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Nucleonic Level Measurement in Fluid Catalytic Cracking Unit, Oil & Gas Refinery

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Abstract

The measurement of 'Level' is crucial in an Industrial Process, as low levels can cause problems and damage equipment. In contrast, high levels can cause overflow and potentially create safety and environmental problems. When working with the Fluid Catalytic Cracking System Unit (FCCU) in Refineries, there are requirements for various types of level measurement instruments. One of them is the Nucleonic Level Measurement device used in the process involved in the separation of catalyst from the Flue gasses passes through types of equipment such as Third Stage Separator, Fourth Stage Separator, Fines Collection Hopper, Fines Disposal Hopper, and End Level Drums or Bins. Nucleonic level measurement works upon radiometric level measurement techniques in which sources and detectors transmit and receive gamma rays to detect the catalyst level of hoppers/vessels. The following are the advantages of Nucleonic Level Measurement: ● Used in level, interface, density, concentration, and point-level measurement, ● It can utilized for measurement in liquids, solids, suspensions, or sludges, ● It's also used in extreme process conditions: high pressure, high temperature, corrosion, abrasion, viscosity, toxicity, and all kinds of process vessels, for example, reactors, autoclaves, separators, acid tanks, and cyclones.

Keywords: Level measurement, types of level measurement, nucleonic gauge, advantages of nucleonic gauge, fluid catalytic cracking unit, separation unit in FCC

INTRODUCTION

Level measurement is a process used in various industries to determine the height or depth of a matter (liquid, solid, or slurry) within a hopper or vessel [1]. In any industrial process application, it's essential to take accurate and reliable level measurements so that constant product quality, plant safety, and economic efficiency can be observed [2,3]. The following Figures (Figure 1A & Figure 1B) indicate how continuous level measurement is taken care of in an industrial process.

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Types of Level Measurement:

There are mainly two types of level measurement [6]:

- Direct Method
- Indirect Method

Nucleonic Level Measurement

Nucleonic level measurement works upon a principle of radiometric level measurement technique, in which sources and detectors are there to transmit and receive gamma rays for detection of the substance level of hoppers / vessels [Ref 3.1]. In fact gamma or neutron radiation sources and detectors are used to determine the density or mass of the substance which is further calculated and provides the proportion of level. This type of level measurement devices are mainly used for non contact type, continuous level measurement, high temperature, high pressure, high density and for slurries or solids [Ref 3.2 Ch 2].

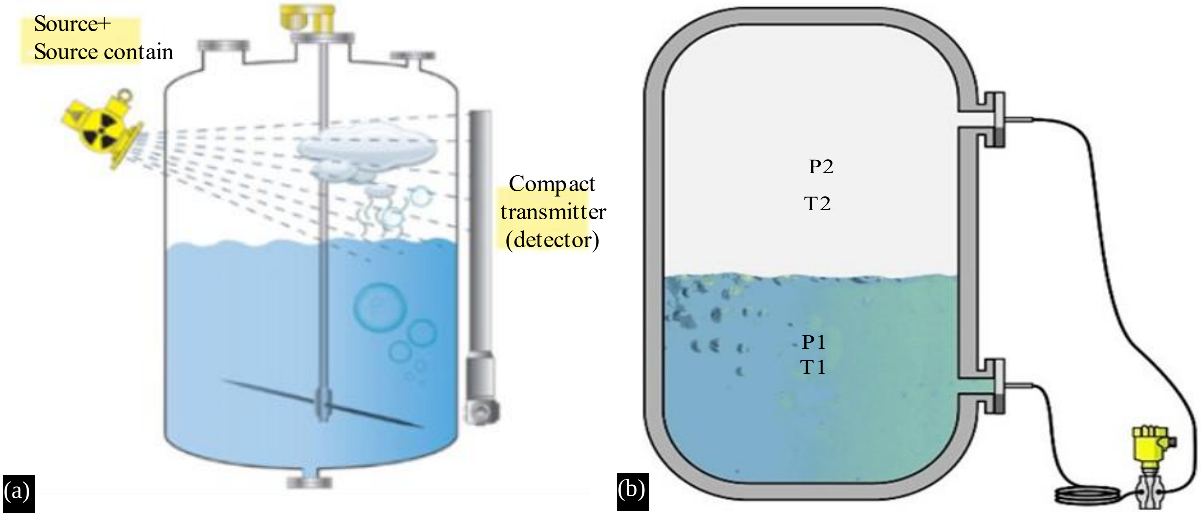

Figure 1. (a). Non-contact type level measurement (b). contact type level measurement.

[Figure 1. (a) https://blog.isa.org/basics-continuous-level-measurement]

[Figure 1. (b) https://www.vega.com/en-in/company/blog/2019/white-paper-level-measurement-101]

Detailed classifications are in the mentioned Table 2 [Ref 1.4, Ref 2.1].

Table 2. Classification of level measurement.

Direct or mechanical	Indirect or inferential
Dip sticks & lead lines	Buoyancy
Sight glass	Hydrostatic head
Chain or float gauge	Sonar or ultrasonic
	Microwave
	Conductance
	Capacitance
	Radiation
	Weight
	Resistance
	Micro - Impulse

[Table. 2 https://instrumentationtools.com/types-level-measurement/#types-of-level-measurement]

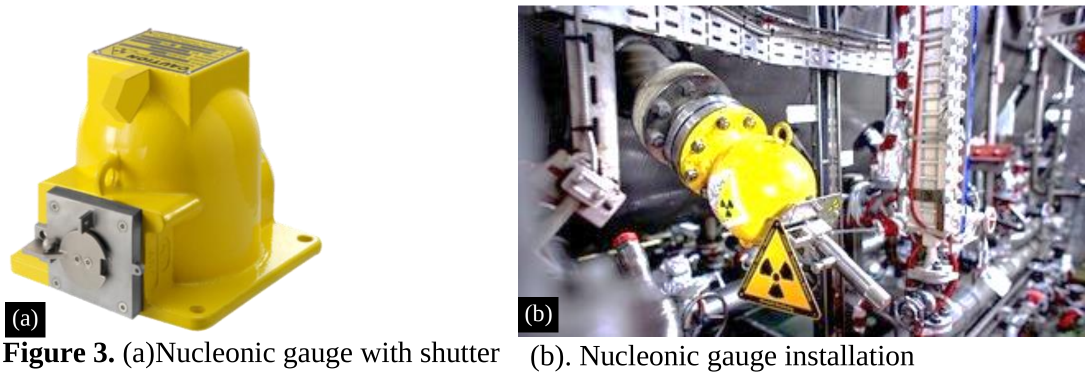

Figure 3. (a)Nucleonic gauge with shutter (b). Nucleonic gauge installation

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[Figure 3. (a) https://www.vega.com/en-us/products/product-catalog/level/radiation-based]

[Figure 3. (b) https://www.endress.com/en/field-instruments-overview/level-measurement]

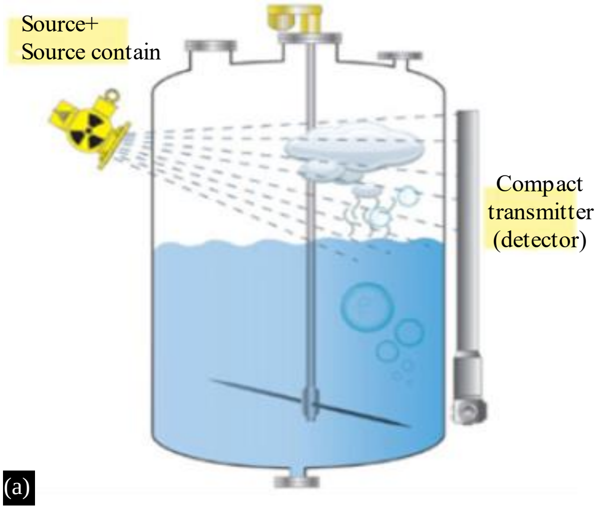
In this type of gauge there are two major components:
1. Source, &
2. Detector

Types of Nucleonic Gauge

There are four types of Nucleonic Gauges:
- Level & interface gauge
- Thickness & mass per unit area gauge
- Density/bulk density gauge
- Nuclear analyzer

Level & Interface Gauge

This type of gauge is based on the gamma-ray transmission technique which are the simplest and most widely nucleonic gauge in the process industry. A transmission level gauge consists of a source and detector placed on opposite sides of a vessel. The source and the detector are so arranged that changes in level cause a complete or partial interruption of the radiation beam, resulting in a change in intensity of radiation at the detector. The radiation sources usually used in level or interface gauges are gamma emitting sources. When the level of the liquid in the vessel rises the associated electronics provide a signal or raises an alarm and accordingly control the filling or emptying process.



(a)

Figure 4.1 (a). Principle of continuous gamma level gauge using transmission technique

[Figure 4.1. (a) https://blog.isa.org/basics-continuous-level-measurement]

In the gamma-ray transmission technique there are two types of radiation sources which are as follows and they are typically used in process vessels in industry.
1. Cesium-137
2. Cobalt-60

The relationship between transmitted and incident intensity of the radiation is given as below:

$$e^{-\mu \rho x} I = B I_0$$

- *μ: Mass absorption coefficient B*: Buildup factor

- *I: Transmitted Intensity I_0:* Incident Intensity
- *ρ*: Density
- *x:* Thickness of an object

Gauges based on the backscattering principle are also used for level measurement in industrial process vessels. They offer specific advantages in cases when only one side of the sample is accessible or there is not enough space to mount the detector to measure the intensity of the transmitted radiation.

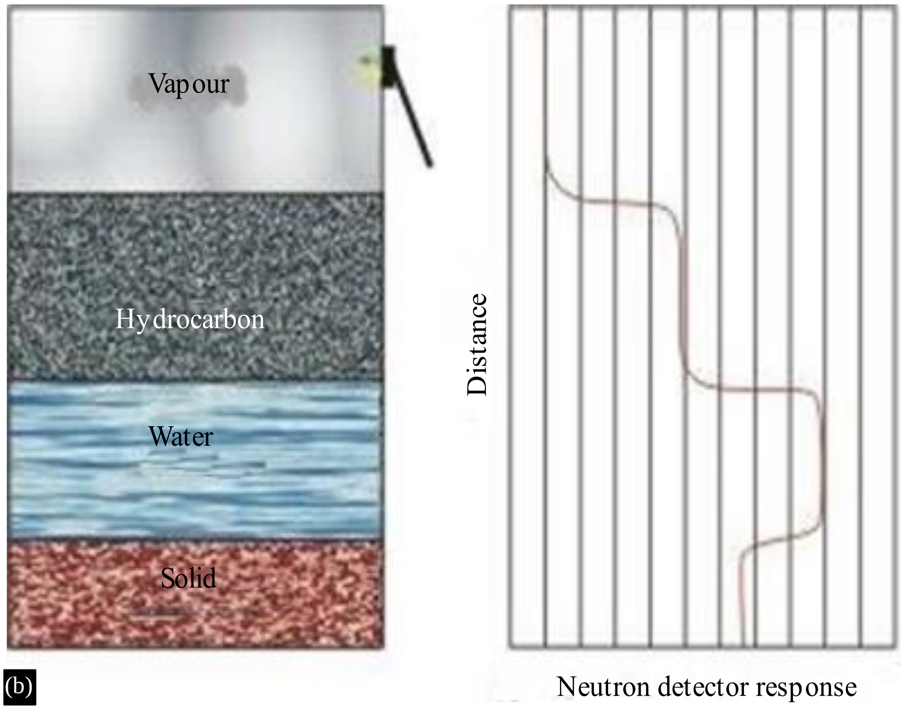


Figure 4.1. (b). Measurement of level & interface using a neutron backscatter technique.

[Figure 4.1. (b) https://www.researchgate.net/figure/Typical-result-of-neutron-backscatter-technique-investigation]

In the backscattering technique, Americon-Beryllium (Neutron) is used whereas it's typically used in applications like hydrogenous materials [8-9].

Types of Detectors

- Geiger-Muller counters
- Scintillation detectors
- Proportional counters
- Semiconductor detectors [1].

Nucleonic Level Calibration

A nuclear system always needs to be calibrated in the field. For interface or profile applications, it is recommended to use two different media for the calibration.

A one or two-point calibration method can be used to set up an interface/profiling application [7].

A one-point calibration (e.g. with water) is more convenient if a vessel can only be filled with one defined homogeneous media.

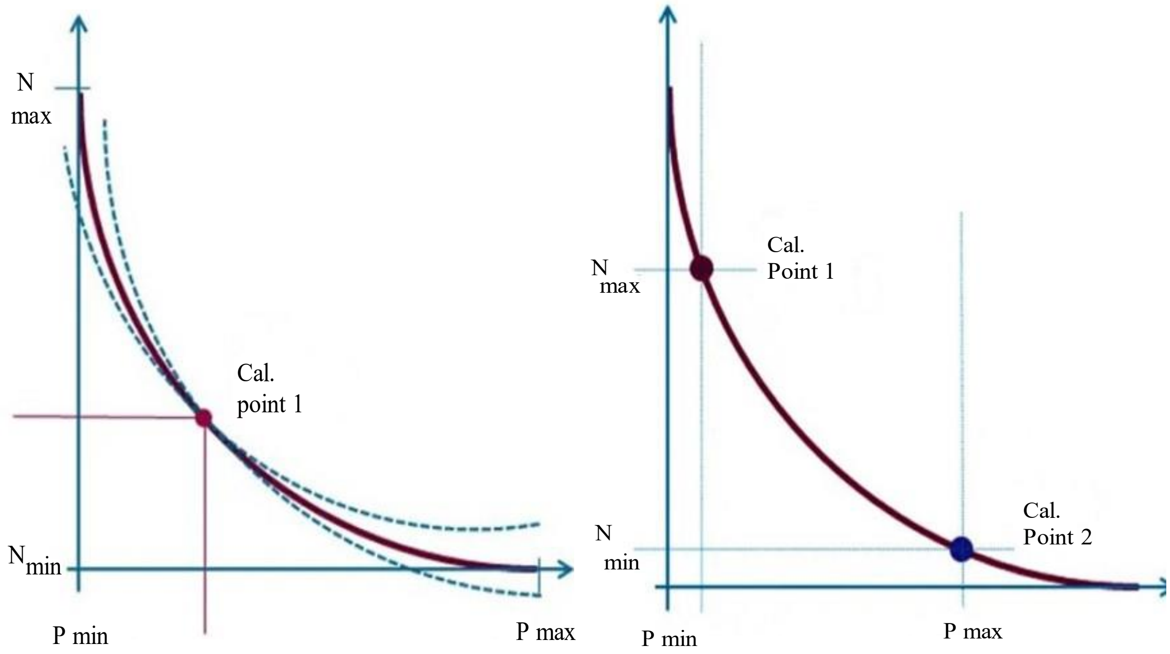


Figure 4.2. (a). Count rate (N) V/S Density (ϼ) curve

[Figure 4.2. (a) https://instrumentationtools.com/types-level-measurement/]

$$fs = e\frac{-uD}{ϼ}$$

- F_S = Attenuation Factor
- μ = Absorption Coefficient D = Pipe Diameter
- ϼ = Density

Nucleonic level calibration is done by detecting radiation using a Gamma-RAE device which can detect energy radiation ranging from 1R to 999R (1 Roentgen = 9.33 milli Sievert)

The calibration points for the measurement are entered in the "calibration" function group. Each calibration point consists of a level and the associated pulse rate.

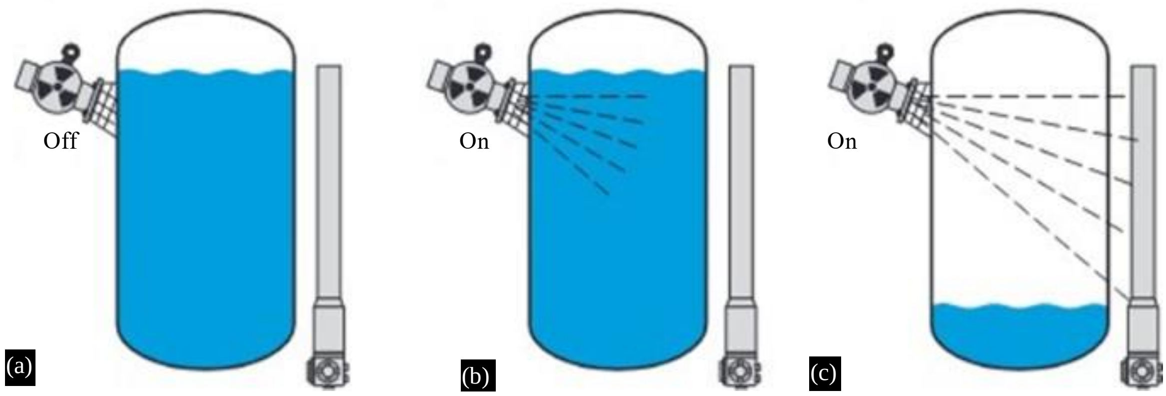


Figure 4.2. (b). (a) = Background calibration, (b) = full calibration, (c) = empty calibration

[Figure 4.2. (b) https://instrumentationtools.com/types-level-measurement]

Background Calibration:

Refers to the following situation:

- The radiation is switched off.
- Within the measuring range, the vessel is filled as far as possible (ideally: 100%)

The pulse rate of this background radiation is automatically subtracted from any other measured pulse rate. That means only the part of the pulse rate which originates from the applied radiation source is taken into account and is displayed.

Full Calibration:

Refers to the following situation:

- The radiation is switched on.
- Within the measuring range, the vessel is filled as far as possible (ideally: 100%, minimum 60%)

Empty Calibration:

Refers to the following situation:

- The radiation is switched on.
- Within the measuring range, the vessel is emptied as far as possible (ideally: 0%, maximum 40%) [7].

Advantages of Nucleonic Level Measurement:

- It's used in Level, interface, density, concentration and point level measurement
- It can be utilize measurement in liquids, solids, suspensions or sludges
- It's also used in extreme process conditions: high pressure, high temperature, corrosion, abrasion, viscosity, toxicity and all kinds of process vessels, e.g. reactors, autoclaves, separators, acid tanks, cyclones. [Ref 1.1]

Disadvantages of Nucleonic Level Measurement:

- It's a Radioactive Material which has 1 mSv / hr (5 cm) radiation emission and 20 uSv / hr (1 m) which is detected by rae.
- Restricted Availability in Market
- It requires periodic maintenance for safety [1].

Mandatory Requirements for Installation:

- To use nucleonic level measurement, it's required to have an authorized license affiliated to BARC, India and Atomic Energy Regulatory Board [13].
- To install Nucleonic level measurement, it'll require special training organized by BARC, India. The officer is a Radiological Safety Officer [14].

Applications of Nucleonic Level Measurement:

- Oil & Gas Industries
- Polymer Processing Unit
- Fluid Catalytic Cracking Unit
- Chemical Processing
- Power Generation
- Mining & Mineral Processing
- Water & Wastewater Treatment

Fluid Catalytic Cracking Unit

In the oil and gas industry, the FCC unit is a very crucial process, it's used to convert high boiling point, heavy hydrocarbons into lighter, more valuable products like gasoline and diesel. The Reactor

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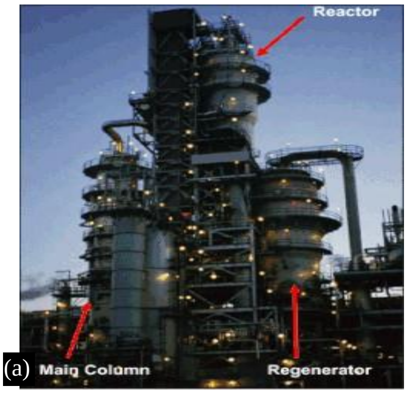
Regenerator is the heart of the FCC unit, which also includes the separation of catalysts from the Flue gasses. Extracted catalysts are disposed of to prevent the emission of catalysts to the environment [8 and L&T Internal Documents].

This unit is used to yield maximum volumes of high-rating gasoline. Images of FCC are as follows.

(a)


(b)


Figure 5. (a)Reactor- regenerator (b) Fluid catalytic cracking unit

[Figure 5. (a) https://en.wikipedia.org/wiki/Fluid_catalytic_cracking]

[Figure 5. (b) https://twitter.com/SPGlobal/status/1725318016303329529]

The following are the parts of the FCC Unit:

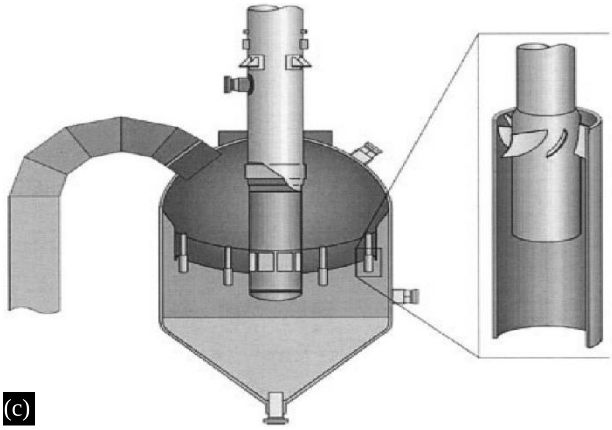
- Feed Preheat System
- Air Supply System
- Reactor / Regenerator
- Flue Gas System
- Catalyst Storage

To prevent catalyst emission to the environment there is a catalyst separation system which includes the Third Stage Separator (TSS), Fourth Stage Separator (FSS), Fluid Collection Hopper (FCH) and Fluid Disposal Hopper (FDH) are present.

In the separation system flue gas enters in TSS from Rx-Rg (Reactor Regenerator). The TSS has a central inlet for the flue gas, which is distributed evenly over several parallel axial flow cyclones, called swirl tubes (see Figure). The swirl tubes allow thermal expansion of all parts of the swirl tubes without the risk of developing stresses, as would be the case with asymmetrical, tangential cyclones.

During the actual separation process, separated dust (catalyst fines) drops into the bottom conical part of the TSS and is removed with the assistance of some gas underflow. The underflow gas and the dust are separated in the Fourth Stage Separator (FSS).

Whereas FSS cleans the underflow gasses coming from TSS which has an operating temperature range of about 650 and 700 in normal conditions, a high particle density of 1450 $kg/m^{3,}$ and a high vapor flow rate of 245,546 kg/hr. During times when the Fines Collection Hopper (FCH) is emptying into the Fines Disposal Hoppe (FDH), the FCH will be closed off from the FSS which is in direct contact with it. During this time, fines will build up in the bottom cone of the FSS Filter vessel. The FSS filter supplier shall determine the storage capacity for the FSS Filter vessel to support this. The FSS will be supplied with a Fines Collection Hopper (FCH) vessel for the transfer of catalyst fines from the FSS towards the Fines Disposal Hopper (FDH). This will allow the Fines Collection Hopper to be operated at a suitable pressure for both catalyst cooling and FCH unloading without affecting FSS /TSS operation.


(c)
Figure 5. (c) Third Stage separator & swirl tubes.

[Figure 5. (c) https://www.semanticscholar.org/paper/Numerical-Model-and-Analysis-on-Performance-of-a-Saberi]

The fines collected by the FSS will be discharged via the Fines Collection Hopper (FCH) into a Fines Disposal Hopper (FDH) for storage and cooling. For the detection of levels in FSS, FCH, and FDH Nucleonic LT is used due to its features such as high temperature, solid substance detection, and high density of catalysts making it a suitable choice concerning other noncontact type LTs. [10-12 and L&T Internal Docs]

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REFERENCES
1. Wikipedia Contributors. Level of measurement [Internet]. Wikipedia. Wikimedia Foundation; 2019. Available from: https://en.wikipedia.org/wiki/Level_of_measurement
2. Level measurement [Internet]. www.endress.com. [cited 2024 Jul 29]. Available from: https://www.in.endress.com/en/field-instruments-overview/level-measurement
3. Abmsensor. What is level measurement? Importance, Methods & Technologies [Internet]. ABM Sensor Technology. 2023. Available from: https://abmsensor.com/level-measurement/
4. Level Measurement | Emerson US [Internet]. www.emerson.com. [cited 2024 Jul 29]. Available from: https://www.emerson.com/en-us/automation/measurement-instrumentation/level
5. Craig B. Types of Level Measurement Transmitters & How Do They Work? [Internet]. www.transmittershop.com. 2018. Available from: https://www.transmittershop.com/blog/level-measurement-transmitters-work/
6. Direct and Indirect Methods of Level Measurement [Internet]. SCG Process. 2020. Available from: https://scgprocess.com/direct-and-indirect-methods-of-level-measurement/
7. Staff E. Nuclear Interface Level Measurement Principle, Limitations, Installation and Calibration [Internet]. Inst Tools. 2018 [cited 2024 Jul 29]. Available from: https://instrumentationtools.com/nuclear-interface-level-measurement

8. Technical data on nucleonic gauges [Internet]. 2005. Available from: https://www-pub.iaea.org/MTCD/publications/PDF/te_1459_web.pdf
9. https://barc.gov.in/ebooks/9788195473328/paper10.pdf
10. Eia.gov. 2016. Available from: https://www.eia.gov/todayinenergy/detail.php?id=9150
11. Wikipedia Contributors. Fluid catalytic cracking [Internet]. Wikipedia. Wikimedia Foundation; 2019. Available from: https://en.wikipedia.org/wiki/Fluid_catalytic_cracking
12. Fluid Catalytic Cracking - an overview | ScienceDirect Topics [Internet]. www.sciencedirect.com. Available from: https://www.sciencedirect.com/topics/chemistry/fluid-catalytic-cracking
13. https://www.barc.gov.in/barc_nl/2023/2023030415.pdf
14. RSO/Safety Training [Internet]. www.aerb.gov.in. [cited 2024 Jul 29]. Available from: https://www.aerb.gov.in/english/rso-training

