NEWSLETTER

April 2016
Year IV - Edition LIII

INSPECTION & ENGINEERING - SOLUTIONS & TRENDS

INSPFALCA INSPECTORES DE FALCON, C.A.

▸ **SPECIAL EDITION**

The Synergy of Degradation Mechanisms and Systems Failures

▸ **EDITORIAL**

In this issue I want to share with all the satisfaction and appreciation of their support for this our Newsletter Inspfalca. This initiative that we started counting on you has resulted in this success that we all celebrate and enjoy – Thank you! Highly appreciated have been timely and accurate feedback we have been receiving from you, which has become the true raw material has allowed us to shape the newsletter to our community what readers want and need. At this level I want to invite you to go forward with us and to share the challenge. Let's all do our interaction more dynamic, we will maximizing the use of Network Inspfalca to discuss and exchange ideas on articles published in this Bulletin and to generate new items - Come on - we count on you.

In this issue we are addressing topics on complex interactions of degradation mechanisms and system failures that in synergistic effect have resulted in catastrophic failures of very severe consequences.

We are also analyzing how complacency becomes the human contributor factor of greater impact on the occurrence of failures, something easy to say but difficult to manage.

Francesco Solari
Inspfalca President.

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ACCIDENTS

Towards 30 Years

INDUSTRY COLUMN

How to Avoid the Complacency Trap

By Rosa Solari
Inspfalca Vice President

In my focus and passion for excellence I frequently find that as we are getting good in something, as we master our skills and as we gain experience in an area; there is an increasing risk to miss things and fail. This is a summary of an article that I found very interesting about this topic of "Complacency"

Complacency is defined as a feeling of being satisfied with how things are and not wanting to make them better. It's usually accompanied by unawareness of actual dangers or deficiencies.

The thing about complacency is it sneaks up on you ever so quietly. It happens slowly over time, going almost unnoticed. It might be disguised as contentment. It becomes invisible in the wake of success. It conceals itself behind relationships you take for granted. It hides beneath the surface of self-justifying statements like, "I had no control over the outcome." The next thing you know, complacency has led you to mediocrity. Mediocrity results in uninspired, undistinguished, unexceptional, lackluster and forgettable performance.

You must guard against complacency at all costs. The best way to do that is to always shake things up. Turn off the TV and put down your phone. Get off the couch and go for a jog. Do something you've never done before. Change your routine so you meet new people. Hire a coach. Go see a marriage counselor. Ask for feedback and then do something with it. Admit your weaknesses and work fervently to minimize them. Pitch an idea to your boss. Ask to lead a major project at work. Pay careful attention to your competitors. Stay current on what's happening in your industry and anticipate how changes in it will affect your business. Move people into new positions within your company. Help your employees and co-workers solve problems. Set goals and make a plan to achieve them.

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Because getting unstuck can be difficult, it's critical to surround yourself with people who can support your efforts to get out of the complacency trap. There is a fantastic book called "Change Anything — The New Science of Personal Success," written by Kerry Patterson, Joseph Grenny, Daniel Maxfield, Ron McMillan and Al Switzler. When complacency and mediocrity have a grip on you, this book is an excellent resource, giving you many ideas on how to release its hold. A key factor of success is having people who are coaches and mentors in your life.

It's also very important to make sure you (and your team) are crystal clear on the why of what you are trying to achieve. Defining the why sets a vision and a path forward. You can come back to it when you start to feel like you are losing your way because wandering around aimlessly without a well-defined (and shared) purpose is a surefire way to cultivate complacency. Doing something just for the sake of doing it is about as uninspiring as it gets.

Most importantly, never ignore the little things that start to tear at the fabric of your personal well-being, family, team and/or organization. Don't sweep problems under the rug. When problems and issues are not addressed and complacency is tolerated, it becomes what's accepted and expected. Act swiftly and with care because, if left alone, you are setting the stage for lackluster performance, unhealthy relationships, general lack of inspiration and even scarier paving the way to failures.

All the above also applies to safety, where mediocrity has high costs in accidents with devastating consequences.

The invitation goes to all of us, to be vigilant on complacency. What are you doing to fight complacency?

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LESSONS LEARNED

How degradation mechanisms and several other circumstances can align to cause a tragedy

At 2:29 a.m. on December 17, 2013, one side (unit 80) of a two-story duplex at a public housing project in Birmingham, Alabama, exploded when natural gas in the apartment ignited. The explosion and fire destroyed unit 80 and heavily damaged the adjoining apartment (unit 79). The explosion also damaged several adjacent homes. One fatality and injured residents made this incident a tragedy that triggered a thorough investigation which lesson learned are here discussed.

Probable Cause

The National Transportation Safety Board (NTSB) determined that the probable cause of the accident was the release of natural gas through a large crack in the 62-year-old, cast iron gas main line that resulted when tree roots growth cracked the corroded pipe. The crack was caused by the combined effect of the pressure built by rock between the roots and the pipe, and a degradation mechanism confirmed with the failure analysis as graphitic corrosion which causes the material to get more fragile.

Another contributing factor was the collapse of the sewer system that collected the gas from the failed line and provided the path of the flammable gas thought the toilets. Once the accumulating gas reached the explosive limit inside the apartment, an active pilot light on an appliance ignited the gas. Contributing to the accident was the absence of the odorant, which was absorbed by the soil and prevented residents from smelling the gas.

In summary here's the list of elements that aligned to cause this tragedy.

- Graphitic Corrosion Degradation Mechanism
- Mechanical Damage Caused in the Pipe due to interference with vegetation growth
- Collapsed Sewer Systems
- Absence of gas odorant caused by soil absorption

We hope this failure analysis findings create awareness in how the interaction of failures in several systems can lead into a catastrophic major event.

For more details about this accident and the NTSB report visit; Link

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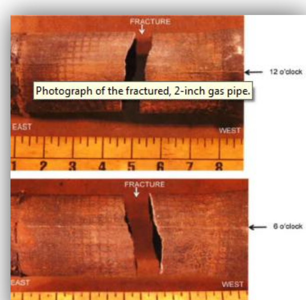

Photograph of the fractured, 2-inch gas pipe.

Risk Mitigation Process for HTHA Failures

The High Temperature Hydrogen Attack (HTHA) failure at a refinery in the state of Washington was a "wake up call" to our industry. On April 2, 2010, the shell of a feed-effluent heat exchanger in the Naphtha Hydrotreating (NHT) unit at the Tesoro Anacortes WA refinery ruptured, ultimately resulting in seven fatalities. The failure mechanism that caused this event was determined to be HTHA. Much speculation arose as to what the actual process temperatures were and whether this failure could have been prevented, but regardless of how well one felt that they were mitigating HTHA, many owner-users took a long, hard look at their existing programs to make certain they had done a thorough job of assessing HTHA risk of their own assets.

The subject of HTHA and inspection for HTHA has become a well discussed, and well attended, topic at NACE, API, and AFPM events since the Tesoro incident, indicative of the high level of attention this subject has been getting. Joint Industry HTHA projects have commenced and new examples of HTHA have been submitted to the API Recommended Practice (RP) 941 committee for consideration to include these new points into future updates. However, despite all this activity, not much has been shared regarding how one goes about setting up and executing an HTHA risk mitigation program at their sites.

High Temperature Hydrogen Attack (HTHA) is an intergranular damage mechanism that occurs in some steels as a result of exposure to hydrogen and elevated temperatures over time. Steels, which include carbon, carbon - 1⁄2 Mo, Mn-1⁄2 Mo, and Cr-Mo steels, have microstructures that contain carbides. These carbides help the steel's mechanical properties, but also contribute to initiating HTHA.

In a new carbon steel component, for instance, iron carbide (Fe_3C) platelets will exist in the steel's grain boundaries. Under high temperature and high hydrogen partial pressure conditions, hydrogen atoms can diffuse into the component and react with the Fe_3C to form methane gas (CH_4) bubbles along these grain boundaries.
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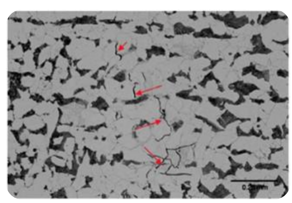

As the process continues, these methane bubbles can link to form small fissures and then larger cracks. If the process continues, cracks can grow and failure can result, sometimes with tragic consequences.

History of HTHA and API RP 941

HTHA was first documented in the 1920s in Germany, as part of coal derived liquids conversion efforts. Even back then, there was general agreement that the attack was a result of hydrogen reacting with carbides in the metal to form methane. Because of the demand for fuel and associated products needed to support the war efforts in the 1940s, new refining and petrochemical processes were developed using hydrogen at high temperatures and pressures. Following World War II, hydrogen based processing (hydrotreating and reforming) became more popular and occurrences of HTHA became more frequent. George A. Nelson, who worked for Shell Development, and several others, started plotting the process data (temperature and hydrogen partial pressure) associated with these failures (or lack of failures), which allowed the industry to begin selecting reliable materials to resist HTHA. The first set of "Nelson Curves", as they have come to be known as, were submitted to API's Division of Refining in 1949. This submission eventually led to API publication 941 in July of 1970. These curves have been modified over time, as new data was submitted to API.

The start of a HTHA risk mitigation program

The first item that has to be addressed when developing an HTHA review process is defining the actual scope of work to be tackled. Are you just doing one unit, the entire plant, or multiple refineries? The answer to that question will help define the resources needed to accomplish the activities. What specific units or assets will need to be assessed? In a refinery, all hydroprocessing units (hydrocrackers, hydrotreaters, and catalytic reformers) along with hydrogen, methanol, and ammonia producing units, should be on the "HTHA potential" list. Other units may be included if any part of the process contains hot hydrogen. Everyone's definition of hot hydrogen might be a little different, but the published API RP 941 Nelson Curves can be used to help define that term. This definition of "hot hydrogen" will also be used to define what will and will not need to be included in the scope of work. Susceptibility to HTHA depends on several factors, but the three most important are the following: Material, Exposure Temperature and Partial Pressure of Hydrogen in the process.

Typically, the assessments will focus on carbon steels, C-1/2 Mo and Mn-1/2 Mo steels. Cr-Mo steels require higher temperatures and/or hydrogen partial pressures before HTHA occurs and therefore are less likely to experience HTHA in normal refinery environments. Still, one needs to assess all operating conditions against the respective alloy's Nelson Curve before determining the likelihood for HTHA. To do this properly, the next step, which is the most labor intensive, will be to collect data on each piece of equipment and piping circuit that meets the definition of "HTHA potential".

Data collected should, at a minimum, include the following:
- Installation date,
- Material of construction,
- Whether the component was heat treated,
- Whether there is any cladding, liner, or overlay present,
- The thickness of any existing cladding, liner, or overlay,
- Whether the component is refractory lined (cold wall design),
- Inspection history,
- Design data (pressure and temperatures),
- Operational data, including process temperatures and hydrogen partial pressures.

Hydrogen Partial Pressure

The process hydrogen partial pressures typically come from the unit process engineer. The calculation sounds simple enough; determine the mole fraction in the process multiplied by the total system pressure. However, it has encountered a wide variance in the initial accuracies of the partial pressure data provided. It always is advisable to double check with another process engineer or review the unit's design premise to establish what the original partial pressures were anticipated to be. If there are significant differences encountered, determine why. If the stream being assessed contains liquid hydrocarbon, the hydrogen partial pressure is calculated a bit differently. One method, cited in API RP 941, involves using the vapor pressure of the gas with which the liquid stream is in equilibrium. This is an important point, as many mistakenly believe that since you have a liquid stream, the amount of hydrogen present is very low, which will lead to underestimating the partial pressure of the gas.

Process Temperatures

If we had working process thermocouples before and after each piece of equipment in our units, this part of the assessment would become much easier, but sadly, this is not the way these units were designed years ago. Each unit and plant will be different, but in general the refineries do not have enough thermocouples from an inspection and metallurgy perspective to adequately assess a components susceptibility to a particular damage mechanism. This statement goes beyond HTHA, as many damage mechanisms are temperature dependent.

You might have a handful of thermocouple data points, but what about everywhere else? What about the stack of exchangers where you know the inlet temperature into the first and the outlet temperature out of the last one? Do you know the middle exchanger's temperature profile? This is where many have unknowingly erred in the past; by assuming a temperature, or relying on a process engineer's "best guess". It is critical to quantify these unknown temperatures, unless it is determined that even a worse case temperature would not be an HTHA concern. To get these unknown temperatures, two methods have primarily been used: infrared (IR) testing and contact pyrometry. Both have limitations. IR testing can have a +/-25°F variance on a good day, and higher variances have been noted when equipment is not operated properly. From experience, the contact pyrometer (thermocouple) has less variance than IR, but IR may be more convenient to use, particularly for equipment that is out of reach. One must be aware that trying to obtain a temperature reading on a non-insulated flange on an insulated line, will likely not give accurate values.

Integration with PMI Program

While setting the scope and reviewing data, it is important to review the site's positive material identification (PMI) records. Have all the alloy systems been subject to that review? Have there been discrepancies detected that have not been addressed yet? If a rogue carbon steel component is left behind or not yet discovered in high temperature chrome-moly piping systems containing hydrogen, an unknown HTHA risk may be present. If PMI has not yet been done in a unit, it is advised to run "what if" scenarios in the alloyed systems to determine what the HTHA risk would be if a carbon steel component was present. This can help prioritize the PMI activities.

In addition to the PMI data review, it is advised to review the unit's P&ID's. Occasionally, a section of lower alloy material can be found in a higher alloyed circuit that was intentionally put there, and if P&ID's are correct, this is the best way to locate these. Sometimes these are circuits that have had a service change and the MOC, if done, did not highlight the HTHA risk.

Bottom Line

HTHA is not new. It is like many mechanical integrity issues that get attention for a while, until a new issue comes along. Then an event like the Tesoro tragedy occurs and regains everyone's interest. Operators need to do whatever they can to prevent another event like this from happening again. Part of that will be developing robust risk mitigation programs in every facility.

As always here in Inspfalca we are ready to support our clients, in this specific case we have the experience and capability to provide solutions to mitigate HTHA risk based on HTHA risk assessment services, IR temperature surveys, UT / RT surveys and retro-PMI programs.