

SPECIALIST PACKAGE

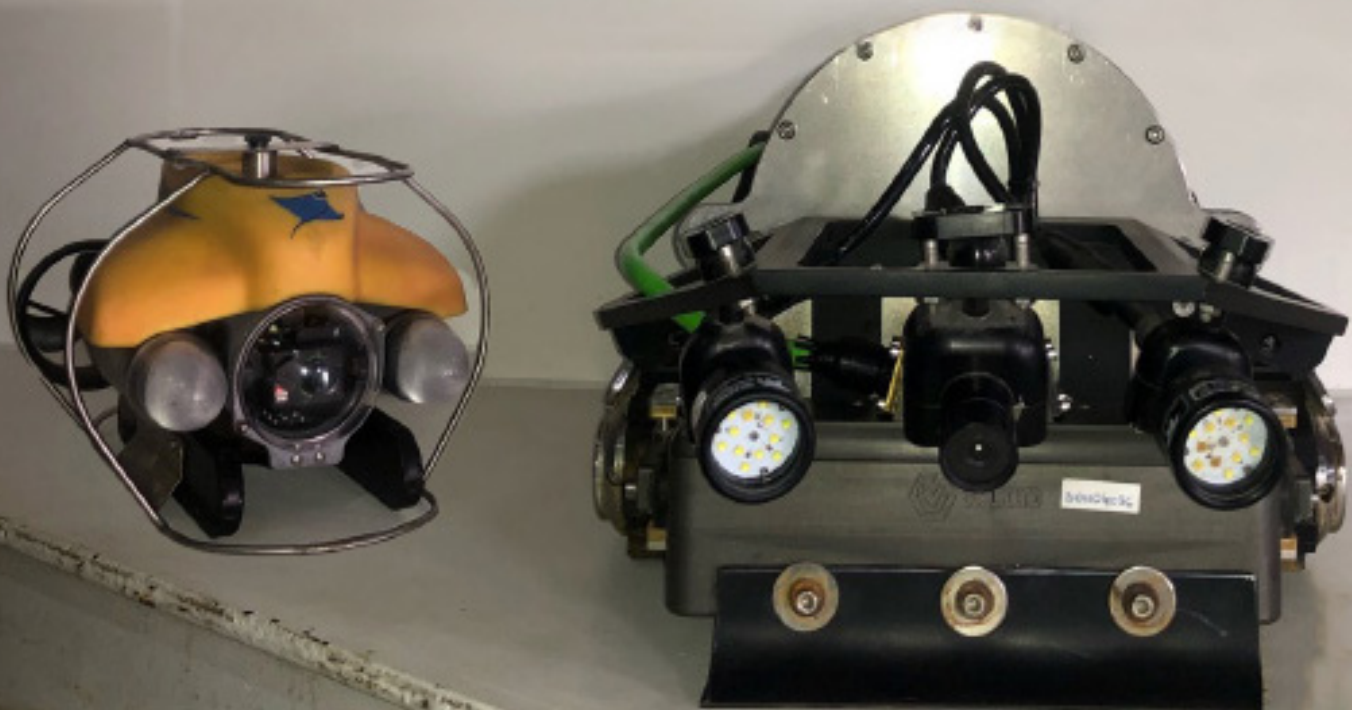
STORAGE TANKS

THE PURPOSE

This document is composed to assist our clients and the supply chain with a high-level understanding of the technical capabilities, benefits and services associated with Storage Tanks.



SONOMATIC



STORAGE TANKS

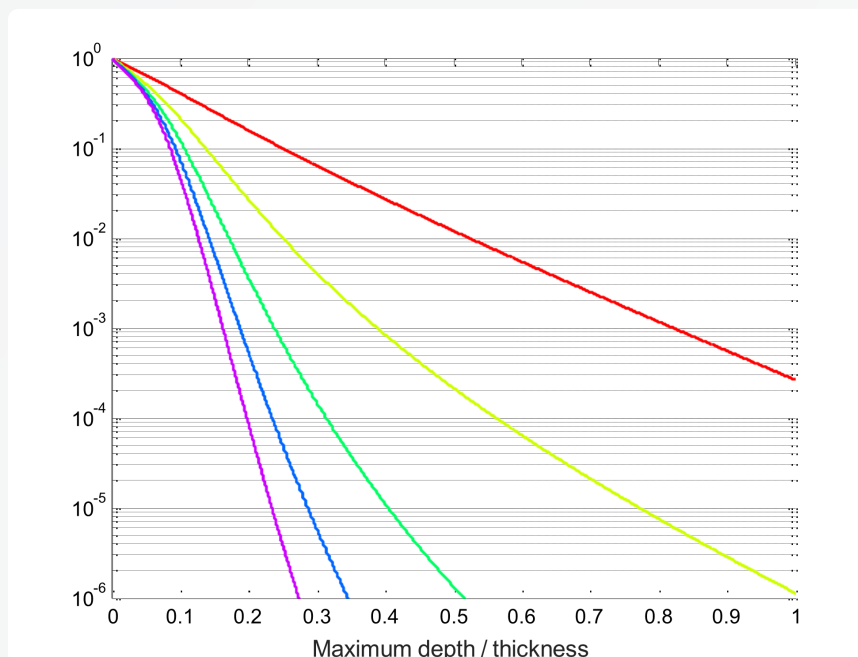
INSPECTION PLANNING

Sonomatic works with clients to plan inspections of atmospheric storage tanks, considering both operational and integrity requirements.

Integrity: An approach similar to planning for pressure vessel NII is adopted. This entails developing a detailed understanding of the degradation threats and associated risks to define the most appropriate inspection strategy, e.g. Type A or Type B NII. Detailed inspection requirements, i.e. probability of detection, accuracy and coverage are then defined for each zone of the tank. Finally, inspection plans, defining the inspection technique(s), coverage and locations for inspection are developed.

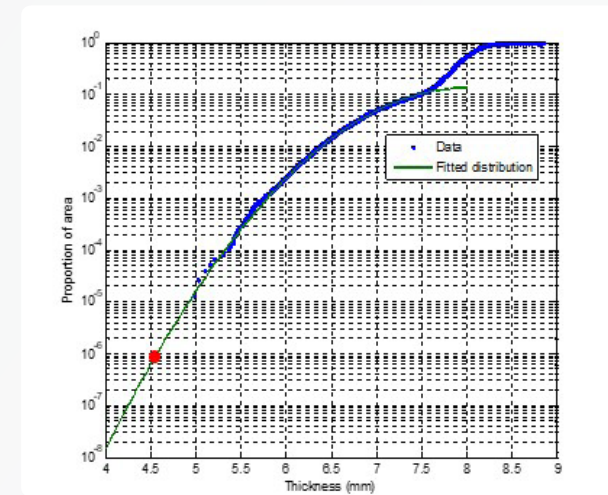
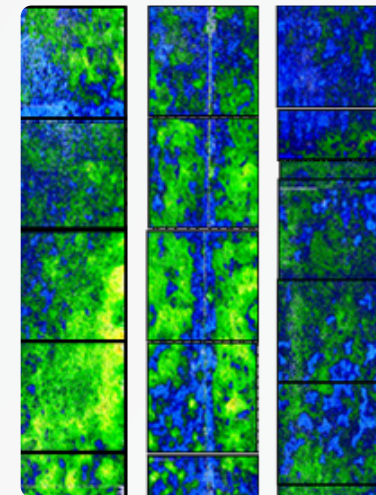
Operational: Successful in-service inspection of tanks relies on comprehensive planning of all operational aspects. This relies on working closely with the tank owner/operator to establish critical design, operational and safety data relevant to carrying out the inspection. With this information Sonomatic develops a detailed project plan. This covers logistics, equipment and manpower requirements as well as site requirements to facilitate the inspection.

Example results of Bayesian analysis for planning of coverage for Type A inspections.



PROCESS WHEN THERE IS EVIDENCE OF DEGRADATION

Sonomatic have considerable experience in the parallel field of Non-Intrusive Inspection (NII) for pressure vessels. Our engineering services team have completed assessments and evaluation on over 1000 pressure vessels of various designs and functions. Sonomatic's technicians are experienced in using a wide variety of inspection techniques on various assets in a multitude of environments. The development engineering department of Sonomatic are capable of adapting existing scanners to various configurations or designing bespoke solutions when required. Sonomatic are also capable of providing fitness for service guidelines for tanks based on the design parameters.



Statistical analysis to make estimates for minimum of complete area and to provide a basis for Fitness for Service assessment if needed.

Justification for continued operation or identification of further inspection requirements and possible repair.

Sonomatic provides full API653 and EEMUA 159 services.

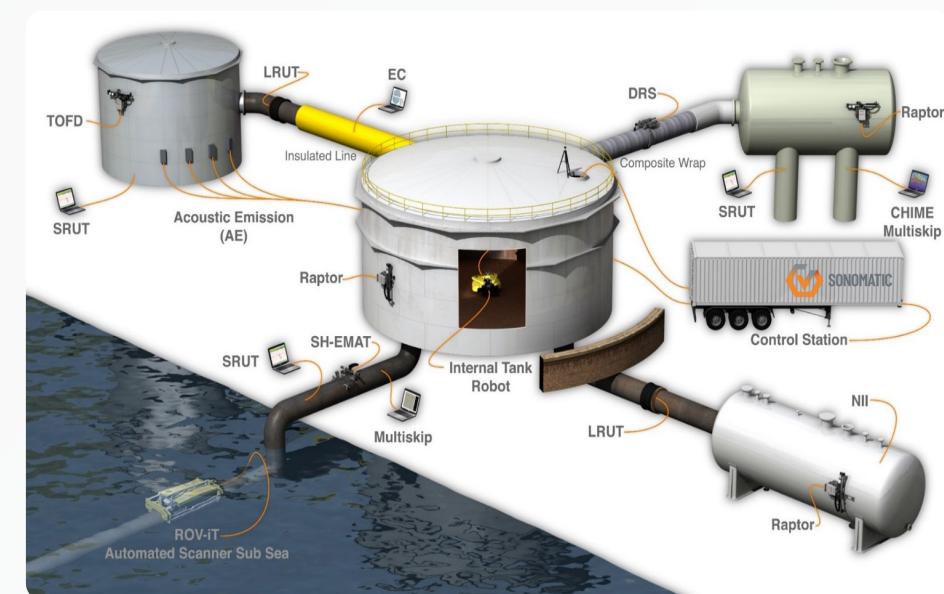
SCREENING FOR TANK FLOOR CORROSION

Sonomatic's inspection approach provides 100% coverage of the tank floor by means of acoustic emission (AE) testing performed prior to inservice ultrasonic inspection. The approach is aligned to the inspection strategy.

In addition a Short Range Ultrasonic Inspection (SRUT) is carried out on the external area of annular plate around the full circumference of the storage tank. Combining the results of these inspection technologies allows the following robotic inservice tank floor inspection to be focussed in specific areas of interest highlighted by the AE and SRUT inspections. The approach is aligned to the inspection strategy.

For tanks where a Type A strategy applies, the acoustic emission is used as confirmation that corrosion is not active. If evidence of corrosion activity is found at this stage then the strategy is revised.

For tanks where a Type B strategy applies, the acoustic emission is used to identify areas of corrosion activity for prioritisation of coverage for the ultrasonic inspection. This ensures that the sample inspection includes representative areas of corrosion.



INSPECTION TECHNIQUES

ON-LINE INSPECTION OF ATMOSPHERIC STORAGE TANKS

Storage tanks typically contain large volumes of valuable but potentially hazardous fluids. Inspection is a key element of integrity management of storage tanks. The objective of inspection is to provide information on the tank condition. Opening storage tanks for internal inspection is a lengthy and difficult process. Not only will the tank be unavailable during internal inspection, but it must be drained and cleaned before entry is possible. There are also safety hazards associated with personnel entry for inspection. As such On-Line Inspection (OLI) methods offer an attractive alternative as they can be conducted whilst the tank is in-service and do not require vessel entry.

CRITICAL ZONE WELD & LOWER SHELL PLATE INSPECTION

The shell to floor joint of an atmospheric storage tank is defined as the 'Critical Zone' in API 579:2016. It is exposed to complex stress loading, and the assessment of weld integrity together with any external, internal or under-floor corrosion is a vital part of any inspection regime.

Loading of the internal fillet weld combined with corrosion that may co-exist with fabrication flaws could potentially lead to catastrophic failure. Edge settlement of the tank floor can lead to sediments and water drop-out collecting in the critical zone. These factors in combination with proximity of the critical zone to environmental factors lead to an increased likelihood of degradation.

Sonomatic have successfully completed field trials following the development of a technique to evaluate the integrity of the critical zone. The development work in the laboratory involved samples with simulated underfloor and top surface corrosion. Three site visits were made on two storage tanks to evaluate original critical zone and repair welds.

The technique is non-intrusive, and involves scanning phased array probes from the tank wall. The tank wall generally presents a better scan surface than other techniques that involve scanning from the external rim or 'chime'. It involves a single-axis scan with multiple PAUT probes. Data collection is rapid, and analysis is carried out offline. Special training is required as interpretation is complex. Sonomatic's data science specialists have developed models to aid data processing and interpretation.

TANK WALL / SHELL INSPECTION

Tank walls may be susceptible to corrosion and inspection is required to assess their condition. Sonomatic carries out corrosion mapping inspections of the tank walls using its Raptor II advanced ultrasonic scanners. Our approach is to carry out a defined coverage sampling inspection and to use the results to make estimates for the minimum thickness of the tank walls.

ANNULAR PLATE INSPECTION AND APPLICATIONS

The Short Range Guided Wave Ultrasonic Technique (SRGUT) was designed to test the annular plate of above ground storage tanks (AST's) while the tank remains in-service and for detecting corrosion under pipe supports. The technique is based on the concept of pulsing guided waves into the base material from the chime area. The waves propagate up to three feet into the annular plate. When corrosion, pitting, erosion are present the ultrasonic waves mode convert and are received by the same transducer. The technique is also being used to test for corrosion at soil air interfaces, and similar difficult to access locations.

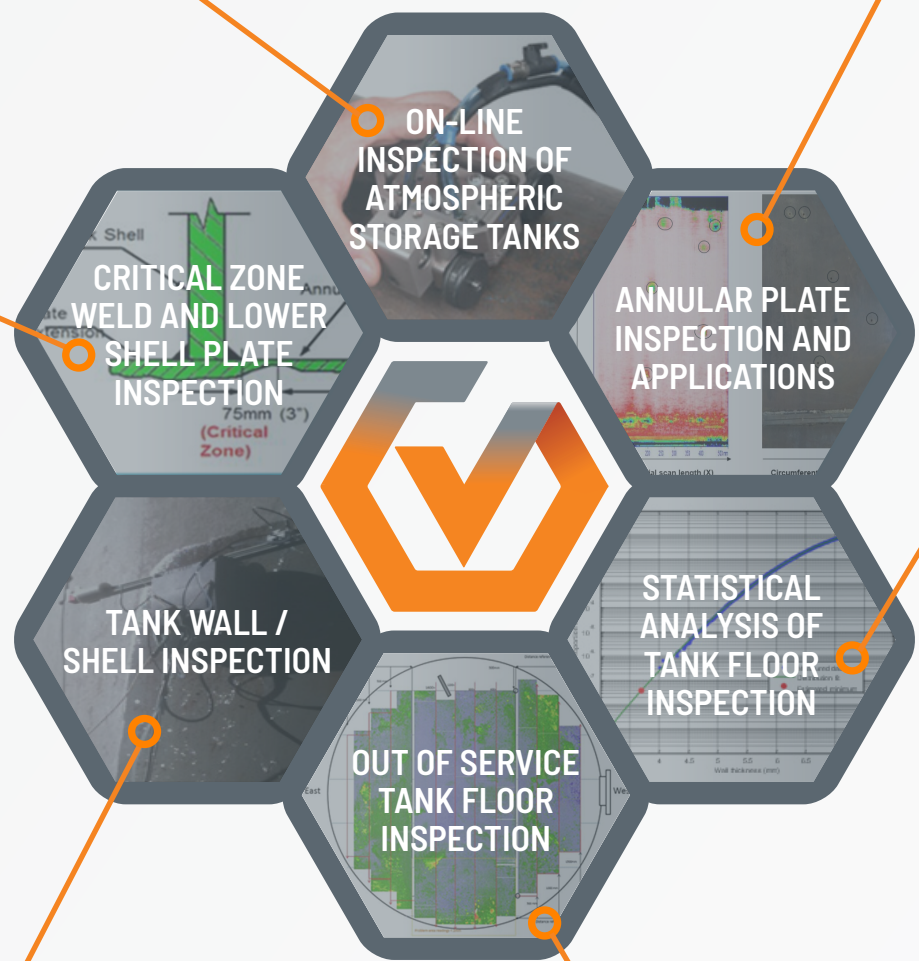
- Tank Floor Annular Plate Testing
- Tank Dyke Piping Interfaces
- Testing Concrete Coated Interfaces
- Scan Under Vessel Supports
- Testing Under Pipe Supports

STATISTICAL ANALYSIS OF TANK FLOOR INSPECTION

Corrosion has been found to show statistically regular behaviour in a wide range of situations including on tank floors. In these situations a sampling approach is applicable, in which the results from a limited coverage inspection can be used to estimate the condition in the areas not inspected. Sonomatic has considerable experience in the development and application of statistical methods for analysis of inspection data and was primary author of the Recommended Practice for Statistical Analysis of Inspection Data developed by the HOIS Joint Industry Project. The methods in this document are used as a basis for statistical analysis of tank floor inspection data. Sonomatic's process covers a automated a nalysis o f t he d ata u sing advanced signal processing algorithms to obtain wall thickness values, derivation of wall thickness distributions, identification of applicable statistical fit type and parameters and estimation of minimum wall thickness and probabilities for limiting conditions. The use of sample inspections supported by statistical analysis conforms to the requirements of API 653 for internal inspection of tank floors.

OUT OF SERVICE TANK FLOOR INSPECTION

Sonomatic undertake storage tank inspections using staff that are trained and competence examined to API 653 and EEMUA 159 standards. In instances where in service inspection using robotic scanners is not a consideration Sonomatic make use of the MFL equipment - Floormap3D which has a wider sensor head than previous models capable of scanning up to 1440 m2 per day, and unlike manual "stop on defect" systems, this is irrespective of the number of indications found. The software guided mapping process encourages the most efficient plate coverage, and helps ensure the maximum area is scanned reducing the chance of missed corrosion.



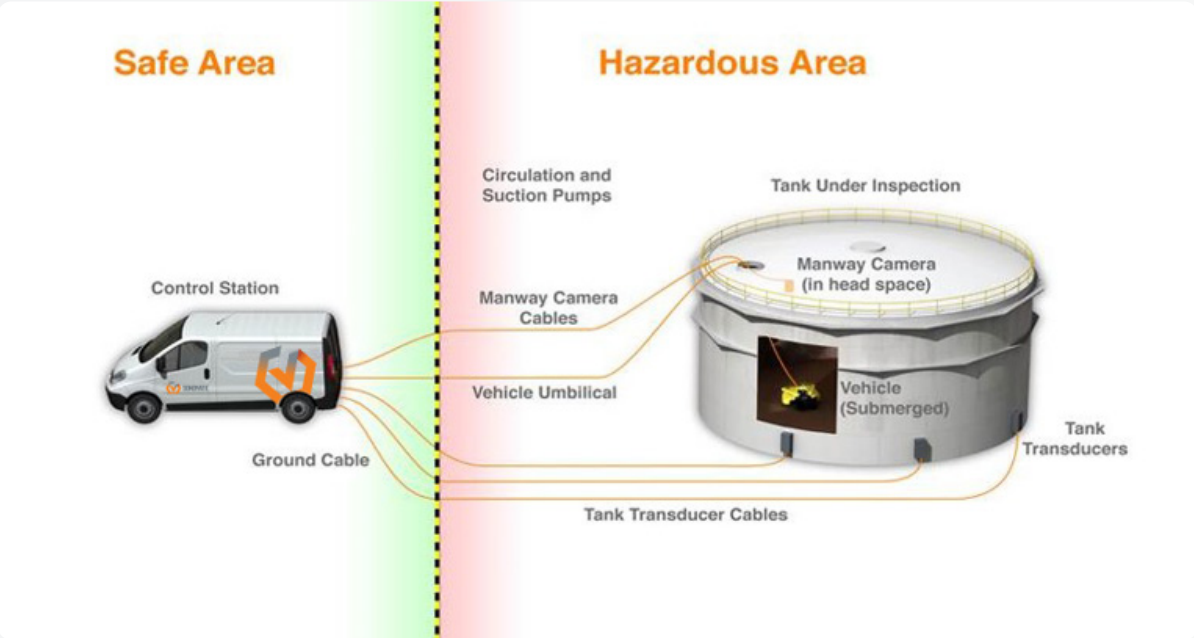
IN-SERVICE INSPECTION OF ATMOSPHERIC STORAGE TANK FLOORS

The floors of storage tanks can be susceptible to internal and/or external corrosion which may lead to failure with severe consequences. Safe management of tanks therefore relies on inspection of the floor at appropriate intervals. Historically this inspection has been carried out by tools and techniques that rely on internal entry following emptying and cleaning. This type of inspection relies on the tanks being taken out of service.

Sonomatic has developed and applies robotic technologies to deploy its world leading automated corrosion mapping to tank floors in-service. This approach gives a high degree of assurance of tank floor integrity while avoiding the need for costly shut downs and minimising the hazards associated with confined space entry.

Sonomatic's SONAR robotic tank floor capability is part of a comprehensive inspection offering in which we deliver a API 653 and EEMUA159 compliant inspection with the tank remaining in operation throughout the inspection activities.

Note: (Isolation of tank is only required during deployment and retrieval of the robot).



In-service inspection provides significant benefits to tank operators. Sonomatic apply AE and SRUT technology in an intelligent manner through screening for active corrosion and directing the quantitative UT SONAR system to the areas of concern. In-service inspection is a cost effective alternative to out of service inspection for situations where the likelihood of degradation requiring repair has been assessed as low.

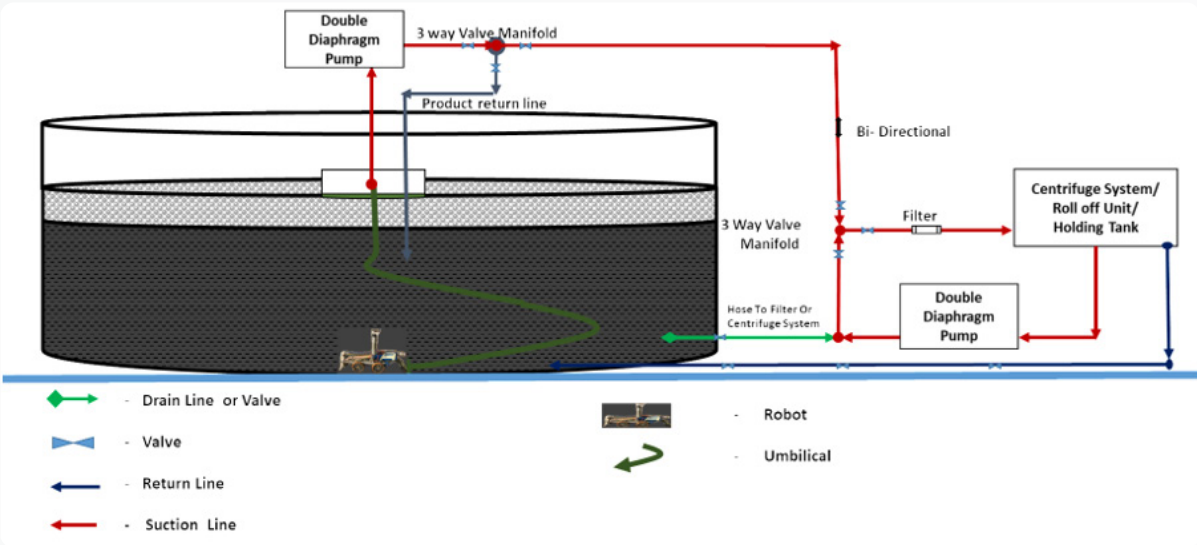
In-service inspection provides significant benefits to tank operators:

- ✧ Removes the need for shut downs
- ✧ No reduction in critical storage capacity
- ✧ Minimises site personnel requirements during plant shut downs
- ✧ Eliminates hazards associated with personnel entry to tank internals
- ✧ Improved knowledge of tank floor condition compared to existing out of service techniques

TANK CLEANING

Sonomatic have experience of cleaning all types of storage tanks and can treat sludge in a number of ways. With highly trained technicians, our cleaning methods meet and exceed the latest compliance and health and safety standards.

1. The sludge can be locally disturbed to clear a space for the ultrasonic inspection.
2. The sludge can be marshalled into a particular location in the tank.
3. The sludge can be mixed in with the product higher up in the tank.
4. The sludge can be pumped from the floor to the roof manway and then into temporary tankage for treatment.
5. The sludge can be pumped from the floor to the roof manway and then into a neighbouring tank.



- ✧ Tank and Frac tank and truck set up
- ✧ Filtration system and product polishing
- ✧ Separator and Bag system
- ✧ Water tank cleaning to a roll-off and bag system
- ✧ Selling of sludge and waste products
- ✧ Planning cleaning cycles maintenance

Effective cleaning is essential for reliable ultrasonic inspection.

Cleaning system options depending on specific requirements:

- ✧ Scraper/brushes ahead of probes
- ✧ Suction ahead of probes
- ✧ Filter and discharge clean fluid ahead of probes
- ✧ Heavy sludges removed by pumping out of tank



SONOR ROBOT



SONOMATIC'S INTEGRATED NII APPROACH

- ✔ Sonomatic advanced ultrasonic immersion transducers system - Phased Array Ultrasonic Transducer (PAUT)
- ✔ Integration with Sonomatic Integrity Management Software (SIMS)
- ✔ Suction and discharge pumps
- ✔ Umbilical cord and carrier with 10 m to 115 m cable length
- ✔ Advanced navigation system and obstacle avoidance system.
- ✔ Purge system for products below 37.5°C flashpoints
- ✔ Camera and light system (optional depending on the product).
- ✔ Temperature range 5°C to 55°C

DIFFERENT ROBOTS ACCORDING TO TANK TYPE

- ✔ Hydraulic for heavy hydrocarbons
- ✔ Electric for light hydrocarbons/water
- ✔ Manual inspection tool

Robotic Tank Floor Inspection System include but are not limited to:

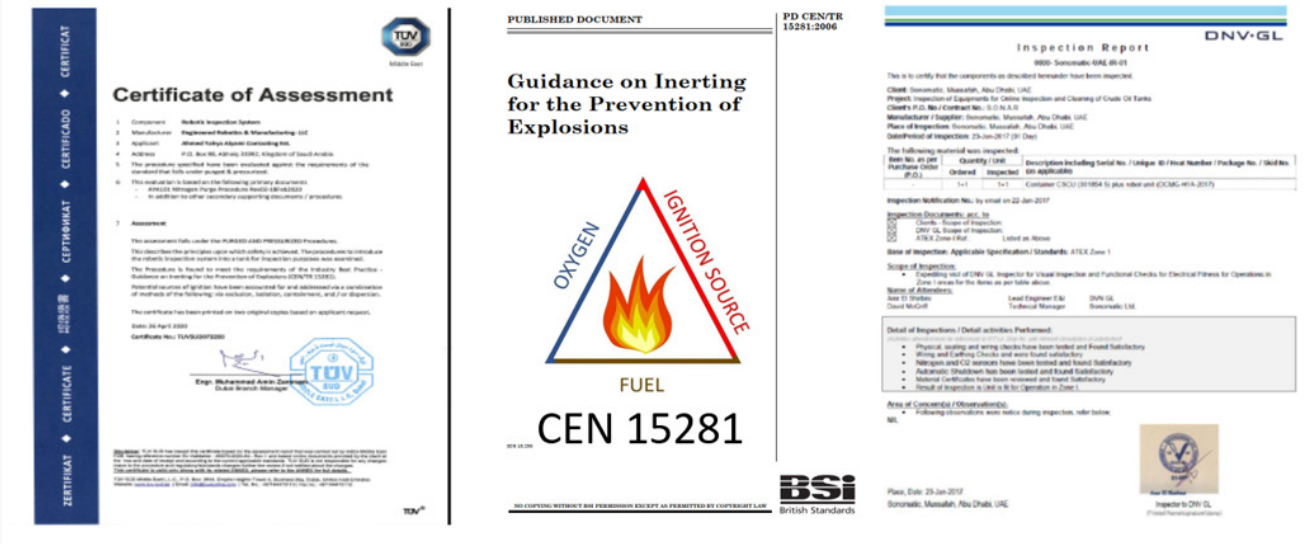
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|--------------|---------------|------------------------|
| ✔ Crude Oil | ✔ Lean MEG | ✔ Kerosene |
| ✔ Condensate | ✔ Water | ✔ #6 Fuel ¹ |
| ✔ Diesel | ✔ #2 Fuel Oil | ✔ Bunker C |

(All products are dependent on a review of its MSDS to confirm compatibility).

SAFETY SYSTEMS

- ✔ Safety interlocks
- ✔ Automatic cut out switches
- ✔ LEL monitors
- ✔ O2 Monitors
- ✔ Safety devices are fully tested with simulation exercises at the test tank.
- ✔ Personnel is trained to provide full service in a safe and disciplined manner.

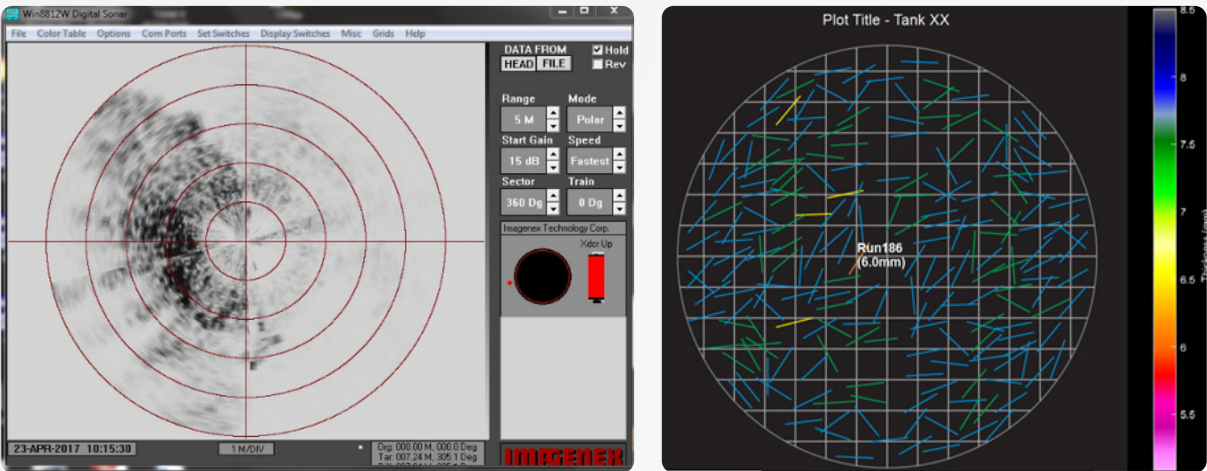
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ANALYSIS AND REPORTING SOFTWARE

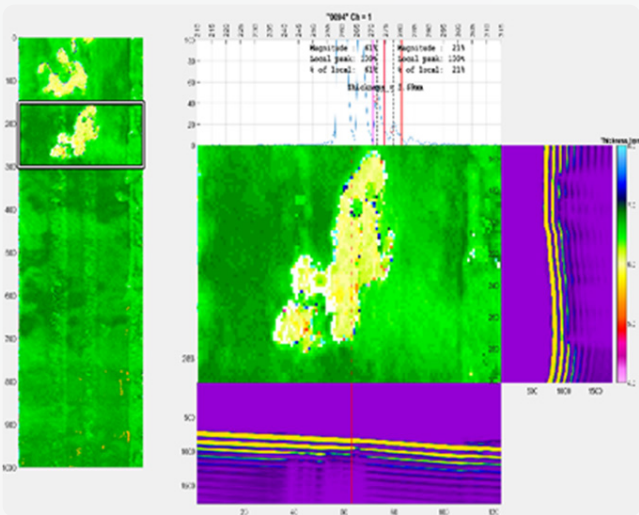
A major part of Sonomatic’s in-service tank floor inspection service (SONAR) is to manage and analyse large volume of navigation, phased array and short range ultrasonic data and acoustic emission datasets. Sonomatic has developed bespoke software to ensure the data is managed efficiently to provide reliable integrity information of the tank floor.

As an example, the plot below illustrates robotic paths captured by the navigation system and overlayed on tank drawing to perform the ultrasonic inspection of the tank floor.



The navigation data is then filtered to provide locations of the tank floor inspection. Along with the extracted steel thicknesses and navigation information, this is translated into showing the steel thickness variations along the robotic paths.

The extracted thickness are then used to estimate the minimum thickness of the inspected tank floor and hence the remaining life.



ROBOTIC TANK FLOOR UT SYSTEM VALIDATION

The ability to examine storage tank floors whilst the asset remains in service (on stream) is an ongoing challenge in the NDE industry, Sonomatic has been committed to developing inspection technologies for use in this sector.

The recent development of an ultrasonic ‘phased array’ multiplexer inspection system for use on the robotic tank inspection system has led to the requirement for Sonomatic Ltd. to validate the systems performance.

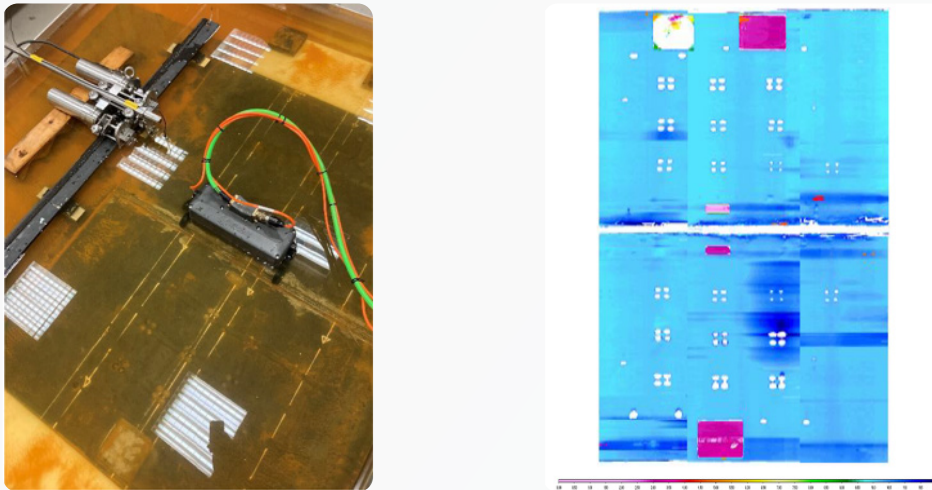
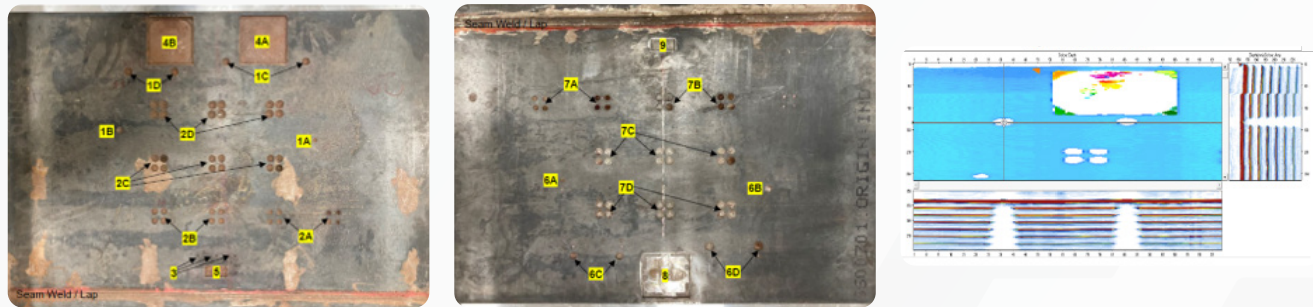


Figure 1: API Qualification Plate and PA MUX System

API Standard 653 Annex G outlines the qualification process for carbon and low alloy steel tank floor examinations for above ground storage tanks, this standard was used as a guideline to assess the performance of the 5MHz 128 Element Phased Array system used in the inspection of Crude Oil storage tanks.

Images represent the API Plates examined, a composite image of the UT data showing detection of the artificial flaws, machined in the API plate and data set showing near through thickness flaws detected.

API Plate Images:



Developments and technology validation exercises continue within Sonomatic for variations of the tank inspection transducer to include performance enhancement in various products and higher content of sludge and sediment.

FITNESS FOR SERVICE AND REMAINING LIFE ASSESSMENTS

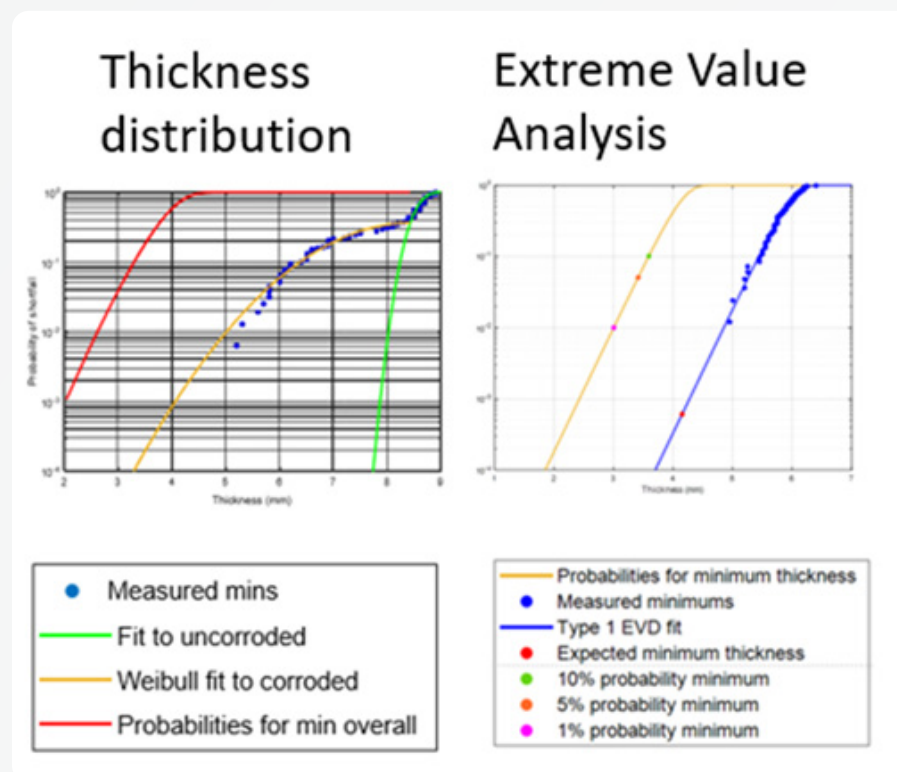
A key aim of Sonomatic's inspection services is to provide information which allows effective integrity management decisions to be made. Sonomatic also supports clients' integrity requirements by providing fitness for service and remaining life assessments based on inspection data collected in the field.

In the case of tanks, this covers complete assessments in accordance with API 653 or EEMUA 159. Our capability covers all levels of assessment from simple hand calculation checks on remaining wall thickness through to advanced nonlinear finite element analysis in accordance with the Level 3 requirements of API 579.

A key part of our approach to fitness for service assessment, is application of statistical methods where the inspection has been performed on a sampling basis.

The fitness for service and remaining life assessments are used to make recommendations on any repair or maintenance requirements as well as defining future inspection intervals.

Sonomatic's fitness for service capability applies to tanks as well as other equipment found on tank farms, e.g. pressure vessels, pipework and pipelines.



QA AND HS&E

Sonomatic operate under an integrated QHSE management system and are committed to the highest quality and safety of service provision | ISO 9001: 2015: 00007140 | ISO 14001:2015:00037371 | ISO 45001:2018:00037372 | ISO 17020: 2012: 4276 | Achilles FPAL Verified: 076712 | SEQual 1988 | British Safety Council Member: S0388440 |



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