FEEDWATER CAPACITY UPGRADE

INTRODUCTION

A fully integrated Kraft mill producing pulp for own consumption as well as newsprints and containerboard, also produces superheated steam that is used internally for various plant processes as well as for electricity generation. In August 2013, the mill added an additional process to its list of steam users, which prompted the mill to upgrade the steaming capacity of some of the boilers on site.

The Chemical Recovery Furnace 2 (CRF #2) forms an integral part of the recovery process on the mill. Thus, the client investigated possible upgrades of CRF #2 to achieve a steaming rate of 350 t/hr. The main restriction for CRF #2 to reaching the target steaming rate was the feedwater supply system, which consisted of a deaerator, two feedwater pumps and two control valves installed in series.

DESCRIPTION OF THE PLANT

The deaerator receives water from the condensate polishers, the demineralization plant, and from the primary and secondary forced draught fans cooling water return lines. The water is sprayed into the primary deaeration zone where it is brought into contact with steam that is drawn from the 415 kPa header. The deaerated water then flows from the deaerator into the feedwater tank where it is mixed with water from the pump leak-off systems. Some of the steam from 415 kPa header is also injected into the feedwater tank to maintain the water temperature. Hydroquinone dosing is performed between the deaerator and the feedwater tank to assist with mixing of the dosing compound.

From the feedwater tank, the water flows into a suction pipe that is connected to the feedwater pumps. Amine and phosphate dosing is performed near the outlet of the feedwater tank. A water strainer is fitted before each feedwater pump to ensure that large particulate matter does not enter the pumps.

A pump protection valve, located at the outlet of each pump, ensures a minimum flow through the pumps. This theoretically protects the pumps against overheating and cavitation. If the flow through the pumps fall below a certain level, the bypass system opens and water flow via the leak-off lines back to the feedwater tank. After the Schroedahl valve the water flow to two feedwater control valves. After the feedwater control valves the feedwater flows to the bottom inlet header of the economiser of CRF #2, situated 24 m above ground level. An accurate model of the feedwater system piping is shown in Figure 1.

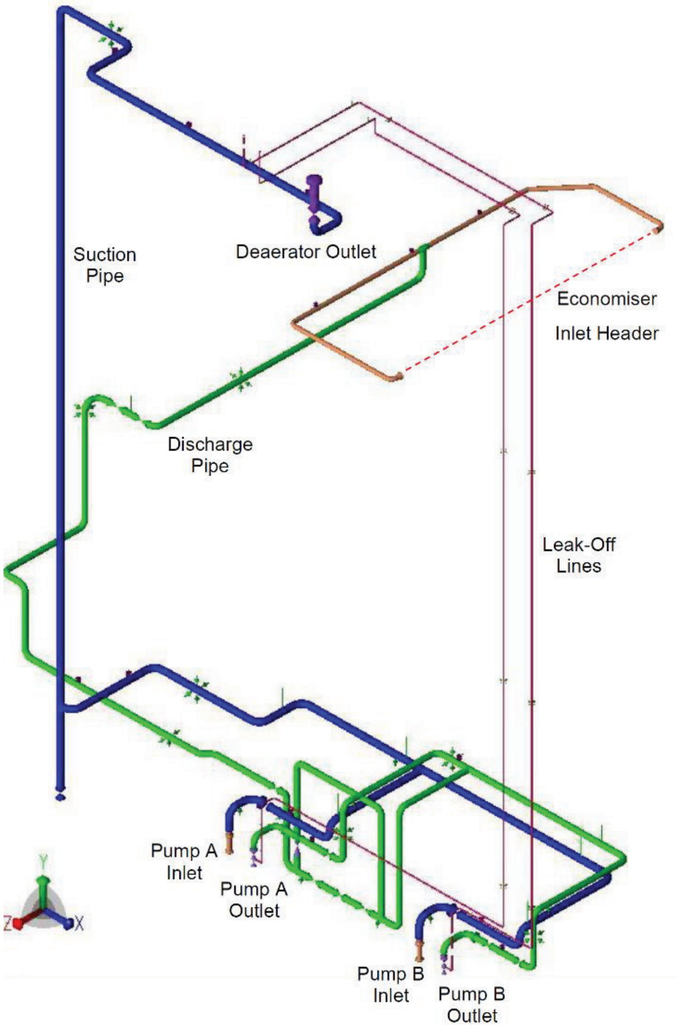

FIGURE 1: FEEDWATER SYSTEM PIPING ARRANGEMENT.

OPERATIONAL ISSUES

Some of the operational issues pertaining to the CRF #2 feedwater supply system at the time are listed below:

- Difficulty in maintaining the temperature within the deaerator,
- Feedwater supply shortage to CRF #2,
- Difficulty in governing the drum level, which prompts the operator to operate the feedwater pumps on a Stop/Start basis,
- Notable vibrations of the second floor structure during operation of the CRF #2 and PF boiler pumps,
- Recurring maintenance work on the feedwater pumps was required,
- The control system could not cope with rapid pressure fluctuations of CRF #2.

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Systemic Review

Various methods were employed in order to correctly identify and address origins of the operational issues. These methods were limited to:

- Static and dynamic stress analysis of the systems.
- Vibration analysis of the pump floor.
- Evaluation of the distributed control system.
- Process evaluations.
- Deaerator/Storage Tank Audit.

Method 1: Piping Stress Analysis:

Piping models of the suction, discharge and leak-off systems were created using the CAESAR II software package, based on such as-built and design data as was available and gathered during site visits. The systems were analysed for static loading and dynamic stability under various conditions.

The systems were independently analysed since the interaction of the systems occurs only at the pumps. This was since no significant transfer of loading or displacement from one system to another is possible due to the mounting arrangements and inertia of the pumps. For the modal analysis, the systems have no effect on each other for the establishment of the systems natural frequencies.

During the analysis, some significant anomalies were identified regarding the supporting of these piping systems. The analysis considered the existing systems, which differed from the original design intention, insofar as could be established. These anomalies were generally seen to be as a result of degradation of the supporting over many years, and undocumented repairs and/or modifications made over this same period.

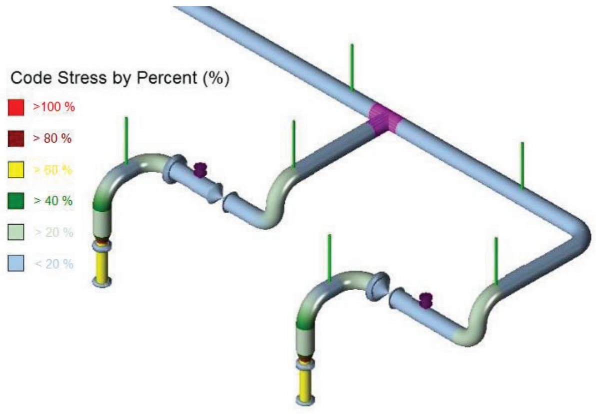

FIGURE 2: STATIC STRESS MODEL AT THE PUMPS.

The static analysis results also indicated that the piping systems were generally acceptable for steady state operation, this can been interpreted from Figure 2, on the other hand better thermal expansion control was also needed. During the modal analysis these systems were found to be dynamically unstable.

Method 2: Pump Floor Vibration Measurements:

During normal operation of the feed water system, some vibration characteristics were identified (or assumed) to be emanating from the floor structure between the CRF2 and PF boiler feed pumps. In discussion with the client's condition monitoring technicians, a so-called "weak point" was identified at this location. Site inspection indicated that this point displayed greater vibration characteristics than the surrounding areas. Vibration measurements were recorded along a grid pattern in this area, to establish if any possible dynamic structure instability contributed to the adverse vibration conditions experienced. Figure 3 below, gives indication to size of the area measured.

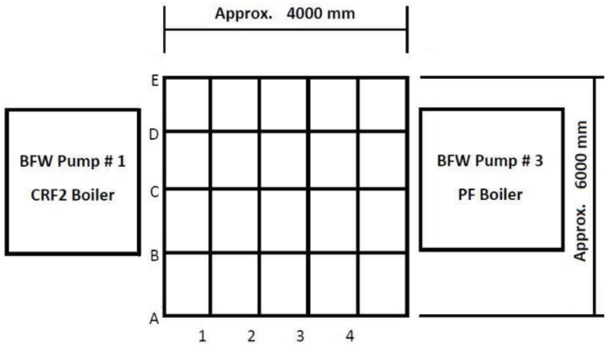

FIGURE 3: STATIC STRESS MODEL AT THE PUMPS.

During this exercise, no abnormal vibration conditions were evident, resulting in measured data representing a steady state of operation. However, as the systems were operating in a steady state during the test and it was expected that amplitudes would increase during any dynamic events.

Method 3: Evaluation of Distributed Control System Data:

The CRF2 boiler feed pump number 2 DCS had valuable historic operational data of detected operational anomalies, which had occurred during an episode of excessive system vibration. From data was evaluated, it was established that two spate dynamic excursions had occurred, with direct correlation to the excessive system vibration experienced at this time.

It was further apparent from scrutiny of the DCS data that:

Suction pressure rapidly fell below saturation temperature and discharge pressure rapidly increased during the specified interval.

Drive end vibrations in the vertical and horizontal direction, were found to be multiple times higher than the measured values during steady state condition operation.

Pump delivery also drastically dropped from 273 t/h to zero.

Flow control valves opening position radically dropped from 95% to zero.

Method 4: Process Evaluation:

A Flownex software model, Figure 4, was developed to assess the overall performance of the systems under steady state and upset condition operation. The control philosophy of the system was assessed to establish if any flow related condition is contributing to the vibrations experienced.

With the operating temperature at 152 ºC, equating to a saturation pressure of 502 kPa. The flow velocities for each pipe section was correspondingly calculated at the average feedwater flowrate. The calculated flow velocities on the suction side was slightly above the allowable value stated in Babcock procedures and technical manuals, but did not pose a risk in terms of vibration excitation.

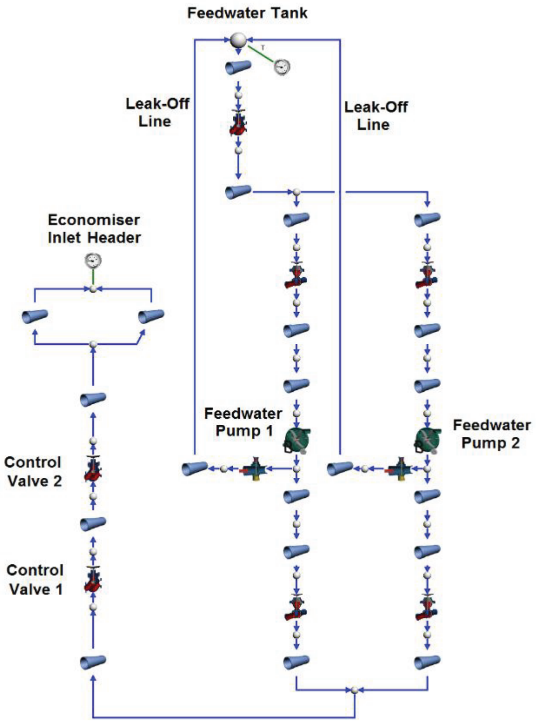

FIGURE 4: L SIMULATION MODEL FOR THERMAL-HYDRAULIC ANALYSIS.

From the simulation results, the following was established:

No unstable behaviour was noted during steady state operation.

During dynamic events the following was noted:

- Sudden valve closure would not pose a risk of feedwater flashing, but would likely lead to a dynamic water hammer incident,
- Any sudden valve closure, followed by a valve opening event (regardless of magnitude) had a string tendency to cause flashing within pump suction lines, causing flow instabilities on the suction side of the pump. Once flow was unstable, this flashing mechanism became self-sustaining. Pump cavitation was also observed during this event,
- Any sudden valve opening event, would lead to feedwater flashing over within individual pump suction lines, which quickly dissipates,

The control philosophy at the time, was scripted in such a fashion as to promote flow instabilities during control valve closure events.

Method 5: Deaerator/Storage Tank Audit:

A comprehensive audit of the deaerator under current loading conditions was undertaken to assess the deaeration capacity and feedwater storage draw-down level.

The audit finding revealed that the deaerator's original design capacity was below the required 350 t/h requirement, but the vessel itself would suffice when slightly modified. It was also pointed out that deaerator was not operating efficiently, as O_2 levels were far above the maximum allowed.

Conclusions

The following conclusions were drawn from the work conducted:

1. The systems were acceptable for steady state operation, but would require slight supporting philosophy modification to allow for better thermal expansion control.
2. The systems were dynamically unstable and would require extensive supporting philosophy modifications to ensure that the resonant response of the systems were averted under any form of dynamic loading.
3. Dynamic analysis of any possible water hammer event should be undertaken.
4. The pipe routings were acceptable.
5. The process and operating philosophies were to be redesigned, to eliminate the risk experiencing future

high vibration amplitudes. High enough amplitudes that could be detrimental to the structure.

6. Excessive vibration characteristics arouse as a function of rapid decrease in flow rate, and the feedwater control philosophy had a direct impact on the vibrations generated.
7. The sudden closure of control valves would cause overall system pressure rise that would also cause a dynamic water hammer event.
8. Sudden opening of control valves caused flow acceleration, which lead to flashing and pump cavitation.
9. Sudden closure of control valves lead to the opening of the leak-off valves. Fluttering of the leak-off valves caused severe flow instabilities within the entire feedwater supply system.
10. Review of the control philosophy of the control valves was recommended. Fine tuning of the leak-off valves was also recommended.
11. A complete re-design of the deaerator internals was recommended to achieve the required 350 t/h at/or below the requisite oxygen content.
