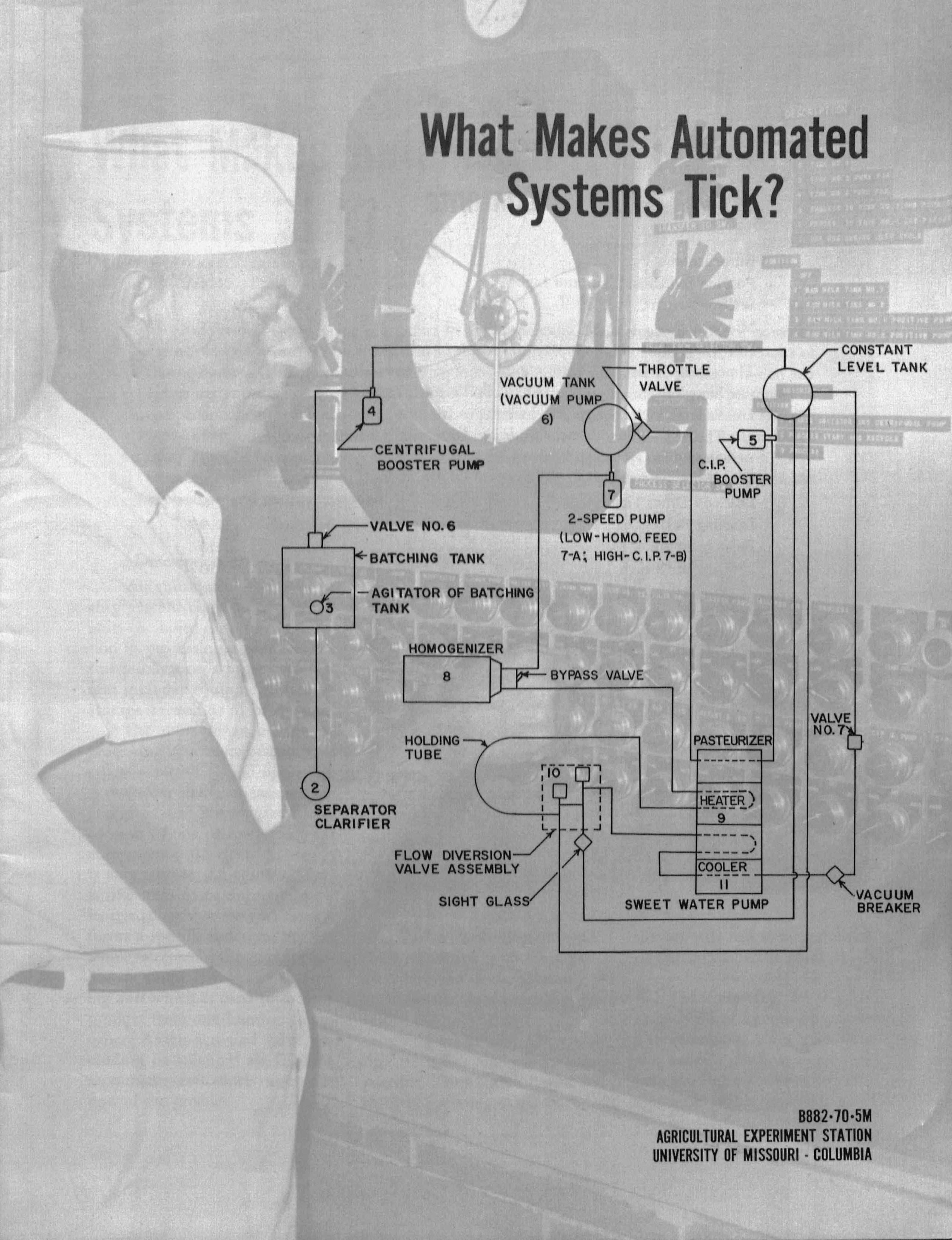
What Makes Automated Systems Tick?



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Contents

What Makes Automated Systems Tick?

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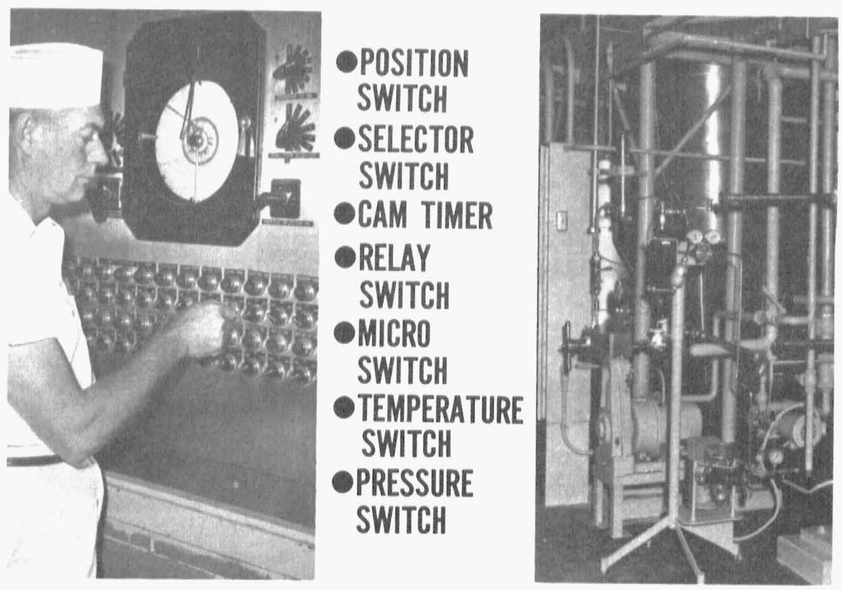
Automation is producing economies in food processing. Management personnel, however, are not always aware of the types of equipment available for automation or the functions of this equipment. Usually engineers of equipment supply firms are available for consultation and aid in designing automated systems. But a basic understanding by management personnel of components and their functions is essential to planning and to operation of automated systems.

This publication contains basic information about essential equipment for automation of many types of food processing lines. The illustrations of components of the automated equipment are typical and serve to show principles of operation. Design may differ depending on the application and the manufacturer.

Description of Units

An automated food processing system consists of various units combined for a specific function in processing a product. For this publication a processing system includes equipment used in storage as well as in processing.

The units in an automated processing system are of two basic types—controlling and operating. A *controlling unit* energizes and de-energizes an *operating unit* and consists of one or more electrical components. An electrical switch is an example. An *operating unit* is one item of equipment (with its related components) which performs a specific function. For example, a centrifugal pump, including its motor starter, is an *operating unit* which is used to move a product from one location to another. An air-actuated valve, including its solenoid air valve, is an *operating unit* which directs the flow of the product.



Various operating units and their respective controlling units are combined in the assembly of an automated food processing system.

The availability of controlling units has made automation possible. They both monitor and regulate operating units, functions that formerly had to be performed by personnel of the plant.

The following are typical components of a controlling unit: a three position switch (hereinafter called a position switch), an indicator light, a selector switch, a pressure switch, and a relay.

Position Switch and Indicator Light

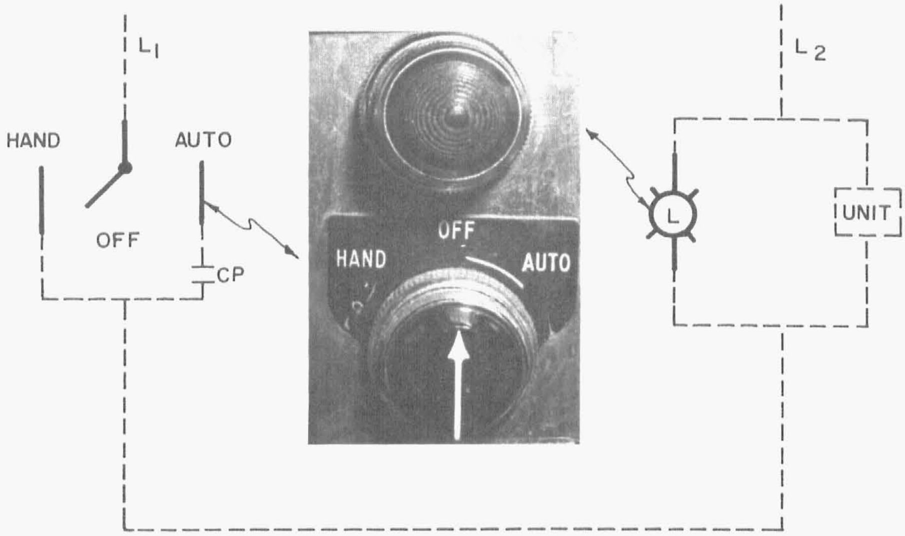


Figure 1. Position Switch and Indicator Light.

A position switch (Fig. 1) is used to energize one or more units. The "hand" setting is used for manual control; whereas, the "automatic" setting transfers control of the operating unit (referred to as Unit in figures) to another controlling unit; for example, a relay. The terms "hand" and "on" are used interchangeably. Here, as in other such figures, L_1 and L_2 refer to lead wires which carry current through the circuit. C P in Fig. 1 represents contactor points within a controlling unit, such as a microswitch on a cam timer or a relay. The operating unit is energized when these contactor points are closed if the position switch is set to "automatic."

An indicator light is used to show when a unit is energized. Fig. 1 shows an indicator light (L) mounted on the control panel with a position swich. The indicator light comes on each time the operating unit (example: a positive pump) is energized, either by the position switch in the "hand" position or by another *controlling unit* when the position switch is in the "automatic" setting.

Selector Switch

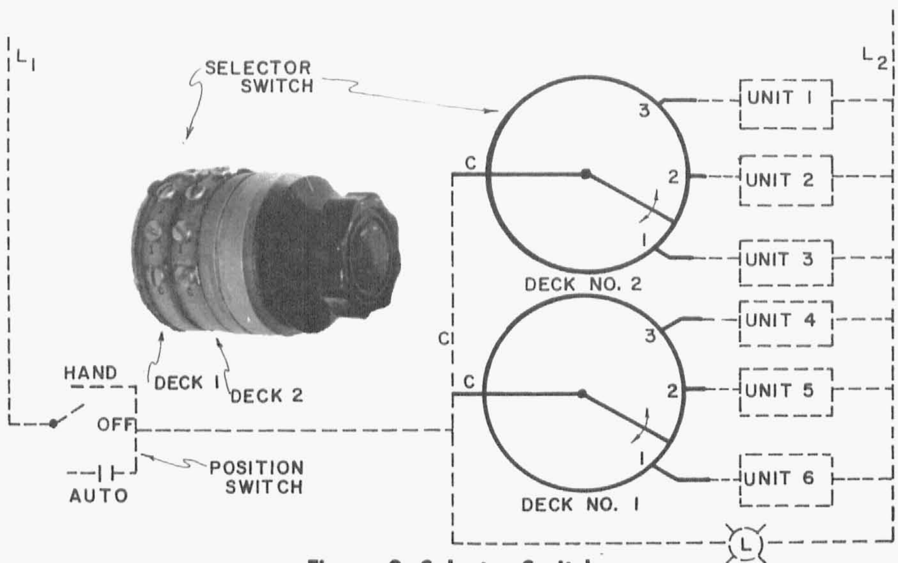


Figure 2. Selector Switch.

A selector switch (Fig. 2), also called a multi-deck rotary switch, is used to select specific operations to be performed simultaneously by various units. It consists of one or more decks which contain a common point (C: a connector for the power supply) and several terminal connectors (1, 2, and 3 on decks).

Common points of all decks may be connected to the same or separate power sources. Each deck contains several terminal connectors or points to which power may flow from the common source. When the selector switch is placed in the No. 1 seting, moving the position switch to the "hand" setting will energize *operating units* Nos. 3 and 6. Placing the selector switch in the No. 2 setting will allow current to flow to units 2 and 5. By placing the position switch in the "automatic" setting, the respective units are energized automatically.

Microswitch

A microswitch, usually a part of an electrical device such as a cam timer, is a mechanically operated switch which is used in a control unit to automatically control an operating unit. When a position switch is placed in the "Automatic" setting as shown in Figure 3, the microswitch energizes and deenergizes the operating unit. Different uses of microswitches will be explained in relation to the different electrical devices used in a control unit.

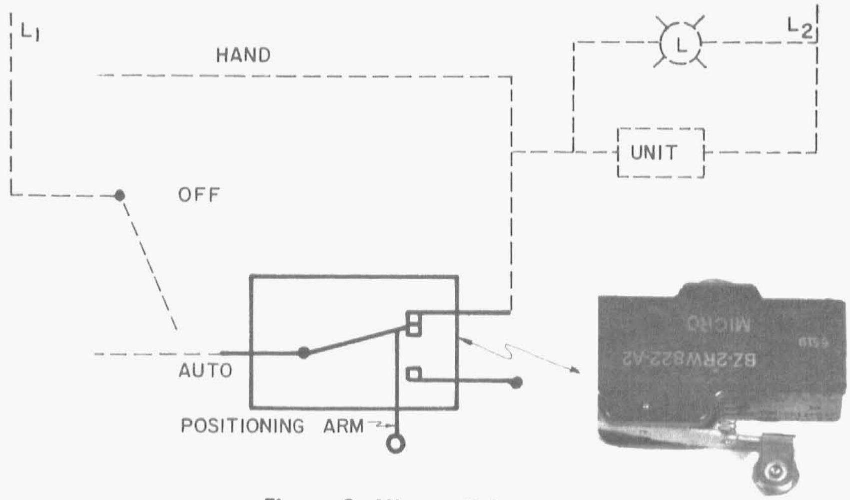


Figure 3. Microswitch.

Relay

Relays are used in control circuits to energize *operating units,* and other *controlling units,* and to prevent feedback. Industrial and plug-in relays are the most common types used in *controlling units.* The industrial type relay (Fig. 4) is used when more than three contactor points are needed; the plug-in type (Fig. 5) is used when three or less are needed.

A relay consists of a coil, a plunger with a position arm and spring, one or more contactor points and a housing. When the coil is energized, the plunger moves, opening or closing the contactor points. As a result, normally open (N O) contactor points close. Normally closed (N C) and normally open contactor points often can be manually changed from NO to NC.

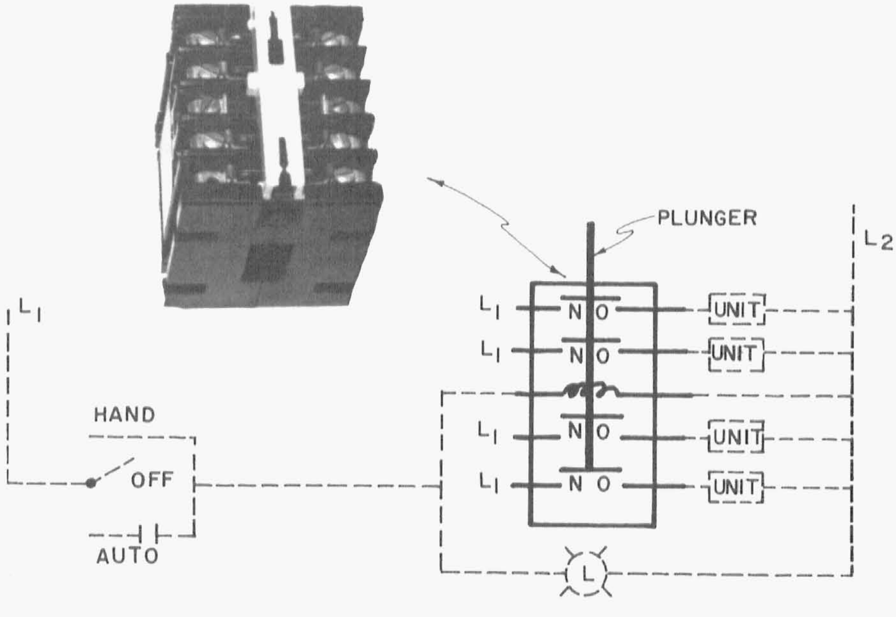


Figure 4. Relay, Industrial Type.

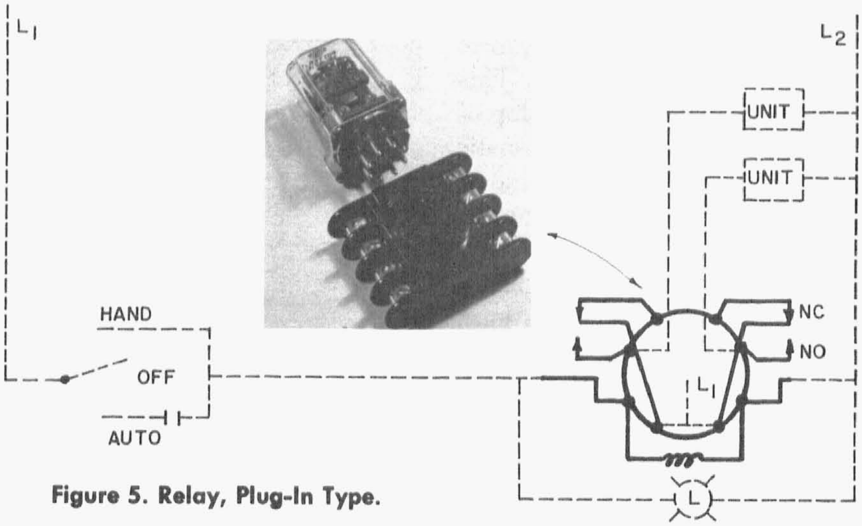


Figure 5. Relay, Plug-In Type.

Time Delay Relay

A time delay relay is used to delay the opening or closing of a set(s) of contactor points in a controlling unit for a predetermined period of time; for example, a centrifugal pump may be delayed in starting to first permit a series of valves to open. There are four types: electrical, pneumatic, thermal, and electronic.

Electrical

The *electrical type* (Fig. 6) consists of an electric motor, a shaft with a slip clutch and a microswitch. When the circuit is energized (by closing the position switch at left), the motor turns the shaft, causing the movable arm to rotate until it trips the microswitch. The delay in time is determined by the length of the arc that the movable arm must travel. The motor continues to operate causing the shaft to slip in the slip clutch. When the circuit is de-energized, the cam is reset to its original position by spring action.

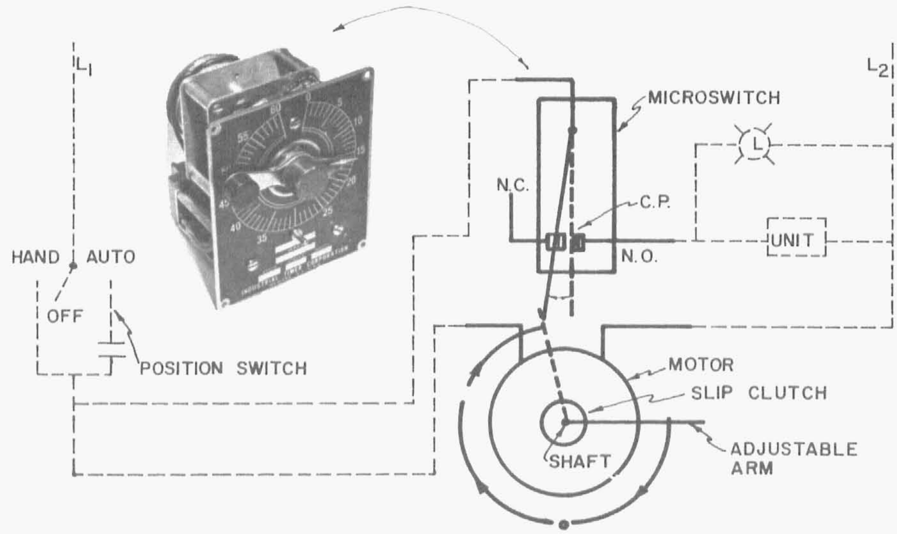


Figure 6. Time Delay, Relay-Electrical Type.

Pneumatic

The *pneumatic type* (Fig. 7) consists of an electric coil, a plunger attached to a set of contactor points and a pneumatic cylinder. When the coil is energized, force is applied to the plunger. This force is opposed by a buildup of air pressure in the pneumatic cylinder which retards the movement of the plunger, causing the delay in time.

The air is gradually released from the cylinder through a small orifice restricted by a needle valve. The delay is varied by turning the needle valve to vary the size of the restrictive orifice. The circuit is energized or de-energized by the opening or closing of the contactor points. When the circuit is de-energized, the contactor points are opened by a spring, forcing the cylinder back to the initial position.

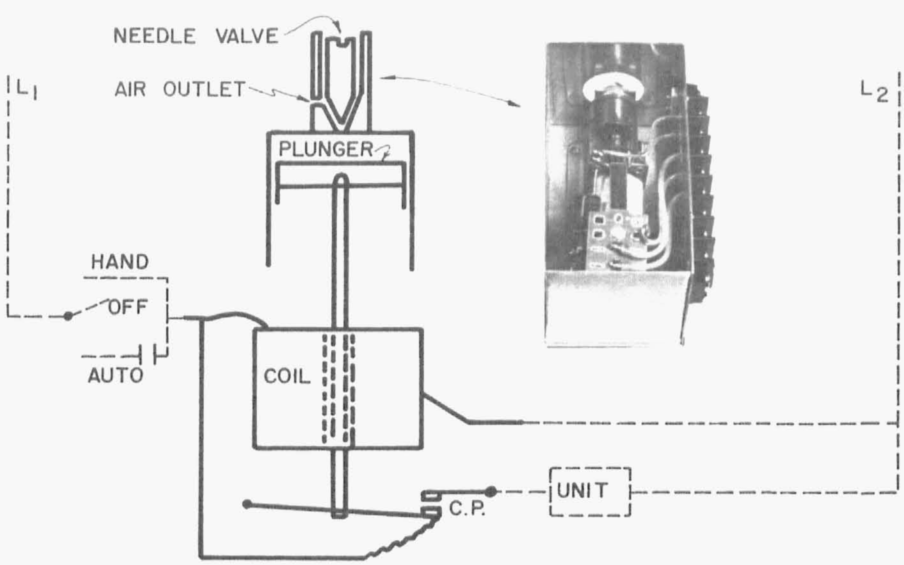


Figure 7. Time Delay, Relay-Pneumatic Type.

Thermal

A *thermal type* time delay relay (Fig. 8) consists of a bimetal strip, a coil, and contactor points. When the relay is energized, the coil heats the bimetal strip causing it to bend, thus making or breaking the electrical circuit. The recycle time for a thermal-time-delay relay is longer than that for other types of relays because the bimetal strip must cool off before reuse.

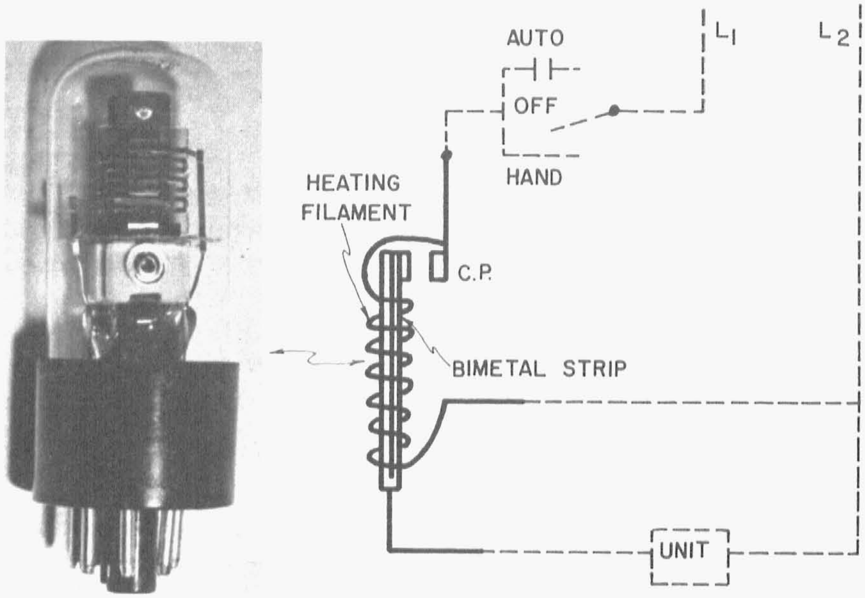


Figure 8. Time Delay, Relay-Thermal Type.

Electronic

The *electronic* time delay relay (Fig. 9) consists of a coil, contactor points (CP), a transistor (or a vacuum tube), a capacitor (C) and several resistors. Current flows from L_1 to L_2 through the unit when the contactor points are closed due to the energizing of the coil in the solid state timing circuit.

Voltage in the timing circuit is supplied from E_2 for energizing the coil. However, current flows through the coil, transistor, and R_2 only after the transistor has been actuated by voltage from E_1. The transistor functions as a triggering device in that it will allow current to flow from E_2 to ground only when sufficient voltage is supplied to the transistor from E_1.

Time of the delay is controlled by varying the resistance at R_1 (a variable resistor or potentiometer). The capacitor, C, stores voltage supplied through E_1 until it is sufficient to actuate the transistor. Resistors R_2 and R_3 balance the circuit.

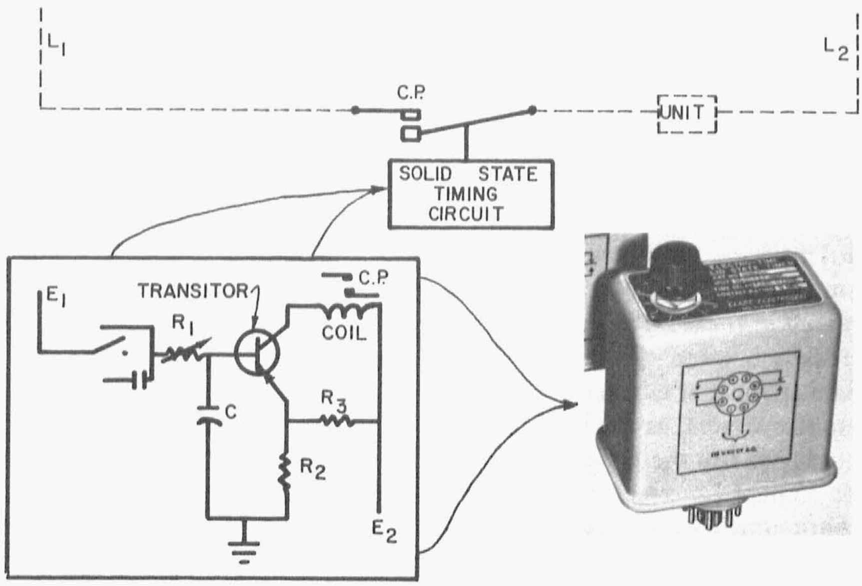


Figure 9. Time Delay, Relay-Electronic Type.

Cam Timer

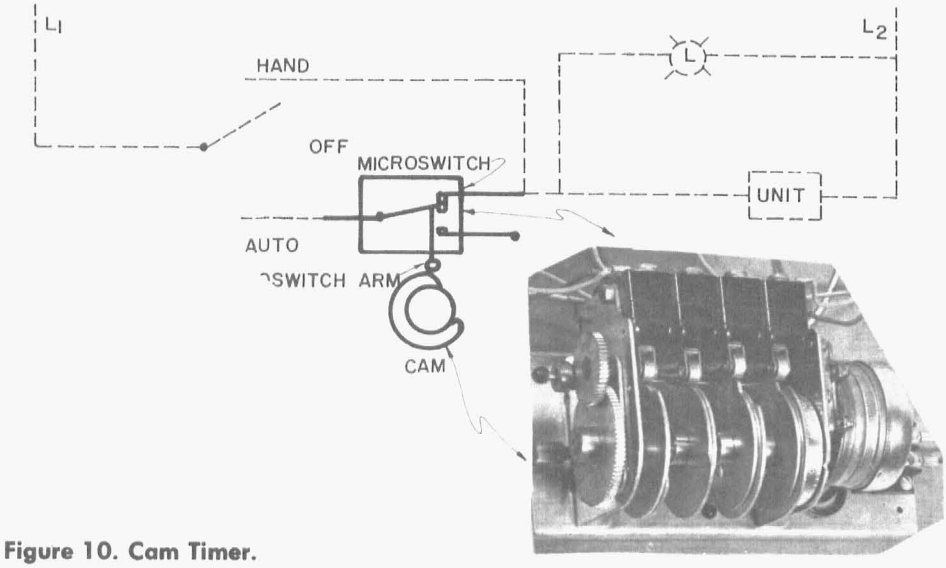


Figure 10. Cam Timer.

A cam timer is used in a *controlling unit* to make or break, for a specific time, an electrical circuit to a series of other units. It consists of a series of cams rotated by an electric motor (Fig. 10) and microswitches. The duration of time each microswitch is energized (hence the time during which a unit operates) is changed by varying the length of the raised portion of the respective cams. As a cam turns, it positions the microswitch arm to open or close the contactor points to the control relay. Because each cam controls the on-off status of one unit, the number of cams must be at least as great as the number of units being controlled. The length of a cycle is determined by the speed of the motor and the size ratio of the gears.

Disc and Drum Timers

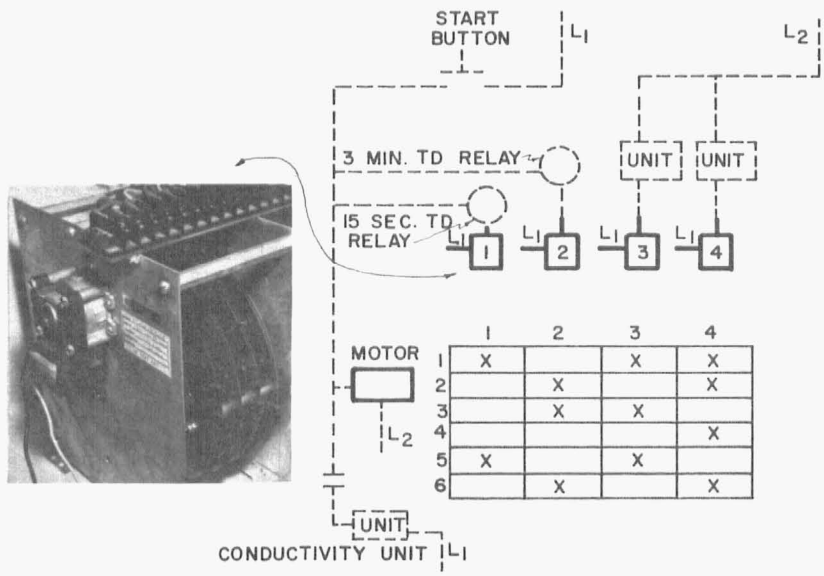


Figure 11. Disc Timer.

Disc and drum timers are similar to cam timers. The cylindrical part of a drum timer contains holes arranged in rows and columns. Metal or plastic plugs are placed in these holes to trip a microswitch when the plug passes. Similarly, metal tabs can be placed on disc timers, as shown in Figure 11, to trip the microswitch.

These timers may be moved continuously by an electric motor or stepwise with a solenoid type motor: each time the solenoid is energized the drum or disc moves one step. An electric motor is usually used when the sequencing of operations is based on duration of time.

A solenoid is used to rotate the drum when the sequencing of operations is dependent on time, as in operating a pump for 2 minutes. It is also used when the sequencing is independent of time for such operations as the filling of a tank when fill rate varies with time. In such cases the timer would remain stationary from the time the tank starts to fill until it is filled.

In Fig. 11 the X's represent plugs or tabs on the timer. The control performed by this particular unit would be as follows. To start the series, depress the start button. This energizes the motor and the drum moves to the first step so that the tabs in columns 1, 3, and 4 trip microswitches 1, 3, and 4. This starts the 15 second time delay relay, 1, and puts units controlled by microswitches 3 and 4 in operation.

After 15 seconds, the motor is energized through the time delay relay microswitch 1 and rotates the discs to the second step in which microswitches 2 and 4 are engaged. The operation started in unit 4 will continue for 3 minutes because the 3 minute time delay relay was activated by microswitch 2.

The timer is then moved to step 3, and microswitches 2 and 3 are energized. After 3 minutes, the timer is moved to step 4. To move to step 5 the conductivity unit must energize the motor. For example, this would happen when the water level in a CIP (cleaned-in-place) solution tank reached the highest electrode, thus completing a circuit. Steps 5 and 6 are similar to steps 1 and 2.

Two common accessories used on a disc or drum timer are terminal strips and time delay relays. Terminal strips permit easy connection of control wires for the various units. A time delay relay is used to control the energizing of the solenoid motor when the duration of a step is to be based on time.

Latching Relay

The latching relay in Fig. 12 consists of two coils, with plungers, contactor points and a latching device. Contactor points are opened or closed by energizing the respective coil. After the coil is de-energized, contactor points are held in position by a latching device. For example, if a controller of a liquid level sensing unit indicates that a storage tank is empty, coil 1 will be energized, causing the pump (which was pumping from the tank) to stop and the alarm to ring. The latching device will prevent the pump from being started until coil 2 is energized by the closing of its switch.

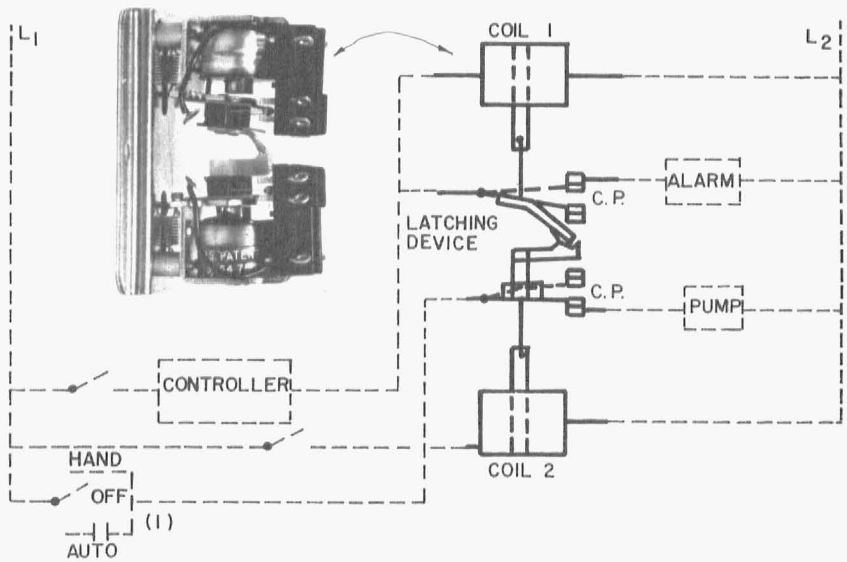


Figure 12. Latching Relay.

The energizing of coil 2 causes the contactor points in the latching relay to close, thus permitting the pump to be started from its position switch (1).

The latching relay may be used as a safety device to protect a *controlling* or *operating* unit.

Pressure Switch

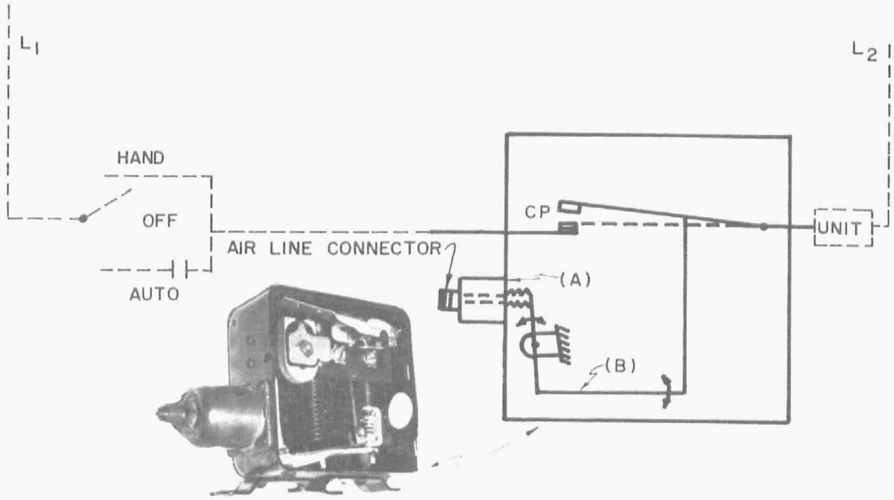


Figure 13. Pressure Switch.

Pressure on a processing line is monitored by a pressure switch. Pressure switches are used to detect:

(1) when pressure drops below a preset level,

(2) when pressure rises above a preset level, or

(3) an unacceptable pressure differential between two fluids or surfaces.

The air contact surface (A) of the pressure switch moves when pressure is applied to it (Fig. 13). The contact surface is attached to an arm (B), which opens or closes contactor points (CP) on the switch. The opening or closing of the contactor points causes a unit to be energized or de-energized.

Temperature Switch

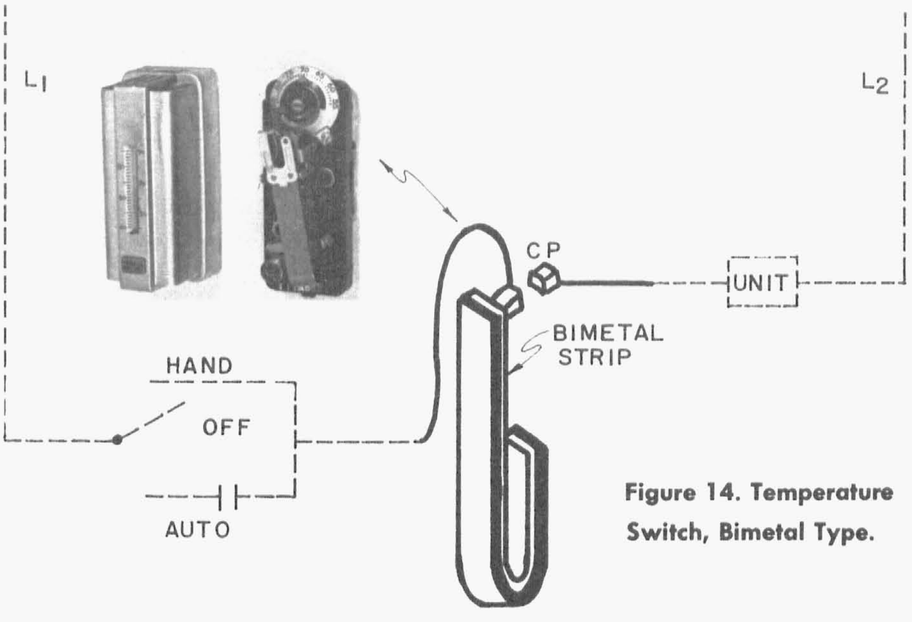


Figure 14. Temperature Switch, Bimetal Type.

A temperature switch is used in a controlling unit to monitor the temperature of a product during processing. It consists of a sensor unit and a controller. The sensor is usually located in the medium which is to be monitored. Changes in temperature in the medium, as monitored by the sensor, are transmitted to a controller. The controller in turn may energize or de-energize a unit and/or move a needle on a recorder indicating a change in temperature.

Temperature sensors are of three general types: bimetal, fluid (gas or liquid), and electrical.

Bimetal Sensor

The *bimetal sensor* is constructed of two metals which expand or contract at different rates when subjected to a temperature change. Attached to the metal strips are contactor points which open or close as the strips expand or contract. For example, the contactor points (Fig. 14) close, causing a heating unit to start when the temperature drops below a preset level. The example pictured is a household thermostat.

Fluid Sensor

The *fluid temperature sensor* (Fig. 15) operates with a sensor fluid that expands when heated and contracts when cooled. When the sensor is heated by the surrounding medium, the fluid expands. The expanding fluid forces the coiled tube to move against the microswitch position arm, causing the contactor points to open (or close).

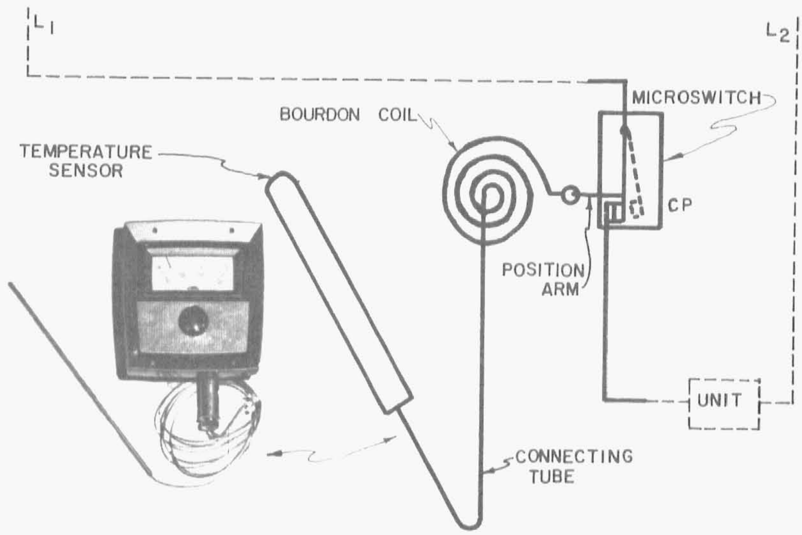


Figure 15. Temperature Switch, Fluid Type.

Electrical Sensor

The *electrical temperature sensor* may contain either a thermistor or a thermocouple. The thermistor contains a material (the bead) which decreases in resistance with an increase in temperature. A change in resistance causes a change in voltage transmitted. The controller detects this change and makes a response such as opening or closing contactor points and thus energizing a unit (Fig. 16).

The thermocouple (Fig. 17), which contains two dissimilar metals, generates a current depending on the temperature of the medium, as compared to a reference temperature. The controller detects this change in the current and in turn energizes the unit. The reference temperature is usually that of an ice bath (32°F.).

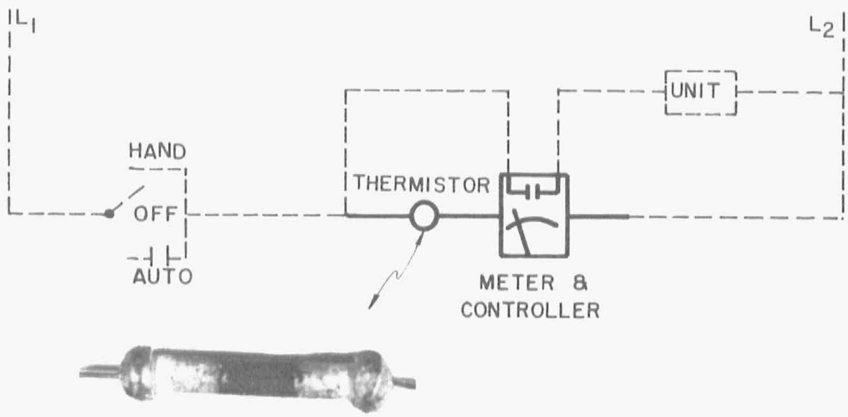


Figure 16. Temperature Sensor, Electrical Type (Thermistor).

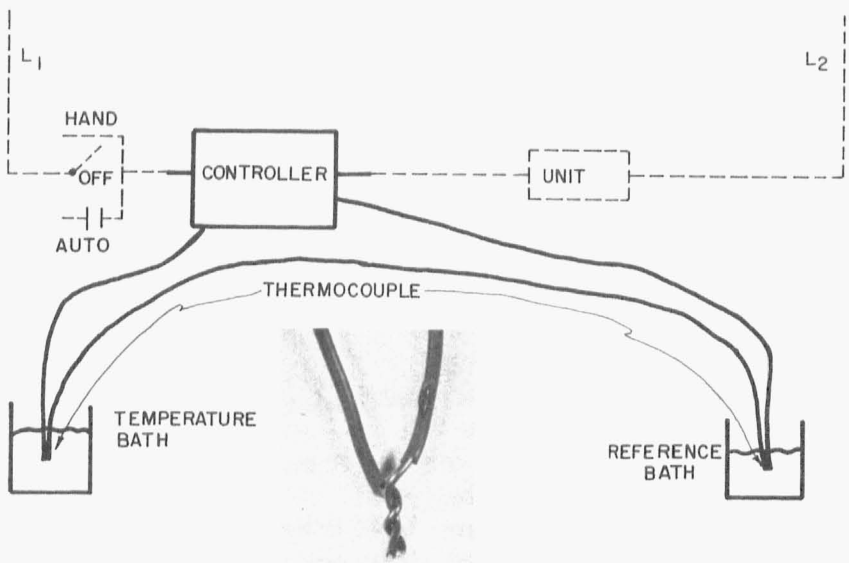


Figure 17. Temperature Switch, Electrical Type (Thermocouple).

Conductivity Switch

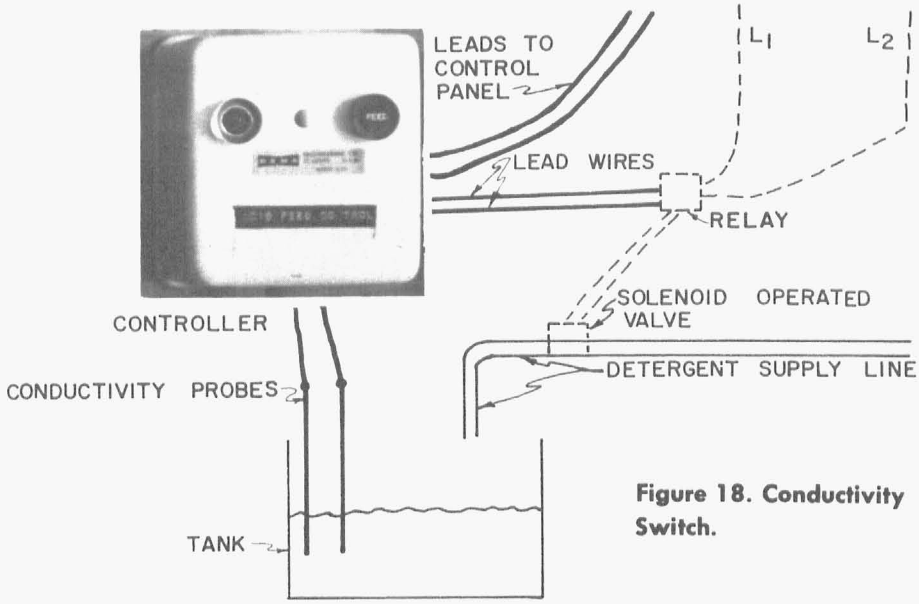


Figure 18. Conductivity Switch.

A conductivity switch is used in a controlling unit to detect the presence of a liquid (e.g., to detect the presence of water in a tank) or variations in the conductivity of a liquid (e.g., to determine the amount of a detergent in a cleaning solution).

A conductivity switch consists of two sensing probes and a controller (Fig. 18). The sensing probes are located in the liquid to be monitored, e.g., a tank or pipe. The controller puts out a low voltage signal through one probe, and picks up the signal through the other probe.

If the signal passes through the liquid (i.e. passes between the probes) and returns to the controller, the controller senses the presence of liquid with sufficient conductivity to carry the signal. If the circuit is open, due to low conductivity of the liquid, no signal will pass, and the controller will then correct the situation; e.g., by opening a solenoid-operated valve which permits detergent to flow into the tank.

Conductivity may also be used to control quantity of a solution in a tank. Solution would be fed into the tank whenever the liquid level was not sufficiently high to contact a probe.

Photoelectric Cell

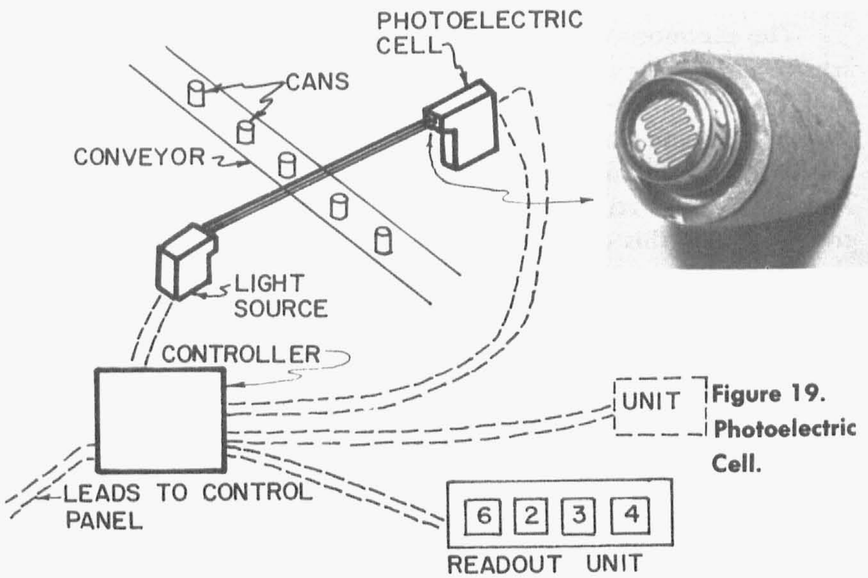


Figure 19. Photoelectric Cell.

A photoelectric cell has many industrial applications such as counting cans on a production line and opening doors for fork lift trucks.

A photoelectric cell (Fig. 19) contains two basic parts, a photocell and a light source. The photocell is a light sensitive switch. One of its electrical properties—voltage, current, or resistance—is affected by intensity of the light. The light source directs a beam of light to the photocell. When the beam of light to the photocell is broken (e.g., by an object on a conveyor) the photocell transmits a signal to the controller. A signal is sent by the controller to the readout unit and/or another controlling unit.

Load Cell

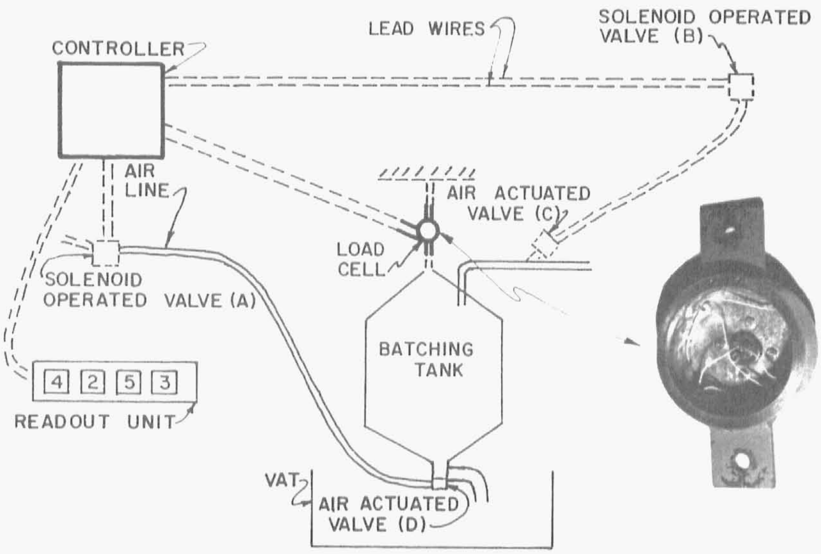


Figure 20. Load Cell.

A load cell is used in a controlling unit to monitor the weight of an object such as a tank.

The load cell unit (Fig. 20) consists of a load cell and a controller. The controller sends a signal of low voltage through the lead wires to thin metal strip(s) attached to the load cell. The voltage through the strip(s) changes with a change in resistance, which varies in proportion to the weight applied to the cell. The controller responds to the change in voltage by sending out a signal which may be fed into a readout device and/or another controlling unit; e.g., the two solenoid operated valves (A and B) which control the air actuated valves (C and D).

The controller energizes solenoid operated valve (B) which causes air actuated valve(C) to open allowing the product mix to flow into the batching tank. When a predetermined weight of product has been transferred to the batching tank as indicated to the controller by the load cell, the controller de-energizes solenoid operated valve (B) causing air actuated valve (C) to close. At the same time solenoid operated valve A is energized causing air actuated valve (D) to open permitting the mix to flow into the vat.

Liquid Level Unit

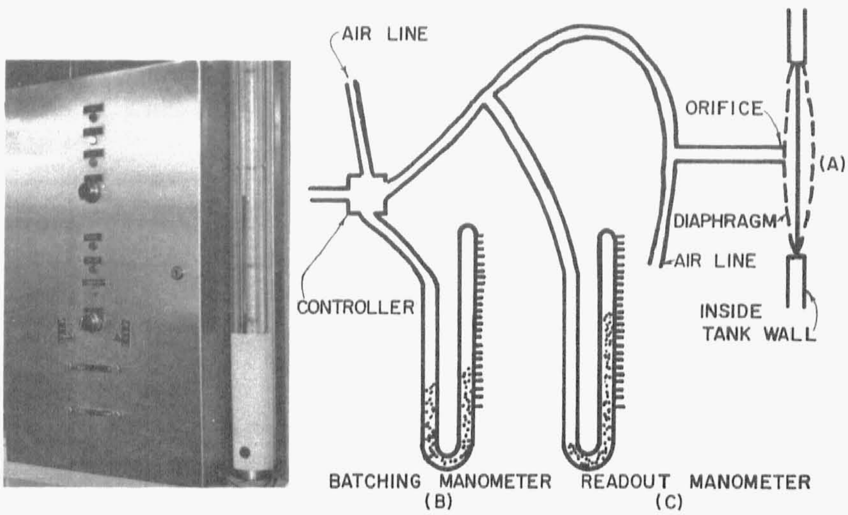


Figure 21. Liquid Level Controller.

A liquid level control unit which contains both electrical and air operated components is used to determine and regulate the amount of a liquid in a tank.

The controlling unit (Fig. 21) consists of a sensing device (A), two manometers (B & C), and a control panel (D). The sensing device (A), located on the side of the tank at the bottom, contains two basic parts, an orifice and a diaphragm. A small volume of air at low-pressure flows through the orifice against the diaphragm and escapes to the atmosphere. The pressure of the liquid in the tank forces the diaphragm against the orifice, restricting the orifice outlet. This restriction results in an increase of pressure in the air line.

The air pressure in the line is registered on a read-out manometer which is calibrated in weight or volume of liquid.

Located next to the read-out manometer is a batching manometer. To remove a specific amount of product from the tank, the batching manometer is adjusted to read the amount which is to remain in the tank. The appropriate switches are moved to their proper settings and the tank-empty switch on the liquid level control panel is moved to the "automatic" setting. When the required weight or volume is removed from the tank, the circuit is de-energized, because the pressure in the two manometers has been equalized.

Solenoid-Operated Valves

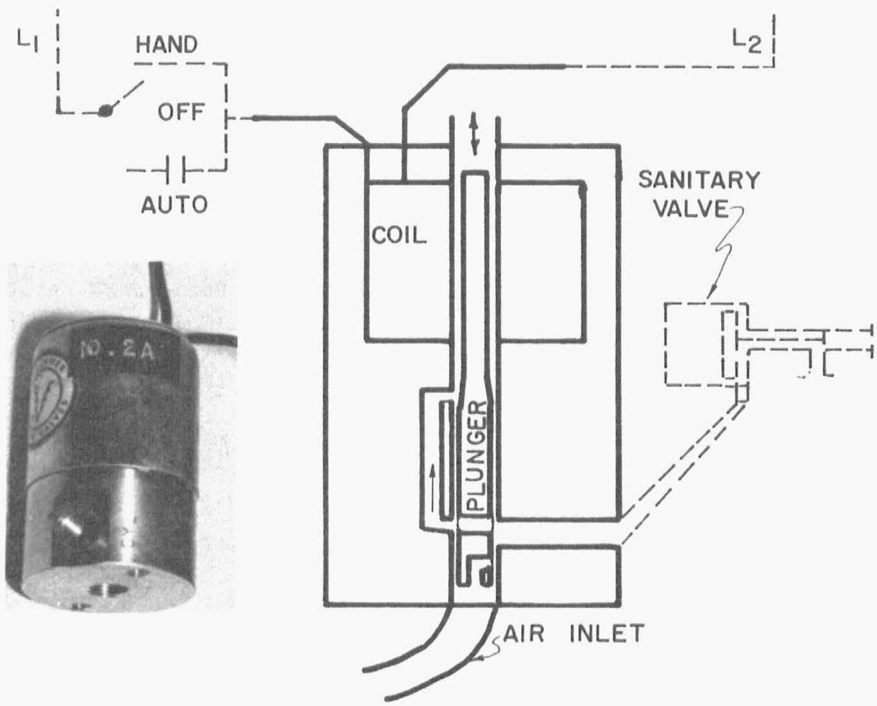


Figure 22. Solenoid-operated Air Valve.

A solenoid-operated valve is used in a unit to actuate and de-actuate an air-operated component; e.g., an air-actuated valve. This type of valve can also be used to control the flow of liquids.

The coil in the solenoid valve (Fig. 22) is energized or de-energized by an electrical component, e.g., a position switch or cam timer, when the air-actuated valve is to be positioned during processing. The energizing of the coil forces the plunger to change positions, and pressurized air flows to the air-actuated valve causing it to change position. When the coil is de-energized, the plunger returns to its normal position (due to spring tension). The pressurized air in the line is thus released to the atmosphere, permitting the air-actuated sanitary valve to return to its normal position.

OPERATING UNITS

An operating unit is defined as one item of equipment with its related components which performs a specific function in the processing line. Only items which are generally required for automation in milk processing plants are described herein.

Air-Actuated Valve Unit

Automated processing and cleaning are made possible by the availability of remotely controllable air-actuated valves. The air-actuated valves used in dairy and food processing plants are classified into two types, sanitary and chemical.

The valve and valve body of both types are constructed of stainless steel. The finish, design, and operation of the sanitary valve must meet 3-A Sanitary Standards. Sanitary valves are used to direct the flow of milk. Chemical valves, which are normally used in the control of cleaning solution flow, do not possess as smooth a finish as the sanitary valves and are not required to meet 3-A Sanitary Standards.

Components of a valve unit (Fig. 23) are an air-actuated valve and a solenoid-operated valve (Fig. 22) which controls the flow of pressurized air. The basic parts of an air-actuated valve are a valve body, valve stem and air-actuator (Fig. 24).

Three types of sanitary valves are commonly used in a milk pro-

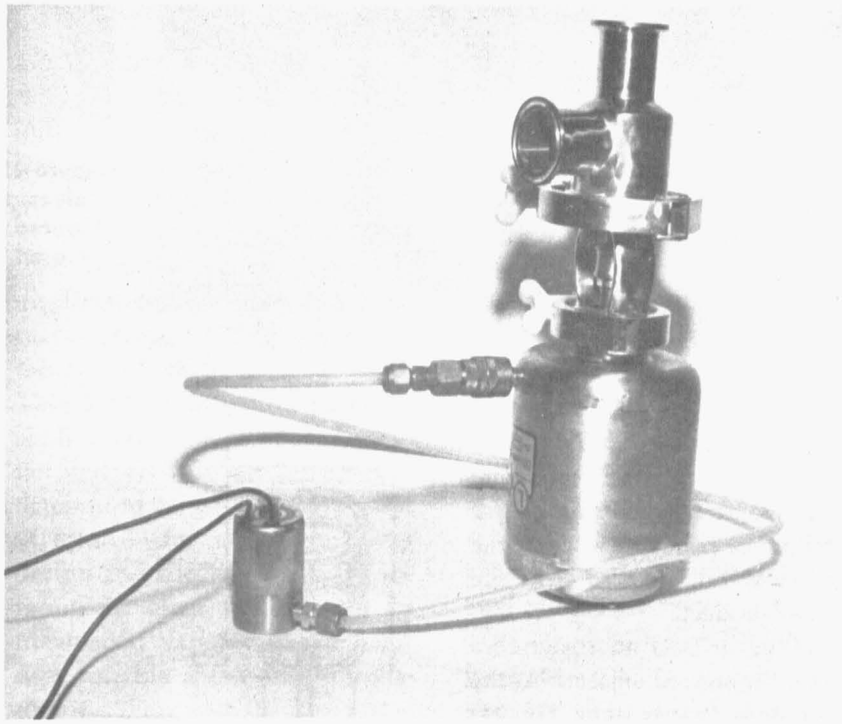


Figure 23. Components of an Air-Actuated Valve Unit.

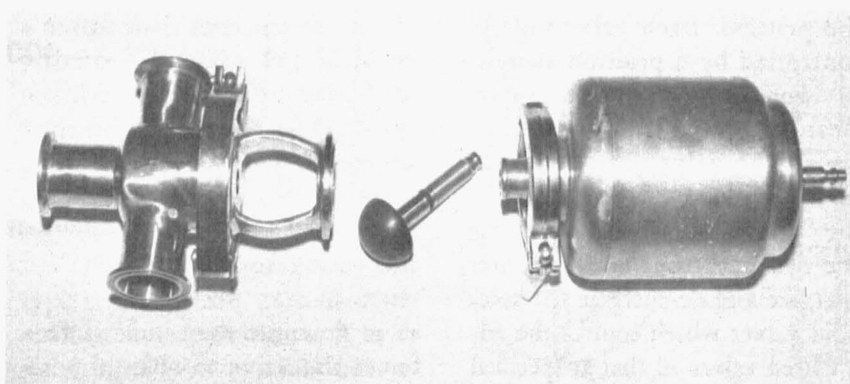
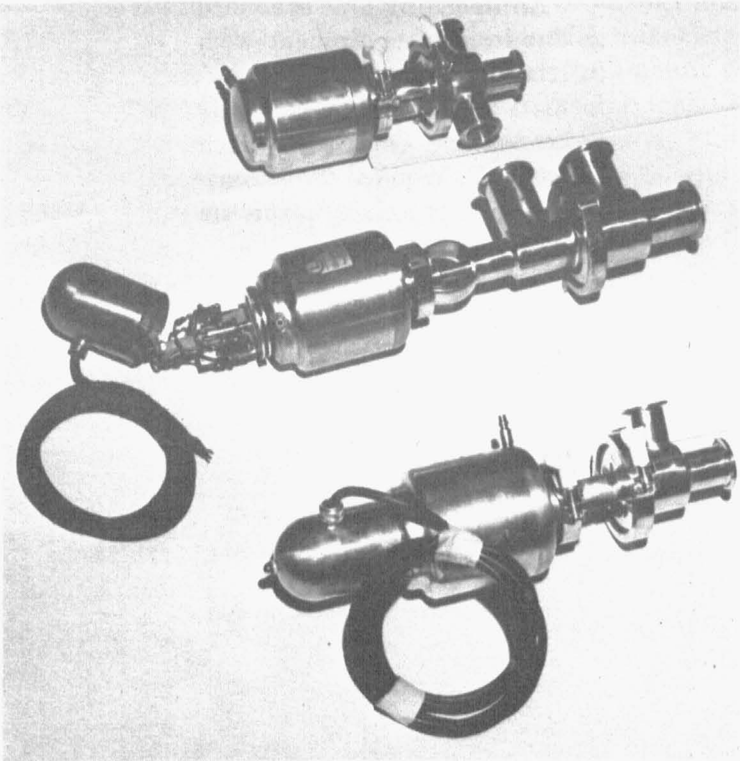


Figure 24 .Basic Parts of an Air-Actuated Sanitary Valve: *valve body, valve stem,* **and** *air actuator.*



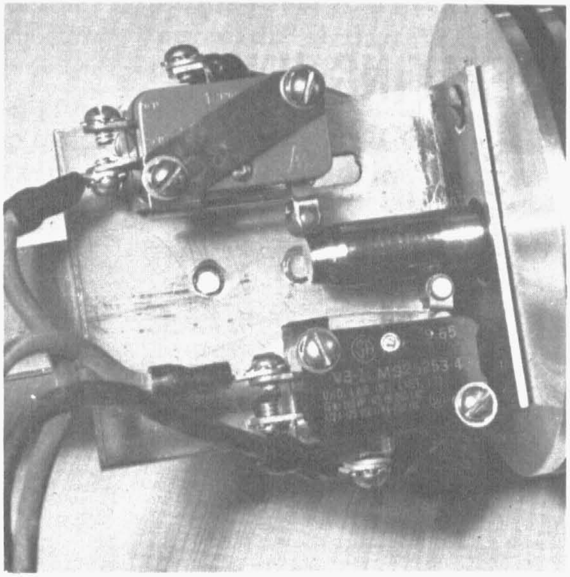


Figure 25. Three types of Air-actuated Sanitary Valves, top to bottom: T-Valve, Divert, shutoff. Pictured above is an enlargement of boxed area on the divert valve.

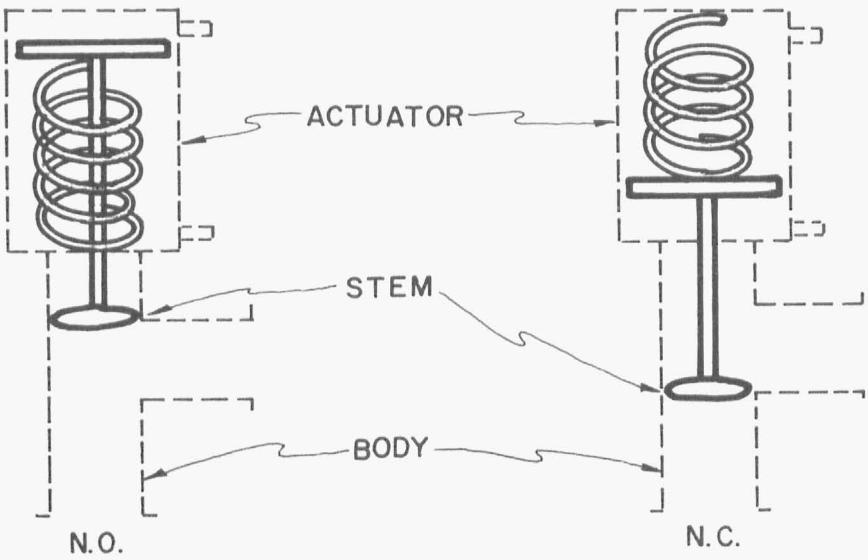


Figure 26. Shut-off-type Sanitary Valve.

cessing line: shutoff, divert, and T-valve (Fig. 25). The shutoff and T-valves are used to *start or stop* the flow of product, whereas the divert valve is used to *direct* the flow of product.

One or two microswitches may be mounted adjacent to the valve stem (upper right, Fig. 25) to signal when the valve has changed positions. This allows positive automatic control over the process. Each valve unit is controlled by a position switch.

For automated processing or cleaning, the position switches for all the valve units involved in the cycle must be turned to the "automatic" setting. During the cycle, various control units energize and de-energize the solenoid valves which control the air-actuated valves so that at specified times processing or cleaning is accomplished. When the solenoid is energized, it opens, allowing air to flow into the actuator. This forces the valve to change positions; e.g., a normally-closed valve is opened, or a normally-open valve is closed (Fig. 26).

Valves are held in normal positions by spring tension. Air pressure used to change positions approximates 35-50 pounds per square inch.

Pumps

Two types of pumps used in milk and food industries are *positive displacement* and *variable displacement* pumps.

The plunger or piston type positive displacement pump (Fig. 27) consists of a piston(s), a crankshaft, connecting rod(s), and seals.

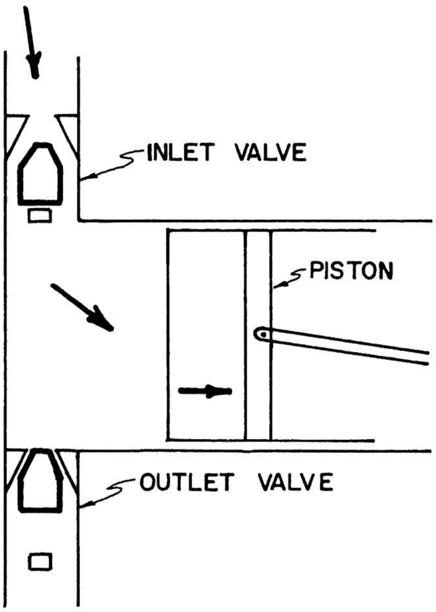


Figure 27. Positive Displacement Pump, Piston Type.

This pump operates as a car engine in reverse. It needs no priming, operates at a slow speed (100-300 rpm), is highly efficient, is capable of pumping against high pressure without significant loss in pumping capacity, and its worn parts are easily replaced. However, the initial cost is high, product flow has a pulsating pressure, and dangerous pressure can build up.

Gear, lobe, vane, and screw type pumps also provide positive displacement. They are classed as rotary pumps due to the rotary motion of their moving parts. They are used in unique pumping applications. The amount of product delivered by these pumps is determined primarily by the speed of rotation for any given pump design and size. The speed of rotation is often controllable by means of a variable speed motor or a variable speed drive mechanism.

The centrifugal pump is a variable output pump. It consists of a rotating impeller mounted on a motor shaft enclosed in the impeller housing (Fig. 28). Fluid enters the pump at the center of the housing, and centrifugal force supplied by the impeller moves the fluid to the periphery of the housing and on to the discharge.

Primary advantages of this type of pump are: ease in disassembly, few working parts, nonpulsating flow, low initial cost, no buildup of dangerous pressures and low maintenance cost. Primary disadvantages are: agitation of product may be excessive, only low pressure applications are possible, and output varies with variations in pressure.

Centrifugal pumps have a narrow range of head pressures over which they are efficient. Therefore, to insure optimum performance careful sizing of the pump is a necessity.

Centrifugal pumps may be attached to variable speed motors to (1) maintain constant volume as pressures vary and (2) provide multiple uses of the pump. (For example, a single pump can be used in both processing and cleaning of fluid milk lines by varying its speed.)

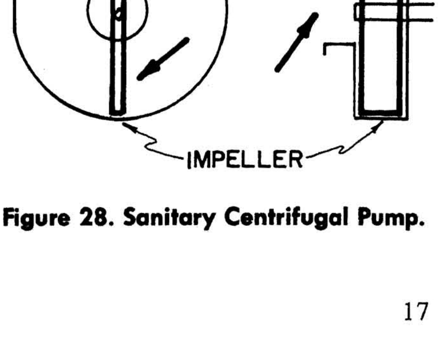


Figure 28. Sanitary Centrifugal Pump.

The various controlling and operating units described herein are normally combined with other operating units in an automated processing line. The *Controlling Units* monitor the processing of the product and regulate the *Operating Units.*

By proper choice and placement of such equipment, economies in operation may be achieved. An understanding of the functions of these units is necessary for managers of food processing plants to fully appreciate their potential.