PID VERSUS ON-OFF CONTROL, WHY USE A VALVE POSITIONER?

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A discussion of the elements of a process control loop as specifically related to lumber dry kilns must delve into such subjects as PID versus On-Off control, valve characteristics and the use of valve positioners, and various types of temperature measuring elements employed in the lumber industry.

The function of a control loop is to maintain a process output (or product) at some desired value, for example, a certain type of wood at a specified moisture content. The type of control loop historically employed in lumber drying is a feedback loop where, ideally, if we could, we would measure the moisture content of the wood product and feed that measurement back to a control device. That device would compare the measured moisture content to the desired moisture content and would produce a controller output to a final operator - a valve. The valve would in turn regulate the flow of energy entering the kiln which would drive the measured moisture content to the desired moisture level.

The four components of this loop are, therefore, the measurement, the automatic controller, the final operator, and lastly the process itself.

MEASUREMENT

While we're most interested in the control of moisture content in lumber drying, that variable is almost never directly measured and fed back to the automatic controller. Instead we measure air temperature or differential temperature, or wet- and dry-bulb temperatures and those variables becomes the controlled variables. In some cases, moisture content is inferentially calculated and controlled.

Early automatic dry kiln controllers employed filled thermal systems to measure and control both wet- and dry-bulb temperatures (of the air) within dry kilns. Such temperature measuring systems are still in widespread use. More recently, thermocouples and resistance temperature detectors (RTD's) are being employed, in part due to their inherent electronic characteristics as opposed to the purely mechanical nature of filled thermal systems.

All three types of measuring elements cover a wide range of temperatures and it can rightly be assumed that any one of the three would provide a measurement that could be used for dry kiln control (See Figure #1). Each has its advantages and disadvantages, however, as this comparison indicates (Figure #2). The practical limits, accuracies, and response figures may vary somewhat from supplier to supplier. These figures are, however, representative.

Figure #3 compares the accuracy of a type "J" thermocouple to a platinum RTD, both measuring a temperature range of 0 to 1000 degrees F. In the normal lumber dry kiln operating range, 0 to 300 degrees F, the filled thermal system's accuracy would be approximately ±2.5 degrees, the RTD ±0.75 degrees, and the thermocouple ±2.25 degrees.

A comparison of response curves (Figure #4) shows that Class II filled thermal systems are quite responsive to changes in temperature as are RTD's.

Small gauge thermocouples also exhibit very rapid response characteristics.

Speaking for one controls supplier, platinum RTD's are recommended for all dry kiln applications and if temperature differential measurement is a consideration, matched RTD's are required because of their better accuracy.

CONTROL MODES

Shifting our attention to the second element in the control loop, namely the automatic controller, it's well to keep in mind that the ultimate objective of the control system is to dry lumber to some measurable end point in the shortest possible time without causing damage to the wood.

Shinskey's process model on drying was based on the principle that the dryer air temperature is reduced proportionally to the evaporation of moisture as the air passes over the material being dried. It's also accepted that the wet-bulb depression creates a driving force for moisture transfer. The air dry- and wet-bulb temperatures, since they can readily be measured, have therefore been the customary controlled variables. The manipulated variable is steam flow, and the process loads include the wood and air with their associated moisture.

Again, looking back on early kiln control, On-Off controllers with On-Off or two-position valves were employed on the steam, spray, and damper operators. On-Off control is the simplest form (or mode) of feedback control, the other basic modes being Proportional, Integral, and Derivative (or PID).

Figure #5 shows the operation of an On-Off controller and an On-Off controller with a "Dead Band". Note that in both cases the valve is always either completely open or completely closed and that the measurement cycles constantly. The only difference in the operation of these two controllers is the difference in the frequency and amplitude of the measurement cycle.

The principal disadvantage of On-Off control is that its normal condition is constant cycling. Its principal advantage is that it's low in cost, that is the controller and valve are usually inexpensive. On-Off control, in fact, does not even require a controller as the controller function can be created with contacts and relays or other such devices.

Whether or not On-Off control is acceptable depends on the effect of cycling in the measured variable both on the product and on upsets to other process units. Constant open-to-shut cycling of steam valves, no matter what their characteristics, is disruptive to boiler houses and steam headers, not to mention damaging to the valves themselves. Constant cycling of the measured variable, namely wet- and dry-bulb temperatures, if large enough, no doubt contributes to poor quality in the final product. Early On-Off kiln controllers found acceptance probably due to the fact that most of them possessed a small amount of dead band and we simply were not doing as good a job of drying as we are today.

On-Off control should only be applied to those situations where three conditions are present - namely:

1. Precise control must not be required because the measurement will constantly cycle.

2. Deadtime in the process must be long enough to prevent excessive valve wear and upset of other process units, and

3. The ratio of dead time to the time constant of the process must be small so as to prevent too large an amplitude in the measurement cycle.

Experience has shown that lumber kilns do not exhibit these conditions at all times and a degree of proportional action is required for good temperature control and valve operation. Proportional control, based on the principle that the size of the controller response should be proportional to the difference between the control point and the measurement value, prevents valve and measurement cycling. It is a major improvement over On-Off control because of its ability to stabilize the loop. Its main disadvantage is its inevitable offset, but in kilns where loads are fairly constant and the required amount of proportional control is small, offset is not a problem. The control point can be adjusted until the measurement is at the desired value and thereafter the set point is simply a reference point for proportional action.

Except in digital control, Integral and Derivative modes of control are rarely if ever used in lumber drying operations. Virtually all modern controllers, digital and otherwise, possess the ability to incorporate PID control into various control schemes and in many systems the values for P, I, and D are automatically determined through the use of self-tuning algorithms.

FINAL OPERATORS

No controller with whatever control modes will control properly, however, if the valve is sized improperly, leaks, sticks, or is otherwise defective. The selection of a valve, therefore, with the proper operating characteristics is one of the most important phases in designing a control loop.

Kiln heating and spray control valves must work in concert with the process and its piping as well as the steam supply source. The control valve, in order to provide consistent control, must contribute a certain increment of the total system pressure loss. That increment is usually arbitrarily set at from 25 to 35% of the total system loss.

Most procedures for selecting and sizing control valves begin with inlet and outlet pressures, both of which rarely if ever remain constant. Valves are usually selected "later" and are often selected ignoring those factors key to optimum performance of the process.

As already noted, early kiln controllers were usually of the On-Off variety and On-Off control valves were appropriately employed with those controllers. Cost was and is still of paramount importance to many people and as a result many kilns today are equipped with the less expensive On-Off valves even when the type of controller and indeed the process itself dictates otherwise.

Basically, the control valve (Figure #6) consists of two major components, the diaphragm operator and the valve subassembly. The actuator should position the inner valve positively and quickly for any change in the controller output. The valve action, either air-to-open or air-to-close is determined by the process.

There are two basic categories of control valves, namely two-position or On-Off in which the inner valve opens or closes completely to a response in signal from the controller, and proportioning valves which provide a proportional response to a change in signal from the controller.

It is well to note that any proportional valve can be used as an On-Off valve but the opposite is not true. Some quick opening valves do provide a degree of proportional control but in actual installations are generally unsatisfactory as proportioning devices.

Figure #7 shows the flow versus lift relationship of On-Off, linear, and equal percentage control valves, each at conditions where the pressure drop across the valve is held constant. An equal percentage valve is so designed that all openings of the valve will produce equal percentage changes in flow for equal incremental changes in lift or stroke. For example, an equal percentage valve that will pass 5 GPM at a 20% opening and will pass 7.5 GPM at 30% opening, will pass 11.25 GPM at 40% opening. In other words, each 10% increase will result in a 50% increase over the previous flow rate. The equal percentage valve provides wide rangeability and permits the use of constant control settings under varying pressure drop conditions.

Linear valves are so designed that all openings of the valve will produce equal change in flow for equal incremental changes in lift. For example, if at 20% of its stroke a linear valve will pass 10 GPM, at 30% it will pass 15 GPM, at 40%, 20 GPM and so forth. The linear valve characteristic provides a fairly wide rangeability, though not as wide as the equal percentage valve, and under most circumstances will permit use of constant control settings when the pressure drop across it remains constant.

In actual practice, however, a valve has two characteristics. One is the design characteristic (just discussed) and the second is the installed characteristic - the latter being the most important. The installed characteristic is the relationship between flow and stroke when the valve is subjected to the pressure conditions of the process. Figure #8 shows the relationships for both linear and equal percentage valves under varying pressure drop conditions. Note that as the ratio of minimum operating pressure drop to maximum operating pressure drop becomes more extreme, the installed characteristic of the equal percentage valves becomes more linear, or in other words the valve gain approaches a constant. The linear valve, on the other hand, becomes less linear and its curve is distorted toward that of an On-Off valve. Consequently, when these conditions are encountered, an equal percentage valve is usually chosen, explaining its predominant use over linear valves in industrial applications.

A rule of thumb for permissible limits for the installed gain of a valve is that a change in gain larger than 2 or a relative gain smaller than 0.5 should be avoided in the process operating range. If the gain is too high or too low, or if it changes too much in the operating range, process control will become very difficult.

The question relative to the use of valve positioners is frequently asked. A valve positioner is a device used on or in conjunction with a valve operator to overcome valve stem friction and accurately position the valve in spite of any unbalanced forces within the valve body. A positioner may also be used to alter valve characteristics, as for example to give a linear valve the characteristics of an equal percentage valve or perhaps to alter the valve characteristics in response to a non-linearity in the process. It is used to close the loop around the valve actuator or valve motor and it will drive the motor until a mechanical measurement of the valve stem position is balanced against the input signal from the controller - in other words the valve is positioned where it's supposed to be in accordance with the signal from the controller.

Since a positioner will act to overcome stem friction, it thereby eliminates or greatly reduces dead band. It has been demonstrated that a positioner forces the valve gain closer to unity or at least a constant value which simplifies the control problem. In general it may be stated that a valve positioner will be helpful in every kind of control loop with the possible exception of the control of flow or liquid pressure.

SUMMARY/CONCLUSIONS

While this short discussion of temperature measurement, control modes, and control valves has barely touched on these subjects, some general conclusions and recommendations are suggested.

With regard to temperature measurements in kilns, both wet- and dry-bulb, the use of platinum resistance temperature detectors (sometimes matched), is recommended over both thermocouples and filled thermal systems.

In general, the type of control recommended is a form of narrow band Proportional control for purely analog systems with the possible addition of Derivative to narrow band Proportional in digital system control.

Finally, the use of equal percentage valves is recommended for virtually all temperature control. As extra insurance against valve sticking and to overcome unforeseen pressure imbalances, the valve may be equipped with a positioner.

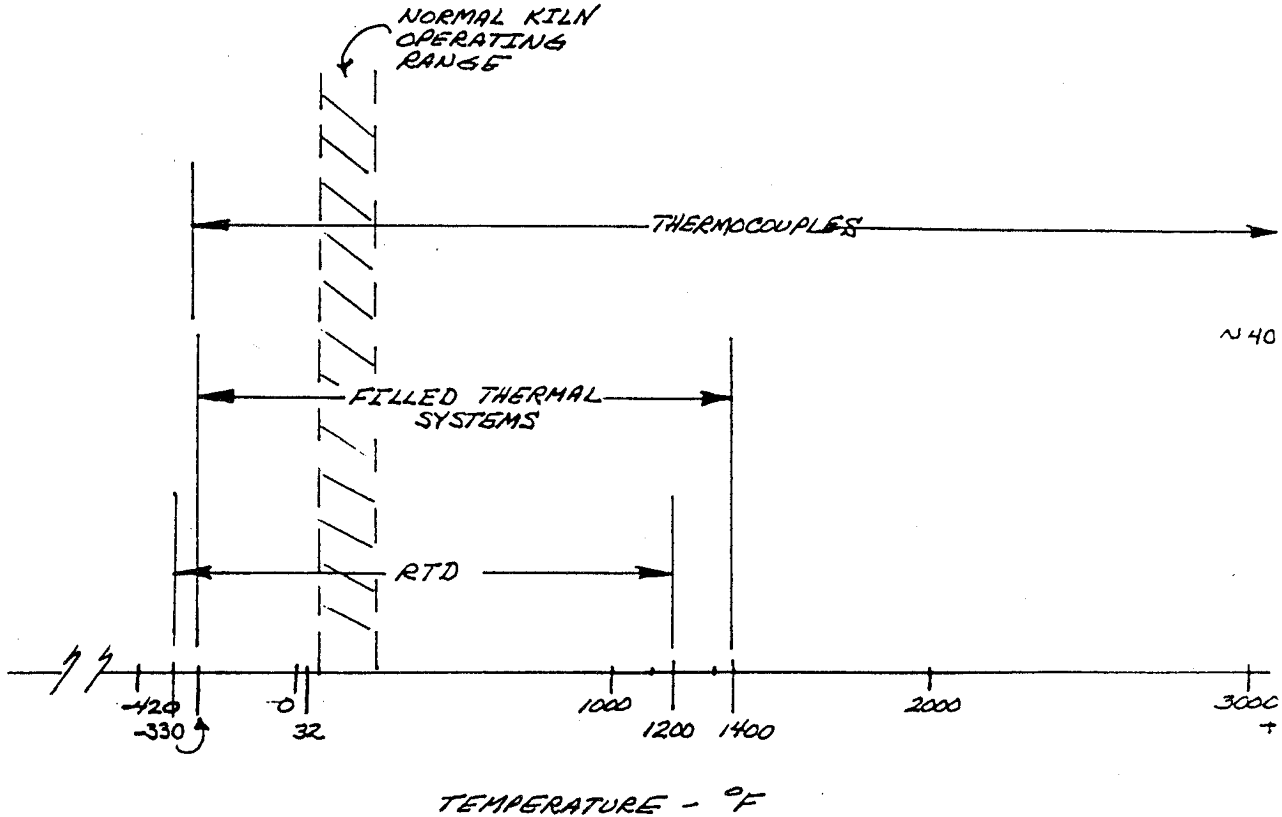
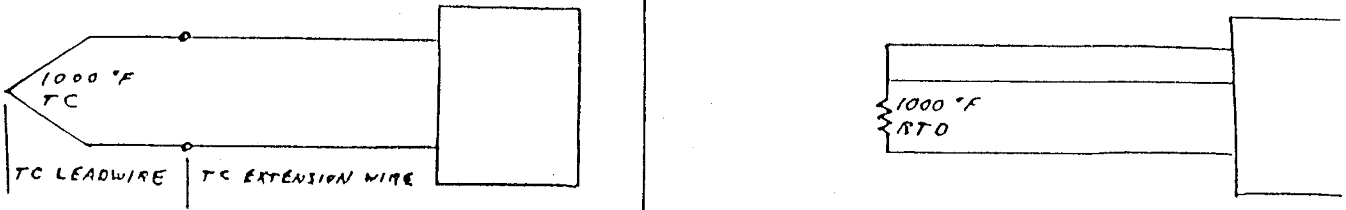


Figure 1. Temperature ranges for various sensor types.

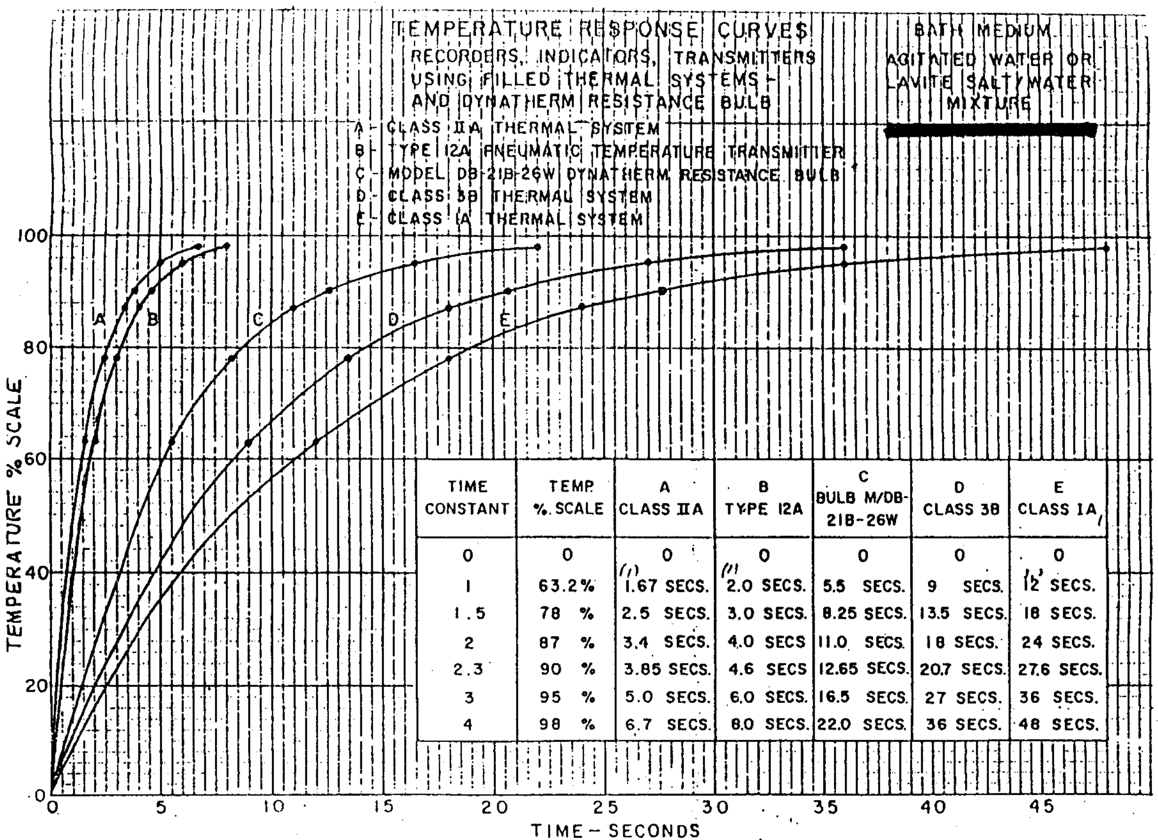
MEDIUM	PRACTICAL LIMITS (^{o}F)	LINEARITY	ACCURACY	COST	ADVANTAGES	DISADVANTAGES
GLASS STEM THERMOMETER	-200 TO +600	GOOD	0.1 TO 2F	LOW	- LOW COST - LONG USEFUL LIFE - SIMPLICITY	- DIFFICULT TO READ - FRAGILE - LOCAL RESTRICTED - NO RECORD/CONTROL
FILLED SYSTEM	-320 TO +1400	FAIR/GOOD	0.5 TO 2%	MED	- NO POWER REQUIRED - HI RELIABILITY	- CAPILLARY RESTRICTED (150 FT., CAN NOT CUT) - SENSOR/REC'R POSITION - RANGE CHANGE DIFFICULT - VERY LARGE - NO MULTIPLEXING - MINIMUM SPAN IS 54^{o}F
RTD	-330 TO +1200	GOOD	0.3F	MED	- HIGH ACCURACY - HIGH SIGNAL LEVEL - LONG TERM STABILITY - COMPENSATED - NO SPECIAL LEADWIRE - NO COLD JUNCT. REQ'D - WORLDWIDE STANDARD	- FRAGILE - GENERALLY LARGE - SELF HEATING - HIGHER COSTS
THERMO-COUPLE	-330 TO 4000	POOR/FAIR	4F	MED	- HIGHER TEMP - MORE RUGGED	- TEMP. COMPENSATION - TC EXTENSION WIRE - LONG TERM STABILITY
PYROMETER	0 TO 7000	POOR	0.5 TO 2%	HIGH	- NON CONTACT - SPOT OR AVERAGE - PORTABLE, SELF CONTAINED	- EXPENSIVE - USED ONLY FOR HI TEMP - VERY NON LINEAR - EMISSIVITY AFFECTED - REQUIRES OPERATOR

Figure 2. Advantages and disadvantages to different temperature measurement methods.



1.	Hot Junction ±.75% x 1000°F	=	±7.5°F	1.	RTD Accuracy ±0.5% x 1000	=	±5.0°F
2.	TC Wire Cold Junction 100°F	=	±4.0°F	2.	Lead Wire Error ±0.1% x 1000	=	±1.0°F
3.	Ext. Wire Hot Junction 100°F	=	±4.0°F				
4.	Ext. Wire Cold Junction 72°F	=	±4.0°F				
5.	Cold Junction Compensation	=	±2.0°F				
	Total Max		±21.5°F		Total Max		±6.0°F
	Total RMS		±10.4°F		Total RMS		±5.1°F

Figure 3. Accuracy of thermocouples versus RTDs.



TIME CONSTANT	TEMP. % SCALE	A CLASS IIA	B TYPE 12A	C BULB M/DB-21B-26W	D CLASS 3B	E CLASS IA
0	0	0	0	0	0	0
1	63.2%	1.67 SECS.	2.0 SECS.	5.5 SECS.	9 SECS.	12 SECS.
1.5	78 %	2.5 SECS.	3.0 SECS.	8.25 SECS.	13.5 SECS.	18 SECS.
2	87 %	3.4 SECS.	4.0 SECS	11.0 SECS.	18 SECS.	24 SECS.
2.3	90 %	3.85 SECS.	4.6 SECS	12.65 SECS.	20.7 SECS.	27.6 SECS.
3	95 %	5.0 SECS.	6.0 SECS.	16.5 SECS.	27 SECS.	36 SECS.
4	98 %	6.7 SECS.	8.0 SECS.	22.0 SECS.	36 SECS.	48 SECS.

Figure 4. Response times for various thermal systems.

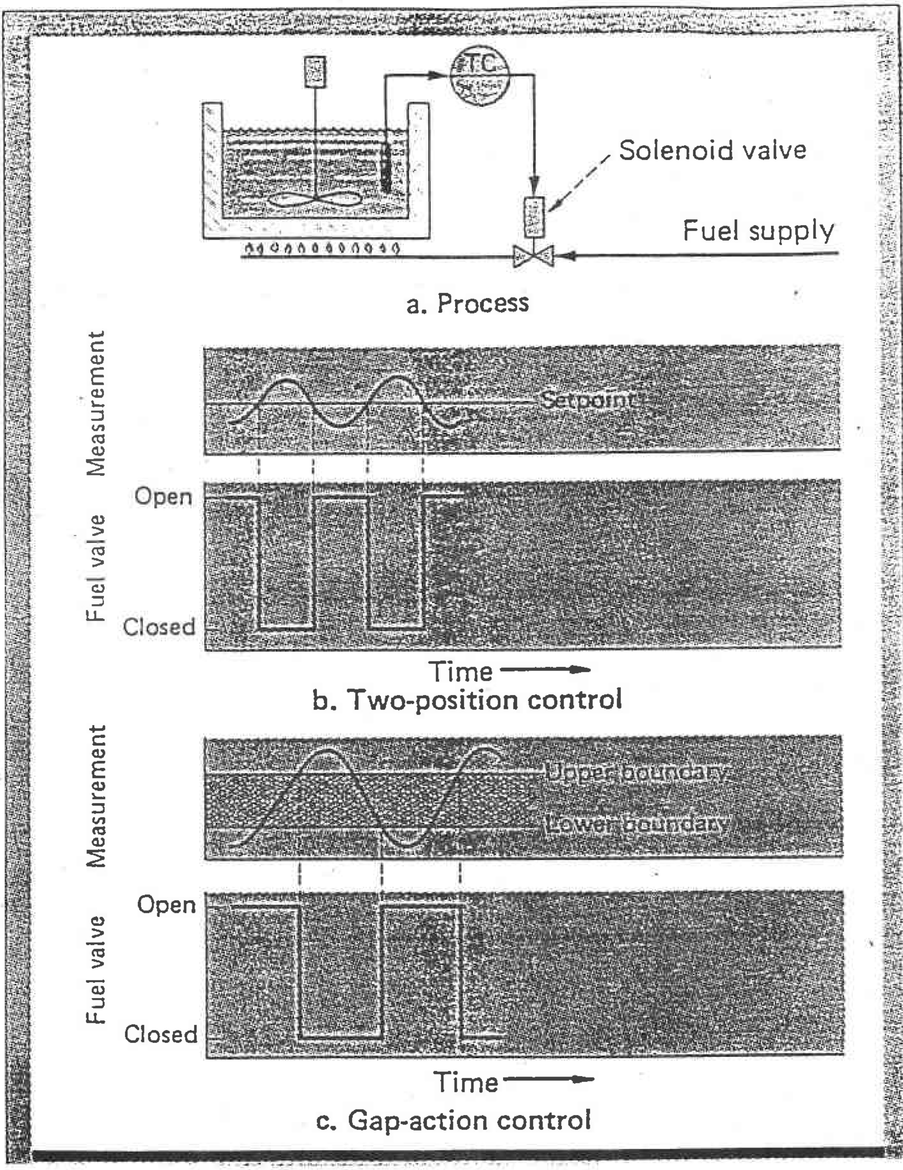


Figure 5. On-off control for temperature control of a system.

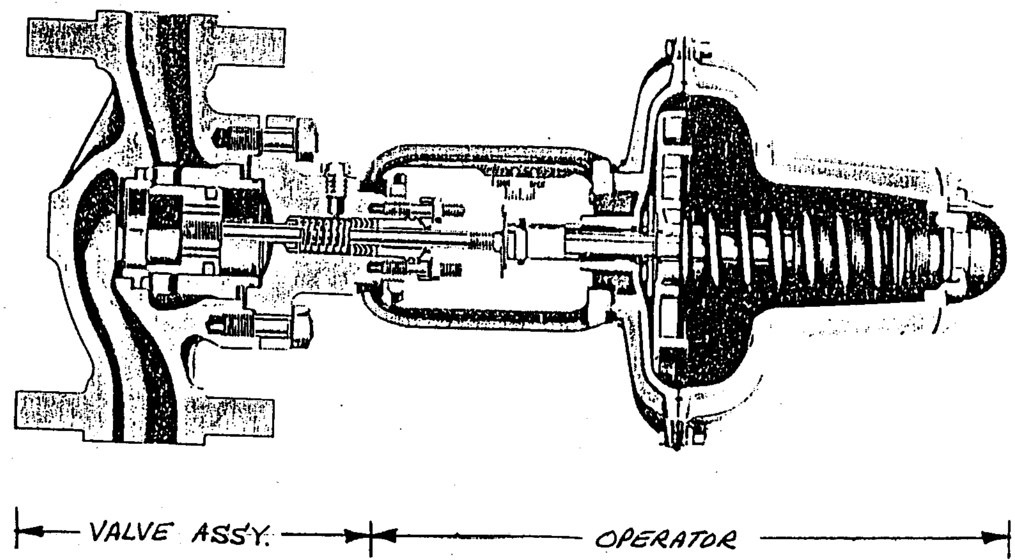


Figure 6. Valve with operator.

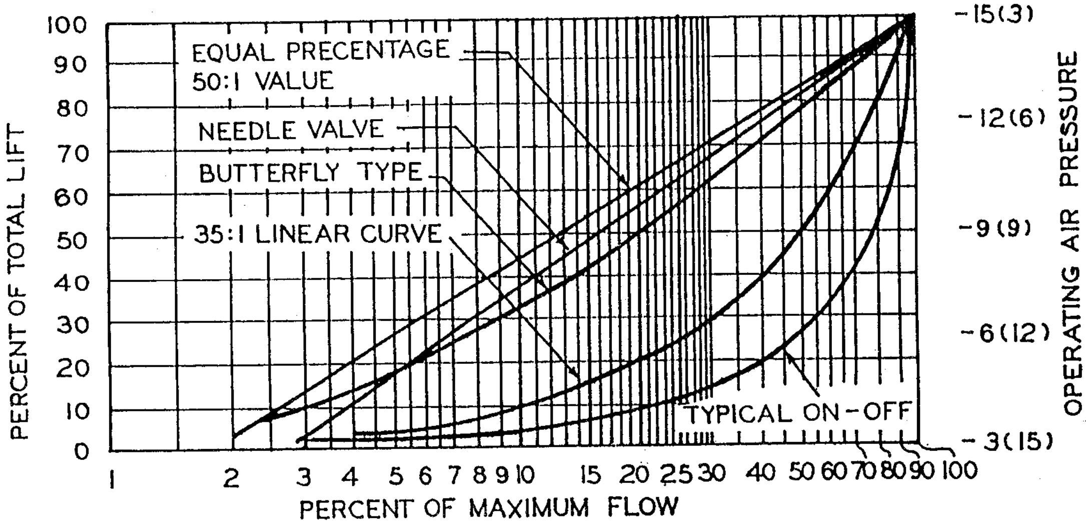


Figure 7. Signal to valve versus flow.

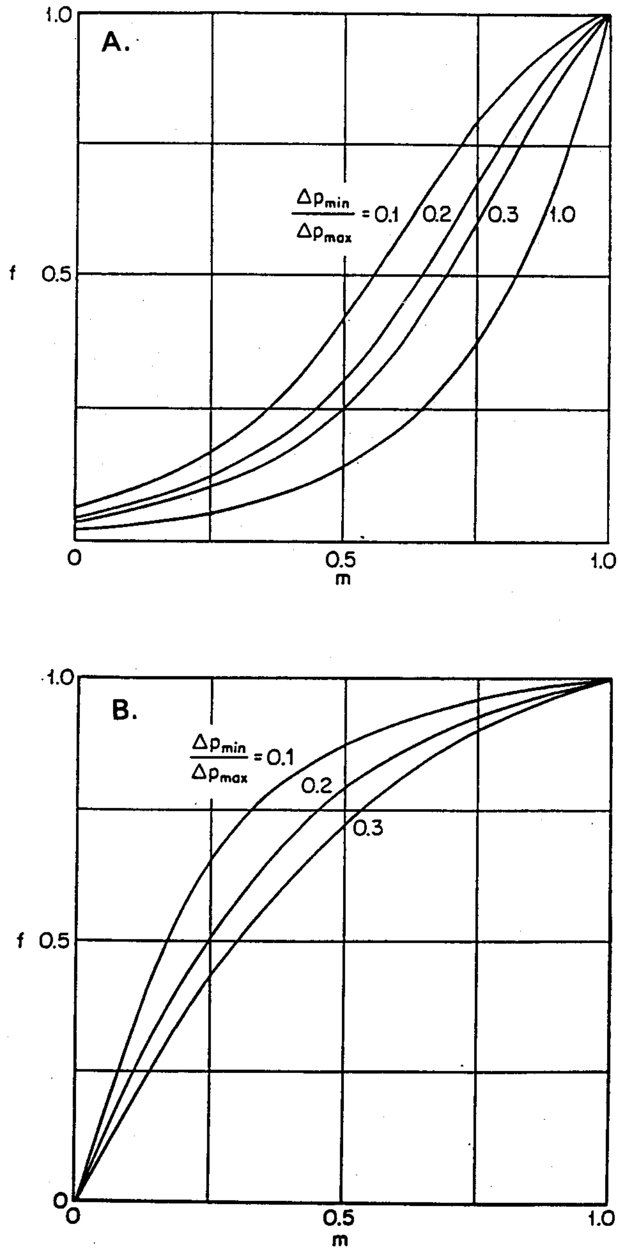


Figure 8. Effect of line resistance. A. an equal percentage characteristic becomes more linear. B. A linear characteristic distorts toward that of a quick-opening valve.