The CARMAGEN Report©
ENGINEERING INC.
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MARCH 2004

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Editor *.................................... Lori Carucci*
Writers *.......... Carmagen Engineering Staff*

We welcome your comments and suggestions for future editions. Please send them to bmesa@carmagen.com.

Thoughts On Crane Safety Prequalification Of Suppliers

By R. M. Hontz, P.E.

Construction Safety has become increasingly important since the advent of OSHA over thirty years ago. Capital projects in the process industry invariably list safety as the number one prioritized project objective followed by cost, schedule, and quality. Because of the risks involved with lifting, crane safety should be a key element of all Construction Safety Programs.

If all lifts were made with competent operators using sound, well maintained equipment (e.g., cranes and rigging) and following a comprehensive, quality lift plan, lifting accidents would be a thing of the past. The following are some thoughts on how to achieve the first two of these three objectives.

Many companies have sufficient demand for cranes to justify owning their own cranes and keeping crane operators on their payroll. They are better able to control the quality of operators, equipment and plans than the company that has an infrequent demand and must rely on third party suppliers. If you're an owner with limited demand for cranes, how can you be assured that whoever is sent to your site is competent and the crane is in good mechanical condition?

The process of "prequalification" is one way. Prequalification means knowing that the company you call for lifting service has previously been checked out and will send a qualified operator and a well cared for crane. In order for a supplier to be prequalified, you will need a lot of information about their business and organization, their personnel and their equipment. You're looking for a basis of confidence that when called, they will send a crane and operator that are "fit for purpose."

Set up a meeting with the supplier's top management at their place of business and be prepared to ask a lot of questions.

BUSINESS AND ORGANIZATION

- Check safety and incident records for the past 3 to 5 years.
- Check their maintenance policy.
- Is preventive maintenance (PM) being done per the crane manufacturer's recommendations?
- Check time spent on emergency maintenance. If more than about 20% is spent on breakdowns you should be suspicious of the PM program.
- Does the supplier comply with your Drug and Alcohol Policy?

PERSONNEL

- Discuss roles and responsibilities, e.g., who does the rigging, who determines the weight of the load, etc.
- Ensure their personnel, especially the operator, have authority commensurate with their responsibility. Make it clear that you will support an operator who refuses to make a lift he thinks is unsafe.
- Check that all operators are certified in compliance with local or state laws and regulations.

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Corporate Office: 4 West Main Street, Rockaway, NJ 07866 • Telephone: (973) 627-4455 • Fax: (973) 627-3133
Gulf Coast Division: PO Box 77910, Baton Rouge, LA 70879 • Telephone: (225) 752-0909 • Fax: (225) 752-0906
E-mail: carmagen@carmagen.com • Web Site: http://www.carmagen.com

Assessing the Creep Life of FCCU Internals

By David R. Thornton, P.E.

Many pressure vessels in the hydrocarbon processing industry contain internals that, like the pressure boundary components, are designed for a given set of conditions. Examples include fixed bed supports in hydrofining reactors, tray supports in fractionation towers, and grids and cyclones in fluidized catalytic cracking unit (FCCU) regenerators. The internal's design involves stipulating the desired operating life, a corrosion rate if applicable, the design temperatures, and usually design differential pressures. The sizing of the internals then involves using this information along with an allowable stress that accounts for the given operating environment and desired life.

For FCCU components operating in the creep regime, such as regenerator grids or cyclone systems, the design of the components involves several operating scenarios each with its own predicted duration, temperature and differential pressure or other load. The engineer designing the components then typically uses a life fraction approach where each combination of stress (a function of load and component thickness or dimension), operating temperature, and duration consumes a portion of the available creep life. Typically in the design, the load, temperature, and operating duration are fixed and component thickness or other dimensions determined so that the stress at the various operating conditions consumes the total desired component life (i.e., the sum of the life fractions equals 1.0).

Often the actual operating conditions vary from those assumed during the design. In such cases, the equipment owner may want to determine the amount of the predicted life used to date by past operating conditions and how various future operations will affect the predicted component life. Having this information allows the equipment owner to make economic decisions regarding the future operating conditions, e.g., by comparing the potential additional revenue from operating at a higher temperature or with a higher loading versus the cost of component replacement. Conducting such an assessment involves the following steps:

1. Determine the history of the past operating conditions (temperature and loading). The history may be constructed from the unit operator's recollection of past conditions but preferably will come from recorded process information such as daily average temperature and differential pressure.
2. Divide the history into periods of substantially uniform temperature and loading.
3. Estimate the desired future operating loading (e.g., differential pressure or catalyst loading).
4. Determine the component stresses for each past or future loading condition.
5. Calculate the life fraction consumed by past operations from the stresses, the operating temperature, and the duration using the Larson-Miller Parameter (LMP) approach of API RP 530, *Calculation of Heater-Tube Thickness in Petroleum Refineries*. The permitted future life fraction is then 1.0 minus the life fraction consumed to date.
6. Determine the allowable life versus operating temperature for each desired future loading condition, again using the LMP approach of API RP 530.
7. Calculate the life fraction consumed by each future operating condition (loading and temperature) by dividing the expected duration of the condition by allowable life at the condition determined in Step 6.
8. Adjust the future operating conditions and durations such that the total of the life fractions equals the permitted future life fraction determined in Step 5.

Using these steps along with information regarding equipment replacement costs and the increased revenues possible by the future operating scenarios permits the owner to make informed economic decisions.

As an example of this type of assessment, Carmagen Engineering, Inc. conducted a study for a large Gulf Coast refinery to evaluate the effect of past operating history on the creep life of a FCCU regenerator grid and determine the life under various operating scenarios. The refinery's operations support department supplied the operating temperatures below and above the grid and the grid differential pressure data for the evaluation of the effects of past operating history.

The study showed that, while the grid had been in service for close to twenty years, past operating conditions used approximately 23% of the creep life. Based on this finding, we advised the refinery that the regenerator grid did not require replacement at the next turnaround.

The creep life curves developed as part of the study (shown in Figures 1 and 2) provided the permissible duration in hours for a particular combination of grid differential pressure and process temperature above the grid.

A summary of the study methodology includes the following:

- We statistically analyzed historical operating data that included process temperatures below and above the regenerator grid and differential pressure across the grid, to determine values to use in the study.
- We calculated grid stresses as a function of grid differential pressure by conducting a series of axisymmetric finite element analyses. The finite element model, shown in Figure 3, included the grid, grid supports, and part of the regenerator vessel. The analyses considered the regenerator operating pressure and regenerator design pressure.
- Based on past heat transfer analyses of the regenerator grid, we equated the grid metal temperature to the average of the process temperatures above and below the grid.
- We obtained an estimate of the creep life consumed to date and generated the creep life curves using the time for stress to rupture versus temperature approach in API RP 530.

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Life Curves Enable Calculation Of Operating Conditions' Effects

The creep life curves for use in evaluating the effects of future operating conditions appear in Figures 1 and 2. Figure 1 provides the predicted regenerator grid life, in hours, for grid differential pressures ranging from 2 to 3 psi and operating temperatures above the grid ranging from 1300°F to 1400°F in seven increments: five 10°F increments from 1300°F to 1350°F and two 25°F increments from 1350°F to 1400°F. Figure 2 provides the predicted regenerator life, in hours, for a slumped catalyst bed as a function of the process operating temperature above the grid just prior to the loss of fluidization in the regenerator.

The basis for use of the grid life curves shown in Figures 1 and 2 comes from API RP 530. API RP 530 contains a set of material based curves that relate the stress in a component to a value called the Larson-Miller Parameter (LMP). Two values of the LMP actually exist, one for the average stress to rupture and one for the minimum stress to rupture, with the latter usually controlling. For a given material, and component stress along the ordinate (i.e., Y) axis, the curves determine the LMP along the abscissa (i.e., X) axis. Once the value of the LMP is known, API RP 530 provides an equation that relates the LMP, the component temperature and the component predicted life:

$$LMP = (T + 460)(C + \log_{10}(L))10^{-3}$$

where: T = component metal temperature, °F
C = a constant that depends on the component material
L = predicted component life, hours

This equation can be rearranged to provide the predicted component life as a function of metal temperature, material, and the LMP determined from the component stress:

$$L = 10^{\left(\frac{(1000\ LMP)}{(T+460)} - C\right)}$$

The portion of life used then depends on the duration at the given stress and temperature:

$$\%\ \text{Life Consumed} = 100\left(\frac{\text{Condition Duration}}{L}\right)$$

The example below shows how to use the curves to assess the effects varying conditions. It assumes that past operations have consumed 0.23 (23 %) of the component life. Thus future operations may account for 0.77 (77 %) of the life.

Example

Table 1 provides the conditions we will assume for the example illustrating how to use the curves. The total duration consists of a four year FCCU run between turnarounds. We have divided the four years into three combinations of operating conditions and one upset where the catalyst "slumps" on the top of the regenerator grid.

Table 1

Condition	Grid Differential Pressure, (psi)(1)	Process Temperature Above Grid, (°F)	Duration (days)	Figure Number
Operating 1	2.2	1330	980	1
Operating 2	2.5	1325	230	1
Operating 3	3.0	1320	248	1
Slumped Bed	-	1340	3	2

(1) Positive value indicates upward pressure

Examining Figure 1 for the grid delta P and process temperature conditions of Operating Condition 1, we see that the permitted life equals about 116,700 hours. The duration of this condition equals 980 days times 24 hours or 23,520 hours. Operating Condition 1 thus consumes a percentage of the grid life equal to:

$$\%\ \text{Life} = \frac{23{,}520}{116{,}700} \times 100\ \% = 20.15\ \%$$

Examining Figure 1 for the grid delta P and process temperature conditions of Operating Condition 2, we see that the permitted life equals about 69,800 hours. The duration of this condition equals 230 days times 24 hours or 5,520 hours. Operating Condition 2 thus consumes a percentage of the grid life equal to:

$$\%\ \text{Life} = \frac{5{,}520}{69{,}800} \times 100\ \% = 7.91\ \%$$

Examining Figure 1 for the grid delta P and process temperature conditions of Operating Condition 3, we see that the permitted life equals about 31,900 hours. The duration of this condition equals 248 days times 24 hours or 5,952 hours. Operating Condition 3 thus consumes a percentage of the grid life equal to:

$$\%\ \text{Life} = \frac{5{,}952}{31{,}900} \times 100\ \% = 18.66\ \%$$

Examining Figure 2 for the process temperature condition just prior to losing fluidization, we see that the permitted life equals about 1,660 hours. The duration of this condition equals 3 days times 24 hours or 72 hours. The slumped catalyst condition thus consumes a percentage of the grid life equal to:

$$\%\ \text{Life} = \frac{72}{1{,}660} \times 100\ \% = 4.34\ \%$$

To evaluate the acceptability of the proposed operating conditions, we add the percent life consumed by each condition to the 23% consumed by the past operating conditions. This value must be less than 100%.

Total
Consumed = 23%+20.15%+7.91%+18.66%+4.34% = 74%
Life

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Since this value is less than 100%, the proposed operating conditions would be considered acceptable from a life standpoint. However, the proposed conditions consumed about 51% of the grid's creep life in a four year time period. Future operations of a similar nature for a subsequent four year run would consume more than 100% of the predicted life.

Figure 1: Grid Life For Various Operating Conditions

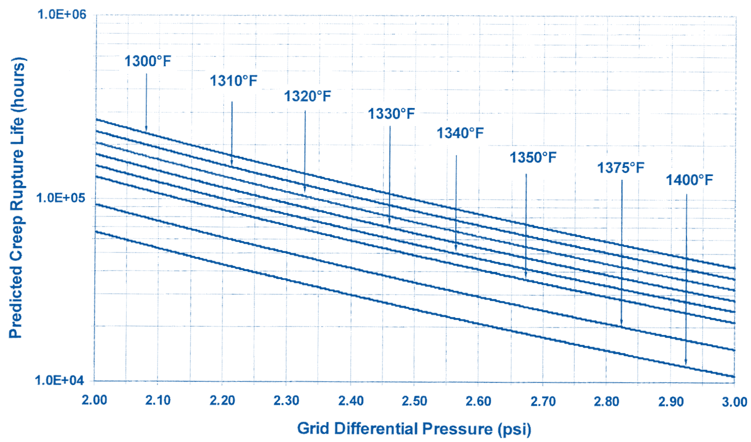


Figure 2: Slumped Catalyst Case

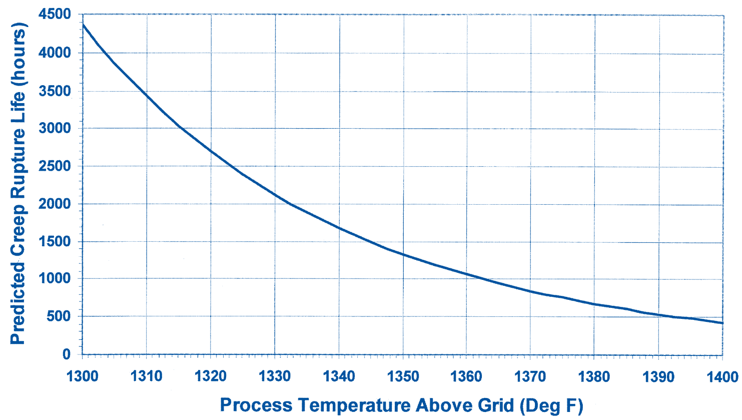
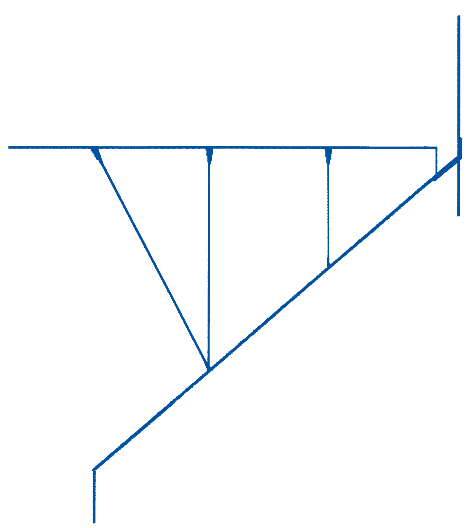


Figure 3: Regenerator Grid Finite Element Model



- If no certification standards exist, thoroughly assess the supplier's training process. How long is the training period? Who supervises the trainees? Are they tested?
- Ask as many questions (and listen carefully to the answers) as it takes to be confident that their operators are competent.
- Inform the supplier that the first time an operator appears at the site he will be given a brief written and hands-on test to demonstrate competency. (Sample tests are available).

EQUIPMENT

- A knowledgeable person should make a general assessment of the mechanical condition of typical cranes. This will confirm that the supplier is not just paying lip service to maintenance.
- Ensure that the maintenance bulletins issued by crane manufacturers are used in the shop. They're not very useful if they're stored in the main office.
- Ensure that electronic safety devices are installed and working. As a minimum, all cranes entering your site should have an anti-two-block alarm or shut down and a load-moment or load-indicating device.
- Inform the supplier that all cranes entering your site will be given at least a cursory inspection before going to work. (Detailed inspection and cursory inspection checklists are available).

Suppliers should be given a reasonable opportunity to correct deficiencies. However, suppliers that fail to comply should be disqualified and removed from further consideration.

It's probably a good idea to consider repeating the process every three or four years. It may make sense to do it more often if:

- Key personnel leave the supplier's organization
- Company ownership changes hands
- The supplier begins to have accidents or incidents, even if on other sites
- The supplier starts to lose money. Maintenance is often one of the first casualties when money gets tight.
- Other factors cause you to be suspicious.

Lifting is a risky business. The approach outlined here will help manage the risks by removing many unknowns concerning cranes and their operators. This is an important contribution not only to crane safety but to an overall construction safety program as well.

New Appendix G of API-653 Provides for Tank Bottom Inspections Qualification Guidelines

By Vincent A. Carucci

Aboveground storage tank bottoms must be periodically inspected and addressed for their integrity. This will generally set the required interval for internal tank inspection. During this inspection, the entire bottom should be visually examined for holes, cracked welds, generally corroded or pitted areas, and previously repaired areas. Additional inspection methods will also typically be used to obtain all the data needed to assess the integrity of the bottom. This can include:

- Magnetic flux leakage and/or eddy current testing of the entire bottom to establish the base values of remaining plate thickness.
- Vacuum box testing of floor seam welds and the bottom-to-shell junction weld to identify through-wall defects that were not apparent from the visual inspection.
- Ultrasonic thickness measurements to quantify the remaining plate thickness.
- Magnetic particle or liquid penetrate testing of the bottom-to-shell junction weld, and possibly floor plate welds, to verify that surface cracks or excessive pitting are not present.

API-653, *Tank Inspection, Repair, Alternation and Reconstruction*, does not explicitly state the inspection procedures that must be used, nor their extent. These are left up to the owner/operator to decide. However, with Addendum 1 issued September 2003, API-653 contains a new Appendix G that provides guidance for qualifying both tank bottom inspection procedures and the personnel who perform tank bottom examinations.

The owner/operator may apply the Appendix G guidelines as written, or modify them to suit their particular applications and needs. The introduction of Appendix G uses the words "guidelines" and "guidance" in describing the information contained in it. However, it is clear that the intent is to follow these guidelines, or at most, adapt them for specific situations while still meeting their intent.

All tank inspections are important in order to evaluate the tank's structural integrity. However, bottom integrity evaluation and the inspection data that is needed to conduct it are clearly the single most important factors to "get right" for obvious reasons.

- Hydrocarbon leaks from the bottom go directly into the foundation and potentially much further.
- The bottom may have been leaking for a long time before being detected.
- Severe bottom leakage could undermine the foundation, which could result in a more extensive tank failure.
- The underside of the bottom is not visible and severe bottom corrosion and pitting often is from the underside.

With the advent of API-653 in 1991, much more attention has been paid to tank inspection and integrity evaluation in general and the bottom in particular. There has thus been a large increase in the number of individuals and companies performing tank inspections. Technology improvements and inspection techniques have also kept pace with this increased demand. Because of all these factors, it is important that qualified inspection tools, procedures, and personnel are used in tank bottom examinations. This is where Appendix G comes in.

The approach that Appendix G uses to present its guidelines is similar to that used with welding procedures and welder qualification. Some of the same terminology is also used. The following highlights the overall structure and some of the information contained in Appendix G. Refer to Appendix G for complete details.

- **Definitions.** Several terms are defined. Among these are essential variables, non-essential variables, qualification test, and a scanning operator. Note the similarities to welding terminology. For example, an essential variable in a tank bottom examination procedure is one that cannot be changed without the procedure and scanning operators being requalified.
- **Tank Bottom Examination Procedures.** An authorized inspection agency that performs bottom inspections must have and use tank qualified bottom examination procedures (TBP). These procedures provide direction for those who perform the bottom inspection. Each TBP must address essential and non-essential variables. Each TBP specifies limits on the appropriate variables. This general approach is analogous to a welding procedure.
- **Tank Bottom Examiners.** Examiners must be qualified for the work that they actually do (e.g., operate scanning equipment or perform follow-up bottom thickness measurement). The purpose of qualifying a tank bottom examiner is to confirm their ability to satisfactorily use a qualified procedure to determine tank bottom condition. This individual is analogous to a welder.

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- **Qualification Testing.** A test must be performed on a sample of the tank bottom with designed flaws in it in order to qualify the examination procedure and equipment. Appendix G specifies the minimum number, type, and location of the flaws to be included in the sample plate. This is analogous to a welding procedure qualification test.

- **Qualification Test Acceptance Standards.** Acceptance criteria is specified that must be met when qualifying either an examination procedure or an examiner.

  - When qualifying either a procedure or a scanning operator, the operator must be able to detect a specified percentage of flaws. For example, if the remaining bottom thickness is less than 0.05 in., 90% - 100% of the flaws must be found.

  - When qualifying either a procedure or examiner who "proves up" indications (i.e., determines remaining thickness), the examiner must be able to determine flaw depth based on the type of tank bottom (i.e., uncoated, coating < 0.03 in. thick, coating > 0.03 in. thick).

- **Qualification Test Variables.** Appendix G presents suggestions for essential and non-essential variables.

  - **Essential variables** are items that may have a significant effect on the examination quality if they are changed from those used in the qualification test. Examples include:
    - Scanner equipment
    - Prove-up equipment
    - Prove-up procedure
    - Plate thickness
    - Coating thickness
    - Distance from shell
    - Critical equipment settings
    - Threshold settings
    - Calibration or functional check

  - **Non-essential variables** are items that will have less effect on the examination quality and may be different for different types of bottom scanners. Examples include:
    - Scanner speed
    - Scanning pattern
    - Height limitations
    - Overlap between scans
    - Plate cleanliness
    - Non-critical equipment settings

Appendix G is an important and welcome addition to API-653. Its use will go a long way toward improving the reliability of tank bottom inspection data.

New Requirements for Welded-On Plates to Storage Tank Bottoms

By Vincent A. Carucci

Welded-on plates may be added to an aboveground storage tank bottom for reasons other than to repair a corroded area. Examples of this include under floating roof support legs, or under the supports for internal heating pipes. Addendum I of API-653 requires that these added plates meet the same design, installation, and inspection requirements as for repair plates (see Figure 9-5 of API-653).

In addition to acceptable design details, Figure 9-5 of API-653 contains minimum weld spacing requirements for welded-on patch plates (e.g., distance to bottom plate lap welds or the bottom-to-shell junction weld). API-653 permits a relaxation in these weld spacing requirements for welded-on plates that are not being used for bottom repair. In this case, if the minimum weld spacing requirement cannot be met, all exposed welds that do not meet the weld spacing criteria must be Magnetic Partial or Dye Penetrant examined. However, any plates that are located within the critical zone must meet all bottom patch plate requirements, including weld spacing.