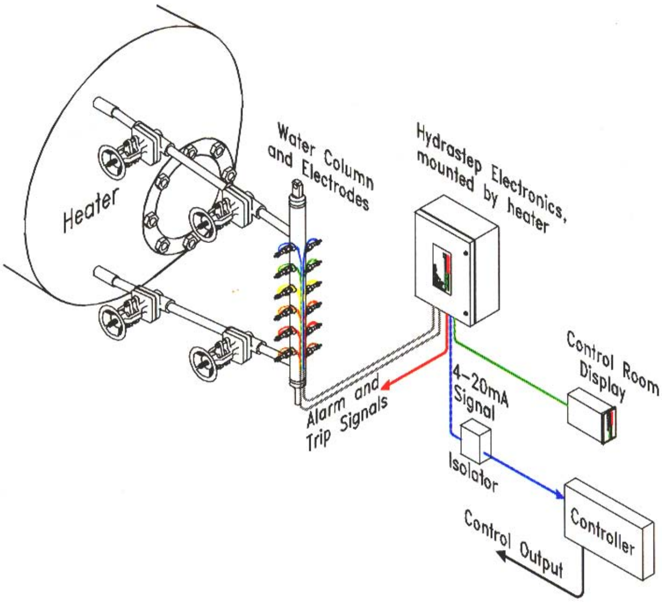
Water level control using Hydrastep

Hydrastep is best known as a rugged remote indication and level alarm/tripping device. However, in certain situations, the system can be used to provide the measurement input to a control scheme for effective water level control.



Heater control schemes can be greatly simplified by using Hydrastep for level control, and as heater level alarms and trips. Hydrastep's fully redundant system provides level alarms and analog outputs to create a completely reliable and repeatable level measurement system.

An update rate of twenty measurements per second allows for precision control even under demanding or emergency situations. With over 4000 installations world-wide, Hydrastep is industry proven and gives virtually maintenance free level measurement.

The stepped nature of Hydrastep is normally the prime concern when implementing such a control strategy. Reducing the spacing between electrodes and increasing the number of electrodes reduces the problems to some extent. However, further consideration of the control algorithm is needed to optimize the performance of the control system.

Control System Definition

The control system consists of a measurement input (in this case Hydrastep) that produces an analog (4-20mA) signal representing the water level. The analog signal is fed to a controller, either a local, standalone controller, or a DCS system. The controller compares the measurement input with the desired level and produces a control output to decrease the error between the desired level (set point) and the measurement input (water level). Control is normally achieved using a three term (PID) controller or an algorithm. Each of the three terms (Proportional, Integral, and Derivative) has an associated variable that alters the response of the control loop.

The basic control loop considered is:

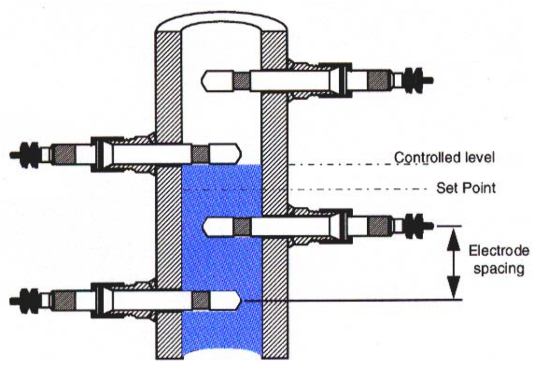
$$m = k_p \cdot e + \frac{k_i}{t_i} \int e dt + k_d t_d \frac{de}{dt}$$

where	m	= control output	t_i	= integral time constant (reset time)
	e	= error from set point	k_i	= integral gain
	k_p	= proportional gain	t_d	= derivative time constant (rate time)
	(proportional band = $1/k_p$)		k_d	= derivative gain

Optimization of Control Loop

To get the best out of the control loop, the disturbance to the control output caused by having the stepped measurement input needs to be minimized, particularly around the set point. This can be achieved by implementing a P.I control only strategy in conjunction with gain scheduling (adaptive gain control). Gain scheduling allows the proportional gain term to vary as the error from set point changes. To minimize the stepped input effect, the gain scheduling should be set such that there is very little or no proportional gain at or near the set point, but as the error from set point increases so does the proportional gain term. This implementation creates a control loop that is 'Integral only' at or near the set point, with proportional control being added as the error from the set point increases beyond a set value so that fast corrective action is taken when necessary.

The set point should be fixed mid-way between the two electrodes; this creates a situation where there is always an error from the set point. At or near the set point, the induced error causes the control loop to continually change the control output, at the rate and time determined by the integral time constant (reset time). As the water level increases and touches the electrode above the set point, the error will be **`+(Electrode spacing)/2`**.



The control loop will respond by lowering the water level. As the water level drops below the electrode the error will become **`-(Electrode spacing)/2`**, causing the control loop to increase the water level. In practice, the implementation described causes the water level to be controlled to a point just touching the electrode above the set point. In steady state situations with the water level at or near the set point, the control output ramps slowly up and down at the time determined by the integral time constant (reset time) creating a smooth control output. If a disturbance in the level is introduced then the proportional gain term takes over and takes quick corrective action. Experience has shown that the following set of values are a good starting point for setting up the control loop for most feedwater heater level control applications.

Proportional gain:	0	if error is less than or equal to (Electrode spacing)/2
	2 x % error	if error is greater than (Electrode spacing)/2 (This gives a proportional gain term that is zero within ±½ Electrode spacing, and then ramps linearly to a maximum value of 1 at 50% error)

Integral time constant: 45 seconds

Derivative time constant: Disabled

The actual values finally used will obviously depend on the installation, valve type, sizing, etc. The above values are only given as a starting point guide.

International:
Emerson Process Management
Mobrey Measurement Division
158 Edinburgh Avenue, Slough,
Berks, SL1 4UE, UK
Tel: +44 (0)1753 756600
Fax: +44 (0)1753 823589
www.mobrey.com

Americas
Emerson Process Management
8200 Market Boulevard
Chanhassen, MN 55317 USA
Tel: (US) (800) 999-9307
Tel: (International) (952) 906-8888
Fax: (International) (952) 949-7001

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