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# Mechanical Backup Systems for Electronic Environmental Controllers

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## Abstract

A series of mechanical backup systems for electronic environmental controllers is presented for a typical finishing swine barn and a typical tunnel ventilated broiler house. The systems consist of mechanical thermostats and timers used in parallel with the electronic controller, designed to ensure animal survival in the event of controller or related hardware failure. For swine housing, three distinct mechanical backup functions are identified; for broiler housing, four distinct mechanical backup functions are identified. Schematic diagrams of the mechanical backup functions are provided and their implementation is described.

**Keywords.** Animal environment, Broilers, Digital controls, Electric controls, Environment, Swine housing.

## Introduction

The use of integrated electronic controllers for environmental control of livestock and poultry housing is rapidly becoming more prevalent as the price of controllers continues to decline and as the available features increase. While the widespread adoption of this technology is expected to greatly benefit producers and consumers through more efficient production (Gates et al., 1992b), proper installation of these controllers, including mechanical backup, is essential to achieving the desired benefits. Controller failures have occurred with catastrophic results. In several instances with which these authors are acquainted, at least partial blame for these failures could be placed on inadequate mechanical backup, and the failure (or manual deactivation) of parallel alarm systems. Given the quantity of sensitive electronics within these controllers and the failures that have been observed, any installation should have a consistent mechanical backup system designed to work in concert with, and be available to take control from, the primary electronic controller.

Mechanical backup systems can be logically categorized as serving one of three distinct and essential functions: 1) low temperature override; 2) high temperature override; and 3) providing minimum ventilation. Providing the first two functions is a straightforward matter of parallel use of mechanical thermostats on appropriate stages of the heating/cooling equipment. Minimum ventilation backup, however, is often neglected. It poses special problems in both swine housing and broiler housing. For swine housing, a variable speed fan often provides minimum ventilation; for broiler housing several constant speed fans run by interval timers typically provide minimum ventilation. The latest development in broiler housing, tunnel ventilation (a system in which all air travels the full length of the broiler house at relatively high velocity, with inlets at one end and exhaust fans clustered at the other end), provides a further complication for providing adequate minimum ventilation when the conventional sidewall fans used during brooding may be shut off.

Mechanical backup systems are recommended as essential by most agricultural equipment manufacturers and distributors. Unfortunately, the current U.S. liability climate has been primarily at odds with their adoption as standard control equipment. This is due mostly to the presumption of liability for the manufacturer and installer if a catastrophic failure should occur with a system that includes mechanical backup, regardless of whether the failure was due to incorrect use by the operator or equipment failure. This curious dilemma has greatly impeded the widespread adoption of systematically designed mechanical backups within this industry.

The objective of this article is to present a consistent set of mechanical backup circuits which, when used with an integrated environmental controller, provide a reasonable level of life support if a controller failure occurs. While the mechanical backup systems presented here are quite straightforward, and most can probably be found as components in existing environmental control systems, it is hoped that this compilation of ideas will serve as a basis for widespread adoption of mechanical backups as an integral part of all future environmental control systems.

## Installation Considerations

Most electronic controllers are not designed to directly switch large electrical loads such as fan motors. Instead, they typically switch a dry contact control relay, which in turn activates the coil of a large capacity power relay (fig. 1). These power relays cost from $25 to $75 each and the use of at least one per each stage of heating and ventilation is usually required. More than one power relay is often needed to activate multiple devices on a single stage, for example. Several companies provide multiple

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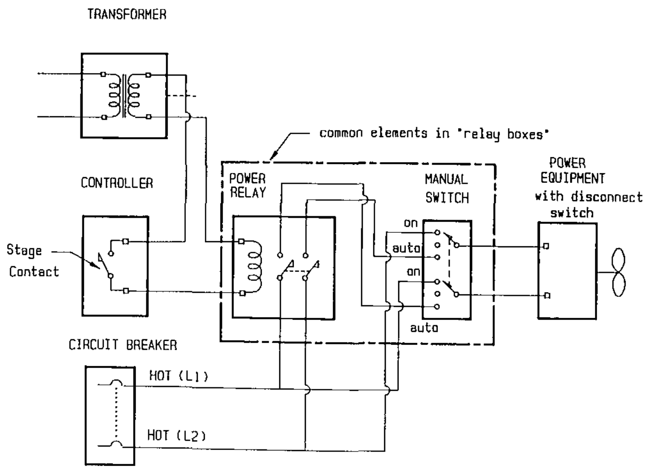


**Figure 1–A relay box provides automatic control functions, when the manual switch is placed in the AUTO position, and allows operation as described in the text. These units are available either individually or with several relays per enclosure. Most also provide a lamp to indicate if power is on the equipment side of the manual switch.**

power relays in a single enclosure, pre-wired with ON/OFF/AUTO switches (fig. 1). The "ON" position provides a manual override of the controller, the "OFF" position typically is used as a disconnect, and the "AUTO" position is used under normal operation. These units have a lamp to indicate voltage on the power relay contacts, or at least control voltage present at the relay coil.

Use of power relays can complicate a mechanical backup system. If both legs of a 240 VAC circuit are switched by the relay to provide a safety disconnect, then the mechanical backup components must also switch both legs of the power circuit. If the backup relay does not also switch both legs, then a power backfeed is possible throughout the circuit and the system will no longer have a safety disconnect.

Some controllers incorporate air inlet control in addition to the ventilation equipment; however, for most installations it is important to determine how the controller will interact with the air inlet system. The most straightforward solution is to use an air inlet controller that is independent from the environmental controller; the inlet controller reacts to changes in static pressure as fans are switched by the environmental controller. An alternative approach for curtain controllers is to connect the curtain controller to one or more stages of the environmental controller; this is useful in tunnel-ventilated broiler houses, for example.

One advantage of electronic controls is that they can be installed in an office or storage room where they are not exposed to the animal environment; or they can be installed in the animal environment at a convenient central location. A very useful technique is to attach all equipment to a board and pre-wire as much of it as possible prior to installation. A 10 or 15 cm (4 or 6 in.) deep raceway mounted at the bottom of the board is essential for a clean installation. Flexible conduit can be used to attach each piece of equipment to the raceway. Power circuits can be intercepted from the service panel, and re-routed into the raceway and to the controls; control outputs can then be connected to the original power circuits that are routed out to the ventilation equipment. On new installations, the raceway and control board becomes the first "stop" for power circuits. An alternative for existing buildings is to install the power relays near the equipment to be activated. This can save wiring costs in large buildings if 20 or 22 AWG wire is used to switch low voltage coils on the power relays. If this option is used, it is recommended that the power relays have the ON/OFF/AUTO switch configuration described above to serve as a safety disconnect near the equipment.

Another very important item to address in conjunction with installation of an electronic controller is appropriate transient overvoltage protection (Gates et al., 1992a). A properly grounded building is an often neglected item that, combined with an appropriate secondary arrestor for the building service, can adequately protect sensitive electronic equipment from a majority of voltage transients on the power supply (Gates et al., 1991). However, some controllers available have been found to have inadequate built-in transient protection for sensor lines (Gates et al., 1992a, 1992b) which further underscores the need for mechanical backup.

A schematic of a full transient overvoltage protection scheme is illustrated in figure 2. The recommended system consists of several cascaded levels of protection, beginning with lightning protection for the building and main service, into the building service entrance (ANSI category C), large sub-panels (ANSI category B), and branch panels (ANSI category A). This information is detailed in the ANSI (1980) transient overvoltage test specification C62.41-1980, NFPA (1986), and Standler (1989). For agricultural facilities such as livestock buildings, the following minimum surge suppression is suggested by these authors:

1. Lightning arrestor on the main service pole.
2. Properly grounded main service, building service, and building.
3. Category A or B arrestor for the building service panel.
4. Secondary arrestor (or Category A) for the controller circuit.

Certainly additional surge protection would be helpful, but this minimum level will provide protection against a majority of surges and at a reasonable cost. While not shown in figure 2, telephone lines also must be protected if they are used as a part of the control or alarm system. A similar cascaded approach is recommended (Standler, 1989).

## Example Mechanical Backup Systems

### Introduction

An independent and reliable alarm system is widely recognized as an essential piece of equipment for sophisticated environmental control systems. The alarm system activates at temperature extremes, and perhaps additional items such as power failure and low water pressure. The system activates one or more alarm-sounding devices, usually a large audible alarm. Many newer installations also activate an automatic telephone dialer that repeatedly calls several preprogrammed numbers with a warning message. Some operators use a telephone pager in

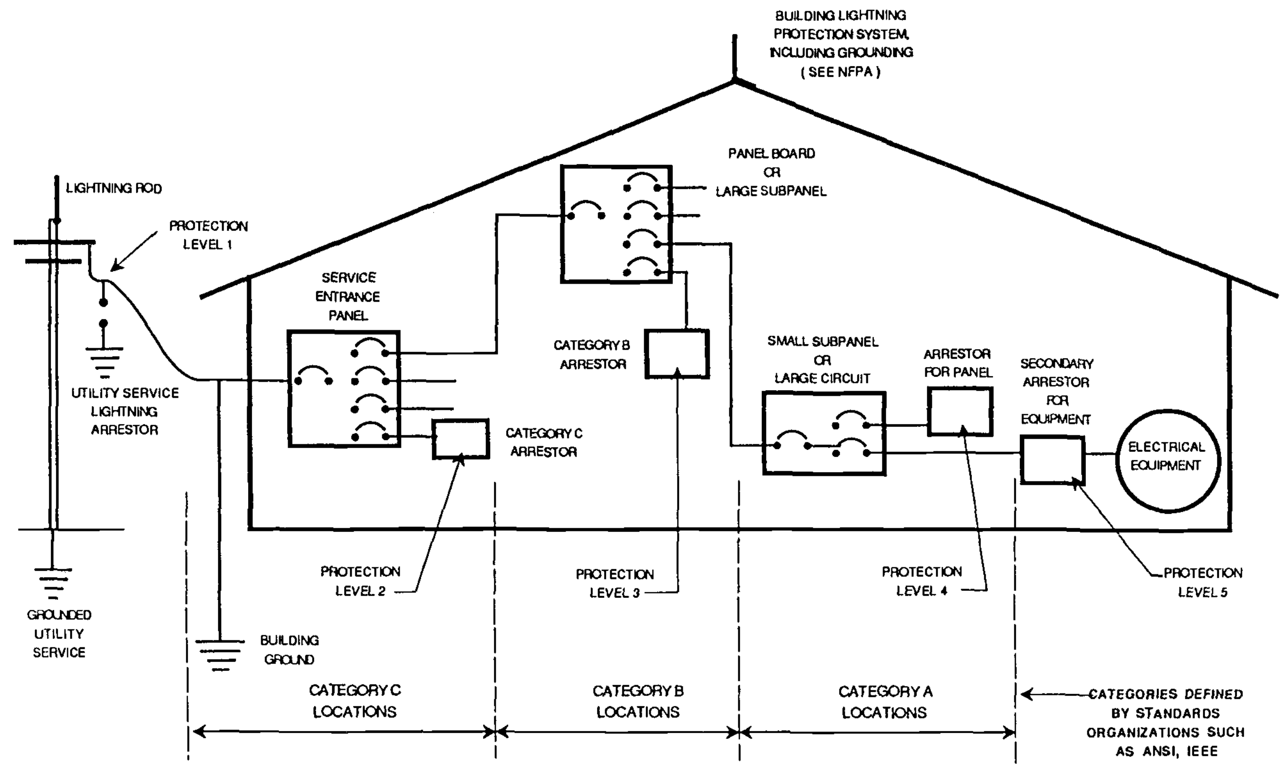


**Figure 2–Schematic illustrating a "completely protected" building electrical service utilizing the recommended cascaded system. Although not shown, telephone service is protected in a similar fashion. Electrical utility service surge arrestor and ground are intended to absorb large transients originating from other sources on the power grid. Category C and B protection levels are designed to further dissipate outside transients, and any generated from within the facility (motor switching, for example). For sensitive electronic equipment, surge suppressor strips are recommended as a sixth level of protection.**

conjunction with the dialer so that they are quickly notified when an alarm is active, even if they are remote from the facility. Another excellent safety feature for curtain-sided houses is an automatic curtain drop system that activates if inside temperature exceeds an upper limit.

As important as the alarm system is, it is imperative to recognize that it should be the last line of defense against a controller failure. While a controller failure is fairly uncommon, it is a real possibility. Any controller with life-support responsibilities should have mechanical backup systems in addition to any alarm system that may be installed.

We have designed three distinct mechanical backup systems for swine buildings: 1) low temperature safety; 2) high temperature safety; and 3) winter minimum ventilation. For broiler houses, we have designed four distinct mechanical backup systems for: 1) low temperature safety; 2) high temperature safety; 3) brooding minimum ventilation; and 4) tunnel minimum ventilation. These systems are described in the following sections.

### Swine Building Mechanical Backups

To illustrate the use of mechanical backup for a swine facility, consider the schematic in figure 3. This example swine barn has one sidewall fan for minimum ventilation, assumed to be a variable speed fan; two sidewall fans for summer ventilation; and one LP gas heater. Each fan is on a separate 240 VAC circuit. The heater is placed on a 120 VAC circuit. For purposes of illustration, assume the staging schedule in Table 1 has been chosen. This staging schedule is depicted graphically in figure 4.

### Low Temperature Safety Override

For low temperature protection in the event of a controller failure, the heater circuit is provided with a

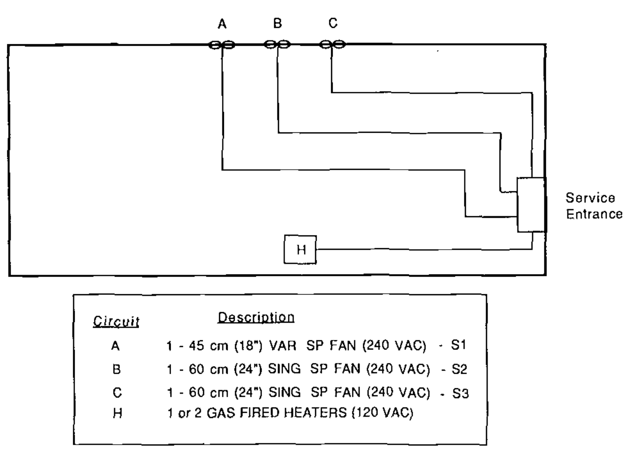


**Figure 3–An example of electrical circuits for ventilation and heating in a swine grower barn. This system uses one variable speed fan (circuit A, fan S1) for minimum ventilation. Two additional fans (S2 and S3), each on separate circuits (B and C), provide additional ventilation in warm weather. One gas-fired space heater is installed on another circuit.**

TABLE 1. Staging schedule for swine barn (fig. 3)

| Stage | Equipment Operated* | Degrees Above / Below Setpoint °C (°F) |
|---|---|---|
| Heat | H1; S1 on minimum speed | −2 (−3.6) |
| 1 | S1 | +2 (+3.6) |
| 2 | S2 | +4 (+7.2) |
| 3 | S3 | +6 (+10.8) |

* Equipment: H = heaters; S = sidewall fans.

mechanical thermostat connected in parallel with the electronic controller (fig. 5). Regardless of the operation of the controller, when the mechanical thermostat senses a temperature lower than its setpoint, contacts will close and provide power to the heater.

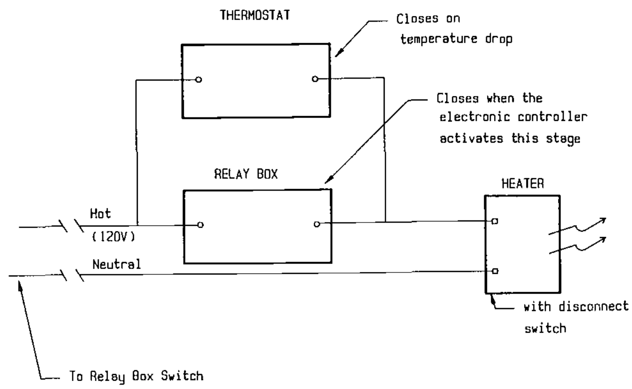


**Figure 5–Low Temperature Safety Override. The heater is placed on a 120 V circuit, and turned on by either the controller or the override thermostat. The override thermostat is set to turn ON if the temperature drops below 15° C (60° F), for example. Note that in 120 VAC circuits, a single-pole thermostat is acceptable.**

### High Temperature Safety Override

For the possibility of controller failure during hot weather, it is essential to activate one or more fans. In principal, this is identical to the low temperature safety override, except that the thermostat contacts must close on temperature rise (fig. 6). This backup should be installed on a large fan (or pair of fans) to provide enough air for survival until a high temperature alarm is activated. If additional ventilation backup is desired, another thermostat could be used; alternatively, a single thermostat could be used to switch the coils of multiple power relays. Note that if an automatic curtain drop unit is installed in the building, then this additional backup is not necessary.

### Minimum Ventilation Override

If the controller fails during minimum ventilation, there is a possibility that animals could suffocate without the high temperature override activating. To cover this event, the schematic in figure 7 illustrates a backup for a variable speed fan.

To override a controller failure, a double-pole thermostat is installed to remove power to the variable speed controller, and shunt power to the fan. If the maximum fan output exceeds approximately four times the minimum ventilation rate, then a conventional mechanical timer could also be installed between the thermostat and the fan. A relay may also be needed between the speed controller output [e.g., the controller's triac (a specialized bidirectional thyristor used to provide phase control of power circuits. See Gustafson, 1988)] and the fan to prevent power backfeed into the controller.

The system works as follows: If the controller fails and ventilation stops, the thermostat contacts close when inside temperature exceeds the thermostat setpoint. Full power is then provided to the fan. If the timer is used, then the fan will operate at full speed according to the timer setting. Note that in warm weather, the mechanical backup thermostat will provide full power to the fan if the setpoint on the thermostat is relatively low compared to ambient conditions. For the spring or fall case where intermediate ventilation rates are needed, it is especially important in this configuration to calibrate the thermostat to the controller. Otherwise, the desired ventilation rate may not be provided. Therefore, the operator must keep the thermostat and timer adjusted to realistic values, appropriate for the outside conditions and animal density.

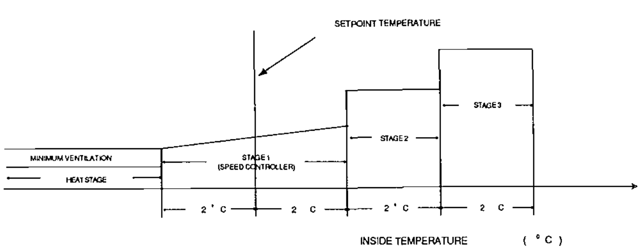


**Figure 4–Staging diagram for the example building in figure 3. As inside temperature varies about the setpoint temperature, different equipment is activated according to what "stage" the system is in. For this example there is a constant 2° C (3.6° F) between each stage. The temperature must drop 2° C (3.6° F) below the setpoint before the heater turns on. See Table 1 for the equipment assigned to each stage.**

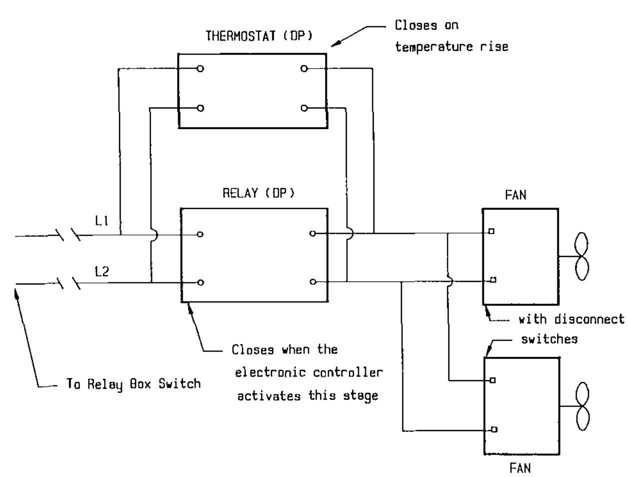


**Figure 6–High Temperature Safety Override. The largest fan(s) on a single 240 VAC circuit are turned ON by either the controller or the override thermostat. The thermostat is set for a temperature above which it is desired that the fans always be on. For this example, using fan S3 on stage 3, a setting of 30° C (86° F) is recommended. Note that for 240 VAC circuits a double-pole (DP) thermostat is necessary if the controller power relay switches both legs (L1 and L2).**

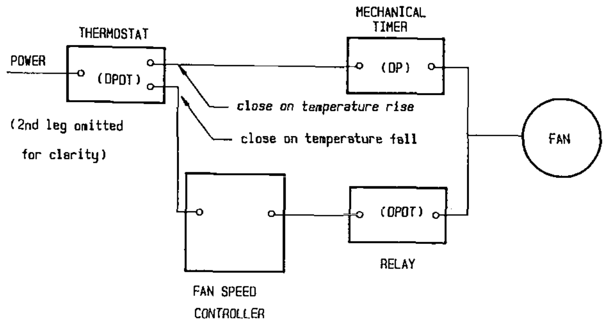


**Figure 7–Minimum Ventilation Override. For this example, minimum ventilation is provided by a fan speed controller connected to a variable speed fan. The speed controller may be a separate unit, or an integral part of the environmental controller. To provide mechanical backup of minimum ventilation, a thermostat is used to override main power and instead direct it to a mechanical timer connected to the fan. If the temperature exceeds the setting on the thermostat, then the fan will be run by the interval timer. Note the use of a DPDT relay to prevent backfeed to the speed controller, which may be unnecessary in some models. The mechanical timer is only needed if the capacity of the fan at full speed exceeds approximately four times the desired minimum ventilation.**

Many minor variations to the schematic in figure 7 are possible. However, the basic intent is always to provide some minimum amount of ventilation to prevent suffocation.

### Broiler House Mechanical Backups

To illustrate the use of mechanical backup for a tunnel ventilated broiler house, consider the schematic in figure 8. This example broiler house has four sidewall fans for minimum ventilation, eight large sidewall fans at one end of the house for tunnel ventilation, and six LP gas heaters. Pairs of the large fans share a common 240 VAC circuit, three pairs of heaters are placed on two 120 VAC circuits, and the timer actuated sidewall fans are placed on two 240 VAC circuits. For purposes of illustration, assume the staging schedule in Table 2 has been chosen. This staging schedule is depicted graphically in figure 9.

**TABLE 2. Staging schedule for broiler house (fig. 8)**

| Stage | Equipment Operated* | Degrees Above / Below Setpoint °C (°F) |
|---|---|---|
| Heat | H1 - H6; S1 & S3 on timers | −2 (−3.6) |
| 1 | S1 and S3 | +2 (+3.6) |
| 2 | S2 and S4 | +4 (+7.2) |
| 3 | T1 and T2 | +6 (+10.8) |
| 4 | T3 and T3 | +8 (+14.4) |
| 5 | T5 and T6 | +10 (+18.0) |
| 6 | T7 and T8 | +12 (+21.6) |

* Equipment: H = heaters; S = sidewall fans; T = tunnel fans.

### Low Temperature Safety Override

For low temperature protection in the event of a controller failure, at least one of the heater circuits is provided with a mechanical thermostat connected in parallel with the electronic controller (fig. 5). This backup is identical to that explained in the swine barn example.

### High Temperature Safety Override

For the possibility of controller failure during hot weather, it is essential to activate fans. This is identical to the swine building example (fig. 6).

### Brooding Minimum Ventilation

During brooding, if the controller fails there is a possibility that the lack of ventilation would be catastrophic. To cover this event, the schematic in figure 10 illustrates one solution. Two sidewall fans (S1 and S3 in figure 8) are the first stage of ventilation, which is assumed to be controlled by a built-in timer for this example. The minimum ventilation is adjusted by selecting the amount of "on-time" which the fans are desired to run during each interval. If the controller's timer failed, so that $CR_2$ never closed, the power relay $PR_2$ would never be actuated and the fans would not run.

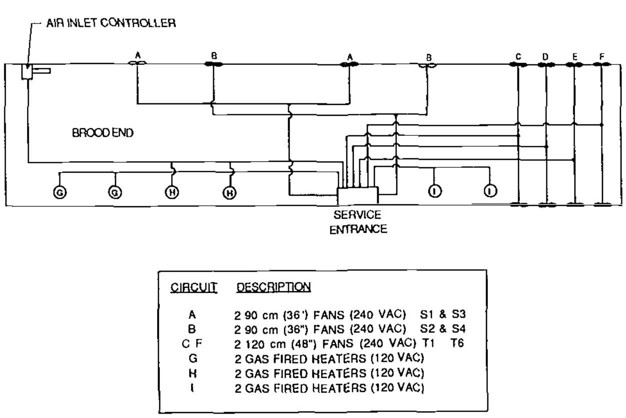


**Figure 8–An example of the electrical wiring for ventilation equipment in a broiler house. This system utilizes four pairs of 120 cm (48 in.) fans on circuits C, D, E, and F at one end of the building to provide tunnel ventilation. Four sidewall fans on circuits A and B are used for minimum ventilation. Six gas-fired space heaters are used on three 120 VAC circuits.**

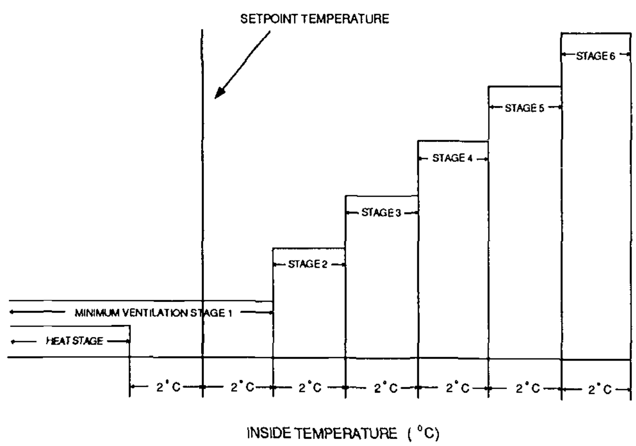


**Figure 9–Staging diagram for the example broiler house. As inside temperature varies about the setpoint temperature, different equipment is activated according to what "stage" the system is in. For this example there is a constant 2° C (3.6° F) between each stage. The temperature must drop 2° C (3.6° F) below the setpoint before the heater turns on. See Table 2 for the equipment assigned to each stage.**

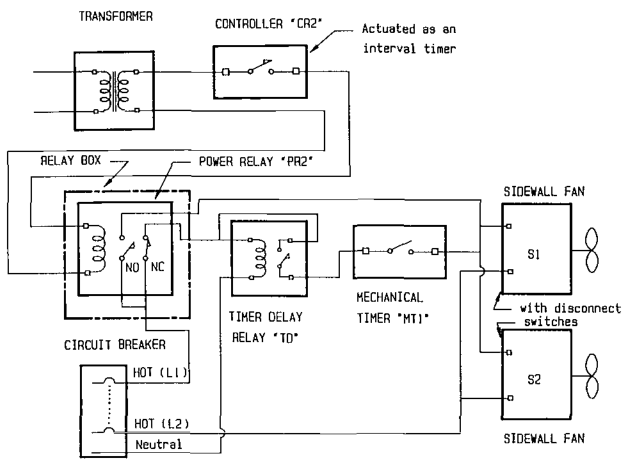


**Figure 10–Brooding Minimum Ventilation Override. During normal operation, the controller switch CR2 acts like an interval timer and turns ON/OFF the power relay $PR_2$, which activates the brooding fans. If $CR_2$ or $PR_2$ fail, then the time delay relay (TD) contacts close after a pre-set interval and provide power directly to a mechanical timer ($MT_2$) which overrides the failure. Note that a double-pole power relay that disconnects both legs of the 240 VAC circuit cannot be used for this to work properly, unless a double-pole mechanical timer and time delay relay are also used.**

To override a controller failure, the normally closed contact of the power relay ("NC" of $PR_2$) is connected to one leg of the power. The contacts of a time delay relay (TD) are connected in series. Finally, a conventional mechanical timer is connected between the TD contacts and the fans.

The system works as follows: the TD contacts are open and remain open (providing a delay) once power is applied to the TD coil. After a delay (which is selected to be 10 to 20% longer than the controller interval timer cycle) if power remains on the TD coil, then the TD contacts will close. If power to the TD coil is removed prior to the time delay, then the relay is reset and the TD contacts remain open. By placing the TD contacts between a mechanical timer and the NC contacts of $PR_2$, the mechanical timer can control the fans if the NC contacts of $PR_2$ are not opened within the delay time of TD. This system does not prevent a situation where the controller fails with additional stages activated such that the minimum ventilation rate is exceeded (in two of three controller failures measured, Gates et al., 1992b, determined that all ventilation equipment would have been activated).

To use the system, the operator must adjust the mechanical timer $MT_1$ to a setting that is appropriate for bird age, litter condition, and outside temperature. Typically, $MT_1$ should be adjusted to the value used by the controller.

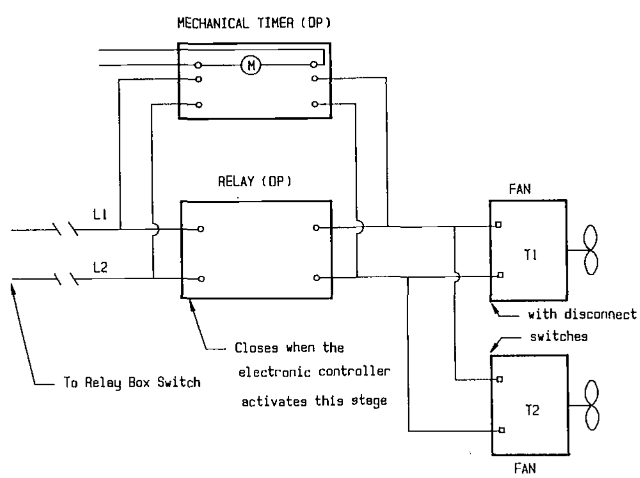


**Figure 11–Tunnel Minimum Ventilation Override. This safety override provides minimum ventilation during whole house operation when the sidewall fans might be shut OFF. If the controller fails, the mechanical timer $MT_2$ continues to work. The operator must keep this timer adjusted to a reasonable value equal to the control valve, and in place with the controller.**

### Tunnel Minimum Ventilation Override

In the event of a controller failure during whole house brooding, the brooding minimum ventilation backup in figure 10 may be insufficient, or as is often the case, power to the sidewall fans may be disconnected. In either case a substantial temperature rise would be needed to activate either the alarm system or the high temperature override (fig. 6). Consequently, a mechanical backup for minimum ventilation in the tunnel operating mode is depicted in figure 11. Its primary purpose is to provide a reasonable amount of ventilation at moderate to cold outside temperatures.

The backup system consists of a mechanical timer wired in parallel with the power relay that the controller activates, for example tunnel fans T1 and T2. The location of this timer should be near the controller so that it is properly adjusted at all times. During brooding, when the sidewall fans are activated (tunnel ventilation is not being used), the mechanical timer should be shut off, or the power to the tunnel fans should be removed.

## Summary

A systematic approach to providing mechanical backup in swine and broiler installations was stressed. Installation considerations appropriate to the use of electronic controllers in existing and new buildings were described. The importance of providing a reasonable level of transient overvoltage protection was described and a recommended minimum protection level was suggested. A detailed set of schematics for the implementation of mechanical backups for integrated environmental controllers has been presented. The salient features for each type of mechanical backup were described for example installations of a swine barn and a broiler house. It is hoped that these backup systems can be used as a prototype for environmental control system designs in all types of plant and animal systems.

While the current liability atmosphere is such that it discourages straightforward discussion of mechanical backups by the industry, perhaps a concerted effort on the part of university extension personnel, engineering consultants, insurance companies, manufacturers, equipment dealers, and installers can change this. It is essential to adopt a design strategy that requires systematic mechanical backup systems as a necessary part of environmental control.

An important issue that must be addressed is the education and training of users to properly adjust the mechanical backup components as conditions warrant. This critical aspect is crucial to adoption of mechanical backup systems. Equally important is the fact that no backup is 100% foolproof; this concept is crucial to the proper design and use of backup systems.

Indeed, education of users and installers is a critical element of intensive livestock and greenhouse production systems and the need is exacerbated as these systems become larger. Integrated environmental controls cannot solve problems created by a poor design or by the operator's lack of knowledge about heating and ventilation. Universities, power cooperatives, and the equipment manufacturers should work to promote basic ventilation education, as well as information on controllers, by standard methods such as agricultural extension fact sheets, power cooperative newsletters and field personnel training. Manufacturers could provide more educational materials and training to equipment dealers, since the dealers are often the first people that prospective buyers turn to for information.

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