

**REGISTRY OF RADIOACTIVE SEALED SOURCES AND DEVICES
SAFETY EVALUATION OF DEVICE
(AMENDED PAGE 1)**

NO.: NC-646-D-130-S

DATE: April 04, 2007

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DEVICE TYPE: Portable Surface Moisture and Density Gauges

MODEL No.: 3400 Series: Models 3430, 3430-M, 3430 Plus, 3440, 3440-M, 3440 Plus, 3450, 3451

MANUFACTURER/DISTRIBUTOR: Troxler Electronic Laboratories
3008 Cornwallis Road, P.O. Box 12057
Research Triangle Park, NC 27709
(919) 549-8661

<u>SEALED SOURCE MODEL DESIGNATION:</u>	<u>ISOTOPE:</u>	<u>MAXIMUM ACTIVITY:</u>
<u>Troxler Drawing No. A-102112 which covers:</u> AEA Technology/QSA, Inc. Model No. CDCW556 Capsule Type XN.30 Special Form Certificate No. USA/0673/S	Cs-137	9 millicuries (333 MBq)
AEA Technology/QSA, Inc. Model No. CDCW556 Capsule Type X1218 Special Form Certificate No. USA/0614/S	Cs-137	9 millicuries (333 MBq)
Isotope Product Laboratories Model # HEG-137 Capsule type: 3024 Special Form Certificate # USA/0356/S	Cs-137	9 millicuries (333 MBq)
<u>Troxler Drawing No. A-102451 which covers:</u> AEA Technology/QSA, Inc. Model # AMNV.997 Capsule type: X.1 Special Form Certificate # USA/0632/S	Am-241:Be	44 millicuries (1.63 GBq)
Isotope Product Laboratories Model # Am1.NO2 Special Form Certificate # CZ/1009/S-85	Am-241:Be	44 millicuries (1.63 GBq)
<u>Troxler Drawing No. C-106580 which covers:</u> Isotope Product Laboratories Model Nos. 3021 or 3027 Special Form Certificate No. USA/0462/S	Am-241:Be	44 millicuries (1.63 GBq)
<u>Troxler Drawing No. A-105779 which covers:</u> Isotope Product Laboratories Model HEG-252 Capsule Type 3024 Special Form Certificate No. USA/356/S	Cf-252	66 microcuries (2.44 MBq)
AEA Technologies Mode No. CVN.CY2, Capsule Type X.1 Special Form Certificate No. USA/0632/S	Cf-252	66 microcuries (2.44 MBq)

LEAK TEST FREQUENCY: 12 months
PRINCIPAL USE: (G) Portable Moisture/Density Gauges
CUSTOM DEVICE: _____ YES _____ X NO

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DEVICE TYPE: Portable Surface Moisture and Density Gauges

DESCRIPTION:

The model 3400 series gauges are portable gauges designed to measure the moisture content and density of soils, soil-stone aggregates, cement and asphalt treated bases and asphalt surfacing. There are several models within the 3400 series that will be described.

The moisture measurement is based on the principle of neutron thermalization by hydrogen in the test material and incorporates a neutron emitting doubly or triply encapsulated radioactive source (40 millicuries +/- 10% Am-241:Be or 60 microcuries +/- 10% Cf-252) and a helium-3 proportional counter tube. The neutron source is held stationary in the base of the gauge in a threaded cavity by a threaded plug made of stainless steel and surrounded by lead. A "Caution-Radioactive Material" label indicating the radioisotope, quantity, serial number and assay date covers the threaded plug. The base of the gauge is placed on the material being tested. Fast neutrons emitted by the source traverse the material and are thermalized by hydrogen atoms in the sample. The thermal neutrons are then detected by the helium-3 proportional counter and counted over a specified time period. Because of the insensitivity of these detectors to fast neutrons, the number of thermalized neutrons detected is directly proportional to the number of water molecules present in the material. The instrument electronics convert the count data to a moisture content based on an internally stored calibration.

The density measurement is based on Compton scattering and photoelectric absorption of photons by the test material. Measurements can be made in a "direct transmission mode" or a "backscatter" mode. The gamma source is located near the end of the extendable source rod. Proper use of the gauge in the direct transmission mode consists of first making a hole approximately 0.625" diameter in the test material with the drill rod provided as an accessory. The gauge is then placed over the hole and the operator pulls a trigger on the source rod handle and inserts the source rod into the test material. The source rod can be inserted to depths from 2" to 12" in increments of either 1" or 2". An "index rod" or "index strip" on the gauge allows the trigger mechanism to be latched at the desired measurement depth. Geiger detectors located in the base of the gauge detect photons that have traversed the test material. The photons are counted over a specified time period and the number of counts detected is converted to a density value based on an internally stored calibration. A backscatter measurement is made by lowering the source rod so that its tip is essentially flush with the surface of the test material. The gauge is designed so that if the operator attempts to pick it up without first returning the source rod to the shielded position, the trigger in the handle releases and the rod retracts to the shielded position. A padlock is provided with the gauge so that the source rod can be locked in the shielded position when the gauge is not in use.

The density measurement uses a sealed source composed of 8 millicuries (+/- 10%) of Cs-137 in special form. The Cs-137 source is placed in the end of the source rod in a source cup and secured by welding. When retracted into the shielded position, the source is surrounded by tungsten or lead. When the operator engages the trigger and lowers the source rod, the spring-loaded tungsten sliding block is moved back allowing the source rod to be inserted into the test material.

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DESCRIPTION (Continued):

The gauge housing consists of two primary components: the aluminum base casting and the top-shell. The base casting holds the detectors, batteries, sources and shielding. The base is covered with a top-shell made of either aluminum or plastic. The electronic circuit boards for the device are attached to both the base casting and top-shell.

Within the 3400 series, there are several models that can be differentiated as described below.

3430-M & 3440-M

These models use a 60 microcurie (+/- 10%) Cf-252 neutron source instead of an Am-241:Be source for the moisture measurement.

3430, 3440, 3430-Plus, 3440-Plus, 3450

These model numbers use an 8 millicurie (+/- 10%) Cs-137 source and a 40 millicurie (+/- 10%) Am-241:Be source.

3451

Identical to the 3450 in construction except that the plastic top shell does not contain a scaler. The scaler has been replaced with a handheld PC (PDA) and the device is controlled either via wireless RF transmitter or RS-232 serial cable.

DETAILS OF CONSTRUCTION:

3430, 3430-M, 3440, 3440-M, 3450, 3451:

These gauges in the 3400 series use similar materials in their construction. The primary materials used are aluminum, lead, tungsten, and stainless steel. When the handle-source assembly is in the safe position, *i.e.*, at the highest vertical setting, the Cs-137 source is contained in the approximate center of a cylindrical tungsten shield 1.75" in diameter and 3.00" high with a 0.640" diameter center hole through which the source rod passes. The thickness of the tungsten in a radial direction is 0.455".

At the safe position, the source is shielded on the bottom of the gauge by a spring-loaded tungsten sliding block 2.00" high by 0.750" wide. The minimum thickness of tungsten provided by the sliding block on the bottom of the gauge is 0.702". The entire tungsten shielding is mounted in a cast aluminum base. The Cs-137 source has additional shielding in the form of cast lead approximately 0.450" thick to the rear of the gauge tower. This lead shielding protects the user who comes into contact with the rear of the gauge. There is also approximately 0.37" of cast lead shielding surrounding the aluminum boss housing the neutron source. This lead shielding also serves to protect the user.

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DETAILS OF CONSTRUCTION (Continued):

3430-Plus & 3440-Plus:

For these models, the cylindrical tungsten shield is replaced by a cylindrical lead shield. The shield diameter was increased from 1.75" to 2.186" to afford the same level of shielding. The sliding block and shielding for the Am-241:Be source remain the same. The Index Rod has been replaced with an extruded metal tower which includes an indexing strip at the back of the tower. This strip serves the same function as the index rod. Furthermore, the extruded tower provides additional mechanical structure and protection for the source rod. The bioshield has been changed from tungsten to lead and the diameter increased to afford the same shielding effectiveness of tungsten. The Plus gauges contain the same tungsten sliding block. The sliding block orientation has been changed. The block now slides towards to rear of the gauge and out of the measurement path.

The following subsections describe the major components of the original design and the revisions to those components which have occurred since the 3440 gauge's original release in January 1986:

Original Design:

- A. **Extendable Source Rod** (Serial Nos. < 25266): The Cs-137 source, 0.238" diameter, was housed inside of a 0.625" diameter x 1.750" long stainless steel source cup. Atop the Cs-137 source, within the source cup, was a 0.450" diameter x 0.250" long tungsten spacer, followed by a stainless steel spring. The source cup was then screwed onto a stainless steel source rod and welded.
- B. **3430 & 3440 Neutron Source Configuration:** The doubly encapsulated neutron source (Am-241:Be) was housed within a threaded cup, approximately 0.5" in diameter x 0.7" deep, located in a boss which was cast as part of the gauge's aluminum base. Between the bottom of the cup and the neutron source, was a 0.44" x 0.062" thick lead plug,. The neutron source was secured to the boss by a 0.48" long x 0.5" diameter plain steel (zinc plated) threaded source plug. Once installed, the neutron source is immobile.
- C. **3430-M & 3440-M Neutron Source Configuration:** The neutron source (Cf-252) is housed in an aluminum source holder, atop a lead disk and aluminum spacer, which is attached to the cast aluminum base with steel screws. The neutron source is then secured to the source holder by a threaded stainless steel plug. An aluminum handle is then screwed into the source holder for safer handling during insertion into the gauges. Once installed, the neutron source is immobile.

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DETAILS OF CONSTRUCTION (Continued):

Revisions to the Original Design:

- A. **Extendable Source Rod** (Serial Nos. > 25265): In November 1995, the Agency authorized a change from the source cup design to a threaded plug design. The Cs-137 source is housed within a 0.625" diameter x 0.725" long stainless steel source plug. The source plug is screwed into the lower end of a stainless steel rod with a similar diameter, which is machined out to hold a 0.448" x 0.250" thick tungsten disk (abuts the source) and a stainless steel spring. The source rod with source plug are then welded.
- B. **3430 & 3440 Neutron Source Configuration**: In March 1997, the Agency authorized a change to the neutron source configuration to permit the use of either doubly or triply encapsulated Am-241:Be sealed sources. In this design, the aluminum base has been modified such that the threaded cup within the boss is larger, approximately 0.688" in diameter x 0.76" deep. The following descriptions briefly detail the differences in affixing the doubly and triply encapsulated sealed sources to the base:
1. The **doubly encapsulated source** sits on two lead disks, each disk approximately 0.625" in diameter x 0.062" thick. An aluminum spacer cap, approximately 0.5" in diameter, which has been machined out at one end, is then placed over the source followed by a threaded stainless steel source cap, approximately 0.688" in diameter.
 2. The **triply encapsulated source** is affixed to the gauge as noted above, less the aluminum spacer and one lead disk.

Please note, the 3430-M and 3440-M source holder design is acceptable for use in the new base design.

LABELING:

The 3400 series gauges are labeled in accordance with 15A NCAC 11 .1626. The labels contain the radiation symbol, isotope, activity, model number, serial number, name of distributor, and the words "CAUTION-RADIOACTIVE MATERIAL."

DIAGRAM:

See Attachments A through E for a three dimensional view of the 3400 Series model gauges, including locations of the sources and labels.

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CONDITIONS OF NORMAL USE:

The 3400 series portable gauges are designed to be used by trained personnel to measure moisture and density of soils, aggregates and paving materials, typically at temporary job sites. The user will normally be near the device only for the time period necessary to set up the gauge and perform the measurement. The gauge has a recommended working life of 30 or more years under normal use conditions and with proper maintenance. However, the gauge should be returned to Troxler Electronics Laboratories, Inc. (hereafter Troxler) every five years for a thorough manufacturer's inspection, to include an extensive inspection of the extendable source rod and its welds.

The device is designed for the following environments:

Operating temperature -10°C to 70°C ambient

Pressure Atmospheric

Vibration Ranges from zero to mild (tested @ a displacement of 0.1" @ 12.5 Hz)

Corrosion Ranges from zero to corrosive

Fire +327°C (to melt the lead shielding used in the base casting around the Am-241:Be source and the lead bioshield in the 3430 Plus and 3440 Plus)

PROTOTYPE TESTING:

The 3400 series model gauges underwent prototype testing for mechanical, structural, and radiological integrity using measurement methodologies and testing procedures found in ANSI Standard N538-1979. This prototype testing included stray radiation measurements of gamma dose rates at 5 cm, 30 cm, and 100 cm for the gauges in both the "on" and "off" configurations; testing of the gauges' safety features at room temperature and at an elevated use temperature of 105°C, and at a decreased use temperature of -40°C; a leak test of the radioactive source after the safety feature/temperature testing; and an engineering evaluation of the likelihood of source retention in the source housing following a severe accident involving fire. The results of the testing showed: (1) no safety feature failure or stray radiation increase over the range of temperatures tested; (2) no loss of radioactive material from the sealed source; and (3) no loss of the shielding integrity of the device at temperatures below 327°C. Although a 327°C temperature would not, based on the ANSI classification of the source capsule, result in leakage of radioactive material, such a temperature would melt the lead shielding used in the cylindrical shield and in the base of the gauge. At this temperature, there would be a loss of some degree of shielding around the Cs-137 source rod and the Am-241:Be capsules although the capsule would remain captive in the source rod and base of the gauge respectively. The results of the prototype testing support the assignment of an ANSI standard rating of ANSI-54-164-154-R1. ANSI testing for the 3430 Plus and 3440 Plus were conducted by the applicant. Results of that testing indicate an ANSI standard rating of ANSI-54-154-154-R1.

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EXTERNAL RADIATION LEVELS:

See Attachments F – K for external radiation levels for the various models of gauge.

QUALITY ASSURANCE AND CONTROL:

Troxler Electronic Laboratories maintains a quality assurance and control program which has been deemed acceptable for licensing purposes by the North Carolina Radiation Protection Section. A copy of the program is on file with the Radiation Protection Section.

LIMITATIONS AND/OR OTHER CONSIDERATIONS OF USE:

Distribution: This device will be distributed as a specifically licensed device in accordance with the requirements of section .0300 of 15A NCAC 11 and/or applicable regulations of the NRC or an Agreement State. This shall not preclude the exportation of this device to a foreign entity following the applicable regulations.

Leak Testing: The device shall be leak tested by the user following the instructions in the "Manual of Operation and Instruction" at intervals not to exceed twelve months using techniques capable of detecting the presence of 0.005 microcurie of removable contamination. If the level of contamination exceeds this limit, the device shall be returned to Troxler for repair/disposal. Please note, Troxler maintains a customer leak test service using the Troxler Model 3880 Leak Test Kit.

Servicing: The 3400 series devices require periodic maintenance of two specific gauge components by the gauge user. The scraper ring/sliding block require periodic cleaning and lubrication, and the source rod bearings require lubrication. The maintenance should be performed according to the manufacturer's instruction located in the operation and instruction manual. In addition, the gauge should be returned every five years for a thorough manufacturer's inspection of the gauge, to include an extensive inspection of the extendable source rod and its pertinent welds. Servicing of the source rod, including but not limited to source replacement, general servicing, repair, and/or disposal, shall be done by the manufacturer.

Dosimetry: All authorized users of these gauges should wear personnel dosimetry (film badges or TLD) in accordance with NRC or Agreement State regulations.

Operating and Safety Instructions: The device shall be operated in accordance with the written operating and safety instructions given in the device manual. The source rod **shall not** be driven or forced into the material to be tested; rather, a hole **must** be formed in the test material with the "drill rod" accessory provided with the gauge. The licensee should not attempt to remove the source rod from the gauge unless specifically authorized by his specific license.

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LIMITATIONS AND/OR OTHER CONSIDERATIONS OF USE (continued):

Training: Use of these gauges is limited to individuals who have completed an approved training class in the basic principles of radiation safety and the proper use of these gauges. Please note, Troxler provides a training program for gauge users.

Use: Any time the gauge is not being used to make a measurement or is not under the physical surveillance of the operator, the source rod should be locked in the safe position. The operator should periodically inspect the source rod release mechanism and the gauge for loose and worn components. If any damaged components are found, the gauge should be returned immediately to the manufacturer for servicing.

Reviewer Notes:

1. This registration sheet and the information contained within the references shall not be changed without the written consent of the North Carolina Radiation Protection Section, Radioactive Materials Branch.
2. The Models 3401/3401-B and 3411/3411-B are included with the 3400 series gauges referenced in this sheet for licensing purposes. These gauges are no longer manufactured by Troxler. However, they will be accepted by Troxler for servicing and disposal. These models have been transferred to SADR# NC-646-D-830-S).
3. The Model 3450 and 3451 Registration Certificate (NC-646-D-138-S) has been moved to inactive status (See SADR # NC-646-D-832-S)

DOCUMENTATION:

The documentation enclosed with the device upon shipment to the user shall include the following:

1. manual of operation and instruction,
2. special form certificate,
3. type "A" package testing results,
4. a copy of the final leak test results made prior to packaging,
5. bill of lading,
6. an emergency response information sheet,
7. Troxler gauge certificate,
8. Troxler transportation guide.

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SAFETY ANALYSIS SUMMARY:

The design of the 3400 series gauges makes the devices safe to operate by personnel trained in radiological safety. The inherent safety features of the device include: (1) a sealed source, doubly or triply encapsulated, and secured into the device; (2) the use of shielding to attenuate the radiation to lower exposure levels; (3) a positive retraction feature to assure that the extended source rod retracts into the shielded position before the gauge is picked up off the surface being tested. The radiation profile for the device both in and out of the transport case show relatively low radiation levels that are acceptable per federal regulations for exposure. Therefore, based on the information cited above and technical information provided in the application attachments, and with the condition that the licensee (*i.e.*, user) maintain the gauge(s) in accordance with the manufacturer's recommendations and the requirements of this registry sheet, we conclude that the Troxler Models 3430, 3430-M, 3430 Plus, 3440, 3440-M, 3440 Plus, 3450 & 3451 gauges meet and exceed the requirements to be manufactured and distributed as specifically licensed devices pursuant to applicable regulations listed in 15A NCAC 11.

REFERENCES:

The following supporting documents are hereby incorporated by reference into this SS&D registry document:

1. All information and engineering drawings submitted by Troxler in the application for a safety analysis of the 3400 series gauges and currently contained in the gauge SS&D review file;
2. The operating and instruction manual for the 3400 series gauges;
3. Testing results for the classification of the Type "A" packages for 3430 and 3440 gauges;
4. Test results from prototype testing carried out on the 3400 series gauges;
5. Troxler Quality Assurance manual, Revision 4, June 26, 1997; and
6. Sealed Source & Device Registry Certificate No. NC-646-D-130-S originally issued in October of 1984.
7. Letter dated February 25, 2000, signed by Stephen A. Browne, Corporate Radiation Safety Officer.
8. Letter with attachments dated November 21, 2001 and facsimile dated November 28, 2001, both signed by Stephen A. Browne, Corporate RSO.

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REFERENCES (continued):

9. a. Electronic mail dated December 16, 2005 from Stephen A. Browne, Corporate R.S.O., and letter with attachments dated February 14, 2006, signed by Stephen A. Browne, Corporate R.S.O.
- b. All information and engineering drawings submitted by Troxler Electronics Laboratories, Inc. as the application for a safety analysis of the Model 3450 gauge and currently contained in the gauge SS&D review file; Appendices A & D of the Manual of Operation and Instruction for the Model 3450 gauge, transmitted on November 28, 2001; Testing results for the classification of the Type "A" package for the Model 3450 gauge; Test results from prototype testing carried out on the Model 3450 gauge; Letter with attachments dated December 03, 1998, signed by Stephen A. Browne, Corporate Radiation Safety Officer Letter dated February 25, 2000, signed by Stephen A. Browne, Corporate Radiation Safety Officer; Letter dated November 21, 2001 and facsimile dated November 28, 2001, both signed by Stephen A. Browne, Corporate R.S.O.; Letter with attachments dated May 15, 2003, signed by Stephen A. Browne, Corporate R.S.O.
10. Letter with attachments dated February 07, 2007, signed by Stephen A. Browne, Corporate R.S.O. and electronic message with attachment dated February 14, 2007.
11. **Electronic message with attachments dated February 21, 2007 from Stephen A. Browne, Corporate R.S.O.**

ISSUING AGENCY:

North Carolina Radiation Protection Section, Radioactive Materials Branch.

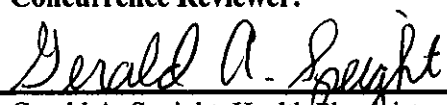
Principal Reviewer



J. Marion Eaddy III, Health Physicist

Date: April 04, 2007

Concurrence Reviewer:



Gerald A. Speight, Health Physicist

Date: April 04, 2007

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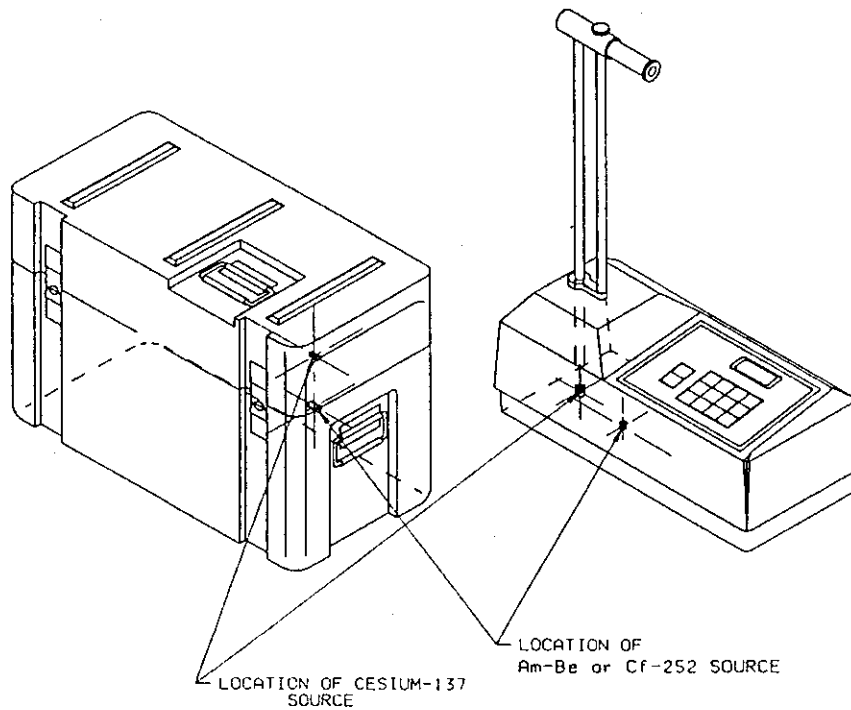
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Attachment A: Three Dimensional View of the Source Locations for Models 3430, 3430-M, 3440, 3440-M, 3450, 3451



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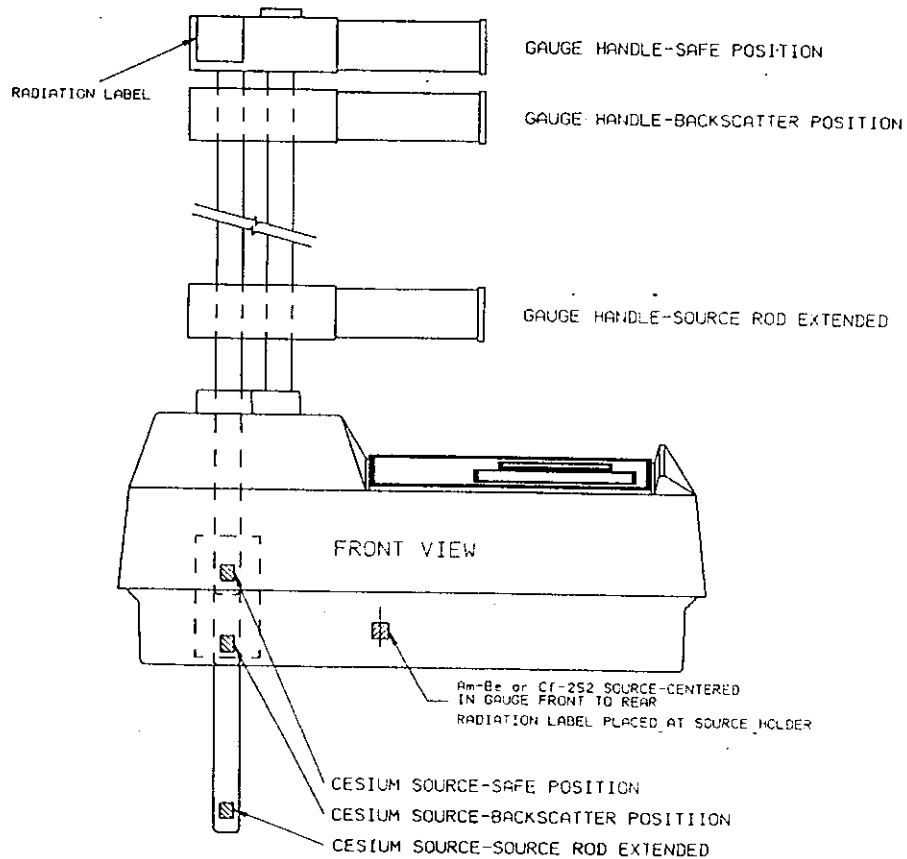
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Attachment B: Gauge Source and Label Locations for Models 3430, 3430-M, 3440, 3440-M, 3450, 3451



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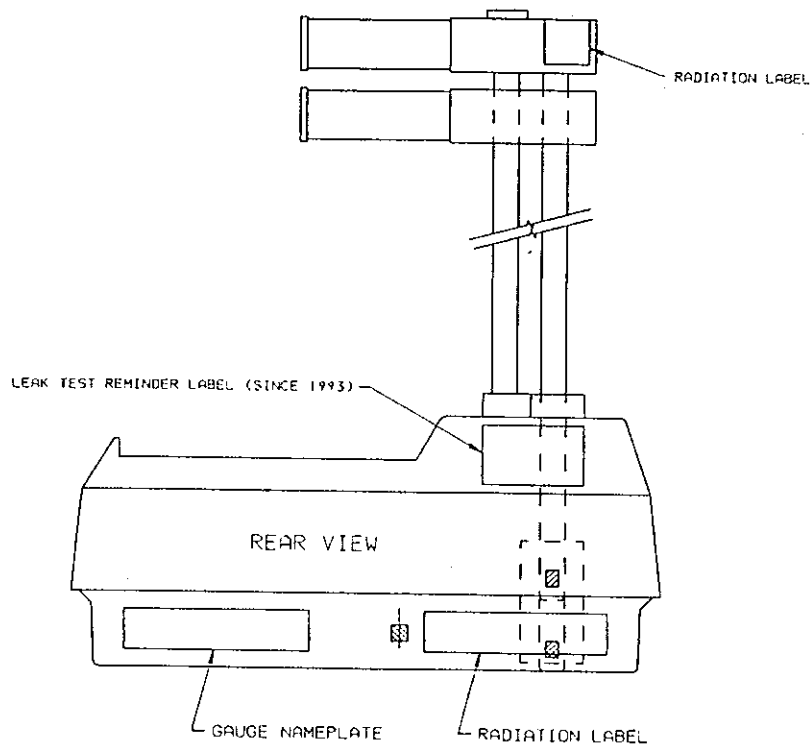
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Attachment C: Gauge Source and Label Locations for Models 3430, 3430-M, 3440, 3440-M, 3450, 3451



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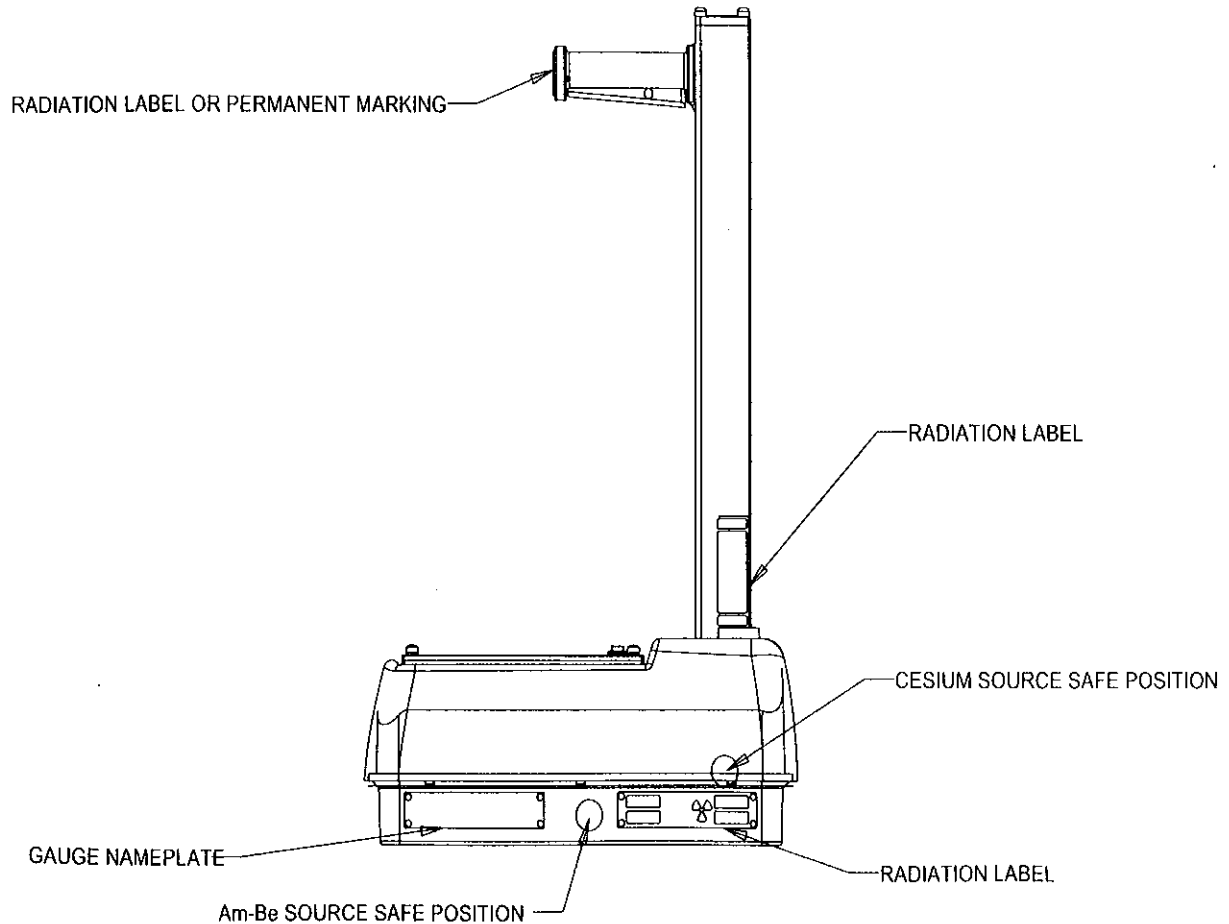
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Attachment D: Gauge Source and Label Locations for Models 3430 Plus & 3440 Plus



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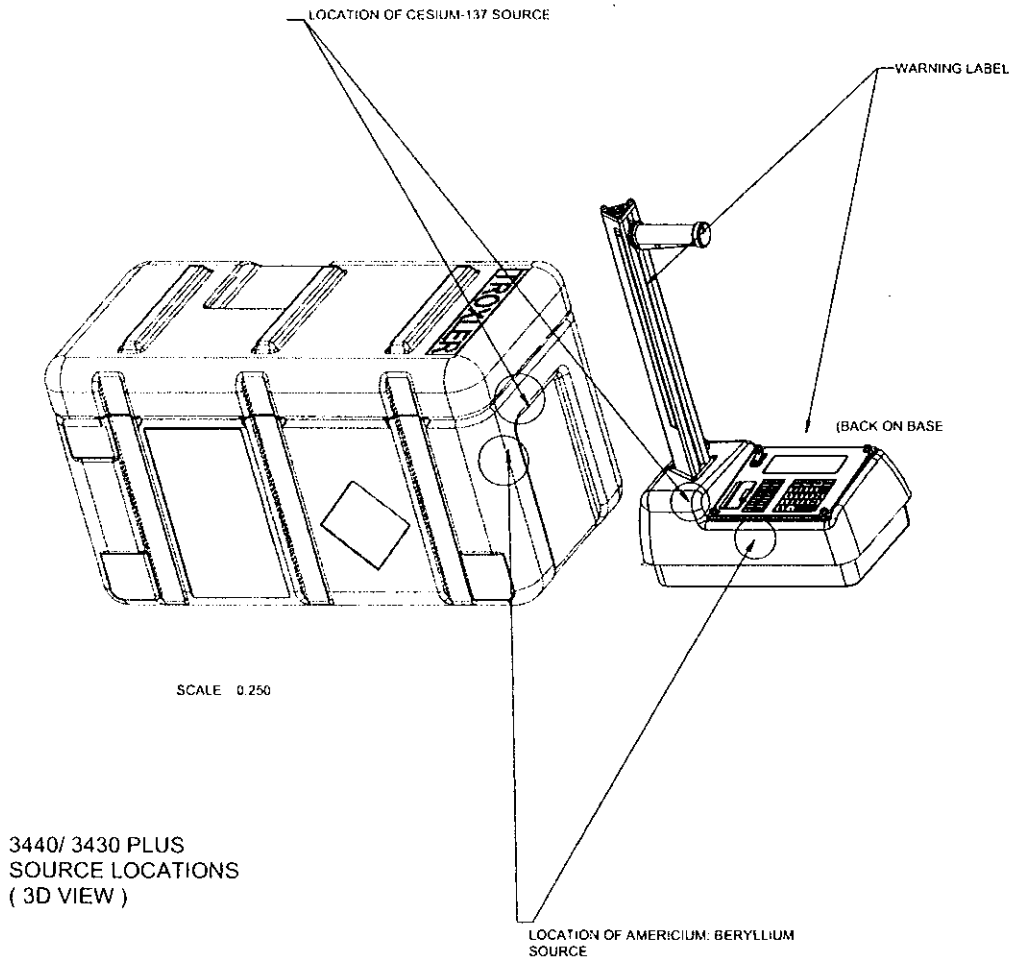
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Attachment E: Source Locations for Models 3430 Plus & 3440 Plus in Transport Case



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Attachment F: Radiation Profiles for 3430 Gauge and Gauge in Plastic Transport Case

Radiation Profile for 3430 Gauge

Location	Surface			10 cm			30 cm			1 meter		
	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$
Front	13	1.7	14.7	5	1.7	6.7	1.1	0.3	1.4	0.3	*	0.3
Back	26	1.4	27.4	8	1.4	9.4	2.5	0.5	3.0	0.4	*	0.4
Left	13	0.5	14	4	0.5	4.5	0.7	0.25	0.95	0.1	*	0.1
Right	12	0.7	13	8	0.7	8.7	2.5	0.25	2.75	0.4	*	0.4
Top	19	1.7	20.7	8	1.7	9.7	0.6	0.7	1.3	0.15	0.1	0.25
Bottom	18	6.0	24	2.5	6	8.5	0.6	0.9	1.5	0.1	0.1	0.2

Radiation Profile for 3430 Gauge in Plastic Transport Case⁶

Location	Surface			10 cm			30 cm			1 meter		
	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$
Front	10	0.7	10.7	5	0.7	5.7	1.2	0.4	1.6	0.25	*	0.25
Back	7	0.8	7.8	3	0.8	3.8	0.8	0.25	1.1	0.1	*	0.1
Left	0.3	0.1	0.4	0.25	0.1	0.35	0.1	0.1	0.2	*	*	*
Right	5	3	8	2	3	5	0.6	0.7	1.3	0.2	0.1	0.3
Top	10	0.4	10.4	2.5	0.4	2.9	0.6	0.3	0.9	0.1	*	0.1
Bottom	10	0.7	10.7	5	0.7	5.7	2	0.2	2.2	0.3	*	0.3

Notes:

1. Radiation measurements were for a gauge containing a nominal 8 millicurie Cesium-137 gamma source and a nominal 40 millicurie Americium 241:Beryllium neutron source.
2. All radiation measurements are in millirems per hour.
3. Gamma (γ) measurements were obtained with a Ludlum 14C survey meter, calibrated March 9, 1990.
4. Neutron (η) measurements were obtained with a Nuclear Research Corp. Model NP-2 survey meter, calibrated March 22, 1990.
5. "*" denotes a radiation measurement less than 0.1 millirems per hour.
6. Orientation of the gauge in the transport case is as follows:
 - a. Back of the gauge to the front of the case;
 - b. Bottom of the gauge to the right side of the case; and
 - c. Top of the gauge to the left side of the case.

REGISTRY OF RADIOACTIVE SEALED SOURCES AND DEVICES
SAFETY EVALUATION OF DEVICE
(AMENDS IN ITS ENTIRETY)

NO. : NC-646-D-130-S

DATE: April 04, 2007

ATTACHMENT: 7 of 11

DEVICE TYPE: Portable Surface Moisture and Density Gauges

Attachment G: Radiation Profiles for 3440 Gauge and Gauge in Plastic Transport Case

Radiation Profile for 3440 Gauge

Location	Surface			10 cm			30 cm			1 meter		
	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$
Front	19.0	1.5	20.5	5.0	0.5	5.5	1.2	0.2	1.4	0.3	0.1	0.4
Back	18.0	0.8	18.8	6.0	0.4	6.4	1.5	0.2	1.7	0.2	0.1	0.3
Left	13.0	0.4	13.4	3.0	0.2	3.2	0.8	0.1	0.9	0.1	0.1	0.2
Right	12.0	0.6	12.6	6.0	0.3	6.3	3.0	0.2	3.2	0.5	0.15	0.65
Top	19.0	0.9	19.9	3.5	0.6	4.1	0.6	0.4	1.0	0.15	0.1	0.25
Bottom	18.0	1.9	19.9	4.0	1.2	5.2	0.7	0.4	1.1	*	0.1	0.1

Radiation Profile for 3440 Gauge in Plastic Transport Case⁶

Location	Surface			10 cm			30 cm			1 meter		
	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$
Front	8.0	0.3	8.3	3.0	0.25	3.25	1.1	0.15	1.25	0.3	*	0.3
Back	7.0	0.3	7.3	3.0	0.2	3.2	1.0	0.1	1.1	0.2	*	0.2
Left	0.4	0.1	0.5	0.3	*	0.3	0.2	*	0.2	0.2	*	0.2
Right	6.0	1.4	7.4	2.0	0.7	2.7	0.6	0.25	0.85	0.2	0.1	0.3
Top	13.0	0.2	13.2	3.0	0.15	3.15	0.9	*	0.9	0.3	*	0.3
Bottom	8.0	0.3	8.3	4.0	0.1	4.1	2.5	0.1	2.6	0.6	*	0.6

Notes:

1. Radiation measurements were for a gauge containing a nominal 8 millicurie Cesium-137 gamma source and a nominal 40 millicurie Americium 241:Beryllium neutron source.
2. All radiation measurements are in millirems per hour.
3. Gamma (γ) measurements were obtained with a Ludlum 14C survey meter, calibrated September 1987.
4. Neutron (η) measurements were obtained with a Nuclear Research Corp. Model NP-2 survey meter, calibrated March 1988.
5. "*" denotes a radiation measurement less than 0.1 millirems per hour.
6. Orientation of the gauge in the transport case is as follows:
 - a. Back of the gauge to the front of the case;
 - b. Bottom of the gauge to the right side of the case; and
 - c. Top of the gauge to the left side of the case.

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NO.: NC-646-D-130-S

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ATTACHMENT: 8 of 11

DEVICE TYPE: Portable Surface Moisture and Density Gauges

Attachment H: Radiation Profiles for 3430-M/3440-M Gauge and Gauge in Plastic Transport Case

Radiation Profile for 3430-M/3440-M Gauge

Location	Surface			30 cm			1 meter		
	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$
Front	12.0	4.5	16.5	1.5	1.4	2.9	0.3	0.2	0.5
Back	20.0	4.5	24.5	2.0	2.0	4.0	0.4	0.2	0.6
Left	13.5	2.0	15.5	3.0	0.8	3.8	0.7	0.2	0.9
Right	19.0	1.5	20.5	0.9	0.8	1.7	0.2	*	0.2
Top	18.0	5.0	23.0	0.8	1.8	2.6	0.3	0.2	0.5
Bottom	18.0	16.0	34.0	0.7	3.0	3.7	0.2	0.4	0.6

Radiation Profile for 3430-M/3440-M Gauge in Plastic Transport Case⁶

Location	Surface			30 cm			1 meter		
	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$	γ	η	$\gamma+\eta$
Front	10.0	1.9	11.9	1.4	0.6	2.0	0.3	0.2	0.5
Back	6.0	1.5	7.5	1.2	0.3	1.5	0.2	*	0.2
Left	8.0	5.0	13.0	0.8	1.6	2.4	0.2	0.3	0.5
Right	0.4	0.2	0.6	*	0.2	0.2	*	*	*
Top	10.0	1.2	11.2	0.9	0.4	1.3	0.2	*	0.2
Bottom	7.0	1.3	8.3	2.5	0.5	3.0	0.6	*	0.6

Notes:

1. Radiation measurements were for a gauge containing a nominal 8 millicurie Cesium-137 gamma source and a nominal 0.060 millicurie Californium-252 neutron source.
2. All radiation measurements are in millirems per hour.
3. Gamma (γ) measurements were obtained with a Ludlum 14C survey meter, calibrated January 7, 1991.
4. Neutron (η) measurements were obtained with a Nuclear Research Corp. Model NP-2 survey meter, calibrated April 18, 1991.
5. "*" denotes a radiation measurement less than 0.1 millirems per hour.
6. Orientation of the gauge in the transport case is as follows:
 - a. Back of the gauge to the front of the case;
 - b. Bottom of the gauge to the right side of the case; and
 - c. Top of the gauge to the left side of the case.

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DEVICE TYPE: Portable Surface Moisture and Density Gauges

Attachment I: Radiation Profiles for 3450 Gauge and Gauge in Plastic Transport Case

Radiation Profile for 3450 Gauge

Location	Surface		5 cm		30 cm		100 cm	
	gamma	neutron	gamma	neutron	gamma	neutron	gamma	neutron
Top	N/A	N/A	3.0	N/A	1.1	0.35	§	0.1
Bottom	N/A	N/A	1.35	N/A	0.45	0.5	§	§
Left	N/A	N/A	7.0	N/A	0.9	0.1	0.13	§
Right	N/A	N/A	0.8	N/A	0.2	§	§	§
Front	N/A	N/A	6.0	N/A	1.6	0.35	0.3	§
Back	N/A	N/A	5.5	N/A	1.4	0.35	0.3	0.1

Radiation Profile for 3450 Gauge in Plastic Transport Case⁶

Location	Surface		5 cm		30 cm		100 cm	
	gamma	neutron	gamma	neutron	gamma	neutron	gamma	neutron
Top	N/A	N/A	4.0	N/A	0.6	0.1	0.1	§
Bottom	N/A	N/A	0.6	N/A	0.25	0.35	§	0.1
Left	N/A	N/A	0.12	N/A	§	0.1	§	§
Right	N/A	N/A	3.5	N/A	0.5	0.8	§	0.1
Front	N/A	N/A	5	N/A	1.1	0.25	0.2	0.1
Back	N/A	N/A	3.5	N/A	0.9	0.25	0.15	0.1

Notes:

1. Radiation measurements were of a gauge containing a nominal 8 millicuries Cesium-137 gamma source and a nominal 40 millicuries Americium-241:Beryllium neutron source.
2. All radiation measurements are in millirem(s) per hour.
3. Gamma measurements were taken with a Bicon Micro Rem survey meter, Serial No. B464Y, calibrated in February, 1998.
4. Neutron measurements were taken with an NRC NP-2 survey meter, Serial No. 183404, calibrated in February 1998.
5. "§" denotes a radiation measurement of less than 0.1 millirem per hour
6. Orientation of the gauge in the transport case is as follows:
 - a. Back of the gauge to the front of the case;
 - b. Bottom of the gauge to the right side of the case; and
 - c. Top of the gauge to the left side of the case.

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DEVICE TYPE: Portable Surface Moisture and Density Gauges

Attachment J: Radiation Profiles for 3451 Gauge and Gauge in Plastic Transport Case

Radiation Profile for 3451 Gauge

Location	Surface		5 cm		30 cm		100 cm	
	gamma	neutron	gamma	neutron	gamma	neutron	gamma	neutron
Top	N/A	N/A	4.0	N/A	0.9	0.5	0.1	§
Bottom	N/A	N/A	1.4	N/A	0.5	0.5	0.1	§
Left	N/A	N/A	7.0	N/A	1.0	0.1	0.1	§
Right	N/A	N/A	0.7	N/A	0.3	§	0.1	§
Front	N/A	N/A	5.0	N/A	1.9	0.3	0.3	§
Back	N/A	N/A	5.0	N/A	1.7	0.4	0.2	§

Radiation Profile for 3451 Gauge in Plastic Transport Case⁶

Location	Surface		5 cm		30 cm		100 cm	
	gamma	neutron	gamma	neutron	gamma	neutron	gamma	neutron
Top	N/A	N/A	2.0	N/A	0.9	0.1	0.1	§
Bottom	N/A	N/A	1.1	N/A	0.4	0.4	0.1	§
Left	N/A	N/A	0.3	N/A	0.1	0.1	§	§
Right	N/A	N/A	3.5	N/A	0.3	0.5	0.1	§
Front	N/A	N/A	4.5	N/A	0.8	0.1	0.2	§
Back	N/A	N/A	5.5	N/A	0.9	0.2	0.2	§

Notes:

1. Radiation measurements were of a gauge containing a nominal 8 millicuries Cesium-137 gamma source and a nominal 40 millicuries Americium-241:Beryllium neutron source.
2. All radiation measurements are in millirem(s) per hour.
3. Gamma measurements were taken with a Bicon Micro Rem survey meter, Serial No. B464Y, calibrated in March 28, 2003.
4. Neutron measurements were taken with an NRC NP-2 survey meter, Serial No. 183404, calibrated in February 11, 2003.
5. "§" denotes a radiation measurement of less than 0.1 millirem per hour
6. Orientation of the gauge in the transport case is as follows:
 - a. Back of the gauge to the front of the case;
 - b. Bottom of the gauge to the right side of the case; and
 - c. Top of the gauge to the left side of the case.

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DEVICE TYPE: Portable Surface Moisture and Density Gauges

Attachment K: Radiation Profiles for 3430-Plus & 3440-Plus Gauge and Gauge in Plastic Transport Case

Radiation Profile for 3430/3440 Plus Gauge

Location ⁶	Surface		5 cm		30 cm		100 cm	
	gamma	neutron	gamma	neutron	gamma	neutron	gamma	neutron
Top	N/A	N/A	11	0.75	1.5	0.2	0.2	§
Bottom	N/A	N/A	17	2	0.5	0.2	0.1	§
Left	N/A	N/A	16	0.3	1.4	§	0.2	§
Right	N/A	N/A	4	0.3	1.6	0.1	0.3	§
Front	N/A	N/A	5.5	0.4	0.9	0.15	0.1	§
Back	N/A	N/A	9	0.6	1.4	0.2	0.3	§

Radiation Profile for 3430/3440 Plus Gauge in Plastic Transport Case

Location ⁶	Surface		5 cm		30 cm		100 cm	
	gamma	neutron	gamma	neutron	gamma	neutron	gamma	neutron
Top	N/A	N/A	9	0.2	1.1	0.1	0.2	§
Bottom	N/A	N/A	3.1	0.3	1.3	§	0.3	§
Left	N/A	N/A	0.4	§	0.1	§	§	§
Right	N/A	N/A	7.5	1	0.7	0.2	0.1	§
Front	N/A	N/A	4	0.3	0.8	0.1	0.1	§
Back	N/A	N/A	2	0.3	0.4	§	0.1	§

Notes:

1. Radiation measurements were of a gauge containing a nominal 8 millicuries Cesium-137 gamma source and a nominal 40 millicuries Americium-241:Beryllium neutron source.
2. All radiation measurements are in millirem(s) per hour.
3. Gamma measurements were taken with a Bicon Micro Rem survey meter, Serial No. B464Y, calibrated in April, 2007.
4. Neutron measurements were taken with an NRC NP-2 survey meter, Serial No. 183404, calibrated in July, 2007.
5. "§" denotes a radiation measurement of less than 0.1 millirem per hour
6. Orientation of the gauge in the transport case is as follows:
 - a. Back of the gauge to the front of the case;
 - b. Bottom of the gauge to the right side of the case; and
 - c. Top of the gauge to the left side of the case.