KNIGHTHAWK TECH NOTES

PHONE: (281) 282-9200 • FAX: (281) 282-9333
WEBSITE: www.knighthawk.com

November, 2016 **Issue 16.04**

"Sizing of Inlet Headers for Cracked Gas Quench Systems"

Your team has been working for over three years to build a world class ethylene plant. Finally the time has come and commissioning has started. Commissioning is expected to last several weeks if not longer. Management is all gathered in the control room to view the "board" because this is the first time feed stock is fed into the cracking furnace to make ethylene. Temperature in the furnace is brought up and things are looking good. Finally you are on line and everyone is excited to see the plant in operation. All the "old timers" are not celebrating because they know it is too early, after all, this is "just another rodeo", and there are always bugs to get out of the system.

Then an alarm sounds at the board, indicating that the cracked gas out of the selective linear exchangers is several hundred degrees high. Inlet is 1550 °F and outlet is usually about 780 °F, but now it is 1100 °F out. Everyone is looking at each other but the guy with gray hair says we have a failure in the quench system. Operators are sent out and steam is clouding the whole furnace area. The unit is shut down.

Going out in the field you look at the failure. Supports are broken on the outlet line, likely because of the high temperature the line experienced. The outer jacket on the "selective linear exchanger" is cracked and steam is shooting out. As the maintenance manager you know that the "head shed" will be calling and asking how you are going to fix it and when can they get it running again. You are "bugged" about this situation because these type units are operated all over the world and they are in general very reliable. There is a rush to fix and start up again only to have another failure.

At this point the Plant Manager gathers the team to discuss the path forward. Now management, after two large failures, are reconciled to the point that a root cause failure analysis (RCFA) must be done. A team has been assembled and you are the lead. Experts are brought in. The following areas are investigated after a metallurgical and material analysis confirms the failure was due to stress rupture due to high temperature. The results of the analysis are:

1. Process checked out OK after exhaustive analysis
2. Controls OK after much testing.
3. Maintenance – all systems are checked and OK
4. Mechanical Design is OK

In short, everything checks out OK. You have an afternoon meeting with the Plant Manager where you and your team are going to have to explain what the root cause is and how it is going to be fixed. Two hours before the meeting and your team has no idea. With a terrible feeling in your gut you know that this is unacceptable. The only thing you know is that the same sector failed in both failures. What is the problem?

The cause of this failure was a maldistribution of the flow on the inlet header. A local section overheated because of the low flow and then "flash off" occurred, causing vapor lock in the system and then catastrophic failure occurred. In order to find out the root cause, a computational fluid dynamics (CFD) analysis was conducted in conjunction with a thermosyphon analysis of the boiler feedwater. These analyses were iterated between each other to converge closely on the actual conditions. The thermosyphon program was able to calculate two phase flow with slip conditions. In other words, it considered the properties of the two phase mixture. In this system, a lab test was conducted to perform cold studies of the flow distribution.

This figure indicated the flow coming out of the header. Notice how the stream is lower on the first pipe. This suggests that the inlet header is not behaving as a true reservoir and the dynamic pressure is affecting the flow field.

Where the flow is the highest at the end of the header more mass flow is experienced and the fire branch gets little flow. If the design was acceptable, then all branches would have the same flow rate. With all analytical models and cold flow models indicating agreement the problem was fixed.

When designing a system like this, consider the following.

1. Perform a thermal layout of the system that will consider two phase flow with slip. If there are feed branches in parallel, then a thermosyphon model must be conducted that can address the complex non-linearity this can cause.
2. Size the inlet head so it behaves like a true reservoir. A CFD model will help to make certain this is the case. In fact, the outlet head should be designed this way as well.
3. A heat and material balance should be conducted to determine the temperature distribution of the cracked gas.
4. Perform pipe stress analysis to confirm it meets Code requirements.

This is not a conclusive list, but it is the high points. It should be noted once the RCFA was complete, the problem was fixed and solved. As always, the work should be done under the direction of a professional engineer competent with this equipment.

Cliff's Notes:

KnightHawk has solved many problems in industry related to selective linear exchangers and quench coolers. We have the people and tools to get the job done. Because we have analyzed so many failures, it's likely we can see what the problem is when we visit the plant on the first day. Our team typically will have answers on the system within the first week of the RCFA.

I want to wish everyone all the best for this Thanksgiving Holiday. Sit back and think about all that you are given and all that you have. I hope you have a great "Turkey Day".

Take care and God Bless,

Cliff Knight

cknight@knighthawk.com

KnightHawk Project Update

- Furnace Tube Failures
- Heat Exchanger Tube Failures
- Hot Tank Structural Failures
- Structural Analysis
- ASME Code Assessment of Vessel Design
- Motor Driven Structural Vibration
- Repaired Tank Fit for Service Analysis
- Fin Fan Cooler Failure Analysis
- Discharge Piping Analysis
- Impeller Resonance Testing
- Process Valve Fit for Service
- Pump Design Assessment
- Structural Vibration Caused by Acoustic Pulsation.
- Steam Let down Valve Vibration
- TLE Inlet Cone Flow Analysis
- Compressor Vibration
- 3rd Party Design Review
- Acoustical Vibration - Reciprocating Compressor
- Compressor Vibration Field Services
- TLE Design Audit
- Low Temperature Brittle Fracture Analysis