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"Advanced Method for Portable Density / Moisture Gauges with Radioactive Sources for Calculating the Field Density"

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Abstract: A **Nuclear Density Gauge** is a tool used in civil construction, the petroleum industry, Highways Networks, Water Engineering etc. as well as for mining and archaeology purposes. It consists of a radiation source that emits a cloud of particles and a sensor that counts the received particles that are either reflected by the test material or pass through it. By calculating the percentage of particles that return to the sensor, the gauge can be calibrated to measure the density and inner structure of the test material.

Soil compaction is essential in filling areas of Industrial building Foundations, Oil well fields, Equipments foundations, Pavements and road construction. The evaluation of the degree of compaction relies on the knowledge of density and moisture of the compacted layers is very important to the performance of the pavement structure. Among the various tests used for making these determinations, the sand replacement density test and the moisture content determination by oven drying are perhaps the most widely used. However, these methods are not only time consuming and need wearing some procedures to obtain the results but also destructive and the number of measurements that can be taken at any time is limited. The test can on be fed back to the construction site the next day. To solve these problems, a nuclear technique has been introduced as a quicker and easier way of measuring the density and moisture of construction materials. Nuclear moisture density gauges have been used for many years in pavement construction as a method of non-destructive density testing. The technique which can determine both wet density and moisture content offers an in situ method for construction control at the work site. The simplicity, the speed, and non-destructive nature offer a great advantage for quality control.

Keywords: Nuclear, Radioactive, Gamma Radiations, Density of Materials, Moisture Contents, Radiography, Quality Control and Quality Assurance, Moisture Content, Surface Modulus.

I. INTRODUCTION

Modern, especially automatic, production methods need to be constantly monitored in order to check the quality of the products and to control the production process. Such monitoring is often carried out by quality control devices using the unique properties of ionizing radiation. These devices are called nuclear gauges. They do not need to be in contact with the material under examination and so can be used to monitor: high speed processes; materials with extreme temperatures or harmful chemical properties; materials that are damaged by contact; and packaged products. The beta, gamma and X radiations used do not damage or change the material in any way. However, neutron radiation can be used specifically to induce changes such as radioactivity as a means of detection.

Different variants are used for different purposes. For density analysis of very shallow objects such as roads or walls, a gamma source emitter such as Cesium is used to produce gamma radiation. These isotopes are effective in analysing the top 10 inches (25 centimetres) with high accuracy. Radium is used for depths of 328 yards (300 meters). Such instruments can help find caves or identify locations with lower density that would make tunnel construction hazardous.

Nuclear density gauges can also be used to measure the density of a liquid in a pipe. If a source is mounted on one side of a pipe and a detector on the other, the amount of radiation seen at the detector is dependent upon the shielding provided by the liquid in the pipe. Tracerco pioneered the use of radiation to measure density in the 1950 and determined that the Beer–Lambert law also applied to radiation as well as optics. Gauges are normally calibrated using gas and a liquid of known density to find the unknowns in the equation. Once it has been calibrated and as long as the source detector alignment remains constant, it is possible to calculate the density of the liquid in the pipe. One factor is the half-life of the radioactive source (30 years for Cs), which means that the system needs to be recalibrated at regular intervals. Modern systems incorporate correction for source decay.

Another variant is to use a strong neutron source like Americium / Beryllium to produce Neutron radiation and then measure the energy of returning neutron scattering. As hydrogen characteristically slows down neutrons, the sensor can calculate the density of hydrogen - and find pockets of underground water, humidity up to a depth of several meters, moisture content, or asphalt content. Neutron sources can also be used to assess the performance of a Separator (oil production) in the same way. Gas, oil, water and sand all have different concentrations of hydrogen atoms which reflect different amounts of slow neutrons. Using a head which contains an AmBe neutron source and a slow neutron detector, by scanning it up and down a separator it is possible to determine the interface levels within the separator.

II. TYPES OF GAUGES

Installed gauges usually operate automatically. They are either of fixed or scanning (moving back and forth) type. Portable gauges are intended for use in different locations. All installed and portable gauges consist of a source housing from which the radiation is emitted and at least one detector which either measures the dose rate after the radiation has interacted with the material or identifies the type and energy of the radiation that reaches it. Gauges can be categorized according to what happens to the radiation before it reaches the detector. There are three categories:
(1) Transmission gauges
(2) Backscatter gauges
(3) Reactive gauges.

A) Transmission Gauges

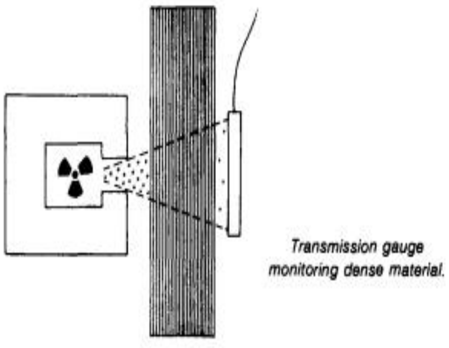


Figure No.1: Transmission gauge Monitoring dense materials

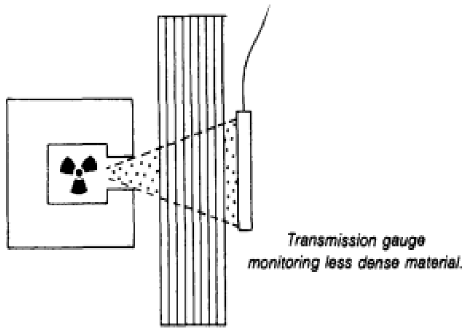
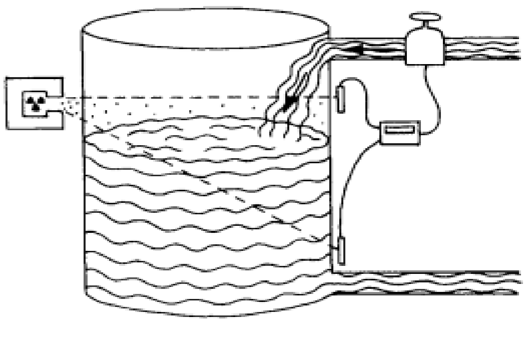


Figure No. 2: Transmission gauge monitoring less dense materials



Transmission level gauges.
Figure No. 3: Transmission gauge monitoring dense materials

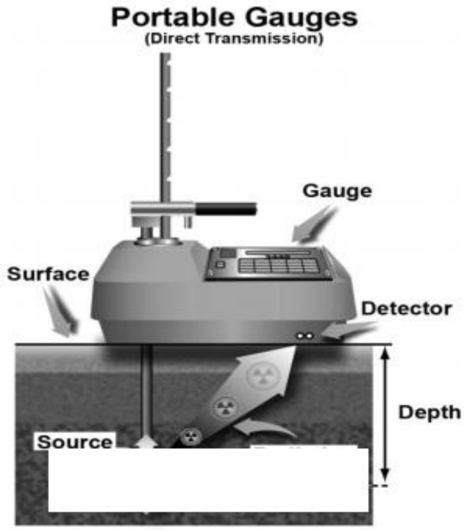
If there is constant geometry, i.e. the radiation passes through a constant thickness of material or through a pipeline or vessel, the detector will measure or respond to changes in the density of the material through which the radiation has travelled. If the radiation has to travel through a more dense material its attenuation increases and the count rate is reduced. The detector similarly senses a reduction in density. This principle is used by density gauges (for example to control the density of cement and drilling lubricants flowing through pipelines) and by level gauges to control the minimum and maximum contents of vessels.

If the density of the material is constant the detector will measure or respond to changes in the geometry such as the thickness of the material passing between the source and detector. The attenuation will increase with increased thickness. This principle is used by thickness gauges, for example to control the production of sheet metal. The radiation source is chosen to provide the range and penetration needed.

Radiation Sources	Typical Transmission Gauge Applications
Promethium - 147 (beta)	Density of Paper
Thalium - 204 (beta)	Thickness of paper, rubber and textiles
Krypton - 85(beta)	Thickness of Cardboard
Strontium / Yttrium - 90 (beta)	Thickness of thin metals, tobacco content of cigarettes and packages
X Rays	Up to 20mm steel; liquid level in cans
Americium - 241 (gamma)	Up to 10mm steel; contents of bottles
Caesium - 137 (gamma)	100mm steel; content of pipelines / tanks
Cobalt - 60 (gamma)	Contents of coke ovens, bricks klins, etc.

Table No. 1: Various Radiation Sources through Transmission Gauge Applications

The beta source activities usually range from 40MBq to 40GBq while gamma sources usually contain between 0.4 and 40GBq.



Direct transmission is typically used for a soils or a PCC bridge deck application. For soils testing, an access hole is made with the drill rod and the source rod is lowered to a predetermined depth, up to 12 inches. To determine the density of plastic PCC, the source rod is lowered into the freshly placed concrete. Direct transmission is more accurate than backscatter transmission.

B) Backscatter Gauges

The detector and the source housing are mounted on the same side of the material. The detector is shielded against primary radiation. The radiation enters the material and interacts with the atoms and molecules. There will be more 9 interactions in thicker or more dense materials. The detector measures the secondary radiations which are scattered back from the interactions. Again, if there is constant geometry, the gauge will indicate the material density and if the density is constant, the gauge will indicate the material thickness.

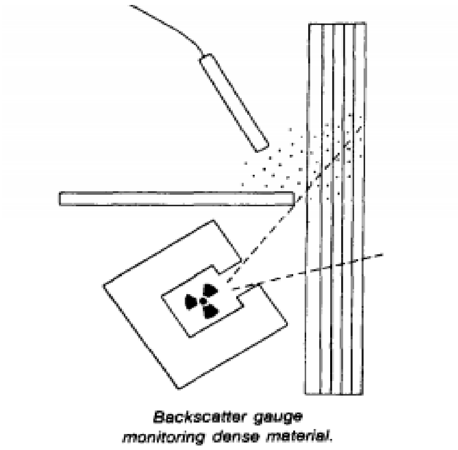


Figure No. 4: Backscatter gauge
Monitoring dense materials

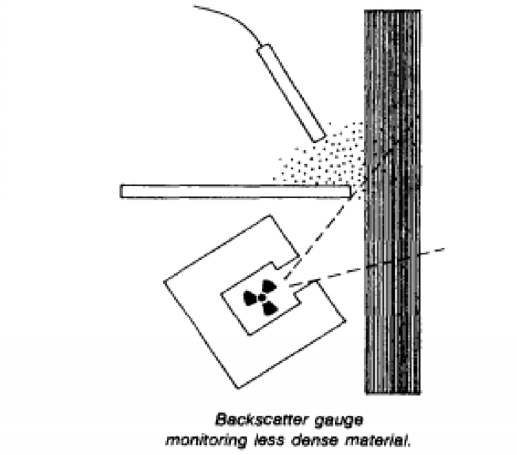


Figure No. 5: Backscatter gauge
monitoring less dense materials

The radiation source is carefully selected to suit the application. Backscatter gauges which use gamma and X radiation can be more sensitive to the presence of lighter elements, such as carbon, than transmission gauges using the same primary radiation. If neutron radiation is used, the amount of backscatter can indicate how many hydrogen atoms are present in the material. This principle is used, for example, by: moisture gauges in paper production; road gauges that measure the characteristics of tarmacadam surfaces; and porosity gauges which measure the water or hydrocarbon content of subsurface rocks.

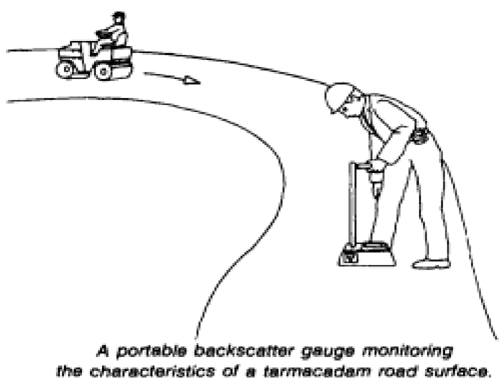
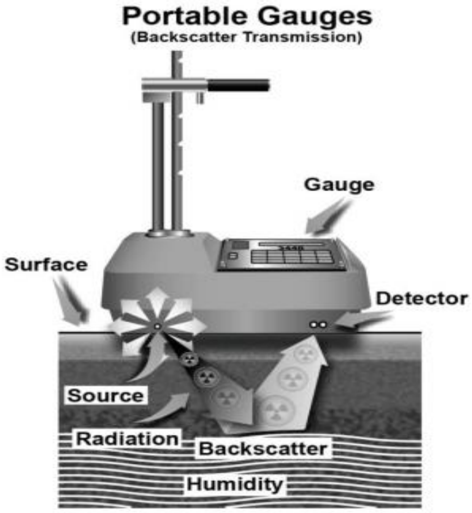


Figure No. 6: Portable Backscatter Nuclear Gauge

Radiation Sources	Typical backscatter Gauge Applications
Promethium - 147 (beta)	Thickness of paper, thin metal coatings
Thalium - 204 (beta)	Thickness of thin rubber and textiles
Strontium / Yttrium - 90 (beta)	Thicknesses of plastics, rubber, glass and thin light alloys
Americium - 241 (gamma)	Up to 10mm glass and 30mm plastic
Caesium - 137 (gamma)	Glass beyond 20mm; rock/coal densities
Americium - 241 / beryllium	Detection of hydrocarbons in rocks

Table No. 2: Various Radiation Sources through Backscatter Gauge Applications

The beta source activities usually range from 40 to 200 MBq while gamma sources can contain up to 100 GBq.



Backscatter transmission is typically used for asphalt tests. The first depth notch on the gauge is the backscatter position. This will open the sliding block and place the source rod at the base of the gauge and at the top of the testing surface (No access hole is drilled for a backscatter test). The gamma ray photons will penetrate the material to a maximum depth of 3–4 inches before making their way to the Geiger-Mueller detector tubes at the far side of the gauge.

C) Reactive Gauges

Certain low energy gamma and x rays can ionize specific atoms, causing them to emit fluorescent x rays of characteristic energy. The detector measurement of the fluorescent X rays indicates not only the presence of the specific atoms but also the amount in the material. This principle is used by gauges which analyze the constituents of materials such as ores and alloys and by gauges that measure the thickness of coatings on substrates of dissimilar materials.

Electrically operated high energy neutron generators can be used to induce non-radioactive substances to become radioactive. The radionuclides formed emit characteristic gamma rays which can be identified by their energy. These gauges or logging tools are used to prospect for oil.

Radiation Sources	Typical Reactive Gauge Applications
Iron - 55 (0.21 MeV X ray)	Analysis : Low mass elements 0 - 25 mm plastic on aluminium
Americium - 241	Analysis : Low mass elements 0 - 100 mm zinc on iron
Cadmium - 109 (0.088 MeV X ray)	Analysis : High mass elements
X rays (up to 60Kv)	Analysis : Range of elements
Neutron Generators	Analysis of Hydrocarbon in rocks

Table No. 2: Various Radiation Sources through Reactive Gauge Applications

The source activities used range from about 200 MBq to 40 GBq.

III. EQUIPMENT USED FOR GAUGING

The radioactive closed sources used in gauges are often in Special Form (see Basics Guide), especially the gamma emitters. The source should be locked into the housing which is usually a sealed, shielded container.

Gamma source housings normally incorporate lead shielding designed to col I i mate the radiation into a primary beam and direct it into the material towards the detector's position. The shielding should preferably reduce all readily accessible dose rates outside the housing to less than 7.5 $\mu Sv\text{-}h^{-1}$. Weight constraints may prevent this, in which case a simple mechanical guard or barrier should prevent access.

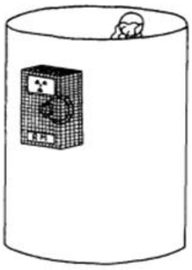


Figure No. 7: A mechanical guard preventing acess to high dose rates clsoe to a level gauge source housing.

A shutter should be provided so that the radiation source can be completely surrounded by shielding when it is not in use. It is often possible to arrange for the shutter to close automatically when there is no material in front of the gauge. A clear indication should be provided and maintained to show whether the shutter is open or closed.

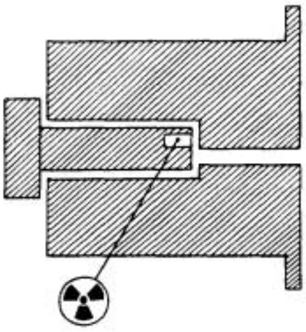


Figure No. 8: A gamma source housing (sectioned) with its shutter closed.

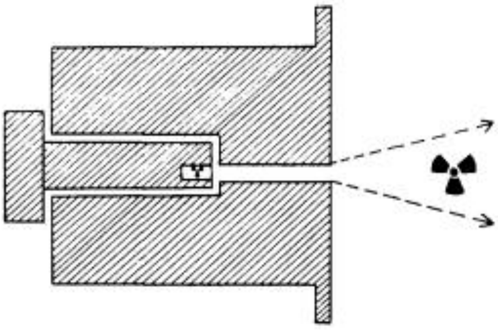


Figure No. 9: A gamma source housing (sectioned) with its shutter open.

Details of the installed source, including the name of the radionuclide, its activity on a specified date and its serial number, should be shown on a tag on the outside of the source housing.

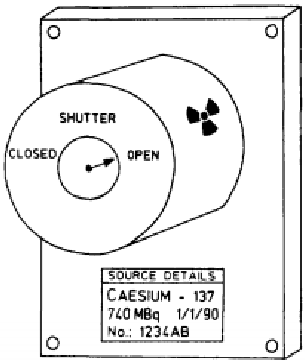


Figure No. 10: Clear markings on the outside of the gauge source housing.

The gauge housing and any guard which marks the extent of a Controlled Area should display suitable warning notices.

IV. RADIATION PROTECTION FOR GAUGES

The main consideration for gauges, especially those which contain beta emitters, is to prevent access to the very high dose rates which are normally in the primary beam close to the outside of the gauge. This can be achieved by arranging for the material to be measured to provide the necessary shielding and by arranging automatic shutters to close when the material is not there. Alternatively, it can be made physically impossible for anything other than the material to enter this area.

Controlled Areas may be necessary on both sides of the material of both transmission and backscatter gauges. Access to these areas, and to the primary beam, can be prevented by fitting narrowly separated parallel plates, called guide plates, through which the material must pass. Access to the primary beam of a level gauge mounted on a large vessel should be possible only when either the gauge is removed from its installed position or the vessel is opened for access. Sufficient warnings should be given to ensure that the gauge shutter is locked in the closed position before these actions are taken.

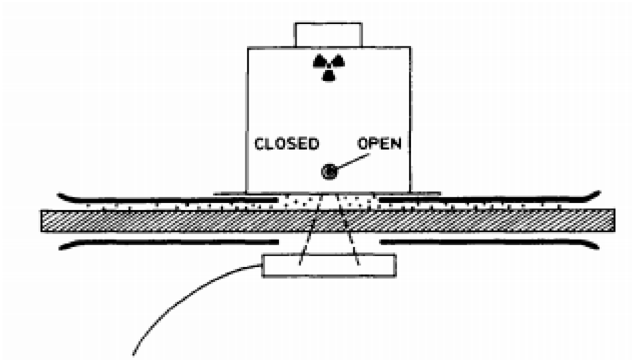


Figure No. 11: Shielding for a transmission gauge to prevent access to the primary beam and scattered radiation.

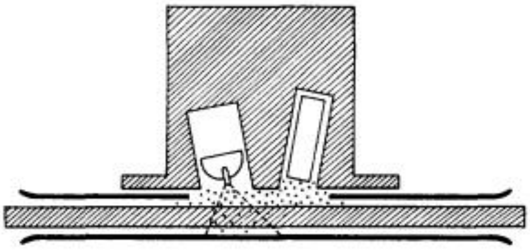


Figure No. 12: Shielding for a backscatter gauge (shown sectioned) to prevent access to backscattered and transmitted radiation.

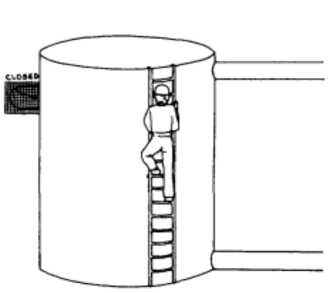


Figure No. 12: A level gauge shutter closed before maintenance is carried out inside the vessel

Local shielding which it has been necessary to add to a gauge, for example as a beam stop to attenuate the beam after it has passed through the detector, should be fixed in place. Essential shielding should, where practicable, be interlocked with the gauge shutter. This means that the shielding is mechanically or electrically linked to the shutter so that the shutter automatically closes when the shielding is removed. A notice which bears the trefoil symbol and a suitable legend should be displayed on essential shielding.

The type of shielding material which might be needed will depend on the type and energy of radiation it is to attenuate. Gauges that contain beta emitters may still need shielding against X rays (bremsstrahlung) which are generated when the beta particles are absorbed by surrounding heavy materials. Measuring the range of the radiation or the half value thickness will indicate which shielding materials, and what thickness, to use.

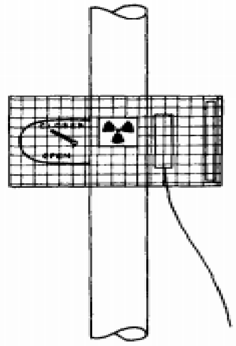


Figure No. 12: A mechanical guard and beam stop prevent access to the primary beam of a transmission density gauge

Distance can be at least as effective as shielding materials in reducing the dose rate. A suitable dose rate meter is necessary for monitoring purposes and establishing that radiation levels are satisfactory.

V. PORTABLE GAUGES

It is not always feasible to install an interlocked shutter in the source housing of a portable gauge and extra care needs to be taken to ensure that the useful beam is not directed towards the operator. When the shutter is open dose rates around the gauge may be such as to require the establishment of a Controlled Area which will need to be identified by a barrier, suitable notices or other means.

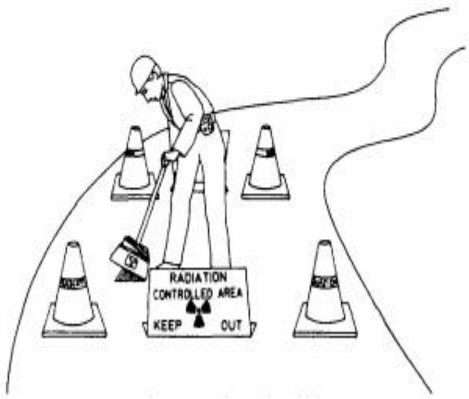


Figure No. 13: A controlled area in which a portable backscatter gauge is being used.

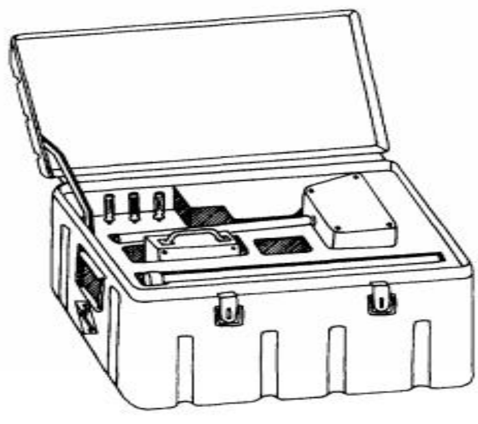


Figure No. 13: A transport container for a portable gauge.

Portable gauges should be transported in accordance with transport regulations. Where the housing of the gauge does not meet these requirements, gauges should be placed within a suitable container that satisfies the transport regulations. Type A containers are often adequate for gauges that contain relatively low activities but if the activity exceeds limits which are specified in the IAEA Regulations for the Safe Transport of Radioactive Materials then a Type B container will be required. These containers are more rigorously tested and certified. In addition to appropriate documentation the transit case will need to display labels to identify the associated dose rates as either category I, II or III:

Transport container label category	**Maximum allowed dose rates (mSv. h-1)**	
	At the surface of the container	**At 1mtr from the surface of the container**
I	5	
II	500	10
III	2000	100

Table No. 3: Various Radiation Sources through Reactive Gauge Applications

The labels have to be marked with the name of the radionuclide and the activity contained (for example 200 MBq). Category II and III labels must be marked with the transport index, which is the maximum dose rate at 1 m from the container surface measured in/iSv-h-1 divided by ten. For example, if 12 ^Sv-h-1 is the maximum measured dose rate at 1 m from a container, its transport index would be 1.2.

VI. HANDLING OF SOURCES

Some gauges, for example reactive gauges, require sources to be changed periodically. Others, for example backscatter gauges (logging tools) used at different locations to measure the characteristics of subsurface rocks, need the source and the gauge housing to be transported separately. These and other source changing operations require special, long handled tools. Their length will range between 10 cm and more than 1 m, depending on the nature of the radioactive sources being manipulated and the frequency of the work.

Figure No. 14: A long handling tool is used to transfer a gamma source from its transport container to the gauge.

The operator should have ready access to a suitable dose rate meter with which to monitor source handling procedures.

VII. MAINTAINING GAUGES

Gauges are often installed in industrial plants and exposed to the weather and other conditions which can cause a significant deterioration of the container's markings and even the shutter mechanism. Regular maintenance of moving parts and refurbishment is therefore particularly important. Such work should not involve removing the source. The condition of portable gauges can also rapidly deteriorate when, like road gauges and ore analysis gauges, they are used under site conditions. Daily cleaning and regular maintenance are vital. A dose rate meter should be used to confirm that the shutter is closed before these operations are carried out.

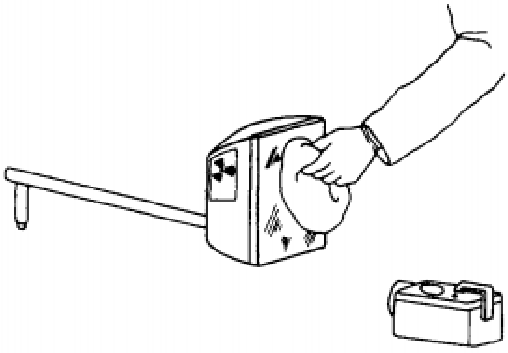


Figure No. 15: A check is made to ensure that the shutter is closed before carrying out essential maintenance on a gauge.

It is likely that the source will give reliable service for a number of years. Leak tests should be carried out at the intervals required by the regulatory authority or recommended by the manufacturer or following any incident in which the source might have been damaged. Permanently installed sources are generally subject to less demanding conditions but even here should be tested at least every two years. They need not be wiped directly. A piece of moistened paper or cloth can be used to wipe around the container where radioactive substance might be expected to emerge if the source was leaking. Sources which are manipulated or are subjected to more adverse conditions will need to be leak tested much more frequently, for example biannually. They are usually tested more directly by wiping a surface that has been in direct contact with the source. Care needs to be taken with sealed sources which emit low energy radiation. Directly wiping the surface of the source could damage a thin 'window' where the radiation is intended to emerge. Wipes should only be handled with tweezers or tongs. Sensitive detectors are needed to measure accurately how much radioactive substance is on a wipe but gross contamination will possibly produce a significant dose rate. For example, gross contamination in excess of 600 kBq caesium-137 or much less cobalt-60 will produce measurable dose rates of at least 5 /xSvh-1 at 10 cm. The amount of leakage which is acceptable is much lower than this.

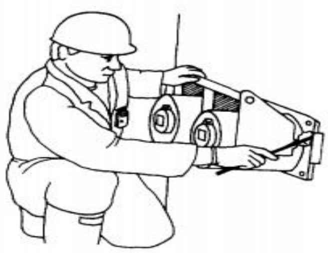


Figure No. 16: A leak test being carried out on an installed gauge which contains a permanently housed source.

VIII. STORAGE AND ACCOUNTING FOR GAUGES

Gauges awaiting installation, and portable gauges and interchangeable sources, may only have sufficient shielding to enable them to be carried for short periods and to be transported. No one should stay close to or handle them for longer than is necessary. A special store reserved for the purpose should be provided where gauges and their sources can be kept while they are not in use. This store should not contain other hazardous materials such as chemicals or compressed gases. It should be dry and, if necessary, ventilated. Clear warning notices should be displayed. The dose rates outside should generally be less than 7.5 ^Svh-1 or, preferably, less than 2.5 ^Svh-1.

The store should be kept locked to prevent unauthorized persons entering the higher dose rate areas inside or tampering with a gauge or its sources. The key should be kept in a safe place.

A record should be kept showing where each source is at all times. A weekly check might be made on portable gauges and sources to ensure that they are safely stored. A less frequent check, perhaps monthly, may be more appropriate for installed gauges.

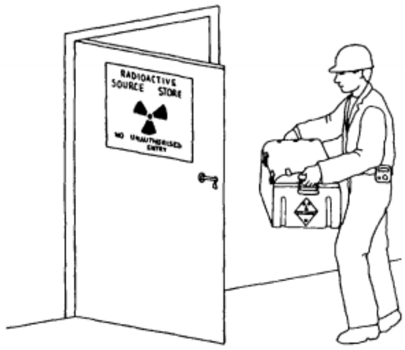


Figure No. 17: A portable gauge is returned to the source store.

IX. WORKER PROTECTION

Workers operating in areas where gauges are installed are not likely to be exposed to significant radiation levels and do not need to wear dosimeters.

Source changing operations can result in the operator accumulating a dose over a short period of time. The dose should be kept as low as reasonably achievable by using the handling tools provided and practicing efficient procedures that will keep the exposure times as short as possible. Therefore, it may be necessary for the operator to wear a personal dosimeter while working close to the source container. In the manipulation of sources that emit short range radiation, it may also be necessary to measure the doses to the hands to ensure that they do not accumulate significant dose.

X. DEALING WITH EMERGENCIES

It is important to be both able to identify, and prepared to deal with, problems involving a nuclear gauge. A thorough assessment of the equipment and its use will indicate abnormal situations which might occur. Contingency plans are needed which can be implemented quickly and effectively to regain control in the event that a problem arises. For example, the plans might define immediate actions to deal with the following:

- A gauge or a source that has been lost or stolen;
- Physical damage to a source housing that has been crushed or involved in a fire or explosion;
- Leakage of radioactive substance from a sealed source;
- The discovery of unacceptably high dose rates after a shutter or warning signal failure;
- The exposure of a person because of a failure of the equipment or procedures

If a radioactive source is lost, even while within its housing, attempts should be made to find it as quickly as possible. High sensitivity radiation monitoring Instruments, capable of measuring low dose rates or contamination, can help to detect radiation from the source, especially if it is unshielded.

A source suspected of leaking a radioactive substance must be isolated as soon as possible. Direct contact with the source and its housing should be avoided. Surfaces that come into both direct and indirect contact with the leaking radioactive source will become contaminated. Measures should be taken to prevent ingestion of radioactive substances that can result when clothing and surfaces of the body become contaminated. Specialist help and the use of surface contamination meters will be needed to identify the affected surfaces and to carry out effective decontamination procedures

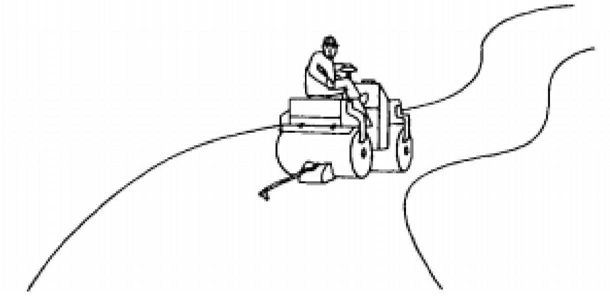


Figure No. 18: An incident which might result in the release of radioactive substance causing surface contamination

Any incident which may have resulted in an internal or an external dose to a person should be investigated. It is important to determine whether a suspected or reported dose was received and whether any part of the body has received a much higher dose which might result in localized tissue injury.

XI. THE SPECIFIC LICENSE

Moisture density gauge owners are required to have a "Specific License" from ***"International Atomic Energy Agency***". A specific license allows for the use of a device with sealed sources and places the responsibility of protecting the general public and environment in the hands of the licensee. The sealed sources must only be used in the device and for the purposes intended as described in the license.

The specific license identifies the radioactive material in its chemical and physical form, maximum activity and the purposes for which it may be used. A specific license requires the licensee to have appropriately trained and qualified personnel, appropriate facilities, equipment and procedures to ensure safe operations.

XII. ENFORCEMENT

The regulations and the conditions of your license can be enforced by the NRC, Agreement States, the U.S. DOT (including divisions such as the FAA), the EPA, law enforcement (including the FBI), fire and rescue, and other federal, state and local agencies.

XIII. PROTECTING THE GENERAL PUBLIC, PROPERTY AND OUR EMPLOYEES

The mission of the regulatory agencies is to protect persons and property from any harmful effects of radioactive materials. That includes our employees. The agencies will conduct inspections and issue penalties to assure their mission is met. The DOT will be charged fees, including those for licensing, amendments, inspections, reciprocity and penalties, to help fund these agencies. Another mission of the regulatory agencies is to help us run an effective and successful gauge radiation safety program.

XIV. THE RADIATION SAFETY OFFICER (RSO)

Your license requires that senior management designate an individual as Radiation Safety Officer (RSO). This individual will establish, maintain, enforce and control the company gauge radiation safety program and act as the contact person for the regulatory agency. When the Department is contacted or inspected by the regulatory agency they will want to speak with the RSO. Senior management is required to supply the RSO with the necessary means, including training, to carry out the position of RSO and should work with the RSO to make sure that all conditions and compliance of the license are met.

The RSO will maintain complete, accurate and organized records. The RSO is responsible for making necessary amendments and notifying the regulatory agency of these amendments. The RSO will keep the safety program updated as to any changes in the regulation

XV. PROCEDURE GUIDE FOR NUCLEAR GAUGES

Procedures Guides - Nuclear Gauges	
	Follow authorized procedures when working with nuclear gauges. Only trained and authorized workers should carry out the work. If appropriate, the workers should have had medical examinations and wear dosimeters. Before proceeding with the work, read and ask questions about these safety guides. Discuss with your colleagues your contributions to this important work.

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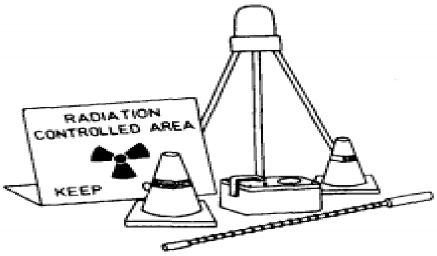
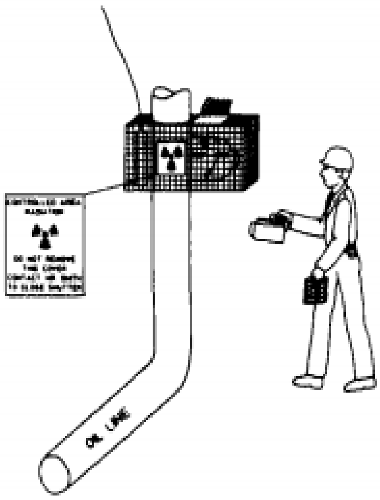


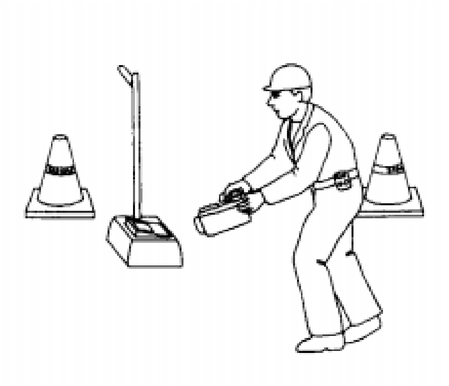
Use only established methods, suitable equipment and a sealed source of an activity which is appropriate to the gauge's purpose. A portable gauge should be used only when all the necessary ancillary equipment which is associated with the particular gauge is also available. This might include source handling tools, barriers, warning notices and signals and a dose rate meter.

Keep safe and properly stored:
— any source or housing which is waiting to be installed;
— any source housing which has been removed from its installation; or,
— any portable gauge which is temporarily not in use.
Make regular, for example weekly, entries in a record to show that a check has been made on the stored items.
Keep a record to show where installed gauges are.

Guides - Nuclear Gauges

Keep the key for the source store in a safe place.
Before removing a gauge or interchangeable source from the

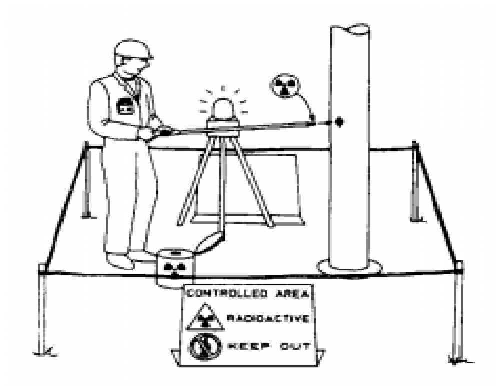
	store remember to record who has them and where they are being moved to. Check that the container is locked and use a dose rate meter to confirm that the source is shielded.This also serves as a check on the dose rate meter. Attach two transport labels to the container and display warning placards on the vehicle. Keep the container segregated from the occupants.
	Check installed gauges periodically, for example monthly, to confirm that they are safely installed. Measure accessible dose rates and ensure that a physical barrier marks the extent of any Controlled Areas. Block any gaps in the shielding which might be inaccessible to the dose rate meter but not to fingers and hands.This is especially important if the gaps provide access to the primary beam. Check that the shielding is firmly secured. Check that warning signs are readable, especially on shielding and access doors or panels. Maintenance workers should be reminded which person is to be contacted to ensure that the shutter is locked in the closed position before they enter these areas.



Before using a portable gauge, or working on an installed gauge, set up a barrier and warning signs either to mark the extent of the Controlled Area or as an indication to otherpersons in the vicinity to keep clear. Never leave a Controlled Area unattended.

Whilst working with a gauge, keep the dose rate meter with you and switched on. Use the dose rate meter to check that the shutter has closed after you have used a portable gauge. Likewise, check that the shutter is locked in the closed position before removing an installed gauge from its position.

Procedures Guides - Nuclear Gauges

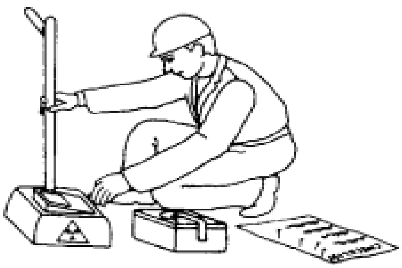


Unless you are specifically trained and authorized to do so:

— never attempt to remove a source from its housing; and,

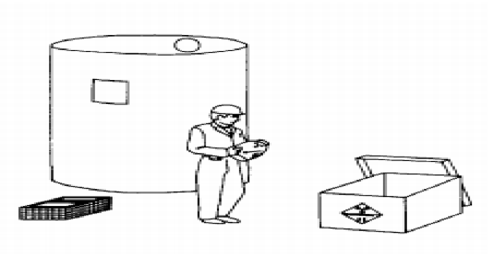
— never attempt to modify or repair the housing.

Appropriate handling tools and approved procedures must be used by persons who are responsible for manipulating sources. A source must not be allowed to be in contact with any part of a person's body



Carry out the necessary routine maintenance. A portable gauge may require attention after each use but, before closely examining it remember to use the dose rate meter to check that the shutter has closed or the source is otherwise safely shielded. Installed gauges will need less attention.Keep a record to show that the regular maintenance hasincluded, for example:
(1) Cleaning the outside of the housing to remove grit and moisture.
(2) Ensuring that external surfaces of the gauge are kept in good condition and that label, warning signals and the tag displaying details of the source remain legible.
(3) Using recommended lubricants to clean and maintain any moving parts.
(4) Examining any screws and nuts for tightness.
(5) Checking to see that the source is securely held within the housing and that uniform dose rates are measurable on all external surfaces of the housing.
(6) Examining source handling tools for damage to springs, screw threads or the like.
(7) At the recommended intervals, and in the prescribed manner, carrying out leakage tests. Report any faults to your supervisor.

Procedures Guides - Nuclear Gauges	
	If a gauge is involved in an accident or incident stay calm. If the gauge is undamaged do what is necessary to make it safe. For example, using a dose rate meter, confirm that the shutter is closed and place the gauge in its transportcontainer. If the housing appears to be damaged move away from it and keep others away.Measure the dose rates and set up a barrier which marks the Controlled Area. If it is suspected that the source has been very badly damaged, prevent access to those surfaces which might be contaminated by the radioactive substance. Detain anyone who may either have received a radiation dose or been in contact with a contaminated surface. Stay close but outside the marked area and send someone to inform your supervisor and obtain help. A leak test will indicate whether a source has been seriously damaged. A gauge which might be damaged should not be reused until it has been examined and, if necessary, repaired by a competent, authorized technician.
	When work involving portable gauges or interchangeable sources is completed, a dose rate meter should be used to confirm that the sources are safely shielded. Ensure that any container still displays two legible transport labels. If a vehicle is used, it should display warning pacards to transport the container back to the source store. A note of the return of sources should be made in the record book. In the event of loss or theft of a source, inform your supervisor at once.

	As soon as you have no further use for a gauge or a radioactive source it should preferably be returned to the manufacturer or supplier. If any other method of disposal is used it must comply with your Government's laws. Radioactive substances being sent for disposal must be appropriately packaged and transported in accordance with the IAEA Regulations for the Safe Transport of Radioactive Material.

XVI. MISCELLANEOUS AUDIT, SOURCE AND GAUGE REQUIREMENTS

The following information should also be considered for inclusion in the Radiation Management Plan.

Results of Audits

The results of any audit of gauges or radioactive sources required by the code should be sent to the relevant regulatory authority.

General Radioactive Source Requirements

The radioactive sources used in portable density / moisture gauges should:-

- Only incorporate radioactive substances that have the minimum activity and half – life, consistent with the projected useful life of the gauge;
- Emit radiation of the type and energy appropriate for the particular application.

Radioactive substances that are very highly radiotoxic should not be used for portable density / moisture gauges, unless:

- No other suitable lower radiotoxicity substance is available; or
- The radioactive substance is being used to produce neutrons.

General Design Requirements of the Gauge

The radioactive sources should be either permanently mounted within the source housing of the gauge or permanently fixed in the moveable assembly. The gauge should be robust, easy to use and portable.

Radiation warning signs and labels

Radiation warning signs and labels, must conform to AS 1319 – 1994 safety signs for the occupational environmental, and AS 2342 – 1992 Development, testing and implementation of information and safety symbol and symbolic signs. Examples of suitable warning signs and labels are given below.

Colors for Radiation warning signs and labels

Background: Yellow
Marking and trefoil: Black

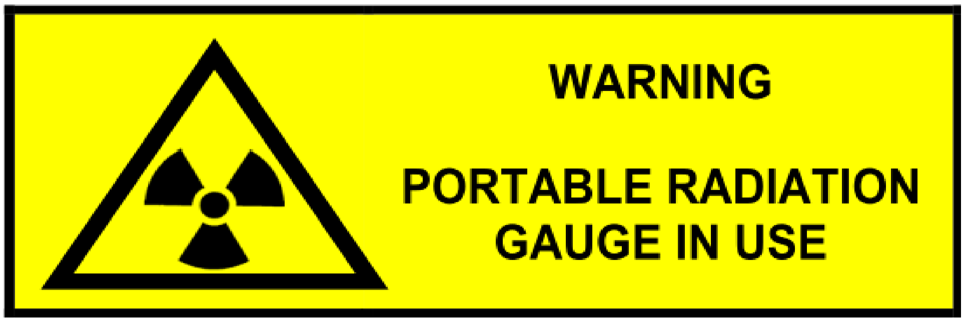


Figure No. 19: Example of a suitable warning sign for posting in the area adjacent to portable density / moisture gauge when in use:

Figure No. 20: Example of a suitable warning sign for a store

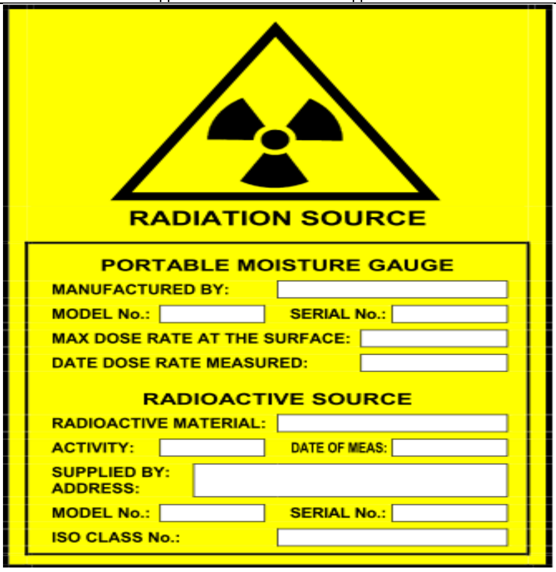


Figure No. 21: Example of a suitable warning label for attachment to a portable Density / Moisture gauge containing a radioactive source

Figure No. 22: Warning Radio – frequency Radiation Hazards

XVII. REFERENCE

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XVIII. AUTHOR PROFILE

Mr. Harshal Shankar Rao Khode is working as **Manager Technical (Corporate) - Consultant and Technical Researcher.** He has done **B. Tech in Civil Engineering** from Nagpur University in **2004.** He will receive him **Executive MBA IN Business Administration and Specialization in Project and Quality Management system** in **July 2012** form Delhi University. Harshal are especially area of Research and development is Advance Concrete Technology. He has published this year (2019-2020) about 8 papers till date in national and international conference and in other International journals also. He is the life and license member of **Institute of Engineer, Bureau of Indian Standards, ACI,ASTM, BSI and many more Technical organizations.**He is continuously involved in Technical research, development and analysis of new concepts evolving in **Technical, Project Management, Quality Management system, Structural Technologies and construction aspects.** Aspiring researchers for new horizons of trends in Civil, Water, Environment, Safety and Structural engineering.