BUILDING SPACE HEATING

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The most common type of space heating system used in homes in the U.S. is forced air. In most cases, the air is heated by a fossil fuel furnace or heat pump. Adapting an existing system to use geothermal heat or designing a system for new construction is a fairly straight forward process. The system consists of a finned coil, normally located in the supply air duct, a motorized valve to control the water flow in response to a signal from a thermostat, piping to deliver the water to and from the coil, and a few associated plumbing and electrical components.

SELECTING THE HEATING COIL

The heating coil is the heart of the system, and proper selection and installation will assure that air delivered to the space is of acceptable temperature and that the coil is properly integrated into the system. Issues which should be addressed in the process of foil selection include:

Heating load	Water temperature
Air pressure drop	Coil location
Duct work transition	Water flow

The heating load is the quantity of heat that the coil must deliver. This is calculated by the contractor using standard procedures long established for this purpose, the details of which are beyond the scope of this document. The building heat loss calculation provides a load the coil must meet. This value is expressed in Btu/hr and is normally the value associated with the heating requirement of the structure at the "design" outside condition. Depending upon construction and location, new homes may require on the order of 5 to 20 But/hr per square foot of floor space.

Hot water, air heating coils are normally designed for a specific application by an engineer or contractor. They are not simply purchased in convenient xxx Btu/hr sizes. As a result, the process of selecting a coil, even using the simplified procedure below, involves "juggling" several issues at once.

Before getting into the specifics of coil selection, it is necessary to define a few coil terms which you are likely to encounter. Hot water coils are basically a group of copper tubes arranged in rows to which the aluminum fins are attached (Figure 1). The tubes are arranged in rows and the greater the number of rows, the greater the ability of the coil to transfer heat. To a lesser extent, the output of a coil can be increased by adjusting the spacing of the aluminum fins. Fin spacing of 8 fin/inch to 12 fin/inch (FPI) is common in heating coils. A deeper (more rows) coil or closer fin spacing also imposes a greater pressure drop on the air passing through it. This increases the fan power necessary to push the air through the coil.

The velocity of the air passing through the coil is also important. Velocity is determined by dividing the flow (in ft^3/min or cfm) passing through the coil by it's face area in ft^2. Nominal coil velocity is 500 ft/min. Increasing the face velocity will greatly increase the pressure drop and require high fan power. An important consideration here is that duct work is often designed for air velocities of 2 to 3 times that recommended for coils. As a result, it is necessary when installing a coil to increase the size of the duct work near the coil to reduce the velocity to a value appropriate to the coil as illustrated in Figure 2. The selection of a heating coil is an effort to meet the heating load with a coil that minimizes the air-side pressure drop (and fan power), and also conforms to the capabilities. To adequately accommodate the pressure

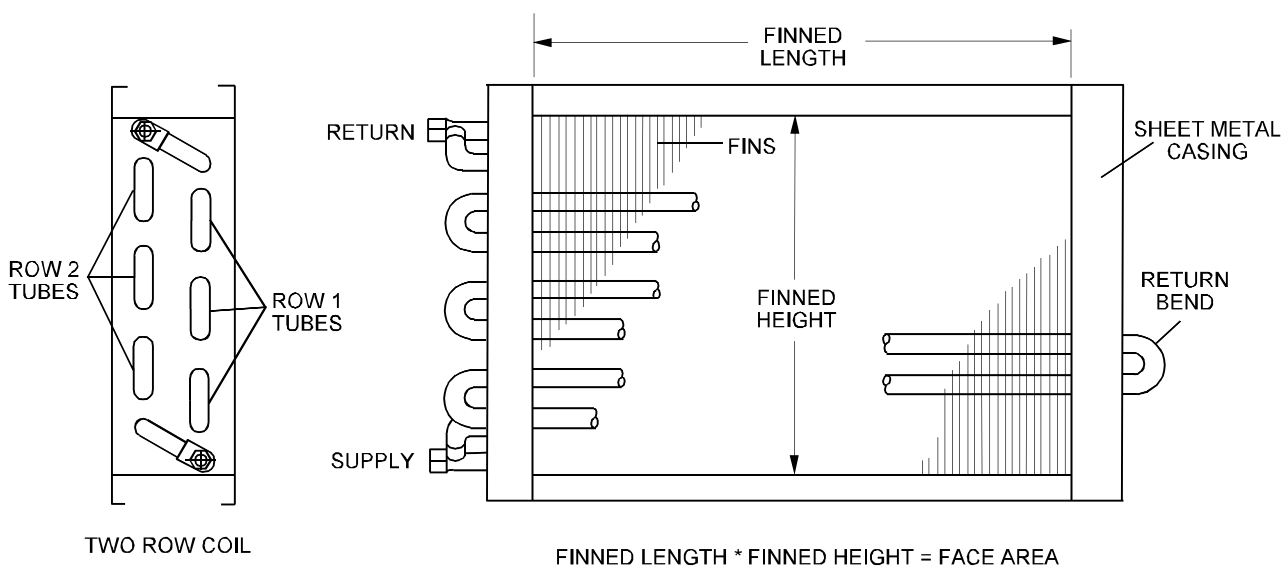

Figure 1.

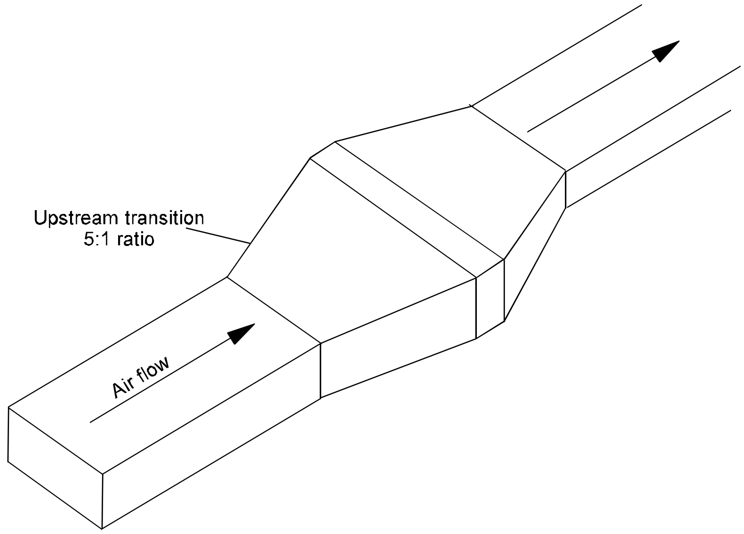

Figure 2.

losses in the duct work and cooling coil (if air conditioning is used), heating coil pressure drop should be limited to 0.25 in. w.g. (inches of water gage) if possible. It may be necessary to reduce face velocity to less than 500 ft/min in 3- and 4-row coils to achieve this loss.

The quantity of heat a coil can deliver is a function of the "face area" and the temperature difference between the water entering the coil (supply water) and the air temperature entering the coil. The face area of the coil is the effective area of th coil exposed to the incoming air stream. Manufacturers often measure this area as the finned height times the finned length. Figure 3 presents the heating capacity of coils in Btu/hr per square foot of face area. As you can see, a 2-row coil provides a substantial increase in capacity over a 1-row coil. The increase in output of a 3-row over a 2-row is much less and the same is true for a 4-row over a 3-row. The required heating load can be divided by the unit output (Btu/hr$\cdot$ft^2) to determine the face area required at a given coil depth. Table 1 presents information on the air side pressure drop for 1- to 4-row coils and correction factors for common fin spacing.

Selecting an air flow for the system can be approached in two ways. For systems where the space will be air conditioned, the air flow is fixed by the AC requirement. Most air conditioning systems operate at flows of between 350 to 450 cfm per ton of capacity. For applications in which AC is not employed, a flow can be selected based on the heating requirements. In this case, the designer has some latitude in the selection. A simple approach is to use the results form Figure 3. The load to be supplied by the coil determines the required coil face area in square feet. Multiplying the nominal face velocity of 500 fpm times the face area required results in the air flow. For example, assume a heating load of 50,000 Btu/hr and a water temperature of 130°F. Using a 2-row coil, this would require a face area of approximately 3.33 ft^2. At 500 fpm and 3.33 ft^2, an air flow of 1667 ft^3/min results. The fan serving this system would have to be capable of supplying approximately 1700 cfm at a pressure drop imposed by the sum of the heating coil, cooling coil (if used) and the duct system (duct, filter, return grilles and supply diffusers).

Table 1. Finned-Coil Air Pressure Drop[1]

Face Velocity	ROWS			
Ft/min	1	2	3	4
300	0.03	0.05	0.07	0.10
400	0.04	0.08	0.12	0.15
500	0.06	0.11	0.17	0.22
600	0.08	0.15	0.22	0.30

1. Based on dry coil, 8 FPI, 3/8" tubes for 70°F. For other fin spacing, multiply table value by 10 FPI by 1.18, 12 FPI by 1.32 and 14 FPI by 1.55.

Example: A home has a heating load of 42,000 Btu/hr and geothermal water at a temperature of 155°F is available. The home will have a 3-1/2 ton air conditioning system installed. Due to space limitations in the basement, coil height must be limited to 12 inches in height.

From Figure 3, it can be determined that a 1-row, 10 fin/in. coil would require approximately 4.2 ft^2 to meet the load. A 2-row coil would require 2.0 ft^2 to meet the load. The 1-row coil would have to be 50 inches wide to provide 4.2 ft^2 at a height limitation of 12 inches. Generally, it is good practice to limit coil dimensions to a maximum 4:1 length to height ratio. This assures more even flow through the coil and simplifies the fabrication of duct transitions. In this case, the 2-row coil appears to be a better choice (which would require a 24-in. wide coil).

To check the air side pressure drop, it is necessary to calculate the face velocity. Since the home will be air conditioned, this establishes the air flow for the system. Air conditioning systems typically operate at flows of 350 to 450 cfm per ton of capacity. Using a value in the middle of this range would result in a flow for this system of 1400 cfm. Based on the face area of the coil selected (2.0 ft^2), this would result in a face velocity of 1400 ft^3/min/2.0 ft^2 = 700 ft/min. This velocity is outside the recommended range.

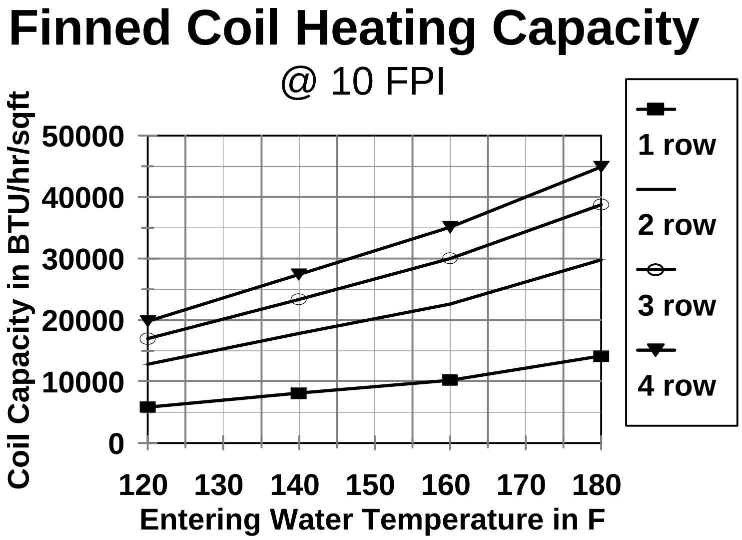

Figure 3.

Returning to Figure 3, we can select a coil with 8 fin/in. spacing. This coil would require 2.35 ft^2 of face area (12" x 28") to meet the load. This would result in a face velocity of 595 fpm, still a little on the high side, but from Table 1, we can see that the air side pressure drop is now a more reasonable 0.15 in. wg. The final coil selection would be 2 row, 8 fin/in., 12" x 28".

A contractor might use a 22" x 10" duct for the main supply air in this case. Since the coil selected is 12 x 28", a transition is required on each side of the coil to increase the duct size to the coil size. The transition on the upstream side of the coil should be gradual as possible. If possible, a 5:1 ratio should be used in the transition. In this case, the largest dimensional change is in the width (22" x 27"). This amounts to 3" on either end of the coil. As a result, the transition on the upstream side of the coil should be at least 5 x 3 = 15" long.

In retrofit applications, it is often difficult to install a coil and conform to the above recommendations for duct work transitions, air side pressure drop and face velocity. In many cases, the coil is installed very near the furnace and there is a choice of installing it in the return air or the supply air. The supply air outlet of most furnaces is relatively small and the air is flowing at a very high velocity (1000 to 2000 fpm). This is too high for a coil installation without a very large duct transition to slow the air. As a result, an installation in the return air is sometimes considered. From an air velocity standpoint, this is attractive since the return duct work is normally much larger than the supply air and thus, better able to accommodate the installation of a coil at reasonable face velocity. Two issues must be considered in a return air coil installation: temperature and mass flow. With the coil in the return air, the temperature of the air entering the furnace is much warmer than the furnace was designed for. The fan motor in the furnace depends on the flow of air around it for cooling. Most fan motors are designed to operate in a maximum ambient temperature of 104ºF. Above this, the life of the motor will be reduced and it may be subject to shut down due to excessive internal temperature. As a result, return air coil locations should be limited to coil leaving air temperature of 100ºF to 105ºF.

In addition to the motor cooling consideration, the higher temperature of the air also reduces it's density. Because fans are a constant volume device, they move the same number of cubic feet of air regardless of its density. This means that the actual mass/pounds of air delivered to the space is reduced when the temperature of the air handled by the fan is increased. Reducing the mass (pounds) of air delivered, reduces the heating capacity of the air. The heating capacity of the system is directly related to the density of the air. A system in which the fan is handling 105ºF air will have a capacity 6% less than that of a system in which the fan is handling 70ºF air.

Control of a system with a hot water coil supplying the heat is a simple matter. As illustrated in Figure 4, a motorized valve (rated for the expected water temperature) is placed in the series with the coil (it can be placed in the supply or return water line). This valve responds to a call for heat from the thermostat and opens to allow hot water to flow to the coil. Increased comfort can be accomplished by using a valve equipped with an "end switch." On a call for heat, the thermostat causes the motorized valve to open and begin delivering hot water to the coil. When the valve is fully open, the end switch allows the fan to start. By delaying the fan start until water flow to the coil is established, the initial cold draft of unheated air to the space is eliminated.

The heating coil selection graph (Figure 3) was based on a water temperature drop of 35ºF. Generally, with water temperatures of 115ºF to 180ºF, it is possible to achieve 30ºF to 40ºF temperature drop on the heating water. The higher the temperature drop, the lower the water flow required. At supply water temperatures of less than 115ºF, it may be necessary to reduce water temperature drop to 25º or even 20º to achieve a practical coil design. By the same token, it is theoretically possible to achieve larger temperature drops with hotter water. At very large temperature drops, water flow can be reduced to the point that it negatively impacts heat transfer from the coil. As a result, the 30º to 40º range is suggested for most applications.

To calculate the water flow required, the following formula can be used:

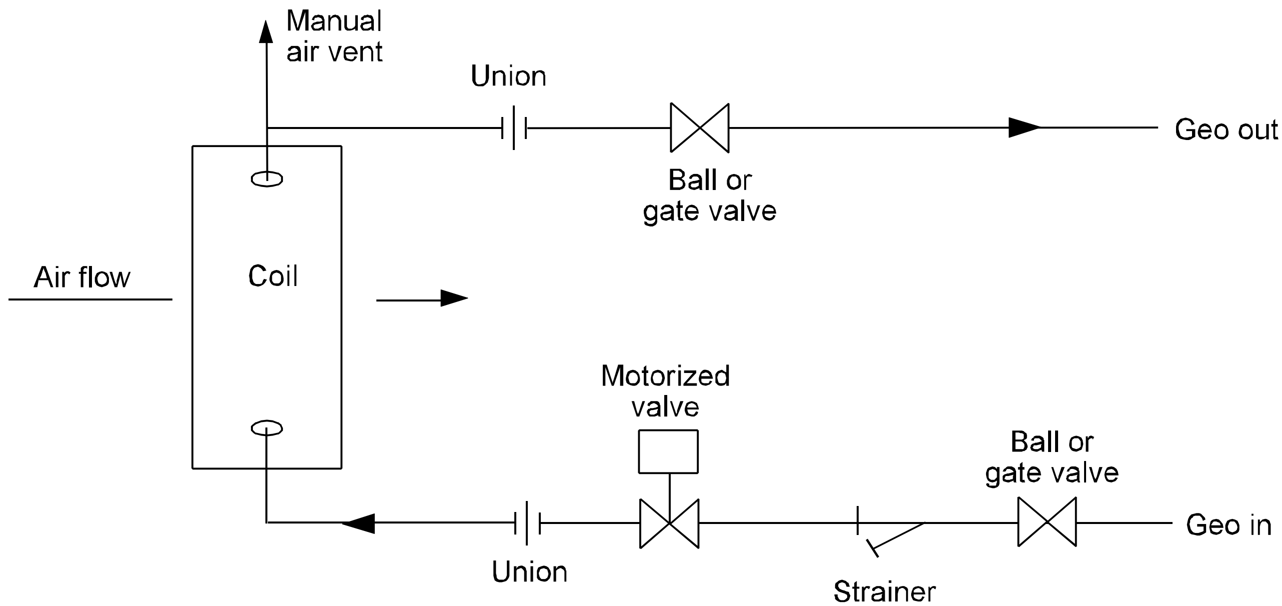

Figure 4.

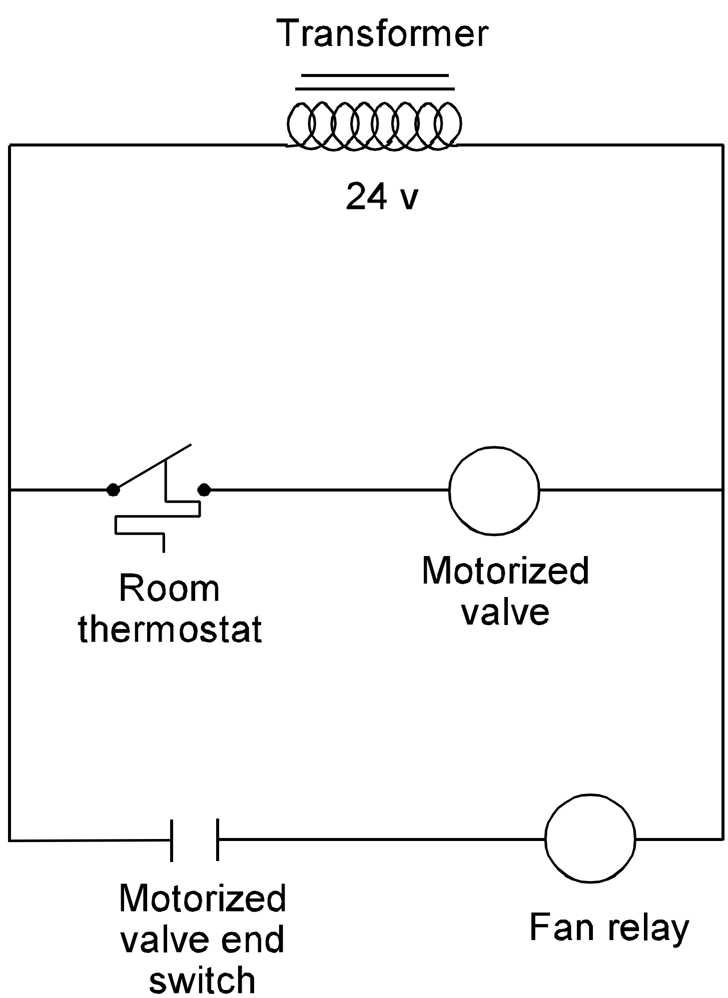

Figure 5.

Water flow rate in gpm = load/(500 x TD)

where:

Load - space heating load to be served by the coil in But/hr
TD - temperature drop on the water side °F

Example: A heating load of 50,000 Btu/hr is to be supplied from a coil. 120°F water is available.

Since the supply water is fairly low temperature, a TD of 30°F will be used.

Flow Required = 50,000/(500 x 30) = 3.33 gpm

Figure 5 presents a generalized diagram for the piping of a hot water coil. The strainer traps debris before it can enter the coil and helps to prevent clogging. Shut off valves at the entrance and exit of the coil facilitate maintenance. Union connections at the coil facilitate removal if necessary. The air vent at the highest point in the piping system is very important. This device allows the removal of air from the system. Air tends to migrate to the highest points in a piping network. If it is not removed, the system can become "air bound" and water flow reduced or completely blocked. Pipe size selection can be based on the criteria in the resource production portion of this publication. It is important to verify that the motorized valve is capable of closing against the pressure supplied by the system.

INSTALLATION NOTES

The air vent should be installed at the highest point in the piping. Automatic air vents are available but are not recommended due to a tendency to leak after a short period of service.

Coil should be piped in such a way as to be self venting–water entering at the bottom and exiting at the top.

Wiring diagram indicates only heating related connections. If air conditioning is to be installed, controls indicated would have to be integrated with cooling. Transformer may be unnecessary if cooling is installed.

Zone valves have limited ability to close against pressure, typically no more than 25 psi difference across the valve. If the system is such that a greater pressure across the valve can occur, a different type of valve must be selected or the system design modified.

An additional ball valve installed on the strainer blow-down connection facilitates screen cleaning.

In large commercial geothermal system installations, coils of the type described for use here are normally protected by the installation of an isolation heat exchanger. The additional cost of the heat exchanger (particularly in the small size necessary for residential systems) and related components (circulating pump, controls, expansion tank, pressure reducing valve, etc.,) are considered uneconomical for small applications. Since hydrogen sulfide is found in most geothermal waters and this chemical is known to attack copper (of which the tubes in the finned coil are constructed), it must be understood that the life of the coil, in many geothermal installations, will be less than in non-geothermal installations and as a result, the installation should be done with consideration of access for replacement.

A 115-v power source is necessary for the transformer. This is normally installed in the furnace (if one is used) or the air handling unit.

A control schematic for this arrangement appears in Figure 5.

MAJOR COMPONENTS AND FITTINGS

1. Hot water heating coil. ___ inches finned height x ___ inches finned length, ___ row, ____ fins/inch, with no more than ____ in wg pressure drop on the air side. To heat ____ cfm from ____°F to ____°F. Copper tubes, 5/8" OD, arranged in a counterflow configuration with respect to the air flow. Specific values determined by application. Cost varies with application,

   eg. 2 row, 18" x 24", 8 fin/in., $550

2. Control valve, motorized zone type, 24v, 3/4" piping connections, end switch equipped. Similar to White Rogers model 13A01-102,

   $170

3. Union, brass, copper, steel or CPVC depending upon the choice for piping, 1" connections, 2 required,

   Galvanized - $5 each

4. Manual air vent, brass construction, 1/8" connection,

   $6

5. Strainer, Y-type, 150 lb, stainless steel 20 mesh screen, 1" screwed connections,

   $30

6. Ball valve, 1", screwed or sweat depending on piping type, 2 required,

   Brass $20 each

7. Transformer, 115 v primary, 24 v secondary, 40 VA,

   $17

8. Fan relay, 24 v coil, contact rating compatible with fan motor required,

   $40.