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# Preliminary Design of IHTS Cold Trap for PGSFR

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## 1. Introduction

The main impurities in liquid sodium of the IHTS are oxygen and hydrogen. These impurities form oxides and hydrides with sodium and cause various problems. In order to eliminate the impurities the Cold Trap is installed in the loop. The life and capacity of the IHTS cold Trap depends the amount of impurities. For IHTS loop, the hydrogen has been identified as the major contamination from Steam Generator (SG) during the normal operation. In this study, the sizing of cold trap based on the source rate of hydrogen from SG from past experiences was conducted. Empirical relations among different variables were adopted to establish the temperature distribution, pressure drops, flow rates and geometries for the cold trap and its associated component.

## 2. Bases and Assumptions

At least two cold traps per loop are proposed for the secondary purification system. Among these two cold traps, one is recommended to be used to purify the sodium during initial system cleanup, and another one is planned to be used to clean up the sodium in the IHTS for the normal operation. The size of cold trap for the normal operation has been estimated based on historical data and past experiences of EBR-II, CRBR and other fast reactor projects. The main impurity source for the normal operation of the IHTS loop is hydrogen permeated from the water side of the steam generator. The permeation rate of the hydrogen in IHTS loop of PGSFR is estimated based on followings:

1. The steam generator heat transfer area of PGSFR[1]
2. The permeation rate of the hydrogen from steam generator of CRBR
3. Corrosion study on Martensitic, Ferritic stainless steels and low alloy steel by ORNL[2]
4. Assume the pressure has little impact on the corrosion rate of Martensitic, Ferritic and low alloy steel
5. Assume the 9Cr-1Mo (T91), a Martensitic-Ferritic stainless steel, is a sort of Martensitic or Ferritic stainless steel

Base on foregoing design data, studies and assumptions, the hydrogen permeation source rate was derived for the PGSFR ITHS loop. The mesh volume of the cold trap is then sized based on this source rate.

## 3. Cold Trap Design

Cold Trap is a major component of a sodium purification system. For the PGSFR IHTS loop, the cold trap takes away the sodium impurities, majorly sodium hydride, from the loop by mechanism of precipitation (Fig. 1). Combining with economizer, the sodium through the cold trap with a nominal flow rate of 0.28 $m^3$/min is cooled down from the temperature of 324°C at the inlet of economizer to the coldest temperature of 110°C at the bottom of the trap. Air blows through the fins on the outer surface of the cold trap is used to cool the sodium to the desired temperature.

The cold trap shell has diameter of 1.37 m and length of 2.99 m. Annulus and central regions of cold trap are structured with packed stainless steel (SS) mesh (Fig. 2). The packing mesh of the cold trap is functioned as the impurity collecting site as the large precipitation surface area is created by stainless steel wire.

The volume of the SS mesh is 2.8 $m^3$. The coldest temperature point is located at the bottom of the cold trap, which is determined by less than 0.2 ppm of hydrogen impurity requirement of IHTS loop. Table 1 shows the design parameters of the IHTS cold trap.

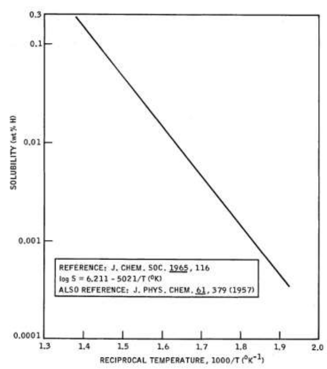


**Fig. 1 Solubility of hydrogen vs. temperature in sodium[3]**

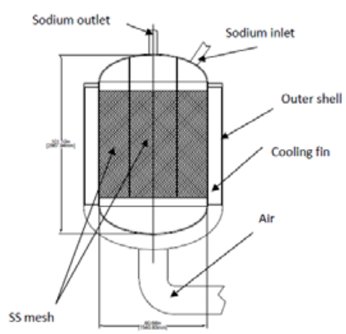


**Fig. 2 Cold Trap assembly**

**Table 1 PGSFR IHTS Cold Trap design parameters**

| Parameters | Values |
|---|---|
| Sodium inlet temperature °C | 149 |
| Sodium outlet temperature °C | 113 |
| Sodium coldest temperature °C | 110 |
| Air inlet temperature °C | 21 |
| Air outlet temperature °C | 50 |
| Nominal sodium volumetric flow rate $m^3$/min | 0.28 |
| Air volumetric flow rate $m^3$/min | 417 |
| Total heat dispatch (kW) | 209 |
| Mesh volume ($m^3$) | 2.8 |
| Mesh wire diameter mm | 0.28 |
| Mesh density g/$cm^3$ | 0.4 |
| Mesh wire material | SS |
| Mesh region diameter (m) | 1.35 |
| Mesh region height (m) | 2.02 |
| Central region diameter (m) | 0.61 |
| Cold trap shell diameter (m) | 1.37 |
| Cold trap shell length (m) | 3.01 |
| Number air cooling fins | 300 |
| Height of air cooling fin (mm) | 40 |
| Length of air cooling fin (m) | 2.28 |
| Capacity of cold trap (kg) | NaH: 160~317 Or $Na_2O$: 258~516 |
| Life of cold trap (years) | 2.84~5.63 |
| Pressure drop Pa exclude entrance and exit losses | 2108 |

## 4. Economizer Design

The economizer is a tube in shell type of heat exchanger (Fig. 3). The purpose of the economizer is to cool down the sodium from the main IHTS loop to a desired temperature at which the cold trap has better performance. The sodium with this temperature is then delivered to the inlet of the cold trap. Another purpose of economizer is to recuperate some heat during the process of purification. The purified sodium that returns from the cold trap to the tube side of the economizer is heated up and feed back to IHTS loop. The temperature difference between the returning sodium and the sodium in IHTS loop is limited to 39°C to reduce the thermal stress on the economizer. Table 2 shows the design parameters of economizer.

## 5. Conclusion

In this study, the IHTS cold trap for normal operation has been analyzed and the preliminary design of corresponding cold trap and economizer has been carried out. For further detailed design, R&D on basic sodium technology will be essential to optimize the Cold Trap.

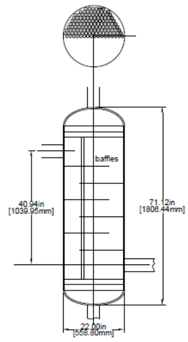


**Fig. 3 Economizer assembly**

**Table 2 PGSFR IHTS economizer design parameters**

| Parameters | Values |
|---|---|
| Type | Tube in shell |
| Shell side inlet temperature °C | 324 |
| Shell side outlet temperature °C | 149 |
| Tube side inlet temperature °C | 113 |
| Tube side outlet temperature °C | 286 |
| Shell outer diameter (m) | 0.559 |
| Shell height (m) | 1.89 |
| Tube diameter (mm) | 25 |
| Effective tube length (m) | 1.04 |
| Number of tubes | 253 |
| Pitch between tubes (mm) | 31.75 |
| Tube arrangement | triangular |
| Baffle pitch (mm) | 152 |
| Baffle cut | 25% |
| Number of baffles | 6 |
| Heat exchange capacity (kW) | 1000 |
| Shell side Pressure drop, exclude the exit and entrance losses Pa | 1998 |
| Tube side pressure drop, exclude the exit and entrance losses Pa | 60 |

## Acknowledgement

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