trolled device from one controller to another, or to reverse the action of a controlled device in response to an impulse from a controller.

4. An *averaging relay* is affected by the forces from two or more controllers, and the resulting flow of energy is in accordance with the average of these forces.

5. A *positioning relay* has a direct connection to a valve or damper motor lever and is affected by both valve or damper position and controller demand. It is repositioned by a thermostat or other controlling device, and is arranged to give a definite motor position for a given force from the thermostat without regard for motor hysteresis, friction, or pressure variations of the controlled fluid.

6. An *electronic amplifier* is used only in *electronic control* circuits to amplify the micro-currents of electronic controllers to usable voltages required by standard electric actuating devices. They may be either two-position or proportioning relays.

A *sequence controller* is used to operate two or more devices in a prearranged sequence. It is generally used in connection with refrigeration compressors, and may be arranged to prevent simultaneous starting in the event of temporary electrical shutdown or control medium failure.

Manual switches are available in the two-position or proportional types. *Two-position switches* change the flow of energy from one line to one or more other lines; or from one pair of lines to another pair of lines. *Proportioning switches* vary the flow of energy as determined by the manual setting of the switch.

RESIDENTIAL CONTROL SYSTEMS

The control equipment function in a residence may vary from the regulation of a coal-fired heating plant to the completely automatic control of an all-year air conditioning system. Regardless of the type of heating or air conditioning system used, the control system should be selected carefully to insure safety and comfort of the occupants, and also economy of operation.

Heating Unit Controls

Typical controls for the appliances used to supply heat in residences are as follows:

1. *Hand Fired Coal Burners.* The control of a hand fired coal burner for a boiler or furnace normally consists of a room thermostat operating a two-position electric control motor, which in turn opens the draft damper and closes the check damper on a demand for heat. The motor then closes the draft damper and opens the check damper when the thermostat is satisfied. A limit control on the boiler or furnace should be connected to the motor so that it may check the fire whenever a predetermined temperature or pressure has been exceeded. A manually operated basement switch is usually included on the motor so that the draft may be opened and the check closed when the boiler or furnace is being filled with coal.

2. *Coal Fired Stokers.* Domestic stokers are usually controlled by a room thermostat, a limit control, and a stoker relay. When the thermostat calls for heat, the relay causes the stoker motor to increase the flow of fuel and air to the burner to its maximum rate. When the thermostat is satisfied, the relay provides for a minimum flow of fuel and air to the burner to maintain the fire at its minimum rate. The limit control prevents the continuance of the maximum fuel rate if the temperature or pressure in the boiler or furnace exceeds a predetermined value, and also stops the feeding of fuel if the fire goes out. Automatic ignition usually is not available and the firing of a stoker is normally on or off.

3. *Automatic Oil Burners.* Automatic oil burner controls normally consist of a room thermostat, a limit control, a combustion safety control, and a control relay. On a call for heat by the thermostat, the relay starts the oil burner motor which supplies oil and air to the burner. An ignition device consisting of an electric spark or a gas flame ignites the oil automatically. If for any reason the oil and gas mixture does not ignite, a time delay mechanism in the relay is operated by the combustion safety control after a predetermined length of time to cause the oil and air

supply to be shut off. If the oil and air mixture ignites properly the buerner continues to run until the thermostat is satisfied, or until the limit control affected by the temperature or pressure in the boiler or furnace stops the burner.

4. *Automatic Gas Burners.* The controls for an automatic gas burner usually include a room thermostat, a limit control, a safety pilot, gas pressure regulator and a gas valve (solenoid, motorized or diaphragm type). Upon a demand for heat at the thermostat, the gas valve is opened, admitting gas to the burner. The safety pilot ignites the gas which continues to burn until the thermostat is satisfied, or until the limit control shuts off the gas valve. The limit control may also reduce (throttle) the gas flame as required to maintain a desired temperature or pressure of the heating medium. If the pilot flame is extinguished for any reason, either before or after the main gas valve is turned on, the safety pilot closes the gas valve, thus eliminating the danger of delivering gas to the burner without ignition.

5. *Electric Heating.* Electric heating has become popular in those areas where electric power is plentiful and inexpensive. The electric heating elements may be located in each individual room and turned on and off by thermostats in each room, or the heat may be supplied by a central heating system. In the case of a central heating system, the control is usually of the proportioning type which energizes from five to ten heating elements in sequence, according to the demand for heat, by means of a sequence controller consisting of a series of switches operated by a proportioning motor. A limit switch recycles the sequence controller if the furnace or boiler exceeds a predetermined temperature.

Limit Controls

A *high limit* control for steam consists of a pressure control, having bellows responsive to the boiler pressure, which breaks an electric contact when the steam pressure exceeds a predetermined point, thereby preventing the burner from delivering additional heat to the boiler. A low water cut-off should also be used to stop the burner if the water in the boiler drops to a dangerous level.

A high limit control for a hot water boiler consists of an immersion thermostat (usually equipped with a bi-metal helix) inserted in a well in the boiler. This control stops the burner when a predetermined water temperature has been reached in the boiler.

In a warm air system the high limit control is a thermostat including a bi-metal helix inserted in the bonnet of the furnace. It will shut off the source of heat when a predetermined furnace temperature is exceeded.

Room Thermostats

Room thermostats are of three types, depending on the temperature sensitive element which they employ. These are: (1) the bi-metallic type which distorts with temperature changes; (2) the vapor filled bellows type which expands or contracts with temperature changes; and (3) the electronic type which employs resistance wires and microcurrents which vary with temperature or humidity changes. The first two types employ either electric currents or compressed air to amplify their effect. In the electronic type the micro-currents are amplified by means of electronic amplifier relays. The amplified effect in each instance is used to actuate valves, damper motors, stokers, oil burners, gas burners, etc. Room thermostats may be of the plain or single temperature type, or of the day-night type providing for automatic night lowering and morning increase of the control point. The automatic setback type usually includes a clock mechanism which accomplishes this result. Opinions vary regarding the amount of fuel that can be saved by automatic setback. Tests made both in the Warm-Air Heating Research Residence and the I = B = R Research Home at the University of Illinois indicate that, on thermostatically controlled systems, a possible fuel saving of from 7 to 10 percent may be obtained by