# DIRECT-USE TEMPERATURE REQUIREMENTS: A FEW RULES OF THUMB

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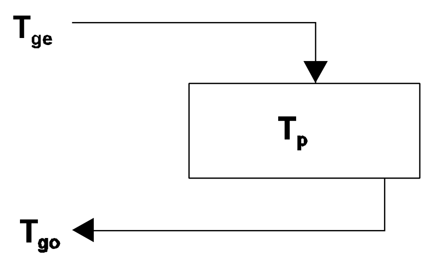
## INTRODUCTION

Over the years, questions posed to Geo-Heat Center engineers have frequently taken the form: "What temperature do I need to do ___________;" or "I have a resource of ____ $^{o}$F, can I feasible run a _____________." This article is intended to provide the reader with a few rules of thumb for the minimum temperature requirements of typical direct-use applications and equipment.

The design of mechanical systems involving heat transfer, such as direct-use geothermal systems, is heavily influenced by temperature. Temperature difference--what engineers refer to as Delta T (often written $\Delta t$)--is particularly important as it frequently governs feasibility, equipment selection and flow requirements for the system. Important though it is, the gruesome intricacies of heat transfer can be a yawner for even the most ardent engineer, but acquiring familiarity with a few key principles is relatively painless.

The flow of heat has close parallels to the flow of water--a phenomenon much more familiar to most people. Water naturally flows from a higher pressure to lower pressure. Causing water to flow from point A to point B requires that a higher pressure exist at A than at B. The higher the pressure difference between the two points, the greater the water flow will be. Pressure is the tool we use to cause the water to flow from A to B. In much the same way, temperature is the "pressure" that is used to cause heat (usually measured in Btus) to flow from Point A to point B. Heat naturally flows from a high temperature to a low temperature. That is, some temperature difference (or $\Delta t$) must exist to cause the heat to flow from one place to another. Just as in the case of water flow, the greater the temperature difference available, the greater the heat flow. In direct-use systems, the goal is to cause heat to flow out of the geothermal water and into a process--aquaculture, greenhouses, buildings, industrial processes, etc. To accomplish this, it is often necessary for the heat to flow through equipment (heat exchangers of various types) that constitutes a resistance to heat flow. To overcome this resistance, a temperature difference or $\Delta t$ must be allowed for at each point where heat is transferred. Understanding the magnitude of the temperature differences required is key to the evaluation of a individual applications.

Two primary temperature differences govern feasibility, flow requirements and design of direct-use equipment. These are illustrated in a simplified way in Figure 1. The first is the difference between the geothermal temperature entering the system (Tge) and the process temperature (Tp). This difference determines whether of not the application will be feasible. For a direct-use project, the temperature of the geothermal entering the system must be above the temperature of the process in order to transfer heat out of the geothermal water and into the process (aquaculture pond, building, greenhouse, etc). Beyond that, it must be sufficiently above the process to allow the system to be constructed with reasonably sized heat transfer equipment. The greater the temperature difference between the geothermal resource and the process, the lower the cost of heat exchange equipment. The key question is how much above the process temperature does the geothermal need to be for a given application.




| Delta T | Influence |
|---|---|
| $T_{ge}$ - $T_p$ | Feasibility, equipment cost |
| $T_{ge}$ - $T_{go}$ | Geothermal flow rate |

***Figure 1.*** ***Fundamental direct-use temperature differences.***

The second temperature difference is the one between the geothermal entering the system and leaving the system (Tgo in Figure 1). This determines the geothermal flow rate necessary to meet the heat input requirement of the application. The greater the temperature difference between the entering and leaving temperatures, the lower the geothermal flow required. Obviously, the resource temperature is fixed. The process temperature plays a role as well since the leaving geothermal temperature cannot be lower than the process temperature to which it is providing heat. In addition, the specifics of the application and the heat transfer equipment associated with it also influence the temperature required. There are two broad groups of applications with similar characteristics in terms of heat transfer–aquaculture and pools, greenhouses and building space heating

## AQUACULTURE AND POOL HEATING

Aquaculture pond heating, as illustrated in Figure 2 is among the simplest geothermal applications; since, it is often accomplished by allowing the available geothermal water to flow into the pond to provide the necessary heat input. In the example of Figure 2, geothermal water is available at a temperature of 125°F and the pond is maintained at a temperature of 85$^{p}$F. If the geothermal water is added directly to the pond, then the leaving geothermal temperature is the same as the pond temperature or 85°F. The amount of heat supplied to the pond by the geothermal can be calculated according to the formula Btu/hr = 500 x gpm x (Tge – Tgo). In this case, assuming that the pond required 100 gpm, the heat supplied would be: 500 x 100 x (125 – 85) = 2,000,000 Btu/hr. It is useful to examine what would happen to the geothermal flow requirement if a lower temperature resource was available. If only 105°F was available, the relationship would be: 2,000,000 / 500 x gpm x (105 -85) Solving for the gpm results in a value of 200 or twice the flow at the 125°F temperature. If only 90°F geothermal was available, the flow requirement would rise to 800 gpm. Obviously, as the available geothermal temperature decreases, the flow requirement to heat the pond rises very rapidly. For applications of this type, reasonable water flows generally require that the heat source water be delivered to the pond (or pool) at a temperature of at least 15°F above the desired pond temperature.

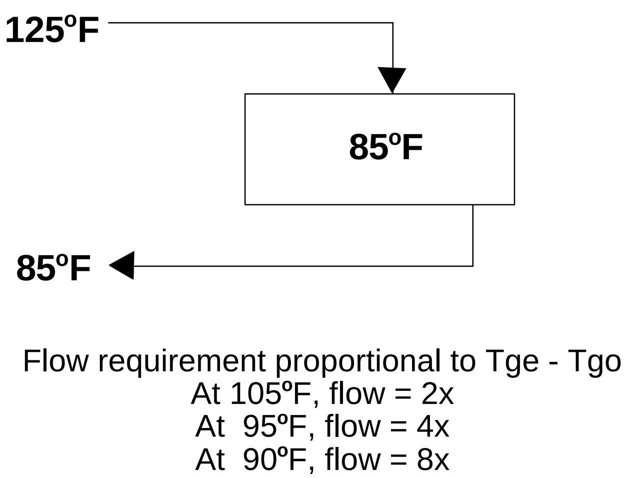



*Figure 2. Direct pool/pond heating.*

In many pool and aquaculture applications, the geothermal water cannot be used directly for heating purposes. In these situations, it is necessary to place a heat exchanger between the pool water and the geothermal water to accomplish the necessary heat transfer. The result is an arrangement such as that appearing in Figure 3. It remains necessary to adhere to the previous rule of delivering the heating water to the pool at a temperature of at least 15°F above the pool temperature. As shown in the figure, this would require a temperature of 100°F. Since the heat must first pass through the heat exchanger, an additional $^{a}$t is required to accommodate this heat transfer. An effective rule of thumb is that the geothermal water on the "hot" side of the heat exchanger must be at least 10°F above the temperature of the water being heated on the "cold" side (pool side) of the

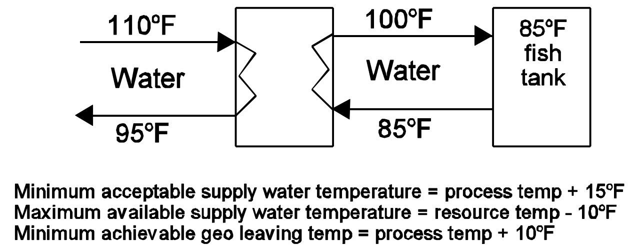



*Figure 3. Pool/pond heating with heat exchanger.*

heat exchanger. In the example, this would require that at least 110°F (100°F +10°F) geothermal water be available. The same Δt is also necessary on the return side of the heat exchanger. In this case, the water to be heated is returned from the pool at a temperature of 85°F. The geothermal water leaving the heat exchanger must be at least 95°F (85°F + 10°F) to meet the heat exchanger Δt requirement.

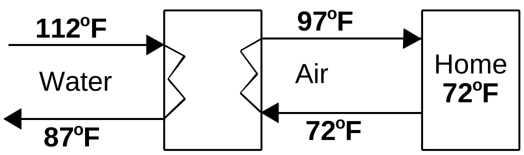
If geothermal water was available above 110°F in this case, the additional temperature would allow reduced geothermal flow and reduced heat exchanger size. Maintaining the leaving geothermal temperature fixed (at higher available geothermal temperatures) would minimize flow requirements. Raising the geothermal leaving temperature would minimize heat exchanger cost.

In summary, the basic rules of thumb for pool and aquaculture heating are as follows:

- Minimum acceptable heating water temperature = pond temperature + 15°F
- Maximum available heating water temperature = geothermal temperature – 10°F
- Minimum achievable leaving geothermal temperature = pond temperature + 10°F

## GREENHOUSE AND BUILDING SPACE HEATING

Heating of greenhouses and buildings often involves the transfer of heat to the air in the structure using some sort of water-to-air heat exchanger. Figure 4 indicates an example of the simplest version of this application. In this case, a home is to be heated and the air maintained at 72°F. To accomplish the heating of the home, it is necessary to deliver the heated air to the space at a temperature of at least 25°F above the space temperature. In the example, this would result in a supply air temperature of at least 72 + 25 = 97°F. There are two reasons for the 25°F Δt between the supply air and the space. The first is to limit the required quantity of air circulated to meet the heating requirements to reasonable levels. The closer the supply air temperature is to the space air temperature, the greater the air flow required to meet the heating needs. At less than the 25°F difference, fan and duct sizes become large and fan power consumption can be excessive. A second issue is occupant comfort. At supply air temperatures below about 95°F, the temperature of the air approaches human skin temperature. This can result in a "drafty" sensation for occupants, even if the desired air temperature is maintained.




Minimum acceptable supply water temperature = spacetemp + 25°F
Maximum available supply water temperature = supply water temp -15°F
Minimum achievable geo leaving temp = air temperature + 15°F

*Figure 4. Space heating without isolation heat exchanger.*

A second issue is that the temperature of the geothermal water delivered to the air heating device (usually referred to as a "coil") must be at least 15°F above the temperature of the desired supply air. This requirement is a result of the need to limit the size of the coil. Although it is possible to design a coil capable of operating at less than the 15 $\Delta t$, its cost and resistance to air flow are such that this is not normally practical. The 15 $\Delta t$ rule also applies to the return side of the air heating coil. If the air returning from the home to be heated is 72°F, then the geothermal water leaving the coil can be no less than 15°F above the return air temperature. In the example, this results in a leaving geothermal water temperature of 72 + 15 = 87°F. As a result of these considerations, to maintain the home at 72°F, a geothermal resource temperature of 72 + 25 + 15 = 112°F would be required. This assumes that the geothermal fluid is suitable for use directly in the coil. Often, this is not the case; since, coils normally have tubes constructed of copper and geothermal water often has hydrogen sulphide--a chemical that attacks copper.

In cases where the geothermal must be isolated from the heating system equipment, a plate heat exchanger is normally placed between the two circuits to protect the heating equipment. This arrangement is illustrated in Figure 5. The right side of the figure is simply a repeat of Figure 4 with the isolation heat exchanger added. All of the temperatures from the previous figure remain valid here. The difference is that with the isolation heat exchanger in place, an additional temperature difference is needed to accommodate the heat transfer through the heat exchanger. Just as in the case of the heat exchanger described for the aquaculture/pool application, the $\Delta t$ required for this heat exchanger is 10°F. The geothermal resource now required to meet the needs of the system would be 10°F higher than in Figure 4 or 122°F. Again, the situation is reflected on the return side of the heat exchanger; where, the geothermal water can be cooled to only 97°F as a result of the intermediate loop return temperature of 87°F and the required 10°F $\Delta t$.

Figure 5 demonstrates the 25/15/10 rule for space heating and greenhouse heating applications:

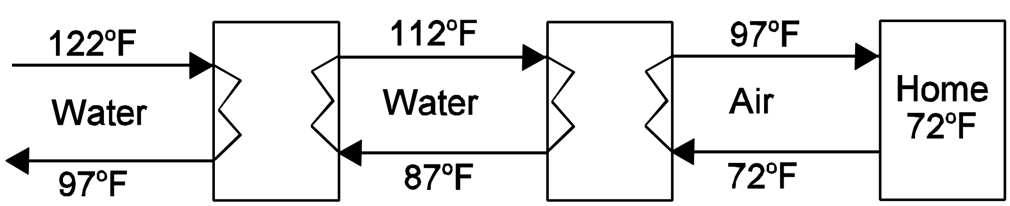
- Minimum supply air temperature = space temperature + 25°F
- Minimum supply water temperature for air heating coil = supply air temperature + 15°F
- Minimum geothermal temperature entering isolation heat exchanger = coil supply water temperature + 10°F

The same temperature differences apply to the leaving side of the heat exchange equipment.

- Minimum air coil leaving water temperature = space + 15°F
- Minimum geothermal temperature leaving isolation heat exchanger = coil leaving temperature + 10°F

All of the rules of thumb discussed here are exactly that. It is possible in all cases to "bend the rules," and design systems and equipment for temperatures closer than the guidelines provided above. The values provided here are intended for initial evaluation of applications by those not in the practice of designing heating systems on a regular basis. The guidelines cited apply to new systems using commercially manufactured equipment. Homemade heat exchangers or existing equipment selected for water temperatures well above available geothermal temperature would require additional analysis.

**25/15/10 Rule**




**Supply air to space air - 25°F**
**Water/air heat exchanger - supply water to supply air 15°F**
**Water/water heat exchanger - supply water to supply water 10°F**

*Figure 5. Space heating 25/15/10 Rule.*