# "ELETTRA" Vacuum chamber Design and Fabrication.

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*Abstract*

The main goal of the "ELETTRA" vacuum chamber fabrication was to guarantee a vacuum level in the Storage Ring better than $1\ 10^{-11}$ mbar without beam and $1\ 10^{-9}$ mbar with circulating beam. To reach this goal a Quality Assurance structure has been developed to performe all the activities from development, design, fabrication, testing up to the assembly of the chamber. The design was performed by using a 3D CAD system to optimize the mechanical and vacuum parameters and to minimize the fabrication costs. A very stringent specification has been choosen to guarantee the low inclusion and low permeability material charactristics. All the welding has been qualified to reduce the permeability in the seams and in the HAZ, to avoid trapped gasses in order to reach the UHV characteristics and to minimize the deformation as required by the very narrow fabrication tollerances. The transfer line vacuum chamber and the septa magnets fabrication has been performed in the specialized mechanical fabrication department of the Sincrotrone Trieste. Other components such as the septa vacuum chamber, the ceramic vacuum chamber for the kickers and the main ring vacuum chamber have been fabricated outside with a continuous inspection and control of the whole fabrication processes. All the components have been baked at 350°C in a special designed vacuum oven of the Sincrotrone Trieste Vacuum Laboratory and then, in the following, baked in situ at 150°C by using a heating system developed at Sincrotrone Trieste.

## 1 INTRODUCTION

"Elettra" is a third generation Synchrotron Radiation facility composed by the following Machine sections:

-Linac 1.5 GeV
-Transfer Line
-Injection Section
-Storage Ring
-Experimental Hall

To reach the high quality performance required for these machines, on any of its components a very restrictive design specification has to be applied. One of them is the Vacuum Chamber (VC) from which performance depend the quality and high lifetime of the stored beam.

This paper will describe the Storage Ring (SR), Transfer Line (TL) and Injection Section (IS) VCs design and fabrication criteria. These components have been developed entirely by ST in a structure organized according to the Quality Assurance (QA) rules. This structure is composed by the following operating units which performe complementary tasks:

Engineering group which performed all the layout studies, the mechanical design and the relative technical specifications of all main components, as well as the manufacturing developement and the management.

Vacuum group which designed the vacuum plant, the bake-out system and developped the vacuum test and treatement specifications; performed the vacuum acceptance tests both in the ST laboratory and in the manufacturing factories .

Mechanical and welding workshop which supports other groups and laboratories developing prototypes and components, and in which important Elettra VC components have been manufactured.

Quality Control which performed the manufacturing management developing fabrication specifications, defining the control plans and performing the welding and welder qualifications.

## 2 STORAGE RING VC DESIGN AND MANUFACTURING

### *2.1 Design*

The main requirements for the VC design was:

a) To reach a vacuum better then $10^{-11}$ mbar without stored beam and than $10^{-9}$mbar with stored beam .

b) To avoid magnetic field distortions from the magnets.

c) To allow a good allignement of all the beam diagnostic instrumentation and photon absorber slot.

To reach all the material specifications it was choosen an AISI 316LN Lic stainless steel.

The design parameters were defined starting from the magnetic lattice, the vacuum pumping system, the support system philosophy and the beam diagnostic instrumentation distribution. All the geometric optimization has been performed using a 3 D CAD system (Euclid 3.1) (fig. 2).

After some studies, a romboidal cross section has been choosen for the VC pipe.

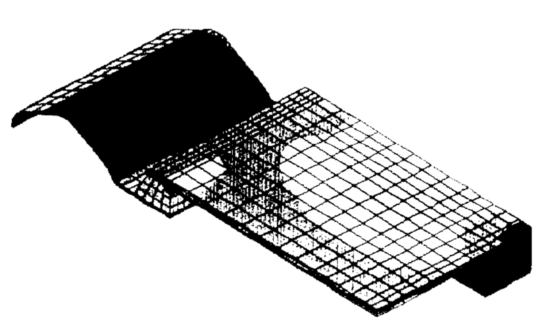

fig. 1- VC crotch 3D FEM calculation

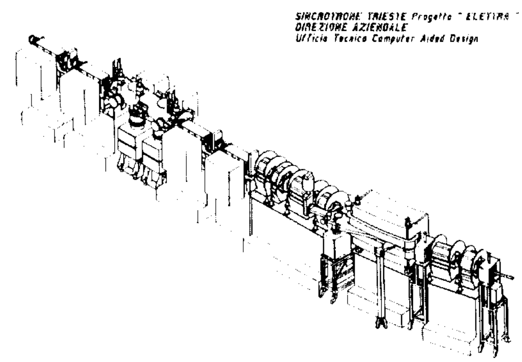


fig 2- 3D CAD lay out

To connect the BPMs, a special gasket of the VAT type and the relative flanges have been developed and tested to qualify them.

Special hydroformed bellows with copper beryllium sliding RF contacts to maintain the romboidal shape have been developed.

All the VC components (24 crotches and pumping sections, straight sections and ID sections) have been designed very carefully to avoid trapped gasses and to limit deformation due to vacuum. All the components have been dimensioned performing FEM calculations (Ansys, Abaqus) (fig. 1).

*2.2 Manufacturing*

To reach the very tight geometric tollerances and the magnetic permeability limits, imposed to the VC pipe, it was decided to start from a 2 mm AISI 316 LN Lic coil for its manufacturing. The pipe has been first produced in circular shape of ø=70 mm, 6 m long on a continous machine with axial electrowelding and a 1100$^{O}$C solution annealing on line. Then the pipes have been polished on the inside surfaces and rolled and drawed to the final romboidal shape within 0.1 mm tollerance.

The crotches have been completely machined starting from a 65 mm AISI 316 LN Lic 1100$^{O}$C solution annealed sheet. The final internal size has been reached using electroerosion machining. The crotches have been TIG welded to the romboidal chamber, bent with 5.5 m radius, using an automatic welding plant.

All the pumping chambers have been welded on a VC section on which a serie of slots has been cut using a laser cutting system .

The ID section of the VC (5 m long), have been designed to allow a minimum gap of 25 mm required for the ID magnets. A solution to weld a bent sheet , with an internal reinforcing structure, to a cilindric prechamber has been choosen. The pumping area has been realized by making axial slots in the reinforced structure. To pump the ID section VC, four SIP pumps are used, two of them connected to the prechamber and the other two to the transition from the romboidal to the rectangular sections.

The VC is sustained by the pumpes assembled on a rigid girder supported by a 3 point regulation system.

The manufacturing of all the components has been controlled in each phase by fabrication cycles, fabrication and control plans and scheduling time tables. For the welding the standard qualification procedures have been followed and all the weldings were performed by qualified operators. All components have been geometrically controlled, vacuum tested and US cleaned directly in the factory. Than they were baked at 350$^{O}$C in the Vacuum Oven of the ST laboratory. Afterwards the cooling circuits were installed on the crotches and VC components . The heating elements have been steaked and the insulation covers mounted orver all the components.

The VC has been assembled using a laminar flow cowl within the scheduled time. The position tollerances required for diagnostic instrumentation have been reached.

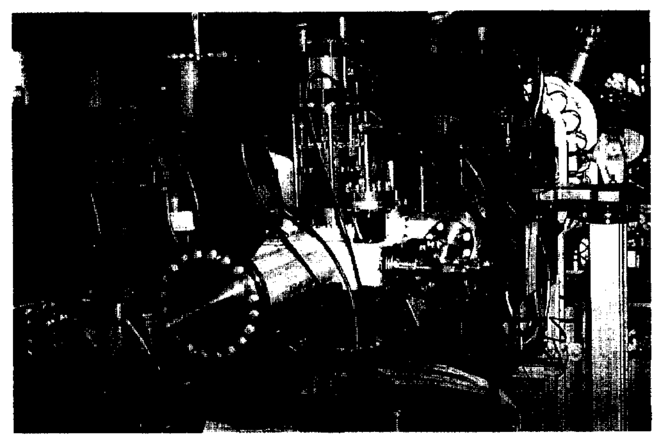

fig 3- VC Assembled in the Magnet lattice

*2.3 Other components*

To collimate the Synchrotron Radiatin entering the beam line, a special Photon Absorber has been desiged and manufactured providing different slots for Bending Magnet BL, ID BL and Wiggler BL. To close the Photon absorber slot when the BL is not in operation, a Beam Shutter has been designed and manufactured.

A Beam Stopper installed in the SR has been designed and completely manufactured in house.

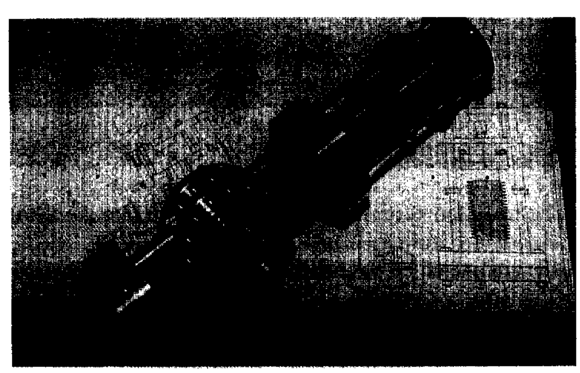

fig. 4- SR Beam Stopper.

## 3 TRANSFER LINE VC DESIGN AND MANUFACTURING

### *3.1 Design*

The goal for the TL VC was to reach a vacuum better than $10^{-8}$ mbar over the whole TL except near the Injection Vessel where it was required to be $10^{-9}$ mbar in order to provide a differential vacuum between TL and SR, avoiding the use of gold foil.

It was decided to use an AISI 316L stainless steel pipe commercially available. On the straight section it was possible to use ø=48 mm inside the Quadrupoles, while it was choosen a ø=70 mm pipe outside the Quadrupoles to improve the vacuum conductance. Inside the Bending Magnets an elliptic VC was taken, obtained by rolling a ø=51 mm pipe, bent with 4.5 m radius. Both side special elliptic hydroformed bellows where welded. In the first TL Bending Magnet a crotch has been installed to allow the electron beam exit also in straight direction. The diagnostic instrumentation has been welded to the chamber or connected by using CF flanges. A Beam Stopper has been designed.

### *3.2 Manufacturing*

All the TL VC components have been designed, manufactured (fig. 4), vacuum tested, cleaned, baked and assembled in house. In this way it was possible to create an internal structure with all the competence in UHV developement and fabrication.

fig. 4-Welding and brazing qualification specimens

## 4 INJECTION VC DESIGN AND FABRICATION

### *4.1 Design and Manufacturing..*

The injection system has the task to inject into the SR the beam coming from the Linac via the TL [1].

It is composed by the following elements:

-Two septa magnets installed in a Vacuum Vessel to deflect the injected beam parallel to the stored beam. The Vacuum Vessel provides the SR VC continuity, allowing independent radial displacement of both septa to optimize their position, electrical supply and cooling of the magnets. Two fluorescent screens to detect the injected beam and the beam after the first turn are installed on the Vacuum Vessel.

-Two pairs of kicker magnets to displace the stored beam parallel to the injected beam. To allow the variable magnetic field to enter the VC, inside the kickers a ceramic VC is mounted. On the internal surface of the ceramic there is a sputtered 3 µm Ti layer to avoid the built up of static load. All the ceramic chambers are connected by hydroformed bellows with internal copper-berylium sliding contacts. Inside the first and last bellows, the transformation from romboidal to rectangular cross sectin is performed.

All the injection components have been designed by ST. The septa magnets have been completely manufactured in the ST workshop. All the other components have been manufactured outside under the supervision of the ST inspectors.

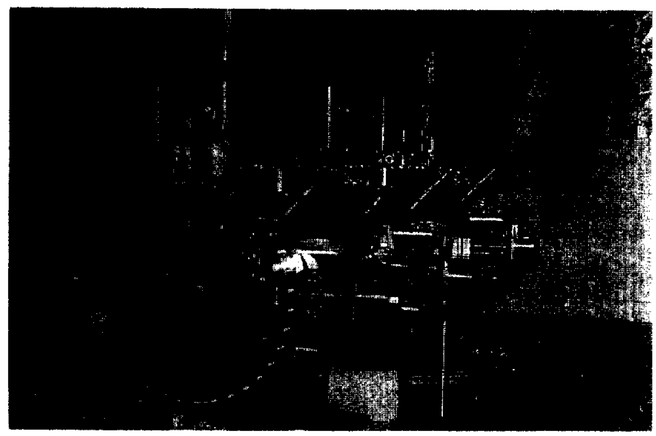

fig. 5-Septum Vacuum Vessel.

## 5 CONCLUSIONS

"Elettra" has been assembled according to the scheduled time and its commissioning started at the beginning of October 1993. After two days we had reached 2000 turns withought RF . On the third day, after switching on the RF, we had a stored beam. To reach this records,it was important to design, fabricate and install all the components within the required specification. Now, after few months of commissionig, "Elettra" is running with two ID BL and one Wiggler BL. After these months of VC conditioning, we are close to the design vacuum values and this even without NEG activation. Besides, the beam Current and Energy have exeded the specified values, and the lifetime is improving more and more.

## 6 REFERENCES


[1] M. Giannini, D. Corso, F. Daclon, G. Pangon, D. Tommasini "Design, Construction and Installation of the ELETTRA Injection System", Proc. EPAC94, London 1994.