TESLA TEST FACILITY (TTF) CRYOSTAT DESIGN AND DEVELOPMENT

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Abstract

We present here the status of the design and operation of the cryostats for the TESLA Test Facility (TTF), in DESY Hamburg. The first TTF cryomodule, built by the Italian company Zanon, has been assembled and cooled down during summer 1997. A substantial revision of the design, which lead to a significant cost reduction, has been carried out for the second and third TTF cryomodules. In the following we discuss the design modifications of the second generation cryostats. The two cryomodules have been built by Zanon and their comonents have been shipped to DESY, where installation is scheduled for spring 1998.

Introduction

The TTF cryomodule contains eight superconducting RF cavities and a superconducting quadrupole package. Cavity support, alignment, cooling and thermal insulation are all provided by the cryomodule. In addition, the cryomodule must provide the feedthroughs for the RF power and instrumentation, as well as the connection to adjacent cryomodules or to the cryogenic supply lines. One of the goals of the TTF project is to reduce the cost of the cryomodules, in view of the feasibility of the TESLA collider. Thus, the design should be as cost effective as possible, while still meeting the operating requirements. These factors implied the need for building and testing a prototype cryomodule.

The first cryomodule was assembled and tested in the first half of 1997[1]. By mid July, 1997, the cryomodule had been cooled down twice, and it was kept at cryogenic temperatures until September, while additional tests on the superconducting cavities, as well as additional cryogenic measurements, were made. Figure 1 shows a cross section of this cryomodule. The superconducting cavities and quadrupole package are connected to a 300 mm (outer) diameter gas return line that acts as the structural backbone for the cryomodule. This pipe is attached to three vertical posts, which, in turn, connect to the top of the vacuum vessel. The cryomodule also includes two actively cooled thermal radiation shields at approximately 70 K and 4.5 K. The cavities are bath cooled in

He II at 1.8 K and the baths are fed by a two–phase He II flow in the pipe connecting the cavity helium vessels. The quadrupole is cooled by 4.5 K helium.

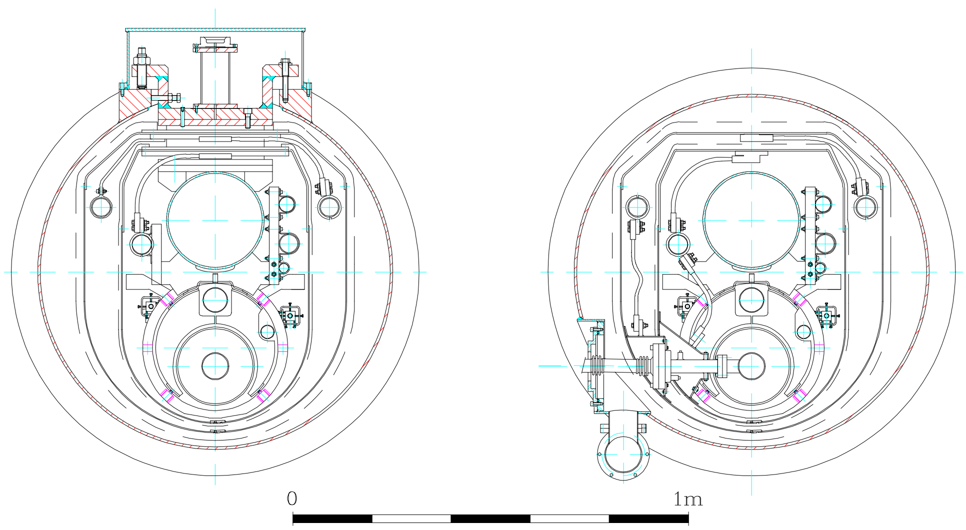

Figure 1. Cross section of the first TTF cryomodule.

The First Cryostat - Project and Results

The two thermal shields, at 4.5 K and 70 K, are cooled by copper braids, linked to the He pipes. These braids have a large cross section to assure good heat transfer properties. In order to avoid problems caused by the different dilatation of copper and aluminum, springs and Indium foils have been used.

A critical aspect of the manufacturing procedure has been the welding of the braid junctions on the steel pipe. This design, even if very interesting from a thermal-mechanical point of view, was responsible for many problems in the construction phase and lead to a very expensive cryostat.

The shield panels have been linked together by aluminum screws and inserts. More than 1000 inserts to fix all the panels. In order to assure a good thermal link an Indium foil has been placed between the panels surfaces. The complexity introduced by the huge number of screws and by the braid cooling is shown by the photographs in Figure 2.

Figure 3 shows the cryostat during the installation in the TTF hall.

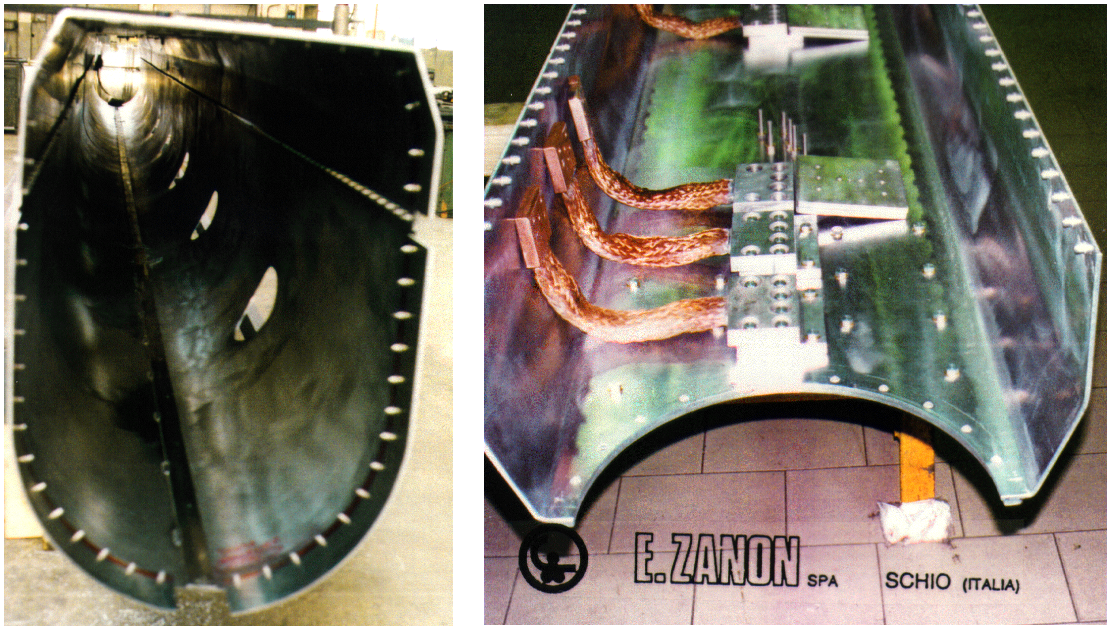

Figure 2. Left: The pre-assembled 70 K shield, showing the screws for the panel joints. Right: view of the heat conducting braids on the top part of the shield.

Structural analysis of the cryostat

The first generation cryostat has been extensively modeled[2] using the 3D Finite Element Analysis code ANSYS[3]. The modeling have been used to check the structural behavior of the cryostat shields during the cooldown procedure. In particular, care has been taken to control the structure deformations due to the thermal gradients and the thermal stresses. The results for the maximum values of the vertical and longitudinal displacements during the cool down process, and for the induced stresses, are shown in Table 1

Table 1. Results of the FEA analysis for the cryostat shields (first generation).

Shield	**Vertical Displacement**	**Longitudinal Displacement**	**Von Mises Stresses**
4.5 K	6.9 mm	8.2 mm	$< 30\ 10^6$ N/m^2
70 K	6.5 mm	8.5 mm	$< 30\ 10^6$ N/m^2

Diagnostics for the alignment of the cold mass of the cryostat

A Wire Position Monitor (WPM) system[4] has been developed for on-line monitoring of the cold mass alignment during cooldown and operation. The analysis of the WPM measurements allowed to check the alignment reproducibility, from warm to cold and from cold to cold (between successive cool down cycles).

Measured heat leaks in the cryostat

The heat leaks have been measured during the cryomodule operation in July 1997 and are shown in Table 2.

These values have to be considered very good given the structure of the feed and end caps of the cryostat, the large opening for the optical target monitoring and the considerable amount of diagnostics in the cryostat, which include 144 coaxial cables for the read out of the signals of the Wire Position Monitor system. All these components, that will not be present in a final cryomodule, justify the difference between the measured values and the design goals.

Table 2. Measured static heat leaks.

Temperature (K)	Measured heat leak (W)	Design goal (W)
70	90	76.8
4.5	23	13.9
1.8	6	2.8

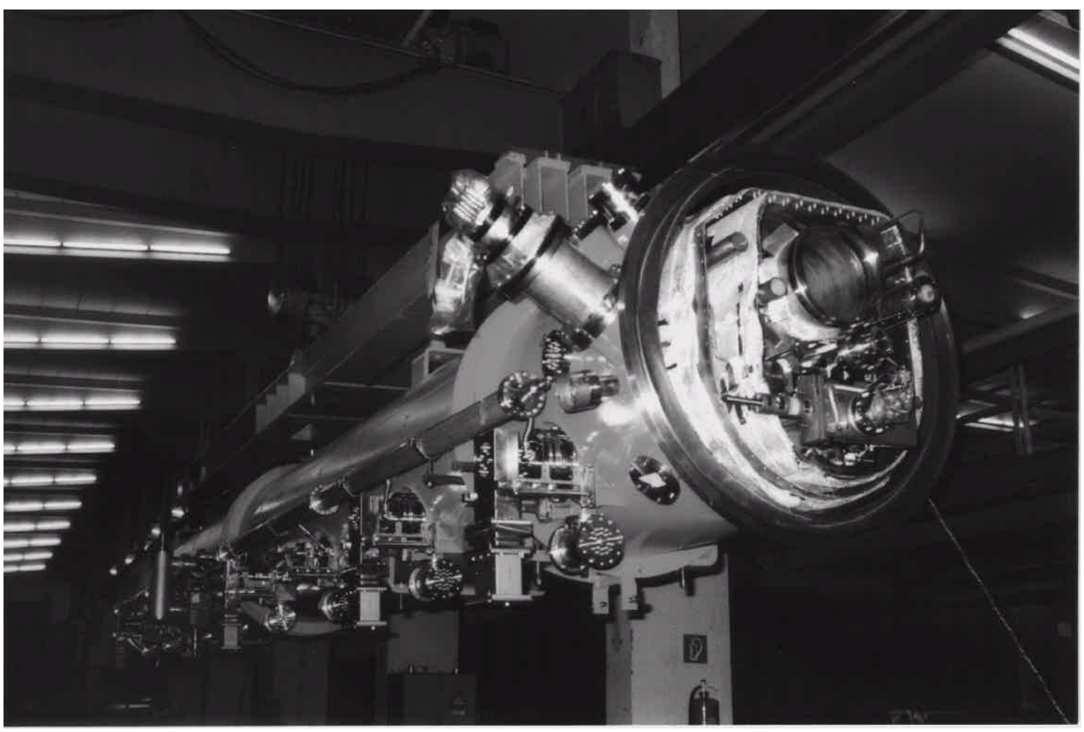

Figure 3. The cryostat during the installation in the TTF experimental hall.

The Second Generation Cryostat

The experience gained during the design and the commissioning of the first cryostat suggested new solutions to improving the technical design[5]. In particular, a different cooling method has been employed.

The complexity of the first design lead to high costs. The copper braids have been identified as one of the critical components, being expensive and labour intensive. An additional complexity was the use of screws and inserts to connect the top and bottom part of the thermal shields.

The most important improvement is the design of the new thermal shields at 4.5 K and 70 K. In this revision the cooling helium pipes are directly welded to the aluminum shields. This solution simplified the technical design of the entire cryomodule and indicated some issues that needed further studies to verify the behavior of the new structure during cooldown and operation. The main aspect studied has been the procedures necessary to avoid stresses and deformations produced during the cooldown which might damage the shields. The solution found also prevents the typical deformations induced by the welding and makes the production pre-alignment easier.

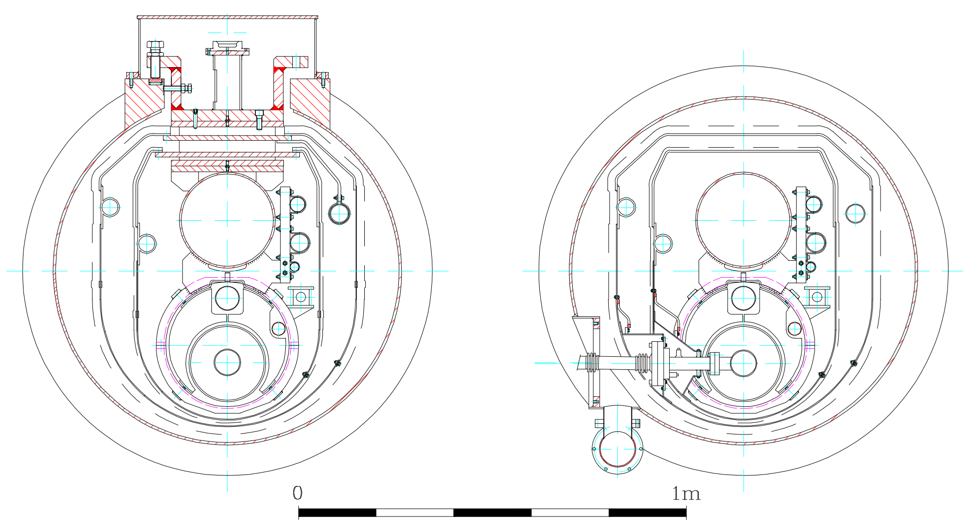

Figure 4. Cross section of the second generation TTF cryomodule.

The shields will be welded through small aluminum fingers that strongly reduce the resistance section of the joint, while unloading the welded joints and preventing possible damage during the cooldown procedure.

The new cryostat has been fabricated at Zanon and the revised design allowed to reduce the cost by a factor of 2.5, with respect to the first prototype cryostat.

Finger welding of the screens

The new welding scheme has been used to join both the cooling pipe to the aluminum shields and, in the opposite side, the shield panels to the upper part. All the weldings are done on the fingers, in order to unload the welded join. The same scheme is used in both shields, and in Figure 5 we show the details of the 4.5 K shield.

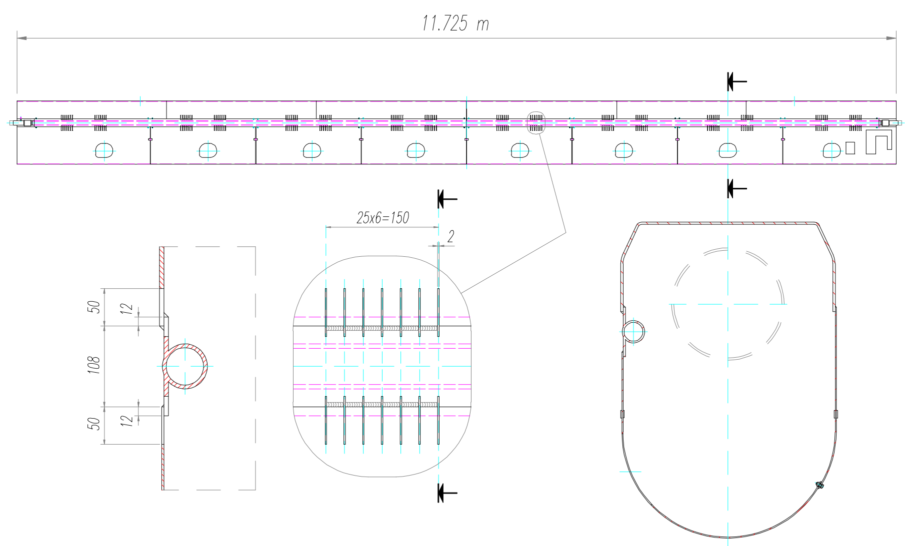

Figure 5. The finger welding scheme of the shields.

This design leads to an asymmetric cool down of the shields. We have checked through ANSYS modeling the stresses and the general deformations produced by the asymmetric thermal fields, and have shown that a linear cool-down procedure from 300 K to 4 K, lasting two days, is completely acceptable for the shields. The results for the maximal values during the cool down are summarized in Table 3, and the stresses in the welded region resulting from the ANSYS simulations are shown in Figure 6. One can clearly see that the welding occurs in a stress free region of the fingers. Figure 7 shows a photograph of the actual shields after welding in Zanon and a photograph of the cross section of the second generation cryostat.

Table 3. Results of the FEA analysis for the second generation cryostat shields.

Shield	**Lateral Displacement**	**Longitudinal Displacement**	**Von Mises Stresses**
4.5 K	4.8 mm	5.5 mm	$< 30\ 10^6$ N/m^2
70 K	5 mm	6.5 mm	$< 30\ 10^6$ N/m^2

Furthermore, since in the TTF cryogenic system the 4.5 K shield is cooled in parallel with the cavities, a similar cooldown procedure is needed to prevent large movements of the cavity string.

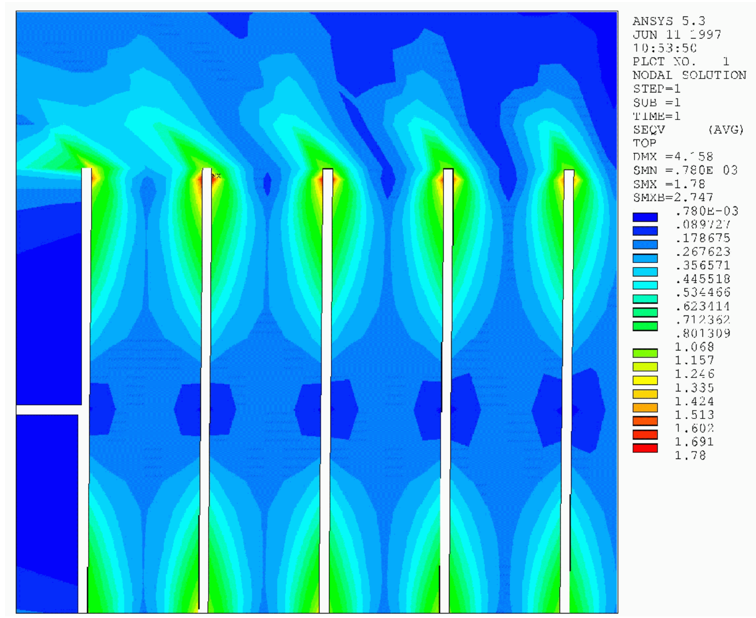

Figure 6. Von Mises stresses. The weld is done in the stress free region at the finger center.

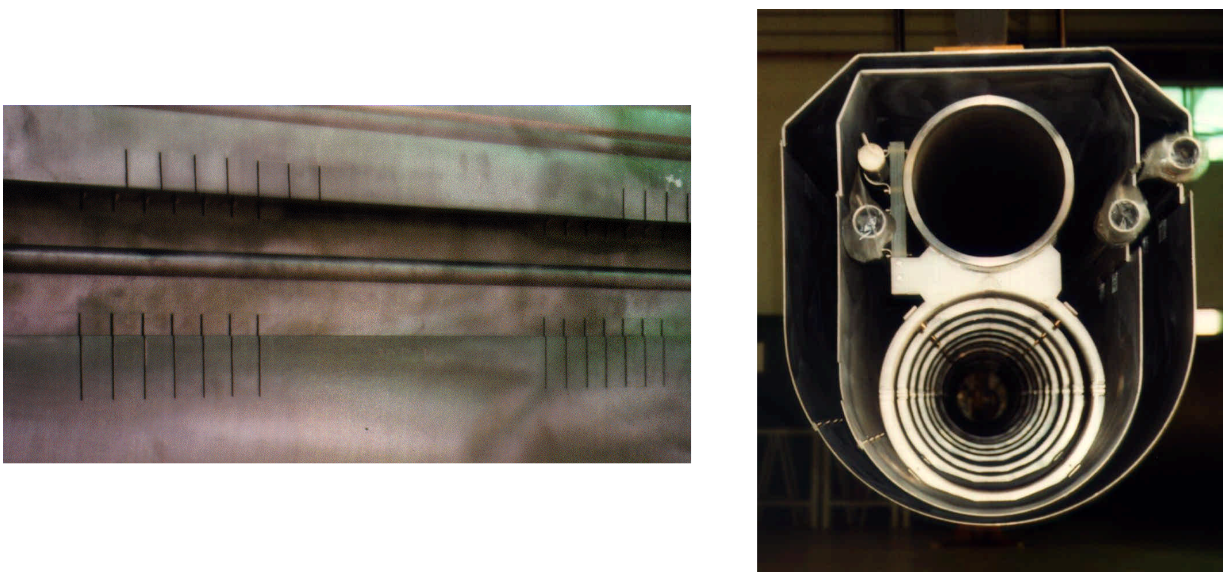

Figure 7. Left: View of the finger welding of the cooling pipes on the shields. Right: cross section of the second generation cryostat.

Alignment and tolerances

The He Gas Return pipe tolerances were relaxed to 5 mm (standard high quality welded pipe), including straightness. When all the ancillary components and supports have been welded, a 14 m milling machine is used to machine the upper three suspension post flanges, to produce the reference axis. As shown in Figure 9, during all fabrication steps the HeGRP can be easily referenced to its previously defined axis, by means of Taylor Hobson spheres or pins, according to the desired precision.

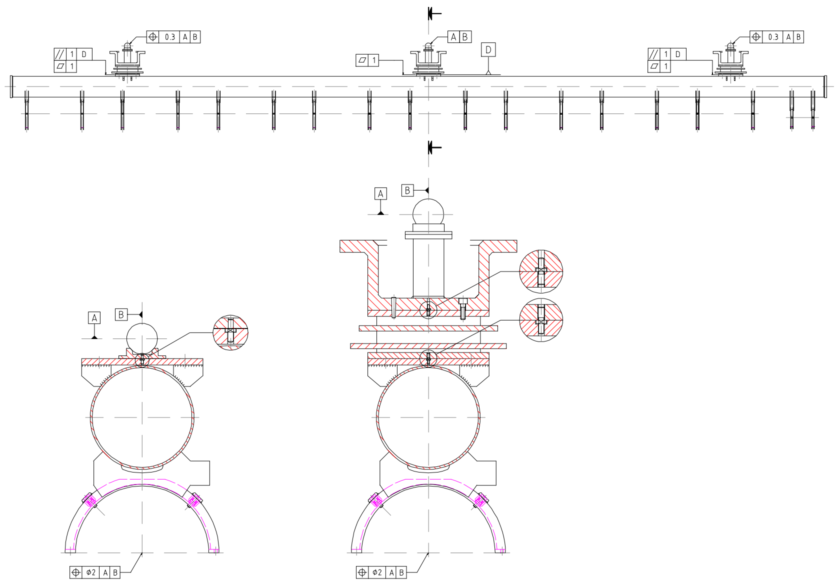

Figure 8. The new alignment scheme.

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