CYCLOTRON R.F. STRUCTURE'S LEAKS, CAUSES AND REPAIR

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SYSTEM DESCRIPTION

The room-temperature cyclotron (K-130) at VECC, Kolkata is delivering beam since June 16, 1977.The R.F. power of the cyclotron 'D' is passed through a cantilever type D-stem structure of 2750 mm long & 1350 wide. This structure has been fabricated by thin OFE grade copper sheet inside which has been reinforced by a structure made of light SS sections. The skin of the structure has been fabricated in a corrugated fashion to increase both surface areas for R.F skin current and mechanical strength (section modulus). A pair of moving panel has been assembled on both top and bottom side of the D-stem for frequency tuning of R. F. The whole system is functioning inside a big resonator tank of 3.1mx 2.4m x 2.1m which is under high vacuum of 10^{-7} m bar. LCW at pressure of 12.5kg/cm^2 flowing through 10mm OD and 1.1mm thick OFE copper tubes to remove the heat generated by the R.F. skin current. These tubes are brazed on the inner surface of corrugated copper sheets.

FABRICATION

Brazing in a vacuum furnace could provide uniform heating, no thermal distortion, uniform filler distribution, no oxidation and clean joint but it was not done because arge size facility was not available at that time. 10mm O.D copper tube to tube was joined by lap joint. Tube to copper strip of 25 mm wide and 1.6 mm thick of different lengths were brazed first. Then 25 mm strips were brazed with 2mm thick sheet of corrugated copper panel. This type of design has created some air gap (between strip and sheet) due to thermal distortion and this prevents efficient heat-transfer. Also it created a small under cut on the thin wall of the cooling tubes along the brazing line.

OBSERVATION OF LEAKS

Round the clock cyclotron operation for last 30 years, brazing joints of the cooling tubes and undercut of tube wall develops water leaks inside the resonator tank working under high vacuum. It is observe that the leaks are more near the 'D' region possibly due to the phenomenon like ion induced desorption, image current, nuclear scattering and high energy scattered beams. It also observe occurrence of leaks increases whenever the RF panels are kept open in atmosphere for considerable period of time. It is also noticed that after repair and during hydraulic testing at 15kg/cm^2 pressure numbers of new leak open-up. This indicates the existence of many other corroded weak points inside the tubes. As the cooling tubes are brazed inner surface of the structure and it is not easily accessible without dismantling. Repair of leak requires shut down of the cyclotron and takes a considerable loss of beam time.

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CAUSES OF LEAKS

The water leaks appear from the under-cut of thin walled of tubes. Because silver brazed alloys has very good compatibility with copper and forms continuous solid solution with copper at lower temperature of eutectic composition. Surface erosion occurred due to large mutual solubility resulting an undercut on the thin walled tubes. Brazing joints leaks of tube-to-tube, tube-to-sheet, SS couplings, bimetallic joint appear mainly due to electro chemical corrosion created over a time span of 30 years. The electrolyte for corrosion forms due to the following reasons.

1. Corrosion caused by spurious free chlorine ions from the irradiated halogen containing products like cable insulation, tapes.

2. Residue of brazing flux, trapped cleaning agents like tricholorethyline, carbon tetra chloride etc forms hydrochloric acid and highly toxic gases in contact with the brazing flame.

3. More than 60% relative humidity in vault atmosphere (when panels & R.T. is in air) is one of the causes of corrosion. The relative humidity is considerably higher close to the cooling tubes outer surface than the remaining vault areas this accelerates corrosion.

4. Presence of radioactivity enhances corrosion due to formation of free radical in the air, ozen, nitrogen oxide and subsequently form acids with surface moisture films.

5. Nitrogen oxide can also be formed by spurious discharge of high electric field.

6. Corrosion occurs in bimetal joints of aluminum &copper tubes in trimmer capacitator cooling tubes due to different electro-chemical potentials.

7. Corrosion also enhance by the speed of the cooling water and its residual impurities

8. Porosity will develop in the joint filler due to presence of low vapor pressure (less than 10^{-3} m bar) elements like zinc, cadmium, phosphorus in the filler alloy during brazing at high temperature. Micro-pores may appear under prolong high vacuum (10^{-7} m bar) and high

operating temperature. So the high vacuum service filler must be free from elements like Zn, Cd, P, Pb or they should be controlled below 0.010 Wt %.

REPAIR OF LEAKS

a) All invisible leaks have been detected by bubble emission tests at 1.5 atmosphere pressure and farther finer leaks are detected by MSLD after draining and drying the LWC from the tubes.

b) All the repair have been done by a design of lap type sleeve joint, with a joint-clearance of 20- 25 micron at brazing temperature. Strength of brazing joint reduces with the increase of filler metal film thickness. Length of lap joint has been made three times of the weaker section thickness to achieve good joint strength.

c) Through cleaning of the joint has been done without any chemical cleaning agent to avoid entrapping in the existing finer gaps.

d) The sheet and tubes materials are of OFE grade copper (C10200), which has high thermal and electrical conductivity. It will not produce any hydrogen embitterment during brazing in atmosphere. Since copper has high thermal conductivity and high thermal expansion brazing has been carried out with faster speed and high heat concentration produced by TIG process. Flow of filler by capillary forces has been achieved by manipulating heat of the TIG torch. Sufficient socking time has been provided for wetting molten filler on the joint surface.

e) No flux has been used to avoid residual contamination inside finer gap and corrosion thereafter. Self-fluxing brazing filler has been used.

f) Vacuum grade self-fluxing silver base eutectic alloy of filler wire diameter of 1.5mm has been used as per AWS designation BVAg-8a. This is an eutectic filler containing 72% Ag, 27.8%Cu and 0.2% Li ("Lithobraze" of Handy & Harman Co). Lithium helps to reduce refractory oxide at brazing temperature on the base metal surfaces while brazing at atmosphere. This filler has high electric conductivity of IACS 72%. This composition has the common solidus and liquidus temperature of 765^0C.

Brazing joints produced in this process gives vacuum leak tightness of 10^{-9} SCC /sec.

QUALITY PERFORMANCE TESTS

The performance of the brazing joint quality has been tested in the following steps.

1. Bubble emission test (1.25 ATM+10% excess pressure with air or N_2)- as per ASTM, E515-94

2. MSLD (mass spectrometer leak detector) test has done as per ASTM, E 499-94 to achieve a leak-tightness of $5x10^{-9}$ SCC/sec.

3. Hydraulic test has done with 1.25 times of delivery pressure, 15kg/cm^2 and if any new leak appear after this test and again repeat test no 1, 2 & 3 tests after repair.

4. Lastly MASLD test for gross/global leaks for all the joints in the panel up to a leak rate of $5x10^{-8}$ SCC /sec.

CONCLUSION

Cyclotron down time increases because of water-leaks in R.F. panel and this became a major concern for smooth cyclotron operation. Careful selection of brazing procedure, filler and necessity quality performance tests could minimize this type of down time.

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