Report from the Field

Radiant Tube Heaters for Poultry Houses

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Over the last several years there has been increasing interest across the poultry industry in infrared radiant tube heating for poultry houses. These are propane- or natural gas-fired heaters in the shape of long tubular cylinders (pipes) that are hung near the ceiling of the house. Several variations of tube heat are being tried in poultry houses. Radiant heat in general has some advantages over forced air heat, as has been seen1 by adoption of radiant brooders. Radiant tube heat might also have attributes that will be beneficial to poultry producers. Radiant tube heating for poultry houses is relatively new and university research is incomplete as yet regarding how they work, possible fuel savings, proper installation and operation, as well as safety considerations. This report explains the engineering principles involved, based on available data and field observations, to clarify issues and address the many questions growers are asking about radiant tube heating.

1. What is so different about radiant tube heaters?

A radiant tube heater is a propane- or natural gas-fired heater that is hung near the ceiling of the chicken house. It consists of a firebox connected to a metal tube, usually 40 to 50 feet long, running lengthwise in the house. Radiant tube heating can be used in combination with forced air heaters or it can be the sole source of heat in a house.

A radiant tube heater is different from radiant brooders or pancake brooders (which also emit radiant heat) in that its burners are enclosed in a firebox instead of being exposed to house air as in a circular brooder. The tube heater draws in combustion air from outside the house with a fractional horsepower motor, then pushes the heated air from the firebox through the tube. Tube temperature right at the firebox can reach as high as 1,000° F and the temperature of the tube 40 feet away might be 350° to 400° F.

The tubes radiate that heat downward to the birds and the litter pack. Reflectors above the tubes protect the ceiling and bounce the heat rays coming from the top of the tube back toward the house floor. Since it is hung near the ceiling and sends radiant heat downward from the long radiant tubes, the tube heater warms a much larger area of the floor than a pancake or radiant brooder much as a long fluorescent light bulb hung near the ceiling would light more floor space than a small light bulb hung 18 inches above the floor.

Note: The terminology can get a bit confusing, since in some installations radiant tube heaters are installed only in the brooding area, and may be called “radiant tube brooders.” A “radiant tube brooder” and a “radiant tube heater” are the same thing, and very different from a “radiant brooder.”

Figure1. Radiant tube heating installed in a high-ceiling poultry house. Burner unit is at far end.

2. What exactly is "radiant" heat?

There are three types of heat transfer:

1. Convection (heat carried by circulating air),
2. Conduction (heat transfer by physical contact), and
3. Radiation (heat transfer by infrared or visible rays).

Space heating, whether of residences, factories or chicken houses, is typically accomplished by either convection or radiant methods (or both).

Radiant heat itself is not brand new in the poultry industry. Pancake brooders, as well as what we call radiant brooders, are (mostly) radiant heating devices. "Radiant" means that the heater gives off infrared rays that transfer heat to any objects in the vicinity. Radiant heat is easy to understand if you think of standing beside a campfire. The air heated by the fire goes straight up into the sky, but you can feel heat being radiated directly to your face. If you put your hand in front of your face, the rays are blocked, and your face instantly feels cooler. Actually, any hot or even warm object, glowing or blazing or not, will put out radiant heat. Think of a cast-iron wood-burning stove. Even if you can't see the fire, you can feel the heat radiating from the front of the hot stove.

In a chicken house, a pancake or radiant brooder is a very hot object suspended above the birds, radiating heat directly to the birds and the litter without significantly heating the air in the space between the heater and the birds. (It also heats the air that comes in contact with it, but like the campfire sends the heated air straight up.) In contrast, a forced-air furnace heats air that is drawn through the heater and blows that heated air out into the house. The circulating heated air then transfers heat to whatever it flows over (including the birds and the litter, if air circulation in the house is good.)

Radiant heating is different from forced-air heating in that a much lower percentage of its heat energy goes into heating house air. Instead of heating house air and blowing the heated air around the house (convection heating), a radiant heater sends its heat energy directly to the birds and the floor.

Note: No radiant heater is 100% radiant, because air will come in contact with the heater, get warmed up and then circulate (convection). But all radiant heaters are designed to warm objects better than they are designed to warm air. Because they have more radiating surface area, radiant brooders put out a higher percentage of their heat as radiant energy than do pancake brooders. Radiant tube heaters also put out a very high percentage of their heat energy as radiant heat

3. What are the main advantages of radiant heating systems?

If we can transfer warmth directly to the birds, without first having to heat the air and then circulate the air in order to heat the birds (and at the same time having heating all the rest of the house), then this type of heating should be more fuel efficient. Bird comfort is the purpose of heating, and if a system gets more heat energy directly to the birds it should be more efficient than any indirect system. Manufacturers of radiant tube heating for people typically recommend installing around 15% less total BTUs of heating capacity than would be used for forced-air furnaces. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) reports fuel savings much greater than that in some situations. We do not, however, currently have good studies showing exactly what fuel savings can be expected in poultry house heating.

There are field reports that improved bird comfort with radiant heating systems has in turn resulted in improved feed conversion and growth rate, but as of yet there is insufficient evidence from the field or from research trials to be able to predict specific gains in bird performance with a high level of confidence.

One benefit of radiant heating (both tube and radiant brooders) is that it does a better job of heating the litter pack. This is because the heat energy is being beamed directly to the floor of the house. Preheat times with radiant devices may be much less than with forced-air systems, and measurements have shown that radiant heats the litter to a greater depth. So we get the effect of good warm toasty litter conditions and a warm bird at a lower ambient air temperature. This is important because if birds are standing on a cold litter pack, their body heat will be drained out of their body through their feet. (This is heat loss by conduction, contact with the colder floor.) Forced-air furnaces create a top-down heating pattern, where we have warm air in the top of the house and are having to circulate that warmth down to the birds and the floor. This can be a challenge in a dropped-ceiling house, and is even more difficult in a high-ceiling house.

The advantage of radiant tube heating over radiant brooders is that the heat source is mounted much higher in the house. This is very convenient, because the heaters are out of the way and do not have to be raised or lowered. Even more important is that the floor area being heated is much greater than for pancake or radiant brooders. The radiant tube system creates much less of a hot spot directly under the heater, as with brooders, and spreads warmth farther out toward the side walls. As with radiant brooders, there will still be temperature gradations, allowing birds to find

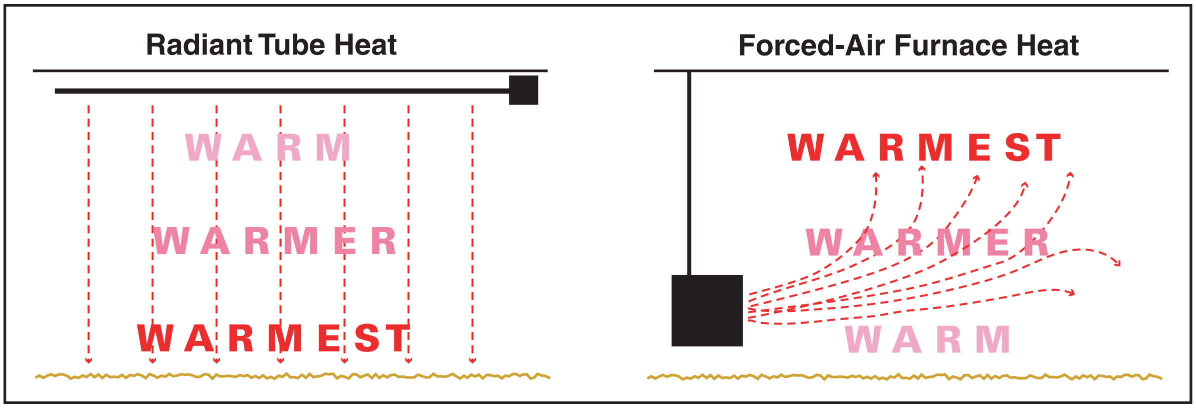

Figure 2. Radiant tube heating transfers most of its warming energy directly to the litter pack (and the birds), so the floor area tends to be the warmest. Forced-air furnaces blow heated air horizontally, and the warmed air tends to rise, making the upper part of the house the warmest area. Proper ventilation management (along with stirring fans) can do a good job of mixing in-house air and getting more heat to bird level, but has to overcome the natural tendency of warmed air to rise.

the spot where they get exactly the warmth they need. But the birds will be much more spread out in a radiant tube heated house, and you generally do not see the doughnut ring that birds will form under a brooder.

Since radiant tube heaters normally draw fresh, outside air into the house for combustion, little dust builds up in the burners and less maintenance is required. The tube heater is also providing some additional ventilation, while the combustion exhaust products inside the house are not significantly different from those contributed by radiant brooders or forced-air furnaces. It should also be noted that when outside air is used for the combustion process, emissions generated may contain less contaminants.

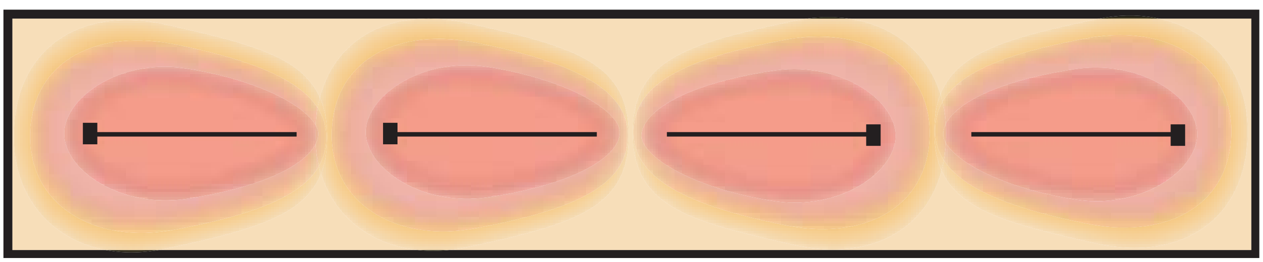

Figure 3. Four 40-foot long radiant tube heaters installed in a 250-foot brood chamber (plan view, looking down at house floor). Warming pattern at floor level is egg-shaped, warmest directly under the heater tubing, less warm toward the walls. Combustion burners are located at end nearest end wall. Total floor area warmed by radiant tube heat is much larger than area warmed by typical radiant brooder installations.

4. Are management considerations for radiant tube heating different from brooders or box furnaces?

Probably the first thing you would notice if you visit two poultry houses with same-age birds sitting side by side in winter time, one house with radiant tube heaters and the other with furnaces, and both houses are well managed for best bird comfort and performance, the air temperature in the radiant tube house will be lower, as is often the case in houses using radiant/pancake brooders. If the desired air temperature that will produce best bird comfort in the furnace-heated house is 92° F, in a radiant tube house we will often get the same best bird comfort conditions at an air temperature around 86-87° F at bird level. If we crank the air temperature up to 92° F in the tube house, the birds will be over-heated. The reason for this, as explained above, is that radiant tube heating transfers heat directly to the birds and the litter. The air in the house gets warmed up only by picking up heat from the litter and the birds.

In other words, in radiant heated houses the air temperature does not need to be quite as high as that of a convectively heated house. In the field we often find this to be 2 to 5 degrees lower in a house with radiant tube heaters, depending on circumstances and weather. This is an important management consideration. In a radiant tube heated house, you cannot set thermostats or temperature sensors according to a target temperature curve designed with forced-air heat in mind, as they typically are. Note that this applies only to periods when heating is required.

The exact temperature setpoint offset to be used (3 degrees lower, 4 degrees, etc) will vary, in large part depending on where the temperature sensor is placed and the height of the tube heater from the floor. If a temperature sensor is placed directly under the radiant tube, it will receive maximum radiant heat energy and will report an unrealistically high temperature. One common recommendation is to place thermostats or temperature sensors about halfway between the outside water line and the feed line, lined up at the midpoint of the tube heater, and raised so as to be out of the main radiant heat zone. A good starting point would be a foot or so off the floor. The exact placement may not be critical, but it is important to use the same placement arrangement consistently in all houses being managed.

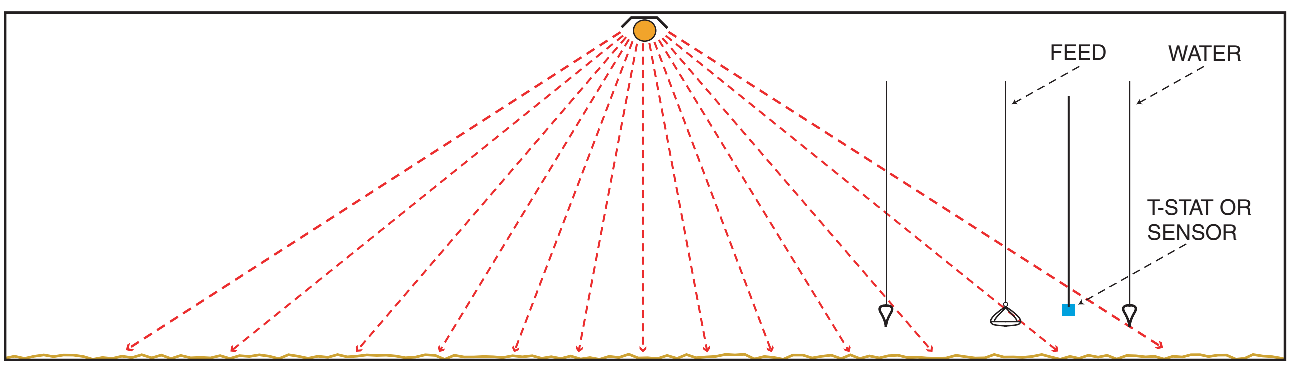

Figure 4. Thermostats or sensors should be placed out of the main radiant heat zone. A common recommendation is to place sensors halfway between the outside water line and the feed line, and a foot or more above the floor. Exact placement may not be critical, but it is important to use the same arrangement consistently in all houses being managed.

It is preferable for each heater to have its own thermostat or electronic controller sensor. For example, if there are four tube heaters in a brood chamber then it is desirable to have four heat zones in that brood chamber. Sensor placement and temperature control offsets should be checked and adjusted according to bird behavior. You want to see birds well spread out in the house and showing no signs of being too cold or too hot.

A definite advantage of tube heaters over radiant brooders is that there are many fewer adjustments to be made and fewer heating appliances to deal with, saving management time.

5. Can radiant tube brooders be used with integrated electronic controllers?

Yes, radiant tube heating works well with controllers, as long as the cautions above about temperature sensor placement and target temp settings are observed. Tube heaters operate at 24, 120, or 240 volts, and are either single or dual-stage heaters.

6. What are the characteristics that would make one brand or model of radiant tube heater better than another?

We do not have independent standards or testing for this type of heater, but some will be more efficient than will others, depending on the engineering design and the type of materials used. That is, the superior model will put out a higher percentage of its heat energy input as radiant heat. As with most equipment, this means that the lowest-cost item may not be the best long-term choice. A higher initial cost may be over-balanced by more efficient operation for better fuel savings over the life of the heating system.

All tube heaters consist of three core components: a burner assembly, radiant tubing, and reflectors. For example, the material used for the heat-shield/reflector can affect the efficiency of the unit. A highly polished, mirror-like finish will reflect down toward the birds much more of the heat energy than will a dull, mill-finished metal, but will likely come with a higher price tag. (Note that this also can be a safety consideration, because much of the heat energy a reflector/shield absorbs will be re-radiated toward the ceiling.) Considerations of engineering and materials used in the combustion chamber and tubing are also important. Having the blower unit and all control components and wiring sealed in a well-insulated burner box is important for best performance and durability.

Figure 5. Workman installing element to help even out temperature from the combustion chamber to the end of the tubing. The device, installed in the last 10-15 feet of tubing, acts as a heat sink to extract heat from the exhaust gases and convert it into radiant energy. Radiant tube manufacturers use various devices of this kind to help improve the radiating efficiency of the heater. Note bracket on tubing that will be used for installing the reflector/heat shield to protect house ceiling and direct radiant energy toward the birds and the litter.

Intake air for radiant tube heaters in chicken houses is normally drawn from outside the house. Using outside air assures complete and clean combustion, and keeps the burner unit and tubing much cleaner, so there is less maintenance required, and does not significantly affect fuel use. In most tube heating systems designed for poultry house applications, as in almost all other agricultural confinement operations, exhaust air is vented to the inside of the house, not to the outside. Ventilation requirements in a chicken house prevent the build-up of carbon monoxide or other harmful elements, and the remaining heat in the exhaust is contributed to the inside of the house through convection. Venting exhaust from a radiant tube heating system to the outside may slightly reduce the minimum ventilation rate needed, but will also reduce the fuel savings that might otherwise be possible.

A feature available from some manufacturers that may contribute to greater fuel savings is the ability to operate at high and low heat levels, depending on heating requirements. This is often called two-stage or dual stage heating. For example, a burner might have a high heat output of 100,000 BTU and a low output of 65,000 BTU. The argument for this type design is that while the high heat is available for times of severe cold, most of the time the heater stays on the lower setting, which means longer on-times and fewer on-off cycles. Any heating element will require warm-up time after ignition, during which it is burning fuel just to warm itself up, and this heat is not getting to the birds. Thus having fewer on-off cycles should cut down on the total amount of warm-up time and thus result in fuel savings. Also, extreme high and low temperature spikes are avoided, which will keep birds more comfortable, and equipment life may be increased. The dual or two-stage heating design has shown merit in field tests and is sure to be one of the items University researchers will be focusing on in the near future.

The usual considerations of manufacturer reputation, quality of construction, and warranty terms offered should be observed. Heaters that include the gas cock, flex connector, vent flapper and hanging hardware may save installation time and money. As for all newer technology, growers who are interested in a radiant tube system should not rely on manufacturer information alone, but should ask for advice from their integrator live production people and growers in their area who have experience with this type of heating system.

7. How much heating capacity should I install in my house, if I am going to the radiant tube type system?

The standard engineering calculations we use to determine optimum heating capacity are based on the difference between the predicted outside low temperature and the desired inside temperature, given a certain rate of heat loss depending on amount of insulation in the building and how well sealed the building is. Since with radiant heating systems we operate at a slightly lower target air temperature, these calculations will show that radiant heating systems can be sized at slightly less heating capacity than forced-air heating systems.

However, it is important to realize that many modern poultry houses using forced-air heat have oversized systems installed because the same rule-of-thumb sizing requirements determined decades ago for under-insulated and leaky, curtain-sided houses are being used for mostly solid-wall and tight, well-insulated newer houses.

For example, consider two 40 x 500 foot houses, one of the older type vs. a modern house, both using forced-air heat. The standard engineering calculation of heating capacity needed for the brood half of typical examples of these types of houses under typical Southeastern conditions where we assume an outside design temperature of 10° F and a design inside temperature of 92° F is:

— 630,250 BTU/hr heating capacity needed for the older house (forced-air heat)
— 301,675 BTU/hr heating capacity needed for the modern house (forced-air heat)

If we take the same modern house and install a radiant heating system in it, instead of forced-air heat, we use the same calculation in figuring the heating capacity needed except that we will use a slightly lower desired inside air temperature, say 88° F instead of 92° F. The result in this case is a slightly lower heating capacity needed:

— 285,613 BTU/hr heating capacity needed for the modern house (radiant tube heat)

See Appendix for exact calculations and assumptions used for all above cases.

The exact heating capacity needed for your particular situation may be very different, whether you use one or the other heating system type. Also, preferences vary on whether to build in a larger or smaller, or even no safety factor. A point to keep in mind is that an over-sized system will not only be more costly to buy, it may be more expensive to operate because it will be running on shorter on-off cycles (see question #5 above).

8. Are there any special safety considerations in using radiant tube heaters?

Yes, there are safety considerations to be observed. Having an intense heat source near the ceiling can create a fire hazard if the manufacturer's installation instructions are not followed carefully. Manufacturers' specifications for clearance distances must be strictly observed. Reflectors must be correctly installed to shield the ceiling material from heat, and must be kept clean. If a reflector gets dirty it will heat up, creating a risk of heating the ceiling vapor barrier to the melting point. The ceiling itself must be in good condition and checked frequently. You do not want to have bands breaking and tri-ply or insulation falling onto a heater. Additional shielding of the ceiling may be desirable.

In high ceiling poultry houses the heater is not as close to combustible materials as in a dropped-ceiling house and it certainly appears that radiant tube heaters have found a place in the higher ceiling poultry houses. A concern in high ceiling poultry houses is interference with tunnel ventilation baffle curtains. In most cases the baffle curtains have holes cut in them and the radiant heater tube goes through the holes. If this is done, the holes must be big enough and care taken to make sure the plastic baffle curtain is kept far enough away from the radiant tube so it does not melt or catch fire. The minimum top clearance manufacturers require varies; for most typical poultry houses, at least one foot clearance should be maintained between the top of the heat shield reflector and the baffle curtain (or ceiling). Bottom clearances (where there is no reflector) are usually significantly greater. An alternative solution is to shield the underside of the radiant tube where it passes through the baffle curtain with a small piece of reflector attached to the tubing.

Another concern with radiant tube heaters in dropped ceiling houses is the fact that the tube heaters can and have melted fogger lines in the ceiling above them. Again, manufacturer specified mounting distances must be observed, and items such as electrical wiring and fogger lines may need extra protection from high heat. Additional shielding of the ceiling may be desirable, especially over the heater combustion section, approximately the first 10 feet of tubing.

9. What about maintenance considerations with radiant tube heating?

Since radiant tube heaters for poultry houses draw combustion air from outside, they stay much cleaner and require much less maintenance than forced-air furnaces do (assuming that the radiant tube heater draws intake air from outside the house and has its blower in a sealed burner box). They do have a moving part, the combustion air blower, which will require periodic attention. Reflectors and radiant tubes must be cleaned periodically to maintain maximum heating efficiency. Overall, the radiant tube heater may require less maintenance attention than either forced-air furnaces or radiant brooders.

10. How are radiant tube heaters installed in a house?

The following diagrams illustrate typical radiant tube heat installations in 400-foot and 500-foot poultry houses.

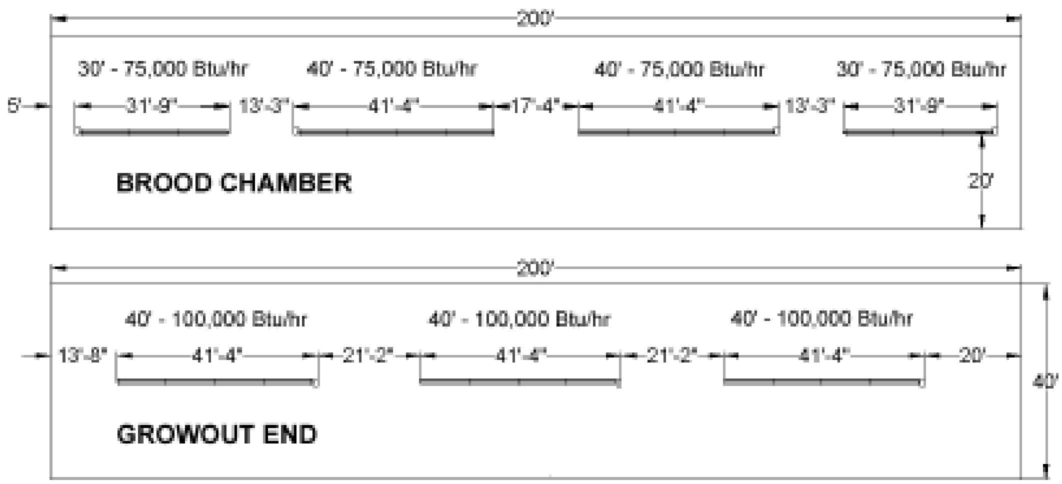

Figure 6. Typical radiant tube heater installation plan for 40 x 400 foot house.

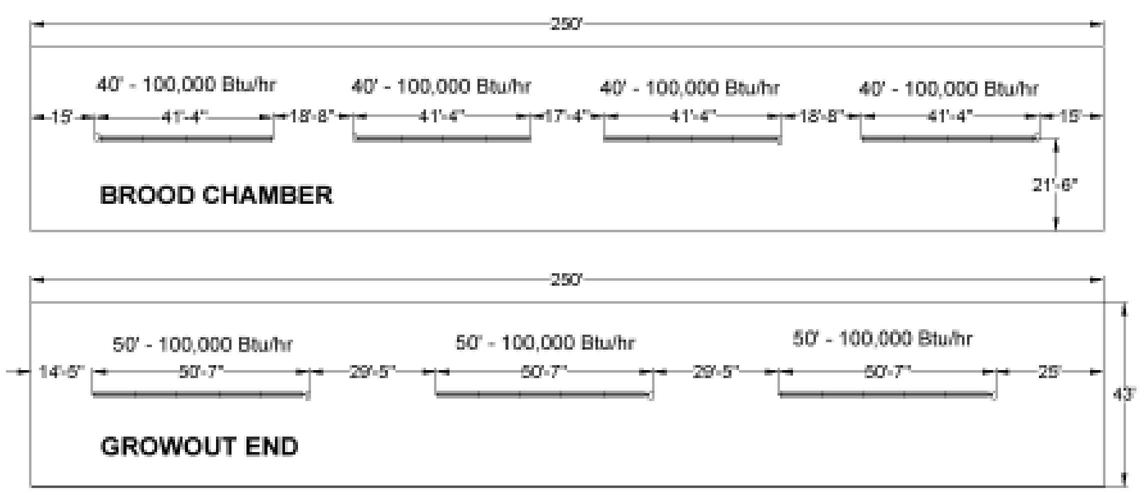

Figure 7. Typical radiant tube heater installation plan for 43 x 500 foot house.

APPENDIX: Heating Capacity Calculations

Comparing three 40 x 500-foot houses, one older, forced-air heated house, one modern forced-air heated house, and one modern, radiant tube-heated house, determining the heating capacity needed for the brood half of the house only:

Assumptions: Outside temperature = 10° F
Growout end temperature = 50° F
Attic temperature = 30° F
House cross-section = 400 sq ft

1. Older house (forced-air heat): 250 ft of 5-ft high curtains on both sides of house, R-1
Brood curtain, R-1
2 x 4 end and side walls, R-4
Ceiling insulation, R-11
Ventilation/air leakage = 0.3 cfm/sq ft
Desired inside temperature = 92° F

Building heat loss calculation: (Area X Temp difference) / R value = BTU/hr heat loss

Side curtains:	(5 X 250 X 2) X (92-10) / R1	=	205,000 BTU/hr
Sidewall above curtain:	(3 X 250 X 2) X (92-10) / R4	=	92,250 BTU/hr
Endwall:	400 X (92-10) / R4	=	8,200 BTU/hr
Ceiling:	(44 X 250) X (92-30) / R11	=	62,000 BTU/hr
Brood curtain:	400 X (92-50) / R1	=	16,800 BTU/hr
	Total building heat loss	=	384,250 BTU/hr

Ventilation/leakage heat loss calculation: cfm/sq ft X Area X Temp difference = BTU/hr heat loss

Ventilation/leakage heat loss: 0.3 X 10,000 X (92-10) = 246,000 BTU/hr

	384,250 BTU/hr
	246,000 BTU/hr
Total heat loss in BTU/hr = Heating capacity needed:	630,250 BTU/hr

2. Modern house (forced-air heat): Solid sidewall, each side, R-11
Tunnel curtain, 70 ft each side, R-1
End walls, R-11
Ceiling, R-19
Brood curtain, R-11
Ventilation/air leakage = 0.2 cfm/sq ft
Desired inside temperature = 92° F

Building heat loss calculation: (Area X Temp difference) / R value = BTU/hr heat loss

Tunnel curtains:	(5 X 70 X 2) X (92-10) / R1	=	57,400 BTU/hr
Sidewall at curtains:	(3 X 70 X 2) X (92-10) / R11	=	3,130 BTU/hr
Sidewall beyond curtain:	(8 X 180 X 2) X (92-10) / R11	=	21,469 BTU/hr
Endwall:	400 X (92-10) / R11	=	2,981 BTU/hr
Ceiling:	(44 X 250) X (92-30) / R19	=	35,895 BTU/hr
Brood curtain:	400 X (92-50) / R1	=	16,800 BTU/hr
	Total building heat loss	=	137,675 BTU/hr

Ventilation/leakage heat loss calculation: cfm/sq ft X Area X Temp difference = BTU/hr heat loss

Ventilation/leakage heat loss: 0.2 X 10,000 X (92-10) = 164,000 BTU/hr

	137,675 BTU/hr
	164,000 BTU/hr
Total heat loss in BTU/hr = Heating capacity needed:	301,675 BTU/hr

3. <u>Modern house (radiant tube heating)</u>: All assumptions and specifications same as for the modern, furnace-heated house above, except that desired target inside temperature = 88° F.

Building heat loss calculation: (Area X Temp difference) / R value = BTU/hr heat loss

Tunnel curtains:	(5 X 70 X 2) X (88-10) / R1	=	54,600 BTU/hr
Sidewall at curtains:	(3 X 70 X 2) X (88-10) / R11	=	2,978 BTU/hr
Sidewall beyond curtain:	(8 X 180 X 2) X (88-10) / R11	=	20,421 BTU/hr
Endwall:	400 X (88-10) / R11	=	2,836 BTU/hr
Ceiling:	(44 X 250) X (88-30) / R19	=	33,578 BTU/hr
Brood curtain:	400 X (88-50) / R1	=	15,200 BTU/hr
	Total building heat loss	=	129,613 BTU/hr

Ventilation/leakage heat loss calculation: cfm/sq ft X Area X Temp difference = BTU/hr heat loss

Ventilation/leakage heat loss:	0.2 X 10,000 X (88-10)	=	156,000 BTU/hr
			129,613 BTU/hr
			156,000 BTU/hr
Total heat loss in BTU/hr = Heating capacity needed:			285,613 BTU/hr