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Conceptual Design of a Calorimeter and Residual Ion Dump for the ITER Negative Ion Injectors

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Neutral Beam Heating Division under Task Agreement T 335.5 ITER

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1. ABSTRACT

A conceptual design for the ITER Negative Ion Injectors' Calorimeter and Residual Ion Dump systems has been carried out. The work was undertaken in support of detailed studies performed by the Russian Federation. Concepts for both systems incorporate actively water cooled Hypervapotrons as the primary beam stopping elements.

The Calorimeter drive has been based on the utilisation of a novel force translation system via magnetic coupling.

The Residual Ion Dump necessitates the use of double sided hypervapotron elements in order to cater for the restricted space envelope defined by the Accelerator Grid hole pattern.

2. CONCEPTUAL DESIGN

2.1 Calorimeter

In order to alleviate the problems associated with kinematic penetration of vacuum boundaries system based on magnetic coupling has been chosen as the actuation method by which the Calorimeter gates are positioned. This method has been successfully demonstrated and life tested on the ITER Neutral Beam Fast Shutter scale model (Task Agreement T 335.6 ITER).

Two options regarding the drive have been considered, a) by the use of individual drive mechanisms to each Calorimeter gate with the line of action along which the force is transmitted being perpendicular to the major axis of beamline and b) using a single common drive mechanism situated at the front of the Injector Vessel with its drive line of action parallel to the beam line axis.

2.1.1 Individual drive mechanism (Option a)

Fig 1 displays the proposed layout. Penetrations on either side of the Injector Vessel and positioned towards the bottom of the vessel house each individual Calorimeter gate magnetic drive system. Each actuation arm has a horizontal pivot in order to facilitate the movement required whilst rotating the bell crank connector through the required angle necessary for Calorimeter Gate operation. The typical stroke required for the Calorimeter gate to translate from fully open to fully closed would be ~ 320mm.

The advantages of this option are:-

- The drive mechanism is less complicated.
- It would enable each Calorimeter gate to be operated separately if required.

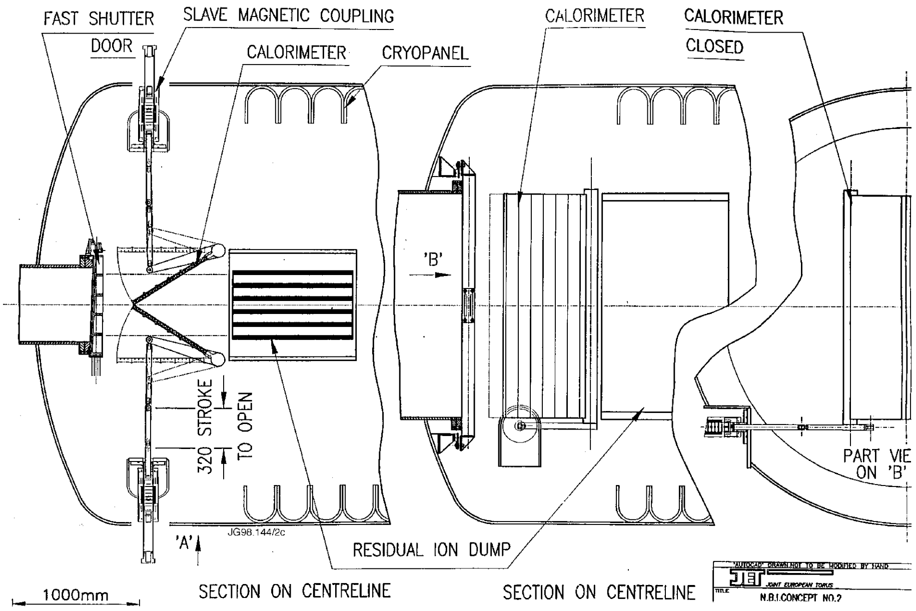

Fig.1:

2.1.2 Common drive mechanism (Option b)

Fig 2 displays the layout for a single drive operating synchronised Calorimeter gates. The single magnetic drive system is positioned well below the beam centre line at the front of the Injector Vessel. The actuation arm divides within the vessel and connects to each Calorimeter gate via a bell crank situated at the gate's axis of rotation. A horizontal pivot is required in each actuation arm in order to facilitate the linear to rotational translations required during operation of the gates.

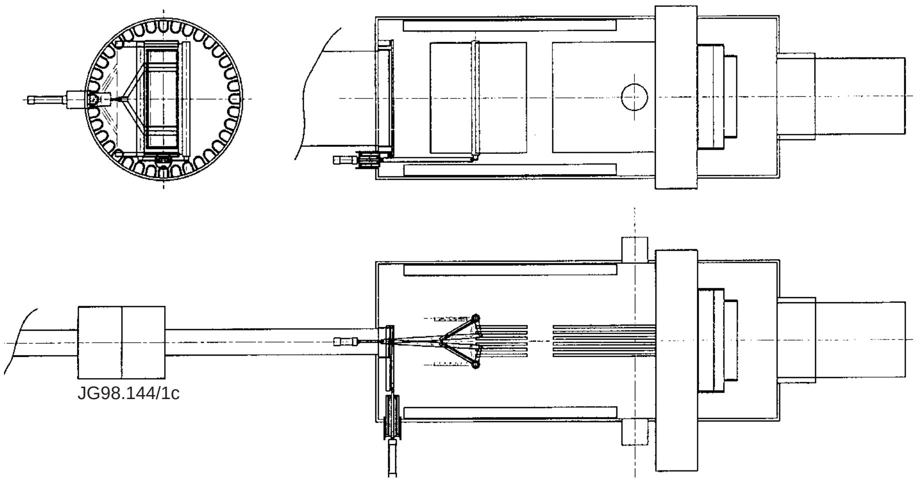

Fig.2: Schematic showing calorimeter doors operated from the front of the NB vessel.

The advantages of this option are:-

* The option requires only one penetration into the Injector Vessel.

- The drive mechanism could be designed into the front end module which also contains the Fast Shutter assembly.
- Integration with the Cryopump may well be less complicated.

2.1.3 Beam stopping elements

It is envisaged that Hypervapotron elements would be used as Calorimeter beam dumps. Swirl tubes were considered but it was thought that a) The data base associated with the usage of this design is limited to small test systems b) The number of Swirl Tubes required would be five times that required for the equivalent Hypervapotron system c) Additional complexity of the water circuits with the increased numbers of elements, in particular an increased number of bellows which therefore increases the probability of failure. d) That no obvious financial savings could be made as it is not at all clear how efficient batch production might be carried out.

2.1.4 Calorimeter gate assembly

The Calorimeter doors would be mounted on a space frame with the axis of rotation centred about one of the vertical edges of each gate. Located on the lower end of each gate 'hinge' is the pivoted bell crank connecting the rotational axis of the gate to the magnetically coupled actuator.

Water is fed to the Calorimeter through the centre of the pivoted support on each gate. Flexible steel hoses from the feed manifold within the Injector vessel to the Calorimeter gates cater for the displacement arising from the thirty five degrees of rotation required to move the gates from the fully open to the fully closed position.

2.1.5 Power handling capability

Experience shows that the typical power handling capability for Hypervapotrons is 10-12 MWm^{-2} Should the required power density be in excess of this figure then the solution would be to increase the effective area of each gate by a series of vees as viewed in plan section. Additionally further optimisation of Hypervapotron geometry with improved water flow might well increase the power handling capability of such elements by 20-30%.

2.2 Residual Ion Dump

The constraints regarding the space envelope available are by necessity severe and thus call for the use of double sided beam stopping elements. Fig 3 shows the proposal for a double sided Hypervapotron element which would, due to the required height (2m) of the Ion Dump, require a two high stacking of elements in the assembly. This in turn would lead to each Vapotron element having it's water flow and return at one end of the element thus producing 'hair pin' flow. Data is available for this type of element. Fig 4 displays the proposed element together with the relevant location dovetails on each side of the element and the associated frame location pins.

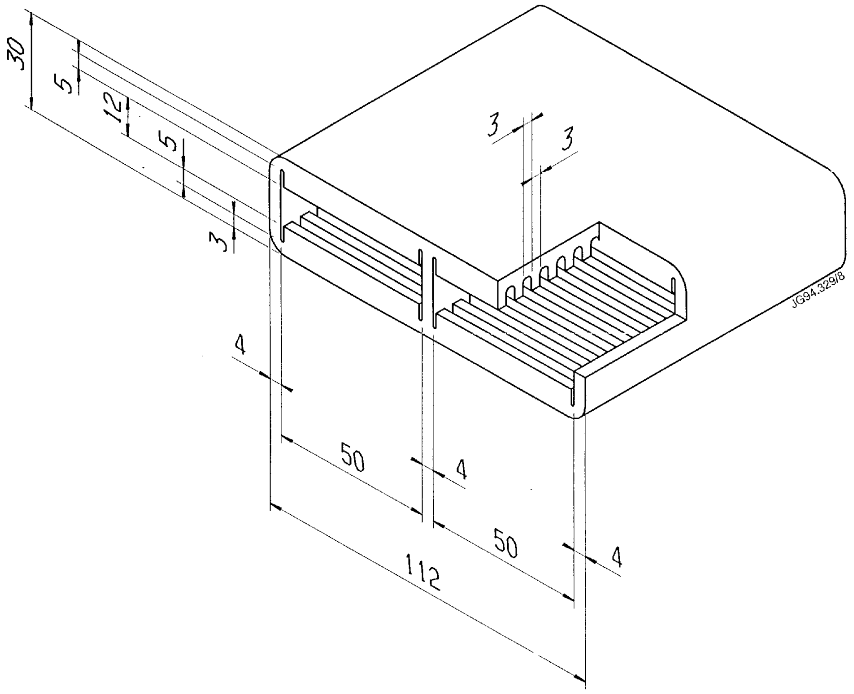

Fig.3:

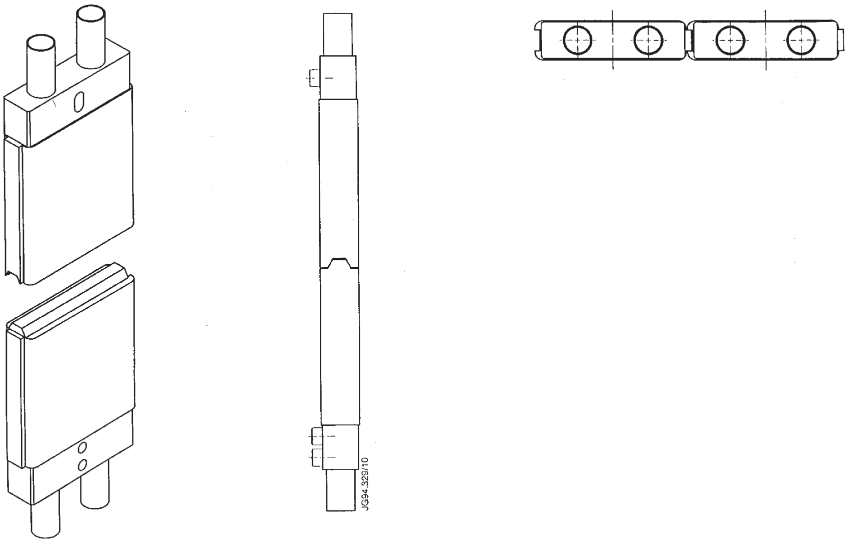

Fig.4:

The problems associated with the location of water manifolds has been investigated and Fig 5 displays a layout of the proposal. Water manifolds have been designed such that sequential construction is possible with sufficient space to carry out the operations with the use of automatic orbital welding techniques. Fig 6 displays the end view of the Ion Dump assembly and the space envelope required for the upper and lower water manifolds.

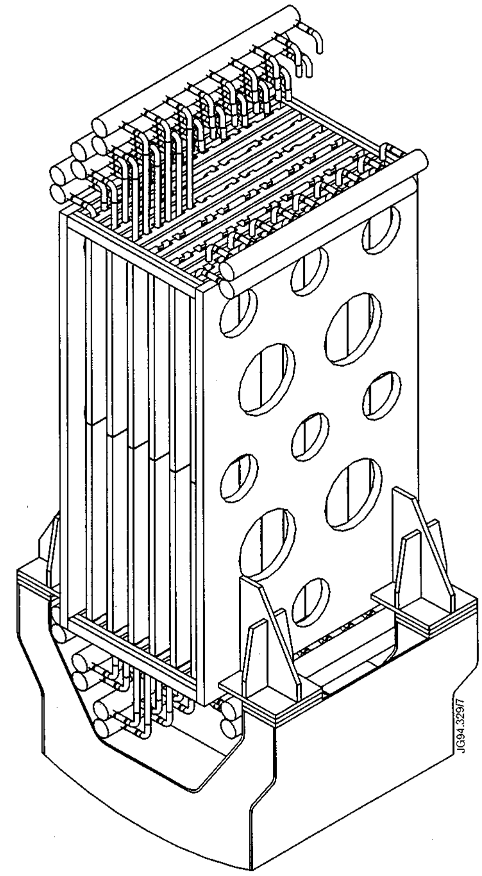

Fig.5:

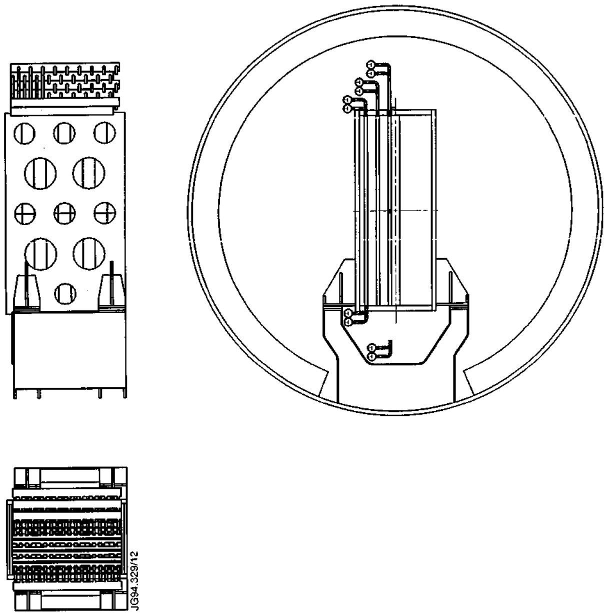

Fig.6:

The Ion Dump base will require a precision location system in order to guarantee its position with respect to the remainder of the beam line. Additional adjustment should be available between the base structure and the bottom of the Ion Dump sub assembly.

Fig 7 displays an isometric scheme of the major components within the Injector vessel.

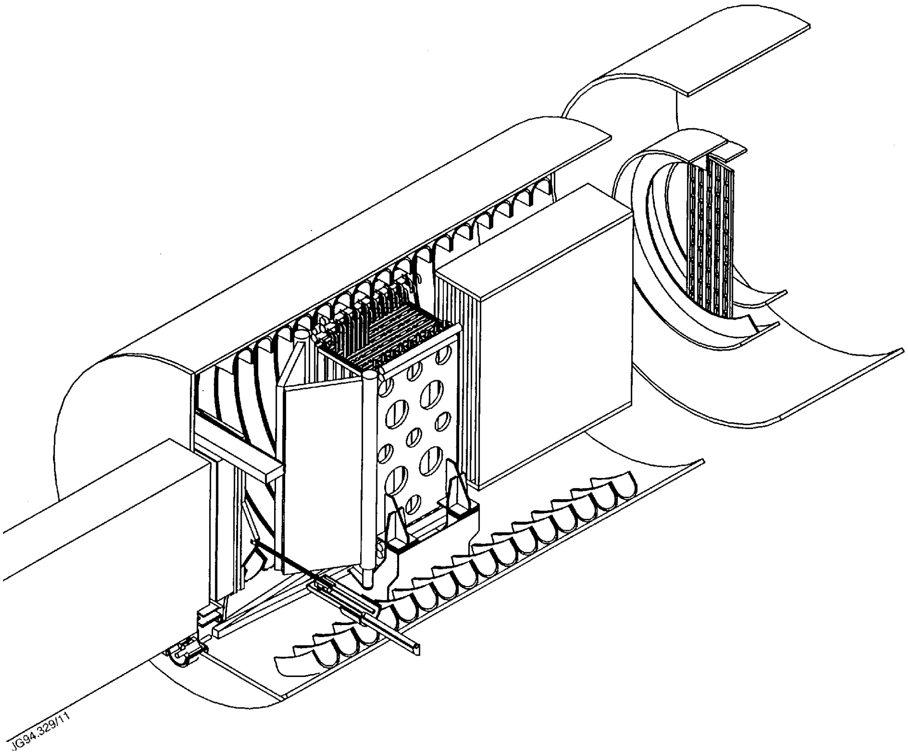

Fig.7: