Development of Cryogenic Cooling System for Sustaining Liquid State of LN2

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1. Introduction

Cryogenic cutting technology that is cutting an object as impinging abrasive and liquid nitrogen is one of the most suitable technologies for dismantling a highly radioactive nuclear facility due to the fact that a secondary waste is not generated during the cutting process. KAERI (Korea Atomic Energy Research Institute) has been developing it as a part of a national nuclear long-term R&D project. Now we have finished the design and manufacturing of the cryogenic cutting system comprised of the cryogenic high compressor unit, attenuator, liquid nitrogen transfer pipes, and injection nozzle. However, we are faced with a serious problem that most of liquid nitrogen was evaporated while passing through the attenuator and pipes due to the heat exchange between liquid nitrogen and the outside. Therefore it is necessary to develop their cryogenic cooling systems for preventing the evaporation of liquid nitrogen. In this paper the design of the cryogenic cooling system by using the CFD simulations and their manufacturing, and experimental results are described.

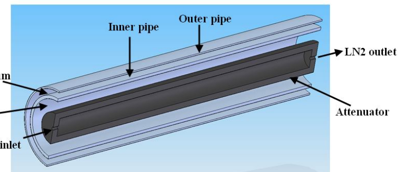
2. Methods and Results

In this section, the CFD results for the attenuator and pipes, manufacturing, as well as test results are described herein.

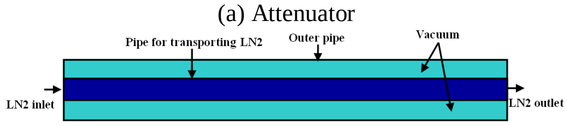
2.1 CFD Simulations

In order to prevent the evaporation of nitrogen in the attenuator and pipes we came up with a double pipe cooling system. Fig. 1 (a) shows the cooling system for the attenuator. The attenuator is covered with the inner and outer pipe and the cooling media (LN2) for cooling the surface of the attenuator flows into the space between the attenuator and inner pipe and the space between inner pipe and outer pipe is in vacuum to prevent from a temperature rising. Fig. 1 (b) shows the cooling system of the pipe for transporting LN2. It is also covered with outer pipe and the space between the pipe and outer pipe is in vacuum as well.

On the basis of these cooling concepts we performed the CFD simulations to find their applicability. Fig. 2 shows the results of the transient CFD simulation of the attenuator. The exit temperature of the attenuator reveals 121 K, which means that LN2 at the exit is the liquid state so this result shows that this method is suitable for cooling the attenuator. The design variables are determined by using the parametric analysis. Table I shows the obtained design values.



(a) Attenuator



(b) Pipe for transporting LN2

Fig. 1. Cryogenic cooling system of attenuator and pipe for transporting LN2.

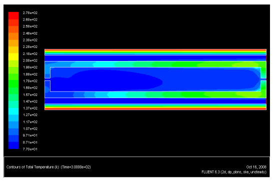


Fig. 2. CFD simulation results of the attenuator.

Table I: Design values of the attenuator

Parameter	unit	value
Inner pipe diameter	mm	180
Outer pipe diameter	mm	250
Cooling media velocity	m/s	1 over

Following the same procedure, the CFD simulation about the LN2 transporting pipe cooling system was carried out. Fig. 3 shows the temperature distribution plot of the pipe. The exit temperature is about 105 K and this temperature is in the range of liquid state of LN2. Therefore this method is also suitable for cooling the LN2 transporting pipe. Table I shows the result of parametric analysis.

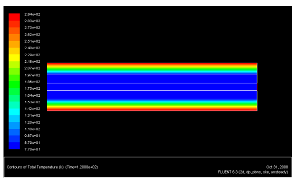


Fig. 3. CFD simulation results of the LN2 transporting pipe.

Table II: Design values of the LN2 transporting pipe.

Parameter	unit	value

Outer pipe diameter	mm	20
Cooling media velocity	m/s	1 over

2.2 Manufacturing

On the basis of the CFD analysis, the cryogenic cooling system of the attenuator and LN2 transporting pipe were manufactured. The cryogenic cooling system is composed of the LN2 supply equipment and the vacuum generation equipment. The LN2 supply equipment is needed to supply pure liquid nitrogen without gas. It separates gas from mixture by using the gravity. Liquid is placed in the bottom and the nitrogen gas is placed in the top due to the weight so the only liquid nitrogen flows out through the valve where it is placed at the bottom of the LN2 supply equipment. The vacuum system is used to generate the vacuum at the attenuator, LN2 transporting pipe, and LN2 supply equipment. It has a buffer tank and several valves to suck up air in several parts simultaneously. Fig. 4 shows the drawing of the LN2 supply equipment and vacuum generation equipment and Fig. 5 shows the drawing of the cryogenic cooling system of attenuator and the pipe for transporting LN2.

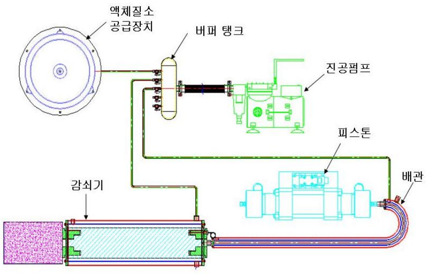
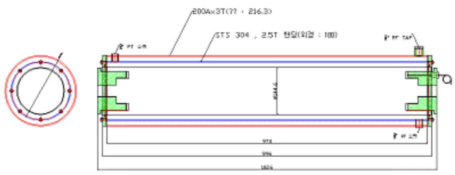
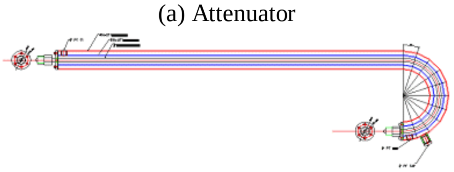


Fig. 4. Figure of LN2 supply equipment and vacuum generation equipment.



(a) Attenuator

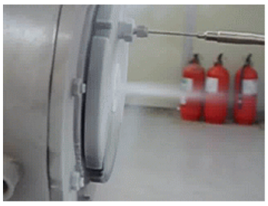


(b) Pipe for transporting LN2

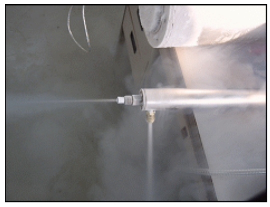
Fig. 5. Figure of cryogenic cooling system of attenuator and pipe for transporting LN2.

2.3 Performance test

In order to find performance of the cryogenic cooling system we conducted the performance tests. Fig. 6 (a) shows the test result about the attenuator. As shown in the figure, it was found that liquid nitrogen jets at the exit of the attenuator were injected well without evaporation. Fig. 6 (b) also shows the test result of the LN2 transporting pipe. In experiment, it was found that the liquid nitrogen jet at the exit of the pipe is projected as well.



(a) Attenuator



(b) LN2 transporting pipe

Fig. 6. Figures of the test of the cryogenic cooling system

3. Conclusions

In this paper the cryogenic cooling systems for attenuator and LN2 transporting pipe were designed and manufactured. To design them we used the CFD simulation technique to obtain the appropriate design values. And also we performed the performance test of the cryogenic cooling systems and found that liquid nitrogen jets were projected well at the exit without the evaporation. Now it is scheduled to combine the cryogenic cooling system with the cryogenic cutting system and is planned to test the cut performance.

It is expected that the cryogenic cutting technology will be a unique cutting solution for a hazardous environment, and if this technology is developed, it might be in great demand in the nuclear industry as well as the aerospace, food, medical industry, etc..

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