MCC POWERS
PROCESS CONTROLS
A UNIT OF MARK CONTROLS CORPORATION

The bottom of some of these pages was cut off in the original (vs. being a scanning error)

Application Eng. Form
AE-22
December, 1970

FUNDAMENTALS OF CONTROL

PURPOSE

The purpose of this article is to introduce you to the principles and terminology used in the automatic temperature control industry. In order to fully understand the principles of control you must first thoroughly understand the terminology.

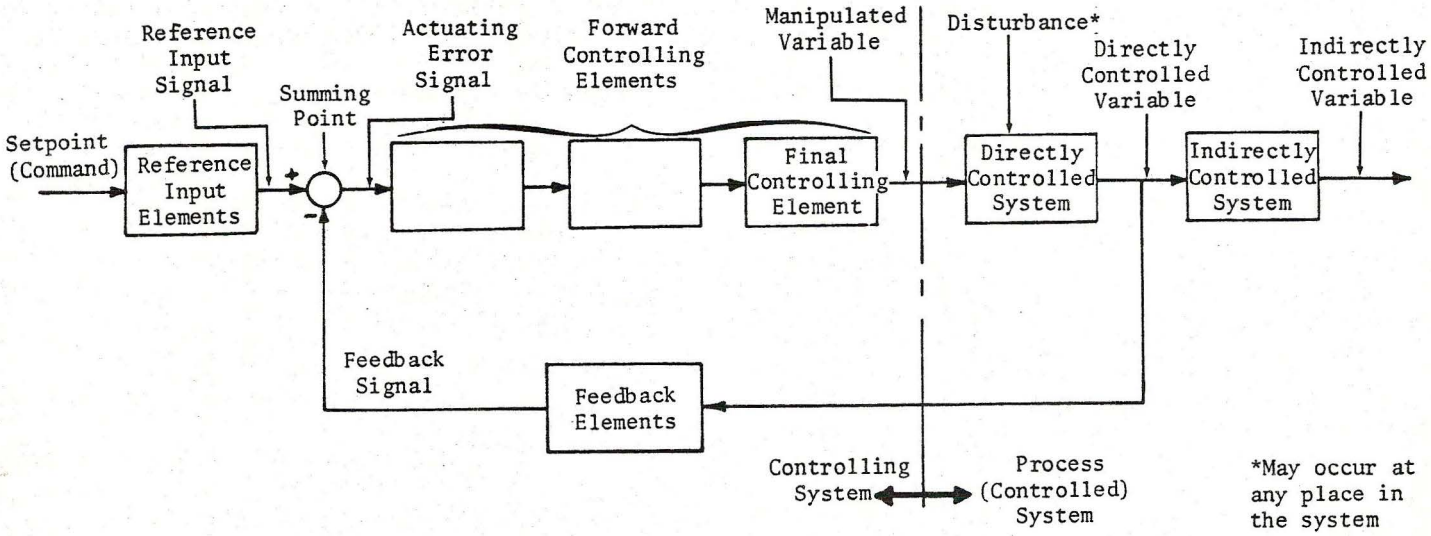


TABLE OF CONTENTS

DEFINITIONS

Amplifier - A device whose output signal is an enlarged reproduction of the essential features of an input signal and which draws its power from a source other than the input signal. ANSI - C85.1-1963

Authority - The ratio of effect upon the manipulated variable of one input signal as compared to that of another.

Capacity - A measure of the maximum amount of energy or material that may be stored in a given system.

Control Action - Of a controller or a controlling system, the nature of the change of the output produced by the input. (See Section II) SAMA PMC-20-2-1970

Control Action, Cascade - Control action where the output of one sub-system is the input of another sub-system. ANSI-C85.1-1963

Control Action, Derivative (rate) - Control Action in which the output is proportional to the rate of change of the input. SAMA PMC 20-2-1970

Control Action, Feedback - Control action in which a measured variable is compared to its desired value to produce an actuating error signal which is acted upon in such a way as to reduce the magnitude of error. SAMA PMC-20-2-1970

Control Action, Feedforward - Control action in which information concerning one or more conditions that can distrub the controlled variable is converted into corrective action to minimize deviations of the controlled variable. SAMA PMC-20-2-1970

Control Action, Floating - A control system in which the rate of change of the manipulated variable is a continuous function of the actuating signal. ANSI C85.1 - 1963

Control Action, Integral (reset) - Control action in which the output is proportional to the time integral of the input i.e., the rate of change of output is proportional to the input. SAMA PMC-20-2-1970

Control Action, Proportional - Control action in which there is a continuous linear relationship between the output and the input. SAMA PMC-20-2-1970

Control Agent - This is the medium manipulated by the controlled device. It may be gas or air flowing through a damper; gas, steam, water, etc., flowing through a valve; or an electric current.

Controlled Device - a device which reacts to the signal received from a controller and varies the flow of the control agent. It may be a valve, damper, electric relay, or a motor driving a pump, fan, etc.

Control Point - The actual value of the directly controlled variable at which the instrument is controlling. Setpoint plus offset

Control Mode - A specific type of control action such as proportional, integral or derivative. ANSI C85.1-1963

Control System, Ratio - A system that maintains two or more variables at a predetermined ratio. ANSI C85.1 - 1963

Controller - A device which operates automatically to regulate a controlled variable through a final controlling element. ANSI C85.1-1963

Controller, on-off - A multi-position controller designed to have two discrete values of output, fully on or fully off.

Damping - The progressive reduction or suppression of the oscillation of a system. ANSI C85.1-1963

Dead Band - The range through which an input signal can be varied without initiating. response.

NOTE: Dead band is usually expressed in percent of span.

Deviation - Any departure from a desired or expected value or pattern. SAMA PMC 20-2-1970

Deviation, steady-state - The system deviation after transients have expired. ANSI C85.1-1963

Also see offset.

Differential Gap - In two position control this is the difference between a setting at which the controller operates to one position, and a setting at which the controller operates to the other position. ASHRAE 1967

Element - A component of a device or system.

Element, final controlling - That forward controlling element which directly changes the value of the manipulated variable. SAMA PMC 20-2-1970

Element, sensing - The portion of a device directly responsive to the value of the measured quantity. SAMA PMC 20-2-1970.

Gain, closed loop - The gain of a closed loop system, expressed as the ratio of the output signal change to the input signal change at a specified frequency. SAMA PMC 20-2-1970

Hunting - In a linear system, an undesirable oscillation of appreciable amplitude, prolonged after external stimuli disappear. ANSI C85.1-1963

Lag - Any retardation of a device's output with respect to its input. (See page 7)

Load - The material, force, torque, energy, or power applied to or removed from a system or element. ANSI C85.1 - 1963

Loop, closed (feedback loop) - A signal path which includes a forward path, a feedback path and a summing point, and forms a closed circuit. ANSI C85.1 - 1963

DEFINITIONS (Cont'd)

Loop, open - A signal path without feedback. ANSI C85.1 - 1963

Offset - The steady-state deviation when a setpoint is fixed. Offset is equal to the difference between control point and setpoint. SAMA PMC 20-2-1970

Range - The region between the limits within which a quantity is measured, transmitted, or received, expressed by stating the lower and upper range values. SAMA PMC 20-2-1970

For example:
0 to 150F
20 to 150F
-20 to 200F

Range, throttling - The amount of change in the directly controlled variable required to move the controlled device through its entire stroke.

Sensitivity - The ratio of a change in output magnitude to the change of input that causes it, after the steady state has been reached. SAMA PMC 20-2-1970

Setpoint (command) - An input variable which sets the desired value of the controlled variable. SAMA PMC-20-2-1970

Signal - Information about a variable that can be transmitted. SAMA PMC 20-2-1970

Signal, actuating error - The reference-input signal minus the feedback signal. SAMA PMC 20-2-1970

Signal, error - In a closed loop, the signal resulting from subtracting a particular return signal from its corresponding input signal. SAMA PMC 20-2-1970

Signal, feedback - That return signal which results from a measurement of the directly controlled variable. SAMA PMC 20-2-70.

Signal, input - A signal applied to a device, element or system. SAMA PMC 20-2-1970

Signal, output - A signal delivered by a device, element or system. SAMA PMC 20-2-1970

Signal, reference-input - A signal external to the control loop which serves as the standard of comparison for the directly controlled variable. ANSI C85.1 - 1963

Signal, return - In a closed loop the signal resulting from a particular input signal, and transmitted by the loop and to be subtracted from the input signal. SAMA PMC 20-2-1970

Span, controller - The algebraic difference between the upper and lower range values. SAMA PMC 20-2-1970

For example:
a) Range 0 to 150F span 150F
b) Range -20 to 200F span 220F
c) Range 20 to 150F span 130F

Steady-state - A characteristic of a condition, such as value, rate, periodicity or amplitude, exhibiting only negligible change over an arbitrarily long period of time. SAMA PMC 20-2-1970

Summing Point - Any point at which signals are added algebraically. SAMA PMC 20-2-1970

System deviation - The instantaneous value of the control point minus the setpoint. ANSI C85.1 - 1963

Time constant - For the output of a first order (lag or lead) system forced by a step or impulse, time constant is the time required to complete 63.2 percent of the total rise or decay. (A system whose dynamic response can be expressed by a first order differential equation is a first order system. For example: A mercury thermometer in air.) ANSI C85.1-1963

Time, dead - The interval of time between initiation of an input change and the start of the resulting response. SAMA PMC 20-2-1970

Value, desired - The value of the controlled variable wanted or desired. (See also setpoint)

Variable, directly controlled - In a control loop, that variable whose value is sensed to originate a feedback signal. SAMA PMC 20-2-1970

Variable, indirectly controlled - A variable which does not originate a feedback signal, but which is related to, and influenced by the directly controlled variable. SAMA PMC 20-2-1970

Variable, manipulated - A quantity or condition which is varied as a function of the actuating error signal so as to change the value of the directly controlled variable. SAMA PMC 20-2-1970

Variable, ultimately controlled - The variable whose control is the end purpose of the automatic control system. ANSI C85.1-1963

INTRODUCTION

Equipment used in a control process should be able to handle maximum load conditions. However, maximum load is infrequently encountered and the process will normally be operating at partial capacity. Automatic control devices are used to provide accurate and stable performance in a process operating at partial capacity. These devices, operating either independently or in combination with other devices, respond to changes in temperature, humidity, pressure, etc., to maintain the desired conditions in the process and in the areas served by the process.

CONTROL CHARACTERISTICS

Open Loop

In the heating process shown in fig. 2, the valve may be positioned to deliver sufficient hot water to meet the load requirements when the outside air temperature is 35F. But when the outside air temperature drops to 10F, the valve must be adjusted to a more open position to supply enough hot water to meet the increased load requirements. Without a means for adjusting the valve, the process is incomplete and represents an open loop system.

An example of open loop control is hot water reset or zone (orificed) steam distribution control for a building. In each case, the manipulated variable (hot water temperature or steam flow) is changed, dependent on the outside air temperature. This aids in more closely matching room losses and loads within the building, but cannot assure maintenance of a desired room temperature.

Closed Loop

For a controlled process to be complete, there must be a closed loop. If a human operator is present to adjust the valve as in fig. 3, the process represents a closed loop system. If the human operator is replaced by a thermostat, the process becomes automatic. This is shown in fig. 4 Here a thermal element, sensitive to temperature, causes the thermostat to pass a variable air signal to the valve as a result of temperature change.

The component parts of a closed loop system are shown in fig. 5. The measuring means consists of those elements which measure and communicate to the controlling means the value of the controlled variable. This may be a pressure sensitive diaphragm, a float device, an electric thermocouple, a thermal bulb, etc.

The controller consists of those elements which are involved in producing a corrective action. This may be an electric, pneumatic or hydraulic operator or human hands.

The control element is that portion of the controlling means which directly changes the value of the manipulated variable. This may be a rheostat, valve or damper. Note that the controller compares the signal from the measuring means with the setpoint in giving a signal to the controlled element.

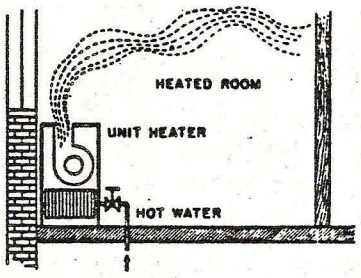


Fig. 2 - Diagram of simple heating process without means of adjusting valve - an open loop system.

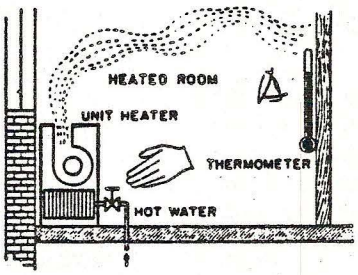


Fig. 3 - Diagram of manual operation of simple heating process - illustrates a simple closed loop system.

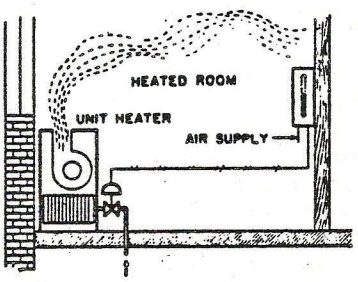


Fig. 4 - The human operator of Fig. 2 is replaced by means of automatic devices - the control process is now automatic.

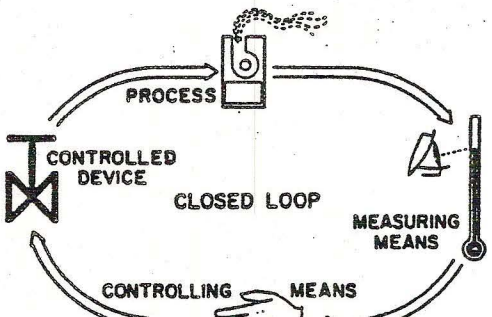


Fig. 5 - Components of a closed loop system.

Dual Loop

Often one closed loop system forms a part of another closed loop. In the room control procedures described, the actions of the human operator represent such an inner loop. The eyes were a measuring means, the brain a controlling means, and the hands the controlled element. A positioning relay connected to a control valve is another example of dual loop control. Positioner to controlled device relationship represents the inner closed loop, and process to transmitter to controller to inner loop to process represents the larger closed loop. See Fig. 6.

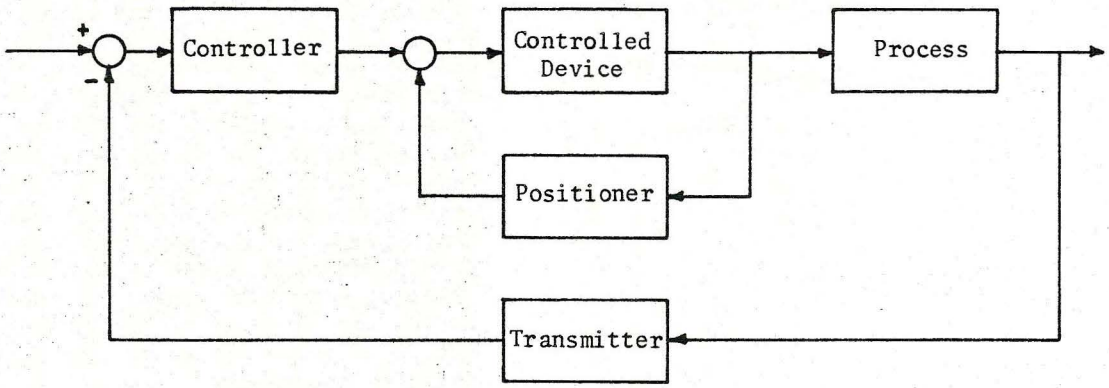


Figure 6

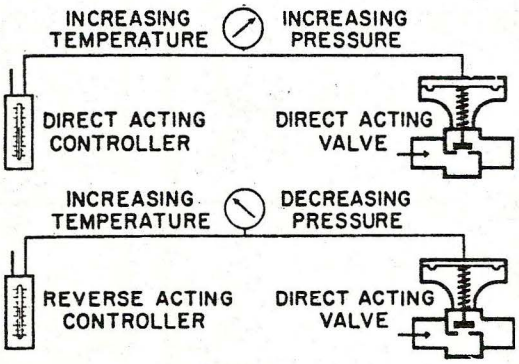


Figure 7
Diagram showing how direct acting and reverse acting pneumatic controllers operate.

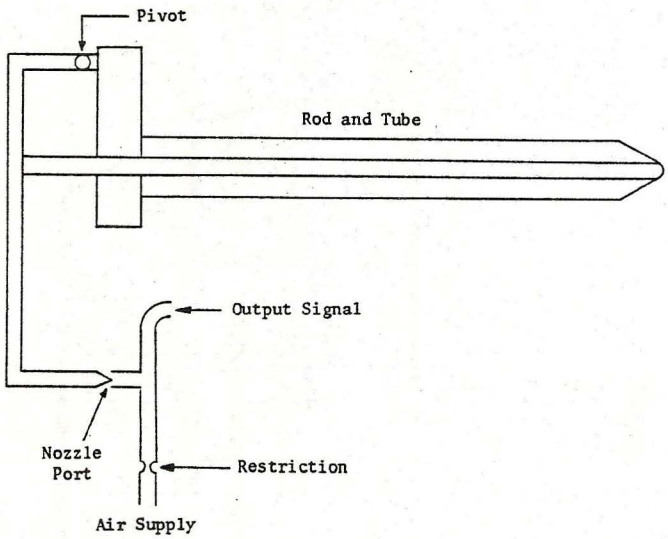


Figure 8

CONTROLLER ACTIONS

Direct and Reverse Acting Operation

Pneumatic controllers may be classified as either direct or reverse acting. Refer to fig. 7. A direct acting controller increases the output signal to the control element as the controlled variable increases. A reverse acting controller decreases the output signal to the control element as the controlled variable increases.

Pneumatic Controller Types(Non-Relay and Relay)

Pneumatic controllers may be either relay or non-relay type. The non-relay type is of simple construction using a restricted air supply and a nozzle port. The measuring element varies the opening at the nozzle, and the resulting output signal is applied to the control element. Limitations of the non-relay type controller are non-linearity and/or limited air capacity. Fig. 8 shows a typical non-relay controller.

The relay type pneumatic controller is divided into two categories, the force balance and motion balance. The ultimate purpose of both these systems is to bring the flapper into a balance position with respect to the nozzle. The force balance controller does this by balancing two opposing forces that are connected to the flapper. Since flapper position is related to the balance of two forces acting on the flapper, this system is refered to as a force balance controller. Fig. 9a shows a simple diagram of a force balance system and fig. 9b shows a controller utilizing this system.

CONTROLLER ACTIONS (Cont'd)

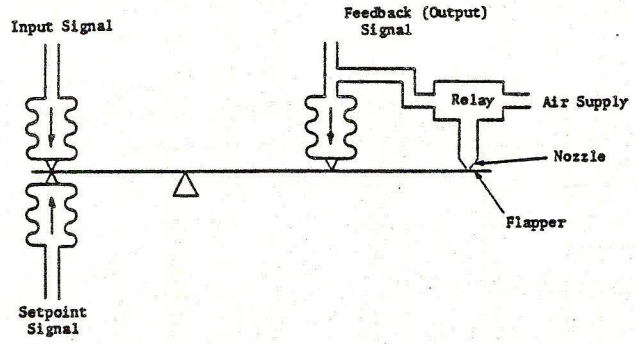


Figure 9a

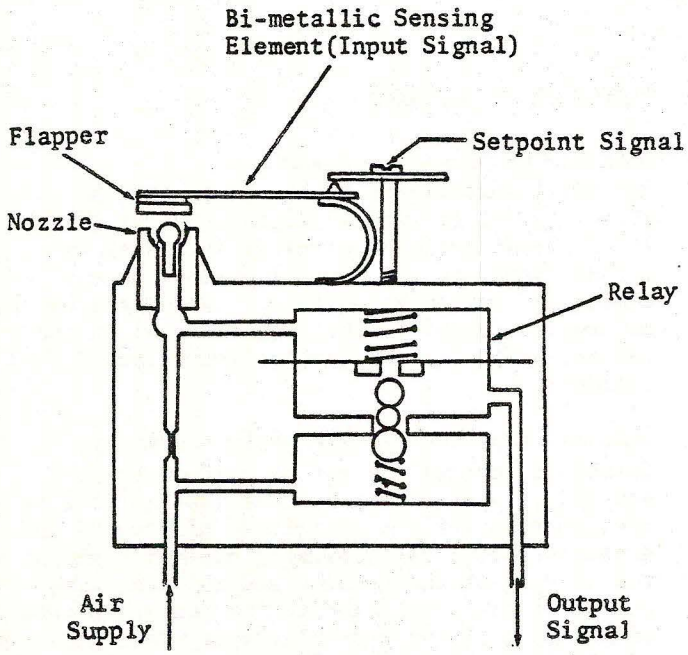


Figure 9b

Motion balance balances the position of the flapper by opposite movement at the ends of the flapper. Opposite movements cause balanced positioning of the flapper and nozzle. Fig. 10a shows a simple motion balance diagram. As the input signal increases, the flapper lifts off the balanced position and causes a reduction in nozzle pressure. The output signal or feedback signal being linearly related to nozzle pressure is also reduced, causing the flapper to come down to its balanced position. Note that as the input signal displaces the flapper up, the output or feedback signal displaces the

Fig. 10b shows a controller utilizing this system. Note that for each part or signal of figure 10a there is a like part or signal in figure 10b. As the spiral (3) expands, it pulls the temperature pointer (5) up scale (to the right) through link (4). While the pointer rotates about pin (6), link (7) is pushed down. Since arm (8) pivots about point (9), its right end will rise, moving the flapper (10) away from the nozzle (11). Raising the flapper from the nozzle reduces the feedback or output signal causing the bellows (17) to contract. This action, transmitted through levers (23) and (18) lowers the flapper, opposing the initial upward movement caused by the expanding spiral. Changing set point signal is equivalent to moving the left end of arm (21) up or down. The nozzle is moved closer to the flapper when the setpoint is raised.

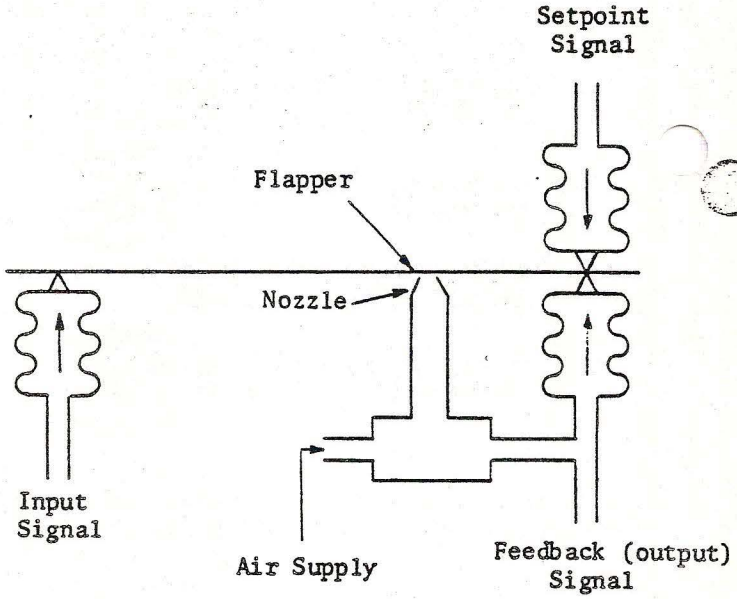
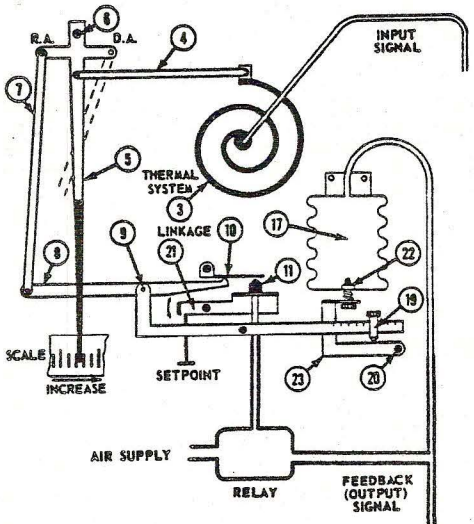


Figure 10a



Lags

At first glance, control of a process may seem quite easy. All that appears necessary is to observe the directly controlled variable and to correct the manipulated variable accordingly, so as to hold or change the directly controlled variable to the desired value. However, processes have the characteristic of delaying and retarding changes in the values of the process variables. This process characteristic greatly increases the difficulty of control. These delays or retardations are generally referred to as process lags. Lags are caused by three properties of the process: a) capacitance, b) resistance, and c) transportation time.

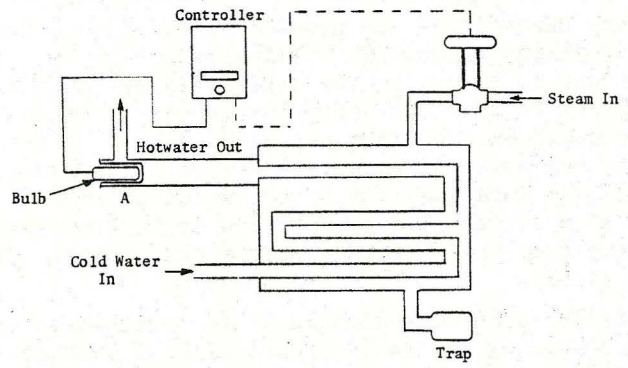


Figure 11

Those parts of a process which have the ability to store energy (or a quantity of material) are termed capacities. In fig. 11, for example, the wall of the steam compartment and the water in the tube can store heat energy. This energy-storing property gives these capacities the ability to retard change. For instance, if the amount of steam is increased, it requires time for the additional energy to increase the water temperature flowing through the heat exchanger.

Those parts of a process which resist transfer of energy (or material) between capacities are termed resistances. In fig. 11, the tube wall between the steam and water resists the transfer of heat energy from the steam to the water. The combined effect of supplying a capacity through a resistance produces time retardations in the transfer of energy between capacities. Such resistance-capacity (R-C) time retardations are often called capacity lags or transfer lags.

A third property found in processes which contributes to time lag is that time required to carry a change from one point to another point in the process. If the temperature (see fig.11) of the incoming cold water drops, some time will elapse before the cold water can travel through the tube and reach the controller bulb.

This time lag is not just a slowing down or retardation of a change, but it is the discrete time delay (dead time) during which no change whatever occurs. The length of this dead time depends both on the velocity with which the change is transported and on the distance over which it is carried. Thus, dead time is also termed distance-velocity lag or transportation lag. For example, if the hot water flows at a velocity of one foot per second with the bulb at point A (20 feet from the tank) the dead time is 20 seconds.

Two Position Control

Two position control is that in which the final controlled device assumes one of two fixed positions. It is also called on-off control, positive action, and high-low control. Two position control is used successfully on applications having large demand-side capacity to demand ratios and small transportation lags, such as, home refrigerators and hot water storage tanks. When the controlled variable increases to a certain high value, the final controlled device assumes one position and remains there until the controlled variable drops to a certain low value. The final controlled device then moves to the other position and remains there until the controlled variable again increases to the high value.

Two position control is cyclical, and the controlled variable will always have a greater amplitude than differential gap. Differential gap is the difference between the high and low switch points of the controller. The cycle which results will depend on system lags and the differential gap.

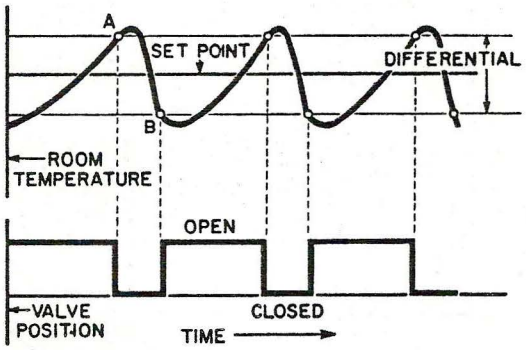


Fig. 12 - Pattern of how room temperatures may be expected to vary with two-position control.

Proportional Control

In proportional control there is a fixed linear relationship between the value of the controlled variable and the position of the final controlling element. (See fig. 13). The proportional controller moves the final controlling element to a definite position for each value of the controlled variable.

Since only one position of the final controlling element corresponds to a chosen value of the controlled variable, called the set-point, a sustained deviation from this chosen value is necessary to reposition the final controlling element when the load changes. This deviation is called offset (See fig.14). That value at which the instrument actually controls for any fixed set of conditions is called the control point.

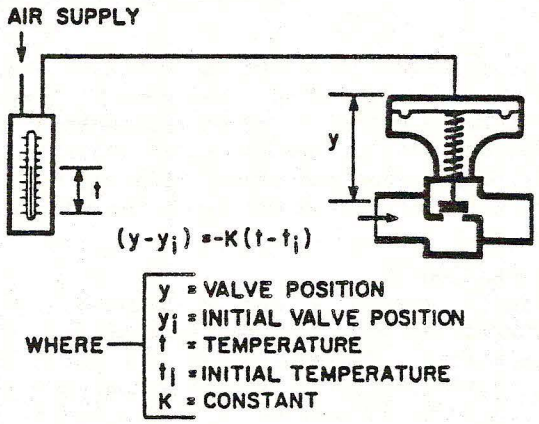


Fig. 13 - Proportional control and its mathematical representation.

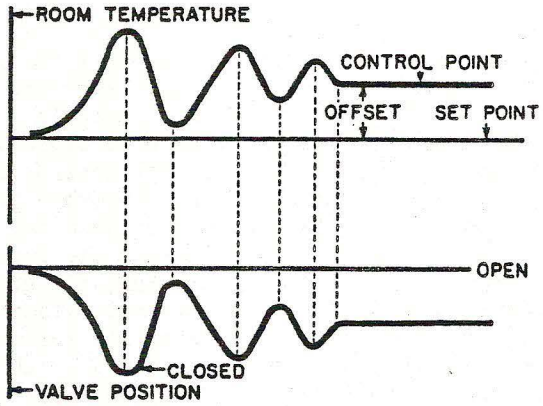
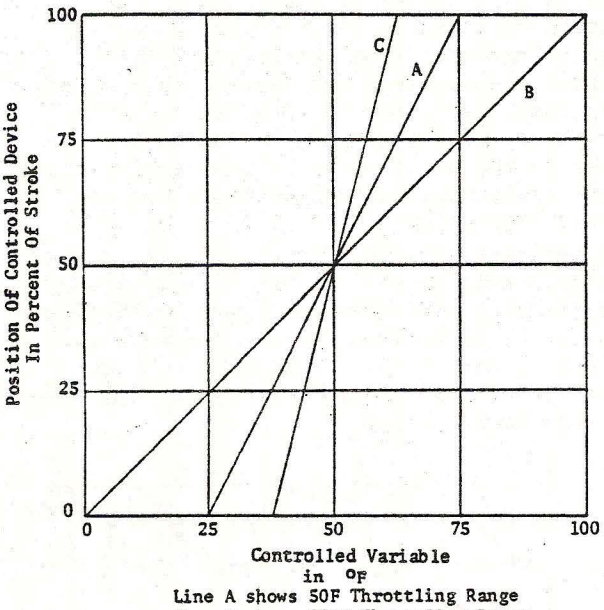
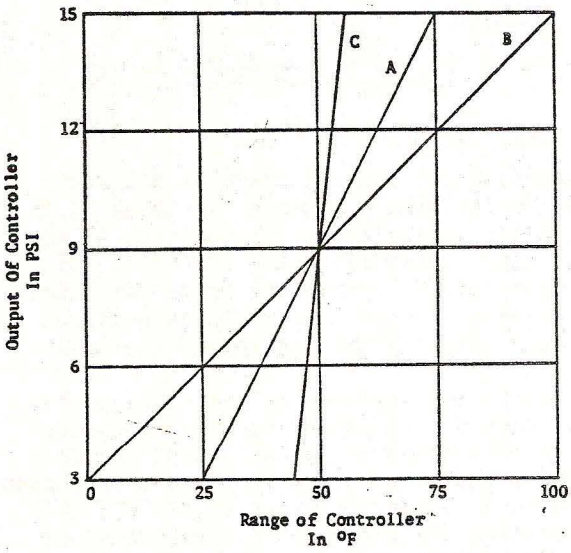


Fig. 14 - Pattern of how room temperature may be expected to vary with proportional control.



Line A shows 50F Throttling Range
Line B shows 100F Throttling Range
Line C shows 25F Throttling Range

Figure 15



Line A shows a Percent Proportional Band of 50%
Line B shows a Percent Proportional Band of 100%
Line C shows a Percent Proportional Band of 10%

Throttling Range, Percent Proportional Band and Sensitivity

Many controllers are provided with an adjustable throttling range. Throttling range* is the amount of change in the controlled variable required to move the controlled device through its complete stroke, from one extreme to the other. For example: if we have a throttling range of 12F, we know that our directly controlled variable must vary 12F to move the controlled device from completely open to completely closed. (See Fig. 15).

Percent proportional band is the percentage of the span of the controller that will produce a "standard 12 psi output". For example, if we have a percent proportional band of 5% and the span of the instrument is 240F, then it takes 12F input change to give us a 12 psi output change. (See fig. 16)

Sensitivity also called proportional gain of a controller is the ratio of change in controller output to change in controlled variable. For example, if we have a sensitivity of 3 psi/°F we know that for every one degree F that the directly controlled variable changes, there will be a three psi change in controller output.

* The term "Proportional band" should not be used as a substitute for throttling range.

Floating Control

Floating control is that control action in which the controller moves the controlled device toward either its open or its closed position. Generally, there is a neutral zone between the two positions which allows the controlled device to stop whenever the controlled variable is within the neutral zone of the controller. When the controlled variable is outside the neutral zone of the controller, the controller moves the controlled device in the proper direction until the controlled variable is again within the neutral zone. The neutral zone does give the system offset but it is very small as compared to a proportional system. Fig. 17 shows a simple floating controller controlling static pressure in a heating duct. There is an electric actuator controlling damper position and a bellows sensing static pressure and operating the electric actuator. If the static pressure increases, the bellows moves upward and makes

Floating Control (Cont'd)

contact with the upper contact. As soon as the static pressure reaches a value within the neutral zone, the actuator stops and remains at that position.

Pressure control applications often employ floating controllers. Figure 18 illustrates a floating differential pressure controller controlling a pressure reducing (throttling) valve. (See fig. 22 for other applications.)

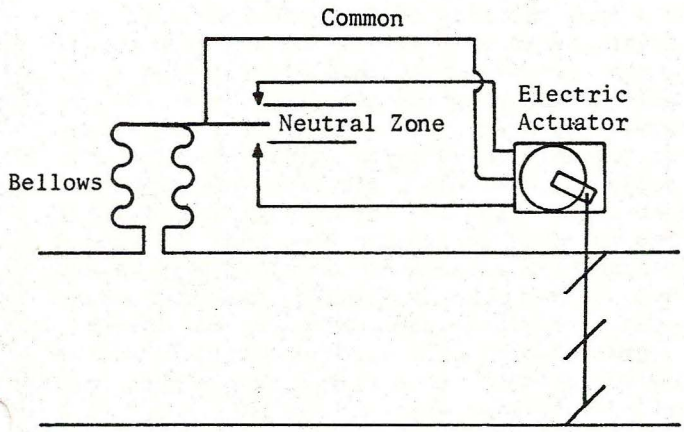


Fig. 17

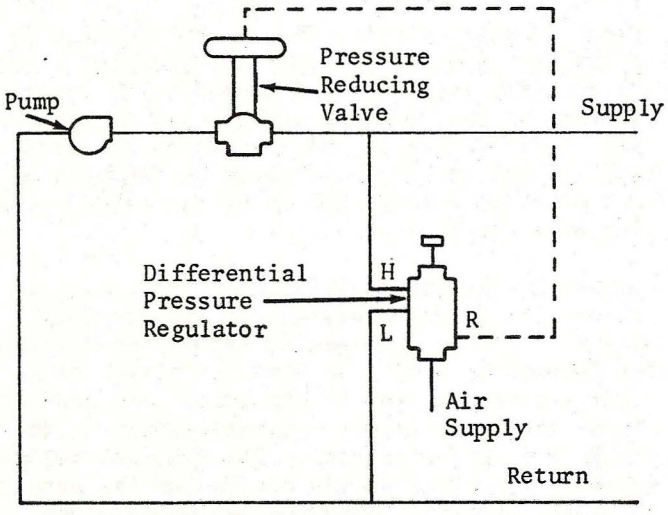


Fig. 18

Proportional Plus Integral Control (Automatic Reset)

The addition of integral control action eliminates the offset that is inherent in purely proportional control action. Proportional plus integral controllers find wide applications in processes where low sensitivity or large and sustained process load changes occur. The proportional plus integral controller is an instrument which will always act to maintain the controlled variable such as temperature, level, or pressure at the desired value. The proportional control mode provides a stabilizing effect, while the integral mode provides the necessary action to continue automatically the output correction until the controlled variable is returned to the setpoint. The combination of proportional plus integral action is most popular on applications such as flow or pressure control where the process lag is small. The small process lag permits the use of high integral gain. In applications such as temperature control where the process lag is large, the use of integral control action is limited. "Reset Windup" or two position cycling often results when the integral portion of the controller is set too high and/or the process lag is too great.

The operation of this controller is very much the same as the unit with proportional control only, except for the additional operational effects of the integral action. Figure 19 shows a simple proportional plus integral controller.

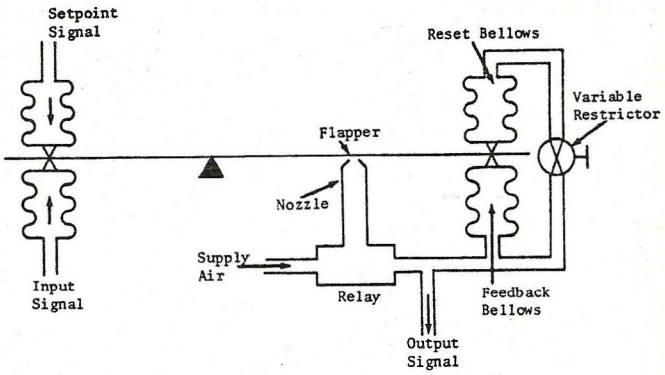


Fig. 19

Referring to fig. 20, assume that the input signal increases above the setpoint of the controller. Since this is a reverse acting controller, the input signal increase will cause an output signal decrease. The throttling bellows (23) contracts immediately causing the flapper to go down. (The repositioning of the flapper to oppose the input signal constitutes negative feedback.) The venting of the reset bellows (25) causes the bellows to contract; the resulting upward motion of the flapper can be considered positive feedback, counteracting the negative feedback of the throttling bellows. The rate of venting of the reset bellows through the needle valve (24) is set by the knob and pointer position. When the input signal returns to the setpoint, the pressure in both bellows will balance out at the control pressure needed to return the input signal to setpoint, not necessarily proportional to the input deviation.

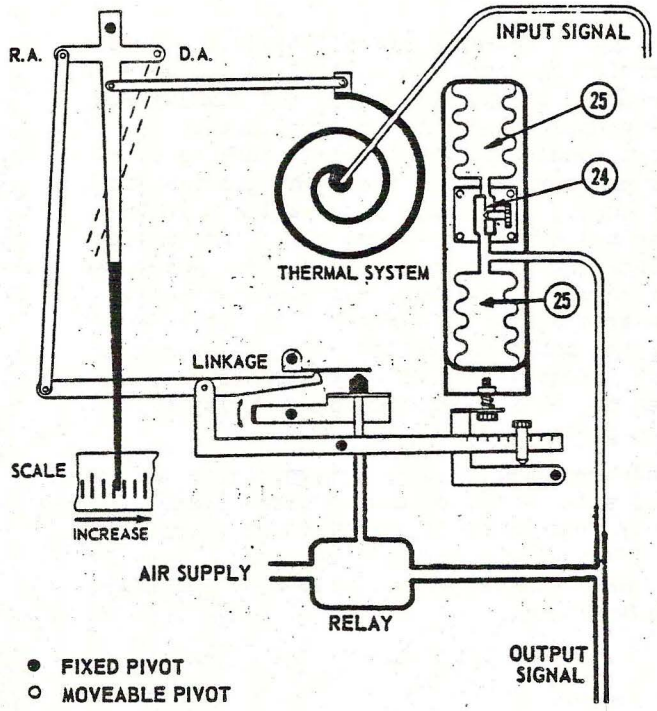


Figure 20

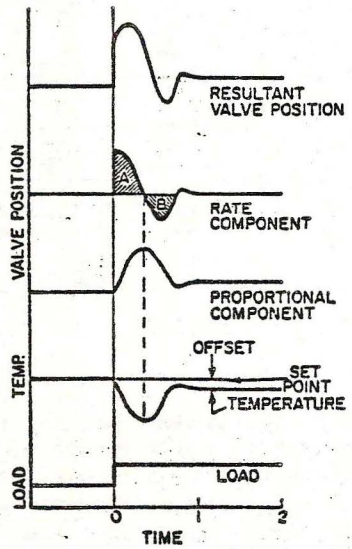
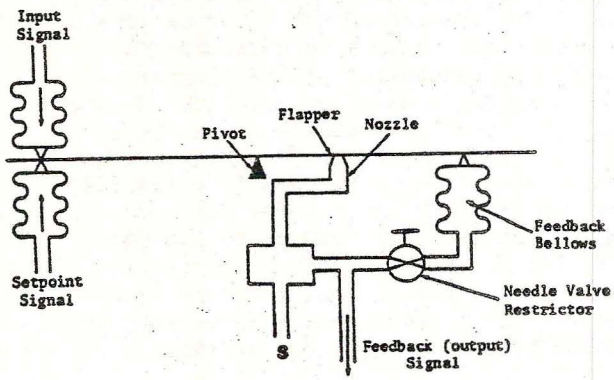


Figure 21



Proportional plus Derivative Control

Derivative control is defined as a control action in which the output is proportional to the rate of change of the input. Although this control mode cannot be used alone since it does not recognize steady - state condition, it is often used in combination with proportional control. The easiest way to explain what proportional plus derivative control does is to picture separately the components of valve motion due to each mode as in figure 21.

Note that the size of derivative control mode correction is proportional to the rate of change of the controlled variable curve. When the variable is changing fastest (time zero), the derivative mode correction is largest. When the variable is reversed (time 0.4), its rate of change is zero; the derivative mode component is also zero. When the variable is changing away from setpoint derivative mode adds the energy (represented by area A) to oppose this change. When the variable is changing toward the setpoint, derivative mode subtracts the energy (represented by area B) to oppose this change. Derivative mode has a stabilizing effect on control. Note that when the variable stops changing (time 1.0) only the valve correction due to the proportional mode is left. Derivative mode has no direct effect on offset.

Figure 22 shows a proportional plus derivative controller. Nozzle pressure and feedback signal are directly related. The needle valve restrictor between the feedback bellows and the feedback signal varies the rate at which the feedback bellows reacts to a change in feedback signal. With no restriction we have a simple proportional controller.

Closing the needle valve halfway causes a lag between the feedback signal and the feedback bellows. A fast increase in input signal causes the flapper to move away from the nozzle causing a decrease in nozzle pressure. The feedback signal decreases almost instantaneously as the nozzle pressure decreases. The feedback bellows pressure decreases slowly because of the needle valve restriction. Note the lag between the feedback signal and the feedback bellows pressure caused by the needle valve restrictor. When the rate of change of the input signal is equal to or less than the rate of change possible between the feedback signal and the feedback bellows, only proportional control functions. When the rate of change of the input signal is greater than that between the feedback signal and the feedback bellows, derivative control functions until the input rate again becomes less than or equal to the rate between feedback signal and feedback bellows.

Proportional plus derivative control is used to overcome transfer lags in temperature processes such as batch cooking and some tank control

Cascade Control

One of the techniques for increasing the stability of a complex circuit is the use of cascade control. Cascade control is a control action where the output of one sub-system is the input for another sub-system. (See figure 23). This type of control accomplishes two important things: it reduces the effect of load changes near their source, and improves the control circuit by reducing the effect of time lags. There are generally two controllers used in a cascade system, (there may be more), the master and the submaster controller. The master controller senses a variable and sends a signal to adjust the setpoint of the submaster controller. The submaster controls a variable at the setpoint determined by the master controller.

An example of open loop-closed loop cascade control would be hot water reset. (See fig.24). The master controller senses outside air temperature and sends a signal to the submaster to control the temperature of the water in the hot water heating system at a predetermined schedule. A typical control schedule might be: "If the outside air temperature is 10F the water would be controlled at 200F. If this outside air temperature was 70F the water temperature would be controlled to 100F." Note that this is a two loop system. The master controller is in an open loop system because there is no action taken to control the medium which the master is sensing. On the other hand, the submaster is in a closed loop system because it is controlling the medium it is sensing.

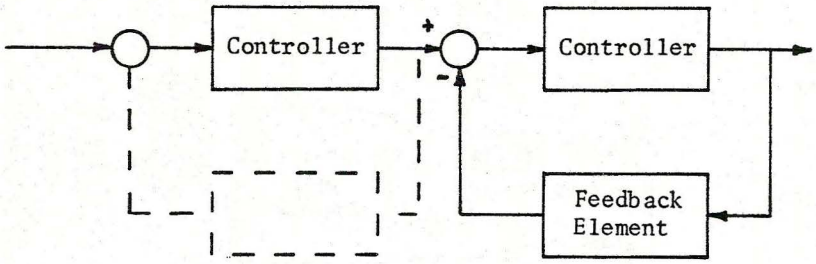


Figure 23

Cascade Loops

Note: Not necessarily both closed loops.

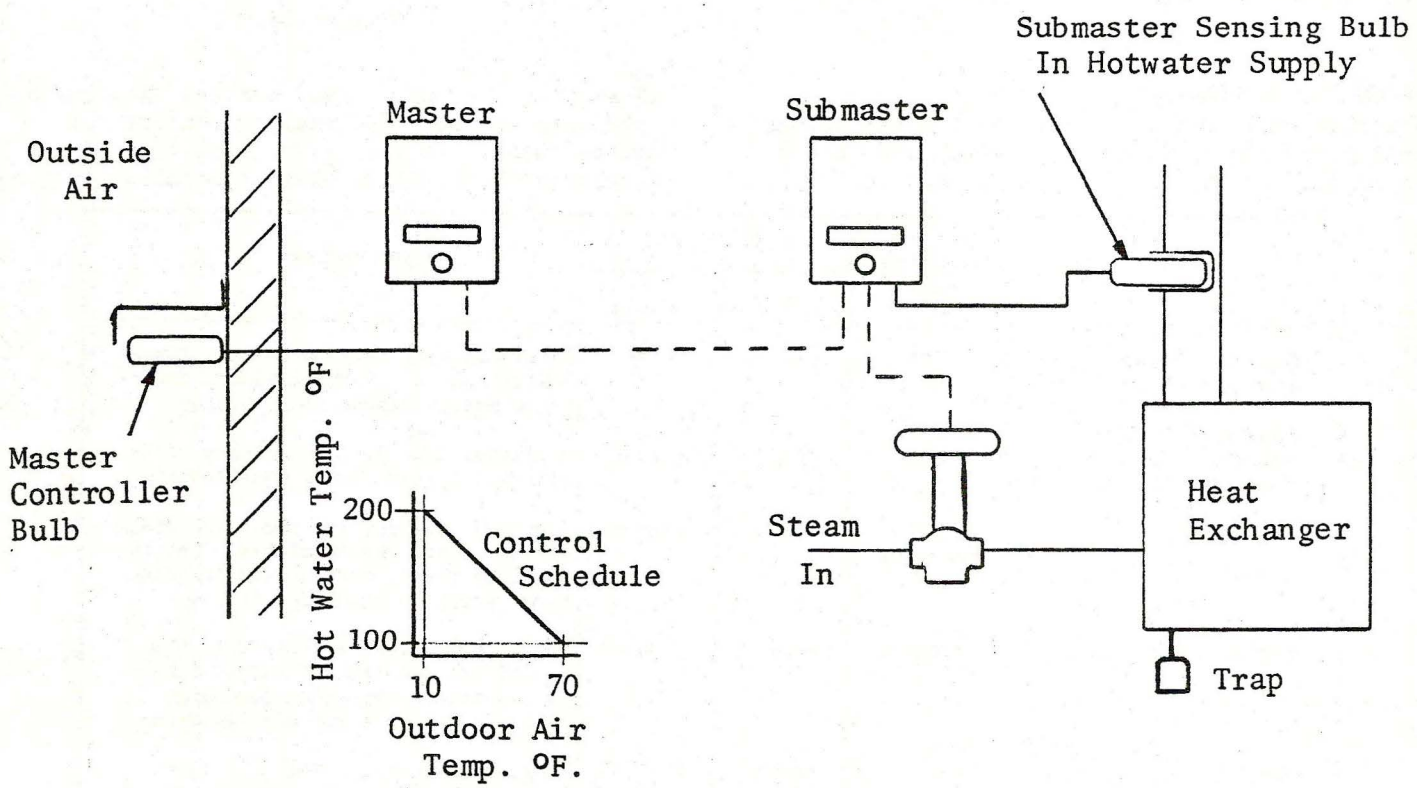


Figure 24

Cascade Control (Cont'd)

Figure 25 shows a process where the product must be kept constant at 250F. Product flow fluctuates radically due to a process further down the line. With single loop control, variations in the heating effect of the steam will be sensed only after the change in product temperature has reached the bulb at the heat exchanger output. It is possible that the pressure of the steam may be reduced because of demands by other processes or by changes in the condensing rate due to a varying product flow rate. A lower steam pressure results in a lower steam flow into the heat exchanger. Less heat is being added to the heat exchanger for the same valve opening. This decrease in heating effect is not felt until the reduced temperature of the product finally reaches the bulb of the controller at the heat exchanger output. By this time, however, the flow through the valve might be restored to its original value so that the corrective signal coming from the controller to open the valve further is not required at this time. This results in excess steam. This cycle could be repeated continuously without the process ever catching up to the actual heat exchanger conditions.

With the master-submaster relationship of a cascade control system, (see fig. 26), changes in steam pressure are immediately compensated for by the submaster pressure control loop. As in this example, a slow-responding system is usually cascaded onto a fast-responding system.

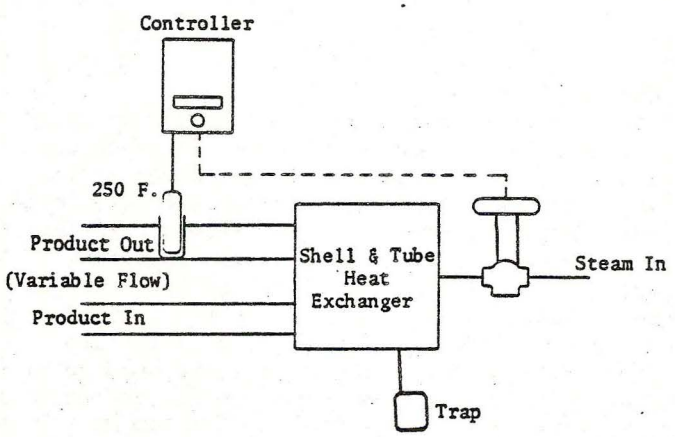


Figure 25

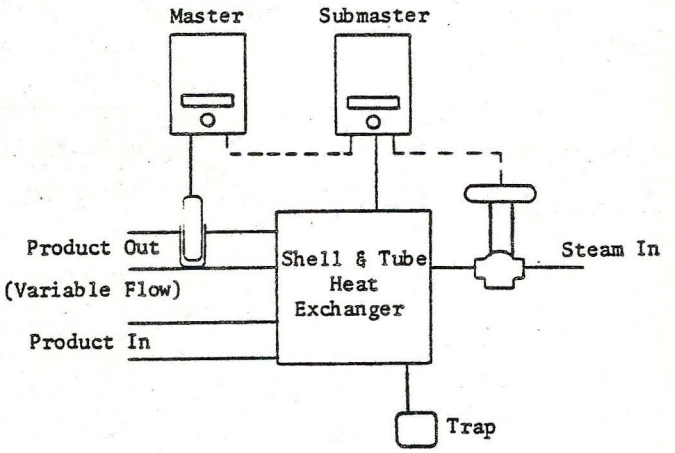


Figure 26

Control Mode Applications

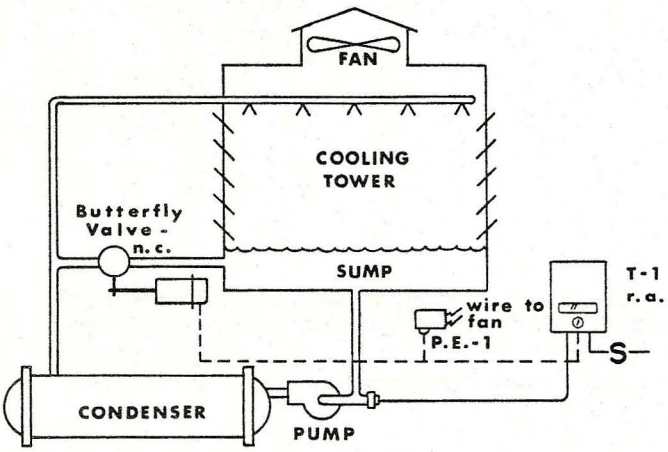
The five basic and most used controller actions that have been explained previously should now be applied to certain types of processes. Fig. 27 shows a list of control actions that can be used with various load changes and process reaction rates. It also gives some typical processes that utilize these controller actions.

Mode	Process Reaction Rate	Load Changes		Applications
		Size	Speed	
On-Off. Two-position with differential gap	Slow	Any	Any	Large-capacity temperature and level installations. Storage tanks, hot-water supply tanks, room heating.
Floating. Single speed with adjustable neutral zone	Fast	Any	Small	Processes with small dead time. Industrial furnaces, air conditioning.
Proportional	Slow to moderate	Small	Moderate	Pressure, temperature and level where offset is not objectionable. Kettle reboiler level, drying-oven temperature, pressure reducing station.
Proportional plus rate	Moderate	Small	Any	Where increased stability with minimum offset and lack of reset wind-up is required. Compressor discharge pressure, paper-strip edge guiding.
Proportional plus reset	Any	Large	Slow to Moderate	Most applications, including flow. Not suitable for batch operations unless overpeaking is allowed.

SYSTEM COMPONENTS

A control system consists of a controller, a controlled device, energy source, and optional auxiliary components. Fig. 28 illustrates a typical control system. The controller contains two basic elements,the sensing element and the controlling element. Sensing elements may be a bimetalic strip, rod and tube, sealed bellows and remote bulb for sensing temperature; wood, hair, or membrane for sensing humidity; and bellows, bourdon tube or diaphram for sensing pressure. Controlling elements transduce the measured variable into a control signal and may consist of a nozzle and flapper or supply and exhaust valve relay. Controllers can do two other functions. By attaching a pointer to the sensing element the controller can now indicate and/or record controlled variable values. Figures 9b and 10b illustrate two different types of temperature controllers. The three controllers that utilize these elements are the thermostat which controls temperature, the hygrostat which controls humidity, and the pressure regulator which controls static pressures.

Controlled devices are valves, dampers, and actuators. (See figures 29 a,b, and 30.) Valves can be of either the two-way or three-way type. Two-way can give modulation or complete shut off of the controlled medium or manipulated variable. The three-way valve mixes or diverts the controlled medium. Valves control the flow of liquids or gases such as water, oil or steam. Dampers are of three types: single blade, multi-blade or mixing. Single blade and multi-blade are self explanatory in that they have either one blade controlling air flow or many blades controlling air flow. Mixing dampers are usually constructed in two sections, with the sections in the same plane or at a 90° angle to each other. Usually one section is normally closed when the other is normally open. Mixing dampers are used to mix room return air and outside air. (See figure 30.) Actuators are used to move the blades of the dampers and plugs in valves.



COOLING TOWER CONTROL
Figure 28

The energy source of a pneumatic control system is the compressor. The controllers and controlled devices must have a form of energy in order to function. An auxiliary component is the relay. The relay and combinations of relays form numerous functions that otherwise could not be achieved. Pneumatic relays can modify a control signal or control signals by switching, selecting, averaging, low limit, high limit, differential pressure, advancing, retarding, amplifying, reversing, balancing and positioning. Other auxiliary components are fire or freeze detection thermostats, sail switches, flow switches, programmers, electro-pneumatic valves, pressure-electric switches, step controllers, etc.

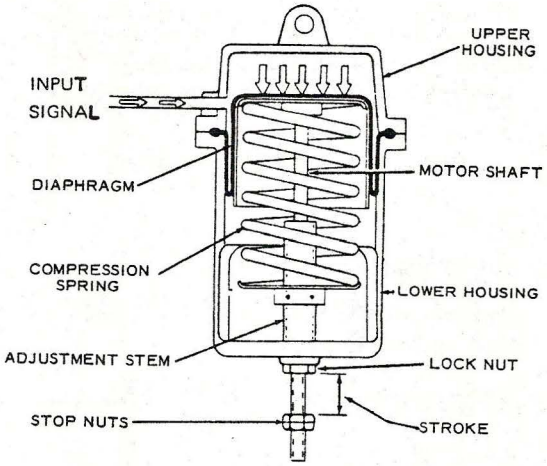


Figure 29A - Damper Motor

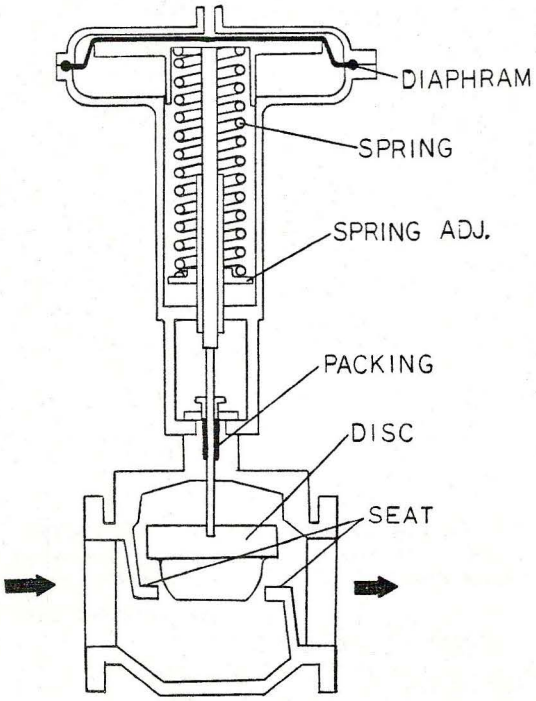
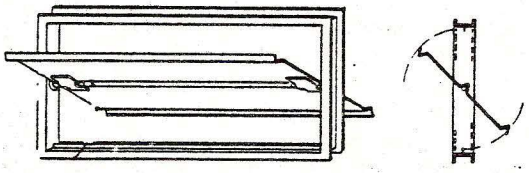
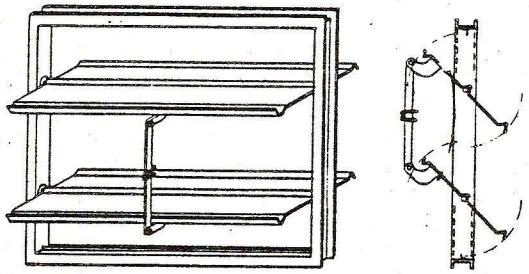


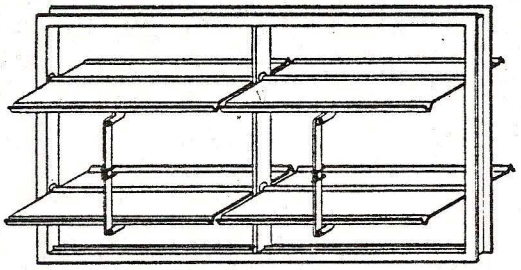
Figure 29B - Pneumatic Valve



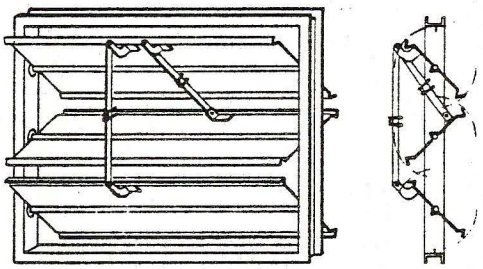
Single Blade



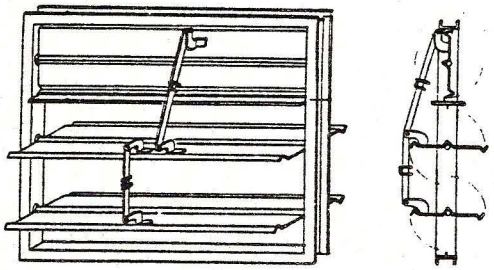
Multi-Blade



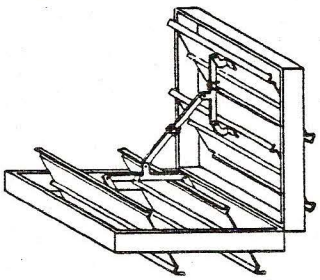
Multi-Blade-Multi-Section



Multi-Opposed Blade



Common Plane Mixing



Right Angle Mixing

Figure 30 - Dampers

Control devices are combined to make a system. Each control device is mechanical in nature and all mechanical components must be regularly serviced to optimize their operation. All Powers branch offices offer service contracts that will insure you continuous, trouble-free system performance.

For Further Information Contact Your Nearest Powers Representative