Standard Guide for
Interpretation of Existing Field Instrumentation to Influence Emergency Response Decisions[1]

This standard is issued under the fixed designation D7316; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The objective of this guide is to provide useful information for the interpretation of radiological instrument responses in the event of a radiological incident or emergency.

1.2 For the purposes of this guide, a radiological incident or emergency is defined as those events that follow the indication of the presence of radioactive material outside of a Department of Energy (DOE) or Nuclear Regulatory Commission (NRC) defined radiological area. The event may be triggered by a law enforcement officer wearing a radiation pager during the course of his routine duties, a first responder at the scene of an accident wearing a radiation pager, a HAZMAT team responding to the scene of an accident known to involve radioactive material surveying the area, etc.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials
C1112 Guide for Application of Radiation Monitors to the Control and Physical Security of Special Nuclear Material (Withdrawn 2014)[3]
D1129 Terminology Relating to Water
D3648 Practices for the Measurement of Radioactivity
D4962 Practice for NaI(Tl) Gamma-Ray Spectrometry of Water
D7282 Practice for Set-up, Calibration, and Quality Control of Instruments Used for Radioactivity Measurements
E170 Terminology Relating to Radiation Measurements and Dosimetry
E181 Test Methods for Detector Calibration and Analysis of Radionuclides

2.2 *Other Documents:*

U.S. Department of Homeland Security National Response Plan, Nuclear/Radiological Incident Annex

3. Terminology

3.1 *Definitions*—See Terminology C859 for terms related to nuclear materials, Terminology E170 for terms related to radiation measurements and dosimetry, and Terminology D1129 for terms related to water.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alpha particle (α), n*—particle consisting of two protons and two neutrons emitted from the nucleus of an atom during radioactive decay.

3.2.2 *beta particle (β), n*—electron or positron emitted from the nucleus of an atom during radioactive decay.

3.2.3 *gamma ray (γ), n*—photon emitted from the nucleus of an atom during radioactive decay.

3.2.4 *Geiger-Mueller (GM), n*—a type of radiation detector with sensitivity to γ–rays and α and β particles.

3.2.5 *national response plan (NRP), n*—a publication by the US Department of Homeland Security which details actions to be taken, with appropriate responsibilities and authorities, in the event of a national-scale emergency.

3.2.6 *naturally occurring radioactive materials (NORM), n*—radioactive materials which occur in nature, often concentrated by an industrial or chemical process.

3.2.6.1 *Discussion*—NORM includes uranium (U) and thorium (Th) and their decay products as well as potassium-40 (^{40}K). U and Th are often found in earthen products and ^{40}K is often found in agricultural products.

3.2.7 *neutron, n*—uncharged particle emitted during fission of an atomic nucleus.

[1] This guide is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.04 on Methods of Radiochemical Analysis.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

3.2.8 *radiological emergency, n*—an event which represents a significant threat to workers and the public due to the release or potential release of significant quantities of radioactive material.

3.2.9 *radiological incident, n*—an unplanned event involving radiation or radioactive materials.

3.2.10 *special nuclear material (SNM), n*—plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235 (USA definition).

3.2.11 *turn-back limit, n*—a condition or set of conditions, which if met, require that the investigation cease and personnel involved in the investigation withdraw from the area to a predetermined "safe" location.

3.2.11.1 *Discussion*—It is the responsibility of the users of this guide to establish both the turn-back limit and withdrawal location, if appropriate.

3.3 *Abbreviations:*

3.3.1 *CsI*—cesium iodide, a scintillation detector material used to detect gamma and X-ray radiation.

3.3.2 ^{3}He—helium-3, used as a pressurized gas in neutron detection systems.

3.3.3 *HPGe*—high purity germanium, a semiconductor material used in high resolution γ–ray spectrometry.

3.3.3.1 *Discussion*—A detection system using high purity germanium may be necessary for positive nuclide identification.

3.3.4 *LiI*—lithium iodide, scintillation detector material used to detect neutron radiation.

3.3.5 *NaI*—sodium iodide, a scintillation detector material used to detect gamma and X-ray radiation.

3.4 *Acronyms:*

3.4.1 *HHRID or RID, n*—[hand-held] radio-isotope identifier.

4. Summary of Guide

4.1 The primary purpose of the guide is to enable first response organizations to properly implement protective actions for themselves and the public. This guide offers a decision-tree approach to the interpretation of radiological instrument responses, plus actions which may be taken with various instrument types, to evaluate the presence of certain types of radioactive materials before, during, or after a radiological incident or emergency. This information may be useful in further emergency or incident response activities. This guide is believed to be most effective when combined with specific training for each emergency response organization, as equipment availability and response scenarios have a significant impact on the decision process.

5. Significance and Use

5.1 This guide is intended for use by field personnel for the rapid evaluation of the presence of and type of radioactive materials, based on information obtained from available field instrumentation. Guidance is offered for actions which may be taken to better understand the instrument indications for various scenarios, and guidance is offered for personnel protection and consultation with additional appropriate authorities.

5.2 This guide does not include policy or procedures for radiation health protection. Such policy and procedures are determined locally by the organization(s) involved (site, city, county, state, federal). The policies and procedures may vary between organizations and may be dependent on the type of radiological incident. Users of this guide should be familiar with the policies of their local organizations.

6. Hazards

6.1 Turn-back limits and actions should be established prior to any type of investigation. These limits should be strictly adhered to by all personnel.

6.2 The vendor supplied safety instructions and organizational safety regulations should be consulted before using electronic and electrical equipment.

7. Equipment

7.1 There are many portable radiation instrument types that can passively or actively be used to evaluate the presence of radioactive materials. For the purposes of this guide they are loosely defined as:

7.1.1 *Radiation Pagers*—Typically worn on the person to act as a personal warning device, giving the wearer an indication of relative or actual dose rate as compared to established background levels. All known radiation pagers provide information about the level of γ-radiation, and many also provide information about the level of neutron radiation. They are typically used in a passive mode and worn on the outer layer of clothing.

7.1.2 *Count Rate Meters (Survey Meters)*—Typically hand-held, which provides the user an indication of counts per second or counts per minute of radiation being measured by the device. Instruments may be sensitive to α, β, γ, or neutron radiation, or a combination thereof.

7.1.3 *RID*—A device typically containing a CsI or NaI scintillation detector and associated software to make a preliminary identification of the source of gamma radiation. Some units use an HPGe detector for high resolution spectrometric analysis.

7.1.4 Fig. 1 describes the radiation-type detection capability of some radiation pagers based on the materials used for detection.

7.1.5 Fig. 2 describes the radiation-type detection capability of some hand-held radiation instruments based on the materials used for detection.

7.2 For a more complete discussion of radiation detection equipment, its operation and calibration, refer to Practices D3648, Test Methods E181, Practice D4962, Guide C1112, Practice D7282, or a combination thereof.

8. Calibration and Response Checks

8.1 Calibration is performed by qualified individuals, usually on an annual basis. This may require instruments to be returned to the manufacturer or other qualified service unit. Operating procedures for the instruments should indicate the

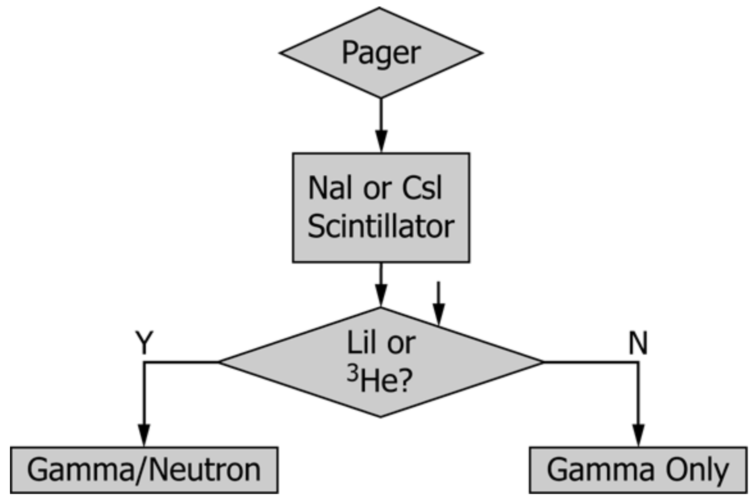

FIG. 1 Simple Chart of Pager Detection Capabilities

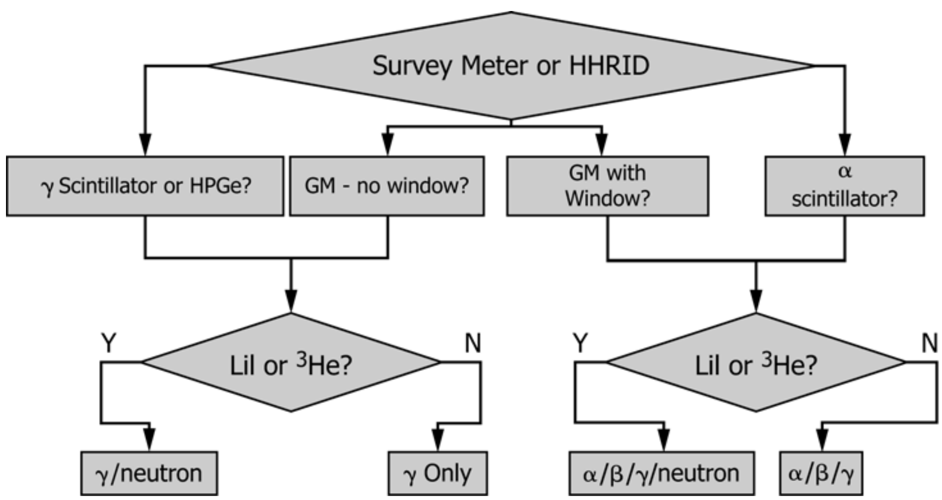

FIG. 2 Simple Chart of Radiation Instrument Detection Capabilities

calibration frequency and a method for users to confirm that an instrument is in calibration prior to use.

8.2 Response checks should be performed by the user prior to deployment of the instrument. The two checks which should be performed are a background check and a source check. RIDs may also be subjected to an identification confirmation check.

8.2.1 *Background Check*—Once the instrument has been turned on and has completed any start up processes, the dose or count rate reading should be compared to normal background. Standard operating procedures should state where this check is performed and what the expected background for this location is. Instruments found to read significantly above or below the normal values should not be used and should be submitted for diagnostic testing and repair.

8.2.2 *Source Check*—Once the background check is completed, a radioactive source should be used to verify the response. Radioactive sources may be commercial sealed sources or NORM. Standard operating procedures should indicate the source material to be used, the distance from the detector and the count rate or dose rate expected for that source, as well as an acceptance range for the instrument response. Instruments found to read outside the acceptance range should not be used and should be submitted for diagnostic testing and repair.

8.2.3 *RID Identification Check*—Once the background and source check are completed, a source of known radioactive material may be used to confirm the RID identification software is calibrated and functioning properly. The check source must include an isotope or isotopes which are included in the identifier library. Standard operating procedures should indicate what material to use for this check, and what the expected identification should be. If the RID does not correctly identify the known material, perform the calibration steps again (if applicable) and retry the identification. If the instrument still will not correctly identify the known material it should be not be used and should be submitted for diagnostic testing and repair.

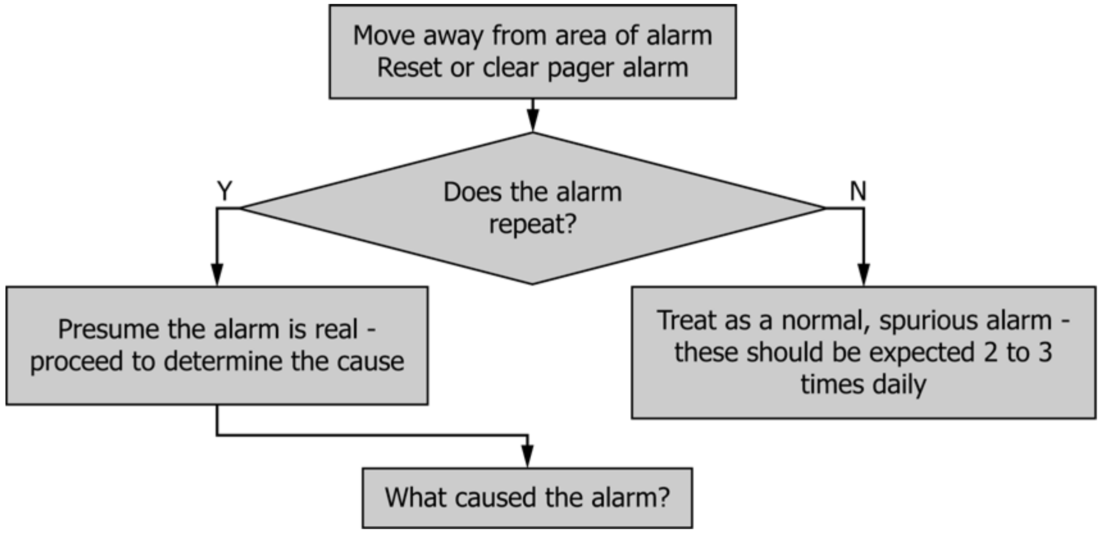

FIG. 3 Actions to be Taken Following Receipt of Pager Alarm

9. Guidance

9.1 The following decision-tree flow charts provide guidance on the interpretation of instrument responses and subsequent actions.

9.2 Fig. 3 describes the actions to be taken upon receipt of an alarm from a radiation pager.

9.2.1 Return to a low-background area to reset or clear the alarm. If you cannot clear the alarm consider the possibility that you may have become contaminated by the source. Warn others and seek additional assistance.

9.2.2 Each organization should provide limits, either dose rate, count rate, or intensity level-based, for which their personnel can continue to resolve an unknown radiation source, or for when they need to call for additional assistance. Limits should also be set regarding when notification of other agencies (for example, state or federal response units) is required (see Fig. 4).[4]

9.3 Once an alarm is determined to be valid, and it is safe to continue (that is, organization limits have not been exceeded), continue to try to localize the source of radiation by following Fig. 5.

9.4 Fig. 6 describes the decision tree to investigate the contents of a vehicle, vessel, or container.

9.4.1 License exempt quantities of radioactive material do not require the use of placards, or to be listed on a shipping manifest. However, they should indicate the type of radioactive material present and the DOT exemption they fall under when in transport.

9.4.2 NORM will not be listed as radioactive on any shipping documents. The pager alarms will often be low-level and isotope identification will be difficult. Some examples of NORM are shown in Table 1.[5]

9.4.3 Medical and industrial isotopes should be properly contained and marked for shipment in accordance with DOT regulations. Some examples of medical isotopes are shown in Table 2.[6]

9.5 If the localization indicates a person is the source of radiation, see Fig. 7.

9.6 If the pager or other survey instruments indicate the presence of neutrons, see Fig. 8.

9.7 To check for loose or removable contamination (transferable contamination) survey the bottom of your shoes once you are in an area that your pager or other detection instrumentation indicates is near background. If the bottom of your shoes causes the dose or count rate to rise, transferable contamination may be present. Alternatively, use a paper towel or other material to wipe a suspect area (for example, the ground or other horizontal surface in the suspect area). Try to move to an area where your instrument no longer alarms and then place the wipe near the detector. It the detector alarms or shows an increased count or dose rate, transferable contamination may be present. (**Warning—**If you cannot move away from the contamination, consider the possibility that you have become contaminated and call for assistance.)

9.7.1 If radioactive material has been spread about and is loose or transferable, secure area and call for radiological response personnel—for example, DOE Radiological Assistance Program (RAP), HAZMAT, Civil Support Teams (CST). Refer to the Nuclear/Radiological Incident Annex of the National Response Plan as appropriate.

[4] Knowledge of available Radiation Protection professional support may be obtained in advance through the Health Physics Society, http://www.hps.org, or the Conference of Radiation Control Program Directors (CRCPD), http://www.crcpd.org.

[5] Some additional information is available at http://www.tenorm.com/bkgrnd.htm#Series%20Radionuclides.

[6] Some additional information is available at http://www.uic.com.au/nip26.htm.

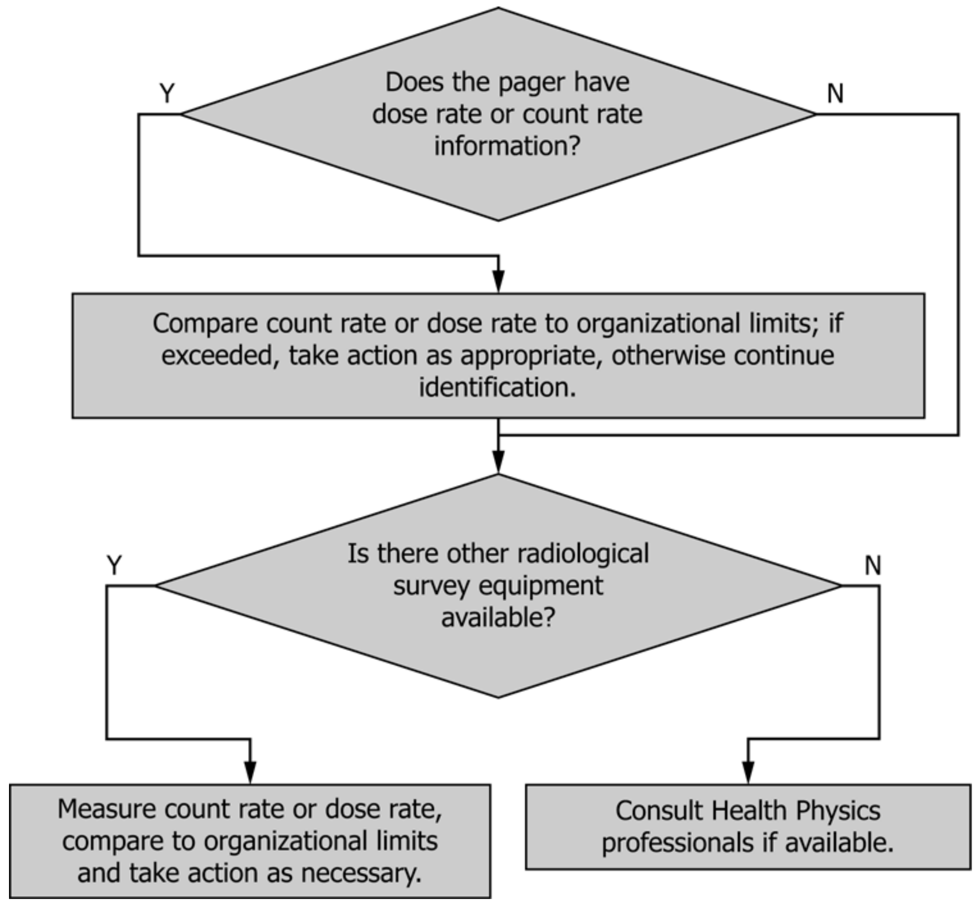

FIG. 4 Actions to be Taken Following Confirmation of Pager Alarm

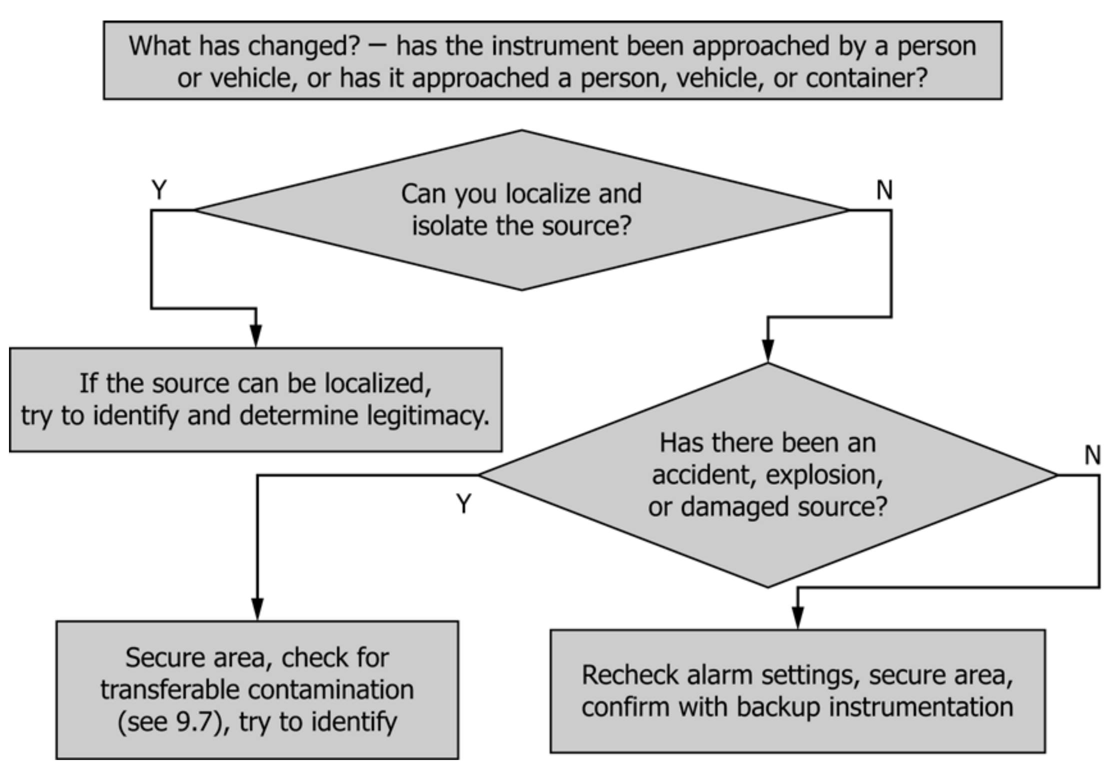

FIG. 5 Actions to be Taken to Localize a Source

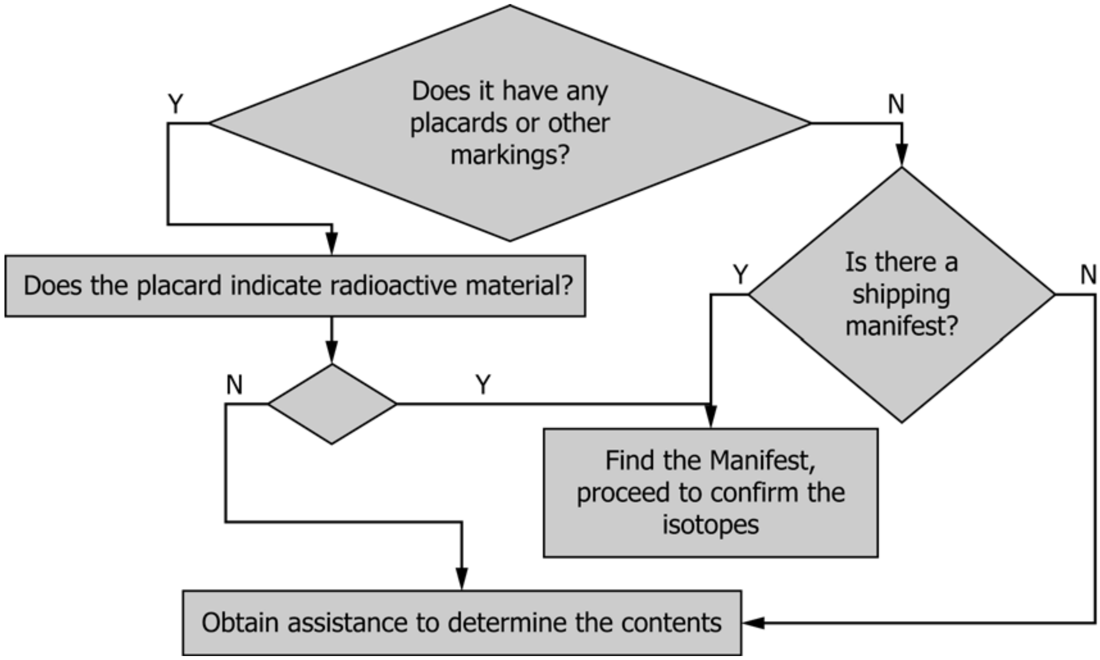

FIG. 6 Actions to be Taken to Investigate a Vehicle, Vessel, or Container

TABLE 1 Some Examples of NORM

Isotope	Material	Radiation
Uranium-238	Porcelain, Tile, Fiesta Ware	Alpha, Beta, Gamma
Thorium-232	Welding Rods	Alpha, Beta, Gamma
Radium-226	Luminescent Devices	Alpha, Beta, Gamma
Potassium-40	Fertilizer	Beta, Gamma

TABLE 2 Some Examples of Medical and Industrial Isotopes

Isotope	Typical Uses	Radiation
Cesium-137	Industrial	Beta, Gamma
Cobalt-60	Industrial	Beta, Gamma
Americium-241	Industrial	Alpha, Gamma
Strontium-90	Medical, Industrial	Beta
Iodine-131	Medical	Beta, Gamma
Iodine-125	Medical	Gamma
Thallium-201	Medical	Beta, Gamma
Thallium-202	Medical	Beta, Gamma
Technetium-99m	Medical	Gamma
Iridium-192	Industrial	Gamma

9.8 If suitable instrumentation is available, a typical, thorough identification would follow the process outlined as follows:

1. Alarm or notification by pager, portal, or other screening device.
2. Search and preliminary identification with conventional radiation protection instrumentation or low resolution spectroscopy equipment.
3. Positive identification with high resolution spectroscopy equipment, possibly including confirmation of materials by the presence or absence of neutrons.

9.9 In many cases, the idealized process may not be able to be followed due to equipment limitations. The following steps provide additional information which may be useful in determining the legitimacy of a radiation source when only limited instrumentation is available:

9.9.1 If you have radio-isotope identification tools, they may be used to determine if the source is natural, medical, industrial, or nuclear. Even with a RID, additional confirmation of the material may be necessary.

9.9.1.1 For example, SNM should have neutron emissions, while natural uranium should not. There should be no neutrons present with medical or most industrial isotopes. The presence of neutrons should always raise suspicion about the nature of the source.

NOTE 1—A few commercial industrial devices could emit neutrons, such as moisture and density gauges that contain ^{252}Cf or use an AmBe source. These should be well marked as containing such sources.

9.9.1.2 Some RIDs may indicate the presence of Beta emitters in the absence of gammas by observing artifacts of beta energy dissipation called Bremstraalung. An example of such an RID indication may be "Possible Beta Radiation" or a similar message. This should be confirmed with other beta detection instrumentation.

9.9.2 If radio-isotope identification tools are not available, other survey instruments may be able to help identify the source.

9.9.2.1 For example, on a survey instrument with a beta-gamma probe, cover the probe window with your hand or a book; if the count rate drops to near background, the radiation is predominantly beta. On an alpha-beta-gamma or alpha-beta instrument, cover the probe window with a piece of paper; if the count rate drops to near background, the radiation is predominantly alpha. See Tables 3 and 4 for examples of beta instrument responses to some nuclides with common absorption materials.

9.9.2.2 Using a survey instrument with a beta-gamma probe, the gamma count rate should be approximately constant

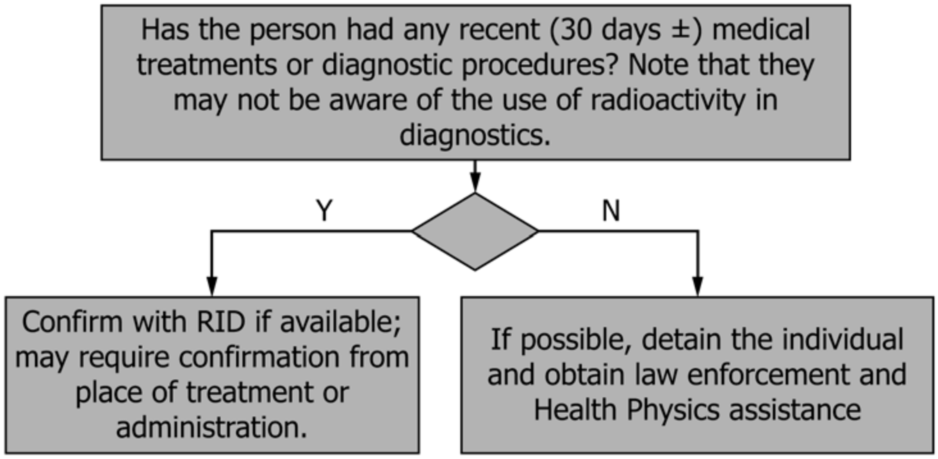

FIG. 7 Actions to be Taken to Investigate an Individual

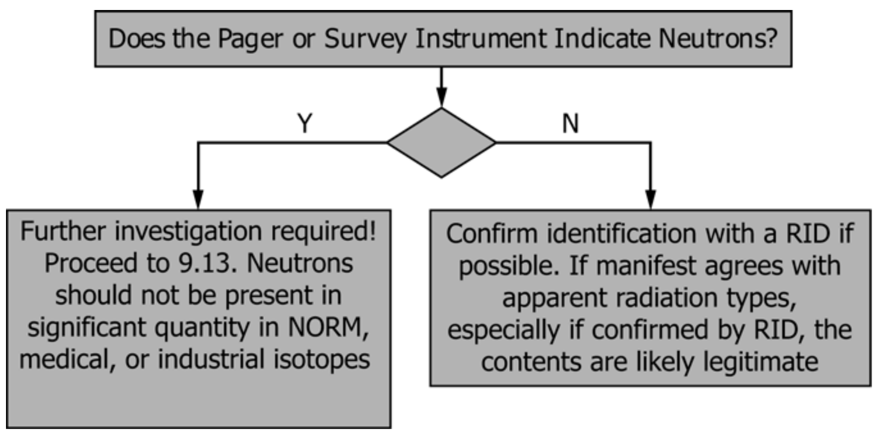

FIG. 8 Actions to be Taken if Neutrons are Indicated

TABLE 3 Approximate Reduction in Count Rate with Aluminum Foil Absorber as a Function of the Nuclide (Average Beta Energy)

Beta Emitter	Average Energy (keV)	Approximate Count Rate Reduction (%) with foil
Mo-99	443	10
Sr-90	195	30
I-131	192	30
Ir-192	188	30
Tc-99m	85	60
C-14	50	80

TABLE 4 Approximate Reduction in Count Rate with Notebook Paper Absorber as a Function of the Nuclide (Average Beta Energy)

Beta Emitter	Average Energy (keV)	Approximate Count Rate Reduction (%) with paper
Mo-99	443	5
Sr-90	195	15
I-131	192	15
Ir-192	188	15
Tc-99m	85	30
C-14	50	40

in any given location regardless of the orientation of the probe. The same is true of neutron detection instruments.

9.10 Tables 3 and 4 provide information about the relative response of beta detection instruments with a nominal 8 mg-cm^{-2} (household) aluminum foil or notebook paper between the source and instrument.

9.11 If the presence of neutrons is indicated, the following steps provide additional guidance for results obtained with simple instruments.

9.11.1 If the only 'survey' instrument is a neutron-gamma pager, it can still be used to distinguish between neutrons and gammas, as follows:

9.11.1.1 The neutron count rate will diminish more slowly with distance from the source than the gamma count rate will.

9.11.1.2 A piece of steel, a brick, or concrete will have a greater effect at reducing the gamma count rate than the neutron count rate.

9.11.1.3 Some pagers can indicate neutrons in a high gamma field, even when neutrons are not present. This is an anomalous (albeit explainable) reading. If the gamma count rate is high and the neutron count rate drops significantly with distance from the apparent source, this is probably the case.

NOTE 2—This effect is observable with LiI neutron detectors but not with ^{3}He neutron detectors.

9.12 The following provides additional guidance for interpreting results obtained with radio-isotope identifiers or other instruments:

Does the RID or other identification methods/process confirm the manifest? Does your RID confirm NORM where expected?

Does the pager indicate the presence of neutrons? Neutrons should not be present with medical or industrial isotopes.

Use your other law enforcement or emergency response training, or both, to "sense" problems.

If the material cannot be confirmed as "innocent," secure area and call for radiological response personnel—for example, Radiological Assistance Program (RAP), HAZMAT, Civil Support Teams (CST). Refer to the Nuclear/Radiological Incident Annex of the National Response Plan as appropriate.

9.13 The following provides additional guidance for communicating results to laboratories or additional responder personnel:

Based on the instrumental analysis thus far, other responders and subsequent laboratory analytical personnel can be assisted by providing the following information, as available:

Relative amount of beta, gamma, and neutron radiation—for example, "mostly gamma with a little beta," "no significant alpha," etc.

If nuclide identifiers have been used, information about the nuclides believed to be present should be passed to the laboratory.

If surface contamination is present, or the dose rate of the sample in its container exceeds 2 mrem/h, the laboratory should be notified.

10. Quality Control

10.1 No quality control guidelines are provided as this guide produces no analytical data; it is to be used to provide screening information only.

10.2 Instruments used should be in calibration and complete response checks prior to use.

11. Keywords

11.1 alpha radiation; beta radiation; first responder; gamma radiation; naturally occurring radioactive material; neutron radiation; radiation detection; radiation dose rate