

Experimental Study on the Pressure Drop and Water Cooling Characteristics by Steam Driven Ejector and Jet Condenser

You Sik Shin¹, Youn Hwan Lee¹, Hyo Min Jeong², Han Shik Chung², Young Heung Chun² and Sun Jung Kim³

¹Graduate School, Dept. of Mechanical and Precision Engineering, Gyeongsang National University, Tongyeong, KOREA

²School of Mechanical and Aerospace Engineering, Gyeongsang National University, Tongyeong, KOREA

³Department of Building Services Engineering, Hanbat National University, Daejeon, KOREA

Abstract: This study performed of a water cooling system by using a steam ejector and jet condenser to drop the temperature of the water in aquafarm by about 5°C from 25°C or higher. In this research, to replace the present water cooling system, we focused on a water cooling system operated by latent heat of evaporation, thus this system needs a vacuum pressure to evaporate the water in enclosed tank. The water cooling effects are dependent on the vacuum pressure in the enclosed tank, and the cooling water is generated by evaporation. As the experimental results, the absolute vacuum pressure obtained was about 5~8mmHg using a steam driven ejector with jet condenser in experiments from Type 1 to Type12. The temperature difference of the water is about 5°C from Figure 8, 10, 12. Figure 13, 15 and 17 is the graphs of temperature difference of heat exchanger. The obtained results are respectively $\Delta T=7^{\circ}\text{C}$, $\Delta T=5^{\circ}\text{C}$ and $\Delta T=5.5^{\circ}\text{C}$. Figure 19, 21 and 23 is the graphs of temperature difference of heat exchanger. The obtained results are respectively $\Delta T=5.5^{\circ}\text{C}$, $\Delta T=5.5^{\circ}\text{C}$ and $\Delta T=5.5^{\circ}\text{C}$.

Keywords: driven ejector, Jet condenser, Aquafarm, Vacuum, Latent heat of evaporation

NOMENCLATURE

L_A : Air volume in enclosed tank [L]

L_w : Water volume in enclosed tank [L]

Q : Flow rate [L/min.]

T : Temperature [°C]

1. INTRODUCTION

In Korean aquaculture industry, flatfish and jacobever are preferred by fishermen on the ground that the former is characterized by the highly added value and better returns and the latter has advantage of raising the creatures. This implies that to help fries to quickly grow and to be strong enough to get over diseases needs to have much of melted oxygen, especially to have a better control on temperature.

Several investigations of aquaculture in sea water have been reported. Kim(1997)^[3] examined the marine pollutions in view of biology. This biological treatment poses no problems to the aquaculture industry because the aquarium tank is separated from the water pollution. Partridge(1989)^[6] and Sannomiya(1987)^[6] examined the swimming

structure and behavior of fish in an aquarium. Takagi et al.(1993)^[2] considered the effect of the aquarium tank size and shape. Generally, the aquaculture equipment has two types of closed and open flow systems. Jeong et al.(1998)^[1] reported the flow characteristic by comparing a numerical analysis and flow visualization images. Hirashi et al. (1995)^[7] examined the effect of water current in the aquaculture environments of the sea. The closed type is the system which the sea water is recirculated again in the aquarium tank. The water in the case of the open flow system is discharged into the sea. The first system needs more expensive equipment, but this system can save energy in heating the aquarium water during the winter season. Lee(1994)^[4] carried out the experiment of a flow characteristics in the closed aquarium. In the design of the aquaculture tank, what need to be emphasized are the aquaculture environments. This means that the wrong design can cause mass mortality of breeding fish.

There are many important factors for breeding fish in an aquafarm. Some of these factors are biological others include sea water

temperature and so on. What is especially important for good quality is the maintenance of the optimum aquaculture temperature. In summertime, when sea temperatures rise above 25°C the growth condition is greater and diseases in fish spread.

Therefore, we performed a study of a sea water cooling system by using a steam ejector to drop the temperature of the water in the aquafarm by about 5°C from 25°C or higher. To replace the present water cooling system, we focused on a system operated by the latent heat of evaporation, using a vacuum pressure to evaporate the water in enclosed tank. The water cooling effects are dependent on the vacuum pressure in the enclosed tank, and the cooling water is generated by evaporation.

2. EXPERIMENTAL APPARATUS AND DESCRIPTION

The cooling effects are dependent on the vacuum pressure, thus the vacuum pump has to achieve the pressure of evaporation. As the general vacuum pump is designed for high vacuuming in a small space, the ejector pump system is more suitable than the vacuum pump. In this paper, the steam driven ejector pump system is proposed for vacuuming in the enclosed tank.

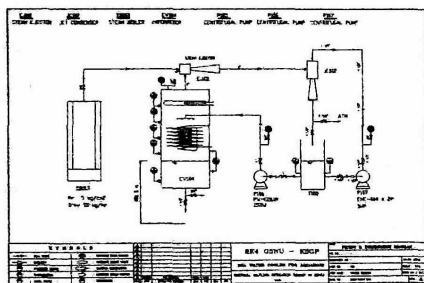


Figure 1: Schematic diagram of the experimental apparatus.

Figure 1 shows the experimental apparatus to measure the effect of vacuum levels in the enclosed tank. The designed vacuum chamber has a capacity of 200L and the inside air of the vacuum tank is evacuated by a steam driven ejector. One heat exchanger was installed in the experimental apparatus.

Figure 1 shows the system generating cooling water by using latent heat of evaporation at low pressure. The low pressure generating system adopts vapor driven in this research. The vapor is created by a steam boiler and goes

through a steam ejector. As the steam which passed the ejector goes through a jet condenser, it drops the pressure inside of the vacuum tank to a vaporable pressure.

The pressure transducer (PSHA0760HAAJ) was installed on the top of the vacuum tank. Six thermocouples (RTD PT100Ω) were installed inside vacuum tank at regular intervals. The pressure signal is transmitted to a personal computer and data logger (DA100, YOKOGAWA).



Figure 2: Photography of experimental setup.

Figure 2 shows photography of experimental setup of steam ejector. The pressure and temperature signal are transmitted to a personal computer and data logger.

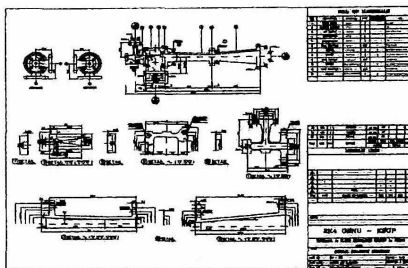


Figure 3: Drawing of steam ejector.

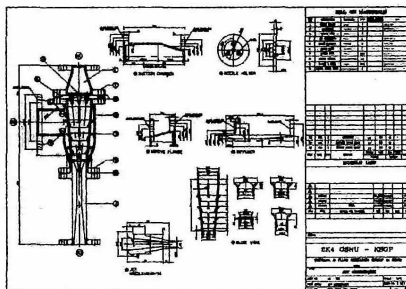


Figure 4: Drawing of jet condenser.

Figure 3 shows the drawing of a steam ejector. The steam ejector is constructed of three parts; a suction chamber, a motive nozzle and a diffuser. The high velocity jet stream of steam emitted by the motive nozzle creates a suction chamber, which draws the low pressure gases. The diffuser converts the kinetic energy of high velocity flow to pressure energy.

Figure 4 shows the drawing of a jet condenser. Jet condenser in an ejector system reduces the amount of vapor load that a downstream ejector must handle. Jet condenser in an ejector system is designed to condense steam.

Table 1: Experimental parameters for water cooling effect and vacuum efficiency of the system.

	Type1	Type 2	Type3	Type4
Enclosed tank volume(Liter)	200	200	200	200
Filled water and air volume(Liter)	0L _w 200L _a	50L _w 150L _a	100L _w 100L _a	150L _w 50L _a
Steam pressure (kgf/cm ²)	4~5gf / cm ²	4~5gf / cm ²	4~5gf / cm ²	4~5gf / cm ²

Table 2: Experimental parameters for water cooling efficiency of heat exchanger flow rate at 4L/M.

	Type5	Type6	Type7
Enclosed tank volume(Liter)	200	200	200
Filled water and air volume(Liter)	50L _w 150L _a	100L _w 100L _a	150L _w 50L _a
Steam pressure (kgf/cm ²)	4~5kgf/ cm ²	4~5kgf/ cm ²	4~5kgf/ cm ²
Flow rate into heat exchanger Q(L/M)	4L/M	4L/M	4L/M

Table 3: Experimental parameters for water cooling efficiency of heat exchanger flow rate at 4.5L/M.

	Type8	Type9	Type10
Enclosed tank volume(Liter)	200	200	200
Filled water and air volume(Liter)	50L _w 150L _a	100L _w 100L _a	150L _w 50L _a
Steam pressure (kgf/cm ²)	4~5kgf/ cm ²	4~5kgf/ cm ²	4~5kgf/ cm ²
Flow rate into heat exchanger Q(L/M)	4.5 L/M	4.5 L/M	4.5 L/M

Table 1,2 and 3 is processed as follow method. The steam ejector is operated after getting 60mmHg vacuum pressure by using a jet

condenser, and then cooling efficiency is measured by experiments with each flow rate of heat exchanger.

3. RESULT AND DISCUSSION

To achieve cooling water, the water should be in an evaporating condition.

This condition can be achieved by vacuuming.

Figure 5 shows the vapor pressure and temperature curve. The pressure in the vacuum chamber has to search the vapor pressure to obtain the cooling effects by using the latent heat of evaporating.

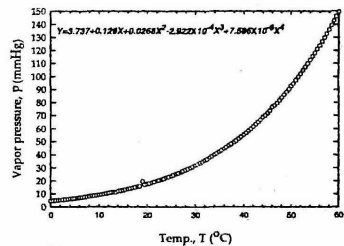


Figure 5: Characteristics curve of vapor pressure by the variation of temperature. at-10°C≤T≤60°C

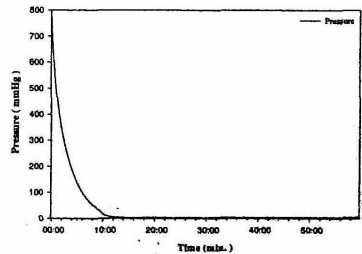


Figure 6: Vacuum pressure of Type1 in table 1.

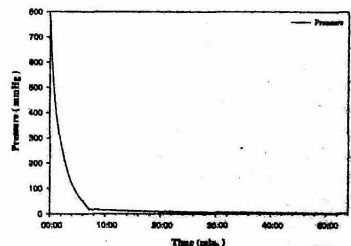


Figure 7: Vacuum pressure of Type2 in table 1.

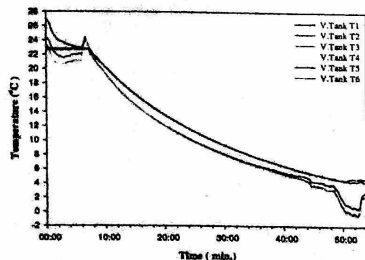


Figure 8: Temperature distributions in enclosed tank of Type2 in table 1.

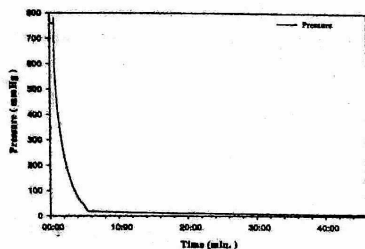


Figure 9: Vacuum pressure of Type3 in table 1.

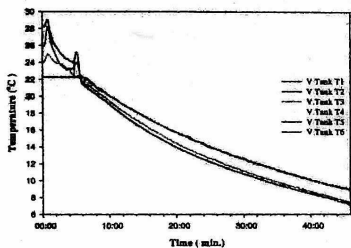


Figure 10: Temperature distributions in enclosed tank of Type3 in table 1.

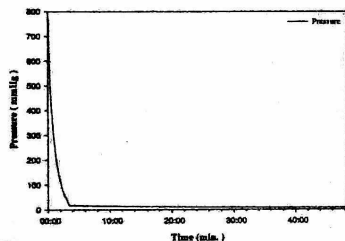


Figure 11: Vacuum pressure of Type4 in table 1.

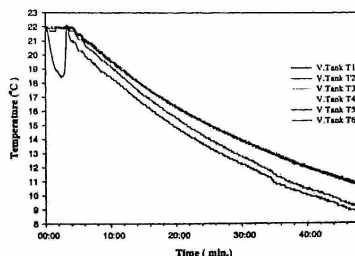


Figure 11: Temperature distributions in enclosed tank of Type4 in table 1.

Figure 6, 7, 9 and 10 represents the vacuum pressure distributions for the four experiments as shown in table 1.

Table 1. After 15–20 minutes, the pressure had an almost steady condition and the pressure values of Type1, Type2, Type3 and Type4 were recorded 5–8 mmHg. abs.

Figure 8, 10 and 11 show the temperature distributions of the enclosed tank for each type. ΔT obtained from each type is about 10°C and the pertinence of this system is proved by experimental graphs of pressure and temperature.

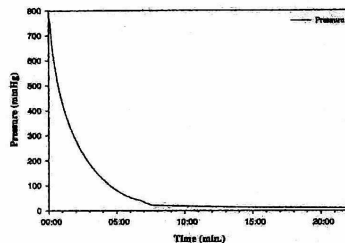


Figure 12: Vacuum pressure of Type5 in table 2.

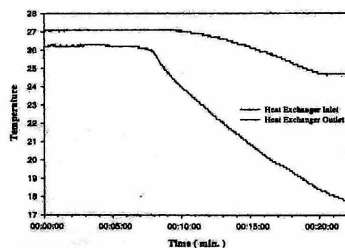


Figure 13: Variation temperature of heat exchanger at Type5 in table 2.

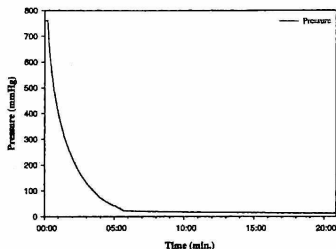


Figure 14: Vacuum pressure of Type6 in table 2.

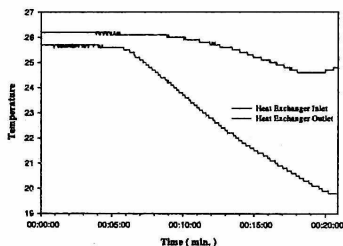


Figure 15: Variation temperature of heat exchanger at Type6 in table 2.

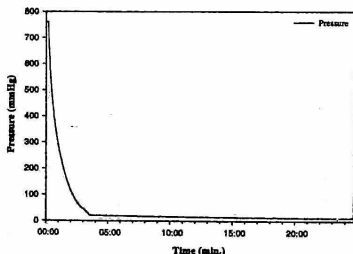


Figure 16: Vacuum pressure of Type7 in table 2.

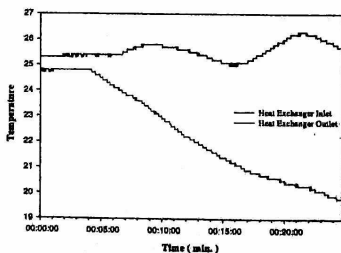


Figure 17: Variation temperature of heat exchanger at Type7 in table 2.

Figure 12, 14 and 16 show vacuum pressure of heat exchanger flow rate at 4L/M and the absolute vacuum pressure obtained was about 5-8mmHg at this point.

Figure 13, 15 and 17 is the graphs of temperature difference of heat exchanger. The obtained results are respectively $\Delta T=7^{\circ}\text{C}$, $\Delta T=5^{\circ}\text{C}$ and $\Delta T=5.5^{\circ}\text{C}$.

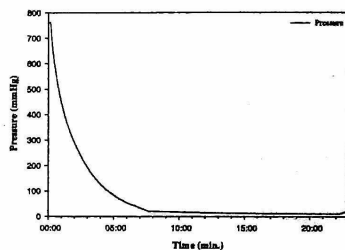


Figure 18: Vacuum pressure of Type8 in table 3.

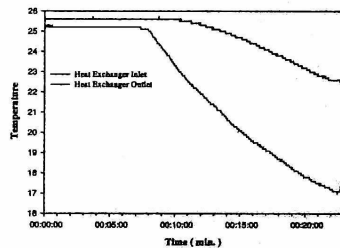


Figure 19: Variation temperature of heat exchanger at Type8 in table 3.

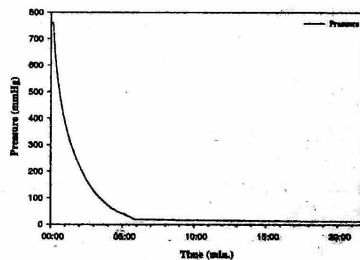


Figure 20: Vacuum pressure of Type9 in table 3.

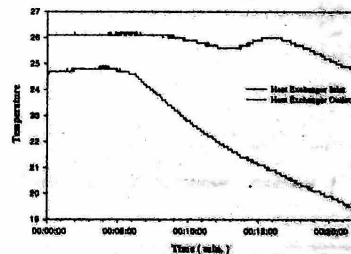


Figure 21: Variation temperature of heat exchanger at Type9 in table 3.

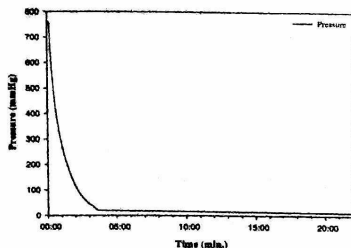


Figure 22: Vacuum pressure of Type10 in table 3.

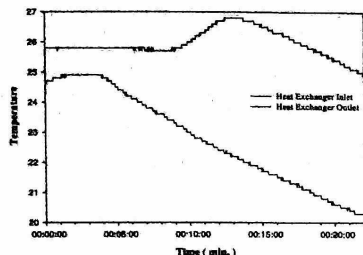


Figure 23: Variation temperature of heat exchanger at Type10 in table 3.

Figure 18, 20 and 22 show vacuum pressure of heat exchanger flow rate at 4.5L/M and the absolute vacuum pressure obtained was about 5~8mmHg at this point.

Figure 19, 21 and 23 is the graphs of temperature difference of heat exchanger. The obtained results are respectively $\Delta T=5.5^{\circ}\text{C}$, $\Delta T=5.5^{\circ}\text{C}$ and $\Delta T=5.5^{\circ}\text{C}$.

When the graphs of heat exchanger flow rate at 4L/M and 4.5L/M are compared bigger temperature difference can be obtained with lower flow rate.

4. CONCLUSION

In this research, we proposed a water cooling system by latent heat of evaporation. This system consists of the enclosed vacuum tank and steam driven ejector with jet condenser.

From an experimental result, the conclusions are summarized as follows;

Water temperature proposed in this research is 25°C and higher and the cooling system that temperature difference is about 5°C was introduced.

As the experimental results, the absolute vacuum pressure obtained was about 5~8mmHg using a steam driven ejector with jet condenser in experiments from Type 1 to Type12. The temperature difference of the water is about 5°C from Figure 8, 10, 12.

Figure 13, 15 and 17 are the graphs of temperature difference of heat exchanger. The obtained results are respectively $\Delta T=7^{\circ}\text{C}$, $\Delta T=5^{\circ}\text{C}$ and $\Delta T=5.5^{\circ}\text{C}$.

Figure 19, 21 and 23 are the graphs of temperature difference of heat exchanger. The obtained results are respectively $\Delta T=5.5^{\circ}\text{C}$, $\Delta T=5.5^{\circ}\text{C}$ and $\Delta T=5.5^{\circ}\text{C}$.

The proper cooling effect needed in this research can be obtained by using heat exchanger.

From Type1 to Type 4, the bigger temperature difference is occurred when heat exchanged is not used. It means that the bigger cooling effect can be obtained with the system of water circulating through inside of tank.

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