CERN

TECHNOLOGY NOTE

V29 THIN-WALL CORRUGATED VACUUM CHAMBER FOR THE PROTON SYNCHROTON BOOSTER

The need for vacuum chambers

The vacuum chamber in a proton accelerator provides the ultra-high vacuum environment needed for the protons circulating on the inside up to nearly the speed of light. In "circular" machines, the chamber is for a large part of its circumference between the poles of electromagnets, which generate rapidly-varying fields of high precision to guide and focus the particles during the acceleration cycle. In consequence, it must be designed so as to obtain the best compromise between the following somewhat contradictory requirements: it should:

The requirements

- cause minimum distortion of constant magnetic fields in order to maintain the precision field requirements
- have high electrical resistance for minimum eddy current effects on the beam due to pulsed magnetic fields
- have the smallest possible outer dimension for a required beam aperture because the larger the chamber, the larger and more costly the magnets, their power supplies and operation
- be low in cost and easy to handle, therefore excluding the large scale use of ceramic chambers.

Meeting the requirements

These requirements are best met by selecting a chamber material having high electrical resistivity, very low magnetic permeability (also after welding), high strength, a large modulus of elasticity, surface characteristics suitable for ultra high vacuum use and made with the thinnest possible wall. The thin wall requirement coupled with the smallest possible deformation when under vacuum suggest the use of a corrugated shape to obtain the required stiffness.

The corrugation height, wall thickness and permissible stress and deformation should be chosen so that all requirements are optimized. Given also the elliptical shape of the vacuum chamber, optimization of all these parameters becomes a lengthy procedure, and as a result a computer program to make the calculations has been written for the most general case which assumes a variable corrugation amplitude around the perimeter of the chamber.

Material selection

Table I lists some of the materials considered for the construction of the chambers for the PSB bending magnet. Given price, weldability and the physical characteristics involved, the choice has fallen on the high nickel alloy Inconel X-750.

Table I, Properties of various vacuum chamber materials

Material	Resistivity $\mu\Omega$ cm	Permeability at 20° C & 200 Oersted	Yield strength kg/mm^2	Mod. of elasticity kg/mm^2	Elongation %
Inconel 625	129	1.0006	42-66	20'400	60-30
Inconel 718	124	1.001	120	20'300	17
Inconel X-750	121	1.002	88-99	21'100	30-15
AISI 316 LN	74	1.003	33	19'100	40
Ti-6 Al-4V	171	1.0004	81	11'200	10

Technical problems encountered in development

The first optimized chamber had a variable corrugation amplitude, details of which are shown in line 1 of Table II. Considering the difficulties involved in producing such a chamber three development contracts were awarded to Calorstat, France, BOA, Switzerland and Orion, Germany. BOA and Calorstat applied their know how gained in the manufacture of bellows to produce this chamber, while Orion Studiengesellschaft experimented with explosive forming. Although the results obtained were not entirely negative, it was decided to adopt the next best compromise, namely the chamber having constant corrugation height shown in line 2 of Table II and in Fig. 1. These chambers (1822 mm long) were produced entirely by Calorstat.

A further series of similar chambers but with larger horizontal aperture is shown in line 3 of Table II, and these were produced by BOA. The last line of Table II shows a non-corrugated chamber made from a titanium alloy. It was rejected on account of its large deformation under vacuum.

Fig. 1, Final chamber

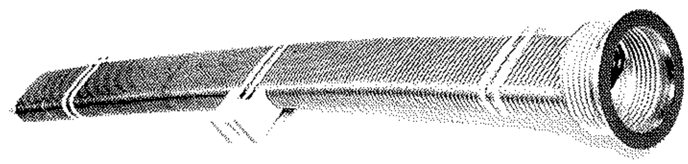

Table II, Results of calculations

Outer dimens. mm		Corrugation height mm		Wall	Max. stress kg/mm^2		Max. deflection mm	
vert.	horiz.	vert.	horiz.	mm	tensile	compr.	vert.	horiz.
68.5	138	2	6	0.4	16.5	-18.1	-1.12	0.30
69.0	138	3	3	0.4	21.9	-23.2	-0.97	0.36
69.0	156	3	3	0.6	26.7	-28.9	-2.28	1.04
69.0	138	0	0	2	14.0	-14.3	-3.0	1.1

References

128 corrugated vacuum chambers have been installed in the PSB bending magnets and so far have given full satisfaction. The computer program (by G. Brianti and K. Schindl) is described in SI/Int. DL/69-5. Further information can be obtained from C. Rufer, MPS Division, CERN.