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Process Design of Cryogenic Loop

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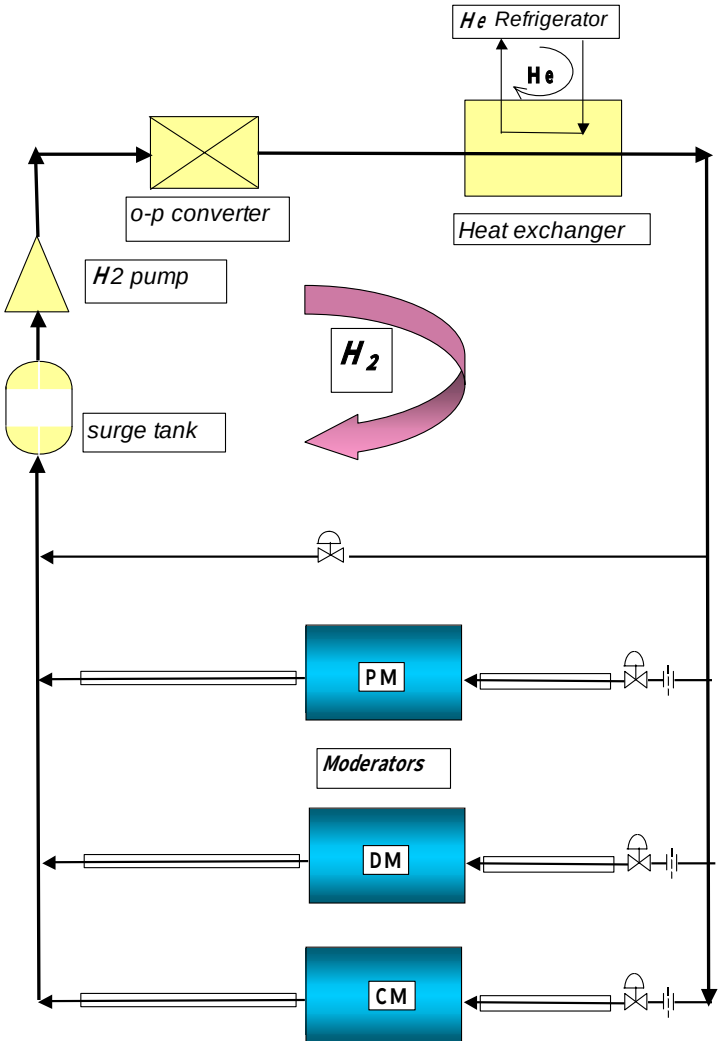
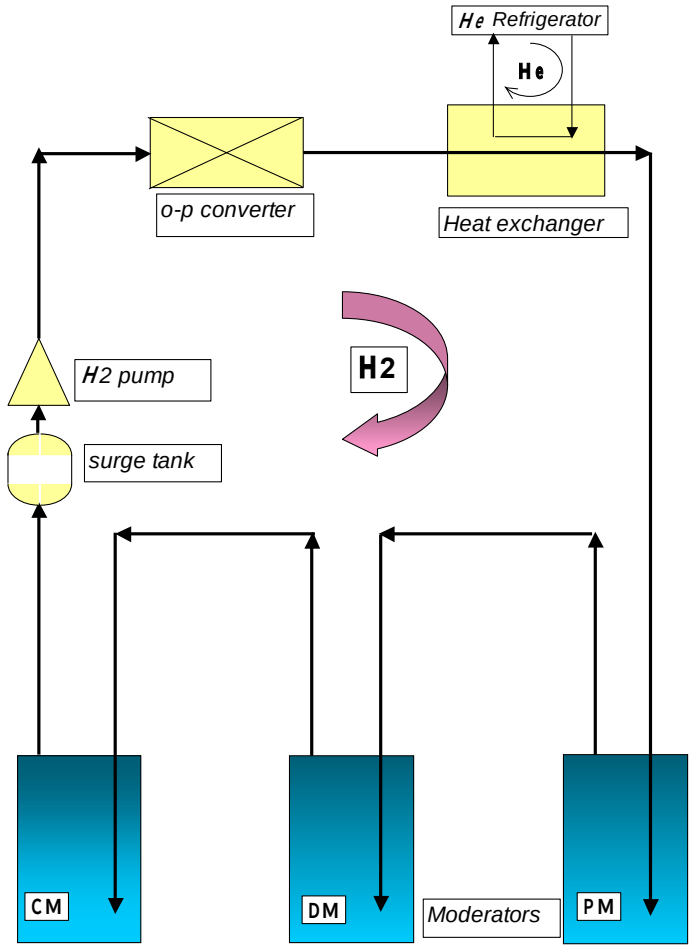
Design Conditions for Hydrogen Loop

- H_2 pressure in moderators : ~ 1.5 MPa
- Temperature increase through the moderators : less than 3 K
- Moderator outlet temperature : less than 21 K
- Para-H_2 concentration at the moderator inlet : more than 99 %

Flow Diagrams of Hydrogen Circulation System

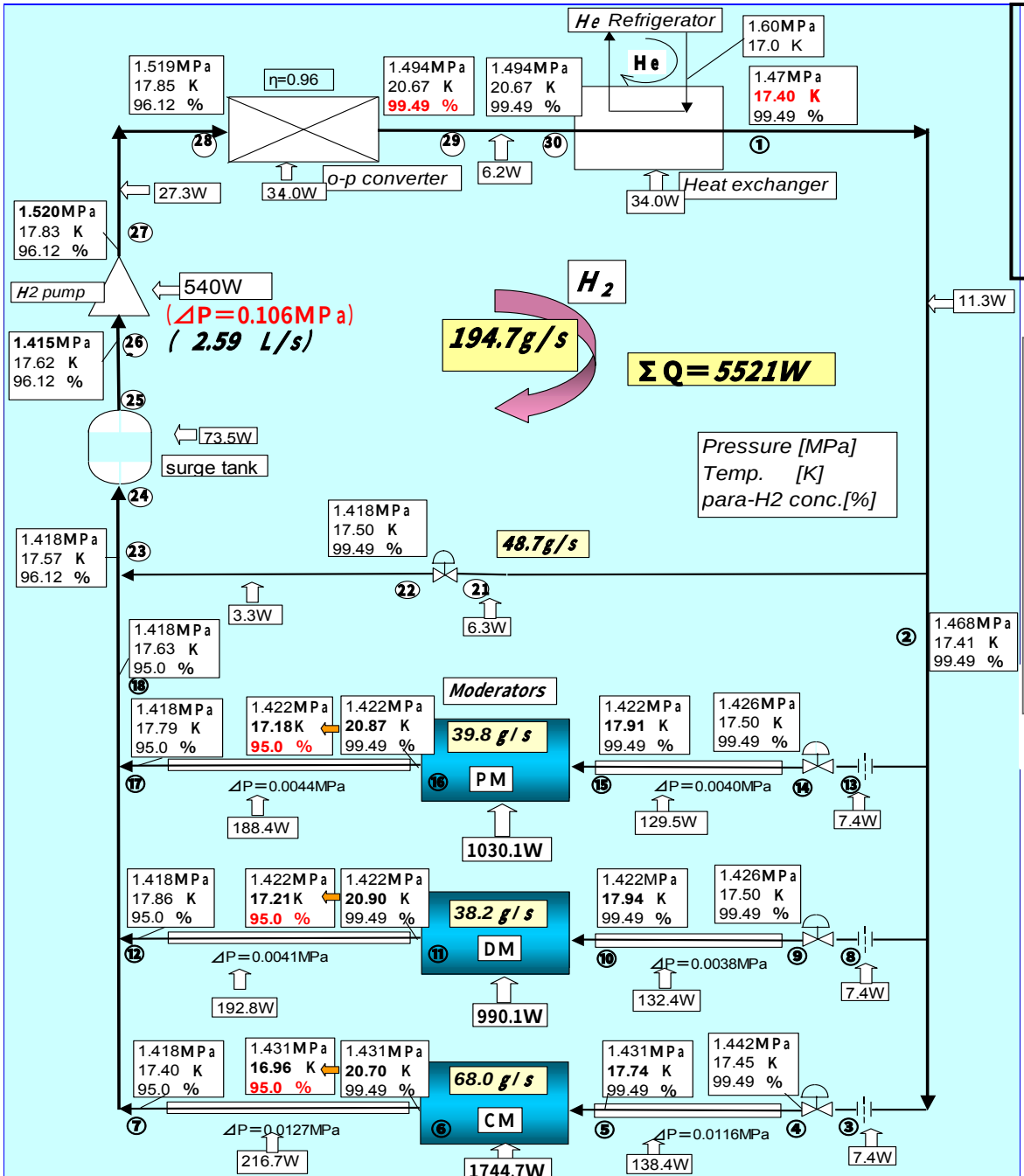


Parallel Cooling



Series Cooling

Process Flow Diagram of H2 loop in Parallel Cooling



Moderators are arranged in parallel flow from the viewpoint of decreasing pressure loss, that is, decreasing kinetic energy of a pump.

So that, the helium refrigerator power could be reduced.

The condition of calculation

This calculation was carried out under following conditions;

Para-hydrogen would be converted into ortho-hydrogen by neutron-beam in moderator. In this calculation, a content of ortho-hydrogen is assumed to be 5% at point ⑦,⑫&⑰

Results

Total flow rate : 195 g/s(=2.6 L/s)

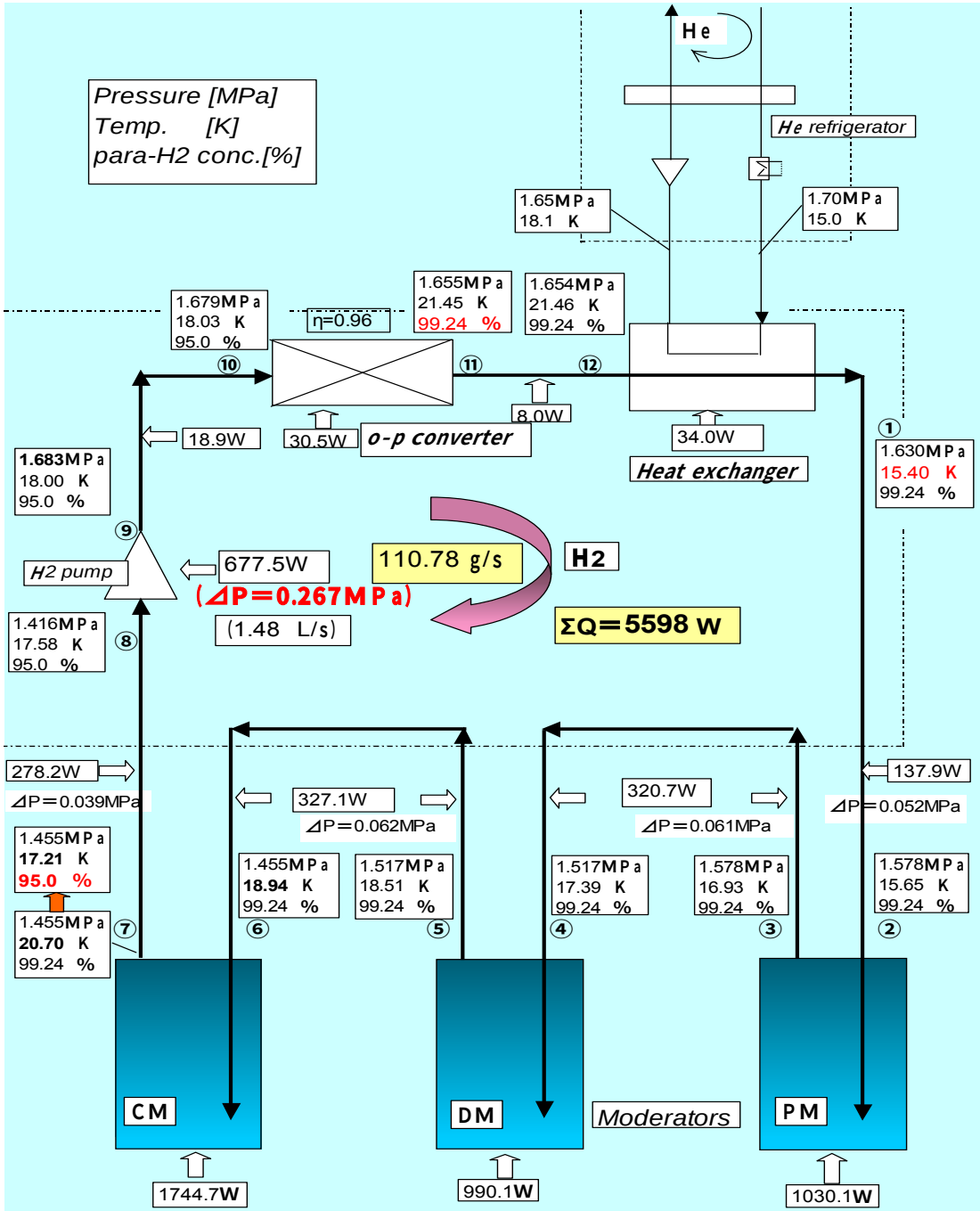
Total pressure drop : 0.106 MPa

Total heat load : 5521 W

Hydrogen supply temp. at heat-exchanger outlet :17.4 K

Para-hydrogen content at moderators' inlet : 99.5%

Process Flow Diagram of H2 loop in Series Cooling



Total flow rate : 111 g/s(=1.5 L/s)

Total pressure drop : 0.267 MPa

Total heat load : 5598 W

Hydrogen supply temp. at heat-exchanger outlet :15.4 K

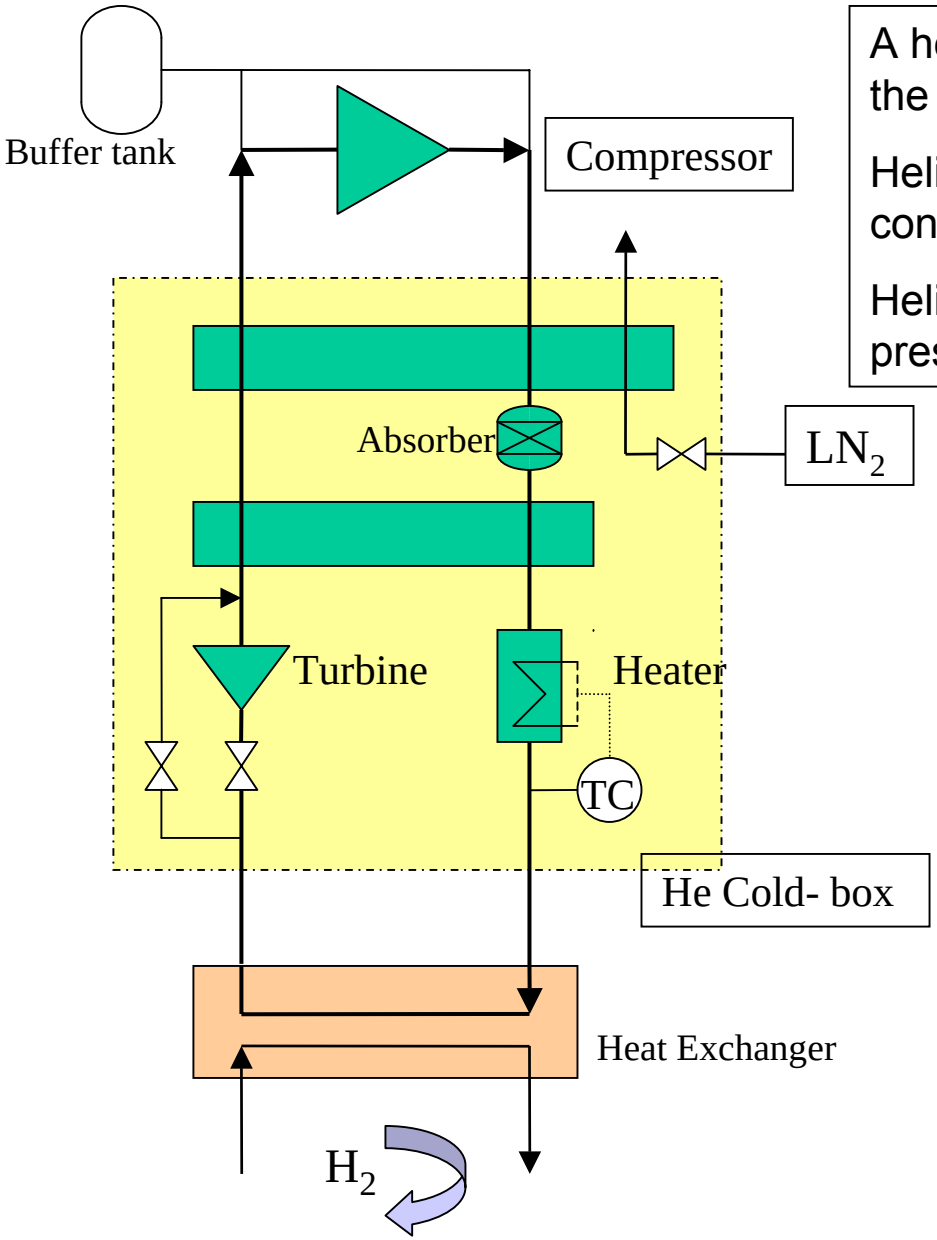
Para-hydrogen content at moderators' inlet : 99.2%

Flow performance of the series cooling is not better than that of the parallel cooling.

Specification of Ortho-Para Converter

Catalyst	$Fe(OH)_3$
Efficiency of conversion	96.0 [%]
Space velocity of catalyst	600 [min^{-1}]
Flow rate	194.7 [g/s]
Inlet pressure	1.52 [MPa]
Inlet / outlet temperature	17.85 / 20.67 [K]
Inlet/outlet para conc.	96.12 / 99.49 [%]
Catalyst filling volume	260 [L] ($^{i}\Phi$550x ^{h}1100 mm)
Dimension of o-p converter	$^{O}\Phi$570x ^{h}1910 [mm]
Allowable pressure drop	< 0.02 [MPa]
H2 volume / inventory	255 [L] / 18.8 [kg]

Flow Diagram of Helium Refrigerator



A helium refrigeration system is designed on the basis of conventional system.

Helium supply temperature (17 K) is to be controlled with an electric heater of 6 kW.

Helium supply pressure is kept higher than the pressure of hydrogen loop.

Helium Cold-box	
Type	Turbine Brayton cycle
Refrigeration power	5600 W at 17 K
Supply pressure	1.6 MPa
LN_2 consumption	150 L/h
Helium Compressor	
Type	Oil injection screw
Suction pressure	0.34 MPa
Delivery pressure	1.7 MPa
Flow rate	320 g/s
Motor input	650 kW

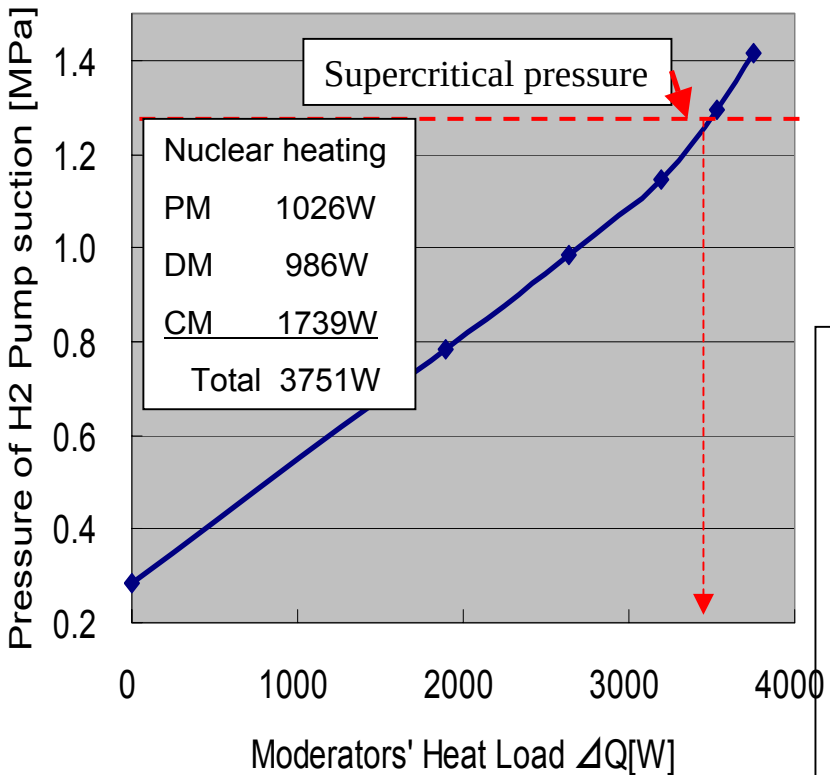
System (Equilibrium) Pressure Change in Case of Reduction in Moderators' Heat Load

Calculation conditions

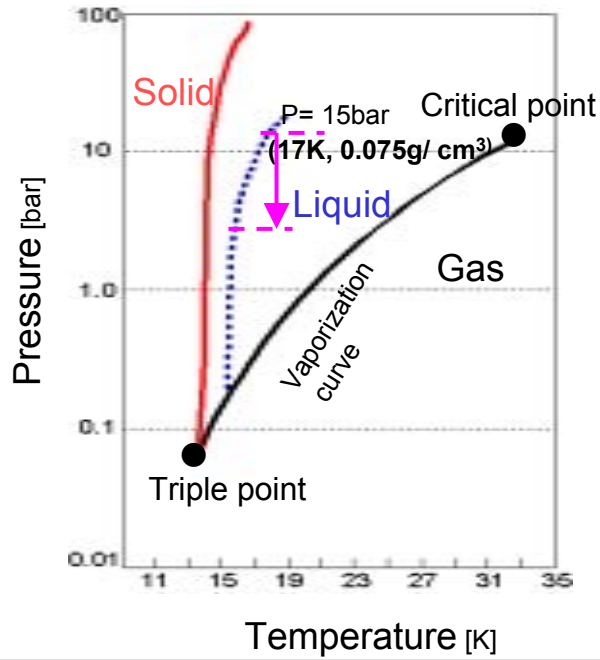
--The hydrogen circulation system is isolated from external hydrogen charge system.

--He refrigeration power and supply temp. is constant, compensating for excess cold with its heater.

--Hydrogen flow rate is constant.



P-T Curve of p-H2



- In the event of proton-beam trip, system pressure of the hydrogen circulation system would be reduced to around 0.3MPa.
- Continuous operation of hydrogen pump would be expected against the beam trip without boiling.
- Pressure control would not be necessary in the event of frequent beam trips .

Concluding Remarks

- Process behaviors of the hydrogen circulation system were estimated under steady state condition.

--Flow performance of the parallel cooling is better than that of the series cooling, so that the helium refrigerator power could be reduced.

- In case of the proton-beam trip, pressure control would not be necessary in spite of decrease of the system pressure.

  Further investigation on another pressure control method (e.g. volume self-adjusting of hydrogen surge tank using bellows) is to be done.