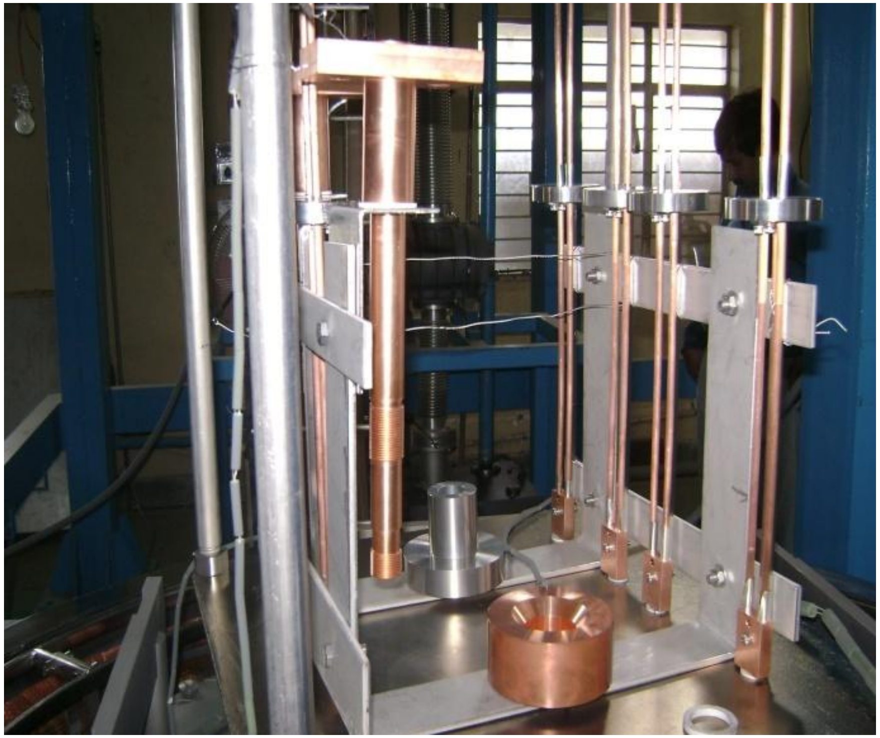


# Front End Components

- **Material of Construction: OFE Cu, SS304L**
- **Brazed joints: OFE Cu –OFE Cu & OFE Cu – SS304L**
- **Water cooling provided to cool the body for dissipating heat produced by Synchrotron Radiation.**

# Brazed  Front End Components


# X-Ray Fluorescence Micro-probe Jaw assembly



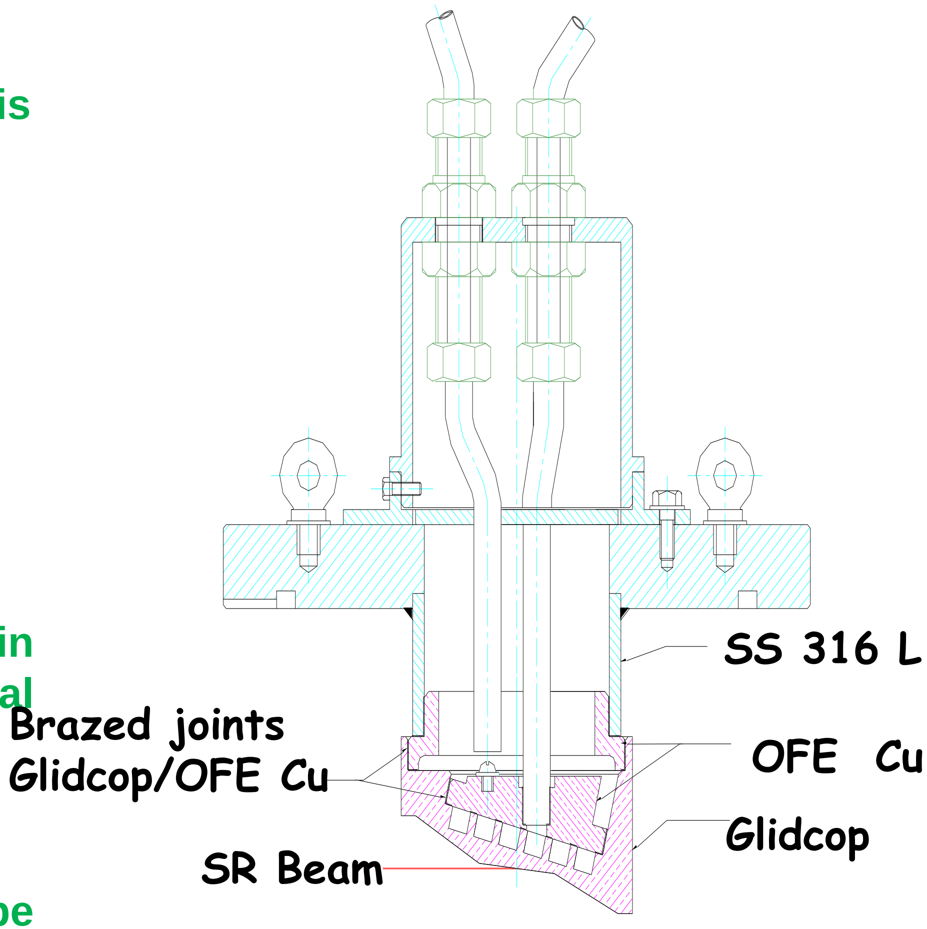
Before Brazing


After Brazing

# Vacuum Brazing of Glidcop® to OFE Cu

- Indus-2 is a 2.5 GeV, 300 mA SR source
- At the design current, 187 kW of SR power is emitted from bending magnet source.
- Only 15% of this power is channelled in beam lines while rest is absorbed by 64 water-cooled photon absorbers.
- Normal incident SR power density on exposed surfaces: 10 - 12 kW/cm$^2$
- In the upgraded design of photon absorber

- Bottom part (body) replaced by Glidcop in place of OFE Copper for enhanced thermal fatigue life
- Intermediate part: OFE Cu
- Bottom & intermediate parts need to be brazed together.



## Glidcop Material:

- Oxide dispersion strengthened (ODS) copper – Cu matrix with uniformly dispersed sub-micron $Al_2O_3$ particles.
- $Al_2O_3$: inert, hard & thermally stable.

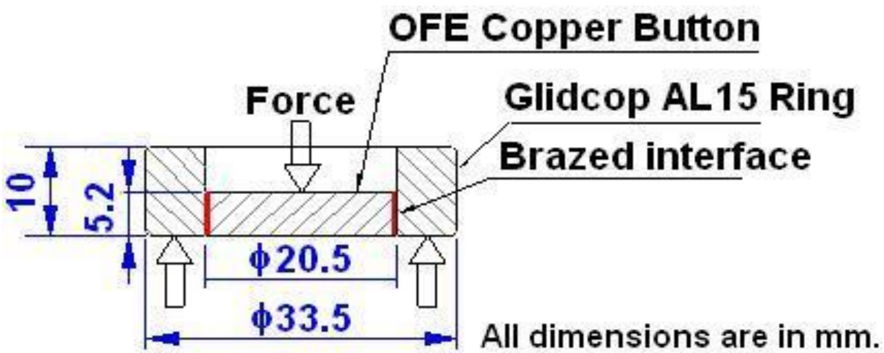
  - prevents re-crystallization & grain growth at high temperature

- Glidcop offers: high tensile & fatigue strength

  - high thermal & electrical conductivity
  - resist softening even at elevated temperatures

**Our Objective** : Standardization of Glidcop/OFE Cu brazing process to meet qualification requirements.

# Detail of  Brazed Specimen

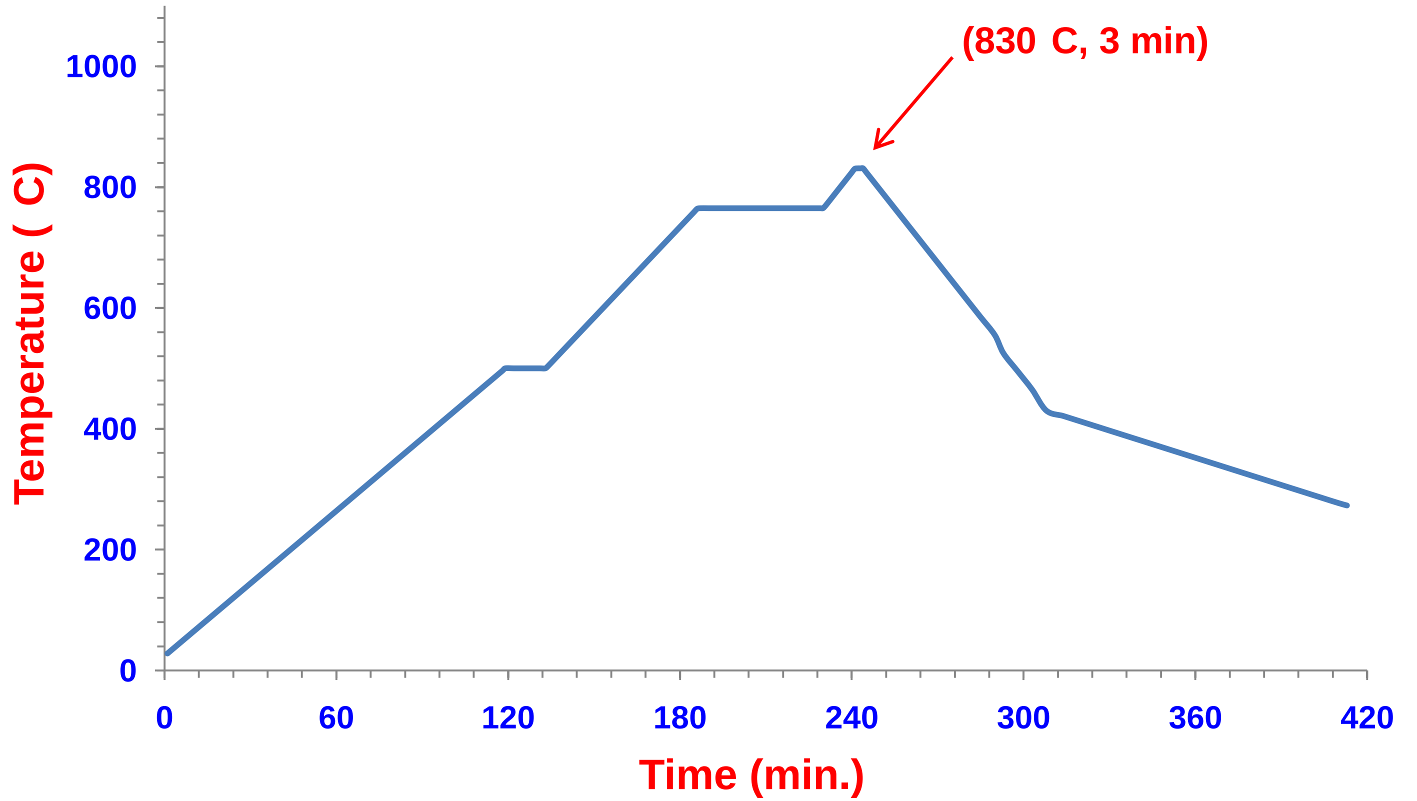



Schematic of specimen used for Brazing


Brazed Specimen

This same specimen used for  helium leak testing as well as shear strength testing both

# Vacuum brazing with BVAg-8 brazing alloy




Operating Pressure ~ 1.3 x $10^{-5}$ mbar

## Characterization of Brazed Specimen

### 1. Helium leak test:

- Leak rate: < 2 X $10^{-10}$ mbar.l/s

### 2. Thermal cycling test:

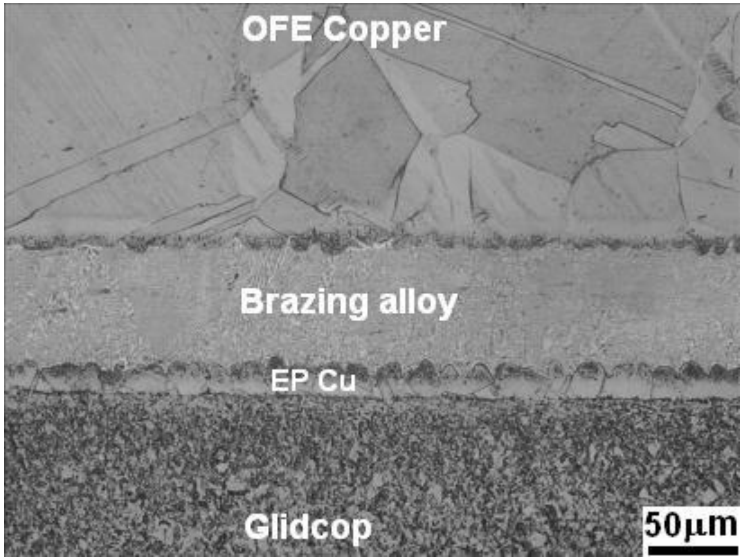
- Brazed specimen sustained 6 nos. of thermal cycles at 150 deg. C without any change in leak rate.

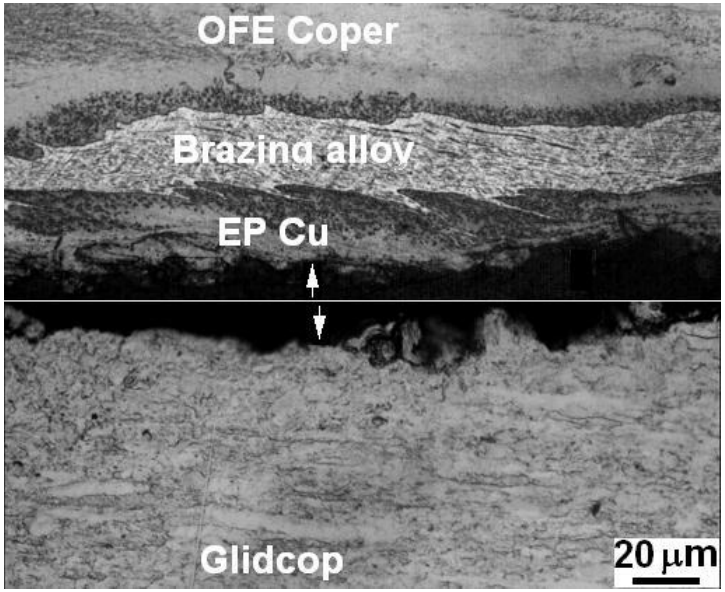
### 3. Metallographic examination:

- Sound substrate/coating interface

### 4. Shear Test

- Shear strength: 136-144 MPa
- Failure site: Glidcop/Ni plating interface



# Conclusion

- Successful Vacuum brazing of Accelerator Components and Assemblies are done at RRCAT, Indore. The Components and Assemblies have been leak tested by using Helium leak detector. **Leak tightness** of the joints found was better than **$5x10^{-10}$ mbar-l/s**. The above process of joining highly useful for developing UHV compatible accelerator components and systems in the future.

# THANKS!!!