PIGMI MECHANICAL FABRICATION*

Valgene E. Hart
University of California
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Introduction

A prime goal of the mechanical design effort associated with the PIGMI (Pion Generator for Medical Irradiations) program is to investigate new materials and fabrication techniques in an effort to obtain increased machine efficiency and reliability at a reasonable cost. The following discussion deals with the modeling program that LASL is pursuing for 450-MHz and 1350-MHz PIGMI development.

Modeling 1350-MHz Components

Several 1350-MHz one-half cell segments have been machined from OFHC copper, 1100 aluminum and 1015 carbon steel. These segments have been used to test copper plating and joining techniques, and also to obtain relative rf "Q" measurements after being assembled into a one-cell cavity. Fig. 1 illustrates a typical one-cell cavity that has been prepared for electron-beam (EB) welding. These cavities are 170-mm O.D. and 76-mm overall thickness. The stepped joints as shown in Fig. 1 are designed to provide three important functions for an rf cavity joint: (1) optimum electrical contact made possible by copper-plated surfaces which are held tightly together by shrinkage of the weld that has a 0.050-mm gap designed to induce shrinkage, (2) a weld penetration stop to preclude welding damage to the electrical joint and copper contamination of the vacuum weld, and (3) precision transverse alignment. Two bright copper-plated aluminum segments prepared for welding are shown in Fig. 2. A completed EB welded cavity is shown in Fig. 3. Cavity wall thickness is 9.52 mm with a weld penetration of 7.94 mm. All EB welds have been vacuum tight. Brazed joints are designed with flat faces and dowel pin alignment to make alloy placement as simple as possible. All brazing is done in our hydrogen furnaces using standard gold, copper, silver and nickel alloys.

Materials used for test segments have included copper, steel and aluminum. OFHC copper can be considered an optimum material for current and heat conduction; plus it can be brazed into complicated assemblies using standard brazing methods. Steel must be copper plated to have acceptable electrical capabilities but can be joined by brazing and welding with little difficulty. Our test cavities were machined from standard 1015 carbon steel. Aluminum is one of the more difficult metals to use for accelerator cavity applications. A zinc pre-plate is required before aluminum can be copper plated. Heavy copper plate (0.25-0.50 mm) can experience skin failure due to differential thermal expansion caused by large temperature changes such as vacuum bake-out or brazing. Joining aluminum cavities is limited to welding because aluminum brazing must be done with flux. The alloy chosen to best satisfy requirements for plating, welding and forming was 1100 aluminum.

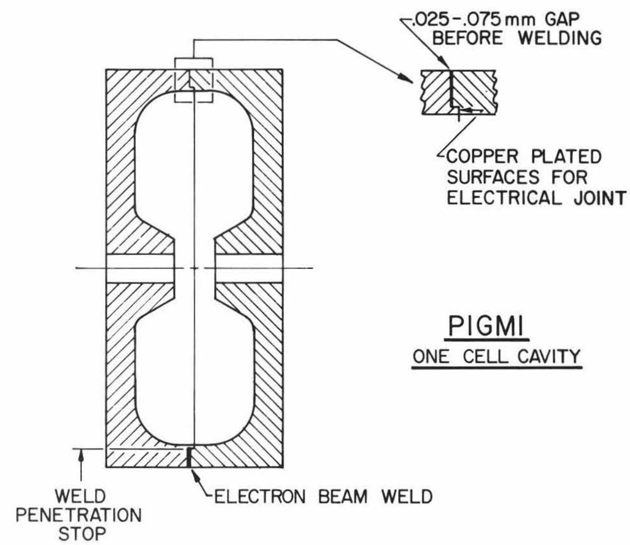

Fig. 1. PIGMI One-Cell Cavity

Fig. 2. 1350-MHz Aluminum Segments -- Bright Copper Plated

Copper plating of aluminum and steel segments has been done using standard eletroplating methods and also by the bright acid copper plating technique. The standard electrolytic copper has the well known problems of rough surface finish and non-uniform plating thickness. Bright leveling copper plating is a standard commercial process that has been used in the automotive industry since 1960 to achieve smooth surfaces for chrome-plated

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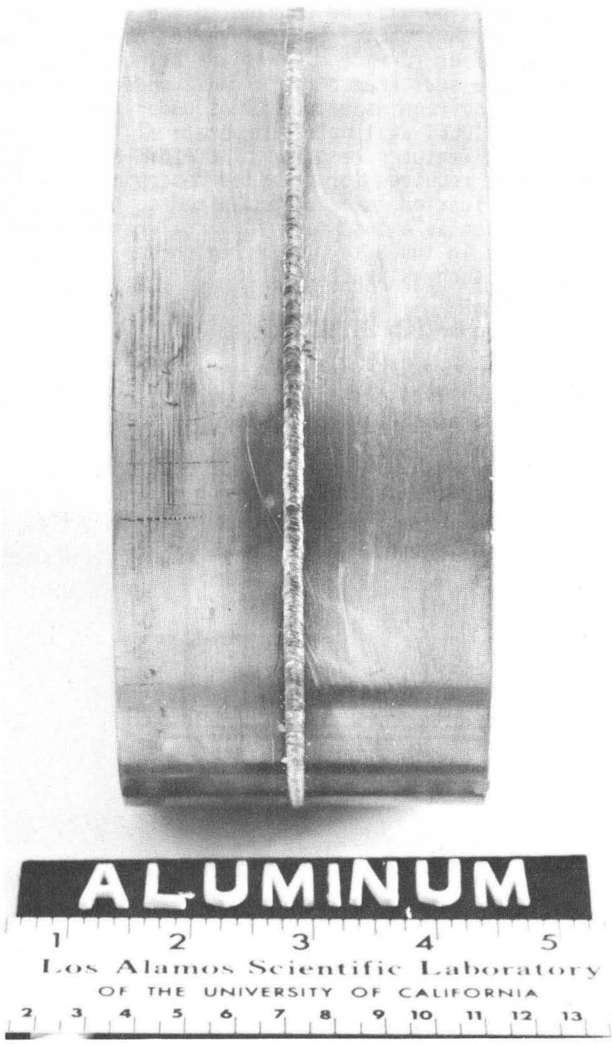

Fig. 3. Electron Beam Welded Cavity

parts.[1] More recently this process is being used by accelerator builders and the electronic industry. The leveling characteristic of bright copper reduces the surface finish quality required of the base material. Aluminum and steel segments have been bright copper plated at LASL with the resulting smooth bright copper finish having a deeper or darker color than standard copper plating. A concern that the organic brightening agent might boil out of a plated surface when exposed to elevated temperatures prompted a bake-out test of plated segments. Bright copper-plated segments of aluminum and steel were heated in an argon atmosphere for two hours at ∿ 480°C with no gross evidence of surface contamination or staining. The color did become darker and the surface of the aluminum part had craze-type marks probably caused by differential expansion as discussed previously. Vacuum bake-out and outgassing studies will be required before the plating can be considered completely tested.

A summary of material fabrication characteristics is given in Table I. Copper with a higher initial cost is still a good value for accelerator fabrication. It does not require secondary operations such as plating, can be joined into assemblies at commercial brazing facilities, and has optimum physical properties. Table II lists the "Q" value measurements obtained on various cavities under different conditions. The increased "Q" value obtained after welding indicates better joint contact due to weld shrinkage pulling surfaces together. Cavities not permanently joined were clamped in a hydraulic press to make joint contact during the measurement. Values obtained for the bright copper-plated cavities indicate that bake-out makes a definite improvement in "Q". This results from decreased surface contamination after bake-out. The standard of comparison was a brazed OFHC copper cavity with a "Q" of 17,125.

TABLE I

PIGMI MATERIAL CHARACTERISTICS

Material	Basic Cost	Density	Volume Cost	Weight Of One Cell Cavity	Initial Form	Copper Plating	Joining Methods
OFHC Copper	\$3.31/kg	8940 kg/m³	\$29591/m³	8.4 kg	Shaped Forging Or Blank Billet	Not Required	Furnace Brazing
1100 Aluminum	\$3.31/kg	2768 kg/m³	\$9162/m³	2.6kg	Shaped Forging Or Blank Billet	Pre-Plate Required	E.B. Welding
1015 Steel	\$0.88/kg	7833 kg/m³	\$6893/m³	7.5kg	Shaped Forging Or Blank Billet	Plate Directly	Furnace Brazing Or E.B. Welding

TABLE II

"Q" MEASUREMENTS 1350 MHz CAVITIES

Cavity Description	Before Welding	After Welding	Before Bake-Out	After Bake-Out	After Brazing
ALUMINUM Electroplate Bare Joint Plated Bore	9518	13700			
STEEL Electroplate Bare Joint Plated Bore	7138	13689			
STEEL Electroplate Plated Joint Plated Bore	11681	16288			
ALUMINUM Bright Plate Plated Joint Bare Bore 1000# Squeeze			13817	16060	
STEEL Bright Plate Plated Joint Bare Bore 7000# Squeeze			10258	13498	
OFHC COPPER					17125

450-MHz Components

A full-power, six-cell model of the 450-MHz drift-tube linac structure, known as "PIGLET" is being designed for use in field gradient studies and mechanical fabrication development. Major design features of "PIGLET" are illustrated in Figs. 4 and 5. The resonant tank is made from a standard 394-mm I.D., 304 stainless-steel pipe which will be copper plated on the interior after the openings have been finish machined. Initial drift tubes will be water-cooled shells without magnets. Later versions of drift tubes will have permanent magnet quadrupole magnets.[2] Drift tubes are installed through a slot in the tank wall and mounted on a rigid stiffback saddle. Drift-tube alignment will be fixed by precision jig boring the stem mounting holes in the tank saddle. A single spherical nut will hold the drift tube in the saddle to provide a simple and reliable stem mounting arrangement. End faces of the drift tubes have 10° slope or cant to test the theory that non-parallel surfaces will be less likely to propagate a spark in high-voltage fields. The drift tube access slot will be filled by a water-cooled copper slug whose mounting flange also functions as a portion of the vacuum manifold. RF power from the WR2100 waveguide will be coupled to the tank by an iris in the tank wall. Several varieties of aluminum and copper rf-vacuum seals are being tested to develop a seal that performs well under rf power and that also remains vacuum tight under thermal cycling. PIGLET will not incorporate all the desirable design features required of a PIGMI accelerator due to time required for detailed design and testing. PIGLET fabrication is being expedited so that its main function as a test tank for acceleration gradient studies in the 5 to 8 MV/m region can be started as soon as practical.

References

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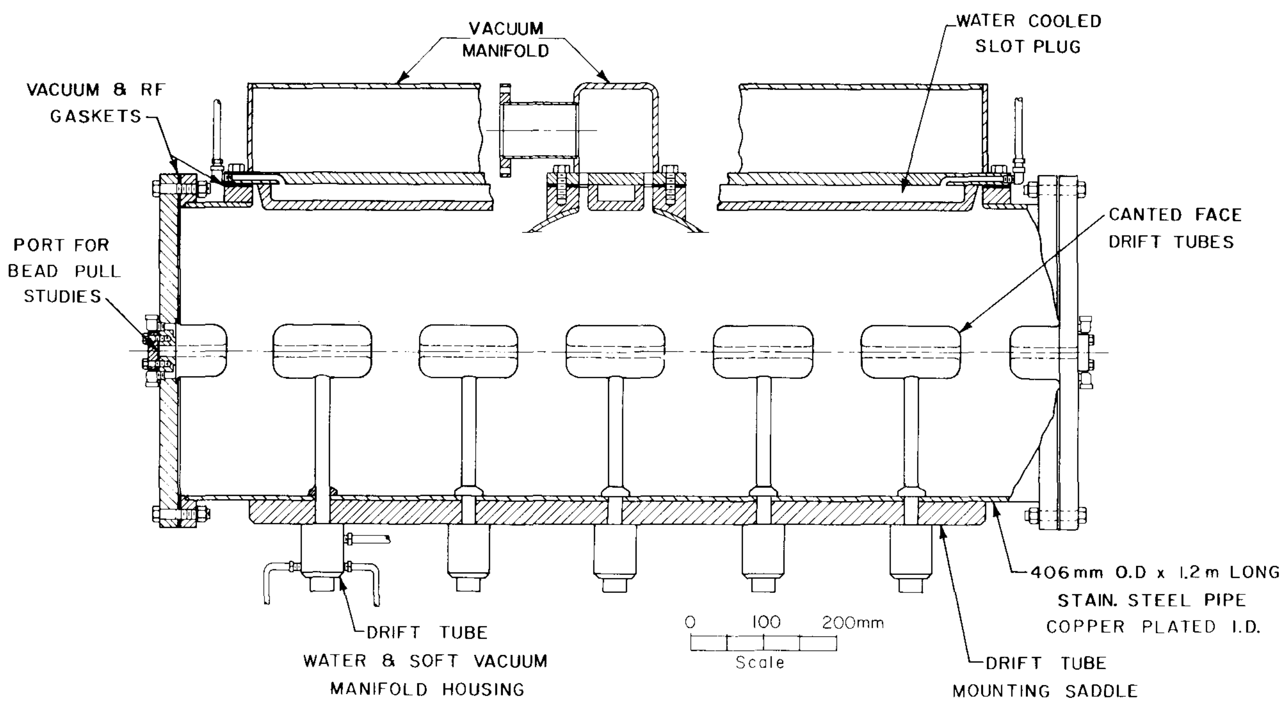

Fig. 4 PIGLET Elevation Section

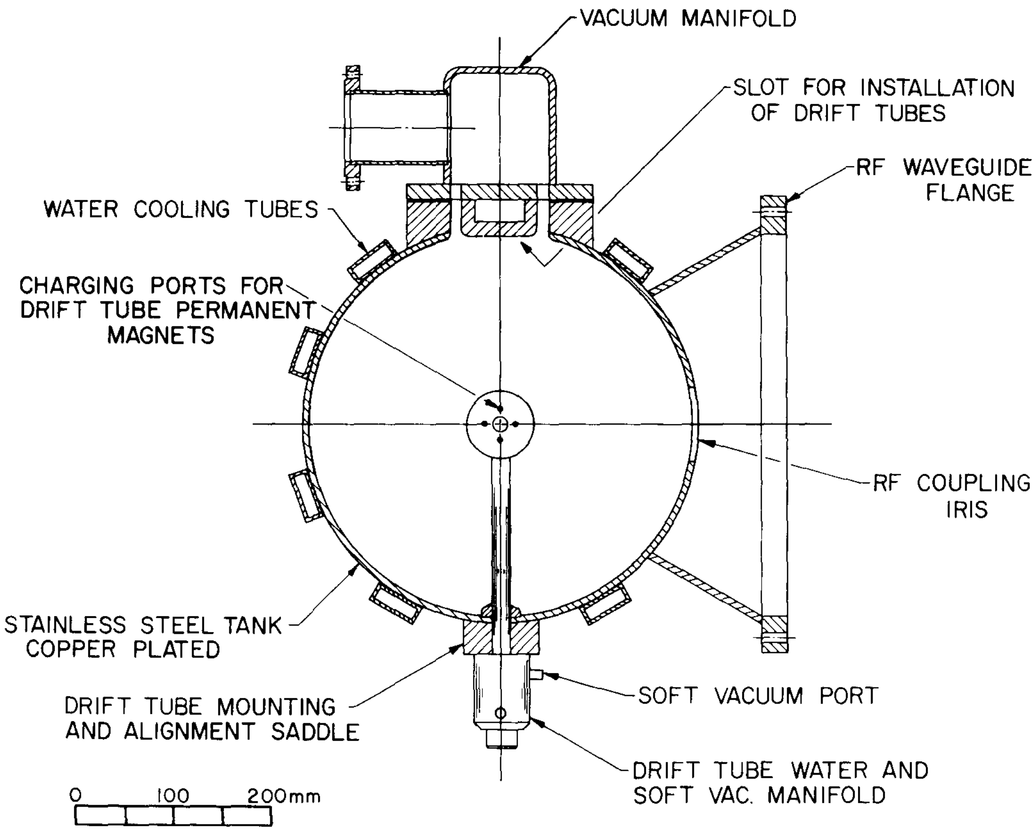

Fig. 5. PIGLET Cross Section