EVALUATION AND ESTIMATION OF COBALT INTRODUCTION INTO SYSTEMS BY VALVES

1. PURPOSE

1.1. The Source Term Reduction Program requires the estimation of cobalt release from hardfaced valve surfaces into plant systems. Stellite® is a cobalt alloy commonly used for hardfacing valve surfaces that are subject to wear and could affect the valve’s operability. The purpose of this T&RM is to provide methodology for the realistic estimation of cobalt released from Stellite® valve surfaces. This will provide information for the practical evaluation of valves as candidates for replacement or modification prioritized in RP-AA-551-1001.

2. TERMS AND DEFINITIONS

2.1. Abbreviations and Acronyms

2.1.1. EPN – Equipment Part Number

2.1.2. EPRI – Electric Power Research Institute

2.1.3. INPO – Institute of Nuclear Power Operation

2.1.4. LLRT – Local Leak Rate Test

2.1.5. P&ID – Piping & Instrument Diagram (a schematic system diagram)

2.1.6. Abrasion – Wear of contacting sliding surfaces when hard particles are present between them.

2.1.7. Adhesion – Wear due to bonding and material transfer that occurs when asperities on sliding material surfaces contact each other.

2.1.8. Cavitation – The phenomena when a liquid passes through a restriction and is transformed momentarily to the vapor state and back to the liquid state due to rapid compression of the vapor bubbles.

2.1.9. Corrosion – The act of chemically attacking a metallic surface by the media, and effectively resulting in a change in structure (e.g. steel rusting).

2.1.10. Disc – The moving portion of the valve assembly that contacts the mating surface of the valve body to effect shut-off.

2.1.11. Erosion – Wear caused by impingement of moving fluids or fluid-borne solid particles. The subdivisions of erosion are solid particle impingement, water droplet impingement, erosion by single-phase fluids, and cavitation erosion.
2.1.12. **Flashing** – The phenomena when a pressurized and heated liquid passes through a restriction to flow and is transformed to the vapor state.

2.1.13. **Galling** – Adhesive wear occurring as a result of high contact stresses.

2.1.14. **Hardfacing** – The application of a harder overlay material to the base material to enhance the wear characteristics and life expectancy of the assembly.

2.1.15. **Normally Closed** – A valve that is positioned to prevent system flow from passing through it during plant operation.

2.1.16. **Normally Open** – A valve that is positioned to allow system flow to pass through it during plant operation.

2.1.17. **Pitting** – Localized corrosion of a metal surface, confined to a point or small area, that takes the form of cavities.

2.1.18. **Seat** – The stationary portion of the valve body that is contacted by the mating surface of the disc to effect shut-off.

2.1.19. **Seat Test** – Measurement of the flow rate through a closed valve that is pressurized to determine the isolation capability. This includes “local leak rate testing” (LLRT).

2.1.20. **Engineering Judgment** – The method of applying engineering knowledge and power plant design experience to form an opinion or perform an evaluation by discerning and comparing that includes:
- A conclusive statement based on quantitative comparison of input data between the case being evaluated and a previous case that was analyzed in detail; or
- A qualitative, logical and conclusive discussion reflecting the general body of knowledge associated with preparing and reviewing a design analysis; or
- Specific numerical results replaced by a “pass/fail” or “greater than/less than” level of accuracy. Engineering judgment shall be documented with a basis for the conclusion.

2.1.21. **Steam Cutting** – The erosive effect caused by small high velocity jets in closely spaced surfaces resulting from an unintentional gap causing localized damage (sometimes referred to as wire drawing).

2.1.22. **Stellite®** – A registered name for hardfacing alloys made by the Deloro Company with high content of cobalt that are used in the valve manufacturing industry.

2.1.23. **Throttling** – The act of varying the flow through a valve by altering the position of the disc relative to the seat in response to system demands. The act of maintaining a constant flow through the valve by altering the disc position relative to the seat in response to upstream conditions.

2.1.24. **Velocity** – The speed at which the media passes over the metallic surface.
3. **MAIN BODY**

3.1. **Evaluation of Valves**

3.1.1. The basics of evaluating the release rates from the Stellite® surfaces of valves may be characterized in the steps that follow:
- Consider how the valve is used in the system (normally open, normally closed, seldom, intermittent, periodically, throttling, etc.).
- Identify the surfaces that are effected by operation or use of the valve.
- Determine, or estimate, the dimensions of the effected surfaces.
- Consider the media, and the operating conditions (air, steam, water, pressure, temperature, flow rate, velocity, etc.).

3.1.2. Using the guidance presented later in this document, and engineering judgment, calculate the estimated release rate of cobalt from each valve.

3.2. **Valve List**

3.2.1. Reference the Component Data Module (CDM) in SAP for each Station’s component inventory.

3.3. **Special Considerations Based on Valve Types, Installations, and Applications**

3.4. Valves in use in the stations are subjected to varying operating conditions that result from the type of valve being used, the orientation of the valve, the configuration of the piping, the flowing media, etc. Each of these has an effect on how the release of Stellite® is determined and quantified.

3.4.1. **Gate Valves:** These valves have four seating surfaces (two on the valve body and two on the disc) that may be hard faced. Normally, these valves are for isolation purposes only, and are either fully open, or closed. A valve that is fully open has the body seats exposed to flow, and a certain amount of turbulence, but the disc surfaces are protected in the valve bonnet, and are not expected to erode. These valves are not typically intended for throttling service, but may be used as such. In these cases, all four seating surfaces are exposed to the flow, and therefore the erosion. This will effectively reduce the minimum valve size to half of the size of a properly applied valve. Valves limited to occasional use in throttling service should be considered in their normal mode of operation only. Valves that are normally closed have **no** continuous flow, and should be evaluated only for the amount of
time when fluid is passing through the valve. Disc guides and back seats are usually Stellite®, but are typically out of the flow stream, and not subject to corrosion. The guides will wear due to stroking of the valve, but will depend on how often and under what conditions.

3.4.2. **Check Valves:** These valves come on a variety of types. The most vulnerable to erosion are the swing and tilting disc types. Each has two surfaces (the seat and the disc) that may be hardfaced. Typically the body seat has a smaller hardfaced surface than that of the disc, but unless the actual dimensions are known, the same dimensions as estimated for gate valves will result in sufficiently conservative results. An error was identified in the EPRI calculations of cobalt release from check valves. EPRI has acknowledged this, and will use corrected data in the next edition of their guidelines. Therefore, PSEG Nuclear will adopt the use of corrected calculations for these valves. Lift type check valves (which include in-line and nozzle checks) should be evaluated in the same manner as a standard globe valve.

If hinge pins and hinge pin bushings of swing or tilting disc type check valves are hardfaced, or made of high cobalt alloys, they must be evaluated separately from the valve seating surfaces. These components will not typically wear due to erosion, but rather due to mechanical wear if the flow is unstable or insufficient to hold the disc in a stable position. In these cases, the disc may flutter and be subjected to significant wear. This wear can result in cobalt release into the system of as much as triple the amount of erosion that may be credited to the seat. The Check Valve Program Engineer should be consulted regarding the stability of these types of valves.

3.4.3. **Globe Valves:** These valves typically have two seating surfaces (one on the disc, and one on the body seat), but there are often four seating surfaces depending on the valve design. Globe valves may also have flow in either direction (termed flow over the disc or flow under the disc), and are considered equal for the calculations of erosion and release of cobalt from the hardfaced surfaces.

Globe valves are also well suited to controlling flow, and therefore fluid velocity should also be considered when calculating erosion rates. Special versions of globe valves are used for regulating flow. These have double discs and cages, and are typically used in pairs, and are responsible for the greatest introduction of cobalt into the feedwater systems where they are used.

Caged globe valves with piston style discs must have the materials of the plug and the cage, and the areas exposed to erosion properly evaluated.

3.4.4. **Butterfly Valves:** Most of these valves have resilient seating elements made of rubber or Teflon type compounds. The mating surface of the seat or the disc is usually stainless steel or some other corrosion resistant alloy. These are typically not high cobalt content valves. Metal to metal seated butterfly valves should be evaluated in the same manner as a gate valve with one or two seating surfaces exposed to the flow if cobalt alloys have been used. Special consideration should also be given to velocity since butterfly valves are often throttling flow.
3.4.5. **Ball Valves:** Most of these valves are of small sizes, and should **not** be expected to have high release rates of cobalt.

3.4.6. **Pilot Operated Relief Valves:** These valves are subjected to wear resulting from seat leakage that results in wire drawing or steam cutting.

3.4.7. **Erosion:** EPRI assumes that erosion is one of the primary causes of cobalt release into plant systems. Fluid velocity and time in service are the most important considerations when evaluating erosive effects on Stellite® surfaces. Low velocity flows, regardless of duration, and minimal usage, regardless of the velocity will **not** result in eroded surfaces. Aggressive flows for long periods of time are the applications that require the greatest attention. Valves that are throttled are most vulnerable to erosion due to the high velocity developed by the partial open condition. Stellite® disc edges and seat surfaces are also known to survive in aggressive flows in long-term continuous usage without degrading.

3.4.8. **Cavitation:** This is another significant source of Stellite® degradation occurring in control valves. The explosive nature of a cavitating liquid causes surface defects that resemble deep pitting, or pock marking. This represents a heavy removal of material, and is dependent primarily on system pressure dropping below the vapor pressure, and recovering as it passes through the valve.

3.4.9. **Corrosion:** If the media can attack the Stellite® chemically, a regular removal of material can result. Generally, the flow will erode the corrosion layer and expose raw metal that will corrode at a faster rate than a protected surface. All cobalt alloys possess excellent corrosion resistance at typical plant operating temperatures.

3.4.10. **Wear:** Mechanically moving two components against each other can result in wear of either or both surfaces, and introduce particles of metal into the system. This probably is the main cause of cobalt release, but performance history must be reviewed to assure that the seating surfaces are wearing rather than some other internal component.

3.4.11. **Local Leak Rate Testing:** Since erosion, corrosion, and mechanical wear are the primary mechanisms that result in release of cobalt into the systems, good leak rate performance should be considered favorably when evaluating cobalt release rates. Therefore, valves that are regularly subjected to LLRTs (either directly, or indirectly), and pass the test on a regular basis should not be considered high contributors of cobalt. The history of a valve should always be considered, and a cause of leak rate failure determined before making assumptions regarding cobalt release from seating surface degradation. The seating surfaces of failed valves should always be evaluated to determine if they are the cause of the leakage.
3.5. **Calculation of Valve Size and Cobalt Release**

3.5.1. Design Engineering at the stations shall be responsible for calculating the cobalt release rates and providing Station Management, and Radiological Engineering, with a valve list table, in order of cobalt introduction, beginning with the highest contributor. The proposed table is provided in Attachment 1. This table provides information for the decision making process in RP-AA-551, RP-AA-551-1001, and RP-AA-551-1003.

3.5.2. Since many valves are ½ inch to 2-inch size, it is assumed that the cobalt contribution would be low. To confirm this assumption, Equation 1 uses information presented above and the information in Table 1 to permit the determination of the valve size that will introduce the threshold quantity of cobalt into a system (a Priority 3 Valve). Equation 2 is then used to determine the estimated cobalt release from valves exceeding that size. Each valve type and size should be evaluated individually. An example (Attachment 2) is for a normally open gate valve.

3.5.3. Valve drawings are **not** typically furnished with sufficient information to determine the dimensions of the seating surfaces of the body and disc. If the necessary information for the valves under consideration is **not** available and **cannot** be obtained, the list below provides generic dimensions that can be used to provide sufficient accuracy for the determinations that must be made.

- 2 inch through 4 inch valve = 0.375 inch wide seat surface
- 6 inch through 10 inch valve = 0.500 inch wide seat surface
- 12 inch through 16 inch valve = 0.750 inch wide seat surface
- 18 inch through 24 inch valve = 1.000 inch wide seat surface
- Greater than 24 inch = 1.500 inch to 1.875 inch wide seat surface

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<th>Valve Body Type</th>
<th>Max Degradation Value/Seat Area</th>
<th>Number of Seat Areas to Consider</th>
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<tr>
<td>Gate Valves</td>
<td>2.0 mg/dm²/mo</td>
<td>2 or 4*</td>
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<tr>
<td>Check Valves</td>
<td>1.5 mg/dm²/mo</td>
<td>2**</td>
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<tr>
<td>Globe Valves</td>
<td>0.5 mg/dm²/mo</td>
<td>2***</td>
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<td>FW Reg Valve</td>
<td>2080 mg/dm²/mo</td>
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<tr>
<td>2 Stage PORV</td>
<td>20 mg/dm²/mo</td>
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* For normally open valves or throttled valves respectively  
** For valves without Stellite® hinge components  
*** For typical globe valves (valve drawings should be reviewed)  
**** For pair of double disc globe valves (includes all surfaces) in BWRs
Equation 1 – Valve Sizing Calculation

\[
P_3 \frac{P}{mdv} \times \frac{100 \text{ cm}^2}{1 \text{ dm}^2} \times \frac{1 \text{ in}^2}{6.45 \text{ cm}^2} = A_{\text{total}}
\]

Equation 2 – Estimated Cobalt Released Monthly

\[
(\pi d w) \times \frac{6.45 \text{ cm}^2}{\text{ in}^2} \times \frac{\text{ dm}^2}{100 \text{ cm}^2} \times (mdv) \times s = CoR
\]

Where:
- \( P_3 \) maximum cobalt release of a Priority 3 valve
- \( d \) valve size in inches
- \( w \) seat width in inches
- \( mdv \) max. degradation value in mg/dm\(^2\)/mo equivalent (mg/dm\(^2\))/mo
- \( s \) number of seating surfaces considered
- \( A_{\text{total}} \) total area to be used in valve sizing
- \( CoR \) estimated amount of cobalt released in mg/mo

4. REFERENCES

4.1. User References

4.1.2 EPRI NP-3444 – Wear Measurements of Nuclear Power Plant Components

4.1.3 EPRI TR-103296 – Cobalt Reduction Guidelines – Revision 1

4.1.4 INPO 05-008 – Guidelines for Radiological Protection at Nuclear Power Stations

4.2 Cross References

4.2.1 RP-AA-551 – Cobalt Reduction Program

4.2.2 RP-AA-551-1001 – Identification, Ranking, and Prioritization of Cobalt Bearing Material

4.2.3 RP-AA-551-1003 – Cobalt Reduction Program Work Process

5 ATTACHMENTS

5.2 Attachment 1, “Tabular Data Required”

5.3 Attachment 2, “Example of Valve Calculations”
<table>
<thead>
<tr>
<th>P/R</th>
<th>Co60 Input</th>
<th>Valve EPN</th>
<th>System</th>
<th>Valve Size</th>
<th>Valve Type</th>
<th>Valve Mfg.</th>
<th>Disc Facing</th>
<th>Seat Facing</th>
<th>Seat Insert</th>
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**Explanation of Column Headings**

- **P/R** – Priority and Ranking based on RP-AA-551-1001
- **Co60 Input** – Results of calculations using Equation 2.
- **Valve EPN** – The Equipment Number of the valve.
- **System** – The system the valve is installed in.
- **Valve Size** – The size of the valve in inches, or the size of the port for reduced port valves.
- **Valve Type** – Gate, Swing Check, Butterfly, Globe, etc.
- **Valve Mfg.** – The manufacturer of the valve
- **Disc Facing** – Stellite® applied to disc face – Yes or No.
- **Seat Facing** – Stellite® applied to seat face – Yes or No.
- **Seat Insert** – Solid Stellite® seat insert – Yes or No.
To determine the maximum size of a normally open gate valve that would contribute less than 10 mgm/dm$^2$/mo (the smallest gate valve size that must be considered), the following values were used for the variables in Equation 1.

Where:  
- $P_3$ - 10.0 mg/mo
- $mdv$ - 2.0 mg/dm$^2$/mo
- Valve Surface Area $\pi dw$ (assume 0.750 inch width)
- Seat Areas Considered 2

The minimum valve size is therefore calculated using Equation 1:

$$A_{total} = \frac{10 \text{ mg/mo}}{2 \text{ mg/dm}^2/\text{mo}} \times \frac{100 \text{ cm}^2}{1 \text{ dm}^2} \times \frac{1 \text{ in}^2}{6.45 \text{ cm}^2} = 77.52 \text{ in}^2$$

2 seat areas $\Rightarrow A = \frac{1}{2}(77.52 \text{ in}^2) = 38.76 \text{ in}^2$

0.750 inch wide seat $\Rightarrow d = \frac{38.76 \text{ in}^2}{\pi(0.75 \text{ in})} = 16.45 \text{ inch valve}$

Therefore, the smallest gate valve that should be considered is a 16-inch size if it is normally open, and only two seating surfaces are exposed to the erosive action of the fluid.

**NOTE:** For a gate valve with all four seating surfaces exposed to the erosive media, it can be shown that the smallest valve size to be considered should be 10 inch due to the smaller seating width of 0.500 inch.

It is now possible to estimate how much cobalt might be released (CoR) into a system for larger valves using Equation 2.

$$CoR = (\pi \times 24 \text{ in} \times 1.0 \text{ in}) \times \frac{6.45 \text{ cm}^2}{\text{in}^2} \times \frac{dm^2}{100 \text{ cm}^2} \times (2.0 \text{ mg/dm}^2/\text{mo}) \times 2 = 19.47 \text{ mg/mo}$$

Therefore, it is estimated that a 24-in. normally open gate valve would release 19.47 mg/mo.