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Application of Temperature Activated Relief Devices Part 1

By Martin Gollin

Background

Under certain conditions, some reactions can undergo an exothermic runaway. Such a reaction occurs when the rate of heat generation exceeds the rate of heat removal. The temperature of the system then increases, which accelerates the rates of reaction and of heat generation. The temperature then increases further, and the reaction experiences a rapid (exponential) temperature and pressure increase. In some cases, the exothermic reaction may generate compounds that can result in secondary consequences that must also be mitigated (e.g., peroxide decompositions can generate oxygen with the potential for the formation of flammable vapor mixtures).

The potential for an exothermic runaway reaction, and its severity, depend upon several factors. These include the:

- Heat of reaction
- Rate of reaction
- Effect concentration changes have upon the reaction kinetics
- Vapor liquid equilibrium (VLE) of the system (i.e., the relationship between the temperature of a given composition of liquid, the vapor composition and the system pressure)
- Sensitivity of the reaction to contaminants
- Sensitivity of the reaction to variations in the amount of catalyst that is present
- Sensitivity of the reaction to upstream upsets
- Mass of the system
- Relative amounts of reactants and inerts in the system
- Amount of cooling which is applied, or could be applied, to the system

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- Physical properties of the reactant and inerts (heat capacity, latent heat, etc.)
- Physical design of the reactor system

Initiating events that may result in an exothermic runaway reaction include fire, loss of cooling, contamination, loss of upstream reaction, control system failure, catalyst deactivation, etc. In order to analyze the response of the system and the requirements of the safety systems, it is important to clearly define the scenarios that could require safety systems to operate.

The effect of using a pressure activated relief device to provide protection in the event of an exothermic runaway reaction is that, when the relief valve opens it is the "light" material that is vented preferentially. This has the effect of changing the Vapor-Liquid Equilibrium (VLE). As a consequence, if the reactants are the "heavies" in the system, when the relief valve closes the temperature is higher than at the same pressure before the relief valve opened. Therefore, if no action is taken, the exotherm will continue, but at an accelerated rate. The cycle of relief valve opening, closing and the increasing reaction rate will continue until, eventually, the relief valve cannot provide adequate cooling and the temperature and pressure of the system accelerate exponentially.

There are systems where, no matter how large a conventional pressure-activated relief valve is installed, it may not be possible to demonstrate analytically that sufficient venting can be provided to protect the system from exceeding the Maximum Allowable Working Pressure (MAWP). Such systems may include polyol reactors, oxidation reactors, epoxidation reactors, etc. Indeed, any system where the reactants are high boiling point materials should be examined for the potential that a conventional spring activated pressure relief valve system might be unable to prevent an overpressure following an exothermic runaway reaction. If protection against overpressure of the system cannot be provided by a conventional spring activated pressure relief system, then some type of instrumented system or a pressure relief system that does not re-close (e.g., a rupture disk) must be used.

ASME Code Considerations

The potential for the situation where conventional pressure-activated relief valves may be unable to fully protect a vessel or system from overpressure is recognized by the ASME Code. ASME approved Code Case 2211 (ASME, 1995) which allows pressure vessels and systems to be protected by system design in lieu of mechanical (i.e., pressure-activated) relief devices, subject to the following conditions:

- The vessel is not exclusively in air, water, or steam service.
- The decision to provide a vessel with overpressure protection by system design is the responsibility of the user. The manufacturer is only responsible for verifying that the user has specified overpressure protection by system design, and for listing this Code Case on the data report.
- The user shall ensure that the MAWP of the vessel is greater than or equal to the highest pressure that can reasonably be expected to be achieved by the system. The user shall conduct a detailed analysis, which examines all credible scenarios that can result in an overpressure condition.

CAUTION: This is a short summary of the discussion and guidance provided by Code Case 2211. Any organization wishing to utilize this approach is advised to study the Code in detail before proceeding with this practice.

Code Case 2211 does not define the level of protection that must be provided by an instrumented system in order that the frequency of a scenario that a mechanical relief device would be required to work is "tolerable." This is designated (implicitly) as the responsibility of the user/owner of the system.

Some governments define acceptable risk levels for facilities constructed within their jurisdiction. This is not the situation in the USA. Various companies have adopted their own internal objective risk tolerance criteria that allow them to determine at what frequency a given consequence should be tolerated. This issue is discussed in the books *"Layer of Protection Analysis - Simplified Process Risk Assessment[1]"* and *"Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires[2]."* Other companies rely upon analyzing each scenario individually and assessing qualitatively whether adequate protection has been provided. However, unless some endpoint is defined, it is difficult for an organization to assess in a consistent manner whether adequate protection has been provided for a given scenario.

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Comparing Knock Engines with NIR Analyzers for In-Line Blending

By Ara Barsamian

Introduction

With the ultra low sulfur/ethanol gasoline blends around the corner, one would like to get the blends done right the first time around, preferably being capable to certify while blending to a ship or pipeline. Currently, the officially sanctioned ASTM method for in-line blend certification of gasoline octanes use CFR knock engines (ASTM D2885); however, these are very maintenance intensive, temperamental, and very difficult to use for routine blending.

In contrast, NIR, NMR or Raman-based analyzer technologies are very easy to set up and run. In addition, they can measure additional properties, thus saving the cost of additional 7 to 10 analyzers for other properties. Their "hassles" include the effort to get "special waivers" to be able to use in the D2885 comparator mode for blend certification, and development of robust property prediction models.

Because of the great interest in the subject, a comparison was made between the Life Cycle Costs of a CFR knock engine installation against a NIR multi-property analyzer. The NIR type analyzers are generally the most cost-effective, and if the modeling is right, very reliable and hassle free.

Comparing CFR Knock Engines with NIR Analyzers

We want to compare two things: life-cycle costs, and ease of use.

Life-Cycle Costs

There are four cost areas considered:

- Initial investment to purchase, install, and validate
- Costs to measure additional properties
- Annual operating costs
- Refinery personnel costs

The bottom line is that NIR (or NMR< Raman) runs circles around a knock engine, with NIR running at about 3.4M$/10 years vs. 5.9M$/10 years for the knock engines. With the knock engines, we need to also add the cost of another five to eight analyzers (e.g., RVP analyzer, distillation analyzer, density analyzer, and aromatics, benzene, olefins and oxygenate analyzers) together with their sampling and sample conditioning systems, protofuel check systems, etc.

Ease of Use

The CFR knock engines require about 24 discrete steps to start up the engine, warm it up, and make it ready to analyze the blended stream; conversely, it requires an additional ten steps to shut it down. Just to give an idea of the typical steps, the following is an abbreviated list for the RON engine:

- Check sight glass on correct proto tank that enough available for blend
- Connect engine to prototank via flex hose
- Check coolant and oil levels
- Zero the knockmeters
- Check the spread
- Load proto data in DCS
- Manually start the engine
- Oil the valves
- Check engine flow
- Adjust flow temperature
- Adjust manually the KI to ~ 50
- If everything ok, switch from Proto to Line
- Wait for ~ 1.5 hours before getting "good" readings

And this assumes you don't have plugged filters, or N_2 blanket in prototanks leaking into the fuel and choking the engine, etc.

Now, this whole sequence has to be done for the second (MON) engine, etc. The start up and shut down can be partially automated with PLC's, but it still requires a technician or blender to keep an eye on it.

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Hot Tap Inspection Considerations

By Vincent A. Carucci

Careful inspection is essential to achieving a successful hot tap. This inspection includes the pipe or equipment being hot tapped, the hot tap equipment, and the hot tap itself. Inspection guidelines are highlighted below and may be used to develop site and application specific inspection requirements.

- Examine the pipe or equipment in the immediate area of a proposed hot tap using UT to check for thin areas and laminations, MT or PT to check for surface defects, and UT if hydrogen attack is suspected.
- If pitting, cracking, or fissuring may be present, check the material by radiography, UT, dye penetrant, or other appropriate methods.
- 100% radiograph any longitudinal weld seams that will be welded over or covered by the hot tap components.
- If other forms of degradation could have occurred that would significantly affect material properties, then determine its extent and confirm that the material condition is safe.
- Inspect components prior to installation, and confirm that they are the proper material, size, rating, etc.
- Inspect the welding electrodes for correct material and condition, and review the welding procedure.
- Review any precautions to be followed before or during welding and hot tapping.
- Confirm that the correct location has been selected for the hot tap.
- Perform a high-pressure seat leakage test on the hot tap valve no more than 24 hours before the hot tap. The allowable leakage should be zero. This is a critical step since if the valve leaks after the hot tap cut is made, the hot tap machine cannot be removed without taking the system out of service.
- Inspect the welded assembly for compliance with specified flange alignment tolerances and clearances.
- Confirm that the hot tap valve and machine are suitable for the service conditions. Witness the pressure tests of the valve and machine.
- After welding the nozzle and before adding any reinforcement, visually and 100% PT or MT inspect the completed nozzle-to-pipe (or equipment) and nozzle-to-flange welds.
- Witness the pressure test of the nozzle assembly.
- Measure the weld hardness if required for particular materials (e.g., 1-1/4 Cr-1/2 Mo), and confirm that it is acceptable.
- Visually, and PT or MT inspect the reinforcing pad welds. Witness the reinforcing pad leak test.
- Verify alignment of the hot tap assembly at each step of the attachment procedure. This includes the nozzle, valve, and hot tap machine.
- Inspect the coupon after it is removed to evaluate the extent of header internal corrosion and verify wall thickness. This is useful information to help plan future inspection needs and intervals for the system based on the amount of corrosion that has occurred.

Comparing Knock Engines with NIR Analyzers for In-Line Blending
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For NIR, the whole start up and shutdown sequence is controlled by the DCS. Since there are no mechanical components, the sequence includes optical and electronic self-diagnostics per ASTM D6122 to make sure it works properly, and then it is checked against the correct protofuel (switched in automatically by the DCS software). If it passes both tests, then it is automatically brought on-line. It typically provides blend line readings every one to two minutes (of all 10-15 properties, not just octanes), depending on design. In addition, every one to two minutes, there are performance monitoring algorithms checking the raw readings against predicted calculations, and the difference has to be less than the ASTM tolerance.

Hot Tap Installation Considerations

By Vincent A. Carucci

Detailed procedures must be used for the fabrication and installation of hot taps. The following highlights several items that must be considered when developing site-specific procedures.

- All welders and welding procedures must be qualified to meet all applicable ASME B31.3 requirements for piping systems, ASME Section VIII requirements for pressure vessels, and API-653 requirements for aboveground atmospheric storage tanks.
- Use full penetration welds for the hot tap nozzle.
- Ensure that weld metal does not project past the nozzle inside diameter. Otherwise, this could impede removal of the coupon.
- Do not weld over known thin areas, material with laminations, or in areas where temporary repairs have been made which may be adversely affected by the hot tap welding and cutting.
- Carbon steel welds made at temperatures below 40°F (4°C) may require special preheat and welding procedures to prevent moisture, high weld metal temperature quench rates, and potential weld cracking. Alloy steel welds may require specific minimum preheat temperatures.
- For double welded joints, perform MT or PT inspection of the back side of the root pass before backwelding.
- Specify appropriate welding electrode type and size, amperage, weld sequencing, and preheat.
- Protect the welding area from strong winds, blowing dirt, snow, or rain.
- Consider doing a practice session on a full size "mock up" in certain situations (e.g., when appropriate flow rates and welding procedures must be established).
- Consider weld overlaying the surface prior to attaching a nozzle to pipe that is fabricated from plate that is 3/4 in. (19 mm) or heavier to prevent lamellar tearing of the header pipe.
- Proper attachment and alignment of the hot tap fitting to the pipe is vital to achieving a successful hot tap. Otherwise, the cutter may damage the pipe wall.
- Full encirclement fittings require special care during nozzle installation. The fit should be checked before installation, and care should be taken to ensure that the matched ends are correctly installed.
- For bolted fittings, thoroughly clean all contact surfaces and grind off any high spots to leave a smooth surface for attaching the fitting.

Use of the above requirements, in conjunction with site and application-specific requirements, will help ensure reliable hot tap installations.

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Summary

Conventional pressure activated relief valves may not be able to provide sufficient venting to protect a system from exceeding its MAWP. In such cases, overpressure protection may be provided by system design. A subsequent article will highlight some ways that this may be done.

References

1. *Layer of Protection Analysis - Simplified Process Risk Assessment,* American Institute of Chemical Engineers, Center for Chemical Process Safety, New York, 2001, ISBN 0-8169-0811-7.
2. *Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires,* American Institute of Chemical Engineers, Center for Chemical Process Safety, New York, 1996, ISBN 0-8169-0646-7.

- Provided extensive Hydrocracking consulting at a European refinery.
- Participating in a major Hydrocracking/ Hydrodesulfurization unit initiative with a large European refiner.
- On behalf of a third party, carried out a European refinery operability/performance audit.
- Conducted a Corrosion Management Scoping Study for a European client and developed a followup action plan.
- Conducted a Turnaround (T/A) Improvement Scoping Study for a European client and developed a followup action plan.
- Provided refractory consulting assistance for two Canadian clients in support of turnaround planning activities.
- Conducted several Construction Site Safety Reviews for US and Canadian clients.
- Assisted a US client with thermal $DeNO_x$ testing.
- Assisted a European client with troubleshooting several furnace operational problems.
- Assisted a European client in evaluating an Asset Management System (AMS) software proposal.
- Continued to provide a US client full-time mechanical engineering assistance in performing Finite Element Analyses.
- Providing extensive heat transfer support to a US client.
- Providing expert witness assistance to three US based clients for major process plant damage incidents.
- Provided waste heat boiler modeling assistance to a US client.
- Conducted a scoping study to support the development of company-wide valve engineering standards for a US client.
- Presented fixed equipment mechanical design and plant reliability and maintenance system training courses for a client in Greece.
- Continue providing extensive process design services to a major technology developer/ licensor.
- Completed crude unit energy assessment at a European refinery.
- Provided crane lifting safety reviews for several clients.
- As part of a refinery-led team, developed Reliability & Maintenance and Turnaround Planning program for a European client. When fully implemented, this program is expected to save the client at least $14M per year in maintenance costs plus increase refinery availability by over 6% (equal to a margin gain of at least $13M per year). We are now assisting this client in program implementation.
- Developed and executing multi-faceted strategic operations reliability initiative program for European refiner.
- Performed scoping assessment of vacuum unit overhead condenser options for European refinery.
- Participated in major domestic refiner's safety survey of atmospheric relief systems encompassing all international and domestic sites.
- Performing pilot plant scale-up development for domestic refiner.
- Performing strategic research for a domestic refiner regarding heavy oil conversion and refinery/chemical plant interface.
- Providing technical consultation related to breakthrough research regarding chemicals recovery and GTL technologies.
- Performed safety consultation on FCCU Reactor/ Regenerator for a local refiner.
- Performing design basis and front end design package for vacuum unit overhead condenser system upgrade for overseas client.
- Performing Technical Audit of shutdown Fertilizer plant in Europe to determine feasibility of returning to service.
- Authorization to proceed received for strategic initiative for vacuum and visbreaker unit(s) operations and reliability improvement.
- Providing technical support for a domestic refiner's development and gas synthesis technology assessment program.
- Providing multi-project plot layout support for a domestic refiner.