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RISK-BASED INSPECTION STUDY OF AN EVAPORATION CONDENSATE TANK SYSTEM

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ABSTRACT

The Risk-Based Inspection (RBI) methodology is a systematic tool that provides essential information to support decisions regarding inspection actions through resource rationalization as a function of the existing risk. The risk-based approach allows focusing more on the components with greater risk and, thus, develop inspection actions to reduce it. The inspection plan is generated based on the risk that is a combination of the probability of an event and its consequence. The study was conducted in a tank and piping of an evaporation condensate system with different design conditions and, consequently, different damage mechanisms. Moreover, the tank suffered some interventions during the operation period that resulted in the activation of certain mechanisms that were not previously expected. All components presented a high risk and inspection actions were recommended depending on the active mechanism. In addition, the RBI methodology is a powerful tool for generating inspection plans to satisfy requirements of Brazilian law NR-13.

Keywords: *RBI, evaporation condensate tank, inspection plan, damage mechanisms*

INTRODUCTION

The Risk-Based Inspection (RBI) methodology is a systematic tool that provides essential information to support decisions regarding inspection actions through resource rationalization as a function of the existing risk. The risk-based approach allows focusing more on the components with greater risk and, thus, develop inspection actions to reduce it [1,2].

In the pulp process, wood is converted to pulp that can be used to produce paper. To separate the fibers from the other constituents, white liquor and steam are added with the wood chips to the digester. The pulp is then washed and screened before it is bleached. After drying, it is ready to be transported to a paper mill [3].

For economic and environmental reasons, the chemicals in the white liquor are recovered in the recovery cycle, which generally consists of an evaporation plant, a recovery boiler and a white-liquor preparation plant. Considering evaporation in particular, the purpose of this stage is to separate water from the weak black liquor to raise its heating value before it is combusted in the recovery boiler [3]. Moreover, modern evaporation plants already include stripping systems for condensate treatment and gas separation [4].

In this work, the RBI study was conducted in a carbon steel tank and the stainless steel pipes of the evaporation condensate system of a pulp and paper mill. The tank stores evaporation secondary condensate and treated condensate from the stripper.

THEORETICAL ASPECTS

The RBI study was conducted based on the API 580 and 581 recommended practices. Moreover, calculations used the software APIRBI® version 10 of the Plant Manager version 2.7.12 supplied by E2G – The Equity Engineering Group.

For the study, different types of information were necessary. For design parameters, the Piping and Instrumentation Diagram (P&I) and drawings of the tank and pipes were collected. Moreover, the inspection history available was analyzed. Data of operation conditions, external environment, leak detection, mitigation and isolation systems are specified according with the current condition of the tank and pipes process.

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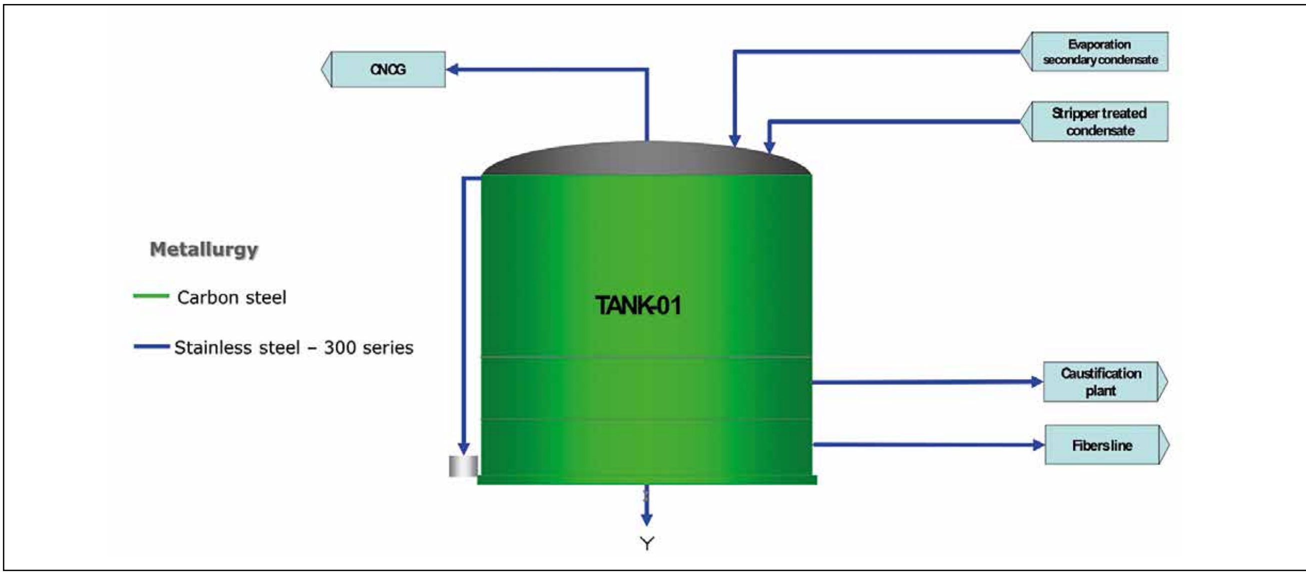

Figure 1. Metallurgy of the condensate tank system

System metallurgy

Despite belonging to the same system, the tank and pipes have different construction materials. Figure 1 shows a schematic diagram of the metallurgy components.

The design project of the tank specified an internal lining of fiber to protect the base material, but during the operation period, this lining presented significant cracking and blistering damage. As a result, the internal lining was removed and, in this study, it only considered the current condition: the tank without internal layer.

Fluid characterization and operating conditions

The tank fluid is condensate with alkalis as NaOH, KOH, Na_2CO_3 and K_2CO_3, all of them dissociated. High concentration of chlorite is not expected (below 0.1 ppm) and the fluid pH is basic, about 10.

In terms of operating conditions, the tank operates at a temperature of 80°C and steam out is not performed during shutdowns.

Damage mechanisms analysis

Based on the design data (equipment without stress relief), fluid characterization and operating condition, the internal damage mechanisms that can be active in the shell course and the tank bottom are Caustic Stress Corrosion Cracking and Alkaline Carbonate Stress Corrosion Cracking (ACSCC). In both of them, the cracks propagate parallel to weld in adjacent base metal, i.e., the zone of the highest welding residual stress, but can also occur in the weld deposit or heat-affected zone and can be transverse to the weld [5].

Caustic SCC is characterized by surface-initiated cracks that occur in piping and equipment exposed to caustic (alkaline hydroxide solutions) at elevated temperatures, primarily adjacent to non-stress-relieved welds. The susceptibility to caustic SCC in caustic soda (NaOH) and caustic potash (KOH) solutions is a function of caustic strength, metal temperature and stress level. Crack-propagation rates increase dramatically with temperature, and cracks can grow through the wall in a matter of hours during temperature excursions, especially in concentrated caustic or if conditions promote caustic concentration. Concentration can occur as the result of alternating wet and dry conditions, localized hot spots, or high-temperature steam out [5].

ACSCC is the common term applied to surface-breaking cracks that occur at or near carbon and low alloy steel welds under the combined action of tensile stress and in the presence of alkaline water containing moderate to high concentrations of carbonate (CO_3). Carbonate cracking can occur at relatively low levels of residual stress, but it usually occurs in welds or coldworked areas that have not been stress relieved. Moreover, pH is a critical factor. Based on industry experience, ACSCC does not occur below pH 7. Susceptibility exists in the pH 7.5 to 11 range; however, most failures have occurred in the pH range of 8 to 10. Likelihood increases with an increasing pH [5].

According to the Handbook of Corrosion Data (1995) and API 571 (2020) carbon steel is resistant to thinning corrosion in this type of fluid.

For pipes, the design material is stainless steel and according to the Handbook of Corrosion Data (1995), this material is

O PAPEL vol. 82, N.º 10, pp. 64 - 67 - OCT 2021

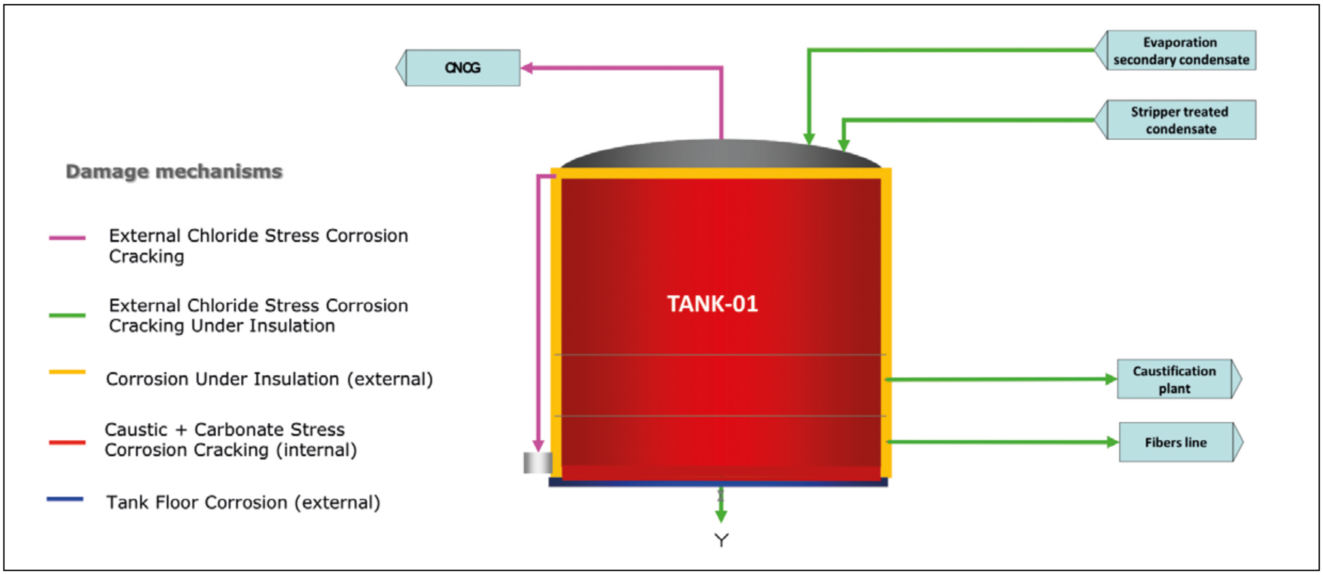

Figure 2. Damage mechanisms of the condensate tank system

resistant to both corrosion under tension and corrosion by loss of thickness in fluids of this characteristic.

Externally, four damage mechanisms are active:

- Corrosion Under Insulation in the tank shell course;
- Tank Floor Corrosion in the tank bottom;
- External Chloride Stress Corrosion Cracking Under Insulation in pipes with thermal isolation; and
- External Chloride Stress Corrosion Cracking in pipes without thermal isolation.

Figure 2 shows the internal and external damage mechanisms that can be active in each component.

RESULTS AND DISCUSSION

Based on the damage mechanisms of the system, component risks were determined considering the probability and the consequence of failure. Figure 3 presents the current risk of the system and Figure 4 the evolution of the risk considering the inspection planning dates.

Through an analysis of the risk matrix, it is possible to see that all system components are at a risk above the established limit and they had their inspection plan generated based on the risk. The high risk of pipes is because of external damage mechanisms, and for the tank the high risk was a combination of external and internal damage factors. The following is an inspection recommendation summary:

- *Stainless steel pipes without thermal isolation:* dye penetrant or eddy current test with ultrasound test follow-up of relevant indications;
- *Stainless steel pipes with thermal isolation:* external visual inspection prior to removal of isolation and dye penetrant or eddy current test with ultrasound test follow-up of relevant indications;

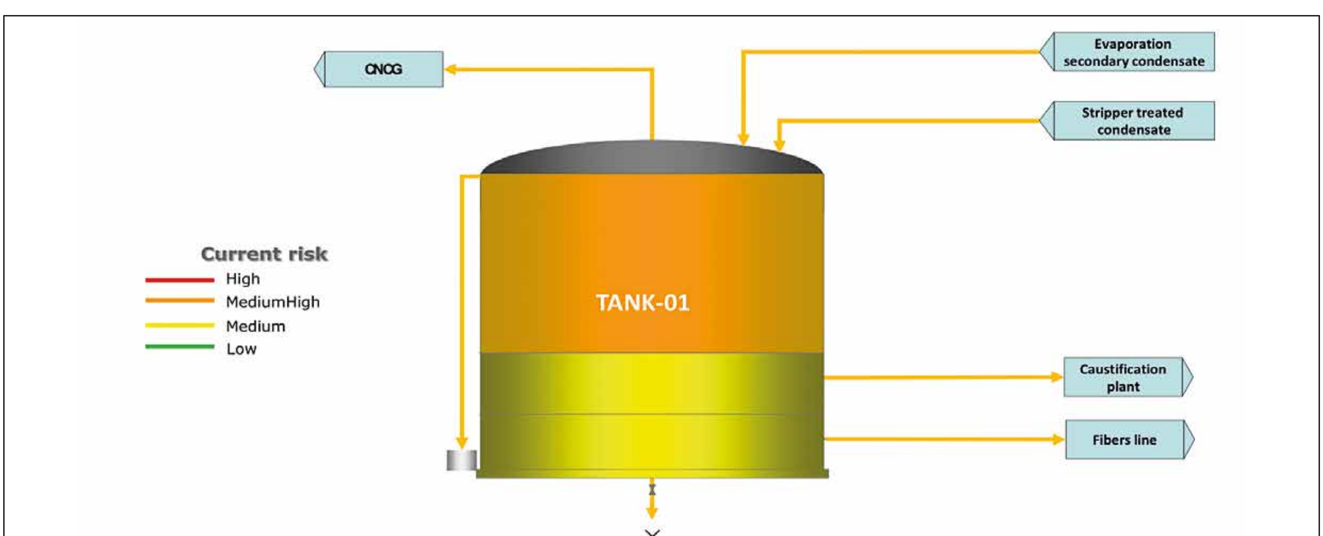

Figure 3. Current risk of the condensate tank system

O PAPEL vol. 82, N.o 10, pp. 64 - 67 - OCT 2021

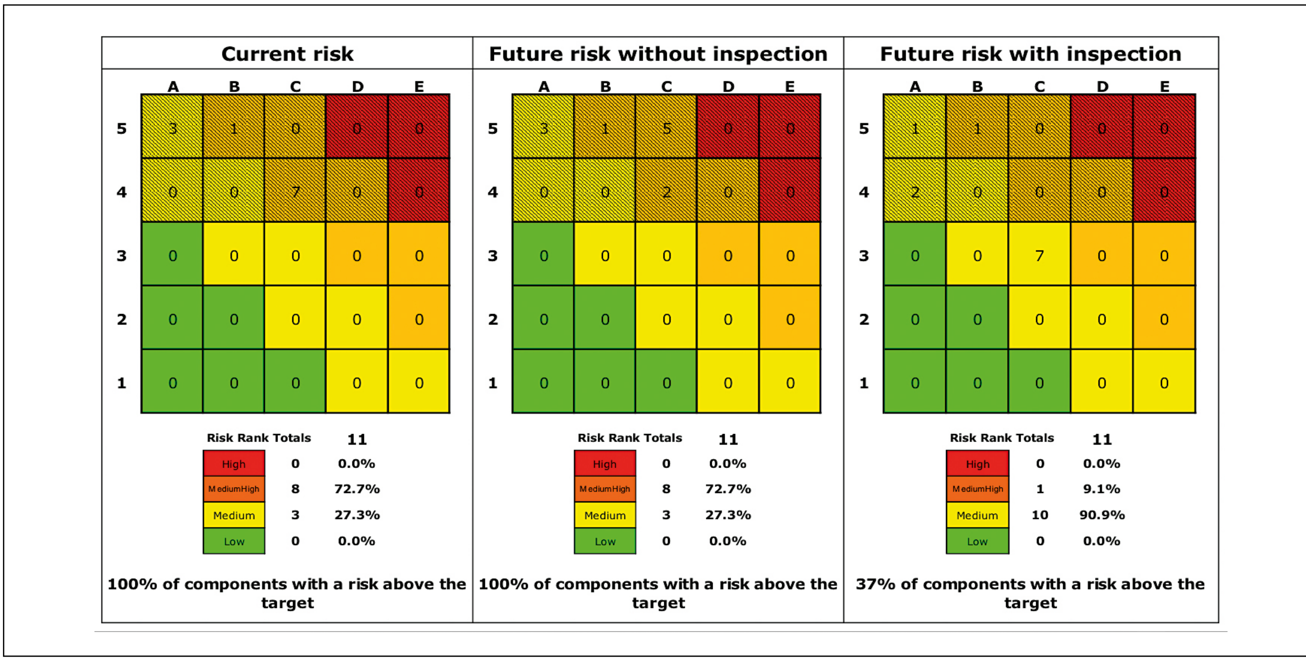

Figure 4. Current risk and future risk with and without inspection.

- *Shell course and the tank bottom (interna*l): ACFM or wet fluorescent magnetic testing with ultrasound test follow-up of relevant indications;
- *Shell course (external):* external visual inspection and removal of isolation; and
- *Tank bottom (externa*l): floor scan inspection.

The analysis shows that if no inspection action is performed on the components, the risk remains high. However, by carrying out an effective inspection, a reduction in the system risk is achieved, and this reduction can be even more significant after insertion of the inspection results and risk recalculation.

The RBI analysis also showed which non-destructive tests must be performed on each component of the system according to the active damage mechanism. Thus, in addition to focusing inspection efforts on the most critical components, the inspection technique that is effective for the evaluation of active damage to the component is defined. This analysis eliminates the use of unnecessary non-destructive testing and also ineffective inspections.

In addition to the gains discussed above, the inspection plan generated by the RBI satisfies requirements specified by Brazilian law NR-13 for metallic tanks and pipes. For pipes, by applying the RBI, it is possible to extend the inspection period by up to 100%. For the tank, the initial and subsequent inspection intervals can be determined according to the results of the RBI study.

CONCLUSIONS

The RBI analysis showed in details the active damage mechanisms for each component based on the current operating condition. In addition, a specific inspection plan was generated for each component of the system. In this way, it was possible to rationalize the inspection resources and eliminate unnecessary non-destructive tests. The matrix analysis also shows how risk evolution is expected and assists in decision-making based on risk management. Moreover, the RBI is a powerful tool for generating inspection plans to satisfy requirements of Brazilian law NR-13. ■

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