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Final design and manufacturing of the Cryolegs of the W7-X-superconducting coil support system

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ABSTRACT

One of the most complicated tasks during the assembly of the Wendelstein W7-X is the installation of the superconductive coil system.

The entire magnet system is enclosed between the Outer Vessel and the plasma vessel in high vacuum at 4 K.

The coils are supported by a support structure, the Central Support Structure (CSS).

The CSS carries all 70 coils, and it is designed as a closed ring made of 5 modules (10 half modules). The whole structure is supported by 10 Cryolegs which rest on the machine base.

This paper describes the final design and manufacture of these Cryolegs.

1. Introduction

The Wendelstein W7-X is a fusion experiment which is currently under construction in the Greifs-wald branch of IPP. Its coil system with its CSS is within the cryostat at 4 K and under high vacuum. Fig. 1 shows a schematic cut through the Cryostat.

The CSS stands on 10 vertical supports that separate the CSS at cryogenic temperature from room temperature. These supports are called Cryolegs. The Cryolegs as vertical support elements of the whole magnet system are static highly loaded components and are located inside the cryostat supporting cylindrical legs. The Cryolegs are at cryogenic temperature at connection with the CSS and at room temperature at the machine base. Stainless steel bellows are used between the Cryolegs and the cryostat supporting legs.

The Cryolegs fulfill five substantial tasks:

- Transmission of high vertical and horizontal forces (max Fv = 1 MN, max Fh = 156 kN).
- Compensation of different thermal expansions between the Central Support Structure (CSS) at 4 K and the machine base at room temperature.
- Thermal insulator between the cold parts (CSS/coil system) and the warm structure.
- Compensation of manufacture and assembly tolerances between the CSS and the Outer Vessel (OV).
- Vertical and horizontal adjustment of the CSS on the machine-base.

All components of the Cryolegs, except the Insulator bush see Fig. 4, are made of stainless steel 1.4429 316LN (yield point Rp 0.2: >900 MPa at 4 K, elongation at fracture: >25%, Young's modulus: >190 GPa at 4 K, cobalt content <500 ppm).

2. Design of Cryolegs

Per module two Cryolegs ensure the support of the modular installed coil and its CSS.

One module is shown in Fig. 2.

The Cryoleg is able to resist the bending moments. Its top part is bolted to a lower flange of the CSS.

Each connection is made with 3 M33 and 3 M30 Inconel studs, see Table 1. The defined pre-loading is realized using superbolt-nuts at all screws.

The foot parts (bearing components) of the Cryolegs make possible the rotation and also the horizontal sliding on the machine basis.

For the toroidal restraining and the centering of the CSS tie rods are used at the base plate of the Cryolegs. The tie rods allow the radial displacements due to thermal expansion of the structures (Fig. 3).

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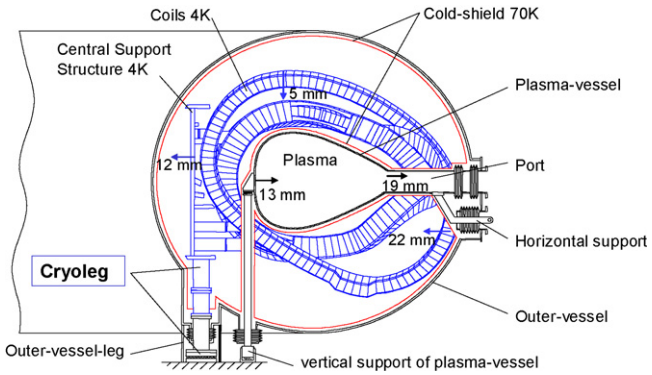

Fig. 1. Schematic view of main cryostat components of Wendelstein W7-X.

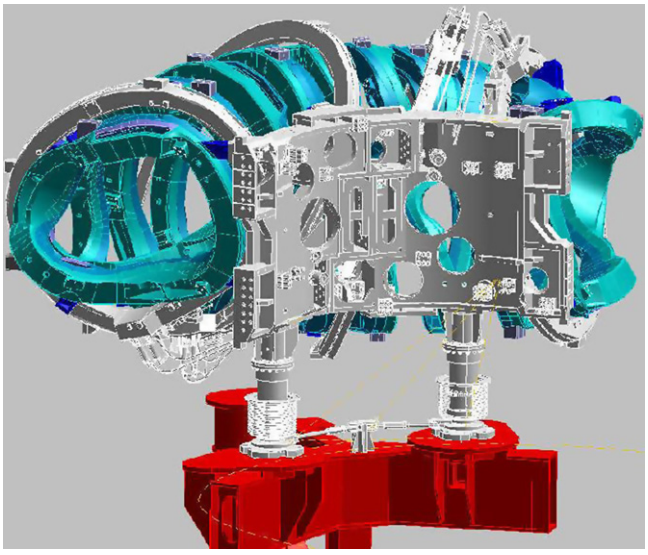

Fig. 2. Module representation of CSS with Cryolegs.

3. Function and structure of the Cryoleg components

The Cryoleg consists of 5 functional components:

Ring fitting
Insulator bush
Bearing components
Bellow
Tie rod (centering component) (Fig. 4)

The 10 Cryolegs are identically designed. Within a module there are only slight constructional deviations in the upper flange plate.

The upper parts of Cryolegs are computed and designed for the transmission of high vertical and horizontal forces.

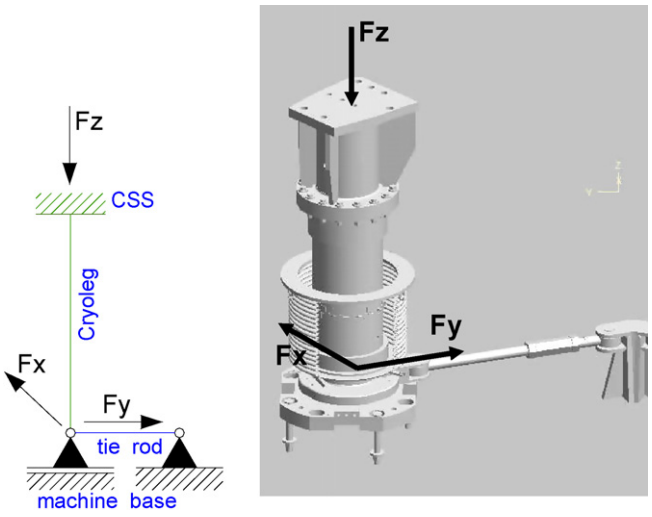

Fig. 3. Sketch of the statical system.

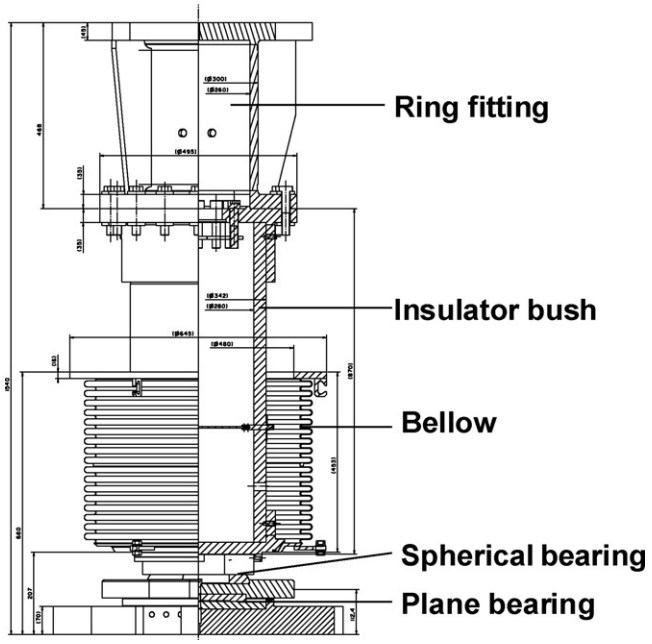

Fig. 4. Structure of Cryolegs.

The overall length of one Cryoleg is 1.54 m. During the experiment time they have to withstand a maximum bending moment of Mb = 234 Nm at the top of the Cryoleg, see Table 2.

3.1. Ring fitting design

The Ring fitting is a welded construction with 4 external stabilizing ribs. The connection between the pipe and the two flanges is achieved by EB-welding.

Table 1
Bolt connection both Cryoleg upper flange to the CSS [5]

Flange bolt layout	Cryoleg upper flange N1 3 × M33 + 3 × M30 Inconel 718		Cryoleg upper flange N2 3 × M33 + 3 × M30 Inconel 718		GRP tube upper flange Circular Ø395. 16 × M20 A4-80
Bolt size	M33	M30	M33	M30	M20
Maximum force per bolt, kN	540	380	480	305	100
Maximum stress in bolt, MPa	780	690	505	440	100