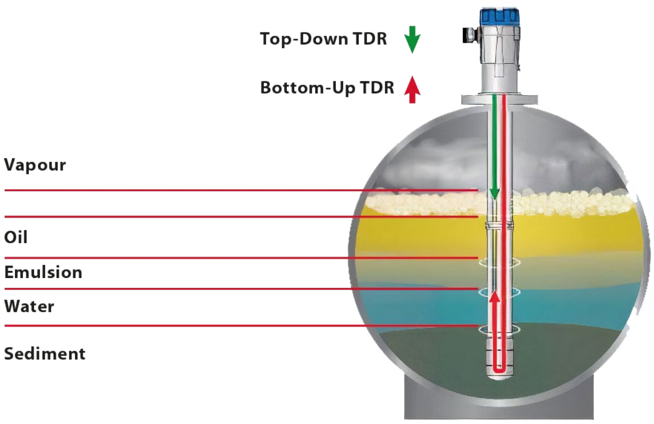
Genesis vs Nucleonic Gauging

Comparing Magnetrol's revolutionary new multiphase detector with the radiometric gauging approach to level profiling.

Magnetrol's Genesis represents the birth of the Guided Wave Radar (GWR) solution to multiphase level measurement. Using Time Domain Reflectometry (TDR) with patented "Top-Down" and Bottom-Up signals and advanced level detection algorithms, Genesis can deliver a full vessel interface profile which transcends many of the more traditional technologies.



Genesis™ Multiphase Detector

When it comes to defining interface measurement in the Oil & Gas and Petroleum Industries, the weapon of choice has typically and historically been nucleonic or radiation gauging. The significance of the measurement is derived from the value associated with effectively separating water and hydrocarbon.

The nucleonic measuring principle is based on the attenuation of gamma radiation as it penetrates materials. The radioactive isotope (gamma source) is installed in a sealed shielded holder which uses a collimated shutter mechanism to isolate the beam when closed and emit radiation in a controlled direction when open.

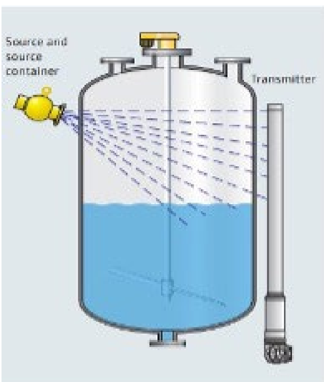


Figure 1 – Basic Mounting Configuration for Total Level

The other component of the gauge is a detector/transmitter, and the source and transmitter are typically mounted on opposite sides of a vessel or pipe. The emitted radiation passes through the vessel walls and the medium contained in the vessel.

The actual measuring effect results from the absorption of the radiation by the medium. The intelligent transmitter calculates the level, density or the concentration of the medium from the radiation received. The higher the level or the density of the medium in the vessel the lower the intensity of the radiation received.

Caesium-137 is typically used for conventional level and density measurements. Where increased energy for greater penetration is required (e.g., thick-walled vessels, long beam path lengths). Americium-241 may be used for heavy element measurement in a medium consisting of lighter elements.

Continuous Level Measurement/Full Absorption

In this measurement principle, the radiation is fully absorbed. The radiation difference between the source and the detector varies given the image of the level. The radiation activity is calculated from the pulse rate received.

Typically, the pulse rate (radiation level) at 100% level is zero, meaning the gamma rays are completely absorbed by the medium (full absorption). For example, at 50% of the full range level, only the upper part of the detector receives the radiation. Consequently, the pulse rate increases.

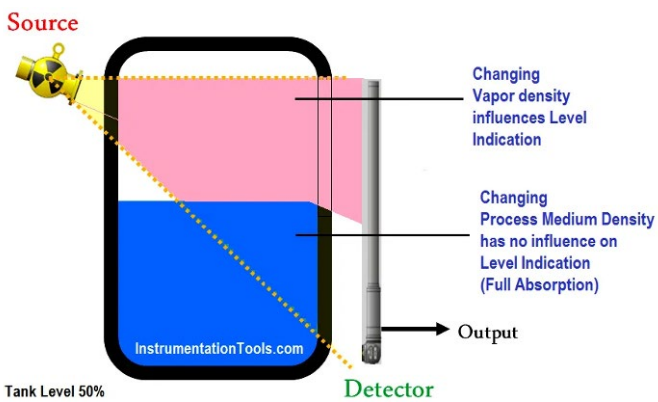


Figure 2 – Changing Process Medium Density has no influence on Level Indication (Full Absorption)

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Single Interface Measurement

When considering nucleonics for a single interface measurement such as oil/water, in an extremely high percentage of cases, the application parameters will dictate that the source be installed inside the vessel is a sealed dip tube, negating any direct contact with the medium.
The source element may be lowered from its container/ holder into position in the vertical dip tube through a mounting flange, using a steel cable.

Depending on the required measurement range and the application, the source may consist of a single pellet or a multiple source assembly. Similarly, the number of detectors and their length will be specified to match the range.

The smart transmitter measures the average density of the medium between the source and the detector from the radiation received. A direct relationship to the interface layer can then be derived from this density value.

Density Profiling For Multiple Interface Detection

In order to define multiple interfaces in a multiphase environment, such as that associated with a Production Separator on an oil rig, the measurement device or profiler, must be able to define position and density. Depending on the nature of the crude and its density differential to the seawater, a thick and dynamic emulsion layer may exist between the oil and water.

This can also be affected by the residence time - i.e., the amount of time the contents are given to settle and equilibrate before oil is removed.

To be able to provide a "window" into the vessel and allow operators to accurately measure and control the distribution of fluid, presents a significant challenge. To be effective, the "profiler" must be able to "see" and define the magnitude of the sand/sediment, water, emulsion and the oil and gas phases.

The nucleonic approach is best epitomised by the Tracerco/ Synetix Profiler GPS. This device comprises 3 titanium sealed dip pipes attached to a common, top entry 6" flange, running vertically parallel inside the vessel. The length of the dip pipes is determined by the required measurement range. Two of the dip tubes contain a chain of Geiger Muller tubes spanning their entire length. The other tube or "leg" contains a string of point Americium-241 gamma radioactive sources traversing the length. The amount of radiation reaching the individual GM tubes is dictated by the density of the media between the tubes and the corresponding source, which in turn dictates the number of counts it generates.

Therefore, if the type of media and its density, covering the length of the detector string varies across its length (sediment – water – emulsion – oil – gas), this will determine the number of counts it produces and the radiation profile this density vs position output describes creates a multiple interface picture of the vessel.

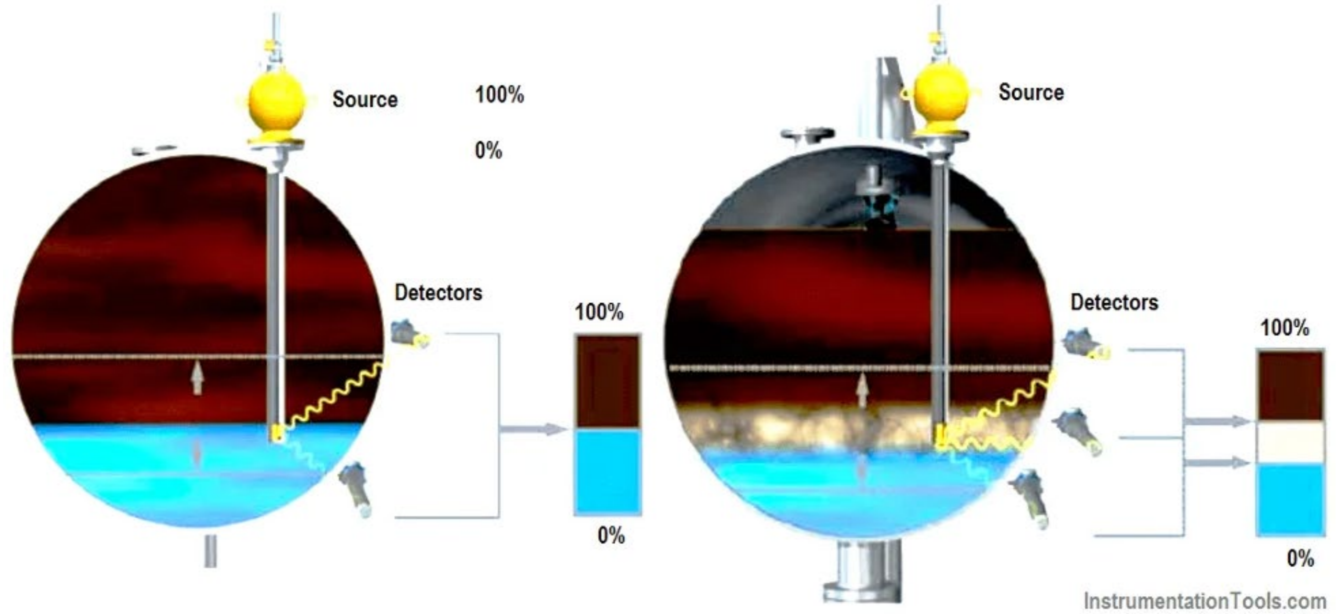

Figure 3 – Nucleonic Interface Measurement Principle

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Figure 4 - Tracerco – Source and Detector Dip Tubes on a Common 6" Flange

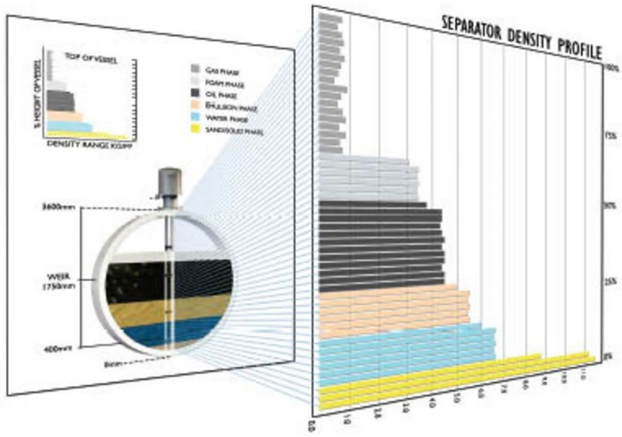

Figure 5 – Tracerco Profiler

Other nucleonic gauging manufacturers take a similar approach, in terms of a top entry internal multi-point strip source but deploy a series of external point scintillator style density detectors. This is known as the density array configuration. The measuring range is subdivided into zones and an applicable density value is calculated for each zone. This arrangement lacks the continuity of the "Profiler" approach.

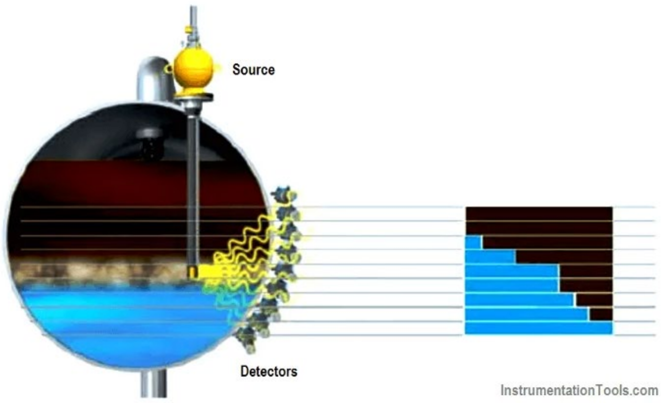

Figure 6 - Density Array Method

Disadvantages of Nucleonics – The Administrative Burden and Infrastructure Requirements for Regulatory Compliance

In the majority of countries, the use of nucleonic gauges requires the possession of a permit/license for their storage and use, due to the hazardous nature of the radioactive sources involved.

In the UK, the permit for storage and use is issued by the Environment Agency (SEPA in Scotland) and can cost several thousand pounds to obtain, followed by a significant annual subsistence cost. The regulations governing the issuing and implementation of the permit are the Radioactive Substances Act 1993 (RSA93) and the Environmental Permitting (England and Wales) Regulations 2016 (EPR16).

The sources used in radiation gauges are defined as Class 7 Dangerous Goods. This description applies to any material that contains unstable isotopes of an element undergoing decay and emitting radiation

In order to qualify for said permit, many criteria regarding safety, security and training have to be met, involving an onerous paper trail. Meeting these criteria can entail significant cost, involving extensive administration, specialist training for responsible personnel and the deployment of various safety measures. Furthermore, the infrastructure, once in place, must keep pace with any changes in the regulations.

Storage

- Radioactive materials when not in use, being moved or transported, must be kept in a suitable radioactive store. A dedicated structure used as a permanent radioactive store must provide sufficient shielding or use controls to ensure that persons outside the store should not experience a radiation dose exceeding 1 mSv in a year*. Any risk assessment for the storage of radioactive materials will indicate likely radiation doses to persons external to the store. For new facilities the dose rate is not to exceed 1µSv/hr unless special conditions apply.
- Any store must be constructed of fire-resistant materials
- Must provide protection against the weather
- Have adequate ventilation
- Offers proper physical security (see below)
- Have a prominently displayed radiation warning sign which complies with the Health and Safety (Safety Signs and Signals) Regulations 1996.

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Security

Regulations pertaining to the security of radioactive materials require that "The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas," and that "the licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

Radioactive materials are to be stored in a manner that will minimize the risk of breakage, leakage or theft. The use and storage of radioactive materials must either be under the constant surveillance and immediate control of a radiation worker or secured from unauthorized removal and access. These requirements apply to stock solutions, sealed sources, materials in process, and radioactive waste.

Each sealed source is to be checked annually to ensure that the radioactive material is still being appropriately contained and does not present a risk to those that are using them. A swab or small absorbent smear can be used to "wipe" an area, the wipe is then placed into a test tube and counted, typically using a gamma counter. This is a chargeable service if carried out by a specialist company.

**Implementing the above criteria carries significant cost - the most recent estimate to build a radioactive store at ABLE to meet the current regulations in terms of correct materials and secondary containment was around £30,000.*

Use

The Ionising Radiation Regulations 2017 (IRR17) govern the operation and use of Class 7 radioactive materials for the purpose of level, density or moisture gauging in the UK. Under IRR17 the operator must comply with the following:

Local Rules

The local rules document the safe working arrangements and administrative controls intended to restrict doses to individuals working in a radiation-controlled area, and other persons who may be affected. The length and complexity of the local rules should reflect the nature and magnitude of the radiation hazard. Local rules describe the appropriate procedures to be followed and responses to incidents or accidents involving ionising radiations.

IRR17 requires employers to keep exposure to ionising radiations as low as reasonably practicable. Exposures must not exceed specified dose limits. Restriction of exposure should be achieved first by means of engineering control and design features.

The Local Rules summarise the key working instructions intended to restrict exposure in radiation areas. They will include at least the following information:

- A description of the area covered by the Rules and its radiological designation.
- The radiological hazards which may be present in the area.
- The formal dose investigation level.
- Names and contact details of responsible people, including the Radiation Protection Supervisor (RPS). The RPS is responsible for supervising working arrangements set out in the Local Rules.
- Detailed working arrangements for the area.
- Contingency plans.

Competent Personnel

Radiation Protection Supervisor (RPS)

Where local rules apply, a radiation protection supervisor (RPS) who is trained in the use of ionising radiation must be appointed to ensure that the arrangements set out in them are followed. As a condition of registration or authorisation under RSA93, you will need to ensure there is adequate supervision by suitably qualified and experienced people to ensure compliance with registration and authorisation conditions.

Radiation Protection Advisor (RPA)

A Radiation Protection Adviser (RPA) is a title used in the UK and is given to those who are competent to advise employers on the safe and compliant use of Ionising Radiations. The post is a legally recognised position and is a requirement of the Ionising Radiations Regulations 2017.

The RPA needs to be appointed by the employer in writing, where the scope of the advice required is clearly defined. The employer also needs to determine if the RPA is suitable to advise on the types of sources of ionising radiation being used. The RPA is required to show the employer that they are 'competent' to be an RPA, this competence being formally and legally recognised (e.g., by RPA2000).

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Personnel Monitoring

An accredited dose monitoring programme is usually required to demonstrate compliance with IRR17. The thermoluminescent dosimeter (TLD) service is designed to provide valuable dose information for a facility's personnel monitoring programme. The dosimeter should be worn at all times when there is a potential for occupational exposure to ionizing radiation.

Area Demarcation

There are two categories of area demarcation under IRR17, defined as follow:

Where radioactive sources are deployed as part of a measurement system a suitable risk assessment should be carried out to determine the correct area demarcation. The employer needs to designate an area under their control as a **Controlled Area**, where the following apply:

— *it is necessary for a person who enters the area to follow special procedures designed to restrict exposure, or prevent or limit a radiation accident*

A **Supervised Area** is defined as an area not designated as a controlled area but for which occupational exposure conditions are kept under review, even though no specific radiological protection measures or safety provisions are normally needed to control radiation exposure. The issue is 'potential' exposure as opposed to expected exposure during routine work. The formal considerations for designating a supervised, after suitable risk assessment are where:

— *it is necessary to keep conditions under review to determine whether the area should be controlled or supervised*

Genesis vs Nucleonics – A Holistic Assessment

The Wireless Telegraphy Act governs the use of Radar Level Gauge Equipment in the UK. However, all radar equipment, except that whose emissions fall within the band 10,6 GHz to 10.7 GHz, is now license exempt. Magnetrol's devices do not operate in this range and therefore require no permit for use.

When this is compared with the **administrative and operational** obligations associated with the use of nucleonic gauges, the disadvantages of the latter on this level become clear. In summary, the following are mandatory:

- Environment Agency Permit for use (RSA93)
- Permit Subsistence (annual)
- Approved Storage Facility
- Source Accountancy & Monitoring
- Security - Protection Against Theft and Abuse. The Three "D"s – Deter, Detect & Delay. Sophisticated Alarms & Camera Based Monitoring
- Risk Assessments based on Commissioning & Operation of Hazardous Materials
- Area Demarcation
- Specialist Support from Nucleonic Vendors
- Development & Implementation of Local Rules
- Training of Personnel – Company Radiation Protection Supervisor
- Contract External Radiation Protection Advisor
- Personnel Dosimetry
- Wipe/Leakage Tests

Whilst several of the above factors contribute to the long-term cost of ownership, the initial purchase price of nucleonics is also relatively expensive. For example, whilst Magnetrol's Genesis costs around £60,000 to £65,000, Tracerco's Profiler sells at about £250,000, with another £100,000 in engineering/commissioning fees. The alternative density array arrangement can cost up to £200,000 depending on the measurement range.

Nucleonic manufacturers will attempt to counter with the claim that their products provide a truly universal "fit and forget" level measurement technology, however, the list above disputes that assertion and reinforces the perception that many of the costs highlighted therein remain hidden until after the nucleonic gauges are procured.

Since nucleonic technology has the key advantage that direct contact with the material being measured is not needed, to this day, some applications do not allow any alternative to nucleonic measurement. This is because only measurement technology using gamma radiation is completely unaffected by high vessel pressures, corrosive media, extreme temperatures or problematic physical product characteristics and is able to continuously deliver exact and reliable measuring results.

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Calibration
However, nuclear devices can be difficult to calibrate accurately. Often the vessel will require to emptied and filled to zero and span the device in order to obtain the desired calibration accuracy. The complexity of the task is normally related to how practical/easy it is to get the required process conditions for calibration. With Genesis, changing media characteristics have no effect on level measurement and there is no need to move levels for calibration.

With nucleonics, interface measurement/density profile may be used if the emulsion layer thickness or the density profile needs to be measured. However, if specific values ρwater and ρoil of an emulsion have been used during the calibration stage, then the operated values of ρwater and ρoil should be the same otherwise it will not be possible to characterize the other layers.

For example, that if the oil density varies from 900 kg/m3 (calibration value) to 800 kg/m 3 and if 800 kg/m 3 have been 'declared' as 'emulsion' then the new oil density will be seen as an emulsion.

Physical Handling
Due to the fact that the source containers typically use lead to shield the radiation, the containers can be very heavy and a crane/hoist might be required for installation.

Depending on instrument design, some applications may require extremely large sources (both in terms of dimensions/weight and activity) which can increase delivery times, licensing requirements, and may require special mounting consideration.

Nucleonic sources for interface profiling measurements can weigh up to a metric ton whilst the average weight of Genesis is 15-20kg. Additional supporting structures may be required for the sources.

Response Time & Density Variation
The use of nucleonic measurement principles for fast control loop or safety application should be evaluated based on required response time (as the profile is reconstructed from density profile using several sources/detectors and calculation units).

Depending on distance and position of source to sensor, small levels of foam can have significant effect on the measurements. This is due to the density difference between foam end gas vapours. As previously stated, changing media characteristics have no effect on Genesis level measurement.

Additional Considerations for Nucleonics

- Internal material build-up on vessel walls will attenuate radiation and compromise calibration
- The Tracerco Profiler uses Americium-241, which is a weak gamma emitter and easily blocked by any wax build-up on the walls of the dip tubes housing the source and detectors, resulting in a loss of viable signal and therefore measurement. The gauge will "flat-line" under these circumstances
- As source activity selection in interface measurement is based on the ability of the radiation to penetrate the various media layers and not just air, e.g., water, it will tend to be very high. This doesn't present a problem whilst the radiation is being absorbed by the process but if the upper layer (oil) is lost then resultant radiation field strengths outside the vessel could be excessive and present all sorts of health & safety problems
- Particular attention should be paid to the temperature of the process. Tracerco's Profiler uses a string of Geiger Muller, tubes housed in a dip tube, which can withstand temperatures up to approximately 100°C whereas Genesis can operate in temperatures as high as 200°C. Separators are often run at temperatures in excess of 100°C in order to keep waxy hydrocarbon liquids and paraffins from forming deposits. In this situation, a nucleonic profiler will require cooling and this will incur significant additional engineering costs
- When a source reaches the end of its useful life, or the process on which it is being used is discontinued, it is the responsibility of the owner/operator to dispose of it. This must be done according to the regulations by a specialist, licensed company and can be an expensive exercise.

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