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Changes Contained in Addendum 4 of API 570: Piping Inspection Code

By Stephen J. Gliebe, P.E.

Addendum 4 of API 570 was released in June 2006. This article highlights several of the changes made since Addendum 3, dated August 2003.

- Para. 3.1. Changed the definition of an alteration. The addition of any reinforced branch connection equal to or less than the size of an existing reinforced branch connection is now considered an alteration.
- Para. 3.56 through 3.59. Added definitions for corrosion specialist, pressure design thickness, required thickness, and structural minimum thickness.
- Para. 7.3. Modified the process for determination of required thickness as defined in paragraph 3.58. Pressure design thickness and structural minimum thickness per paragraphs 3.57 and 3.59, respectively, must now be considered.
- Para. 8.1.3.1. Added requirement to perform a fitness-for-service analysis before installing a temporary repair by fillet welding a split coupling or plate patch over a locally thinned area. Prohibits installing a fillet-welded patch on top of an existing fillet-welded patch. Added minimum spacing criteria for installing a fillet-welded patch adjacent to an existing fillet-welded patch.
- Para. 8.1.4. Expanded the list of non-welded repairs to include nonmetallic composite wraps, metallic and epoxy wraps, or other non-welded applied temporary repairs. Added the requirement to consider any resulting crushing forces when using procedures that include pumping leak sealing fluids.
- Para. 8.2.6. Changed to require consultation with the inspector and the piping engineer before substituting NDE for a pressure test after a rerate. Added guidance for performing pressure tests on insulated lines after repairs, alterations, or rerating, without stripping the insulation.
- Appendix A, Para. A.3.1 through A.3.3. Added details on inspector recertification requirements.

Changes Contained in the 9th Edition of API 510, Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration

By Stephen J. Gliebe, P.E.

The 9th Edition of API 510, "Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration," was released in June 2006 and became effective no later than December 2006. It is a total revamp of Addendum 4 dated August 2003.

The changes made since the prior version have not been highlighted in the 9th Edition, and many of the existing paragraphs have been moved to other sections. A careful review of the new document is recommended to ensure that all the changes and new requirements are identified, and are reflected in your organization's quality control systems.

Below are some of the key changes.

- Section 1 - Scope
  Added a statement recognizing risk-based inspection concepts for determining inspection intervals. Refers the user to API 580 for guidelines for conducting a risk-based assessment.
- Section 2 - References

Change	Document	Title
Added	API RP 571	Damage Mechanisms Affecting Fixed Equipment in the Refining Industry
	API RP 577	Welding Inspection and Metallurgy
	API RP 578	Material Verification Program for New and Existing Alloy Piping Systems
	API RP 580	Risk-Based Inspection
	API Publ 581	Risk-Based Inspection - Base Resource Document
	NACE MR 0103	Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments
	OSHA 29 CFR Part 1910	Occupational Safety and Health Standards
Deleted	ASME Sections VI, VII, and XI	Recommended Rules for the Care and Operation of Heating Boilers Recommended Guidelines for the Care of Power Boilers Rules for In-Service Inspection of Nuclear Power Plant Components
	NACE MR 0175	Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment

- Section 3 - Definitions
  Over 40 new definitions have been added. Examples include:
  - Corrosion Under Insulation (CUI) - Refers to all forms of corrosion under insulation including stress corrosion cracking.
  - In-service inspection - All inspection activities associated with a pressure vessel once it has been placed in service. A pressure vessel not in operation due to an outage is still considered an in-service pressure vessel.

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- Inspection plan - A strategy defining how and when a pressure vessel or pressure-relieving device will be inspected, repaired and maintained.
- On-Stream - A condition where a pressure vessel has not been prepared for an internal inspection.

- Section 4 - Owner/User Inspection Organization
  Expanded the owner/user organization responsibilities to include:
  - Developing and documenting inspection plans.
  - Developing and documenting risk-based assessments.
  - Establishing and documenting the appropriate inspection intervals.
  - Implementing the controls necessary so that all repairs are performed in accordance with this inspection code and applicable specifications.
- Section 5 - Inspection, Examination and Pressure Testing Practices
  Revamped the entire section. For example:
  - Added guidelines for the development and contents of an inspection plan.
  - Expanded the susceptible temperature range for CUI for carbon and low alloy steels from between 25°F (-4°C) and 250°F (120°C) to bewteen 10°F (-12°C) and 350°F (175°C).
  - Defined a susceptible range for CUI for austenitic stainless steels as operating between 140°F (60°C) and 400°F (205°C).
  - Added information related to general types of inspection and surveillance and condition monitoring methods.
- Section 7 - Inspection Data Evaluation, Analysis, and Recording
  Revamped the entire section. For example, added guidelines for evaluation of existing equipment with minimal documentation.
- Section 8 - Repairs, Alterations, and Rerating of Pressure Vessels
  Revamped the entire section. For example:
  - Added guidance on documentation and removal of temporary repairs.
  - Added requirements for the minimum distance between fillet welded patches.
  - Engineering approval of alterations is now required.
- Appendix A - ASME Code Exemptions
  Added - Vessels that do not exceed three ft^3 (0.08 m^3) in volume and 350 lbf/in^2 (4136.9 KPa) design pressure are excluded from the specific requirements of this inspection code.
- Appendix B - Authorized Pressure Vessel Inspector Certification
  Added - Once every other recertification period (i.e., every six years), inspectors actively engaged as an inspector shall demonstrate knowledge of revisions to API 510 that were instituted during the previous six years.

Steve Gliebe is a Professional Engineer with 30 years experience in the refining and chemical industries. He is well-versed in both engineering and supervision including hands-on experience managing maintenance and capital projects, training union and management colleagues, supervising maintenance/inspection organizations, developing programs for preventative maintenance of fixed equipment and piping per industry standards, and performing root-cause analyses to improve equipment reliability. Please contact Vince Carucci if you'd like more information on Carmagen's expertise in this area.

Achieving Full Reliability of *Typical Bad Actor* Heat Exchangers in Crude Units, Catalytic Reformers, and FCCUs

By Lev Serebrinsky

As we mentioned in Article 1 in the March 2007 newsletter on the subject of Description of Methodology, the Refinery Bad Actors List is the major tool for resolution of heat exchanger problems across the refinery. When the refineries started to apply the tools, it was noticed, however, that while Bad Actors vary dramatically from refinery to refinery, there are five heat exchangers which are in each Refinery's Bad Actors List. We focus this article, therefore, on reliability recommendations to these *Typical Bad Actors* as follows:

- Atmospheric Tower Overhead Condensers (AT OHC) in Crude Units
- Hottest Crude Train Exchangers in Crude Units
- Vacuum Tower's Bottoms/Crude Exchangers in Crude Units
- Feed/Effluent Exchangers in Catalytic Reformers
- Slurry/Feed Exchangers in FCCUs

AT OH Condensers in Crude Units cause significant Lost Opportunity Costs to the whole refinery and substantially increase Crude Unit Maintenance Costs when they are frequently taken out of service to repair internal leakage from tubes or for mechanical/chemical cleaning.

Experience has demonstrated that the root cause of 95% of the outages was shell side corrosion of the tubes. Therefore, a massive program of eddy current tube wall thickness measurements was taken followed by reliability analysis of the data. The analysis revealed a common pattern of corrosion development in all AT OHCs bundles. That was that, first, the corrosion is localized to certain areas of the bundles, and, second, that the corrosion strikes a certain group of tubes within the areas.

In addition, review of the maintenance history of these bundles showed that the groups of tubes are attacked by corrosion in a certain sequence, with a four to six month interval between the attacks. Further, the inspection reports showed that the shell side of the bundles was fouled so severely by the tube corrosion products that the condensers had to be mechanically cleaned after the third group of tubes was leaking. Furthermore, the maintenance practice was that after the fourth leakage the bundles were, as a rule, retubed due to concerns with their ability to make the next run.

Based on these studies, all AT OHC tube bundles were "re-engineered for reliability." This re-engineering included:

- Installation of individual impingement protection devices for each group of affected tube
- Changed tube material and wall thickness
- Modification to tube and baffle layouts

To minimize the cost for the re-engineering, the recommendations were implemented during the re-tubing of existing bundles or during manufacturing of the replacement bundles. Since then there has been no unscheduled outages of any AT OH Condensers, and the bundle's design life was increased from 4 to 12 years.

Hottest Crude Train Exchangers in Crude Units are responsible for Crude Unit High Maintenance Costs due to (aaa) external leakage from the Stationary Tubes Sheet Flange Joint and (bbb) costly mechanical cleaning of severely fouled tube bundles.

(aaa) Costly repair of external leakage from the Stationary Tubes Sheet Flange Joint. These exchangers have the highest temperature crude inside the tubes and the tower's hottest side stream in the shell side. Their stationary tube sheet flange joint often leaks each time the tower's side stream is temporarily lost due to a tower's upset. When this happens, the temperature across the joint swings down and then up in the range of 350 - 400°F in a short period of time. In reliability engineering this is known as a "high temperature swing." For all "regular" flange joints the temperature swing means nothing. But because the stationary tubesheet (STS) flange joint is unique (it has two gaskets, one tube sheet sandwiched between the gaskets, two flanges abutting the tubesheet, and the longest studs), the high temperature swing is critical.

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That is that during the temperature swing of that magnitude, all six components of the STS flange joint experience the large and uncontrollable expansion-contraction movements which result in relaxation of the studs and loosening of the flange joint itself.

Reliability re-engineering of the joint consists of:

- Installation of *specifically designed* Spiral-Wound Gaskets *around* the Stationary Tube Sheet
- Application of a multi-step, controlled high stress torque of the studs during assembly of the joint
- Application of one-step hot torque of the studs when the heat exchanger reaches the operating temperature.

This complex approach eliminated the leaks totally.

(bbb) Costly mechanical cleaning of severely fouled tube bundles. The hot crude plugs the tubes end-to-end because the crude's heavy hydrocarbons are solidifying and sticking to the tube inner wall at these exchangers' operating temperature. Anti-fouling programs typically do not work, and many bundle mechanical redesigns did not work either. The problem was typically resolved completely by application of On-Line-Mechanical-Cleaning-Technologies (OLMCTs) which constantly scrubs the asphalt-like compounds from the tube internal wall on the run thus providing a between-the-cleanings run of these exchangers of up to five (5) years.

There are several OLMCTs available commercially (e.g., *Spirelf Turbulence Promoters, Brush-and-Basket Technology*, etc.). The selection of an individual OLMCT should be evaluated locally based on specific unit operating conditions, manufacturer's experience, and cost.

Vacuum Tower Bottoms/Crude Heat Exchangers in Crude Units suffer from High Maintenance Costs due to coking up of the bundle while the heat exchanger is being steamed out as a part of preparation for unit shut down. The bundles are often stuck inside the shell cylinder so tightly that it could require several days of expensive work to pull the bundle and to clean the shell. In many cases, however, it was impossible to clean the coked-up bundles so that they had to be retubed on an overtime basis.

The problem was resolved by application of a multi-step procedure of washing the shell side using certain hydrocarbons, and by injecting brake-up-coke chemicals during preparation of the unit for the turnaround. It also sometimes required some redesign of circulation connections in the shells.

Feed/Effluent Exchangers in Catalytic Reformers suffer from external leakage of hydrogen from the STS Flange Joint and from the shell cover-to-shell flange joint during routine switch of the reactors during operation. For small size exchangers, reliability improvements made to gaskets and bolting were successful. For large size exchangers, however, gasket and bolting changes did not work reliably. The best industry experience for large exchangers was achieved using a welded-in stationary tubesheet and with a welded-on shell cover. This design has resulted in 16 years of leak-free, fouling-free run of all these heat exchangers.

Slurry/Feed Exchangers in FCCU suffer from end-to-end plugging of tubes by the catalyst's slurry fluid.

The root cause of the problem is the low velocity of the slurry flow. Depending on local guidelines, the reliability-recommended velocities are 4 ft/s as a minimum, and 10-12 ft/s as a maximum (the maximum is limited by erosion concerns). These guidelines should be applied to all slurry circuit piping as well.

Some mechanical reliability features such as certain tube size, tube material, and the floating head pull-thru bundle design should be applied as well.

General. Remember that the exchanger reliability improvements noted above will not happen "automatically" for new exchangers just by meeting the relevant API, TEMA, and even most owner-company engineering standards. They must be specified as part of the technical specification that is prepared for exchanger services where experience has demonstrated them to be worthwhile.

Lev Serebrinsky has over forty years experience in the field of mechanical engineering with emphasis during the last twenty-five years on the design, reliability and troubleshooting of heat exchangers used in refineries and chemical plants. Very familiar with the requirements of heat exchanger engineering standards and best practices for the reliable operation of these mechanical components. Please contact Vince Carucci if you'd like more information on Carmagen's expertise in this area.

- Working as part of a joint client/Carmagen Engineering team, conducted reliability and maintenance audit at a plant location in the Far East of a major international pharmaceutical company. A number of improvement opportunities were identified that will enhance system reliability.
- Process plant turnaround (T/A) manual prepared for a major European refiner. This manual was based on Carmagen's Best Turnaround Practices and covers all the major stages of a major refinery turnaround from initial planning through detailed planning, T/A execution, and post-T/A assessment and documentation. Through the application of consistent practices, a plant will be able to plan and execute turnarounds more effectively and efficiently, resulting in lower costs and better overall turnaround performance. The manual was customized to suit the client's specific situation and experience and is now being used. Client feedback has indicated that application of the methods contained in this manual has reduced the planned T/A duration by approximately 10%.
- Fabrication details and welding recommendations were provided for replacement support skirts of existing delayed coker drums. The skirt redesign and replacement project came as a result of extensive cracking that was found in the drum shells. Specific fabrication details, locations, and sequence were optimized to reduce the amount of unit downtime as much as possible.
- Fired equipment support being provided for a crude unit furnace revamp project that is being done for a European client. Thus far, the results of a thermal study performed by a contractor were reviewed and recommendations made. Additional work will involve technical support for furnace test runs, technical bid conditioning of vendor proposals, and then engineering auditing of the selected vendor's detailed engineering.
- Continued to provide significant project management and cost engineering consulting support for multiple clients in US and overseas.
- Continued to provide welding, materials, and process engineering litigation consulting support for multiple major cases.
- Continued providing onsite and remote mechanical engineering assistance for a European client in their project to review the condition of their offsite piping systems and make any necessary modifications. Work includes performing RBI assessments in order to identify and then prioritize systems that should be addressed.
- First time sessions of introductory piping design and heat exchanger design training courses were presented for the engineers of a major US-based refining client. These one-day courses were originally prepared by the client and then presented by Carmagen engineers who have both the required technical expertise and are seasoned instructors. Both courses were very well received, and additional presentations have already been scheduled at another client location.
- Completed assessment of multiple piping failures that occurred at small diameter branch connections at a petrochemical plant located in the Middle East. It was concluded that the failures were due to vibration-induced fatigue stresses caused by the normal pressure pulsations generated by the reciprocating pumps that are in the systems. Recommendations to mitigate the problem included bracing all small diameter connections in the suction and discharge systems, and adding more restraints and supports to the main process piping systems to reduce the overall system vibration levels.
- Multiple refractory failures and hot spots in the cyclone system and regenerator overhead system forced an unplanned shut down of an FCCU. Onsite refractory engineering assistance was provided on an emergency basis to develop refractory repair and dryout recommendations to enable bringing the unit back onstream as soon as possible. It is anticipated that additional refractory system recommendations to improve long-term reliability will be provided that can be implemented during an upcoming, planned turnaround.
- Presented course covering the design and installation of refractory systems for a major, US refiner. Almost 30 participants from several refineries attended the course, which was very well received. The same course was also presented at a major process plant located in Canada. As always when this course is presented, attendees walked away with information that they can immediately apply on the job, especially when they have upcoming turnarounds with significant refractory work anticipated.
- Presented a "public", 4-day course covering the maintenance of process plant equipment in Greece. This course is unique in that it discusses maintenance requirements for pressure vessels, heat exchangers, piping systems, and aboveground atmospheric storage tanks in a single course.
- Presented two separate "public" training courses covering machinery in Greece. The first course discussed the selection, operation, and maintenance of mechanical seals. The second discussed the basic operation and theory of steam and gas turbines, co-generation, and combined cycle plants.
- Presented a "public", 5-day course covering Risk Based Inspection (RBI) in Greece. This course presents a very practical, applications-oriented, cost-effective approach to developing and implementing an RBI program that is based on both API criteria and broad industry experience.

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- Providing plot layout support for domestic and international refiners.
- Completed preliminary flare network hydraulic analysis, including selected relief valves flare load development.
- Continue relief system helpdesk support for major refiner.
- Performing long-term coordination/support on-site at international refiner's facility during development of their strategic refinery reliability and improvement program.
- Performing strategic reliability initiatives for an international refiner, including the vacuum units, visbreaker, and two hydrocrackers and hydrotreaters and H_2 management system.
- Completed high level fluid coker fluid solids section debottlenecking study and cost estimate.
- Providing on-going fractionation specialist support to a major refiner.
- Providing on-going lubes consultation to a major refiner.
- Conducted hydrodesulfurization unit operator training at a refinery in Europe.
- Developing LOPA standards for a domestic refiner.
- Preparing standardized process design notes for a client's licensed technology.
- Providing MTG mentoring for a technology licensor's staff.
- Performing expanded scope of an Energy Management Study for two Crude Distillation units for a major Gulf Coast refiner.
- Providing process design support in a major technology provider's offices.
- Preparing a Mogas blending study/contractor evaluation for a domestic refinery.
- Providing limited process, operating guides, mechanical and metallurgical study assistance to a contractor assessing suitability of moth-balled pipeline crude unit equipment for reuse overseas.
- Providing technical mentoring/consulting to a university in Ohio.
- Provided extended lube hydrotreating pilot plant support services.
- Providing ongoing environmental support to domestic refiner.
- Provided support to a refiner's Patent/Legal Department.
- Completed jet fuel treating evaluation scoping and consultation.
- Providing ENCON optimization support for a first commercial plant of a novel polymer technology.
- Providing global training course development support covering multiple topics for a major refiner.
- Providing technical litigation support in analytical chemistry, process and metallurgical areas to defend major refiner in class action suit.
- Providing technical support to provide design packages at two major refineries to design MHO and slide valve specs in the FCC flue gas system, and improve mechanical reliability. Includes review of CFD and FEA models.
- Conducted noise and vibration assessment on FCC flue gas line.
- Providing support to investigate design and operating problems in an overseas BDO unit.
- Providing refinery and offsite tankage planning assistance to a contractor relocating refinery units overseas.
- Conducting logistics economics course for major refiner.
- Performing PIMS modeling and refinery planning support.
- Performed SWS/SRU HAZOP support in China.
- Providing process design consultation on revamp of C4 treater.
- Providing technical litigation support associated with OSHA and API safety issues related to domestic refinery explosion.
- Conducted octane laboratory assessment for domestic refiner.
- Providing process and mechanical technical support to refiner and contractor for selected FCC regenerator internals, J-bends, and standpipes in detail design phase.
- Provided FCC and Coker CO boiler assessment of performance and reliability with HTRI case evaluation.
- Provided sulfuric acid alkylation troubleshooting and scoping support.
- Provided CDU desalter performance/reliability assessment and scoping.
- Completed work on assessment of risk and recommended procedures for processing mustard ton containers, which contain (or could contain) hydrogen in the vapor space.
- Providing process support for evaluating the feasibility of various aspects of "oil sands" processing schemes.
- Provided process and catalysis consultation for TCC kiln temperature runaway.
- Providing Heavy Oils Process Intellectual Property Support.
- Provided process, furnace technology and materials engineering assistance to a brand new Biomass fuels process currently under detailed engineering design and construction in USA.
- Evaluated new NO_x standards from Alberta Research Council for a Canadian refiner. Also evaluated and recommended means to reduce the NO_x emissions to meet the new guidelines in the client's grassroots design currently in detailed engineering.
- Evaluated (via detailed simulations) the feasibility of expansion for a delayed coker heater for a domestic refiner in the Gulf Coast.
- Carried out CO Boiler reliability and performance assessment including material evaluation for an East Coast refiner.