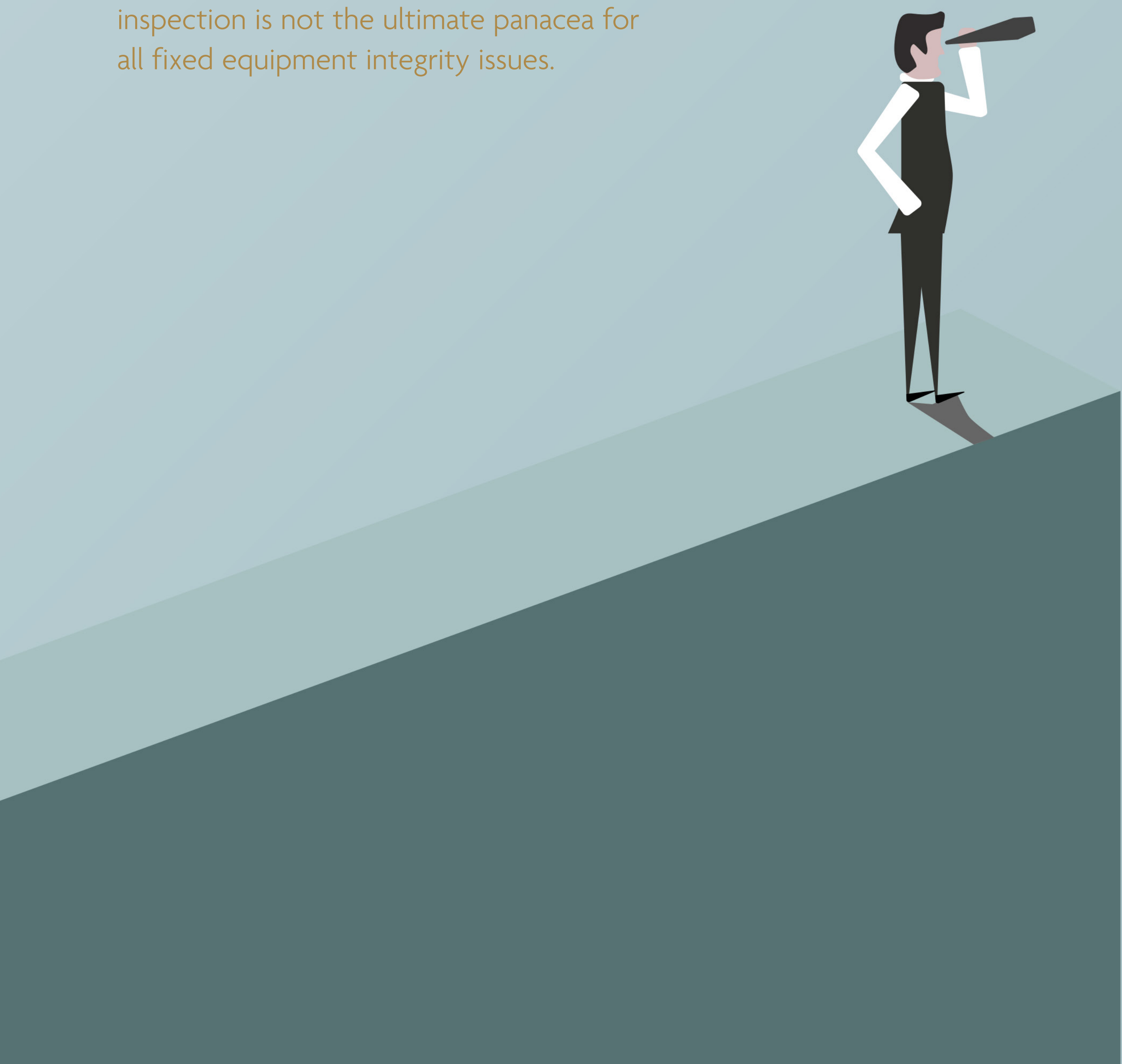
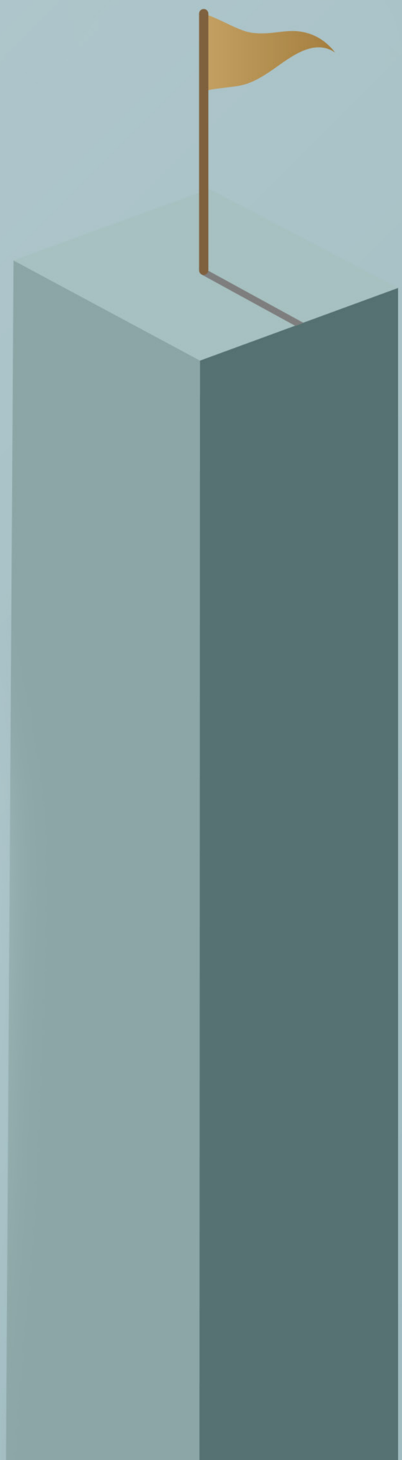
# RISK VS REWARD

**Cesar Espinoza and Ian Diggory, ROSEN Group, USA,** explain why risk-based inspection is not the ultimate panacea for all fixed equipment integrity issues.



Reprinted from Spring 2023 TANKS & TERMINALS



Although risk plays a pivotal role in any modern asset integrity management scheme (see ISO 5500), a risk-based inspection (RBI) scheme alone is not a panacea for all integrity issues in the fixed equipment (FE) universe. This article follows on from a previous piece that featured in the Summer 2022 issue of *Tanks & Terminals*, 'Risk-based inspection: misconceptions vs realised benefits', to highlight those occasions when it can be beneficial to supplement an RBI process by incorporating other asset integrity information.[1]

From manufacture, through service life, all the way to decommissioning, items of equipment are at constant risk of degradation and failure from a wide variety of threats. As Figure 1 illustrates, there are numerous standards and methodologies available from which to construct risk management schemes. Remember, these standards and methodologies are dynamic, continuously evolving and advancing as new technology appears and more data becomes available – or when we learn the hard way through incidents.

The oil and gas industry is under pressure from many quarters, not least due to public scepticism over new pipelines and the focus on the energy transition to combat climate change, which has resulted in a switch of energy investments to renewables. The challenge for the industry will be to keep what are increasingly ageing assets – many beyond their design life – operating safely and economically at a time when investment funding is far less readily available.

These statements reinforce the message that maintaining an effective integrity management (IM) programme is an ongoing challenge. Operators need to fully understand the current condition of their assets in the context of their IM scheme. Failure to do so could result in excessive RBI expenditures or, more seriously, give a false sense that a facility is safe and compliant.

## What to expect from an RBI

RBI is a central piece of the asset risk management jigsaw. It is a logical and structured process for planning and evaluating equipment inspection activities. The principal outcome of an effective RBI scheme is an optimised inspection plan for each item of equipment being evaluated. In addition to detailing the level of equipment risk, these plans include descriptions of the type, scope, and recommended frequency of inspection.

Ranking of equipment according to risk level allows operators to prioritise their inspection schedule and optimise their inspection, maintenance and replacement (IMR) budgets. For risks considered unacceptable, the plan should contain recommendations on mitigation actions that will reduce the risk to acceptable levels or, alternatively, a repair/replacement recommendation.

## Can RBI and fitness-for-service be leveraged together?

Pressurised equipment is constructed to design codes, usually with built-in safety factors, such as ASME BPVC Section VIII Div. 1, or to alternative rules, such as ASME Section VIII Div. 2. Equipment is designed to operate safely and reliably over its design life within a defined envelope of temperatures, pressures, flows, corrosion rates, fatigue cycles, etc. Once the equipment is commissioned and becomes operational, it is subject to the types of standards and codes shown in Figure 1. Based on risk assessments, these standards are intended to provide guidance for decision-making on inspections, repairs and replacements during service life.

RBI provides a structured framework to detect and characterise anomalies in equipment, but once the equipment condition reaches a certain threshold, there comes a point where the continued performance of inspections adds little to no value from a risk management perspective. In those instances, the right course of action is to remove that item from the RBI scope and treat it on a special-regime basis until its condition is properly evaluated by a fitness-for-service (FFS) analysis or possibly mitigated by being rerated, repaired or replaced, for example.

A FFS analysis may be performed to determine whether the equipment can continue to be safely operated and, if so, under what conditions and for what length of time. Such an analysis can also be performed to determine critical anomaly sizes that, if found in future inspections, would require equipment repair or replacement.

The example in Figure 2 illustrates a case where a pressure vessel had been inspected as part of an RBI programme. The inspections were considered highly effective because they systematically targeted the detection and measurement of identified and expected damage mechanisms. The results of the inspection indicated the presence of locally thinned areas exceeding the minimum wall thickness design threshold. An FFS Level 2 was performed, resulting in criteria that allowed the operator to continue operating the vessel. Since the damaged areas were confined to a few discrete locations, those condition monitoring locations (CML) were placed on a special regime for close monitoring, rather than applying the increased inspection frequency to the entire vessel. In other words, it is possible to know where the greatest risks are, and to focus inspection efforts on those critical locations.

Continuing the example in Figure 2, a more detailed integrity assessment was performed. Since the damage mechanisms and their rates were well understood ($CO_2$ corrosion – localised thinning), an API-579-1 Part 5 FFS assessment was performed iteratively until the Level 2 assessment failed. At that point, the design minimum wall thickness was replaced by the Level 2 failure thickness (called T-Min) and applied to RBI calculations for the whole vessel. This process resulted in a more favourable risk scenario while maintaining vessel safety, compared to the previous scenario where the original design considerations were used to assess risk.

The concept of using an FFS-derived T-Min in the RBI analysis as the minimum acceptable thickness limit may be new to some but can be a powerful element in maintaining safe operations or in making an equipment remaining service life decision.

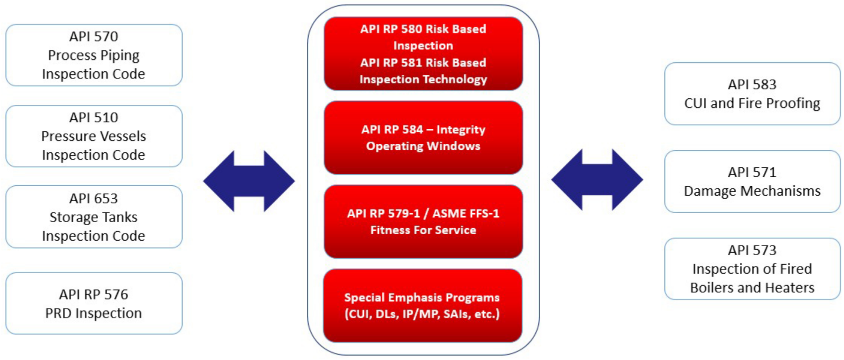



**Figure 1.** Suite of standards and methodologies for fixed equipment IM.

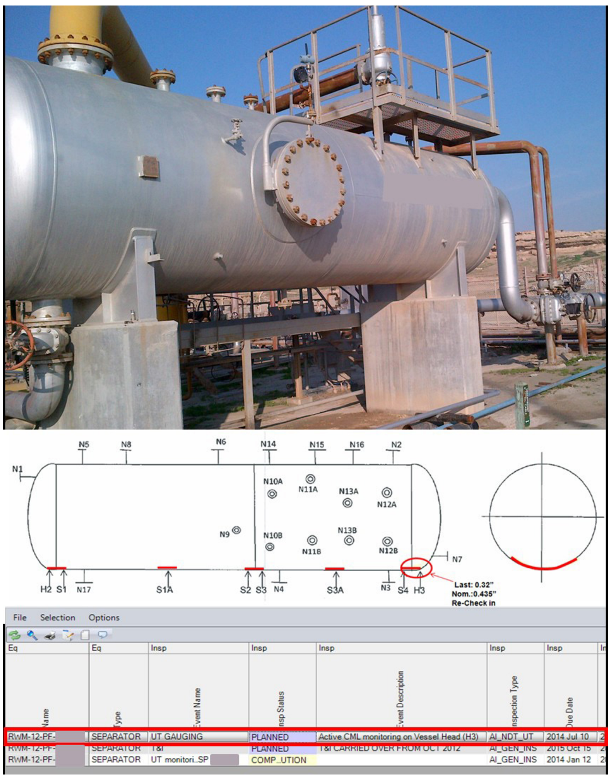



**Figure 2.** A pressure vessel with localised corrosion. The corroded areas were marked up externally. A special thickness monitoring regime was applied only to this location, while the rest of the equipment remained under the RBI scheme.

## When standard RBI methodologies need help

Even though there are different avenues to producing RBI plans, standard RBI methodologies like API-581 may not be entirely suited to supporting the risk management of certain equipment types and their associated damage mechanisms. Their RBI output needs an extra step or an accompanying methodology to achieve good results, as illustrated in the following three examples.

### Corrosion under insulation (CUI)

Affecting process plants around the world, CUI is one of the most widespread damage mechanisms. The main problem with CUI management lies in the way inspections are executed rather than in the way the risk associated with this damage mechanism is determined. Insulation removal and replacement for inspection has proven problematic and costly. Replacement of insulation is often detrimental to future integrity because it introduces potential deficiencies into the original insulation, thereby creating future CUI susceptibility. Developing an effective CUI inspection plan is unlikely to be achieved without a supplementary strategy.

CUI is caused by the condensation or penetration of water through the outer jacketing and insulation on to the metal surface. Corrosion may occur wherever water accumulates and contacts unprotected steel in the presence of oxygen from the air. As shown in Figure 3, external coatings provide the primary barriers to CUI, preventing water from reaching and then remaining on the metal surface.

An effective CUI inspection strategy consists of a number of elements:

- External visual inspection:
  - Inspection conducted to identify susceptible locations that are potentially vulnerable to CUI damage aimed at establishing the condition of the insulation jacketing and developing an inventory of damaged and susceptible locations.
  - Results from the external visual inspection are used to prioritise damaged and susceptible areas for follow-up inspection. Table 1 provides typical findings that will classify as susceptible locations for further CUI inspection.
- Moisture detection: infrared thermography (IR) aids in locating cooler areas where water could be condensing and accumulating. IR should be used as a supplement to visual inspection.
- Detection/screening: examination of susceptible locations that were found wet or with insulation/jacketing damage to locate CUI damage or confirm that none exists. NDE techniques that do not require insulation removal are available, including real-time tangential radiography (RT-TRT) and guided wave testing (GWT).
- Sizing: inspection to obtain quantitative information at locations identified as having CUI damage. This is the only stage of the process where insulation removal is required.

**Table 1.** **Susceptible locations for CUI damage**

| | |
|---|---|
| Bulging areas | Missing caulking on insulation jacketing |
| Rust stains | Jacketing seams on top of horizontal piping |
| Wet jacketing or insulation | Inspection ports without covers or plugs |
| Areas exposed to steam tracing leaks | Damage due to foot traffic or vibration |
| Jacketing with mould or organic growth | Areas where water travelling from another damage area could gather or be trapped, especially at low points |
| Missing bands or jacketing | |

This strategy eliminates the potentially damaging legacy practice of removing good insulation to detect CUI damage to verify the condition of the primary coating barrier. It also reduces the not inconsiderable risk of introducing defects during field-applied reinstatement of insulation.

## Deadleg management

Deadlegs are components of a piping system that experience intermittent or insignificant flow. Deadleg management has been a historical challenge, mainly due to the large number of deadlegs that can be present in a facility. They may also be neglected due to their small size with respect to the main pipe or vessel they are attached to or because they are part of an auxiliary system. However, incorporating all deadlegs into the RBI process as individual corrosion circuits will typically cause duplication or excessive granularity in the RBI outputs, which may become unmanageable from a logistics perspective.

In the authors' experience, successful integrity management schemes for deadlegs have considered the implementation of robust deadleg management programmes that incorporate a risk assessment (see Figure 4). These programmes maintain a comprehensive register of all deadlegs to ensure they are individually accounted for in the inspection planning process and corrosion management programme. The deadleg register records the location of deadlegs along with their orientation and type (e.g., operational, permanent or temporary) and is used to facilitate the planning and execution of deadleg inspections.

Determination of deadlegs' susceptibility to damage mechanisms is based on selected criteria. For example, do deadlegs of a 'certain type' exhibit a different risk, susceptibility, or threat change when compared to the main flow pipe? The 'certain type' could be in relation to orientation (vertical with up/down flow or horizontal), definition (operational/ physical/permanent), or some other criteria.

The essential question to answer is: 'based on your criteria, does this deadleg experience a different level of susceptibility to risk from that of the main flow pipe or vessel to which it is connected.' If the answer is 'no,' then there is no need to inspect the deadleg separately from the main component. If the answer is 'yes,' then the deadleg requires its own inspection.

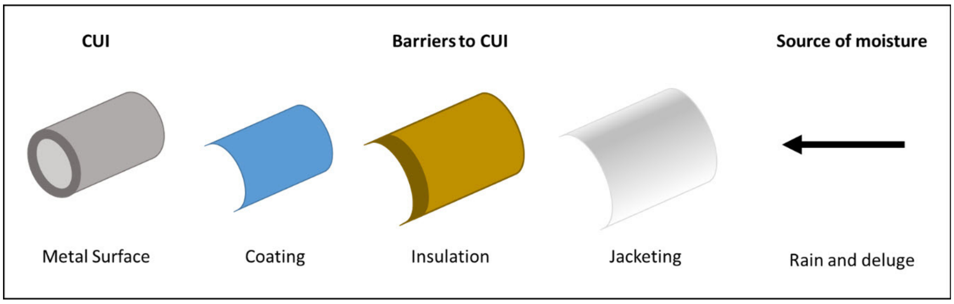



**Figure 3.** CUI protection layers.

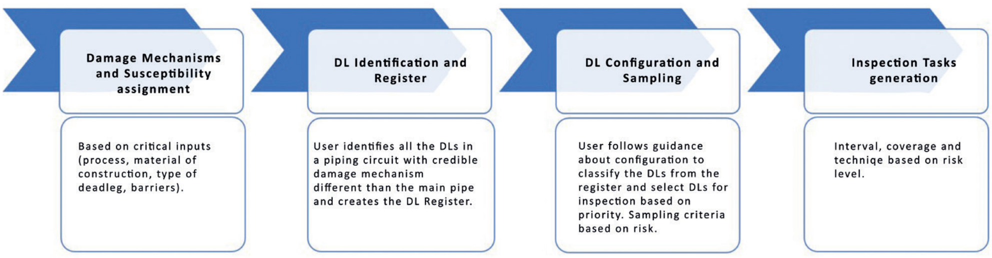



**Figure 4.** Deadleg integrity management process.

## Mechanical fatigue

Mechanical fatigue is a damage mechanism that can cause sudden and unexpected failures on piping, particularly small-bore piping and equipment subject to vibration or cyclic service. API-581 is clear in the application of its mechanical fatigue risk calculation methodology; however, it poses challenges to its users. Considering the significant amount of piping at a process plant, the effort required to gather the required information to perform the risk calculations is impractical in many cases.

A more realistic and practical approach is to screen piping components for potential mechanical fatigue by answering the following questions:

- Have there been any previous failures due to fatigue?
- Are there any audible, visible or otherwise noticeable piping vibrations?
- Are there connections to reciprocating machinery or any equipment that can cause excessive vibration (compressors, let-down or mixing valves, relief valves, etc.)?

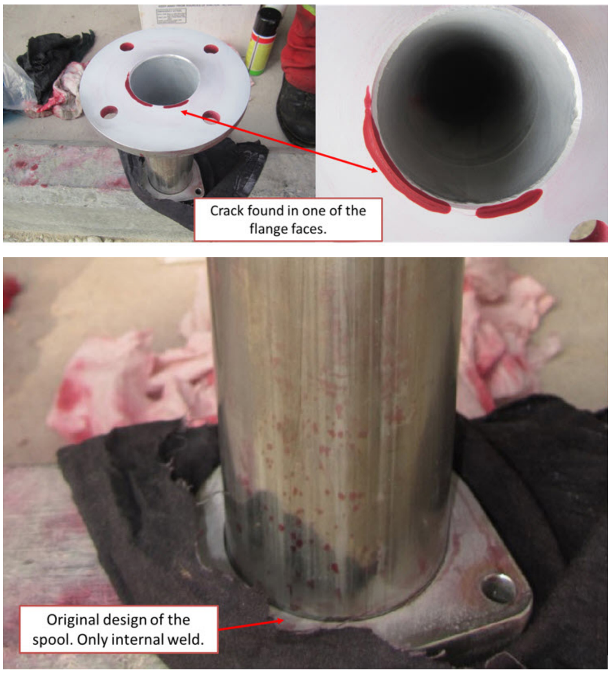



**Figure 5.** Cracked spool showing internal weld only.

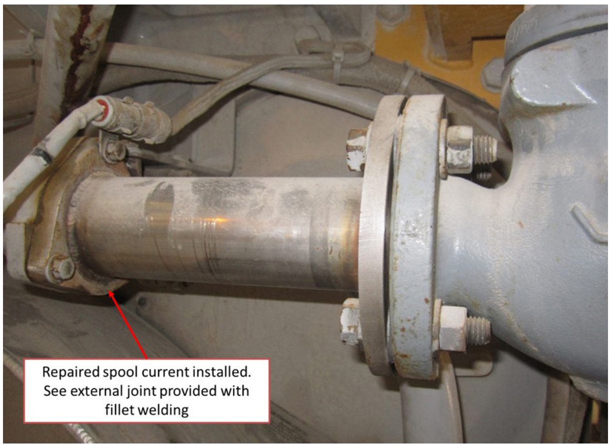



**Figure 6.** Repaired spool with external fillet welded joint.

If the answer to any of these three questions is 'yes,' then a fatigue inspection should be performed on that component and the results documented.

Another consideration is that fatigue damage is only detectable by standard examination methods once a failure is imminent (cracking). A more proactive approach would be to remove from service a piping component identified as being in potentially the most severe location and perform destructive testing to determine any early signs of fatigue. Depending on the results of that examination, similar components may be considered for assessment.

The case illustrated in Figure 5 shows a spool that was proactively removed for examination following the aforementioned approach. The examination showed cracks around the circumferential weld between the spool and its flange, with the potential for an imminent flammable gas leak. Mechanical fatigue had been excluded from the damage mechanisms under the scope of the RBI implementation in this facility due to the lack of relevant and representative data to perform the likelihood-of-failure calculation. However, it was evident that a standard RBI assessment would have neither identified nor flagged this condition.

Root cause analysis identified that the spool failure was due to a design flaw. The original design only had an internal weld of the flange-spool joint. This joint design is prone to fatigue cracking if the component is exposed to load cycling. The solution was to externally fillet weld the spool to the flange (see Figure 6).

Being a multistage compression station with identical trains in series and parallel, the proactive inspection was extended to cover all similar components across the station. Cracks were found in five additional spools. A design review was performed and double-welded joints were implemented in all spools in similar operating conditions across the station.

## Conclusion

The development and implementation of RBI methodologies has contributed significantly to advances in asset integrity management over the past three decades. These RBI schemes have helped numerous operators around the world to better understand the risks associated with their assets and to generate optimised inspection plans that positively influence their budgeting and expenditure planning.

However, RBI does have its limitations; and operators need to be aware of the boundaries of its applicability within the context of their overall asset integrity management scheme. Nevertheless, it is often possible to extend some of these boundaries by leveraging other aspects of integrity management, such as FFS analysis or proactive inspection strategies.

Rather than being the ultimate solution to all the integrity management challenges, the RBI process should be seen as just one element of a suite of integrity management methodologies working in unison to address and manage the many challenges associated with maintaining the reliable operation of their assets.

## Reference

1. ESPINOZA, C., and ELSDON, R., 'Risk-based inspection: misconceptions vs realised benefits', *Tanks & Terminals*, (Summer 2022), pp. 20 - 23.