3. *Pneumatic-electric relays*, which are actuated by air pressure and make or break an electrical circuit.

4. *Pneumatic relays*, which are actuated by the pressure from a controller and perform numerous functions. They may be divided into two groups:

a. *Two-position relays*, which permit a controller actuating a proportional device to also actuate one or more two-position devices. They also are used in various automatic switching operations.

b. *Proportional relays*, which are used to reverse the action of a proportional controller, select the higher or lower of two pressures, average two or more pressures, respond to the difference between two pressures, add or subtract pressures, amplify or retard pressure changes, and perform other similar functions.

5. *Positioning relays*, which are devices for assuring accurate positioning of a valve or damper operator in response to changes in pressure from a controller. They are affected by the position of the operator and the pressure from the controller, and whenever the two are out of balance will change the pressure applied to the operator until balance is restored.

6. *Switching relays*, which are pneumatically operated air valves for diverting air from one circuit to another or for opening and closing air circuits.

7. *Pneumatic switches*, which are manually operated devices for diverting air from one circuit to another or for opening and closing air circuits. They may be of two-position or multiple-position type.

8. *Gradual switches*, which are proportional devices for manually varying the air pressure in a circuit.

Auxiliary control devices common to both electric and pneumatic systems include:

1. *Sequence controllers* for operating a number of electric switches in sequence by means of a proportional electric or pneumatic operator. They are commonly used for controlling a number of steps of refrigeration capacity and may be arranged to prevent simultaneous starting of compressors and to alternate the sequence to equalize wear. They may also be used for sequence operation of electric heaters and other equipment in response to the demands of a proportional controller.

2. *Clocks or timers* for turning apparatus on and off at predetermined times, for switching control systems from day to night operation, and for other time sequence functions.

PART II—CONTROL APPLICATIONS

Applications of controls to systems or apparatus of a general nature will be found in this chapter. Applications pertaining to specific systems or apparatus will be found in the chapters covering those subjects.

CONTROLS FOR AUTOMATIC FUEL BURNING EQUIPMENT

Controls for the automatic fuel burning equipment described in Chapter 15 are outlined here. The basic requirements for oil burners, gas burners and coal burners (stokers) are included and the term *burner* refers to all three types of fuel burning equipment. Controls for these burners can be classified as *operating controls*, *limit controls* and *primary controls*. The schematic diagrams shown in Fig. 6 indicate the relationships of the basic components. The *power supply* may be line voltage for each type of burner. In control systems for domestic burners the line voltage may be stepped down by means of a transformer for those portions of the circuits indicated by dotted lines. Such transformers are usually built into the stoker and oil burner *primary controls*. Control systems for domestic gas burners frequently use a separate transformer as shown. There are domestic gas burner control systems which obtain their electrical power supply from the conversion of heat to low voltage electrical energy, in which case no transformer would be required. As the burner sizes increase, the tendency to use all line voltage controls increases in each of these general categories.

Operating Controls

Operating controls initiate the starting and stopping of the burner and on larger burners they usually vary the fuel and air input to the combustion chamber in response to varying load demands. For residential and small commercial heating plants with fuel inputs up to approximately 500,000 Btu per hour, the *operating controller* is usually some form of room thermostat which automatically starts and stops the burner through the *primary control* as the *limit controls* permit. As the size of the heating system increases, the use of a room thermostat as the *operating controller* for the burner becomes less common. An insertion thermostat (for furnaces), immersion thermostat (for hot water boilers) or pressure controller (for steam boilers) may be applied as an *operating controller*. Also, such

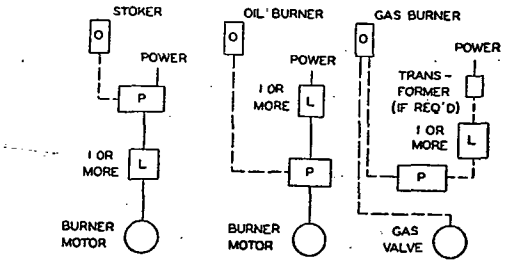

FIG. 6. SCHEMATIC DIAGRAMS OF SOME TYPICAL BURNER CONTROL SYSTEMS (O = Operating Control; P = Primary Control; L = Limit Control)

devices as submaster and compensated controllers (which are reset from outdoor temperature for governing the bonnet temperature in large furnaces or the water temperature in a boiler) come into more frequent use on the larger installations. The still larger burners are usually equipped to vary the rate of fuel and air input in response to varying load demands.

Limit Controls

Limit controls guard against unsafe temperature, pressure or water level to assure that safe conditions prevail for the operation of the burner. Draft controls protect the firebox against excessive drafts, regardless of the type of fuel being burned, to increase combustion efficiencies and reduce stack losses. For fuel input requirements above approximately 1,000,000 Btu per hour some additional factors become common to all types of burners. For example, the draft in the firebox is controlled at a suitable constant for all firing rates, including the *off* period, by measuring the draft conditions in the firebox and actuating a *damper operator* to position the damper at the boiler outlet. Where necessary, provision may be made to open the boiler outlet damper wide before permitting the burner to start and then return this damper to automatic control after the burner has been started. Also, the firing rate of these larger burners is frequently automatically adjustable and provisions are made for always starting the burner on its low firing rate, with facilities for increasing the firing rate slowly after the burner has been started. It is not recommended and codes seldom permit the use of one and the same instrument as both an *operating controller* and a *high limit control*. In such cases an *operating controller* will be adjusted to control at the desired set point while the *high limit*