the instrument. Instruments of this type are available either with a rigid bulb or with a flexible tubing which connects the control bulb to the head of the instrument. This tubing is usually protected by a flexible metal covering or armor and is available in varying lengths.

Electrically Operated Equipment

Electrically operated equipment for either two position control or throttling control is available in either low voltage or high voltage type. Low voltage equipment usually is designed to operate on 20 to 24 volt current. High voltage equipment may be used in connection with any of the standard voltages. The individual units of this type of system are interconnected by wiring circuits which carry the commands of the controller to the motors operating the controlled valves or dampers and to stop and start electric motors driving the controlled equipment. Simple make and break electric thermostats are used to stop and start motors and for two-position control of valves and dampers. Modulating electric control may be accomplished by the unbalancing of some form of Wheatstone bridge which in turn causes the repositioning of a motor element which moves the valve or damper. In some controllers the impulse from more than one Wheatstone bridge can be integrated in one motor element.

Controllers for modulating electric control vary from the contact type in that the electrical mechanism consists of a variable potentiometer. The potentiometer includes a contact finger which moves across a coil of resistance wire wrapped on a suitable bobbin. The contact finger is actuated by a temperature, pressure, or humidity sensitive element.

When the same amount of current is flowing through both coils of a balancing relay the contact blade will be in the center of the space between the two contacts and the motor will be at rest.

Changes in the conditions at the controller will affect the circuit so that the amount of current flowing through the two relay coils will not be identical. Whenever the current through these two coils becomes unbalanced, one of them will become stronger and the *U* shaped armature will be tilted. The movement of the armature will close one of the relay contacts which in turn will start the motor running either clockwise or counter-clockwise, until the circuit is again balanced by the resulting movement of the motor balancing potentiometer, whereupon the relay contact will break and the motor will stop.

The development of specialized industrial control equipment using *electronic* principles has made rapid progress during recent years. Temperatures may be measured and controlled to fractions of a degree by new applications of the photo-electric cell. Its accuracy and flexibility make it applicable to a variety of automatic devices and controllers.

Pneumatically Operated Equipment

In *pneumatically operated equipment* the primary source of power is compressed air at a pressure of 15 to 25 lb per square inch which should be clean, dry and free from oil vapor. It is desirable to compress the air to a pressure of 70 lb per square inch or more to provide for a precipitation of moisture due to temperature drop in the high pressure receiver in order to reduce the dew-point of the air to the controllers below that of the lowest ambient temperature of the air lines.

The compressed air piping from the source of supply to the inlet side of the controller is known as the *main*. The connections from the outlet of the controller to the pneumatic motors, are known as *branches*.

Throttling type controllers, of the pneumatic type, are basically air pressure regulating valves actuated by the controlled condition to vary the *branch line pressure* and thereby reposition the controlled valves or dampers as required to maintain the desired condition of the controlled media. A direct acting controller increases its branch pressure on an increase of the controlled condition. A reverse acting controller increases its branch pressure on a decrease of the controlled condition. Several different devices may be operated from the branch line of a single controller in selected sequence by the proper spring loading of the respective pneumatic diaphragm motors. Small air pressure gages connected into the branch at each controller will indicate the controller action and are of great convenience to the operator in adjusting the system.

The simplest form of pneumatic thermostat is based on the leak stat principle which consists of a restrictor in the air supply to the instrument, a leak port having a larger port than the restrictor and a bi-metallic strip or diaphragm chamber which expands on a rising temperature and contracts on a falling temperature. This power is used to reposition the lid seat to close or open the leak port. As the leak port is gradually closed the pressure in the *branch* increases until it approaches the full *main* pressure in the fully closed position. As the lid seat moves away from the leak port the pressure in the *branch* decreases until the *branch* is fully exhausted when the lid seat restriction of the leak port is entirely removed. The basic leak stat principle of operation has been refined by the addition of supplemental relays in nearly all current types.

TYPES AND FUNCTIONS OF CONTROLLERS

Descriptions or functions of various types of controllers follow.

A *single-duty room thermostat* controls the heating or cooling devices to maintain the desired temperature.

A *dual or two-temperature room thermostat* controls the respective heat sources to maintain alternately two selected temperatures. They may be indexed manually or by time switch from central points in selected zones.

A *high-low room thermostat* is similar to the dual thermostat, except that it is indexed individually by the manual operation of a push button or switching device built into the individual instrument.

A *sub-master or remote readjustable room thermostat* is a pneumatic room type instrument fitted with a readjusting diaphragm to which a separate pilot air line connection is made. As the pressure in the pilot line is raised from 1 lb to 13 lb, or as selected, the operating point of the controller may be increased or decreased within predetermined limits. Indexing may be done by a manual gradual switch or master thermostat.

A *pneumatic master or pilot thermostat* varies the pilot pressure to the readjusting diaphragm of one or more sub-master thermostats to vary their operating point in accordance with a predetermined change in the temperature sensed by the master thermostat.

A *summer-winter room thermostat* operates at any selected temperature as a direct acting controller during the heating season and operates at the same or any other selected temperature as a reverse acting controller during the cooling season. Groups of these instruments may be indexed from a central point or individually indexed by a manual push button or a switching lever built into each instrument. They may be used to control volume dampers of a summer-winter air conditioning system to maintain a desired temperature condition in the controlled space, and will operate to close normally open dampers on a rising temperature during the heating season and to open same on a rising temperature during the cooling season.