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Reciprocating compressors running together: Is it a problem?

You have just started your new job as a maintenance engineer. Contained within your facility are vent gas compressors that in general run well but on occasion fail. The system consists of three compressors in parallel. The compressors have had a remarkable number of valve failures and, on occasion, some instrumentation connections have broken off.

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The suspected culprit was acoustical driven vibration issues. In a nutshell, every contained volume has a set of acoustical natural frequencies. When a forcing function is coincident with one of the acoustic natural frequencies, the fluid contained within the volume will experience pulsations that can be remarkable at that frequency. When these frequencies are coincident with the structural natural frequency, the piping can vibrate. In this particular problem, there were several areas where the actual field conditions conflicted with the study. First, each compressor was analyzed on a unit basis and not as a combined parallel system. The second problem was the molecular weight varied, causing different acoustical natural frequencies. The final challenge to the system with the drivers was variable speed. One approach to solve the problem is:

1. Historical review — It is important to look at the original design basis. As with the given problem above, the way the machine was running did not match the way the analysis was performed. Acoustic analysis is different from many forms of engineering analysis in that the actual response has to be evaluated based on the actual operating conditions. Sometimes, there is a misconception with this work that there is a factor of safety for the acoustical analysis. It is important the final piping configuration be evaluated based on the "as built" from the field. The suction and discharge pulsation bottles must be acoustically tuned to the actual piping system for the best results.

2. Field study — A field study should be conducted on a multichannel system that measures both vibration and dynamic pressure. It is important to place the pressure transducers in a location where the system can pick up any pressure pulsation that may be present. If the location is at a "node" point in the domain, one may falsely conclude there is no pulsation present. Also, another problem with this measurement is the location of the dynamic pressure transducer may be too far away from the flow field. This may be the case, for example, if the pressure transducer is contained within a double block and bleed. The other issue is to make sure the process conditions are recorded at the time of the test. If valves are failing as described in the problem above, it is desirable to have dynamic pressure readings in the head.

3. Structural dynamics/digital pulsation study — This involves the development of two numerical models that duplicate the response in the field study. One model predicts the acoustical response and the other predicts the mechanical structural response. Once the model is reconciled or validated to match the field data, the "what if" question can be asked. In other words, the "fix" can be determined on a numerical basis with the confidence of a valid numerical model. Remember every process scenario should be evaluated including the variable speed range as in this problem. Unless the supports are approximately 10 times stiffer than the piping, it generally should be considered part of the domain of the structural model. For the acoustic model, the side branches for instrumentation are important as these could act as side branch resonators. For variable systems, it is sometimes desirable to design the pulsation bottles to "snuff" out everything from the compressor, especially to avoid interaction problems.

4. Design review — Once the proposed design is determined, it should be reviewed with plant team members from operations, process engineering, mechanical and controls. The design basis should be discussed and approved by the team.

5. Installation — Once the modification is installed in the field, measurements should be taken to validate the response.

The resulting analysis should be reviewed and approved by a professional engineer.

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