Flow balancing orifice for ITER Toroidal Field Coil


Abstract: Flow balancing orifice (FBO) are used in ITER Toroidal Field coil to uniform flow rate of the cooling gas in the side double pancakes which have a different length of the conductor of 99 m and 305 m, respectively. FBO consist of straight parts, elbows which are produced from 316L, tube 21.34 x 2.11 mm and orifices which are machined from the 316L rod. Each of right and left FBO contains 6 orifices, straight FBOs contain 4 and 6 orifices. Before manufacturing of qualification samples, JSC NIIEFA proposed to ID ITER new approach to provide the seamless connection between tube and plate therefore the most critical weld between orifice with 1mm thickness and tube was removed from the final design of FBOs. Since the proposed design of diameter of orifice is 4.5 mm which is three times less than the minimum requirement of the ISO 5167, therefore has been taskd to define correctness of calculation flow characteristic at room temperature and compare with experimental data. In 2015, the qualification samples of flow balancing orifices were produced and tested. The results of experimental data shown, that the deviation of calculated data less than 7%. Based on this result and other tests ID ITER approved design of FBO, which made it possible to start the serial production. In 2016 JSC “NIIEFA” delivered 50 FBOs to the IO ITER, i.e. 24 left side, 24 right side and 2 straight FBOs. To define the quality of FBOs has been prepared the test facility in NIIEFA. The helium tightness test at 10^-5 m²/Pa/s under the pressure up to 3 MPa, the measuring of flow rate at the various pressure drops, the non-destructive tests of orifices and weld seams (ISO 5817 class B). Also other tests such as check dimensions and thermocycling 300 - 800 K were carried out for each FBO. 

Testing of FBO

Thermal cycles test

Range of helium leak detector from 10^-8 Pa·m³/c to 10^-12 Pa·m³/c

Criterion of leak tightness -1x10^-4 Pa·m³/c

Thermal cycles:10

Leak tightness test

Range of helium leak detector From 10^-9 Pa·m³/c to 10^-12 Pa·m³/c

Criterion of leak tightness –1x10^-8 Pa·m³/c

Flow Test

Range of differential pressure Varies from 0.2 up to 1.5 depends of pressure in inlet(P1) and outlet (P2). Shown in Table 1.

Check Dimension

Inspection of assembly parts: Tube ± 0.1 mm; Orifices ± 0.01 mm and 0.005 mm; Elbows 0.15 mm and 0.005; 15° and overall dimension of manufactured FBO ± 2 mm

Table 1. Pressure drop FBO

The flow test results have confirmed the correctness of calculations.

The following tests were carried out for each FBO according to the Test Program and ITER Technical Specifications:

- Non Destructive Tests (X-Ray, Visual control, Penetrant test) of the weld seams and tubes with the orifice;
- Leak test under pressure of 3 MPa;
- Ten thermal cycles in the temperature range of 300-77K;
- Two pressure/leak test cycles: 3 MPa at the room temperature before and after thermal cycles;
- Dimensional Check of FBO assembly parts and the manufactured FBO;
- The flow test results have confirmed the correctness of calculations.

Conclusion

All delivered flow balancing orifices fulfill the requirements of Technical Specification “Flow balancing orifice for TF coil”, The performed NDT tests have confirmed that the quality of the weld seams satisfies the requirements according to ISO 5817 class B. Each FBO and parts of the FBO assembly meet the requirements of dimension tolerance.

The leak test and thermal shock do not affect the integrity of the product. According to the obtained results of qualification phase, the FBO design was approved for serial manufacturing. JSC “NIIEFA” has manufactured and delivered 50 FBOs (24 left+24 right and 2 straight FBOs with six and four orifices) to the ITER Organization.