Three Element Feed Control System

The feedwater control system is a three element type, designed to monitor changes in steam flow, water flow and drum level. Steam flow is the rate of steam leaving the boiler - the demand. Water flow is the rate of feedwater flow into the boiler - the supply. Drum level reflects the amount of water in the boiler - the inventory. With changes in boiler load (steam flow), steam and water flow become unbalanced and water level consequently deviates from the normal position. In such an event, the system changes water flow to the extent necessary to restore the balance between steam flow and feed flow and return the water level to normal.

Three Elements Measured by this System:
- Steam flow - considered demand signal
- Feed flow - considered response signal (feedback)
- Drum level - considered supervisory signal

REFERENCES
(a) Principles of Naval Engineering NAVPERS 10788-Series
(b) Boiler Technician 3 & 2 NAVEDTRA 10535-Series
(c) Automatic Combustion and Feedwater Control System NAVSEA 0951-LP-036-9010

Three-Element Drum Level Control
A common application in boiler control is three-element drum level control. Boiler drum level is a critical variable in the safe operation of a boiler. Low drum level risks uncovering the boiler tubes and exposing them to heat stress and damage. High drum level risks water carryover into the steam header and exposing steam turbines to corrosion and damage. The level control problem is complicated by inverse response transients known as shrink and swell.

The three transmitters, or variables, are the three elements referred to in the name of the control strategy. The feedwater flow setpoint is set automatically by the steam flow signal to keep the feedwater supply in balance with the steam demand; this is the feedforward component of the control strategy. The drum level controller trims the feedwater flow setpoint to compensate for errors in the flow measurements or any other unmeasured load disturbances (e.g. blowdown) that may effect the drum level; this is the cascade component of the control strategy. The summing function is used to combine these two components.

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This example shows the application of cascade control as well as feed forward control.

The cascade portion of the control is the output of the level controller used as the set point of the feed water controller.

For the feed forward part, the steam flow signal is added to the level controller's output. The flow instruments are set for the same range, therefore a change in steam flow will cause an immediate change in the set point to the boiler feed water controller.

This system is frequently called a three-element drum-level control system.

As the Siemens article states, the level signal's actual behavior is complicated by inverse response transients known as *shrink* and *swell*.

Swell is an apparent increase in the level signal when the steam flow increases. This is because the froth volume increases in the boiler when the pressure decreases. This increased froth volume appears as a momentary increase in the level signal, which is the opposite direction to the actual level, which should be decreasing. The opposite occurs when the steam flow decreases. Under those conditions, the level signal appears as a momentary decrease. This effect is further described in your text as an inverse response.
Impulse Feed Forward

Feed forward is a control technique that improves the control response by changing the controller’s output in anticipation of the load change. Most control engineers apply a simple feed forward algorithm, one without a lead lag element, when they see the need for it. In this case, a scaled percentage of the signal is added or subtracted directly on the controller output. The problem with this is that with some controllers, the reset term is still integrating the error and the system will be offset by some fraction of the feed forward signal. A better approach is one that implements the feed forward signal through function blocks to create an impulse function. The technique is called impulse feed forward. Some authors show the feed forward signal operating directly on the controller output. The problem with this is that if the controller is placed in manual, the feed forward signal will still be active. This gives the operator loss of control of the output. Some controllers bypass the reset function and implement the feed forward signal directly on the output. This limits the reset action and forces the output to some elevated level, which the reset action will have to overcome. An alternate way is to modify the set point. This technique is similar to the one used to implement a Smith Predictor.

Impulse Feed Forward
Features

The lag time constant is not critical, it should be much smaller than the process time constants. A gain factor can be applied to the signal to improve the correction.

The function output is at zero when the input signal is at steady state.

The impulse direction can be either direction, changed by the summer sign.

The impulse function can be implemented at many points in the control system to improve performance.

  Can be applied to modify the remote set point signal, thereby allowing the controller to provide the correction.
  Can be applied to the controller output to change the process' manipulated variable before the controller senses the change in signal.

The impulse feed forward is robust, should only improve the closed loop response since it has no contribution to the steady state loop errors.

The function can be implemented in almost all configurable control systems.

How can we use an impulse feed forward compensator to overcome the drum level control shrink and swell problem?