HOT WATER HEATING

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Hot water heating (hydronic heating) is a popular and effective method of heating agricultural buildings. There have been great technological advances in hydronic heating controls and products since this bulletin was first done in 1984. This leaflet gives design and installation guidelines for both floor and space heating systems.

Hot water can be used for many heating applications in farm structures, including:
- Space heating of livestock buildings, usually with black steel pipe, finned-tube convectors or hot water unit heaters. Hog, dairy, and poultry buildings lend themselves well to this.
- Floor heating of shops, which commonly supplies all of the heating needs.
- Localized floor heat in hog barns, such as in baby pig creeps and sleeping areas of grower hog pens.
- Heated floor broiler chicken houses.
- Other specialized floor heating, such as in honey houses or processing rooms.
- Greenhouse heating, usually with finned-tube convectors or unit heaters to give the greater heating capacity these buildings require.

Hot water is the obvious choice for floor heating. In addition, hot water space heating offers several advantages for confinement livestock buildings:
- Heating several areas from one central boiler is easy, with zone control of each.
- Problems with dust, clogged air filters, and the fire hazards of dust in ducts and furnaces are avoided.
- It is compatible with ventilation systems; desirable air flow patterns can be reinforced by correct location of the heating units, and furnace backdrafting due to ventilation fan suction is avoided by putting the boiler in a separate room.
- It is usually more efficient and has a lower operating cost than forced air.
- Floor heat is placed in the optimum location where it is most effectively utilized.
- Hot water can be the principle heat source for ducted air systems for heating, ventilation and air conditioning, such as offices in large farm building complexes.
- It is easy to clean and maintain.

The initial cost of a hot water system is often higher than that of other types, particularly when used for smaller one-room buildings. For large buildings with several heating zones, hot water is usually more economical. The system should be designed for each building, and alternatives evaluated to make an objective comparison.

HEATING SYSTEMS

The basic hot water heating system, as illustrated in **Figure 1**, consists of the following components:
- hot water heater or boiler,
- circulating pump,
- expansion tank,
- distribution piping,
- radiators in the space to be heated; black iron or steel pipe, finned-tube convectors, unit heaters or under-floor pipes,
- controls, valves, temperature and pressure gauges, air bleeding valve, pressure relief valve, and pressure regulator.

LAYOUT: The sequence of equipment and circuit design (illustrated in **Figure 1**) is important to get optimum flow, with minimum problems balancing the system. The pump should be on the outlet side of the boiler, and close to the expansion tank, as this is the point of least pressure change in the system.

The Canada Plan Service prepares leaflets showing how to construct modern farm buildings, livestock housing systems, storage and equipment for Canadian agriculture. Permission is given to copy this leaflet. You may contact the Canada Plan Service through your provincial agriculture department or on the internet at www.cps.gov.on.ca.

HEATING UNITS: Several types of heaters can be used, ranging from a small residential heater to large commercial boilers. Domestic hot water heaters will satisfy requirements up to 12 kW (40,000 BTU/h). They are cheap to install but will not last as long as a boiler. A circulating pump, expansion tank, and controls must be added.

Commercial water boilers are recommended for larger systems. These are designed for high output and higher flow rates, and will provide the best long-term performance. Most are either gas or oil-fired.

Coal or wood-fired boilers are also available. Though these are less convenient and have higher emissions, they may be more economical in some situations. Be sure that such boilers are fully equipped with safety and functional controls (see the section on controls).

Boilers are classified by three categories:

- Type of fuel - gas, oil or solid fuel.
- Physical structure - sectional or tube type, “wet” or “dry” based.
- Heat exchanger material - copper, steel, cast iron or combination alloy.
- Type of heat exchanger, condensing or non-condensing.

Non-condensing boilers are most common. They are so named because the water vapour component of the products of combustion is totally exhausted with the flue gas. These boilers generally should not operate with water jacket temperatures below 58°C (135°F) because this results in partial condensing of the water vapour which leads to corrosion and early failure.

In condensing boilers, the water vapour fraction is condensed in the heat exchanger, capturing the extra energy of vaporization, resulting in higher efficiency - typically 95% rather than 80 - 85%. Each Gigajoule (million BTU) of natural gas produces about 40 L (9 gal) of water vapour. To perform effectively, these boilers require lower return water temperatures, as well as non-corroding and specially designed secondary heat exchangers.

EFFICIENCIES: Combustion efficiency, the input/output ratio on the nameplate, is only one component in the overall system performance. Other factors affecting efficiency are the cycle efficiency and seasonal performance. Simply stated, an oversized boiler that cycles frequently is less efficient than one exactly sized to the heating need. Also, a boiler system that requires high heat for cold weather, but operates at fractional load the other 9 months, is less efficient than the nameplate rating. **Table 1** shows typical efficiency ratings for boilers.

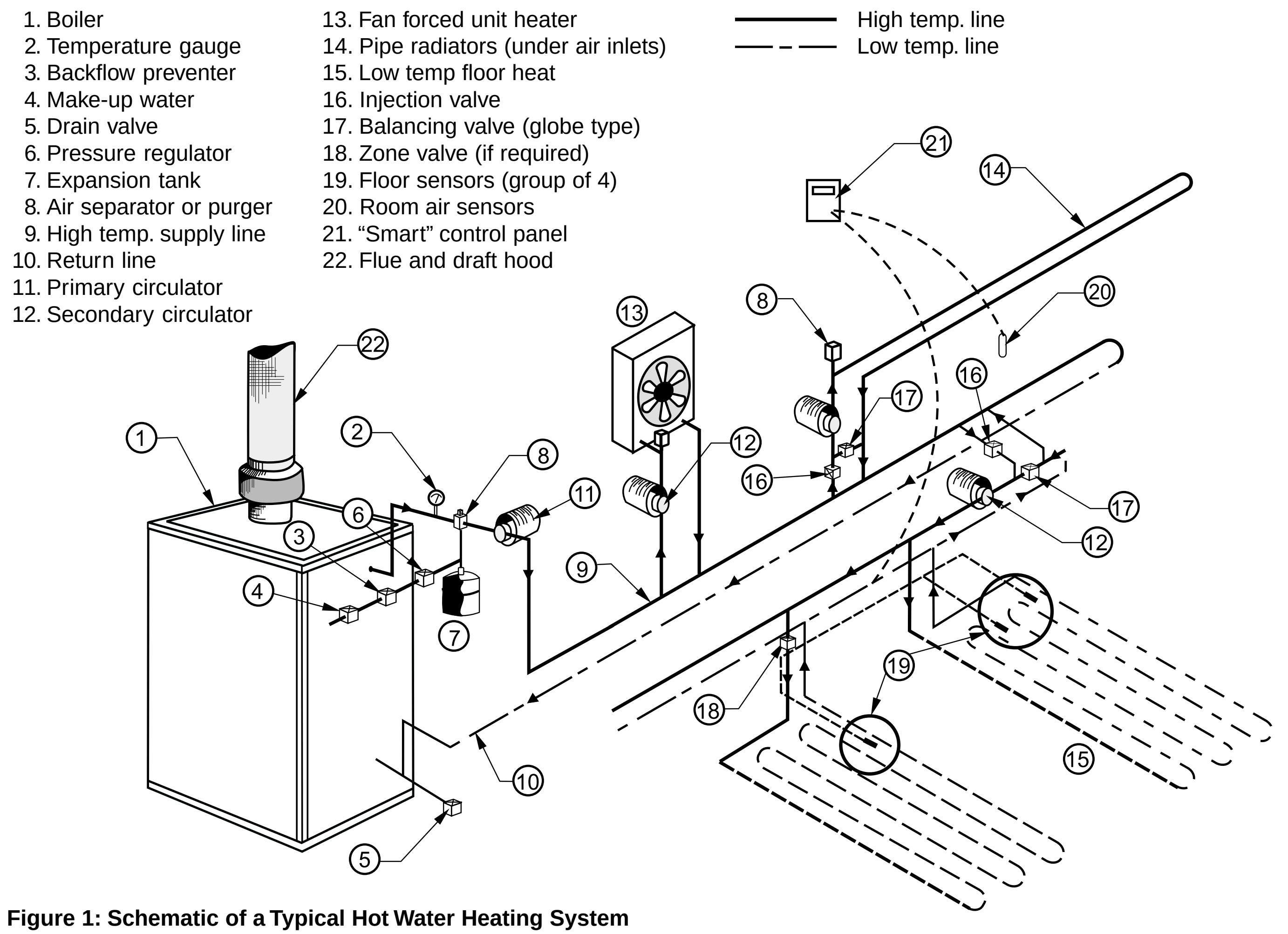


Figure 1: Schematic of a Typical Hot Water Heating System

Methods for achieving better cycle and seasonal efficiencies are:

1. Do not oversize the boiler; an oversize factor of 15 - 20% is recommended.
2. Use a modulating control boiler that adjusts the flame to suit the heating load.
3. Use an "outdoor reset controller," a system that adjusts boiler temperature relative to outdoor conditions.

Table 1: Typical Boiler Cycle and Seasonal Efficiencies.

% Run Time	Cycle Efficiency % of Steady States	Oversize Above Design Load	Seasonal Efficiency * %
100	100	1.0	70
80	97	1.5	60
60	95	2.0	50
40	92	2.5	45
20	85	3.0	40
10	60		

* Based on boiler steady state efficiency of 84%
Example: a boiler of 80% efficiency, operating at 40% run time, would have a cycle efficiency of 0.92 x 80 = 73.6%.

The boiler should be in a separate mechanical room. At a barn, it should have an outside entrance to avoid back-draft problems caused by ventilation fans. This room must have the required vents for combustion air supply from outdoors. This varies with the fuel, the type of heater and building construction in accordance with the applicable installation code.

CONTROLS: Hot water heating systems should have:

- high-limit water temperature shut-off;
- low-limit water temperature start-up;
- high-limit safety switch;
- low-water-volume safety shut-off;
- pressure relief valve on the heater outlet (located where it will not cause injury if it should blow);
- modulating control and/or outside temperature reset (optional);
- flow switch (for some types).

RADIATORS: These are the elements that transfer the hot water's heat to the room. Black steel pipe, finned-tube convectors, plate radiators, and fan-forced hot water unit heaters are the main types. **Figure 2** shows some types and their application.

Black steel pipe: Most commonly used in livestock buildings, it is easy to clean, least affected by dust, and not easily damaged. Bare pipe may be more costly and require more labour to install than finned-tube convectors because it is larger and more pipe is required. Galvanized pipe should not be used since the galvanizing restricts heat transfer.

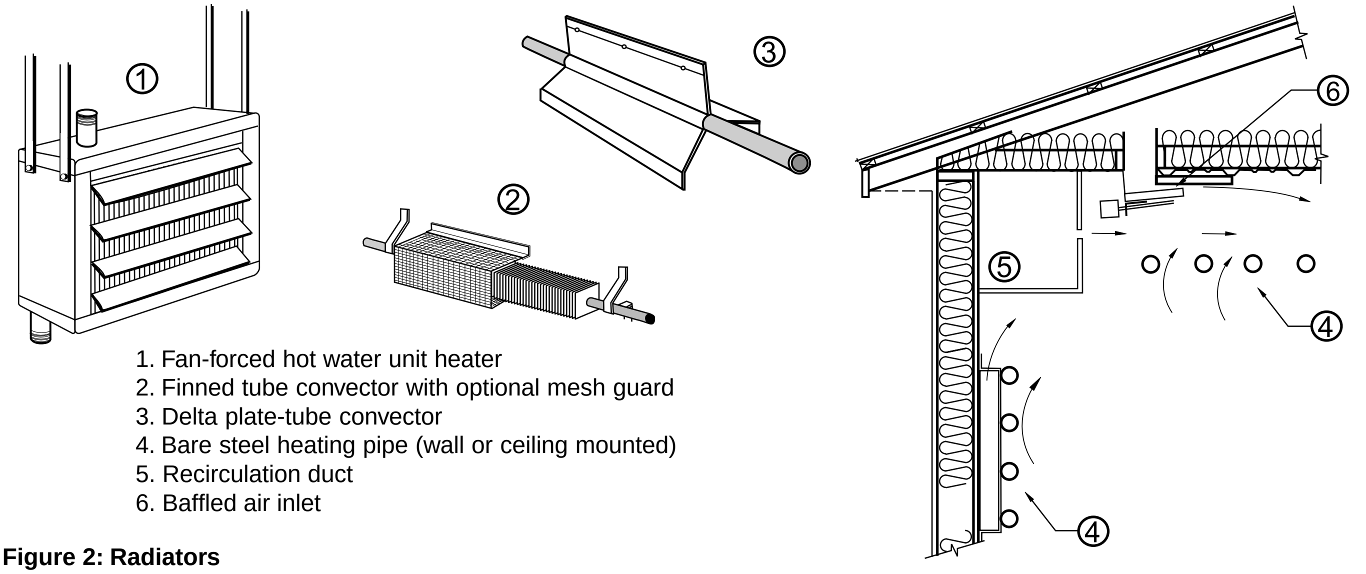
Black steel pipe is usually mounted under air inlets or on wall brackets. Pipe radiators should be mounted at least one pipe diameter from the wall to permit free air circulation. Heat output for bare steel pipe, and the length of pipe needed can be determined from **Table 2**. Livestock rooms usually have from one to four loops of pipe.

Table 2: Heat Output From Bare Steel Pipe, (W/m or BTU/h·ft^2) [7.]

Nominal Pipe Size			Pipe-to-air Temperature Difference: °C (°F)					Pipe Volume	
mm	in.	C W	35 (65)	45 (85)	55 (100)	65 (117)	75 (135)	L/m	gal/ft
38	1.5	C	72	100	127	154	181	1.32	0.016
		W	70	94	118	142	166		
50	2.0	C	92	125	158	191	223	2.16	0.174
		W	75	100	121	145	174		

Notes:

1. Data is from Feddes et al, University of AB, 1988, in a simulated hog barn environment.
2. C = ceiling mounted; W = wall mounted
3. Refer to **Figure 2** for typical application detail.
4. Dusty conditions reduce values by up to 5 - 8%.
5. Forced convection will increase values 10 - 15%.
6. Pipe volume is used to estimate system fluid volume required.
7. 1.0 W/m = 1.04 BTU/h·ft, which is practically equal.



1. Fan-forced hot water unit heater
2. Finned tube convector with optional mesh guard
3. Delta plate-tube convector
4. Bare steel heating pipe (wall or ceiling mounted)
5. Recirculation duct
6. Baffled air inlet

Figure 2: Radiators

Example: What length of 2 in. steel pipe is required to input 30 kW (102,000 BTU/h) of heat to a hog barn maintained at 15°C (60°F), if the average hot water temperature is 80°C (175°F); pipe is ceiling mounted? Answer: The temperature difference is 80 - 15°C = 65°C; from the table, read a heat output of 190 W/m for 2 in. pipe. Pipe length required is 30,000 W ÷ 190 W/m = 160 m (525 ft). Four lines (two loops) would be typical.

Finned-tube convectors: These have four to five times the heat transfer capacity of bare pipe. Output varies with fin size and spacing, so consult manufacturer's design data. They are particularly suitable for small rooms or greenhouses where the length of bare pipe may be excessive. Where less heat is required, short sections of convector can be spaced along a wall.

The main drawbacks to finned-tube systems are that they collect dust (reducing performance), require frequent cleaning and can easily be damaged. They are not recommended for dusty livestock buildings.

Plate-type radiators: These are a combination of fins and bare pipe by adding flat or triangular plate fins to the pipe. These offer the advantage of high output and ruggedness with less dust problem than fin-tubing.

Hot water unit heaters: These are excellent for small livestock rooms, shops, milkhouses, and similar areas where a concentrated heat source is desired. They can also be incorporated with ventilation ducts or other types of air circulation systems. In dusty buildings, these radiators should be inspected and cleaned regularly to maintain heating effectiveness.

SYSTEM DESIGN

Here is a summary of system design, followed by details on some of the main components.

1. Size the heater unit to meet the requirement of the building or the particular application (such as floor heat).
2. Select the appropriate size or length of radiator based on the heat required for each room.
3. Lay out the system on a plan.
4. Determine the circulating pump capacity to match the heater size or the individual circuit requirements.
5. Identify the required equipment - expansion tank, controls, valves, etc.

SIZING THE HEATER: The building's supplementary heating requirement can be calculated from the insulation level of the building, ventilation rate, livestock heat output, outdoor temperature and other factors. Livestock housing references give general guidelines. These values, usually in terms of heat required per animal, are reliable for most situations. Also see the floor heat section for designing floor systems.

A heating unit should be selected by its net or output rating, not its input. Input is important for gas supply, flue sizing and combustion air supply. Both ratings are listed on the unit's nameplate. Note that the high-altitude rating is used for elevations higher than 600 m (2000 ft). Add 15 - 20% as a safety factor.

WATER FLOW RATE: Water flow and temperature must be adequate to provide the desired heat output and to allow for a temperature drop through the system. Heat output of pipe convectors and unit heaters depends on water and air temperatures. Most systems are designed for 85 - 95°C (185 - 200°F) water. Lower water temperatures require larger radiators or longer heating pipes, cost more, and are less efficient.

Circulating water gives up its heat in the radiator, and regains it at the boiler. The flow rate should be sufficient to keep this temperature change within acceptable limits; the higher the flow rate, the lower this change. This change should normally be 10 - 14°C (18 - 25°F) for space heating, and less than 10°C for floor heating to maintain uniform floor temperatures.

Flow rate, temperature change, and heat output are related by the following equation:

$$F = \frac{14.33\ Q}{T_i - T_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Where:

F = flow rate, L/min (GPM)

Q = energy exchange by the water, kW (BTU/h)

$T_i - T_o$ = temperature change of water from inlet to outlet of the boiler or radiator, °C (°F).

[$F = 2.0\ Q/(T_i - T_o)$ for F in USGPM, Q in MBTU/h, T in °F]

Example: What flow rate is required for a 60 kW (205 MBTU/h) system to maintain the water temperature change at 10°C (18°F)?

$F = 14.33\ Q/(T_i - T_o)$

$= 14.33 \times 60/10$

$= 86$ L/min (22.7 GPM)*

Imperial:

($2 \times 205/18 = 22.8$ GPM)

* The US gallon is usually used in equipment specifications.
L x 0.264 = gallon

Make sure that the line size is adequate to carry this flow, based on the length of each loop, flow in each loop, and pressure loss characteristics of the pipe. For black steel pipe, the pipe size selected for heat output is usually larger than needed to handle the flow. Long runs or small pipe sizes should be checked for pressure loss using pressure loss tables or a computer program.

Select a circulating pump that provides the desired flow rate at the pressure loss for the entire system. Pressure loss should not exceed 60 kPa (20 ft of head) for most systems. It is a good idea to have a spare pump on hand.

EXPANSION TANK: Water expands about 4% as it heats from room temperature to near boiling. This is accommodated by the expansion tank. The expansion tank is also the point of least change in pressure in the system. The pump should always be located immediately after the expansion tank for best performance.

Consult the equipment supplier for the correct tank for the system. To select an expansion tank, the volume of water in the entire system has to be calculated. Tank size will usually be about 10% of the system volume. **Table 2** gives the capacity of standard pipe as an aid in computing the system volume. To this, add the water in the heater itself.

OTHER CONSIDERATIONS

It is beyond the scope of this leaflet to provide a complete manual on hot water heat, but the following are some of the details that should be considered. The service of experienced heating contractors or equipment suppliers is valuable in assuring that the right components are in place. System and equipment suppliers all have computer assisted design services to optimize the design and performance of these systems.

Automatic temperature control and zone control: These thermostatically controlled flow regulators or valves regulate the hot water circuit in each room or zone, and are actuated by the thermostat for that room. The circulating pump usually runs continually, and the valves open or close as required. Alternatively, the pump can be started by thermostat or aquastat, as one or more zones call for heat. Variable speed pumps, which regulate the flow as required, are excellent for some applications.

Valves should isolate and control all zones or circuits. Install valves with unions or flanged connections on both sides of the pump, or other equipment that may need servicing, so it can be removed for repairs. Manual valves (use globe valves) are usually required to balance the system in multi-zoned installations, for system shut down, or if a thermostatic controller fails. Select a valve of the required capacity to match the flow rate.

Draining and venting: Both are facilitated if heating lines slope uniformly to one end (or one point). Install drain cocks at the low points and air vents at the high points. One of each may be all that is required for simple systems, others may require several.

Heating fluids: Quality of the heating fluid is the life blood of the system. Commercially available heating fluids are recommended; they contain corrosion inhibitors to maintain long-term performance of systems and components. If water is used, it should be demineralized or soft water, with corrosion inhibitors, added. Hardness causes scale build-up which is harmful to the system. For freeze protection use an ethylene glycol solution specially formulated for hot water heating systems. Do not use automotive antifreeze. Check the fluid solution every year, and add inhibitor if needed. Most chemical suppliers provide this service.

Thermometers and pressure gauges: These are handy for balancing the system; besides thermometers on the return and supply side of the boiler, and a system pressure gauge, other permanent in-line gauges are not required. In some situations it may be desirable to read fluid temperatures for secondary loops or floor heating.

Expansion and contraction: Take changes in pipe length into account when choosing pipe supports and planning the layout. Provide sleeves or adequate clearance where pipes pass through walls or floors. Pipe supports should allow for this movement.

Allow for expansion at the end of a long pipe line or loop by stopping short of the end wall. For a 100°C change in temperature, steel expands 0.12% in length; most rigid plastics expand 5 to 10 times as much as steel.

Pressure regulator and backflow preventer: Required on the water supply connection. Most systems work best under a moderate pressure of about 125 kPa (20 psi) for better circulation and to avoid vapour locks.

MAINTENANCE
Maintenance is critical to efficient and trouble-free performance of hydronic heating systems. Here are the most important considerations:

1. Pumps and mixing valves should be exercised at least once a month during the off-season to prevent seizure and deterioration.
2. Pumps should be oiled regularly as required.
3. The flue passages and combustion chamber should be cleaned on an annual basis and the burner checked to ensure efficient and correct combustion.
4. Check system pressure which should be maintained at about 125 kPa (20 psi). Too high a pressure can cause blow-off from the pressure relief valve, too low causes cavitation in pumps or indicates a leak.
5. Conventional boilers should not operate below 60°C (140°F) to avoid flue gas from condensing.
6. Check for areas of reduced heat output from floor heating; this could indicate air being trapped, a kink in the pipe, or control failure.
7. Hydronic systems should be maintained at about pH 9 - 10, and tested annually for effectiveness of corrosion inhibitor and antifreeze protection.
8. Sludge can form in presence of glycol and oxygen. Inspect water and pipe for signs of sludge formation and microbial growth; if necessary the system should be flushed and purged.

TWO-TEMPERATURE SYSTEMS
Two or more water temperatures may be required in livestock barns. Floor heat requires water at 40 - 45°C (100 - 110°F), while space heating requires water at 88°C (190°F). There are several options:

- Use two separate systems. This may be best for large multi-room buildings.
- Use a thermostatic mixing valve to blend hot water into the floor circuit to maintain the desired temperature.
- Use an injection control loop for the low temperature circuit. This is the latest and most reliable technology for multi-circuit systems.

The first method allows for the completely independent operation of each system (e.g. if space heating is shut down for the summer).

The last two methods use a separate circulating pump for the floor heating circuit. These systems have the most flexibility, best control strategies, and least problems with flow balancing. Consult suppliers of these systems for installation details.

FLOOR HEATING

Floor heating is accomplished by circulating hot water through lines of plastic pipe placed in the reinforced concrete floor. Floor heat is used in farm shops and in livestock housing for creep or weaner pig areas. **Figure 5** illustrates a typical shop floor heating installation. **Figure 6** shows details for a hog barn floor.

The following is a guide to heating levels for various farm applications.

Application	Floor Temp °C (°F)	Heat Output W/m^2 (BTU/h·ft^2)
Shop floors	24 - 30 (75 - 86)	100 - 130 (32 - 45)
Office or Utility	24 - 28 (75 - 82)	90 - 110 (30 - 35)
Baby pig creeps	28 - 32 (82 - 90)	100 - 125 (32 - 40)
Weaner pigs	24 - 28 (75 - 82)	90 - 110 (28 - 35)
Grower pigs	22 - 25 (72 - 77)	80 - 105 (25 - 32)

DESIGN

Floor systems are designed using the same principles outlined for space heating. Most of the equipment is the same; heater or boiler, circulating pump, expansion tank, valves and controls.

Heat transferred from the concrete floor to the building depends on both floor and the air temperature. Heat input to the floor will depend on the inlet water temperature, pipe spacing and water flow, if the heating unit has enough capacity to keep up to the floor heat loss.

Heat output from a floor slab to room air can be calculated by this equation:

$$Q = 12.0\ (T_f - T_a), \ldots\ldots\ldots\ldots \quad [2]$$

where:
Q = heat transfer W/m^2 (W/m^2 x 0.32 = BTU/h·ft^2)
T_f = floor temperature, °C
T_a = air temperature, °C
[$Q = 2.12\ (T_f - T_a)$ for T in °F and Q in BTU/h·ft^2]

For a floor at 30°C and air of 20°C, heat output would be 12.0 x 10°C = 120 W/m^2 (38 BTU/h·ft^2). Greater heat output from the floor system is obtained as air temperature drops. For example, at 12°C air to 30°C floor, the heat flux is 216 W/m^2 (70 BTU/h·ft^2). This is a nice self-regulating feature of floor heat.

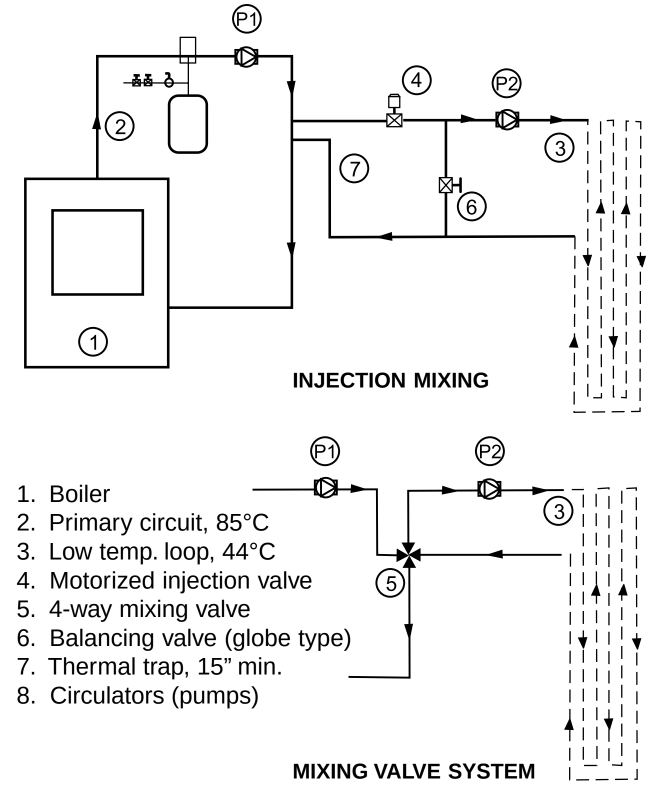


Figure 3: Methods of Achieving Multi-temperature Zones.

Water flow and pump capacity are calculated as outlined earlier (equation1), using a temperature change of 5 - 8°C (9 - 15°F), depending on the uniformity required. Flow through each loop, for checking pressure drop and sizing valves, is the total flow divided by the number of loops. The flow rate should usually be higher than for space heat to keep the temperature more uniform.

The header system may be of steel pipe, copper or rigid plastic, with T-fittings for attaching the floor lines. The header should be sized for the total water flow in the system. Valves are recommended on each floor line to balance or control flow; one on the supply and another on the return are best in case one loop springs a leak.

Water temperature for floor heating is much lower than for space heating. Water temperature will be 10 - 15°C (18 - 25°F) warmer than the floor slab. Floor temperature is best controlled by the water or slab temperature, rather than by starting or stopping the flow. Control of small sections, such as in baby pig creeps, may be more precise and adjustable if injection or mixing valves regulate water temperature while maintaining full flow to each section.

Two control strategies apply to heated floors: 1) set floor slab temperature for occupant comfort, typical of piggery floors, and some other applications, or 2) provide variable heat output according to the room thermostat, the typical mode for floor heated houses. For the special case of a farm shop, it is desirable to increase heat output to maintain room temperature, but at the same time the slab temperature should not exceed 30°C (85°F) for comfort. This can be done by limiting floor water temperature in conjunction with in-slab sensors.

It is often useful to know the floor temperature. An ordinary thermometer, covered with a small slab of foam insulation, in contact with the floor can measure temperature directly. Modern control systems use thermistors for temperature sensing for both control and read out.

Piping: Modern hydronic floor systems use cross-linked polyethylene (PEX) pipe. It is available with or without an oxygen barrier. Oxygen-limiting piping is highly recommended for systems of iron or steel. Special proprietary connectors are also used.

Floor heat may require long runs. Pipe size and loop length should match the flow and pump head. For complex situations, obtain technical assistance in checking flow and pressure loss. Otherwise, the following is a safe guide for minimum pipe size:

Pipe Size mm (inch)	Allowable Loop Length m (ft)
12 (1/2)	60 - 80 (200 - 275)
15 (5/8)	90 - 120 (300 - 400)
20 (3/4)	120 - 150 (400 - 500)

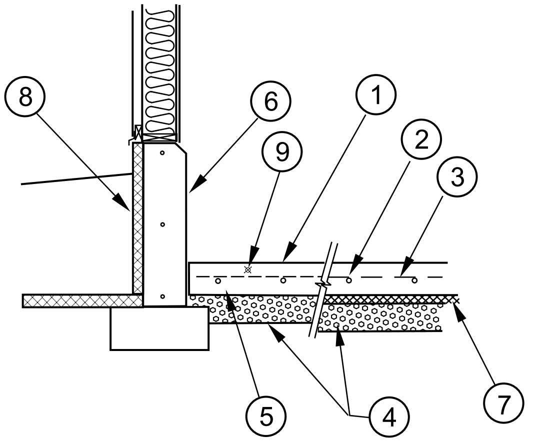
Use shorter lengths for higher flows where a small temperature drop is desired; longer where greater temperature change is practical.

Installation: Pipe spacing is not critical, since temperatures can be adjusted as required. As a guide, use a spacing of 150 - 250 mm (6 - 10") for small areas like pens or creeps, and 250 - 300 mm (10 - 12") for large areas and for thicker floors, like in farm shops. Closer pipe spacing reduces the flow per line which may help where pressure loss is a concern.

The layout of the floor circuit is critical to achieving the most uniform temperature. Several configurations can be used, but the most effective is reverse counter-flow loop, where the return line doubles back along the supply line to average out the slab temperature (**Figure 5**). For the case of multiple floor loops, it is important to have the system properly balanced. The layout in **Figure 5** achieves this by making all loops equal in length.

PEX piping has great strength and ductility; it thus does not fail due to normal floor cracking. Where floor lines cross expansion joints or other floor breaks, run the line in a 300 mm (12”) long sleeve of larger pipe to provide the necessary room to stretch. Pressure test all lines before the concrete is placed.

Floor design: When concrete cures it shrinks, which causes cracks. Reinforcing is required to reduce cracking to small hairline cracks. To control cracking, the recommended cross-section area of reinforcing steel is 0.15 to 0.20% of the cross-section area of the floor slab. For example, 10 m rebar at 400 mm (16") spacing in a 140 mm (5.5") floor is 0.18% steel. Equivalent heavy gage wire mesh can also be used. Reinforcing can benefit any floor, but less is needed if control joints are part of the design for large floors.



1. Reinforced concrete floor
2. Floor heating lines
3. Reinforcing steel or mesh
4. Compacted granular fill, 150 mm
5. Vapour barrier (if ⑦ not used)
6. Foundation wall
7. Under-floor insulation (optional)
8. Exterior foundation perimeter insulation
9. Sensor location for heat control

Figure 4: Installation Detail for Floor Heating

Floor heating pipe should be placed near the centre of the reinforced concrete slab. Reinforcement is most effective just above slab centre. Though most contractors place the steel first, the ideal is to place the water lines just below the reinforcing. Use of pipe support tracks or clips are highly recommended for precise pipe placement. Floor heat mats of small-diameter plastic pipe are effective for special area applications.

Insulation under fully heated floors, such as in farm shops, is marginally cost-effective. However, perimeter foundation insulation is important. Insulating under the heated portions of livestock floors will improve comfort and heat distribution.

FLOOR HEAT FOR FARM SHOPS

Heated concrete floors are popular for farm shops. Design the system following the guidelines outlined previously. For shops, floor heat is more expensive than most other heating systems; however, most people prefer it. It is probably most suited to the owner who makes a great deal of use of the shop during winter.

Floor heat has several advantages:

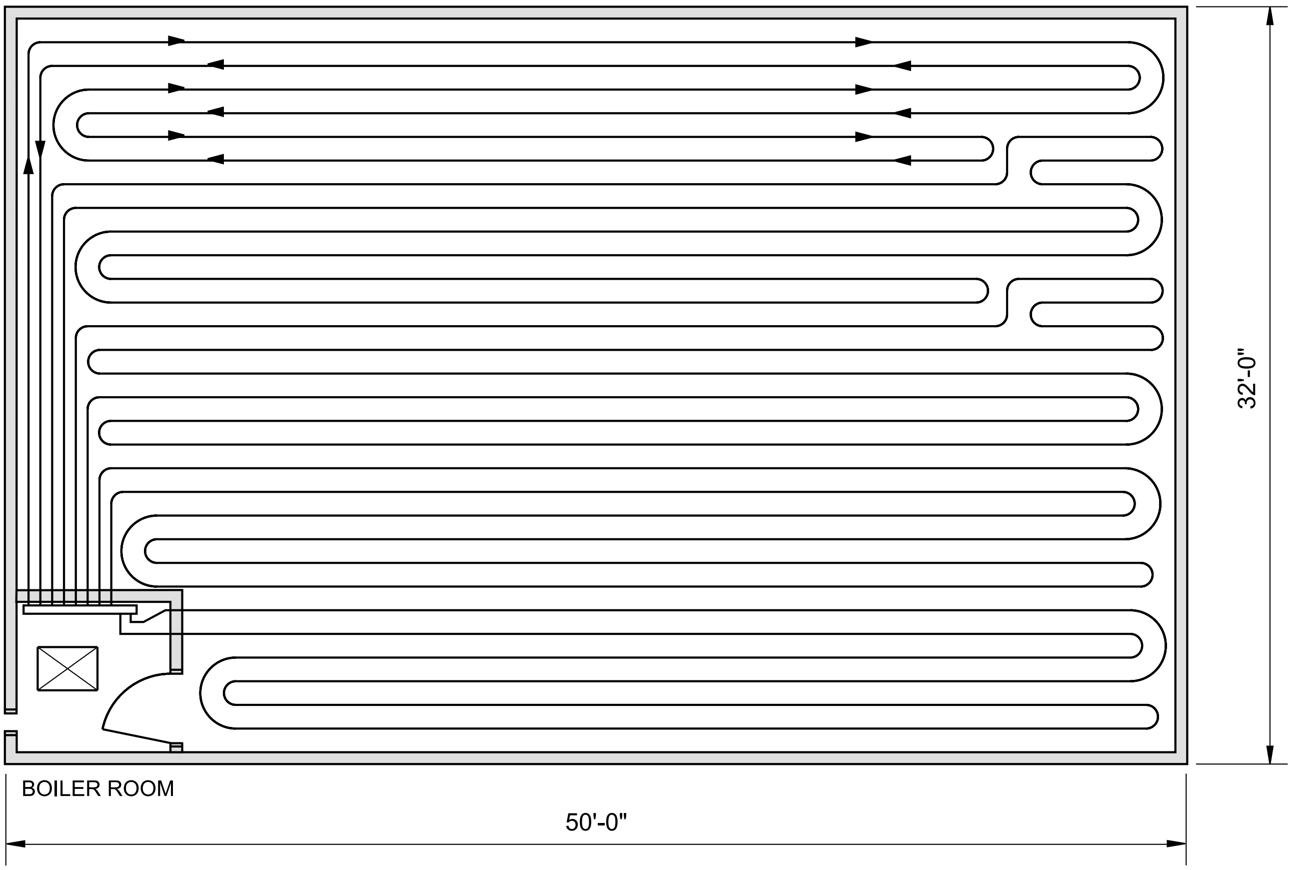
- Warm floors dry quickly.
- Snow and ice melt faster from vehicles.
- Heating is very uniform and recovery rapid.
- Floor has high thermal mass, thus retains heat for a long time.

It also has some disadvantages:

- Relatively high cost compared with other methods.
- System can be damaged if the floor cracks badly.
- Not suitable for occasional use.
- By itself, the floor may not maintain 20°C room temperature during the coldest weather.

The best floor temperature for a shop is 25 - 30°C (75 - 85°F); warmer floors are uncomfortable, and cooler ones are less effective in keeping the building warm. As noted earlier, for a floor at 30°C and air temperature of 20°C, heat output is about 120 W/m^2 (38 BTU/h•ft^2). If the building cools to 15°C, the heat flux will increase. It is recommended to design for 140 W/m^2 (45 BTU/h•ft^2) and size the system slightly larger to account for system losses.

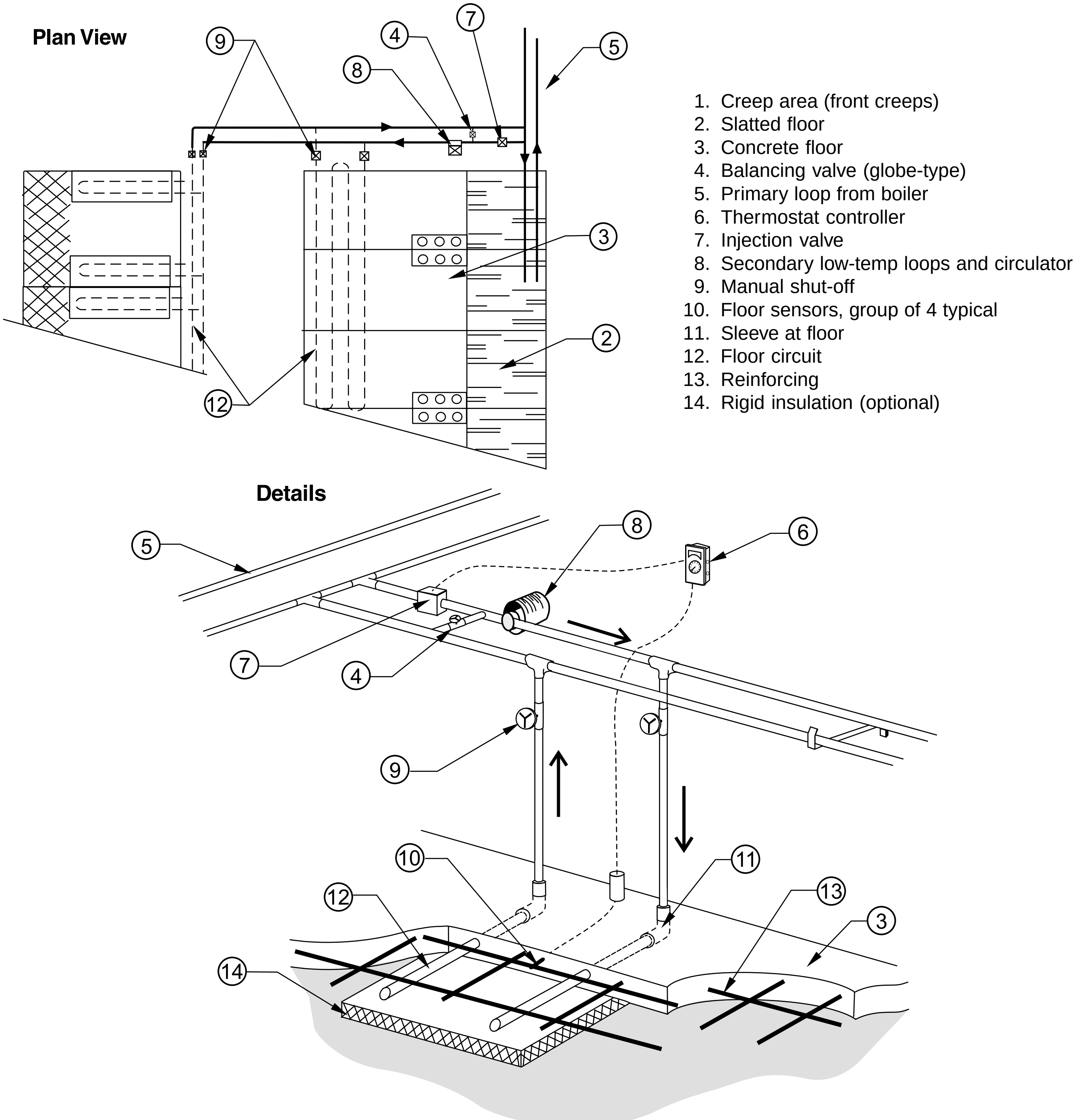
This heat output will keep a reasonably well-insulated shop at 12 - 15°C but does not have extra capacity for reserve heat. It is also possible to get by with a smaller heating unit, down to about 100 W/m^2 (30 BTU/h•ft^2), if cooler floors are acceptable.



5 - Loops @ 300 ft each, 5/8” PEX pipe at 12” spacing.

Each loop (follow the arrows) is “reverse counter - flow” for optimum flow and balace.

Figure 5: Floor Heat for Farm Shop



1. Creep area (front creeps)
2. Slatted floor
3. Concrete floor
4. Balancing valve (globe-type)
5. Primary loop from boiler
6. Thermostat controller
7. Injection valve
8. Secondary low-temp loops and circulator
9. Manual shut-off
10. Floor sensors, group of 4 typical
11. Sleeve at floor
12. Floor circuit
13. Reinforcing
14. Rigid insulation (optional)

Figure 6. Hog Barn Floor Heating Installation

LIVESTOCK FLOOR HEATING

Apply the same installation and design principles used with other floor heat systems. Injection mixing, coupled with solid state control systems are ideally adapted to situations where several floor sections are heated from one system. Most accurate floor temperature regulation is obtained by using in-floor sensors. A bank of four is recommended.

The simplest method is to supply all floor areas with the same water at about 45°C. The baby pig creep areas, if insulated, will be 2 - 5°C warmer than the weaner floors. This works, but the weaner floor may still be warmer than desired. The valve to that floor circuit could be closed down to regulate temperature.

Figure 6 illustrates a typical farrowing barn system and some methods of installation and control. For operating heated floor barns, it is desirable to know floor temperature to be sure equipment is working and as a guide for making adjustments. Insulating under and beside creep floors will concentrate the heat, improving the baby pigs' comfort without overheating the sow. For large heated pen areas insulation is less important. There should be no floor heat under the sow.

Design example:
Design a floor heating system for a shop 9.6 m by 15 m (32 x 50 ft), (**Figure 5**). Floor area inside the foundation is about 9 m x 14 m = 126 m^2 (1350 ft^2).

1. Calculate system size based on 140 W/m^2 heat input (45 BTU/h$\cdot$$ft^2$):

   140 W/m^2 x 130 m^2 = 18 000 W or 18 kW.
   Select a unit of 20 - 24 kW (70 - 80,000 BTU/h).

2. Determine flow rate for a temperature change of 8°C (15°F) across the system, using equation 1:

   $F = 14.33\ Q/(T_i - T_o)$ Q = 18kW
   $T_i - T_o = 8°C$

   F = 14.33 x 18/8 = 32 L/min (8.5 GPM)

3. At 300 mm (12") spacing, the pipe length is approximately 130 m^2/0.3 m = 430 m (1450 ft). Try 5 loops of about 90 m (300 ft) long, thus 15 mm (5/8") pipe will be adequate. Water flow in each loop = 32/5 = 6.4 L/min; 25 mm (1 in) pipe is adequate.

4. Size the header system for a flow of 35 L/min; 25 mm (1 in) pipe is adequate.

5. Estimate the volume of the system.
   430 m of 15 mm floor pipe x 0.18 L/m = 80 L
   2 m of 25 mm header x 0.5 L/m = 1 L
   Boiler unit volume (estimated) = 10.0 L
   Total = 90 L (25 gal)
   Minimum expansion capacity required is 5% of 90 L = 5 L (1.3 gal); obtain an expansion tank with at least 5 L net expansion capacity.

Note: a check on head loss at a flow of 1.7 L/min through a 90 m (300 ft) loop indicates about 40 kPa (14 ft); 4 loops of 115 m (375 ft) would require higher flow and greater head of 60 kPa (21 ft), which is marginal for some pumps.

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