INSPECTION TECHNIQUES FOR DIGESTION PRESSURE RELIEF SYSTEM

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Abstract

Gramercy Alumina's refinery operates with a single high pressure Digestion unit. Pressure vessels contained therein are equipped with conventional pressure relief devices that discharge into dedicated branch and large diameter header piping systems. Activation of a slurry service relief valve has the potential of depositing process scale within the discharge piping network thereby reducing available cross-sectional area and diminishing capability to adequately relieve a high pressure event. Isolating piping to assess whether system integrity had been compromised after four years of operational service would require a total plant shut-down.

In lieu of suspending operations, the plant developed and implemented a program which facilitated inspection of the relief system's piping and headers while still in service. The established protocol relied heavily on techniques involving radiography, thermography, and gauging. This paper will present details and findings associated with the on-line inspection of the Digestion unit's pressure relief system.

Recent History

The Gramercy facility while operating under the ownership of Kaiser Aluminum & Chemical Cooperation experienced a catastrophic explosion within its Digestion unit on July 5, 1999. A series of events compounded by a plant-wide electrical power failure, resulted in an operating pressure excursion that overwhelmed the capability of the installed pressure relief system. Pressure vessels at the low pressure end of the flash tank train eventually ruptured with devastating affects. Much of Digestion's equipment was either destroyed or damaged beyond economic repair. Significant blast damage was also sustained throughout the remainder of the facility. In those areas, equipment was first opened and cleaned of scale formations left by the unexpected cessation of operations. Extensive inspection, testing, and repair activity then followed to ensure that equipment was worthy of an eventual return to service.

Gramercy production was totally suspended during the eighteen months required to rebuild the Digestion area. Limited production was restored in December 2000 after erecting a new Digestion unit, overhauling essentially all remaining plant rotating equipment, and inspecting stationary equipment such as storage tanks, piping, and pressure vessels. Full production capability was achieved in July 2001, exactly two years after the explosion.

OIMS

Numerous federal, state, and company investigations accompanied the explosion's aftermath. Prior to the resumption of plant operations, settlement agreements with regulatory agencies mandated that the company establish and then implement a program designed to integrate its management system of control. Such comprehensive measures would utilize much of the Process Safety Management (PSM) initiative that is commonly found in non-mining industries. With this as a backdrop, Gramercy developed its Operational Integrity Management System (OIMS) [1].

The purpose of OIMS is to provide the necessary directives and information to ensure the following:

- Processes and systems of production (operations) are reviewed for operational hazards and risks, and operated within safe limits.
- Operational hazards are mitigated, controlled, or eliminated.
- Releases of hazardous chemicals that could affect employees, the community, or the environment are prevented.
- Continued mechanical integrity of process equipment, vessels, and/or process safety controls is maintained.
- Modifications or changes to operations, processes, equipment, or procedures are reviewed prior to implementation, and do not add significant risk.
- A comprehensive emergency contingency plan exists, which will enable the facility to respond appropriately to significant incidents or adverse events. The plan promotes protection of life, property, and the environment, and addresses the issues of business recovery, and the restoration of operations following an emergency situation.

The methodology of OIMS follows the general principles identified by PSM. The thirteen elements comprising the program are as follows:

- Employee Participation
- Operational Safety Information
- Operational Hazard Analysis
- Standard Operating Procedures
- Safe Work Procedures
- Training
- Contractor Safety
- Pre-Startup Safety Review
- Mechanical Integrity
- Management of Change
- Incident Investigation

- Compliance Assessment / Audits
- Emergency Planning and Response

Within the plant's organization, various elements of OIMS are championed by assigned employees who are responsible for execution and periodic assessment. Overall program leadership is provided by the plant's Safety & Health Manager. Today, even though plant ownership has transferred from Kaiser Aluminum, Gramercy Alumina LLC, continues to recognize OIMS as a mainstay of daily plant operations.

Mechanical Integrity

One of the more significant elements within OIMS is Mechanical Integrity [2]. Its stated purpose is to:

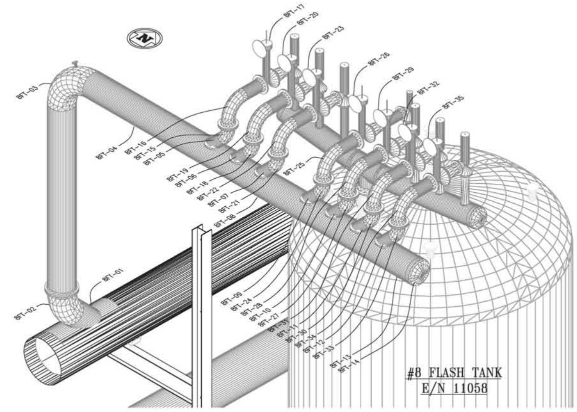
- Ensure that the plant equipment operates in a safe and reliable state, and to adjust, as necessary, equipment operating limits such that it is consistent with equipment condition.
- Develop programs, procedures, and systems for maintaining the ongoing integrity of process and production equipment and facilities in accordance with design specification (or approved modifications).

Key elements of the Mechanical Integrity program include:

- Development of procedures for inspection, preventive, and predictive maintenance activities which are updated and reviewed at specific intervals.
- A requirement that new or modified equipment is to conform to design specifications and that installation / repairs are properly executed.
- Suitable replacement parts are to be purchased via a quality control process, and that the Warehouse properly receives, stores, distributes, and reorders each item.
- Process safeguards, interlocks, and protective systems / devices are to be recognized and functionally tested on a periodic basis.
- Procedural requirements that control the temporary disarming or deactivation of protective systems with defined authority levels.
- Use of accepted industry practices for inspection and testing frequencies of plant equipment and adjustment of these intervals to reflect specific characteristics of the Gramercy process.

Digestion Relief Header Inspection

An example of the application of Mechanical Integrity can be found in the recent effort to inspect the Digestion Relief Header. The Gramercy facility is dependent on a single digestion unit. While the unit has been designed to enable individual vessel outages for periodic cleaning, inspection and repair, the majority of the unit's equipment must remain operational to support plant production. The pressure relief system which encompasses the unit's digesters, decanters, and flash tanks consists of piloted and spring loaded relief valves whose discharge is conveyed into either a high or low pressure relief header to the Relief Tank. These headers are in continuous service, yet require periodic assessment to ensure that sufficient cross sectional area remains to provide adequate pressure relief during an upset condition.



TYPICAL ARRANGEMENT AT FLASH TANK

While consideration of a parallel pressure relief system was contemplated, the final design of the new Digestion unit incorporated only a single high and low pressure system. However, the design included several features that were intended to minimize the effects of scale deposition brought about by relief valve activation. The concern confronted by the designers was that scale would gradually reduce pipe area and disrupt system capability. Relief system design features included:

- A 48" diameter high pressure and 54" low pressure relief header that are 50% larger than required by design.
- Headers are sloped at a sufficient grade to encourage drainage.
- Operating pressures are significantly below vessel design pressure thereby providing ample cushion for surges without triggering a relief valve response.
- Flash Tank pilot relief valves are set to lift at 80 to 94% of vessel maximum allowable working pressure (MAWP).
- Spare relief valves are installed at the Digesters and Flash Tanks.
- A steam pad is provided at the top of each vessel to block process scale formation within the relief valve inlet nozzle.
- Temperature sensing devices are installed on vessel relief valve branch piping and collection headers.

Various design considerations were utilized to reduce the likelihood of a compromised pressure relief system. However, this approach alone was incapable of ensuring sustained system performance during continuous Digestion unit operation; hence the need for an inspection to verify system integrity. The initial thought at the time of the plant's restart was to undergo a plant shutdown within five years of that occasion so that a visual examination could confirm relief header condition. That thinking subsequently evolved into a challenge to assess header integrity without having to rely on a visual examination.

After careful consideration, it was decided to execute a series of external checks that collectively would be used to determine whether scale accumulation was present and if so, to determine whether system integrity had been compromised. The protocol developed in support of this effort relied on six areas of interest.

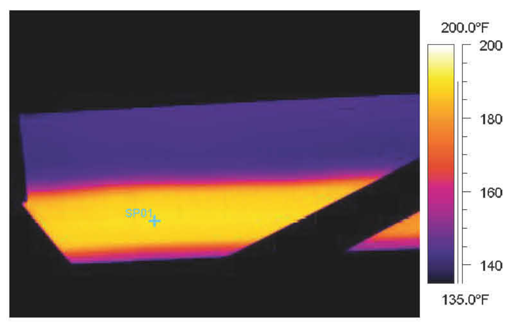
1) Acceptable Cross Sectional Area
The plant commissioned a local independent engineering firm to identify required cross sectional area within relief system branch piping and collection headers in order to support the design basis for the Digestion relief system. The purpose of this investigation was to confirm that actual piping and header diameters were indeed oversized and to quantitatively determine the point at which scale accumulation would threaten relief capability. Results of this investigation confirmed that a sizeable amount of scaling could be encountered without affecting pressure relief performance.

2) Visual Examination of Available Relief Piping
It was recognized shortly after the plant resumed operations that vessels removed from service for turnaround purposes provided an opportunity to visually assess whether scaling had been experienced in the relief system's piping. To the extent available because of vessel isolation purposes, relief valve branch piping was inspected between the vessel and relief valve inlet as well as in the discharge piping. During the four years of this activity, scale was observed in only one instance and that was attributable to inadvertent closure of the vessel's purge steam supply. Without it, process steam was allowed to deposit scale within the inlet nozzles of a decanter. Corrective measures have since been taken to prevent a similar occurrence. These visual inspections have confirmed the value of clean steam purging.

3) Relief Valve Performance
A review of relief valve test results was conducted to determine whether relief valve performance had deteriorated while in service. All of Gramercy's pressure relieve valves are removed from service at pre-determined intervals and inspected by an external vendor. The procedure to recertify the valve for additional service includes an "as received" functional test followed by disassembly and inspection. An audit of shop reports found that 99% of the valves lifted during the Pre-test; an indication that functionality was available. The audit also discovered that indications of light scale deposition were evident in approximately one quarter of the Digester valves but less than 10% of the flash tank and decanter valves. In summary, this investigation confirmed that relief valves were providing the intended level of pressure protection and that some amount of relief activity had occurred thereby exposing the discharge relief system to potential scale deposition.

4) Thermographic Scans
Use of infrared imagery has been utilized within the plant for electrical, refractory, and mechanical applications for many years. In evaluating available techniques to assess header scale accumulation, it became apparent that a thermographic scan could provide the desired on-line verification. The key to its successful use involved securing a means for raising header temperature some 30 to 50 degrees F above ambient conditions. After several false starts at providing this heat source, it was finally discovered that temperatures could be elevated by introducing condensate at 200+ degrees F at the upper ends of both headers. Condensate was pumped into each header and the header's slope encouraged water to flow towards the Relief Tank. After allowing time for the headers to absorb heat, technicians walked each line with an infrared camera. Images were recorded for future analysis.

Results of the scan found no indication of appreciable scale build-up throughout 99% of the header system. There were three areas of interest that were characterized by differential temperatures. Those locations were subjected to additional inspection via radiography. Subsequent analysis found very minimal scale growth along with foreign objects possibly left from initial construction activity.



Infrared Image of Digestion Relief Header

5) Radiographic Scans
With branch piping and headers normally empty of any process fluids and with near ambient temperatures, radiographic inspection was initially thought to be the preferred means for determining the presence of scale. Given the magnitude of involved piping and limited accessibility, the use of radiography was confined to branch piping and specific header locations.

Quantifying the amount of identified scale within a pipe presented a unique challenge with radiography. Plant Maintenance Reliability personnel resolved the issue by developing standards which allowed use of a densitometer to grade radiographic film. The standards were determined by recording film densities from known scale thickness within various diameters and thickness of pipe. Test values were identified for a scale free pipe surface through 3 inch thicknesses at 1" increments. Source strength, exposure time, type of film, film development chemical temperatures, and developing time were all additional variables that required control. Once the standards had been established and the nominal pipe diameter and thickness of the x-rayed site known, a technician would view the film with the densitometer. The indicated density would be compared to the standards and a scale thickness was then associated with that particular location. Tests results found no more than a one half inch accumulation of scale. The majority of radiographed sites found no scale growth.

2" Thick Block of Scale for Radiographic Standard

Film Density Measurement for 10" dia. x .500" thk. Pipe with 1" Thick Scale

6) Gauging
An additional test for determining the presence of scale within the relief headers was to physically gauge the pipe with a calibrated insertion rod. 2" diameter nozzles were welded to the high and low pressure headers at strategic locations along their lengths. A gate valve was mounted atop the flanged nozzle through which a hot tap was made to provide an opening into the header.

The test consisted of inserting a calibrated steel rod into the nozzle and then allowing it to slowly drop until it made contact. The distance traveled during the insertion was measured and compared to the theoretical distance assuming no scale accumulation. It should be noted that the nozzle contained a restriction bushing within it that was sized to allow passage of the rod with minimal clearance. The intent of the bushing was to reduce exposure to testing personnel from potential process exposure since the test was being performed with the relief system in service. Additional precautions called for personal protective equipment and direct communications with operating personnel. The tests could have been suspended and the gate valve secured in the event of a process upset.

No significant scale deposits were found during the gauging. The greatest deviation noted from theoretical was three quarters of an inch. Taps are permanently mounted atop the headers and will be used for future gauging.

Auditing

Gramercy has committed itself to periodic internal auditing of OIMS policy administration and execution so that the program remains a way of life within the facility. A coordinator has been appointed with primary responsibility for overseeing program functionality. This individual serves as a resource for policy interpretation as well as assuming the lead auditor role when it comes time to review compliance of the thirteen elements that comprise the OIMS program.

Auditing is set to occur every three years for administrative policy compliance and annually for execution. In addition to the OIMS Coordinator, the audit team consists of a Safety Department representative, and at times, a 3rd party member (e.g. an Owner's representative). When conducting the audit, the team relies heavily on interviews with the various element champions and other employees normally associated with its function. Validation of discussions occurs in the form of a file search and/or field inspection. Criteria have been developed for each of the thirteen elements, and such serves as the basis for the audit. Ultimately, results are summarized with findings provided to plant upper management.

Conclusion

Institution of Gramercy's Operational Integrity Management System has forced, and rightfully so, the plant to take a much harder look at its operations and maintenance practices. Policies and procedures are now in place to govern decisions associated with both new installations as well as with changes to existing processes. The effort extended with the on-line inspection of the Digestion unit's pressure relief headers is testimony to Gramercy's commitment to the OIMS program. Inspection findings confirmed that initial design considerations such as the introduction of purge steam to protect inlet relief system are functioning as intended, that relief valves are operational as evidenced by shop Pre-tests, and that creative inspection techniques can be utilized to confirm capability of an in-service relief header. Routine monitoring of the relief header and other critical systems throughout the plant will ensure safe and reliable operations.

References

1. "Operational Integrity Management System" (Internal policy, Gramercy Alumina, LLC, 2001).
2. "Mechanical Integrity" (Internal policy, Gramercy Alumina, LLC, 2003).