An Algorithm for Improved Feedwater Heater Control & Monitoring

Michael Neundorfer

Neundorfer Engineered Systems

Donald K. Frerichs

Bailey Controls Company

AN ALGORITHM FOR IMPROVED FEEDWATER HEATER CONTROL AND MONITORING

Donald K. Frerichs
Chief Application Engineer
Bailey Controls Co.
Wickliffe, Ohio

Michael Neundorfer
President
Neundorfer, Inc.
Willoughby, Ohio

ABSTRACT

Feedwater heater liquid level has typically been controlled by a single set point feedback controller. This method has proven to be a primary cause of heater damage and/or poor heat rate. There are two basic reasons the single set point method is inadequate: (1) There is no single set point which is optimal for both thermal efficiency and heater safety. The optimal set point varies with unit load conditions and heater aging. (2) The set point is established by the operator or instrument technician and is often based on poor information.

This paper describes an algorithm (Mdc2000) which automatically: (1) Creates a dataset of optimal liquid levels for each heater, (2) Adjusts the set point based on the dataset and unit load, and (3) Monitors the heater performance and compares it to the dataset values for automatic adjustment and alarm. Implementation of this algorithm significantly improves heater protection and performance monitoring.

Background

In the mid-nineteen eighties, we at Neundorfer, Inc. began to study ways to improve and automate control of feedwater heater liquid level. It has been well documented that much damage and premature failure of feedwater heaters are due to poor liquid level control.

file: NUSpaper95.pmmac

Fred Linley, Jr., a feedwater heater designer and consultant, had for many years been promoting the use of DCA for establishing safe heater liquid levels. (DCA, drains cooler approach temperature, is the difference between the outlet drains temperatore and the feedwater inlet temperature). Fred, through his plant consulting and publications encouraged feedwater heater operators to manually generate DCA curves for each heater. These curves were analyzed to determine the break point, the point of sharp increase in the temperature difference caused by steam blow-by or flash in the subcooler. After the break point was established, a safety margin was added to the break point level which was then used as the operating level for the heater.

Although this approach to determine liquid level set points was theoretically appropriate, manually establishing and analysing the curves was time consuming and subject to human error. It relied on operators to, (1) take the data (while manually adjusting the heater liquid level), (2) to interpret the data, and, finally, (3) to set the heater level set point consistent with the data. Moreover, safe liquid level varies with process conditions for each heater. Therefore, the manual approach of DCA curve generation and set point adjustment does not address process change needs.

Development Challenges

We looked at many approaches to the problem of providing safe liquid level control. We realized that there were several benefits of referencing heater level to DCA: (1) DCA is already available on nearly all heaters. (2) It is available in real time. (3) It doesn't rely on any physical reference such as tube level inside the shell or a physical mark on the external of the shell; and (4) It directly measures the condition (two phase flow in the subcooler) which causes most heater damage.

After choosing DCA as the primary control parameter, the next task was to develop an automatic method of finding the break point of a DCA curve. The break point occurs at different liquid levels at different unit loads. This is due to the changing level along the length of the heater as load changes. The liquid level is not level and the slope changes with changing load. *(See Figures 1 and 2)*

The liquid level in an operating heater varies even when load conditions are held constant. Fluctuations are usually a low frequency oscillation. We built a test "heater" to develop parameters for automatic DCA data collection and analysis. The rig had a Fischer 2502 typical liquid level buoyancy control. We simulated random level oscillations similar to what we found in the field. The objective was to find a rate(s) of level change and data sampling that would reliably determine break point while completing the process in minimal time.

The result was a rate of level change between 0.05 and 0.15 inch/min and a total sample of about 2000 points per DCA curve. The following is a nine step summary of the DCA curve routine. [1]

Figure 3 is a computer plot of setpoint vs. time data from an actual flash/breakpoint determination for a high pressure heater. The data were logged each minute by the plant's computer. (Tuning adjustements allow for faster/slower test).

Each numbered step is amplified in the steps that follow:

1. Normal
Normal operation with the load being held constant. Therefore the setpoint and DCA are constant (except for mild DCA oscillations).

2. Start Routine
The overall blowby/flash breakpoint curve routine has been succesfully initiated.

3. Move Up to Start-Seek Point
The first operation in the breakpoint routine is to raise the setpoint above the as-found setpoint, but only as necessary. The objective: to ensure enough pre-breakpoint analysis data will be collected during the curve breakpoint seek steps.

4. Start Breakpoint Seek
The setpoint begins to drop, and Mdc2000 begins to collect and analyze DCA vs. setpoint data. The setpoint is changed so slowly that the liquid level control barely notices the change.

[1] *From MDC 2000 Users Manual Copyright 1994, Neundorfer, Inc. Willoughby, Ohio*

5. Approximate Blowby/Flash Breakpoint
At this point a preliminary blowby/flash breakpoint is detected by the Mdc2000. This is used to judge how much additional, post-breakpoint data will be needed to complete the analysis. In the illustration shown the breakpoint is very sharp with little ambiguity. In other instances the breakpoint may be less sharp, the rise in DCA less steep, and DCA may oscillate more (e.g. up and down fluctuations of a degree or two every two minutes, in addition to the more steady changes). Tests have demonstrated the capability of the Mdc2000 to find flash/blowby breakpoints in such situations.

6. Get Post-Breakpoint Data
The setpoint lowering is continued to acquire additional data for analysis of the breakpoint.

7. Seal Drains Cooler
The liquid level at which blowby/flashing stops is typically somewhat higher than the level at which it starts. (This is sometimes referred to as hysteresis). After the breakpoint data is acquired the Mdc2000 raises the level setpoint to ensure the drains cooler is sealed at the end of the experiment.

8. Finished. Restore Normal
The experiment is complete, including sealing of the drains cooler. At this time the setpoint is moved to the "operating point" that has been found for this load, which is blowby/flash breakpoint plus a safety margin.

9. Normal

The new operating point is reached and normal level control resumes. Variable load control may now be resumed at any time.

Note that the breakpoint evaluation occurs in sections 4-6 of Figure 3. (The other sections of the routine prepare the heater for this determination and restore normal operation thereafter).

The Figure 3 DCA curve routine finds the breakpoint for one unit load condition. In order to optimize level at all operating loads, it is necessary to repeat the process for at least three unit loads; minimum, intermediate, and full load.

The curve defining the breakpoints for all unit loads is;
Breakpoint = a + b(load) + c(laod)2. the values of constants a, b, and c are calculated using a second order least squares routine.

A user selected safety factor is added to the break point curve and the dataset of setpoint versus load information is complete. The result is a set of safe operating levels that are generated from heater thermal performance perameters. The levels correspond to unit load for the heater. This dataset used in combination with a unit load signal to modulate the heater control set point met our objective for safe, automatic control of heater liquid level. However, now that the data was available, we could take a step or two further with heater protection.

Monitoring

The heater level control was set up to monitor a boiler load signal every second and adjust the liquid level set point according to the load and the dataset of minimal safe liquid levels. In order to assure that the system and thermal transducers were working, we decided to include a monitoring function in the algorithm.

A scheme was created to check the operating DCA values compared to the dataset of expected values. If actual values are consistently higher than expected, the dataset of liquid levels is increased and the operator is notified. If the DCA is subsequently found to be lower than expected, the added safety margin is reduced. Higher than expected DCA can be the result of tube plugging, heater deterioration, blowby/flashing in the heater, or thermocouple drift.

Heat Rate

The primary motivation for developing the MDC-2000 patented feedwater heater liquid level algorithm was to prevent heater damage. In most cases, heat rate improvement justification relies on improved heater availability. Although it is well accepted that many heaters are damaged due to poor level control, there is not enough emperical information to quantify the improvement. There is much interest in using the algorithm as a tool for monitoring heater condition. since it automatically determines and alarms changes in the heater thermal efficiency.

There is some argument that maintaining the minimal safe liquid level allows the heater to perform closer to design because the convective section is not operating as a conductive section due to tube flooding. Better documentation of future installations of the algorithm will help to put a range of values on potential heat rate improvement.

Summary

The MDC 2000 (U.S. Patent 5,012,429) has been developed and tested with input from utilities and consultants. It has been licensed to Bailey Controls who have added control algorithms which improve the control loop response at all operating levels.

The MDC 2000 creates a dataset of DCA values which are used in conjuction with an existing feedback type liquid level control system and boiler load input signal to continuously operate the feedwater heater at it's minimal safe liquid level. It monitors the real time DCA and compares the values to the data set and makes appropriate correction and alarm for out of tolerence conditions.

Reference:

American Power Conference
April, 1995
Technical Paper
"ADVANCED FEEDWATER HEATER CONTROL"

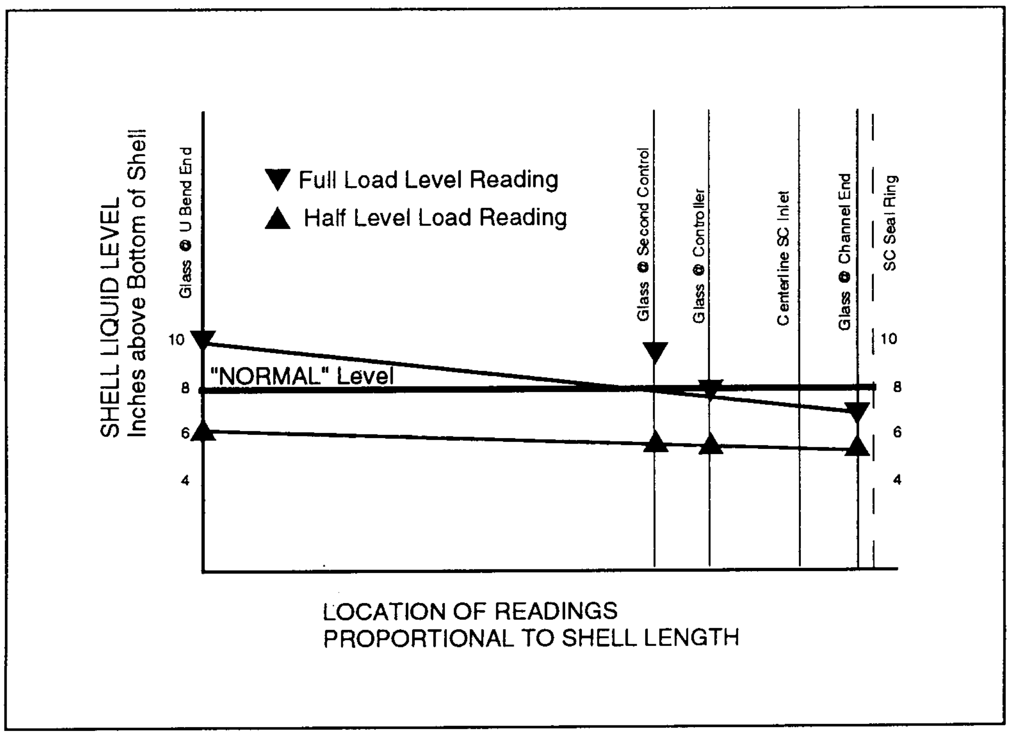
Authored by:

Donald K. Frerichs
Chief Application Engineer
Bailey Controls Co.
Wickliffe, Ohio

Michael Neundorfer
President
Neundorfer, Inc.
Willoughby, Ohio

Figure 1:

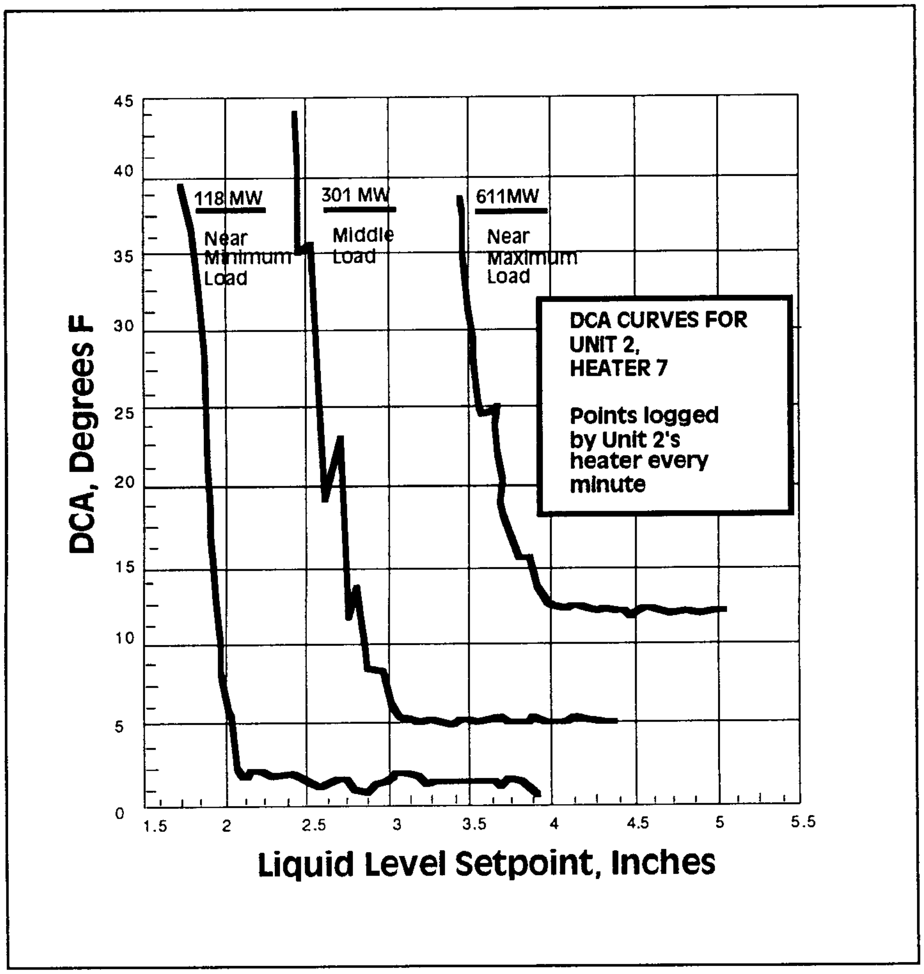
EXAMPLE OF LOAD-VARIABLE LIQUID LEVEL GRADIENTS IN THE SHELL OF A HORIZONTAL FEEDWATER HEATER



From: Fred H. Linley, Jr., "Feedwater Heater Operation," Southeastern Electric Exchange, 1983 Annual Conference, Engineering and Operating Division and Real Estate Section, New Orleans, LA, April 13-15, 1983. Similar results have been observed for other heaters.

Figure 2:

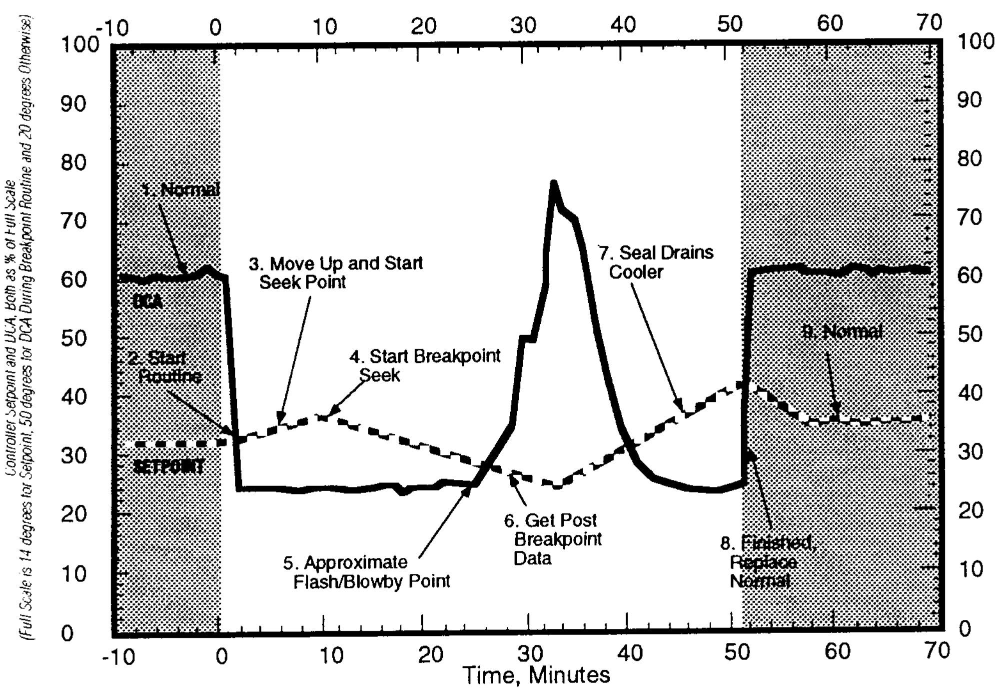
BLOWBY/FLASH BREAKPOINT CURVES, DCA VS. SETPOINT, FOR THREE DIFFERENT LOADS



file: NUSpaper95.pmmac

Figure 3:

ACTUAL BLOWBY/FLASH DETERMINATION DCA AND LIQUID LEVEL SETPOINT VS. TIME



file: NUSpaper95.pmmac