

TRACERCO Diagnostics™ FMI (Flooded Member Inspection)

A Proven Cost Effective Inspection Technique

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Inspection of platform jacket members can be challenging using conventional methods in water depths below 150 feet. A few of the obstacles encountered include the time involved to remove marine growth prior to a measurement being taken, diving safety, associated costs of using divers in deep water and the expensive use of a dive support vessel over the time period of the inspection campaign.

Tracerco has been providing a cost effective approach for the rapid surveying of Oil & Gas platform jacket members to determine the presence and degree of water ingress for over 20 years. The TRACERCO Diagnostics™ FMI (Flooded Member Inspection) system can measure the degree of flooding into platform structural members without any need to remove marine growth or specialist coatings. It is operable as a simple attachment to any Remotely Operated Vehicle (ROV) or can be manually used by a suitably trained diver. Due to its' speed and accuracy, The TRACERCO Diagnostics™ FMI system is the only FMI technology approved by Lloyd's register.

FMI Technique

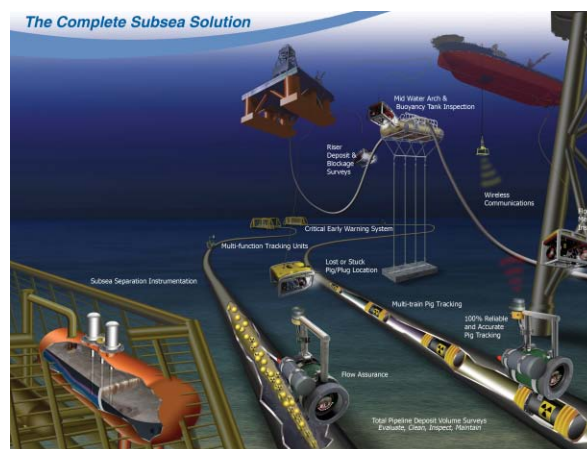
A highly focused beam of electromagnetic radiation and an ultra sensitive detector unit are mounted on opposite forks of a variable yoke system and positioned across the diameter of the member under inspection. The transmitted radiation intensity is measured and compared to the intensity expected for a dry member based upon the particular member's diameter, wall thickness and the system calibration. Water inside the member will result in a decrease in the expected "dry

member" transmitted signal. Each response is collated by our trained Offshore Technologist's working in conjunction with the ROV or dive team to provide a full report of platform jacket integrity. The following case study provided by a major Oil and Gas producer illustrates the benefits and costs of the TRACERCO Diagnostics™ FMI system when compared to more common sub-sea inspection methods.

TRACERCO Diagnostics™ FMI Case Study

The structural member inspection of an offshore platform using conventional methods can involve high risks, excessive costs, elevated manpower workloads as well as limited diving support vessel resource. This case study compares the advantages of using the Tracerco Diagnostics™ FMI technology to conventional inspection methods when used in water depths below 165 ft. (50 m).

The FMI inspection program was carried out successfully by Tracerco on 2 offshore platforms. The platforms were put into service in 1994 and 1995



respectively. Both the platform jackets consist of eight legged structures with 6 elevation levels. The jacket's support 3 decks, consisting of production, drilling, and living quarters. The jackets are in a water depth of approximately 328 ft. (100 m). There was a need to undertake a comprehensive inspection program on the underwater structures to ensure that they continued to meet necessary safety requirements. The first stage of the subsea inspection program was to determine the specific scope of work and which of the members were going to be inspected by Tracerco Diagnostics™ FMI or other methods. According to API 2A-WSD level three inspection requirements for underwater structures, inspection for the presence of flooded members can be used to replace detailed visual inspection.

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Flooded Member

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Defining the Work Scope Based on Risk Analysis

Based on certified platform design and sub-sea inspection company assessments, including

- structural modeling analysis,
- jacket static analysis,
- seismic and fatigue analysis,
- comparison of actual load-bearing with the original design,
- jacket node actual stress and allowable stress ratio,
- impact of marine growth, etc;
- jacket’s previous inspection and damage records,
- current offshore operation and inspection capacity,

as well as a risk assessment on the use of divers and/or ROV operations, high risk members were selected by the company and included in the flooded member inspection work scope.

It is necessary for conventional ultrasonic inspection techniques to use divers. This operation is associated with high risk at water depths of more than 165 feet (50 m). Beyond 165 feet (50 m), diving operations must be carried out with mixed gas or saturation diving. Due to safety concerns and additional costs associated with this activity Tracerco was selected to conduct the FMI inspection with the use of a ROV for jacket member’s below 165 feet (50 m).



Illustration of a TRACERCO Diagnostics™ FMI yoke system positioned across the member under inspection.



Using Gamma Ray FMI Method Instead Of Traditional Ultrasonic On Deep Water Inspections

The more common ultrasonic inspection technique has a number of limitations:

1. Low efficiency. Below 165 feet (50m) water depths, diver movement is slow. For helium-oxygen diving operations, as the water depth increases, the diver’s allowed effective working time is very limited.
2. Required to remove the marine growth on the members, as the marine growth on the members causes a disturbance with the ultrasonic technology increasing the sub-surface workload.
3. Low reliability with ROV. If it were deployed with an ROV, the ultrasonic probe has problems getting sufficient contact with the member, thus causing the results to be unreliable.

Results and Benefit

It was calculated that the use of ultrasonic detection technology would require 20 days to complete due to the requirement to remove marine growth or specialist coatings from the members before starting the inspection of the selected 82 members of the platform jackets.

However, it only took 4 days to complete the specified scope of work using the TRACERCO Diagnostics™ FMI method reducing operating costs. Table 1 shows a comparison of the two inspection programs for the jackets and it clearly shows that the TRACERCO Diagnostics™ FMI technique has a great advantage to both efficiency and cost saving respectively. As both of the platforms have been in operation for more than 10 years, documentation identifying the reasons for flooded members confirmed that man made flood holes based on repair or design requirements had caused some members to flood. This then ruled out the possibility of natural damage or corrosion and thus provided strong support for establishing the maintenance measure and life span assessment of the platform.

Conclusion

The use of TRACERCO Diagnostics™ FMI technique for jacket inspections below 165 feet (50 m) has proven that the technology can be successfully applied to inspect members on 2 platforms with significant cost savings. Therefore, considering both the operational cost saving, minimum safety risk and the approval from Llyod’s Register, the TRACERCO Diagnostics™ FMI technique with ROV operation was found to be superior and more advantageous when compared to ultrasonic FMI detection technology.

For more information on how Tracerco’s Flooded Member Inspection technology can support your platform inspection needs please contact a Tracerco technical representative in your region or visit our website at www.tracerco.com.

Acknowledgements

Tracerco would like to thank Wu Zhiwei, Qiu Daqing, and Chen Longsheng-Shenzhen Branch of CNOOC Ltd., Guang-dong, China for their contributions to this article.

Inspection Technique	Operation Way (below 50 m water depths)	Member Surface Requirement	Work Day	Support Vessels Requirement	Cost Per Day (USD)	Total Cost (USD)
Ultrasonic	Mixture gas diving or saturation diving	Need to clear marine growth or specialist coatings	20	DP2 Power Support Vessels	\$150,000	\$3,000,000
TRACERCO Diagnostics™ FMI	ROV Operation	No need to clear marine growth or specialist coatings	4	Commonly Support Vessels	\$20,000	\$80,000

Table 1 Comparison of different inspection methods on the platforms flooded member. (82 selected members)

Using Tracers to Calibrate/ Verify Produced Water Flow Rates

By Paul Hewitt – President The Americas, Pasadena, Texas

Ongoing concerns for offshore discharge and tightening environmental legislation in most parts of the world requires oil and gas producers to more accurately report volumetric flow rates of discharge water along with hydrocarbon concentrations. In many cases existing flow metering systems do not meet measurement requirements due to a number of reasons including;

- fundamental design not meeting current accuracy demands
- location in variable and hostile environments
- age
- lack of maintenance

In many cases there is a need to use onshore calibration facilities leading to delays between removal and reinstallation offshore. In addition there is a safety concern during the removal and reinstallation of a meter as well as a cost implication related to the actual calibration process and potential lost production while the meter is out of service.

To counter some of these issues, methods have been developed using tracer technologies and radioisotope scanning that allow produced water flow rates to be measured to less than 1% uncertainty. The use of this technology at various produced water flow rates provides a calibration option to oil and gas producers eliminating the need to shutdown and transport to an onshore facility.

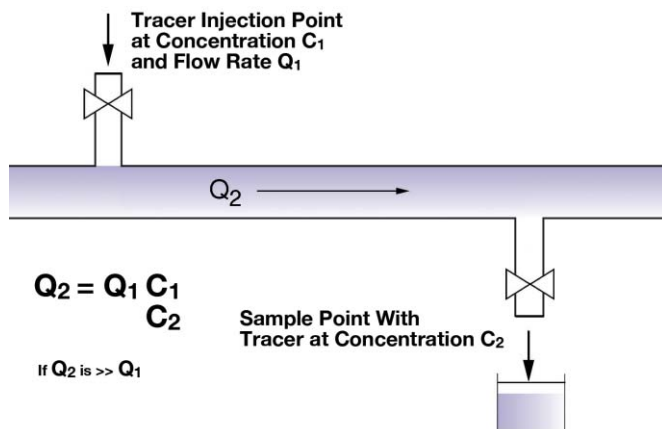


Figure 1 – Constant Rate Method based on the Dilution Principle

Introduction

The measurement and record keeping of water discharge flow rates to an uncertainty of +/- 10% forms part of OSPAR rules which is the current organization guiding international cooperation on the protection of the marine environment in the North-East Atlantic. To help achieve this there are many types of installed flow meters. Many have been operational for a number of years with others retrofitted by operators to ensure that they stay in compliance with legislation. This article describes how the application of different tracer techniques can be used to verify flow rates in produced water systems.

Measuring Flows Using Two Tracer Techniques

Constant Rate/Dilution Method

Accurate measurement of produced water flow through a piping system can be achieved using one of two tracer methods. The first is known as the constant rate method. This is based on a dilution principle whereby a tracer solution of known concentration is injected into the water flowing within the pipe. Samples are taken downstream after adequate mixing has been achieved and the tracer concentration counted. The ratio of tracer concentrations within the injected and sampled water together with the injection rate of the tracer into the line allows the main water flow to be determined (Figure 1).



Figure 2 – Tracerco's UV/VIS spectrometer used to analyze produced water samples.

An Example of Dilution Technique

A 250 ppm solution of fluorescent dye was used with an air driven metering pump delivering a 1 ml per second tracer injection rate. Samples were taken over a 7 minute time interval every 15 seconds at a point downstream. The flow rate was adjusted prior to each of the three tests. Tracer concentration within the produced water samples was analyzed using a UV/VIS spectrometer at a specific wavelength (Figure 2).

Results were plotted over time. A graphical representation is shown in Figure 3 of the data. Sample data on each plateau was averaged and input into the formula giving flow rate measurements of 2736 +/- 28, 5450 +/- 65 and 18170 +/- 345 bbl per day.

Mean Transit Time Method

The second method of measurement is known as the mean transit time. In this instance several radiation detectors are positioned at known distances apart along the flow line. A short half-life radiotracer is injected into the pipeline and the time taken by the tracer to travel a specified length is measured by the rise and fall in radiation signal (Figure 4).

Flow rate measurement by the transit time method is based on measuring the transit time of "tagged" fluid particles between two

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Using Tracers to Calibrate

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cross-sections of a pipe a known distance apart. Tagging of the fluid particles is achieved by injecting a tracer into the flow upstream of the two measurement cross-sections (i.e. detector positions) and the transit time is determined from the difference in the arrival times of the tracer at each of the detector positions.

Example of a Mean Transit Time Project

Four detectors were positioned at known locations downstream of the injection point. There were several pipe bends and an acceptable distance between the injection point and the first detection location. A small amount of radiotracer was injected into the line and the

responses measured using a real time data acquisition system. A total of ten injections were carried out at each of several flow rates across the range of a downstream meter. Figure 5 illustrates one of the detectors positioned externally on the flow line. Figure 6 represents the tracer responses and set up with various permutations of distance and transit times.

Distance (meters)	Time (seconds)	Velocity (m/sec)	Volume Flow in 8" pipe
A+B+C = 16.2	(1) = 21.06	0.77	2157 m ³ /day
A+B = 10.0	(2) = 13.62	0.74	2073 m ³ /day
A = 5.4	(3) = 7.24	0.75	2101 m ³ /day
B+C = 10.8	(4) = 15.08	0.72	2017 m ³ /day
B = 4.6	(5) = 6.06	0.76	2129 m ³ /day
C = 6.2	(6) = 8.60	0.72	2017 m ³ /day
		Mean	2082 +/- 58 m³/day

Table 2

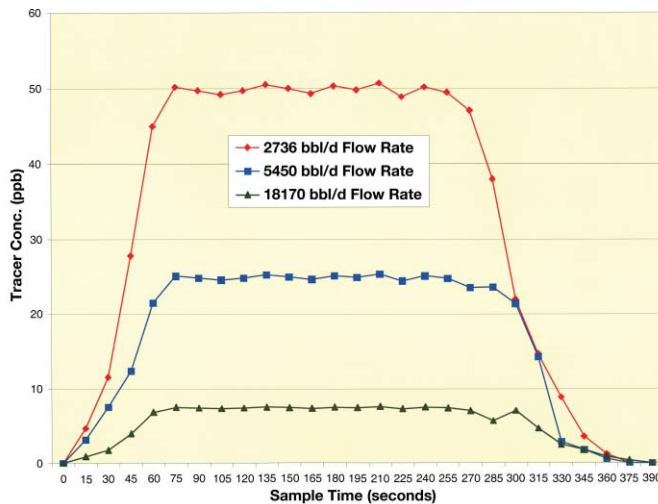


Figure 3 – A graphical representation of 3 test results plotted over time.

Table 2 shows how each of the permutations can be used to determine the average flow rate from one tracer injection at one of the targeted flow rates. In both of these methods, the advantages of which are considered later, the distance between injection and measuring sections must be large enough to achieve adequate mixing of the tracer with the water flowing through the pipe. In the case of the constant rate method a large number of different tracers may be used, such as radioactive or non-radioactive, mineral or organic materials. The mean transit time method tends to use radioisotope tracers that emit gamma energies as it is necessary to detect the tracer pulse flowing through the pipe on its external wall.

Choice of Tracer Method

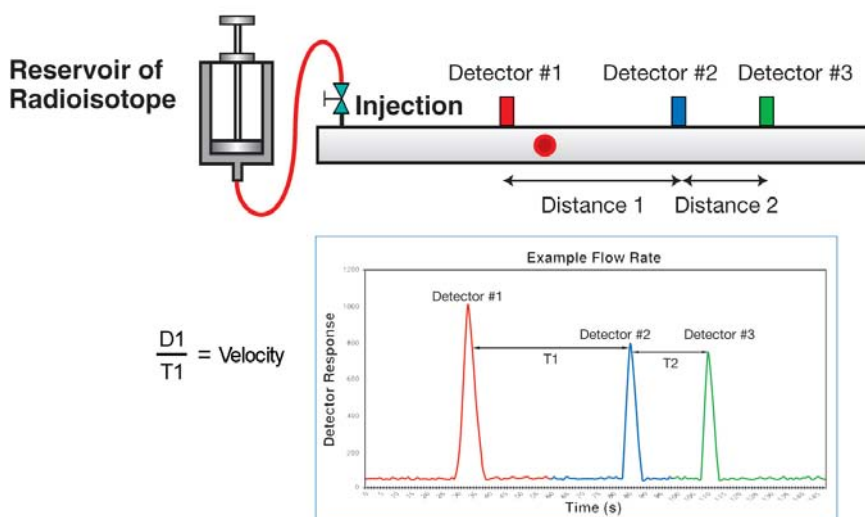
With the dilution and mean transit time techniques to choose from several operational criteria determine which is best suited for a particular system. In the case of the dilution method advantages include;

- It is not necessary to know the geometrical characteristics of the pipe
- Dimensional tolerances are not relevant with error propagation only with measurement of tracer concentrations in dilute and concentrated forms making this the most accurate method of measurement
- It can be carried out in a partially filled pipe (although not relevant to this particular application)
- If carried out over an extended period of time it allows for system flow rate fluctuation to be averaged

Using the mean transit time method advantages include;

- It is not necessary to measure the concentration of tracer material used

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$$\frac{D1}{T1} = \text{Velocity}$$

Figure 4 – Mean Transit Time Method

Using Tracers to Calibrate

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- It can be carried out without the need to take samples from the line
- Measurements can be carried out faster than the dilution method as instantaneous data is generated

Choice of Tracer

The basic principle of tracer investigation is to “tag” a substance or phase and then follow it through a system. Looking at tracer studies from a problem solving point of view, if problems of fluid transport can be described in terms of ‘When?’ ‘Where to?’ and ‘How Much?’ then they can be solved by means of tracer techniques.

The basic requirements of a tracer include:

- It should behave in the same way as the material under investigation
- It should be easily detectable at low concentrations
- Detection should be unambiguous
- Injection and detection should be performed without disturbing the system under investigation
- The residual tracer concentration in the system must be minimal.

The criteria can be met by the use of either chemical or radioisotope tracers and by careful selection of the most appropriate tracer for a particular application.



Figure 5 – External detector placement on flow line.

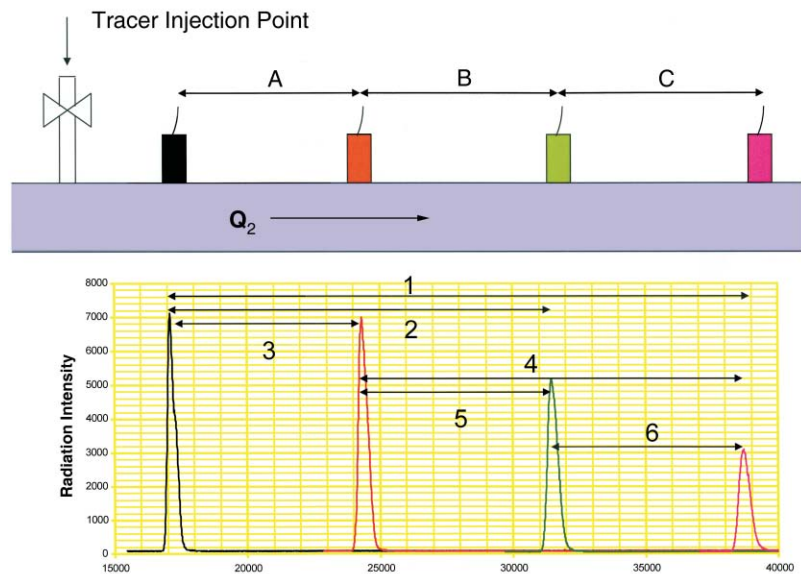


Figure 6 – The illustration above shows various distance and transit time tracer responses along with the detector set-up.

The main advantage of using a radiotracer is that its’ emissions can be detected on the outside of a pipe using a sensitive radiation detector. Measurement of a radiotracer is also not affected by the matrix if used during dilution flow methodology as it is not affected by problems such as the turbidity of the water. One other benefit to radioisotope use is the fact that only short lived radiotracers are used and as such they decay to background levels very quickly with no residual material in the discharge water causing permanent pollution.

Benefits of using chemical tracers include the fact that there are fewer legislative and safety related licensing requirements. In addition it is not necessary for the service provider’s crew to be specially trained and classified as

radiation handlers and there is no time limit on performing the project due to radioactive half-life decay. However, chemical tracers can not be used if the mean transit time method is to be applied due to their inability to be detected on the external walls of a pipe.

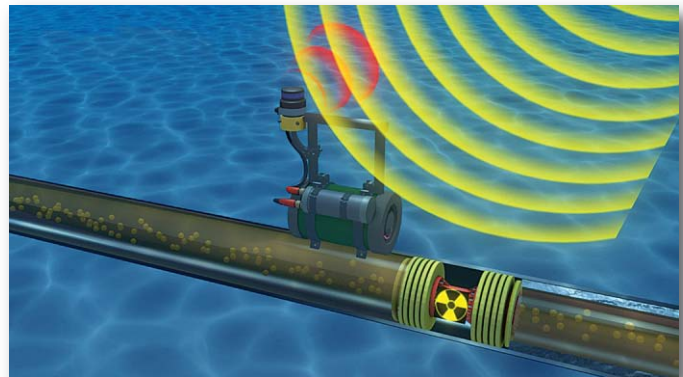
Summary

Tracers have been proven as an extremely flexible and cost effective means of calibrating flow meters without the need to shut down and send the meter to an onshore facility for calibration. The technology is accurate enough to allow an operator to prove compliance to required uncertainties, does not take a significant time period to carry out and has the flexibility to cover all turbulent flow rates across the calibration range of any meter. The selection of a specific tracer flow rate technique allows uncertainties such as pipe solids deposits and gas carry through to be discounted.

In addition to water flow rate measurement the technology is commonly used to verify gas, oil and multiphase flows thus proving compliance with other operator and legislative requirements.

Tracerco's Evolutionary Pig Tracking Technology

As a major force in the subsea sector, Tracerco has played a significant role in many successful developments across the world. Andy Hurst, Tracerco's Managing Director said "We are constantly investing in the development of our people and our technologies to ensure that Tracerco continues to offer the industry the most advanced solutions in this increasingly challenging sector. Our ability to take on challenging projects and deliver them on time, within budget and to the highest safety standards has been a major factor in the continued growth of our business."



The TRACERCO Diagnostics™ Pig Tracker is the most reliable method of tracking pipeline pigs or plugs available on the market today. It can be used to track pigs or monitor isolation plugs for movement in pipelines that are difficult to monitor by conventional tracking devices.

Tracerco's GammaTrac™ systems provide real-time, low risk methods of tracking pigs through pipeline systems and can be deployed topside, subsea and along pipelines of any diameter or thickness. If the pipeline is subsea, the GammaTrac™ units can be

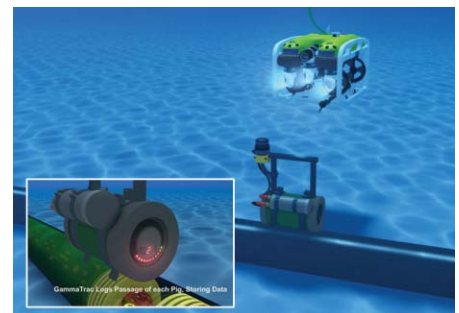
attached to the pipeline by divers or ROV, and can be either battery operated or powered through the ROV umbilical or independent cables from a platform or dive support vessel. The GammaTrac™ units are functional in water depths to 10,000 ft. (3,000 metres) sub-sea. The unit can flag the passing of a pig, locate lost pigs, count and time numerous pigs past a set point, and function as an alarm unit for monitoring isolation plug movement.

Tracerco has further developed its unique pig tracking technology so that it can now be equipped with a wireless communication device, resulting in significant cost savings for pipeline operators undertaking pipeline assurance work. Tracerco's remotely operated GammaTrac™ unit can now communicate to a vessel or platform without the need for in-situ ROV monitoring and without incurring significant time delays.

The unique pig tracking technique works by 'tagging' the pig with a small purpose-designed radioisotope, which can pinpoint its location within two inches, providing in-situ,

real-time tracking of pigs. It helps provide customers with vital information concerning the performance of their pipelines and reduces the lengthy delays and costs that can be incurred locating pigs that become lodged. The system can track different types and sizes of pigs from foam to intelligent pigs, to very small, less than 1", to very large.

If you would like to learn more about Tracerco's pig tracking technology visit our website at www.tracerco.com or contact a Tracerco Technical Advisor to schedule a lunch and learn presentation.



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