# FISH REARING PONDS CASCADED FROM BINARY POWER GENERATION

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This article presents result of an investigation into heating fish ponds using geothermal effluent from a binary power generation plant. The investigation was the result of an inquiry to the Geo-Heat Center and is based on a particular location–but should be applicable to any location with similar climate–with appropriate modifications.

**GIVEN INFORMATION**

4,000 gpm of 205°F geothermal effluent available (not suitable for fish habitat).

| | |
|---|---|
| Minimum temperature | -30°F |
| Coldest month average temp. | 20.6°F |
| Coldest month average wind | 10 mph |

4 ponds, 30 ft x 90 ft x 4 ft average depth

Desired temp. 70-75°F

Ponds plastic lined to prevent seepage with sand on plastic

Approximately 2 acres of fire suppression ponds available as bio-filter and source of oxygenated water adjacent to fish pond site

25% of fish pond volume exchange with fire pond water per week

Heating design assumptions, 0°F, 10 mph wind

Calculated heat loads:

| | |
|---|---|
| Evaporation | 440,850 Btu/hr/pond |
| Convection | 384,910 |
| Radiation | 15,470 |
| Total | 841,230 x 4 = 3,365,920 Btu/hr |

Makeup water @ 25%/wk is a bit more than evaporation at design heating conditions–and a bit less than evaporation during summer months.

The proposer presented the idea of heating the ponds by flowing the 205°F geothermal effluent through steel pipes on the pond bottoms or resting the pipes on cement blocks. After some thought, it was proposed that:

1. Pipes on the bottom would not transfer heat effectively; since, they would likely be partially buried and there would be no water circulation around them. Also, they may rapidly deteriorate the plastic liners; unless, there was considerable depth of sand.

2. Pipes on blocks would promote heat transfer but present problems in harvest using sein nets.

3. In both 1 and 2, water near the pipes would be much too hot for the fish, and with only natural convection, there may be cold spots–promoting crowding in the desired temperature zones. Also, the hot pipes would present a danger to workers during the occasional need to wade in the pond for husbandry purposes.

4. A recirculating system utilizing a heat exchanger to supply relatively hot water to one end of the pond with return at the other would also result in a temperature gradient promoting crowding. Supplying warm water closer to fishes desired temperature would require larger more expensive heat exchanger and/or increased flow rates requiring larger more expensive pumps and higher operating costs.

The final proposed system was patterned after ponds successfully used to grow prawns, mosquito fish and rainbow trout some 20 years ago at Oregon Institute of Technology. That system used 135°F geothermal effluent cascaded from one of the campus buildings in the ponds; since, the chemistry was suitable for the animals.

A proposed schematic for the system is shown in Figure 1. The pumps, controls and heat exchanger could all be located in a small shelter near the ponds.

Geothermal effluent from the power plant is teed off from an existing pipeline between the power plant and injection well. Peak flow would be 55 gpm. Geothermal enters the heat exchanger at 205°F and exits at 76°F at peak load conditions. Pressure drop is 0.98 psi. Fluid chemistry dictates titanium plates in the exchanger. Steel or FRP piping will be required on the geothermal side of the exchanger.

PVC piping was proposed for the fish pond side of the system; where, the supply side is at 135°F. Although PVC pressure rating is reduced at elevated temperature, at 135°F it has 0.26 of its pressure rating at 73°F or 55 psi in sizes up to 4 inches. Proposed maximum pressure is 15-20 psi.

From pump #1, 108 gpm of about 70°F water flows through the heat exchanger and is heated to 135°F, then through an adjustable pressure limiting valve, and to the distribution and diffusion piping. Distribution and diffuser piping are 2-in. PVC. (More about diffuser hole size and spacing later.) Pond level is controlled by 4-in. screened

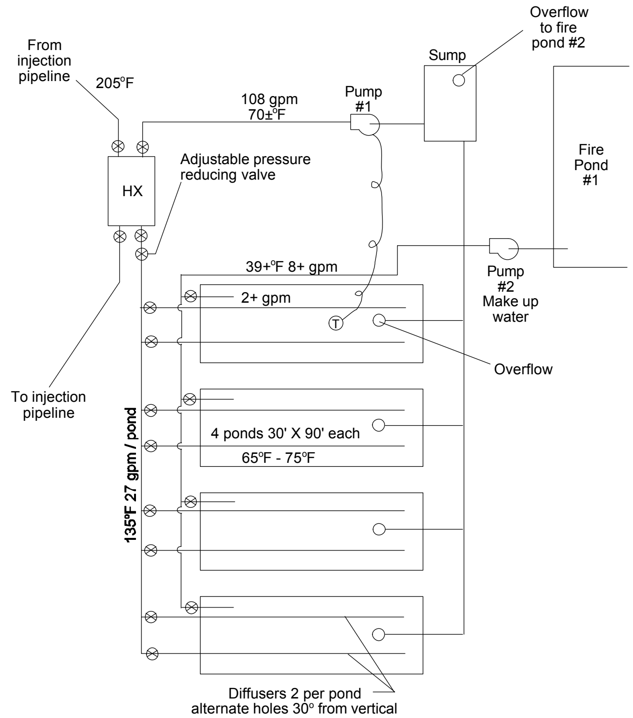


*Figure 1. Pond layout.*

overflow pipes set at the appropriate level and connected to a sump via underground PVC. Over flow from the sump goes to a fire pond. Pressure drop across this side of the exchanger is 3.7 psi.

Makeup water is supplied by pump #2 at a minimum of 8 gpm (2 gpm per pond) as required for bio-filtering. Manual balancing valves permit adjusting each pond's flow. During summer, this must be increased to allow for higher evaporation rates.

Geothermal fluid flow through the heat exchanger is continuous; although, it can be controlled manually by one of the isolation valves. Pond temperature is sensed in one or more of the ponds, and controlled by turning pump #1 on or off. Some experimentation may be required to find the best location for the sensor. Alternatively, each pond could be controlled by a temperature sensor and a solenoid valve at each pond (not shown). When ponds are at temperature and all solenoid valves closed, a pressure switch at the pump would turn it off and on again, when one or more solenoid valves opened.

Flow through the holes in a diffuser pipe is somewhere between the flow through a short pipe connecting two tanks with unequal fluid levels and a square edged thick plate orifice. The general equation is of the form:

$$Q = C_D A \sqrt{2g P_1 - P_2}$$

where, $C_D$ is an experimental-derived coefficient of discharge ranging from 0.61 for the tanks to about 0.80 for the orifice. Not finding a good reference for the value of $C_D$ in this configuration and remembering that the people who made OIT's diffusers 20 years ago made several trial runs before they arrived at the proper size, it was decided to experimentally determine some flows versus pressure and hole diameter. The experimental setup is shown in Figure 2. The results are shown graphically in Figure 3.

For instance, results indicate that at 12 psi at the pressure valve and allowing for 2 psi loss in piping, 0.607 gpm will flow through a 3/32-dia. Hole, requiring 23 holes per diffuser pipe to supply 27 gpm per pond at peak load. At 3-ft hole spacing, 69 ft of diffuser is required. Other combinations of pressure and hole size result in other numbers of holes and spacing.

A caveat: when drilling small holes by hand in soft materials, the holes are almost invariably larger than the drill size. Our $C_D$ values based on the equation above were 0.72-0.73.

## MAJOR COMPONENT COSTS

| | |
|---|---|
| Heat exchanger | $5,640 |
| Pump #1 4-hp | 780 |
| Pump #2 ½-hp | 150 |
| Pressure control valve | 450 |
| PVC 2-in, 1,000 ft | 310 |
| PVC 4-in., 250 ft | 280 |
| 8 2-in. PVC valves | 200 |

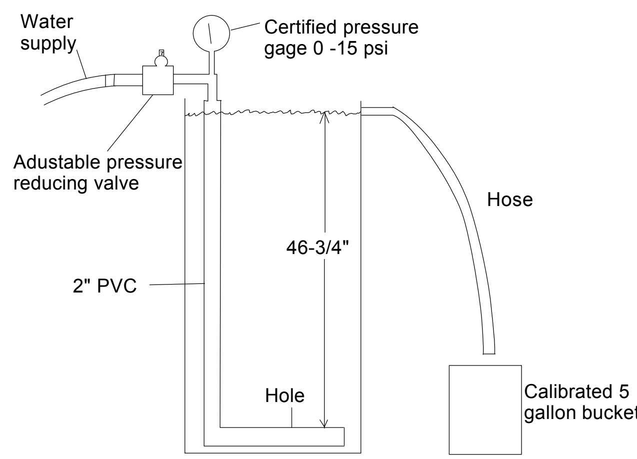


*Figure 2. Experiment setup.*

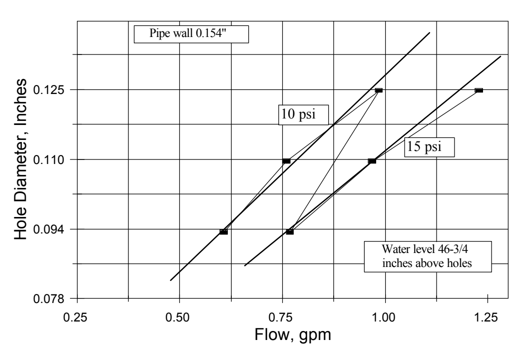


*Figure 3. Experiment results.*