Conf-731114--11

DEVELOPMENT, FABRICATION AND ASSEMBLY OF A THIN WALL, LOW ASPECT RATIO LINER AND THE ENCLOSED TUNGSTEN LIMITER FOR ORMAK

S. M. DeCAMP, Jr., and J. D. RYLANDER, Oak Ridge National Laboratory*, Oak Ridge, Tennessee

Summary

The regime in which a Tokamak operates depends largely on the amount of impurities present. To keep the plasma as pure as possible, the plasma region is surrounded by a thin but vacuum tight stainless steel liner.

The ORMAK liner is a stainless steel torus having a major radius of 31 5/16 inches and a minor radius of 9 7/8 inches. Wall thickness of the liner is 10 mils. The liner consists of 26 sections welded together to form two halves plus two special sections. These special sections contain the limiter and laser ports[1]. The two special sections are also used to make the final closure of the liner after it has been placed inside the aluminum torus (see Fig. 1). The liner contains 53 diagnostic ports and 4 injection beam ports.

Design criteria for the liner were as follows:

1. total vacuum leak rate of less than 10 l/sec
2. high ohmic liner resistance
3. many ports for diagnostic access
4. tangential injection ports capable of limited angular change
5. ability to assemble liner inside the torus with minimum clearance and maintain registration of diagnostic ports with torus and have electrical isolation of the liner
6. should be able to operate over a temperature range of -200°C to +200°C
7. outgassing rate of the liner should be held to a minimum
8. must have electrical continuity in all directions

## Liner Problems

In order to obtain high ohmic resistance it was decided to make the liner of .010 thick 304L stainless steel. The difficulty of welding this thin material suggested roll seam welding or continuous spot welding as a method of fabrication. Spot welding equipment readily available led us to follow the spot welding approach. Liner design indicated only two roll spot welding techniques need be worked out. One is to join one liner section to another (.010 to .010) and the second to join heavier pieces to the liner, such as access ports and beam tube assemblies. All heavy parts to be attached to the liner were designed to have a .038 thick flange suitable for welding to the liner. Welding heads were designed with driven roller contacts to permit coordination of spot location and current pulse. Fig. 2 shows a typical welding head. Individual spot welds are used to hold pieces together during the roll spot operation.

Liner sections are formed on a mandrel with a 1/10 inch flange turned up on both sides to allow for welding to the adjacent section. The flange also gives the liner dimensional stability.

While the liner section is on this forming mandrel, an index mark is scribed for reference in locating access ports and registration of one section to another in final assembly.

Access ports are made up of a machined socket with a "c" ring seat in the bore and bayonet studs on the outside. The machined part is then TIG welded to a .038 thick flange shaped to fit the liner. Since the liner has very little strength, a socket and plug arrangement using a metal "c" ring is used to make a vacuum tight seal. Both the socket and plug have bayonet studs arranged such that a special tool (Fig. 3) can apply the necessary 200 pounds of force between the socket and plug to make or break the seal without applying undue force to the liner. Special adaptations in tooling are required for some of the more difficult port locations. Three different size plugs and sockets are used to accommodate space requirements around the liner.

After fabrication of a liner section, access port locations are marked and appropriate holes cut into these sections. Index marks are also scribed for socket locations. Sockets are then spot welded to the liner. A number of individual spot welds between socket flange and liner must be made to prevent creep between the two parts which would cause difficulty in obtaining a vacuum tight weld during the roll spot welding operation. Clips, both internal and external, to hold diagnostic equipment are welded on next since almost no work can be done on a section once it has been assembled to its neighbor. After a liner section is finished it is vacuum baked and gold plated[2].

Assembly of a liner half is accomplished by placing all sections in a fixture and checking proper location of ports and overall liner dimensions; then one section at a time is spot welded to its adjacent section. The two pieces now spot welded together are removed from the assembly fixture and put in a special welding head (Fig. 4) and the sections joined with a vacuum tight (roll spot) weld. After welding the joined sections are returned to the assembly fixture and the process just described is repeated until the liner half is completed. As additional sections of the liner are welded together it becomes more difficult to handle, therefore an assembly sequence is followed that keeps handling of large pieces to a minimum.

One of the more difficult problems in constructing the liner was to fabricate a flexible joint for attaching the injection beam drift tube to the liner (Fig. 5). The opening into the liner is an ellipse about 3 x 6 inches. The joint had to allow for angular movement for beam alignment, while at the same time it could not extend outside or inside the liner more than about 3/8 inch.

Flexibility was obtained by hand fabricating an elliptical offset bellows of three convolutions. Each section of the bellows was formed over a die using .005 thick stainless steel. The sections are then roll spot welded together to form the bellows. The offset in the bellows is obtained by forming the inner and outer flanges about different centers. The ends of the bellows are roll spot welded to .038 material which on one end is attached to the liner and on the other end to a 1/2 inch thick elliptical flange used to join the drift tube to the bellows after the liner is assembled in the torus. An aluminum foil gasket is used to seal this joint.

The copper drift tube of .090 material was hand formed in two pieces over a mandrel and then TIG welded together. The drift tube dimensions vary from a 3" diameter on one end to a 3 x 6 ellipse on the other with two small offsets in between to allow for clearance between toroidal field coils.

Final closure of the liner is accomplished by inserting the limiter and laser sections between the liner halves. The joint is made using special marmon flanges with a gold "o" ring seal.

The limiter (Fig. 6) is a link-belt assembly of forged tungsten pieces approximately 1/8 x 1/2 x 2 in size. The height of the tungsten pieces is varied slightly so that a maximum side area is exposed to the plasma without one link having to take all the heat load. The links are mounted on stainless steel pins supported by a stainless steel frame which is made in two parts. The links are a loose fit on the pins to allow for thermal expansion between parts. The supporting frame is made in two parts, again, to allow for expansion. A 1/4 inch O.D. stainless steel tube forms a part of the frame and can be used for cooling if necessary. These parts are mounted inside a second ring or frame which forms a part of the liner shell and contains the marmon flanges for liner closure. Each of the two limiter halves is attached to the outer shell at one point by insulated feed through bushings. Other parts are supported by alumina stand offs.

The liner has to float, both mechanically and electrically, inside the aluminum torus and, at the same time, operate over a 400°C differential. To meet these requirements a set of eight radial pins are mounted in the torus using Teflon bushings as sliding mounts. The pins are free to move in the radial direction but are restrained in other directions. Since the pins are all radially placed, any unbalanced forces should restore the liner to its correct position in the center of the torus.

After several months in operation the liner has a leak rate of slightly more than 10 l/sec, ohmic resistance of the liner is as predicted, and no difficulty has been experienced with the drift tube or drift tube bellows. Liner assembly occurred with a minimum of trouble and diagnostic ports were within tolerance with respect to the aluminum torus.

The liner has been cycled many times from -200°C to 150°C and has worked satisfactorily over a period of several months; however, some difficulty has been experienced with the liner support system.

Outgassing of the liner has been satisfactory but additional work is required on some sections of the liner pumping system.

[1] J. S. Culver and M. Murakami Mechanical and Optical Coupling of a Thomson Scattering Laser $T_e$ Measurement to the ORMAK Machine.

[2] J. E. Simpkins Passivation of the ORMAK Vacuum Liner.

*Operated by Union Carbide Corp. for the USAEC.

## Figure Captions

Fig. 1. Section of ORMAK Liner During final assembly.

Fig. 2. Roll Spot Welding Head Used to Weld Sockets to Liner.

Fig. 3. Socket, Plug and Assembly Tool.

Fig. 4. Welding Head and Fixture Used to Join Liner Sections Together.

Fig. 5. Drift Tube and Bellows Assembled to Liner.

Fig. 6. ORMAK Limiter Assembled to Liner Section.

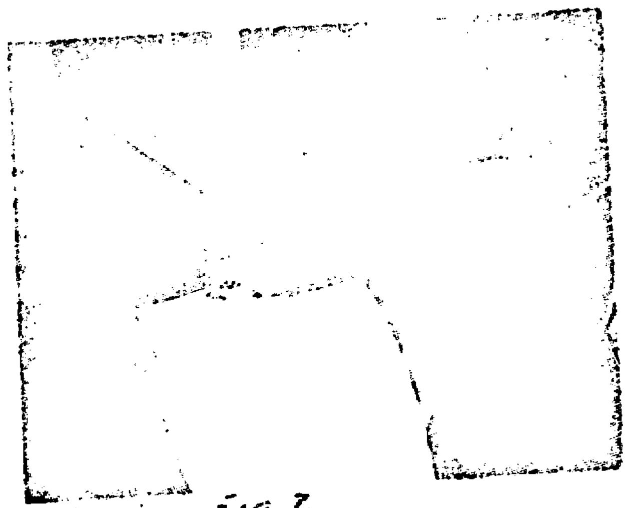

FIG 2