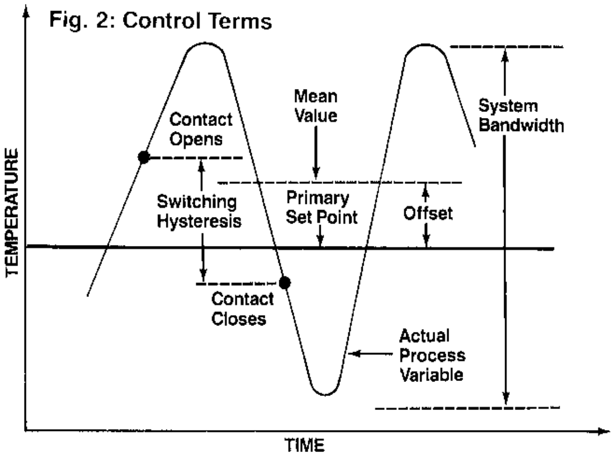
FACTORS EFFECTING SYSTEM ACCURACY

A product within acceptable quality tolerances with lowest possible scrap levels are the ultimate measures of system accuracy. Generally, a constant mean temperature and the system bandwidth determine accuracy. The system bandwidth is the temperature variance measured at the work *(Fig. 2)*. Several factors affect the accuracy of the system.

Fig. 2: Control Terms



Thermal Lag is the time delay for a temperature change in one part of the system to be recognized in another part of the system. As power is applied to the heat source, a temperature rise will occur in the transfer medium in the area of the heat source, and then flow to other parts of the system. The Temperature Gradient is the range of temperatures at different locations in the system measured at the same time. Both thermal lag and temperature gradients are influenced by the conductivity of the transfer medium. Conductivity is the measure of the rate at which heat travels through a medium. See Chart 11T.

Cost considerations, thermal properties, availability and the application determine what material is most practical for use as a heat transfer medium.

The application will also determine what method of heat transfer is most practical. Conduction takes place in solids, liquids and gases, and is the transfer of heat from one material, at a given temperature, to another material at a lower temperature while in direct contact with each other.

Natural convection occurs in a liquid or a gas when heat is generated from the source causing the surrounding mass to become warm and expand. The mass decreases in density (becomes lighter), mixes with and warms the cooler mass. Forced convection can be produced by mechanically mixing the warm with the cool mass.

The transfer of heat from one body to another by emitting and absorbing radiant energy is the third method of heat transfer. No transfer medium is required, for an electromagnetic wave phenomena similar to light carries energy from a radiant heat source, passes some distance through the surrounding space to the work. The work absorbs the radiant energy and converts it to molecular-vibration heat energy. An oven utilizing tubular heaters may receive heat by all three methods. See section on Process Infrared Heating.
The following heat transfer medium comparison list is in order of descending preference:

Well agitated liquids
Rapidly moving gases
High conductivity metals
Low conductivity metals
Stagnant gas
Stagnant liquid

Temperature gradients can be observed by measuring the temperature at different points in the thermal system at the same time. Starting at the heat source, the temperature would decrease progressively as you move to the edge. Every thermal system has a gradient at all times because of heat source cycling and heat losses. These changes are not transmitted or compensated for immediately throughout the system. Some gradient is necessary for heat flow, since heat can only be conducted, convected or radiated to areas lower in temperature.

Also inevitable in every system is the delay in the distribution of heat. Thermal Lag is influenced by the distance between the heat source and the work and the heat conduction capacity of the transfer medium. Thermal Lag delays information about temperature changes in the system to the control. This delay can prevent the control from sensing a need for heat soon enough, resulting in temperature undershoot. Thermal Lag can also delay the arrival of heat at the work long enough to where the heat source has produced more than what is required, producing temperature overshoot. Both overshoot and undershoot can create too large a system bandwidth, and unsatisfactory control.

Temperature gradients and thermal lag exist and are necessary to an extent as stated, but can be reduced for more accurate control. Applying as much insulation as practical to reduce heat losses from the system is the first step.

The location of the heat source and control sensor relative to the work can produce a wide range of accuracies. It is ideal to group these components in a compact area. The short distance from the heat source and control sensor to the work would enable heat requirements to be detected and responded to quickly producing the ultimate system bandwidth and a constant mean temperature *(Fig. 5a)*. As this placement is often not practical due to the size of a system, a compromise in the placement of the component is necessary.

Maintaining a narrow bandwidth may be important in processes which are being heated close to decomposition, vaporization or other critical points. A narrow bandwidth does not guarantee perfect control, however, since the mean temperature can drift (offset or droop) *(Fig. 2)*.

Where the heat demand is variable, the best results can be achieved by placing the control sensor closer to the work. The difference between the heat source and the control sensor is significant, causing thermal lag and sizable temperature overshoot at the work. The control selected should have compensating features (PID) for this situation *(Fig. 5b)*.

Where the heat demand is steady, the sensor should be placed closer to the heat source. The short distance between the heat source and control sensor will allow minimal thermal lag and reduced potential for temperature overshoot and undershoot. Temperature changes are quickly detected *(Fig. 5c)*.

When a system is both steady and variable, placing the sensor mid-way between the heat source and the work will reduce thermal lag. Some overshoot and undershoot will occur. For this arrangement, the control should also have compensating features (PID) *(Fig. 5d)*.

Matching the wattage requirement of the system with the capacity of the heat source will also help to achieve the best possible temperature control *(Fig. 6)*. When the desired operating temperature (set point) is reached, the heat source should be on 50% of the time. Heat loss from the thermal system, voltage fluctuations, changes in ambient temperatures, and other process upsets can also affect heat balance. Allowances need to be made for these factors when determining wattage requirements and the heat source.

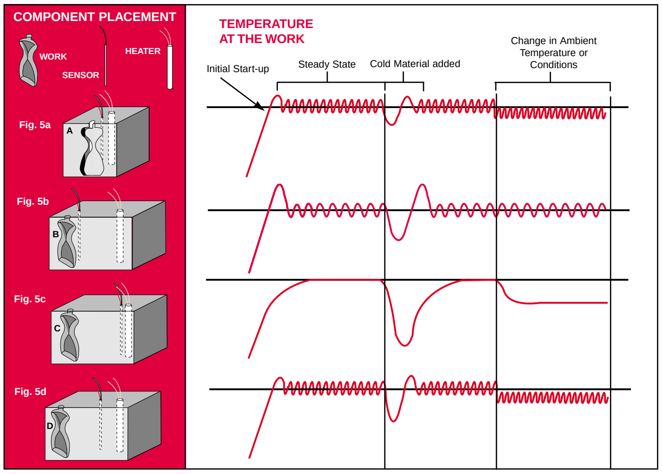
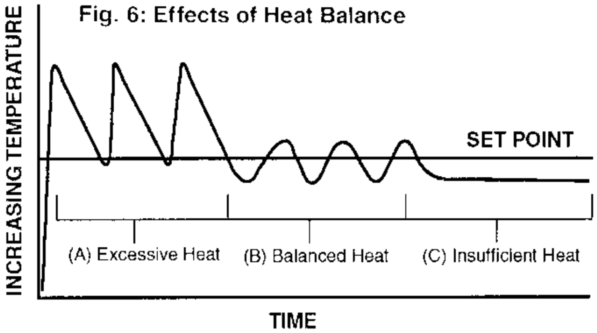


Fig. 6: Effects of Heat Balance



In general, if after system start-up the heat source is on more than 60% of the time, the wattage rating should be increased. If the heat source is on less than 40% of the time, the rating should be decreased. Heat conductivity is most efficient when good contact exists between the heat source and the material being heated. Rather than one large heater, several smaller rated heaters to better distribute heat throughout the system will further reduce temperature gradients *(Fig. 7)*.

Fig. 7: Effects of Distributed Heat Source