FIRST SECTION OF A 352 MHz PROTOTYPE ALVAREZ DTL TANK FOR THE CERN SPL*

D. A. Kashinsky, V. A. Koshelev, T. V. Kulevoy, S. A. Minaev, V. A. Pershin, S. V. Plotnikov [#], B. Y. Sharkov, V. S. Skachkov, A. P. Durkin, ITEP, Moscow, Russian Federation

V. F. Basmanov, V. A. Demanov, I. D. Goncharov, E. S. Mikhailov, N. I. Moskvin, S. T. Nazarenko, V. S. Pavlov, V. V. Porkhaev, V. T. Punin, A. V. Telnov, V. N. Yanovsky, V. P. Zavyalov, S. A. Zhelezov, VNIIEF, Sarov, N. Novgorod region, Russian Federation

Abstract

In the Linac4/SPL projects at CERN, 352 MHz DTL Alvarez accelerating structures will be used to accelerate protons between 3 and 40 MeV. The R&D for the development of a prototype structure for the energy range from 3 to 10 MeV is taking place jointly at ITEP and VNIIEF. The design of this 2.7 m Alvarez tank containing 27 drift tubes is described in this document. Results of calculations of the section parameters are presented. One of the main features of the design is the use of permanent magnets made of $SmCo_5$ alloy as quadrupole focusing lenses (PMQ) inside the drift tubes. Details of the experimental PMQ-equipped drift tube are described.

INTRODUCTION

The 2.2 GeV, 4 MW Superconducting Proton Linac (SPL) is proposed as proton driver for a second-generation radioactive beam facility and for the production of high-intensity conventional neutrino beams at CERN [1]. One of the ideas of the new linac design is to re-use the 352 MHz RF equipment of LEP (klystrons, waveguides and power supplies) reducing cost as much as possible.

The aim of the actual project is the design, production and tuning of full-scale prototype of Alvarez tank 1 with drifr tubes (DT), accelerating protons from 3 MeV to 10 MeV. In the frames of this project, this prototype must be tested with the drift tube dummies without focusing lenses (only the 1st drift tube equipped with PMQ lens is the real one). Real quadrupole magnets will be installed into the drift tubes and high power beam tests will be carried out at the next stage. In the case of successful results, developed design and production technology may be applied to other tanks of Alvarez DTL structure.

GENERAL RF DESIGN OF THE ALVAREZ TANK SECTION

Main calculated parameters of tank 1 are shown at the Table 1. Protons are accelerated from 3 MeV to 9.8 MeV in 28 gaps on the total length of 2.63 m. High accelerating rate exceeding 2.5 MeV/m is obtained due to increased average electric field and optimal choice of synchronous phase profile. Estimated RF power consumption of around 700 kW is within safety margins for existing klystron.

*The work is supported by the ISTC project # 2888.

#plotnikov@itep.ru

Table 1: General design parameters of the Alvarez tank

Parameter	*Unit*	*Value*
Operating frequency	MHz	352.2
Proton energy, input / output	MeV	3.0 / 9.796
Tank length	mm	2634.2
Tank diameter	mm	520
Number of gaps		28
Average electric gradient	MV/m	3.3 (unif.)
Gap-to-period ratio		0.127..0.151
Max. surface electric field	Kp	1.74
Synchronous phase	deg	-30…-20
Quality factor		43250
RF power dissipation in Cu	kW	427
Total RF power with 40 mA beam	kW	699

Drift tubes supplied with PMQ focusing magnets are attached to the balk on tank top by the vertical stems through the large rectangular opening. Five fixed plungers distributed along the tank are intended for correction of errors in resonant frequency and field distribution originated from finite accuracy of calculation and manufacturing. Inevitable thermal drift of the resonant frequency is expected to be compensated by two additional movable plungers driven by electric motors. Diameter of both fixed and movable plungers is 90 mm.

Stabilization of field profile against small perturbations in the structure (tank deformations, etc.) is reached by use of post-couplers installed in front of every the third drift tube.

DESIGN OF THE ALVAREZ LINAC SECTION

The configuration of the model of Alvarez-type acceleration section is presented in fig.1.

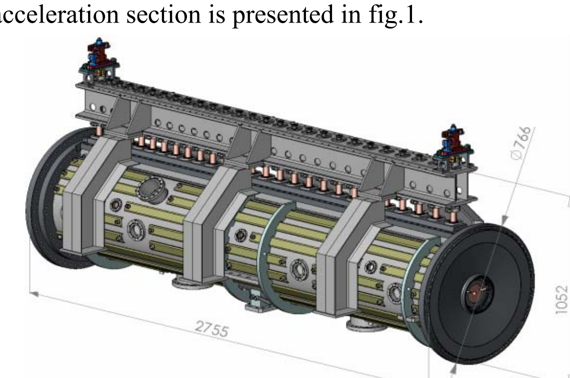

Figure1: General view of the Alvarez tank.

Characteristic features of design model of acceleration section are as follows:
- adjustment of drift tube is performed on load-bearing beam by means of demountable adjustment units**.** The amount of adjustment units should be as few as possible and will be determined after working-off technology of drift tubes adjustment.
- all drift tubes are fixed on the load-bearing beam by compound-filling method (terminal DTs are anchored on end disks);
- load-bearing beam has three supports, the beam is fixed on bearing frame. The end supports are disposed within the distance providing minimum bending deflection.

Cavity Body

The body of the cavity is furnished with three supports. Central part of the cavity is fixed rigidly on the bearing frame. Terminal supports of cavity body are free-moving on the bearing frame along beam axis.

Cavity body is designed as welded structure made of steel AISI 304L. The joint welds are arc-welded in inert gas environment according to GOST 14771 standard. The preform for course manufacturing is made by rolling from a sheet 20 mm thick (perform thickness is determined by the manufacturer) from two jointly welded parts.

The upper flange is designed as a plate (preform thickness 70 mm) with milled through-windows meant for drift tubes installation. The size of windows is determined by overall dimensions of drift tubes and guaranteed gap within 3-5 mm necessary for their mounting into cavity body.

The thickness of cavity body wall is set to be 10 mm based on requirements to its durability and stiffness and also on manufacturing possibilities.

The finishing treatment of cavity body, namely, mounting and thickening surfaces, is made after welding. The internal surface of the body is copper-coated of 35 μm thick.

Drift Tubes

Characteristic features of design model of drift tubes #1-27 are as follows:
- drift tube body is a hermetic welded construction.
- material of drift tube is copper of ***Ob GOST 859*** grade.
- magnetic lens incorporated into the drift tube is a holder made of aluminium alloy with double-row cylindrical constant magnets.
- magnet lens is centered within drift tube body relative to the holder external diameter.
- cooling water is supplied to drift tube through internal tube and removed via a channel formed as a gap between drift tube body and water supplying tube.
- bellows unit is meant for hermetic joining of drift tube and cavity body and also for compensation of shifts caused by drift tube adjustment and by cavity body deformation because of vacuum and heat loadings. The connection of bellows unit with drift tube rod is made by silver soldering - the final machining of internal diameter of drift tube and coupling radii is performed after final assembling.

Assembly drawing contains complete information about final assembly and machine working of drift tube. The technology of drift tube making is agreed with the manufacturer. Complete design documentation package is developed. Working-off of drift tube technology was performed in parallel with working-off of laser welding technology.

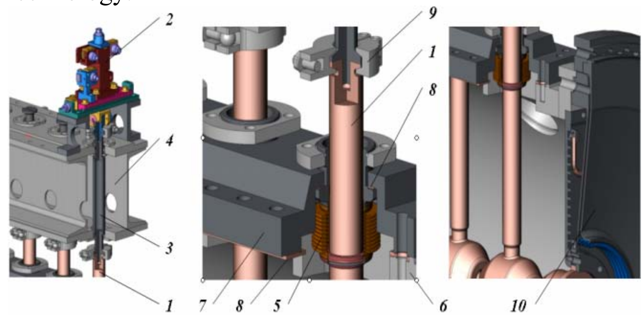

Figure 2: Accelerating section: Basic units.
1 - drift tube; 2 – adjustment unit; 3 – fixing unit of drift tube; 4 – load-bearing beam; 5 – bellows unit; 6 – body; 7-cover; 8-copper tightening; 9- clamp; 10 - junction unit.

The necessity of laser welding in process of drift tube manufacturing is determined by the need of limited heating of drift tube containing magnet lens. Three prototype samples were manufactured. All joint welds were tested for strength and air tightness by an overpressure. Recently the improvement of laser welding technology on samples having the same exterior geometry as drift tubes #1-27 is carried on. The variant of the joining unit of accelerating sections is presented in Fig. 3.

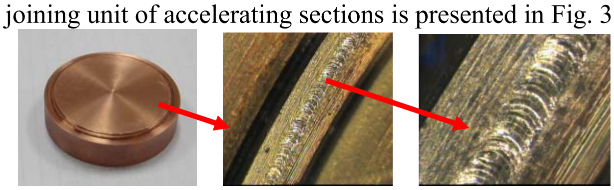

Figure 3: Sample for laser welding. Outward appearance of laser joint-weld.

Electroplating with Copper

To decrease a heat load on the linac body caused by RF currents induced over its internal surface it is necessary to coat it with copper, 25-45 microns thick. Copper coating is plated by electrolytic method over the internal surface of the cavity made of stainless steel AISI 304. It is known that the obtaining of well-cohesive electroplating on stainless steel presents definite difficulties because a passive film is formed on steel surface that prevents firm cohesion of coatings. This is aggravated by the fact that the cavity is a tube, 2.7 m in length and 0.5 m in diameter, therefore, in this case it is impossible to rapidly change operations during coating process for preventing steel passivation.

The reliable technology providing a good adhesion of galvanic copper to a base made of steel AISI 304 has been elaborated. The variant of engineering solution ensuring the validity of required technological parameters has been worked out.

EXPERIMENTAL QUADRUPOLE LENS BASED ON PERMANENT MAGNETS(PM)

Experimental quadrupole lens consists of two 45 mm long aluminum holders with PM rods in them (Figure 4).

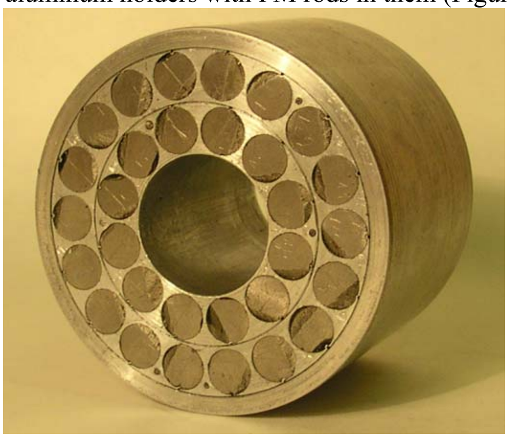

Figure 4: $SmCo_5$ quadrupole prototype.

The inner holder of ∅ 22 mm aperture contains 12 $SmCo_5$ rods while the outer holder – 18 rods and has ∅ 54.6 mm outer dimension. In order to simplify mounting in a drift tube, the outer holder is pressed into the aluminum ring of ∅ 60 mm diameter. Before mounting the lens in the drift tube some special groove will be cut on the quadrupole surface.

Longitudinal field gradient distribution along z-axis uses the results of Hall probe field measurements in median lens plane along two z-lines: $x= \pm 1.5$ mm by 2 mm step in z.

The effective field gradient of 51.5 T/m or 2.32 T – integrated in z corresponds to the 0.84 T rod magnetization measured previously.

The field is measured in numerous z = const planes by 2 mm step in four states, which correspond to maximum Hall probe signals that are attained when the probe is subsequently rotated by 90° and the normal vector to probe plane is directed at the corresponding lens pole. By the technique we evaluated the magnetic axis offset as a function of z. After tuning stage the offset was reduced down to much less than 0.1 mm required. General magnetic measurements fulfilled on the CERN harmonic bench showed that the r.m.s. magnetic axis deviation from the geometrical one is less than 30 µm. At such small number it is not necessary to compensate offset in the drift tube that was previously foreseen.

The magnetic field B in the central cross-section of the quadrupole along x-axis with 0.5 mm step was measured (see Fig.5). Analyzing the radial field distribution it was found the non-linearity $\Delta B/B$ is less than 1% in zone that covers 75% of the ∅20 mm beam aperture near axis.

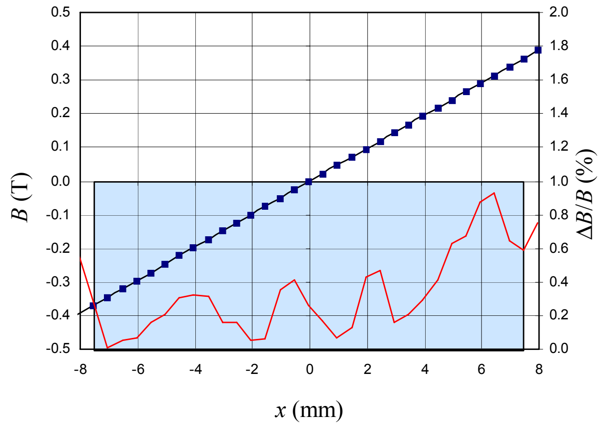

Figure 5: Radial field distribution in the quadrupole lens and non-linearity

Field harmonic spectrum measured on the CERN bench showed that all higher order field harmonics until 14-th and especially 6-th harmonic are suppressed enough.

During quadrupole fabrication the gradient integral may vary because of mechanical errors as well as due to the spread of rods magnetization. To provide the gradient integral adjustment with ±0.5 % accuracy two shim-washers were attached from both sides of the quadrupole. The influence of a single steel shim put closer to one of the quadrupole sides upon the field gradient as well as its integral were investigated. The simulations showed that single 0.5-1 mm thick washers provide smooth gradient integral adjustment up to 5 % when the inside hole in the washer is the variation parameter.

PM quadrupole design investigation and measurement shows the following: two-layer experimental quadrupole lens on PM with required aperture has been manufactured and investigated; magnetic field characteristics of the PMQ lense are in good agreement with calculated values.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Roland Garoby as well as all the key members of the Linac4/SPL team in CERN for their attention and help in the work.

REFERENCES

[1] M. Vretenar, R. Garoby et al. “Design of Linac4, a New Injector for the CERN Booster”. – Proc. of the LINAC’04 Conf., Lubeck, 2004, p. 291, http://www.jacow.org.