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Bioclimatic Chambers for Poultry Research: Design and Preliminary Results of Testing

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ABSTRACT

The 12 new environmental chambers for poultry research recently completed at the University of Arkansas feature solid state electronic systems to control dry bulb temperature and dew point of the chamber air. Dry bulb temperature is controlled by reheating previously cooled and dehumidified air by an electric heater installed in each supply air duct. Solid state controls proportion the flow of electricity to the heater to match the demand. The system is arranged to maintain constant temperature on a diurnal temperature cycle. A solid state time-proportioning control maintains a pre-selected dew point in each chamber. The control operates a solenoid valve to admit steam in regular pulses of varying duration to add moisture to the supply of air as needed. Automatic systems to control drinking water temperature and air flow rate also are included. The use of electronic controls, with electric heat, has resulted in environmental control systems of high precision with minimal mechanical complexity. The chambers are being used to study the response of broilers to different brooding temperature schedules and drinking water temperatures.

INTRODUCTION

Dependable facilities, capable of maintaining desired environmental conditions, are essential for research in environmental effects on animals and poultry. With financial aid from the poultry industry and allied industry, a laboratory for environmental research with poultry was constructed at the University of Arkansas. The major feature of this laboratory is a set of 12 environmental chambers in which the environmental variables of dry bulb temperature, dew point, light quality and duration, and water temperature can be controlled.

The environmental chambers, designed by the Agricultural Engineering Department, incorporate novel control systems which are expected to provide improved performance and dependability. The purpose of this paper is to describe the control methods used.

CHAMBER DESIGN CRITERIA

To provide for a broad spectrum of research environments, the following criteria were established.

1. Dry bulb temperature range 35 to 105 F (2 to 41 C).
2. Dew point temperature range 35 to 95 F (2 to 35 C).
3. Air movement not to exceed 300 fpm at floor.
4. Air exchange rate fixed at 300 cfm.
5. Size approximately 8 ft wide x 12 ft deep x 7 ft high.
6. Chamber ambient conditions - design value of 80 F (27 C) maximum dry bulb; 69 F (20 C) maximum wet bulb in summer to 70 F (21 C) dry bulb minimum in winter.
7. Automatically controlled lighting schedule.
8. Controlled drinking water temperature.

PHYSICAL ARRANGEMENTS

The 12 chambers are arranged in two continuous rows of six each, as shown in Figure 1. Each chamber is controlled independently but has airtight insulated partitions in common with its neighbors. Control of environment is achieved by continuous flow of temperature- and moisture-controlled air. No air is recirculated, and no control equipment except sensors is in the chambers. The chambers are organized further into four groups. One group of four chambers is equipped for dry bulb temperatures and dew points down to 36 F, another group of four is equipped to go down to 50 F, and two groups of two chambers are equipped for 60 F minimum operation. All the chambers within a group have common air filtration, cooling and dehumidifying, and exhaust systems. Within each group air from the room passes through a filter, across a direct-expansion coil where it is cooled and dehumidified, and then is discharged into a supply plenum. Cold air (300 cfm) enters a separate branch to each individual chamber, passing first through a measuring orifice, then over an electrical duct heater and a steam-jet humidifier, and through a manually adjusted damper before entering the chambers. Exhaust air is removed from the chamber through a system of ducts by an exhaust fan and is discharged above the roof of the building. Conditions in the plenum are maintained constant. Control of the chamber conditions is accomplished by controlling the inputs to the electric heater and to the humidifier, to reheat and rehumidify air from the plenum to the desired condition. A schematic diagram of the system is shown in Figure 2.

CONTROL SYSTEM DESIGN

The control functions of the air-handling system are fourfold.

1. Cooling and dehumidification of the room air entering the system by a direct-expansion coil. Control is by automatic by-pass valves supplying hot refrigerant gas to the low side of the refrigerant circuit to maintain constant suction pressure.

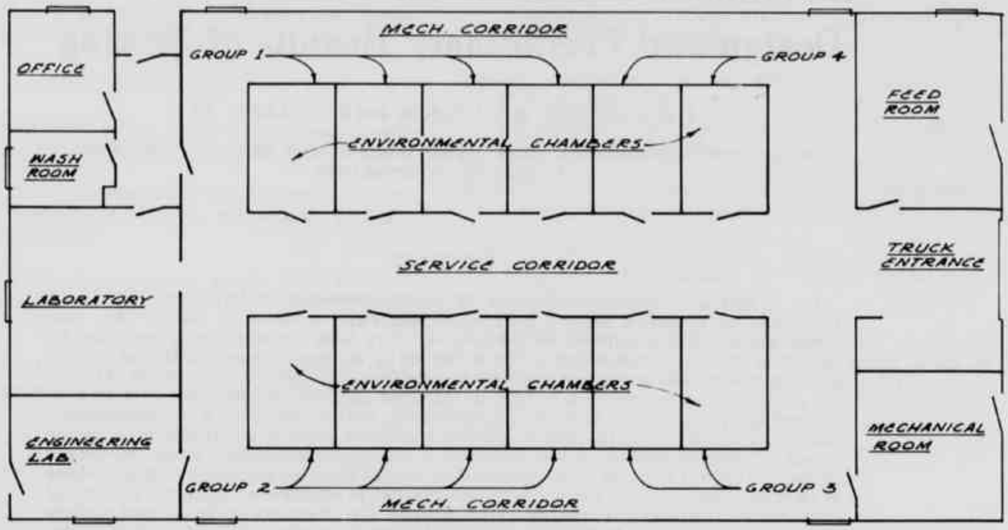

Figure 1. University of Arkansas Poultry Environmental Research Laboratory.

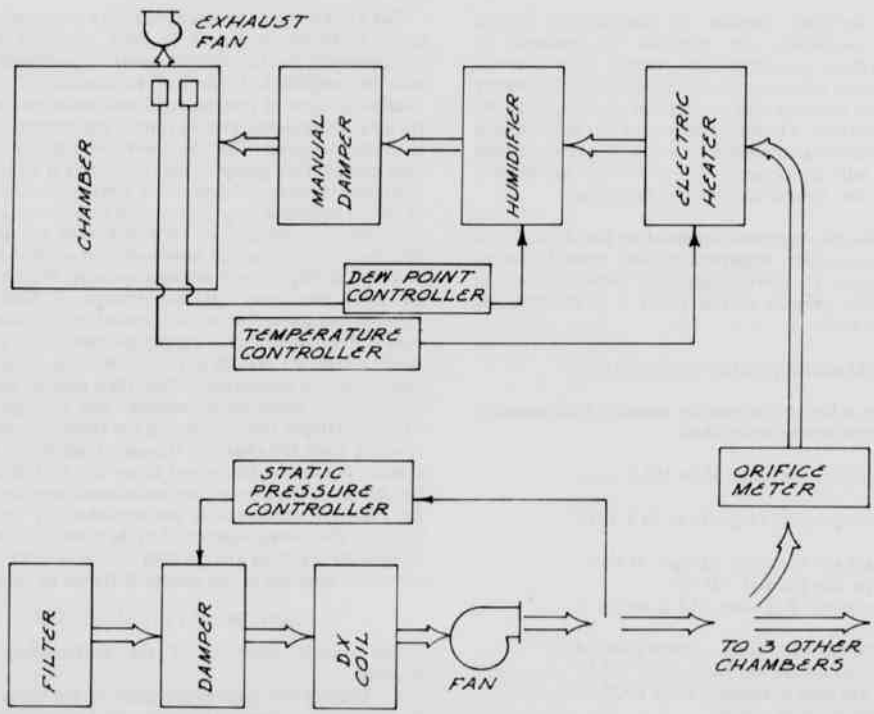

Figure 2. Air handling system for environmental chambers.

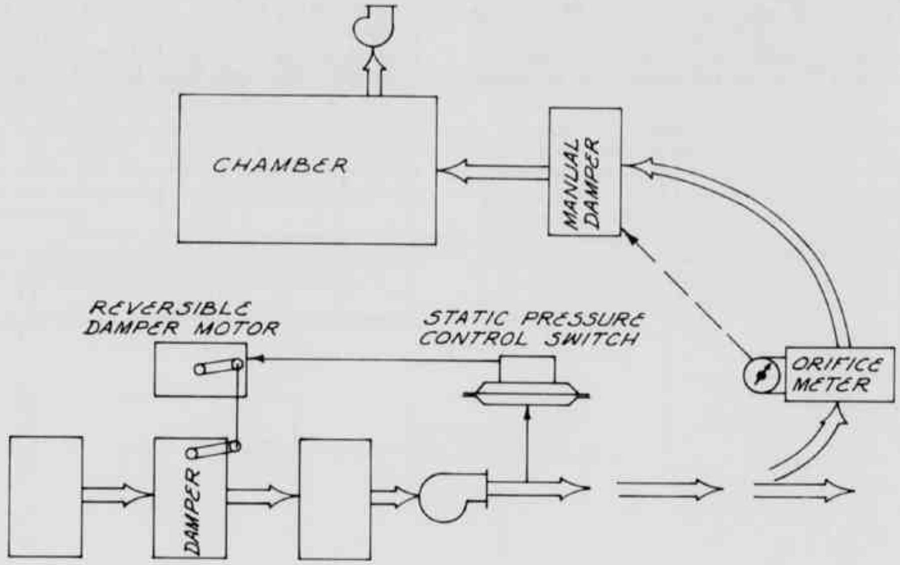

Figure 3. Air flow rate control system.

2. Control of air volume to each chamber. Volume is adjusted by a manual damper in conjunction with a measuring orifice in each branch. Static pressure in the supply plenum is maintained constant by a slack-diaphragm pressure controller operating in conjuction with a reversing slow-speed damper motor to position a restricting damper in the inlet to the plenum. This system is shown schematically in Figure 3.

3. Control of air temperature is by reheating of the cold supply air to the required level by an electric duct heater in each branch. A thermocouple near the exhaust outlet from the chamber senses the chamber temperature. A temperature controller (Honeywell R7272B) senses the departure of the thermocouple temperature from the set point (which may be established internally or by an external programmer, one-half of a Honeywell W806A two-cam programmer, at the user's option) and provides a signal voltage to control the power supply to the heater. The power supply is a 240-v, 6-kw, solid-state controller (Honeywell R7291A) which supplies a variable-length pulse of energy, typically consisting of several complete cycles of electric power, at a constant time interval. Typically the interval is 2 sec, but is adjustable. The power-pulse duration may range from 0 to 100% of each time interval, as shown in Figure 4. Arrangement of the system is shown in Figure 5.

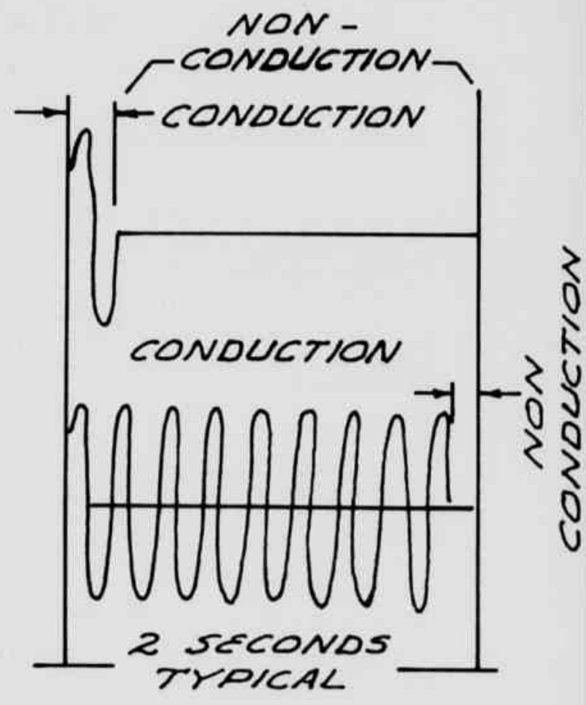

Figure 4. SCR power supply outlet wave form.

4. Control of dew point is by adding low-pressure steam as required to the air stream before it enters the chamber. The dew point of the air in the chamber is sensed by a Dew Probe sensor near the exhaust outlet. A Thermistor sensor in the probe cavity senses the cavity temperature. A solid-state time-proportioning temperature controller (Honeywell R7113A) controls at 25-sec intervals (intervals are adjustable) by opening a solenoid valve admitting steam to a nozzle in the air duct. The system thus admits pulses of steam of varying duration to maintain the temperature of the Dew Probe cavity constant. With frequent pulses the dew point of the comparatively large chamber is maintained essentially constant, although there must be some cyclic effect. A diagram of the dew-point control system is shown in Figure 6.

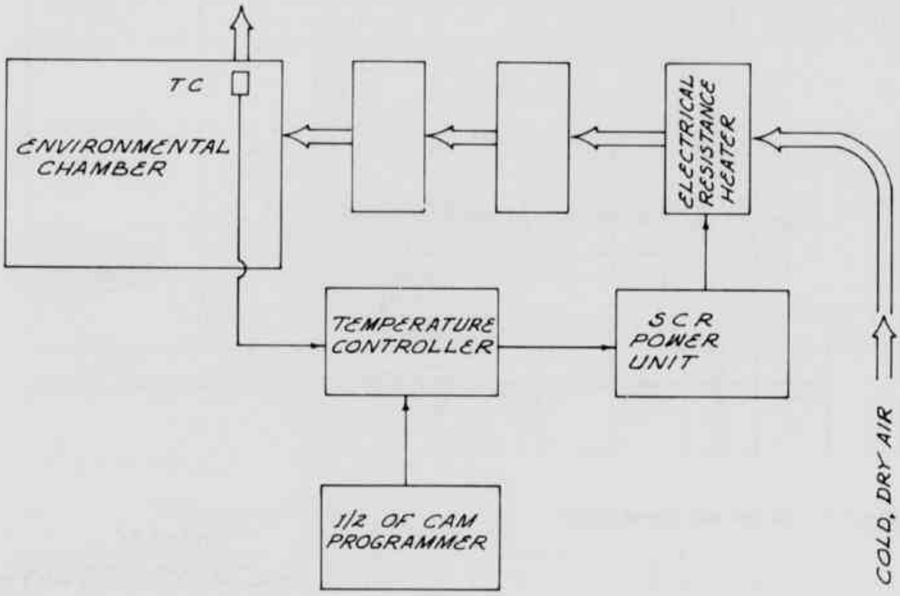

Figure 5. Temperature control system.

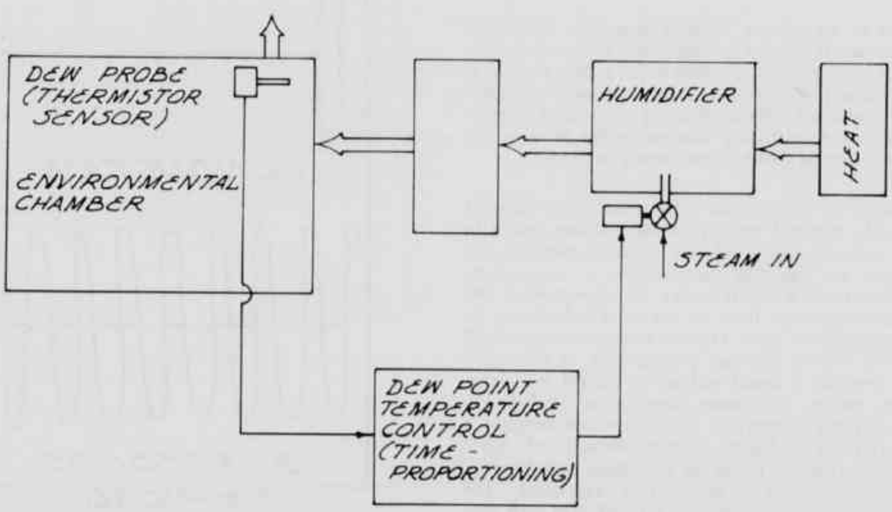

Figure 6. Dew point control system.

PERFORMANCE

Experience in raising the first flock of broilers in the chambers indicated that the control systems will nearly attain design performance. The temperature-control system performed very successfully but some failures occurred in electronic components, which necessitated careful supervision and occasional repair. The air-flow control system required no maintenance. Adjustments to the dew-point control system were needed to increase sensitivity and to eliminate condensation within the ducts. Some shakedown problems developed in the refrigeration equipment but have been corrected satisfactorily.

The time-proportioning action of the Honeywell Burst-Fire regulator gave exceptionally good temperature control.

Major problems developed with the water systems, mainly because of the need for continuous flow to maintain the drinking water at the desired temperature. Litter would get into the system and stop up the waste-water lines. Some problems also occurred with the temperature-control units. Redesign of the water systems and replacement of the mechanical controls with electronic controls has reduced these problems but has not eliminated them entirely.

The first year of operation was spent in investigating the response of broiler chickens to various brooding temperature regimes and drinking water temperatures. Different initial brooding temperatures, different rates of temperature decline with age, and different water temperatures were investigated. Analysis of results is incomplete, but indicates that growth and feed conversion are best with initial brooding temperature of 89 F (32 C), and that cooling the drinking water can help the chicken to adapt to higher ambient temperatures.