Assembling a viable, generic Risk-Based PV&T program for a Typical Mill

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Presentation Background

This presentation is a revision of a presentation originally given at the TAPPI EPE conference in 2008 by the author.

RBI as developed in the refinery industry is very established and specific for managing large numbers of equipment. The available software can be both expensive and unwieldy for the relative small size of a typical mill. RBI programs for mills may be created more cost effectively and be just as useful. Specific guidelines for RBI program development are often difficult to make through for the lay-person. This presentation provides a generic qualitative approach to risk-based inspection concepts.

The risk-based approach in the broadest sense seeks to focus efforts on the most critical and likely to fail equipment, but goes beyond simple prioritization / condition-monitoring and details targeting inspection techniques to damage mechanisms to maximize return on investment and quality of results.
Risk-Based? Benefits?

- Justification for non-standard inspection intervals (extended intervals).
- Reduced scopes of inspection and hence reduces costs.
- Provides systematic rationalization for focused inspections.
- Reducing downtime and unscheduled repairs by using resources more wisely.
- Improved data quality from inspectors.

What a RBI program is not:

A Risk-Based program is not the panacea of Mechanical Integrity. It doesn’t guarantee there will be no leaks, cracks, deterioration or damage.

No inspection is 100%. In RBI world, this concept is called ALARP – as low as reasonably practical, the goal being a reasonable reduction of risk.
What a RBI program is:

It provides the next logical step in condition-based mechanical integrity programs by focusing specifically on high risk items and associated damage mechanisms.

It provides the right information needed to predict the remaining service life or the safe interval to the next inspection.

Setting up a RBI program (guiding documents):

(4) Specific goals of any program

1. Protection of employees and the public.
2. Protection of the environment.
4. Complying with local and federal requirements (OSHA, EPA, local and state governments).

So where do we start???
Implement a 6 step “inspection loop”

Refer ASME PCC-3-2007, Fig. 3.3.4
The 6 step “Inspection Loop”

1. Data and Information gathering (catalog)
2. Risk analysis.
3. Risk ranking.
4. Inspection planning.
5. Mitigation activities (if needed).
6. Re-analysis and repeat.

Cataloging the equipment:

What’s in and what’s out? **Tanks**, vessels, heat exchangers, deaerators, FRP, plastics, brick and tile, stacks, piping?

What data do we need? **Material**, contents, operating and design parameters, year built and inspection history (if any)
Cataloging the equipment:

- What is our identification scheme? We need a unique designation in order to use a spreadsheet or database.
- What about a way to find the tank? Make the most of cataloging the equipment and create a plot or numerical locator to prevent duplicate inspection by NDE technicians, consider permanent labels, barcodes, QR codes etc. that correspond to the identification scheme.

Cataloging the equipment can be as basic as a simple excel sheet.
What is Risk?

Risk is defined as probability of failure (POF) versus consequence of failure (COF). Or simply:

Risk = Probability x Consequence

Probability may be expressed in frequency (# of events / time), i.e. →>0.01 annual occurrences or simply - High

Consequence may be expressed as Economic Loss i.e. → <$10,000 or simply - Insignificant

Risk analysis: Continuum of RBI Approaches

Refer API 580, Figure 3
Risk analysis (Qualitative Approach):

Instead of discrete values (such as frequency of occurrence), general ranges are used such as low – medium – high.

The value of this approach is it simple, easy to maintain, and can be done without detailed quantitative data (which may likely not exist – particularly early on in a program).

Further it can form the basis to use more quantitative approaches on high risk items (screening).

Risk analysis (Qualitative Approach): The drawback is it is highly dependent on the expertise of the analyst.

It typically implies less accuracy than quantitative, which can overstate the true accuracy by using precise #s.

When performing the analysis, API 653, 6.4.2.2.2, provides an excellent list of likelihood and consequence factors.

Don’t link the worst case consequence with the most likely failure mode (a small isolated leak resulting in a major fire), a lack of realism will be no better than the generic API condition-monitoring.
Why risk analysis / ranking?

- We have to come up with a systematic way to prioritize our inspections since we don't have unlimited budgets.
- Our budget is more effectively used by reducing inspection frequencies on low COF equipment.
- We reduce the POF by detecting deterioration early through targeted inspections.
- We reduce risk on high COF equipment by more frequent inspections.

Qualitative Risk Matrix

API RP 580 (ref. fig 7) or API RP 581 (ref. fig 4.2)

This can be used to graphically illustrate the concepts or even as screening tool to see where mitigation efforts should be focused.
Risk ranking (one qualitative example):

- Everything is ranked on a scale from 1 to 3, with 1 being the greatest risk and 3 being the least risk.

- Each rank is then prefixed with one of two letters: P or S – as in Pressure vessel or Storage tank.

- So a P-1 is a High Risk pressure vessel.

?-1 (high risk):

- Located where failure poses serious risk to employees or public.
- Located where failure will shutdown the mill.
- Located where failure will jeopardize the environment.
?-2 (moderate risk):

- Items of concern that don’t fall into high risk.
- They will impact production but can be bypassed, have contents that are harmful but not hazardous, pose minimal risk to employees and the environment, have some level of significant economic or safety concern.

?-3 (low risk):

- Items of limited concern.
- They have low POF and low COF.
- They don’t impact production, their contents are not harmful nor hazardous and pose no risk to employees or limited or no real risk to the environment.
P-1 or S-1 (high risk):

Examples include:

Digesters (batch and continuous, deaerators, dryer cans, condensate storage tanks, impregnation vessels, and vessels operating above 140F, CS liquor tanks, PSM covered tanks (acids, ClO2, chlorate, turpentine), caustic tanks, hot water tanks.

P-2 or S-2 (moderate risk):

Examples include:

heat exchangers, condensers, natural gas and propane vessels, chip bins, water treatment tanks, cold water, HD storage, and emergency fire water tanks.
P-3 or S-3 (low risk):

Examples include:

- compressed air receivers, compressed air dryers and some condensate tanks, oil storage tanks (SPCC), FRP brine tanks, HDPE containing inert chemicals.

Often require no internal inspection since no real attack from the contents.

API 653 /510 Default Inspection Intervals

- External visual: 5 yr tank or vessel.
- Internal visual: 10 yr vessel, 30 yr tank.
- Thickness measurement: 10 yr vessel, 15 yr tank.

Intervals are reduced for UT based on $\frac{1}{2}$ remaining life.
RBI Inspection Intervals

- Intervals can go longer than API intervals, in theory as long as is justifiable.
- Low risk items may have NO re-inspection interval.
- The RBI assessment should be reviewed at intervals of 10 years or less.
- Management of change approach is warranted.
- Part of the risk mitigation is recognizing IOWs (integrity operating windows) – established limits for process variables.

Inspection Planning

- “Measure twice cut once”.
- For each item determine the most probable damage mechanisms (internal and external) based on the information gathered during the cataloging step.
- For those damage mechanisms determine the most appropriate way to apply NDE to quantify the extent.
- Don’t confuse MECHANISM with MODE. The MODE is critical in applying NDT technique (i.e. scanning for pitting).
Where to go for help with Inspection Planning?


WRC-488 *Damage mechanisms affecting fixed equipment in the pulp and paper industry*

ASME PCC-3-2007 – *Appendices have Damage Mechanism definitions, defects screening tables, and monitoring methods tables.*

*API 581 also has similar definitions and tables.*

When in doubt find a good corrosion specialist who is experienced in your industry damage mechanisms that can work with you on this process.

*Identifying the potential damage mechanisms is mandatory to targeted inspections.*

HOWEVER, don’t outsource this entirely. Outside consultants may be used, but not having mill employee involvement is a recipe for an inaccurate analysis, inspection planning and NO plant buy-in – “everybody needs a partner in crime”. 
What goes in an inspection plan??

- A picture so you know the techs are inspecting the correct equipment.
- What are the anticipated damages mechanisms and what is their mode.
- What and where specific NDE techniques need to be performed.
- NDT technique must be able to adequately quantify the damage mode, i.e. spot UT is worthless for pitting modes.

Establish a scope for both internal and external inspections.
- Inspection by itself doesn’t reduce risk, it quantifies it.
- Inspection most importantly aids in predicting when a critical level of damage is reached, requiring other mitigation.
- Assumes mill will act on the findings in a timely manner.
Sample Inspection Plan

**INSTRUCTIONS FOR THE NO. 6 INSTRUMENT BLOW TUBE:**
This is a vertical, carbon steel tank with a flat bottom and a dome roof. The tank process is green liquid held at atmospheric pressure and ambient temperature.

**EXTERNAL INSPECTION (FROM INTERNAL):**
- **VT inspection of general condition:**
- **VT inspection for corrosion under product deposits or other locations where corrosion can be hidden (supplemented UTT).**
- **VT inspection for cracks in the base plate or dome roof.**
- **VT for leaks in nozzles and nozzles flanges.**
- **UTT for flaws of the depth inaccessible (based on internal VT otherwise minimum at two continuous scans).**
- **Spot UTT on roof.**
- **All accessible nozzles should be end using a heat-invariant scan recording the readings at 90, 180, and 270 for the three betweens.**

**EXTERNAL INSPECTION (SUPPLEMENTAL UTT):**
- **VT inspection of general condition:**
- **VT to determine side line or corrosion patterns.**
- **Additional UTT should be performed at worst areas of shell not accessible otherwise.**
- **Multiple UTT line scans of the floor for under-floor corrosion (based on external VT).**

**EXTERNAL DAMAGE MECHANISMS:**
- Atmospheric Corrosion: Can occur in uncoated areas and will be more rapid at tank roof opening where vapors con condense.
- Under-Floor Corrosion: Can occur on uncoated floor joints.

**INTERNAL DAMAGE MECHANISMS:**
- Fatigue cracking: Can occur in areas of high vibration and may be accelerated due to corrosion.
- Liquor Corrosion of Carbon Steel: Can occur around tramp zone and areas of high flow/impingement of coarse sludge and can produce a hot corrosion.


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**Inspection execution (Mitigation Activities):**

- API 653 / 510 / 570.
- TIP 402-28 Guidelines for inspecting used FRP equipment.
- TIP 402-22 Guideline for batch digester inspection.
- TIP 402-16 Guideline for inspection and NDE of paper machine dryers.
- TIP 402-27 Guideline for inspection of continuous digesters and impregnation vessels.
- NACE Standard RP0590-96 Recommended practice for the prevention, detection and correction of deaerator cracking.
Inspection execution (three points):

1. Be involved or use a competent person who can be involved.
2. Use ASNT qualified inspectors and API certified inspectors who understand an RBI approach. Listen to their advice, but remember we aren’t blindly following API guidelines. Using run-of-the-mill techs will have bad results.
3. Remember the internal inspection often validates and determines all. Don’t discount performing at least one good internal inspection. You can’t account for manufacturing or design defects.

The internal inspection is the key (and top priority) because it allows verification of the actual damage mechanism present and the resulting corrosion pattern on the side that you can’t visually observe.

Once the pattern is established it may be possible to use external monitoring only for the equipment (all things being equal) or NO future monitoring.

One set of flow channels that I have monitored for the last 8 years has become so predictable, that while the mill has requested performing thousands of UT measurements for justification, the key controlling wear point can really be monitored with just a few readings in the correct external location. The thousands of measurements clearly demonstrated this point.
A classic example is in this carbon steel black liquor storage tank. As typically known, they develop a distinct corrosion band around the tidal zone (assuming a steady liquor level). Once this is verified and an accurate rendering of the pattern documented, external UT line scans can be used to monitor the deterioration and trend the remaining service life of the tank.

Other Risk Mitigation Activities:

- Replacement or Repair.
  - Perform API 579 FFS analysis.
  - Perform repair (temporary or permanent).
  - Replace the item (if material is not conducive to achieving acceptable risk – change the metallurgy)

- Modification or Re-rating.
  - Reduce MAWP.
  - Lower operating level.
  - Install coatings and linings.
  - Make use of cathodic or anodic protection.

An simple example is remove unneeded insulation from the base of storage tanks to reduce likelihood of CUI damage.
Analyze the Results:

- For the most part the corrosion allowance technique works for overall structural integrity.
- API 653 provides the basic calculations needed to determine minimum required thicknesses for most storage tanks.
- ASME sec VIII provides the basic calculations needed to determine the minimum required thicknesses for most pressure vessels.
- STI SP001 for SPCC tanks.
- API 579 provides calculations when outside the bounds of the above.
- Use serious caution on assumptions, whether on operating practices or on equipment history.

Analyze the Results:

- Software is available to aid in calculating minimum required thickness and remaining life.
- No software does it all and those that try seem to be the worst overall.
- Garbage in = garbage out.
- Be cautious with interpretation.
- Check everything by hand and ask the question “does this make sense?”. 
Revise and Repeat / Re-analysis (close the loop):

- Adjust the rankings to reflect the actual field findings.
- Remove out of service equipment.
- Correct the catalogue parameters (true pressure, temp and contents, etc.).
- Revise inspection intervals. Typically the intervals are held at the default values until two data points are created. **Sometimes the nominal construction thicknesses can be used, BUT WATCHOUT – this can mask true rates!**
- Revise the inspection plan.
- File all of the documentation.

Documentation:

- A good program is only as good as it’s documentation. I tell my inspectors “if the inspection is **not** well documented, then it never took place, so I don’t have to pay you”.
- There are several software programs available.
- In selecting a software think “electronic file cabinet”, not calculation / analyzer tool.
- Good documentation allows for easy changes of risk analysis and inspection planning when the process or equipment is changed.
Questions?