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A LARGE RECTANGULAR BELLOWS VALVE

T. H. Batzer, M. O. Calderon, R. T. Hawkins, R. J. Nagel, and S. R. Thomas, Jr.

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Magnetic fusion energy is one of the more viable alternatives today for extending electric power production beyond available reserves of petroleum and coal for the future. One of the essential steps in extending knowledge in this field is the development of hardware which can cope with the extremes of temperature and vacuum projected for the reactor technology of the future. Such a device requires a plasma confined by a magnetic field at temperatures of millions of degrees and at high vacuum. To maintain this plasma requires the injection of neutral molecules of hydrogen or deuterium in high energy beams which are then trapped in the magnetic field by exchanging electrical charge with the confined plasma. (See Fig. 1.) These beams require periodic maintenance while the machine operates, so isolation of these components by valving is a desirable characteristic.

The energy densities of these beams have practical limits, which requires them to have large rectangular cross-sections. Thus, large valves having areas of 1 m^2 would be typical. Traditional cam-seated vacuum gate valves have been built on this order; but are bulky, costly, and heavy. Improvement is possible by using a bellows gate for the seal (Fig. 2.) Instead of a large plate with cams requiring rigid components for mechanical advantage, one can use low internal pressures to attain the high seal forces necessary for vacuum valves. In the case of this design, 30 psi internal pressure will give 200 lbs./in. load for o-ring sealing. This is an adequate load for sealing against vacuum in either direction. The entire gate assembly travels on wheels which roll into detents in the valve body when positioned over the aperture to allow proper seating and unseating. Scale-model testing of the bellows

proved this necessary because the bellows showed an increase of spring rate with cycling.

The important feature of this design is the bellows and the welding techniques which have been developed for it. Originally, the rectangular welded bellows were developed as adjustable seals between a vacuum vessel and the neutral beam modules. As experiments grew, and the number of beams increased, physical separation from the magnetic confinement area for maintenance reasons became more important; hence, the need for a compact valve.

The bellows consists of thin sheet bands, called convolutions, which are milled along their interior and exterior perimeters and then continuously edge welded by heliarc. (Fig. 3.) The length of the perimeter of the convolutions is independent of the bellows design. Experience has shown that the bellows forces can best be modeled as diaphragm stresses. Therefore, the important parameters besides material properties are the convolution-band width, thickness, and imposed stress normal to the surface (external pressures). In the valve designed, the bandwidth is 1 inch, the thickness is .036 inches and design normal stress is 30 psi. Experience has shown type 316 stainless steel to be preferred stock for fabrication because of its non-magnetic properties, behavior at cryogenic temperatures and resistance to carbon precipitation at the weld joints. The convolutions are all deburred before welding and welded with beads sufficient to cover the combined thickness of the joined sheets. The number of convolutions is based upon the amount of travel desired. Usually, the travel is equal to one-half the combined thickness of the total number of sheets.

The mating of the bellows weldment to the gate plate is accomplished by machining the edge of the plateface to resemble another convolution edge,

though it is considerably thicker than the bellows convolutions. (See Fig. 4.) The size and shape of this edge has been found to be most resistant to fatigue failure. Type 304 stainless steel is an acceptable material here.

Before design of the valve was completed, a model of the bellows, which was quarter-size in perimeter and full-size in all other respects, was constructed and tested for fatigue failure of the welds. The model (Fig. 5.) was placed in a vacuum as high as 2×10^{-7} Torr with helium as the inflating gas. This allowed the most stringent leak detection possible as the model was cycled. After 1000 cycles at design pressure (30 psi) and about 250 cycles which ranged up to twice design pressure, the bellows weldment has not developed any fatigue crack leaks. This represents about 2 to 3 years of operation and includes foreseeable mistreatment of the valve without a failure.

Present design allows a valve aperture of 20 inches X 36 inches, a valve body which is about 5 inches thick X 47 inches wide X 120 inches tall, and weighs approximately 3000 lbs. A cam-seated valve would be about twice as thick, weigh four times as much, and by our estimate, cost twice as much.

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FIG. 1 SCHEMATIC OF A MAGNETIC CONFINEMENT EXPERIMENT

FIG. 2 A RECTANGULAR BELLOWS VALVE

SECTION OF BELLOWS WELDMENT

FIG 3

SECTION DETAIL OF GATE PLATE JOINT
TO BELLOWS WELDMENT

FIG 4

FIG. 5 TEST MODEL OF THE BELLOWS WELDMENT

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