Application Note AN0713
Manual Setup of Control Parameters (PID)

1.) Introduction

Ex-Factory settings of control parameters provide excellent loop characteristics for most applications due to continuous self optimization of the bentrup controller. In rare cases adjusting control parameters manually might be advantageous. Some basic considerations are provided by this application note to support customers.

It is noted digital control loops and how to adjust parameters is a sophisticated topic subject of university courses; this brief overview is limited to very basic information. Parameters explained below are accessable by the configuration of your bentrup controller.

2.) In General

On heating devices once power is applied the increase in temperature is delayed as well as temperature rises for a short time after power cut off. These delayed reactions are caused by the lag of the heating device, air convection resp. temperature propagation and temperature acquisition. A properly adjusted control loop anticipates such physical restrictions and ensures smooth and steady, non oscillating temperature.

3.1.) Physical Limitations

Any optimization of a control loop should start to minimize the physical delays:

- Does the heating device affect the kiln chamber resp. unit as direct as possible? Optimize transitions by avoiding gaps or ensure direct radiation etc.
- Does temperature sensor acquire temperature as direct/quick as possible? Again, avoid additional (ceramic) covers, to fastest reaction tip of sensor should be exposed to heat directly.

Although digital control loops are getting smarter every day it is still recommended to optimize system design as outlined to set the base for best control results.

3.2.) Cycle Time

When using analog power control (e.g. thyristors) or fast switching solid state relays (SSR) you can skip this section.

On contactors requested power is converted into ON/OFF pulses. By default a cycle time of 30 seconds is set causing e.g. a 50% power demand to switch the contactor 15 seconds ON followed by 15s OFF. On slow reacting heating elements this ensures steady power. However, on high temperature devices or fast reacting heating elements (like infrared radiators or gas burners) it might be advantageous to reduce cycle time to 20 seconds or even lower. Indirectly this increases reaction of the control loop therefore improving temperature control.

Contactors lifetime is limited by roughly 500.000 cycles therefore cycle time should be set as short as necessary and as long as possible.

3.2.) Proportional Band (P)

Range in which temperature reduces from 100% to 0% when approaching setpoint temperature. Value is give in % of maximum adjustable temperature (e.g. P = 2.0%, T_{max}=1000°C resulting in 20°K control range). Minimize this value as far as possible. If the system oscillates proportional band is too low. Proportional band corresponds to 1 / loop gain.

For manual adjustment set Integral and Derivative time (I, D, as described below) to zero (causing to disable these parameters). Decrease P until system starts to oscillate then multiply value by about 1.5. Ensure typical operating temperature and kiln filling during this process.

Higher temperatures and small kiln load decrease optimum P value.

A large proportional band delays the temperature to approach setpoint, also consider at I = 0 (deactivated integral time) it is not guaranteed the setpoint is reached.

3.3.) Integral Time (I)

Time in seconds the control loops uses to eliminate deviation in the Proportional Range (see 3.2.). Similar to the Proportional Band a short Integral Time causes the system to oscillate. After having determined Proportional Band start with a time of 200 seconds and reduce until system starts to oscillate. Multiply time by 1.5

Keep in mind that actual time required to eliminate deviation is higher than configured time since it refers to full proportional band deviation.

3.4.) Derivative Time (D)

Derivative Time (D) in seconds can be seen as the time temperature will increase after immediate power off. It is used by the control loop for forecast the excess in temperature expected. Typically this time is set to 10 seconds.

Use caution when entering large values especially if temperature measuring is unsteady. This will cause the control loop to bounce back and forth even on small temperature moves. Do not try to fully compensate increasing temperatures e.g. on kilns at low temperatures since they tend to increase temperature for several minutes after power off.

Derivative time is designed to reduce power on a step response if a powerful heating device causes overshooting the temperature (and vice versa, e.g. if temperature drops below setpoint).

4.) Self Optimization

Some of our controllers provide a self optimization process option (see manual for details). During this procedure a step response and an oscillation is provoked. The controller logs temperature profile causing to calculate parameters P, I and D by the Ziegler & Nichols method.

Even if your bentrup controller provides this feature it is not necessary to do this procedure, it might be actually counterproductive depending on the circumstances of the process. Due to the continuous optimization of the control parameters during operation default ex factory parameter settings provide fairly good results in most scenarios.

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