# Final Control Elements. The devices that modulate process heat

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These are the devices that obey the controller output and provide the muscle to modulate the process heat. That means turn it up and down. Although on/off devices figure prominently in power modulation we will ignore their use in on/off control which does not count as modulation. We start at the point where they perform time-proportioning action.

**Electric heat**

A separate article deals with time-proportioning control of electric heat, cycle time, feedforward and line voltage compensation. From that point we move on to compare common switching devices.

**Magnetic Contactors**. Energisation of the operating coil pulls in the magnetic core that actuates the contacts. The coil takes typically 120Vac and could consume anything from 10 to 200VA depending on the size of the contactor. A typical contact arrangement is 3 normally open + 3 normally closed contacts. Rating can go to some 200A at 600V ac. Optionally you can have an auxiliary low current contact for control or logic functions. Because of the erosion damage caused by frequent switching of high currents, the contacts are usually designed to be replaceable. This type of contactor can be clunky and somewhat noisy but is economical in first cost. To conserve service life, cycle times faster than 10 seconds are not recommended.

**Mercury Displacement Contactors**. The coil takes typically 120V at about 50VA. This operates a plunger that raises the level of mercury in a sealed capsule to bridge a pair of contacts.

One, two and three-pole normally open models are available with a common coil or with one coil per capsule. Operation is silent and a long reliable life is obtained. You will need to evaluate any environmental hazards on disposal or in the event of ruptured capsules, especially if used in a food or container plant.

**Solid-state Contactors**. In place of a coil there is a logic circuit which can take 120Vac or low voltage dc. Cycle time can be as short as a half cycle of the ac supply. There is no wear-out mechanism related to number of operations. You can operate fast responding heaters which are beyond the reach of magnetic contactors. Ratings usually go from 10A to 1000A at up to 660V ac. Unlike metal to metal contactors you need to allow about 1 watt per ampere when sizing an enclosure for heat dissipation.

If your process allows you a choice of heater voltage, higher the voltage means you go correspondingly lower on current. This reduces heat dissipation and heat sink size.

The control logic signal wires can double as a data route to feed back such signals as: heater current value for readout, faults such as heater on when logic called for turn off (danger) and heater current low or off when logic called for turn on.

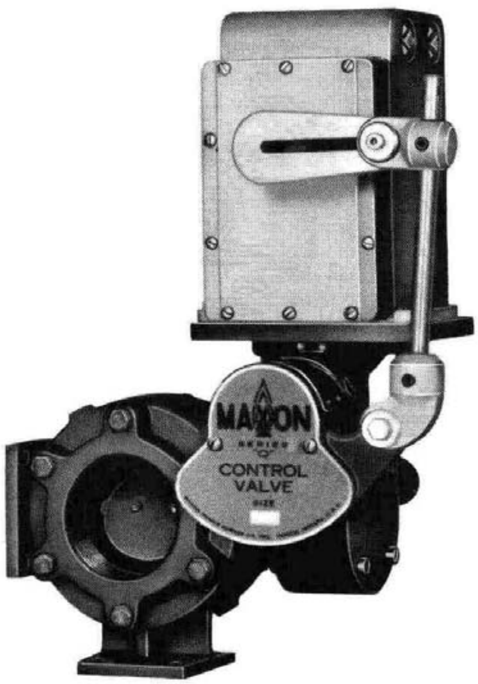
This class of device, the silicon controlled rectifier, can have many other features and firing modes such as smooth phase-angle control. This topic would fill a separate article so will not be covered here.

**Gas and fuel-oil heating**

Time proportioning control is also applicable here, using a solenoid valve or an equivalent on/off valve or burner contactor. As with electric heat, power can be modulated in a precise linear manner following control signal as the controller adjusts t/T (on-time/cycle-time). This gives two advantages. Control loop gain, therefore control loop stability, does not change with power output as might be the case with a throttling valve. Optimum fuel/air ratio can be maintained since you don’t have to cope with a range flow rates.

Note that OFF here usually means LOW FIRE and ON means HIGH FIRE. This avoids the purge and ignition cycle that follows a period with the burner off.

**Steam or heat transfer fluid**
Time-proportioning is equally applicable to delivery of heat by steam or heat transfer fluid. Note that these heat sources need to be reasonably stable in pressure and temperature in order to avoid changes in control loop gain.




Electric Motor Actuated


Air Diaphragm Operated

**Two gas control butterfly valves with adjustable cam linearisation**

**DEVICES THAT USE POSITION CONTROL**
**Control valves**. Flow of gas, air, oil etc depends on rotation for butterfly valves, ball valves and dampers and linear travel for plug- and-seat valves. You can readily convert torque to linear thrust and vice versa.
Flow/position relationship is often crude in the face internal valve geometry, linkage design, friction, backlash, pressure and mixing method. To preserve control system gain, therefore stability, try to ensure that flow (translating to delivery of heat) is reasonably proportional to the control signal. You can achieve this by using valves having cam linearisation. Bear in mind that some processes are very tolerant of low cost, crudely responding devices and still remain stable.
**VALVE ACTUATORS**
**Spring opposed pneumatic diaphragm actuator**. Advantage; high thrust, equal to the diaphragm area times the air pressure. Pressure, typically 3 – 15 PSI, could be more. This would often come from a current/pressure (I/P) converter whose 4 – 20mA input comes from the temperature controller. For precise positioning you can add a pneumatic or an electropneumatic positioner.

Analyze the hazards of air pressure failure and/or loss of controller power. Process safety may demand air-to-close or air-to-open the valve; or current to close or current to open.
Consider whether the controller should have upscale or downscale sensor break action. A sensor break can send the indication upscale and turn the heat off or downscale putting the heat on.
Electric actuators. The constant speed, single phase, reversing, induction motor is very common and economical. It has two windings connected together at a common terminal. You energize one winding for forward and the other winding for reverse rotation. The non-common ends are joined by a capacitor so that the winding not energized receives a phase-shifted current when its partner is energized. This determines the direction of rotation.

The stroke (rotation) is usually limited to 160°, adjustable down to 60°. The motor is geared down to a stroke travel time of typically 15 to 60s with torque about 150 lb-in (17N-m). Adjustable switches on the motor limit the travel at each end of the stroke.

**Position mode (bounded control)**

In this mode, a feedback potentiometer working with the controller's output signal makes a servo control loop within the overall temperature control loop. The motor shaft is positioned proportional to the control signal.
Note: if the potentiometer fails or has a faulty wiper or wiring, control will fail. The feedback signal can also drive a meter or digital display showing shaft position from which you infer valve position.

**Velocity mode (boundless control)**

You can get good temperature control without the potentiometer and servo loop. The controller simply detects deviation from set point and pulses the motor in a time proportioning mode to move the valve in a direction to minimize deviation. This makes the average velocity of travel proportional to temperature deviation thus providing integral action in the control loop.
You can still make good use of a potentiometer. First, to show valve position to the operator. Second, to let the controller put top and bottom limits on position, these settings being adjustable at the controller.

**Manual control**

With position mode the operator or an external signal can set the valve to any desired position. If this is a requirement at some stage of your process you should go with position control.
With velocity mode the operator would have to press OPEN and CLOSE buttons until he sees valve the come to the desired position.
Controllers are now available which work in position mode and switch to velocity mode if the potentiometer or feedback wiring fails.

**Motor linkages**

A butterfly valve would have a crank arm linked to another one on the motor shaft.
You can vary linkage geometry and adjust cam profiles to reduce non-linearities of the angle/flow relationship and to define the zero and span of the stroke. Some zero/span adjustment can be done very handily at the controller.

**Blower speed control**

In controlling air flow it is quite common to use a blower driven by a constant speed induction motor then throttling the flow with a valve or damper. The motor can waste a lot of energy. A variable speed ac drive can do the same job without valve or damper, reducing your electric bill and often using the same motor.