Ultra High Vacuum Testing of the new RF cavity of INDUS-1

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Abstract. INDUS-1 is a 450 MeV electron storage ring operating since 1997. Its RF cavity needed replacement. R.F Cavity is a very important and critical component of the storage ring. It is a vacuum vessel having large number of ports for vacuum pumps, gauges, view port, RF tuners, RF sensors etc. The welded parts were leak checked at various stages during the fabrication. Prior to final welding of two halves, the cavity was assembled using large viton O-ring, leak tested and baked for 48 Hrs. Ultimate vacuum in 10^{-8} mbar range was obtained. Cavity was also subjected to RF power conditioning. The final welding was done after confirming all other functional tests. Again the cavity was baked and tested for the vacuum, without connecting in the storage ring. Finally, it was connected in the ring, baked along with all other portion of the ring. This paper gives the details of these tests.

1. Introduction
INDUS-1 is an operating machine, which was working since 1997 as an electron storage ring. The ring was working in the ultimate vacuum range of 10^{-9} mbar and the RF cavity was in the 10^{-8} mbar range. As there was a need of replacing the then existing aluminium RF cavity of booster with this stainless steel cavity of INDUS-1, a new RF cavity was proposed to be made and installed in INDUS-1. The new RF cavity was conceived to be a stainless steel cavity without O-ring, but instead welded at the joint between two halves of the cavity. The cavity has an inside diameter of 840 mm and a length of 600 mm comprising of 2 X 300 mm halves. The diagram is shown in Appendix A.

The RF cavity has a surface area of 4 sq.m in the inner side of the cavity, which has been plated with copper. The outgassing rate measurement of the stainless steel with copper plating was performed to establish the outgassing property of the material (Ref 1). The outgassing of the sample, at room temperature was 5.6 X 10^{-12} mbar.l/s/sq.cm, after the second baking cycle of the sample at 180-200 °C, followed by pumping for 48 hrs.

The stage wise inspection of the subassemblies was done prior to the complete assembly and commissioning of RF cavity. RF Cavity shell seam welding joint was leak tested with Helium leak detector on 20/12/06 and was found OK in 4x10^{-10} mbar.l/s. Further to this every subassembly was leak tested with HLD over a period of 4 months for their vacuum worthiness. This is done mainly to ensure the vacuum worthiness of the final component.

2. Description
The stainless steel cavity was initially made in two halves fastened with Viton O ring as a seal between them. The cavity was assembled after it was chemically cleaned. It was shifted to INDUS-1 building and placed in its intended position. It was fitted with all the subassemblies like tuners, RF
ports, plumbing arrangements, BA gauge head and 2 SIPs along with one TMP with a HV valve. All the joints were leak checked and were found to be leak tight at \(1 \times 10^{-10}\) mbar l/s, except the plumbing joint on the RF cavity connecting to SIP which was found to be leak tight at \(5 \times 10^{-10}\) mbar.l/s.

The cavity had a limitation in baking with the viton O ring as its seal. Hence care was taken to wrap the cavity with heating tapes of different power capacity in different locations so that the temperature on the O-ring joint never exceeded 140°C. The total power capacity of the tapes on the cavity was 5KW. This cavity was baked for 48 hrs at 150 °C. and a vacuum of \(4 \times 10^{-8}\) mbar, after ~20 hrs, and 2 \(x\) 10^8 mbar after ~ 40 hrs were obtained. The cavity was removed from the position to remove the O-ring and was welded on the lip. The groove where the O-ring was in position was vented with four annular holes for removing trapped gases.

3. Procedures

The RF cavity after the lip welding was brought back to INDUS-1. A 250 l/s TMP was connected with RF Cavity for initial pumping before leak detection and after 1 hour pumping, the Helium leak detector was connected for leak testing. Since the cavity was purged with He gas during welding, the Helium background was not coming down from \(10^{-5}\) mbar.l/s. The cavity was shifted to INDUS-1 building and vented with LN2 followed by pumping with TMP two times, but the He background signal was not reduced. Hence, the TMP pumping was continued for more than 12 hours.

It was leak tested with \(5 \times 10^{-7}\) mbar.l/s He background and no leak was found. It was connected with 500 l/s TMP and DN 63 Right angle valve and pumped for three hours. Then, this was leak tested with 1\(x\)10^8 mbar.l/s He background and no leak was found.

After 12 hrs, the cavity was leak tested with \(5 \times 10^{-9}\) mbar.l/s He background and no leak was detected. To improve the response of He leak detection, the cavity was finally leak tested with fore line connected with 500 l/s TMP and was found to be leak tight.

3.1 RF cavity after leak testing was kept in the ring. All the subassemblies were connected and the plumbing line along with SIPs and TSPs was connected. The mounting of these pumps was made on the stand fitted to the cavity base stand itself. Two BA gauges were provided on a Tee connected to RF cavity. All the joints were tested to a leak tightness of \(2 \times 10^{-10}\) mbar.l/s. The baking arrangements were made so that the cavity is uniformly baked. RFC was independently baked in a temperature range of 150°C to 200°C for 24 hrs on 09-05-07. The ring was not being baked at this juncture in order to qualify the cavity for UHV.

After 24 hrs of baking, the following results were seen. \(2.5 \times 10^{-7}\) mbar vacuum was obtained after ~3 hrs, \(< 5 \times 10^{-8}\) mbar after ~20 hrs and \(< 2.5 \times 10^{-9}\) mbar after ~24 hrs. Leak detection of RF cavity after this preliminary baking was done (LD on backing port of TMP). This baking was necessitated to clean the cavity, which had undergone lip welding and handling in the workshop. And also this step was required to save the INDUS-1 ring from any undesired impurities from the cavity. All the joints were found to be leak-proof below a range of 2 to \(5 \times 10^{-9}\) mbar.l/s.

The ring was completely leak tested before final baking. The ring was found to have a leak tightness of \(2 \times 10^{-9}\) mbar.l/s. All the SIPs and then BAGs were switched on, to check their performance. BAGs were showing vacuum ~1 \(x\) 10^{-5} mbar. All the SIPs and Gauges were switched off.

3.2 The cavity was ready for final baking along with the ring. The baking cycle was started on 14/05/07 and the cycle was ON for 24 hrs. The temperature was maintained between 130°C and 200°C. The SIPs and TSPs were baked at higher temperatures. After 22 hours, the vacuum reading was \(4.61 \times 10^{-5}\) mbar and after 24 hrs the vacuum was \(3.88 \times 10^{-5}\) mbar.

- Heaters for INDUS-1 ring were switched off initially without stopping RF cavity baking.
- SIP flashing, TSP and BA gauge degassing were done in the ring.
- RF cavity heating was stopped.
- When the cavity reached a temperature of 100°C, SIPs, TSPs and BA gauges were all flashed.
- At 60°C, SIPs came into protection mode.
• High vacuum valve was closed and the TMP was isolated.

4. Results
The graph below shows the vacuum behaviour as the RF cavity was cooling down to room temperature. The Ultimate vacuum that could be achieved was dependent on the trapped volume near the lip welding. Hence it is seen that the achievable vacuum has not been obtained even after 48 hours.

![Graph: Pump down curve - Indus-1 cavity](image)

The RF power given to the cavity had initially affected the vacuum in the cavity during the RF power testing. The vacuum on 18th May'07 had deteriorated to nearly 10^{-5} mbar with a RF gap voltage of 30KV.

The following graphs show the behavior of the vacuum in the RF cavity during initial conditioning, vacuum over a time period of 3 months and vacuum behaviour during the beam circulation. As the cavity got conditioned over a period of time, the vacuum with the RF power also improved.

![Graph: Pressure / Voltage KV Vs Time (May 18, 2007)](image)
Conclusions
The RF cavity after regular cleaning effects and conditioning is giving a required satisfactory performance in terms of UHV requirement. The operating voltage at present is around 20 KV and the corresponding vacuum is \(2.8 \times 10^{-8}\) mbar

References
Paper titled “Outgassing rate measurement of Copper plated on Stainless steel” by Ms Ratnakala etal in IVS2007, Mumbai

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Appendix A.
The Assembly diagram of RF cavity with the pumps