15th International Symposium on Fusion Nuclear Technologies (ISFNT-15)

Topic: B. Blanket Technology

Design and construction of a helium cooling experimental loop for tritium blanket

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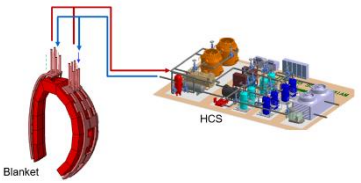
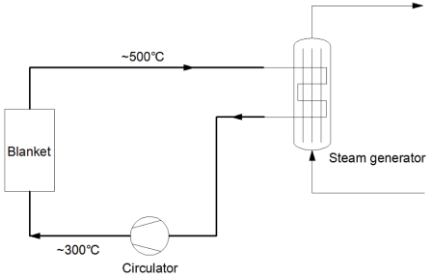
CONTENTS

Introduction

- Helium cooling system (HCS) for CFETR blanket
  - Many tritium blankets are in vacuum vessel
  - Blankets absorb energy and produce tritium
  - HCS takes heat out of blankets to generate electricity
  - HCS is expected to adopt an “O” shaped loop
  - High inlet temperature for circulator

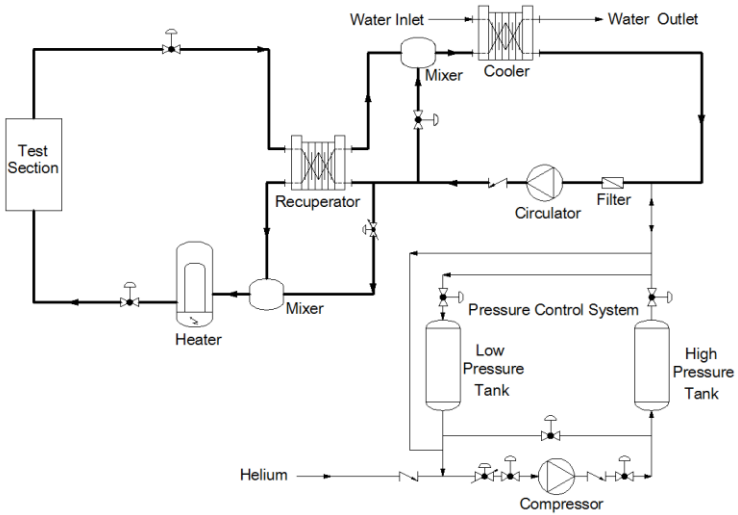


HCS concept in CFETR



“O” shaped loop for reactor

- Helium cooling experimental loop was built
  - Under the support of the CFETR project
  - Verify the thermal and hydraulic performance of blanket components
  - Accumulate cooling system design and construction knowledge
  - “8” shaped loop
  - Low inlet temperature for circulator
  - Pressure control by control helium stock in main loop though pressure control system (PCS)
  - Test section maximum parameters: 550℃, 12MPa, 2.5kg/s

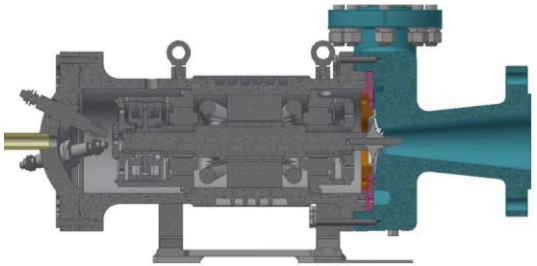


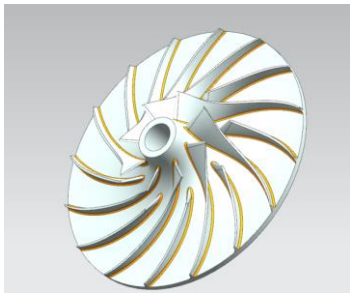
“8” shaped loop for experiment

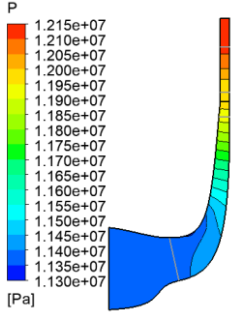
R&D-circulator design

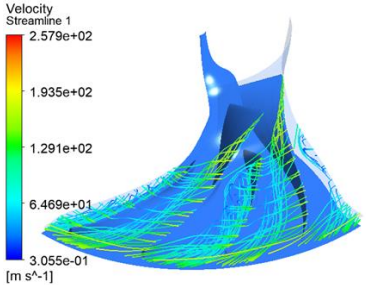
- ➢ Leakage rate requirement
  - 10^{-6}Pa·m3/s
  - No dynamic seal: canned motor
- ➢ Oil-free lubrication
  - Magnetic bearing
- ➢ High pressure rise (△P)
  - High speed motor
- ➢ No need cooling water
  - Part of the outlet helium flows through the motor back to the inlet

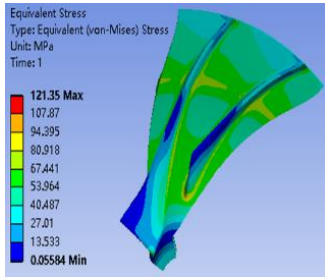
	Parameters
Inlet temperature	≤50℃
Flow rate	2.5kg/s
Inlet pressure	11.4MPa
Outlet pressure	12.2MPa
Rotational speed	35000RPM
Other characteristics	Variable frequency speed control

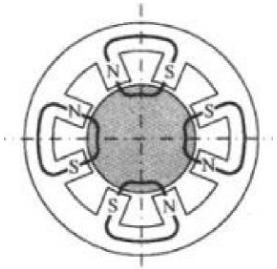


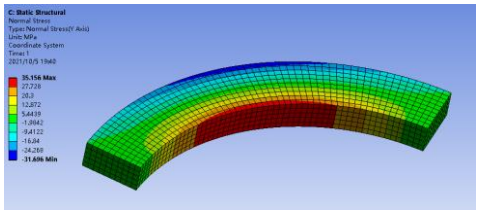


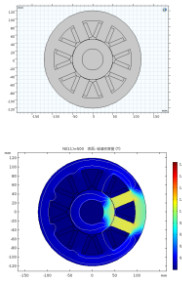


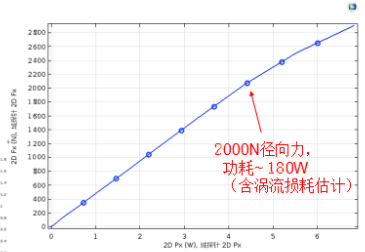






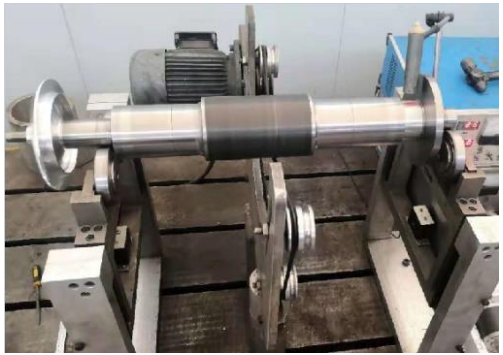


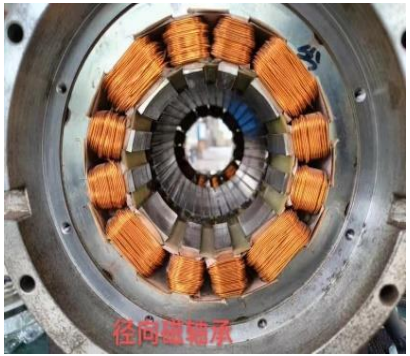


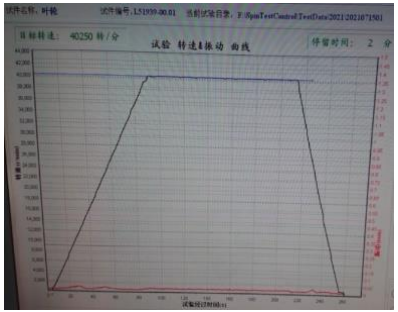


R&D-circulator manufacture

- Manufacture



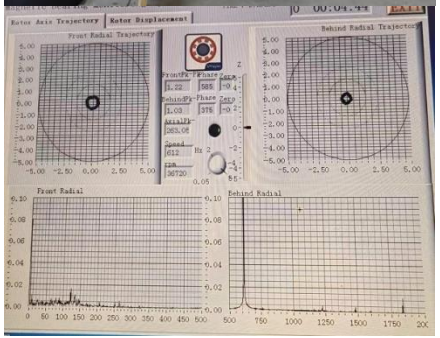


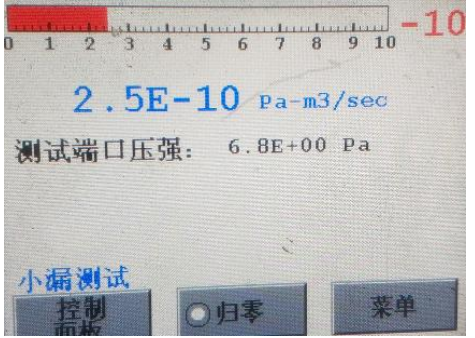


R&D-circulator factory test

➢ Factory test

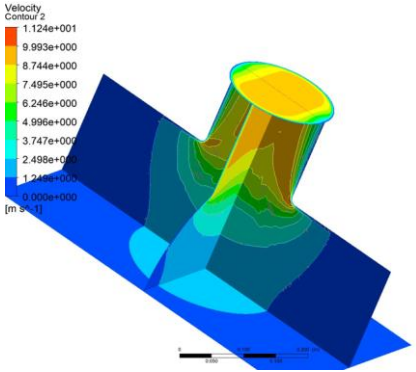
- Underwater gas tightness test at 12.8MPa
- Maximum speed test at 36750rpm
- Shaft motion monitor
- Helium leak test

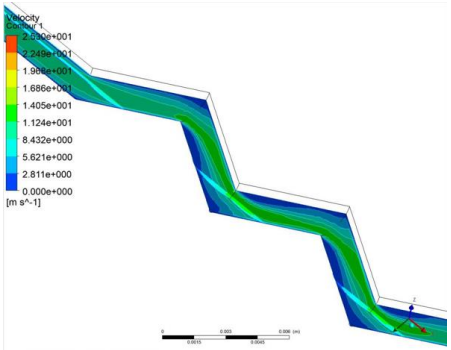


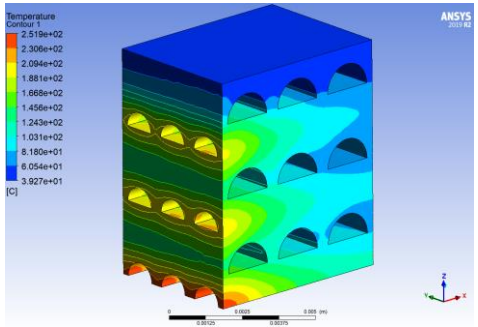


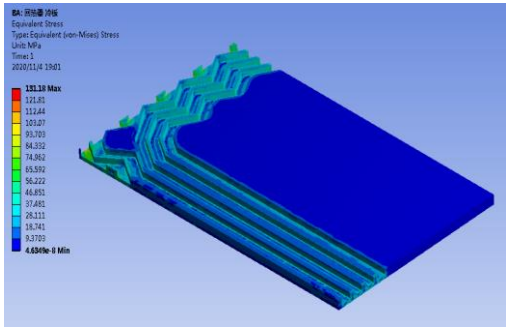
R&D-PCHE design

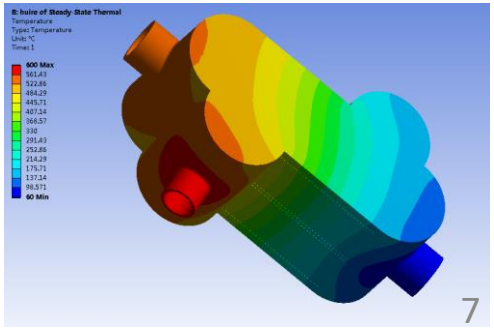
- Printed Circuit Heat Exchanger (PCHE)
- Compact heat exchanger can withstand high temperature and pressure
- Small flow channel: 1-2 mm in diameter
- High temperature (up to 550℃), high pressure (12MPa), Heat transfer temperature difference (> 200℃)





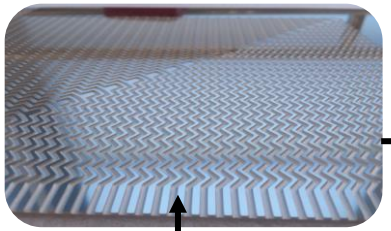
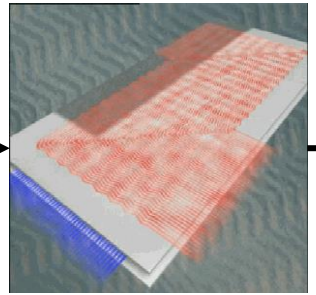


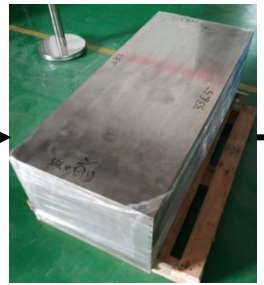


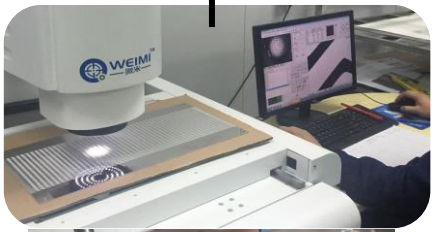
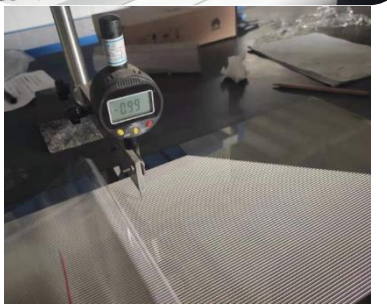


R&D-PCHE manufacture

- Manufacture process

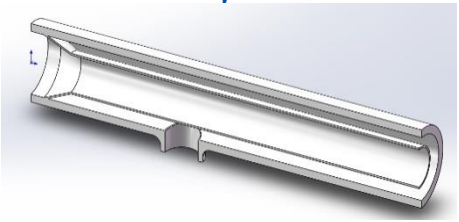


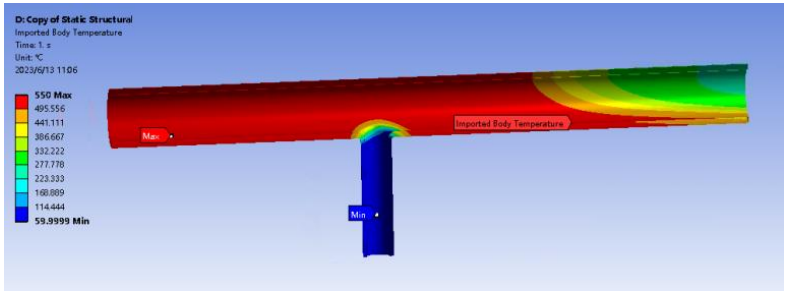



Special mixer

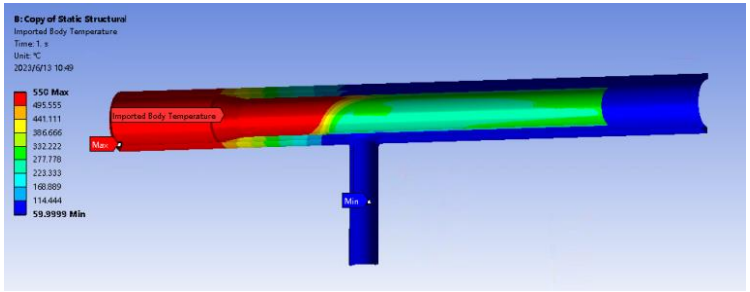
- Large temperature difference mixing
- Ordinary tee cannot pass stress analysis
- A special tee mixer is designed
- Simple structure, reduce pressure loss
- Material TP347H

Tee	Outside diameter/mm	Inside diameter/mm
Main pipe	219.1	22.2
Branch pipe	114.3	14.2
Inner pipe	139.7	6.3

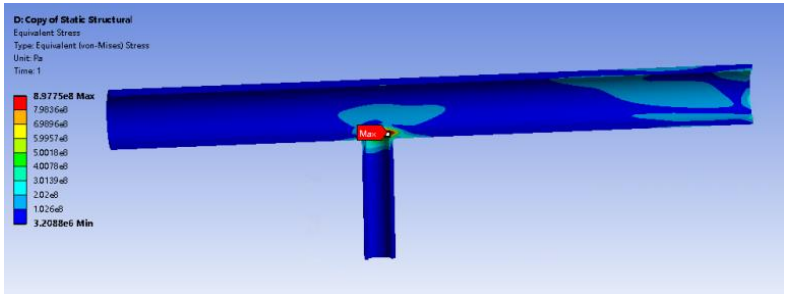




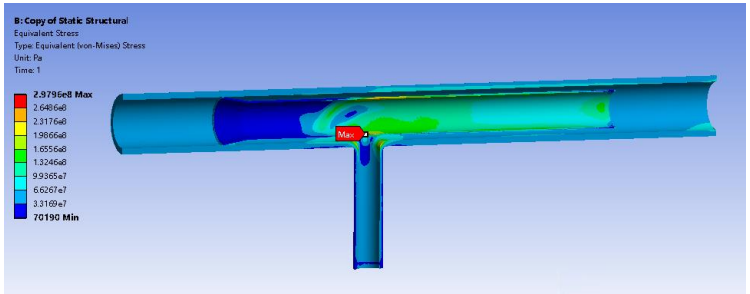
Tee temperature



Mixer temperature



Tee stress 890MPa>3Sm=414MPa



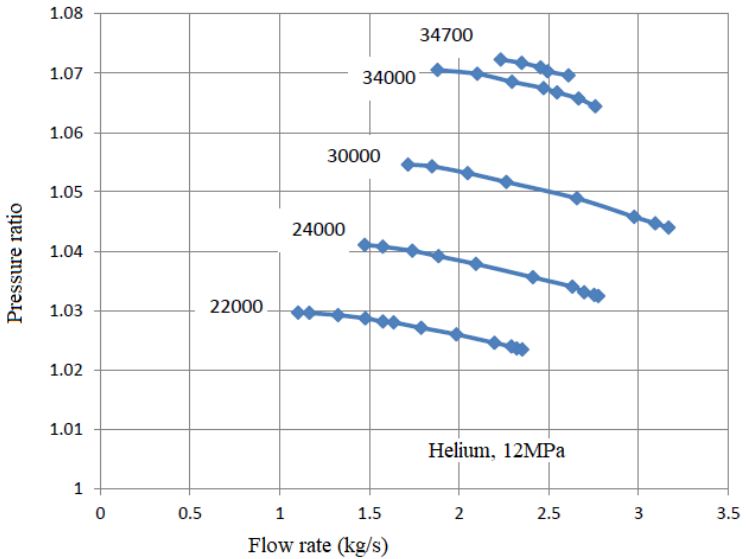
Mixer stress 290MPa<3Sm=414MPa

Other equipment

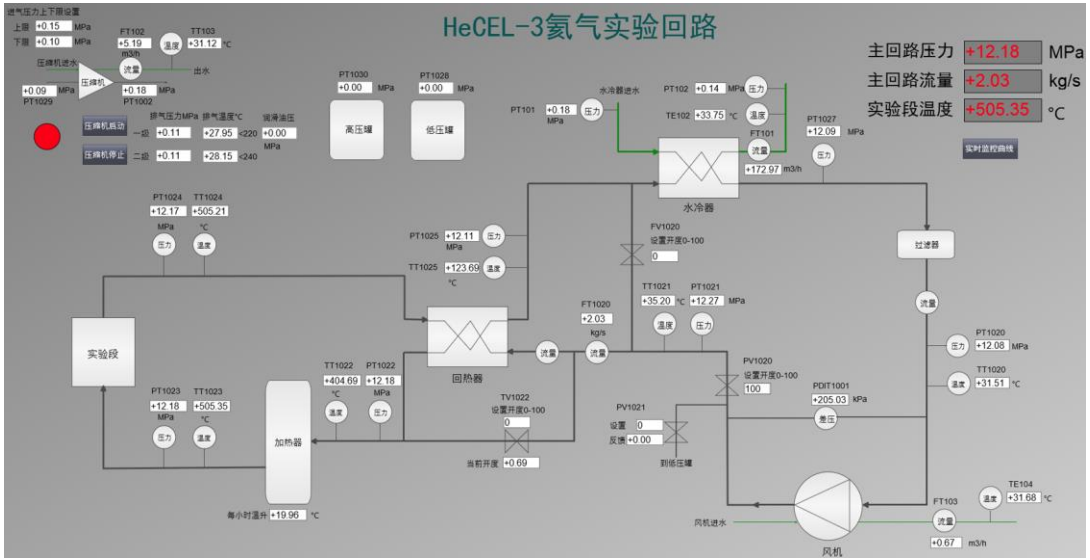
Installation

Test run

- Test section achieved: 12MPa, >2kg/s, > 500℃ (without test section heating device)
- Stable operation for 72-hours



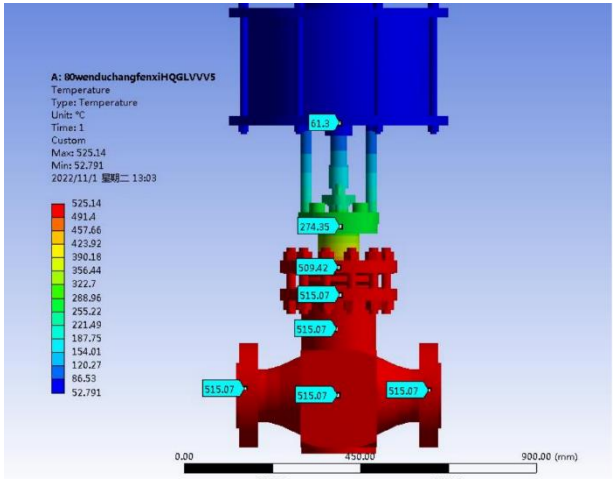
Circulator performance curve

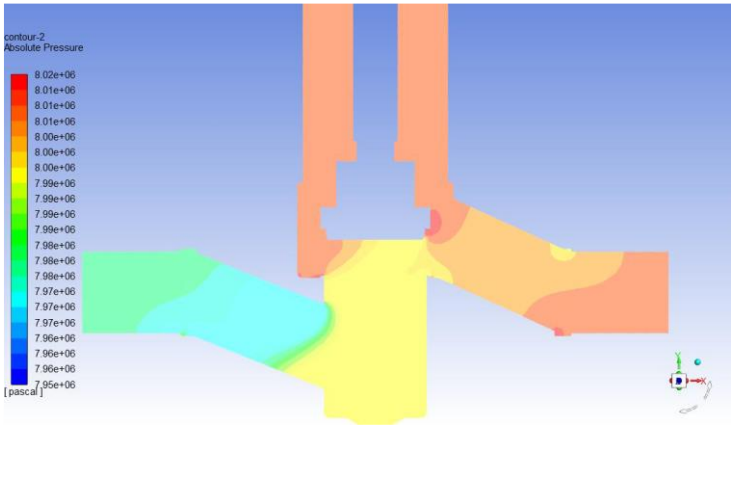


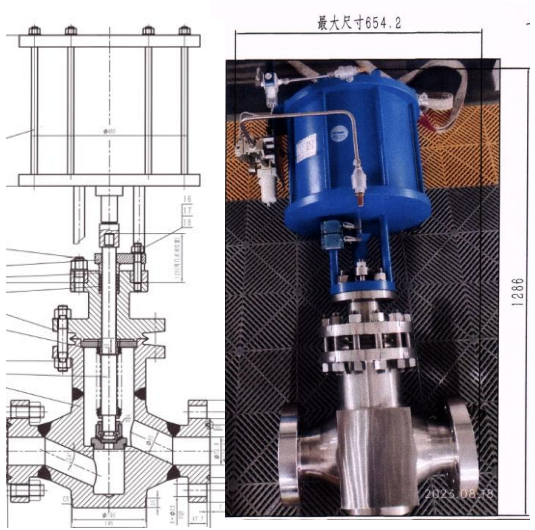
I&C interface

R&D-Isolation valve for HCCB TBM

- To isolate HCS from blanket when emergency situation
- Close time <2s, by springs and compressed air
- Pressure drop is about 32kPa (at 1kg/s, 8MPa)
- Bellow valve
- Will be tested on helium loop





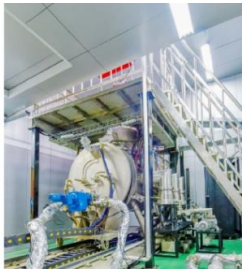


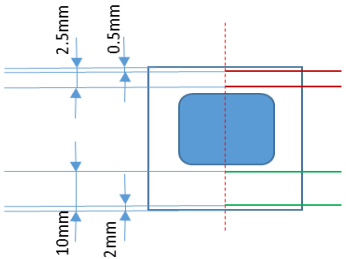
Temperature analysis

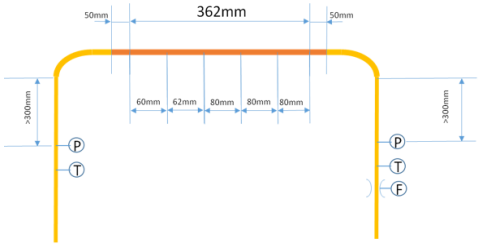
Pressure drop analysis

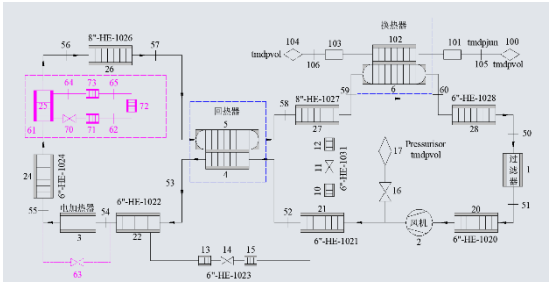
Experiment consideration

- Flow resistance test;
- Heat transfer experiment;
- New circulator test;
- High heat flux test (with electron beam device);
- LOCA, LOFA and other safety accident experiments









Experiments that are expected to be carried out

Summary

- Through the cooperation of Chinese manufacturer, key equipment such as magnetic bearing circulator has been developed.
- The helium experiment loop reached the design goal: temperature of 550℃, pressure of 12MPa and flow rate of 2.5kg/s
- The loop will provide thermal-hydraulic experiment conditions for helium blanket, helium cooled diverter and other components.

Thank you for your attention!

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