COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY • COLLEGE OF AGRICULTURE

# Poly-tube Heating-Ventilation Systems & Equipment

by George A. Duncan, John N. Walker and Larry W. Turner

The need for better environmental conditions to enhance plant growth in greenhouses and livestock performance in confinement facilities has prompted numerous developments in air handling techniques and equipment. The poly-tube system and equipment is a method developed to provide combined heating, circulation, and partial ventilation in a package of related equipment as illustrated by Figure 1. The mechanical equipment and perforated polyethylene air distribution tube combine to provide a rather simple system which is somewhat tedious to get fully installed and properly connected for functional operation. Companies providing this equipment generally have brochures and instructions available to explain operation and installation. However, inadequate information and misunderstandings in equipment selection, installation, and operation can cause poor performance. This publication summarizes the primary functional features necessary for a successful system. Other articles and publications that discuss alternate and equally successful heating and ventilation systems are available.

Present recommendations for a good greenhouse or livestock environment involve three factors: (1) good air circulation within the facility for uniform temperature, humidity, and certain gases, (2) adequate heat supply and distribution in winter to maintain minimum temperature desired, and (3) ventilation in warm and hot weather to limit temperature rise in the facility. The gross heating and ventilation requirements are generally easily determined, but many operators ignore the importance of good air movement and distribution which provide uniform temperature, relative humidity, and gaseous condition within the facility.

## Air Circulation & Distribution with Poly-tubes

The main function of the perforated poly-tube is to convey and distribute air from a supply fan at one end of the ventilated or heated space through the pressurized tube and into the house as uniformly as possible. Heated air, cool fresh air, and/or recirculated interior air can be conveyed through the tube and distributed as illustrated by Figure 2. High velocity jets of air exiting from the tube perforation create a mixing and distribution pattern in the house that “entrains” and stirs a larger volume of air than passes through the poly-tube. Figure 3 illustrates the “jet” priniciple.

Proper performance in a greenhouse or other facility requires tubes sized and punched (perforated) for a given house length and fan capacity. Shortened tubes or tubes with too small or too few holes restrict air flow which may overload and damage certain type fans or cause inadequate air movement in the house. Conversely, excessively large holes or long tubes on undersized fans will not give satisfactory distribution. This poor match is sometimes shown by the tube contracting and flapping near the fan. Attention must be given to both the house length and fan capacity for proper performance.

### *Tube Design & Performance Characteristics:*

Even though perforated polyethylene ducts have been used for several years, air flow and discharge characteristics apparently were not thoroughly studied or reported until recently. “Uniform” distribution requires a “designed” tube of given diameter with a calculated number and diameter of punched holes to match the fan’s capacity at the static back-pressure created by the pressurized tube. Contrary to popular opinion, uniformly sized and spaced holes do not provide uniform distribution along the full length of a tube. The air discharge through a circular hole in the sidewall of a thin-walled polyethylene duct is affected by: the area of the hole, the density of the air, the pressure within the duct, the pressure outside the duct, a discharge coefficient, and gravitational forces. The speed of the air within the duct also influences the air discharge.

Research on the performance of perforated polyethylene and other permeable tubes has found that:

1. Using standard propeller fans, there is a critical total area of holes per tube. The term “aperture coefficient” is suggested as the ratio of total hole area to duct cross-sectional area. Valves of aperture coefficient below 1.3 give reduced fan output and coefficients above 2.4 give duct instability. Aperture coefficients between 1.5 and 2.0

are recommended, meaning the total area of the holes should be 1.5 to 2.0 times the cross-sectional area of the duct.
2. Sizes of holes up to 2 inches in diameter have negligible effect on fan and duct performance, other than possibly affecting the air patterns and drafts within the building.
3. With uniform hole spacing, the quantity and velocity of air discharged from holes near the closed end is typically twice that from holes near the fan. By modifying the hole spacing, the quantity of air discharged per unit length of duct can be made uniform.
4. The performance of ducts shorter than and up to 100 ft. in length is similar and the same design principles apply. A long duct should have the same number of holes as a short one for a given air flow. The larger duct would merely have more widely spaced holes. Above 100 ft. in length, frictional losses change the pattern of velocities from the holes. (Note: Larger diameter tubes than those studied may permit longer lengths without the excess friction losses.)
5. Ducts can be used for fan speeds down to 20 percent of maximum speed, provided the duct is straight and suspended correctly.
6. An air straightener downstream from the propeller fan should be used to counteract circular air motion and a radial angle of emergence from the tube. Angles were found to vary from 30 to 25 degrees from normal for the first 50 percent of the tube length and then decrease somewhat linearly to a normal emergence angle for the remaining tube length.
7. A "forward" angle of air emergence was found that varied from approximately 63 degrees from normal at the fan to less than 5 degrees at the closed end. The forward directional effect can be eliminated only by having a directional outlet, which is difficult to achieve and generally not practical.

Thus, it has been found that tubes with uniformly spaced holes, which is common, do not produce uniform distribution of air. Instead, a greater amount of air emerges toward the closed end of such tubes. This appears to be beneficial. Logically, more air released close to the fan would merely provide "short-circuit" movement and intensify local mass flow, while limiting circulation at the far end of the building. Thus, the greater air flow to the far end provides better air movement and uniformity throughout the building length.

Arrows drawn on all figures of this article represent air discharge from the tubes. They are angled at the fan end to illustrate the forward emergence angle, and are longer at the closed end to illustrate the greater relative quantity of air released.

### *Location:*

Positioning of the tube within the house is important. Tubes are generally suspended overhead. The discharge holes for overhead tubes are normally punched off-center (in "4 o'clock" and "8 o'clock" positions), which provides a slight downward direction to the discharging air for better air mixing at plant and animal level. Only when you have tall crops or low tube mounting height should the tube be installed to direct the air upward and prevent direct air blasts onto plants and animals.

Poly-tubes must have sufficient size and capacity to force air down near the floor level and throughout the crop zone. Continuous air circulation of at least 20 to 30 percent of the house volume (in C.F.M.) is recommended.

Recent studies have shown that even with a proper commercial tube, air movement near ground level in a greenhouse is marginal for a specified minimum air velocity of 40 feet per minute. The adequacy or inadequacy of air movement at low levels will vary, of course, with types of crops and animals within the facility. If you are on the borderline of two commercial tube sizes for your facility, choose the larger size for better overall performance.

## Ventilation with Poly-tubes

A second capability of the poly-tube system is to bring fresh air from the outside and distribute it through the tube for the first stages of cooling. The earlier types of poly-tube equipment served only this function. With presently available equipment, fresh air enters the house when the motorized shutter behind the poly-tube fan is opened and an exhaust fan elsewhere in the building evacuates air as illustrated by Figure 4. This in-rushing air is received by the poly-tube fan and distributed through the tube, thus mixing and tempering cold outside air with the warm inside air. This first stage of ventilation should be 10 to 20 percent less in C.F.M. than the operational capacity of the poly-tube fan so excess cold air will not overflow directly onto plants and animals. Occasionally, producers are observed to have a 36" high-volume exhaust fan coming on for first ventilation with only an 18-inch lower volume poly-tube system. Since the poly-tube fan cannot pick up all the incoming air, some cold air bypass will certainly occur and may injure plants and animals in the draft.

A second level of ventilation may be activated for warmer temperatures and still pull additional air through the one shutter. However, it is necessary that additional motorized inlet shutters be used in larger facilities to provide adequate air inlet for summer ventilation as illustrated by Figure 5.

Manufacturers' literature states that most poly-tube equipment recommendations are sized only for enough ventilation capacity to hold the inside house temperature of greenhouses within approximately 15° F of the outside temperature. This may be acceptable for fall, winter and spring conditions, but inadequate for summer in both animal and greenhouse facilities. When larger summer ventilation fans operate, the poly-tube becomes rather ineffective since 4 to 5 times more air is being moved through the house by the ventilation equipment. The poly-tube fans can be turned off to conserve electricity and wear. The total exhaust ventilation fan capacity should provide an air exchange rate to control the building temperature as desired or as practical (normally about 1 air change per minute).

## Heating with Poly-tubes

Heated air can be injected into the poly-tube for mixing and distribution. Two commercial methods and equipment are illustrated by Figure 6. One company builds a combination fan and heater unit (hot water, steam, or gas fired) that is located between the inlet shutter and poly-tube. These fan and heating units are designed and sized to match certain tube sizes and lengths. Connecting a tube directly to any heater could soon result in a burned-out heater or a melted poly-tube due to restricted air flow.

Another company provides a special housing around the fan into which standard unit heaters blow heated air. The poly-tube fan then entrains and forces the heated air, along with other returned air, through the poly-tube. The poly-tube fan motor is shielded from the heated air to prevent overheating. This method requires a pair of unit heaters spaced a few feet apart opposite the housing to direct air "head-on" into the housing. Both heaters have to be wired to operate simultaneously, since one operating alone might blow the air straight through the housing.

Other types of furnaces and/or heating units could be used, providing the heated air is properly ducted or released where the poly-tube fan will draw the heated air in and distribute it through the tube without overheating components.

Both of the above commercial heating methods may require a poly-tube fan and tube a size larger than needed for air circulation alone to ensure adequate heat handling capacity and distribution. Thus, don't add heat to your existing poly-tube unit unless it meets the manufacturer's recommendations for the heat capacity required.

## Electrical Wiring

Electrical wiring and thermostat hookup gives many producers some problems. Some suppliers of the poly-tube equipment do not even provide wiring diagrams, which adds to the difficulty of understanding connections for a particular system. Generally, the equipment functions as follows and should be wired accordingly:

1. The poly-tube fans are on manual switches, or "normally closed" terminals of a ventilation thermostat, to allow continuous operation from late summer through fall, winter, spring, and until early summer.
2. The heating equipment is wired through a thermostat to maintain the desired minimum temperature. An interconnection of the heater thermostat and the ventilation thermostat should be made so the heater and ventilation fans cannot be on at the same time.
3. As the weather warms and some ventilation is required, the first small exhaust fan, or low speed of a two-speed exhaust fan, should operate simultaneously with the motorized shutter behind the poly-tube fan to provide the first fresh air ventilation. This exhaust fan rate, as described previously, should be 10 to 20 percent less than the poly-tube fan rate so that all cool fresh air is drawn into and distributed through the poly-tube.
4. As the temperature rises more, additional exhaust fans and motorized shutters should come on by thermostat control to provide cooling until the maximum fan ventilation capacity is reached. The poly-tube circulation fans can be turned off in warm summer weather or wired through one of the higher temperature thermostats to cut off automatically when the last one or two ventilation fans are powered.

## Other Characteristics of Poly-tubes

Plastic tubes, when used for greenhouse and animal facilities, have several characteristics worthy of mention. One is the affinity for collecting dust and insects in the bottom curvature after a period of operation. If the duct is slightly disturbed a blast of dust or debris is expelled. Opening the end and cleaning out the duct is sometimes necessary.

Second, the tube diameter often protrudes down below head height in ceiling-type livestock buildings. Installation in these facilities should be planned to avoid interference with human passage in alleys or other pathways. Some facilities are built with a higher ceiling to overcome this problem. Open gable-type buildings such as greenhouses or rigid-frame roof-insulated structures generally have sufficient overhead room to permit installation without such interference.

Finally, the tubes eventually begin tearing apart and require replacement, often yearly in greenhouses. The tubes may last two years in livestock facilities.

Be sure to suspend the tube properly to reduce tearing and to ensure maximum life. Replacement is not too expensive, but adds another maintenance chore that may occur at your busiest time. Remember, always keep a spare on hand, or at least the proper repair tape for an emergency.

## Summary

The commercially available poly-tube system of air circulation, heat distribution and partial ventilation has been incorporated into a package of environmental equipment adaptable to many facilities. The equipment can function only if properly selected and installed. A better understanding of the equipment will result in better environmental control and crop or animal production by the producer.

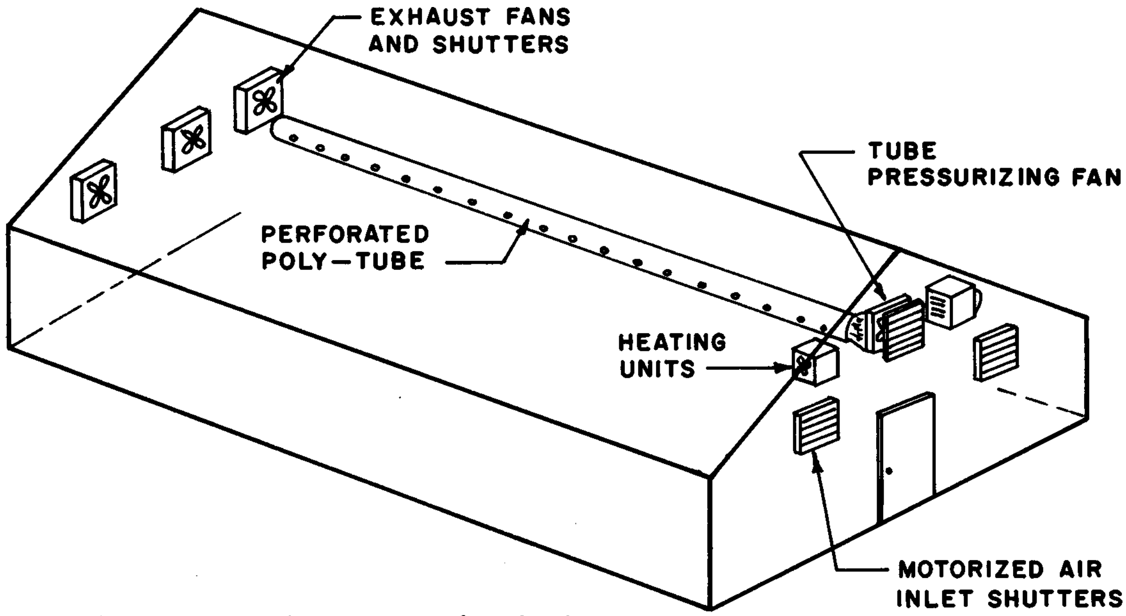



Figure 1: Typical components and arrangement of a poly-tube heating-ventilation system.

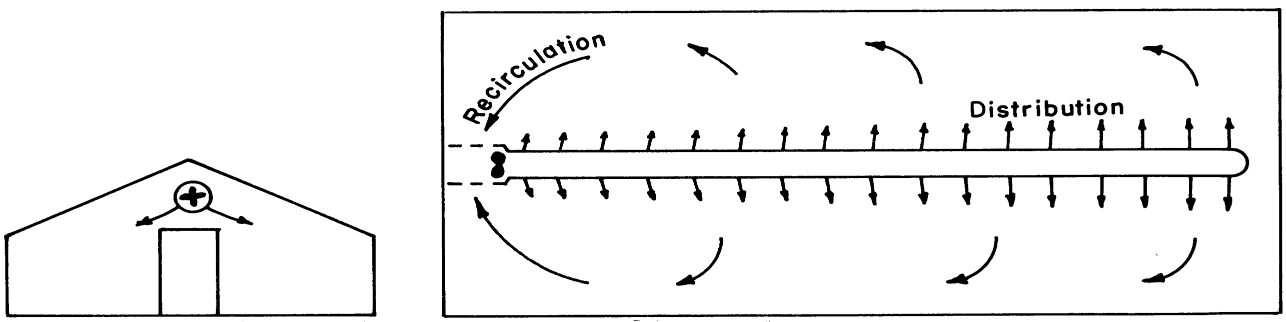



Figure 2: Air distribution and circulation function of poly-tube equipment.

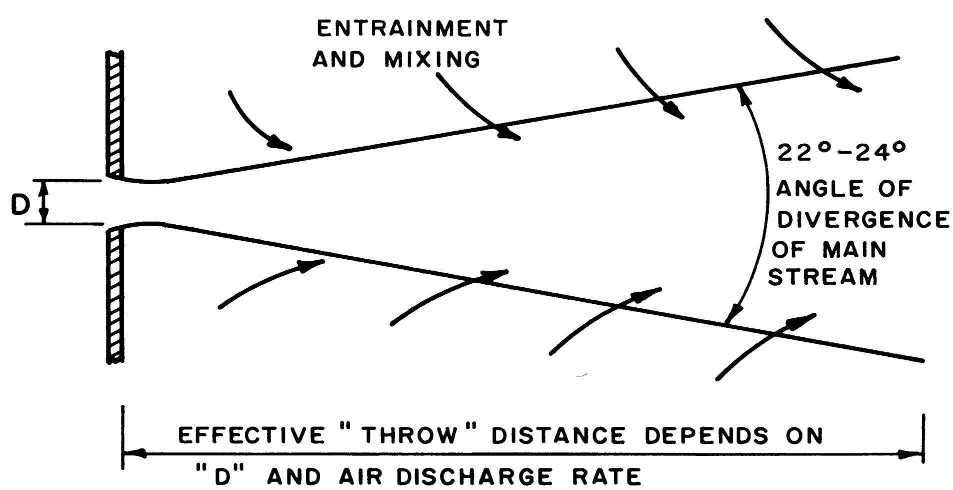



Figure 3: Pattern of an air jet emerging from a round hole or orifice.

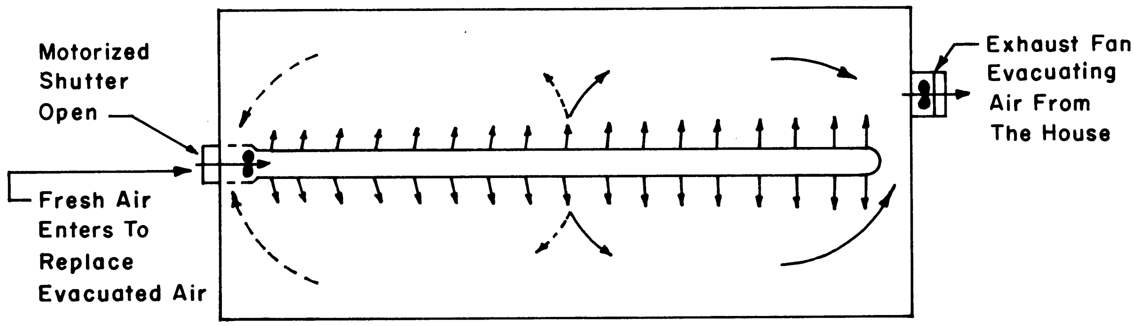



Figure 4: Low rates of fresh air ventilation with mixing and distribution by poly-tube and ventilation equipment.

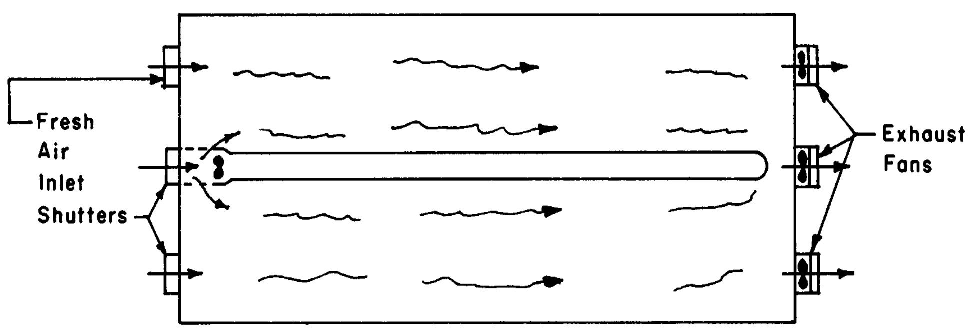
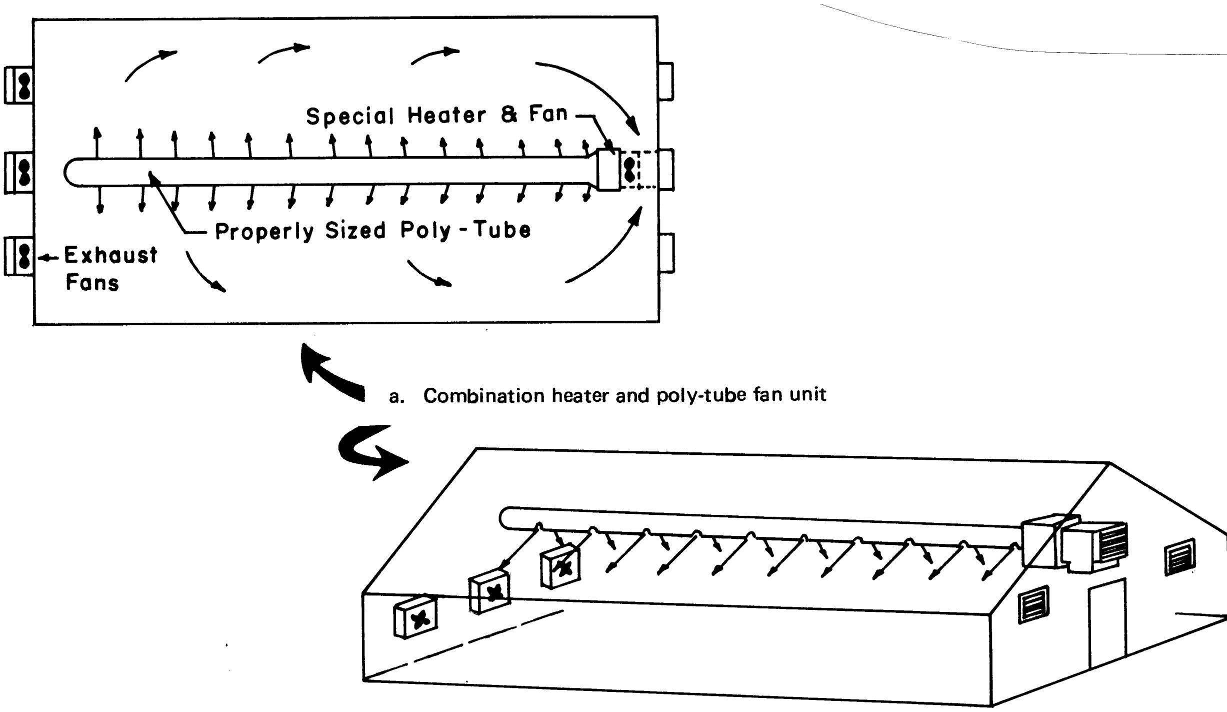
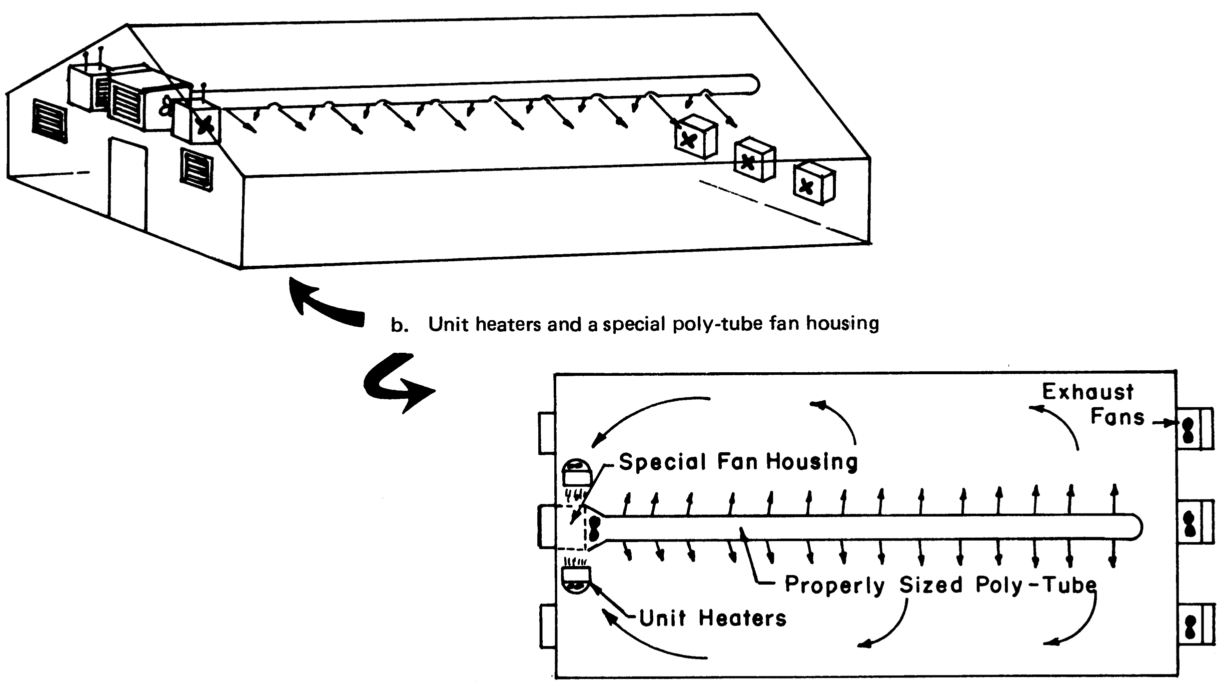



Figure 5: Total summer ventilation is provided by additional high-volume exhaust fans, thus rendering the poly-tube less effective for summer use.




a. Combination heater and poly-tube fan unit

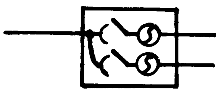



b. Unit heaters and a special poly-tube fan housing

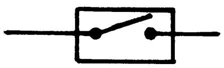
Figure 6: Alternate commercial equipment and methods for heat addition and distribution with a poly-tube fan unit.

## Wiring Diagrams

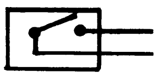
*Equipment Symbols:*



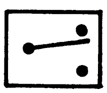
Fused or breaker type circuit protection and disconnect device.



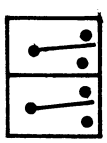
Manual toggle switch for motor or equipment control.



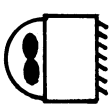
Single-pole single-throw thermostat.



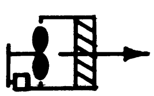
Single-pole double-throw thermostat (C/R = close on rise)



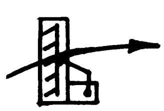
Two-stage (2-SPDT) thermostat (C/R = close on rise).



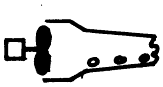
Gas-fired unit heater or equivalent heating device.



Exhaust ventilation fan (single or two-speed).



Motorized air inlet shutter.



Poly-tube pressurizing fan.

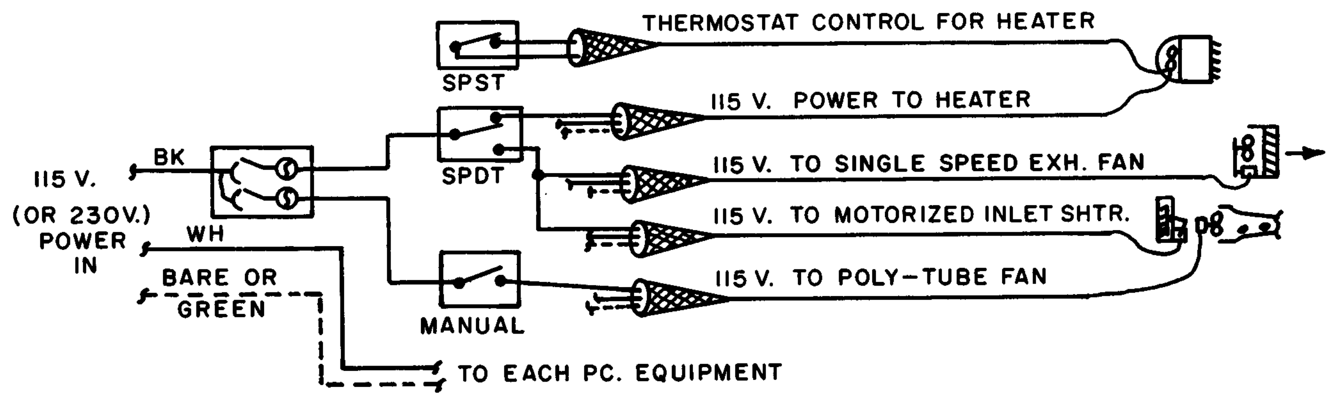



Figure 7: Wiring for a poly-tube heating ventilation system with one heater, one motorized inlet shutter, and a single-speed exhaust fan.

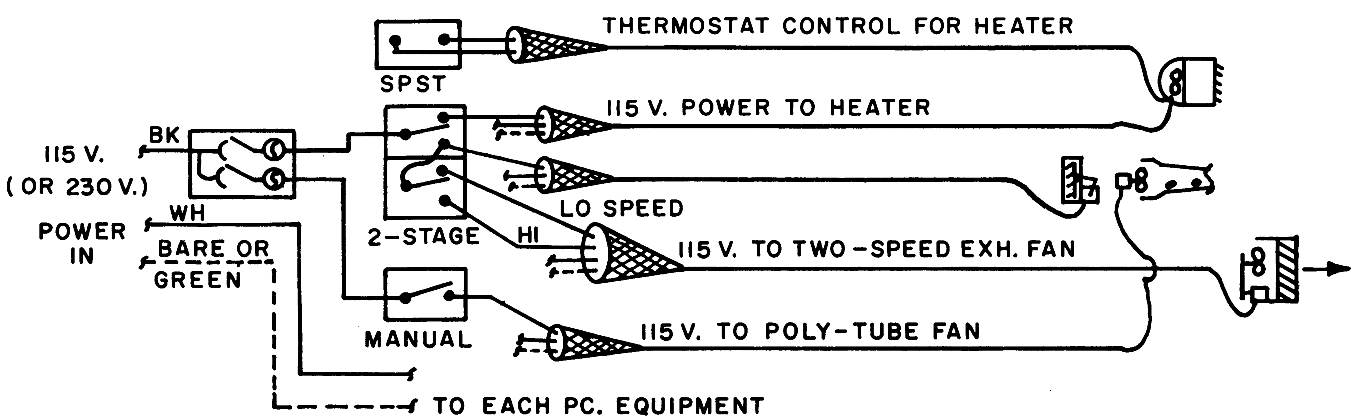



Figure 8: Wiring for a poly-tube heating-ventilation system with one heater, one motorized inlet shutter and a two-speed exhaust fan.

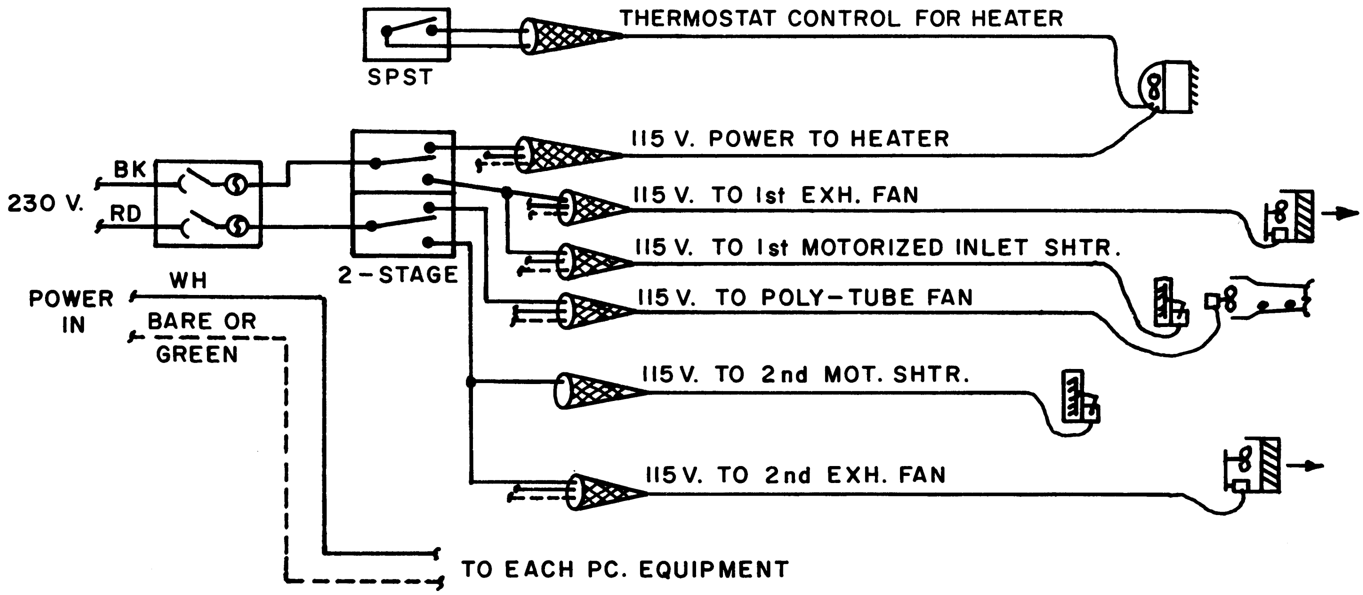



Figure 9: Wiring for a poly-tube heating-ventilation system with one heater, two motorized inlet shutters, and two single-speed exhaust fans.

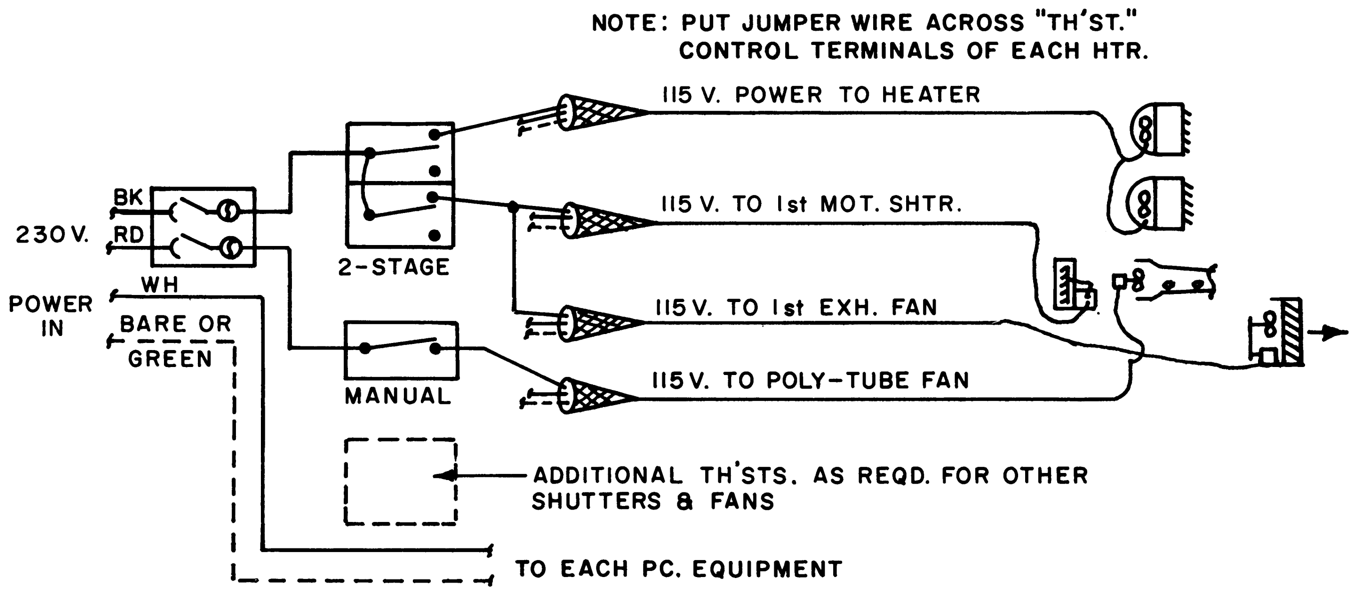



Figure 10: Wiring for a poly-tube heating ventilation system with two heaters and other equipment as in Figures 7-9.

Educational programs of the Kentucky Cooperative Extension Service serve all people regardless of race, color, age, sex, religion, disability, or national origin.
Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, C. Oran Little, Director of Cooperative Extension Service, University of Kentucky College of Agriculture, Lexington, and Kentucky State University, Frankfort.
Issued 9-73; 9M to 1-79; revised 11-91, 1M