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'Feeling the pulse' in hard to solve problems

The morning meeting at the plant was long. Especially for you, because operations had a lengthy discussion over vibrations in a pump and pipe system. This is the third verse of the same song and dance, and you have worked at length to solve the problem. You had thought the problem was "nailed," and you were on to the next priority. The vibration is a major concern because of fatigue failures in the piping and because the instrumentation was shaking loose and shutting the plant down.

The production supervisor met with you after the meeting and said, "Whatever it takes, get it done and fix it." With the reverberations of the production supervisor still sounding, you reflect on all the failed attempts. The process is a slightly subcooled (meaning just below saturation conditions) fluid. You reflect on all the teams and their various attempts to fix the problem:

1. The first team that looked at the problem concluded that the piping was not supported properly and the process caused the vibration. The team decided to add more supports and improve the welding process. Metallurgical analysis indicated fatigue failures in the heat-affected zone of the welds.

After a major review, it was decided to stress relieve the welds after repair. After this investigation, everyone felt confident the problem was identified and a solution had been implemented. Unfortunately, after the startup another failure quickly occurred. Once again, the team met in the conference room and realized that there is more to this problem than they anticipated. A vibration expert was called in and he suggested that the supports "tuned in" the system to a critical natural frequency and that is what caused the problem. The supports were reworked with the help of the piping vibration expert and the vibration did subside, but a failure still occurred.

2. A second team started thinking about a control valve upstream of the failure areas. It was noticed that the control valve oscillated greatly and it was concluded that that must have been causing a pulse. After talking to vendors, a control valve was selected to provide better stability. The valve was installed and the plant noticed some improvement, but failures still occurred. This time the failures started on irregular cycles and were completely unpredictable. Although better, the job was not done.

3. The third team started looking at the pump upstream of the control valve. The inlet and outlet piping system was not in accordance with generally accepted standards. It was felt the configuration was leading to cavitations. The piping was revised with high optimism, but no remarkable improvement was achieved.

Obviously, the plant engineer is dealing with a complex problem. All the teams consisted of an excellent staff with proven track records. The source of the problem was not identified until a process evaluation of the system was included in the root cause analysis. The process was determined to be a slightly subcooled state. The overall process based on steady state conditions suggested there should not be a problem. However, the system had several process streams coming together. When a control valve opened, a pressure pulsation would send a pressure wave and the fluid would flash off. This led to further pulsations and then the system would go unstable. Hence, the root cause was a thermodynamic instability.

The problem was diagnosed and solved using the following procedure:

1. Metallurgical analysis to evaluate the failures to characterize the fracture surface.
2. Structural dynamics analysis to understand what "drives" vibration.
3. Acquire field data to determine the dynamic pressures and vibration during all operational modes.
4. Perform a process analysis to determine the thermodynamic limits of the system.

In this particular case, determining how much subcooling is required to keep the system stable solved the problem. The key to understanding the cause and effect, is understanding the process. Be careful when looking at the process conditions, as there may be several species in the fluid that can flash out.

Dynamic instability problems are often complex and involved. An integrated systems approach as defined above is the best approach. Each problem is specific to itself and the governing conditions. Have a professional engineer, competent in this type of work, involved with the problem solving process.

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