# Ready to operate

From integrity assessment to repairs, a lot goes into getting an oil and gas terminal facility back in operation. **Rei Wizwan Abdullah Nawawi and Sherman Anthony Nunis, ROSEN Malaysia, explain.**

Oil and gas terminals often change hands. During such changeovers, information and knowledge about the individual assets in a facility can get lost. This is the case even more so with ageing infrastructure or terminals that have not been in operation for a long period of time, where the information that is available is also outdated. This article will outline an example of one such case at an oil terminal which required an all-encompassing integrity assessment and extensive refurbishment before it could go back into operation after many years. Initially, the scope included the inspection of two tanks and a 450 m, 8 in. loading line. However, as the project progressed, ROSEN delivered more than just inspection work and integrity assessments.

## Step-by-step towards operation

After conducting a full site visit and assessing the state of the facility, ROSEN proposed a comprehensive integrity campaign, which included tank inspection, shell corrosion scanning, piping inspection, 3D laser scanning for dimensional assessment, as-built drawing, and tank and piping calibration.

Based on the assessments, the company was able to provide repair recommendations and was then appointed to lead the project management consultancy to conduct the necessary refurbishments of the facility. The scope of this refurbishment would include not only the provision of a project management team but also the coordination and completion of repairs to ensure that the facility would go back into operation. This included repair work on both tanks and piping inside the facility fence.

## Tackling the tanks

In order to ensure the structural integrity of the two tanks, the ROSEN Group performed a series of inspections, including an out-of-roundness survey, scanning and floor mapping of bottom

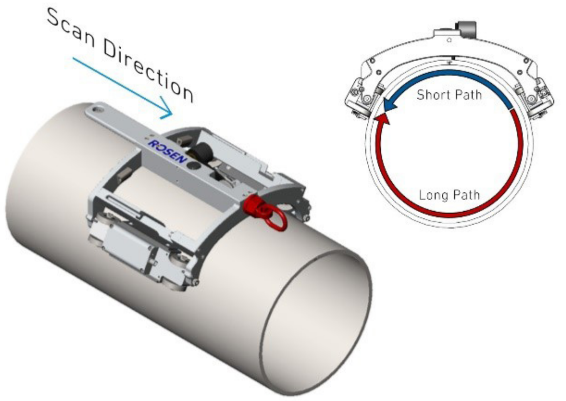


**Figure 1.** CIRC is suitable for the inspection of the entire pipe body, including its supports and hangers.

**Table 1.** Acceptable radius tolerances by tank dia. according to API 653, Section 10.5, Table 10.2

| Tank dia. (ft) | Radius tolerances (in.) |
|---|---|
| < 40 | +/- 0.5 |
| 40 to < 150 | +/- 0.75 |
| 150 to < 250 | +/- 1 |
| ≥ 250 | +/- 1.25 |

plates, and a shell corrosion screening. The two tanks were 870 $m^3$ and 2070 $m^3$, respectively, and were intended to store oil when back in operation.

To begin, a qualified surveyor conducted the out-of-roundness survey from the bottom of the shell to the top. As the name describes, this survey indicates the roundness of the tank based on the outside diameter. The collected data from this survey is used for comparison to allowable values. Out-of-roundness, among other things, is a threat that addresses the proper functionality of the floating roof of the tank. According to API 653, defined radius tolerances are permitted (as seen in Table 1). If the tolerances are greater, remedial action is required.

The most common damage mechanism that affects storage tanks is corrosion. Typically, features include pitting corrosion and general corrosion. The potential for corrosion is due to the fact that most storage tanks are built from carbon steel, which is prone to reacting with oxygen in its environment, thereby forming iron oxide – oxidisation, commonly known as corrosion. The tank bottom, for example, is prone to soil-side pitting and general corrosion, which can be caused due to a bad foundation, such as corrosive soil, inadequate drainage, pebbles, etc. Atmospheric corrosion, on the other hand, can be found on the tank shell, roof and appurtenances.

Mechanical fatigue is another leading cause for damage in storage tanks. Over the course of years, the tank foundation might suffer from washed-out areas or improper design (under-designed), often due to a lack of knowledge at the time of construction. When the foundation is not strong enough, it results in even or uneven settlement. Uneven settlement, in particular, presents a danger to the tank integrity because the steel plates (on the bottom and/or the shell) are then exposed to stresses beyond what they were designed to handle. This can lead to a loss of containment or, in the worst-case scenario, a total failure of the tank.

Therefore, scanning and floor mapping of the bottom plates was carried out to determine any corrosion pitting, primarily on the underside of the tank floor where visual inspection is not possible. It also encompassed a survey of the top surface, hereby providing a 100% floor thickness survey. Before starting the scan, the surface condition of the tank bottom must be assessed for its suitability to scanning; this ensured that any cleaning work required could be done prior to the scan so that only high-quality data would be collected. The scanning method then utilised a high-resolution magnetic flux leakage (MFL) floor scanner and digital floor mapping with c-scan, which covered the critical zone to once again ensure 100% inspection coverage. When combining these two techniques, both top surface pitting and underfloor corrosion can be identified, measured and recorded, along with the location. Once the data was collected and assessed, any necessary repair recommendations could be made.

Due to the age of the tank, insufficient historical information on its operations, and the fact that it had been idle for a period of time, scattered internal corrosion at the shell plates was very likely to be present. A preliminary visual inspection confirmed this as a fact. Isolated corrosion on large surfaces such as tank shells can be very hard and extremely time-consuming to identify. Therefore, as a third survey, an automated crawler system equipped with electro-magnetic transducer (EMAT) technology scanned the entire wall area.

The shell and vessel scanner is based on an ultrasound (UT) signal generated by EMAT sensors. These sensors have the ability to scan an object using UT without requiring a liquid couplant. Sensors are integrated in a remotely operated vehicle (ROV) that climbs along the wall using strong magnetic wheels. The entire inspection can be controlled from the ground level, keeping operators safe and saving significant scaffolding costs. Online data analysis and feature identification allow for real-time monitoring and recording. After the inspection, the large amounts of data are stored and processed, and the results are summarised in a clear and informative report. Data visualsation provides an overview of defect positions and severity, enabling the operator to take action.

## A look at the loading line

The majority of piping within facilities is constructed above ground to accommodate the fast paced, multiple product movements and frequent pipe reconfigurations that occur in routine facility operation. To mitigate corrosion potential and meet design constraints, much of this piping is elevated above the surrounding grade using various types of supports. However, inherent in aboveground piping structures are multiple contact points between piping and the associated supports. These points of contact throughout terminal piping systems are well known to be the most susceptible to a wide range of damage mechanisms, including corrosion.

Based on the piping inspector's visual assessment, the loading line was found to have extensive external corrosion. The internal condition of the pipe was still unknown. Hence, a selected combination of ROSEN's EMAT in-field service

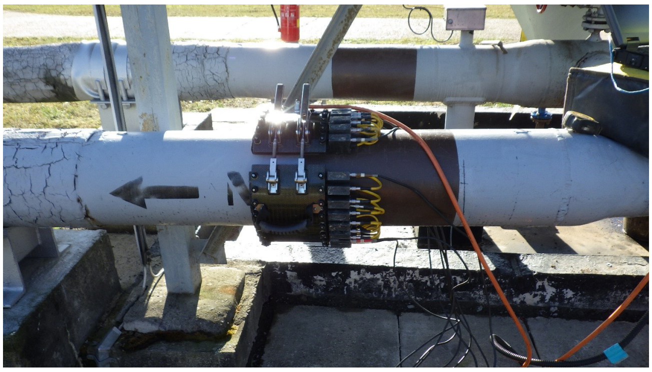

**Figure 2.** The LRUT collar with multi-mode modules and transducers emits soundwaves that move tens of metres in both directions.

equipment was proposed to address the short piping and piping supports. In addition, a long-range ultrasound (LRUT) was introduced for the longer lengths of the pipe. This ensured 100% coverage, internally and externally.

In-field service equipment (IFSE) is a set of manually operated devices ideal for inspecting aboveground piping from the outside while still gaining the integrity data of the interior and exterior of the pipe wall. It is also used to inspect piping at supports where localised corrosion can occur on the exterior of the pipe underneath coating or paint, causing the location to slightly bulge. The equipment has two different setups: circumferentially orientated (CIRC) and axially orientated (AXUS). It uses EMAT technology, which induces a soundwave into the pipe wall. The technology provides many different wave modes to inspect a structure, each with unique characteristics and their own specific application for optimal feature detection. The circumferential inspection is performed rather quickly as the CIRC tool travels along the entire length of the pipe, sending the EMAT signal through the entire circumference of the line. The tool provides an axial profile of the corrosion, allowing for integrity status on both pipe body and possible corrosion under external pipe supports.

To complement the IFSE inspection, an LRUT inspection was conducted for the longer sections of the pipe. This technology propagates a low-frequency, guided ultrasonic bulk wave transmission into the pipe from a transducer array affixed to the pipe; the technology operates just above audible frequencies. These low frequencies are necessary to enable an appropriate wave mode to travel the surface of the pipe.

## The findings

The comprehensive inspections of the tanks and piping rendered the data needed to make repair recommendations. These included the replacement of a tank roof, external coating of tanks and rafter replacement work. The refurbishment recommended for piping within the facility included the replacement of certain sections of the pipe modifications to prolong the service life of the pipe. The data allowed the operator to make educated decisions on how to move forward in getting the facility into operation safely and efficiently.