IMPROVED FURNACE COOLING WATER PRESSURE LEAK DETECTION SYSTEM AT VALE

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ABSTRACT

Vale have improved the safety, reliability and operability of the Flash Furnace No. 1 and Flash Furnace No. 2 with the installation of the Hatch Pressure Leak Detection System on each furnace and associated mechanical and controls improvements therein. The Pressure Leak Detection System monitors the integrity of the 99 tested water circuits per furnace with an accuracy in the order of drops of water per minute. Compared to other techniques, pressure leak detection is the best method known by Hatch to detect small leaks. The project incorporated novel design to allow installation and commissioning to take place without impact on production. The system was retrofitted in a very tight timeframe. The systems have been accepted by Vale and are being fully used by operations. This paper further clarifies the design of the system and its associated benefits.
***KEYWORDS**: Leak detection system, water pressure, copper coolers.*

1. INTRODUCTION

Vale have installed, in 2011, a Hatch Pressure Leak Detection System on two furnaces in Copper Cliff and improved the safety, reliability and operability. This Pressure Leak Detection System compliments the existing course continuous flow leak detection system on both flash furnaces as it uses the detection principle of loss of static pressure.

The design and installation were organized to minimize the impact on production, while still completing the full header replacement in a short time frame. The system incorporates mechanical and controls design improvements which improve the Vale operability of the furnaces.

This paper elaborates the drivers for the installation of the system, compares different detection techniques, describes the system in technical details, including the mechanical details and discusses the performance of the system.

2. WHY LEAK DETECTION IS IMPORTANT

The operating of a water cooled furnace involves the continuous maintenance of the required pipes in and around the walls of the furnace. A water pipe with even a small leak can cause permanent damage by hydrating the refractory brick in the wall, as well as cause explosions if coming into contact with super heated matte.

Companies leading in the safe operation of their capital equipment understand that equipment damage significantly impacts their business. Ore smelting furnaces are core process equipment operating at high temperatures in a hazardous environment and are a priority area for companies to improve safety, operation and longevity. Governments are also promoting best practice in order to improve operator safety in hazardous environments. Improvements in Plant safety improves asset protection and lowers the operating cost of the facility. Furnace damage would result in loss of production, which overwhelms the safety system, installation and repair costs. Asset protection concepts include a properly designed, well built and a correctly operated furnace. With the operation portion of the work, including regular valid integrity checks (frequency dependent on data being measured), monitoring furnace integrity provides the information for maintenance to repair weak or worn components in a planned manner. Additionally, operators and maintenance personnel would receive warnings and integrity check feedback that can prevent major damage from occurring to a furnace when small problems start to develop. Taken together, this monitoring and operations philosophy increases the productivity of a furnace.

3. AVAILABLE LEAK DETECTION TECHNOLOGIES

There are a number of methods that are adopted to detect leaks in furnace cooling systems. Leak Detection in its simplest form involves a regular visual inspection of the water pipes by the maintenance department. This method is limited in that leaks inside copper cooling blocks or in concealed piping are not visible. There is the added safety risk of persons spending more time within close proximity of the furnace.

A continuous course leak detection system using flow rate comparison is a popular form of leak detection used on furnaces. By measuring the flow on the supply and return side of the furnace water cooling circuit, a greater reading on the supply side would represent a leak in the piping. The strength of this method being that this is a continuous form of leak detection which is quick to detect a hose from completely disconnecting. The weakness is that it is susceptible to measurement errors due to air in the water, flow meter installation and instrument inaccuracies. In some cases only leaks greater than 4 litres per minute can be detected.

Leak detection based on the change of static pressure is the best method for detecting small leaks in a water circuit. The approach is to momentarily stop the flow in the water circuit and trap the pressurized water between the two newly installed entry and exit valves. The return valve is closed before the supply valve to make sure there is water in the coolers at all times and that the supply header water pressure is maintained in-between the valves. When the short test is complete, the valves are automatically opened and water flow is returned to that circuit. A pressure transmitter is used to accurately monitor a drop in pressure which can be equated to a leak. Leaks as small as a few drops per minute can be detected. This is not a continuous leak detection method, but it can be automatically run at regular intervals.

4. WHAT WAS INSTALLED AT VALE

The Nickel Smelter at Vale already had, on some critical circuits, a flow leak detection system based on two flow meters. The pressure leak detection system was installed on the Vale furnaces to complement the existing flow leak detection system. The pressure leak detection system was installed on 99 circuits per furnace (198 total). The system not only detects a leak, but indicates on which circuit it is on.

The water quality at Vale, because of the open sump pump feed system, was a concern for the implementation of the system. This was evident with the build-up in the old headers replaced during the shutdown and the effect on existing valves. Modifications were made to the seals of the valves installed for the leak detection to make them more resilient to build-up of debris. The pressure transmitters installed were less sensitive than the valves to dirt build-up.

The air quality was also a concern due to the moisture content, as well as the variable pressure experienced in some areas the Plant. Specialized air filters and upsized valve diaphragms were installed to provide reliability for the system.

The system was controlled independently to the furnace control to prevent any interference. The system was based on two Foxboro DCS (Distributed Control System) controllers per furnace installed in the field and developed on Foxboro's FCS (Foxboro Control Software), also known as IEE (Infusion Engineering Environment).

Below is a layout of the equipment that was used to perform the pressure leak detection. The flow transmitters and RTD existed prior to the installation.

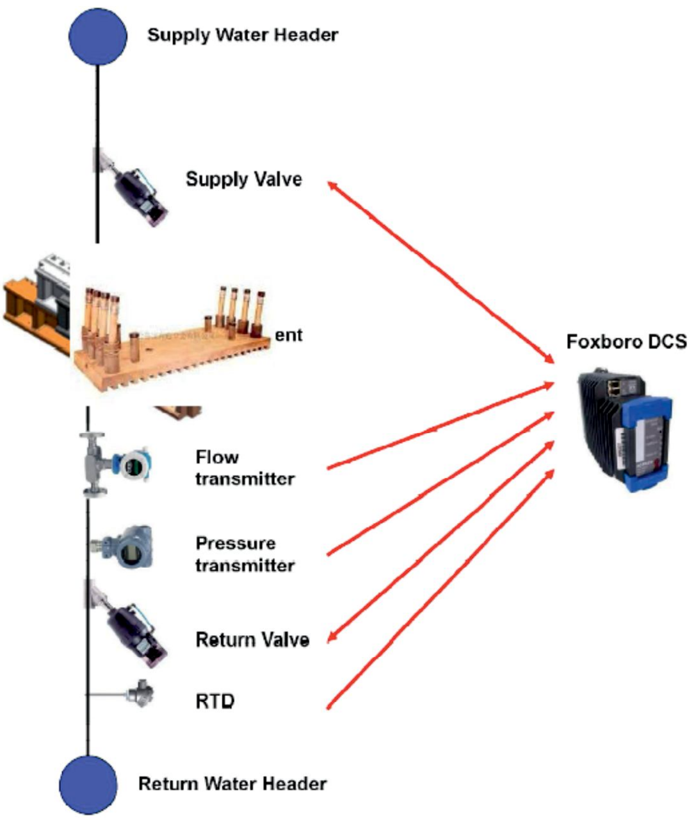

Figure 1: Pressure leak detection system equipment

The valves used for the pressure leak detection are critical for safe repeatable operation and so the valve selection was subject to the following criteria:

- Valve able to release water pressure, in the closed pressure vessel created between the valves, when pre-determined levels are reached.
- Valve set to fail open – This is to ensure that the water cooling is not inhibited for long enough to cause damage to the equipment in the event of a failed valve.
- Ability to seal closed against the system water pressure with the available instrument air pressure.
- Resilient to dirty water.
- Easy to service and replace.

5. PROJECT REALIZATION

5.1. Mechanical design and installation

The mechanical design and installation portion of the Project provided a number of challenges. The amount of equipment installed would have to increase, the schedule was predetermined and Vale wished for improved equipment access and ergonomics.

To understand the magnitude of the changes, it is important to understand the existing piping situation before the start of the Project:

- Zero allocation for spares to the point that previous additional loops of pipe had to be installed in circuits to accommodate new instruments.
- Some instruments required a ladder for access.
- The water circuits were so close to each other that the instrumentation had to be staggered forward and back to allow it to fit. Sometimes the instrumentation from an adjacent circuit would have to be removed to allow the instruments of a circuit to be removed.

A picture is provided in figure 2, for the reader to understand the congested nature of the cooling water headers.

Figure 2: Original and new headers

Due to the time constraints out the box thinking was used to make the minimal amount of changes possible, but still achieve the objectives.

The following header improvements were made to achieve the objectives:

- Simplified Maintenance: Completely new supply and return headers were designed for offsite prefabrication as modules and then retrofitted to the existing piping tie in points. The new headers allowed instrumentation and mechanical equipment to be installed in a new location around the furnaces, improving ergonomics and simplifying maintenance.
- Improved ergonomics: The header layout was improved to provide front and back access to equipment and instrumentation. This design provided additional space for the new instruments and ensured that all instruments were within comfortable reach of maintenance or operational personnel.
- Improved Access: Headers were made accessible by relocating them to areas where they could be more easily maintained and accessed.
- Improve instrumentation data: The pressure transmitters installed were based on the Rosemount Foundation Fieldbus (FF) network type. The FF transmitters have the advantage of

being able to self diagnose if their elements have build-up and signal that they require maintenance. Additionally, they were designed into the header in a protected location, to improve their longevity.

- Speed up installation: The pneumatic piping was based on a new heat resistant flexible hose technology. This material reduced the installation time and the space required to run the hosing for the 396 valves installed.

The engineering design, manufacturing and installation processes were very compressed because of the schedule. To minimize total manufacturing and installation time, the headers were manufactured, assembled and tested off-site and installed as complete units at Vale.

The controls and installation work was organized into work which would need to be performed during the furnace shutdown and work which could be completed while the furnaces were operating. The in-line piping equipment and instrumentation were installed during the shutdown, so as not to interfere with the production. As a result the work fitted within the Plant shutdown period, which resulted in less potential downtime for the Plant. The remainder of the installation was completed on the operating furnaces in 24 working days.

5.2. Controls commissioning

With the shutdown window for the rebuild kept to a minimum, final installation and commissioning of the leak detection system could be performed after restart of furnace operation. With the Plant at full production, time could be taken to ensure that the installation of the system could be performed with the highest safety and quality standards and to the clients installation preferences.

Upon completion of the installation work, an integrated team of Vale, Hatch and the installation Contractor was created to commission the system. A total of 99 circuits per furnace (198 total) had to be commissioned with the leak detection system. This was completed in 30 working days. The integrated team provided the controls, operations, construction and engineering capability to speed up commissioning while safely maintaining Plant operation. The integrated team eased the transfer of operational and maintenance information to the operating Plant.

5.3. SOFTWARE DEVELOPMENT AND CUSTOMIZATION

The Standard Hatch Pressure Leak Detection software is supported on the Allen-Bradley and Siemens platform although custom platforms are possible based on owners standards. Vale wished to standardize their controls on the new Foxboro DCS known as the Foxboro Control Software (FCS). This system represents the first ever implementation of FCS in Canada. Creative engineering was required by Hatch to implement the sequential state logic on the DCS using the new FCS development. Typically a DCS is not efficient with performing sequential logic which made a large proportion of this system. To execute this, task time slicing and task prioritization was used to reduce the loading on the processors.

6. SAMPLE DATA

The leak detection system assumes that, when both valves are closed, there is a fixed volume of water in the pipe at a given pressure. Furnace equipment that are exposed to a lot of heat flux might show a slight increase in pressure during a test if there is no leak. In this case the length of the test is reduced if necessary to ensure that the equipment doesn't approach its maximum operating temperatures. A leak would cause a reduction in water quantity and a corresponding drop in water pressure, even if a heat flux is being applied.

The precision of the system is dependent on the length of piping and the supply header pressure. At Vale furnaces, a leak of a drop every few seconds was successfully detected on multiple circuits, verifying the expected accuracy of the system.

Below is a screenshot showing the pressure trend during a test that failed due to a 30 drop measured leak test. The water leak was simulated at the return end of the circuit, near the pressure transmitter and the return valve.

The phases of the test can be seen in figure 3 and are detailed below:

1. The flat line section at 250 kPa is the return header water pressure with the water flowing before the test starts.
2. When the return valve is closed, the flow stops and the header pressure is transferred through the water piping up to the return valve with a static pressure of approximately 730 kPa (dependant on the header).
3. The supply valve is closed. There is no effect seen on the graph as the flow is already stopped and the pressure on either side of that valve is equal.
4. The negative slope on the graph shows the loss of pressure due to the measured 30 drops released from the water pipe over 10 seconds. The pressure reading dropped by 35 kPa. The pressure drop is related to the volume of water in the pipe.
5. Both valves are re-opened.
6. The return header pressure returns to normal as the flow through the circuit returns.

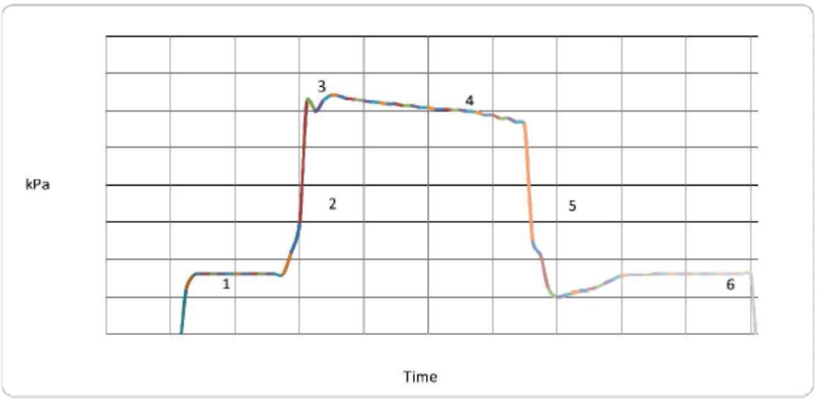

Figure 3: **Pressure transmitter trend with a 30 drop per 10 second leak**

A summary of various test results are shown in the figures 4 below:

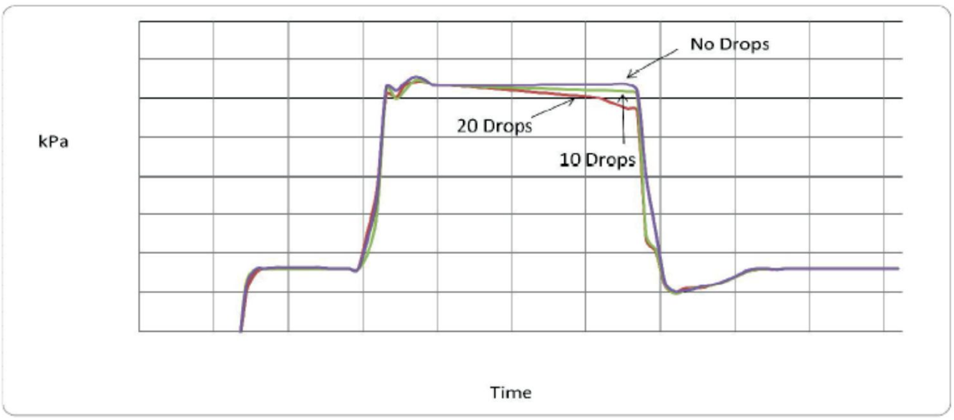

Figure 4: Pressure transmitter trends (from left to right) 20 drop leak, 10 drop leak and no leak

The table 1 below summarizes the data from the above trends and highlights the system's ability to accurately depict leaks in circuits.

The Vale operations personnel physically confirmed the water dripping from a valve interface outside of the furnace. The system detected a leak of 1 drop in the water circuit every three seconds. This test result developed the operations confidence in the system.

Table 1: Results from Simulated Water Leaks

	Change in water pressure during the simulated leak test
30 drop leak in 10 seconds	-35 kPa
20 drop leak in 10 seconds	-24 kPa
10 drop leak in 10 seconds	-11 kPa
No leak	+1 kPa

In the first three months following the commissioning of the system, three water leaks around the furnace, two of which were concealed, have been detected by the system. Two additional leaking bypass valves were detected at the headers. With these results, the system has added its intended value to the Client.

7. EXPECTED ISSUES GOING FORWARD

The Hatch Pressure Leak Detection System has improved the safety of the Vale flash furnaces. The system detects fine water leaks on furnace coolers and the associated water pipes, accurately, reliably and safely.

Engineering challenges associated with system have been:

- Engineering configuration of pressure drop threshold, as well as an operating time, sufficient to detect any leaks that may occur in the circuit. The threshold is a dead band set before a circuit is marked as having a leak. The threshold needs to be fine tuned over time as the system is operated. A threshold too low will result in maintenance crews looking for leaks that don't exist or are too small to find. A threshold too high will limit the systems accuracy and early detection of small leaks.
- Development of an investigation procedure to identify the root cause of a pressure test failure and to ensure that the appropriate action is taken. A software manual with maintenance recommendations and guidelines was provided to Vale. Vale further incorporated this manual information into the Plant standard Operating Procedures. The success of the system going forward is dependent on the operating personnel taking ownership.
- Training of operators to facilitate understanding and acceptance of the pressure testing system. This challenge was overcome by both Hatch and Vale effort by demonstrating the system and responding to any questions.
- The quality of the cooling water at the Vale furnace could create potential issues going forward for the valves, piping and headers. This is the first time that the leak detection system has been installed on a Plant with water quality concerns and the effectiveness in spite of these conditions is still to be proven.

8. CONCLUSIONS

The opportunity to improve the safety, ergonomics and equipment will improve the operation of flash furnaces. The Hatch Pressure Leak Detection System installation at Vale on flash furnace

No. 1 and flash furnace No. 2 has improved the safety of the furnaces, by detecting fine water leaks, a few drops a second detection range. This system has clearly shown that it can provide accurate information about failures of circuits around the furnace for both operations and maintenance personnel.

The Project was a success because of the comprehensive team of project, controls, operations, installation contractor and engineering, who ensured the success of the project for all involved parties.

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