CAVITY AND DRIFT TUBE TECHNOLOGY FOR THE UPGRADED UNILAC

D. Böhne, H. Gaiser, E. Malwitz
GSI, Gesellschaft für Schwerionenforschung mbH
Darmstadt, Fed. Rep. of Germany

Summary

The extension of the Unilac poststripper section from the present 2 to 4 Alvarez cavities should be completed as early as possible. There was, however, concern whether the old drawings should be used with the appropriate changes in the drift tube table, or a redesign of essential mechanical details (simplifications) would be possible in the tight time schedule. As a result, the saving in fabrication time seems to compare favorably with the effort spent in redesigning the cavity and drift tubes. The net gain would be a cost saving of a factor of two.

This paper describes an in-place plating method for welded tank sections and a fabrication scheme for the drift tubes out of inexpensive sheet metal components.

Introduction

The design decisions on various mechanical components of the Unilac, which have been evaluated in prototype activities, were outlined in 1972.[1] A review of the actual performance of most components was given in a 1976 Status Report.[2] A strongly recommended redesign of a few mechanical components, which are exposed to high power rf fields, is described elsewhere.[3]

The Unilac upgrading program[4] includes the extension of the poststripper section by two more Alvarez cavities for the energy range of 5.9 to 11.3 MeV/u. The cavity length and the rf parameters are chosen to be identical to the existing cavities, which accelerate the stripped ions from 1.4 to 5.9 MeV/u.

The cavity and drift tube design is reconsidered here, this is not meant as an improvement over the original design, but rather as an allowable simplification. The associated cost saving was not a primary concern here.

While many of the ideas presented here were conceived earlier, it seemed to be too risky to incorporate them in the original Unilac construction. Experience with the operating machine and results of prototype studies substantiate the practicability of the proposed alternate designs.

Cavity and Endwalls

In the existing machine, copper plating technique has been used for all rf surfaces. It proved to be highly reliable and resilient. In two cases of severe burn-out of the goldwire rf contact rings, due to inadequate stress load, the copper surface remained intact. Depth limitations of plating bath containers restricted the sectional length of cavity units to 2.6 m. The assembly of one 13 m long tank required five bolted joints and hence expensive flange machining. These joints, which were not expected to be reopened, developed small leaks from an accidental heating-up of the tank as a consequence of a cooling fault.

Dispensable joints should be eliminated as much as possible in the redesign. The well established copper clad steel approach was reconsidered and bids obtained revealed that this material is available in adequate quality and quantities (this was not the case 12 years ago). As the result of detailed conceptual design studies, this approach was discarded for the following reasons: the copper is too soft to allow for all-metal seals and rf contact rings; nozzles had to be fitted with copper skirts and inserts; the many leak-tight welding operations and the finish of the rf surfaces seem to be laborious and expensive.

It was decided then, to reuse the plating technique, applied to rolled mild steel cylinder sections. The previous plating facility was restored at modest expense. After plating the individual sections, the ends of which are left copper free for a few cm, they will be welded together. The welding area will be plated over by a locally attached bath reservoir, which covers a segment of about one-fifth of the circumference. For the five sequential plating steps per seam, the tank must be turned in order to keep the reservoir perpendicularly positioned at the inner side of the cylinder. Gas bubbles and dust particles are thus kept away from the plating surface. Figure 1 shows a sectional view of the joint area. In order to avoid longitudinal shrinkage , a light welding seam is applied on the inside. The heavy weld will be applied to the stiffening ring at the outside, which also serves a centering fixture for both cylinder ends. The groove left by the shaped ends of the mating tank sections is used as a forevacuum channel for leak checking the welding seam. In general, a weld does not have to be leak checked if plated over subsequently.

The rolled sections are sanded on the inner surface . The final plating will reduce the roughness from about 15 μm to 0.5 to 1 μm. In the original tank design, the inner surface was machined on a vertical lathe, since the end flanges had to be machined anyway. The applied conical shape of the section was used for cell tuning, keeping the g/L ratio constant along the whole cavity. In the new design, the sections are kept cylindrical and of a constant diameter. For cell tuning, the g/L ratio is tapered. Cell dimensions are derived from LALA computations and corrected for a systematic frequency error of + 0.03 %. This error was determined by recalculations of the existing cavities.

Postcouplers were not considered in the redesign because the cavity length, normalized to the wavelength, is relatively short and field flatness is not a relevant problem, rather than the attainment of the correct frequency.

It is believed that tolerances of the average inner diameter as close as $\pm \frac{1}{0}$ mm can be obtained. The length of the steel slab is cut to the length of the neutral line of the circumference. After tag welding of the longitudinal seam, the average diameter is derived from eight diameter measurements equally distributed over the inner circumference. If the result is found to be off tolerance, the tag weldings will be opened and the mating edges will be ground, or sheet metal spacers will be inserted, when the diameter turned out to be larger or smaller respectively. No further shrinkage during the final weld will occur if only a light welding seam is applied. As in the existing cavities, no tuning bar is necessary if the above-mentioned tolerances are observed. Fixed tuning bodies of 15 cm diameter can be inserted via flanges, four of which are provided on each section for fixed and movable tuners.

As a standard at the Unilac, the Con Flat seal will be used on all usual flanges for tuners, vacuum pumps, pick-up probes and drift tube stem heads. On the existing cavities, those joints have been machined directly into the cavity wall. At the delicate knife-edge, none of the nearly 300 flanges has ever been damaged or worn out from frequent openings. In order to avoid the requirement of large and expensive milling machines for cavity manufacturing, the Con Flat profile will not be cut into an oversized wall thickness. Instead, flat blocks of adequate thickness and size will be machined on small automated milling machines and welded into a flame-cut hole on the 20 mm thick cavity wall. Figure 2 shows an example.

Wall cooling will be provided by cooling jackets, welded on the cavity in four segments; the clearance is set by pressed-in dimples. The earlier concept of counter flow channels was never applied and no thought will be given to temperature control of the coolant circuit.

Figure 3 shows the stem head. The adjustment fixture is kept identical to the first design. The adjustment base is now a plate, levelled by three threaded studs, instead of a machined nozzle. The stainless steel bellow is placed outside the cavity field as before.

All accessory components, monitoring probes, tuners, tank supports and the vacuum system will be as in the first design. The drive loop concept, however, was changed.[3]

The end walls of the original design consisted of a thin rf wall, supported by a heavy spider, and a cast bulkhead exposed to atmospheric pressure. The volume in between, containing water joints and quadrupole leads, was pumped by an auxiliary vacuum system. Though the pressure interlock and the safety valve connecting the high vacuum and the auxiliary vacuum volume never failed in case of an accidental pressure rise in either system, this concept is felt to be overly sophisticated. A 90-mm thick endplate is planned as a rf and pressure wall, which eventually has to be reinforced by stiffening ribs. The resulting inward bend of 0.3 mm is tolerable from the field flatness consideration. Cooling channels will be cut into the plate on the rf side and covered by a welded strip. The piece will be copper plated on the machined inside surface.

The above mentioned endplate design, requiring machined surfaces and a vacuum joint, seems to present an inconsistency in the concept of a simplified design. Therefore it was at first envisaged, to weld a deep pressed bulkhead with a cylindrical collar to the end sections of the tank. Copper plating of the seam could have been performed as described before. Considerations on the rf field pattern in the end cell with a slightly spherical end wall (bulk head) did not result in a consistent cell geometry, which meets the boundary conditions of the field pattern in the neighboring cylindrical cell, and probably would have presented a flatness perturbation. This bulkhead approach, which really would reduce an Alvarez cavity to an oil-tank item, could unfortunately not be brought to a viable solution under the time constraints of the upgrading project. A bolted end joint had to be used instead, because the rectangular corner area of a welded flat end-plate could not be copper plated reliably.

At the Unilac the standard approach for making a large diameter cavity joint is to use a 1.5 mm diameter gold wire squeezed to 50% of its original thickness between properly machined and copper plated flange surfaces. Wire gages ranging from 1.2 to 1.8 mm are stocked in case of tolerance excursions of flange dimensions. For the purpose of leak checking without pumping the whole cavity, an elastomer-sealed fore-vacuum groove is provided behind the gold wire gasket. In the few cases where the metal seal became leaky, the flange rings were found to be too weak. A considerably heavier flange geometry was selected for the new design, as in Fig. 4; the machining will be done before welding the flange to the cylinder wall.

The question of whether gold wire is really superior to aluminum wire, was not reconsidered. Earlier experience on models and on one-scale cavities indicated a Q loss of several percent. Techniques for plating gold and silver on aluminum wires were developed, but no convincing cost savings over a reprocessible pure metal wire can be expected. Alternative contact schemes, like an O-ring surrounded partly by a copper strip as used in the KEK linac, have also been considered, but finally were discarded because of the lack of experience in a high duty factor machine.

The above-outlined design changes have been applied to a prototype, made up of two short tank sections of full scale diameter. Tolerance expectations and plating technology were derived from this experience.

Drift Tubes

The original drift tube design was mostly a copy of the NAL and BNL concept, equipped with a dc quadrupole equal to the LAMPF design. The components were machined from OFHC copper to close tolerances and assembled by furnace brazing and electron beam welding. Those sophisticated technologies are probably mandatory for microwave tubes, but are unnecessary for Alvarez drift tubes of usual size. None of the nearly 200 units in the Unilac ever developed a leak or a quadrupole failure; however, this design would be overly expensive to fabricate today.

When reconstructing the HILAC in 1971[5] LBL engineers demonstrated a much cheaper solution, based on tape-wound quadrupoles and flood-cooling of coil and outer shell by a single coolant circuit. No commercial manufacturing sources for the tape-wound technique could be found in Europe and therefore the LBL design could not easily be adopted.

The solution presented here was stimulated by the following facts: a) dimensional tolerances of ± 0.2 mm, as used in the first design, can be relaxed to ± 0.5 mm if they are of random nature; b) plating techniques can avoid the expensive solid copper approach; c) subcontracting mechanical pieces and inhouse assembly and testing avoids the overhead charges of the microwave tube industry.

Figure 5 presents a longitudinal section of the assembly. The quadrupole, with classical hollow conductor coils, is assembled on the machined stainless steel bore-tube, which supports the magnet inside the drift-tube can and provides a close target fit for the optical alignment of the magnetic axis.

In the earlier drift tube procurement, not a single one was found with the magnetic axis being off the mechanical axis. Therefore, the measurement of the magnetic axis and eventual correction of the bore-centering was not considered; the dimensional inspection of yoke and pole pieces was deemed to be sufficient. Coils will be checked for shorted windings prior to assembly. The dimensions of the quadrupole are all the same throughout the 69 tubes and identical to the last drift tube of the existing Alvarez Tank II. From the particle dynamics standpoint, one could consider leaving out every second quadrupole, or even more, but this would impair eventual future multi-particle acceleration. All lenses in a tank are connected in series. No flow switches will be used for coil protection, as is also the case on the existing machine. Instead, thermal switches are soldered to the current leads leaving the stem heads.

The rf power dissipation on the drift tube surface is in the order of 2 kW and perfect shell cooling is necessary. It is provided by a double wall design for caps and cylinder body, made from stainless steel for welding considerations. The caps are simply roll-pressed over a mandril on a lathe, starting from a disc-shaped sheet metal piece, 2 mm thick. The cylindrical body is rolled from a sheet metal slab and longitudinally seam welded. Caps and cylinders obtain a shoulder fit, cut on a lathe, in order to ease assembly and centering prior to welding the joint.

Stems are welded to extruded nozzles on the cylindrical parts. An eventual tilt of the stems will be corrected for by hand bending during the final alignment in the tank. Two stems per drift tube will be used as in the existing machine, which has demonstrated perfect beam stability. On several occasions of alignment check-out, not a single drift tube was found to be displaced from the original specifications.

No particular care is taken in protecting the drift tube surface, nor in removing the welded beads. Scratches on the cap surfaces, originating from the roll-pressing, are not considered to be detrimental for reliable high gradient operation. The completely assembled drift tube will be electropolished briefly, to remove oxides and grease. During the plating process, the drift tube is just hung between two anode plates. No auxiliary anodes, screening or fluid steering fixtures are used. After receiving a thin nickel strike, copper plating takes four hours for the specified thickness of 0.2 mm to be obtained. In the area between the stems and at the entrance of the bore-tube, the plating is only about 0.07 mm, but still thick enough.

In addition to one plating sample, a complete drift tube assembly was manufactured and plated. The dimensional tolerances seem to be easily kept below ± 0.2 mm, which is less than necessary. This prototype is installed in the existing Alvarez tank, Tank II, for long term examination of the surface properties.

The author acknowledges the enthusiastic effort of W. Bleuel during the drift tube design and fabrication.

References

[1] T. Niewodniczanski, E. Malwitz,"Mechanical Design Features of the Unilac," 1972 Proton Linear Accelerator Conference, 103 (1972) Los Alamos.

[2] D. Böhne,"The Unilac, Development and Present Status", 1976 Proton Linear Accelerator Conference Chalk River, 2 (November 1976).

[3] D. Böhne,"Recent Improvements of Accelerator Components at the Unilac," proceedings this conference.

[4] N. Angert et al.,"The Unilac Upgrading Program," proceedings this conference.

[5] R.M. Main,"Modifications of the Berkeley Hilac," Proceedings of the 1970 Proton Linear Accelerator Conference, 949, NAL, Batavia, Ill. (1970).

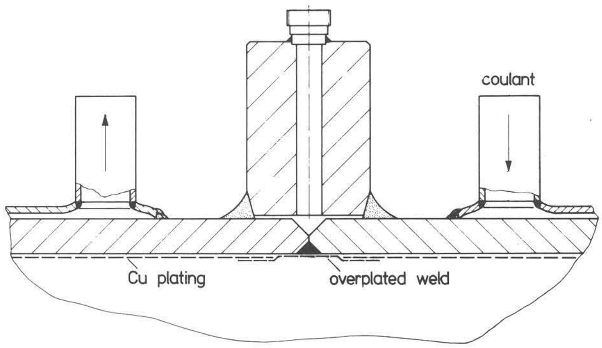

Fig. 1 Welded joint of copper plated cavity sections. The welding seam is plated over by a locally attached bath reservoir.

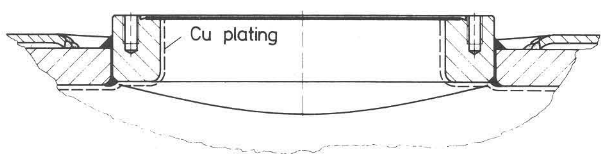

Fig. 2 Con Flat flange welded into the cavity wall. The copper deposit smoothly covers the flange surface and the knife-edge area on the outside.

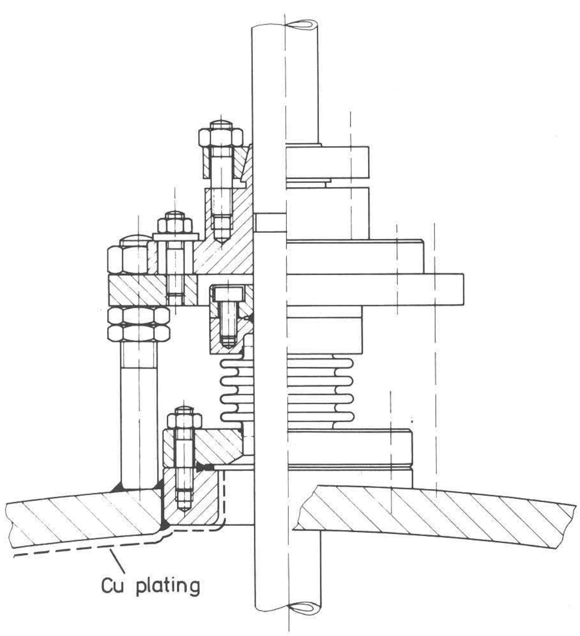

Fig. 3 Stem head supported by a levelled plate. The stem can be adjusted in three dimensions and is sealed to the cavity by the bellow assembly clamped to the stem and bolted to the welded-in Con Flat flange.

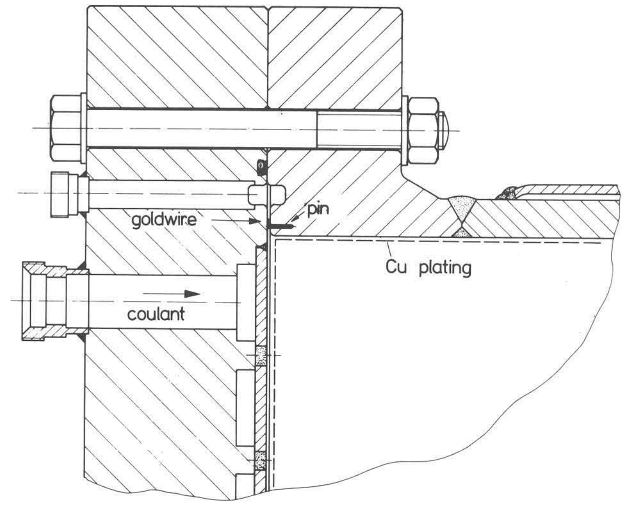

Fig. 4 End wall sealed by a gold wire to the cavity flange. The gold wire is held in place by small pins. A backing vacuum groove allows leak checking individual seals.

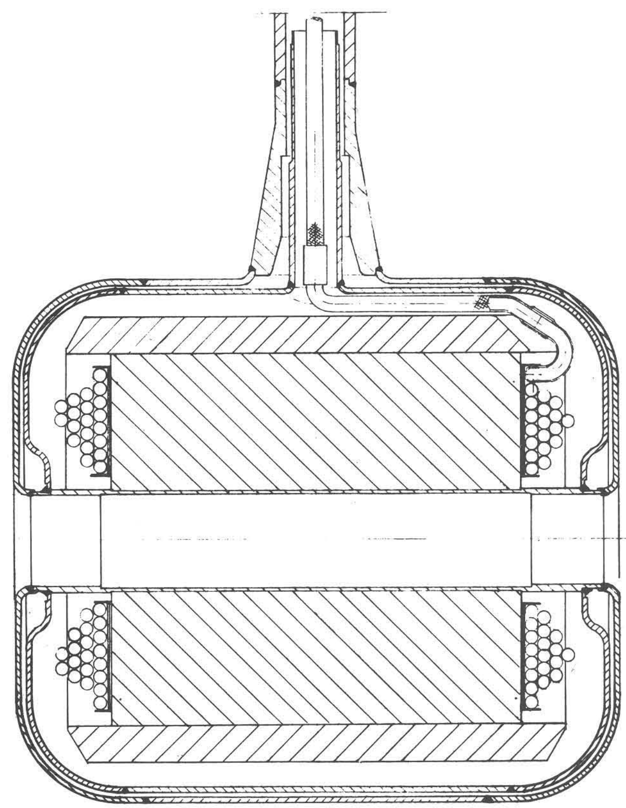

Fig. 5 Drift tube assembly. The quadrupole is supported by the bore-tube and held in place by a positioning screw in the second stem base. Joints of caps, bore tube, cylindrical body and stems are welded to plating.