ECONOMIC ANALYSIS OF HEAT PUMP USED AS HEAT AND COLD SOURCE FOR MARICULTURE

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ABSTRACT

Aiming at the shortages of conventional heat and cold source for mariculture, the paper points out the scheme that the heat pump should be used to heat and cool seawater for mariculture, and proves it is reasonable by economic analysis. As one of no-polluted and economical ways of heat and cold source, this project should be largely utilized for practical engineering of mariculture in China.

Keywords: economic analysis, heat pump, heat and cold source, mariculture

INTRODUCTION

How to control the water temperature is one of key techniques for mariculture. Different fishes breeding requires different water temperature. For example, the prawn and seashell's early raising requires the water temperature of about 25℃, but for the cold-water fishes such as turbot etc, the temperature should be under 20℃. Under general condition, we raise scallop and prawn in March and April, but at this period, the coastal water temperature of Shangdong Peninsula is about 10℃, so the water temperature need to be raised. On the other hand, at certain time in summer, the water temperature is about 25℃. For cold fishes the water temperature need to be lowered.

In China, the scheme of traditional heat and cold source for aquatic breeding is the following. In March and April, the boiler (include coal-fired boiler, oil-fired boiler or electrically heated boiler) is often used to supply the heat to produce an increase in temperature of sea water for breeding, and in summer, the ground water is used as cold source to produce a decrease in temperature of sea water. There are some shortages of this scheme as follows.

⑴ As the ground water is much limited, it is not reasonable to take out the ground water to cool seawater. It not only wastes the valuable natural source but also may make the ground water dry up gradually and give rise to the earth's surface sinking. However, some aquatic breeding

enterprises don't realize the seriousness of this problem and so over extract the ground water. As the lack of ground water, lots of wells in some turbot's aquatic breeding farms can't take out enough groundwater, which declines the output of turbots seriously. For example, Qingdao Liuting aquatic breeding farm, as the short of the ground water, the output is lower than the requirement of design. On the other hand, in some areas there is no groundwater to use, which seriously limits the turbot's production.

⑵ Although the cost of coal-fired boiler and the running charges are low, the coal-fired boilers may cause serious pollution to our environment. Because of this, the coal-fired boiler under 10t/h was forbidden to use in Qingdao city. And the running cost of Oil-fired and electrically heated boilers is comparatively high. On the other hand, heating directly by electricity has not only high running cost but also comparatively low utilizing efficient of original energy source. It isn't advisable for this scheme.

⑶ There are lots of quantity of heat or cold (i.e. energy) in the aquatic breeding farms' drainage. For example, in winter the temperature of water for raising prawn and scallop is about 25℃, higher than the temperature of the water in sea, while in summer, the temperature of water for raising turbot is about 20℃, lower than the temperature of the water in sea. The water with energy is usually drained into sea without retrieve of heat or cold. Which leads to the waste of energy.

Some turbot's breeding farms adopt special equipment to reclaim the drainage's quantity of heat or cold, but there are existing some problems as follows. First, the primary investment is high，taking 1000 cubic meters water as example, only the cost of equipments that reclaims the drainage's energy is about 3 million yuan. Second, the running cost is high, and disposal of one ton of water needs about 0.3-0.4 yuan. Third, the areas occupied by equipments of reclaiming the drainage's energy are large. At last, the operation is complex for adopting organism treatment. Because the alive organism would be destroyed when the operation being stopped every time and it is hard to run again for culturing the new alive organism.

1. HEAT PUMP USED AS HEAT AND COLD SOURCE FOR MARICULTURE

According to the analysis above, the conventional scheme of heat and cold source for aquatic breeding must be changed to meet our country's economic persistence development . Heat pump can absorb the heat from the low temperature environment(such as atmosphere, groundwater, seawater, soil etc),then give out heat to those required areas. Heat pump units possess two functions, that is to say, it is used to supply heat in winter and to supply cold in summer. As one of heat and cold source, heat pump has always be used in the building's air-conditioning and heating system. Being a form of heat and cold source, it can also be applied for the seawater's heating and cooling to provide an appropriate water condition for aquatic breeding, to increase the aquatic products' output. Using the heat pump as heat and cold source to supply heat and cold for seawater, it is effective and easy to control water temperature in mariculture.

For aquatic breeding, there are several kinds of heat pumps to be selected, the air-cooled heat pump, the ground source heat pump, and the seawater source heat pump. Air-cooled heat

pumps have some shortages, such as the volume of equipment is large, the running noise is high and the technology of removing frost is complex etc. Due to the climatic feature, the air-cooled heat pumps are often used in the Changjiang River basin for the building's air-conditioning and heating system. For aquatic breeding, air-cooled heat pump is not used in the icy winter, it is used in March for the early raising period. So that the areas to use air-cooled heat pump can be expanded largely. It is no longer the principal contradiction that the heat quantity supplied by air-cooled heat pump is lesser with a decease in temperature of outdoor air in winter.

Ground source heat pump uses the ground energy(ground water, soil or surface water) as the heat or cold source. In winter it absorbs heat from the ground energy, which is called "heat source". In summer it takes out the controlling area's heat and discharges it into ground water, soil or surface water. When ground source heat pump is used as heat and cold source for aquatic breeding, the heat exchange coil made of high intensity plastics should be set in the sea to release or absorb heat to seawater. The closed recycle pipe is full of the medium, which is usually water solution against freezing. Because of closed circulation, the medium don't mingle with seawater, the materials made up heat pump isn't constrained by corrosion. Ground source heat pump couldn't cause any pollution to the seawater.

Seawater heat pump adopts opened water circulation system, and utilizes seawater as the direct medium to exchange heat. That's to say, the seawater is pumped into the evaporator to exchange the heat, then the seawater returns to the sea again, which is continuously circulated to collect or emit heat to seawater. This heat pump may be regarded as a special form of ground source heat pump that the endothermic side of the ground source heat pump unit (when supply heat) or the exothermic side(when supply cold) adopts open recycle water system. Because the heat exchanger is exposed to the seawater, the evaporator (or condenser) should be made of the anticorrosive materials. In addition, the marine alga and the floating things in the sea may decrease the efficiency of heat exchange of seawater heat pump, so some steps to prevent the alga from growing should be taken. Similarly, seawater heat pumps don't pollute the sea as the ground source heat pumps.

When the closed circulating project is utilized, the heat exchange coils made of intensive plastics are used in the sea, so the efficiency of heat exchange is lower. This kind of heat pump should not be adopted in the aquatic breeding.

In winter the quantity of heat that the aquiculture needs includes two parts: the quantity of heat which heats the water exchanged and the quantity of heat emanated to the surroundings. Similarly, in summer the quantity of cold also include the exchanged water's quantity of cold and the quantity of cold emanated to the environment. Different breeding requires different water temperature and varied numbers of water exchanged. Consequently it is distinctive to determine the heat or cold quantity according to the requirement of the aquiculture.

There are two ways to heat the pool's water for traditional aquatic breeding. One way is to heat the water inside breeding pool by using heating coils, i.e. heating coils are set up in each breeding pool to heat up the seawater directly. There are independent valves to control temperature of the water inside breeding pool. The other is to set up a special heating pool in which the water is heated up, then lets the heated water flow into each breeding pool to meet the requirement of the temperature. Generally, raising the scallops often adopts the first way and the breeding of prawns can use two ways either.

When seawater heat pumps are used as the heat source for aquatic breeding, the temperature of the water supplied by heat pump is about 40～50℃. There is no point to set up the special heating pool to heat up water, the water supplied by heat pump can flow into the breeding pool to make the pool's water temperature rise according to the requirement.

Similarly in summer when using heat pump to cool seawater the water supplied by heat pump can also be contributed to the breeding pool according to the required water temperature.

If the water inside breeding pool is heated by using heating coils, the heat exchange coils should be set up in the pool to supply heating for water indirectly. For steel pipes can be corroded seriously in the seawater and the corrosive substance can lead bad influence on the water quality of pool, the heat exchange coils must be made of plastics and should be installed about 200mm apart from the bottom of pool where at each certain distance to put up a padding block (concrete piece) to fix it.

When seawater heat pumps are used as the heat and cold source for the aquatic breeding, the heat or cold quantity of the drainage of breeding pool should be reclaimed. For example, in winter the water temperature of raising prawns and scallops is about 22~25℃,which is equal to the temperature of drainage, while at this moment the temperature of seawater is below 10℃, so the drainage should be mixed with seawater in the intake of water pumps used to pump seawater in order to reclaim the drainage's heating. And in summer the temperature of raising turbots is about 20℃, which also is equal to the drainage temperature. While at this time the temperature of seawater is above 20℃， usually about 24℃, accordingly drainage's cold quantity should be reclaimed to improve the coefficient of performance of heat pump.

2. ECONOMIC ANALYSIS FOR HEAT PUMP

The primary investment of heat pump is larger than that of the boiler, but the boiler can only be used to supply heat in winter, and when in summer the cooling equipment must be set up for breeding cold fishes. The traditional scheme to reduce the seawater temperature by mixing the ground water can cause the serious waste of ground water. Moreover there have no ground water to use in some areas. At the same time, if the electrically heated boiler is used, the large capacity of supplying power equipments must be set up, and utilizing efficient of original energy source is lower. However using the heat pump units can easily solve the problem, and only a set of equipment is used to get heat or cold.

According to the test data in 1995, the seawater temperature(under water surface 5 meters) around the Yellow Sea coast near Qingdao city is about 21～25℃ on the 15th～31st of January, which is higher than the air temperature and comparatively stable. In summer from the 16th of July to the 23rd of August the seawater temperature(under water surface 5 meters) is about 21～25℃, which is lower than the air temperature and stable relatively (Nengzhao Jiang 1999). So it is concluded that the seawater is one of the best heat and cold source for aquatic breeding when seawater heat pump is used.

When heat pump is used for aquatic breeding, the temperature of supplied water by heat pump should be 10℃ under refrigeration condition and 45℃ under heating condition. In this case, the COP (coefficient of performance) of air-cooled heat pump for model of 30GQ-100 are

shown in fig.1, the COP of seawater heat pump for model of LSQR-90 are shown in fig.2.

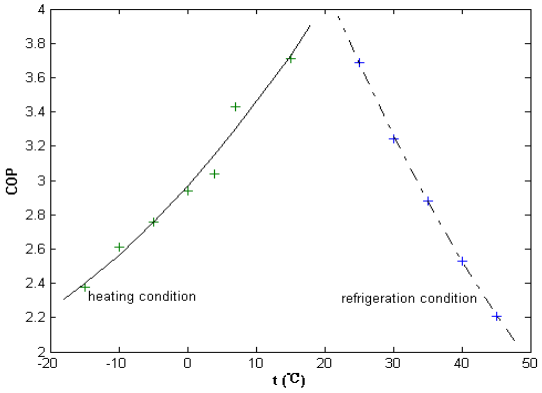

Fig1. The COP of air-cooled heat pump of 30GQ-100 under variety of air temperature

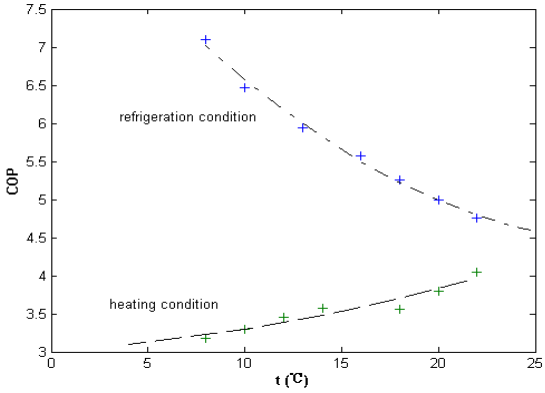

Fig2. The COP of seawater heat pump of LSQR-90 under variety of seawater temperature

Comparing the seawater heat pump with the air-cooled heat pump, the seawater heat pump has lots of advantages.

(1). In winter the seawater temperature is higher than that of air, and while in summer it is lower than that of air. So the coefficient of performance of seawater heat pump is higher than the air-cooled heat pump's ,which is more than about 10%～30% in summer. Because the air temperature is higher than seawater temperature in spring, the air-cooled heat pump with higher coefficient of performance can also be used for breeding.

(2). The Seawater heat pump needn't defrost and so it reduce the heat loss of frosting.

(3). The heat or cold quantity of the drainage of aquatic breeding farm can be reclaimed to improve the coefficient of performance of heat pump.

At the beginning of 1990s, the seawater heat pump in our country mainly relied on the imports whose price is so high that the breeding corporation couldn't buy and use it. At present this heat pump has already been manufactured in china, and its technical functions have been reached the international standard and its price can be accepted by the breeding enterprise. It is possible to use the heat pump units for breeding economical fishes (such as turbot). Temperature adjustment is convenient for heat pump, which possesses the advantages of high efficiency, saving energy, economy, no pollution and safety etc.

Taking an example of building 1000 cubic meters synthesis breeding pool, the equipment's investment and running cost of heat and cold source are listed in table 1. In the table the water temperature rises from 15℃ to 25℃ for raising the prawn and scallop in spring, and the cycle of running is about three months. In summer, when using the heat pump, the water temperature drops from 25℃ to 18℃, the water should be exchanged four times a day, and the cycle of running is about three months. The oil price is about 3.2 yuan per kilogram, and the electrovalence is in about 0.35 yuan per KWH drafted in[2000]3 document by Qingdao municipality. The thermal efficiency oil-fired boiler's is about 88%, the heat quantity from diesel oil's burning is about 40610 KJ/KG, the price of diesel oil is about 3.2 yuan per kilogram, the thermal efficiency of electrically heated boiler is about 98%, the COP for heat pump is given by the practical running condition.

Table 1. Equipment Investment and Running Cost

	Equipment of Heat Source (yuan)	Construction Investment (yuan)	Digging Well Cost (yuan)	Total Investment (yuan)	Cold Quantity (KW)	Heat Quantity (KW)	Running Cost in Winter (yuan)	Running Cost in Summer (yuan)
Oil-fird Boiler	260000	60000	300000	620000	1220	1000	696000	62000
Electrically Heated Boiler	380000	60000	300000	740000	1220	1000	772000	62000
Air-cooled Heat Pump	1600000	20000		1620000	1220	1000	180000	332000
Seawater Heat Pump	1580000	30000		1610000	1220	1000	180000	212000

According to the analysis above, using the seawater source heat pump has many advantages. It can meet the demand for aquatic breeding and can be used in different season for supplying the heat and cold quantity. It can also be managed easily and has low running cost. Compared to the oil-fired and electrically heated boiler, the saved running cost by using the heat pump could take back the excess investment of equipments in about two or three years. So it is economical to be used in mariculture.

3.CONCLUSIONS

In aquiculture, using the heat pumps as heat and cold source are low operating cost and no-polluted. It accords with the national basic policy of energy and environment protection and may satisfy the strategy demand of economic persistence development. There are some obvious advantages in using heat pump for aquatic breeding, such as sufficiently recycle and utilize the drainage energy of breeding pool, saving the occupied areas, no-pollution and low running cost etc. Moreover, the excess of equipment investment may be taken back from the saved running cost of using heat pump in two or three years. Using the heat pump to supply heat and cold in aquiculture can promote its extensive development, lessen the excessive exploitation of ground water and save the natural resources. So heat pumps can substitute for the coal-fired boiler, oil-fired boiler and electrically heated boiler.

Using the heat pump can bring greatly economic and social benefits. The heat pump should be largely utilized in aquiculture in China.

REFERENCES

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