

Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production

API BULLETIN E2
SECOND EDITION, APRIL 2006



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Upstream Segment

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FOREWORD

This bulletin on the management of naturally occurring radioactive materials (NORM) has been prepared by API to provide relevant guidance to oil and gas operating companies. This publication is under the jurisdiction of the API Production Waste Issues Group under direction of the Executive Committee of Environmental Conservation.

Cooperative efforts between federal and state regulatory agencies, industry, and other interested parties are expected to generate much useful information regarding NORM in the next several years. This document will be updated as new scientific information becomes available concerning NORM.

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Suggested revisions are invited and should be submitted to the Standards and Publications Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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SECTION 1—GENERAL

1.1 INTRODUCTION

Naturally occurring radioactive materials (NORM) are present in oil and gas operations at some locations and can deposit in well tubulars, surface piping, vessels, pumps, and other producing and processing equipment. The purpose of this document is to inform oil and gas operators of the possible presence of NORM and to provide relevant information on protecting workers, the public, and the environment. The objective of this document is to provide general information to users so that they have an understanding of the fundamental radiation issues associated with the management of NORM. Issues where the advice of a professional health physicist, industrial hygienist, or other technical expert may be useful are identified and guidance provided. Readers are advised to contact their state regulatory office and work very closely with that office on all NORM issues.

Radiation can result from both man-made and natural sources. Man-made sources include dental x-rays and well logging tools. Natural sources of radiation include the sun (cosmic rays) and radiation from naturally occurring materials found in the earth's crust and in living organisms. Radioactive materials are unstable and decay over time, emitting ionizing radiation. If body tissue or organs are exposed to excessive radiation, biological damage can occur in the individuals exposed or in their descendants, increasing the risk of cancer or birth defects. Thus, it is important to protect humans from unnecessary exposure to excessive levels of radiation.

NORM is found throughout the natural environment and in man-made materials such as building materials and fertilizer, as well as in association with some oil and gas production. NORM found in oilfield operations originates in subsurface oil and gas formations and is typically transported to the surface in produced water. As the produced water approaches the surface and its temperature drops, precipitates form in tubing strings and surface equipment. The resulting scales and sludges may contain radium and radium decay products as well as other uranium and thorium progeny. In addition, radon is sometimes contained in produced natural gas and can result in the formation of thin radioactive lead films on the inner surfaces of gas processing equipment.

Measurements on the outer surfaces of equipment containing NORM usually indicate levels of radiation that are below levels considered to be of concern. When equipment is opened for inspection or repair, inhaling or ingesting NORM can expose personnel to radioactivity. Therefore, in these situations, workers should take precautions to prevent the generation of dust and wear protective equipment. It is also important that NORM waste or equipment containing NORM be managed and disposed by methods that protect the public from unnecessary exposure.

1.2 HISTORY

During the early 1980s, radioactivity was observed in North Sea oil and gas operations, and in 1986 NORM was identified in tubing removed from a well in Mississippi during a routine workover. Since that time, many operators in the United States have surveyed their operations. NORM was found to be present at some locations. In oil and gas operations, NORM is typically present at widely scattered locations, in small quantities, and at low levels of radioactivity.

After the discovery of NORM in Mississippi in 1986, the American Petroleum Institute:

- Gathered more than 36,000 nationwide measurements of external radioactivity
- Studied methods for measuring NORM in petroleum equipment
- Evaluated alternatives for disposing of NORM waste

API has continued to study the management of NORM issues. API has prepared reports on the following topics:

- Disposal cost studies
- Surveys of NORM in petroleum production and gas processing facilities
- Methods for measuring NORM in petroleum production equipment
- Management and disposal alternatives for NORM in oil production and gas plant equipment
- Dose estimates and indoor radon concentrations attributed to remediated oilfield NORM

Reports on these studies are available by writing the Coordinator—Upstream Environmental Affairs, American Petroleum Institute, 1220 L Street Northwest, Washington DC 20005. These studies and similar studies performed by individual companies are the basis for much of the material in this document.

This document represents API's guidelines on practical methods for managing NORM as of the publication date. IT IS RECOMMENDED THAT OPERATORS CONSULT FEDERAL AND STATE REGULATORY AGENCIES TO ASCERTAIN WHAT LEGAL REQUIREMENTS MAY APPLY.

1.3 NORM IN OIL AND GAS PRODUCTION

NORM represents a wide range of materials that are radioactive in their natural state. These materials include carbon 14 and potassium 40, both of which are present in the human body. The radioactive elements of concern in oil and gas production occur naturally throughout the earth's crust and are sometimes present in the formations from which oil and gas are produced. These elements include uranium, thorium, and their respective progeny. The isotopes of concern are radium-226 (Ra-226), radium-228 (Ra-228) and their progeny (Appendix A).

Small amounts of uranium are occasionally produced with the oil and gas. These elements, like other mineral elements, are present in oil and gas bearing formations in varying concentrations. Many oil and gas bearing reservoirs contain shales that may contain higher than average amounts of these radioactive elements. Depending on their solubility, these elements may find their way into production fluids since they are present in the formation. Many of the physical and chemical characteristics of oil and gas formations tend to increase the solubility of these elements in production fluids.

When the radioactive elements are brought to the surface with the produced fluids, a number of changes can take place depending on the characteristics of the specific site. Usually the radioactive elements stay with the water phase of the production fluids and may either incorporate themselves in pipe scale (radium coprecipitated in barium sulfate), or precipitate into sludges. Formation of NORM scale occurs when radium substitutes for barium in barite scale, producing a coprecipitated (Ba, Ra)SO₄ scale. Substitution of radium for calcium and strontium occurs in a similar manner.

The ability of radium to substitute is due to the similarity in ionic radius, molecular size, and valence of the elements. The amount of substitution is often small, due to the higher abundance of barium in solution versus radium. Usually, very little remains in the oil. Consequently, radioactive sludges and scales can build up within process equipment such as pipes, heater treaters, separators, and salt water tanks. In addition to radium containing scales; scale containing lead (Pb-210) and polonium (Po-210) may accumulate in pipelines, in down hole piping and separators, although this is less common. It is usually associated with the formation of sulfide precipitates.

Radon may be dissolved in produced water and/or oil and released at atmospheric pressure; however it usually follows the gas production stream. Since the boiling point of radon lies between that of ethane and propane, the highest levels of the longer-lived radon progeny, lead-210 (Pb-210), bismuth-210 (Bi-210), and polonium-210 (Po-210), are generally found in pumps, tanks and product lines associated with ethane/propane processing in gas operations. These radon progeny may also accumulate in gas processing equipment such as inlet filters and reflux pumps. The accumulations may be associated with a thin black film coating (ferric sulfide), a sludge (also known as pipe rouge), or a clean metal surface. It is important to note that accumulations of these types, e.g. ferric sulfide or sludge may not have any associated increased level of radioactivity. The affinity for the accumulations also varies. They may be easily removable (typically observed with sludge or pipe rouge) or require more aggressive techniques such as grinding. The formation of ferric sulfide in gas vessels is caused by the action of hydrogen sulfide on steel.

Various NORM occurrence surveys have found significant concentrations of NORM in only a small percentage of oil and gas production operations. These facilities are generally limited to certain geographical areas: the Gulf Coast (from the Florida panhandle to Brownsville, Texas), northeast Texas, southeast Illinois and southern Kansas. This suggests that operations located in those areas may have a higher probability of finding significant occurrences of NORM. This does not mean that NORM is absent in other locations. The only way to be sure that oil and gas operations do not have significant levels of NORM is to survey the site as detailed in Section 3.

NORM may be found in downhole tubing as well as in above-ground processing equipment, saltwater disposal/injection wells and associated equipment; in soils containing NORM as a result of well workovers; tank cleaning and salt water leaks; in tubing; and in pipe cleaning and other associated operations. In production facilities, water-handling equipment exhibits the greatest NORM activity levels. Depending on the location the NORM activity level in pipe scale can range from background levels to thousands of picocuries/gram (pCi/g) [tens of becquerels/gram (Bq/g)], while NORM activity in oilfield sludges ranges from background levels to several hundred pCi/g (tens of Bq/g). The average value of NORM activity associated with pipe scale and oilfield sludges is typically less than 1000 pCi/g (37 Bq/g).

1.4 UNITS OF MEASUREMENT

An understanding of NORM requires an understanding of the various forms of radiation measurement (Appendix B). NORM measurements are taken to determine the concentration of radioactive materials present in scale, sludge, soil, etc., or to determine the potential for radioactive exposure to people near the material. Currently in the United States, there are two systems of measure for units of radioactivity and radiation levels. This document will use the traditional and indicate the international system (SI) units in parenthesis. Table 1.1 summarizes the units used in each system.

Table 1.1—Units of Radioactivity and Radiation Levels

Application	SI units	Traditional US units	Conversion factors
Radioactivity	becquerel (Bq)	picocurie (pCi)	1 Bq = 27 pCi
Concentration	becquerel/gram (Bq/g)	picocurie/gram (pCi/g)	1 Bq/g = 27 pCi/g
Surface activity	Bq/100 cm ²	disintegrations per minute/100 centimeters ² (dpm/100 cm ²)	1 Bq/100 cm ² = 60 dpm/100 cm ²
Exposure	Coulomb/kilogram (C/kg)	Roentgen (R)	1 C/kg = 3876 R
Dose equivalent	sievert (Sv)	rem	1 Sv = 100 rem

1.4.1 Concentration/activity level

The quantity of a radioactive material is not determined by weight or volume, but by level of radioactivity. The activity is the number of radioactive atoms that will disintegrate and emit radiation in a given unit of time. The unit of measurement for activity is the curie (1 curie equals 2.2 trillion disintegrations per minute). The curie represents a relatively large amount of radioactive material. The activity of radioactive material found in most oil and gas production operations is relatively small. Therefore, the unit most frequently used to describe these materials is the pCi (1-trillionth of a curie). The unit most used in the SI system is Bq (1 Bq equals 27 pCi).

The concentration of NORM in scale, sludge, soil, water, or air is determined by laboratory analysis of a sample of the material, and is generally expressed in terms of pCi/gm (Bq/g) of solid material or pCi per liter (pCi/l) of water or air. Average background soil values for Ra-226 may range from one-half to several pCi/g (less than 1 Bq/g), whereas NORM-impacted oilfield scales and sludges may range from 50 to several thousand pCi/g, or from a few Bq/g to approximately 100 Bq/g. As noted above, the average value of NORM activity associated with pipe scale and oilfield sludges is typically less than 1000 pCi/g (37 Bq/g).

1.4.2 Surface activity

Radioactive material that has been deposited on surfaces is called surface activity. It may be loosely deposited, much like ordinary dust, or it may be fixed quite firmly by some chemical or physical means such as chemical bonding, adsorption, or adhesion. This distinction is important, and surface activity is classified on the basis of how easily it can be removed. Measurement of surface activity is reported in units of disintegrations per minute per 100 centimeters squared (dpm/100 cm²) or Bq per 100 centimeters squared (Bq/100 cm²). Measurements are performed to determine total and removable surface activity. An example of the application of this measurement in oilfield NORM is the measurement of Pb-210 and associated progeny when workers access pressure vessels to inspect and clean the welds at gas plants. Measurements are collected in units of cpm, which are converted to dpm (Bq) using appropriate conversion factors based on the detector used.

1.4.3 External measurements

When scales and sludges are contained within equipment or tubulars and cannot be sampled, the presence of NORM can be determined through external measurement taken with an instrument such as a calibrated scintillation detector. This instrument measures the gamma rays that are emitted by the scale and penetrate the equipment wall. Readings are commonly taken in counts per minute (cpm) or microroentgens per hour (μR/hr). The rem has recently been replaced with the sievert (1 Sv = 100 rem).

SECTION 2—INFORMATION ON CONTROLLING THE DEPOSITION OF NORM-CONTAINING SCALE

The deposition of NORM-containing scale and the costs associated with its disposal can be reduced by the use of scale inhibitors in some cases. A scale inhibition program allows the NORM to remain in solution in the produced water. A successful inhibition program requires a thorough understanding of the water chemistry present in the formation as well as a cost benefit evaluation. It is rare that NORM control alone will be sufficient to justify the cost of scale inhibition. This section discusses the following topics:

- Scale formation
- Controlling scale deposition
- Application of scale inhibitors
- Implementation of a successful scale control program

2.1 SCALE FORMATION

NORM-containing scale results from the coprecipitation of radium sulfate along with barium sulfate or strontium sulfate scale. This can occur due to the mixing of incompatible formation waters with injection brines or workover fluids or during surface processing of produced water. Changes in temperature or pressure during the production of fluids can also result in scale formation.

Scale formation, whether it involves NORM or not, is a multi-step process. First, the concentration of a crystallizing mineral must exceed its solubility limit. Second, small particles or rough surfaces must be present to serve as sites where scale crystallization can start. These sites can result from either the spontaneous crystallization of the scaling mineral or from the presence of corrosion products, fines from the producing formation, or roughened surfaces on production equipment. Third, mineral ions must adsorb onto the surfaces of these sites and be incorporated into the crystal structure. Finally, scale deposits can develop if conditions permit adherence of crystals to the surfaces of production equipment. Interference with any of these steps can be a useful part of a scale control strategy.

2.2 CONTROL OF SCALE DEPOSITION

Engineering controls are the first line of defense against any form of scale deposition. Scale tends to accumulate in mechanical components downstream of points where excessive pressure drop and turbulence occur. Modification of these components can reduce scale formation. In some cases, the mixing of incompatible waters can be avoided by treatment of injection fluids or by proper design of surface facilities.

Scale inhibitors may be useful in situations where scaling conditions cannot be avoided through the use of engineering controls. Scale inhibitors are compounds that act at low concentrations (1-50 ppm) to interfere with the formation or growth of scale crystals. The low concentrations at which scale inhibitors are effective distinguish them from chemicals that dissolve existing scale or prevent scale formation by chelation. These materials must be applied at concentrations greater than those of the scaling species. The types of compounds in common use as scale inhibitors are phosphonates, polycarboxylates, and phosphate esters.

Screening tests that determine the minimum concentration of inhibitor needed to prevent scaling under the proposed conditions of application provide the basis for inhibitor selection. Temperature of application, brine pH, and brine composition are significant factors in inhibitor selection. Phosphate esters exhibit good performance per unit cost, but their application is limited to temperatures below 212°F. Phosphonates may be applied up to 250-300°F. Polycarboxylates are the most temperature stable and may be used up to 450°F. System pH has a significant influence on inhibitor performance. All three types of inhibitors have similar performance in near-neutral pH. As the pH drops, higher inhibitor concentrations are needed to prevent scaling. Divalent ions in highly saline brines can cause precipitation of inhibitors. Polycarboxylates suffer marked degradation in performance under acidic conditions and are particularly subject to precipitation in highly saline brines. The pH sensitivity of inhibitor performance depends on the molecular structure of the inhibitor and can vary significantly among inhibitors of a given type.

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SECTION 3—SURVEY TECHNIQUES AND APPLICATIONS

This section provides information describing radiation measurement and sampling techniques and appropriate applications in NORM surveys. This section also gives information on instrument maintenance and calibration and associated records.

3.1 SURVEY MEASUREMENT AND SAMPLING TECHNIQUES

NORM surveys generally involve the following measurement and sampling techniques:

- Gamma surface scans
- Exposure rate measurements
- Direct measurements for total and removable alpha or beta surface activity
- Radionuclide concentrations in media (e.g., soil, sediment, sludge, water, air)
- Personnel monitoring for external radiation exposure
- Personnel monitoring for internal radiation exposure

The following sections discuss each measurement or sampling technique and describe the application of the technique to monitoring for oilfield NORM.

3.1.1 Gamma surface scans

Instrumentation used to perform gamma surface scans typically includes a ratemeter/scaler coupled to a 1 or 2 inch sodium iodide scintillation detector. Surfaces are scanned to identify areas of elevated direct radiation which, based on the results of the scan, may require further investigation. The surveyor passes the detector slowly over the surface while keeping it as close to the surface as conditions allow. Increases in the count rate, as indicated by the audible output of the instrument, are monitored, and areas of elevated direct radiation are identified for further investigation.

The area or item under investigation should be systematically surveyed. The surveyor should pay particular attention to areas such as pipe elbows where solids may accumulate. The meter probe should be in close proximity with the external surface of the equipment (normally not more than 1 centimeter away) and moved slowly across the equipment surfaces. The survey instrument's response switch should be set to the "fast" position during the initial scanning of the equipment. This setting minimizes the possibility of not detecting NORM deposits. Wherever NORM deposits have been identified, the response switch should be set to the "slow" position in order to obtain more accurate readings.

Production equipment, particularly water-handling equipment, should be surveyed for external gamma radiation. In addition, equipment being removed from service, released for maintenance work, or released for unrestricted use (e.g., sold or scrapped) should be surveyed for NORM.

Gamma surface scans of soil areas should be conducted over the subject land area on a delineated grid. The grid spacing should be optimized for the size of the area to be surveyed, as well as for the potential for identifying areas with elevated readings: the smaller the area to be surveyed, the smaller the grid spacing. Some regulatory agencies require that grid spacing not exceed 10 meters (30 feet). One technique that has been particularly useful for large areas is the use of a gamma-sensitive detector used in conjunction with a global positioning system. Use of this type of system allows simultaneous recording of detector response and positioning information. Areas exhibiting elevated readings should be identified for follow-up investigations, which may include additional radiation measurements (e.g. exposure rate measurements) and soil sampling.

3.1.2 Exposure Rate Measurements

Exposure rate measurements are performed using a gamma-sensitive survey instrument. Instruments may be a single unit that contains a read-out device and detector (for example, a micro-R meter) or two units such as a rate meter/scaler attached to a sodium iodide detector. To perform the measurement, the surveyor places the detector in a location where the measurement is desired and allows the meter to stabilize. The average value observed is recorded.

Many states have established exposure rate guideline values for equipment and areas. These guidelines specify the measurement location. Exposure rate measurements are usually performed at contact or at 1 meter.

Exposure rate measurements are usually performed on NORM-impacted soil areas, tubulars or equipment, and areas identified by gamma surface scans. The following measurement locations are recommended:

- Both ends of tubulars and pipes
- All openings in fittings (i.e. Ts, elbows), manifolds, etc.
- Both ends and the throats of valves
- Individual deposits or accumulations within vessels and tanks

Correlations can be developed to relate gamma or exposure rate measurements to concentrations of NORM in scale or sludge. The operator should exercise caution when using relationships of this type because of the many variables that can affect the relationship. Some of these variables include NORM density, volume, thickness, nuclide composition, and detector efficiency. Facility and equipment-specific correlations will yield better results than generic correlations. Generally, this will require the laboratory analysis of a number of samples collected from equipment reading at different exposure rates to develop a reliable correlation. In a similar fashion a correlation for solid waste could be generated by collecting a number of measurements from samples of known concentrations in a repeatable geometry such as a 1 liter open mouth plastic jar. Typically the accuracy of these correlations is on the order of plus or minus 50%.

3.1.3 Direct Measurements

Measurements for total and removable alpha and beta activity are performed on surfaces of equipment. For direct measurements, an appropriate detector is coupled to a ratemeter-scaler. A Geiger-Mueller (GM) tube is usually used for beta measurements, and a zinc sulfide scintillator is usually used for alpha measurements. However, many types of detectors are currently available. The surveyor places the detector in contact with the surface at the location where the measurement is desired and counts are accumulated for a predetermined length of time, typically 1 minute. The resulting value is in cpm. Conversion factors that correct for detector efficiency, count time, and geometry are applied to convert cpm to more useful units such as disintegration per 100 cm² (dpm/100 cm²) or Bq per 100 cm² (Bq/100 cm²).

Measurements to determine removable activity levels are collected by applying moderate pressure to a piece of filter paper or smear paper and wiping the surface over an area of approximately 100 cm². The activity on the smear can be determined by counting the filter paper using the survey instrumentation described above, or the smear can be sent to a radioanalytical laboratory to be counted. Appropriate conversions are applied to report results in units of dpm/100 cm² or Bq/100 cm².

Measurements to determine total and removable surface activity are usually performed at gas plants. During operations, while gas is flowing through the process equipment, locations where radon progeny are being accumulated may be detectable through external surveys. However, if the equipment item has been out of production service for more than 4 hours or the production stream has changed and does not contain radon, it is unlikely that such external surveys would detect internal accumulations of radon progeny. Such equipment could contain significant quantities of Pb-210 and progeny. Under such conditions, internal surveys should be made while the equipment is opened. Suitable limits used to assess radon progeny deposits are listed in state radiation control regulations as surface activity or contamination limits.

3.1.4 Radionuclide Concentration In Media

In some instances it may be necessary to determine concentrations of NORM in media such as air, soil, scale, and water. Collection techniques vary and require specialized equipment. Analytical laboratories or environmental professionals can provide additional information and describe appropriate sampling techniques. Upon collection, care should be taken to maintain a documented history of the sample. This is referred to as maintaining chain of custody. Samples are sent to radioanalytical laboratories for determination of radionuclide concentration.

Soil sampling is the most common form of media sampling at NORM-impacted sites. Reasons for soil sampling may include determining the concentration of radionuclides before the land is released for unrestricted use, or before the sale or purchase of the lease, and characterizing the existing surface activity. Additional soil samples should be collected from a non-NORM impacted area of the site to document the existing soil background levels. It is also possible to make rough estimates for radionuclide concentrations based on external measurements if enough field correlation data exists for the given site. As a general rule these estimates would be used to make follow up analysis decisions when addressing a NORM impacted site and would not be a sufficient basis to plan a remediation effort unless the correlations were specifically developed for a particular area.”

3.1.5 Personnel External Radiation Dose Assessment

Personnel radiation exposures may be evaluated either by having personnel wear thermoluminescent dosimeters or film badges, which must be returned to and analyzed by the supplier. An alternative method is to survey with a tissue-equivalent scintillation

detector, a shielded energy compensated GM probe, or an ion chamber survey meter capable of providing a readout in mrem/hour may be conducted. When the survey method is used, information on work location and time is required to estimate radiation dose.

The State organizations or the Occupational Safety and Health Administration (OSHA) establish limits for exposure of personnel. The annual occupational limit listed in 29CFR1910.1096(b)(1) is 5 rem (0.05 Sv). During any calendar quarter, the dose to the whole body shall not exceed 3 rem (0.03 Sv) as listed in 29 CFR 1910.1096(b)(2)(i); however, monitoring is done at some fraction of the limit value, generally 10 to 25% of the allowable limit. Work area radiation levels in the general industry segment are typically far below this regulatory level. Therefore, routine personnel radiation exposure surveys are not frequently done.

3.1.6 Personnel Internal Radiation Dose Assessment

Ambient airborne NORM concentrations are normally evaluated by filtering a high-volume air sample and having the filter analyzed by a radiometric laboratory. NORM deposits in equipment and piping do not present any airborne exposure concerns during normal operations. During maintenance or dismantling activities, airborne NORM exposure concerns are minimized by the application of typical industrial hygiene practices such as keeping NORM deposits wet and using respiratory protective equipment. On the other hand, during grinding, cutting, chipping and sanding, and during removal of NORM scale, airborne activity may occur. Under such conditions, it is advisable to evaluate employee exposure to ambient airborne concentrations of NORM.

Personnel exposures are evaluated by the same sampling and laboratory methodology except that personnel wear lapel air samplers that operate at 2 to 5 liters per minute versus the higher flow rate ambient air pumps. In both techniques, it is essential to know the volume of air sampled along with the radiometric results in order to calculate the airborne NORM concentrations.

3.2 INTEGRATION OF SURVEY TECHNIQUES

Numerous radiological measurement techniques have been discussed above. It is important that the individual performing the survey clearly understand and be trained in the procedures being used. The operator should identify the purpose of the survey and the values to which the results will be compared. The appropriate measurement technique will be selected based on this information. For example, if the objective of the survey were to determine the need for workers who need to be monitored for occupational exposure to radiation and radioactive materials, the survey would include determination of exposure rate and an evaluation of estimated internal doses. Survey measurements might include exposure rates and airborne concentrations of radioactive material. In contrast, if a property is being released from regulatory licensing, survey techniques would likely include gamma surface scans, exposure rate measurements, and determination of concentrations of NORM in soil. The selection of survey techniques is based on the objective of the survey and the guidelines to which the results of the survey will be compared.

3.3 INSTRUMENT CARE, MAINTENANCE, AND CALIBRATION

Portable survey meters typically used to conduct NORM surveys are generally quite rugged; however, the associated detectors and probes must be handled with care. As a matter of good practice, connecting cables should not be sharply bent because frequent sharp bending of the connecting cables will break the internal cable wire. Battery contacts need to be kept clean and free of corrosion residue. In humid environments, or if instruments are used infrequently, batteries should be removed from survey meters when the instruments are not being used. Survey instruments should be kept clean, and detectors (probes) need to be kept free of NORM residue.

NORM survey instruments should be returned to the manufacturers (or other qualified instrument calibration agents) at least annually (semi-annually in some jurisdictions) for general maintenance and calibration. Individual meters, detectors, and connecting cables should be calibrated as discrete instruments (units). Switching components between units voids the calibration(s). It is particularly important to ensure that instruments that are used to measure exposure rate are calibrated and respond appropriately to the radiation field present.

Instrument operational checks should be conducted before each use of an instrument (or after the detector has been dropped or banged against a solid object, etc.) to ensure that the instrument is functioning properly and providing representative readings. Operational checks include:

Battery check. Switch the meter dial to the “Battery” position and observe that the meter indicator moves into and remains in the accepted range, or depress the “Battery” button on the meter and observe the dial.

Source check. Expose the detector (probe) to a source of radioactivity of known strength and confirm that the meter registers the proper reading. It is not adequate to merely confirm a positive response by the meter. A damaged detector may provide a positive response, but the response will be much lower than the proper reading.

Various types (and strengths) of radioactive check sources may be purchased from most survey instrument suppliers. Operation checks of NORM survey instruments should be recorded on a form.

Note: There is some potential for sparking when detector cables are connected or disconnected, or when switches are turned on or off. Where explosive atmospheres may be encountered, tests for the presence of flammable gas/vapor should be made prior to the radiation survey.

3.4 RECORDS

All data collected during a NORM survey should be properly documented and accurate records should be maintained. Information and data collected may be subject to review and evaluation many years in the future.

All NORM survey information and data should be recorded on a form. Such forms should be completed in full for each survey. Example equipment classification abbreviations are provided in Table 3.1 to aid in the identification of equipment surveyed.

The records that should be maintained include:

- Field survey forms
- Instrument operational checks
- Instrument maintenance and calibrations
- Sample analytical results
- Thermoluminescent dosimeter (TLD) analyses

Table 3.1—Equipment Example Classification

<i>Production Facilities:</i>	
PROD	Production wellhead
WINJ	Injection wellhead
WOTHER	Other wellheads
MANIFOLD	Manifold/header piping, valves, etc.
SEP	Separators, including production separators, gunbarrels, etc.
FWKO	Free water knockouts
FLOAT	Flotation cells, wemcos, etc.
H/T	Heater treater
STANK	Stock Tanks
CTANKP	Condensate tank production
WTANK	Water tanks
PUMP	All pumps
SUMP	Sumps, including pits, pigtraps, ponds, etc.
FLINE	Flowlines, including all valves and elbows
GLINE	Gathering lines before processing
VRU	Vapor recovery units
PDEHYDRATOR	Production dehydration equipment
PIG	Production pig launcher/receiver
OTHER	All other measurements of in service equipment
SOIL	Soil readings at pipe yards, tank battery pads, etc.
TUBE	Production tubulars at pipe yards, etc.
SCALE	Scale sample readings

<i>Gas Processing</i>	
INLET LINE	All inlet lines to facility
SCRUBBER	Inlet scrubber, separators, etc.
SWEETENER	All gas sweetening equipment, including amine systems, etc.
DEHYDRATOR	Dehydration equipment: Glycol, EG and TEG systems, etc.
HEAT EXCH	Heat exchangers
FRAC TOWER	All process towers/columns
CYRO UNIT	All equipment associated with cryogenic process except reflux pumps
REFLUX PUMP	All reflux pumps
BOTTOMS PUMP	Pumps transferring liquid off the bottom of towers
METER	All metering equipment: meters, meter runs, screens, strainers, filters, etc.
GAS PIG	Gas processing pig launcher/receiver
PPUMP	Propane pump
OPUMP	All other pumps
PTANK	Propane tanks
CTANK	Condensate tank
OTANK	All other tanks
PRODUCT LINE	All product pipelines
COMPRESSOR	Compressors and associated equipment
REFRIG	All equipment associated with propane refrigeration system
GOTHER	All other gas processing equipment