UDC 3500 Application Note

Three Element Boiler Drum Level Control plus Pressure Compensation

Problem

Until recent years, only the largest boilers could justify sophisticated boiler controls. Now high fuel costs and occasional limited fuel availability make it necessary to improve boiler efficiency and minimize costly steam losses and disturbances. Drum level controls have become more important because boiler loads are being varied to meet needs, rather than operating at full capacity and wasting fuel and steam. The effects of pressure surges and steam flow on drum level dictate more complex controls on this important parameter.

Solution

Use of more advanced automatic controls on critical boiler control loops provides improved efficiency and stability under varying steam demands and eliminates the need for operator input to trim out load changes. Honeywell can provide a cost-effective drum level control system featuring the *UDC 3500 Universal Digital Controller* to meet these requirements. The package features:

- Pre-engineered compatibility
- Single source convenience
- Pre and Post-sale technical support
- Field Proven equipment
- On and Off-line configuration and alarms capability

Boiler Drum Level Control

The Steam drum is an integral part of a boiler. This vessel's primary function is to provide a surface area and volume near the top of the boiler where separation of steam from water can occur. It also provides a location for (1) chemical water treatment, (2) addition of feedwater, (3) recirculation water, and (4) blowdown which removes residue and maintains a specified impurity level to reduce scale formation. Because these functions involve the continual addition a loss of material, the water-steam interface level is critical.

Low level affects the recirculation of water to the boiler tubes and reduces the water to the boiler tubes and reduces the water treatment effectiveness. High level reduces the surface area, and can lead to water and dissolved solids entering the steam distribution system. The objective of the drum level control system is to maintain the water-steam interface at the specified level and provide a continuous mass balance by replacing every pound of steam and water removed with a pound of feedwater.

The interface level is subject to many disturbances, steam pressure being a major one. As steam pressure changes due to demand, there is transient change in level due to the effect of pressure on entrained steam bubbles below the steam interface level. As pressure drops, a rise in level, called swell, occurs because the trapped bubbles enlarge. As pressure rises, a drop in level occurs. This is called shrink.

There are three basic types of drum level control systems; single-element, two-element, and three-element. Their application depends upon the specific boiler size and load changes.

Drum Level Control Systems

The *Single-Element System* is the simplest approach. It measures level and regulates feedwater flow to maintain the level. This system is only effective for smaller boilers supplying steady processes which have slow and moderate load changes. This is because shrink and swell causes an incorrect initial control reaction. As steam demand increases, lowering the pressure, the drum level increases sending a false control signal to reduce feedwater flow when actually the feedwater flow should increase to maintain mass balance. More complex systems are required to handle significant shrink and swell effects.

The *Two-Element Drum Level Control* is suitable for processes with moderate load swings and can be used on any size boiler. The Two-Element Drum Level Control uses two variables, drum level and steam flow to manipulate the feedwater control valve. Steam flow load changes are fed forward to the feedwater control valve providing an initial correction for the load changes. The steam flow range and feedwater flow range are matched so that a one pound change in steam flow results in a one pound change in feedwater flow. The summer combines the steam flow signal with the feedback action of the drum level controller which makes trim adjustments in feedwater flow, as required, to compensate for unmeasured blowdown losses and steam flow measurement errors. The UDC 3500 can be placed into Manual mode to permit manual control of the feedwater valve.

Two-element control is adequate for load changes of moderate speed and magnitude, and it can be applied to any size boiler. It has two drawbacks which must be considered. It cannot adjust for pressure or load disturbances in the feedwater system and it cannot eliminate phasing interaction between the various portions of process because only the relatively slow responding drum level is controlled. If these disturbances are a concern, than three-element drum level control an correct the drawbacks

The *Three-Element Drum Level control System* adds a third variable, feedwater flow rate, to manipulate the feedwater control valve. This system basically cascades the summer output of the two element system to the Feedwater Flow Controller as a remote set point signal as shown in Figure. This system provides close control during transient condition because the two controllers provide independent tuning to minimize phasing interaction present in the two element approach.

The addition of the faster feedwater secondary loop assures an immediate correction for feedwater disturbances. The drum level controller accurately compensates for effects of smaller unmeasured flows such as blowdown and mismatch between the two flow measurements. As in the two-element system, nearly all the compensation for load changes is handled by the feedforward portion while the drum level feedback loop provides only trimming action. This system can handle large and rapid load changes and feedwater disturbances regardless of boiler capacity. This approach is required on multiple boilers having a common feedwater supply. It is ideal for plants with both batch and continuous processes where sudden and unpredictable steam demand changes are common.

Drum Level Control Systems

Steam pressure variations cause density changes in both steam and water in the drum. These density changes affect the differential pressure (DP) between the variable water head in the steam drum and the fixed reference leg which is measured by the level transmitter. Therefore the actual tank level does not agree with the DP head measurement as the pressure in the tank varies due to the steam demand.

In applications with large steam demand fluctuations, the solution to this drum level problem is to use a controller which provides continuous correction or compensation of the measured drum level to correct for variations in steam pressure. This technique is illustrated in the attached drawing.

The drum level is derived from the following equation:

$$h = DP + H(\gamma r - \gamma s) \div (\gamma w - \gamma s)$$

Where:

h = True drum level – Inches
DP = Measured DP head – Inches
H = Distance between taps – Inches
γ s = Steam Specific Gravity (S.G.)
γ r = Reference leg (S.G.)
γ s = Drum Water (S.G.)

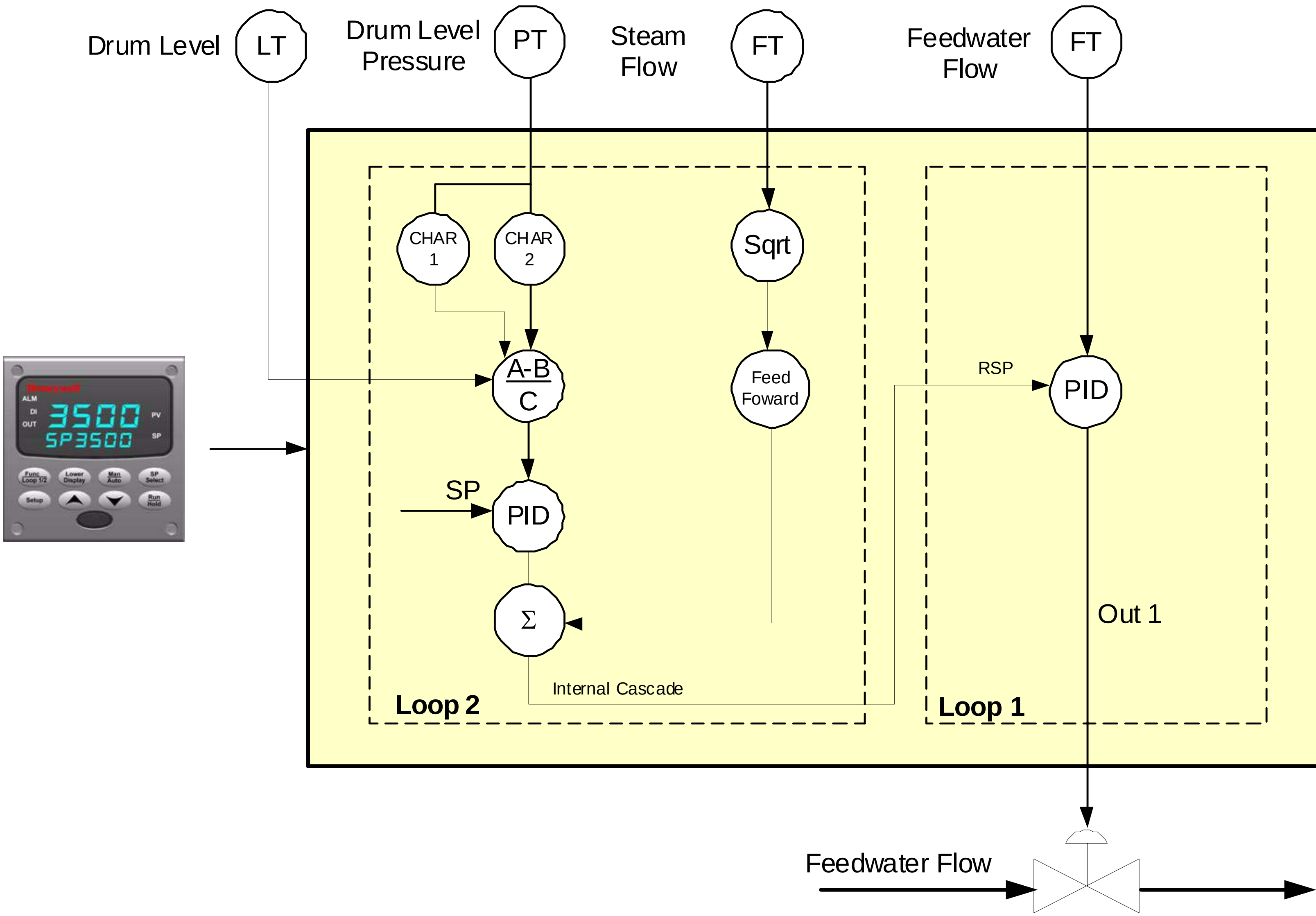
Drum Level Controller

This device is usually an indicating two-mode (proportional and integral) controller with high and low alarms regardless of which type system is being considered. Honeywell can supply the dual loop *UDC 3500 Universal Digital Controller* for this function. It also includes, as a standard feature, the feedforward summer function as well as square root extraction for the steam flow differential pressure signal required to linearize the system.

When drum level pressure compensation is required, a UDC 3500 with optional math algorithms can be supplied to provide three-element drum level control plus the level compensation in a single device. Two 8-segment characterizers are used to define the net effect of density changes as a function of steam pressure. These are then used with the math algorithm configured as a “Summer-divider” to calculate the effect of variations in steam pressure on the DP measurement of the liquid interface level in the steam drum. The error caused by the varying steam density is continuously compensated by the math equation, so the calculated process variable used by the level controller PID algorithm is corrected actual level, not the DP head measured by the pressure controller. The level controller output is then used in the same manner as the output in a non-pressure compensated drum level application.

Feedwater Flow Controller

This is loop 1 of the *UDC 3500 Universal Digital Controller*. Loop 1 uses the output of Loop 2 in a cascade configuration as the remote setpoint. Most feedwater flow application only require Proportional and integral to position the feedwater control valve. The loop includes square root extraction for the feedwater flow transmitter plus auto-manual functionality that allows manual control of the feedwater valve. This device is included as part of the dual-loop UDC 3500 that controls the drum level. This dual-loop feature saves cost and panel space while providing a simple operator interface.


Drum Level
LT
Drum Level Pressure
PT
Steam Flow
FT
Feedwater Flow
FT
CHAR 1
CHAR 2
Sqrt
A-B
C
Feed Foward
RSP
PID
SP
PID
Σ
Out 1
Internal Cascade
Loop 2
Loop 1
Feedwater Flow