THE CARMAGEN Engineering, Inc. REPORT

Partnering in Engineering Excellence

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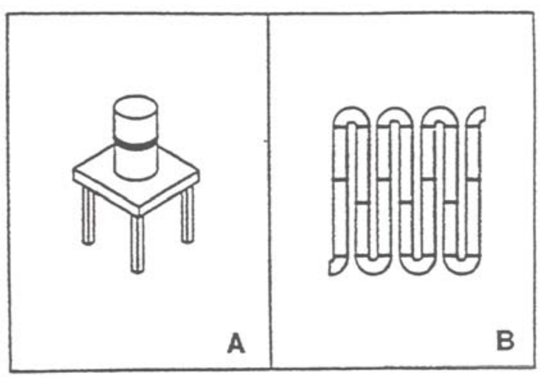
A Realistic Approach to Weldor Training and Testing

By Harry W. Ebert

Most Codes, such as ASME Section IX and AWS D1.1, permit the testing of weldors without imposing any space or access limitations. As indicated by Sketch "A", weldors can perform their tests in the middle of an empty dance floor. That qualifies them to perform typical field welds in refineries, chemical plants and power plants such as the ones illustrated by Sketch "B". Weldors confronted with such space and access limitations will encounter a high rejection rate unless they are trained and tested under realistic conditions.



Recognizing this inconsistency and the resulting quality problems, some organizations have added the following type of statement to their QA documents:

"Additional procedure and performance qualifications shall be performed whenever the accessibility or the working conditions of the Code qualifications fail to simulate the production conditions."

In other words, the employment of mock-up test conditions is demanded.

While there are many designs for such mock-up test samples, Supplement F to AWS QC7-93, *"Standard for AWS Certification of Weldors,"* represents one option. It represents typical field welds on piperacks and in tight spaces. When one field location implemented Supplement F, it took more time to qualify their field weldors, but the rejection rate of pipe butt joints dropped from about 25% to about 7 1/2%.

Harry Ebert has over 50 years of engineering experience in welding for construction, maintenance, modification, and repair of power and process-plant components. Please contact Vince Carucci if you'd like more information on Carmagen's expertise in this area.

Does Your Plant Have a Turnaround Manual?

By Robert J. Motylenski, P.E.

In the process industry, plant and process unit turnarounds are major undertakings and have significant impact on the maintenance expenses and future plant operations. They also affect operating and maintenance performance metrics. The cost of a turnaround is the single biggest annual maintenance expense a process plant can expect to encounter. In addition to the maintenance expense, there is lost revenue because the process unit or plant is shut down during the turnaround. In order to minimize the business losses, it is important that the planning, scheduling, and execution for the turnaround is done in an efficient manner.

With the time period between turnarounds usually very long, the procedures for planning the turnaround are generally forgotten and the personnel doing the planning are usually different from the previous turnaround. Any lessons learned from previous turnarounds are generally forgotten if they are not documented. It doesn't matter whether plant personnel or contractors do the planning. Documenting turnaround procedures can improve turnaround performance and ensure that consistent planning and Best Practices are implemented in each turnaround.

The purpose of the Turnaround Manual is to document procedures and practices that are to be used in planning, executing, and closing out a turnaround. Through the application of consistent practices, the plant will be able to plan and execute turnarounds more effectively and efficiently, resulting in lower costs and better overall turnaround performance. The Turnaround Manual includes sections for all aspects of a turnaround, from planning the plan, to work scope generation, contracting, and execution. Typically, nineteen sections are included in a Turnaround Manual. Each section includes key elements, plant procedures and practices, Best Practices, and actions required by the organization.

Carmagen Engineering has experience in preparing turnaround manuals and in populating them with proven Best Practices. All the practices included in the manual are based on experience and have proven to be successful in lowering turnaround cost and reducing turnaround duration. While the typical Best Practices are universally applicable, information that is contained in the Turnaround Manual is also tailored to meet the specific needs and preferences of the plant location. As a result of preparing a Turnaround Manual with a European refinery, the refinery has improved its planning procedures by applying the Best Practices that are incorporated in the manual.

Bob Motylenski has over 40 years experience in the reliability and maintenance area, mostly with the Reliability and Maintenance Services Group of Exxon Research and Engineering Company. Please contact Vince Carucci if you'd like more information on Carmagen's expertise in this area.

Experience with 100% Mechanical Reliability of Refineries' *Bad Actor* Heat Exchangers

By Lev Serebrinsky

This is the first in a planned series of four articles and two appendices as follows:

- Article 1 of 4: Description of Methodology
- Article 2 of 4: Typical Reliability Experience with Bad Actors in Crude Units, Catalytic Reformers, and FCCUs.
- Article 3 of 4: Typical Reliability Experience with Water Coolers
- Article 4 of 4: Reliability Experience with Advanced Heat Exchanger Technologies.
- *Appendix 1*: Designer Guide on Typical Heat Exchanger Reliability
- *Appendix 2*: Guide on Troubleshooting Typical Heat Exchanger Mechanical Problems.

Article 1 of 4: Description of Methodology

Experience with achieving *100% Mechanical Reliability of Refinery Bad Actor Heat Exchangers* shows that this was achieved by development and introduction of highly specific, many-faceted Programs. Thus, the experience is reviewed here in a series of 4 Articles and 2 Appendixes.

This is Article 1 of 4, and it presents a Methodology for instituting a Heat Exchanger Bad Actor Resolution Program. The first step of the Methodology is the official kick-off of a Bad Actor Heat Exchangers Resolution Program (we are using a generic name here). However, a certain precondition for the success of the Methodology must be in place. That is, the Organization must be ready to dedicate a heavy involvement of many Mechanical, Technical, and Operations specialists in the Program's three parallel, never ending activities as follows:

- Revealing and prioritizing the Reliability Bad Actor Exchangers.
- Developing recommendations on design improvements to the "A" priority Bad Actor Exchangers.
- Implementing the recommendations during the Major Turnarounds.

The Program is based on the following **four principles**:

- **Principle # 1**. The Bad Actor Heat Exchangers Resolution Program shall be formally announced by top Management.
- **Principle # 2**. The Announcement shall declare the Program's Goals as follows:
  - 2a. Zero Refinery Downtimes Caused by Heat Exchangers, and
  - 2b. Zero Refinery Lost Opportunity Costs Caused by Heat Exchangers.
- **Principle # 3**.The Announcement shall appoint the Program Steward.
- **Principle # 4**. The Announcement shall specify the Steward's duties as follows:
  - 4a. Development and Publication of the Prioritized Bad Actor Heat Exchangers List;
  - 4b. Development of Resolution Recommendations for "A" Priority Bad Actors for Each Process Unit's Turnaround.
  - 4c. Updating the Bad Actor Heat Exchangers List every Two Years; and
  - 4d. Publication of the Program Stewardship Report every Two Years.

Since the full implementation of these fundamental principles makes the difference between the Program's failure and success, the following summarizes some experience with the implementation of Principles #3 and #4.

Principle #3: At a large Refinery, the Steward's assignment must be their full-time job; at a small Refinery the Steward's job could be at least a three year special assignment. There is no exception to this rule: all failed Programs did not have a full time Steward, but all successful Programs have a full-time Steward to this day.

Principle # 4a: In no case should the Steward develop and prioritize the Bad Actors List alone. The Steward compiles a Draft List by soliciting input during personal interviews with Process, Maintenance, Inspection, and Technical personnel on each Process Unit. These interviews are a time consuming and scrupulous process which must be based on a Bad Actors Questionnaire which, in turn,

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is developed by the Steward. The Questionnaire reflects the Organization's approved Bad Actor Heat Exchanger Criteria (e.g., the number of unscheduled outages, Maintenance Costs, Lost Opportunity Costs, or all the above plus whatever else the Organization wants to steward).

Further, the final number of Bad Actors must not exceed 6% of the Refinery total count of its shells. If the number is higher, the Bad Actors Criteria are either too many, or too loose, or both, and must be reconsidered. There is no exception to the "maximum 6%" rule: several large Refineries foiled their Programs solely because their Bad Actors Lists were so large that they made the implementation of the Program totally unrealistic.

The List, furthermore, must have several columns such as Resolution Priority, Problem Mode(s), Problem Root Cause, Lost Opportunity Costs, etc., and when the Final Draft is ready, each Bad Actor must get its Resolution Priority. The "A" priority shall be given solely to those Bad Actors which are scheduled to be opened at the Process Unit's Major Turnaround within the next two years. All other Bad Actors receive "B" or "C" Resolution Priorities at the Steward's discretion.

Upon releasing a Resolution Recommendation on any "A" priority Bad Actor, the Steward removes it from the Bad Actors List conditionally (until the Recommendation is implemented and proven correct by Operations one year afterwards). Meanwhile, the Steward moves the nearest "B" priority Bad Actor into the "A" Group, and the cycle repeats itself.

Principle # 4b: Since all Resolution Recommendations will require re-engineering the existing Bad Actors, their follow-up takes the Bad Actor out of service. The overwhelming experience shows that the best time to implement the Recommendation is during the Process Unit Turnaround when all Bad Actors at the given Process Unit are budgeted for pulling and shipping anyway. This approach has proven to be so time and cost-effective that we consider it to be the key to the fast resolution of Bad Actors.

Principle # 4d: The Program Stewardship Report must report the status of the #2a and #2b Goals, plus the Overall Refinery Trend of Annual Heat Exchanger Maintenance Costs during the past four years, plus any other Criteria selected by the Management. Note, that many seeming Criteria (e.g., the number of Bad Actors in the List) were dropped from data gathering after the first Stewardship Report since, contrary to the original expectations, they either said nothing to anyone or were simply misleading.

In conclusion, the successful Bad Actor Heat Exchangers Programs delivered some amazing findings and results. These are summarized as follows:

- The first **finding** was that, contrary to general beliefs, the number of Bad Actors is surprisingly small. Depending on the size and diversity of the given Refinery, it varied from 4% to 6% of the Refinery's heat exchanger population.
- The second finding was that Bad Actors alone are responsible for *35%* of the Overall Refinery *Annual* Heat Exchanger Maintenance Costs.
- The third finding was that Bad Actors alone are responsible for **all** Refinery process units' downtimes.
- And the fourth finding was that contrary to rosy expectations, at every Refinery during the first year the Program resolved – i.e., actually re-engineered - just a few Bad Actors. However – and it is a big "however" – all successful Programs have resolved more Bad Actors in the second year, then even more in the third year, and the resolution of *all* originally "A" prioritized Bad Actors was completed in the fourth year almost everywhere. Meanwhile the "B" and "C" priority Bad Actors are gradually getting the "A" priority, while new Bad Actors are identified almost every year.

The most visible and important results of the Programs are as follows:

From its third year, Refineries have not had a single Process Unit Downtime caused by heat exchangers. Compare this to the well know fact that heat exchangers are the second leading cause of Refinery Downtime Worldwide, and by the fourth year, the Overall Heat Exchanger Maintenance Costs at these Refineries was gradually reduced to 60% of their pre-Program years. These are still about 1/3 less than current costs at comparable Refineries that have not implemented any Program at all.

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.

Calculating the Potential Surge Pressure in Liquid Filled Piping Systems

By David R. Thornton, P.E.

Previous articles on piping vibration posted on Carmagen's web site gave summary information regarding:

- The types and causes of piping vibration
- Screening the severity of vibration
- The fundamentals of mitigating vibration and its effects

In this article we concentrate on transient vibration caused by rapid closure of a valve in a loading system for a tanker or tank truck. Figure 1 shows a simplified typical flow arrangement of such a loading system for a marine terminal operation. The operation consists of onshore product storage tanks connected to a berthed tanker ship via a pipeline that contains pumping, metering, and flow control facilities. The operational sequence normally consists of establishing flow to the tanker, pumping a measured amount of product to the ship, then reducing flow before closing the valve that connects to the tanker's onboard manifold.

Most jurisdictions have regulations that require that a rapidly closing, emergency isolation valve exist in the piping system to:

- Limit the amount of product loss should the loading facilities separate from the tanker
- Isolate the tanker manifold from the onshore piping system should the tanker have an emergency.

Typically, the emergency isolation valve will be a quarter-turn ball valve. If not properly considered, the rapidly closing valve could transform the kinetic energy of the flowing product into the potential energy of a pressure wave that propagates from the valve towards the onshore storage facilities. This pressure wave could result in excess pressure, possibly leading to flange leakage, damage to pressure sensitive equipment, and/or damage to pipe supports and restraints. The pressure wave could also result in significant forces and displacements, particularly if the pipeline contains one or more directional changes. Typically such offsite piping is not provided with sufficient restraint to absorb the possibly large forces. The potential magnitude of the pressure wave when the valve closes can be estimated from the equation:

$$P = (\rho)(a)(\Delta V)$$

where:

P	=	potential pressure rise, Pa
ρ	=	density of fluid, kg/m^3
a	=	speed of sonic wave in fluid/pipe, m/sec
ΔV	=	change in fluid velocity when valve closes, m/sec

The following table shows the typical range for the sonic speed in the fluid / pipe combination, the flow velocity, and the fluid density and the corresponding potential pressure increase.

Sonic Speed, m/sec (ft/sec)	700 -1500 (2300-4900)
Flow Velocity, m/sec (ft/sec)	2-5 (6-15)
Fluid Density, kg/m^3 (lb/ft^3)	500-1000 (30-63)
Potential Pressure Rise, MPa, (psi)	0.7-7.5 (100-1090)

Since the flow in the entire pipeline must be stopped due to the valve closure, the pressure increase propagates in a wavelike manner from the closed valve towards the tankage pumping facilities. As the pressure wave propagates through each segment of piping where a change in direction exists, the pressure wave causes a transient unbalanced force in the piping segment as illustrated in Figure 2.

The magnitude of the force will depend on the amount of pressure rise and the internal area of the pipe. As an example, suppose we have an NPS 10, Schedule Std pipeline transferring gasoline to a ship at a flow velocity of 3 meters per second (9.84 feet per second). The density is about 700 kg/m^3 (43.7 lb/ft^3) and the wave speed is 1175 meters per second (3855 feet per second) . This gives us a potential pressure rise of 2.4675 MPa (360 psi). The pipe has an internal diameter of about 255 mm (10.04 inches) and an area of 51,070 mm^2 (79.16 in^2). Thus the potential pressure rise could produce a force along the axis of the pipe of 126,000 N (28,330 lb). Unless the pipe and its restraint system have been designed for this force, it could cause damage similar to that shown in Figures 3 and 4.

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However, by altering (i.e., reducing) the closure time of the isolation valve, particularly in the last 15 to 20 percent of its total movement, it may be possible to considerably reduce the magnitude of the pressure rise and the accompanying forces. Alternatively, devices may be installed in the piping system near the closing valve to remove some of the liquid from the pipeline and thus mitigate the effects of the rapid valve closure.

The suitability of a device or action to mitigate the transient pressure and forces cannot be determined by simple equations. Usually, a computer-based study of the piping system must be conducted to determine the complicated time and spatial variation of the pressure, flow, and forces in the system. Such an analysis considers the characteristics of the pipeline components, including the isolation valve and controls or devices used to mitigate the potential for transient vibration. In addition to valve closure, other transient events such as pump start-up or power failure to a pump can also be studied.

Conducting a transient pressure study of a piping system to determine the effects of valve closure requires obtaining information regarding the:

- Pipeline size and layout
- Fluid properties, particularly the density and compressibility
- Valve characteristics (pressure drop versus percent closed)
- Proposed total closure time

Subsequent to the transient pressure study, sometimes it is also necessary to perform a structural analysis of the piping system for the transient forces generated. This can usually be done using a commercially available piping analysis program such as Caesar II or CaePipe.

Figure 1

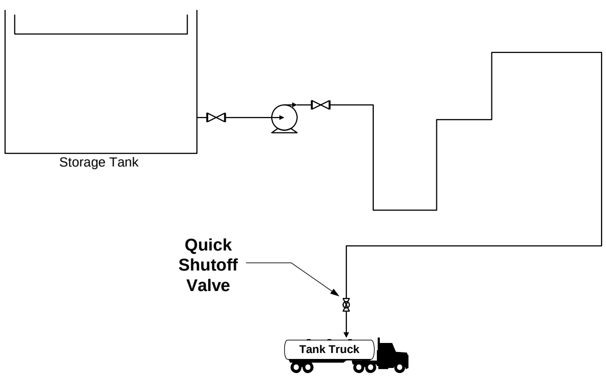

Figure 2

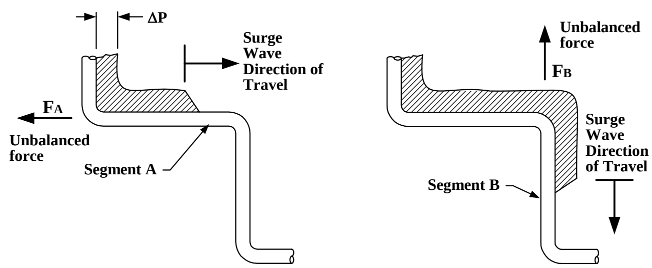

Figure 3

Figure 4

David Thornton has 27 years experience in solving problems related to the mechanical design and continued operation of pressure vessels, heat exchangers, piping systems and storage tanks and their support structures; 21 years experience in the application of thermal and structural finite element analysis to evaluate fixed process equipment. Additional experience includes design and maintenance of wind-loaded open frame structures and their foundations and the application of transient hydraulic analysis to liquid filled equipment. Please contact Vince Carucci if you'd like more information on Carmagen's expertise in this area.

HIGHLIGHTS

- Completed revisions to a Marine Terminal Berth Operating Guide for a major international refiner. Also completed reviewing their marine engineering design practices.
- Completed an audit of a refinery's machinery maintenance program. Potential program improvements were identified that, if implemented, will result in improved machinery reliability and probable reduction in long-term machinery maintenance costs. The basic maintenance principals that were identified are also applicable to the maintenance programs of other equipment.
- Poor lining design and internals installation details were identified as the most likely causes of hot spots that occurred on an internally lined, FCCU throttling valve. Recommendations for design improvements were provided that can be implemented during a later turnaround.
- Working as part of a joint client/Carmagen Engineering team, conducted reliability and maintenance audits at two plant locations of a major international pharmaceutical company. A number of improvement opportunities were identified that will enhance system reliability.
- Conducted an onsite review of the RBI program and procedures being used by a pharmaceutical client at one of their overseas facilities. Recommendations being developed to consider expected damage mechanisms and to make overall improvements to the program. A client-specific RBI training course is also being developed.
- Provided refractory and mechanical engineering consulting support related to multiple refractory lining failures that have occurred in an FCCU Regenerator Overhead line. Damage appears to have been caused by a combination of factors including more than normal solids content in the flow, high line velocities, and possibly less than ideal lining installation. Repair recommendations were provided to facilitate bringing the unit on-stream as fast as possible after this unplanned shutdown. It was also recommended that additional work be done to develop a long-term solution to overhead line reliability issues.
- Onsite mechanical engineering assistance provided to evaluate the cause of through-wall cracks that occurred in the shell of a delayed coking unit drum, causing a shut down. It was concluded that the cracks were caused by high, localized thermal stresses in the shell and initiated at pre-existing cracks that were not located/repaired during a prior turnaround. Crack repair recommendations were provided. Improvements to the process operating conditions and procedures were also recommended that would reduce the localized cyclic thermal gradients and resulting stresses.
- Recommendations were provided that will reduce the time needed to replace the support skirt of an existing delayed coker drum. The new skirt design will have slots in the upper portion in order to increase its flexibility, reduce local thermal stresses, and significantly increase the estimated cycle life without cracking at the skirt-to-shell junction. Finite element analyses were used to identify the maximum number of skirt sections that can be simultaneously removed to permit their replacement with the new design, thus reducing the estimated turnaround time by about a week.
- Fired equipment and process engineering support provided to evaluate existing hydrogen plant fired heaters for new conditions. In separate jobs, continued to provide fired equipment and heat exchanger support for a major international refining company.
- Continued to provide significant project management and cost engineering consulting support for multiple clients.
- Continued to provide welding, materials, and process engineering litigation consulting support for multiple cases.
- Onsite visit concludes that the root cause of major refractory lining failures inside an FCCU Regenerator vessel were caused by higher than expected operating temperatures. Recommendations were provided for immediate repairs during this unplanned shut down. Additional recommendations were provided for consideration after the unit is restarted, and for later implementation during a planned upcoming turnaround.
- Completed multiple refractory lining consulting jobs related to furnace ducting, stacks, and casing.
- Completed multiple equipment rerates to determine if available surplus equipment can be used in new refinery service applications at other locations.
- Providing plot layout support for domestic and international refiners.
- Provided continuous support of a major Middle Eastern LNG project via engineering services at the contractor and the sub-contractor's offices in Europe, with follow-up domestically.
- Performing 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.

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- Performing fluid coker on-site test run support, and a high level 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.
- Supported hydrotreater startups in Louisiana.
- Developing LOPA standards for a domestic refiner.
- Preparing standardized process design notes for a client's licensed technology.
- Performed construction site safety reviews for a major refiner at various refinery locations.
- Providing operating manual support for a major Middle Eastern LNG project via engineering services at the contractor's offices in Japan.
- Performing ASU vendor bid evaluation, Hazop and P&ID review support for a major refining and ethylene project in China.
- Providing 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 regarding GTL and other related areas.
- Preparing a Mogas blending study / evaluation of a domestic refinery.
- Completed consultation for technical evaluation to improve the reliability of incinerator, waste gas preheater, and vaporizer feed pump, etc.
- Completed a consequence analysis study utilizing PHAST modeling for a Middle Eastern client.
- Providing limited process, mechanical and metallurgical study assistance to a contractor assessing suitability of moth-balled hydrotreaters and a crude unit equipment for reuse overseas.
- Providing Hazop leader support for a new CCR located in Europe.
- Providing hydrogen plant technical and reliability support for domestic refiner in the Northwest.
- Provided CER support on Jet Fuel Treater located in Australia.
- Performed scoping study for offsite potential fire hazard.
- Providing technical mentoring / consulting to a University in Ohio.
- Providing extended lube hydrotreating pilot plant support services.
- Providing ongoing environmental support to domestic refiner.
- Provided support to a refiner's patent / legal department.
- Provided CER support on corrosion sensors in crude pipestill.
- Providing jet fuel treating problem scoping and consultation.
- Executed a technical consulting agreement with a major domestic refiner.
- Providing ENCON optimization support for a first commercial plant of a novel polymer technology.
- Providing refiner training course development support.
- Provided hydrcracker internals technical site consultation during turnaround.
- Performed noise study of chemical company's selected facilities.
- 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's in FCC flue gas system and improve reliability.
- Providing support to investigate design and operating problems in an overseas BDO unit.
- Providing limited refinery and offsite tankage planning assistance to a contractor relocating units overseas.
- Providing technical litigation support to client.
- Conducting logistics economics course at multiple locations for major refiner.