January 18, 1982
Attachment

NUCLEAR SURFACE MOISTURE-DENSITY GAUGE TRAINING MANUAL

IN-HOUSE TRAINING SEMINAR

EARTH SCIENCES DEPARTMENT

L. ROBERT KIMBALL & ASSOCIATES, Consulting Engineers & Architects
Ebensburg, Pennsylvania
1982

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SIMULATED FIELD TESTING

Upon completion of the classroom instruction, participants of the training program will receive four hours of simulated field testing instruction. The training will consist of actual hands on use of the 2400 and 3411-B series gauges. The major emphasis of the instruction will be to familiarize the operators with the gauge controls, use of the equipment and understanding of the data obtained.

PREFACE

The primary purpose of this training program is to educate selected employees and clients of this firm as to the proper use, safe operation and handling of the company's nuclear moisture-density testing equipment.

It is our basic objective to provide the best possible professional service to our clients and to the public. In keeping with this objective we recognize our responsibility to maintain the necessary technical support to include the use of the latest state-of-the-art engineering techniques and equipment.

L. Robert Kimball and Associates would like to thank Troxler Electronic Laboratories for their permission to reproduce the Troxler 2400 and 3400-B series manuals (See Appendix A) for use in this training manual.

INTRODUCTION

Nuclear moisture-density test equipment has in recent years become more prevalent for use in performing density tests on compacted earth and gravel fills and asphalt paving. While the method of obtaining engineering properties of compacted fills has become somewhat more sophisticated than traditional methods the capabilities of nuclear techinques have become a formitable alternative. Every engineering test method utilized to assist in the design and analysis of civil projects has its advantages and disadvantages of course. Nuclear moisture-density gauges utilize gamma and alpha rays, and therein is the principal element of most concern to be considered when contemplating use as an engineering testing aide. Testing equipment utilizing nuclear methods has progressed to the point where relevant federal and state regulatory agencies have allowed their use under properly supervised conditions and where safeguards have been met to ensure the well being of persons who operate the equipment or are otherwise exposed to the effects of the equipment.

This education and training program is to provide our firm's nuclear gauge operators with a basic understanding of the equipment, its use, and the potential hazards associated with improper operation, storage and transportation of the gauge.

Our goal is to obtain competant nuclear gauge operators capable to being added to our present group of licensed operators. In addition, we plan to familiarize the present licensed operators with the latest equipment, techniques and operation of the equipment. It is our

intention to continue to provide our clients with the professional service and attitude synonomous with our firms image.

The in-house training program will be limited to employees and clients of L. Robert Kimball and Associates. Instructors for the program will consist of licensed gauge operators and supporting technical professional personnel employed by the firm.

Individuals participating in the education and training program will receive four hours of classroom instruction as well as a minimum of four hours of actual hands on training simulating field conditions. A test will be administered upon completion of the training program and successful candidates will receive a certificate stating successful completion of the course.

EDUCATION AND TRAINING PROGRAM

Planning:

1. The primary purpose of this education and training program is to educate employees and representatives of the firm as to the proper use and safe handling of the firms nuclear moisture-density gauge equipment.

2. Our firms basic objective is to provide the best possible professional services to our clients and the public. The use of nuclear moisture-density gauges has become an integral part of our firms field construction inspection services. Licensed operators are necessary in order for us to continue to provide such services.

3. The specific goals to be accomplished by this education and training program are as follows:

   a. Educate and train a sufficient number of company employees to maintain our firms capability to provide field inspection personnel utilizing nuclear methods for testing compacted earth, gravel fills and asphalts.

   b. Amend the firms present federal and state licenses, as necessary, to represent the actual list of competent operators eligible for certification as licensed gauge operators.

4. Specific manpower assignments are as follows:

   a. Course Instructors and Qualifications;

      (1) R. JEFFREY KIMBALL - Introduction and discussion of course objectives, limitation of nuclear moisture-

density methods and importance of compliance with current federal and state regulations regarding the use of nuclear equipment.

Qualifications - Mr. Kimball is Vice President of the Earth Science division of L. Robert Kimball and Associates. Mr. Kimball is a registered professional engineer in 8 states and is responsible for the firms geotechnical and construction inspection capabilities.

(2) Dr. ROGER SHINGLER - Responsible for course discussion regarding the radiation characteristics associated with the use of the firms nuclear moisture-density gauges.

Qualifications - PH.D, 1970 in Physical Chemistry, Brooklyn Polytechnic University. Mr. Shingler is the director of the Analytical Laboratory.

(3) O.T. McCONNELL - Description and discussion of theory of measurement, factory calibration and gauge capabilities.

Qualifications - Mr. McConnell is a registered professional engineer in Pennsylvania and has had extensive experience in field and laboratory testing of soils. He is a licensed nuclear gauge operator and is familiar with the operation and use of the firm's Troxler 2400 and 3400 series gauges. His name appears on the list of persons recognized as familiar

with the F.A.A. Eastern Regional Laboratory Procedures Manual. Mr. McConnell is the director of field and laboaratory soil testing for the firms Earth Science Department.

(4) TED ZEEDICK - Discussions of field measurements and special use procedures relative to gauge operation and asphalt paving, maintenance and service.

Qualifications - Mr. Zeedick is a licensed nuclear gauge operator and has 3 years experience as an engineering technician and construction inspector with this firm. Mr. Zeedick was previously employed by PennDOT and was responsible for inspection of various paving and structural projects. His name appears on the list of persons recognized as familiar with the F.A.A. Eastern Regional Laboratory Procedures Manual.

(5) DREW SMITH - Discussion of field measurements and special use procedures relative to gauge operation and earth and gravel fill construction inspection, maintenance and service.

Qualifications - Mr. Smith is currently the senior soils laboratory technician and the Earth Science Departments Radiological Safety Officer. He is a licensed nuclear gauge operator. Mr. Smith has been associated with the firm since 1977 and has had extensive experience in earthfill and asphalt construction inspection utilizing the firm's 2400 and

3400 series Troxler Nuclear Gauges. His name appears on the list of persons recognized as familiar with the F.A.A. Eastern Region Laboratory Procedures Manual.

5. The basic education and training manual will be the instruction manual prepared by the supplier of the firms 2400 series and 3400 series surface moisture-density gauges. The Troxler Instruction Manual is an approved training aide and our firm has received permission from Troxler Electronic Laboratories, Inc. (See Appendix A) to reproduce the manuals for use as the basic text for our firm's training course.

   The firm's nuclear gauges (Troxler 2400 series and 3400 series) will be utilized during the training course to familiarize the course candidates with operator and handling procedures.

6. The course training time and necessary instructional facilities are supplied by the firm as part of the company's dedication to the continual training of its employees for their individual improvement and professional capabilities to better serve our clients and the community.

SPECIFIC HANDLING PROCEDURES

The following will be adhered to at all times:

1. At no time shall an operator leave a nulcear gauge unattended except whenever the gauge is returned to the designated storage area in the Earth Science Soils Laboratory or another location as approved by the company safety officer.
2. Radiation detection film badges shall be worn at all times during the use of the nuclear gauges.
3. Keep all children under the age of 18 and pregnant women away from the gauge at all times.
4. Any non-licensed personnel who does not have a film badge and works around the gauge should be provided with one.
5. Do not store film badge near any of the gauges.
6. Do not mix equipment from one gauge to another without first consulting the safety officer.
7. All film badges are sent to the R.S. Landaurer Company for processing by the 5th of every month. Turn in all film badges to the safety officer between the 1st and 5th of each month.
8. Do not transport the gauge outside of its case, and be sure the lock is in place.
9. Keep gauge away from moist areas.
10. The daily log will be completed prior to each days test as complete as possible, with a maximum of:

    Name of job
    Specific area of job, if applicable
    Name of operator
    Names of personnel in constant contact
    Special job or weather conditions
    Standard Counts - all counts taken
    Problems with gauge

Telephone 919/549-8661, Cable Troxeloc, Telex 579474

TROXLER ELECTRONIC LABORATORIES, INC.

P. O. Box 12057, Cornwallis Road, Research Triangle Park, North Carolina 27709, U. S. A.

August 6, 1981

AUG 11 1981
L. ROBERT KIMBALL
AND ASSOCIATES
EBENSBURG, PENNA.

L. Robert Kimball & Associates
615 West Highland
Ebensburg, Pennsylvania 15931

ATTN: Mr. Tom McConnell

Dear Tom:

This will confirm our telephone conversation this morning and our permission to reproduce portions of the 2400 Series and 3400 Series manuals for use as training aids for your employees.

If I can provide additional assistance, please do not hesitate to contact me.

Sincerely,

TROXLER ELECTRONIC LABORATORIES, INC.

William E. Worrell
Sales Manager, Nuclear

WEW:jj

McConnell

APPENDIX A
3400-B SERIES MANUAL

3400-B SERIES

SURFACE MOISTURE-DENSITY GAUGES

TROXLER ELECTRONIC LABORATORIES, INC.

and subsidiary

TROXLER INTERNATIONAL, LTD.

P.O. BOX 12057
RESEARCH TRIANGLE PARK, N.C., 27709
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I-A. INTRODUCTION

This instrument is specifically designed to measure the moisture content and density of soils, soil-stone aggregates, cement and asphalt treated bases and asphalt surfacing. With suitable calibration, it can also be used to measure these parameters for other materials having approximately the same range of density and/or moisture content.

The instruments incorporate the latest state-of-the-art in solid state semiconductor design to provide a high degree of accuracy and reliability. The nuclear geometry and radioactive source design are the culmination of some twenty years of research and experience in developing instruments of this type. In addition to laboratory work, user experience of over 5000 instruments aided in the selection of the required design criteria and desired specifications.

This manual covers the operation and maintenance of two basic instruments, the 3401-B and the 3411-B. Both instruments provide the same end results. The 3401-B is a lower cost instrument which provides measurement results through the use of computer derived tables, requiring calculations on the part of the operator. The 3411-B contains a microprocessor which contains all calibration information and algorithms to compute and display all end results, thus eliminating one source of operator error. The latter instrument also, provides a means of compensation for hydrogen not in the form of water, contained in the measured material.

This manual is the basic text for training courses offered by the manufacturer to assist the purchaser in obtaining a Radioactive Materials License from either the U.S. Nuclear Regulatory Commission or an Agreement State. It may also be used for additional operator training, and the manufacturer encourages owners to require the study of this manual before allowing any prospective operator to use the instrument.

While no radiation hazard is imposed on the operator when following the normal recommended procedures of use, a potential hazard does exist if improperly used. All operators should read the sections covering Radiological Safety. If these are not completely understood, they should seek assistance from the factory or others designated within the user organization.

Since changes are continually made in State and Federal Regulations, the user must keep up-to-date with the appropriate regulations. The final responsibility for compliance with the regulations falls upon the owner. He may wish to purchase and subscribe to Title 10 and Title 49 of the Code of Federal Regulations, as well as the applicable State Regulations which apply to his license.

I-8. DEFINITION OF TERMS

PRECISION - Defines the statistical limits of the instrument based on changing rates of radioactive decay. The value stated is the standard deviation limit. It may be determined by statistical analysis of repetitive measurements (20 or more) or may be computed by the square root of the actual counts accumulated divided by the slope (first differential) of the calibration equation. It defines the repeatability of the measurement or the minimum change in density or moisture which is detectable by the instrument.

COMPOSITION ERROR - The error which exists due to the variation in photon scattering and absorption coefficients for limestone and granite. Most natural soils and stone are between these limits.

SURFACE ERROR - This term defines the error which can exist due to surface voids which are not representative of the subsurface material. It is determined by measuring the density or moisture content of a smooth surfaced standard and repeating the measurement with the instrument base elevated 1.25 mm (0.05 inch) above the standard. The error quoted may be assumed to apply for a 2.5 mm (0.1 inch) void for 50% of the surface, 5 mm (0.2 inch) void for 25% of the surface, etc.

EXPECTED TOTAL ERROR - The RMS sum of: two times the precision plus the composition error plus one-half the surface error plus two times the calibration precision. This term, while somewhat arbitrary, predicts that the 95% confidence limit of measurement will fall within these boundaries. It does not take into account possible operator caused errors.

DEPTH OF MEASUREMENT - The depth through which 95% of the counted photons and thermal neutrons pass before reaching the detectors. This method assumes that material below the depth of measurement is different than the measured layer, but between the limits of 1100-2700 kg/m^3 (70-170 PCF).

* * NOTICE * *

Due to the large percentage of international users of these gauges and the growing acceptance of the metric system in professional environments, the SI (Systeme International) units are used as the standard in this manual. The U.S. customary units are shown in parenthesis for convenience. We have also taken the liberty of rounding numbers (in both units) where the exact conversion might cause unnecessary accuracy or confusion for the operator.

The SI units for radiation measurements are not in general use so the older units are used throughout the manual and conversions quoted here as a reference.

1 Ci = 3.7×10^{10} Bq (37 gigabequerels)
1 Rem = 3.876×10^{3} C/kg (3.876 kilocoulomb/kilogram)

I-C-1. MEASUREMENT SPECIFICATIONS (SI UNITS)

BACKSCATTER DENSITY	FAST	NORMAL	SLOW	
Precision at 2000 kg/m^3	16.6	8.30	4.15	$\pm kg/m^3$
Composition Error at 2000 kg/m^3	40.0	40.0	40.0	$\pm kg/m^3$
Surface Error (1.25mm, 100% void)	64.0	64.0	64.0	$-kg/m^3$
Expected Total Error	62.4	54.4	52.8	$\pm kg/m^3$
Depth of Measurement (95%)	75	75	75	mm

DIRECT TRANSMISSION DENSITY, 150 mm				
Precision at 2000 kg/m^3	7.68	3.84	1.92	$\pm kg/m^3$
Composition Error at 2000 kg/m^3	22.4	22.4	22.4	$\pm kg/m^3$
Surface Error (1.25 mm, 100% void)	14.4	14.4	14.4	$-kg/m^3$
Expected Total Error	28.8	25.6	24.0	$\pm kg/m^3$
Depth of Measurement	50-200	50-200	50-200	mm

MOISTURE CONTENT				
Precision at 250 kg/m^3	10.2	5.10	2.55	$\pm kg/m^3$
Surface Error (1.25mm, 100% void)	17.6	17.6	17.6	$-kg/m^3$
Expected Total Error	24.0	14.4	11.2	$\pm kg/m^3$
Depth of Measurement at 250 kg/m^3	125	125	125	mm

MEASUREMENT SPECIFICATIONS (U.S. CUSTOMARY UNITS)

BACKSCATTER DENSITY	FAST	NORMAL	SLOW	
Precision at 120 PCF	1.04	0.52	0.26	±PCF
Composition Error at 120 PCF	2.50	2.50	2.50	±PCF
Surface Error (.05 inch, 100% void)	4.00	4.00	4.00	-PCF
Expected Total Error	3.90	3.40	3.30	±PCF
Depth of Measurement (95%)	3.00	3.00	3.00	inches

DIRECT TRANSMISSION DENSITY (6")				
Precision at 120 PCF	0.48	0.24	0.12	±PCF
Composition Error at 120 PCF	1.40	1.40	1.40	±PCF
Surface Error (.05 inch, 100% void)	0.90	0.90	0.90	-PCF
Expected Total Error	1.80	1.60	1.50	±PCF
Depth of Measurement	2-8	2-8	2-8	inches

MOISTURE CONTENT				
Precision at 15 PCF	0.64	0.32	0.16	±PCF
Surface Error (.05 inch, 100% void)	1.10	1.10	1.10	-PCF
Expected Total Error	1.50	0.90	0.70	±PCF
Depth of Measurement at 15 PCF	6.00	6.00	6.00	inches

I-C-2. MECHANICAL SPECIFICATIONS

Case		Epoxy finish aluminum casting
Vibration test		2.5 mm (0.1 inches) at 12.5 Hz
Drop test		300 mm on 25mm diameter steel ball
Operating temp.:	Ambient	-10 to 70°C (14 to 158°F)
	Surface	175°C (350°F)
Storage temp.		-55 to 85°C (-70 to 185°F)
Size (excluding handles)		368 x 229 x 183 mm (14.5 x 9 x 7.2 inches)
Height (including handles)		495 mm (19.5 inches)
Weight		16 kg (36 pounds)
Shipping weight		32 kg (75 pounds) w/o ABS Case 39 kg (87 pounds) with ABS Case

I-C-3. CALIBRATION SPECIFICATIONS

Number of Standards	6
Accuracy of Density Standards	±0.1%
Accuracy of Moisture Standards	±4.0%

Method: Computer reduction of count rate data based on U.S. National Bureau of Standards Photon Cross Sections, Neutron Cross Sections and Absorption Coefficients. Data is reduced to the form $D = (\ln(A/CR + C))/B$ for density and $M = (CR - E)F$ for moisture where A, B, C, E, and F are constants and CR is count ratio.

Field Data Conversion

3401-B - User is supplied with conversion tables for wet density and moisture content. User must compute dry density, percent moisture, and percent compaction.

3411-B - Contains μP (Microprocessor) providing direct reading in both SI and U.S. Customary units for wet density, dry density, moisture content and percent moisture. The algorithm corrects for hydrogen photon scattering coefficients and provides means for offsetting non-water hydrogen.

If the optimum density has been preset by the operator, the μP can compute % of Marshall or % of Proctor.

A method has also been provided to allow the operator to negate the effects of sidewall moisture should it become necessary.

I-C-4. RADIOLOGICAL SPECIFICATIONS

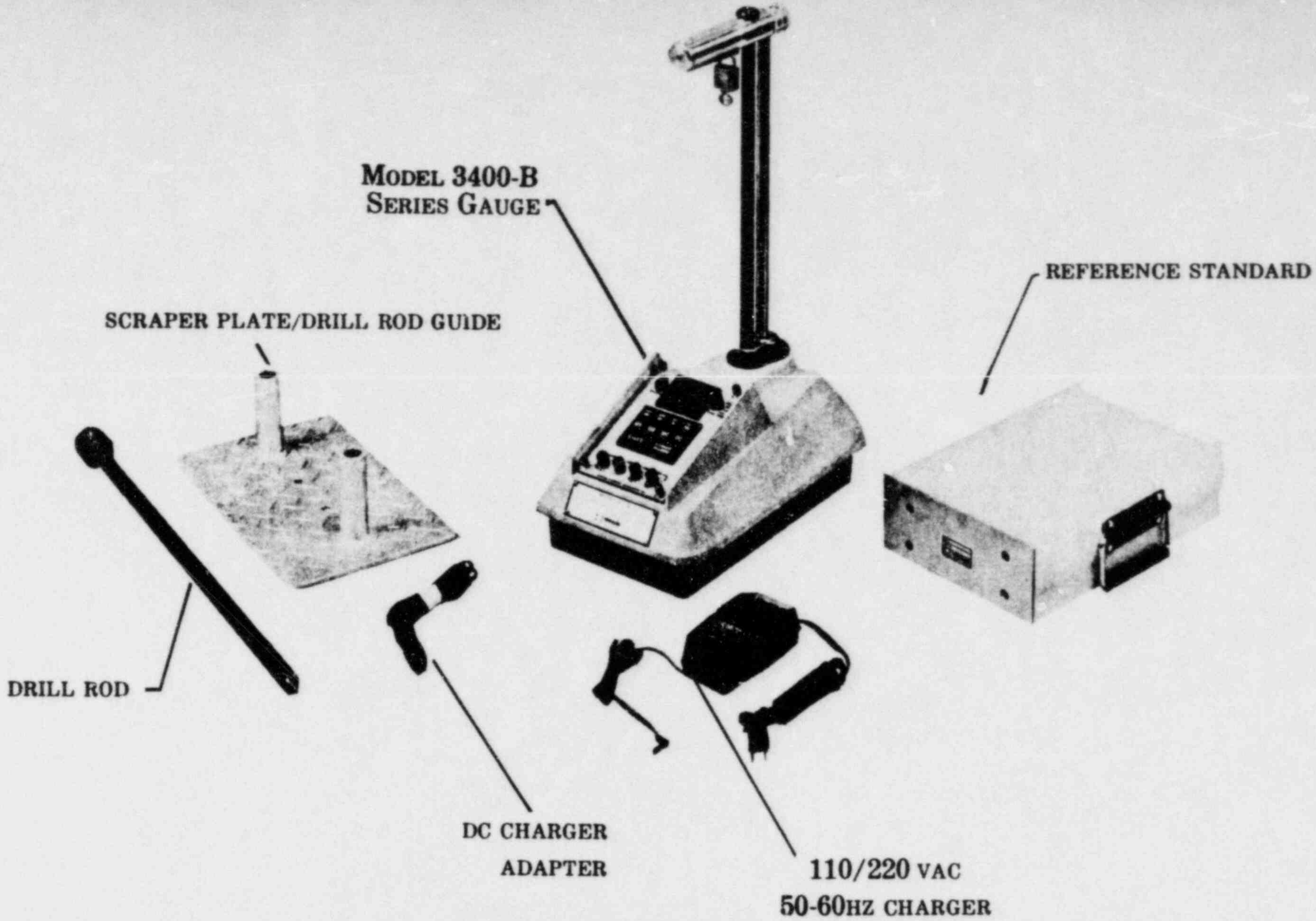
Gamma source	8 ±1 mCi cesium-137, TEL A-102112
Neutron source	40 ±10% mCi americium-241:beryllium with 70,000 N/sec. yield, TEL A-102451
Source form	Stainless steel doubly encapsulated
Shielding	Tungsten and lead
Surface dose rates	15 mrem/hour max., neutron and gamma
Source rod containment	Stainless steel, 55 C Rockwell hardness
Shipping case	DOT 7A, TYPE A, Yellow II Label 0.1 Transport Index
Source seal approval for domestic and international shipment	Cs-137, SPECIAL FORM Certificate GB:SFC 140 Am-241, SPECIAL FORM Certificate GB:SFC 7

I-C-5. ELECTRICAL SPECIFICATIONS

Time accuracy and stability	±0.005% ±0.0002%/°C
Power supply stability	±0.01%/°C
Stored power	40 watt-hours
Battery recharge time	14 hours
Charge source	110/220V, 50-60Hz or 12-14 VDC

	3401-B	3411-B
Readout (LCD) LIQUID CRYSTAL DISPLAY	4 digits	4 1/2 digits
Largest number displayable	9999	19999
Count registers (moisture, density)	2	2
Standard registers (moisture, density)	0	2
Power consumption (watts)	0.09	0.15
Power consumption after automatic battery cutoff (watts)	0.001	0.001

Battery packs are fully protected against over-charge and over-discharge. Low battery alarm is indicated by the display several hours prior to automatic cutoff.



3400-B Series Gauge and Accessories
Figure 2-1

II. OPERATING INSTRUCTIONS

II-A. GETTING ACQUAINTED

The 3400-B Series of instruments provide a fast and economical method for determining the moisture content and density of construction type materials. Before you attempt to use your gauge, spend a few minutes learning its features and controls. This section will act as a "dry run" to acquaint you with the instrument.

Remove the gauge and accessories from the shipping case and identify all the items by referring to figure 2-1. A brief description of the parts is;

Gauge: Portable instrument containing all electronic modules, rechargeable battery packs, and radioactive sources.

Reference Standard (also called the "standard"): This block serves two purposes. First, it is used to establish the standard counts against which all measurements are proportional; second, it serves as a known repeatable reference for checking long term stability.

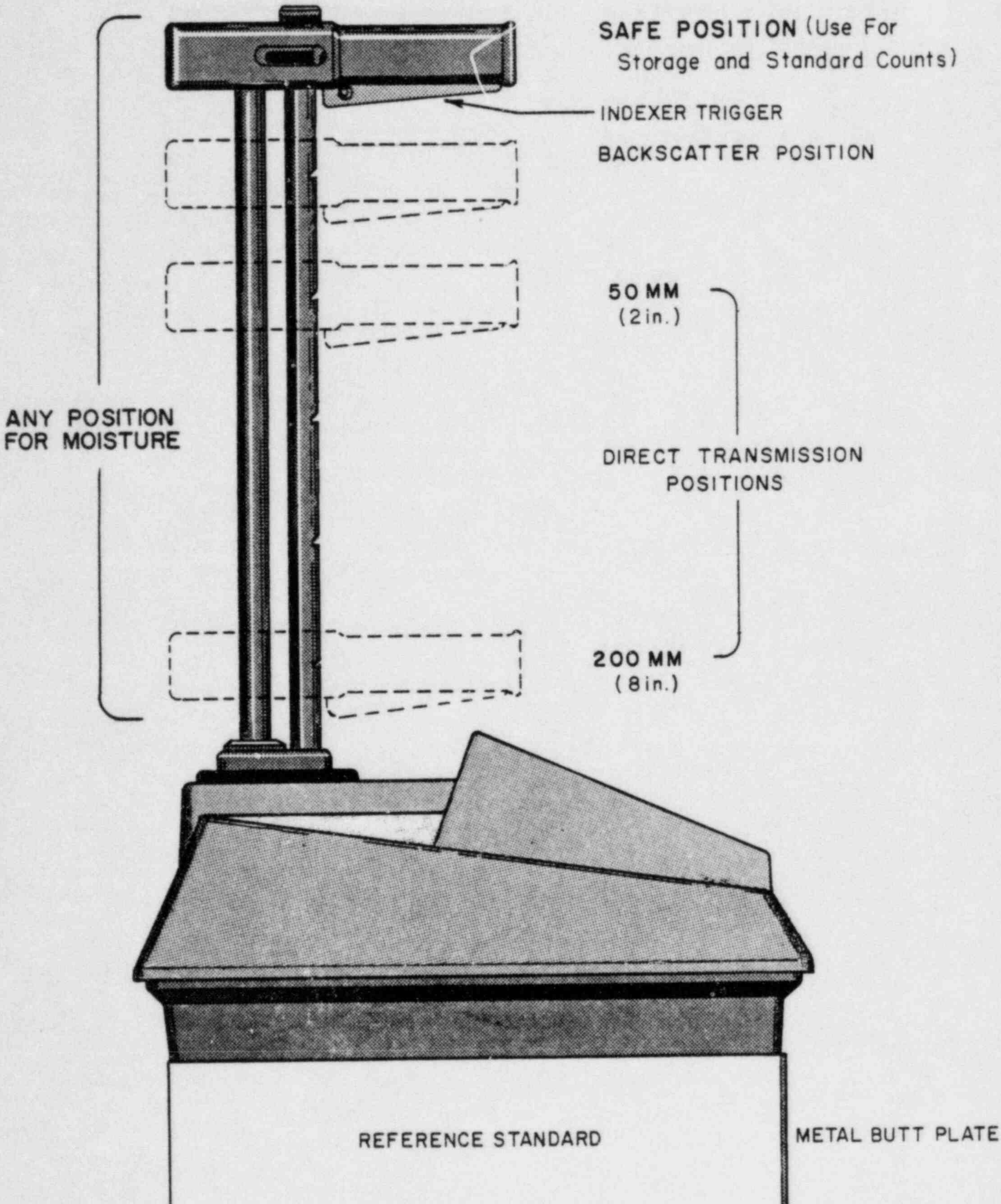
Drill Rod: Used with a hammer to punch the hole required for direct transmission measurements.

Scraper Plate: Functions as a guide for the drill rod. Also aids in smoothing the test site.

Charger: Two chargers are supplied. Refer to section VII-A for use of these units.

Now place the gauge in front of you such that the panel is sloping toward you. The part of the gauge closest to you is the front of the gauge. At the back of the gauge are two rods. The gauge handle is at the top of the rods. The handle also contains the trigger mechanism for lowering the source rod. The smooth, polished rod is the source rod. The bottom of this rod contains one of the radioactive sources. The dark rod with the notches is the index rod. This rod is used to precisely locate the source rod for the various positions. Refer to figure 2-2 for the labeling of these positions. When the source rod is pulled all the way up, it is in the storage or safe position. At this position the source on the source rod is retracted into a shield inside the gauge. When the gauge is not in use the source rod should always be in the storage position.

There are two nuclear sources in the gauge. The cesium source is used for density measurements and is located on the end of the source rod as discussed above. The americium source is used for moisture measurements and is located in the approximate center of the gauge base. The location of this source can be seen by removing the front panel from the gauge and looking into the cavity. At the back of the printed circuit board, a yellow and magenta label can be seen. The americium source is located under this label.



Reference Standard Orientation
Figure 2-2

II-A-1. USE OF REFERENCE STANDARD

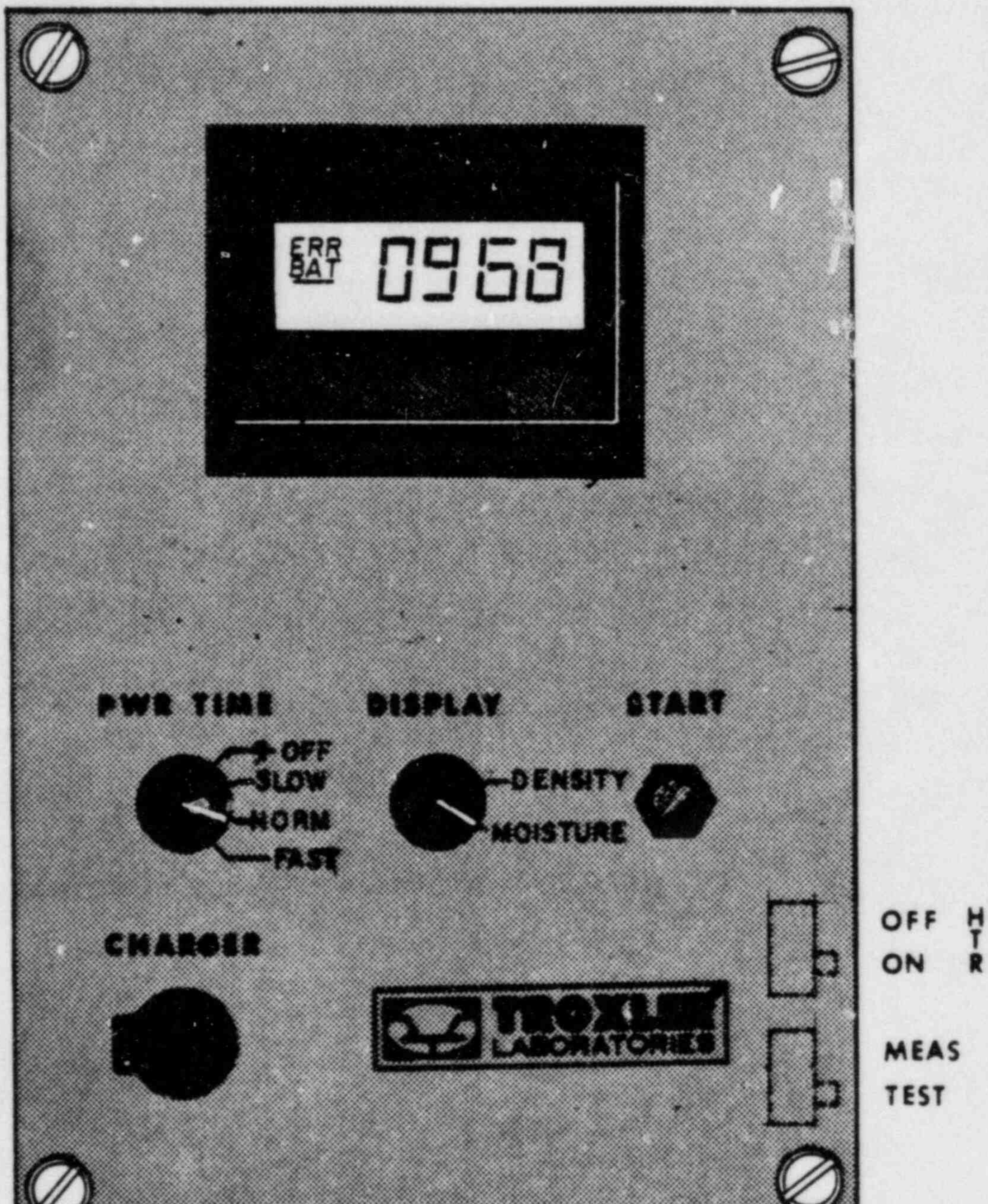
The calibration of this instrument is made in terms of a ratio to a count made on the Reference Standard which is supplied with the instrument. For this reason, measurements made with the instrument can be no more accurate than the accuracy of the standard counts. The operator should therefore use care to establish a set of standard counts for moisture and density. A log should be kept of these counts throughout the life of the instrument since this will establish a norm for the rate of change per unit time and allow the user to determine when a defect occurs either in the procedure or the instrument.

In general, a sudden shift of more than 1% in the density standard count or 2% in the moisture standard count, as compared to the average of the previous four sets, would indicate some abnormality in gauge operation or procedure.

The Reference Standard should be placed on a dry, flat surface at least two meters (six feet) away from any building or other large structure and at least ten meters (thirty feet) from any other radioactive source. The surface can be asphalt or concrete paving, compacted aggregate or similar surface with not more than 240 kg/m^3 (15 PCF) moisture. Sites not to be used are truck beds or tailgates, table tops or similar structures.

Locate the instrument on the Reference Standard as shown in figure 2-2. Make certain that the standard top and the gauge base are clean and do not have soil or other material in the seating area which would prevent good surface contact. The base must be seated between the raised edges of the standard and firmly pulled against the metal butt plate on the end of the standard. The operator end of the gauge must be next to the butt plate.

The gauge can now be used to accumulate (count) the standard counts. Since this procedure is different for the two models, they will be discussed separately.



3401-B Front Panel Controls
Figure 2-3

II-A-2. 3401-B CONTROL FUNCTIONS AND OPERATIONS

The front panel module is the only difference between the 3401-B and 3411-B. The 3401-B Scaler Module does not have electronics that store the reference standard counts for later use. It also requires some calculations by the operator. A step-by-step procedure for use of the 3401-B gauge follows. Refer to figure 2-3 as needed.

a. Place the gauge on the reference standard adhering to the precautions outlined in the previous section. Remove the lock from the trigger and make certain that the handle is indexed at the standard or safe position. This position of the source rod will always be used to obtain the moisture and density standard counts.

b. Refer to figure 2-3 or the front panel of the instrument and note that there are two rotary switches and one pushbutton switch. The left switch, labeled PWR/TIME, controls power to the instrument and also selects the time period of an accumulation. The time periods for SLOW, NORM and FAST are 4, 1, and 0.25 minutes, respectively. The rotary switch labeled DISPLAY indicates which register is being displayed. The START pushbutton initiates an accumulation for the time period selected by the PWR/TIME switch.

   Turn the PWR/TIME switch to SLOW. The standard counts should always be taken in the SLOW position. The notation BAT will appear if the instrument batteries are in need of a recharge.

   The remaining front panel item is the connector for the charger cables. Access to this connector is made by lifting the cover.

c. Allow at least 10 minutes to elapse after powering the instrument before taking the standard counts.

d. Depress the START pushbutton. Observe that the notation ERR appears in the upper left corner of the display.

e. Assuming that the ERR notation still appears, one can watch the accumulation of the standard counts. This accumulation can be seen in either the Density Register or the Moisture Register, depending on the position of the DISPLAY switch.

f. When ERR disappears, set the DISPLAY switch on DENSITY. The number which appears is the density standard count (DS) and should be within 2% of the density standard count as noted on the factory calibration data sheet. This assumes that the background radiation levels are the same as the factory area. The count will decrease at a rate of 2% per year from the date of calibration due to decay of cesium-137.

Set the DISPLAY switch on MOISTURE. The displayed number is the moisture standard count (MS) and should be within 4% of the moisture standard count as noted on the factory calibration data sheet. Since the half-life of americium-241 is very long, this count should not normally decrease with time.

Both standard counts may change with time due to aging of the detectors, which affects their efficiency, and long term changes in the high voltage and counting threshold. Since all calibration and measurements are made as ratios to the Reference Standard, these changes will not affect the calibration. A log of the standard counts should be kept for each gauge. Any sudden change in either of the standard counts may indicate a defect in the instrument.

At this time, record the density and moisture counts just obtained in the gauge standard count log and on the daily work sheet under the headings DS (Density Standard) and MS (Moisture Standard).

g. Remove the gauge from the Reference Standard and place it on a smooth surface (concrete, asphalt or compacted soil). Depress the trigger and move the handle to the backscatter position. Be certain that the trigger is indexed into the slot in the index rod and not pushed below the slot with the tip of the source rod resting on or in the material being tested. This is easily determined by pulling up and down on the handle without depressing the trigger or by noting that the padlock hole in the trigger is fully outside of the handle body.

h. Set the PWR/TIME switch on NORM and depress START. Note that ERR appears in the display. At the end of the NORM time period (1 minute), ERR will disappear and the density (DC) and moisture (MC) measurement count registers can be read by turning the DISPLAY switch.

i. You have now completed a moisture measurement and a backscatter density measurement. If on soil, the procedure could have been a moisture and direct transmission density measurement by punching a hole using the drill rod, guide, and a hammer. The source rod is then inserted into the prepared hole to the proper depth. The hole for the source rod should always be at least 50 mm (2 inches) deeper than the depth of measurement.

* * * CAUTION * * *

WHEN DRIVING THE ROD INTO SOIL, BASE MATERIAL OR HOT ASPHALT, REMEMBER THAT YOU ARE DRIVING A STEEL PIN WITH CONSIDERABLE FORCE. THIS PIN WILL WORK HARDEN OVER A PERIOD OF TIME AND PRODUCE METAL CHIPS WHICH COULD CAUSE INJURY TO THE OPERATOR OR BYSTANDERS. THE USE OF SAFETY GLASSES IS STRONGLY ADVISED.

j. The data can now be reduced to the desired parameters.

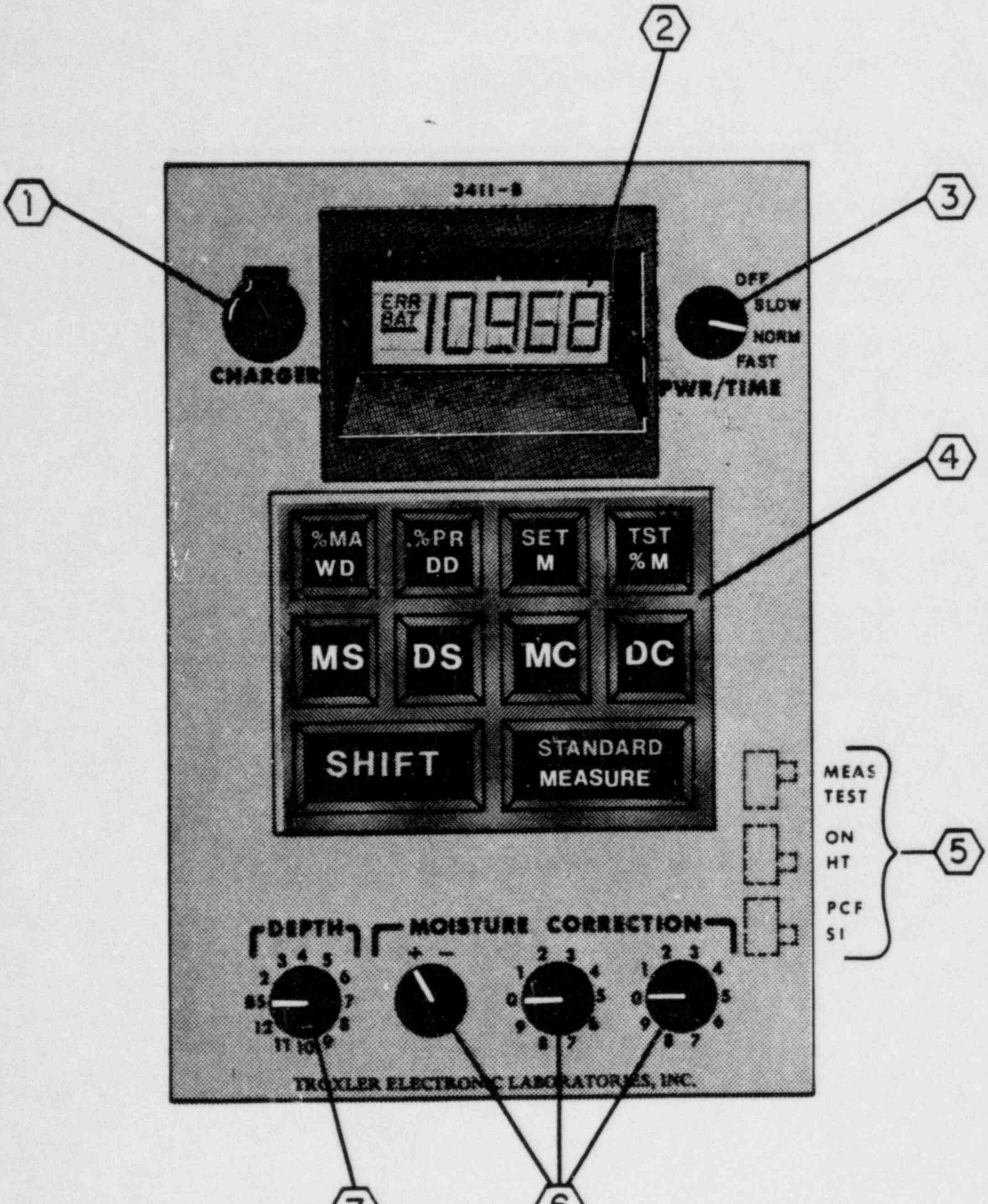
First, divide DC by DS, and using the obtained ratio, refer to the proper density calibration table (in this case, backscatter). The table is generated in 10 kg/m^3 (0.5 PCF) increments and mental interpolation will allow a quick determination to within 5 kg/m^3 (0.25 PCF). This is the wet density.

Next, divide MC by MS and use this ratio to determine the moisture content by using the moisture calibration table. If the measurement was made on concrete or asphalt, the value obtained should be quite low and represents the water equivalency of the hydration of the concrete or the hydrogen content of the asphalt mix.

The dry density is obtained by subtracting the moisture content from the wet density. The moisture content in percent is obtained by dividing the moisture content by the dry density and multiplying by 100.

Note that the FAST time period (0.25 minutes) could have been used. The displayed values for MC and DC would have been the same (the electronics adjust for the different time periods), but there will be a statistical difference in the results. The FAST test time may be used where only density is involved, since the expected total error is not much degraded by the difference in time. However, where moistures are required, it is advisable to use NORM in order to obtain the necessary accuracy for the percent moisture. These relative errors can be noted by referring to section I-C.

k. Note that the value obtained for moisture is uncorrected for chemically bound hydrogen and may be in error. Section III will discuss the methods of correcting this value.



3411-B Front Panel Controls
Figure 2-4

II-A-3. 3411-B CONTROL FUNCTIONS AND OPERATION

The Data Processor Module used in the model 3411-B gauge contains a µP (Microprocessor) as its key component. The µP has been programmed to provide a variety of functions. While the computational power of this module is quite large, considerable effort was spent making the unit as easy to use as possible.

a. Below is a functional description of the 3411-B controls. The number before the description corresponds to the labels in figure 2-4.

(1) Connector cover for battery charger cables. If the batteries need recharging the BAT symbol on the left side of the display will appear. Refer to section VII for battery charging instructions.

(2) The instrument display is a type of liquid crystal. In addition to displaying accumulated counts and computed results, it also has status indicators as shown below:

ERR - Accumulation in progress or a computational error has occured.

BAT - Low battery warning. Instrument batteries are in need of a recharge. The gauge will still function normally for several hours before it automatically shuts off.

— - Displayed number is negative in value.

HTR - Heater symbol was used on earlier production units to indicate that the display heater is on. See section II-E for a full description.

(3) PWR/TIME switch turns the unit on and also selects the time period for an accumulation. The SLOW, NORM, or FAST position correspond to accumulate periods of 4, 1, or 0.25 minutes, respectively.

(4) The keyboard is color coded for ease of use. Five keys are "dual function". The large yellow SHIFT key determines which mode the dual function keys are in. The functions labeled in yellow (STANDARD, %MA, %PR, SET, and TST) are valid <u>only</u> when the SHIFT key is depressed. The functions labeled in white are operational when the SHIFT key is <u>not</u> depressed.

The STANDARD/MEASURE key is used to start an accumulation of either a standard or a measure count period.

The second row of keys are used to determine which register will be displayed. The MS (Moisture Standard) and DS (Density Standard) keys are used to display the standard counts. The MC (Moisture Count) and DC (Density Count) keys are used to display the measure counts.

II-A-3. 3411-B CONTROL FUNCTIONS AND OPERATION (cont'd)

The top row of keys are for computations and test functions. The white keys on the top row (WD, DD, M, %M) compute wet density, dry density, moisture content, and % moisture, respectively. The %MA and %PR keys are used to compute % of Marshall and % of Proctor. The SET key is used to read or change the value of the established standard density. (See section II-B for a detailed description of the Marshall and Proctor functions.)

The TST key is used to initiate the self-test routines. Section II-D describes these routines.

⟨5⟩ This group of slide switches are located on the printed circuit board behind the front panel. To gain access to these switches you must loosen the four thumbscrews in each corner of the front panel and lift the module out of the gauge cavity. The function of the switches are listed below:

MEAS/TEST - In the TEST position, a known signal is applied to the counter inputs for testing purposes. In the MEAS position the gauge functions normally. See section II-D-3 for a full description.

HRT - This switch was on early units and is used to turn on a display heater if needed. See section II-E for a full description.

PCF/SI - This switch is used to determine the display units for computed results. In the PCF position, computational results are displayed in pounds-per-cubic foot. In the SI position, results are displayed in kilograms-per-cubic-meter. Select the preferred mode.

⟨6⟩ Moisture Correction switches are used to compensate or correct for errors in the moisture calculations caused by neutron absorbing materials or chemical bound hydrogen. The method for determining the moisture correction value is covered in Section IV-E.

⟨7⟩ The Depth Switch is always set to the same value as the depth of the source rod. This ensures that the proper calibration is being used during calculations.

II-A-3. 3411-B CONTROL FUNCTIONS AND OPERATION (cont'd)

Now that you are familiar with the controls on the 3411-B, proceed as below to use the gauge.

b. Place the gauge on the reference standard, adhering to the precautions outlined in section II-A. Remove the lock from the trigger and make certain the handle is indexed at the standard or safe position. This position of the source rod will always be used to obtain the standard counts, i.e. MS (Moisture Standard) and DS (Density Standard).

c. Turn the PWR/TIME switch to SLOW. The standard counts will always be taken in the SLOW position. The notation BAT will appear of the

The notation BAT will appear on the left side of the display if the instrument batteries are in need of a recharge.

d. Allow at least 10 minutes to elapse after powering the instrument before taking the standard counts.

e. A set of standard counts can be accumulated as follows:
   1) depress and hold the key labeled SHIFT,
   2) depress the STANDARD key and release it,
   3) release the SHIFT key.

Use your finger tip, NOT the point of a pencil or other sharp object. The SHIFT and STANDARD/MEASURE keys are interlocked to prevent accidental initiation of a standard count. Observe that the notation ERR appears in the upper left corner of the display.

f. Depress MS or DS. Assuming that the ERR notation still appears, one can watch the accumulation of the standard counts. This accumulation will also be seen in the MC and DC registers. At the end of the SLOW time period (4 minutes) the standard counts will be retained in memory until another set is taken or the instrument is turned off.

g. When ERR disappears, depress DS. The number which appears is the density standard count and should be within 2% of the density standard count as noted on the factory calibration data sheet. This assumes that the background radiation levels are the same as the factory area. This count will decrease at a rate of 2% per year from the date of calibration, due to decay of cesium-137.

Depress MS. The displayed number is the moisture standard count and should be within 4% of the moisture standard count as noted on the factory calibration data sheet. Since the half-life of americium-241 is very long, this count should not normally decrease with time.

Both standard counts may change with time due to aging of the detectors, which affects their efficiency, and long term changes in the high voltage and counting threshold. Since all calibration and measurements are made as ratios to the Reference Standard, these changes will not affect the calibration. A log should be kept of the gauge with a record of the standard counts. Any sudden change in either of the numbers may indicate a defect in the instrument.

h. Remove the gauge from the Reference Standard and place it on a smooth surface (concrete, asphalt or compacted soil). Depress the trigger and move the handle to the backscatter position. Be certain that the trigger is indexed into the slot in the index rod and not pushed below the slot with the tip of the source rod resting on or in the material being tested. This is easily determined by pulling up and down on the handle without depressing the trigger or by noting that the padlock hole in the trigger is fully outside of the handle body.

i. Set PWR/TIME on NORM and depress MEASURE. Note that ERR appears in the display. At the end of the NORM time period (1 minute), ERR will disappear and the moisture and density measurement counts can be displayed by depressing MC and DC respectively. Note that MS and DS are still contained in memory and may be displayed at any time by depressing MS and DS. They will remain until the instrument is switched OFF or until another set of standard counts is accumulated.

j. You have now completed a moisture measurement and a backscatter density measurement. If on soil, a moisture and direct transmission density measurement could have been performed by punching a hole using the drill rod, guide, and a hammer. The source rod is then inserted into the prepared hold to the proper depth. The hole for the source rod should always be at least 50 mm (2 inches) deeper that the depth for measurement.

* * * CAUTION * * *

WHEN DRIVING THE ROD INTO SOIL, BASE MATERIAL OR HOT ASPHALT, REMEMBER THAT YOU ARE DRIVING A STEEL PIN WITH CONSIDERABLE FORCE. THIS PIN WILL WORK HARDEN OVER A PERIOD OF TIME AND PRODUCE METAL CHIPS WHICH COULD CAUSE INJURY TO THE OPERATOR OR BYSTANDERS. THE USE OF SAFETY GLASSES IS STRONGLY ADVISED.

k. The 3411-B can display computed results in either PCF or SI(kg/m^3). The SI/PCF switch that allows the operator to change from one system to the other is located behind the module panel on the lower right corner of the circuit board. This switch is accessed by removing the module. Refer to figure 2-3 for the exact location of the switch.

The data may now be processed to obtain the desired parameter.

Set the Depth switch on BS and MOISTURE CORRECTION on +00. Depress WD and the value of the wet density will appear in the display. Depress DD and the value of dry density will appear. Repeat for M (moisture content) and %M (percent moisture). If the measurement was made on concrete or asphalt, the moisture content obtained should be low and represents the water equivalency of the hydration of the concrete or the hydrogen content of the asphalt mix.

Note: If a computation produces a negative result, a (-) symbol will appear on the left side of the display.

Note that the FAST time period (0.25 minutes) could have been used. The displayed values for the counts and computations would have been the same (the electronics adjust for the different time periods) but there will be a statistical difference in the results. The FAST test time may be used where only density is involved, since the expected total error is not much improved by the difference in time. However, where moistures are required, it is advisable to use NORM in order to obtain the necessary accuracy for the percent moisture. These relative errors are in Section I-C.

l. Note that the values obtained for moisture are uncorrected for chemically bound hydrogen and may be in error. Section IV will discuss the methods of correcting these values.

m. In the event an accumulation or processing error occurs, the ERR symbol and a two digit error code will be flashed on and off. A list of the error codes and possible causes is in section II-D. One should read these codes and become familiar with corrective actions.

Note: If an error occurs during an accumulation period, the count will be terminated and a flashing error code will appear. Since one or both of the counts may be in error, calculations will be inhibited until another set of counts is taken. If recovery from the error condition is made by depressing a display key (MS, DS, MC, or DC) the "ERR" symbol will remain and calculation will still be inhibited.

II-B. USE OF %MA AND %PR FUNCTIONS

The % of Marshall and % of Proctor functions are controlled by the top row of keys and the SHIFT key. The calculations preformed by the %MA and %PR keys are shown below.

$$\% \ MA = \frac{WD}{z} \times 100$$

$$\% \ PR = \frac{DD}{z} \times 100$$

Where z is a user defined value.

To read or change the value of z, depress and hold the SHIFT key while you momentarily depress the SET key. The display will now show the value of z in kg/m^3 or PCF depending on the position of the SI/PCF switch.

When the gauge is first powered up, z is preset to a value of 2000 kg/m^3 (124.8 PCF).

The processor will display the value of z for approximately 5 seconds after the last depression of the SET key. If you wish to change the value of z, then depress and hold the SET key while the processor is in the "display z" mode. The display will change the value of z as long as the SET key is depressed. The direction of this change (increase or decrease) is determined by the position of the MOISTURE CORRECTION +/- switch. If the SET key is depressed for longer than 5 seconds the rate of change increases to over 10 times the slow rate. This makes it easy for the user to rapidly offset z by large amounts. The rate of change returns to the slow rate each time SET is released. After the desired value of z has been obtained, the %MA and %PR functions can be used by pressing the SHIFT key and then the %MA and %PR key.

Note: The %PR key can also be used to compute the % Solids if the "voidless density" of the material can be determined. The "voidless density" is the density of the material if no air void were present. The equation would be:

$$\% \ Solids = \frac{DD}{z} \times 100$$

In this case "z" is the user preset value. This value is preset by the method shown above.

II-C. 3401-B TEST FUNCTIONS

The 3401-B has a built-in test feature which can be used if defective operation is suspected. This test may not be conclusive but it should help isolate the defect to either the 3401-B Scaler Module or the gauge base. The test results will also aid factory personnel to diagnose the problem.

Since the count rate from the moisture and density modules varies under normal conditions, it is necessary to substitute a signal of known rate for testing purposes. This is accomplished by the TEST/MEAS switch.

Loosen the four thumbscrews and lift the electronic module out of the base. Refer to figure 2-3 and locate the TEST/MEAS switch. Place the switch in TEST and replace the module.

Place the PWR/TIME switch on FAST and depress START. At the end of 0.25 minutes, a count of 8192 should be stored in both the density and moisture registers. Place PWR/TIME on NORM and repeat. After one minute, 8192 should be stored in both registers. Place PWR/TIME on SLOW and repeat for the same count after four minutes.

If the scaler accumulates the correct count in both registers for the three time positions, then you can be reasonably confident that the scaler module is functioning correctly.

II-D. 3411-B TEST FUNCTIONS

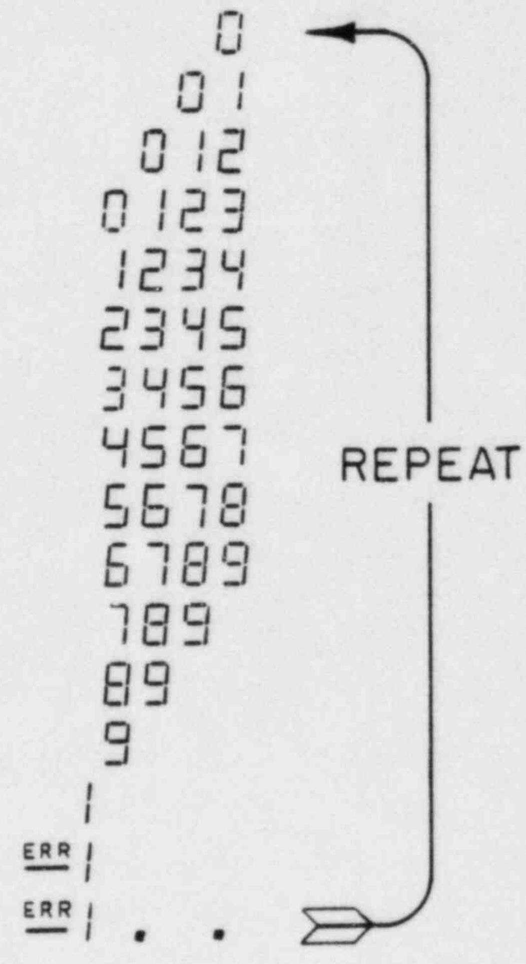
The 3411-B contains a μP (Microprocessor) which controls the majority of the instrument's functions. The μP, in conjunction with its crystal oscillator, provides the time standard for the accumulation cycle. The μP also updates the display, accumulates the moisture and density data counts, responds to the keyboard and rotary switches, and generates error codes if improper operation is detected. Therefore, the μP must be operational before any test can be performed. Fortunately, if the μP fails, it normally fails catastrophically. If the display indicates four zeros when the instrument is turned on, the μP is probably working normally.

II-D-1. SELF-TEST ROUTINES

If the µP is working, there are three self-test routines that can be used to verify proper operation. To enter the routines it is necessary to depress the SHIFT key and, while holding the SHIFT key down, depress the TST key. Each repeated depression of the SHIFT and TST keys, indexes to the next test. To return the instrument to the normal mode of operation, depress the SHIFT key and, while holding the SHIFT key down, depress and release the STANDARD key. Now release the SHIFT key. The instrument will also return to the normal mode of operation if it is turned off and on again.

II-D-1-a. DISPLAY TEST

This routine produces a cyclic number sequence that ripples across the display. The exact sequence is shown in figure 2-5. By watching each digit "count up" you can verify that the LCD (Liquid Crystal Display) and its associated electronics are operating properly.

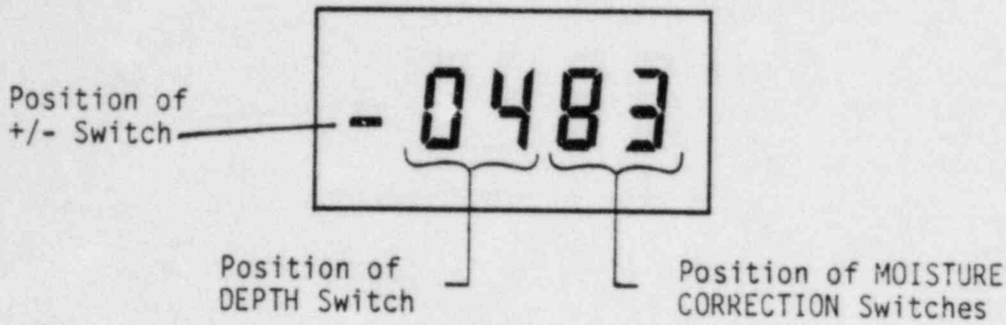


Display Test Sequence
Figure 2-5

II-D-1. SELF-TEST ROUTINES (cont'd)

II-D-1-b. ROTARY SWITCH TEST

Assuming that the display test above is correct, this routine can be used to verify that the μP is reading the rotary switches correctly. The μP reads the rotary switches and indicates the switch position via the display. The display format is shown in figure 2-6. Simply rotating a switch and watching the corresponding location on the display is all that is necessary to verify correct operation. A blank indicates a defective switch position.



Rotary Switch Test Format
Figure 2-6

II-D-1-c. KEYBOARD TEST

This routine will display "----" until a key is depressed. As long as the key is depressed a two digit code is shown in the display. The code indicates the row and column of the depressed key. The left digit is the row. Figure 2-7 shows the keyboard and the key codes produced by the test routine. If other codes are produced or, if only one code is shown and does not change, the keyboard or associated circuits are defective.

11	12	13	14
21	22	23	24
31		32	

KEY CODES FOR KEYBOARD TEST ROUTINE
Figure 2-7

II-D-2. ERROR CODES

If the µP detects an error condition it will halt normal operation and begin indicating an error code via the display. The ERR symbol and a two digit error code are flashed on and off. The table below shows the error codes and probable causes. If a hardware failure is indicated by the error code, refer to section II-D-1 and use the self-test routines for help in isolating the fault condition.

ERROR CODE	INDICATED FAILURE MODE	PROBABLE CAUSE
01	System failed internal test condition	Hardware failure on µP Memory board
02	Accumulated number exceeds display size	Position of PWR/TIME switch was changed during accumulation Hardware failure on I/O board
10,11, or 12	Bad keyboard input	Two keys depressed, defective keyboard or hardware failure on I/O board
20	µP tried to evaluate the log of a negative number	Uncalibrated depth selected by DEPTH switch
30	µP attempted to divide by zero	No standard counts in the MS α DS registers
31	Negative overflow in division	Incorrect depth selected by DEPTH switch Standard or measure counts are not valid
32	Positive overflow in division	Same as above
40	Invalid input from MOISTURE CORRECTION switches	Switch failure, hardware failure on I/O board, or operator induced error during chain calculations
41	Invalid input from DEPTH switch	Same as above

II-D-3. OSCILLATOR AND PRESCALERS

As mentioned in the first paragraph of Section II-D., the μP and its crystal oscillator provide the time standard for the instrument. To check the oscillator and the moisture and density prescalers, first remove the electronic module and refer to figure 2-4 for the location of the TST/MEAS switch. Slide the switch to the TST position and replace the module. Place the PWR/TIME switch on FAST. Depress the SHIFT key and, while holding the SHIFT key down, depress the STANDARD/ MEASURE key. At the end of 0.25 minutes, a 14646 ±2 count should be in the MS, DS, MC and DC registers. Place the PWR/TIME switch on NORM and repeat. At the end of one minute, 14646 should again be stored in the registers. Place PWR/TIME on SLOW and repeat for the same indication at the end of four minutes.

II-D-4. PROCESSOR COMPUTATIONAL CHECK

Supplied with the instrument is a sheet labeled 3411-B TEST VALUES. The results on this sheet where computed by a large mainframe computer. Because of differences in machine precision, algorithms, and round-off routines; the results shown on this sheet may not agree exactly with the 3411-B results. Also because of the range of numbers that can be displayed by the 3411-B, the %M calculation may produce an overflow condition. This overflow condition may exist when DC/DS = 1.0 and MC/MS = 1.0.

Place the PWR/TIME switch on FAST and depress the SHIFT key. While holding the SHIFT key down, depress the STANDARD/MEASURE key. At the end of 0.25 minutes, verify that DS = DC and MS = MC. The actual magnitude of the numbers isn't important. Also the TST/MEAS switch can be in either position. Place the DEPTH switch on "BS" and the MOISTURE CORRECTION switches on "00". At this time the processor results for WD, DD, M and %M should agree with the TEST VALUES sheet. Repeat this test for other DEPTH postions and "+99" and "-99" values of MOISTURE CORRECTION.

If the proper results are obtained, the processor operation is correct.

II-E. USE OF DISPLAY HEATER

Early production units of the 3401-B and 3411-B used a Liquid Crystal Display (LCD) that had definite temperature limitations.

The current production units (and any replacement displays obtained from the factory) do not have this temperature limitation and therefore do not need the display heater. Also the electronic circuitry and heater switch are not contained on current units.

The following comments apply only to units which contain the display heater. For the location of the heater switch, refer to figure 2-3 for a 3401-B and figure 2-4 for a 3411-B.

The LCD used in this instrument has definite temperature limitations. Storage temperatures outside of these limits cause no damage to the display, but it will not be functional outside of these limits.

At some temperature between 75°C (170°F) and 85°C (185°F), the display will turn dark over the entire face to the extent that it cannot be read. At these temperature other portions of the system may cause problems and, of course, the ambient should never reach this temperature. If the gauge is used on hot asphalt, the internal temperature may reach 60°C (140°F), but if the sunlight is bright and shining directly on the face of the display, the additional energy absorbed by the display may sufficiently elevate its internal temperature to the point of blacking out. This can be aleviated by turning the face of the gauge away from direct sunlight or otherwise shading the display.

Around 0°C (32°F) the display will require several seconds to change numbers and at -10°C (15°F) a minute or more will be required. Under these low temperature conditions, which seldom occur in field use, some external heat is required to warm the liquid.

There is a 0.7 watt heater attached to the display which will allow use at ambient temperatures down to -10°C (15°F) with little or no delay. When switched on, a HTR symbol will appear on the display to remind the operator of the power being consumed. The heater is turned off by the normal power switch and low-battery shutdown circuits.

III. 3401-B FIELD MEASUREMENTS

The importance of obtaining a set of accurate standard counts can not be over emphasized. The accuracy of measurements made with this instrument is directly related to the accuracy of the reference counts. Review section II-A-1 if you are not familiar with this procedure.

III-A. DAILY STANDARD COUNT

Turn the PWR/TIME switch to the SLOW postion and locate the instrument on the Reference Standard as shown in figure 2-2.

Remove the lock from the trigger and make certain that the handle is indexed in the standard or safe position.

Do not proceed unless gauge power has been on for at least 10 minutes. This time is to allow stabilization of the regulators and detectors.

With the PWR/TIME switch at SLOW, press START. After 4 minutes the ERR symbol will disappear and either the moisture or density standard count can be displayed by turning the DISPLAY switch to the desired position. These counts must be recorded on the daily work sheet since they will be used in computations at a later time. The counts should also be recorded in the gauge log.

In general, a sudden shift of more than 1% in the density standard count or 2% in the moisture standard count, as compared to the average of the previous four sets, would indicate some abnormality in gauge operation or procedure.

If an instablility is suspected, four or five sets of standard counts may be run in the field. If the highest and lowest counts are different by more than 25 for density or 12 for moisture, the gauge should be returned to the laboratory and a complete stability check run as explained in Section VIII-E.

III-B. SITE PREPARATION

In order to obtain optimum accuracy from the gauge, site preparation is normally required. The method for site preparation varies, depending on the surface and the type test to be performed.

III-B-1. EMBANKMENT OR SUBGRADE

Using the scraper plate supplied with the instrument, carefully scrape the surface to a smooth condition, removing all dried and loose material If the scraping action dislodges surface stones, remove them, fill the voids with fine material and lightly tamp the surface.

Place the scraper plate in the middle of the site and drive the drill rod into the soil using a four pound hammer. Placing one foot on the plate will prevent it from slipping or otherwise damaging the site by allowing the drill rod to move from side to side. The rod should be driven into the soil at least 50 mm (2 inches) further than the depth of measurement.

* * * CAUTION * * *

WHEN DRIVING THE ROD INTO SOIL, BASE MATERIAL OR HOT ASPHALT, REMEMBER THAT YOU ARE DRIVING A STEEL PIN WITH CONSIDERABLE FORCE. THIS PIN WILL WORK HARDEN OVER A PERIOD OF TIME AND PRODUCE METAL CHIPS WHICH COULD CAUSE INJURY TO THE OPERATOR OR BYSTANDERS. THE USE OF SAFETY GLASSES IS STRONGLY ADVISED.

In most cases, the rod can be withdrawn simply by pulling upward on the rod cap. If required, the scraper plate can be lifted up and used to lightly tap and pull the rod from the soil. Care should be used to prevent damage to the hole.

Place the instrument over the site so that the source rod lines up with the hole. Depress the trigger and push the handle down to the properly indexed position at the desired depth. With the operator facing the scaler module, pull the gauge towards the operator to seat the source rod against the side of the hole.

III-B-2. BASE OR SUBBASE

In most cases, the site preparation is the same as for embankments with the exception that more filling may be necessary for surface voids. Graded sand or other material may be necessary in order to obtain a filled surface.

Situations may occur in which it is impossible to drive the drill rod into the material without destroying the surface. In this case, it will be necessary to use the backscatter geometry.

Under backscatter conditions, site preparation must be more thorough and all voids filled as closely as possible to the same or similar density as the compacted material. The gauge must not rock on its base when seated.

When the source rod is indexed into the backscatter position, be careful not to bypass the detent and force the source rod tip on or into the material.

III-B-3. ASPHALT PAVING

When using a nuclear instrument for compaction control of asphalt paving, the Control Strip Method outlined under section V is recommended; however, there may be a time when direct density measurements are desired. If the compacted lift is is at least 50 mm (2 inches) thick, the direct transmission geometry is recommended. If a thinner wear layer or blanket is involved, the backscatter geometry is more appropriate.

In both cases, and paricularly backscatter, site preparation consists of filling the surface voids with the minimum amount of graded sand required to produce a smooth condition. It is important not to elevate the gauge above the surface by applying too much filler material. An easy way of accomplishing proper seating is to put a handful of sand in the surface and slide the scraper plate or gauge base back and forth on the site to remove excess material.

While the paving is still hot or even within a few days after installation, it is not difficult to drive the drill rod into the paving. After curing, it may become necessary to drill the hole or use backscatter methods.

III-C. DATA ACCUMULATION

With the gauge properly seated on the prepared site, turn the PWR/TIME switch to NORM and depress START. The ERR symbol will appear for one minute. When the timing period expires, turn the DISPLAY switch to display the moisture count and density count. Read and record these counts under the heading of MC for Moisture Count and DC for Density Count.

If the measurement was made on asphalt paving or other materials where moisture was not a factor, one could have used the FAST timing of only 0.25 minutes.

A moisture measurement on asphalt paving will include the hydrogen contained in both the asphalt and any water that may have infiltrated the surface from rain or a wetted roller. Assuming the material is free of water, the moisture count will be an indication of the asphalt content; however, the precision is only in the order of 0.5 percent asphalt and not usable as a measurement.

III-D. DATA CONVERSION

Using a hand calculator or slide rule, divide the recorded value of DC by DS to obtain a count ratio. Refer to the proper page of the calibration tables, and using the count ratio, obtain the value for the wet density (WD) of the material.

Using the values of MC and MS, obtain the ratio and refer to the moisture calibration table to obtain the moisture content (M) of the material. This value is uncorrected for offset due to hydrogen other than that contained in water. This correction will be covered in section III-E.

Using the values of WD and M, obtain the dry density (DD) by subtraction:

$$DD = WD - M$$

Using DD and M, obtain the percent moisture (%M) by division:

$$\%M = \frac{M}{DD} \times 100$$

If the original measurement had been made on asphalt paving, it would only be necessary to obtain the WD value.

III-E. CORRECTIONS

It may be necessary to correct the measurements due to composition of the material or hydrogen content of the dry material. This may be accomplished by comparison to sand cone and oven dry or other methods of test acceptable to the user.

III-E-1. DENSITY CORRECTION

Only on a very few occasions will it be necessary to correct the wet density measurement. This will probably occur with material which may be composed of industrial waste, mine tailings or similar material having a chemical composition which is different than the normal range of soils.

A comparison may be made between accurately controlled sand cone and nuclear densities or by compacting soil in a box and measuring the density by weighing and by nuclear. The box size should be at least 450 x 450 mm (18 x 18 inches) and 100 mm (4 inches) deeper than the depth of measurement. The material should be at optimum moisture.

If a field sand cone is used, the correction factor should be the average of four or more comparisons between conventional and nuclear. Multiple tests must be used to improve the precision of both types of tests. Reports of standard deviations (68.3% confidence level) for conventional tests range from 4.2% for the small water balloon down to 1.2% for the glass jar and funnel. The deviations for the 7 inch and 10 inch sand cylinders are about 0.6%.

The correction factor obtained should be applied as a plus or minus figure to the measured wet density.

III-E-2. MOISTURE CORRECTION

The correction for moisture content is a little more complicated since the gauge measurement is in volumetric units, whereas, the oven dry is a percent of dry weight.

First, one must assume that the gauge wet density is accurate or has been corrected as noted above. Next, measure the moisture content in PCF with the gauge at four or more sites which are close to optimum moisture. Remove a soil sample from each site and determine the percent moisture by oven dry. The minimum recommended sample size is 500 g (1 pound). The moisture content can now be computed by:

$$M = \frac{\%M \times WD}{\%M + 100}$$

where: WD = Gauge Wet Density
%M = Oven Dry Percent Moisture

The correction factor can now be obtained by taking the difference between the gauge moisture and the computed moisture.

It is necessary to apply the correction factor at the gauge moisture level in order to obtain the correct wet density. The correction factor obtained is strictly valid only at the same values of wet density and moisture content so they should be obtained as close as possible to optimum compaction.

In reality, the moisture correction factor is a variable related to the dry density since the material causing the error is a part of the soil and not a part of the contained water. While it is possible to obtain a correction factor related to dry density, the application in the field is too complex for rapid use. Generally speaking, the correction factor obtained above is satisfactory since field measurements will be at approximately the same degree of compaction as the optimums.

IV. 3411-B FIELD MEASUREMENTS

The importance of obtaining a set of accurate standard counts can not be over emphasized. The accuracy of measurements made with this instrument is directly related to the accuracy of the standard counts. Review section II-A-1 if you are not familiar with this procedure.

IV-A. DAILY STANDARD COUNT

Turn the PWR/TIME switch to the SLOW postion and locate the instrument on the Reference Standard as shown in figure 2-2.

Remove the lock from the trigger and make certain that the handle is indexed in the standard or safe position.

Do not proceed unless gauge power has been on for at least 10 minutes. This time is to allow stabilization of the regulators and detectors.

With the PWR/TIME switch set on SLOW, a set of standard counts can now be accumulated. This is accomplished by:

1) depressing and holding down the key labeled SHIFT,

2) depressing the STANDARD/MEASURE key and then releasing it,

3) releasing the SHIFT key.

The SHIFT and STANDARD/MEASURE keys are interlocked to prevent accidental initiation of a standard count.

After four minutes, the ERR symbol will disappear and the moisture and density standard counts can be displayed by depressing MS and DS respectively. These counts should be recorded in the gauge standard count log, but they will remain in the memory unless the power is switched OFF.

In general, a sudden shift of more than 1% in the density standard count or 2% in the moisture standard count, as compared to the average of the previous four sets, would indicate some abnormality in gauge operation or procedure.

If an instability is suspected, four or five sets may be run in the field. If the highest and lowest counts are different by more than 25 for density or 12 for moisture, the gauge should be returned to the laboratory and a complete stability check run as explained in Section XIII-E.

IV-B. SITE PREPARATION

In order to obtain optimum accuracy from the gauge, site preparation is normally required. The method for site preparation varies, depending on the surface and the type test to be performed.

IV-B-1. EMBANKMENT OR SUBGRADE

Using the scraper plate supplied with the instrument, carefully scrape the surface to a smooth condition, removing all dried and loose material. If the scraping action dislodges surface stones, remove them, fill the voids with fine material and lightly tamp the surface.

Place the scraper plate in the middle of the site and drive the drill rod into the soil using a four pound hammer. Placing one foot on the plate will prevent it from slipping or otherwise damaging the site by allowing the drill rod to move from side to side. The rod should be driven into the soil at least 50 mm (2 inches) further than the depth of measurement.

* * * CAUTION * * *

WHEN DRIVING THE ROD INTO SOIL, BASE MATERIAL OR HOT ASPHALT, REMEMBER THAT YOU ARE DRIVING A STEEL PIN WITH CONSIDERABLE FORCE. THIS PIN WILL WORK HARDEN OVER A PERIOD OF TIME AND PRODUCE METAL CHIPS WHICH COULD CAUSE INJURY TO THE OPERATOR OR BYSTANDERS. THE USE OF SAFETY GLASSES IS STRONGLY ADVISED.

In most cases, the rod can be withdrawn simply by pulling upward on the rod cap. If required, the scraper plate can be lifted up and used to lightly tap and pull the rod from the soil. Care should be used to prevent damage to the hole.

Place the instrument over the site so that the source rod lines up with the hole. Depress the trigger and push the handle down to the properly indexed position at the desired depth. With the operator facing the scaler module, pull the gauge towards the operator to seat the source rod against the side of the hole.

IV-B-2. BASE OR SUBBASE

In most cases, the site preparation is the same as for embankments with the exception that more filling may be necessary for surface voids. Graded sand or other material may be necessary in order to obtain a filled surface.

Situations may occur in which it is impossible to drive the drill rod into the material without destroying the surface. In this case, it will be necessary to use the backscatter geometry.

Under backscatter conditions, site preparation must be more thorough and all voids filled as closely as possible to the same or similar density as the compacted material. The gauge must not rock on its base when seated.

When the source rod is indexed into the backscatter position, be careful not to bypass the detent and force the source rod tip on or into the material.

IV-B-3. ASPHALT PAVING

When using a nuclear instrument for compaction control of asphalt paving, the Control Strip Method outlined under section V is recommended; however, there may be a time when direct density measurements are desired. If the compacted lift is is at least 50 mm (2 inches) thick, the direct transmission geometry is recommended. If a thinner wear layer or blanket is involved, the backscatter geometry is more appropriate.

In both cases, and paricularly backscatter, site preparation consists of filling the surface voids with the minimum amount of graded sand required to produce a smooth condition. It is important not to elevate the gauge above the surface by applying too much filler material. An easy way of accomplishing proper seating is to put a handful of sand in the surface and slide the scraper plate or gauge base back and forth on the site to remove excess material.

While the paving is still hot or even within a few days after installation, it is not difficult to drive the drill rod into the paving. After curing, it may become necessary to drill the hole or use backscatter methods.

IV-C. DATA ACCUMULATION

With the gauge properly seated on the prepared site, turn PWR/TIME to NORM and depress MEASURE. The ERR symbol will appear for one minute. When the timing period expires, depress MC and DC to display the moisture count and density count respectively. Depressing MS or DS will display the standard counts which were previously taken and stored.

If the measurement was made on asphalt paving or other materials where moisture was not a factor, one could have used the FAST timing of only 0.25 minutes.

A moisture measurement on asphalt paving will include the hydrogen contained in both the asphalt and any water that may have infiltrated the surface from rain or a wetted roller. Assuming the material is free of water, the moisture count will be an indication of the asphalt content; however, the precision is only in the order of 0.5 percent asphalt and not usable as a measurement.

IV-D. DATA CONVERSION

Set the DEPTH switch to the same depth which was used to take the measurement, set the MOISTURE CORRECTION switches to "00".

The processor is now ready to process the count data. If your instrument was shipped within the U.S., it is set up to display in U.S. Customary Units (PCF). If it was shipped outside the U.S., it should be set up to display SI Units (kg/m^3). If the results appear in the wrong units for your use, release the four thumbscrews which retain the electronic package. Behind the front panel on the lower right side there is a slide switch labeled SI and PCF. Place the switch in the desired mode. Replace the electronic assembly.

Wet Density (WD), Dry Density (DD), Moisture Content (M) and Percent Moisture (%M) can now be computed and displayed by depressing the desired key. Since the moisture content has not been corrected for soil hydrogen, DD, M and %M may be in error. Section IV-E explains the procedure for correction.

If asphalt paving was involved, only WD applies for compaction control since DD would reduce the density by some value of M dependent on the asphalt content.

Since the %MA and %PR functions are dependent on the preset "optimum density", it is advisable to check this value before using these functions. Refer to section II-B if you are not familiar with this procedure.

If the preset "optimum density" is correct then the %MA and %PR functions can be used by pressing the SHIFT key and the %MA or %PR.

IV-E. CORRECTIONS

It may be necessary to correct the measurements due to composition of the material or hydrogen content of the dry material. This may be accomplished by comparison to sand cone and oven dry or other methods of test acceptable to the user.

IV-E-1. DENSITY CORRECTION

One of the possible density errors which normally requires correction is automatically taken care of by the data processor in the 3411-B. Hydrogen in the measured material creates an error in the density measurement due to the high mass attenuation coefficient as compared to other elements found in soil. During the data processing, the true hydrogen density is evaluated prior to any corrections for moisture content. The hydrogen density is used to correct the WD for this possible error and significantly improves the density accuracy.

If density corrections are still required on some materials, it will be necessary to manually apply the correction and perform the computation of DD and %M. This will probably occur with material which may be composed of industrial waste, mine tailings, or similar material having a chemical composition which is different than the normal range of soils.

A comparison may be made between accurately controlled sand cone and nuclear densities or by compacting soil in a box and measuring the density by weighing and by nuclear. The box size should be at least 450 x 450 mm (18 x 18 inches) and 100 mm (4 inches) deeper than the depth of measurement. The material should be at optimum moisture.

If a field sand cone is used, the correction factor should be the average of four or more comparisons between conventional and nuclear. Multiple tests must be used to improve the precision of both types of tests. Reports of standard deviations (68.3% confidence level) for conventional tests range from 4.2% for the small water balloon down to 1.2% for the glass jar and funnel. The deviations for the 7 inch and 10 inch sand cylinders are about 0.6%.

The correction factor obtained should be applied as a plus or minus figure to the measured wet density.

IV-E-2. MOISTURE CORRECTION

The 3411 has a "built-in" provision to allow the insertion of a "K" factor to correct for hydrogen in the measured material which is not contained in the free water removed during standard oven drying procedures. This correction factor as used with other types of equipment is a function of the dry density and is only valid for one value of dry density. The correction used in the 3411-B is independent of dry density and correctly adjusts the apparent moisture to a true moisture, regardless of the dry density.

There are two methods of arriving at the correction factor. The first and easiest method makes use of the data processor to arrive at the value of "K".

Assuming that the soil is a type which allows an accurate "fast dry", a sample can be taken from under the gauge and a value of %M obtained while the count data is stored in the gauge memory.

Depress %M; if the displayed value is higher than the value obtained from the "fast dry", set the sign switch on "-". Use "+" if the computed %M is lower than the "fast dry". Increment the MOISTURE CORRECTION switches beginning with 00 until the computed value is equal to the "fast dry" value, and record the final switch setting. Repeat this procedure for four or more sites and average the "K" values. This average can now be set up as the MOISTURE CORRECTION constant and used for all future tests on this soil.

An easy way to set the MOISTURE CORRECTION switches is to depress and hold down the %M key while turning the correction switches. This places the processor in a continuous calculate mode. If Error 40 appears while adjusting the switches, release and depress the key again. Error 40 occurs if the processor attempts to read the switches at the instant the switch was rotated between detents.

If "fast dry" methods are not available in the field, then four or more gauge %M measurements will have to be made with the MOISTURE CORRECTION switches set to "+" 00. Samples from each site should be taken to the laboratory for the oven dry. The <u>minimum</u> recommended sample size is 500 g (1 pound). Care should be taken to keep the samples from drying out.

For each sample the K factor can be computed by:

$$K = \frac{\%M\ (True) - \%M\ (Gauge)}{\%M\ (Gauge) + 100} \times 1000$$

The final value of K should be the average of four or more samples rounded to an integer. The value will fall between -99 and +99.

K value will usually be (-).

This value is then set into the gauge MOISTURE CORRECTION switches and used for all measurements on the particular soil.

V. SPECIAL USE PROCEDURES

V-A. TRENCH MEASUREMENTS

When a nuclear moisture-density gauge is operated close to large vertical structures, the moisture counts obtained may not be valid. The problem arises because hydrogen bearing material, located above the gauge base, reflects a small percentage of neutrons back toward the detector. The 3400-B Series was designed to minimize these effects. Generally speaking, the gauge may be used next to a vertical, massive structure with the back of the instrument no closer than 150 mm (6 inches) from the wall face provided there is no additional structure within 0.6 meter (24 inches) of either gauge side. The error, in this situation, will be no greater than 16 kg/m^3 (1 PCF) in either moisture or density due to effects of the wall.

In trenches of 1.2 meters (48 inches) or more in width, where the walls contain not more than 240 kg/m^3 (15 PCF) water, no special procedures are required for any mode of operation if the gauge is place in the center of the trench. For trenches with a width down to 0.6 meter (24 inches), direct transmission will have no error due to sidewall effect and the moisture error will be less than 24 kg/m^3 (1.5 PCF).

Since the 3401-B and 3411-B have identical bases, their susceptibility to sidewall reflection is the same. Therefore the procedure for obtaining the moisture offset value is similar. Once this value is obtained the procedure for the two gauge changes. In the 3401-B the moisture measure count must be manually adjusted for each measurement count. In the 3411-B the processor will automatically offset each moisture measure count once a correction has been entered. The procedure for using each gauge follows.

V-A-1. 3401-B TRENCH PROCEDURE

It is necessary to determine for the increase in the moisture count due to the hydrogen bearing material in the trench walls. Once this difference has been found, this number will be subtracted from the moisture measurement counts before the moisture ratio is determined. The step-by-step procedure is shown below.

1) Obtain the daily standard counts following the steps outlined in section III-A. If a valid set of standard counts has already been obtained, they may be used. Note that the standard counts are taken at a site <u>away</u> from the trench.

2) Enter the trench and take another set of counts with the gauge placed on the reference standard at the desired test site. The distance from the wall must be the same as the area to be tested. This count may be taken with the PWR/TIME switch set on NORM.

V-A-1. 3401-B TRENCH PROCEDURES (cont'd)

3) Determine the moisture offset value by subtracting the moisture standard count from the moisture count obtained in the trench. This moisture offset number will be valid for all tests performed at this site with the gauge at the same distance from the wall. Record this number on the work sheet.

4) To use the moisture offset value it is necessary to subtract this number from the moisture measurement count before you divide by the moisture standard count.

V-A-2. 3411-B TRENCH PROCEDURES

It is necessary to determine the increase in the moisture count due to the hydrogren bearing material in the trench walls. Once this difference has been found, it will be entered into the processor. The processor will offset all future measurement counts by this number. This is accomplished by presetting the moisture register to the negative number at the start of a count. Once an offset has been entered, you can see this effect by starting a measure count and pressing the MC key. The counter will start at the negative number, count up through zero, and then continue to count up.

1) Obtain the daily standard counts following the steps outlined in section IV-A. If a valid set of standard counts has already been obtained, they may be used. Note that the standard counts are taken at a site <u>away</u> from the trench.

2) Enter the trench and take another set of standard counts with the gauge placed on the reference standard at the desired test site. The distance from the wall must be the same as the area to be tested. This count may be taken with the PWR/TIME switch set on NORM.

   Please note this test is made by taking measure count even though you are using the reference standard. Do not press the SHIFT key as this would destroy the standard counts taken previously.

3) Subtract the number in MS from number in MC. This difference should then be set on the MOISTURE CORRECTION switches. This value is preset as a negative number into the moisture count register (MC) by depressing and holding the SHIFT key and depressing MC. The value set on the MOISTURE CORRECTION switches should now appear on the display.

   The entered value for moisture offset will be retained by the gauge until; a) it is changed by entry of a new offset, b) a new set of standard counts are taken, c) the gauge is turned off.

   The moisture offset value can be removed by setting the MOISTURE CORRECTION switches to "00" and entering this value.

   BE SURE TO RETURN THE MOISTURE CORRECTION SWITCHES TO "00" OR THE PROPER CORRECTION FACTOR AFTER ENTERING THE MOISTURE OFFSET VALUE.

V-B. CONTROL STRIP FOR SUBBASE, BASE, AND ASPHALT PAVING

Using the nuclear density gauge for compaction control of asphalt paving creates some problems due to the normal specification requiring 98% of Marshall density. This is particularly true when the backscatter geometry is used. With a Marshall density of 2240 kg/m^3 (140 PCF), the passing limit would be 2195 kg/m^3 (137.2 PCF); but assuming a true density of 2240 kg/m^3 (140 PCF), the gauge could indicate 2175-2190 kg/m^3 (136-137 PCF) based on the total expected error of 50-65 kg/m^3 (3-4 PCF). This can be overcome by correcting the calibration to account for the composition error and by good site preparation to reduce the surface roughness error. By doing this, the expected error can be reduced to 15-25 kg/m^3 (1-1.5 PCF) and allow the use of nuclear testing.

The Virginia Highway Research Council developed an alternate method which now has been in use for many years and has proven to take advantage of the fast testing capability of the instrument and eliminate the shortcomings. The procedure involves the use of a "control strip" and, while originally developed for paving, it may be used whenever plant mixed base material is used.

The normal procedure involves the selection of a test site 100 meters (300 feet) long and the width of the paver. Compaction is accomplished with rollers and nuclear density gauge is used to measure density between passes of the roller. Compaction is continued until there is no further increase in density. At this point, the maximum density is determined by taking the average of 10 randomly selected sites on the control section.

Specifications for the project are normally established as 98% of the control section density. Tests are usually run on 2800 square meter (2800 square yard) sections and the average of five tests used to establish passing conditions for each section. Each test must be 95% or over, and the average must be 98% or over.

A new control section must be established when a change in the source of the material has occurred or after 10 test sections have been approved.

V-C. ROOF MOISTURE MEASUREMENTS

Until recently, no satisfactory method has been available to determine the condition of built-up flat roofs other than waiting for a leak to appear or replacement after the design life has expired. Even when a leak has occurred, it is sometimes difficult to determine the failed section.

While the 3400-B Series of gauges can be used for roof moisture measurements, Troxler Model 3205 Roof Moisture gauge should be considered if roof measurements are to be performed routinely. The 3205 is a moisture only gauge designed specifically for roof moisture measurements. It is much lighter than the 3400-B Series and has increased precision.

Several procedures have been devised using the moisture detecting capability of the nuclear moisture gauge to evaluate the degree of water migration within layers of a built-up roofing system. The most practical procedure yielding the best results was devised by the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi on projects under the Strategic Air Command.

A 3 x 3 meter (10 x 10 foot) grid is laid out on the roof and on a drawing of the roof. Nuclear moisture counts are then taken at the grid intersections. A frequency histogram is next plotted of all the data points and used to separate the wet and dry areas. A typical bimodal histogram is shown in figure 5-1.

With this type of distribution, the 95% confidence limits can be established for a normal distribution.

The nuclear gauge, in addition to its radiation statistics, measures the hydrogen in the asphalt, organic felts and any wood structure. This will produce a distribution of counts in the dry areas as shown in figure 5-1.

Core samples are then taken in areas which indicate definite wet conditions in order to obtain conversion factors to determine the amount of moisture involved.

Under some conditions, a bimodal distribution may not be present and additional samples may be required to separate the wet and dry areas.

Once the "wet" threshold has been determined, the gridded roof drawing can then be used to map the roof for repairs.

1

V-D. THIN LIFT OVERLAYS

Thin lift overlays are becoming common on jobs requiring road maintenance or resurfacing, and on bridge deck overlays. Nuclear gauges when used in the backscatter mode on overlays have certain limitations which must be overcome in order to obtain correct densities. The problem arises due to the depth of penetration of gamma rays. The gauge "sees" through the thin overlay and the underlying material influences the gauge reading.

Recognizing this gauge use problem, in 1976 Troxler Labs undertook a study to determine the effects of thin overlays and to establish a procedure for gauge use on overlays. A nomograph was developed which allows rapid determination of overlay density. In order to obtain the density of the top layer, it is necessary to know the density of the bottom layer and the thickness of the top layer. The simplest method of determining the bottom layer density is by taking nuclear density test before the overlay is applied. Pavement is then placed and compacted. Backscatter density tests are performed on the top of the pavement and the mat thickness determined. With this data, the density of the top layer may be determined from the nomograph.

If tests are performed on materials which have basically the same top and bottom layer density, the nomograph is not needed. Also if the bottom layer density is greater than the top layer density, the slope of the line is reversed and the gauge "reads" a density greater than the true density of the top layer.

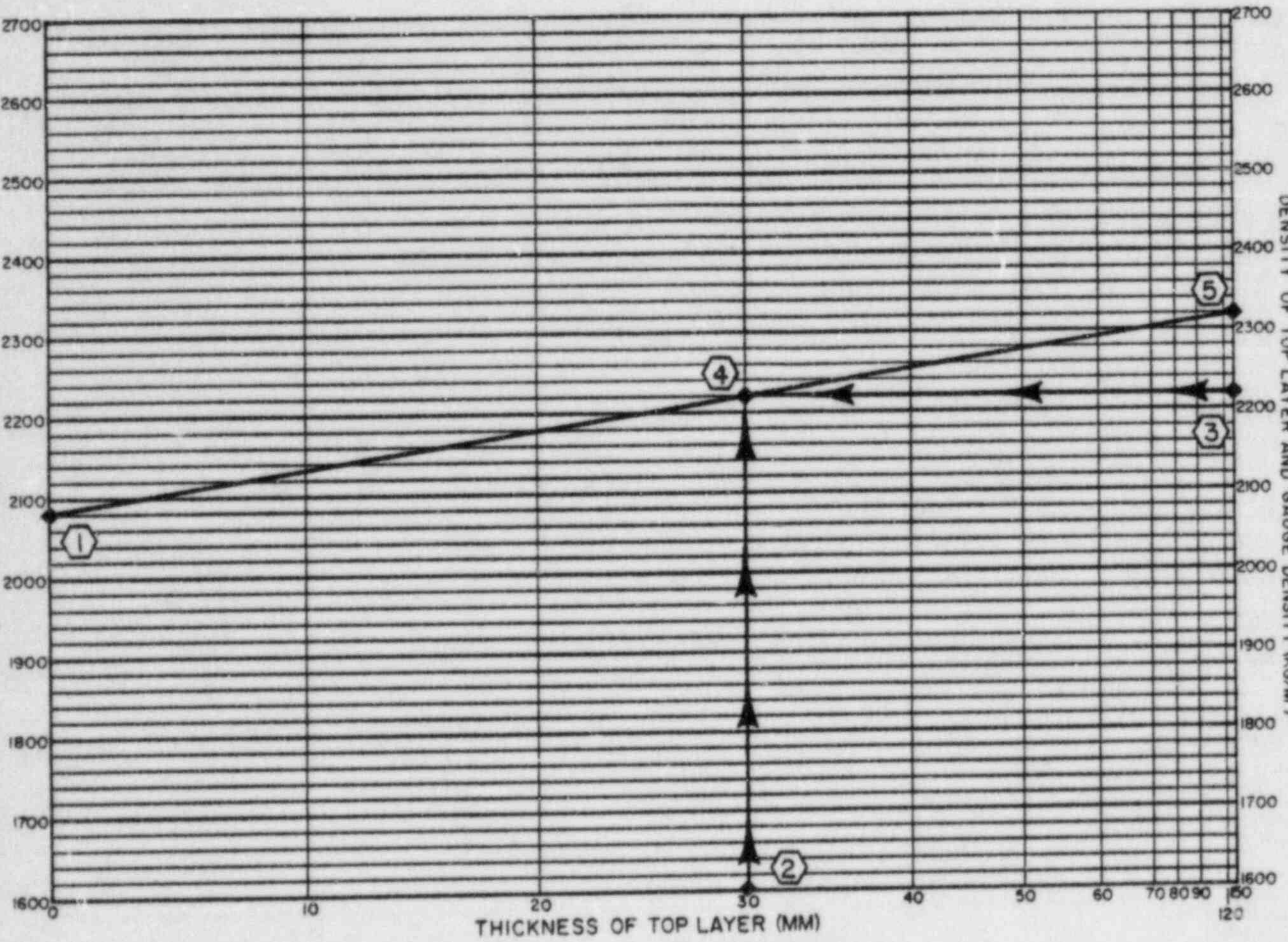
* * NOTICE * *

> These procedures and nomographs are applicable only to the 3400 and 3400-B series of gauges. They are not valid for other Troxler gauges or gauges from other manufacturers.

Following are examples with nomographs for SI and U.S. Customary units. Blank nomographs, suitable for reproduction, are included in the appendix.

V-D-1. OVERLAY EXAMPLE - SI UNITS

In this example the bottom layer density (left scale) is 2080 kg/m^3 with a mat 30 mm thick overlaying it. A backscatter density test on the top of the mat (right scale) yielded a result of 2220 kg/m^3. A line is then drawn from 2080 kg/m^3 on left scale through the intersection of 30 mm (bottom) and 2220 kg/m^3 (right) and extended to the right. The correct density for the top layer is then read from the nomograph as 2321 kg/m^3 on the right scale.

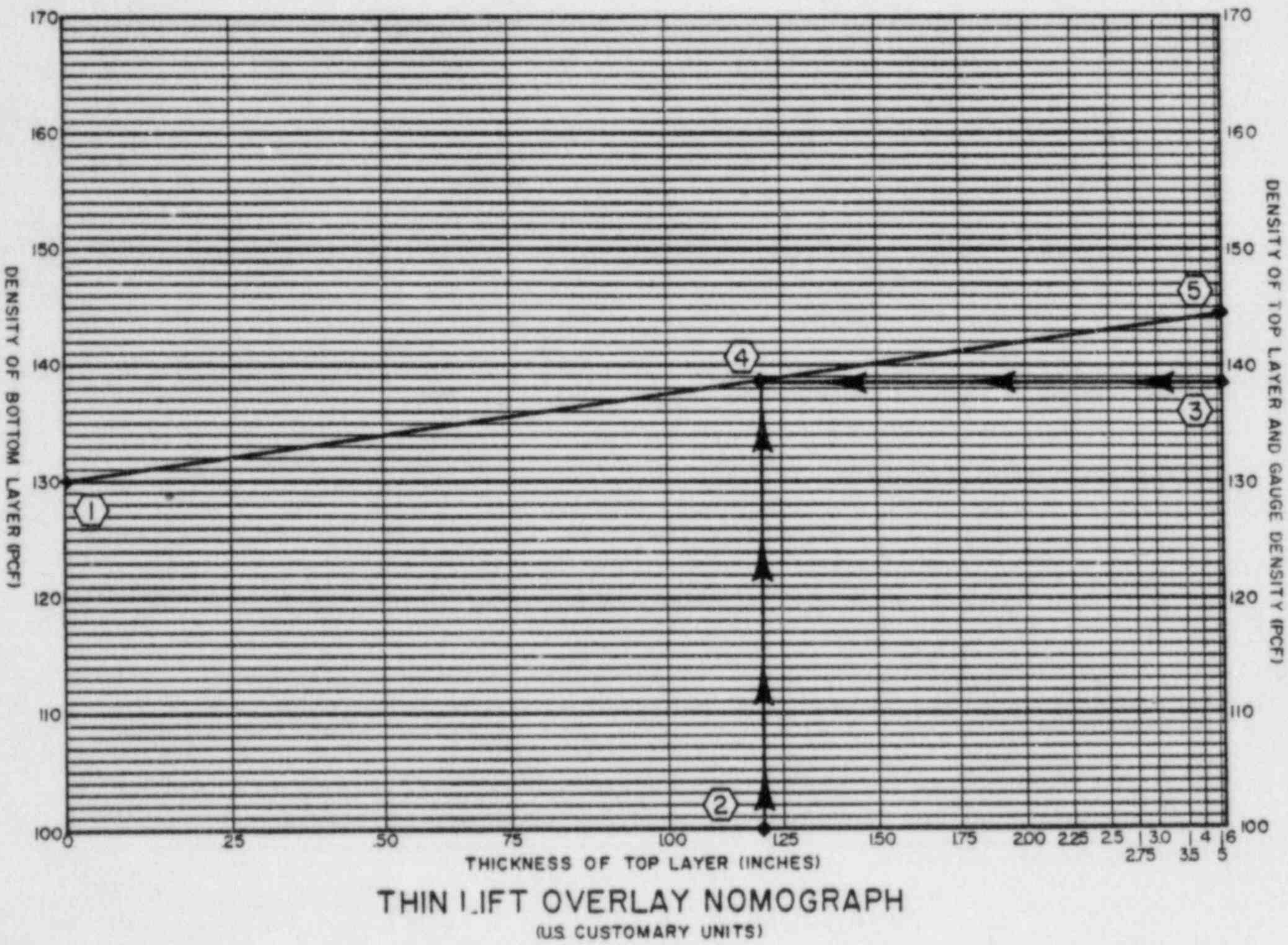


Nomograph for Thin Lift Overlays
SI Units

Figure 5-1

V-D-2. OVERLAY EXAMPLE - U.S. Customary Units

In this example the bottom layer density (left scale) is 130 PCF with a mat 1.2 inches thick overlaying it. A backscatter density test on the top of the mat (right scale) yielded a result of 138.5 PCF. A line is then drawn from 130 PCF on the left scale through the intersection of 1.2 inches (bottom) and 138.5 PCF (right) and extended to the right. The correct density for the top layer is then read from the nomograph as 144.5 on the right scale.



Nomograph for Thin Lift Overlays
U.S. Customary Units

Figure 5-2

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VI. 3400-B SENSITIVITY DATA

Some users of nuclear gauges find it disconcerting that repetitive measurements on the same site produce different counts. It is only natural to wonder how much effect this has on the density computation. The tables below denote the change in density per change in displayed count, at various depths and for a wide range of densities. This number is the slope of the calibration curve at the selected points.

Depth (mm)	Density (kg/m^3) 1200	1500	1800	2100	2400	2700
BS	0.423	0.595	0.837	1.178	1.658	2.332
50	0.132	0.179	0.242	0.329	0.446	0.604
100	0.104	0.147	0.207	0.292	0.412	0.582
150	0.098	0.147	0.222	0.333	0.500	0.751
200	0.105	0.170	0.277	0.450	0.732	1.191
250	0.119	0.208	0.364	0.638	1.118	1.959
300	0.147	0.284	0.549	1.060	2.047	3.953

Slope (kg/m^3/count) for Density Calibration

Depth (inches)	Density (PCF) 70	90	110	130	150	170
BS	0.024	0.035	0.050	0.072	0.104	0.149
2	0.008	0.011	0.015	0.020	0.028	0.039
4	0.006	0.009	0.012	0.018	0.026	0.037
6	0.006	0.009	0.013	0.020	0.031	0.048
8	0.006	0.010	0.016	0.027	0.046	0.077
10	0.006	0.012	0.021	0.039	0.070	0.128
12	0.008	0.016	0.032	0.064	0.129	0.260

Slope (PCF/count) for Density Calibration

VI. 3400-B SENSITIVITY DATA (cont'd)

Also useful for evaluating data obtained with the instrument, is a table showing the precision of the gauge for various depths and densities. This table is valid only for the NORM (1 minute) accumulate period. For the SLOW (4 minute) period the values should be divided by two. For the FAST (0.25 minute) period the values should be doubled. The values shown are for 1-sigma deviations with a confidence limit of 68%. By doubling the values, a 2-sigma deviation with a confidence limit of 95% would be realized.

Depth	Density (kg/m^3)					
(mm)	1200	1500	1800	2100	2400	2700
BS	[illegible].992	6.001	7.250	8.815	10.805	13.377
50	2.829	3.288	3.817	4.427	5.127	5.924
100	2.360	2.792	3.298	3.885	4.562	5.328
150	2.118	2.590	3.164	3.859	4.694	5.687
200	2.012	2.568	3.278	4.187	5.355	6.860
250	1.996	2.648	3.518	4.686	6.270	8.452
300	2.062	2.882	4.052	5.752	8.312	12.359

Standard Deviation in kg/m^3

Depth	Density (PCF)					
(inches)	70	90	110	130	150	170
BS	0.297	0.361	0.442	0.544	0.676	0.849
2	0.170	0.199	0.234	0.274	0.320	0.374
4	0.141	0.169	0.202	0.240	0.285	0.337
6	0.125	0.156	0.193	0.238	0.294	0.360
8	0.118	0.153	0.198	0.258	0.335	0.437
10	0.116	0.156	0.212	0.288	0.392	0.540
12	0.118	0.169	0.242	0.352	0.521	0.797

Standard Deviation in PCF

The same type of information, shown above for densities, is tabulated below for moisture content.

	Moisture (kg/m^3)						
	0	100	200	300	400	500	600
Slope (kg/m^3/count)	<------------------- 1.523 ------------------->						
Standard Deviation	1.424	3.398	4.590	5.530	6.332	7.044	7.690

	Moisture (PCF)						
	0	5	10	15	20	25	30
Slope (PCF/count)	<------------------- 0.095 ------------------->						
Standard Deviation	0.089	0.194	0.259	0.312	0.356	0.396	0.431

VII. PERIODIC MAINTENANCE

VII-A. BATTERY CHARGING

Since the life of rechargeable batteries is a function of the number of charge-discharge cycles, it is best not to recharge unless a low state of charge exists, or at least limit the recharge to the amount required to bring the battery up to full charge.

The 3401-B instrument has a power consumption of 90 milliwatts. The 3411-B has an average power consumption of 150 miliiwatts assuming an average of four site measurements per hour of use.

Since the battery stores approximately 40 watts, the 3401-B will operate for 400 hours and the 3411-B for 250 hours before requiring a full recharge. If the battery has been used to the point where either the BAT alarm is displayed or the battery voltage is below the automatic shutdown, the recharge period will be 14 hours or overnight for a full charge.

Using the above figures, one hour of recharge will replace approximately 25 hours of usage.

The AC charger will operate from 115 or 230 volt power at 50-60 Hz. While it will not damage either the charger or instrument to connect it to 115 volts with the charger switch set for 230, damage to the charger will occur if it is connected to a 230 volt supply with the switch set for 115 volt operation.

The DC charger cable supplied will operate while plugged into a cigarette lighter receptacle in a 12 volt negative ground vehicle system. No damage will occur, but no charging will be possible in 6 volt or positive ground systems.

With the vehicle engine in operation or with a fully charged vehicle battery, the charge rate is approximately the same as with the AC charger. The charge rate will decrease rapidly as the vehicle battery voltage decreases, and little or no charging will occur as the vehicle battery approaches 11 volts.

The DC charger is intended for emergency use when required. A thirty minute recharge will allow use of the gauge for many hours.

VII-B. CLEANING AND LUBRICATION

The source rod in the 3400-B Series is supported in linear bearings packed with a molybdenum disulfide grease (Molykote Type G Paste). The grease is retained within the bearings and soil kept out by a system of wipers and seals at the top and the bottom of the bearings. The bearings will require little or no service, unless the gauge is overhauled or excess soil is allowed to accumulate.

On the bottom surface of the gauge is a removeable plate with a metal wiper ring mounted in it. This ring will remove most of the soil from the source rod. However, under some soil conditions, small amounts will be carried into the sliding shield assembly. If allowed to build up, this soil can cause wear in the shield cavity and can ultimately be forced into the bearings and ruin them.

Cleaning the cavity is relatively simple. Place the gauge on its side on a bench with the base away from the operator. The source rod should be latched in the SAFE position. Using a Phillips screwdriver, remove the four screws holding the bottom plate assembly in position and pry out the assembly using a flat blade screwdriver. Using the screwdriver, remove the sliding shield and spring.

The radiation dose rate at the entrance to the cavity (flush with the bottom surface) is approximately 300 mrem per hour, and the hands should not be exposed to this dose rate for more than four hours per week. The cleaning time should take no more than five minutes, so the procedure is quite safe.

Using a rag, stiff brush, and compressed air (if available) remove all soil and clean the cavity, sliding shield, and bottom plate assembly. Inspect all items for excessive wear and replace if required. Check the scraper ring to insure that it is free to move in its groove. If the ring is damaged or worn excessively it should be replaced or replace the assembly.

Coat all of these items, including the cavity and the inner surface of the plate assembly with a bonded molybdenum disulfide lubricant (Molykote Type 321 Spray). Reassemble all items.

Using the rag, clean the source rod and index rod and coat the index rod with bonded lubricant. Using a cotton tipped stick (Q-Tip), lubricate the visible portions of the trigger and indexer with paste lubricant.

If the last items have soil embedded in the mechanism, they should be removed for cleaning. Lower the handle to the backscatter position and, using a 3/32 pin punch, remove the roll pin in the index rod. Remove the index rod cap by unscrewing.

VII-B. CLEANING AND LUBRICATION (cont'd)

Depress the trigger and lift the handle clear of the index rod. Before releasing the trigger, note the position of the indexer pin and trigger to facilitate replacement. With the trigger released, the indexer can be slid forward and sideways out of the handle. Clean all moving parts and the handle cavity. If the indexer shows signs of wear, it should be replaced. Lubricate these parts and reassemble.

To replace the index rod cap, latch the handle in the SAFE position, and screw the cap down until the neoprene bumper puts a light pressure on the handle. Drop the handle, look into the roll pin hole and line up the hole in the cap with the hole in the index rod by unscrewing the cap if necessary. These holes must be in alignment to replace the roll pin. If the cap is screwed too tightly, pressure against the bumper will prevent the indexer from latching in the SAFE position.

Using a mineral solvent, clean all of the outer surfaces of the instrument.

VII-C. FRONT PANEL MODULE REMOVAL

Unscrew the thumbscrews located at the front panel corners and lift the module from the opening. There is a cable connecting the module to the base assembly. Disconnect the cable, noting the relative position of polarizing key on the cable connector and the position of the slot in the mating connector.

When replacing this connector, it must be done carefully and in the proper orientation. The pins are small and can be easily bent if not aligned properly.

VII-D. INTERNAL CONDENSATION

Under some climatic conditions, changes in atmospheric pressure will cause some flow of moist air in and out of the gauge case since it is not pressure sealed. This will result in the formation of water inside the case due to condensation. This water must be removed or erratic operation and possibly failure may occur. The gauge cavity will dry if it is stored in a warm, dry room with the front panel electronic module removed.

VII-E. LEAK TEST PROCEDURE

State and Federal laws require that the radioactive sources be leak tested every six months and records maintained of the results. Personnel safety must be considered and leak tests performed to eliminate possible contamination by radioactivity materials.

It is also worthwhile noting that of over 10,000 sealed radioactive sources delivered by Troxler Electronics Laboratories, Inc. in this type of equipment during the past twenty years, not one has ever shown a positive leak test even though some instruments have been totally destroyed by fire or accident.

The leak test is performed by using the Troxler type 3880 Leak Test Kit (part number 102868) or similar kit. The 3880 kit contains an instruction manual, pair of metal tongs, wood dowel, solvent, and five leak test packets. Each packet contains: 1) pre-addressed envelope, 2) leak test form, 3) plastic bag, 4) self-adhesive label, and 5) 55mm filter paper. The instruction manual should be read prior to use of the kit.

Using a ball point pen, write the gauge type, serial number and source serial numbers around the edge of the filter paper. Since this instrument contains two sealed sources, both areas must be wiped with the same piece of filter paper.

Remove the electronic module as noted in section D above. Wet the filter paper with solvent. Looking into the gauge cavity, a yellow and magenta label will be seen just forward of the printed circuit board assembly. Using the tongs and dowel wipe this label with the filter paper. After wiping the first source, the filter must <u>not</u> be touched with any part of the hands.

With the gauge on its side and base <u>away</u> from the operator, position the handle in the 4 inch direct transmission position. Using the tongs and wood dowel for pressure, wipe the weld area above the source rod tip with the filter paper. Retract the source and sit the gauge in an upright position.

Lay the filter paper on a paper towel and allow it to air dry in a flat position before sealing in the plastic envelope. While drying is taking place, complete all requested information on both the plastic bag label and the leak test analysis form. Please type or print legibly to insure that all information is readable. When dry, place the filter paper in the plastic bag using the tongs and press the seal to close. Attach the completed plastic bag label to the bag. Retain the middle copy of the form as your record of having made the leak test. Place the plastic bag and the two remaining copies of the form in the pre-addressed envelope, put your return address on the outside, seal, stamp, and mail.

Safety regulations require that the factory leak test all sealed sources prior to entering our plant; therefore, this service will be performed on all instruments returned for checkout and repair. The leak test report will be sent to the owner, and charges for the service will be included with other charges.

VII-F. SOURCE ROD REMOVAL

On occasion it may be necessary to remove the entire source rod assembly to facilitate repairs to the instrument. This is easily accomplished, but provision must be made for shielded storage of the rod while it is out of the gauge. The Troxler 100761 Source Rod Pig will provide this shielding but other similar storage may be used.

In an emergency, the rod can be stored for short periods, without shielding, at a distance of at least two meters (six feet) from all personnel.

The procedure is the same as noted in section VIII-B, which details the removal of the index rod roll pin and cap. At this point the source rod can be lifted entirely out of the gauge shield and stored in a separate shield. While handling the source rod, keep the tip away from the body and other personnel, and do not touch the tip of the rod. The dose rate at the handle with the rod removed is approximately 15 mrem per hour.

Replace the source rod assembly as outlined in section VII-B.

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VIII. SERVICE

The 3400-B Series utilizes a high degree of intergrated circuit technology in custom modules. For this reason, the reliability level is very high and repair is relatively simple since it consists of module replacement. 100% of the electronics may be replaced in the field without recalibration other than establishing a new set of standard counts.

VIII-A. EQUIPMENT REQUIRED

VIII-A-1. HAND TOOLS

Screwdriver, 1/8" flat blade
Screwdriver, 1/16" flat blade
Screwdriver, No. 1 Phillips
Screwdriver, No. 2 Phillips
Pliers, 4 1/2" chain nose
Nutdriver, 1/4"
Nutdriver, 5/16"
Nutdriver, 3/8"
Screwdriver, 1/16" Allen Hex
Screwdriver, 5/32" Allen Hex
Pin Punch, 3/32"
Hammer, Machinist, 8 oz.
Wrench, 1/4", combination

The hand tools listed are contained in the 3400 Series Tool Kit (Troxler P/N 102436)

VIII-A-2. INSTRUMENTS

While not required for service, the following instruments will make troubleshooting easier. The manufactures' models listed are reasonable choices, but other manufactures' equipment could be used equally well.

Digital Multimeter:
3 1/2 digit display 0-20 volt DC ranges, 0-500 mA DC range
1) John Fluke model 8010A
2) Hewlett-Packard model 3476A

Oscilloscope:
10 MHz bandwidth, 10 mV to 10 V vertical deflection/division, 1μs/cm to 100 ms/cm sweep rate (triggered)
1) Tektronix model T922
2) Hewlett-Packard model 1222A

Power Supply:
0-20 VDC, 400 mA, constant-voltage/current limiting
1) Hewlett-Packard model 6215A
2) Tektronix model PS501-2 with TM501

Electrostatic Voltmeter:
0-1500 VDC, 1% accuracy
1) Sensitive Research (Electrical Instrument Service, Inc.) model ESD-7

VIII-B. GAUGE BASE ELECTRONICS

A block diagram of the gauge base electronics is shown in figure 8-1. This assembly consists of four sealed modules which are field replaceable. It is not anticipated that field repairs will be made to the modules.

This unit contains HIGH VOLTAGE which can cause severe shock to a technician. In addition to turning off the unit before working on it, the high voltage should be discharged by shorting across the HV DISCHARGE and GND test points. A wide blade, insulated handle, screwdriver is useful to this purpose. These test points are located on the preamplifier board adjacent to the spare fuse holders.

Power is supplied to the system from two 102057 battery packs which total 10 volts at 40 watt-hours, each of which is separately replaceable and fused to protect against damage to the packs.

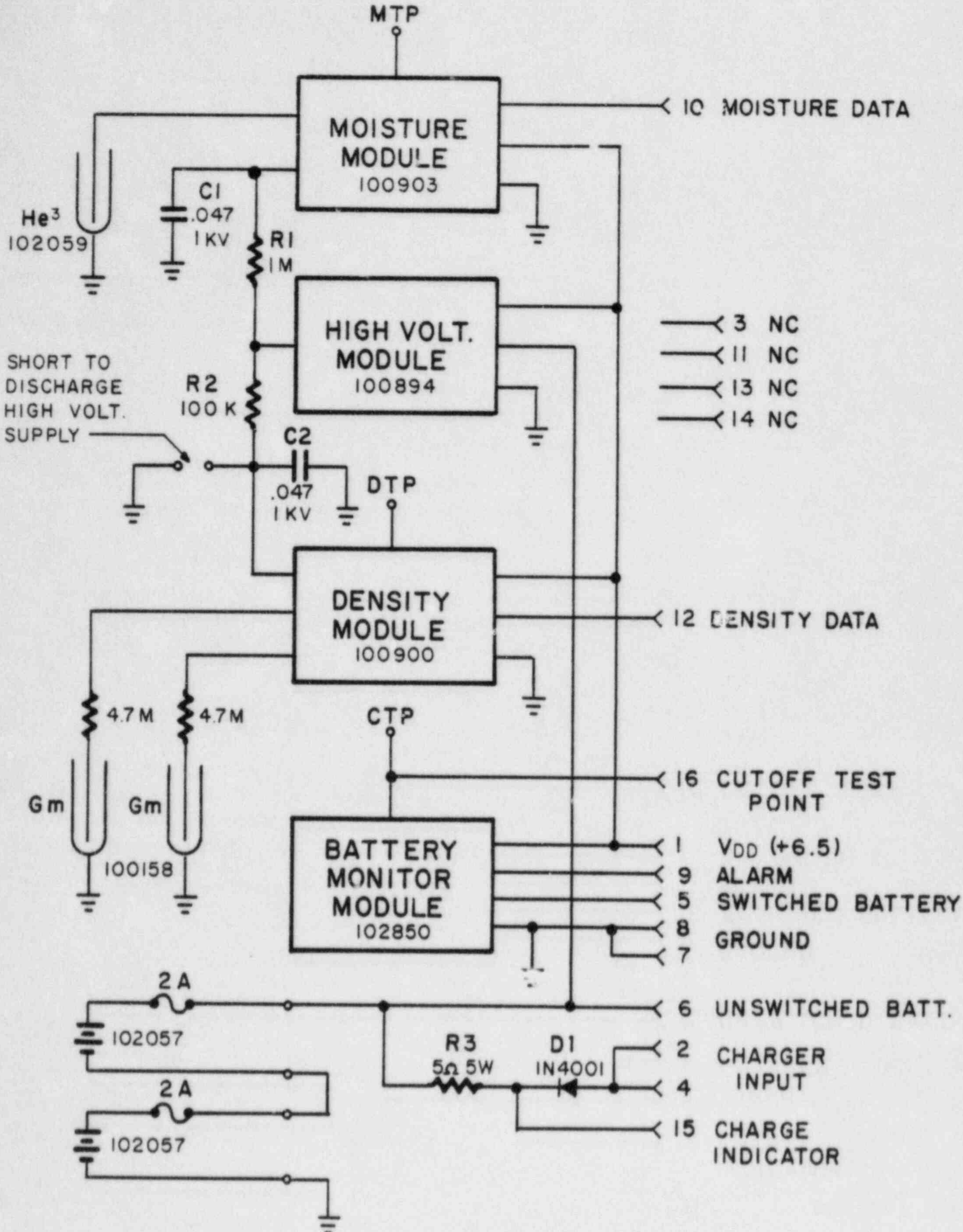
Charging current is supplied from pins 2 and 4 through diode D1 (to protect against external shorts or discharge) and resistor R3 (to limit charge current under extreme low battery conditions).

Current from the battery is supplied through pin 6, switched by the PWR/TIME switch on the front panel module, and returned to the 102850 Battery Monitor Module via pin 5. Unswitched power is suppled directly to the 100894 High Voltage Module. These modules contain electronic switches to demand power as required.

The Battery Monitor contains voltage sensing circuits to activate the BAT alarm symbol when the battery voltage drops below 9.2 ±0.1 volts. Another voltage sensing circuit detects when the battery voltage drops below 8.4 ±0.1 volts and cuts off the gauge electronics. Both the alarm and cutoff circuits have at least 0.15 volts of hystersis designed into the trip points.

The Battery Monitor also contains a precision 6.5 volt regulator which supplies power for the digital and linear circuits, in addition to serving as a precision reference for the counting thresholds. The 6.5 volt regulator is turned off by the cutoff signal when the battery voltage drops below 8.4 volts.

The H.V. Module is powered directly from the batteries but is turned on by the 6.5 volt supply. It contains a very precisely regulated (.05%) voltage for all conditions of line, load, and temperature. The absolute voltage is 1000 ±20 volts. This high voltage is supplied to the Moisture and Density Modules through filters R1-C1 and R2-C2 which prevent cross coupling.



Block Diagram of 3400-B Gauge Base Electronics
Figure 8-1

VIII-B. GAUGE BASE ELECTRONICS (cont'd)

The 100900 Density Module and 100903 Moisture Module contain protection circuits, amplifiers, threshold detectors, and logic conversion to accept pulses from the Geiger Mueller (GM) and He-3 detectors and supply count pulses to the front panel module. If a suitable oscilloscope is available, the gain of these modules may be checked by monitoring the test points located next to each module. Gain adjustments are located under the label to adjust for a 1.5 volt pulse height on density and a 2.0 volt pulse height on moisture. When properly adjusted, the detectors will be operating on their plateaus.

Voltages and logic levels between the base and the front panel electronics are supplied through a 16 wire cable and connectors. This connector is polarized and care should be taken to insert it correctly.

NOTE: Either the 3401-B or 3411-B may be operated with a "non-B" base by use of an adapter cable (part number 102885).

VIII-C. 3401-B SCALER MODULE ELECTRONICS

The 3401-B Scaler Module contains the oscillator and time base circuits, prescale circuits, dual accumulators, multiplexing, decoding, and display circuits. A self test feature is built in to allow checkout by the user.

On the lower right corner of the circuit board, there is a slide switch labeled TEST-MEAS. With this switch on TEST, the unit can be checked completely by accumulating a count. 8192 should appear in both registers for each of the accumulation periods.

Due to the degree of large scale integration, it is recommended that no field repairs be considered other than the replacement of the liquid crystal display, which is a plug-in device. The factory has an exchange program for the module, or the unit can be repaired and returned. The compactness and small conductors on the circuit board require specialized equipment for fault location and component replacement.

VIII-D. 3411-B PROCESSOR MODULE ELECTRONICS

The 3411-B Processor Module contains a Microprocessor (μP) which acts as the control processing element. The μP has a fixed set of instructions that it can execute. The sequence in which the instructions are executed is called the program. Therefore, the functional characteristics, or "personality", of the module is determined by the program. The program and the calibration data are stored in a Programmable-Read-Only-Memory (PROM). This device is plugged in and is reprogrammable at the factory and at suitably equipped facilities.

A complete checkout of the processor module is covered in section II-D.

Two (or three) slide switches are located on the lower right corner of the front circuit board. The use of the MEAS/TST switch is covered in Section II-D. The middle switch, if present, is for the liquid crystal display heater. The use of the heater is covered in Section II-E. The remaining switch is labeled SI/PCF. This switch allows the operator to choose either kilograms-per-cubic-meter or pounds-per-cubic-foot for displayed computations.

Due to the degree of large scale integration and the complexity of the digital electronics, it is recommended that no field repairs be considered other than the replacement of socketed components. These components include the liquid crystal display and four integrated circuits located on the CPU circuit board. The factory has an exchange program for the module, or the unit can be repaired and returned.

NOTE: As mentioned above, the gauge calibration data is stored in the Programmable-Read-Only-Memory (PROM). This part is IC4 (manufacturer's part number 2716 or 2516) and is located in the approximate center of CPU board. If for any reason, it is necessary to swap processors modules with another gauge base, please observe the following precautions:

1) The 2716 contains the calibration data for a particular serial number gauge and it must remain with that gauge.

2) The 2716 used in the 3411-B is NOT compatible with the 1702 used in the first series of 3411 gauges.

3) The 3401-B or 3411-B may be operated with a "non-B" base by use of an adapter cable (Part number 102885). A 3411 "non-B" processor can not be used with a 3400-B gauge base.

4) If a 3411-B processor is used in a "non-B" base, the computation keys will produce invalid results unless the PROM is reprogrammed with the correct calibration data for the different base. The accumulation and display of counts will still be valid.

VIII-E. STATISTICAL STABLILITY AND DRIFT

Radiation and the detection of radiation involves statistics in the form of Poisson distribution. This subject is covered in Section X-F. If analysis of count rate data does not follow normal distribution analysis, it is an indication of false counting due to noise or instability of detectors and/or high voltage power supply.

After the gauge has been on for 15 to 20 minutes, take a series of 20 one-minute moisture and density standard counts and record them as shown in figure 8-2. Obtain the averages for the two sets of 20 counts and compute the predicted deviation by obtaining the square root of the average. Next, compute the actual standard deviation using:

$$\sigma = \left[\frac{1}{N-1} \sum_{1}^{N} (n-\bar{n})^2 \right]^{\frac{1}{2}}$$

Now compute the ratio of the actual standard deviation to the predicted deviation by using:

$$\text{Ratio} = \frac{\sigma}{\sqrt{\bar{n}}}$$

A test of this type should yield a ratio of actual to predicted standard deviation of 1; however, since per-minute-count-rates in the 3400 are divided internally by 16, the ratio is reduced by the square root of 16, or 4. Therefore, ideally the ratio should be 0.25. Acceptable limits are between 0.18 and 0.35. A definite instability exists if the ratio is less than 0.12 or higher than 0.40. In between the definitely good and definitely bad limits there are points which are statistically questionable and the data should be retaken.

After the instrument has been in operation for 4 to 6 hours, 5 additional sets of standard counts should be taken in the SLOW (four-minute) time period and averaged.

One now has a set of 20 minute averages before and after five hours of operation. The drift of the instrument can now be calcualted as shown in figure 8-2. The drift should not be greater than 1% for moisture or 0.5% for density. The two limits are different because of the statistical limit in obtaining each set of numbers.

STATISTICAL STABILITY TEST

Test Number N	Moisture Standard Counts	ERROR $E=(n-\bar{n})$	E^2	Density Standard Counts	ERROR $E=(n-\bar{n})$	E^2
1	526	3.3	10.89	2400	6.9	47.61
2	521	-1.7	2.89	2379	-14.1	198.81
3	509	-13.7	187.69	2379	-14.1	198.81
4	523	.3	.09	2410	16.9	285.61
5	516	-6.7	44.89	2412	18.9	357.21
6	527	4.3	18.49	2388	-5.1	26.01
7	521	-1.7	2.89	2376	-17.1	292.41
8	522	-.7	.49	2387	-6.1	37.21
9	527	4.3	18.49	2410	16.9	285.61
10	525	2.3	5.29	2394	.9	.81
11	522	-.7	.49	2402	8.9	79.21
12	526	3.3	10.89	2390	-3.1	9.61
13	527	4.3	18.49	2391	-2.1	4.41
14	533	10.3	106.09	2393	-.1	.01
15	524	1.3	1.69	2371	-22.1	488.41
16	525	2.3	5.29	2401	7.9	62.41
17	515	-7.7	59.29	2402	8.9	79.21
18	516	-6.7	44.87	2375	-18.1	327.61
19	533	10.3	106.09	2395	1.9	3.61
20	516	-6.7	44.89	2407	13.9	193.21
	$\bar{n}$ = 522.7		Σ = 690.18	$\bar{n}$ = 2393.1		Σ = 2977.80

$\sqrt{\bar{n}} = 22.86 \qquad \sigma = \sqrt{\frac{\Sigma}{N-1}} = 6.03$

$\text{Ratio} = \frac{6.03}{22.86} = 0.26$

$\sqrt{\bar{n}} = 48.92 \qquad \sigma = \sqrt{\frac{\Sigma}{N-1}} = 12.52$

$\text{Ratio} = \frac{12.52}{48.92} = 0.26$

INSTRUMENT DRIFT TEST

Test Number	Moisture Standard Counts		Density Standard Counts	
1	520		2392	
2	522	Total	2390	Total
3	522	Average	2397	Average
4	520	=(522.7+520.4)/2	2384	=(2393.1+2391.2)/2
5	518	=521.6	2393	=2392.2
Avg =	520.4		2391.2	

Difference = 522.7 - 520.4 = 2.3 = 2393.1 - 2391.2 = 1.9

$\text{Drift} = \frac{2.3}{521.6} \times 100 = .44\% \qquad = \frac{1.9}{2392.2} \times 100 = .08\%$

Statistical Test Data
Figure 8-2

VIII-F. TROUBLESHOOTING HINTS

The 3400-B instruments, while complex, can generally be repaired in the field by isolating problems to one or two modules by the process of elimination.

1. Instrument fails to display when power is turned on.
   - (a) Batteries are discharged below cut-off voltage. Plugging in the charger will turn on the instrument.
   - (b) If the charge light on the charger did not light-up when it was plugged in, the fuses may be burnt out on one or both of the battery packs. If so, they must be replaced with a Bussman type GMW, two ampere fuse. Also, check the receptacle into which the charger is plugged. Power may not be available to operate the charger.

2. Charger lamps come on, but unit still does not indicate a turned on condition.
   - (a) Replace Battery Monitor Module.
   - (b) Replace Front Panel Module.

3. Instrument turns on but will not indicate counting condition when MEASURE is attempted.
   - (a) Replace H.V. Module.
   - (b) Replace Front Panel Module.*

4. Instrument counts moisture but not density.
   - (a) Replace Density Module.
   - (b) Replace Front Panel Module.*
   - (c) Replace GM tubes.

5. Instrument counts density but not moisture.
   - (a) Replace Moisture Module.
   - (b) Replace Front Panel Module.*
   - (c) Replace He-3 tube.

6. Instrument counts moisture and density, but is erratic and will not meet stability test.
   - (a) Replace Density or Moisture Module as required.
   - (b) Replace detectors as required.

7. Instrument counts moisture correctly, but density count if approximately half the normal value.
   - (a) Replace the defective GM tube.

* Before replacing the Front Panel Module, set the TEST/MEAS switch on TEST and attempt to accumulate a set of counts. If the TEST count is correct, the Front Panel Module is probably functioning correctly.

VIII-G. DEDICATED SERVICE EQUIPMENT

In addition to the general purpose test equipment listed is section VIII-A-2, there are three instruments built especially for the 3400 Series gauges. These instruments and a brief description of their capabilities are listed below.

VIII-G-1. SCALER TEST STATION - MODEL 3940

This instrument generates test signals that simulate the 3400 gauge base electronics. It is used to verify proper operation of the 3401, 3401-B, 3411, and 3411-B modules. An external DC power supply is required for the 3401, 3401-B, and 3411-B. Two external DC supplies are needed if the "non-B" 3411 module is to be checked.

VIII-G-2. PROM PROGRAMMER - MODEL 3954

This is a microprocessor based PROM programmer designed specifically for entering calibration data into the ultraviolet erasable PROM's used in Troxler gauges. The programmer is capable of reading, editing, and programming PROM's. All necessary "prompts" and messages are shown on a sixteen character alphanumeric display. The programmer automatically converts calibration data from decimal (base 10) to hexadecimal (base 16) during data entry and from hexadecimal to decimal during read operations. The user need not concern himself with base conversions.

VIII-G-3. MICROPROCESSOR TEST STATION - MODEL 3960

This piece of equipment was designed primarily to aid the technician in debugging the 3411-B Processor Module. The test station automatically generates a series of pass/fail tests. If the module fails a test, means are provided for extensive testing of the three boards that comprise a 3411-B Processor Module. Hexadecimal and binary displays are provided for the Address, Data, and State Codes.

The design of the test station assumes use by a skilled technician with digital logic experience. Also, use of the test station beyond the "pass/fail" mode will require the use of instruments similar to those listed in section VIII-A-2.

VIII-G-4. CALIBRATION STANDARDS - MODEL 3875

A set of six rectangular blocks used to calibrate the 3400 series gauges. The set of standards consist of:

1) Magnesium Block
2) Laminated Block of Magnesium and Aluminum Sheets
3) Limestone Block
4) Granite Block
5) Aluminum Block
6) Laminated Block of Magnesium and Polyethylene Sheets

The first five blocks are used to perform the denisty calibration. The magnesium and the laminated magnesium/polyethylene blocks are used for the moisture calibration.

VIII-G-4. CALIBRATION STANDARDS - MODEL 3875 (cont'd)

The density standards have an accuracy of ±0.1% and magnesium/polyethylene has an accuracy of ±4%.

All blocks have predrilled holes to accept the source rod in the direct transmission mode.

A listing of the computer program, necessary to perform the data reduction, is also supplied with the standards.

IX- PARTS LIST

IX-A. REPLACEMENT PARTS

12177	Handle Lock
12750	Source Rod Bearing (2 required)
12751	Source Rod Bearing Seal (2 required)
12752	Source Rod Wiper Seal (2 required)
12753	Retaining Ring
12754	Scraper Ring (2 required)
16245	Fuse, 2 Amp, Type GMW (2 required)
100158	G.M. Detector (2 required)
100528-1000	Captive Screw for Front Panel Module (4 required)
100894	H.V. Power Supply Module
100900	Density Amplifier Module
100903	Moisture Amplifier Module
100989	Post Gasket
100990	Gauge Gasket
100993	Ground Spring for G.M. Detector (2 required)
100996	Sliding Shield
101604-1610	Roll Pin, Trigger
102054	Gasket for Front Panel Module
102057	Battery Pack Assembly (2 required)
102059	He-3 Detector
102067	Bottom Plate Assembly
102069	Wiper Cap
102076	G.M. Detector Mounting Block
102077	G.M. Detector Connector Assembly
102088-2000	Top Shell Assembly
102096	Cap Screw for Index Rod
102103	Cap Screw Bumper
102116	Indexer Assembly
102117	Trigger
102140	Seal Retainer
102383	Trigger Spring
102399	Sliding Shield Spring
102847	3411-B Data Procesor Module
102850	Battery Monitor Module
102888	Cable, Front Panel Module to Gauge Base
102891	Preamplifier Board (printed circuit board only, no modules or mounting plate)
102900	3401-B Scaler Module
103013	G.M. Detector Center Contact Spring (2 requir
103023	Liquid Crystal Display

IX-B. ACCESSORIES

12767	Model 492 Survey Meter
12767-1000	Model 2000A Dosimeter Charger
12767-2000	Model 541/R Dosimeter
21140	Radiation Sign Kit
100421	Drill Rod
102106	Molded ABS Trasnport Case
102107	Foam Inserts For Shipping Case
102110	Reference Standard
102111	Scraper Plate/Drill Rod Guide
102118	115/230 Volt 50-60 Hz Battery Charger
102187	Molded ABS Transport Case With Foam Inserts
102391	12 Volt D.C. Charger Cord
102436	3400 Tool Kit
102713	Drill Rod Jack
102868	Leak Test Kit, Model 3880
102876-0005	Replacement Packets For Leak Test Kit (5 Units)
102885	Adapter Cable (allows use of 3401-B Scaler or 3411-B Processor in a "non-B" gauge base)

IX-C. MAINTENANCE SUPPLIES

12774	Molykote Type G Paste Lubricant
12776	Molykote Type 321 Spray Lubricant
100761	Source Rod Pig

X. THEORY OF MEASUREMENT

X-A. GAMMA RADIATION AND MATTER

The interaction of gamma radiation with matter is far too complex to be covered in its entirety in this manual; therefore, this discussion will be limited to the pertinent details which apply to this particular type of instrument.

Since the cesium-137 source has a maximum energy of 0.662 MeV, the attenuation of gamma by pair production need not be considered; therefore, only photoelectric absorption and Compton scattering are of interest. Likewise, only the elements having atomic numbers of 30 and below need to be considered since only trace amounts of the elements above 30 are likely to found in construction materials. Because the maximum energy involved in fluorescence for these elements is below 30 keV and detectors are effectively cut off at this energy, we need not consider this effect, nor the results of it.

The most important quantity related to the penetration and diffusion of gamma radiation in matter is the attenuation coefficient, μ. This quantity depends on the photon energy, E, and the atomic number, Z, of the medium and may be defined as the probability per unit path length that a photon will interact with the medium. As a typical situation, a slab of material of thickness, x, is placed between a narrowly collimated detector. In a layer within the slab, there will occur a reduction of the intensity, I, of the gamma ray beam due to total absorption or scattering of the beam. The resulting fractional reduction of the beam is proportional to the narrow beam attenuation coefficient, μ, and to the layer thickness, x. For a homogeneous medium this reduces to:

$$I = I_o e^{-\mu x}$$

From the above it is apparent that the attenuation coefficient has dimensions of an inverse length. Although linear attenuation coefficients are convenient for engineering application, they are proportional to density, ρ. For this application, it is more convenient to remove the density dependence and use the mass attenuation coefficent, μ/ρ. The customary units are g/cm^2. Using this, the above equation expands to:

$$I = I_o e^{-[(\mu/\rho)x\rho]}$$

X-A. GAMMA RADIATION AND MATTER (cont'd)

For situations more complicated than the narrow beam consideration, the attenuation is still basically exponential but is modified by other factors. The first of these is sometimes called the "geometry factor" and involves the source and detector size, since they are not points but displace somewhat larger volumes. The second involves a "build-up factor" which takes into account secondary photons in the medium as a result of one or more Compton scatters which reach the detector. This factor is quite noticeable when the detector is not collimated or energy selective which is the case with a soils instrument.

The third, which is a secondary effect of the "build-up factor", is more complex and again modifies the attenuation response with respect to density. At energies above 0.08-0.10 MeV, the attenuation due to scattering is larger than the attenuation due to absorption. At energies below these values, absorption is the predominant process of attenuation. As the energy levels continue to decrease, absorption increases at a much higher rate than scattering. When a large percentage of the photons have been reduced to 0.08-0.10 MeV by scattering, the attenuation reverts to the exponential function. Therefore, the rate of attenuation is not a constant over the total range of density but instead increases with density.

The various interactions of gamma radiation and matter in the energy ranges of .662 MeV and below involve the transfer of energy to and from electrons which are set in motion as a result of the interaction and then dissipate their energy as they are brought to rest.

In photoelectric absorption, a photon transfers all of its energy to an electron and the electron is ejected from the atom. The electron carries away all of the energy of the absorbed photon, minus the energy binding the electron to the atom. The K-shell electrons, which are the most tightly bound, are the most important for this effect. The absorption cross section in the energies below .662 MeV is proportional to the fourth or fifth power of the number of electrons involved.

In Compton scattering, a photon collides with an electron, loses some of its energy, and is deflected from it original direction of travel. Assuming the electron to be initially free and stationary, the relation between photon deflection and energy loss is determined from conservation of momentum and energy between the photon and the recoiling electron [Compton (1923), Klein and Nishina (1929)]. The scattering cross section of the interaction is directly proportional to the number of electrons involved (Z of the particular atom).

X-A. GAMMA RADIATION AND MATTER (cont'd)

Since this instrument is concerned primarily with "mass density" instead of "electron density", we are concerned with the Z/A relationship of the elements involved in construction materials. Figure 10-1 is a table of the major earth elements with their weight fractions and Z/A ratios. Note that Z/A varies between 0.466 and 0.500 for all of the elements making up 98.5% of the weight fractions of the earth. The values of μ/ρ are also included.

It is this variation which causes the so called compostion error of gamma density gauges. This will be discussed in more detail in section XI.

Element	Weight Fraction	Z/A	Mass Attenuation Coefficient μ/ρ (.662 MeV)
Oxygen	0.466	.500	.0806
Silicon	0.277	.498	.0805
Aluminum	0.081	.482	.0777
Iron	0.050	.466	.0762
Calcium	0.036	.499	.0809
Sodium	0.028	.478	.0772
Potassium	0.026	.486	.0787
Magnesium	0.021	.494	.0796
Hydrogen	---	.992	.1600

Average Earth Crust Elements
Figure 10-1

X-B. DIRECT TRANSMISSION DENSITY GEOMETRY

Figure 10-2 represents a typical geometry for a direct transmission density gauge. Note that the vertical displacement of depth is variable and while there are no theoretical limits, 300 mm (12 inches) is approximately the maximum practical depth which allows the use of a cesuim-137 source of a size that is easily shielded in portable equipment. The detectors are placed at a horizontal distance from the source which allows an angular measurement through the material to prevent gamma "streaming" on the surfaces from affecting the measurement. This keeps the maximum and minimum radiation levels at the detectors to reasonable differences for the various depths.

Since all of the photons arriving at the detectors have passed through the full distance from the source depth, the measured density is a true average for the material between the surface and the source. Assuming a horizontal distance of 250 mm (10 inches), the measured path length varies from 260 to 395 mm (10.2 to 15.6 inches) for depths between 50 and 300 mm (2 and 12 inches).

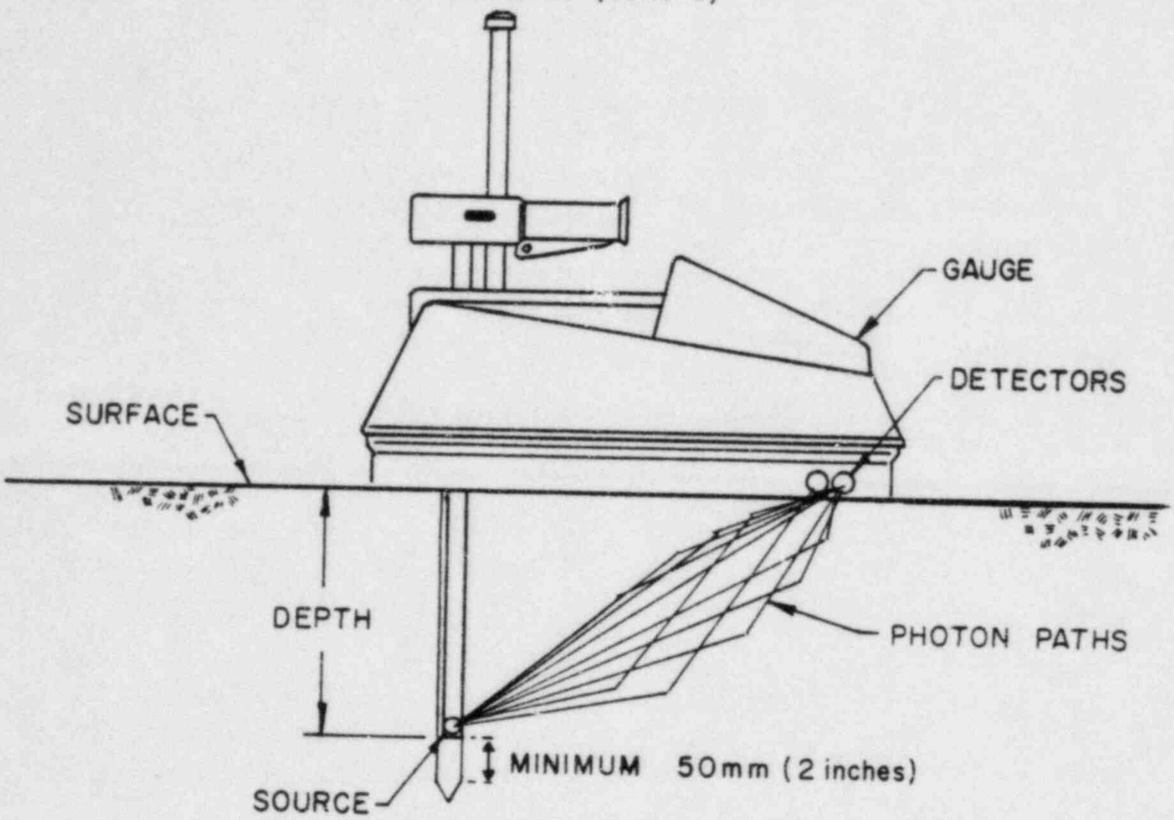
Using the equations from paragraph A above, the relationship between density (D) and count rate (R) can be expressed as:

$$R = A\ e^{-BD} - C$$

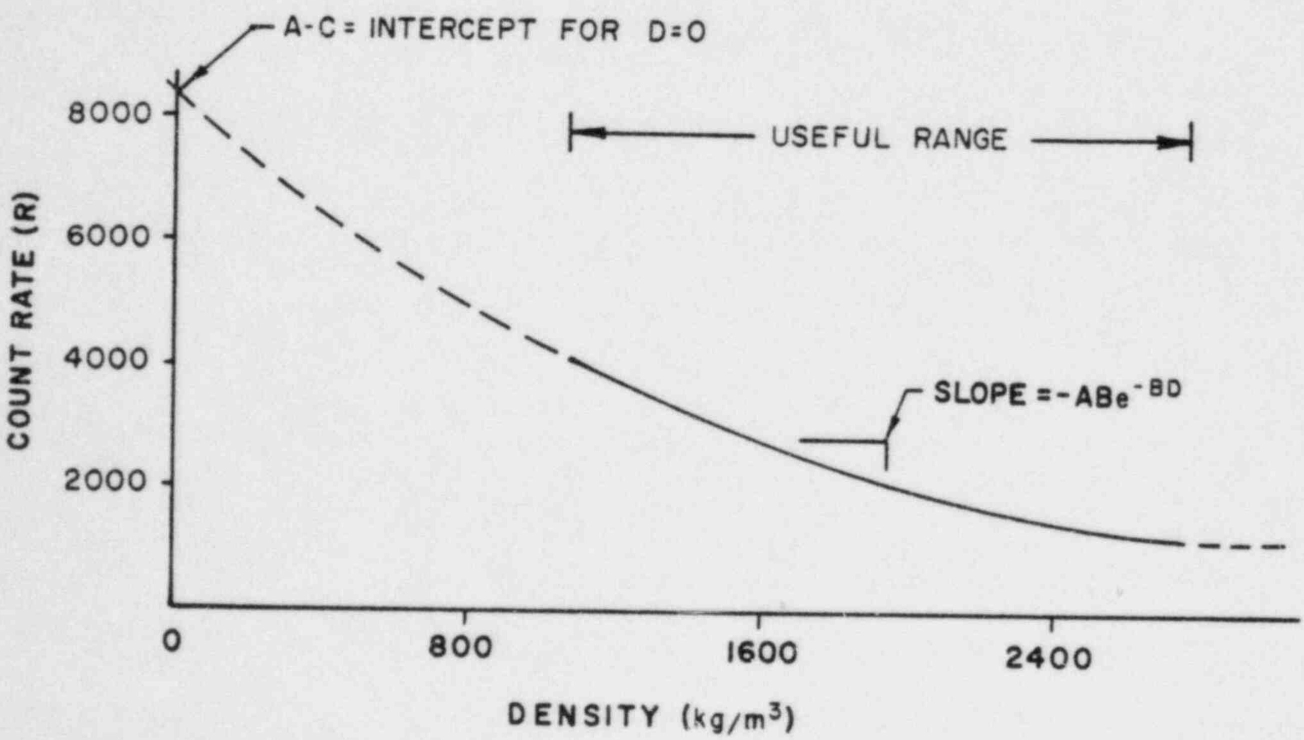
where A, B and C are constants which may be derived from a calibration procedure involving three or more data points. The B constant contains μ/ρ and x, while A and C are related to the source size and detector efficiency. The relationship between A and C determine the degree of deviation from the theoretical exponential function. A plot of this equation is shown in figure 10-3.

Since B contains μ/ρ, it is obvious that there is a family of equations representing each of the chemical elements contained in the measured materials. As will be shown later, an average can be used and the error associated with this average evaluated.

X-B. DIRECT TRANSMISSION DENSITY GEOMETRY (cont'd)



Direct Transmission Density Geometry
Figure 10-2



Direct Transmission Density Response
Figure 10-3

X-C. BACKSCATTER DENSITY GEOMETRY

A typical backscatter geometry is shown in figure 10-4. Note that the source and detectors are in the same horizontal plane. Desirably, no photons should reach the detectors in a path direct from the source. This, of course, is not possible in a practical instrument and is generally held to 10% or less of the backscattered photons.

It is worthwhile to note that, while the terminology has been accepted by the industry, this geometry is technically one of forward scatter. In a true backscatter geometry, the center of the source and the center of the detector are on a line perpendicular to the test surface. The density-count rate response would have a positive slope.

Since all of the photons which have passed through the material under test have been scattered at least once, the average energy at the detectors is lower than the average energy under direct transmission conditions. For this reason, the error due to chemical composition is significantly larger.

Figure 10-5 illustrates a typical backscatter relationship between count rate and density. At zero or very low density, the number of photons arriving at the detectors is very low and represents those which pass through the gauge shielding. As the material density increases, the number of scattered photons reaching the detectors increases until an equilibrium is reached where the rate of initial scatter photons reaching the detectors is equal to the mass attenuation rate. At densities above this point, the count rate at the detectors decreases with increasing density and follows the standard attenuation equation throughout the usable density range.

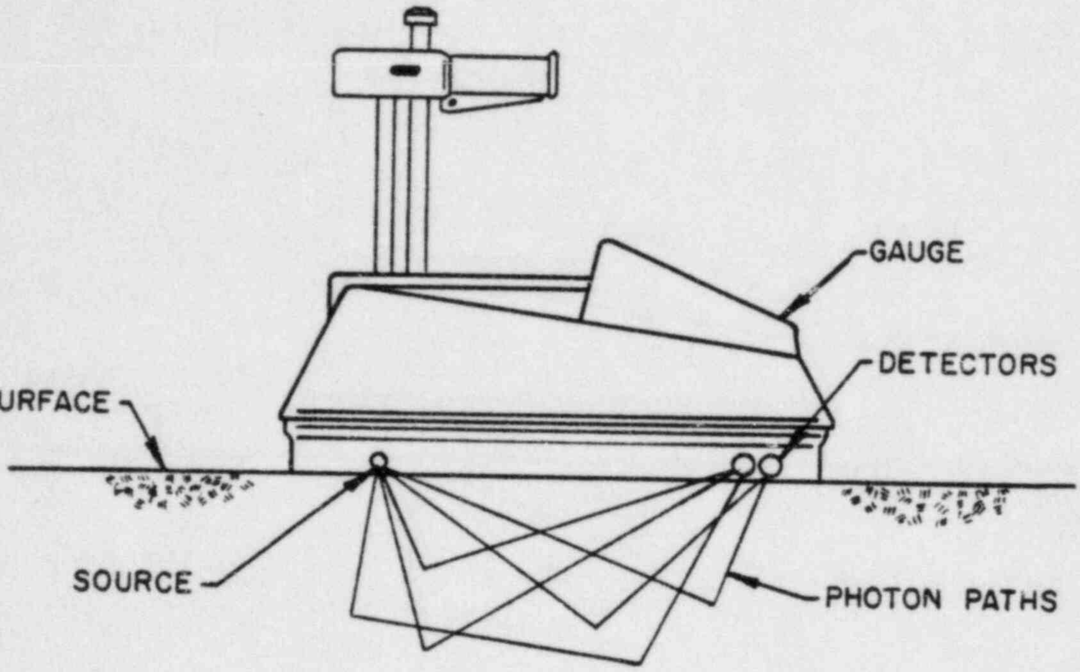
Since the standard equation is valid for the range of densities involved, it is usable even though it does not follow the response over the low density area.

While the direct transmission geometry measures the average density from the source depth to the surface, the backscatter geometry yields an average which is heavily weighted by the surface density. Since the photon path length increases for photons passing through deeper material, this is a normal phenomena as most of the photons reaching the detectors will have passed through the surface material and have decreasing percentages through the deeper materials.

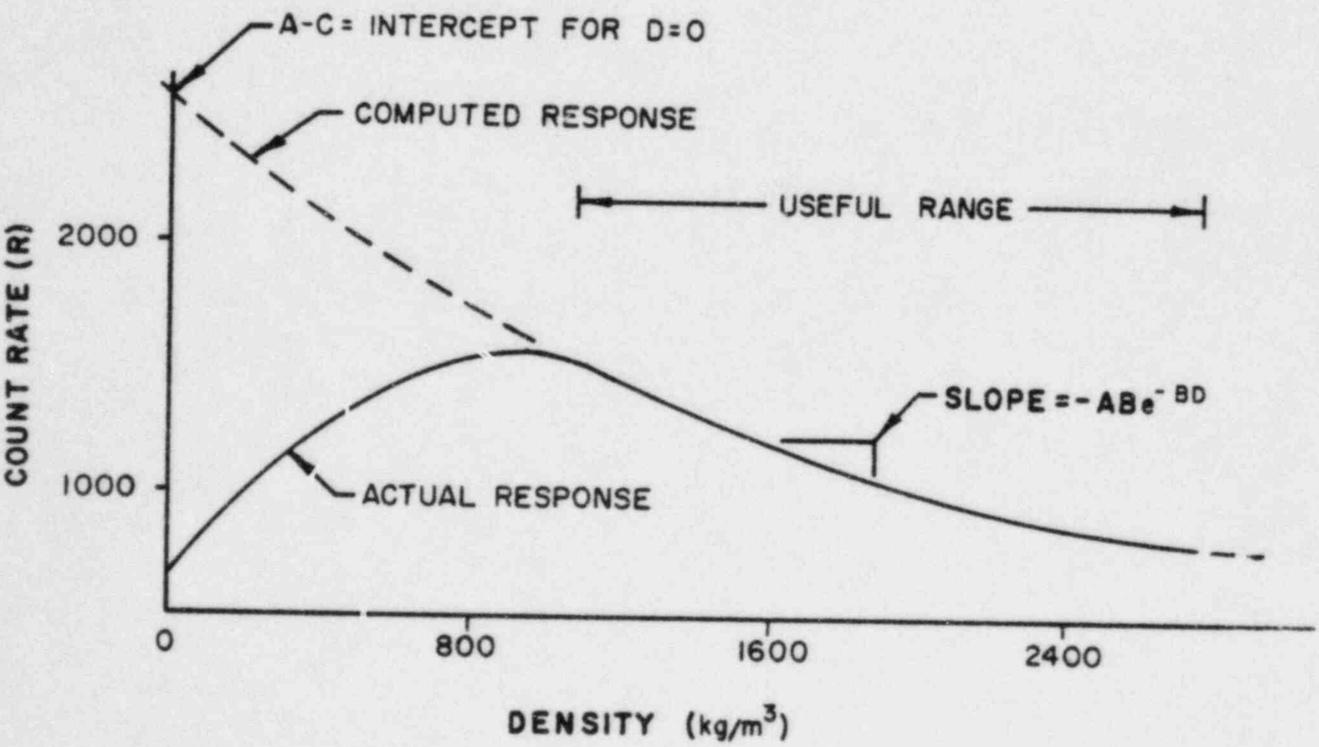
A normalized curve showing the percentages of photons at the detectors for various depths is shown in figure 10-6. This curve can be used to compute the gauge response to layered materials of different densities. As an example, if a 20 mm thick material of 2000 kg/m^3 overlays material of 2150 kg/m^3, the gauge measurement will indicate a density of 2089 kg/m^3 [2000 x 0.41 + 2150 x 0.59].

It is this same phenomena that causes the large error due to surface voids as compared to direct transmission measurements.

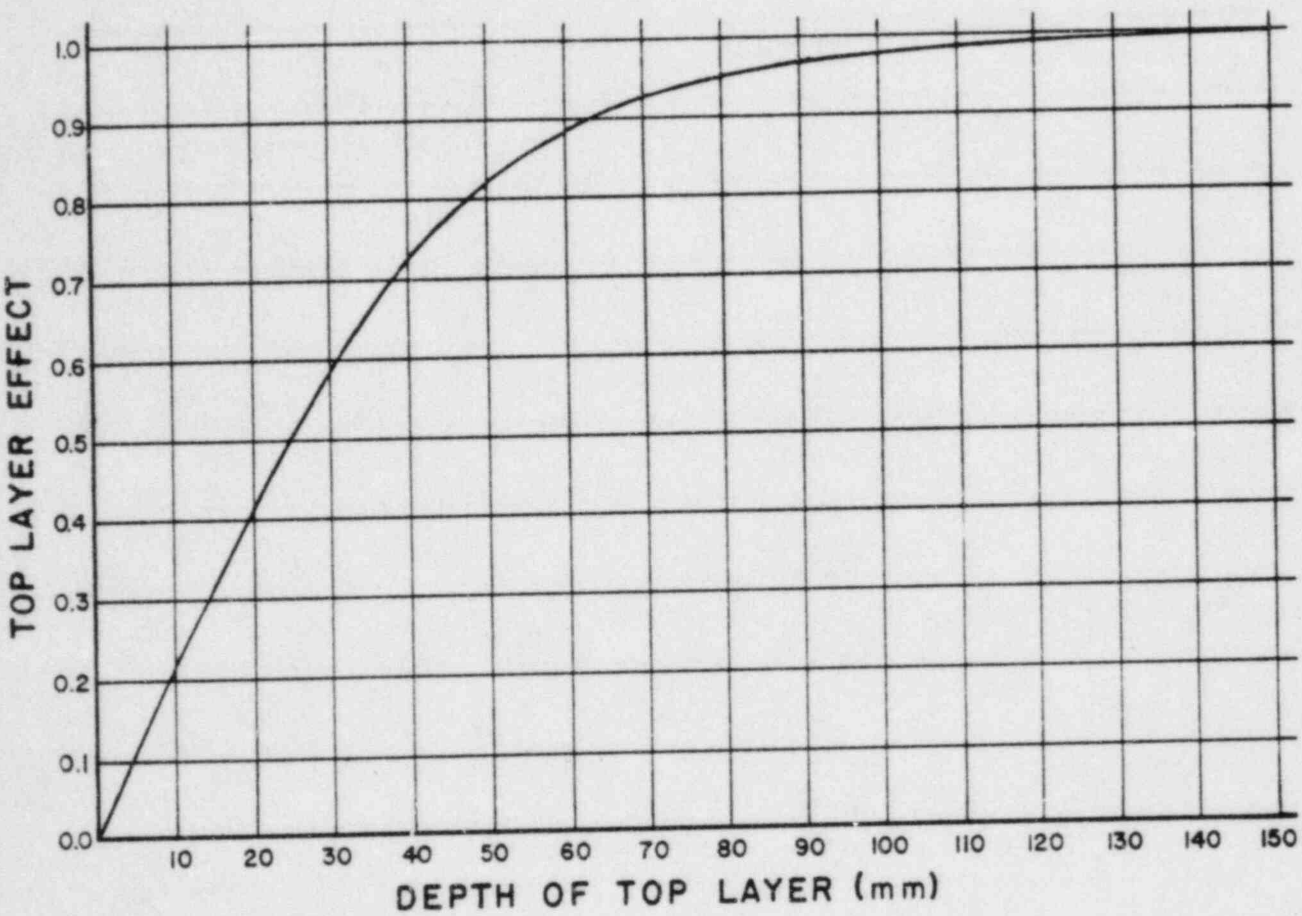
X-C. BACKSCATTER DENSITY GEOMETRY (cont'd)



Backscatter Density Geometry
Figure 10-4



Backscatter Density Response
Figure 10-5



Backscatter Surface Density Effects
Figure 10-6

X- D. NEUTRON RADIATION AND MATTER

As noted in section X-A, photons interact with the orbital electrons of matter and since there is a very large quantity of them in relation to the number of atoms, the probability of interaction is very high. On the other hand, neutrons only react to a significant degree with the nucleus of the atom such that the probability is very small.

While the nucleus carries a positive charge, the neutron has no electric charge, therefore it must approach the nucleus much more closely than a charged particle to interact. The probability of interaction can be related to the ratio of the cross sectional area of the nucleus to the cross sectional area of the atom. Since this ratio is very small, the neutron has a path length much greater than other particles and is able to penetrate very large masses of high density material in contrast to high energy photons.

Isotopic sources of neutrons are produced by (α,n) and (γ,n) reactions. The americium-241:beryllium source in this instrument is of the first type. The americium-241 is used as a source of alpha particles and beryllium as the target material. The reaction may be expressed as:

$$Be^{9}\ (\alpha,n)\ C^{12}$$

which states simply that the (α,n) reaction with beryllium-9 produces carbon-12. Neutrons produced by this reaction have a spectrum of energies ranging from 0 to approximately 10 MeV, the average neutron energy being about 4.5 MeV. The carbon-12 is left in an excited state and produces a 1-10 MeV photon going to the ground state.

Neutron interactions with matter are very complex, involving probability and diffusion theories for the calculation of neutron fluxes. But for engineering measurement applications, the problems can be greatly simplified. The three primary interactions are: inelastic scattering, elastic scattering and absorption.

Inelastic scattering or collisions involve the transformation of kinetic energy to some other form of energy and is only important for fast or high energy neutrons, generally above 10 MeV and are not generally involved in this instrument to any large degree.

Elastic scattering involves the transfer of kinetic energy from the neutron to the nucleus, and is by far the dominant interaction when moderate (<10 MeV) neutron energies are involved.

The maximum amount of energy that can be transferred per collision is only dependent on the mass of the nucleus that is involved: the smaller the nucleus, the greater the energy that can be transferred. When a neutron collides with the normal hydrogen nucleus, all of the kinetic energy could be transferred to the hydrogen nucleus or proton. For any nucleus of mass number A, the maximum energy transfer can be calculated from:

$$E_1 - E_2 = \frac{4A}{(1 + A)^2} E_1$$

where: E_1 = Initial Energy
E_2 = Final Energy

This equation assumes a "dead center" collision. From a probability standpoint this seldom occurs; the collision is usually a glancing situation where only a portion of the maximum loss takes place. As multiple collisions take place, the energy of the neutron is reduced to the point where it is in thermal equilibrium with a gas at 20°C (68°F). In this situation, it may gain as much energy as it loses from the collision. In this condition, the neutron is defined as "thermal" and, on an average, has an energy of .025 eV and a velocity of approximately 2200 meters per second.

The average number of collisions required to "thermalize" neutrons is given by the equation:

$$N = \frac{\text{Ln } (E1/E2)}{1 + \frac{(A-1)^2}{2A} \text{ Ln } \frac{A-1}{A+1}}$$

Figure 10-7 list the common earth crust elements and the average number of collisions required to produce the thermal condition.

The third interaction of neutrons with matter is neutron absorption. In this situation, the neutron enters the nucleus of an atom; the nucleus is raised to a high energy state and particles or photons are emitted from the nucleus.

As an example, boron-10 absorbs a neutron, becomes boron-11, which decays with an alpha particle yielding lithium-7. This example is the (n,α) process. Another example is helium-3, which is transformed into hydrogen-3 by the (n,p) process. Both of these examples are good processes for the detection of thermal neutrons, since the probability of their occurring is quite high.

The probability of absorption is given in terms of barns which have units of 10^{-24} cm^2. It is related to the probability that a thermal neutron will be captured by a nucleus. A table of absorption cross sections for earth crust elements is given in figure 10-7. These values are given for the average of naturally occurring isotopes for various elements, but some isotopes are vastly different from the average. For example, the boron absorption cross section is 759 barns, but is 3840 for the boron-10 isotope. Natural helium is 0.007, but helium-3 is 5327.

The absorption cross section is a value established for thermal energies and decreases rapidly with an increase in neutron energy. For this reason, the absorption process is a good means of detection of thermal neutrons. The neutron, having no electric charge, cannot be detected directly; but, the resulting α particles or protons from the (n,α) or (n,p) reactions can be easily detected and boron triflouride or helium-3 detectors are generally used for this purpose. The helium-3 is more critical, since at its higher pressure, it is more sensitive to detection of gamma.

It is apparent from figure 10-7 that if thermal neutrons are produced in normal soil, the probability is very good that they are produced by the interaction with hydrogen. The next element commonly found in soil, oxygen, requires over eight times the number of collisions to produce a thermal neutron.

Element	Weight Fractions of Earth's Crust	Collisions	Absorption Cross Section
Hydrogen	---	19.0	.33
Boron	*	109.2	759.00
Carbon	*	120.6	.0034
Nitrogen	*	139.5	1.90
Oxygen	0.466	158.5	.0002
Sodium	0.028	224.9	.53
Magnesium	0.021	237.4	.063
Aluminum	0.081	262.8	.23
Silicon	0.277	273.3	.16
Phosphorous	0.001	300.8	.19
Sulfur	*	311.1	.51
Chlorine	*	343.3	33.00
Potassium	0.026	378.0	2.10
Calcium	0.036	387.3	.43
Titanium	0.004	461.6	6.10
Manganese	0.001	528.5	13.30
Iron	0.050	537.2	2.53
Cadmium	*	1074.6	2390.00
Lead	*	1975.5	.17
Uranium	*	2268.6	4.20

* Note: Weight fraction is less than 0.1%.

Neutron Interaction Data
Figure 10-7

X-E. MOISTURE GEOMETRY

The moderation of fast neutrons to thermal energy levels and detection of the thermal neutrons can be a useful means of measurement of moisture content if certain assumptions can be made. The ideal situation would reequire that all thermal neutrons produced within the material be the result of interaction with hydrogen in the form of water. Since this situation does not exist, one must assume that other moderating elements and hydrogen not contained in water be reasonably constant. Fortunately this situation does exist in construction type materials. The lowest mass number element in the earth's crust is oxygen with a concentration of roughly 47 percent and is constant to within a few percent. The other moderators, such as deuterium (H-2), helium, lithium, beryllium, carbon, or nitrogen, are not present in sufficient quantities to create large errors. Agricultural soils may contain sufficient organic materials and nitrogen to cause errors.

One must also assume that no elements are contained in the material which would absorb thermal neutrons. This would also create errors since the absorbed neutrons would not reach the detectors. For construction type soils, only boron is likely to be encountered and could cause large errors. Coastal soils may also contain sufficient chlorine to be significant and iron oxide deposits above 35-40 percent may cause errors.

Since the above elements may exist in sufficient quantities, a means must be provided to compensate for errors. These procedures were covered in sections III-E and IV-E on field use of the equipment. The use of He-3 detectors provides some improvement over BF-3 detectors since they are also sensitive to neutron energies higher than the thermal level.

In choosing a geometry for the source and detector, one must consider the diffusion of thermal neutrons through the material. If small quantities of water are present, the neutrons become thermalized at a large distance from the source and as the quantity of water per unit volume increases, the average neutron becomes thermalized closer to the source. The neutron flux density (neutrons per cubic centimeter) decreases as the square of the distance from the source, therefore the location of the detector becomes critical.

In order to obtain maximum sensitivity (thermal neutrons detected per unit water density), the source and detector should occupy the same space. This, however, produces a response which is very good (linear) at high water contents but has a poor response at low moisture contents since the average neutron becomes thermalized at a large distance from the detector, which reduces its probability of being detected due to the diffusion of the thermal neutron. This response is shown in figure 10-8.

At the other extreme, if the source and detector are separated by a large distance [100-150 mm (4-6 inches)] the linearity at low moisture contents is very good, but at high moistures, the average neutron become thermalized at a point close to the source but at an increasing distance from the detector and the response begins to flatten and ultimately decrease.

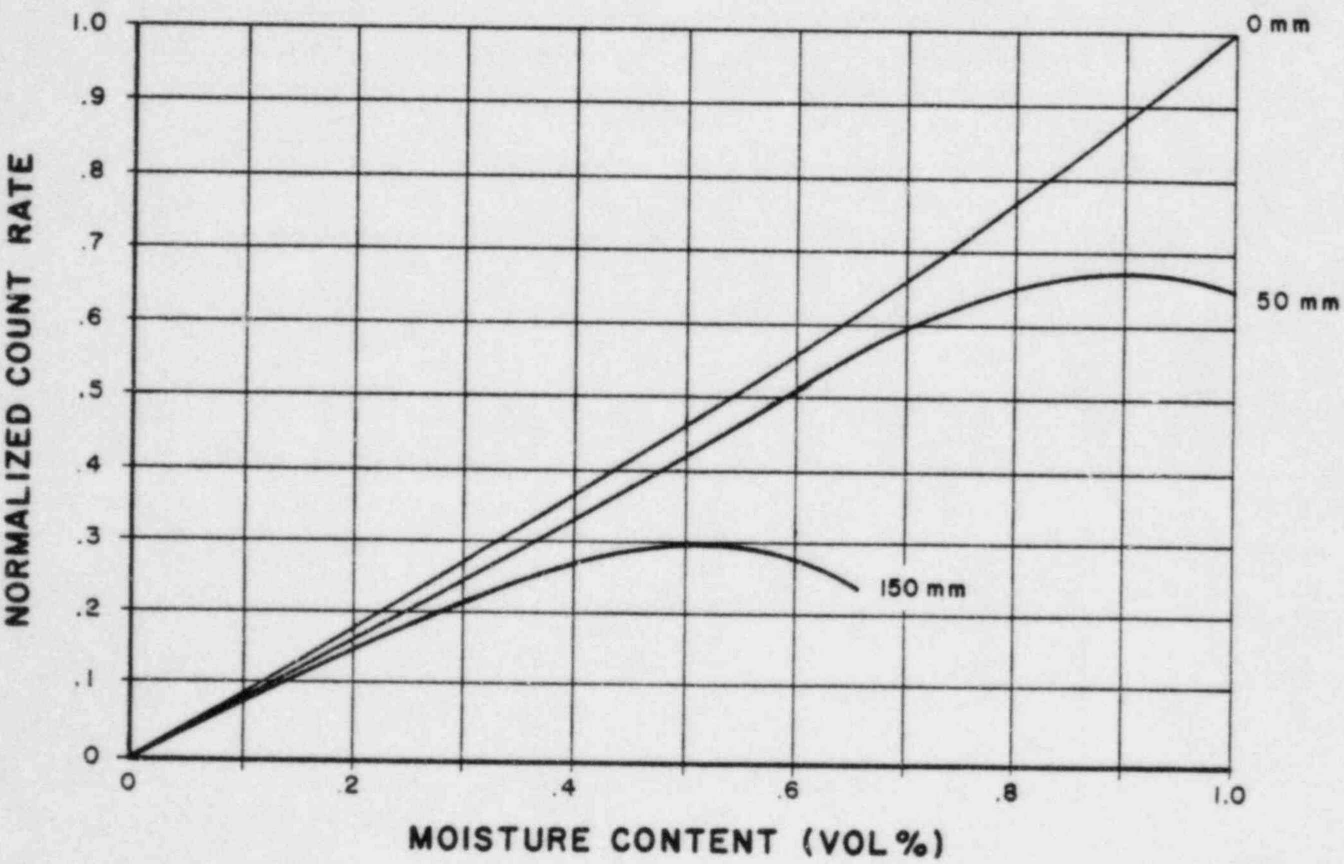
X-E. MOISTURE GEOMETRY (cont'd)

By carefully choosing the source to detector spacing, an "S" shaped response can be obtained which is linear over the 0-650 kg/m^3 (0-40 PCF) range to within ± 20 kg/m^3 (± 1.25 PCF).

In a manner similar to the backscatter density geometry, the instrument is more sensitive to a unit mass of water which is located close to the source-detector plane than an equivalent amount which is further from the center of measurement.

The location of the source and detector within the intrument is chosen to sample the same volume of material as that included in the density measurement. This criteria is not important if the material measured is a homogeneous mix at a uniform moisture and density, but soils do not generally fulfill this requirement.

Since the detector response to a unit mass of water is dependent on the distance between them, the measurement is not a true average of the wet material under the gauge but is an average heavily weighed by the water closest to the detectors. The response is similar in this respect to the backscatter density geometry.



Effect of Neutron Source-Detector Distance
Figure 10-8

X-E. MOISTURE GEOMETRY (cont'd)

Defining the depth of measurement for moisture is not as simple as the backscatter density as shown in figure 10-6 since the moisture depth of measurement is a function of the moisture content and decreases with an increase in moisture. A set of normalized curves are shown in figure 10-9, which illustrate the effects of moisture content on the depth of measurement.

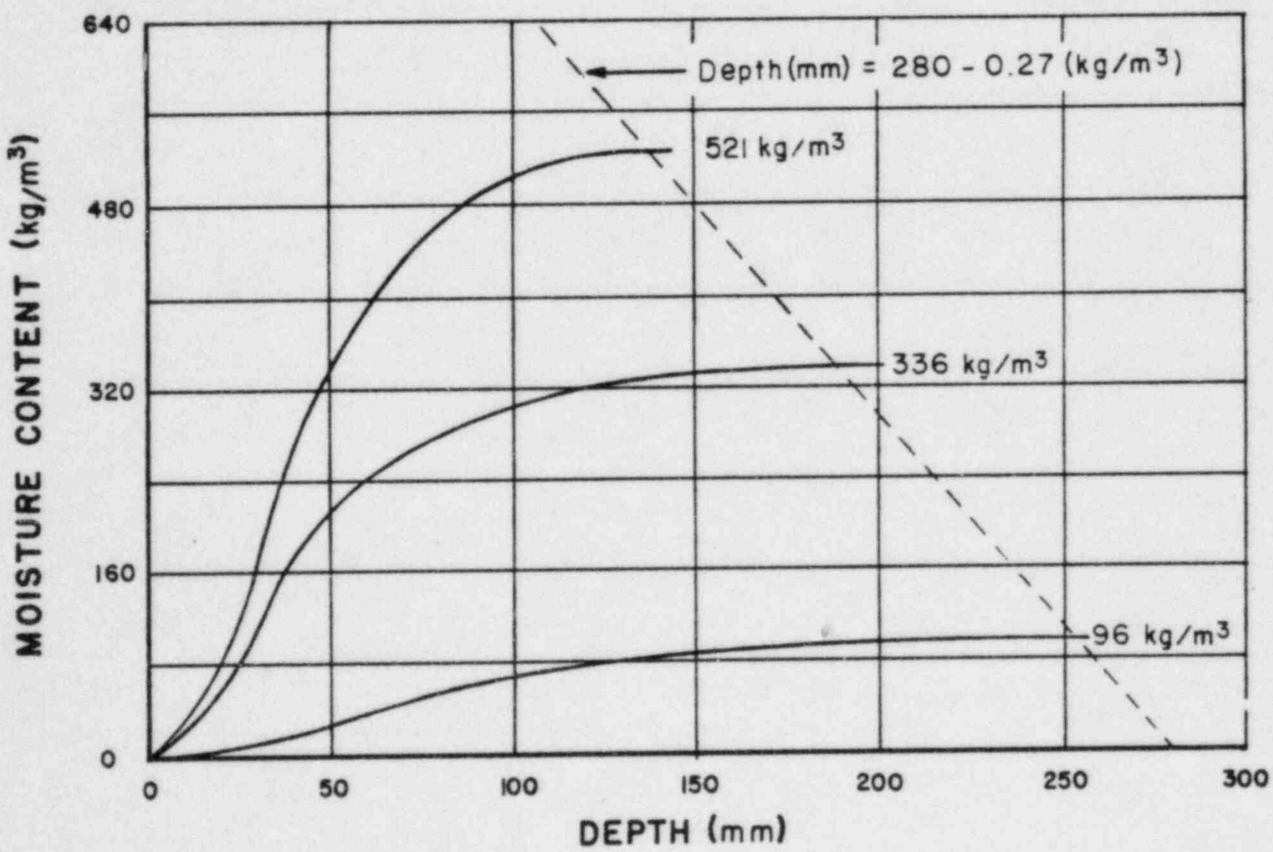
Using the data taken to arrive at the curves shown in figure 10-9, we can express the relationship between the depth and the moisture content as:

$$\text{Depth (mm)} = 280 - 0.27\ M\ (\text{kg/m}^3)$$

or

$$\text{Depth (inches)} = 11 - 0.17\ M\ (\text{PCF})$$

This equation covers 98% of the measured volume and is valid over the moisture content range of 0-640 kg/m^3 (0-40 PCF).



Effect of Moisture on Depth of Measurment
Figure 10-9

X-F. RADIATION STATISTICS

The subject of radiation statistics cannot be completely covered in this short section; however, sufficient detail can be given to enable the user to perform the operations required and understand the statistics pertaining to this equipment.

The binomial distribution describes the probability of random events and its limiting case, the Poisson distribution, accurately defines the probability of radioactive decay. The most significant property of the distribution applying to this equipment is that the variance of the rate of decay is equal to the mean rate of decay. Therefore, the standard deviation (σ) is equal to the square root of the true mean rate of decay (m). Since m cannot be determined, it is convenient to substitute the sample mean $\bar{n}$ where:

$$\bar{n} = \frac{\Sigma n}{N}$$

for N number of samples n. The standard deviation of a given sample n within a population can be expressed as:

$$\sigma(n) = (\bar{n})^{\frac{1}{2}}$$

Further, it is possible to define the precision of a single n as:

$$n = n \pm (n)^{\frac{1}{2}}$$

The deviation of N samples thus becomes:

$$\sigma(\bar{n}) = \frac{\left[\frac{\Sigma n}{N}\right]^{\frac{1}{2}}}{N^{\frac{1}{2}}} = \left[\frac{\bar{n}}{N}\right]^{\frac{1}{2}} = \frac{\sigma(n)}{N^{\frac{1}{2}}}$$

and the precision of $\bar{n}$ is:

$$\bar{n} = \bar{n} \pm \left[\frac{\bar{n}}{N}\right]^{\frac{1}{2}} = \bar{n} \pm \frac{\sigma(n)}{N^{\frac{1}{2}}}$$

The foregoing demonstrates that the accuracy of a given gauge measurement can be improved by accumulating and averaging multiple measurements and the deviation is improved by a factor of two for four measurements, three for nine, four for sixteen, etc. The time consumed increases geometrically however, and is not economical beyond four measurements. This quantity is used for calibration and field determination of the standard count. The 3400 Series obtains the average of four one-minute measurements automatically in the SLOW position of the TIME switch.

It should be obvious that it is necessary to obtain the square root of the true count rate in order to compute the standard deviation; i.e., first multiply moisture and density count rates by 16. The same result can be obtained by dividing the standard deviation of the prescaled count rate by the square root of 16, or 4.

It is often convenient to express the precision as a percentage of the count rate:

$$\sigma(\%) = n \pm \frac{n^{\frac{1}{2}}}{n} \times 100 = n \pm \frac{100}{n^{\frac{1}{2}}}$$

This further demonstarates the futility of using more than four or, at the most, nine samples to determine a calibration count or a standard count. If a gauge has a true count rate of 36,000 cpm for a given test, the precision represents a stability of 0.5% for a single count or 0.25% for four counts. Assuming that the gauge electronics must be more stable than the decay of the source, the electronics must be more stable than 0.1% for all possible sources of drift: detector efficiency, high voltage supply, threshold levels and time base. Few pieces of field operated equipment can demonstrate this order of stability and this explains the careful choice of fixed regulated high voltage supplies and the crystal clock used in the 3400 Series, rather than variable high voltage supplies and tuning fork timers used in other equipments.

Standard deviations in terms of counts-per-minute have little meaning to the gauge user since the desired results are to be kilograms-per-cubic-meter or PCF. In order to determine units, it is necessary to obtain the relationship between the count rate and the desired units. This is not a ratio of the values but a ratio of the change in counts-per-minute to the change in density. The change or slope (S) can be computed by:

$$S = \frac{\Delta n}{\Delta D} \quad \text{or} \quad \frac{\Delta n}{\Delta M}$$

X-F. RADIATION STATISTICS (cont'd)

therefore:

$$\sigma(D) = \frac{n^{1/2}}{\frac{\Delta n}{\Delta D}} = \frac{\sigma(n)}{S} \text{ (Density)}$$

or:

$$\sigma(M) = \frac{\sigma(n)}{S} \text{ (Moisture)}$$

Since the gauge response to density is basically an exponential function, the slope is different at different densities and the density must be stated in order to specify a deviation in terms of density.

While the Poisson distribution describes the probability of decay, the normal or Gaussian distribution is more useful and convenient when predicting or comparing values by the statistical theory of errors. No error is introduced with $n > 100$ and probability > 0.01. Assuming normal distribution, the probability of obtaining a measurement within a specified deviation is:

Deviation	.5	1	2	3
Probability	.383	.683	.944	.997

From this table, one can see that 94.4% of the measurements will be within 2σ and the probability of obtaining a measurement outside of 3σ is remote.

The procedure outlined above predicts the precision of measurements assuming the gauge stability to be greater than the decay stabilities. Obviously this may not be a correct assumption and it is necessary to test the gauge stability in terms of the decay stability. In order to accomplish this test, it is necessary to accumulate a number (20 or more) of sample counts. Normally the moisture and density standard counts are used.

X-F. RADIATION STATISTICS (cont'd)

The standard deviation may be determined by:

$$\sigma = \left[\frac{1}{N-1} \sum_{1}^{N} (n-\bar{n})^2 \right]^{\frac{1}{2}}$$

or:

$$\sigma = \left[\frac{1}{N-1} \left(\Sigma n^2 - \frac{(\Sigma n)^2}{N} \right) \right]^{\frac{1}{2}}$$

The latter equation is sometimes referred to as the working formula and is convenient for use on desk calculators. The deviation obtained is the root-mean-square (RMS) error of the individual measurements from the mean.

A ratio of the RMS deviation to the predicted deviation should fall between .7 and 1.4. Ratios outside of .5 and 1.6 definitely indicate a defective system while ratios between these values indicate possible defects and the test should be repeated. If raw displayed data (in the NORM mode) from the 3400 Series is used, these limits must be divided by 4.

The gauge stability over a working day should be such that the drift in standard count is less than that required to cause an error in excess of one standard deviation. For the 3400 Series gauges this maximum difference is 0.5% for the density standard count and 1% for the moisture standard count. An example of these calculations is given in section VIII-E.

It is difficult to set a maximum for the long term drift of the standard count since it is dependent on the source of the drift. Detectors display an aging which is temperature dependent and this type of drift is compensated by the standard count procedure. A gradual shift of even 10% may be of no concern if it has occurred over a long period of time: however, any sudden shift in excess of 2 to 3% may indicate a mechanical shift in the gauge geometry or incipient detector failure, and the calibration should be checked against a known reference.

XI. FACTORY CALIBRATION

XI-A. DENSITY CALIBRATION

The density calibration method used at the factory consists of the accumulation of count rate data on five standard density blocks for determination of density versus count rate computations, and on standard density block to verify calibration accuracy. Sufficient data is accumulated on each block to insure a standard deviation of ± 2.4 kg/m^3 (± 0.15 PCF) or better for all data points. In order to eliminate long term effects of source decay and electronic drift, all data is normalized to the reference standard count and expressed as a ratio.

The mass attenuation coefficients for the five calibration standards are listed in figure 11-1 for photon energies between 0.10 and 0.60 MeV. The densities of these blocks have been determined to an accuracy of 0.1 percent by gravimetric methods.

Calibration	Photon Energy (MeV)						
Standard	0.10	0.15	0.20	0.30	0.40	0.50	0.60
Magnesium	.1643	.1369	.1223	.1060	.0943	.0860	.0795
Mag/Alum	.1636	.1353	.1210	.1042	.0931	.0849	.0784
Aluminium	.1631	.1344	.1202	.1031	.0922	.0841	.0777
Limestone	.1920	.1459	.1277	.1079	.0960	.0874	.0808
Granite	.1635	.1370	.1236	.1066	.0950	.0867	.0802

Mass Attenuation Coefficients for Various Photon Energies
Figure 11-1

The calibration result consists of a solution of the equation:

$$CR = Ae^{-BD} - C$$

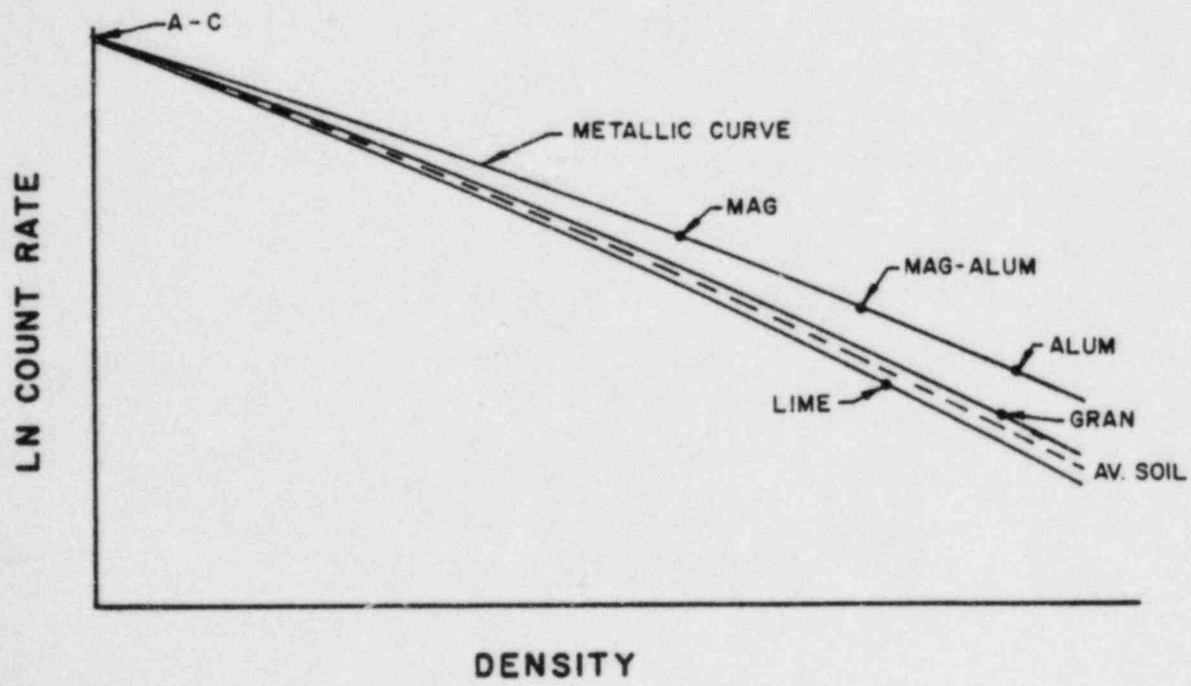
where: CR = Count Ratio
D = Density
A,C = Constants Dependent on Gauge Geometry
B = Constant Dependent on Mass Attenuation Coefficient

Ideally, one would like to have standards of various densities with the same mass attenuation coefficient as the material to be measured. Since this is not possible, other means must be provided to simulate this situation.

XI-A. DENSITY CALIBRATION (cont'd)

The three metallic standards (magnesium, laminated mag/alum, and aluminum) were chosen because, while their mass attenuation coefficients are not identical, their relationship to each other is constant within ± 1% over the desird energy range. Since this is true, their apparent densities can be changed to give the effect of having the same mass attenuation coefficient. Making this assumption and using count ratios from the three standards, one can compute the unknown values of the A, B, and C constants. To attempt this same procedure using standards such as limestone and granite could create very large errors since their relationship, with respect to mass attenuation coefficient, varies about ± 7% over the desired energy range.

The value for B obtained from this computation has no relationship to soil or other construction materials. As shown in figure 11-2 (exaggerated), these constants only determine the intercept at zero density and the general shape of the calibration curve.



Graphic Solution to Density Calibration
Figure 11-2

XI-A. DENSITY CALIBRATION (cont'd)

Using data from the granite and limestone standards, the values for B can be computed for these two materials. The spread in density between these two lines at 2000 kg/m^3 (125 PCF) will typically be 50 kg/m^3 (3 PCF) for direct transmission geometries and 65 kg/m^3 (4 PCF) for backscatter. If one can assume that most soils fall between these two limits (limestone and granite), then the average of the two values of B will produce a calibration which will be suitable for all normal soils.

In order to obtain a quality control check on the validity of the calibration, it is necessary to take data on an independent standard which is not used in the computation but, rather, is used to compute a density from the final calibration equation which can be compared to the true density of the standard. The most severe test would be a standard whose density is outside of the magnesium to aluminum density range since this portion of the calibration is obtained by extrapolation rather than interpolation.

A standard of polyethylene and magnesium having a density of 1402 kg/m^3 (87.5 PCF) was chosen since it is about the low limit of wet density and can also be used for a moisture calibration point. A measured density of the standard should fall within ± 16 kg/m^3 (± 1.0 PCF) since the mass attenuation coefficient is similar to soil rather than the metallic blocks. This is due to the large amount of hydrogen in the polyethylene.

(I-B. DENSITY PERFORMANCE PARAMETERS

Figure 11-3 is a typical computer printout of the calibration data taken during the calibration prodedure and a listing of the various parameters from which the gauge performace can be determined. An explanation of these parameters and the methods used to obtain them is in order.

The first section of figure 11-3 is a listing of the gauge type and serial number, source serial numbers, standard counts, and the dates of calibration and printing along with an indication of which set of factory standards were used to accumulate the data.

The second section lists the density standards, the densities of these standards, and the density measurement counts made on these standards.

The third section headed "Density Performance Parameters" includes all of the computed values used to evaluate the gauge operation and obtain the density conversion tables.

1. The first three items (headed A, B and C) are the constants derived from the equation given in section X-A for each of the depths. Depth "0" is the backscatter geometry.
2. The value headed "Bend" is the computed maximum deviation between a pure exponential function between the densities of aluminum and magnesium and the modified equation using the data from the laminated mag/alum standard. The value serves no useful purpose for the operator but is a quality control check on the gamma filter, detector dead-time, and high voltage regulation under load.
3. The item headed "Y" is a computed value of the mag/alum standard density and represents a check on the simultaneous solution of the equation set.
4. "MP-D" is the computed density of the mag/poly standard and is a final check on the validity of the A, B and C values in the low density range. It should agree with the actual density of this standard within ± 16 kg/m^3 (± 1 PCF) for all direct transmission modes and -16, -40 kg/m^3 (-1.0, -2.5 PCF) for the backscatter mode.
5. "RAT" is the ratio of the count rate at 1762 kg/m^3 (110 PCF) to the count rate at 2243 kg/m^3 (140 PCF). This value is utilized by some users as a measure of the gauge sensitivity and is computed for their information. The larger the numerical value of this number, the larger the slope of the calibration curve when plotted on semi-log graph paper. The value is relatable to the value of "B".

TROXLER ELECTRONIC LABORATORIES, INC.

GAUGE MODEL -3411B
SERIAL- 4100

STANDARD COUNT, DENSITY - 2751.
MOISTURE- 547.

SOURCE TYPE- CS-137 AM/BE
SERIAL- CC-2000 CAA-2000

CALIBRATION DATE 07-20-79 BAY- 9
PRINTING DATE 07-20-79

DENSITY CALIBRATION COUNTS

DEPTH	MAG (1772.)	MAG-ALUM (2227.)	LIME (2291.)	GRAN (2638.)	ALUM (2701.)	MAG-POLY (1402.)	S-R
0.0	1271.	846.	707.	573.	573.	1865.	747.
5.0	4232.	2736.	2273.	1700.	1723.	6031.	2347.
10.0	4353.	2635.	2142.	1512.	1535.	6484.	2195.
15.0	3549.	1985.	1571.	1048.	1069.	5635.	1606.
20.0	2466.	1258.	968.	613.	626.	4239.	988.
25.0	1632.	756.	587.	343.	346.	3053.	598.
30.0	961.	406.	310.	180.	180.	1974.	314.

DENSITY PERFORMANCE PARAMETERS

DEP	A	B	C	BEND	Y	MP-D	RAT	PREC	CE	SR	EX ER
0.0	2.95742	0.11378E-02	-0.05440	-19.	2227.	1368.	1.59	7.8	42.2	-60.9	54.9
5.0	9.19389	0.10157E-02	0.03324	3.	2227.	1397.	1.65	4.1	29.5	-30.3	34.3
10.0	12.05120	0.11466E-02	0.05687	6.	2227.	1402.	1.78	3.5	26.9	-19.9	29.7
15.0	13.89638	0.13561E-02	0.02334	4.	2227.	1404.	1.95	3.4	24.9	-15.6	27.2
20.0	14.96618	0.16205E-02	-0.00460	-2.	2227.	1405.	2.17	3.6	23.9	-12.8	26.1
25.0	15.46284	0.18700E-02	-0.00902	-6.	2227.	1413.	2.40	4.0	17.0	-10.4	19.9
30.0	15.65059	0.21935E-02	-0.01493	-22.	2227.	1415.	2.66	4.7	18.2	-6.7	21.3

MOISTURE CALIBRATION COUNTS

MAG (0.0)	MAG-POLY (586.)	S-R
14.	399.	388.

MOISTURE PERFORMANCE PARAMETERS

	F	RAT	PREC	SR	EX ER
0.02559	0.12005E-02	3.37	1.4	-16.8	9.0

3400-B Series Calibration Data
Figure 11-3

XI-B. DENSITY PERFORMANCE PARAMETERS (cont'd)

6. "PREC" is the statistical precision of the gauge computed at the 68.3% confidence level. It states simply that the repeatability of the gauge is such that 68.3% of repeated measurements on the same site will fall within the average ± the "PREC" value. It also represents the minimum change in density which can be measured with the instrument. A more useful number would be twice this computed value which represents the 95% confidence level.

   "PREC" is computed by the equation:

$$\text{PREC} = \frac{(\text{actual accumulated counts at } 1922\ \text{kg/m}^3)^{1/2}}{\text{slope of the calibration curve at } 1922\ \text{kg/m}^3}$$

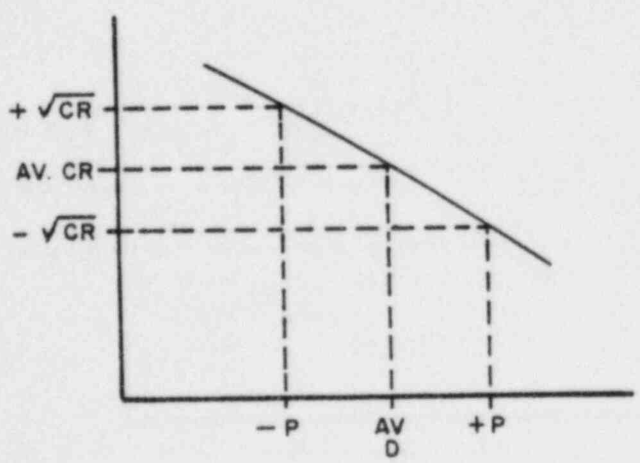
$$1922\ \text{kg/m}^3 = 120\ \text{PCF}$$

   Graphically it is represented in figure 11-4. A more detailed explanation of radiation statistics is covered in section X-E.

   Since the 3400-B Series prescales the actual counts-per-minute by 16 before displaying, the equation for this instrument must be modified to:

$$\text{PREC} = \frac{(\text{displayed counts} \times 16)^{1/2}}{\text{slope} \times 16} = \frac{(\text{displayed counts})^{1/2}}{\text{slope} \times 4}$$

   This equation is for the NORM (1 minute) timing period. For the SLOW (4 minute) period, the precision is improved by a factor of 2 and for the FAST (.25 minute) period, it is degraded by a factor of 2.



Graphic Solution of Precision
Figure 11-4

XI-B. DENSITY PERFORMANCE PARAMETERS (cont'd)

7. As covered in previous sections, an instrument using the attenuation of photon energy to measure density has an error caused by variations in the chemical composition of the material being measured. This is a difficult error to define without being very restrictive on the method of determination. Fortunately, for soils, very good homogeneous standards are available which have compositions which bracket the mass attenuation coefficients of most natural soils. Limestone, due to its high calcium content, has a coefficient higher than natural soils; and granite, due to its high silicon content, has a coefficient lower than natural soils. These materials have reasonable uniform compositions and, in most cases, are of a uniform density throughout their mass. This criteria is not easily met by other natural mineral blocks and cannot be met by manufactured or cemented aggregates.

   The value quoted under the "CE" heading is one half the difference between the granite equation and the limestone equation at the density of 1922 kg/m^3 (120 PCF).

8. "SR" is a measurement of the surface roughness or surface void error. The gamma density gauge, since it yields an average density from the surface down to the depth of measurement, has an error which is associated with the surface voids which may exist to a different degree than sub-surface voids. This creates an error which can be significant, particularly in the backscatter geometry since it heavily weights the surface density.

   No uniform standard method of test has been accepted for the evaluation of this error. Troxler Electronic Laboratories, Inc., in 1968, began using a standard void of 1.25 mm (0.050 inch) under 100% of the bottom surface of the gauge as a reasonable void limit. This is equivalent to a 2.5 mm - 50% void (0.10 inch), etc.

   The error stated under "SR" is the difference between a measurement of the limestone standard with the gauge flush on the surface and a measurement with the base elevated 1.25 mm (0.050 inch) above the surface by means of metal spacers placed along the sides of the instrument. These spacers must not interfere with the measurement geometry.

XI-B. DENSITY PERFORMANCE PARAMEATERS (cont'd)

9. The final density performance parameter is a root-mean-square (RMS) sum of the other errors in addition to a statistical calibration error.

Several attempts have been made to define overall gauge performance factors. Most of these have been dimensionless factors which are useful for comparing one instrument to another but give no indication of errors to be expected in the field. The "EX ER" value is computed from:

$$EX\ ER = [(2 \times PREC)^2 + (CE)^2 + [SR/2]^2 + (PREC)^2]^{1/2}$$

$(2 \times PREC)^2$	is included to allow for the 95% confidence limit for field measurement statistics.
$(CE)^2$	assumes that 95% of all soils will be within the limestone-granite spread of composition.
$[SR/2]^2$	assumes that site preparation can be accomplished to limit the void to the 1.25 mm - 100% level and is divided by two since the error is uni-directional (always negative). The final calibration curve is shifted positive by one-fourth SR in order to partially compensate for the error. This makes the error bi-directional.
$(PREC)^2$	allows for statistical error of the instrument during the calibration and assumes a 4-minute measurement and 95% confidence limit.

XI-C. MOISTURE CALIBRATION

Many attempts have been made to satisfactorily create stable moisture standards either by using actual water and soil mixes or simulating moisture by mixes of hydrogen bearing materials with other materials simulating soils. Some are totally inaccurate and some are very unstable unless particular attention is made to maintaining water levels and preventing evaporation.

During the development of the 3400-B Series, Troxler Laboratories, Inc. developed a set of six standards made from laminated sheets of polyethylene and magnesium. The equivalent water content was computed using the thermalizing and absorption characteristics of hydrogen and carbon in the polyethylene as opposed to the same characteristics of hydrogen and oxygen in water. The equivalent water content ranged from zero to 1163 kg/m^3 (72.6 PCF). These laminated standards were necessary in order to design the neutron geometry of the instrument.

Data from the standards agreed with the thermal response and absolute values agreed with data from saturated graded sand. Since the final geometry design yielded a response which was linear within 16 kg/m^3 (± 1 PCF) over the desired range, two standards, zero and 641 kg/m^3 (40 PCF) were reproduced as production standards.

The zero standard is the same magnesium standard with is used for the density calibration and yields a count rate equal to an air count, i.e., a count made with no material other than air within a 3 meters (10 feet) circumference of the instrument.

The 641 kg/m^3 (40 PCF) standard is made from vertically laminated sheets of 0.76 mm (.030 inch) thick magnesium and polyethylene. The exact sheet thicknesses must be used in the computation to yield correct results since even very small errors in sheet thickness creates large errors in computed moisture.

As with the density count rate data, the moisture count rate data is normalized to a moisture standard count to eliminate long term drift in the instrument. These count ratios are then used to solve the equation:

$$CR = E + (F \times M)$$

where:

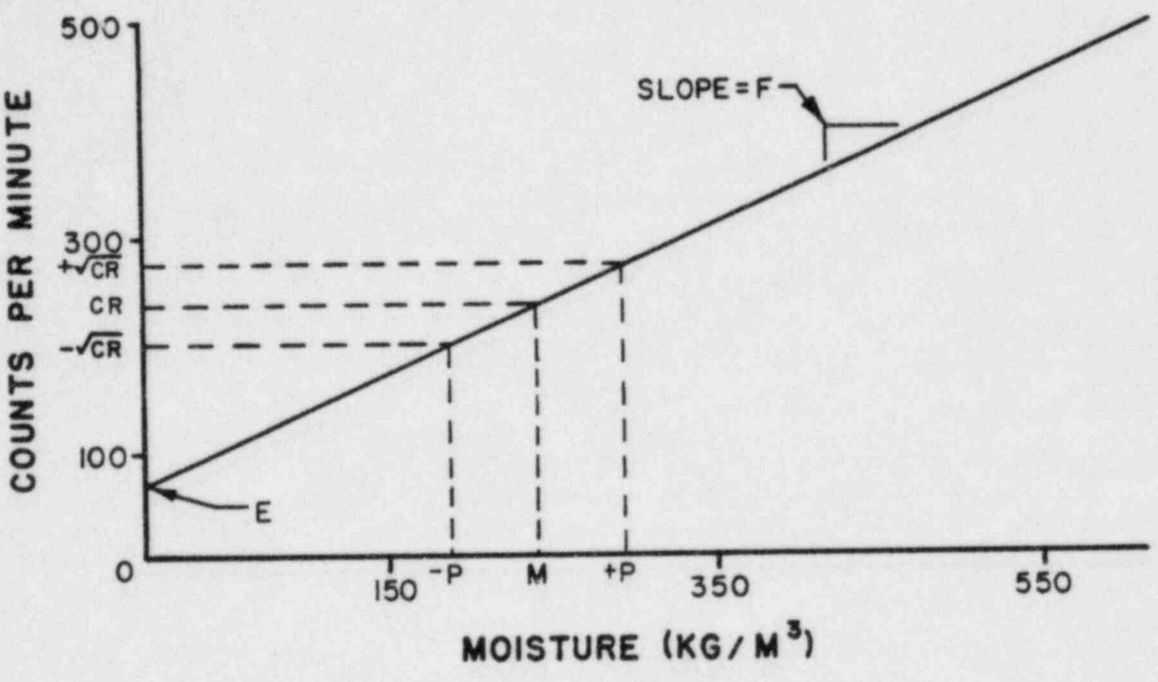
CR = Count ratio
E = Offset at zero moisture content
F = Slope
M = Moisture content

Data is taken in all density geometries and averaged for the final data stated in the fourth section of figure 11-3.

XI-D. MOISTURE PERFORMANCE PARAMETERS

The fifth section of figure 11-3 lists various moisture performance parameters which, in some respects, are similar to those for density.

1. E and F are constants computed from the count rate data to satisfy the equation shown in section XI-C.
2. "RAT" is the ratio of the count rate at 320 kg/m^3 (20 PCF) to the count rate at 80 kg/m^3 (5 PCF). As with the density, "RAT" is related to the slope of the calibration line.
3. "PREC" is the statistical precision of the gauge computed at the 68.3% confidence level and has the same meaning as that computed for the density "PREC". The same equations are used however, the count rate and slope are taken at 240 kg/m^3 (15 PCF) moisture content. The moisture calibration and precision are illustrated is figure 11-5.



Graphic Solution To Moisture Calibration
Figure 11-5

4. "SR" is the surface roughness error caused by a 1.25 mm (.050 inch), 100% void under the gauge and has the same characteristics as the backscatter density "SR". It is a small magnitude since the volume measured for moisture is larger than the volume measured for backscatter density. It is determined by taking the difference between a flush measurement of moisture and one with the gauge elevated by 1.25 mm (.050 inch). The error quoted will be much lower on materials with a moisture content less than 641 kg/m^3 (40 PCF); in fact, it will be directly proportional to the moisture content.
5. "EX ER" is computed in the same manner as the "EX ER" for density with the exception that "CE" is omitted. The value is valid for field measurements provided all errors due to hydrogen not contained in water and high neutron absorbers have been accounted for in the field correction procedure.

XII. RADIOLOGICAL SAFETY

The quantities of radioactive material contained in Troxler moisture and density gauges are quite small, and an operator may safely use a gauge daily without receiving any bodily damage due to radiation. In addition, each radioactive source is doubly encapsulated to afford even greater protection for the operator. However, all radioactive sources, no matter how small, should be handled with care.

The purpose of this section is to acquaint the operator with the types and characteristics of radiations with which he will be working, and to describe the routine handling procedures and precautions which should be followed in order to obtain safe and efficient operation of Troxler gauges.

XII-A. RADIATION CHARACTERISTICS

XII-A-1. TYPES OF RADIATION

The radioactive materials in Troxler gauges emit four types of radiation which the operator should know about: alpha and beta particles, photons, and neutrons. Of these four, the alpha and beta particles are completely stopped by the walls of the source container; therefore, only the characteristics of the photons and neutrons need to be discussed in detail.

Photons (sometimes called gamma rays) are a form of electromagnetic radiation, somewhat similar to radio waves and rays of light, and are electrically neutral. However, unlike light rays, photons are extremely penetrating and may pass through several inches of lead or concrete without being deflected. The energy of a photon is usually expressed in units of millions of electron volts, or MeV. This need not be discussed any further except to state that, in general, the higher the energy, the more penetrating the photon will be.

When a photon (gamma ray) enters a slab of material, any of three things may happen. First, the photon may be absorbed (stopped) by the material. Second, the photon may be deflected or "scattered" in the material, and come out of the material with a different direction and lower energy than when it entered (of course, sometimes the photon is scattered several times before being absorbed or coming out of the material). Third, the photon may pass through the material without being scattered or absorbed.

XII-A-1. TYPES OF RADIATION (cont'd)

It is impossible to accurately predict what will happen to a single photon entering a certain material. However, if a beam of photons is directed at the material, it is possible to calculate the percentages of the beam that will be absorbed, scattered, or transmitted. The percentage of photons that will pass through a material depends mostly on the energy of the photons and the density of the material. For example, if a beam of 1.25 MeV photons was directed at a concrete block 285 mm (11.2 inches) thick, 10% of the beam would be transmitted. However, only 44 mm (1.73 inches) of lead would be required to cut this same beam down to 10% because lead is much denser than concrete.

Neutrons are extremely small, very dense particles. They are electrically neutral and quite penetrating. Unlike gamma rays, the penetrating power of neutrons through a material does not depend on the density of the material, but on the material composition. Neutrons are slowed down most effectively by a material containing a high percentage of hydrogen atoms (such as water or polyethylene) For this reason, neutrons are used to measure the moisture content of soils or other materials.

XII-A-2. TYPES OF SOURCES

The 3400-B Series of instruments are only available with cesium-137 gamma sources for measuring density and americium-241:beryllium neutron sources for measuring moisture.

Both sources meet or exceeed NRC, DOT, and IATA regulations for "SPECIAL FORM" or sealed source materials. Except for the direct radiation hazards, the sources are extremely safe.

The first encapsulation of the cesium-137 material is a glass bead approximately 1.5 millimeters in diameter which is wipe free even if broken up into pieces. This bead, if ingested, would pass through the digestive system without leaving any traces of absorbed material. The glass bead contains nominally 8 mCi of cesium-137. The second encapsulation is vacuum melted stainless steel in which the closure is fusion welded. This source capsule is fusion welded into the source rod to provide a third encapsulation.

XII-A-2. TYPES OF SOURCES (cont'd)

The americium-241 material is a compacted mixture of americium oxide and the beryllium metal target. The pressed pellet nominally contains 40 mCi of americium-241. This pellet is fusion welded in two separate stainless steel capsules and is contained within the instrument in another stainless steel housing embedded in lead.

The cesium-137 material decays with the emission of a beta particle with a maximum energy of 1.167 MeV and an average energy of .195 MeV. The half-life of this decay is 30 years. With this emission the cesium-137 material is transformed into barium-137m, which is still unstable and decays with the emission of a .662 MeV gamma photon with a half-life of 2.5 minutes. The beta emission is absorbed by the stainless steel capsule, and the result is effectively a .662 MeV gamma source with a yield of 2.5×10^8 photons per second.

The americium-241 material decays with the emission of an alpha particle having an average energy of 5.45 MeV and a gamma photon of 0.06 MeV. The half-life of this decay is 458 years. Other minor emissions of daughter products are present but are not significant. The gamma yield of 5.6×10^8 photons per second is mainly absorbed by the capsule along with all of the 1.5×10^9 alphas per second. Some of the alphas are absorbed by the beryllium target material, producing a $Be^9(\alpha,n)C^{12}$ reaction. Other alpha particles are self-absorbed by the americium-241. The carbon-12 has excess energy and produces a small quantity of 1-9 MeV photons. The final result is effectively a neutron source of 7.0×10^4 neutrons per second with an average energy of 4.5 MeV and less than 5.6×10^8 gammas per second at an energy of 0.06 MeV.

XII-A-3. RADIATION UNITS

Although there are several units of radiation measurements, there are only two with which the operator of the gauge needs to be familiar. These are the curie (Ci) and the Roentgen Equivalent Man (rem). The curie is defined as the quantity of any radioactive material giving 3.7×10^{10} disintegrations per second and is approximately equivalent to the number of disintegrations in one gram of radium-226. The sources used in this gauge are small and are expressed in millicuries (mCi).

The effect of the various types of radiation on the human body is defined as the quantity of radiation of <u>any</u> type that produces the same effects in man as those resulting from the absorption of one roentgen of X or gamma radiation. The unit is "roentgen equivalent man" (rem). Since the absorbed dose is generally small, the millirem (mrem) is generally used.

XII-A-3. RADIATION UNITS (cont'd)

The gamma dose rate (mrem/hour) at any point from the unshielded cesium-137 source in this gauge can be calculated for any distance (D) in millimeters and is equal to $2,500,000/D^2$. For several values of "D", the dose rate in mrem/hour is given in the table below. The neutron dose rate (mrem/hour) at any point from the unshielded americium-241:beryllium source can be calculated for any distance (D) in millimeters and is equal to $62,500/D^2$. This dose rate is also given in the table below.

Distance (mm)	Gamma Dose Rate (mrem/hr)	Neutron Dose Rate (mrem/hr)
10	25,000.0	625.0
50	1,000.0	25.0
100	250.0	6.3
500	10.0	0.25
1000	2.5	0.06

Dose Rates For Unshielded Gauge Sources
Figure 12-1

XII-A-4. EXPOSURE LIMITATIONS

In order to protect personnel from overexposure to radiation, the Nuclear Regulatory Commission and the Federal Radiation Council have established exposure limits for radiation workers. These limits, expressed in mrems, are reproduced in the following table.

EXPOSURE LIMITS FOR RADIATION WORKERS

Type of Exposure	Millirem Limits for 13 weeks	1-week rate
Sensitive Regions (whole body, eyes, gonads, skull)	1,250	96
Kidneys, spleen, lungs, liver	5,000	385
Skin of whole body	7,500	577
Hands, arms, feet, ankles	18,750	1,442

XII-A-4. EXPOSURE LIMITATIONS (cont'd)

A licensee may permit an individual to receive a dose to the whole body greater than that above, provided: (1) the dose during the 13 week quarter does not exceed 3 rems and (2) the dose to the whole body does not exceed [5 x (N-18)]rems; where N equals the individual's age.

These limits are intended to be highly conservative, and do not represent the absolute maximum exposure a person could receive without becoming ill or suffering radiation damage. However, it is advisable to remain under the limits whenever possible. This can be done quite easily with Troxler gauges, by following established handling precautions.

XII-A-5. SHIELDING

There are two basic ways in which a person can protect himself from a radioactive source: distance and the interposition of shielding material.

As a person moves away from a source, the amount of radiation which he is receiving from the source falls off sharply. In fact, the radiation obeys the "inverse square" law which states that the radiation intensity decreases as the inverse square of the distance from the center of the source to the "target". For example, if a person standing one foot from a source were receiving forty millirem per hour, moving back another foot would cut the intensity to ten millirem per hour. By moving back, the person represents a smaller "target area" to the source.

The other method of shielding is obtained by placing matter between the source and the target. To a reasonable approximation, it makes no difference where the shielding material is placed between the source and the target, as long as the thickness of the material remains the same.

As was mentioned earlier, dense material provides the best shielding against gamma radiation; while hydrogeneous (hydrogen containing) material affords good protection against neutrons.

The 3400-B Series gauge uses tungsten as the biological shield for gamma radiation. Tungsten offers many advantages over lead, such as: higher melting point, greater density, higher scattering and absorption coefficients, and much greater dimensional stability. Since the shield is also a part of the gauge geometry for backscatter measurements, tungsten prevents a calibration shift caused by cold-flowing of lead. The tungsten shield provided in the 3400 Series produces a reduction of gamma dose rate on the surface of approximately 50 to 1.

XII-A-5. SHIELDING (cont'd)

Since any shielding of neutrons also produces thermal neutrons which affect the measurement of moisture, no provision is made to reduce the neutron dose rate except distance. Small amounts of thermal neutron absorbers are included to eliminate neutrons thermalized by components of the instrument. The neutron dose rate is kept within reasonable levels by simply limiting the neutron yield of the source. Dose rates for the 3400-B Series gauge with the source rod in the SAFE or BACKSCATTER positions are shown below. The measurements given are for the right or left side of the instrument and are the highest levels around or over the instrument.

Distance (meters)	Gamma Dose (mrem/hr)	Neutron Dose (mrem/hr)	Total (mrem/hr)
Surface	14.0	1.0	15.0
0.1	2.5	0.5	3.0
0.2	0.7	0.2	0.9
0.4	0.2	0.1	0.3
1.0	0.1	0.05	0.15

3400-B Series Dose Rates
Figure 12-2

XII-A-6. OPERATOR EXPOSURE

Using the dose rate data for the 3400-B and exposure limits as prescribed by the NRC, it can be easily shown that no hazardous dose can be received by the operator if reasonable procedures are used. As an example, the operator could place his hands on the surface of the instrument for 90 hours each week before reaching the maximum recommended level for the hands. Assuming the distance of 0.4 meters (16 inches) from the instrument during operation, he could use the instrument for 300 hours each week without exceeding the maximum recommended levels for these parts of his body. Obviously, these conditions would never normally exist.

Under average conditions, a full time operator working a 40 hour week can expect to receive about 4 mrem per week or 50 mrem per 13 weeks for his whole body and approximately 50% higher for his hands and feet. This dose is only 4% of the maximum recommended level for radiation workers.

XII-B. HANDLING PROCEDURES

This instrument was designed with operator safety as a prime consideration. However, as with any piece of potentially hazardous equipment, some general precautions should be observed.

1. Do not operate or attempt to operate the instrument unless you have been authorized to do so.
2. Keep the source position in the "SAFE" or stored position when not in use.
3. If required by your license or organizational procedures, wear a Film Badge or other dose measurement device when using or transporting the instrument.
4. While exposure dose levels are well within limits for radiation workers, never expose yourself to the bare source without sufficient reason for justification of the additional dose.
5. Keep all unauthorized persons out of the operating area. A suggested distance is 5 meters (15 feet). The general public must not be unnecessarily exposed to radiation.
6. Maintain security of the instrument at all times. The source lock should be in place when not in use and the instrument should be kept on a locked vehicle when transported. When stored, the area should be locked. Not only is it an expensive piece of equipment but, if stolen, could be abandoned under conditions which could be a hazard to the general public.
7. Every user organization has standard operating procedures; the operator should follow those procedures and report any that he feels unsafe.
8. Insure that the gauge has had leak test measurements at the proper intervals as required by your Radioactive Materials License.
9. If you have any doubts about use of the instrument, ASK. Your Radiological Safety Officer either has the answer or can obtain one.

XII-C. DISPOSAL

Title 10 CFR, part 20 of the Federal Regulations and Regulations of the Agreement States require the disposition of radioactive materials be accomplished by very restrictive methods.

In general, no licensee shall dispose of licensed material except by transfer to an authorized receipient as provided by regulations. The material may be returned to the factory for disposition or may be sold as an instrument to another licensed user. If the instrument is damaged beyond repair, the source may be transferred to an approved burial facility as provided by Federal Regulations.

XII-D. SECURITY

Regulations require that locks be maintained on radiographic equipment to prevent accidental exposure of a sealed source when not under the direct supervision of approved personnel. In addition, storage containers shall be physically secured to prevent tampering or removal by unauthorized personnel.

XII-E. PERSONNEL MONITORING

The licensee shall not permit any person to use this equipment unless at all times the user is in the possession of a film badge dosimeter or pocket chamber. Chambers shall be read daily and records maintained. Film badge reports shall be maintained for inspection.

The film badge requirement may be waived upon application by the licensee if it can be demonstrated that the waiver is authorized by law and will not result in undue hazard to life or property.

XII-F. RECORDS AND REPORTS

1. Each licensee shall conduct a quarterly physical inventory to account for all sealed sources received and possessed under his license. The record shall be maintained for inspection.

2. Each licensee shall have all sealed sources leak tested at intervals not to exceed six months. In the absence of a certificate, the source shall not be put into use until tested.

3. Reports from film badge service shall be maintained for inspection.

4. When an individual terminates employment with a licensee, a record of his total received dose must be made available to the employee.

XII-G. INCIDENTS

1. The licensee must report any theft or loss of licensed material by telephone or telegram to the appropriate agency. A listing of NRC regional offices are noted in figure 12-3. If operating under state license, the appropriate state agency must be notified.

   Within 30 days after the loss, a written report must be filed giving detailed description of the source, circumstances of the loss, statement of disposition, possible radiation exposures or hazard, actions taken to recover the source and procedures which will be implemented to prevent a recurrence of the loss or theft.

2. The licensee must report any overexposure of operators which exceeds the limits given in section XI-B-4, detailing circumstances of the exposure and possible injury.

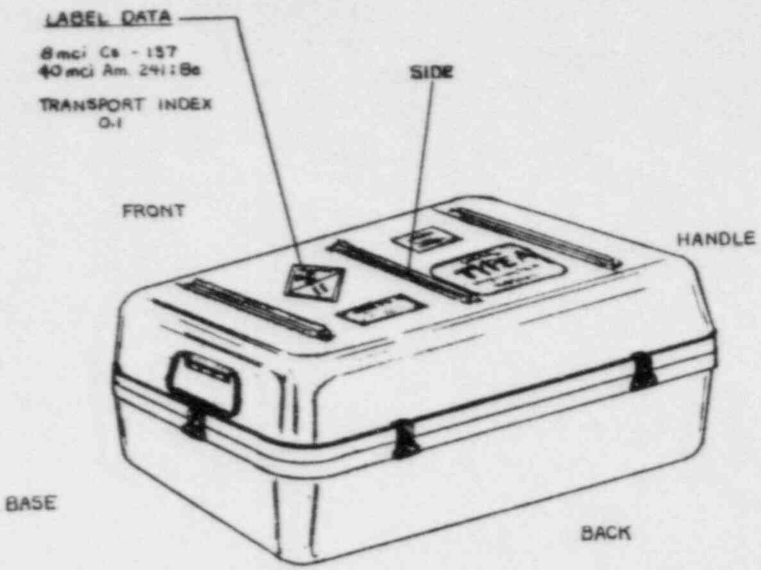
XII-H. NRC AND AGREEMENT STATE REGULATIONS

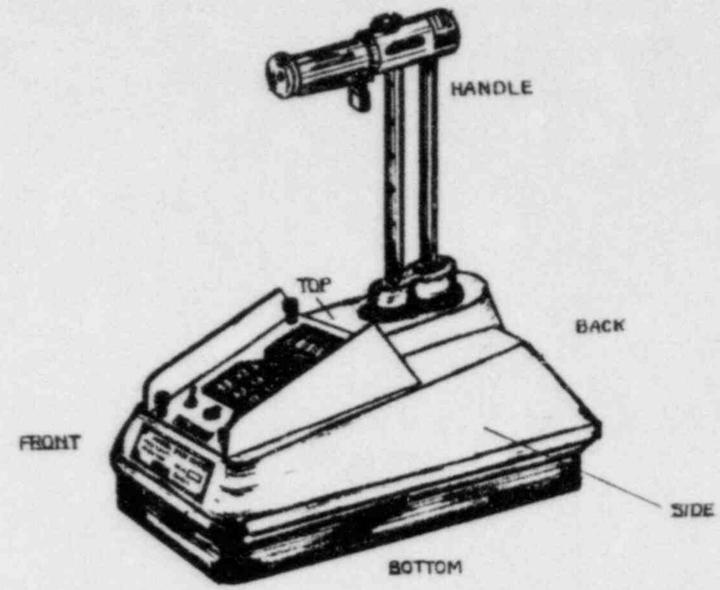
Many sections of State and/or Federal Regulations are referred to in this manual. Troxler Electronic Laboratories, Inc. cannot guarantee the accuracy of these references since the regulations change. The statements do represent our interpretations at the time of issue of this manual.

It is the final responsibility of the gauge owner to obtain copies of regulations which apply to his situation and comply with them.

Region	Address	Telephone	
		Daytime	Nights and Holidays
I Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont	Region I, USNRC Office of Inspection and Enforcement 631 Park Avenue King of Prussia, Pa. 19406	(215) 337-5000	(215) 337-5000
II Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, Panama Canal Zone, Puerto Rico, South Carolina, Tennessee, Virginia, Virgin Islands, and West Virginia	† Region II, USNRC Office of Inspection and Enforcement 101 Marietta Street Suite 3100 Atlanta, Georgia 30303	(404) 221-4503	(404) 221-4503
III Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin	Region III, USNRC Office of Inspection and Enforcement 799 Roosevelt Road Glen Ellyn, Ill. 60137	(312) 858-2660	(312) 858-2660
IV Arkansas, Colorado, Idaho, Kansas, Louisiana, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming	Region IV, USNRC Office of Inspection and Enforcement 611 Ryan Plaza Drive Suite 1000 Arlington, Texas 76012	(817)-334-2841	(817) 334-2841
V Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, and U.S. territories and possessions in the Pacific	Region V, USNRC Office of Inspection and Enforcement 1990 N. California Blvd. Suite 202 Walnut Creek, Calif. 94596	(415) 932-8300	(415) 932-8300

United States Nuclear Regulatory Commission
Inspection and Enforcement Regional Offices
Figure 12-3





3400 SERIES RADIATION DOSE RATES (mrem/HR)

	SURFACE			10 cm.			30 cm.			100 cm.		
GAUGE	GAMMA	NEUTRON	TOTAL	GAMMA	NEUTRON	TOTAL	GAMMA	NEUTRON	TOTAL	GAMMA	NEUTRON	TOTAL
FRONT	4.0	1.0	5.0	.40	.50	0.9	.16	.10	.26	.06	.01	.07
BACK	14	1.0	15	1.5	.50	2.0	.18	.10	.28	.02	.01	.03
SIDES	13	1.0	14	2.5	.50	3.0	.60	.10	.70	.10	.01	.11
TOP	6.0	0.5	6.5	.52	.20	0.7	.20	.05	.25	.08	.01	.09
BOTTOM	9.0	3.0	12	.70	1.0	1.7	.18	.10	.28	.05	.01	.06
HANDLE	.20	.32	.52	.09	.21	.30	.01	.05	.06	—	—	—
TRANSPORT CASE												
GAUGE HANDLE	.08	.10	.18	.06	.05	.11	.03	.02	.05	.01	.01	.02
GAUGE BASE	.90	1.0	1.9	.31	.20	.51	.12	.08	.20	.05	.02	.07
GAUGE FRONT	.60	1.0	1.6	.35	.20	.55	.15	.08	.23	.06	.02	.08
GAUGE BACK	2.5	1.0	3.5	1.2	.20	1.4	.14	.08	.22	.04	.02	.06
GAUGE SIDES	2.0	1.8	3.8	.90	.40	1.2	.25	.10	.35	.06	.03	.09

NOTES:
1. GAMMA MEASUREMENTS MADE WITH A VICTOREEN MODEL 2055 IONIZATION CHAMBER CALIBRATED 10/8/75
2. NEUTRON DOSE RATES CALCULATED USING 4.5 Mev AVERAGE ENERGY
3. DOSE RATES ARE FOR 8mCi Cs-137 GAMMA SOURCE AND 40mCi Am-241 NEUTRON SOURCE WITH A YIELD OF 7.0×10^4 NEUTR: ER SECOND

Radiation Profile
Figure 12-4

XIII. LICENSING

The possession and use of by-product radioactive materials requires a special license issued by the Nuclear Regulatory Commission or the equivalent agency of a state which has entered into an agreement to assume control of the distribution and use of radioactive materials.

XIII-A. UNITED STATES REQUIREMENTS

An application must include the following information.

1. Initial training.
2. Periodic training.
3. On-the-job taining.
4. A means of determining the operator's knowledge and understanding of the regulations and emergency procedures.
5. Applicant's written operating and emergency procedures.
6. Specified delegation of authority or supervision.
7. Leak test procedures and agency who will certify test. If performed by the licensee, equipment methods and personnel experience.
8. Types, sizes, chemical and physical form of the sources, maximum quantity to be possessed, and manufacturer.

XIII-B. NON-UNITED STATES REQUIREMENTS

Import controls are in effect in every country to control the import of this equipment in addition to controls for the distribution and use. In general, where Troxler International, Ltd. operates through an agent, he will make available to the user all information required. Where no agent is involved, the purchaser must obtain this information from his government's agency controlling the distribution and use of radioactive materials.

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XIV. TRANSPORT AND SHIPPING

XIV-A. GENERAL

The transportation of devices containing radioactive material requires conformance to regulations which are very restrictive in order to prevent possible damage to either the population or the environment. Within the United States, the controlling regulacions for packaging, transport and shipping are contained in various sectio: ; of the Code of Federal Regulations as follows:

Title 10 CFR, Part 71 (large quantity shipments)

Title 14 CFR, Part 103 (air transport)

Title 39 CFR, Parts 124.2 (d), 125.2 (d) (parcel post)

Title 46 CFR, Part 146, 149 (water transportation)

Title 49 CFR, Parts 170-190 (packaging, rail, water, highways)

In addition, some states have regulations which may be more restrictive than the above and the Air Transport Restriced Articles Tariff imposes some additional requirements. In general, these regulations are in agreement with and are, in fact, controlled by the Code of Federal Regulations.

International transportation of radioactive materials come under the regulations issued by the International Atomic Energy Agency (Regulations for the Safe Transport Radioactive Materials, 1973 edition, Safety Series No. 6) and the International Air Transport Association (Restricted Articles Regulations).

Within the borders of other countries, their own statutory regulations apply but are, in general, similar to the international regulations.

Devices approved for transportation within a country may meet the requirements for international shipment but Competent Authority Certification of the encapsulation design must be obtained and copies supplied to the carrier.

XIV-B. TESTS AND CERTIFICATIONS

1. The sealed sources in this instrument (Troxler A-102112, 8 mCi cesium-137 and A-102451, 40 mCi americium-241) have been tested to an ANSI rating of C54444 and meet or exceed the requirements of :

   a. Part 15 of the Official Air Transport Restriced Articles Tariff No. 6-D.
   b. IATA regulations relating to carriage of Restricted Articles by air.
   c. IAEA Safety Series No. 6.
   d. US 49 CFR 173.398.
   e. US 14 CFR 103.

   The Special Form Certificate has been issued and the Competent Authority Identification mark is: GB:SFC 140 for the cesium-137 source and GB:SFC 7 for the americium-241 source.

2. The 3400-B Series meets all requirements and is labeled as required by 10 CFR Parts 20 and 34.

3. The packaging for this instrument (Troxler 102187 or 102382) has been tested and meets the requirements of Spec 7A containers for "TYPE A" quantities and is in compliance with:

   a. Parts 6 and 11 of the Official Air Transport Restricted Articles Tariff No. 6-D.
   b. IATA Regulations relating to carriage of Restricted Articles by air.
   c. IAEA Safety Series No. 6.
   d. US 49 CFR 172-178.
   e. US 14 CFR 103.11.

4. The following labels are displayed on the transport containers as required by 14 CFR 103, 49 CFR 170-190 and the Official Air Transport Restricted Articles Tariff No. 6-D:

   a. "USA DOT 7A Special Form Radioactive Material"
   b. Two "YELLOW II" labels indicating the contents as: 8 mCi CS-137/ 40 mCi Am-241.
   c. Troxler label indicating the gauge type and serial number.

XIV-C. TRANSPORT

XIV-C-1. TRANSPORT BY PRIVATE MOTOR VEHICLE

This instrument, in its container, may be transported by motor vehicle under the "YELLOW II" label without placarding the vehicle as required by 49 CFR 177.823.

The source rod lock should be in place and the container placed in a portion of the vehicle which can be locked. When not in transit the instrument should be stored in a secured area.

Since the container has a Transport Index of 0.1, it may not be stored less than 0.3 meters (1 foot) from passengers per 49 CFR 174.586. It should also not be stored for more than 8 hours at less than 1 meter (3 feet) from undeveloped film.

XIV-C-2. TRANSPORT BY COMMON CARRIER

This instrument, with the source rod lock in place and with either a wire seal through two or more latches or strapping around the outer container, meets all of the requirements of the Official Air Transport Restricted Articles Tariff No. 6-D, 14 CFR 103, 49 CFR 170-190, and the IATA Regulations relating to carriage of Restricted Articles by Air. Air transport is limited at the present time to "CARGO-ONLY" aircraft.

The shipping documents must include the Shipper's Certifications for radioactive materials as shown on the following page. The shipper retains one copy, the originating carrier retains one copy and one copy accompanies the shipment.

The Airbill (or waybill if other than air shipment) must include the following description:

RADIOACTIVE MATERIAL
SPECIAL FORM, (N.O.S.)

Cesium-137, 8 mCi, Group III
Americium-241, 40 mCi, Group I
Type A Packaging, Transport Index 0.1
Radioactive "Yellow II" Label Required

SHIPPER'S CERTIFICATION FOR RADIOACTIVE MATERIALS

Two completed and signed copies of this certification shall be handed to the carrier. (Use block letters)

WARNING: Failure to comply in all respects with the applicable regulations of the Department of Transportation, 49-CFR, CAB 82 and, for international shipments, the IATA Restricted Articles Regulations may be a breach of the applicable law, subject to legal penalties. This certification shall in no circumstance be signed by an IATA Cargo Agent or a consolidator for international shipments.

This shipment is within the limitations prescribed for: (mark one)

☐ passenger aircraft and contains radioactive material intended for use in, or incident to, research, or medical diagnosis or treatment.

☒ cargo-only aircraft

NATURE AND QUANTITY OF CONTENT					PACKAGE			
PROPER SHIPPING NAME	RADIONUCLIDE	GROUP	FORM	ACTIVITY		CATEGORY	TRANSPORT INDEX	TYPE
FOR U.S. SHIPMENTS SEE SECTION 2, CAB 82 TARIFF 6-D	NAME OR SYMBOL OF PRINCIPAL RADIOACTIVE CONTENT	GROUP NUMBER OF GROUPS I TO VII	CHEMICAL FORM AND PHYSICAL STATE (GAS/LIQUID/SOLID), or SPECIAL FORM, or SPECIAL ENCAPSULATION	NUMBER OF CURIES or MILLI-CURIES	Number of Packages	I-WHITE or II-YELLOW or III-YELLOW LABEL	FOR YELLOW LABEL CATEGORIES ONLY	INDUSTRIAL or TYPE A, or TYPE B
Radioactive Materials Special Form (N.O.S.) IATA Article #2129	Cesium 137 Americium 241: Beryllium	III I	Spec. Form Type "A" Spec. Form Type "A"	.008 Curies .040 Curies	(1)	II-Yellow	0.1	Type A

ADDITIONAL INFORMATION REQUIRED FOR FISSILE MATERIALS ONLY

EXEMPTED FROM THE ADDITIONAL REQUIREMENTS FOR FISSILE MATERIALS SPECIFIED IN 8.1 OF PART 2 OF THE IATA RESTRICTED ARTICLES REGULATIONS ☐
NAME PLUS QUANTITY IN GRAMS, OR CONCENTRATION, OR ENRICHMENT IN U235:

NOT EXEMPTED: FISSILE CLASS I ☐ FISSILE CLASS II ☐ FISSILE CLASS III ☐

Additional certificates obtained by the Shipper when necessary:

- Special Form Encapsulation Certificate(s) ☐
- Type "B" Packaging Certificate(s) ☐
- Certificate(s) for Fissile Material ☐
- Certificate(s) for Large Radioactive Source ☐
- Government Approvals/Permits ☐

Special Handling Information

I hereby certify that the contents of this consignment are fully and accurately described above by Proper Shipping Name and are classified, packed, marked, labelled and in proper condition for carriage by air according to applicable national governmental regulations, and for International Shipments the current IATA Restricted Articles Regulations.

Name and full address of Shipper:
Troxler Electronic Labs., Inc.
P.O. Box 12057
Research Triangle Park, N. C. 27709

Name and title of person signing Certification:
Ruth Scarborough
Secretary

Date: June 21, 1979 (WO-9281)

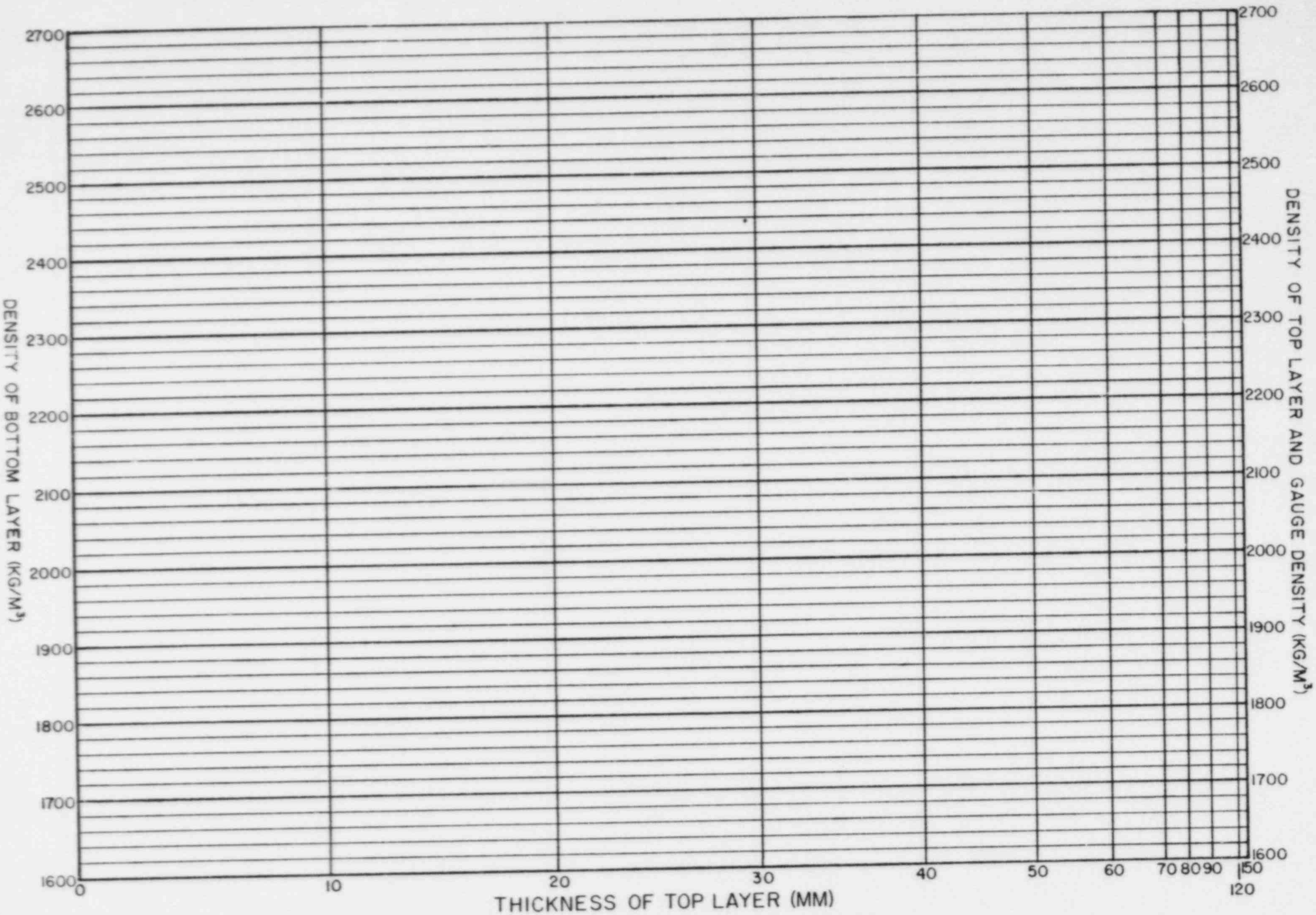
Signature of the Shipper (see WARNING above): Ruth Scarborough

Air Waybill No.*	Airport of Departure*	Airport of Destination*

*This box is optional for completion by issuing carrier. Form 30-087 Printed and Sold by Unz & Co., Division of Scott Printing Corp., 190 Baldwin Ave., Jersey City, N.J. 07306 — N.J. (201) 795-5400/N.Y. (212) 344-2270 Toll Free (800) 631-3098

Sample of
Shipper's Certifications
Figure 14-1

APPENDIX



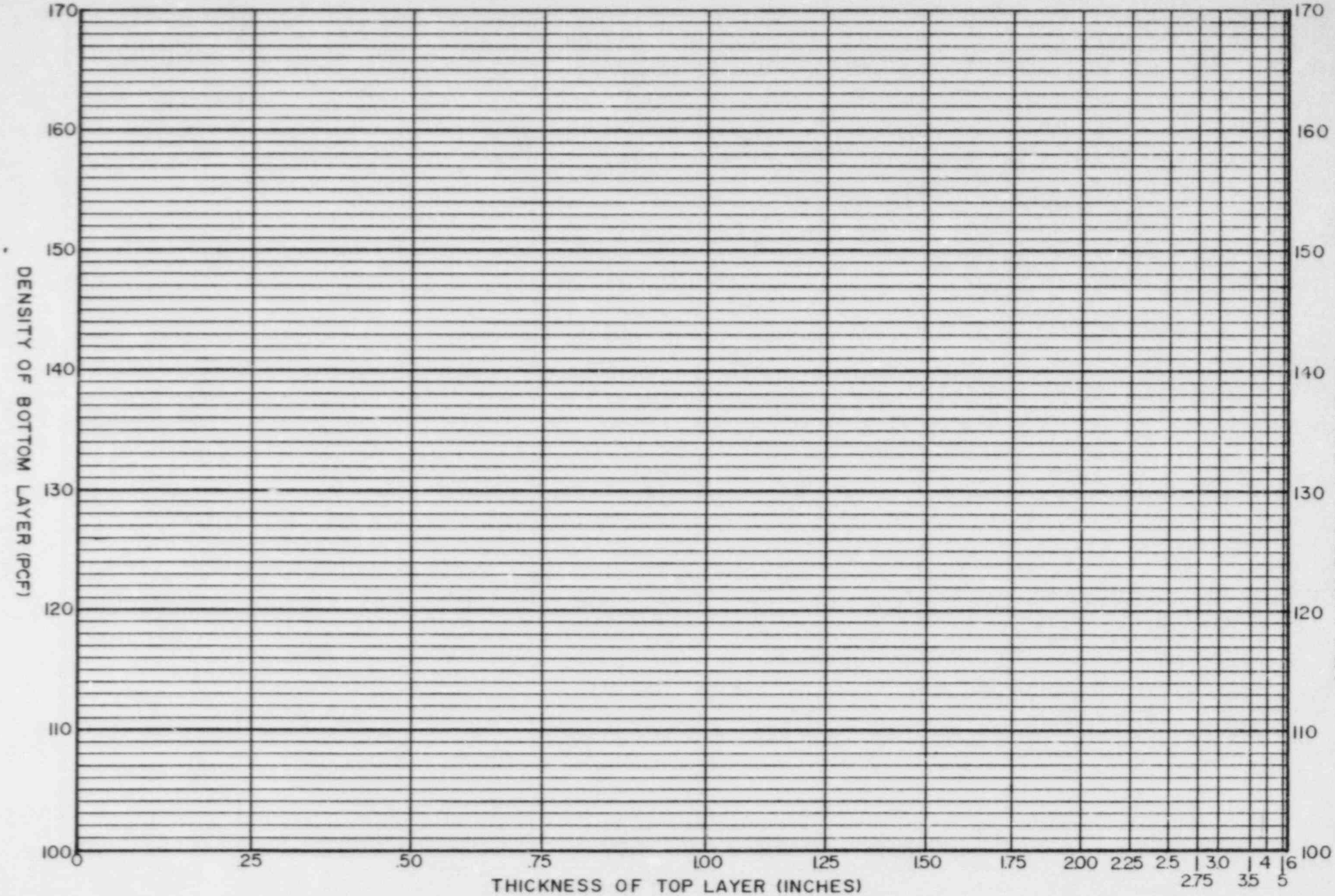
THIN LIFT OVERLAY NOMOGRAPH

(SI UNITS)

AI

TROXLE

TROXLER



THIN LIFT OVERLAY NOMOGRAPH

(U.S. CUSTOMARY UNITS)

A11

Form NRC-3
(6-77)
10 CFR 19
10 CFR 20

UNITED STATES OF AMERICA NUCLEAR REGULATORY COMMISSION
Washington, D.C. 20555

NOTICE TO EMPLOYEES

STANDARDS FOR PROTECTION AGAINST RADIATION (PART 20); NOTICES, INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS (PART 19)

In Part 20 of its Rules and Regulations, the Nuclear Regulatory Commission has established standards for your protection against radiation hazards from radioactive material under license issued by the Nuclear Regulatory Commission. In Part 19 of its Rules and Regulations, the Nuclear Regulatory Commission has established certain provisions for the options of workers engaged in NRC-licensed activities.

YOUR EMPLOYER'S RESPONSIBILITY

Your employer is required to—

1. Apply these NRC regulations and the conditions of his NRC license to all work under the license.
2. Post or otherwise make available to you a copy of the NRC regulations, licenses, and operating procedures which apply to work you are engaged in, and explain their provisions to you.
3. Post Notices of Violation involving radiological working conditions, proposed imposition of civil penalties and orders.

YOUR RESPONSIBILITY AS A WORKER

You should familiarize yourself with those provisions of the NRC regulations, and the operating procedures which apply to the work you are engaged in. You should observe their provisions for your own protection and protectio.. of your co-workers.

WHAT IS COVERED BY THESE NRC REGULATIONS

1. Limits on exposure to radiation and radioactive material in restricted and unrestricted areas;
2. Measures to be taken after accidental exposure;
3. Personnel monitoring, surveys and equipment;
4. Caution signs, labels, and safety interlock equipment;
5. Exposure records and reports;
6. Options for workers regarding NRC inspections; and
7. Related matters.

REPORTS ON YOUR RADIATION EXPOSURE HISTORY

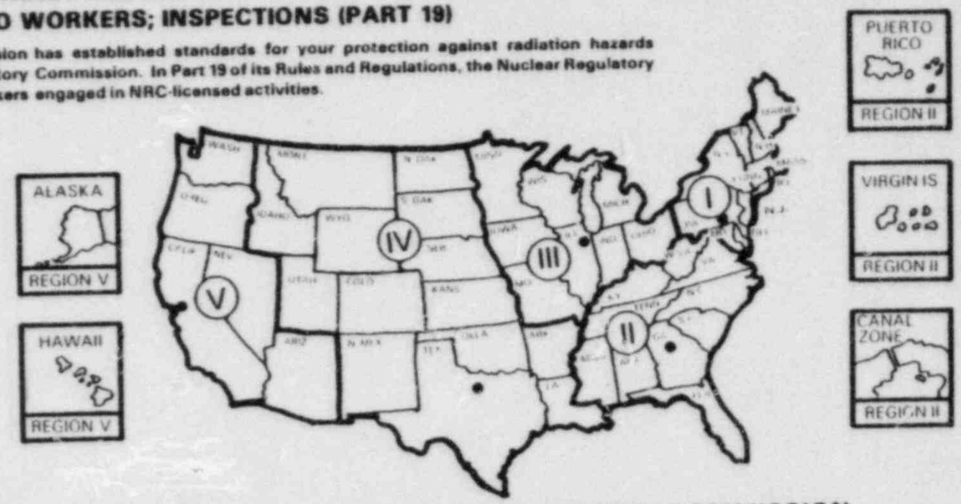
1. The NRC regulations require that your employer give you a written report if you receive an exposure in excess of any applicable limit as set forth in the regulations or in the license. The basic limits for exposure to employees are set forth in Sections 20.101, 20.103, and 20.104 of the Part 20 regulations. These Sections specify limits on exposure to radiation and exposure to concentrations of radioactive material in air.
2. If you work where personnel monitoring is required pursuant to Section 20.202:
   (a) your employer must give you a written report of your radiation exposures upon the termination of your employment, if you request it, and
   (b) your employer must advise you annually of your exposure to radiation, if you request it.

INSPECTIONS

All activities under the license are s... ...e inspection by representatives of the NRC. In addition, any worker or representative of workers who believes that there is a violation of the Atomic Energy Act of 1954, the regulations issued thereunder, or the terms of the employer's license with regard to radiological working conditions in which the worker is engaged, may request an inspection by sending a notice of the alleged violation to the appropriate United States Nuclear Regulatory Commission Inspection and Enforcement Regional Office (shown on map at right). The request must set forth the specific grounds for the notice, and must be signed by the worker or the representative of the workers. During inspections, NRC inspectors may confer privately with workers, and any worker may bring to the attention of the inspectors any past or present condition which he believes contributed to or caused any violation as described above.

POSTING REQUIREMENTS

Copies of this notice must be posted in a sufficient number of places in every establishment where activities licensed by the NRC are conducted, to permit employees working in or frequenting any portion of a restricted area to observe a copy on the way to or from their place of employment.

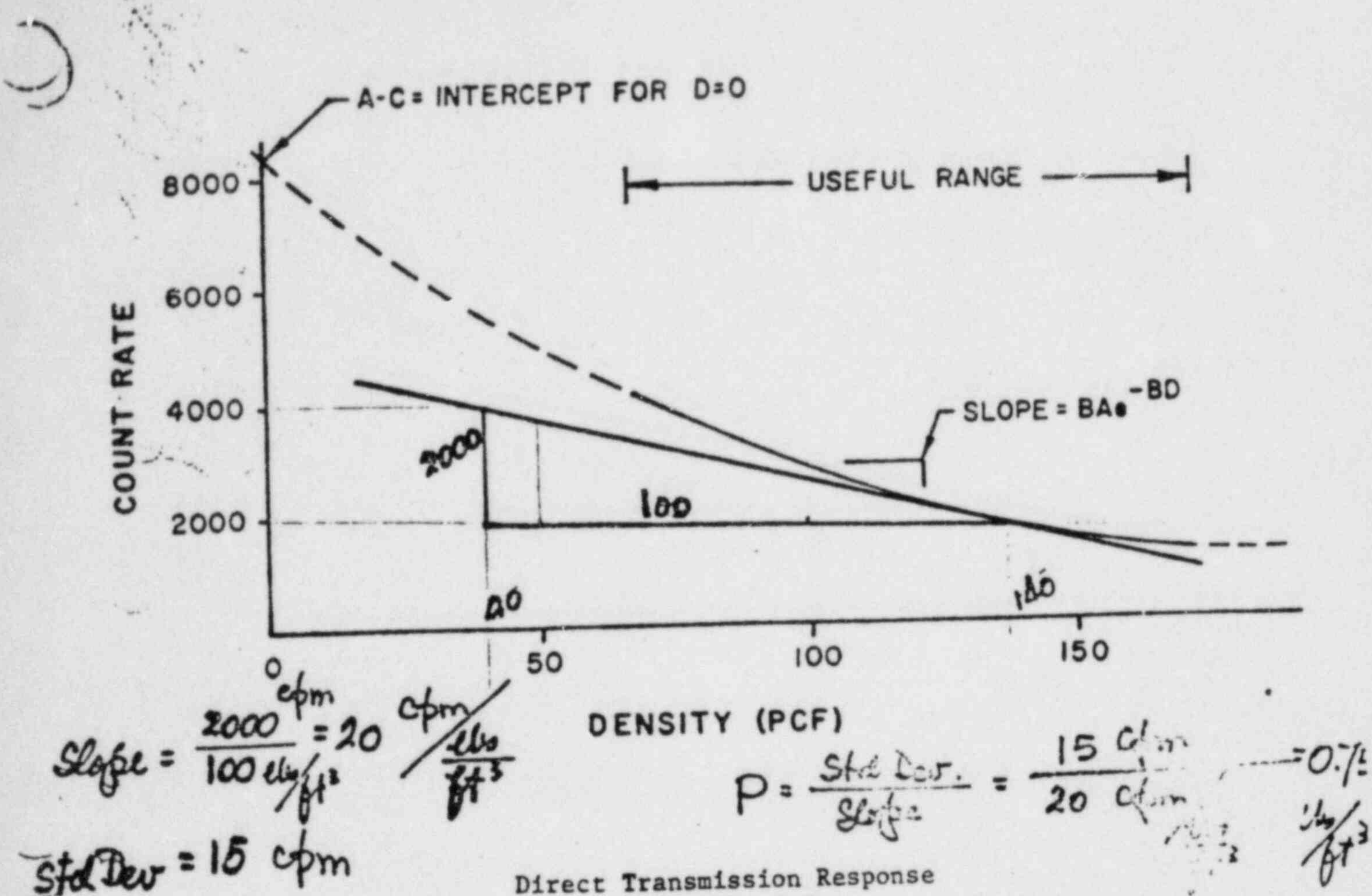


UNITED STATES NUCLEAR REGULATORY COMMISSION

A representative of the Nuclear Regulatory Commission can be contacted at the following addresses and telephone numbers. The Regional Office will accept collect telephone calls from employees who wish to register complaints or concerns about radiological working conditions or other matters regarding compliance with Commission rules and regulations.

Regional Offices

REGION	ADDRESS	TELEPHONE DAYTIME	TELEPHONE NIGHTS AND HOLIDAYS
I	Region I, Office of Inspection and Enforcement, USNRC 631 Park Avenue King of Prussia, Pennsylvania 19406	215 337-1150	215 337-1150
II	Region II, Office of Inspection and Enforcement, USNRC 230 Peachtree Street, N.W., Suite 1217 Atlanta, Georgia 30303	404 221-4503	404 221-4503
III	Region III, Office of Inspection and Enforcement, USNRC 799 Roosevelt Road Glen Ellyn, Illinois 60137	312 858-2660	312 858-2660
IV	Region IV, Office of Inspection and Enforcement, USNRC 611 Ryan Plaza Drive, Suite 1000 Arlington, Texas 76012	817 334-2841	817 334-2841
V	Region V, Office of Inspection and Enforcement, USNRC 1990 N. California Boulevard, Suite 202, Walnut Creek Plaza Walnut Creek, California 94596	415 486-3141	415 486-3141



Direct Transmission Response
Figure 3-3

Since all of the photons which have passed through the material under test have been scattered at least once, the average energy at the detectors is lower than the average energy under direct transmission conditions. For this reason, the error due to chemical composition is significantly larger.

Figure 3-5 illustrates a typical backscatter relationship between count rate and density. At zero or very low density, the number of photons arriving at the detectors is very low and represents those which pass through the gauge shielding. As the material density increases, the number of scattered photons reaching the detectors increases until an equilibrium is reached where the rate of initial scatter photons reaching the detectors is equal to the mass attenuation rate. At densities above this point, the count rate at the detectors decreases with increasing density and follows the standard attenuation equation throughout the usable density range.

Since the standard equation is valid for the range of densities involved, it is usable even though it does not follow the response over the low density area.

APPENDIX B
2400 SERIES MANUAL

2400 Series
COMPAC

Surface Moisture-Density Gauge

TROXLER ELECTRONIC LABORATORIES, INC.
Hwy. 70W, P.O. Box 5997
Raleigh, North Carolina 27607 USA

TABLE OF CONTENTS

ILLUSTRATION LIST

I. INTRODUCTION

This instrument is specifically designed to measure the density and moisture content of soils and soil-stone aggregates. It may also be used to measure the density of hot asphalt while the mix is being compacted.

All electronic components are either integrated circuit packages or discrete solid-state devices. Conservative design, using high reliability components, insures minimal maintenance under environmental conditions associated with the construction industry.

The system is housed in a stress-relieved 356 aluminum alloy casting and will withstand a considerable amount of abuse in field usage. All openings are gasketed for protection against dust and moisture.

The radioactive isotope is triple sealed in 304 stainless steel, and is virtually indestructible. The source is automatically retracted into an integrally cast lead shield when not in use and radiation levels are well below those recommended by the Atomic Energy Commission for radiographic devices.

This manual is intended to co. r the entire 2400 Series of gauges. There are, however, some variances in the equipment. The 2451 and 2452 contain only one detector of each type. Users of this equipment should ·sregard any references to multiple detectors in the manual.

Also, in the 2451 and 2452, the density data is only divided by 10. This is accomplished by omitting the divide by 10 network on the Input and Clock Board. Therefore, in any statistical calculations for these two gauges, the 2451 and 2452, the density data should only be multiplied by 10.

Other values (DC voltages, power consumptions, etc.) are the same for the gauges in this series. The only difference is a slight increase in the values of precision stated on pages 3 and 4 of the manual. The values printed are for the 2401 and 2402.

Before attempting to use the instrument, the operator should read this manual thoroughly. Particular interest should be taken in the section on field measurements. The section on Radiological Safety covers the basic requirements and precautions to be observed and is considered to be required knowledge by many State Public Health Departments and the Atomic Energy Commission.

II. DESCRIPTION

A. MEASUREMENT SPECIFICATIONS

	RA:BE	Cs/AM:BE
BACKSCATTER DENSITY		
Precision at 120 PCF	±0.65 PCF	±0.60 PCF
Composition error at 120 PCF	±2.00 PCF	±1.50 PCF

Calibration error	±0.50 PCF	±0.50 PCF
Surface error (.050" 100% void)	-8.00 PCF	-8.00 PCF
Depth of measurement	2-3 inches	2-3 inches
Range of calibration	70-170 PCF	70-170 PCF
AIR GAP/BACKSCATTER DENSITY		
Precision at 120 PCF	±0.75 PCF	±0.70 PCF
Composition error at 120 PCF	±0.75 PCF	±0.60 PCF
Calibration error	±0.50 PCF	±0.50 PCF
Surface error (.050" 100% void)	-8.00 PCF	-8.00 PCF
Depth of measurement	2-3 inches	2-3 inches
Range of calibration	70-170 PCF	70-170 PCF
DIRECT TRANSMISSION DENSITY (6" DEPTH)		
Precision at 120 PCF	±0.30 PCF	±0.25 PCF
Composition error at 120 PCF	±0.50 PCF	±0.40 PCF
Calibration error	±0.50 PCF	±0.50 PCF
Surface error (.050" 100% void)	-0.50 PCF	-0.50 PCF
Depth of measurement	2-8 inches	2-8 inches
Range of calibration	70-170 PCF	70-170 PCF
MOISTURE CONTENT		
Precision at 15 PCF	±0.35 PCF	±0.25 PCF
Surface error (.050" 100% void)	-0.50 PCF	-0.50 PCF
Depth of measurement at 15 PCF	5 inches	5 inches
Range of calibration	0-40 PCF	0.40 PCF

B. CONTROL FUNCTIONS

POWER - This is a three position switch with OFF, STDBY and ON positions. The switch is normally placed in the STDBY position twenty to thirty minutes before use and between measurements. In the STDBY position, the power consumption is less than one-half the ON power yet all critical circuits including the detector high voltage supplies remain on.

TIME - This rotary switch controls the counting period. The .25, .5, 1 or 2 minute positions may be used for field measurements; however, the 1 minute position is normally used. The CALIB position switches several internal functions to allow the instrument to automatically take four one-minute counts, sum, divide by four and display the mean one-minute count rate. The STOP and COUNT positions may be used for controlled scaling with a watch in the event of a timer failure, for long scaling periods, and for troubleshooting the instrument.

FUNCTION - The three position switch selects the proper logic for MOISTURE or DENSITY measurements. The center or TEST position scales the internal clock and checks the time base division and accumulators. The readout will indicate counts of 819, 1638, 3276, 6553 and 3276 for the .25, .5, 1, 2 and CALIB periods respectively.

START - This pushbutton switch resets the accumulator and starts a new counting period for a time dependent on the TIME switch setting.

SUM - This pushbutton switch starts a new counting period without resetting the accumulator. The counting period is dependent on the TIME switch setting, and the new count is added to the count previously stored in the accumulator.

READ - Under normal conditions the digital indicators are not illuminated in order to conserve power. This pushbutton applies voltage to the indicators and may be pressed at any time without affecting the accumulator operation or data storage. The power consumption is very high so use should be limited to short read periods.

GATE INDICATOR - The flag to the lower left of the display area is an indicator which turns red during the counting period and white when the counting period has ended.

BATTERY INDICATOR - The small meter to the lower right of the display area indicates the charge state of the batteries. The gauge may be used as long as the meter deflects into the white area. At the division of the red-white area, only a few minutes of operation remains. If the gauge is used when the meter is deflected into the red area, internal circuits will automatically shut the system down to prevent damage to the batteries.

DISPLAY - The instrument contains a four decade in-line display. MOISTURE data is divided by 10 before display and DENSITY data is divided by 100. The additional digits are not used in normal operation, and a decimal point may be considered to exist to the right of the last digit.

SOURCE INDEX HANDLE - The lifting handle also controls the source position and automatically positions the source in the shield when lifted. All standard count data is taken with the handle latched in the top or stored position. <u>Always insure that the gauge lock is removed before taking any standard counts</u>. Pressing the trigger forward on both sides releases the source rod and allows the source to be positioned by detents in the index rod (See Figure 1). The first detent below the safe position is used for backscatter density, air gap density, and moisture determinations. The remaining detents are used for direct transmission density measurements, and the depth is marked on the index rod. The standard model of the 2401 and 2451 have detents in two inch increments, from 2 to 8 inches. The 2402 and 2452 have no direct transmission positions.

CHARGER CONNECTOR - A connector is located on the right side of the gauge in which the charger cable is plugged. When connected to 115 VAC, the batteries may be charged in an eight hour period. Excessive charging will not cause destructive failure, but does shorten the life of the battery system. The charger may be operated on 220 VAC with an optional power cable.

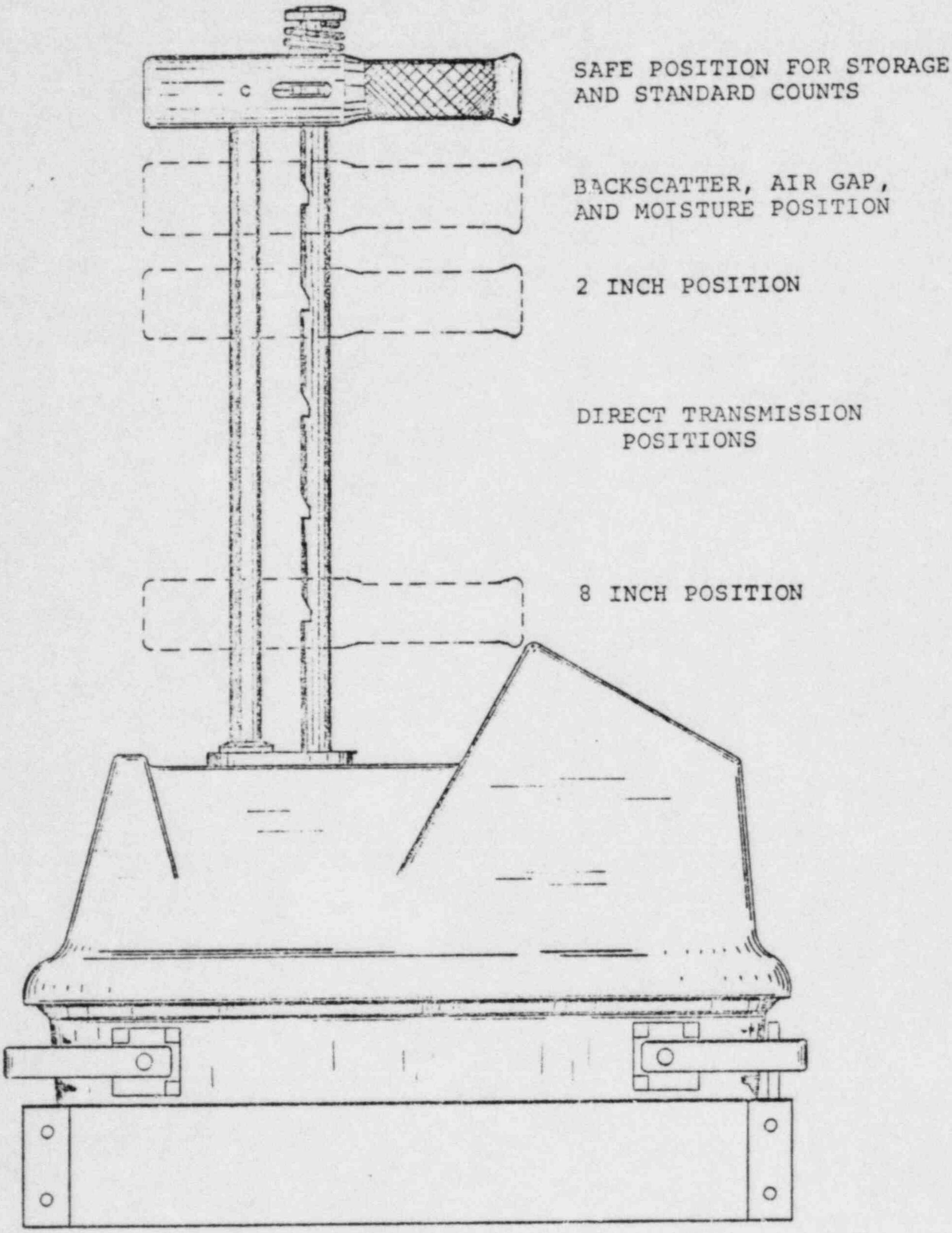


FIGURE 1

INDEX ROD POSITIONS

III. DENSITY MEASUREMENTS

The instrument utilizes Compton scattering and photoelectric absorption of gamma photons to measure the total or wet density of materials being tested. The dry density may be determined by subtracting the moisture content from the wet density.

A. BACKSCATTER DENSITY

The simplest but least accurate method of measuring density involves the so-called backscatter method. To make this measurement, the source and detectors are both on the surface and gamma photons passing into the soil are scattered back to the detectors. At zero density the detected photons are essentially zero and increase with density to a point where the backscattered photons are approximately equal to the losses due to additional scattering and photoelectric absorption (See Figure 2). The quantity of photons detected then becomes an approximate negative exponential function as the count decreases with increasing density.

The backscatter method, while simple to perform, has many possibilities for error. Surface roughness is a problem due to photon streaming through surface voids. A large portion of the initial scatter takes place at a shallow depth (50% in the top one inch) and it is not possible to detect changes of 100 to 150 PCF at depths greater than three inches. Consequently, the measurement is heavily weighted by the surface density which is generally low. An example of the possible error is shown in Figure 4.

Error due to soil composition is caused by photoelectric absorption which is inversely dependent on the mean photon energy and dependent to the fifth power of the mean atomic number of the soil. Composition errors can be two to five times greater than that of other modes of measurement primarily due to the lower mean photon energy caused by the multiple scattering process.

Assuming the same source size and detection system, the statistical precision is worse by a factor of two to one over other available methods.

B. BACKSCATTER/AIR GAP DENSITY

This method provides a means of improving the composition error with a slight decrease in statistical precision.

A peculiarity of the backscatter response is used to provide a measurement which is generally independent of density but contains a variation which is partially dependent on the photoelectric absorption.

As noted in the previous section, there is a density at which the count rate response peaks in terms of density. At this point, small variations in density cause little change in count rate; however, the

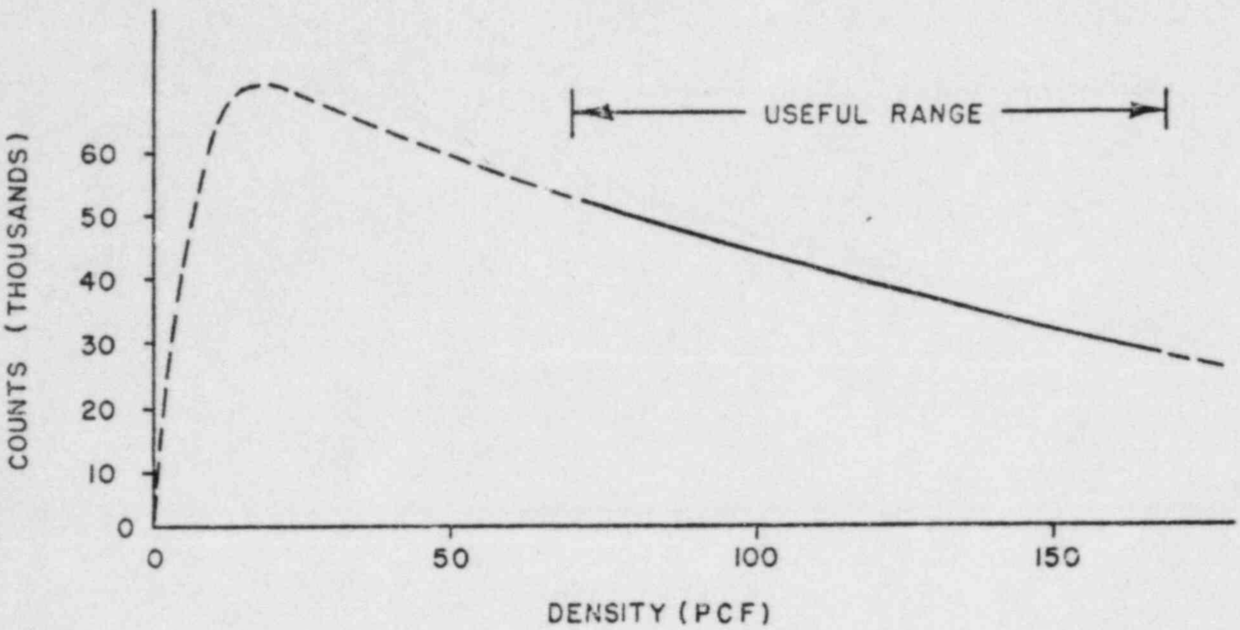


FIG. 2 - BACKSCATTER DENSITY RESPONSE

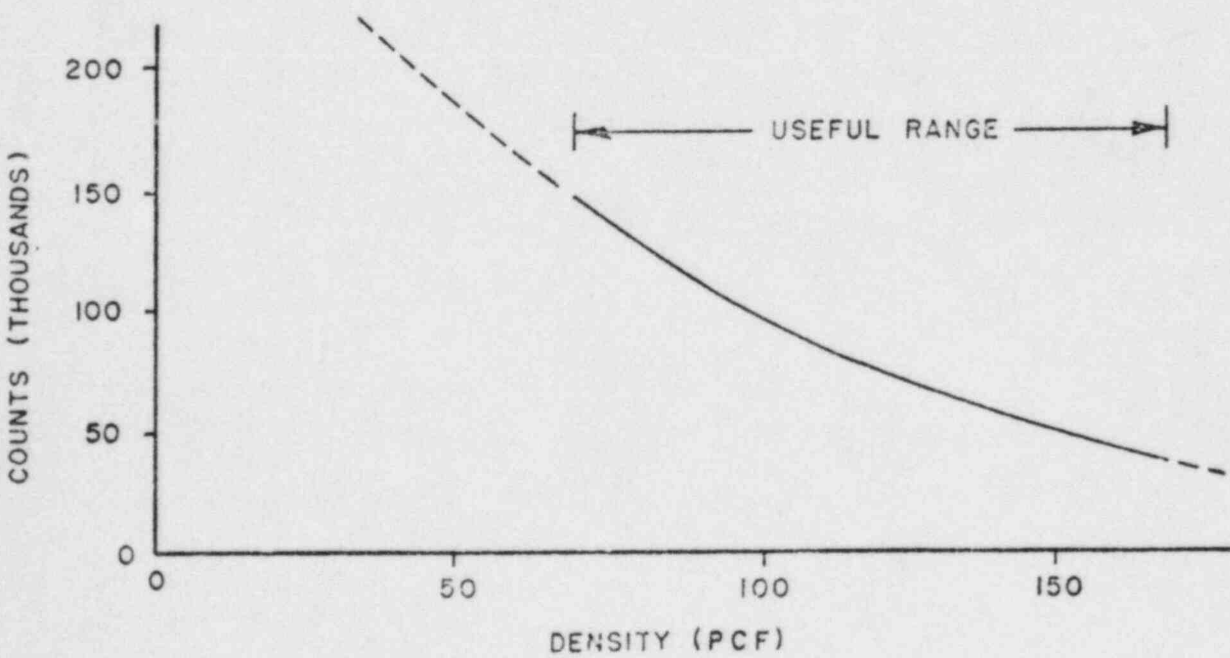
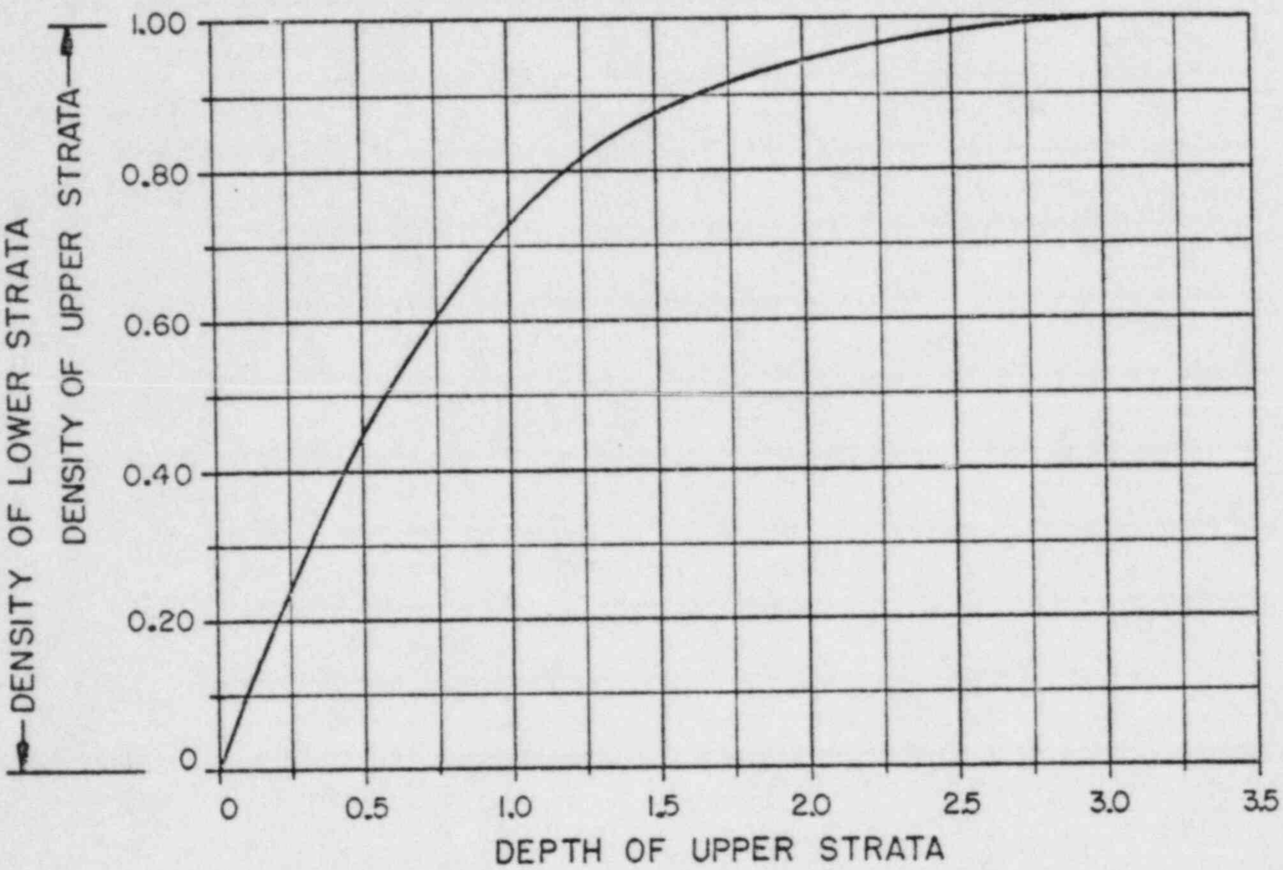


FIG. 3 - DIRECT TRANSMISSION DENSITY RESPONSE



EXAMPLE: If a 0.5 inch of 130 PCF material overlays material of 135 PCF, the gauge response will be .45 of the upper strata and .55 of the lower strata and the measurement will indicate a density of 132.8 PCF. An upper strata thickness of 0.6 inch will cause the gauge to measure half-way between the upper and lower strata density.

BACKSCATTER SURFACE DENSITY EFFECTS

FIGURE 4

photoelectric absorption due to soil composition affects the count rate. This peak response can be simulated by raising the gauge above the soil and effectively averaging the air density and the top portion of the soil to produce the required low density. While the proper height required to produce the effect is dependent on the soil density, the height determined at 120 to 140 PCF is satisfactory for use over the range from 70 to 170 PCF. This height has been determined by the factory for your 2400 Series gauge and a stand has been built into the instrument.

Ratioing the flush or backscatter measurement to the gap measurement partially cancels the composition error. It is worthwhile to note that backscatter gauges with a high initial composition error due to poor design have a higher degree of correction than gauges with an initially low error; however, the resultant error is still much less when the initial error is less. This fact can easily be demonstrated by comparing data made on varying composition standards by two different gauge systems.

Some users and manufacturers of nuclear gauges have implied that the air gap method improves surface roughness error. This implication cannot be demonstrated nor is it technically feasible since the gap measurement is necessarily independent of density or serious degradation of the gauge precision will result.

The choice of utilizing the backscatter/air gap method is left to the operator. The 2400 Series COMPAC generally has a sufficiently low composition error in the normal backscatter method that the additional time required to make the gap measurement is seldom worthwhile.

C. DIRECT TRANSMISSION DENSITY

The most accurate method in terms of precision and composition error involves placing the source at a precise depth in the measured material and the detection system on the surface. In addition, a true average of the vertical density is obtained. The gauge response is approximately a negative exponential relationship with respect to density, (See Figure 3).

Surface roughness errors are virtually eliminated or greatly reduced over the other methods, since the void volume is averaged into the much larger measured volume.

Composition error is small compared to backscatter and less than air gap since the average photon energy is much higher yielding lower degrees of photoelectric absorption.

The statistical precision is better by a factor of two to one over backscatter due to initially higher photon yield and higher scattering losses per unit density.

A further advantage of the direct transmission method with the source in the soil or other material is the accurately-defined depth of measurement. By making density measurements at various depths a profile of density may be approximated by calculation.

IV. MOISTURE MEASUREMENTS

The nuclear gauge measures the moisture content of materials by thermalization of fast neutrons by the hydrogen content of the water. Fast neutrons having a mass of slightly more than one atomic mass unit (amu) are rapidly slowed by elastic scattering from collisions with hydrogen atoms which have almost the same mass. Other materials with higher atomic weight cause lesser degrees of thermalization or slowing down. The quantity of thermal neutrons is linear over the normally encountered range of moisture content.

Four possible sources of error exist in nuclear moisture measurements. While not normally encountered in construction materials, organic matter (containing hydrogen) or other low atomic weight materials may cause small errors in measurement.

Elastic or inelastic scattering by heavy elements in the compacted materials cause an error which is dependent on the bulk density of the material. This error is small in a properly designed gauge over the density range of 110 to 140 PCF; however, larger errors which may require correction may be encountered on higher or lower density materials.

Water bound in crystalline form in materials such as gypsum is not evaporated by low temperature drying; however, the nuclear gauge detects this water and includes it in the total measurement.

Materials containing iron or iron oxides and rarely encountered elements, such as boron or cadmium, have a high capture cross section for thermal neutrons and thus cause the gauge to read lower than the actual water content.

Surface voids, or surface conditions such as material with higher or lower than average moisture content cause errors but can be eliminated by surface preparation in field use.

Since wide errors can exist due to soil composition, it is advisable to check and correct the calibration data as covered later in other parts of this manual.

V. FACTORY CALIBRATION

This gauge has been calibrated against carefully established working standards. Three sets of standards are maintained and periodically checked against each other and against weight and water displacement methods. Certified 0.1% scales are used and cross checking insures a basic accuracy to 0.2% or better.

A. DENSITY CALIBRATION

Five basic density standards, 12 x 14 x 24 inches are used for the density calibration. These standards and approximate densities are magnesium - 110.5, magnesium/aluminum laminate - 139.1, limestone - 145.6, granite - 164.6, and aluminum - 168.6 (PCF).

Several values regarding the measurement characteristics of the gauge are printed on the second sheet of each calibration. A typical set of constants is shown in Figure 5A. Values for A, B, and C are the calculated constants for the particular gauge function. The values for Y are a check of the program accuracy. The value for BEND is the degree of deviation from a pure exponential function. A portion of a typical gauge calibration is shown in Figure 5B.

The value for composition error is the maximum error to be expected for materials with a mean atomic number ranging between that for granite and limestone. Since the calculated value is the difference between two numbers involving statistical variations, the actual value printed has a standard deviation equal to that of the gauge precision.

The value for the gauge precision (Standard Deviation) is computed at 120 PCF and assumes normal radiation statistics (square root of the mean count rate) and is based on the slope of the calibration response in counts-per-minute per PCF. Refer to Section XII Radiation Statistics.

In order to check the gauge stability, twenty one-minute counts are made before and after calibration and the RMS deviation is compared to the normal radiation deviation.

Data taken from the metallic standards which have a low photo-electric absorption are used in a computer program to solve for the basic gauge response function

$$\text{COUNT RATIO} = A \times \text{EXP}(-B \times \text{DENSITY}) - C$$

where A, B and C are constants. The exponent constant B is discarded since it does not apply to soils and two additional values for B are established using the data from the limestone and granite standards. The arithmetic average of the mineral values of B is used with the metallic values of A, C and the density standard count to compute a table of count ratios and densities between 70 and 170 PCF in 0.5 PCF increments.

The density standard count is a reference measurement taken under standard repeatable conditions, and is used as a ratio to the actual measurement count in order to cancel long term drift of the equipment

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CALIBRATION CONSTANTS

VALUES FOR COMPOSITION ERROR AND PRECISION CALCULATED AT 120 PCF

FIRST LINE AT EACH DEPTH FOR NORMAL- SECOND LINE FOR AIR GAP

DEPTH	A	B	C	Y	BEND	COMP.ERR.	PREC.
0.	4.61361	0.007600	0.35435	139.60	0.72	0.99	0.52
0.	1.63619	0.010850	-0.03985	139.60	-0.37	0.21	0.60
2.	14.24970	0.007609	1.99217	139.60	1.75	0.88	0.27
2.	4.91294	0.010189	0.24098	139.60	0.90	0.29	0.38
4.	15.53472	0.010956	1.01255	139.60	1.59	0.80	0.23
4.	5.63883	0.013076	0.15172	139.60	0.90	0.32	0.32
6.	16.09697	0.015529	0.37010	139.60	1.29	0.83	0.22
6.	5.94528	0.017270	0.06017	139.60	0.74	0.43	0.28
8.	17.79452	0.021641	0.07428	139.60	0.56	0.63	0.23
8.	6.57361	0.023077	0.00709	139.60	0.21	0.30	0.27

FIGURE 5A

CALIBRATION CONSTANTS

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6.0 INCH DIRECT TRANSMISSION

CR=MEASUREMENT COUNT/STANDARD COUNT

CR	DEN	CR	DEN	CR	DEN	CR	DEN
4.974	71.0	3.254	96.0	2.088	121.0	1.297	146.0
4.932	71.5	3.226	96.5	2.069	121.5	1.284	146.5
4.891	72.0	3.198	97.0	2.050	122.0	1.271	147.0
4.851	72.5	3.171	97.5	2.031	122.5	1.258	147.5
4.810	73.0	3.143	98.0	2.013	123.0	1.246	148.0
4.770	73.5	3.116	98.5	1.994	123.5	1.233	148.5

FIGURE 5B

SAMPLE DENSITY CALIBRATION TABULATION

due to aging. Air gap calibration utilizes the gap count for the ratio instead of the standard count.

All data taken during the calibration process is accumulated in sufficient quantity to insure that the data values have one-half the statistical deviation of the field measurement deviation of the instrument.

B. MOISTURE CALIBRATION

Two working standards are used to establish the moisture calibration. The magnesium density standard is used as a reference for zero moisture since the magnesium simulates field density and has very low thermalization and capture cross section. A standard made from compressed asbestos 24 x 24 x 12 inches simulates a moisture content of approximately 17 PCF. This standard has a moisture content equivalent established from a compacted saturated sand standard. The value has been checked against oven dried samples in the field.

Data taken from these standards are used to compute the constants for:

COUNT = A + B x MOISTURE

The constants A and B and the moisture standard count are used to compute a table of moisture content and count ratio from 0 to 40 PCF in 0.25 PCF increments. The values of A, B and the statistical precision are printed on the calibration sheet. A typical calibration data sheet is shown in Figure 6.

The moisture standard count is established using the same procedure as with the density standard count.

VI. FIELD MEASUREMENTS

A. DAILY STANDARD COUNT

The gauge calibration data has been ratioed to standard moisture and density counts made at the factory on the reference standard supplied with your gauge. New reference counts must be made in the field in order to compensate for component aging and drift within the instrument. By using this technique, the gauge calibration becomes dependent on the gauge mechanical geometry; therefore, it is not necessary to calibrate the system more than once a year, or whenever major repairs are performed. A set of standard counts should be taken at least every day that the gauge is used. It is advisable to take this data twice a day when the gauge is first received in order to detect any shift during daily use.

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A= 223.0 B= 49.0686 PRECISION= 0.199 PCF(STD. DEV.)

MOISTURE CONTENT

MOISTURE STANDARD COUNT- 1303.6
CR=MEASUREMENT COUNT/STANDARD COUNT

CR	PCF	CR	PCF	CR	PCF	CR	PCF
0.180	0.25	0.556	10.25	0.933	20.25	1.309	30.25
0.189	0.50	0.566	10.50	0.942	20.50	1.319	30.50
0.199	0.75	0.575	10.75	0.952	20.75	1.328	30.75
0.209	1.00	0.585	11.00	0.961	21.00	1.337	31.00
0.218	1.25	0.594	11.25	0.970	21.25	1.347	31.25
0.227	1.50	0.603	11.50	0.980	21.50	1.356	31.50
0.236	1.75	0.613	11.75	0.989	21.75	1.366	31.75
0.246	2.00	0.622	12.00	0.999	22.00	1.375	32.00
0.255	2.25	0.632	12.25	1.008	22.25	1.384	32.25
0.265	2.50	0.641	12.50	1.017	22.50	1.394	32.50
0.274	2.75	0.650	12.75	1.027	22.75	1.403	32.75
0.283	3.00	0.660	13.00	1.036	23.00	1.413	33.00
0.293	3.25	0.669	13.25	1.046	23.25	1.422	33.25
0.302	3.50	0.679	13.50	1.055	23.50	1.432	33.50
0.312	3.75	0.688	13.75	1.065	23.75	1.441	33.75
0.321	4.00	0.698	14.00	1.074	24.00	1.450	34.00
0.331	4.25	0.707	14.25	1.083	24.25	1.460	34.25
0.340	4.50	0.716	14.50	1.093	24.50	1.469	34.50
0.349	4.75	0.726	14.75	1.102	24.75	1.479	34.75
0.359	5.00	0.735	15.00	1.112	25.00	1.488	35.00
0.369	5.25	0.745	15.25	1.121	25.25	1.497	35.25
0.378	5.50	0.754	15.50	1.130	25.50	1.507	35.50
0.387	5.75	0.763	15.75	1.140	25.75	1.516	35.75
0.396	6.00	0.773	16.00	1.149	26.00	1.526	36.00
0.406	6.25	0.782	16.25	1.159	26.25	1.535	36.25
0.415	6.50	0.792	16.50	1.168	26.50	1.544	36.50
0.425	6.75	0.801	16.75	1.177	26.75	1.554	36.75
0.434	7.00	0.810	17.00	1.187	27.00	1.563	37.00
0.443	7.25	0.820	17.25	1.196	27.25	1.573	37.25
0.453	7.50	0.829	17.50	1.206	27.50	1.582	37.50
0.462	7.75	0.839	17.75	1.215	27.75	1.592	37.75
0.472	8.00	0.849	18.00	1.225	28.00	1.601	38.00
0.481	8.25	0.859	18.25	1.234	28.25	1.610	38.25
0.491	8.50	0.867	18.50	1.243	28.50	1.620	38.50
0.500	8.75	0.876	18.75	1.253	28.75	1.629	38.75
0.509	9.00	0.886	19.00	1.262	29.00	1.639	39.00
0.519	9.25	0.895	19.25	1.272	29.25	1.649	39.25
0.528	9.50	0.905	19.50	1.281	29.50	1.657	39.50
0.538	9.75	0.914	19.75	1.290	29.75	1.667	39.75
0.547	10.00	0.923	20.00	1.300	30.00	1.676	40.00

FIGURE 6

MOISTURE CALIBRATION DATA SHEET

Place the Reference Standard on compacted soil, asphalt or concrete paving at least 10 feet from any large object and at least 30 feet from another gauge. The gauge is seated into the recessed area of the standard with the scaler end pulled against the butt plate on the Reference Standard (See Figure 1). The source index handle should be placed in the safe or stored position (the top notch on the index rod). Always insure that the gauge lock is removed before taking any standard counts. Place the POWER switch in STANDBY and the TIME switch to CALIB. Wait approximately 15 minutes for all critical circuits to stabilize.

After the stabilization period, place the POWER switch to ON and the function switch to MOISTURE. Press the START Pushbutton and note that the GATE INDICATOR flag deflects to a red condition. At the end of four minutes, the GATE INDICATOR flag will return to a white condition. Depress the READ pushbutton and record the data as moisture standard count. The true count is 10 times the indicated value; however, only the actual reading need by recorded.

Place the function switch to DENSITY and repeat the above steps. Record this value as the density standard count. The true count is 100 times the indicated value. Return the POWER switch to STANDBY.

If the day-to-day shift in standard count is greater than 2% for moisture, or 1% for density, there is a possibility of a gauge malfunction or operator error in placing the gauge on the standard. Since the radiation statistics may on occasion cause this degree of shift, a second attempt to acquire usable standard counts is permissible. If, over a long period of time (several months), the accumulative shift in standard count exceeds 6% for moisture or 3% for density, the gauge calibration should be checked. For this reason, a log should be kept of the gauge standard counts. The initial standard counts will normally be less than the factory standard counts due to the higher background radiation levels in the factory.

If repetitive readings vary greater than normal radiation statistics or if sudden large variations in data are encountered, refer to the section of the manual on troubleshooting hints.

B. SITE PREPARATION

Any random method of site selection may be used. In any case, the actual spot on which the gauge is to be placed should be representative of the area to be tested. If the test does not immediately follow compaction, the top surface should be removed with a grader blade or other method in order to prevent errors due to dry surface material.

Using the scraper plate supplied with the gauge, scrape and lightly tamp an area equal to the bottom of the gauge. All loose stone

should be removed and small voids filled with native fines or sand. The gauge should sit solidly on the site without rocking.

Moisture and/or backscatter density measurements should be made prior to punching the access hole for direct transmission measurements. In the event these measurements must be made after punching the access hole, slide the gauge at least 3 inches towards the scaler end in order to move the source off of the hole.

Using the drill rod guide (scraper plate), drill rod and a four or six pound hammer, punch a hole into the material at least two inches deeper than the direct transmission depth to be used. Place one foot on the rod guide while driving the rod into the material. Remove the rod by pulling straight up in order to avoid disturbing the access hole. In heavy clay, it may be necessary to lightly tap the rod to loosen it or use an optional rod jack for removal.

C. MOISTURE MEASUREMENTS

Place the gauge on the prepared site, place the POWER switch to ON, function switch to MOISTURE, and the TIME switch to 1. Place the index handle in the backscatter notch (the first position below the safe position) and press the START pushbutton. After the GATE INDICATOR returns to white, press the READ pushbutton and record the value as the moisture count. Using a slide rule, divide the moisture count by the moisture standard count recorded under paragraph A above and record the value as the moisture count ratio. Using this ratio, refer to the moisture calibration table and record the moisture value to the nearest 0.25 PCF. Interpolation may be used to obtain a closer reading; however, it will have little significance.

D. BACKSCATTER DENSITY MEASUREMENTS

With the gauge on the site as covered in paragraph C above, place the function switch in the DENSITY position, press START and record the reading as the backscatter density count. Determine and record the ratio of the backscatter density count to the density standard count. Refer to the backscatter density calibration data and record the density to the nearest 0.5 PCF. Interpolation may be used to obtain a closer reading.

E. AIR GAP DENSITY MEASUREMENTS

After taking the backscatter density count as in paragraph D above, tilt the gauge up on each end, and position the air gap legs by pulling out from the gauge, tilting the leg down and pushing the leg into the detent. With both legs down, the gauge will sit approximately 1-5/8" off of the material.

Take and record a reading as the air gap count. Divide the backscatter count by the air gap count and record as the air gap ratio. Note that no standard count is used, the air gap count replaces the

density standard count for this measurement. The air gap ratio is then used along with the air gap calibration data to obtain the air gap density.

F. DIRECT TRANSMISSION DENSITY MEASUREMENTS

Place the gauge over the access hole and push the index handle down until the source has reached the desired depth. On a standard gauge, this may be accomplished by counting 2 inches for each detent below the backscatter position. Depth markings are stamped into the index rod just above the notch. If one has difficulty positioning the gauge over the access hole, it may be tilted slightly to one side with the source pushed through the bottom for correct location. With a little experience, the operator will be able to correctly locate the gauge over the access hole.

With the source at the desired depth, take and record a density count. Obtain the ratio to the standard count and use the correct data table to obtain the density.

G. DRY DENSITY AND PERCENT MOISTURE DETERMINATION

The gauge densities obtained above are wet densities. The dry density necessary for compaction control is obtained by subtracting the moisture content in PCF from the wet density. The percent moisture is then obtained by dividing the moisture content in PCF by the dry density and multiplying by 100.

DRY DENSITY = WET DENSITY - MOISTURE CONTENT (PCF)

PERCENT MOISTURE = (MOISTURE CONTENT x 100)/DRY DENSITY

H. ALTERNATE PROCEDURES

Usually all of the count data is obtained for the necessary measurements and the gauge switched back to STANDBY before calculating the data. This method will conserve battery power.

Timing periods other than one minute may be used to speed up operations unless maximum accuracy is desired. Using 1/4 minute periods will double the statistical error stated on each calibration data sheet. The standard count used for calculations with shorter or longer intervals will have to be initially divided by two or four if the 1/2 or 1/4 minute periods are used. The 1/4 minute intervals are very useful when attempting to take a lot of measurements on a hot asphalt test strip.

In the event a large number of measurements have been taken and the user desires to process the data by computer, the following FORTRAN expression may be used to evaluate backscatter and direct transmission densities:

```
DENS = (ALOG((A*DSC2)/(DC*DSC1 + C*DSC2)))/BAV
```

where: DSC1 = Calibration standard count from the gauge data sheets
A,BAV,C = Constants from gauge data sheets
DSC2 = Field standard count taken at the time of the measurements
DC = Field measurement count
DENS = Density in PCF

The moisture data may be processed by:

MOIST = (MC*MSC1 - A*MSC2)/(B*MSC2)

where: MSC1 = Calibration standard count from the gauge data sheets
A,B = Constants from gauge data sheets
MSC2 = Field standard count taken at the time of the measurements
MC = Field measurement count
MOIST = Moisture content in PCF

I. HOT ASPHALT DENSITY

No special precautions are needed when using the gauge on hot asphalt. Either backscatter, air gap or direct transmission density measurements may be made.

The surface temperature of hot asphalt is generally sufficiently low that no excessive temperature rise will be experienced with the equipment. In the event of high air temperatures and high asphalt surface temperature, the gauge should not be left in place unnecessarily long. If the gauge case becomes uncomfortably hot to the bare hand, a longer cooling period between measurements is necessary.

Mineral spirits or other solvents should be used occasionally to clean the bottom surface of the gauge to prevent a build-up of asphalt.

VII. FIELD CALIBRATION (Alteration to Factory Data)

It may become necessary to alter the factory calibration in order to obtain correct results on particular soil types. Several methods are acceptable, but extreme care should be taken.

A. MOISTURE ALTERATIONS

In the event the soils contain hydrogen other than water, mica or chemically bound water, such as gypsum, it is possible to correct the calibration data by subtracting an average error PCF value determined by a series of not less than 10 oven dry samples from the factory data. The oven dry PCF value may be obtained from sand cone density calculations; however, it is more desirable to use the oven

dry percent moisture and the gauge wet density to calculate the moisture content in PCF. The equation is:

$$\text{MOISTURE CONTENT (PCF)} = \frac{\text{PERCENT MOISTURE X WET DENSITY}}{\text{PERCENT MOISTURE + 100}}$$

If the gauge reading is higher than the values obtained by oven dry samples, the error is due to hydrogen containing materials and the correction may be made by subtracting a constant value from the gauge reading.

If the gauge reading is lower than that obtained by oven drying, the error is likely due to materials in the soil which absorb thermal neutrons. In this case, the error is not a constant offset but varies directly with the moisture content. The compensation is made by adding the full error at moisture contents used to obtain the error data and reducing the added value at lower moisture contents. At zero moisture, the error would be zero.

B. BACKSCATTER AND AIR GAP DENSITY ALTERATIONS

If the gauge indicates a density less than that obtained by conventional methods, it usually is due to low surface density where the gauge is most sensitive. It is not advisable to alter the gauge calibration under these conditions since they will vary from site to site with the degree of surface compaction. If it is necessary to use backscatter or air gap methods, it is generally better to allow lower compaction requirements unless it is known that the soils contain high atomic weight elements. In this case, follow the instructions under paragraph C.

C. DIRECT TRANSMISSION DENSITY ALTERATIONS

This gauge has been calibrated for soils with a mean atomic weight between that for granite and limestone. With the exception of backscatter measurements, soils falling in this range will have very little composition error. Very few soils will have a mean atomic weight less than granite and seldom will the gauge indicate densities less than the actual values. In most cases of error, the mean atomic weight will be higher than limestone and the gauge will indicate a high density.

While composition errors reduce with lower densities, it is generally acceptable to assume that the error is constant and establish a correction factor by obtaining the average error of at least 10 conventional tests and applying the correction to all future gauge reading on the particular soil. Portions of the calibration data may be retyped with corrected densities over the range of interest.

D. FACTORY CORRECTIONS FOR FIELD DATA

If the gauge user will forward certain data to the factory, a corrected calibration sheet can be computed to normalize the gauge for the particular soil. A nominal charge will be made to cover the computer time.

For each function desired, i.e.: Moisture, BS Density, AG Density or a particular DT Depth, it is necessary to supply the gauge serial number, standard count, measurement counts and established values for the density or moisture content for each set of count data.

VIII. POWER PACK RECHARGE

A fully charged power pack will operate the instrument for 16 to 20 hours in the ON power condition or 30 to 40 hours in the STDBY position. Careful use of the ON condition and short read cycles will enable the operator to take and record approximately 300 one minute measurements over a forty hour work week.

When the gauge is in continuous daily use, it is best to utilize daily short recharge cycles of about 2 hours in order to insure a safety margin of operational power. If the gauge is used continuously in the ON condition each day, a daily recharge cycle of 4 to 5 hours will be necessary to maintain the charge.

Overcharge will not cause immediate damage to the power pack but repeated overcharge will ultimately reduce the available stored power. It is never necessary to charge the pack for more than 8 to 10 hours in a single cycle.

When the batteries are below a full charge, nearly all of the charger power is converted to chemical changes in the cells. After the pack is fully charged, the power is converted to heat. At any time the top of the case over the power pack is warm to the bare hand, the operator can be certain that the pack is fully charged.

The instrument is normally supplied with a charger cable wired for 115-125 volts, 50-60 Hz. Cables for 230 volt operation are available on request and are normally supplied with the instruments when shipped to areas in which 230 volt, 50 Hz is standard power.

Charging from 12 volt vehicle batteries may be accomplished by using auxiliary DC-AC invertors. An invertor is available from the factory or any standard solid-state invertor, rated for 100 watt continuous duty may be used. Units which connect through cigarette lighter attachments are not considered satisfactory due to operational time limits. Normal usage of this equipment will not require on-the-road recharging, since daily access to 120 volt, 60 Hz power will guarantee 16 hours of daily use.

IX. PERIODIC MAINTENANCE

This instrument has been designed for rugged field use and will withstand considerable abuse. Relatively simple precautions and maintenance will greatly reduce damage, and extend the time between major repairs.

1. Routine cleaning of the gauge exterior with compressed air and a damp cloth will help maintain the appearance and finish.

2. Monthly, or more often if extensively used in sand or sticky soils, the pocket under the bottom access plate of the gauge should be cleaned. If any binding is noticed during the operation of the source index handle, it indicates that soil has accumulated in this pocket. To minimize radiation exposure, the following procedure for this operation is recommended:

   a. Make sure the source rod handle is in the storage position.

   b. Orient the gauge so that the bottom is facing away from the person performing the work.

   c. Place a mirror in front of the gauge bottom so as to afford an indirect view of the work being performed.

   d. Remove the four retaining screws and lift off the access plate.

   e. Clean the pocket containing the sliding shield and spring with a stiff bruxh and compressed air.

   f. Lubricate the shield using a dry lubricant.

   g. Replace the access plate and put the four retaining screws back in place.

   h. Place the gauge upright, and use a light oil sparingly on the source and index rod.

   Normally, this operation should take approximately 8 to 10 minutes to perform. Normal radiation exposures obtained would be 4 mrem to the whole body and 25 mrem to the hands.

3. When the gauge is used on hot asphalt mix, any accumulation of asphalt on the bottom surface should be removed with a suitable solvent.

4. Even though every opening in the housing is sealed with a gasket, the case breathes with changes in barometric pressure. In areas of high humidity and widely varying temperatures, some moisture may accumulate on the interior of the instrument.

A simple procedure will prevent this build-up of moisture and subsequent damage. During the recharge cycle, remove the scaler module by loosening the four thumb screws in the corners of the module. The heat produced by the charger will dry out the interior of the housing. When replacing the scaler module, the card connector can be easily felt and inserted. This procedure, while difficult at first, is relatively simple after a little practice.

5. During transport in a vehicle, the gauge should be supported and padded to prevent shock damage. The electronics and mechanical parts of the gauge are extremely durable; however, the radiation detectors are fine wire anode devices with glass and ceramic seals, and must be protected from high shock loads.

X. SERVICE

The major portion of the electronics in this system involves complex integrated circuit modules. Most field service can be accomplished by replacement of printed circuit boards and the factory has set up standard exchange rates for defective board assemblies. Due to the complexity of trouble location and replacement, the factory does not recommend field service of the circuit board, except where trained personnel with circuit board experience are involved. An additional service manual is available where complete field service by trained technicians is contemplated.

A. RECOMMENDED EQUIPMENT

1. Multimeter, Triplett Model 630NS or equivalent.
2. Electrostatic voltmeter, 1500 VDC, Singer Model ESD or equivalent.
3. Oscilloscope, Tektronix Model 422 or equivalent.
4. Power Supply, Hewlett Packard Model 6215A or equivalent.
5. Tools:

   Screwdriver, 1/4" Blade
   Screwdriver, #1 Phillips
   Screwdriver, #2 Phillips
   Nut Driver, 3/8"
   Pliers, 4 1/2" Diagonal Cutting
   Pliers, 4 1/2" Chain Nose
   Pliers, 6" Combination
   Wrench, 11/32" Open End
   Wrench, 5/16" Open End
   Wrench, 5/32" Allen Head
   Tuning Wand, General Cement, GC-8276
   Pin Punch, 3/32"
   Hammer, Machinist, 8 oz.
   Soldering Iron, 40 Watt, Chisel Point
   Board Extractor, Troxler A-100454
   Board Extender, (28 Pin) Troxler A-100455
   Board Extender, (6 Pin) Troxler A-100639
   Termination Board, Troxler B-100456
   External Power Cable, Troxler B-100457
   BF-3 Amplifier Termination, Troxler A-100670

B. CHECKOUT PROCEDURE

1. Place the gauge on the reference standard, source in the safe position, and the POWER switch to ON. The physical location should be well away from high density or high hydrogen containing materials and at least 30 feet from other nuclear gauges. The floor under the standard should be concrete or other material of at least 100 PCF density.

2. Set the function switch to TEST and the TIME switch to .25. Press START and the GATE INDICATOR should change to red if it is not already red. When the GATE INDICATOR turns white, press READ and the DISPLAY SHOULD INDICATE 819. The counting period should have been 15 seconds as measured with a watch second hand. If a timing error exists, it will be in error by at least a factor of two-to-one so any standard watch is sufficiently accurate.

3. Repeat 2 above with the TIME switch set on .5, 1 and 2. The DISPLAY shall indicate 1638, 3276 and 6553. The counting period should be 30, 60 and 120 seconds.

4. Set the TIME switch to CALIB and press START. The display shall indicate 3276 and the counting period should be 4 minutes.

5. Set the TIME switch to STOP, the GATE INDICATOR shall be white, press READ and no scaling shall be indicated. Press START and all display units shall indicate zeros. Set the TIME switch to COUNT, the GATE INDICATOR shall be red; press READ and the display units shall be sequentially counting.

6. If the above tests are completed and agree with the requirements, the scaler module is operative and the checkout can proceed. If the conditions are not met, refer to Section X, paragraph C, TROUBLESHOOTING HINTS.

7. Place the FUNCTION switch to DENS and the TIME switch to 1. Press START and after one minute, press READ and record the display reading. Repeat this function until a total of twenty density standard counts have been recorded. Compute the RMS standard deviation (Refer to Section XI, page 34). Using the average of the twenty readings, compute the standard deviation by the square root method. The ratio of the RMS deviation and the square root deviation shall be between 0.8 and 1.25. This procedure tests the short term stability of the density system. If the ratio falls outside of this range, the system is possibly defective.

8. Repeat paragraph 7 above with the FUNCTION switch on MOIST. This procedure tests the short term stability of the moisture system.

9. If either of the above averages differ greatly from the moisture or density standard counts which have been previously used for measurements, there is a possibility of detector failure. This is particularly true if the density count has dropped to 1/3 or 2/3; if the moisture count has dropped to 1/2 or if either of the two are two or more times the normal standard counts. If the counts have decreased by approximately 1/3, 1/2 or 2/3, yet the short term stability requirement has been met, the system may be used for field measurements, but should be taken out of service for repair as soon as possible.

10. After leaving the equipment ON for a period of 4 hours, the average of 10 standard counts (moisture and density), should be taken. If the difference between the original and second set is greater than .5%, (density) or 1% (moisture) of the average of the two sets, the short term drift is excessive. The system may be used by taking and using a new standard count every hour or two but the system should be removed from service for repair as soon as possible.

11. If all the conditions above are met, the system may be continued in service.

C. TROUBLESHOOTING HINTS

This section will serve to assist the owner in locating the source of difficulty in an inoperative gauge. Many gauge failures can be rectified by exchanging printed circuit boards with spares or by obtaining replacements from the factory. Technicians with general electronic knowledge equipped with the instruments and tools listed in paragraph A of this section should be able to effect any repair or adjustment. In general, repairs of the logic circuits in the scaler module should be made at the factory where special test equipment and tools are available.

1. BATTERY INDICATOR does not deflect when the POWER switch is placed to ON or STDBY.

   a. Replace DC fuse.
   b. Recharge/replace battery pack.
   c. Defective battery saver on pre-amp circuit board.

2. Battery will not charge.

   a. Replace AC fuse.
   b. Check AC power source.
   c. Replace battery pack.

3. Battery will not hold charge.

   a. Replace battery pack.

4. With POWER ON, BATTERY INDICATOR deflects to white area but

digital indicators do not light when READ is depressed.

a. Replace Indicator Power Supply.

5. All numbers of the indicators light when READ is depressed.

a. Replace Logic Power Supply.

6. Any single digit fails to light.

a. Replace the Decoder-Indicator Board Assembly.

7. Performing the test procedure listed under paragraph B of this section does not produce the proper sets of numbers.

a. Replace the defective indicator if only one digit of each number set is wrong.

b. Replace the Accumulator Board if more than one digit of each set is wrong.

c. Replace the Time Base Divider if the number set is wrong and the time period is not as set on the Time Switch. The time period will be in error by a factor of two or more.

d. Replace the Input and Clock Board if the number sets are correct but the time period is wrong.

e. Replace the Accumulator Board if the time period is four minutes but the number indicated for the CALIB function is incorrect.

8. Timing periods restart and cycle without pressing the START or SUM pushbuttons.

a. Replace the Time Base Divider Board.

9. GATE INDICATOR deflects to red when START is depressed but indicators do not count.

a. Replace Input and Clock Board.
b. Replace Accumulator Board.
c. Replace Time Base Divider Board.

10. Indicators do not reset when START is depressed.

a. Replace the Time Base Divider Board if all digits fail to reset to zeros.

b. Replace the Accumulator Board if only one or two digits fail to reset to zero.

The following defects are likely if the TEST functions are correct but difficulties are experienced in MOISTURE and DENSITY functions.

11. System fails to count on MOISTURE and DENSITY functions.

    a. Replace H. V. Supply Board.
    b. Replace Input and Clock Board.

12. System fails to count on MOISTURE but DENSITY standard count is normal.

    a. Replace Preamplifier Board.
    b. Replace Input and Clock Board.

13. System fails to count on DENSITY but MOISTURE standard count is normal.

    a. Replace Preamplifier Board.
    b. Replace Input and Clock Board.

14. MOISTURE standard count is normal but DENSITY standard count is erratic and high or reduced to approximately 1/3 or 2/3 of normal.

    a. Replace one or more G. M. Detectors.
    b. Replace Preamplifier Board.

15. DENSITY standard count is normal but MOISTURE standard count is high and erratic or reduced to 1/2 of normal.

    a. Replace one BF-3 Detector.
    b. Replace Preamplifier Board.

16. A series of DENSITY counts do not meet statistical tests.

    a. Replace H. V. Supply.
    b. Replace G. M. Detectors.

17. A series of MOISTURE counts do not meet statistical tests.

    a. Replace H. V. Supply.
    b. Replace BF-3 Detectors.
    c. Replace Preamplifier Board.

18. Day to day abnormal changes or long term drift in the DENSITY standard count.

    a. Replace Input and Clock Board.
    b. Replace H. V. Supply.
    c. Replace one or more G. M. Detectors.
    d. Replace Preamplifier Board.

19. Day to day abnormal changes or long term drift in the MOISTURE standard count.

    a. Replace Input and Clock Board.
    b. Replace H. V. Supply.
    c. Replace Preamplifier Board.
    d. Replace BF-3 Detectors.

D. GAUGE DISASSEMBLY

Several stages of disassembly of the system may be accomplished. The factory does not recommend disassembly beyond the point required for a particular repair.

CAUTION! Before connecting or disconnecting any detectors or the H. V. Supply, the high voltage must be discharged by shorting across the 1400 V corona regulator mounted on the Preamplifier Board Assembly in order to prevent damage to the amplifier.

1. Remove the Scaler Module by releasing the four screws at the corners of the module. The frame may then be withdrawn from the case. Care should be exercised during replacement to insure that the module mates with the connector.

   All Scaler Module adjustments may be made at this point by plugging the Board Extender, Troxler B-100455 into the Preamplifier connector and the scaler module into the extended connector.

   All Preamplifier Board adjustments may be made at this point by plugging the Termination Board, Troxler B-100456 into the Preamplifier Board connector. CAUTION! This turns on all power on the board including the H. V. Supply.

2. If it is necessary to remove the Preamplifier Assembly or Detectors, it is necessary to remove the top shell. Disconnect the A. C. power harness by separating the connector between the top shell and the Battery Pack Assembly. Tilt the gauge on its side and remove the six rim screws using a 5/32" Allen wrench. Return the gauge to the upright position. Slip the top casting up by lightly tapping around the rim. In order to keep the top out of the way, it may be necessary to tie it to the Index Handle using a strong cord. If it is necessary to lift the Battery Pack out of the way such as during the replacement of the H. V. Supply, disconnect the power cable by separating the connector between the Preamplifier Board and the Battery Pack Assembly. The Battery Pack may then be raised out of the way.

3. The H. V. Supply Board may be removed by taking out the two hold down screws using a #2 Phillips screwdriver. The BF-3 Detectors may be removed by taking out the four reflector hold-down screws. Carefully disconnect the BF-3 cable connectors at the preamplifier using the 11/32" and 5/16" open end wrenches to

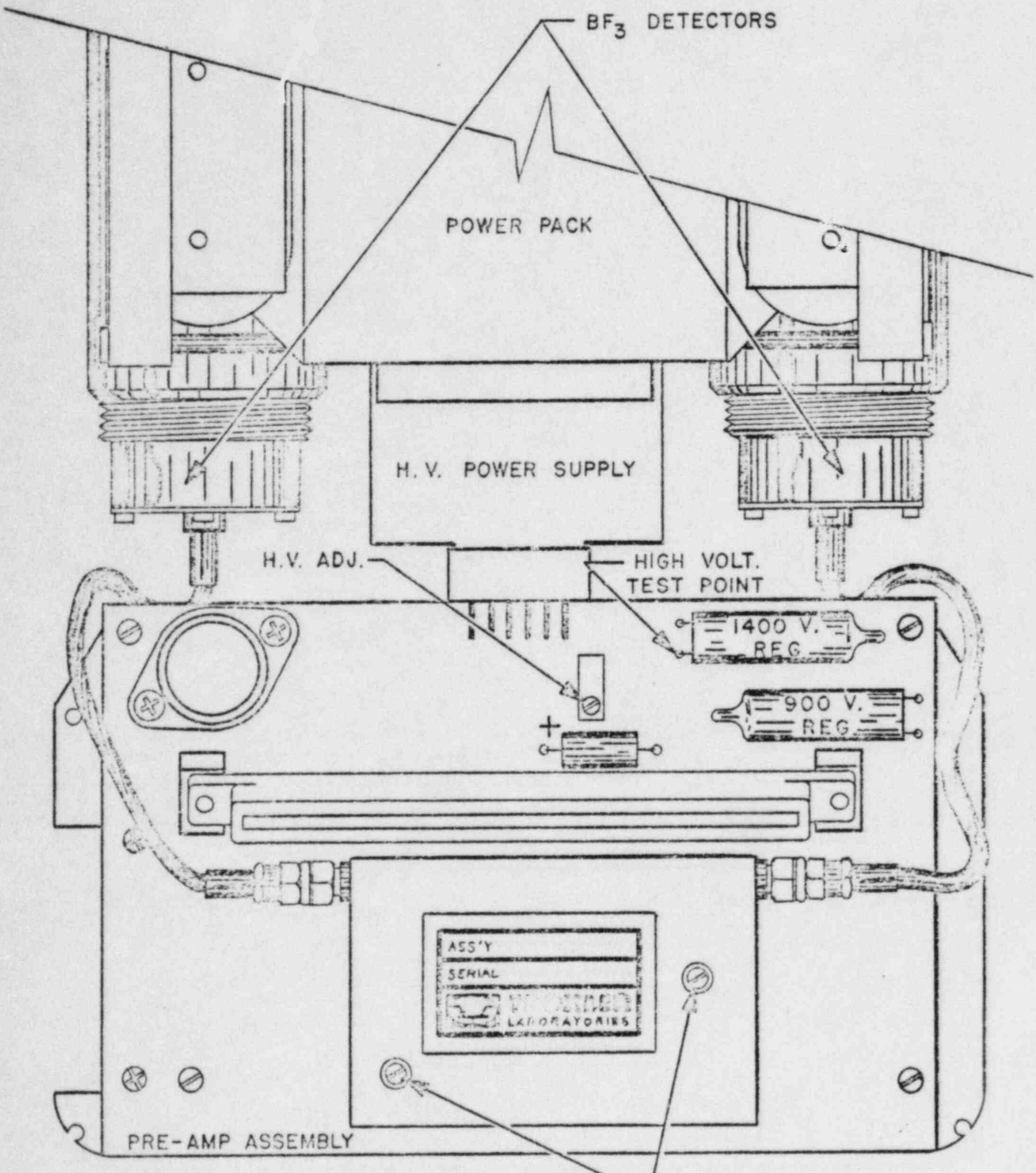


FIGURE 7

GAUGE ASSEMBLY

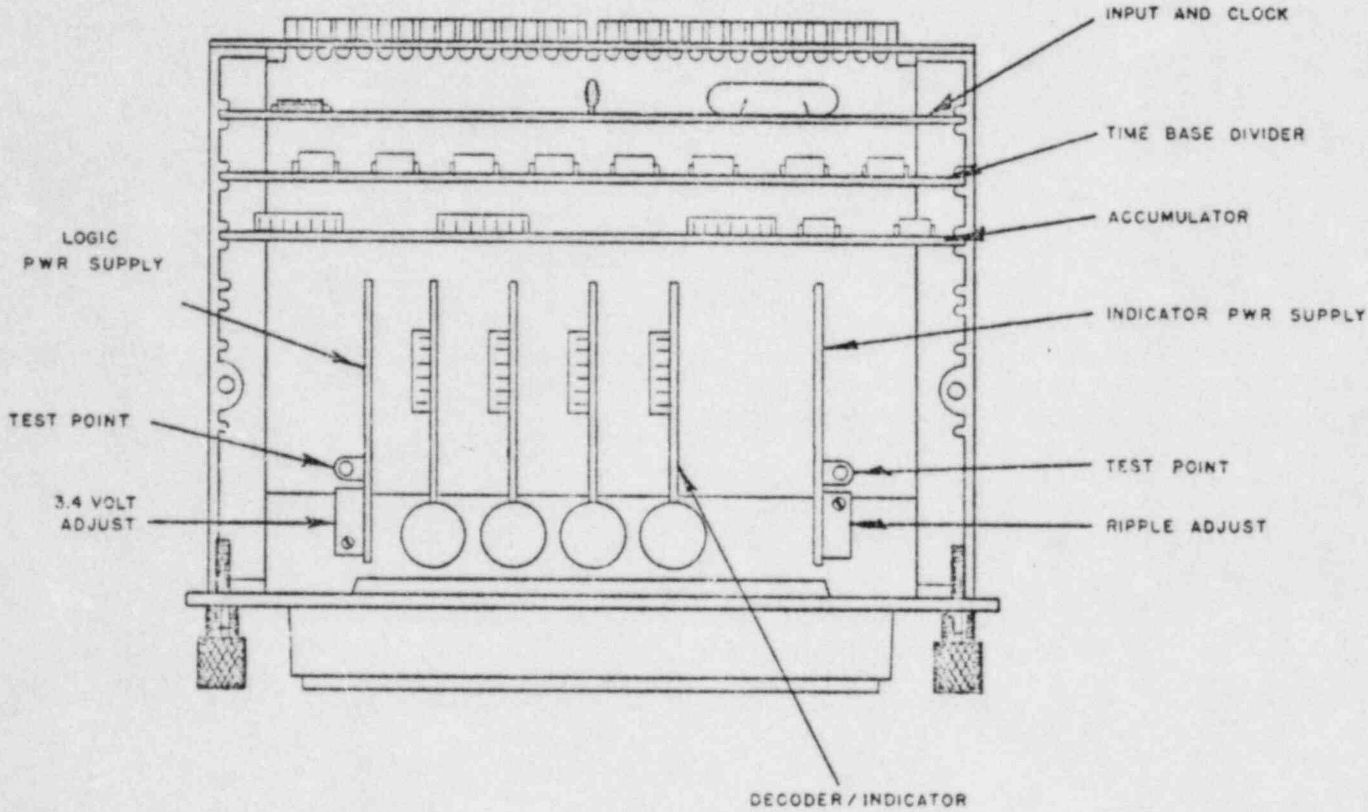


FIGURE 8

SCALER ASSEMBLY

prevent damage to the connectors. The Preamplifier Assembly may be removed by taking out the four corner screws and lifting the assembly out of the base casting. The G. M. Detectors are mounted on the bottom of this assembly. They may be removed by taking out two screws on the G. M. tube retainer, removing the retainer and unplugging the detectors. Care should be exercised in all of the operations in order to prevent damage to the various assemblies. Save all screws and note the locations.

4. If it becomes necessary to replace the Battery Pack Assembly or for other reasons to completely disassemble the gauge, it is necessary to remove the source rod assembly.

   Place the Index Handle in the backscatter position. Just below the index rod cap screw there is a hole containing a roll pin. Drive this pin out using a 3/32" pin punch and a small hammer. The top cap may be removed by unscrewing. Remove the Source Rod and handle by lifting straight up. Note that the flat side of the trigger wedge is on the bottom side. If the Trigger Assembly is removed from the handle, it must be correctly replaced in order to insure proper indexing. Store the Source Rod in a calibration standard or in a 4" x 4" x 6" lead pig with a 3/4" hole 4" into the long dimension. If shielding is not available, store the Source Rod at least 10 feet from all personnel. When holding the rod, keep the tip away from the body.

5. Reassemble the gauge in the reverse order of the above. Use care to prevent damage and tighten all screws to prevent their working loose under field use. A small amount of fingernail polish around screw heads helps to retain them in place.

E. INTERNAL ADJUSTMENTS

Unless a gauge malfunction is experienced no attempt should be made to alter the internal adjustments as they are quite stable. Refer to Figure 8 for circuit location of the adjustments and the circuit block diagram. Refer to Figures 7, 8 and 9 for the physical location of the adjustments and test points. The tools and equipment required for these adjustments are listed in Section X, paragraph A. All or parts of this equipment are available from the factory.

1. Remove the Scaler Module Assembly from the gauge and disconnect the cable between the Battery Pack Assembly and the Preamplifier Assembly. Connect the external power cable between the Preamplifier Assembly and the Power Supply (H. P. 6215A). Turn on the supply and adjust to 12.5 volts. Insert the Termination Board (B-100456) into the Scaler Module connector on the Preamplifier Assembly.

2. Connect the multimeter to the 9.2 V and Ground test points on the Termination Board and determine its nominal value. Vary the power supply between 10.5 and 14.5 volts; the 9.2 volt test point shall not vary over ± 0.1 volt from its nominal value.

3. Adjust the power supply to 10.5 volts. Connect the Electrostatic Voltmeter (Singer EDS) to the 1400 volt test point on the Preamplifier Board and Ground on the Termination Board. Turn the H. V. adjust on the Preamplifier Board counter-clockwise until either the end of the adjustment is reached or the high voltage begins to fall. Turn the adjustment clockwise until the high voltage reaches a plateau and then turn three additional full turns clockwise. If the voltage failed to fall at the full counter-clockwise position, simply turn the adjustment 3 full turns clockwise from the counter-clockwise position. Set the power supply at 12.5 volts. The high voltage shall be between 1380 and 1420 volts. Vary the power supply between 10.5 and 14.5 volts. There shall be no measurable change in the high voltage reading. Readjust the supply to 12.5 volts.

4. Connect the Oscilloscope to the Density Test point on the Termination Board. Set the sweep speed to 50µs/cm and the vertical sensitivity to .5 volt/cm. The negative pulse heights shall be between 1 and 2 volts. It may be possible to visually separate the pulses from each of the three G. M. Detectors. The pulse heights shall be uniform.

5. Turn off the power supply and short across the 1400 volt corona regulator to discharge the high voltage. Using care to prevent damage, disconnect the BF-3 cable on the left side of the Preamplifier Assembly. Attach a Termination (A-100670) to the left side of the Preamplifier Assembly. Failure to do so may cause the preamp to oscillate. Reapply power to the assembly and connect the Oscilloscope to the moisture test point on the Termination Board. With the sweep speed on 20 µs/cm and the sensitivity on .5 volts/cm adjust the moisture gain on the right side so that the thermal pulse height (See Figure 10) falls between .8 and 1.2 volts.

6. Turn off the power supply and short across the 1400 volt corona regulator. Remove the Termination. Using care to prevent damage, reconnect the left BF-3 cable and disconnect the right cable. Attach Termination (A-100670) to the right side of the preamp. Repeat the instructions in 5 above. Turn off the supply, short across the 1400 volt regulator, remove the Termination, and reconnect the right cable.

7. Remove the Termination Board and insert the Extender Board into the same connector. Insert the Scaler Module into the Extender Board. Turn on the power supply and adjust to 12.5 volts. Set the scaler POWER switch to ON. Connect the multimeter to the 3.4 volt test point on the Logic Supply and adjust for a 3.4 volt indication. Adjust the power supply between 10.5 and 14.5 volts. The logic voltage shall not vary greater than 3.2 to 3.6 volts.

8. The ripple adjust on the Indicator Supply has been set for minimum current at the factory and will not require adjustment in the field.

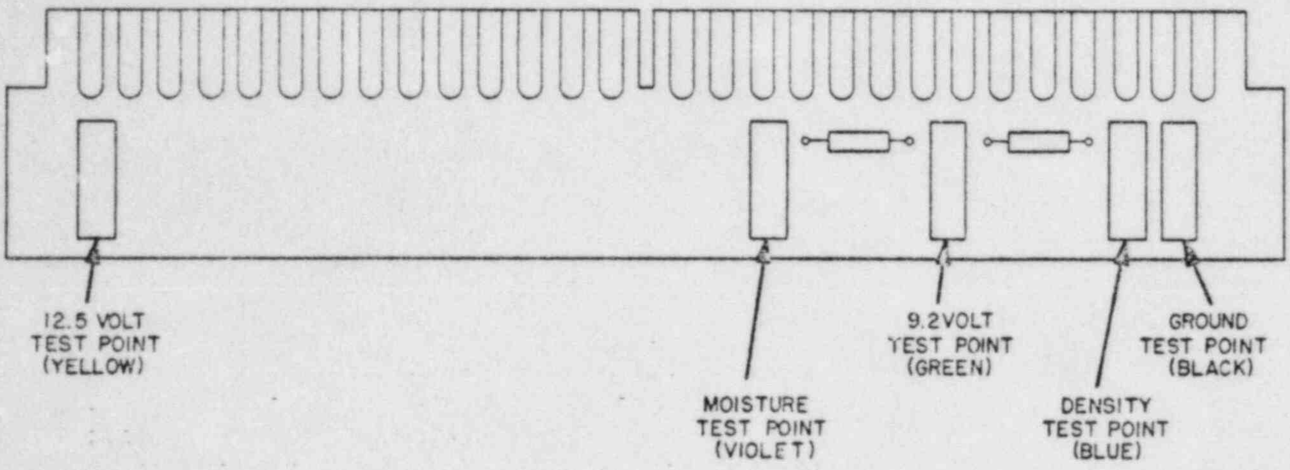


FIGURE 9

TERMINATION BOARD B-100456

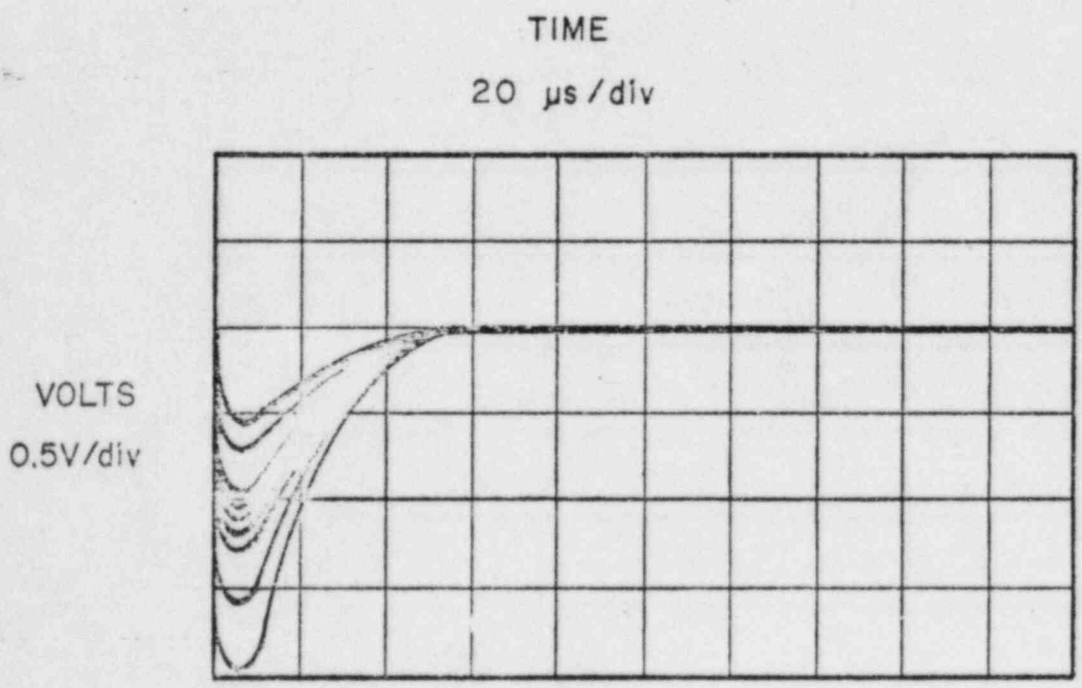


FIGURE 10

MOISTURE PULSE SHAPE

The moisture and density level adjustments have been set to 150 mv at the factory and will not require field adjustment.

9. Set the power supply to 12.5 volts and set the supply meter select switch to current. With the gauge POWER switch in STDBY, the current drain shall be no greater than 120 ma. With the POWER switch in ON, the current drain shall be no greater than 230 ma. Press the READ pushbutton and the current drain shall be no greater than 450 ma.

10. Reduce the power supply voltage until the current drain drops to less than 10 ma. The power supply voltage at this point shall be between 9 and 10 volts.

F. Refer to Figure 11 for the system block diagram. The signal paths for data are designated by the heavy lines.

Power from the batteries goes through the 2 Amp fuse, the STDBY/ON section of the POWER switch to the battery saver circuit on the Preamplifier Assembly. From this point, power is delivered to the 12.5 volt bus and to the H. V. and 9.2 volt Power Supplies and to the Scaler Module. In the Scaler Module, 12.5 volts is delivered to the BATTERY INDICATOR, through the ON section of the POWER switch to the Logic Power Supply and through the READ pushbutton to the Indicator Supply. When the POWER switch is on STDBY, power is available to the 9.2 volt supply, the H. V. Supply and to the BATTERY INDICATOR. When the switch is in the ON position, power is connected to everything listed above plus the Logic Power Supply and is available to the Indicator Supply when the READ pushbutton is depressed. The Indicator Power Supply provides 170 volts to the decade indicator tubes. The Logic Power Supply provides 3.4 volts to all logic circuits on the Input and Clock Board, Time Base Divider Board, Accumulator Board, Decoder/Indicator Boards and to the SUM and START switches on the front panel. The H. V. Supply provides voltage to the 1400 volt regulator for the BF-3 Detectors and to the 900 volt regulator for the G. M. Detectors. The 9.2 volt supply provides power for the moisture and density amplifiers on the Preamplifier Board and to the threshold level and crystal oscillator circuits on the Input and Clock Board. This completes the power distribution system. During recharge, 110 V or 220 V AC power is supplied through the .5 A fuse to the charger and from the charger approximately 700 ma is supplied to the batteries.

Pulses from the radiation detectors are fed through their respective amplifiers, threshold detectors and to the function gate. The density pulses are divided by 10 prior to the function gate. Low level logic switching is provided to select either moisture or density data or if neither is selected, test data from the clock is supplied to the accumulator data input where any one of the three inputs may be scaled for selective time periods. The function selector switch (DENSITY/TEST/MOISTURE) provides selection by grounding lines from the Input and Clock Board. A line is provided from the Input and Clock Board to the Accumulator Board to provide TEST control.

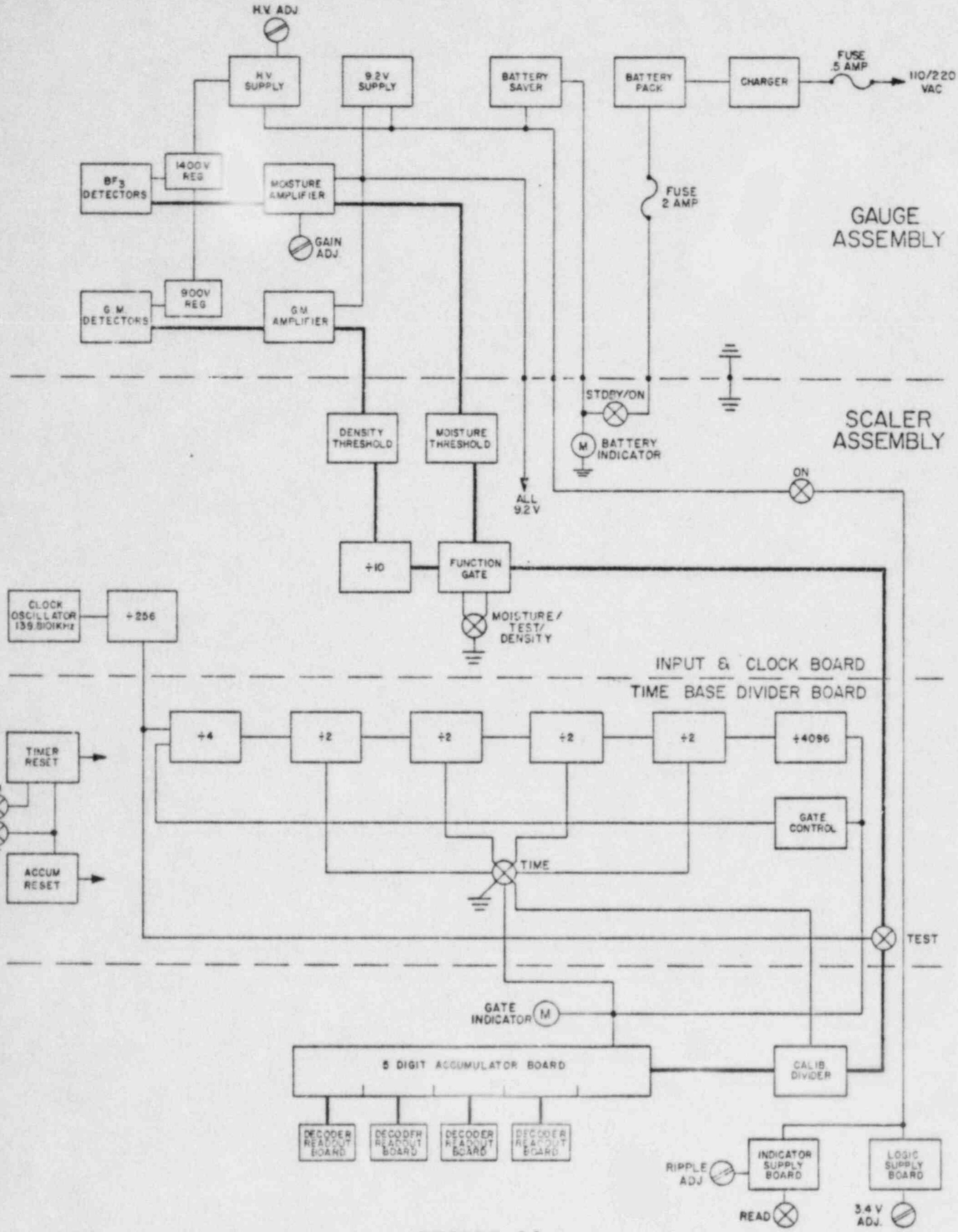


FIGURE 11

SYSTEM BLOCK DIAGRAM

The 139.810 KHZ Oscillator is divided by 256 on the Input and Clock Board and this provides a 546.133 Hz clock signal to the Time Base Divider Board and to the Accumulator Board for the TEST function. The signal provided to the Time Base Divider is selectively scaled down to provide a gate of .25, .5, 1, 2 or 4 minutes duration for the Accumulator Board. The selection is provided by grounding lines available on the TIME selection switch. This switch also controls pre-scaling for the CALIB function and grounds the gate lines for the COUNT function. The START pushbutton generates a reset pulse on the Time Base Divider Board which resets the Accumulator and Time Base circuits while the SUM pushbutton generates a reset pulse for the Time Base circuits only.

All front panel switching except for power is accomplished by grounding lines. No signals are switched at the front panel.

Data to the Accumulator is prescaled by ten and then accumulated in binary coded decimal (1,2,4,8) form before being decoded and indicated at the front panel. At the indicators, the moisture data has been prescaled by 10 and the density data by 100. In addition, all data is prescaled by 4 during the CALIB function.

XI. RADIATION STATISTICS

The subject of radiation statistics cannot be completely covered in this short section; however, sufficient detail can be given without proof to enable the user to perform the operations required and understand the statistics pertaining to this equipment.

The binomial distribution describes the probability of random events and its limiting case, the Poisson distribution accurately defines the probability of radioactive decay. The most significant property of this distribution applying to this equipment is that the variance of the rate of decay is equal to the mean rate of decay. Therefore, the standard deviation (σ) is equal to the square root of the true mean rate of decay (m). Since m cannot be determined it is convenient to substitute the sample mean $\bar{n}$ where:

$$\bar{n} = \frac{\Sigma n}{N}$$

for N number of samples n. The standard deviation of a given sample n within a population can be expressed as:

$$\sigma(n) = (\bar{n})^{1/2}$$

Further, it is possible to define the precision of a single n as:

$$n = n \pm (n)^{1/2}$$

The deviation of N samples thus becomes:

$$\sigma(\bar{n}) = \frac{(\frac{\Sigma n}{N})^{1/2}}{(N)^{1/2}} = (\frac{\bar{n}}{N})^{1/2} = \frac{\sigma(n)}{(N)^{1/2}}$$

and the precision of $\bar{n}$ is:

$$\bar{n} = \bar{n} \pm (\frac{\bar{n}}{N})^{1/2} = \bar{n} \pm \frac{\sigma(n)}{(N)^{1/2}}$$

The foregoing demonstrates that the accuracy of a given gauge measurement can be improved by accumulating and averaging multiple measurements and the deviation is decreased by a factor of two for four measurements, three for nine, four for sixteen, etc. The time consumed increases geometrically however, and is not practical beyond four measurements. This quantity is used for calibration and field determination of the standard count. The 2400 Series COMPAC obtains the average of four one-minute measurements automatically in the CALIB position of the TIME switch.

It should be obvious that it is necessary to obtain the square root of the true count rate in order to compute the standard deviation; i.e., first multiply moisture count rates by 10 and the density count rates by 100.

It is often convenient to express the precision as a percentage of the count rate:

$$\sigma(\%) = n \pm \frac{(n)^{1/2}}{n} \times 100 = n \pm \frac{100}{(n)^{1/2}}$$

This further demonstrates the futility of using more than four or at the most nine samples to determine a calibration count or a standard count. If a gauge has a count rate of 62,500 cpm for a given test, the precision represents a stability of 0.4% for a single count or 0.2% for four counts. Assuming that the gauge electronics must be more stable than the decay of the source, the electronics must be more stable than 0.1% for all possible sources of drift; detector efficiency, high voltage supply, threshold levels and time base. Few pieces of field operated equipment can demonstrate this order of stability and this explains the careful choice of fixed regulated high voltage supplies and the crystal time clock used in the 2400 Series COMPAC rather than variable high voltage supplies and tuning fork or DC motor timers used in other equipments.

Standard deviations in terms of counts-per-minute have little meaning to the gauge user since the interested units are PCF of density or moisture content. In order to determine these units, it is necessary to obtain

the relationship between counts-per-minute and PCF. This is not a ratio of the values but a ratio of the change in counts-per-minute for a given change in PCF or slope (S):

$$S = \frac{\Delta n}{\Delta D} \quad \text{or} \quad \frac{\Delta n}{\Delta M}$$

therefore:

$$\sigma(D) = \frac{(n)^{1/2}}{\frac{\Delta n}{\Delta D}} = \frac{\sigma(n)}{S} \text{ (Density)}$$

or:

$$\sigma(M) = \frac{\sigma(n)}{S} \text{ (Moisture)}$$

Since the gauge response to density is basically an exponential function, the slope is different for different densities and the density must be stated in order to specify a deviation in terms of density.

While the Poisson distribution describes the probability of decay, the normal or Gaussian distribution is more useful and convenient when predicting or comparing values by the statistical theory of errors. No error is introduced with $n > 100$ and probability > 0.01. Assuming normal distribution, the probability of obtaining a measurement within a specified deviation is:

Deviation	.5	1	2	3
Probability	.383	.683	.944	.997

From this table, one can see that 94.4% of the measurements will be within 2σ and the probability of obtaining a measurement outside of 3σ is remote.

The procedure outlined above predicts the precision of measurements assuming the gauge stability to be greater than the decay stabilities. Obviously this may not be a correct assumption and it is necessary to test the gauge stability in terms of the decay stability. In order to accomplish this test it is necessary to accumulate a number (20 or more) of sample counts. Normally the moisture and density standard counts are used.

The standard deviation may be determined by:

$$\sigma^2 = \frac{1}{N-1} \sum_{1}^{N} (n-\bar{n})^2$$

or:

$$\sigma^2 = \frac{1}{N-1} \left(\Sigma n^2 - \frac{(\Sigma n)^2}{N} \right)$$

The latter equation is sometimes referred to as the working formula and is convenient for use on desk calculators. The deviation obtained is the root-mean-square (RMS) error of the individual measurements from the mean.

A ratio of the RMS deviation to the predicted deviation should fall between .8 and 1.25. Ratios outside of .7 and 1.4 definitely indicate a defective system while ratios between these values indicate possible defects and the test should be repeated.

The gauge stability over a working day should be such that the drift in standard count is less than that required to cause an error in excess of one standard deviation. For the 2400 Series gauges this maximum difference is 0.5% for the density standard count and 1% for the moisture standard count. These values were picked at 120 PCF density and 15 PCF moisture content.

The long term drift of the standard count is difficult to set a maximum for, since it is dependent on the source of the drift. Detectors display an aging which is temperature dependent and this type of drift is compensated for by the standard count procedure. A gradual shift of even 10% may be of no concern if it has occurred over a long period of time; however, any sudden shift in excess of 2 to 3% may indicate a mechanical shift in the gauge geometry and the calibration should be checked against a known reference.

XII. RADIOLOGICAL SAFETY INFORMATION

A. GENERAL

The quantities of radioactive material contained in Troxler moisture and density gauges are quite small, and an operator may safely use a gauge day after day without receiving any bodily damage due to radiation. In addition, each radioactive source is doubly sealed to afford even greater protection for the operator. However, all radioactive sources, no matter how small, should be handled with care.

The purpose of this appendix is to acquaint the operator with the types and characteristics of radiations he will be working with, and to describe the routine handling procedures and precautions which should be followed in order to obtain safe and efficient operation of Troxler gauges.

B. RADIATION CHARACTERISTICS

1. Types of radiation

The radioactive materials in Troxler gauges emit four types of radiation which the operator should know about: alpha particles, beta particles, gamma rays, and neutrons. Of these four, the alpha and beta particles are completely stopped by the walls of the source container; therefore, only the characteristics of the gamma rays and neutrons need to be discussed in detail.

Gamma rays (sometimes called photons) are a form of electro-magnetic radiation, somewhat similar to radio waves and rays of light. They travel in straight lines with the speed of light, and are electrically neutral. However, unlike light rays, gamma rays are extremely penetrating, and may pass through several inches of lead or concrete without being deflected. The energy of a gamma ray is usually expressed in units of millions of electron volts, or MeV. This need not be discussed any further except to state that, in general, the higher the energy, the more penetrating the gamma ray will be.

When a gamma ray (photon) enters a slab of material, any of three things may happen. First, the photon may be absorbed (stopped) by the material. Second, the photon may be deflected or "scattered" in the material, and come out of the material with a different direction and lower energy than when it entered. (Of course, sometimes the photon is scattered several times before being absorbed or coming out of the material.) Third, the photon may pass through the material without being scattered or absorbed.

It is impossible to accurately predict what will happen to a single gamma ray entering a certain material. However, if a beam of photons is directed at the material, it is possible to calculate the percentages of the beam that will be absorbed, scattered or transmitted. The percentage of photons that will pass through a material depends mostly on the energy of the photons and the density of the material. For example, if a beam of 1.25 MeV photons were directed at a concrete block 11.2 inches thick, 10% of the beam would be transmitted. However, only 1.73 inches of lead would be required to cut this same beam down to 10%, because lead is much heavier than concrete.

Neutrons, instead of being rays, are extremely small, very dense particles. They are electrically neutral and quite penetrating. Unlike gamma rays, the penetrating power of neutrons through a material does not depend on the density of the material, but on the material composition. Neutrons are slowed down most effectively by a material containing hydrogen atoms (such as water or polyethylene). For this reason, neutrons are used to measure the moisture content of soils or other materials.

2. Characteristics of Troxler Radioactive Source Materials

Almost all Troxler gauges use as source materials Radium-226, Cesium-137, or Americium-241, either singly or in combination. A brief description of the characteristics of each type of source is now given.

Radium-226 emits alpha particles and low-energy gamma rays. It has a half life of 1620 years, which means that in a given sample of pure Radium-226 atoms, half of these atoms would decay in 1620 years. Of the Radium-226 atoms remaining after the first 1620 years, half again would decay in 1620 more years, and so on. However, when a Radium-226 atom undergoes radioactive decay, it is transformed into Radon-222, which is also radioactive, and in turn decays into still another radioactive element. Actually, each original atom of Radium-226 must decay a total of eight times before it finally becomes a stable (non-radioactive) element. For each decay process, energy is given off in the form of alpha particles, beta particles, gamma rays, or combinations of these. Therefore, even though the Radium-226 atom gives off a low energy gamma ray, several members of its following decay chain emit gamma rays with high energies.

Cesium-137 decays with the emission of a beta particle, which is stopped by the walls of the source container. However, when Cesium-137 decays, it is transformed into an unstable Barium-137 atom, which in turn decays to a stable state with the emission of a gamma ray. Cesium-137 has a half life of 30 years.

Americium-241, like radium, is a member of a long decay chain, which emits alpha, beta, and gamma radiations before achieving stability. Americium is not a suitable source for density measurement because practically all of the gamma rays emitted by the members of its decay chain are of low energy, and would be absorbed by soil or asphalt before being transmitted or scattered back to a detector. For this reason, Troxler gauges use Radium and Cesium sources for density measurements, while Americium (and also Radium) are used for moisture determinations. Moisture is measured by counting the number of neutrons which are slowed down by water in soil or other material.

Americium and Radium (and their by-products) do not emit neutrons. Beryllium is used as a neutron source. Although Beryllium by itself is a stable element, it emits neutrons when it is struck by alpha particles from Radium or Americium. Therefore, a combination moisture and density gauge would use a source such as Radium-Beryllium (where Radium would provide gamma rays for density measurements and Beryllium would provide neutrons for moisture determination), or a combination Cesium-Americium-Beryllium source, where Cesium would provide gamma rays and Americium would be used to bombard the Beryllium atoms for a source of neutrons.

3. Radiation Units

Although there are several units of radiation measurement, there are only two with which the operator of a Troxler gauge needs to be familiar. These are the curie and the rem.

The curie is defined as the quantity of any radioactive material giving 3.7×10^{10} disintegrations per second (dps). That is, in a curie of radium, 3.7×10^{10} atoms would decay each second.

The strength of sources used in Troxler gauges is usually expressed in millicuries (one millicurie is one-thousandth of a curie, or 3.7×10^7 dps). Therefore, a 3 millicurie Radium source would yield $(3)\ (3.7 \times 10^7) = 11.1 \times 10^7$ dps, or 111 million dps.

In order to calculate the amount of radiation absorbed by a human being, a unit called the rem is used. Because the amount of absorbed radiation is usually small, doses are usually expressed in millirem (thousandths of a rem). The millirem is actually a measure of the effectiveness of the body in absorbing radiation, and depends on the type and energy of the radiation.

4. Exposure Limitations

In order to protect personnel from overexposure to radiation, the Atomic Energy Commission and the Federal Radiation Council have established exposure limits for radiation workers. These limits, expressed in millirems, are reproduced in the following table.

EXPOSURE LIMITS FOR RADIATION WORKERS

Type of Exposure	Millirem Limits for 13 weeks	Millirem Limits for 1-week rate
Sensitive Regions (whole body, eyes, gonads, skull)	1,250	96
Kidneys, spleen, lungs, liver	5,000	385
Skin of whole body	7,500	577
Hands, arms, feet, ankles	18,750	1,442

These limits are intended to be highly conservative, and do not represent the absolute maximum exposure a person could receive without becoming ill or suffering radiation damage. However, it

is advisable to remain under the limits whenever possible. This can be done quite easily with Troxler gauges, by following established handling precautions.

5. Shielding

There are two basic ways in which a person can protect himself from a radioactive source: distance and the interposition of shielding material.

As a person moves away from a source, the amount of radiation which he is receiving from the source falls off sharply. In fact, radiation obeys the "inverse square" law which states that the radiation intensity falls as the inverse square of the distance from the center of the source to the "target". For example, if a person standing one foot from a source were receiving forty millirem per hour, moving back another foot would cut the intensity to ten millirem per hour. By moving back, the person represents a small "target area" to the source.

The other method of shielding is obtained by placing matter between the source and the target. To a reasonable approximation, it makes no difference where the shielding material is placed between the source and the target, as long as the thickness of the material remains the same. As was mentioned earlier, dense material provides the best shielding against gamma radiation, while hydrogeneous (hydrogen-containing) material affords good protection against neutrons. The type of shielding in general use is as follows for the various encapsulated source materials:

RA226	Heavy material
Cs137	Heavy material
Ra226 + Be	Heavy material and hydrogeneous material
Am241 + Be	Hydrogeneous material

C. HANDLING PROCEDURES

Although Troxler gauges can be operated quite safely, the following general precautions should be observed:

1. Do not operate or attempt to operate a gauge unless you have been authorized to do so.

2. Keep the gauge in the "SAFE" or storage position when not in use.

3. Wear a film badge or other radiation measurement device at all times while operating or transporting a gauge.

4. Keep unauthorized persons away from the gauge.

5. Be sure that the gauge is locked up or otherwise secured when it is not in use.

6. Follow established operating procedures when using the gauge.

7. Insure that the gauge is leak tested at proper intervals.

8. When in doubt, ASK.

D. ACCIDENTS AND INCIDENTS

In case a gauge is lost or stolen, or involved in an accident which might cause physical damage to the source, notify your Radiological Safety Officer, IMMEDIATELY. He will notify the proper authorities.

XIII. SHIPPING

A. GENERAL

Shipping procedures for 2400-Series gauges are governed by applicable Department of Transportation Regulations for Shipment of Radioactive materials. These regulations are contained in Title 49, Code of Federal Regulations.

B. PACKAGING

2400-Series gauges are shipped from the factory in shipping cases which contain the proper labeling. This labeling consists of a Radioactive Yellow-II label on either side of the package. DO NOT REMOVE THESE LABELS. Information on these labels include:

a. Type of material
b. Number of curies
c. Transport Index (This is the highest reading in mr/hr at one meter from any part of the package).

These original shipping cases should be used whenever it is necessary to ship the gauges anywhere. If it is desired to ship empty shipping cases, an "EMPTY" label must be affixed to the package, instead of placing tape over the radioactive labels.

Each package should have a seal (such as banding or a lock) which, while intact, will be evidence that the package has not been illicitly opened.

Since the 2400-Series gauges contain sealed sources which meet "Special Form" requirements, the shipping cases are considered as Type "A" packaging. This fact should be shown on the case by another label on each side which states:

SPECIAL FORM
TYPE "A"
RADIOACTIVE MATERIAL
SEALED SOURCE

C. SHIPPING DOCUMENTS

1. Waybill

The Waybill must include the following information:

SPECIAL FORM, TYPE "A"
RADIOACTIVE MATERIAL

Cs-137/Am-241:Be 8/50 mCi
or
(Ra-226:Be 2 mCi)

SEALED SOURCE
LABEL: RADIOACTIVE YELLOW-II

2. Restricted Article Statement

When gauges are to be shipped by air, a Restricted Article Statement must accompany the shipment.

3. Sample Documents

Sample copies of the Waybill and the Restricted Article Statement for both Ra:Be and Cs/Am:Be sources are given on the following pages. While the Restricted Article Statement is needed only for air shipments, the Special Form statement on the Waybill must be included regardless of the mode of shipping.

RESTRICTED ARTICLE STATEMENT

This is to certify that the contents of this consignment are properly described by name and are packed, marked and labeled, and are in proper condition for carriage by air according to all applicable carriers and to the I. A. T. A. restricted articles regulations. This consignment is within the limitations prescribed for passenger or carrying aircraft.

SHIPPED TO: Troxler Electronic Labs., Inc. FOR EXPORT TO: ____________

P.O. Box 5997

Raleigh, North Carolina 27607

Number of cartons: 1

Contents: Ra-226:Be

Net Quantity: 2 mCi

ACE TESTING LABORATORIES, INC.

By: John Doe

Title: Testing Engineer

Signature: ____________

FIGURE 12

RESTRICTED ARTICLE STATEMENT FOR RADIUM SOURCES

● Use typewriter or ballpoint pen. Bear down.

UNIFORM AIRBILL NON-NEGOTIABLE

Refer to SP 82-9305

Subject to Conditions of Contract on the Back of the Airbill

CARRIER	ORIGIN	AIRBILL NUMBER		DECLARED VALUE	CUBIC INCHES
007		2798 8995	THE CARRIER'S LIABILITY IS LIMITED PER ITEM 3 ON REVERSE SIDE, UNLESS A HIGHER VALUE IS DECLARED. SHOW DECLARED VALUE TO NEAREST WHOLE DOLLAR. →		

ROUTING: Airline routing applies unless shipper inserts specific routing here

[X] PREPAID [ ] COLLECT

AIR FREIGHT-DOMESTIC AIRBILL

TO	VIA	TO	VIA	TO	VIA	TO	VIA

CONSIGNEE'S ACCOUNT NUMBER

CONSIGNEE

NAME
Troxler Electronic Laboratories, Inc.

STREET ADDRESS
P.O. Box 5997

CITY / STATE / ZIP CODE
Raleigh, North Carolina 27607

DEL. ZONE / SPECIAL INSTRUCTIONS, INCLUDING CUSTOMER REFERENCE NUMBER

SHIPPER'S ACCOUNT NUMBER

SHIPPER

NAME
Ace Testing Laboratories, Inc.

STREET ADDRESS
121 Elm Street

CITY / STATE / ZIP CODE
Cleveland, Ohio 44128

PCS/PKGS / LENGTH / WIDTH / DEPTH / CUBIC INCH
X X =

DIMENSIONAL WGT.-LBS

C.O.D. SHIPMENT
If amount entered here by Shipper

CARRIER USE ONLY		
RATE		CHARGES
		WEIGHT CHARGES $
		PICK UP
		DELIVERY
		EXCESS VALUE
		ADVANCES
		OTHER
		SHIPPER'S C.O.D.
		C.O.D. FEE
		TAX
		TOTAL CHARGES $

PICK UP ZONE / ORIG. ADV. CHGS / DESCRIPTION OF ORIGIN ADVANCE CHGS / DEST. ADV. CHARGES / DESCRIPTION OF DESTINATION ADV. CHGS

OTHER CHARGES / DESCRIPTION OF OTHER CHARGES / G.B.L. NUMBER

NO. PCS.	WEIGHT	DESCRIPTION OF PIECES AND CONTENTS PACKING, MARKS, NUMBER
–		SPECIAL FORM, TYPE "A" RADIOACTIVE MATERIAL
–		Ra-226:Be 2 mCi
–		SEALED SOURCE - LABEL RADIOACTIVE YELLOW - II
–		

THIS IS NOT AN INVOICE

EXECUTED AT/BY: / DATE / TIME

CARRIER	ORIGIN	
007		2798 8995

① SHIPPER'S RECEIPT

ABG 70534 REV. 5/71 AC-17

FIGURE 13

SAMPLE WAYBILL FOR RADIUM SOURCES

RESTRICTED ARTICLE STATEMENT

This is to certify that the contents of this consignment are properly described by name and are packed, marked and labeled, and are in proper condition for carriage by air according to all applicable carriers and to the I. A. T. A. restricted articles regulations. This consignment is within the limitations prescribed for passenger or carrying aircraft.

SHIPPED TO: Troxler Electronic Labs., Inc. FOR EXPORT TO: ____________

P.O. Box 5997

Raleigh, North Carolina 27607

Number of Cartons: 1

Contents: Cs-137/Am-241:Be

Net Quantity: 8/50 mCi

ACE TESTING LABORATORIES, INC.

By: John Doe

Title: Testing Engineer

Signature: ____________

FIGURE 14

RESTRICTED ARTICLE STATEMENT FOR CESIUM SOURCES

• Use typewriter or ballpoint pen. Bear down.

UNIFORM AIRBILL NON-NEGOTIABLE

Subject to Conditions of Contract on the Back of the Airbill

Refer to SP 82-9305

CARRIER	ORIGIN	AIRBILL NUMBER		DECLARED VALUE	CUBIC INCHES
007		2798 8995	THE CARRIER'S LIABILITY IS LIMITED PER ITEM 3 ON REVERSE SIDE, UNLESS A HIGHER VALUE IS DECLARED. SHOW DECLARED VALUE TO NEAREST WHOLE DOLLAR.		

ROUTING. Airline routing applies unless shipper inserts specific routing here

[X] PREPAID [ ] COLLECT

AIR FREIGHT-DOMESTIC AIRBILL

TO	VIA	TO	VIA	TO	VIA	TO	VIA

CONSIGNEE'S ACCOUNT NUMBER

CONSIGNEE

NAME: Troxler Electronic Laboratories, Inc.

STREET ADDRESS: P.O. Box 5997

CITY / STATE: Raleigh, North Carolina ZIP CODE: 27607

DEL. ZONE / SPECIAL INSTRUCTIONS, INCLUDING CUSTOMER REFERENCE NUMBER

SHIPPER'S ACCOUNT NUMBER

SHIPPER

NAME: Ace Testing Laboratories, Inc.

STREET ADDRESS: 121 Elm Street

CITY / STATE: Cleveland, Ohio ZIP CODE: 44128

PCS/PKGS	LENGTH	WIDTH	DEPTH	CUBIC INCH
	x	x	=	

DIMENSIONAL WGT.-LBS

C.O.D. SHIPMENT
If amount entered here by Shipper

CARRIER USE ONLY		
RATE		CHARGES
		WEIGHT CHARGES $
		PICK UP
		DELIVERY
		EXCESS VALUE
		ADVANCES
		OTHER
		SHIPPER'S C.O.D.
		C.O.D. FEE
		TAX
		TOTAL CHARGES $

PICK UP ZONE | ORIG. ADV. CHGS. | DESCRIPTION OF ORIGIN ADVANCE CHGS. | DEST. ADV. CHARGES | DESCRIPTION OF DESTINATION ADV. CHGS.

OTHER CHARGES | DESCRIPTION OF OTHER CHARGES | G.B.L. NUMBER

NO. PCS.	WEIGHT	DESCRIPTION OF PIECES AND CONTENTS PACKING, MARKS, NUMBER
–		SPECIAL FORM, TYPE "A" RADIOACTIVE MATERIAL
–		Cs-137/Am-241: Be 8/50 mCi
–		SEALED SOURCE - LABEL RADIOACTIVE YELLOW - II
–		

THIS IS NOT AN INVOICE

EXECUTED AT/BY	DATE	TIME

CARRIER	ORIGIN	
007		2798 8995

① SHIPPER'S RECEIPT

ABG 70534 REV. 5/71 AC-17

FIGURE 15

SAMPLE WAYBILL FOR CESIUM SOURCES

XIV. TRENCH CORRECTIONS

Often, when nuclear densities are performed on backfill in trenches, the dry density is suspect. The usual cause is a high moisture count due to the reflection into the detectors of thermalized neutrons by the moisture in the side walls of the trench. This may easily be corrected for by taking a moisture standard count in the trench and using the difference between this and a normal standard count as a correction in the field moisture data.

Mathematically this may be stated as:

$$\text{Correction Factor (CF)} = \text{Std Ct}_{\text{Trench}} - \text{Std Ct}_{\text{Surface}}$$

Count ratios are then calculated by:

$$CR = \frac{(\text{Meas Ct}_{\text{Trench}} - CF)}{\text{Std Ct}_{\text{Surface}}}$$

Corrections for wet density determinations in the direct transmission mode are not necessary. However, the above procedure should be used for the density counts when using backscatter.

In a wide trench a correction factor may only be needed when performing tests within 3 feet of the trench wall. In this case, the trench standard count should be taken at approximately the same distance from the trench wall with the gauge in the same orientation as the measurement will be made. A correction may also be necessary when performing tests close to bridge abutments.

XV. REPLACEMENT PARTS LIST

When ordering the main assemblies listed below give the model and serial number of the gauge, or part number of the unit and its name. For example:

Model 2401 Gauge
Serial number: 852
Part number: C-100139
Name: Scaler Module Complete

MODEL OR PART NO.	DESCRIPTION	EXCHANGE PRICE	SALE PRICE (EA.)
C-100139	Scaler Module, Complete (2401 & 2402)	$ 346.00	$ 692.00
B-100675	Scaler Module, Complete (2451 & 2452)	346.00	692.00
C-100139 OR B-100675	Scaler Module (Less Boards & Clamp)		182.00
B-100031	Input and Clock Board (2401 & 2402)	51.00	102.00*
B-100674	Input and Clock Board (2451 & 2452)	51.00	102.00*
B-100034	Time Base Divider Board	42.50	85.00*
C-100036	Accumulator Board	41.00	82.00*
A-100038	Decoder-Indicator Board (4 required)	18.00	36.00*
A-100128	Indicator Power Supply	23.00	46.00*
A-100134	Logic Power Supply	24.00	48.00*
A-100150	Board Clamp Assembly		3.00
C-100210	Preamplifier Board Assembly (2401 & 2402)	93.00	186.00*
C-100688	Preamplifier Board Assembly (2451 & 2452)	75.00	150.00*
C-100212	Preamplifier Ass'y (Less G.M's, 2401 & 2402)	150.00	243.00
C-100681	Preamplifier Ass'y (Less G.M, 2451 & 2452)	132.00	207.00
C-100212	Preamplifier Ass'y (With G.M's, 2401 & 2402)		483.00
C-100681	Preamplifier Ass'y (With G.M, 2451 & 2452)		287.00
A-100159	G.M. Detector		80.00*
A-100184	High Voltage Power Supply	29.00	58.00*
C-100190	Battery Charger Assembly	90.00	152.00*
A-100085	Transformer		5.00
A-100097	Battery Pack (2 required)		45.00
B-100570	Boron-Triflouride Detector		225.00*
A-100318	Neutron Reflector		15.00
D-100271	Top Shell Assembly		95.00
A-100246	Charger Harness		8.00
C-100232	Base Assembly (Complete, minus source, 2401 & 2451)		315.00
C-100229	Base Assembly (Complete, minus source, 2402 & 2452)		311.00
A-100218	Source Rod Assembly (2401 & 2451)		64.00
A-100220	Source Rod Assembly (2402 & 2452)		60.00
A-100221	Trigger Assembly		25.00
A-100222	Trigger Spring (Set)		2.00

APPENDIX C

N.R.C. REGULATIONS

PART 19

NOTICES, INSTRUCTIONS, AND REPORTS TO WORKERS; INSPECTIONS

AUTHORITY: Secs. 53, 63, 81, 103, 104, 161, Pub. L. 83-703, 68 Stat. 930, 933, 935, 936, 937, 948, as amended (42 U.S.C. 2073, 2093, 2111, 2133, 2134, 2201); Sec. 401, Pub. L. 93-438, 88 stat. 1254 (42 U.S.C. 5891)

§ 19.1 Purpose.

The regulations in this part establish requirements for notices, instructions, and reports by licensees to individuals participating in licensed activities, and options available to such individuals in connection with Commission inspections of licensees to ascertain compliance with the provisions of the Atomic Energy Act of 1954, as amended, Title II of the Energy Reorganization Act of 1974, and regulations, orders, and licenses thereunder regarding radiological working conditions.

§ 19.2 Scope.

The regulations in this part apply to all persons who receive, possess, use, or transfer material licensed by the Nuclear Regulatory Commission pursuant to the regulations in Parts 30 through 35, 40, or 70 of this chapter, including persons licensed to operate a production or utilization facility pursuant to Part 50 of this chapter.

40 FR 8774

§ 19.3 Definitions.

As used in this part:

(a) "Act" means the Atomic Energy Act of 1954, (68 Stat. 919) including any amendments thereto;

(b) "Commission" means the United States Nuclear Regulatory Commission;

(c) "Worker" means an individual engaged in activities licensed by the Commission and controlled by a licensee, but does not include the licensee.

(d) "License" means a license issued under the regulations in Parts 30 through 35, 40, or 70 of this chapter, including licenses to operate a production or utilization facility pursuant to Part 50 of this chapter. "Licensee" means the holder of such a license.

(e) "Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

38 FR 22217

§ 19.4 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 19.5 Communications.

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part should be addressed to the Director, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications, reports, and applications may be delivered in person at the Commission's offices at 1717 H Street, NW., Washington, D.C.; or at 7920 Norfolk Avenue, Bethesda, Maryland.

40 FR 8774

§ 19.11 Posting of notices to workers.

(a) Each licensee shall post current copies of the following documents: (1) The regulations in this part and in Part 20 of this chapter; (2) the license, license conditions, or documents incorporated into a license by reference, and amendments thereto; (3) the operating procedures applicable to licensed activities; (4) any notice of violation involving radiological working conditions, proposed imposition of civil penalty, or order issued pursuant to Subpart B of Part 2 of this chapter, and any response from the licensee.

(b) If posting of a document specified in paragraph (a) (1), (2) or (3) of this section is not practicable, the licensee may post a notice which describes the document and states where it may be examined.

38 FR 22217

(c) Form NRC-3, "Notice to Employees", shall be posted by each licensee wherever individuals work in or frequent any portion of a restricted area.

NOTE: Copies of Form NRC-3 may be obtained by writing to the Director of the appropriate U.S. Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix "D", Part 20 of this chapter, or the Director, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

40 FR 8774

(d) Documents notices, or forms posted pursuant to this section shall appear in a sufficient number of places to permit individuals engaged in licensed activities to observe them on the way to or from any particular licensed activity location to which the document applies, shall be conspicuous, and shall be replaced if defaced or altered.

(e) Commission documents posted pursuant to paragraph (a)(4) of this section shall be posted within 2 working days after receipt of the documents from the Commission; the licensee's response, if any, shall be posted within 2 working days after dispatch by the licensee. Such documents shall remain posted for a minimum of 5 working days or until action correcting the violation has been completed, whichever is later.

38 FR 22217

§ 19.12 Instructions to workers.

All individuals working in or frequenting any portion of a restricted area shall be kept informed of the storage, transfer, or use of radioactive materials or of radiation in such portions of the restricted area; shall be instructed in the health protection problems associated with exposure to such radioactive materials or radiation, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed; shall be instructed in, and instructed to observe, to the extent within the worker's control, the applicable provisions of Commission regulations

and licenses for the protection of personnel from exposures to radiation or radioactive materials occurring in such areas; shall be instructed of their responsibility to report promptly to the licensee any condition which may lead to or cause a violation of Commission regulations and licenses or unnecessary exposure to radiation or to radioactive material; shall be instructed in the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation or radioactive material; and shall be advised as to the radiation exposure reports which workers may request pursuant to § 19.13. The extent of these instructions shall be commensurate with potential radiological health protection problems in the restricted area.

§ 19.13 Notifications and reports to individuals.

(a) Radiation exposure data for an individual, and the results of any measurements, analyses, and calculations of radioactive material deposited or retained in the body of an individual, shall be reported to the individual as specified in this section. The information reported shall include data and results obtained pursuant to Commission regulations, orders or license conditions, as shown in records maintained by the licensee pursuant to Commission regulations. Each notification and report shall: be in writing; include appropriate identifying data such as the name of the licensee, the name of the individual, the individual's social security number; include the individual's exposure information; and contain the following statement:

38 FR 22217

This report is furnished to you under the provisions of the Nuclear Regulatory Commission regulation 10 CFR Part 19. You should preserve this report for further reference.

(b) At the request of any worker, each licensee shall advise such worker annually of the worker's exposure to radiation or radioactive material as shown in records maintained by the licensee pursuant to § 20.401(a) and (c).

(c) At the request of a worker formerly engaged in licensed activities controlled by the licensee, each licensee shall furnish to the worker a report of the worker's exposure to radiation or radioactive material. Such report shall be furnished within 30 days from the time the request is made, or within 30 days after the exposure of the individual has been determined by the licensee, whichever is later; shall cover, within the period of time specified in the request, each calendar quarter in which the worker's activities involved exposure to radiation from radioactive materials licensed by the Commission; and shall include the dates and locations of licensed activities in which the worker participated during this period.

(d) When a licensee is required pursuant to § 20.405 or § 20.408 of this chapter to report to the Commission any exposure of an individual to radiation or radioactive material the licensee shall also provide the individual a report on his exposure data included therein. Such report shall be transmitted at a time not later than the transmittal to the Commission.

(e) At the request of a worker who is terminating employment in a given calendar quarter with the licensee in work involving radiation dose, or of a worker who, while employed by another person, is terminating assignment to work involving radiation dose in the licensee's facility in that calendar quarter, each licensee shall provide to each such worker, or to the worker's designee, at termination, a written report regarding the radiation dose received by that worker from operations of the licensee during that specifically identified calendar quarter or fraction thereof, or provide a written estimate of that dose if the finally determined personnel monitoring results are not available at that time. Estimated doses shall be clearly indicated as such.

44 FR 32352

§ 19.14 Presence of representatives of licensees and workers during inspections.

(a) Each licensee shall afford to the Commission at all reasonable times opportunity to inspect materials, activities, facilities, premises, and records pursuant to the regulations in this chapter.

38 FR 22217

(b) During an inspection, Commission inspectors may consult privately with workers as specified in § 19.15. The licensee or licensee's representative may accompany Commission inspectors during other phases of an inspection.

(c) If, at the time of inspection, an individual has been authorized by the workers to represent them during Commission inspections, the licensee shall notify the inspectors of such authorization and shall give the workers' representative an opportunity to accompany the inspectors during the inspection of physical working conditions.

(d) Each workers' representative shall be routinely engaged in licensed activities under control of the licensee and shall have received instructions as specified in § 19.12.

(e) Different representatives of licensees and workers may accompany the inspectors during different phases of an inspection if there is no resulting interference with the conduct of the inspection. However, only one workers' representative at a time may accompany the inspectors.

(f) With the approval of the licensee and the workers' representative an individual who is not routinely engaged in licensed activities under control of the license, for example, a consultant to the licensee or to the workers' representative, shall be afforded the opportunity to accompany Commission inspectors during the inspection of physical working conditions.

(g) Notwithstanding the other provisions of this section, Commission inspectors are authorized to refuse to permit accompaniment by any individual who deliberately interferes with a fair and orderly inspection. With regard to areas containing information classified by an agency of the U.S. Government in the interest of national security, an individual who accompanies an inspector may have access to such information only if authorized to do so. With regard to any area containing proprietary information, the workers' representative for that area shall be an individual previously authorized by the licensee to enter that area.

§ 19.15 Consultation with workers during inspections.

(a) Commission inspectors may consult privately with workers concerning matters of occupational radiation protection and other matters related to applicable provisions of Commission regulations and licenses to the extent the inspectors deem necessary for the conduct of an effective and thorough inspection.

(b) During the course of an inspection any worker may bring privately to the attention of the inspectors, either orally or in writing, any past or present condition which he has reason to believe may have contributed to or caused any violation of the act, the regulations in this chapter, or license condition, or any unnecessary exposure of an individual to radiation from licensed radioactive material under the licensee's control. Any such notice in writing shall comply with the requirements of § 19.16(a).

(c) The provisions of paragraph (b) of this section shall not be interpreted as authorization to disregard instructions pursuant to § 19.12.

38 FR 22217

§ 19.16 Requests by workers for inspections.

(a) Any worker or representative of workers who believes that a violation of the Act, the regulations in this chapter, or license conditions exists or has occurred in license activities with regard to radiological working conditions in which the worker is engaged, may request an inspection by giving notice of the alleged violation to the Director of Inspection and Enforcement, to the Director of the appropriate Commission Regional Office, or to Commission inspectors. Any such notice shall be in writing, shall set forth the specific grounds for the notice, and shall be signed by the worker or representative of workers. A copy shall be provided the licensee by the Director of Inspection and Enforcement, Regional Office Director, or the inspector no later than at the time of inspection except that, upon the request of the worker giving such notice, his name and the name of individuals referred to therein shall not appear in such copy or on any record published, released, or made available by the Commission, except for good cause shown.

(b) If, upon receipt of such notice, the Director of Inspection and Enforcement or Regional Office Director determines that the complaint meets the requirements set forth in paragraph (a) of this section, and that there are reasonable grounds to believe that the alleged violation exists or has occurred, he shall cause an inspection to be made as soon as practicable, to determine if such alleged violation exists or has occurred. Inspections pur-

suant to this section need not be limited to matters referred to in the complaint.

(c) No licensee shall discharge or in any manner discriminate against any worker because such worker has filed any complaint or instituted or caused to be instituted any proceeding under the regulations in this chapter or has testified or is about to testify in any such proceeding or because of the exercise by such worker on behalf of himself or others of any option afforded by this part.

§ 19.17 Inspections not warranted; informal review.

(a) If the Director of Inspection and Enforcement or of the appropriate Regional Office determines, with respect to a complaint under § 19.16, that an inspection is not warranted because there are no reasonable grounds to believe that a violation exists or has occurred, he shall notify the complainant in writing of such determination. The complainant may obtain review of such determination by submitting a written statement of position with the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, who will provide the licensee with a copy of such statement by certified mail, excluding, at the request of the complainant, the name of the complainant. The licensee may submit an opposing written statement of position with the Executive Director for Operations who will provide the complainant with a copy of such statement by certified mail. Upon the request of the complainant, the Executive Director for Operations or his designee may hold an informal conference in which the complainant and the licensee may orally present their views. An informal conference may also be held at the request of the licensee, but disclosure of the identity of the complainant will be made only following receipt of written authorization from the complainant. After considering all written and oral views presented, the Executive Director for Operations shall affirm, modify, or reverse the determination of the Director of Inspection and Enforcement or of the appropriate Regional Office and furnish the complainant and the licensee a written notification of his decision and the reason therefor.

(b) If the Director of Inspection and Enforcement or of the appropriate Regional Office determines that an inspection is not warranted because the requirements of § 19.16(a) have not been met, he shall notify the complainant in writing of such determination. Such determination shall be without prejudice to the filing of a new complaint meeting the requirements of § 19.16(a).

38 FR 22217

§ 19.30 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Act or Title II of the Energy Reorganization Act of 1974, or any regulation or order issued thereunder.

40 FR 8774

A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of section 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act or any rule, regulation, or order issued thereunder, or any term, condition or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and upon conviction, may be punished by fine or imprisonment or both, as provided by law.

38 FR 22217

§ 19.31 Application for exemptions.

The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

§ 19.32 Discrimination prohibited.

No person shall on the ground of sex be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity licensed by the Nuclear Regulatory Commission. This provision will be enforced through agency provisions and rules similar to those already established, with respect to racial and other discrimination, under title VI of the Civil Rights Act of 1964. This remedy is not exclusive, however, and will not prejudice or cut off any other legal remedies available to a discriminatee.

40 FR 8774

PART 20 STANDARDS FOR PROTECTION AGAINST RADIATION

AUTHORITY: The provisions of this Part 20 issued under secs. 53, 63, 65, 81, 103, 104, 161, 68 Stat. 930, 933, 935, 936, 937, 948, as amended; 42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201. For the purposes of sec. 223, 68 Stat. 958, as amended; 42 U.S.C. 2273, §§20.401-20.409, issued under sec. 161 o., 68 Stat. 950, as amended; 42 U.S.C. 2201 (o). Secs. 202, 206, Pub. L. 93-438, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846).

§ 20.1 Purpose.

40 FR 8774 (a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Nuclear Regulatory Commission and are issued pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974.

44 FR 32352 (b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that the total dose to an individual (including exposures to licensed and unlicensed radioactive material and to other unlicensed sources of radiation, whether in the possession of the licensee or any other person, but not including exposures to radiation from natural background sources or medical diagnosis and therapy) does not exceed the standards of radiation protection prescribed in the regulations in this part.

40 FR 58847 (c) In accordance with recommendations of the Federal Radiation Council, approved by the President, persons engaged in activities under licenses issued by the Nuclear Regulatory Commission pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974 should, in addition to complying with the requirements set forth in this part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as low as is reasonably achievable. The term "as low as is reasonably achievable" means as low as is reasonably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest.

§ 20.2 Scope.

40 FR 8774 The regulations in this part apply to all persons who receive, possess, use, or transfer material licensed pursuant to the regulations in Parts 30 through 35, 40, or 70 of this chapter, including persons licensed to operate a production or utilization facility pursuant to Part 50 of this chapter.

§ 20.3 Definitions.

(a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

40 FR 42567 (4) "Calendar quarter" means not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January and subsequent calendar quarters shall be such that no day is included in more than one calendar quarter or omitted from inclusion within a calendar quarter. No licensee shall change the method observed by him of determining calendar quarters except at the beginning of a calendar year.

(5) "Commission" means the Nuclear Regulatory Commission or its duly authorized representatives;

(6) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(7) "Individual" means any human being;

(8) "Licensed material" means source material, special nuclear material, or by-product material received, possessed, used, or transferred under a general or specific license issued by the Commission pursuant to the regulations in this chapter;

(9) "License" means a license issued under the regulations in Part 30, 40, or 70 of this chapter. "Licensee" means the holder of such license;

(10) "Occupational dose" includes exposure of an individual to radiation (i) in a restricted area; or (ii) in the course of employment in which the individual's duties involve exposure to radiation; provided, that "occupational dose" shall not be deemed to include any exposure of an individual to radiation for the purpose of medical diagnosis or medical therapy of such individual.

(11) "Person" means (i) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Administration (except that the Administration shall be considered a person within the meaning of the regulations in this part to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission pursuant to section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244)), any State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (ii) any legal successor, representative, agent, or agency of the foregoing.

(12) "Radiation" means any or all of the following: alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but not sound or radio waves, or visible, infrared, or ultraviolet light;

(13) "Radioactive material" includes any such material whether or not subject to licensing control by the Commission;

(14) "Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area;

(15) "Source material" means (i) uranium or thorium, or any combination thereof, in any physical or chemical form; or (ii) ores which contain by weight one-twentieth of one percent (0.05%) or more of (a) uranium, (b) thorium or (c) any combination thereof. Source material does not include special nuclear material.

(16) "Special nuclear material" means (i) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (ii) any material artificially enriched by any of the foregoing but does not include source material;

(17) "Unrestricted area" means any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

(18) "Department" means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c) and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93–438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565 at 577–578, 42 U.S.C. 7151).

(19) "Termination" means the end of employment with the licensee or, in the case of individuals not employed by the licensee, the end of a work assignment in the licensee's restricted areas in a given calendar quarter, without expectation or specific scheduling of reentry into the licensee's restricted areas during the remainder of that calendar quarter.

(b) Definitions of certain other words and phrases as used in this part are set forth in other sections, including:

(1) "Airborne radioactivity area" defined in § 20.203;

(2) "Radiation area" and "high radiation area" defined in § 20.202;

(3) "Personnel monitoring equipment" defined in § 20.202;

(4) "Survey" defined in § 20.201;

(5) Units of measurement of dose (rad, rem) defined in § 20.4;

(6) Units of measurement of radioactivity defined in § 20.5.

§ 20.4 Units of radiation dose.

(a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad) = 0.001 rad.)

(c) The rem, as used in this part, is a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem) = 0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X– or gamma radiation;

(2) A dose of 1 rad due to X–, gamma, or beta radiation;

(3) A dose of 0.1 rad due to neutrons or high energy protons;

(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye;

If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in subparagraph (3) of this paragraph, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

NEUTRON FLUX DOSE EQUIVALENTS

Neutron energy (Mev)	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm²)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm² per sec.)
Thermal	970×10^6	670
0.0001	720×10^6	500
0.005	820×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

(d) For determining exposures to X or gamma rays up to 3 Mev, the dose limits specified in §§ 20.101 to 20.104, inclusive, may be assumed to be equivalent to the "air dose". For the purpose of this part "air dose" means that the dose is measured by a properly calibrated appropriate instrument in air at or near the body surface in the region of highest dosage rate.

§ 20.5 Units of radioactivity.

(a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie=3.7x10[10] disintegrations per second (dps)=2.2x10[12] disintegrations per minute (dpm). Commonly used submultiples of the curie are the millicurie and the microcurie:

(1) One millicurie (mCi) [1]=0.001 curie (Ci) [1]=3.7x10[7] dps.

(2) One microcurie (μCi) [1]=0.000001 curie=3.7x10[4] dps.

(b) [Deleted 40 FR 50704.]

(c) [Deleted 39 FR 23990.]

§ 20.6 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 20.7 Communications.

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part should be addressed to the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications, reports, and applications may be delivered in person at the Commission's offices at 1717 H Street NW., Washington, D.C.; or at 7920 Norfolk Avenue, Bethesda, Maryland.

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

§ 20.101 Radiation dose standards for individuals in restricted areas.

(a) In accordance with the provisions of § 20.102(a), and except as provided in paragraph (b) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of one calendar quarter from radioactive material and other sources of radiation a total occupational dose in excess of the standards specified in the following table:

	Rems per calendar quarter
1. Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	1¼
2. Hands and forearms; feet and ankles	18¾
3. Skin of whole body	7½

(b) A licensee may permit an individual in a restricted area to receive a total occupational dose to the whole body greater than that permitted under paragraph (a) of this section, provided:

(1) During any calendar quarter the total occupational dose to the whole body shall not exceed 3 rems; and

(2) The dose to the whole body, when added to the accumulated occupational dose to the whole body shall not exceed 5 (N−18) rems where "N" equals the individual's age in years at his last birthday; and

(3) The licensee has determined the individual's accumulated occupational dose to the whole body on Form NRC-4, or on a clear and legible record containing all the information required in that form; and has otherwise complied with the requirements of § 20.102. As used in paragraph (b), "Dose to the whole body" shall be deemed to include any dose to the whole body, gonads, active blood-forming organs, head and trunk, or lens of eye.

§ 20.102 Determination of prior dose.

(a) Each licensee shall require any individual, prior to first entry of the individual into the licensee's restricted area during each employment or work assignment under such circumstances that the individual will receive or is likely to receive in any period of one calendar quarter an occupational dose in excess of 25 percent of the applicable standards specified in § 20.101(a) and § 20.104(a), to disclose in a written, signed statement, either (1) that the individual had no prior occupational dose during the current calendar quarter, or (2) the nature and amount of any occupational dose which the individual may have received during that specifically identified current calendar quarter from sources of radiation possessed or controlled by other persons. Each licensee shall maintain records of such statements until the Commission authorizes their disposition.

(b) Before permitting, pursuant to § 20.101(b), any individual in a restricted area to receive an occupational radiation dose in excess of the standards specified in § 20.101(a), each licensee shall:

(1) Obtain a certificate on Form NRC-4, or on a clear and legible record containing all the information required in that form, signed by the individual showing each period of time after the individual attained the age of 18 in which the individual received an occupational dose of radiation; and

(2) Calculate on Form NRC-4 in accordance with the instructions appearing therein, or on a clear and legible record containing all the information required in that form, the previously accumulated occupational dose received by the individual and the additional dose allowed for that individual under § 20.101(b).

(c)(1) In the preparation of Form NRC-4, or a clear and legible record containing all the information required in that form, the licensee shall make a reasonable effort to obtain reports of the individual's previously accumulated occupational dose. For each period for which the licensee obtains such reports, the licensee shall use the dose shown in the report in preparing the form. In any case where a licensee is unable to obtain reports of the individual's occupational dose for a previous complete calendar quarter, it shall be assumed that the individual has received the occupational dose specified in whichever of the following columns apply:

Part of body	Column 1 Assumed exposure in rems for calendar quarters prior to Jan. 1, 1961	Column 2 Assumed exposure in rems for calendar quarters beginning on or after Jan 1, 1961
Whole body, gonads, active blood-forming organs, head and trunk, lens of eye	3¾	1¼

(2) The licensee shall retain and preserve records used in preparing Form NRC-4 until the Commission authorizes their disposition.

If calculation of the individual's accumulated occupational dose for all periods prior to January 1, 1961 yields a result higher than the applicable accumulated dose value for the individual as of that date, as specified in paragraph (b) of § 20.101, the excess may be disregarded.

§ 20.103 Exposure of individuals to concentrations of radioactive materials in air in restricted areas.

(a)(1) No licensee shall possess, use, or transfer licensed material in such a manner as to permit any individual in a restricted area to inhale a quantity of radioactive material in any period of one calendar quarter greater than the quantity which would result from inhalation for 40 hours per week for 13 weeks at uniform concentrations of radioactive material in air specified in Appendix B, Table I, Column 1.[1,2,3] If the radioactive material is of such form that intake by absorption through the skin is likely, individual exposures to radioactive material shall be controlled so that the uptake of radioactive material by any organ from either inhalation or absorption or both routes of intake [1,2] in any calendar quarter does not exceed that which would result from inhaling such radioactive material for 40 hours per week for 13 weeks at uniform concentrations specified in Appendix B, Table I, Column 1.

[1] Wherever possible, the appropriate unit should be written out as "curie(s)," "millicurie(s)," or "microcurie(s)," and the abbreviations should not be used.

** Amended 36 FR 1466.

43 FR 29210

Since the concentration specified for tritium oxide vapor assumes equal intakes by skin absorption and inhalation, the total intake permitted is twice that which would result from inhalation alone at the concentration specified for H 3 S in Appendix B, Table I, Column 1 for 40 hours per week for 13 weeks.

For radon-222, the limiting quantity is that inhaled in a period of one calendar year. For radioactive materials designated "Sub" in the "Isotope" column of the table, the concentration value specified is based upon exposure to the material as an external radiation source. Individual exposures to these materials may be accounted for as part of the limitation on individual dose in § 20.101. These nuclides shall be subject to the precautionary procedures required by § 20.103(b)(1).

Multiply the concentration values specified in appendix B, table I, column 1, by 6.3×10^{8} ml to obtain the quarterly quantity limit. Multiply the concentration value specified in appendix B, table I, column 1, by 2.5×10^{9} ml to obtain the annual quantity limit for Rn-222.

Footnotes 4 and 5 on page 20-4.

(2) No licensee shall possess, use, or transfer mixtures of U-234, U-235, and U-238 in soluble form in such a manner as to permit any individual in a restricted area to inhale a quantity of such material in excess of the intake limits specified in Appendix B, Table I, Column 1 of this part. If such soluble uranium is of a form such that absorption through the skin is likely, individual exposures to such material shall be controlled so that the uptake of such material by any organ from either inhalation or absorption or both routes of intake[4] does not exceed that which would result from inhaling such material at the limits specified in Appendix B, Table I, Column 1 and footnote 4 thereto.

41 FR 52300

(3) For purposes of determining compliance with the requirements of this section the licensee shall use suitable measurements of concentrations of radioactive materials in air for detecting and evaluating airborne radioactivity in restricted areas and in addition, as appropriate, shall use measurements of radioactivity in the body, measurements of radioactivity excreted from the body, or any combination of such measurements as may be necessary for timely detection and assessment of individual intakes of radioactivity by exposed individuals. It is assumed that an individual inhales radioactive material at the airborne concentration in which he is present unless he uses respiratory protective equipment pursuant to paragraph (c) of this section. When assessment of a particular individual's intake of radioactive material is necessary, intakes less than those which would result from inhalation for 2 hours in any one day or for 10 hours in any one week at uniform concentrations specified in Appendix B, Table I, Column 1 need not be included in such assessment, provided that for any assessment in excess of these amounts the entire amount is included.

(b)(1) The licensee shall, as a precautionary procedure, use process or other engineering controls, to the extent practicable, to limit concentrations of radioactive materials in air to levels below those which delimit an airborne radioactivity area as defined in § 20.203(d)(1)(ii).

(2) When it is impracticable to apply process or other engineering controls to limit concentrations of radioactive material in air below those defined in § 20.203(d)(1)(ii), other precautionary procedures, such as increased surveillance, limitation of working times, or provision of respiratory protective equipment, shall be used to maintain intake of radioactive material by any individual within any period of seven consecutive days as far below that intake of radioactive material which would result from inhalation of such material for 40 hours at the uniform concentrations specified in Appendix B, Table I, Column 1 as is reasonably achievable. Whenever the intake of radioactive material by any individual exceeds this 40-hour control measure, the licensee shall make such evaluations and take such actions as are necessary to assure against recurrence. The licensee shall maintain records of such occurrences, evaluations, and actions taken in a clear and readily identifiable form suitable for summary review and evaluation.

41 FR 52300

(c) When respiratory protective equipment is used to limit the inhalation of airborne radioactive material pursuant to paragraph (b)(2) of this section, the licensee may make allowance for such use in estimating exposures of individuals to such materials provided that such equipment is used as stipulated in Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection."[5]

(d) Notwithstanding the provisions of paragraphs (b) and (c) of this section, the Commission may impose further restrictions:

(1) On the extent to which a licensee may make allowance for use of respirators in lieu of provision of process, containment, ventilation, or other engineering controls, if application of such controls is found to be practicable; and

(2) As might be necessary to assure that the respiratory protective program of the licensee is adequate in limiting exposures of personnel to airborne radioactive materials.

(e) The licensee shall notify, in writing, the Director of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D at least 30 days before the date that respiratory protective equipment is first used under the provisions of this section.

(f) A licensee who was authorized to make allowance for use of respiratory protective equipment prior to December 29, 1976 shall bring his respiratory protective program into conformance with the requirements of paragraph (c) of this section within one year of that date, and is exempt from the requirement of paragraph (e) of this section.

25 FR 10914

§ 20.104 Exposure of minors.

(a) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area who is under 18 years of age, to receive in any period of one calendar quarter from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in the table in paragraph (a) of § 20.101.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area, who is under 18 years of age to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than a week.

41 FR 52300

(c) The provisions of §§ 20.103(b)(2) and 20.103(c) shall apply to exposures subject to paragraph (b) of this section except that the references in §§ 20.103(b)(2) and 20.103(c) to Appendix B, Table I, Column 1 shall be deemed to be references to Appendix B, Table II, Column 1.

25 FR 10914

§ 20.105 Permissible levels of radiation in unrestricted areas.

(a) There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

(b) Except as authorized by the Commission pursuant to paragraph (a) of this section, no licensee shall possess, use or transfer licensed material in such a manner as to create in any unrestricted area from radioactive material and other sources of radiation in his possession:

(1) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(2) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days.

29 FR 14434

§ 20.106 Radioactivity in effluents to unrestricted areas.

(a) A licensee shall not possess, use, or transfer licensed material so as to release to an unrestricted area radioactive material in concentrations which exceed

[4] Significant intake by ingestion or injection is presumed to occur only as a result of circumstances such as accident, inadvertence, poor procedure, or similar special conditions. Such intakes must be evaluated and accounted for by techniques and procedures as may be appropriate to the circumstances of the occurrence. Exposures so evaluated shall be included in determining whether the limitation on individual exposures in § 20.103(a)(1) has been exceeded.

[5] Regulatory guidance on assessment of individual intakes of radioactive material is given in Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program," single copies of which are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

[5] This incorporation by reference provision was approved by the Director of the Federal Register on October 19, 1976. Single copies of Regulatory Guide 8.15 are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

the limits specified in Appendix "B", Table II of this part, except as authorized pursuant to § 20.302 or paragraph (b) of this section. For purposes of this section concentrations may be averaged over a period not greater than one year.

(b) An application for a license or amendment may include proposed limits higher than those specified in paragraph (a) of this section. The Commission will approve the proposed limits if the applicant demonstrates:

(1) That the applicant has made a reasonable effort to minimize the radioactivity contained in effluents to unrestricted areas; and

(2) That it is not likely that radioactive material discharged in the effluent would result in the exposure of an individual to concentrations of radioactive material in air or water exceeding the limits specified in Appendix "B", Table II of this part.

(c) An application for higher limits pursuant to paragraph (b) of this section shall include information demonstrating that the applicant has made a reasonable effort to minimize the radioactivity discharged in effluents to unrestricted areas, and shall include, as pertinent:

(1) Information as to flow rates, total volume of effluent, peak concentration of each radionuclide in the effluent, and concentration of each radionuclide in the effluent averaged over a period of one year at the point where the effluent leaves a stack, tube, pipe, or similar conduit;

29 FR 14434

(2) A description of the properties of the effluents, including:

(i) chemical composition;

(ii) physical characteristics, including suspended solids content in liquid effluents, and nature of gas or aerosol for air effluents;

(iii) the hydrogen ion concentrations (p^H) of liquid effluents; and

(iv) the size range of particulates in effluents released into air.

(3) A description of the anticipated human occupancy in the unrestricted area where the highest concentration of radioactive material from the effluent is expected, and, in the case of a river or stream, a description of water uses downstream from the point of release of the effluent.

(4) Information as to the highest concentration of each radionuclide in an unrestricted area, including anticipated concentrations averaged over a period of one year:

(i) In air at any point of human occupancy; or

(ii) In water at points of use downstream from the point of release of the effluent.

(5) The background concentration of radionuclides in the receiving river or stream prior to the release of liquid effluent.

(6) A description of the environmental monitoring equipment, including sensitivity of the system, and procedures and calculations to determine concentrations of radionuclides in the unrestricted area and possible reconcentrations of radionuclides.

(7) A description of the waste treatment facilities and procedures used to reduce the concentration of radionuclides in effluents prior to their release.

(d) For the purposes of this section the concentration limits in Appendix "B", Table II of this part shall apply at the boundary of the restricted area. The concentration of radioactive material discharged through a stack, pipe or similar conduit may be determined with respect to the point where the material leaves the conduit. If the conduit discharges within the restricted area, the concentration at the boundary may be determined by applying appropriate factors for dilution, dispersion, or decay between the point of discharge and the boundary.

29 FR 14434

(e) In addition to limiting concentrations in effluent streams, the Commission may limit quantities of radioactive materials released in air or water during a specified period of time if it appears that the daily intake of radioactive material from air, water, or food by a suitable sample of an exposed population group, averaged over a period not exceeding one year, would otherwise exceed the daily intake resulting from continuous exposure to air or water containing one-third the concentration of radioactive materials specified in Appendix "B", Table II of this part.

(f) The provisions of this section do not apply to disposal of radioactive material into sanitary sewerage systems, which is governed by § 20.303

§ 20.107 Medical diagnosis and therapy.

Nothing in the regulations in this part shall be interpreted as limiting the intentional exposure of patients to radiation for the purpose of medical diagnosis or medical therapy.

§ 20.108 Orders requiring furnishing of bio-assay services.

Where necessary or desirable in order to aid in determining the extent of an individual's exposure to concentrations of radioactive material, the Commission may incorporate appropriate provisions in any license, directing the licensee to make available to the individual appropriate bio-assay services and to furnish a copy of the reports of such services to the Commission.

25 FR 10914

Precautionary Procedures

§ 20.201 Surveys.

(a) As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.

(b) Each licensee shall make or cause to be made such surveys as may be necessary for him to comply with the regulations in this part.

§ 20.202 Personnel monitoring.

(a) Each licensee shall supply appropriate personnel monitoring equipment to, and shall require the use of such equipment by:

(1) Each individual who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 25 percent of the applicable value specified in paragraph (a) of § 20.101.

(2) Each individual under 18 years of age who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 5 percent of the applicable value specified in paragraph (a) of § 20.101.

(3) Each individual who enters a high radiation area.

(b) As used in this part,

(1) "Personnel monitoring equipment" means devices designed to be worn or carried by an individual for the purpose of measuring the dose received (e. g., film badges, pocket chambers, pocket dosimeters, film rings, etc.);

25 FR 10914

(2) "Radiation area" means any area, accessible to personnel, in which there exists radiation, originating in whole or in part within licensed material, at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirems;

(3) "High radiation area" means any area, accessible to personnel, in which there exists radiation originating in whole or in part within licensed material at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

35 FR 5033

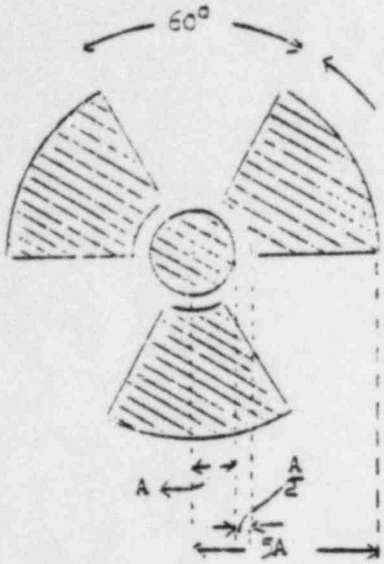
§ 20.203 Caution signs, labels, signals, and controls.

(a) *General.* (1) Except as otherwise authorized by the Commission, symbols prescribed by this section shall use the conventional radiation caution colors (magenta or purple on yellow background). The symbol prescribed by this section is the conventional three-bladed design:

RADIATION SYMBOL

1 Cross-hatched area is to be magenta or purple.

2. Background is to be yellow.



(2) In addition to the contents of signs and labels prescribed in this section, licensees may provide on or near such signs and labels any additional information which may be appropriate in aiding individuals to minimize exposure to radiation or to radioactive material.

(b) *Radiation areas.* Each radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]
RADIATION AREA

(c) *High radiation areas.* (1) Each high radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]
HIGH RADIATION AREA

35 FR 5033

(2) Each entrance or access point to a high radiation area shall be:

(i) Equipped with a control device which shall cause the level of radiation to be reduced below that at which an individual might receive a dose of 100 millirems in 1 hour upon entry into the area; or

(ii) Equipped with a control device which shall energize a conspicuous visible or audible alarm signal in such a manner that the individual entering the high radiation area and the licensee or a supervisor of the activity are made aware of the entry; or

(iii) Maintained locked except during periods when access to the area is required, with positive control over each individual entry.

(3) The controls required by subparagraph (2) of this paragraph shall be established in such a way that no individual will be prevented from leaving a high radiation area.

(4) In the case of a high radiation area established for a period of 30 days or less, direct surveillance to prevent unauthorized entry may be substituted for the controls required by subparagraph (2) of this paragraph.

(5) Any licensee, or applicant for a license, may apply to the Commission for approval of methods not included in subparagraphs (2) and (4) of this paragraph for controlling access to high radiation areas. The Commission will approve the proposed alternatives if the licensee or applicant demonstrates that the alternative methods of control will prevent unauthorized entry into a high radiation area, and that the requirement of subparagraph (3) of this paragraph is met.

35 FR 5033

42 FR 64619

(6) Each area in which there may exist radiation levels in excess of 500 rems in one hour at one meter from a sealed radio-active source[1] that is used to irradiate materials shall[2]:

(i) Have each entrance or access point equipped with entry control devices which shall function automatically to prevent any individual from inadvertently entering the area when such radiation levels exist; permit deliberate entry into the area only after a control device is actuated that shall cause the radiation level within the area, from the sealed source, to be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and prevent operation of the source if the source would produce radiation levels in the area that could result in a dose to an individual in excess of 100 mrem in one hour. The entry control devices required by this paragraph (c)(6) shall be established in such a way that no individual will be prevented from leaving the area.

(ii) Be equipped with additional control devices such that upon failure of the entry control devices to function as required by paragraph (c)(6)(i) of this section the radiation level within the area, from the sealed source, shall be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and visible and audible alarm signals shall be generated to make an individual attempting to enter the area aware of the hazard and the licensee or at least one other individual, who is familiar with the activity and prepared to render or summon assistance, aware of such failure of the entry control devices.

(iii) Be equipped with control devices such that upon failure or removal of physical radiation barriers other than the source's shielded storage container the radiation level from the source shall be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and visible and audible alarm signals shall be generated to make potentially affected individuals aware of the hazard and the licensee or at least one other individual, who is familiar with the activity and prepared to render or summon assistance, aware of the failure or removal of the physical barrier. When the shield for the stored source is a liquid, means shall be provided to monitor the integrity of the shield and to signal, automatically, loss of adequate shielding. Physical radiation barriers that comprise permanent structural components, such as walls, that have no credible probability of failure or removal in ordinary circumstances need not meet the requirements of this paragraph (c)(6)(iii).

42 FR 64619

(iv) Be equipped with devices that will automatically generate visible and audible alarm signals to alert personnel in the area before the source can be put into operation and in sufficient time for any individual in the area to operate a clearly identified control device which shall be installed in the area and which can prevent the source from being put into operation.

(v) Be controlled by use of such administrative procedures* and such devices as are necessary to assure that the area is cleared of personnel prior to each use of the source preceding which use it might have been possible for an individual to have entered the area.

(vi) Be checked by a physical radiation measurement to assure that prior to the first individual's entry into the area after any use of the source, the radiation level from the source in the area is below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour.

(vii) Have entry control devices required in paragraph (c)(6)(i) of this section which have been tested for proper functioning prior to initial operation with such source of radiation on any day that operations are not uninterruptedly continued from the previous day or before resuming operations after any unintended interruption, and for which records are kept of the dates, times, and results of such tests of func-

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[1] Or "Danger."

[1] This paragraph (c)(6) does not apply to radioactive sources that are used in teletherapy, in radiography, or in completely self-shielded irradiators in which the source is both stored and operated within the same shielding radiation barrier and, in the designed configuration of the irradiator, is always physically inaccessible to any individual and cannot create high levels of radiation in an area that is accessible to any individual. This paragraph (c)(6) also does not apply to sources from which the radiation is incidental to some other use nor to nuclear reactor generated radiation other than radiation from byproduct, source, or special nuclear materials that are used in sealed sources in non-self-shielded irradiators.

[2] These requirements apply after Mar. 14, 1978. Each person licensed to conduct activities to which this paragraph (c)(6) applies and who is not in compliance with the provisions of this paragraph on Mar. 14, 1978, shal file with the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, on or before June 14, 1978, information describing in detail the actions taken or to be taken to achieve compliance with this paragraph by Dec. 14, 1978, and may continue activities in conformance with present license conditions and the provisions of the previously effective § 20.203 until such compliance is achieved. For such persons compliance must be achieved not later than Dec. 14, 1978.

‡ Amended 43 FR 2167.

*Amended. *

tion. No operations other than those necessary to place the source in safe condition or to effect repairs on controls shall be conducted with such source unless control devices are functioning properly. The licensee shall submit an acceptable schedule for more complete periodic tests of the entry control and warning systems to be established and adhered to as a condition of the license.

(viii) Have those entry and exit portals that are used in transporting materials to and from the irradiation area, and that are not intended for use by individuals, controlled by such devices and administrative procedures as are necessary to physically protect and warn against inadvertent entry by any individual through such portals. Exit portals for processed materials shall be equipped to detect and signal the presence of loose radiation sources that are carried toward such an exit and to automatically prevent such loose sources from being carried out of the area.

42 FR 54619

(7) Licensees with, or applicants for, licenses for radiation sources that are within the purview of paragraph (c)(6) of this section, and that must be used in a variety of positions or in peculiar locations, such as open fields or forests, that make it impracticable to comply with certain requirements of paragraph (c)(6) of this section, such as those for the automatic control of radiation levels, may apply to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, for approval, prior to use of safety measures that are alternative to those specified* in paragraph (c)(6) of this section, and that will provide at least an equivalent degree of personnel protection in the use of such sources. At least one of the alternative measures must include an entry-preventing interlock control based on a physical measurement of radiation that assures the absence of high radiation levels before an individual can gain access to an area where such sources are used.

(d) *Airborne radioactivity areas.* (1) As used in the regulations in this part, "airborne radioactivity area" means (i) any room, enclosure, or operating area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations in excess of the amounts specified in Appendix B, Table I, Column 1 of this part; or (ii) any room, enclosure, or operating area in which airborne radioactive material composed wholly or partly of licensed material exists in concentrations which, averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in Appendix B, Table I, Column 1 of this part.

(2) Each airborne radioactivity area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

AIRBORNE RADIOACTIVITY AREA

(e) *Additional requirements.* (1) Each area or room in which licensed material is used or stored and which contains any radioactive material (other than natural uranium or thorium) in an amount exceeding 10 times the quantity of such material specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

RADIOACTIVE MATERIAL(S)

(2) Each area or room in which natural uranium or thorium is used or stored in an amount exceeding one-hundred times the quantity specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

RADIOACTIVE MATERIAL(S)

(f) *Containers.* (1) Except as provided in subparagraph (3) of this paragraph, each container of licensed material shall bear a durable, clearly visible label identifying the radioactive contents.

(2) A label required pursuant to subparagraph (1) of this paragraph shall bear the radiation caution symbol and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL". It shall also provide sufficient information[1] to permit individuals handling or using the containers, or working in the vicinity thereof, to take precautions to avoid or minimize exposures.

(3) Notwithstanding the provisions of subparagraph (1) of this paragraph, labeling is not required:

31 FR 10514

(i) For containers that do not contain licensed materials in quantities greater than the applicable quantities listed in Appendix C of this part.

(ii) For containers containing only natural uranium or thorium in quantities no greater than 10 times the applicable quantities listed in Appendix C of this part.

(iii) For containers that do not contain licensed materials in concentrations greater than the applicable concentrations listed in Column 2, Table I, Appendix B of this part.

(iv) For containers when they are attended by an individual who takes the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established by the regulations in this part.

(v) For containers when they are in transport and packaged and labeled in accordance with regulations of the • Department of Transportation.

(vi) For containers which are accessible[2] only to individuals authorized to handle or use them, or to work in the vicinity thereof, provided that the contents are identified to such individuals by a readily available written record.

(vii) For manufacturing or process equipment, such as nuclear reactors, reactor components, piping, and tanks.

43 FR 22171

(4) Each licensee shall, prior to disposal of an empty uncontaminated container to unrestricted areas, remove or deface the radioactive material label or otherwise clearly indicate that the container no longer contains radioactive materials.

[1] Or "Danger".

*Amended.

[1] As appropriate, the information will include radiation levels, kinds of material, estimate of activity, date for which activity is estimated, mass enrichment, etc.

[2] For example, containers in locations such as water-filled canals, storage vaults, or hot cells.

• Amended 34 FR 19546.

§ 20.204 Same: exceptions.

Notwithstanding the provisions of § 20.203,

(a) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level twelve inches from the surface of the source container or housing does not exceed five millirem per hour.

(b) Rooms or other areas in hospitals are not required to be posted with caution signs, and control of entrance or access thereto pursuant to § 20.203(c) is not required, because of the presence of patients containing byproduct material provided that there are personnel in attendance who will take the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the limits established in the regulations in this part.

(c) Caution signs are not required to be posted at areas or rooms containing radioactive materials for periods of less than eight hours provided that (1) the materials are constantly attended during such periods by an individual who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established in the regulations in this part and: (2) such area or room is subject to the licensee's control.

(d) A room or other area is not required to be posted with a caution sign, and control is not required for each entrance or access point to a room or other area which is a high radiation area solely because of the presence of radioactive materials prepared for transport and packaged and labeled in accordance with regulations of the Department of Transportation.

§ 20.205 Procedures for picking up, receiving, and opening packages.

(a)(1) Each licensee who expects to receive a package containing quantities of radioactive material in excess of the Type A quantities specified in paragraph (b) of this section shall:

(i) If the package is to be delivered to the licensee's facility by the carrier, make arrangements to receive the package when it is offered for delivery by the carrier; or

(ii) If the package is to be picked up by the licensee at the carrier's terminal, make arrangements to receive notification from the carrier of the arrival of the package, at the time of arrival.

(2) Each licensee who picks up a package of radioactive material from a carrier's terminal shall pick up the package expeditiously upon receipt of notification from the carrier of its arrival.

(b)(1) Each licensee, upon receipt of a package of radioactive material, shall monitor the external surfaces of the package for radioactive contamination caused by leakage of the radioactive contents, except:

(i) Packages containing no more than the exempt quantity specified in the table in this paragraph;

(ii) Packages containing no more than 10 millicuries of radioactive material consisting solely of tritium, carbon-14, sulfur-35, or iodine-125;

(iii) Packages containing only radioactive material as gases or in special form;

(iv) Packages containing only radioactive material in other than liquid form (including Mo-99/Tc-99m generators) and not exceeding the Type A quantity limit specified in the table in this paragraph; and

(v) Packages containing only radionuclides with half-lives of less than 30 days and a total quantity of no more than 100 millicuries.

The monitoring shall be performed as soon as practicable after receipt, but no later than three hours after the package is received at the licensee's facility if received during the licensee's normal working hours, or eighteen hours if received after normal working hours.

(2) If removable radioactive contamination in excess of 0.01 microcuries (22,000 disintegrations per minute) per 100 square centimeters of package surface is found on the external surfaces of the package, the licensee shall immediately notify the final delivering carrier and, by telephone and telegraph, mailgram, or facsimile,† the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office shown in Appendix D.

TABLE OF EXEMPT AND TYPE A QUANTITIES

Transport group [1]	Exempt quantity limit (in millicuries)	Type A quantity limit (in curies)
I	.01	0.001
II	0.1	0.050
III	1	3
IV	1	20
V	1	20
VI	1	1000
VII	25,000	1000
Special Form	1	20

(c)(1) Each licensee, upon receipt of a package containing quantities of radioactive material in excess of the Type A quantities specified in paragraph (b) of this section, other than those transported by exclusive use vehicle, shall monitor the radiation levels external to the package. The package shall be monitored as soon as practicable after receipt, but no later than three hours after the package is received at the licensee's facility if received during the licensee's normal working hours, or 18 hours if received after normal working hours.

(2) If radiation levels are found on the external surface of the package in excess of 200 millirem per hour, or at three feet from the external surface of the package in excess of 10 millirem per hour, the licensee shall immediately notify by telephone and telegraph, mailgram, or facsimile, the director of the appropriate NRC Regional Office listed in Appendix D, and the final delivering carrier.

(d) Each licensee shall establish and maintain procedures for safely opening packages in which licensed material is received, and shall assure that such procedures are followed and that due consideration is given to special instructions for the type of package being opened.

§ 20.206 Instruction of personnel.

Instructions required for individuals working in or frequenting any portion of a restricted area are specified in § 19.12 of this chapter.

[1] The definitions of "transport group" and "special form" are specified in § 71.4 of this chapter.

†Amended 41 FR 16445.

§ 20.207 Storage and control of licensed materials in unrestricted areas.

(a) Licensed materials stored in an unrestricted area shall be secured from unauthorized removal from the place of storage.

(b) Licensed materials in an unrestricted area and not in storage shall be tended under the constant surveillance and immediate control of the licensee.

WASTE DISPOSAL

§ 20.301 General requirement.

No licensee shall dispose of licensed material except:

(a) By transfer to an authorized recipient as provided in the regulations in Part 30, 40, or 70 of this chapter, whichever may be applicable; or

(b) As authorized pursuant to § 20.302; or

(c) As provided in § 20.303, applicable to the disposal of licensed material by release into sanitary sewerage systems, or in § 20.106 (Radioactivity in effluents to unrestricted areas).

§ 20.302 Method for obtaining approval of proposed disposal procedures.

*(a) Any licensee or applicant for a license may apply to the Commission for approval of proposed procedures to dispose of licensed material in a manner not otherwise authorized in the regulations in this chapter. Each application should include a description of the licensed material and any other radioactive material involved, including the quantities and kinds of such material and the levels of radioactivity involved, and the proposed manner and conditions of disposal. The application should also include an analysis and evaluation of pertinent information as to the nature of the environment, including topographical, geological, meteorological, and hydrological characteristics; usage of ground and surface waters in the general area; the nature and location of other potentially affected facilities; and procedures to be observed to minimize the risk of unexpected or hazardous exposures.

*(b) The Commission will not approve any application for a license to receive licensed material from other persons for disposal on land not owned by the Federal government or by a State government.

(c) The Commission will not approve any application for a license for disposal of licensed material at sea unless the applicant shows that sea disposal offers less harm to man or the environment than other practical alternative methods of disposal.

§ 20.303 Disposal by release into sanitary sewerage systems.

No licensee shall discharge licensed material into a sanitary sewerage system unless:

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of subparagraphs (1) or (2) of this paragraph:

(1) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of this part; and

(d) The gross quantity of licensed and other radioactive material released into the sewerage system by the licensee does not exceed one curie per year.

Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

§ 20.305 Treatment or disposal by incineration.

No licensee shall treat or dispose of licensed material by incineration except as specifically approved by the Commission pursuant to §§ 20.106(b) and 20.302.

RECORDS, REPORTS, AND NOTIFICATION

§ 20.401 Records of surveys, radiation monitoring, and disposal.

(a) Each licensee shall maintain records showing the radiation exposures of all individuals for whom personnel monitoring is required under § 20.202 of the regulations in this part. Such records shall be kept on Form NRC-5, in accordance with the instructions contained in that form or on clear and legible records containing all the information required by Form NRC-5. The doses entered on the forms or records shall be for periods of time not exceeding one calendar quarter.

(b) Each licensee shall maintain records in the same units used in this part, showing the results of surveys required by § 20.301(b), monitoring required by §§ 20.205(b) and 20.205(c), and disposals made under §§ 20.302, 20.303, and deleted § 20.304.[1]

(c)(1) Records of individual exposure to radiation and to radioactive material which must be maintained pursuant to the provisions of paragraph (a) of this section and records of bioassays, including results of whole body counting examinations, made pursuant to § 20.108, shall be preserved until the Commission authorizes disposition.

(2) Records of the results of surveys and monitoring which must be maintained pursuant to paragraph (b) of this section shall be preserved for two years after completion of the survey except that the following records shall be maintained until the Commission authorizes their disposition: (i) records of the results of surveys to determine compliance with § 20.103(a); (ii) in the absence of personnel monitoring data, records of the results of surveys to determine external radiation dose; and (iii) records of the results of surveys used to evaluate the release of radioactive effluents to the environment.

(3) Records of disposal of licensed material made pursuant to §§ 20.302, 20.303, and deleted § 20.304[1] are to be maintained until the Commission authorizes their disposition.

(4) Records which must be maintained pursuant to this part may be the original or a reproduced copy or microform if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by Commission regulations.

(5) If there is a conflict between the Commission's regulations in this part, license condition, or technical specification, or other written Commission approval or authorization pertaining to the retention period for the same type of record, the retention period specified in the regulations in this part for such records shall apply unless the Commission pursuant to § 20.501, has granted a specific exemption from the record retention requirements specified in the regulations in this part.

§ 20.402 Reports of theft or loss of licensed material.

(a) Each licensee shall report by telephone† to the Director of the appropriate Nuclear Regulatory Commission of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D, immediately after its occurrence becomes known to the licensee, any loss or theft of licensed material in such quantities and under such circumstances that it appears to the licensee that a substantial hazard may result to persons in unrestricted areas.

(b) Each licensee who is required to make a report pursuant to paragraph (a) of this section shall, within thirty (30) days after he learns of the loss or theft, make a report in writing to the appropriate NRC Regional Office listed in Appen-

*Redesignated 36 FR 23138.

[1] Section 20.304 provided for burial of small quantities of licensed materials in soil. Notice of its deletion appears in the Federal Register of October 30, 1980 (45 FR ——).

†Amended 42 FR 43965.

dix D with copies to the Director of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, setting forth the following information:

(1) A description of the licensed material involved, including kind, quantity, chemical, and physical form;

(2) A description of the circumstances under which the loss or theft occurred;

(3) A statement of disposition or probable disposition of the licensed material involved;

(4) Radiation exposures to individuals, circumstances under which the exposures occurred, and the extent of possible hazard to persons in unrestricted areas;

(5) Actions which have been taken, or will be taken, to recover the material; and

(6) Procedures or measures which have been or will be adopted to prevent a recurrence of the loss or theft of licensed material.

(c) Subsequent to filing the written report the licensee shall also report any substantive additional information on the loss or theft which becomes available to the licensee, within 30 days after he learns of such information.

(d) Any report filed with the Commission pursuant to this section shall be so prepared that names of individuals who may have received exposure to radiation are stated in a separate part of the report.

34 FR 7500

§ 20.403 Notifications of incidents.

(a) *Immediate notification.* Each licensee shall immediately notify by telephone and telegraph, mailgram, or facsimile, the Director of the appropriate NRC Regional Office listed in Appendix D of any incident involving byproduct, source, or special nuclear material possessed by him and which may have caused or threatens to cause:

41 FR 16446

(1) Exposure of the whole body of any individual to 25 rems or more of radiation; exposure of the skin of the whole body of any individual of 150 rems or more of radiation; or exposure of the feet, ankles, hands or forearms of any individual to 375 rems or more of radiation; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 5,000 times the limits specified for such materials in Appendix B, Table II; or

(3) A loss of one working week or more of the operation of any facilities affected; or

(4) Damage to property in excess of *$200,000. ‡

27 FR 5906

(b) *Twenty-four hour notification.* Each licensee shall within 24 hours notify by telephone and telegraph, mailgram, or facsimile, the Director of the appropriate NRC Regional Office listed in Appendix D of any incident involving licensed material possessed by him and which may have caused or threatens to cause:

41 FR 16446

(1) Exposure of the whole body of any individual to 5 rems or more of radiation; exposure of the skin of the whole body of any individual to 30 rems or more of radiation; or exposure of the feet, ankles, hands, or forearms to 75 rems or more of radiation; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 500 times the limits specified for such materials in Appendix B, Table II; or

(3) A loss of one day or more of the operation of any facilities affected; or

(4) Damage to property in excess of $2,000.‡

27 FR 5906

(c) Any report filed with the Commission pursuant to this section shall be prepared so that names of individuals who have received exposure to radiation will be stated in a separate part of the report.

28 FR 6822

(d) For nuclear power reactors licensed under § 50.21 or § 50.22, the incidents included in paragraph (a) and paragraph (b) in this section shall in addition be reported pursuant to § 50.72.

45 FR 13434

‡Amended 42 FR 43965.

*Correction

§ 20.404 [Deleted 38 FR 22220.]

42 FR 20138

§ 20.405 Reports of overexposures and excessive levels and concentrations.

(a) In addition to any notification required by § 20.403, each licensee shall make a report in writing within 30 days to the appropriate NRC Regional Office listed in Appendix D with a copy to the Director of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, of:

41 FR 52300

(1) each exposure of an individual to radiation in excess of the applicable limits in §§ 20.101 or 20.104 (a) or the license; (2) each exposure of an individual to radioactive material in excess of the applicable limits in §§ 20.103(a)(1), 20.103(a)(2), 20.104(b) or the license; (3) levels of radiation or concentrations of radioactive material in a restricted area in excess of any other applicable limit in the license; (4) any incident for which notification is required by § 20.403; and (5) levels of radiation or concentrations of radioactive material (whether or not involving excessive exposure of any individual) in an unrestricted area in excess of ten times any applicable limit set forth in this part or in the license. Each report required under this paragraph shall describe the extent of exposure of individuals** to radiation or to radioactive material, including estimates of each individual's exposure as required by paragraph (b) of this section; levels of radiation and concentrations of radioactive material involved; the cause of the exposure, levels or concentrations; and corrective steps taken or planned to assure against a recurrence.

35 FR 16067

(b) Any report filed with the Commission pursuant to this section shall include for each individual exposed the name, social security number, and date of birth; and an estimate of the individual's exposure. The report shall be prepared so that this information is stated in a separate part of the report.

(c) [Deleted 38 FR 22220.]

§ 20.406 [Deleted 38 FR 22220.]

43 FR 44827

§ 20.407 Personnel monitoring reports.

Each person described in § 20.408 of this part shall, within the first quarter of each calendar year, submit to the Director of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, the reports specified in paragraphs (a) and (b) of this section covering the preceding calendar year.[1] All other persons specifically licensed by the Commission shall, within the first quarter of calendar years 1979 and 1980, submit to the Director of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, the reports specified in paragraphs (a) and (b) of this section covering the preceding calendar years 1978 and 1979.[2]‡

(a) A report of either (1) the total number of individuals for whom personnel monitoring was required under §§ 20.202(a) or 34.33(a) of this chapter during the calendar year; or (2) the total number of individuals for whom personnel monitoring was provided during the calendar year: *Provided, however,* That such total includes at least the number of individuals required to be reported under paragraph (a)(1) of this section. The report shall indicate whether it is submitted in accordance with paragraph (a)(1) or (a)(2) of this section. If personnel monitoring was not required to be provided to any individual by the licensee under §§ 20.202(a) or 34.33(a) of this chapter during the calendar year, the licensee shall submit a negative report indicating that such personnel monitoring was not required.

(b) A statistical summary report of the personnel monitoring information recorded by the licensee for individuals for whom personnel monitoring was either required or provided, as described in paragraph (a) of this section, indicating the number of individuals whose total whole body exposure recorded during the previous calendar year was in each of the following estimated exposure ranges:

Estimated whole body exposure range (rems)[1]	Number of individuals in each range
No measurable exposure	
Measurable exposure less than 0.1	
0.1 to 0.25	
0.25 to 0.5	
0.5 to 0.75	
0.75 to 1	
1 to 2	
2 to 3	
3 to 4	
4 to 5	
5 to 6	
6 to 7	
7 to 8	
8 to 9	
9 to 10	
10 to 11	
11 to 12	
12	

[1] Individual values exactly equal to the values separating exposure ranges shall be reported in the higher range.

The low exposure range data are required in order to obtain better information about the exposures actually recorded. This section does not require improved measurements.

§ 20.408 Reports of personnel monitoring on termination of employment or work.

(a) This section applies to each person licensed by the Commission to:

(1) Operate a nuclear reactor designed to produce electrical or heat energy pursuant to § 50.21(b) or § 50.22 of this chapter or a testing facility as defined in § 50.2(r) of this chapter;

(2) Possess or use byproduct material for purposes of radiography pursuant to Parts 30 and 34 of this chapter;

(3) Process or use at any one time, for purposes of fuel processing, fabrication, or reprocessing, special nuclear material in a quantity exceeding 5,000 grams of contained uranium-235, uranium-233, or plutonium or any combination thereof pursuant to Part 70 of this chapter; or

(4) Possess or use at any one time, for processing or manufacturing for distribution pursuant to part 30, 32, or 33 of this chapter, byproduct material in quantities exceeding any one of the following quantities:

[1] A licensee whose license expires or terminates prior to, or on the last day of the calendar year, shall submit reports at the expiration or termination of the license, covering that part of the year during which the license was in effect.

[2] The Commission will evaluate the data obtained for 1978 and 1979 pursuant to this paragraph, and the benefits derived therefrom and may take action, including publication of notice of proposed rulemaking, to extend or otherwise modify this reporting requirement.

‡Amended 42 FR 43965.

**Amended 43 FR 29270.

Radionuclide [1]	Quantity in curies
Cesium-137	1
Cobalt-60	1
Gold-198	100
Iodine-131	1
Iridium-192	10
Krypton-85	1,000
Promethium-147	10
Technetium-99m	1,000

[1] The Commission may require, as a license condition, or by rule, regulation or order pursuant to § 20.502, reports from licensees who are licensed to use radionuclides not on this list, in quantities sufficient to cause comparable radiation levels.

43 FR 44827

(b) When an individual terminates employment with a licensee described in paragraph (a) of this section, or an individual assigned to work in such a licensee's facility but not employed by the licensee, completes the work assignment in the licensee's facility, the licensee shall furnish to the Director of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, a report of the individual's exposures to radiation and radioactive material, incurred during the period of employment or work assignment in the licensee's facility, containing information recorded by the licensee pursuant to §§ 20.401(a) and 20.108. Such report shall be furnished within 30 days after the exposure of the individual has been determined by the licensee or 90 days after the date of termination of employment or work assignment, whichever is earlier.

38 FR 22220

§ 20.409 Notifications and reports to individuals.

(a) Requirements for notifications and reports to individuals of exposure to radiation or radioactive material are specified in § 19.13 of this chapter.

(b) When a licensee is required pursuant to §§ 20.405 or 20.408 to report to the Commission any exposure of an individual to radiation or radioactive material, the licensee shall also notify the individual. Such notice shall be transmitted at a time not later than the transmittal to the Commission, and shall comply with the provisions of § 19.13(a) of this chapter.

EXCEPTIONS AND ADDITIONAL REQUIREMENTS

25 FR 10914

§ 20.501 Applications for exemptions.

The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

25 FR 10914

§ 20.502 Additional requirements.

The Commission may, by rule, regulation, or order, impose upon any licensee such requirements, in addition to those established in the regulations in this part, as it deems appropriate or necessary to protect health or to minimize danger to life or property.

40 FR 8774

§ 20.601 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Atomic Energy Act of 1954, as amended, or Title II of the Energy Reorganization Act of 1974, or any regulation or order issued thereunder. A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of section 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act, or section 206 of the Energy Reorganization Act of 1974, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

APPENDIX A [Reserved]

NOTE.—The reporting and record keeping requirements contained in this part have been approved by the General Accounting Office under B-180225 (R0043), (R0044), and (R0084).

APPENDIX B

Concentrations in Air and Water Above Natural Background

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-5}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-8}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-8}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		* I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 244	S	4×10^{-6}	1×10^{-1}	1×10^{-7}	5×10^{-3}
		I	2×10^{-5}	1×10^{-1}	8×10^{-7}	5×10^{-3}
Antimony (51)	Sb 122	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub[2]	6×10^{-3}		1×10^{-4}	
	A 41	Sub	2×10^{-6}		4×10^{-8}	
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-2}	1×10^{-8}	5×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-2}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-2}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-4}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	* S	6×10^{-12}	2×10^{-4}	2×10^{-13}	7×10^{-6}
		* I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
		I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C 14	S	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	(CO_2)	Sub	5×10^{-5}		1×10^{-6}	
Cerium (58)	Ce 141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce 143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce 144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs 131	S	1×10^{-5}	7×10^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-2}	1×10^{-7}	9×10^{-4}
	Cs 134m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs 134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	Cs 137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-8}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl 36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	2×10^{-8}	2×10^{-3}	8×10^{-10}	6×10^{-5}
	Cl 38	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr 51	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	2×10^{-6}	5×10^{-2}	8×10^{-8}	2×10^{-3}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Cobalt (27)	Co 57	S	3×10^{-6}	2×10^{-2}	1×10^{-7}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	6×10^{-9}	4×10^{-4}
	Co 58m	S	2×10^{-5}	8×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	6×10^{-2}	3×10^{-7}	2×10^{-3}
	Co 58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-8}	3×10^{-3}	2×10^{-9}	9×10^{-5}
	Co 60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	9×10^{-9}	1×10^{-3}	3×10^{-10}	3×10^{-5}
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
		* I	2×10^{-10}	7×10^{-4}	6×10^{-12}	2×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-13}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m	S	5×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-5}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europ[ium] (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2 – 9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-8}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2 – 13 yrs)	I	2×10^{-8}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}

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Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	6×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge 71	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au 196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au 198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au 199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf 181	S	4×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
		I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H3	S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		Sub	2×10^{-3}		4×10^{-5}	
Indium (49)	In 113m	S	8×10^{-6}	4×10^{-2}	3×10^{-7}	1×10^{-3}
		I	7×10^{-6}	4×10^{-2}	2×10^{-7}	1×10^{-3}
	In 114m	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In 115m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	In 115	S	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
		I	3×10^{-8}	3×10^{-3}	1×10^{-9}	9×10^{-5}
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}

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Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Iodine (53)	I 134	I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}		1×10^{-7}	
	Kr 85	Sub	1×10^{-5}		3×10^{-7}	
	Kr 87	Sub	1×10^{-6}		2×10^{-8}	
	Kr 88	Sub	1×10^{-6}		2×10^{-8}	
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	* S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}

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(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
		I	8×10^{-7}	6×10^{-2}	3×10^{-8}	2×10^{-3}
	Ni 63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	7×10^{-4}
	Ni 65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41).	Nb 93m	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Nb 95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb 97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os 185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os 191m	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os 191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os 193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-2}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
*	Pt 193	S	1×10^{-6}	3×10^{-2}	4×10^{-8}	9×10^{-4}
		I	3×10^{-7}	5×10^{-2}	1×10^{-8}	2×10^{-3}
	Pt 197m	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-12}	1×10^{-4}	7×10^{-14}	5×10^{-6}
		I	3×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 239	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 240	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-12}	2×10^{-4}
		I	4×10^{-8}	4×10^{-2}	1×10^{-9}	1×10^{-3}

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(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Plutonium (94)	Pu 242	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	9×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 243	S	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-2}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-5}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-4}	7×10^{-12}	3×10^{-5}
Potassium (19)	K 42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-5}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-8}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-5}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-8}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-5}
Radon (86)	Rn 220	S	3×10^{-7}		1×10^{-8}	
	Rn 222[3]	...	... 3×10^{-8}		3×10^{-9}	
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-2}	9×10^{-8}	6×10^{-4}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-4}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Re 187	S	9×10^{-6}	7×10^{-2}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-2}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Rhodium (45)	Rh 103m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-5}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}

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Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-5}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-8}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-5}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-5}
	Sm 151	S	6×10^{-8}	1×10^{-2}	2×10^{-9}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	4×10^{-5}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium (34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-8}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}
		I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr 90	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
		I	5×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Sr 91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr 92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S 35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
		I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}
Tantalum (73)	Ta 182	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	7×10^{-10}	4×10^{-5}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)		Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Technetium (43)		Tc 96m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
			I	3×10^{-5}	3×10^{-1}	1×10^{-6}	1×10^{-2}
		Tc 96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
		Tc 97m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-4}
		Tc 97	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
			I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
		Tc 99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
			I	1×10^{-5}	8×10^{-2}	5×10^{-7}	3×10^{-3}
		Tc 99	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
			I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Tellurium (52)		Te 125m	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		Te 127m	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
			I	4×10^{-8}	2×10^{-3}	1×10^{-9}	5×10^{-5}
		Te 127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		Te 129m	S	8×10^{-8}	1×10^{-3}	3×10^{-9}	3×10^{-5}
			I	3×10^{-8}	6×10^{-4}	1×10^{-9}	2×10^{-5}
		Te 129	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
			I	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
		Te 131m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		Te 132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
			I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Terbium (65)		Tb 160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
Thallium (81)		Tl 200	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
		Tl 201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		Tl 202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-5}
		Tl 204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	3×10^{-8}	2×10^{-3}	9×10^{-10}	6×10^{-5}
Thorium (90)	*	Th 227	S	3×10^{-10}	5×10^{-4}	1×10^{-11}	2×10^{-5}
			I	2×10^{-10}	5×10^{-4}	6×10^{-12}	2×10^{-5}
		Th 228	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
			I	6×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		Th 230	S	2×10^{-12}	5×10^{-5}	8×10^{-14}	2×10^{-6}
			I	1×10^{-11}	9×10^{-4}	3×10^{-13}	3×10^{-5}
	*	Th 231	S	1×10^{-6}	7×10^{-3}	5×10^{-8}	2×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
		Th 232	S	3×10^{-11}	5×10^{-5}	1×10^{-12}	2×10^{-6}
			I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-5}
	**	Th natural	S	6×10^{-11}	6×10^{-5}	2×10^{-12}	2×10^{-6}
			I	6×10^{-11}	6×10^{-4}	2×10^{-12}	2×10^{-5}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)		Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Thorium (90)		Th 234	S	6×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
			I	3×10^{-8}	5×10^{-4}	1×10^{-9}	2×10^{-5}
Thulium (69)		Tm 170	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		Tm 171	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	5×10^{-4}
			I	2×10^{-7}	1×10^{-2}	8×10^{-9}	5×10^{-4}
Tin (50)		Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
			I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-5}
		Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
			I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Tungsten (Wolfram) (74)		W 181	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	1×10^{-7}	1×10^{-2}	4×10^{-9}	3×10^{-4}
		W 185	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Uranium (92)		U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
			I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}
		U 232	S	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
			I	3×10^{-11}	8×10^{-4}	9×10^{-13}	3×10^{-5}
		U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	**	U 234	S[4]	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	**	U 235	S[4]	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
		U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	**	U 238	S[4]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
			I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
		U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	**	U-natural	S[4]	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
			I	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
Vanadium (23)		V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
			I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)		Xe 131m	Sub	2×10^{-5}		4×10^{-7}	
		Xe 133	Sub	1×10^{-5}		3×10^{-7}	
		Xe 133m	Sub	1×10^{-5}		3×10^{-7}	
		Xe 135	Sub	4×10^{-6}		1×10^{-7}	
Ytterbium (70)		Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)		Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
			I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
		Y 91m	S	2×10^{-5}	1×10^{-1}	8×10^{-7}	3×10^{-3}
			I	2×10^{-5}	1×10^{-1}	6×10^{-7}	3×10^{-3}
		Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
			I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
			I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

25 FR 10914

Element (atomic number)	Isotope [1]		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn 69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	8×10^{-4}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}
	Zr 97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	9×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.		Sub	1×10^{-6}		3×10^{-8}	
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.			3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.			6×10^{-13}	4×10^{-7}	2×10^{-14}	3×10^{-8}

[illegible]

[illegible] for submersion in [illegible] cloud of [illegible] material

40 FR 50704

[3] These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (⅓) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3×10^{5} MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth ($\frac{1}{30}$) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

39 FR 23990

‡4. For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight (enrichment) of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8×10^{-3} SA μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

SA = 3.6×10^{-7} curies/gram U   U-depleted
SA = $(0.4+0.38\,E+0.0034\,E^2)\ 10^{-6}$ $E\geq0.72$

where E is the percentage by weight of U-235, expressed as percent.

*Amended 37 FR 23319.

**Amended 39 FR 23990; footnote redesignated 40 FR 50704.

***Amended 40 FR 50704.

†Amended 38 FR 29314.

‡Amended 39 FR 25463; redesignated 40 FR 50704.

NOTE TO APPENDIX B

25 FR 10914

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\frac{C_C}{MPC_C}\leq 1$$

30 FR 15801

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1—6×10^{-13}
b. For purposes of Table I, Col. 2—4×10^{-7}
c. For purposes of Table II, Col. 1—2×10^{-14}
d. For purposes of Table II, Col. 2—3×10^{-8}

26 FR 11046

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

30 FR 15801

c. Element (atomic number) and isotope	Table I		Table II	
	Column 1 Air (μCi/ml)	Column 2 Water (μCi/ml)	Column 1 Air (μCi/ml)	Column 2 Water (μCi/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131, (I 133, table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	----------	9×10^{-5}	----------	3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129, (I 131, I 133, table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	----------	6×10^{-5}	----------	2×10^{-6}
If it is known that Sr 90, I 129, (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present	----------	2×10^{-5}	----------	6×10^{-7}
If it is known that (I 129, table II only), Ra 226, and Ra 228 are not present	----------	3×10^{-6}	----------	1×10^{-7}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present	3×10^{-9}	----------	1×10^{-10}	----------
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 228, and Pu 241 are not present	3×10^{-10}	----------	1×10^{-11}	----------
If it is known that alpha-emitters and Ac 227 are not present	3×10^{-11}	----------	1×10^{-12}	----------
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present	3×10^{-12}	----------	1×10^{-13}	----------

40 FR 50704

4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-226, instead of those from paragraphs 1, 2, or 3 above.

39 FR 23990

a. For purposes of Table I, Col. 1—1×10^{-10} μCi/ml gross alpha activity; or 5×10^{-11} μCi/ml natural uranium; or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1—3×10^{-12} μCi/ml gross alpha activity; or 2×10^{-12} μCi/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

26 FR 11046

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Appendix B (MPC_A) does not exceed 1/10

(i.e. $\frac{C_A}{MPC_A}\leqq\frac{1}{10}$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed ¼

(i.e. $\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\ .\ .\ .\ .\ .\ \leqq ¼$).

APPENDIX C

35 FR 6425

Material	Microcuries
Americium-241	.01
Antimony-122	100
Antimony-124	10
Antimony-125	10
Arsenic-73	100
Arsenic-74	10
Arsenic-76	10
Arsenic-77	100
Barium-131	10
*Barium-133	10
Barium-140	10
Bismuth-210	1
Bromine-82	10
Cadmium-109	10
Cadmium-115m	10
Cadmium-115	100
Calcium-45	10
Calcium-47	10
Carbon-14	100
Cerium-141	100
Cerium-143	100
Cerium-144	1
Cesium-131	1,000
Cesium-134m	100
Cesium-134	1
Cesium-135	10
Cesium-136	10
Cesium-137	10
Chlorine-36	10
Chlorine-38	10
Chromium-51	1,000
Cobalt-58m	10
Cobalt-58	10
Cobalt-60	1
Copper-64	100
Dysprosium-165	10
Dysprosium-166	100
Erbium-169	100
Erbium-171	100
Europium-152 9.2 h.	100
Europium-152 13 yr.	1
Europium-154	1
Europium-155	10
Fluorine-18	1,000
Gadolinium-153	10
Gadolinium-159	100
Gallium-72	10
Germanium-71	100
Gold-198	100
Gold-199	100
Hafnium-181	10
Holmium-166	100
Hydrogen-3	1,000
Indium-113m	100
Indium-114m	10
Indium-115m	100
Indium-115	10
Iodine-125	1
Iodine-126	1
Iodine-129	0.1
Iodine-131	1
Iodine-132	10
Iodine-133	1
Iodine-134	10
Iodine-135	10
Iridium-192	10
Iridium-194	100
Iron-55	100
Iron-59	10
Krypton-85	100
Krypton-87	10
Lanthanum-140	10
Lutetium-177	100
Manganese-52	10
Manganese-54	10
Manganese-56	10
Mercury-197m	100
Mercury-197	100
Mercury-203	10
Molybdenum-99	100
Neodymium-147	100
Neodymium-149	100
Nickel-59	100
Nickel-63	10
Nickel-65	100
Niobium-93m	10
Niobium-95	10
Niobium-97	10
Osmium-185	10
Osmium-191m	100
Osmium-191	100
Osmium-193	100
Palladium-103	100
Palladium-109	100
Phosphorus-32	10
Platinum-191	100
Platinum-193m	100
Platinum-193	100
Platinum-197m	100
Platinum-197	100
Plutonium-239	.01
Polonium-210	0.1
Potassium-42	10
Praseodymium-142	100
Praseodymium-143	100
Promethium-147	10
Promethium-149	10
Radium-226	.01
Rhenium-186	100
Rhenium-188	100
Rhodium-103m	100
Rhodium-105	100
Rubidium-86	10
Rubidium-87	10
Ruthenium-97	100
Ruthenium-103	10
Ruthenium-105	10
Ruthenium-106	1
Samarium-151	10
Samarium-153	100
Scandium-46	10
Scandium-47	100
Scandium-48	10
Selenium-75	10
Silicon-31	100
Silver-105	10
Silver-110m	1
Silver-111	100
Sodium-24	10
Strontium-85	10
Strontium-89	1
Strontium-90	0.1
Strontium-91	10
Strontium-92	10
Sulphur-35	100
Tantalum-182	10
Technetium-96	10
Technetium-97m	100
Technetium-97	100
Technetium-99m	100
Technetium-99	10
Tellurium-125m	10
Tellurium-127m	10
Tellurium-127	100
Tellurium-129m	10
Tellurium-129	100
Tellurium-131m	10
Tellurium-132	10
Terbium-160	10
Thallium-200	100
Thallium-201	100
Thallium-202	100
Thallium-204	10
**Thorium (natural)[1]	100
Thulium-170	10
Thulium-171	10
Tin-113	10
Tin-125	10
Tungsten-181	10
Tungsten-185	10
Tungsten-187	100
**Uranium (natural)[2]	100
Uranium-233	.01
Uranium-234— Uranium-235	.01
Vanadium-48	10
Xenon-131m	1,000
Xenon-133	100
Xenon-135	100
Ytterbium-175	100
Yttrium-90	10
Yttrium-91	10
Yttrium-92	100
Yttrium-93	100
Zinc-65	10
Zinc-69m	100
Zinc-69	1,000
Zirconium-93	10
Zirconium-95	10
Zirconium-97	10
Any alpha emitting radionuclide not listed above or mixtures of alpha emitters of unknown composition	.01
Any radionuclide other than alpha emitting radionuclides, not listed above or mixtures of beta emitters of unknown composition	1

45 FR 71761

Note.—For purposes of § 20.303, where there is involved a combination of isotopes in known amounts, the limit for the combination should be derived as follows: Determine, for each isotope in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific isotope when not in combination. The sum of such ratios for all the isotopes in the combination may not exceed "1" (i.e., "unity").

[1] Based on alpha disintegration rate of Th-232, Th-230 and their daughter products.

[2] Based on alpha disintegration rate of U-238, U-234, and U-235.

* Amended 36 FR 16898.

** Amended 39 FR 23990.

Appendix D

UNITED STATES NUCLEAR REGULATORY COMMISSION

INSPECTION AND ENFORCEMENT REGIONAL OFFICES

Region	Address	Telephone	
		Daytime	Nights and Holidays
I Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont	Region I, USNRC Office of Inspection and Enforcement 631 Park Avenue King of Prussia, Pa. 19406	‡ (215) 337-5000	‡ (215) 337-5000
II Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, *** Puerto Rico, South Carolina, Tennessee, Virginia, Virgin Islands, and West Virginia	† Region II, USNRC Office of Inspection and Enforcement 101 Marietta Street Suite 3100 Atlanta, Georgia 30303	* (404) 221-4503	* (404) 221-4503
III Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin	Region III, USNRC Office of Inspection and Enforcement 799 Roosevelt Road Glen Ellyn, Ill. 60137	** (312) 932-2500	** (312) 932-2500
IV Arkansas, Colorado, Idaho, Kansas, Louisiana, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming	Region IV, USNRC Office of Inspection and Enforcement 611 Ryan Plaza Drive Suite 1000 Arlington, Texas 76012	(817) 334-2841	(817) 334-2841
V Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, and U.S. territories and possessions in the Pacific	Region V, USNRC Office of Inspection and Enforcement 1990 N. California Blvd. Suite 202 Walnut Creek, Calif. 94596	** (415) 943-3700	** (415) 943-3700

40 FR 42557

*Amended 41 FR 55851.

†Amended 43 FR 32741.

‡ Amended 43 FR 52201.

** Amended 44 FR 63515.

*** Amended 45 FR 18905

PART 30

RULES OF GENERAL APPLICABILITY TO DOMESTIC LICENSING OF BYPRODUCT MATERIAL★★

† Amended 37 FR 9207.
‡ Added 37 FR 9207.

AUTHORITY: Secs. 81, 82, 161, 182, 183, 68 Stat. 935, 948, 953, 954, as amended (42 U.S.C. 2111, 2112, 2201, 2232, 2233); secs. 202, 206, 88 Stat. 1244, 1246 (42 U.S.C. 5842 and 5846).

Section 30.34(b) also issued under sec. 184, 68 Stat. 954, as amended (42 U.S.C. 2234). For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), § 30.34(c) issued under sec. 161b., 68 Stat. 948 (42 U.S.C. 2201 (b)) and §§ 30.51 and 30.52 issued under sec. 161, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

40 FR 8774

§ 30.1 Purpose and Scope.

This part prescribes rules applicable to all persons in the United States governing domestic** licensing of byproduct material under the Atomic Energy Act of 1954, as amended (68 Stat. 919), and under Title II of the Energy Reorganization Act of 1974 (88 Stat. 1242), and exemptions from the domestic** licensing requirements permitted by section 81 of the Act.

30 FR 8185

§ 30.2 Resolution of conflict.

The requirements of this part are in addition to, and not in substitution for, other requirements of this chapter. In any conflict between the requirements in this part and a specific requirement in another part of the regulations in this chapter, the specific requirement governs.

** Amended 43 FR 6915.

30 FR 8185

§ 30.3 Activities requiring license.

Except for persons exempt as provided in this part and Part 150 of this chapter, no person shall manufacture, produce, transfer, receive, acquire, own, possess, or use,** byproduct material except as authorized in a specific or general license issued pursuant to the regulations in this chapter.

§ 30.4 Definitions.

As used in this part and Parts 31-35** of this chapter:

(a) "Act" means the Atomic Energy Act of 1954, (68 Stat. 919)* including any amendments thereto;

45 FR 14199

(a–1) "Department" and "Department of Energy" means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c) and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93–438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565 at 577–578, 42 U.S.C. 7151).

30 FR 8185

(b) Terms defined in section 11 of the Act shall have the same meaning when used in the regulations in this part and Parts 31-35** to the extent such terms are not specifically defined in this part;

* Amended 36 FR 1466.

(c) "Agreement State" means any state with which the Atomic Energy Commission or the Nuclear Regulatory Commission has entered into an effective agreement under subsection 274b. of the Act. "Non-Agreement State" means any other State;

(d) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

(e) "Commission" means the Nuclear Regulatory Commission and its duly authorized representatives;

(f) "Curie" means that amount of radioactive material which disintegrates at the rate of 37 billion atoms per second;

(g) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(h) "Human use" means the internal or external administration of byproduct material, or the radiation therefrom, to human beings;

(i) "License" except where otherwise specified means a license for byproduct material issued pursuant to the regulations in this part and Parts 31-35† of this chapter;

(j)(1) "Microcurie" means that amount of radioactive material which disintegrates at the rate of 37 thousand atoms per second;

(2) "Millicurie" means that amount of radioactive material which disintegrates at the rate of 37 million atoms per second;

(k) "Person" means (1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department**, except that the Department** shall be considered a person within the meaning of the regulations in this part to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission pursuant to section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244),[5] any State or any political subdivision of or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing;

(l) "Physician" means an individual licensed by a State or territory of the United States, the District of Columbia or the Commonwealth of Puerto Rico to dispense drugs in the practice of medicine;

(m) "Production facility" means production facility as defined in the regulations contained in Part 50 of this chapter;

(n) "Radiographer" means any individual who performs or who, in attendance at the site where the sealed source or sources are being used, personally supervises radiographic operations and who is responsible to the licensee for assuring compliance with the requirements of the Commission's regulations and the conditions of the license;

(o) "Radiographer's assistant" means any individual who, under the personal supervision of a radiographer, uses radiographic exposure devices, sealed sources or related handling tools, or radiation* survey instruments in radiography;

(p) "Radiography" means the examination of the structure of materials by nondestructive methods, utilizing sealed sources of byproduct materials;

(q) "Research and development" means (1) theoretical analysis, exploration, or experimentation; or (2) the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes. "Research and development" as used in this part and Parts 31-35† does not include the internal or external administration of byproduct material, or the radiation therefrom, to human beings;

(r) "Sealed source" means any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material;

(s) "Source material" means source material as defined in the regulations contained in Part 40 of this chapter;

(t) "Special nuclear material" means special nuclear material as defined in the regulations contained in Part 70 of this chapter;

(u) "United States", when used in a geographical sense, includes Puerto Rico and all territories and possessions of the United States;

(v) "Utilization facility" means a utilization facility as defined in the regulations contained in Part 50 of this chapter;

(w) "Commencement of construction" means any clearing of land, excavation, or other substantial action that would adversely affect the natural environment of a site but does not include changes desirable for the temporary use of the land for public recreational uses, necessary borings to determine site characteristics or other preconstruction monitoring to establish background information related to the suitability of a site or to the protection of environmental values.

§ 30.5 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part and Parts 31-35† by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 30.6 Communications.

Except where otherwise specified, all communications and reports concerning

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[5] The ** Department facilities and activities identified in section 202 are:

(1) Demonstration Liquid Metal Fast Breeder reactors when operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor.

(2) Other demonstration nuclear reactors, except those in existence on January 19, 1975, when operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor.

(3) Facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from licensed activities.

(4) Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive waste generated by the ** Department, which are not used for, or are part of, research and development activities.

† Amended 43 FR 6915.

* Amended 36 FR 1466.

** Amended 45 FR 14139

30 FR 8185
the regulations in this part and Parts 31-35† and applications filed under them, should be addressed to the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C., 20555. Communications, reports and applications may be delivered in person at the Commission's offices at 1717 H Street N.W., Washington, D.C., or **7920 Norfolk Avenue, Bethesda, Md.

EXEMPTIONS

37 FR 5745
§ 30.11 Specific exemptions.

(a) The Commission may, upon application of any interested person or upon its own initiative, grant such exemptions from the requirements of the regulations in this part and Parts 31-35† of this chapter as it determines are authorized by law and will not endanger life or property or the common defense and security and are otherwise in the public interest.

30.11(b) [Deleted 45 FR 65521

40 FR 8774
§ 30.12 Persons using byproduct material under certain *** Department of Energy Nuclear Regulatory Commission contracts.

Except to the extent that *** Department facilities or activities of the types subject to licensing pursuant to section 202 of the Energy Reorganization Act of 1974 are involved, any prime contractor of the *** Department is exempt from the requirements for a license set forth in sections 81 and 82 of the Act and from the regulations in this part to the extent that such contractor, under his prime contract with the *** Department manufactures, produces, transfers, receives, acquires, owns, possesses, or uses† byproduct material for: (a) the performance of work for the *** Department at a United States Government-owned or controlled site, including the transportation of byproduct material to or from such site and the performance of contract services during temporary interruptions of such transportation; (b) research in, or development, manufacture, storage, testing or transportation of, atomic weapons or components thereof; or (c) the use or operation of nuclear reactors or other nuclear devices in a United States Government-owned vehicle or vessel. In addition to the foregoing exemptions and subject to the requirement for licensing of *** Department facilities and activities pursuant to section 202 of the Energy Reorganization Act of 1974, any prime contractor or subcontractor of the *** Department or the Commission is exempt from the requirements for a license set forth in sections 81 and 82 of the Act and from the regulations in this part to the extent that such prime contractor or subcontractor manufactures, produces, transfers, receives, acquires, owns, possesses, or uses† byproduct material under his prime contract or subcontract when the Commission determines that the exemption of the prime contractor or subcontractor is authorized by law; and that, under the terms of the contract or subcontract, there is adequate assurance that the work thereunder can be accomplished without undue risk to the public health and safety.

37 FR 3985
§ 30.13 Carriers.

Common and contract carriers, freight forwarders, warehousemen, and the U.S. Postal Service are exempt from the regulations in this part and Parts 31-35† of this chapter and the requirements for a license set forth in section 81 of the Act to the extent that they transport or store byproduct material in the regular course of carriage for another or storage incident thereto.

30 FR 8185
§ 30.14 Exempt concentrations.

(a) Except as provided in paragraphs (c) and (d) of this section, any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in this part and Parts 31-35† of this chapter to the extent that such person receives, possesses, uses, transfers, owns or acquires products or materials containing byproduct material in concentrations not in excess of those listed in § 30.70.

(b) This section shall not be deemed to authorize the import of byproduct material or products containing byproduct material.

(c) A manufacturer, processor, or producer of a product or material in an Agreement State is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in this part and Parts 31, 32, 33, and 34,† to the extent that he transfers byproduct material contained in a product or material in concentrations not in excess of those specified in § 30.70 and introduced into the product or material by a licensee holding a specific license issued by an Agreement State, the Commission, or the Atomic Energy Commission expressly authorizing such introduction. This exemption does not apply to the transfer of byproduct material contained in any food, beverage, cosmetic, drug, or other commodity or product designed for ingestion or inhalation by or application to, a human being.

(d) No person may introduce byproduct material into a product or material knowing or having reason to believe that it will be transferred to persons exempt under this section or equivalent regulations of an Agreement State, except in accordance with a license issued pursuant to § 32.11 of this chapter or the general license provided in § 150.20 of Part 150.

34 FR 19546
§ 30.15 Certain items containing byproduct material.

34 FR 6651
(a) Except for persons who apply byproduct material to, or persons who incorporate byproduct material into, the following products, or persons who initially transfer† for sale or distribution the following products containing byproduct material, any person is exempt from the requirements for a license set

† Amended 43 FR 6915.
** Amended 34 FR 19546.
*** Amended 45 FR14199

forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires the following products:

(1) Timepieces or hands or dials containing not more than the following specified quantities of byproduct material and not exceeding the following specified levels of radiation:

(i) 25 millicuries of tritium per timepiece,

(ii) 5 millicuries of tritium per hand,

(iii) 15 millicuries of tritium per dial (bezels when used shall be considered as part of the dial),

(iv) 100 microcuries of promethium-147 per watch or 200 microcuries of promethium-147 per any other timepiece,

(v) 20 microcuries of promethium-147 per watch hand or 40 microcuries of promethium-147 per other timepiece hand,

(vi) 60 microcuries of promethium-147 per watch dial or 120 microcuries of promethium-147 per other timepiece dial (bezels when used shall be considered as part of the dial),

(vii) The levels of radiation from hands and dials containing promethium-147 will not exceed, when measured through 50 milligrams per square centimeter of absorber:

(*a*) For wrist watches, 0.1 millirad per hour at 10 centimeters from any surface,

(*b*) For pocket watches, 0.1 millirad per hour at 1 centimeter from any surface,

(*c*) For any other timepiece, 0.2 millirad per hour at 10 centimeters from any surface.

(2) Lock illuminators containing not more than 15 millicuries of tritum or not more than 2 millicuries of promethium-147 installed in automobile locks. The levels of radiation from each lock illuminator containing promethium-147 will not exceed 1 millirad per hour at 1 centimeter from any surface when measured through 50 milligrams per square centimeter of absorber.

(3) Balances of precision containing not more than 1 millicurie of tritium per balance or not more than 0.5 millicurie of tritum per balance part.

(4) Automobile shift quadrants containing not more than 25 millicuries of tritium.

(5) Marine compasses containing not more than 750 millicuries of tritium gas and other marine navigational instruments containing not more than 250 millicuries of tritium gas.

(6) Thermostat dials and pointers containing not more than 25 millicuries of tritium per thermostat.

(7) [Deleted 34 FR 6651.]

(8) Electron tubes: *Provided*, That each tube does not contain more than one of the following specified quantities of byproduct material:

(i) 150 millicuries of tritium per microwave receiver protector tube or 10 millicuries of tritium per any other electron tube;

(ii) 1 microcurie of cobalt-60;

(iii) 5 microcuries of nickel-63;

(iv) 30 microcuries of krypton-85;

(v) 5 microcuries of cesium-137;

(vi) 30 microcuries of promethium-147;

And provided further, That the levels of radiation from each electron tube containing byproduct material do not exceed 1 millirad per hour at 1 centimeter from any surface when measured through 7 milligrams per square centimeter of absorber.[3]

(9) Ionizing radiation measuring instruments containing, for purposes of internal calibration or standardization, a source of byproduct material not exceeding the applicable quantity set forth in § 30.71, Schedule B.

(10) Spark gap irradiators containing not more than 1 microcurie of cobalt-60 per spark gap irradiator for use in electrically ignited fuel oil burners having a firing rate of at least 3 gallons per hour (11.4 liters per hour).

(b) Any person who desires to apply byproduct material to, or to incorporate byproduct material into, the products exempted in paragraph (a) of this section, or who desires to initially transfer* for sale or distribution such products containing byproduct material, should apply for a specific license pursuant to § 32.14 of this chapter, which license states that the product may be distributed by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section.

§ 30.16 Resins containing scandium-46 and designed for sand-consolidation in oil wells.

Any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires synthetic plastic resins containing scandium-46 which are designed for sand-consolidation in oil wells, and which have been manufactured or initially transferred* for sale or distribution, in accordance with a specific license issued pursuant to § 32.17 of this chapter or equivalent regulations of an Agreement State. The exemption in this section does not authorize the manufacture or initial transfer for sale or distribution* of any resins containing scandium-46.

§ 30.18 Exempt quantities.

(a) Except as provided in paragraphs (c) and (d) of this section, any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 30-34 of this chapter to the extent that such person receives, possesses, uses, transfers, owns, or acquires byproduct material in individual quantities each of which does not exceed the applicable quantity set forth in § 30.71, Schedule B.

(b) Any person who possesses byproduct material received or acquired prior to September 25, 1971, under the general license then provided in § 31.4 of this chapter is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 30-34 of this chapter to the extent that such person possesses, uses, transfers, or owns such byproduct material.

(c) This section does not authorize for purposes of commercial distribution* the production, packaging, repackaging, or transfer* of byproduct material, or the incorporation of byproduct material into products intended for commercial distribution.

(d) No person may, for purposes of commercial distribution,* transfer byproduct material in the individual quantities set forth in § 30.71 Schedule

* Amended 43 FR 6915.

[3] For purposes of this subparagraph "electron tubes" include spark gap tubes, power tubes, gas tubes including glow lamps, receiving tubes, microwave tubes, indicator tubes, pickup tubes, radiation detection tubes, and any other completely sealed tube that is designed to conduct or control electrical currents.

B, knowing or having reason to believe that such quantities of byproduct material will be transferred to persons exempt under this section or equivalent regulations of an Agreement State, except in accordance with a license issued under § 32.18 of this chapter, which license states that the byproduct material may be transferred by the licensee to persons exempt under this section or the equivalent regulations of an Agreement State.

§ 30.19 **Self-luminous products containing tritium, krypton-85, or promethium-147.**

(a) Except for persons who manufacture, process, produce, or initially transfer for sale or distribution* self-luminous products containing tritium, krypton-85, or promethium-147,* and except as provided in paragraph (c) of this section, any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires tritium, krypton-85, or promethium-147 in self-luminous products manufactured, processed, produced, or initially* transferred in accordance with a specific license issued pursuant to § 32.22 of this chapter, which license authorizes the initial* transfer of the product for use under this section.

(b) Any person who desires to manufacture, process, or produce self-luminous products containing tritium, krypton-85, or promethium-147, or to transfer* such products for use pursuant to paragraph (a) of this section, should apply for a license pursuant to § 32.22 of this chapter, which license states that the product may be transferred by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section or equivalent regulations of an Agreement State.

(c) The exemption in paragraph (a) of this section does not apply to tritium, krypton-85, or promethium-147 used in products primarily for frivolous purposes or in toys or adornments.

§ 30.20 **Gas and aerosol detectors containing byproduct material.**

(a) Except for persons who manufacture, process, produce, or initially transfer for sale or distribution* gas and aerosol detectors containing byproduct material,* any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires byproduct material in gas and aerosol detectors designed to protect life or property from fires and airborne hazards, and manufactured, processed, produced, or initially* transferred in accordance with a specific license issued pursuant to § 32.26 of this chapter, which license authorizes the initial* transfer of the product for use under this section.

(b) Any person who desires to manufacture, process, or produce gas and aerosol detectors containing byproduct material, or to initially* transfer such products for use pursuant to paragraph (a) of this section, should apply for a license pursuant to § 32.26 of this chapter, which license states that the product may be initially* transferred by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section or equivalent regulations of an Agreement State.

LICENSES

§ 30.31 **Types of licenses.**

Licenses for byproduct material are of two types: General and specific. Specific licenses are issued to named persons upon applications filed pursuant to the regulations in this part and Parts 32-35.* General licenses are effective without the filing of applications with the Commission or the issuance of licensing documents to particular persons.

§ 30.32 **Application for specific licenses.**

(a) Applications for specific licenses should be filed in duplicate on Form NRC-313, "Application for Byproduct Material License," with the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Applications may be filed in person at the Commission's offices at 1717 H Street, N.W., Washington, D.C., or 7920 Norfolk Avenue, Bethesda, Maryland. Information contained in previous applications, statements, or reports filed with the Commission or the Atomic Energy Commission may be incorporated by reference, provided that such references are clear and specific.

(b) The Commission may at any time after the filing of the original application, and before the expiration of the license, require further statements in order to enable the Commission to determine whether the application should be granted or denied or whether a license, should be modified or revoked.

(c) Each application shall be signed by the applicant or licensee or a person duly authorized to act for and on his behalf.

(d) An application for license filed pursuant to the regulations in this part and Parts 32-35* will be considered also as an application for licenses authorizing other activities for which licenses are required by the Act, provided that the application specifies the additional activities for which licenses are requested and complies with regulations of the Commission as to applications for such licenses.

(e) Each application for a byproduct material license, other than a license exempted from Part 170 of this chapter, shall be accompanied by the fee prescribed in § 170.31 of this chapter. No fee will be required to accompany an application for renewal or amendment of a license, except as provided in § 170.31 of this chapter.

(f) An application for a license to receive and possess byproduct material for commercial waste disposal by land burial or for the conduct of any other activity which the Commission determines will significantly affect the quality of the environment shall be filed at least 9 months prior to commencement of construction of the plant or facility in which the activity will be conducted and shall be accompanied by any Environmental Report required pursuant to Part 51** of this chapter.

§ 30.33 **General requirements for issuance of specific licenses.**

(a) An application for a specific license will be approved if:

(1) The application is for a purpose authorized by the Act;

(2) The applicant's proposed equipment and facilities are adequate to protect health and minimize danger to life or property;

(3) The applicant is qualified by training and experience to use the material for the purpose requested in such

* Amended 43 FR 6915.

** Amended 39 FR 26279.

30 FR 8185

manner as to protect health and minimize danger to life or property;

(4) The applicant satisfies any special requirements contained in Parts 32-35;* and

45 FR 65521

(5) In the case of an application for a license to receive and possess byproduct material for commercial waste disposal by land burial or for the conduct of any other activity which the Commission determines will significantly affect the quality of the environment, the Director of Nuclear Material Safety and Safeguards or his designee, before commencement of construction of the plant or facility in which the activity will be conducted, on the basis of information filed and evaluations made pursuant to Part 51 of this chapter, has concluded, after weighing the environmental, economic, technical, and other benefits against environmental costs and considering available alternatives, that the action called for is the issuance of the proposed license, with any appropriate conditions to protect environmental values. Commencement of construction prior to such conclusion shall be grounds for denial of a license to receive and possess byproduct material in such plant or facility. As used in this paragraph the term "commencement of construction" means any clearing of land, excavation, or other substantial action that would adversely affect the environment of a site. The term does not mean site exploration, necessary roads for site exploration, borings to determine foundation conditions, or other preconstruction monitoring or testing to establish background information related to the suitability of the site or the protection of environmental values.

(b) Upon a determination that an application meets the requirements of the Act, and the regulations of the Commission, the Commission will issue a specific license authorizing the possession and use of byproduct material (Form NRC-374, "Byproduct Material License").

§ 30.34 Terms and conditions of licenses.

(a) Each license issued pursuant to the regulations in this part and the regulations in Parts 31-35* shall be subject to all the provisions of the Act, now or hereafter in effect, and to all valid rules, regulations and orders of the Commission.

(b) No license issued or granted pursuant to the regulations in this part and Parts 31-35,* nor any right under a license shall be transferred, assigned or in any manner disposed of, either voluntarily or involuntarily, directly or indirectly, through transfer of control of any license to any person, unless the Commission shall, after securing full information, find that the transfer is in accordance with the provisions of the Act and shall give its consent in writing.

(c) Each person licensed by the Commission pursuant to the regulations in this part and Parts 31-35* shall confine his possession and use of the byproduct material to the locations and purposes authorized in the license. Except as otherwise provided in the license, a license issued pursuant to the regulations in this part and Parts 31-35* of this chapter shall carry with it the right to receive, acquire, own, and possess,* byproduct material. Preparation for shipment and transport of byproduct material shall be in accordance with the provisions of Part 71 of this chapter.

(d) Each license issued pursuant to the regulations in this part and Parts 31-35* shall be deemed to contain the provisions set forth in section 183b.-d., inclusive, of the Act, whether or not these provisions are expressly set forth in the license.

(e) The Commission may incorporate, in any license issued pursuant to the regulations in this part and Parts 31-35,* at the time of issuance, or thereafter by appropriate rule, regulation or order, such additional requirements and conditions with respect to the licensee's receipt, possession, use and transfer of byproduct material as it deems appropriate or necessary in order to:

(1) Promote the common defense and security;

(2) Protect health or to minimize danger to life or property;

(3) Protect restricted data;

(4) Require such reports and the keeping of such records, and to provide for such inspections of activities under the license as may be necessary or appropriate to effectuate the purposes of the Act and regulations thereunder.

(f) Each licensee shall notify the Commission in writing when the licensee decides to permanently discontinue all activities involving materials authorized under the license. This notification requirement applies to all specific licenses issued under this Part and Parts 32 through 35 of this chapter.

(g) Each licensee preparing technetium-99m radiopharmaceuticals from molybdenum-99/technetium-99m generators shall test the generator eluates for molybdenum-99 breakthrough in accordance with § 35.14(b)(4) (i) thru (iv).

§ 30.35 [Deleted 40 FR 8774.]

§ 30.36 Expiration of licenses.

Except as provided in § 30.37(b), each specific license shall expire at the end of the day, in the month and year stated therein.

§ 30.37 Applications for renewal of licenses.

(a) Applications for renewal of a specific license shall be filed in accordance with § 30.32.

(b) In any case in which a licensee, not less than thirty (30) days prior to the expiration of his existing license, has filed an application in proper form for renewal or for a new license, such existing license shall not expire until the application has been finally determined by the Commission.

§ 30.38 Applications for amendment of licenses.

Applications for amendment of a license shall be filed in accordance with § 30.32 and shall specify the respects in which the licensee desires his license to be amended and the grounds for such amendment.

§ 30.39 Commission action on applications to renew or amend.

In considering an application by a licensee to renew or amend his license the Commission will apply the applicable criteria set forth in § 30.33 and Parts 32-35* of this chapter.

§ 30.41 Transfer of byproduct material.

(a) No licensee shall transfer byproduct material except as authorized pursuant to this section.

(b) Except as otherwise provided in his license and subject to the provisions of paragraphs (c) and (d) of this section, any licensee may transfer byproduct material:

(1) To the Administration;

(2) To the agency in any Agreement State which regulates radioactive material pursuant to an agreement under section 274 of the Act;

(3) To any person exempt from the licensing requirements of the Act and regulations in this part, to the extent permitted under such exemption;

(4) To any person in an Agreement State, subject to the jurisdiction of that State, who has been exempted from the

* Amended 43 FR 6915.

** Amended 39 FR 26279.

licensing requirements and regulations of that State, to the extent permitted under such exemption;

38 FR 33968 (5) To any person authorized to receive such byproduct material under terms of a specific license or a general license or their equivalents issued by the Atomic Energy Commission, the Commission, or an Agreement State; or

43 FR 6915 (6) To a person abroad pursuant to an export license issued under Part 110 of this chapter;

(7) ‡ As otherwise authorized by the Commission in writing.

(c) Before transferring byproduct material to a specific licensee of the Commission or an Agreement State or to a general licensee who is required to register with the Commission or with an Agreement State prior to receipt of the byproduct material, the licensee transferring the material shall verify that the transferee's license authorizes the receipt of the type, form, and quantity of byproduct material to be transferred.

(d) The following methods for the verification required by paragraph (c) of this section are acceptable:

38 FR 33968 (1) The transferor may have in his possession, and read, a current copy of the transferee's specific license or registration certificate;

(2) The transferor may have in his possession a written certification by the transferee that he is authorized by license or registration certificate to receive the type, form, and quantity of byproduct material to be transferred, specifying the license or registration certificate number, issuing agency and expiration date;

(3) For emergency shipments the transferor may accept oral certification by the transferee that he is authorized by license or registration certificate to receive the type, form, and quantity of byproduct material to be transferred, specifying the license or registration certificate number, issuing agency and expiration date: *Provided*, That the oral certification is confirmed in writing within 10 days;

(4) The transferor may obtain other sources of information compiled by a reporting service from official records of the Commission or the licensing agency of an Agreement State as to the identity of licensees and the scope and expiration dates of licenses and registration; or

38 FR 33968 (5) When none of the methods of verification described in paragraphs (d)(1) to (4) of this section are readily available or when a transferor desires to verify that information received by one of such methods is correct or up-to-date, the transferor may obtain and record confirmation from the Commission or the licensing agency of an Agreement State that the transferee is licensed to receive the byproduct material.

RECORDS, INSPECTIONS, TESTS, PROCEDURES, AND REPORTS†

§ 30.51 Records.

(a) Each person who receives byproduct material pursuant to a license issued pursuant to the regulations in this part and Parts 31-35* shall keep records showing the receipt, transfer,* and disposal of such byproduct material.

30 FR 8185 (b) Records which are required by the regulations in this part and Parts 31-35* or by license condition shall be maintained for the period specified by the appropriate regulation or license condition. If a retention period is not otherwise specified by regulation or license condition, such records shall be maintained until the Commission authorizes their disposition.

41 FR 18300 (c)(1) Records of receipt of byproduct material which must be maintained pursuant to paragraph (a) of this section shall be maintained as long as the licensee retains possession of the byproduct material and for two years following transfer,* or disposal of the byproduct material. (2) [Deleted 43 FR 6915.] (3) Records of transfer of byproduct material shall be maintained by the licensee who transferred the material for five years after such transfer. (4) Records of disposal of byproduct material shall be maintained in accordance with § 20.401 (c) of this chapter.

(d)(1) Records which must be maintained pursuant to this part and Parts 31-35* may be the original or a reproduced copy of microform if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by Commission regulations.

(2) If there is a conflict between the Commission's regulations in this part and Parts 31-35,* license condition, or other written Commission approval or authorization pertaining to the retention period for the same type of record, the retention period specified in the regulations in this part and Parts 31-35* for such records shall apply unless the Commission, pursuant to § 30.11, has granted a specific exemption from the record retention requirements specified in the regulations in this part or Parts 31-35.*

§ 30.52 Inspections.

(a) Each licensee shall afford to the Commission at all reasonable times opportunity to inspect byproduct material and the premises and facilities wherein byproduct material is used or stored.

(b) Each licensee shall make available to the Commission for inspection, upon reasonable notice, records kept by him pursuant to the regulations in this chapter.

§ 30.53 Tests.

Each licensee shall perform, or permit the Commission to perform, such tests as the Commission deems appropriate or necessary for the administration of the regulations in this part and Parts 31-35,* including tests of:

(a) Byproduct material;

(b) Facilities wherein byproduct material is utilized or stored;

(c) Radiation detection and monitoring instruments; and

(d) Other equipment and devices used in connection with the utilization or storage of byproduct material.

§ 30.54 Control and accounting procedures for tritium.

37 FR 9207 (a) Except as specified in paragraph (b) of this section, each licensee who is authorized to possess at any one time and location more than 10,000 curies of tritium shall establish and maintain written material control and accounting procedures that are sufficient to enable the licensee to account for the tritium in his possession under specific license.

41 FR 18300 The written material control and accounting procedures shall be maintained as long as the licensee retains possession of the tritium and for two years following transfer* of the tritium.

37 FR 9207 (b) Written material control and accounting procedures are not required for (1) tritium produced or possessed within a production or utilization facility inci-

† Amended 37 FR 9207.

‡ Redesignated 43 FR 6915.

* Amended 43 FR 6915.

dental to the operation of the facility; and • (2) tritium contained in spent fuel, other than tritium intentionally produced in or recovered from a production or utilization facility for any subsequent use. • (3) [Deleted 43 FR 6915.] (4) [Deleted 43 FR 6915.]

§ 30.55 Tritium reports.

(a) Except as specified in paragraph (d) of this section, each licensee who transfers or receives at any one time 1,000 curies or more of tritium shall complete and distribute a Nuclear Material Transaction•• Report on Form NRC-741, in accordance with the printed instructions for completing the form. Each licensee who transfers such material shall submit a completed copy of Form NRC-741 to the Commission and three copies to the receiver of the material promptly after the transfer takes place. Each licensee who receives such material shall submit a completed copy of Form NRC-741 to the Commission and to the shipper of the material within ten (10) days after the material is received. The Commission's copies of the report shall be submitted to the U.S. Energy Research and Development Administration, Post Office Box E, Oak Ridge, Tennessee 37830, and shall include the Reporting Identification Symbol (RIS) assigned by the Commission to the licensee.

(b) Except as specified in paragraph (d) and (e) of this section, each licensee who is authorized to possess at any one time and location more than 10,000 curies of tritium shall submit to the Commission within thirty (30) days after March 31 and September 30+ of each year a statement of his tritium inventory to the nearest hundredth of a gram calculated at 10,000 curies per gram.

The reports shall be submitted to the U.S. Energy Research and Development Administration, Post Office Box E, Oak Ridge, Tennessee 37830, and shall include the Reporting Identification Symbol (RIS) assigned by the Commission to the licensee.

(c) Except as specified in paragraph (d) of this section, each licensee who is authorized to possess • tritium shall report promptly to the appropriate NRC Regional Office listed in Appendix D of Part 20 of this chapter by telephone and telegraph, mailgram, or facsimile any incident in which an attempt has been made or is believed to have been made to commit a theft or unlawful diversion of more than 10 curies of such material at any one time or more than 100 curies of such material in any one calendar year. The initial report shall be followed within a period of fifteen (15) days by a written report submitted to the appropriate NRC Regional Office which sets forth the details of the incident and its consequences. Copies of such written report shall be sent to the Director of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Subsequent to the submission of the written report required by this paragraph, the licensee shall promptly inform the Office of Inspection and Enforcement by means of a written report of any substantive additional information, which becomes available to the licensee, concerning an attempted or apparent theft or unlawful diversion of tritium.

(d) The reports described in this section are not required for tritium possessed pursuant to a general license provided in Part 31 of this chapter or for tritium contained in spent fuel.

(e) The reports described in paragraph (b) of this section are not required for (1) tritium produced or possessed within a production or utilization facility incidental to the operation of the facility, other than tritium intentionally produced by or recovered from a production or utilization facility for any subsequent use. • (2) [Deleted 43 FR 6915.] (3) [Deleted 43 FR 6915.]

ENFORCEMENT

§ 30.61 Modification and revocation of licenses.

(a) The terms and conditions of each license issued pursuant to the regulations in this part and Parts 31-35 • shall be subject to amendment, revision or modification by reason of amendments to the Act, or by reason of rules, regulations and orders issued in accordance with the terms of the Act.

(b) Any license may be revoked, suspended or modified, in whole or in part, for any material false statement in the application or any statement of fact required under section 182 of the Act, or because of conditions revealed by such application or statement of fact or any report, record or inspection or other means which would warrant the Commission to refuse to grant a license on an original application, or for violation of, or failure to observe any of the terms and provisions of the Act or of any rule, regulation or order of the Commission.

(c) Except in cases of willfulness or those in which the public health, interest or safety requires otherwise, no license shall be modified, suspended or revoked unless, prior to the institution of proceedings therefor, facts or conduct which may warrent such action shall have been called to the attention of the licensee in writing and the licensee shall have been accorded an opportunity to demonstrate or achieve compliance with all lawful requirements.

§ 30.62 Right to cause the withholding or recall of byproduct materials.

The Commission may cause the withholding or recall of byproduct material from any licensee who is not equipped to observe or fails to observe such safety standards to protect health as may be established by the Commission, or who uses such materials in violation of law or regulation of the Commission, or in a manner other than as disclosed in the application therefor or approved by the Commission.

§ 30.63 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Atomic Energy Act of 1954, as amended, or Title II of the Energy Reorganization Act of 1974, or any regulation or order issued thereunder. A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of sections 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act, or section 206 of the Energy Reorganization Act of 1974, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

+ Amended 42 FR 33265.

• Amended 43 FR 6915.

•• Amended 38 FR 2330.

SCHEDULES

§ 30.70 Schedule A—Exempt concentrations.

30 FR 8185

Element (atomic number)	Isotope	Column I Gas concentration μCi/ml[1] †	Column II Liquid and solid concentration μCi/ml[2] †
Antimony (51)	Sb 122	-----	3×10^{-4}
	Sb 124	-----	2×10^{-4}
	Sb 125	-----	1×10^{-3}
Argon (18)	A 37	1×10^{-3}	-----
	A 41	4×10^{-7}	-----
Arsenic (33)	As 73	-----	5×10^{-3}
	As 74	-----	5×10^{-4}
	As 76	-----	2×10^{-4}
	As 77	-----	8×10^{-4}
Barium (56)	Ba 131	-----	2×10^{-3}
	Ba 140	-----	3×10^{-4}
Beryllium (4)	Be 7	-----	2×10^{-2}
Bismuth (83)	Bi 206	-----	4×10^{-4}
Bromine (35)	Br 82	4×10^{-7}	3×10^{-3}
Cadmium (48)	Cd 109	-----	2×10^{-3}
	Cd 115m	-----	3×10^{-4}
	Cd 115	-----	3×10^{-4}
Calcium (20)	Ca 45	-----	9×10^{-5}
	Ca 47	-----	5×10^{-4}
Carbon (6)	C 14	1×10^{-6}	8×10^{-3}
Cerium (58)	Ce 141	-----	9×10^{-4}
	Ce 143	-----	4×10^{-4}
	Ce 144	-----	1×10^{-4}
Cesium (55)	Cs 131	-----	2×10^{-2}
	Cs 134m	-----	6×10^{-2}
	Cs 134	-----	9×10^{-5}
Chlorine (17)	Cl 38	9×10^{-7}	4×10^{-3}
Chromium (24)	Cr 51	-----	2×10^{-2}
Cobalt (27)	Co 57	-----	5×10^{-3}
	Co 58	-----	1×10^{-3}
	Co 60	-----	5×10^{-4}
Copper (29)	Cu 64	-----	3×10^{-3}
Dysprosium (66)	Dy 165	-----	4×10^{-3}
	Dy 166	-----	4×10^{-4}
Erbium (68)	Er 169	-----	9×10^{-4}
	Er 171	-----	1×10^{-3}
Europium (63)	Eu 152 (T/2=9.2 Hrs)	-----	6×10^{-4}
	Eu 155	-----	2×10^{-3}
Fluorine (9)	F 18	2×10^{-6}	8×10^{-3}
Gadolinium (64)	Gd 153	-----	2×10^{-3}
	Gd 159	-----	8×10^{-4}
Gallium (31)	Ga 72	-----	4×10^{-4}
Germanium (32)	Ge 71	-----	2×10^{-2}
Gold (79)	Au 196	-----	2×10^{-3}
	Au 198	-----	5×10^{-4}
	Au 199	-----	2×10^{-3}
Hafnium (72)	Hf 181	-----	7×10^{-4}
Hydrogen (1)	H 3	5×10^{-6}	3×10^{-2}
Indium (49)	In 113m	-----	1×10^{-2}
	In 114m	-----	2×10^{-4}
Iodine (53)	I 126	3×10^{-9}	2×10^{-5}
	I 131	3×10^{-9}	2×10^{-5}
	I 132	8×10^{-8}	6×10^{-4}
	I 133	1×10^{-8}	7×10^{-5}
	I 134	2×10^{-7}	1×10^{-3}
Iridium (77)	Ir 190	-----	2×10^{-3}
	Ir 192	-----	4×10^{-4}
	Ir 194	-----	3×10^{-4}
Iron (26)	Fe 55	-----	8×10^{-3}
	Fe 59	-----	6×10^{-4}
Krypton (36)	Kr 85m	1×10^{-6}	-----
	Kr 85	3×10^{-6}	-----
Lanthanum (57)	La 140	-----	2×10^{-4}
Lead (82)	Pb 203	-----	4×10^{-3}
Lutetium (71)	Lu 177	-----	1×10^{-3}
Manganese (25)	Mn 52	-----	3×10^{-4}
	Mn 54	-----	1×10^{-3}
	Mn 56	-----	1×10^{-3}
Mercury (80)	Hg 197m	-----	2×10^{-3}
	Hg 197	-----	3×10^{-3}
	Hg 203	-----	2×10^{-4}
Molybdenum (42)	Mo 99	-----	2×10^{-3}
Neodymium (60)	Nd 147	-----	6×10^{-4}
	Nd 149	-----	3×10^{-3}
Nickel (28)	Ni 65	-----	1×10^{-3}
Niobium (Columbium) (41)	Nb 95	-----	1×10^{-3}
	Nb 97	-----	9×10^{-3}
Osmium (76)	Os 185	-----	7×10^{-4}
	Os 191m	-----	3×10^{-2}
	Os 191	-----	2×10^{-3}
	Os 193	-----	6×10^{-4}
Palladium (46)	Pd 103	-----	3×10^{-3}
	Pd 109	-----	9×10^{-4}
Phosphorus (15)	P 32	-----	2×10^{-4}
Platinum (78)	Pt 191	-----	1×10^{-3}
	Pt 193m	-----	1×10^{-2}
	Pt 197m	-----	1×10^{-2}
	Pt 197	-----	1×10^{-3}
Potassium (19)	K 42	-----	3×10^{-3}
Praseodymium (59)	Pr 142	-----	3×10^{-4}
	Pr 143	-----	5×10^{-4}
Promethium (61)	Pm 147	-----	2×10^{-3}
	Pm 149	-----	4×10^{-4}
Rhenium (75)	Re 183	-----	6×10^{-3}
	Re 186	-----	9×10^{-4}
	Re 188	-----	6×10^{-4}

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[1] Values are given only for those materials normally used as gases.

[2] μCi/gm for solids.

† Amended 38 FR 29314.

Element (atomic number)	Isotope	Column I Gas concentration µCi/ml[1] †	Column II Liquid and solid concentration µCi/ml[2] †
Rhodium (45)	Rh 103m	-----	1×10^{-1}
	Rh 105	-----	1×10^{-3}
Rubidium (37)	Rb 86	-----	7×10^{-4}
Ruthenium (44)	Ru 97	-----	4×10^{-3}
	Ru 103	-----	8×10^{-4}
	Ru 105	-----	1×10^{-3}
	Ru 106	-----	1×10^{-4}
Samarium (62)	Sm 153	-----	8×10^{-4}
Scandium (21)	Sc 46	-----	4×10^{-4}
	Sc 47	-----	9×10^{-4}
	Sc 48	-----	3×10^{-4}
Selenium (34)	Se 75	-----	3×10^{-3}
Silicon (14)	Si 31	-----	9×10^{-3}
Silver (47)	Ag 105	-----	1×10^{-3}
	Ag 110m	-----	3×10^{-4}
	Ag 111	-----	4×10^{-4}
Sodium (11)	Na 24	-----	2×10^{-3}
Strontium (38)	Sr 85*	-----	1×10^{-3}
	Sr 89	-----	1×10^{-4}
	Sr 91	-----	7×10^{-4}
	Sr 92	-----	7×10^{-4}
Sulfur (16)	S 35	9×10^{-8}	6×10^{-4}
Tantalum (73)	Ta 182	-----	4×10^{-4}
Technetium (43)	Tc 96m	-----	1×10^{-1}
	Tc 96	-----	1×10^{-3}
Tellurium (52)	Te 125m	-----	2×10^{-3}
	Te 127m	-----	6×10^{-4}
	Te 127	-----	3×10^{-3}
	Te 129m	-----	3×10^{-4}
	Te 131m	-----	6×10^{-4}
	Te 132	-----	3×10^{-4}
Terbium (65)	Tb 160	-----	4×10^{-4}
Thallium (81)	Tl 200	-----	4×10^{-3}
	Tl 201	-----	3×10^{-3}
	Tl 202	-----	1×10^{-3}
	Tl 204	-----	1×10^{-3}
Thulium (69)	Tm 170	-----	5×10^{-4}
	Tm 171	-----	5×10^{-3}
Tin (50)	Sn 113	-----	9×10^{-4}
	Sn 125	-----	2×10^{-4}
Tungsten (Wolfram) (74)	W 181	-----	4×10^{-3}
	W 187	-----	7×10^{-4}
Vanadium (23)	V 48	-----	3×10^{-4}
Xenon (54)	Xe 131m	4×10^{-6}	-----
	Xe 133	3×10^{-6}	-----
	Xe 135	1×10^{-6}	-----
Ytterbium (70)	Yb 175	-----	1×10^{-3}
Yttrium (39)	Y 90	-----	2×10^{-4}
	Y 91m	-----	3×10^{-2}
	Y 91	-----	3×10^{-4}
	Y 92	-----	6×10^{-4}
	Y 93	-----	3×10^{-4}

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[1] Values are given only for those materials normally used as gases.

[2] µCi/gm for solids.

† Amended 38 FR 29314.

Element (atomic number)	Isotope	Column I Gas concentration µCi/ml[1] †	Column II Liquid and solid concentration µCi/ml[2] †
Zinc (30)	Zn 65	-----	1×10^{-3}
	Zn 69m	-----	7×10^{-4}
	Zn 69	-----	2×10^{-2}
Zirconium (40)	Zr 95	-----	6×10^{-4}
	Zr 97	-----	2×10^{-4}
Beta and/or gamma emitting byproduct material not listed above with half-life less than 3 years.	--------	1×10^{-10}	1×10^{-6}

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NOTE 1: Many radioisotopes disintegrate into isotopes which are also radioactive. In expressing the concentrations in Schedule A, the activity stated is that of the parent isotope and takes into account the daughters.

NOTE 2: For purposes of § 30.14 where there is involved a combination of isotopes, the limit for the combination should be derived as follows:

Determine for each isotope in the product the ratio between the concentration present in the product and the exempt concentration established in Schedule A for the specific isotope when not in combination. The sum of such ratios may not exceed "1" (i.e., unity).

Example:

$$\frac{\text{Concentration of Isotope A in Product 1}}{\text{Exempt concentration of Isotope A}} + \frac{\text{Concentration of Isotope B in Product}}{\text{Exempt concentration of Isotope B}} \leq 1$$

§ 30.71 Schedule B.

Byproduct material	*Microcuries*
Antimony 122 (Sb 122)	100
Antimony 124 (Sb 124)	10
Antimony 125 (Sb 125)	10
Arsenic 73 (As 73)	100
Arsenic 74 (As 74)	10
Arsenic 76 (As 76)	10
Arsenic 77 (As 77)	100
Barium 131 (Ba 131)	10
**Barium 133 (Ba 133)	10
Barium 140 (Ba 140)	10
Bismuth 210 (Bi 210)	1
Bromine 82 (Br 82)	10
Cadmium 109 (Cd 109)	10
Cadmium 115m (Cd 115m)	10
Cadmium 115 (Cd 115)	100
Calcium 45 (Ca 45)	10
Calcium 47 (Ca 47)	10
Carbon 14 (C 14)	100
Cerium 141 (Ce 141)	100
Cerium 143 (Ce 143)	100
Cerium 144 (Ce 144)	1
Cesium 131 (Cs 131)	1,000

35 FR 6425

** Added 36 FR 16898.

* Added 35 FR 3982.

Byproduct material	*Microcuries*
Cesium 134m (Cs 134m)	100
Cesium 134 (Cs 134)	1
Cesium 135 (Cs 135)	10
Cesium 136 (Cs 136)	10
Cesium 137 (Cs 137)	10
Chlorine 36 (Cl 36)	10
Chlorine 38 (Cl 38)	10
Chromium 51 (Cr 51)	1,000
Cobalt 58m (Co 58m)	10
Cobalt 58 (Co 58)	10
Cobalt 60 (Co 60)	1
Copper 64 (Cu 64)	100
Dysprosium 165 (Dy 165)	10
Dysprosium 166 (Dy 166)	100
Erbium 169 (Er 169)	100
Erbium 171 (Er 171)	100
Europium 152 9.2h (Eu 152 9.2h)	100
Europium 152 13 yr (Eu 152 13 yr)	1
Europium 154 (Eu 154)	1
Europium 155 (Eu 155)	10
Fluorine 18 (F 18)	1,000
Gadolinium 153 (Gd 153)	10
Gadolinium 159 (Gd 159)	100
Gallium 72 (Ga 72)	10
Germanium 71 (Ge 71)	100
Gold 198 (Au 198)	100
Gold 199 (Au 199)	100
Hafnium 181 (Hf 181)	10
Holmium 166 (Ho 166)	100
Hydrogen 3 (H 3)	1,000
Indium 113m (In 113m)	100
Indium 114m (In 114m)	10
Indium 115m (In 115m)	100
Indium 115 (In 115)	10
Iodine 125 (I 125)	1
Iodine 126 (I 126)	1
Iodine 129 (I 129)	0.1
Iodine 131 (I 131)	1
Iodine 132 (I 132)	10
Iodine 133 (I 133)	1
Iodine 134 (I 134)	10
Iodine 135 (I 135)	10
Iridium 192 (Ir 192)	10
Iridium 194 (Ir 194)	100
Iron 55 (Fe 55)	100
Iron 59 (Fe 59)	10
Krypton 85 (Kr 85)	100
Krypton 87 (Kr 87)	10
Lanthanum 140 (La 140)	10
Lutetium 177 (Lu 177)	100
Manganese 52 (Mn 52)	10
Manganese 54 (Mn 54)	10
Manganese 56 (Mn 56)	10
Mercury 197m (Hg 197m)	100
Mercury 197 (Hg 197)	100
Mercury 203 (Hg 203)	10
Molybdenum 99 (Mo 99)	100
Neodymium 147 (Nd 147)	100
Neodymium 149 (Nd 149)	100
Nickel 59 (Ni 59)	100
Nickel 63 (Ni 63)	10
Nickel 65 (Ni 65)	100
Niobium 93m (Nb 93m)	10
Niobium 95 (Nb 95)	10
Niobium 97 (Nb 97)	10
Osmium 185 (Os 185)	10
Osmium 191m (Os 191m)	100
Osmium 191 (Os 191)	100
Osmium 193 (Os 193)	100
Palladium 103 (Pd 103)	100
Palladium 109 (Pd 109)	100
Phosphorous 32 (P 32)	10
Platinum 191 (Pt 191)	100
Platinum 193m (Pt 193m)	100
Platinum 193 (Pt 193)	100
Platinum 197m (Pt 197m)	100
Platinum 197 (Pt 197)	100
Polonium 210 (Po 210)	0.1
Potassium 42 (K 42)	10
Praseodymium 142 (Pr 142)	100
Praseodymium 143 (Pr 143)	100
Promethium 147 (Pm 147)	10
Promethium 149 (Pm 149)	10
Rhenium 186 (Re 186)	100
Rhenium 188 (Re 188)	100
Rhodium 103m (Rh 103m)	100
Rhodium 105 (Rh 105)	100
Rubidium 86 (Rb 86)	10
Rubidium 87 (Rb 87)	10
Ruthenium 97 (Ru 97)	100
Ruthenium 103 (Ru 103)	10
Ruthenium 105 (Ru 105)	10
Ruthenium 106 (Ru 106)	1
Samarium 151 (Sm 151)	10
Samarium 153 (Sm 153)	100
Scandium 46 (Sc 46)	10
Scandium 47 (Sc 47)	100
Scandium 48 (Sc 48)	10
Selenium 75 (Se 75)	10
Silicon 31 (Si 31)	100
Silver 105 (Ag 105)	10
Silver 110m (Ag 110m)	1
Silver 111 (Ag 111)	100
Sodium 24 (Na 24)	10
Strontium 85 (Sr 85)	10
Strontium 89 (Sr 89)	1
Strontium 90 (Sr 90)	0.1
Strontium 91 (Sr 91)	10
Strontium 92 (Sr 92)	10
Sulfur 35 (S 35)	100
Tantalum 182 (Ta 182)	10
Technetium 96 (Tc 96)	10
Technetium 97m (Tc 97m)	100
Technetium 97 (Tc 97)	100
Technetium 99m (Tc 99m)	100
Technetium 99 (Tc 99)	10
Tellurium 125m (Te 125m)	10
Tellurium 127m (Te 127m)	10
Tellurium 127 (Te 127)	100
Tellurium 129m (Te 129m)	10
Tellurium 129 (Te 129)	100
Tellurium 131m (Te 131m)	10
Tellurium 132 (Te 132)	10
Terbium 160 (Tb 160)	10
Thallium 200 (Tl 200)	100
Thallium 201 (Tl 201)	100
Thallium 202 (Tl 202)	100
Thallium 204 (Tl 204)	10
Thulium 170 (Tm 170)	10
Thulium 171 (Tm 171)	10
Tin 113 (Sn 113)	10
Tin 125 (Sn 125)	10
Tungsten 181 (W 181)	10
Tungsten 185 (W 185)	10
Tungsten 187 (W 187)	100
Vanadium 48 (V 48)	10
Xenon 131m (Xe 131m)	1,000
Xenon 133 (Xe 133)	100
Xenon 135 (Xe 135)	100
Ytterbium 175 (Yb 175)	100
Yttrium 90 (Y 90)	10
Yttrium 91 (Y 91)	10
Yttrium 92 (Y 92)	100
Yttrium 93 (Y 93)	100
Zinc 65 (Zn 65)	10
Zinc 69m (Zn 69m)	100
Zinc 69 (Zn 69)	1,000
Zirconium 93 (Zr 93)	10
Zirconium 95 (Zr 95)	10
Zirconium 97 (Zr 97)	10
Any byproduct material not listed above other than alpha emitting byproduct material	0.1

NOTE.—The reporting and record keeping requirements contained in this part have been approved by the General Accounting Office under B-180225 (R0079), (R0089), and (R0173).

NUCLEAR REGULATORY COMMISSION

[10 CFR Part 71]

Packaging of Radioactive Material for Transportation and Transportation of Radioactive Material Under Certain Conditions; Compatibility With IAEA Regulations

AGENCY: U.S. Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Nuclear Regulatory Commission is considering revising its regulations for the transportation of radioactive material to make them compatible with those of the International Atomic Energy Agency (IAEA) and thus with those of most major nuclear nations of the world. Although several substantive changes are proposed in order to provide a more uniform degree of safety for various types of shipments, the Commission's basic standards for radioactive material packaging would remain unchanged. The Department of Transportation is also proposing a corresponding rule change to its Hazardous Materials Transport Regulations.

DATES: Comments must be received on or before October 16, 1979.

ADDRESSES: Interested persons are invited to submit written comments and suggestions on the proposal and/or the supporting value/impact analysis to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch. Single copies of the value/impact analysis may be obtained on request from the contact identified below. Copies of the value/impact analysis and of comments received by the Commission may be examined in the Commission's Public Document Room at 1717 H Street, N.W. Washington, D.C.

FOR FURTHER INFORMATION CONTACT: Mr. Donald R. Hopkins, Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Teleph[illegible] 301-443-5946.

SUPPLEMENTARY INFORMATION: In 1968 the Atomic Energy Commission (AEC) amended its regulations in 10 CFR Part 71, then entitled "Packaging of Radioactive Material for Transport" (33 FR 17621), to be compatible with the Department of Transportation's revision (33 FR 14918) of its regulations pertaining to safety in the transport of radioactive material. The AEC regulations at that time applied to the packaging and transportation of radioactive materials in greater than "Type B" quantities and of fissile materials.[1]

Subsequently, AEC regulations were extended to include Type B (greater than Type A) quantities. Among the requirements adopted was one that packages for greater than Type A quantities of radioactive materials and packages for fissile materials had to satisfy certain specified performance criteria when subjected to severe conditions known as "hypothetical accident conditions."

A Type A quantity of non-fissile material is considered not a serious hazard if packaging failure occurs in an accident; however, Type A packages must be able to withstand a wide range of specified conditions which may be experienced in normal transport. The regulations of the Department of Transportation in 49 CFR Parts 170–179 specify the requirements for these packages.

The regulations in the AEC's 10 CFR Part 71, as revised in 1968, were substantially in accord with the recommendations of the International Atomic Energy Agency (IAEA) as published in IAEA Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Materials" (1967 edition). Only minor changes have been made to 10 CFR Part 71 since that time except for the change in the administration of Type B packaging requirements and the addition of § 71.42 placing restrictions on shipment of plutonium.

No special restriction on air transport of plutonium is imposed by the present or proposed 10 CFR Part 71, because the congressional legislation restricting such shipment and resulting in the NRC development of a Plutonium Air Transport (PAT) package is a separate and overriding requirement. A separate rulemaking is being undertaken by the Commission to address restrictions on the air transport of plutonium.

Several years of experience in the United States and other countries indicated that the IAEA regulations were generally sound and practical and that they provided a reasonable degree of safety. Although several Type B packages (i.e., packages containing more than a Type A quantity) have been involved in severe accidents in the United States, no known escape of

[1] Present regulations distinguish among Type A quantity (the maximum amount of a particular radionuclide that may be transported in a package designed to withstand specified conditions of normal transportation but not the simulated accident conditions), Type B quantity (a specified amount greater than a Type A quantity but ordinarily requiring no special provision for heat removal), and a large quantity (greater than a Type B quantity).

radioactive material has resulted. It did appear, however, that a more uniform degree of safety for various designs and for different package contents was desirable and could be achieved without undue restriction by some modification of the design requirements and performance criteria of the IAEA regulations.

The IAEA convened panels in 1971 and 1972 to review their transportation regulations and to recommend appropriate amendments. All member countries with a well developed nuclear industry and many international organizations were represented on the panels, the United States participated in the program and in fact initiated many of the amendments. The IAEA subsequently issued the 1973 edition of Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Materials." Reasons for significant changes from the 1967 edition are documented in proposals submitted in advance to the IAEA by member countries, in working papers prepared by study groups during the course of the meetings, and in the taped record. Much of this background information is summarized in IAEA Safety Series No. 37, "Advisory Material for the Application of the IAEA Transport Regulations."

Based on figures compiled for the calendar year 1975, more than 10,000 packages of radioactive material are exported annually from the United States. In order to minimize complication and delay and encourage uniform safety of these export shipments and those which are imported, revision of United States domestic regulations in 10 CFR Part 71 is proposed. This revision, in combination with a corresponding amendment by DOT of Title 49 of the Code of Federal Regulations, will bring the U.S. regulations into accord with relevant portions of the IAEA design and performance requirements to the extent considered feasible, thereby making them compatible with the domestic regulations of most of the international community; remaining differences are discussed below. Although procedures for implementing and enforcing the regulations necessarily vary somewhat among countries, the IAEA administrative requirements are also being adopted where appropriate.

Packages of design having a valid certificate of compliance as of the effective date of this amendment will be treated as complying with the amended regulations provided fabrication is in accordance with design and has been completed within two years after the effective date or before expiration of the certificate of compliance, whichever is later.

It is essential that NRC and Department of Transportation regulations be consistent and that related changes to the regulations of the two agencies be made simultaneously. The proposed changes to DOT's 49 CFR Parts 170–179 and DOT's proposed new Part 127 to Title 49 to make them consistent with the relevant portions of the 1973 IAEA requirements have already been published in the January 8, 1979 issue of the **Federal Register**.

Major Changes

The major changes to 10 CFR Part 71 being proposed deal with assignment of individualized Type A quantities for each radionuclide, and the addition of new Type B(U) and Type B(M) packaging standards. These major changes are discussed in the following paragraphs.

Individualized Type A Quantities

One important change that would be made by the proposed regulations is the elimination of the system used to specify the quantity of radioactive material permitted in Type A packages. Under the present system, radionuclides are divided into seven transport groups which take account of toxicity and specific activity, plus a "special form" category for materials which are not dispersible because of their inherent physical form or because of suitable encapsulation. Under this system, the allowable number of curies for each radionuclide in a group is in most cases the same as the allowable number of curies for the most toxic member of the group. This method is unnecessarily restrictive when applied to the less toxic group members, which in some cases have a maximum permissible body burden more than ten times that of the more toxic members.

The proposed regulation eliminates transport groups. Instead, it assigns to each radionuclide two values, A_1 and A_2, which are the maximum number of curies permitted in Type A packages in special form and normal form, respectively. The A_1 and A_2 values for various radionuclides are listed in the proposed regulation.

The value of A_1 for special form material is intended to limit the possible external radiation dose rate to 1 rem/hour at 3 meters from the source if the contents of the package are released, except that an upper limit of 100 curies is imposed. Special form material must also be nondispersible as determined by certain stringent criteria (which differ somewhat from present criteria for special form) which are set forth in Appendix D of Part 71.

The bases for the A_2 value for normal material (that is, material not in special form) are: (1) and accident of moderate severity might release 0.1% of the contents, and 0.1% of the amount released might then be taken into the body of a human being in the vicinity; this intake should not exceed half the maximum permissible annual intake for workers as given in IAEA Safety Series No. 9, "Basic Safety Standards for Radiation Protection" (1967 Edition); and (2) A_2 shall not exceed A_1. Intake values are based on the International Commission on Radiological Protection (ICRP) 1966 recommended limits for radiation exposure.

The following table compares the present special form and normal form limits with the limits that would be applicable under the proposed rule, for several of the more commonly shipped radionuclides.

The adoption of A_1 and A_2 values will sometimes permit a single Type A package to replace two or more present Type A packages. Also, some of the small number of Type B packages with contents near the lower limit for Type B could be reclassified as Type A. However, the number of Type A packages and the total amount of material in Type A packages is not expected to be significantly affected.

	Limit in type A packages, in curies				
	Present group	Present		Proposed	
		Special form	Normal form	Special form	Normal form
^{241}Am	I	20	0.001	8	0.008
^{14}C	IV	20	20	1000	100
^{252}Cf	I	2	0.001	2	0.009
^{60}Co	III	20	3	7	7
^{137}Cs	III	20	3	30	20
^{131}I	III	20	3	40	10
^{192}Ir	III	20	3	20	20
^{99}Mo	IV	20	20	100	100
^{24}Na	IV	20	20	5	5
^{239}Pu	I	20	0.001	2	0.002
^{90}Sr	II	20	0.05	10	0.4
^{235}U	III	20	3	100	0.2

For some radioactive materials in special form the Type A limit will be increased and for some the Type A limit will be decreased. The change in the number of such packages is also expected to be small.

Type B(U)—Type B(M) Packaging Standards

Type B packages regulated by the NRC currently fall into two categories: those containing Type B quantities and those containing "large quantities" of radioactive material. The present upper limit for Type B quantities and the designation of amounts greater than that limit as "large quantity" were established at a time when large quantities of radioactive material, particularly in the form of irradiated fuel, were thought to require special provision for heat removal and special consideration of the possible escape of coolant under accident conditions. However, experience has shown that, while some present Type B quantities do require special consideration of heat removal, some large quantities do not require such consideration. Also, the hazard associated with escape of radioactive material is not appreciably dependent upon whether the accompanying non-radioactive material is classified as a coolant. Therefore, the proposed rule would combine the existing Type B and large quantities.

Two classifications of Type B packaging, designated as Type B(M) and Type B(U) have been established by the IAEA and are included in the proposed regulations. For international shipment, the Type B(M) package requires approval by the competent authority of each country into or through (but not over) which the package is transported, i.e., multilateral approval. Any special design features or operational controls of the Type B(M) package will thus be subject to review for consistency with the practices and procedures of more than one country. The Type B(U) package is intended to require approval only by the country of origin (i.e., unilateral approval) and for this reason has numerous special features of design and performance as described in proposed § 71.34. Proposed Part 71, however, makes no distinction between Type B(M) and Type B(U) package designs with respect to required approvals. Both types will fall within the general license provisions of § 71.12 for import and export, and will require specific NRC approval for shipments wholly within the United States. In some circumstances, the NRC must also approve the conditions of transport for a Type B(M) package.

Comparison With Current Regulations

Set forth below in a cross-index of paragraphs contained in the proposed revision of Part 71, the present Part 71, and IAEA Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Materials" (1973 Revised Edition). Omissions from proposed Part 71 of requirements in IAEA Safety Series No. 6 are not shown; however, such omissions of a technical and substantive nature are discussed later. Where no entry is shown, there is no closely corresponding paragraph or section.

The administrative requirements in the United States for application to the Nuclear Regulatory Commission for approval of a package design, for review by the Commission staff, and for documentation of design and approvals necessarily differ from those described in IAEA Safety Series No. 6. For most of these items, no cross-index with IAEA Safety Series No. 6 is shown.

Cross Index

	Proposed regulation	Present regulation[1]	IAEA safety series No. 6
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Requirement for license	71.3	71.3	
Definitions	71.4	71.4	
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Homogeneous hyd. mixt	71.9(c)	71.9(d)	601(c)
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Fissile matl. < 5 gm/10l	71.9(e)	71.9(e)	601(e)
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Fissile class III, Case 1	71.11(c)	71.11(a)	
Fissile class III, Case 2	71.11(d)		623
Fissile class III, Case 3	71.11(e)		624
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Valves	71.32(g)		222
Performance in normal transport	71.32(h)	71.35(a)	225
Additional requirements for B(M) pkgs: Performance in accidents	71.33(a)	71.36(a)	229, 243
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Venting system	71.34(c)		235
Pressure relief system	71.34(d)		236
Operating pressure limit	71.34(e)		239
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Liquid leakage assumption	71.35(a)(2)	71.33	602
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[1] All references to sections or paragraphs which begin "173" are to the provisions of 49 CFR Part 173 of the regulations of the Department of Transportation.

Detailed Changes

In addition to the major substantive changes to Part 71 previously discussed and numerous editorial changes for the purpose of clarity or conciseness, there are several other minor modifications. These changes are described below and are accompanied by a reference to the section or paragraph of the proposed rule where the change appears.

1. *Section 71.4—Definitions.* Many definitions needed to reflect the proposed changes to Part 71 have been added, and some existing definitions have been appropriately modified. These changes reflect the meanings of terms as used in the proposed revision to the regulations.

The term "containment system," defined in proposed § 71.4(c), replaces the existing term "containment vessel." The containment system may include a vessel as well as other components intended to retain the radioactive material during transport.

A new classification of radioactive material, "low level solid" (LLS) radioactive material, is being added to the regulations. It is defined in proposed § 71.4(g) and is similar to "low specific activity" (LSA) material, except that the LLS concept permits a greater concentration of radioactive material in the contents of a package and a higher surface contamination, while imposing greater restrictions on the dispersibility and on the permissible method of shipment.

Some changes have also been made for LSA material, defined in proposed § 71.4(h). The specific activity limits will be related to A_2 values rather than to transport group. Articles, such as contaminated equipment, with non-fixed surface contamination have been included within the LSA definition. Methods of concentrating the activity in transport, such as leaching and evaporation, must now be considered. Finally, the limit for tritium oxide in aqueous solution, after consideration of the hazards due to wetting of the skin and to possible inhalation of vapors, has been increased from 5 curies/liter to 10 curies/liter.

The IAEA regulations define "maximum normal operating pressure" (MNOP) as the maximum pressure that would develop in one year without venting or special cooling, under expected but unspecified ambient conditions for that period of time. The concept is applied in those regulations only to Type B(U) packages, for which upper limits of allowable pressure and allowable stresses are imposed.

In the regulatory changes proposed herein, the MNOP concept is applied to Type B(M) packages, and the MNOP is then assumed to be a normal condition of transport at the time of the tests described in Appendices A and B. At the same time the regulations recognizes, in § 71.31(c), that in some cases operational controls, as with a sole-use shipment, may justify assuming a period of time shorter than a year for pressure buildup.

A definition of "stress intensity" has been added in proposed § 71.4(q). This term is used in proposed § 71.34 (f) and (g).

2. *Section 71.8—Exemption for low level materials.* Low-level solid materials and low specific activity materials, even if they should escape from the packaging, present little hazard to individuals in the public because the concentration of radioactivity is small and individuals have a limited capability for inhalation and ingestion of the material. The risk to an individual does not depend to a significant extent on the curie quantity. These materials have therefore been exempted from the requirements of the proposed Part 71, but must satisfy the requirements of the applicable regulations of the Department of Transportation. This exemption was requested in three petitions currently pending before NRC. Type A quantities continue to be exempt from the requirements of Part 71.

3. *Section 71.9—exemption for fissile material.* Proposed § 71.9(a) will require that for up to 15 grams of fissile material to be exempt from the requirements of § 71.35 (standards for fissile material packages), the smallest external dimension of the package shall be not less than 10 cm. Since 15 grams of some fissile materials could physically be contained in a smaller package, the requirement is consistent with proposed § 71.35 (a)(3)(iv) relating to size of aperture in outer surface of packaging. Paragraphs (c) through (g) of § 71.9 contain several changes and additions to the exemptions for fissile material. These changes and additions to the exemption standards for fissile material include:

a. Reduction from 7600 to 5200 of the minimum value of the atomic ratio of hydrogen to fissile material (H/X) that must be exceeded for 500 grams of any fissile radionuclide to be exempt from the packaging requirements of proposed § 71.35. A concentration limit of 5 grams per liter will be imposed on this material. These changes eliminate the need for the H/X requirements presently imposed by § 71.7(b)(4)(iii) and § 71.9(d)(3).

b. Application of quantity limits for bulk shipment to the vehicle rather than to the package.

c. Extension to uranium metal of the present limitations for exemption of uranium compounds.

d. Removal of the restriction on the total amount of fissile radio-nuclides per package, provided the concentration does not exceed 5 grams per 10 liters.

e. Exemption from fissile material packaging requirements of plutonium up to 1 kilogram, but with imposition of certain restrictions on its isotopic composition.

f. Exemption of uranyl nitrate solutions, subject to certain restrictions on fissile content.

4. *Section 71.11—General license for shipment of licensed material.* Paragraphs 71.11(b), (d), and (e) of the proposed regulations for certain fissile Class II and Class III packages correspond to paragraphs 620, 623, and 624 of IAEA Safety Series No. 6 and are added specifications within the scope of a general license.

5. *Section 71.23—Package evaluation.* In accordance with the basis for establishing Type B(M) and B(U) packages, the proposed package evaluation must include a description of any special controls or precautions during the shipping and handling of Type B(M) packages.

6. *Section 71.32—Standards for all Type B packages.* Proposed § 71.32(a), which relates to the strength of lifting attachments, is more general than the existing § 71.31(c). The proposed rule will require the package to withstand abrupt lifting without developing unsafe stresses. At present, packages must withstand three times the weight of the package (or lid) without exceeding yield strength. This change will permit adjustment of the strength requirement in situations where a factor other than three may be appropriate or where the design is intended to safely accommodate a stress exceeding yield strength in some component. In addition, the proposed rule requires the package to satisfy the performance standards even if the lifting attachments should fail under excessive load, as is required for tiedown devices in present and proposed regulations. This new requirement for lifting attachments takes account of the possibility of some obstruction or wedging while handling the package during transshipment.

Proposed paragraphs (b), (c) and (d) of § 71.32, imposing package design features, correspond respectively to present 49 CFR 173.393 (c) and (b) and 10 CFR 71.31(b).

Proposed § 71.32(e), relating to tie-down, is a modification of the existing § 71.31(d). The present specification of strength corresponding to 2, 10, and 5 times the weight of the package in the vertical, longitudinal, and lateral directions, respectively, has been eliminated because for normal transport the required strength depends on the shipping mode and is addressed in DOT regulations, and for accident conditions the tiedown attachments are assumed to fail.

Proposed § 71.32(f), dealing with reactions among package components, corresponds to the present § 71.32(a), but with the added requirement that the consequences of any credible water inleakage must be taken into account. This requirement is included because packages sometimes contain substances that are highly reactive with water.

Proposed § 71.32(g), corresponding to paragraph 222 of IAEA Safety Series No. 6, requires protection of valves. Although this requirement is not in the present regulations, such protection is needed for safety and has been provided in practice.

Proposed § 71.32(h) sets forth general acceptance criteria for normal conditions of transport. This corresponds to paragraphs 225 and 231(a) of IAEA Safety Series No. 6. However, the proposed regulations will require design to be based on an unattended time period of one year for all Type B packages except when, in accordance with § 71.3[illegible], a shorter time is justified by operational controls. During this time, which allows for possible delays in shipping, pressure may continue to develop as a result of chemical reaction (e.g., corrosion) and radiolytic decomposition. By way of comparison, the IAEA regulations in paragraphs 231(a) and 242 require considering for all Type B packages only the effects of heat and only for one week; the one year period is specified only for Type B(U) packages (by requiring them to be designed to withstand "maximum normal operating pressure.")

Paragrphs 233A and 243 of Safety Series No. 6 permit escape of radioactive material at the rate of $A_2 \times 10^{-6}$ per hour in normal transport. This amount is considered to be an insignificant hazard, and was introduced in the 1973 edition of Safety Series No. 6 in recognition of the fact that zero leakage is neither necessary nor attainable for some types of shipments. The reqirements of "no loss or dispersal" in normal transport is being retained in proposed Part 71, but with an acceptance test sensitivity of 10^{-6} A_2 per hour or better. The acceptance criteria and methods of demonstration, which take account of the relative toxicities of the various radionuclides, are addressed in Regulatory Guide 7.4, "Leakage Tests on Packages for Shipment of Radioactive Materials."

The IAEA option of designing Type B(M) packages for continuous venting, with specified limits for escape of radioactive material, hs been omitted from proposed Part 71. There is no apparent need for such design in the United States at present; if the need should arise and if the adequacy of controls is demonstrated, exemptions might be granted on an individual basis.

The present requirement of § 71.32(a) that the strength of a package be analyzed as a simple beam has been eliminated because greater strength is required in order to satisfy the impact tests of the hypothetical accident.

The following IAEA package requirements have been omitted from revised Part 71; several of them are subjects for discussion in existing and contemplated regulatory guides:

a. Paragraphs 201–203 relating to means for handling.

b. Paragraphs 206–207 relating to external crevices or pockets and to decontaminability.

c. Paragraph 208 requiring that any features added at the time of transport shall not reduce safety. Currently in the United States, any such features are considered in the safety analysis.

d. Paragraph 212 requiring that external protrusions be avoided as far as practicable.

e. Paragraph 213 requiring consideration of the ambient temperature range and calling attention to the phenomenon of brittle fracture.

f. Paragraph 214 requiring fusion joints to be in accordance with recognized standards.

g. Paragraph 217 permitting credit to be taken for "special form" as a means of containment. Special form is advantageous because it permits a larger amount of radioactive material per Type A package than does normal form. However, the indispersible nature of special form material in Type B quantities is necessarily taken into account in the evaluation of containment.

h. Paragraph 218 requiring a separate fastening device for a containment system that is a separate unit of the packaging.

i. Paragraph 223 requiring a separate fastening device for a radiation shield that encloses a part of the containment system.

j. Paragraph 233 requiring thermal protection (e.g., insulation) to remain effective under normal and accident conditions and under other conditions, such as cutting or skidding, not simulated in the specified tests. Effectiveness under specified normal and accident conditions is necessarily considered in the safety analysis. The nature of other conditions such as cutting or skidding would require further definition before inclusion in Part 71.

7. *Section 71.33—Additional requirements for Type B(M) packages.* Proposed § 71.33(a)(2) specifies the allowable radiation level after the hypothetical accident as 1000 mrem/hour at 1 meter rather than at 3 ft from the package surface. This change will not significantly affect package design or performance.

The requirements of paragraph 244 of IAEA Safety Series No. 6 that limit stress in the containment system to the yield strength under normal and accident test conditions have not been included in proposed Part 71 because, as specified in the American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, acceptable stresses may be higher or lower depending on details of design. In particular, stresses above yield strength are acceptable at points of stress concentration where local deformation provides stress relief. This subject is treated in Regulatory Guide 7.6, "Stress Allowables for the Design of Shipping Cask Containment Vessels."

The proposed allowable escape of radioactive material from Type B(M) packages under accident conditions is not greatly different from existing limits except to the extent A_2 values differ from present transport group values. Present regulations restrict the loss to gases or contaminated coolant. This restriction is deleted in the proposed revised regulations because the concept of an identifiable coolant is no longer included in the regulations. The following tabulation shows the changes in the allowable release for some radionuclides of particular concern in the shipment of irradiated fuel. The proposed revised regulations specify that the allowable release must not be exceeded in a period of one week.

Allowable Release in Hypothetical Accident (Curies)

	Present [1] (total)	Proposed (in one week)
^{137}Cs	10	20
^{131}I	10	10
^{239}Pu	0.01	0.002
^{133}Xe	1,000	1,000
^{85}Kr	1,000	10,000

[1] Or 0.1% of contents, whichever is less.

In most cases the release rate would decrease shortly after the accident, and the recovery of the damaged package would be expected within less than a week. However, a time limit is necessary for demonstration of compliance, and the NRC considers that the one week specified in IAEA regulations is adequate for corrective action.

Because of its relatively innocuous nature and rapid dispersion in air, special consideration was given to Kr-85, and its limit was increased from 1,000 to 10,000 curies. On the other hand, the allowable release of many present Group I radionuclides will be reduced because the present limit of 0.01 curie exceeds the A_2 value. This is illustrated by the values for ^{239}Pu in the table.

8. *Section 71.34—Additional requirements for Type B(U) packages.* Only a few of the requirements for Type B(U) packages have counterparts in the present regulations. These are identified in the cross-index.

Analysis taking into account the atmospheric dispersal and possible inhalation has shown that any serious radiological injury due to release of an amount A_2 from a package is quite unlikely. The proposed allowable release of this amount from a Type B(M) package under hypothetical accident conditions is thus considered adequately safe. As an added factor of safety for Type B(U) packages, which are intended to be universally acceptable without review by countries other than the country of origin, the specified maximum release under hypothetical accident conditions is smaller than the Type B(M) limit by a factor of 1000. This factor takes into account the possible differences in methods of evaluation in different countries and the freedom from any restrictions on handling or shipment.

Proposed § 71.34 (f) and (g), imposing internal pressure limitations, correspond to paragraphs 237 and 238 of Safety Series No. 6, but use the term "stress intensity" rather than simply "stress," and state which stresses to consider. This change should help to clarify this requirement. Although these requirements, in amplified form, might seem more appropriate for a regulatory guide, they are included in proposed Part 71 because of the need for consistency with IAEA regulations, particularly for Type B(U) packages.

9. *Section 71.35—Standards for fissle material packages.* The editorial arrangement of proposed § 71.35, which contains the revised requirements for fissle material packaging, differs significantly from that of IAEA Safety Series No. 6. However, there is no essential difference in technical requirements and assumptions for evaluation of criticality or in controls required during shipment, except that the requirement for no more than 5% reduction of volume or spacing and no aperture greater than 10 cm in normal transport applies to all fissile material packages in the existing and proposed Part 71, but only to Fissle Class II packages in IAEA Safety Series No. 6. Retention in Part 71 of these requirements for all fissile material packages is considered justified by the added margin of safety for package integrity.

10. *Section 71.54—Rountine determinations.* Proposed § 71.54(b) corresponds to the present 49 CFR 173.393(j) and to paragraphs 534 and 537 of IAEA Safety Series No. 6. A change from the present regulations is that the allowable maximum radiation level for a package transported as a full load in a closed vehicle will be 1000 mrem/h on the surface of the package, rather than at 3 ft from the surface as presently measured. In practice, only small packages are affected since the controlling radiation level for large packages remains the allowable radiation level at the edge of the vehicle or at 2 m from the vehicle. The change reduces allowable surface radiation levels and thus for small packages increases the margin of safety in handling.

Proposed § 71.54(c), specifying allowable surface temperatures, corresponds to the present 49 CFR 173.393(e)(2) and to paragraphs 231(b) and 240 of IAEA Safety Series No. 6. Present NRC and DOT regulations, however, do not specify the ambient air temperature. In accordance with IAEA regulations, ambient air temperature will be assumed to be 38° C (100° F).

The IAEA regulations, however, impose only on Type B(U) packages the limit of 82° C (180° F) for the temperature of readily accessible surfaces with full load shipment; Part 71 will impose this limit on both Type B(U) and Type B(M) packages.

Proposed § 71.54(d), limiting external radioactive contamination, corresponds to present 49 CFR 173.397.

11. *Section 71.62—Records.* Proposed § 71.62(a) defines the records that must be kept for shipment of fissile material and Type B quantities of radioactive material.

12. *Appendix A—Normal conditions of transport.* Proposed Appendix A

describes environmental conditions considered to represent normal transport. Paragraph 232 of IAEA Safety Series No. 6 Specifies 38° C (100° F) as ambient temperature. However, the matter of diurnal variation is not addressed. There are only a few spots in the United States (e.g., Death Valley) where a few days in the year the daily average temperature exceeds 38° C, and then it exceeds that temperature by only a small amount. However, to avoid the need for more complex analysis to consider diurnal variation, and because of other considerations which may increase ambient temperature above that of outside air (e.g., closed vehicles, assembly of multiple heat producing packages, insulating effects of other cargo), the present ambient temperature of 54° C (130° F) has been retained.

The present Part 71 does not specify ambient temperature or internal pressure preceding the normal transport and accident tests. The IAEA regulations specify an ambient temperature of 38° C (100° F) but do not specify a time period during which pressure could develop. Proposed Part 71 will require selecting the most unfavorable ambient temperature between −29° C (−20° F) and 38° C (100° F), and internal pressure equal to the MNOP adjusted for ambient temperature. Although the high temperature is unfavorable with respect to the effects of fire, a low temperature is unfavorable with respect to possible brittle fracture and perhaps other effects. Thus some intermediate temperature may be most unfavorable for a prescribed sequence of tests.

The present § 71.32(b) and Part 71, Appendix A, paragraph 3, require the package to withstand ambient pressures of 25 psig and 0.5 atmosphere, respectively. The requirement to withstand an ambient pressure of 25 psig without damage is not contained in the IAEA regulations, although there is an accident test of immersion in 15 m of water, which results in a pressure of about 21 psig. The resistance to external pressure is considered desirable as a way of providing ruggedness for unspecified rough handling conditions and is in most cases easily satisfied. The low ambient pressure in the proposed Appendix A, as in IAEA Safety Series No. 6, is about 0.25 atmosphere rather than the presently specified 0.5 atmosphere. This change recognizes the possibility of transporting packages in unpressurized compartments of aircraft at altitudes of 10 km or about 33,000 ft.

Although proposed Part 71 requires a water spray test, details of this test as given in IAEA Safety Series No. 6 will be omitted because they are more suitable for a regulatory guide. The specifications for the compression test in proposed paragraph (d), which contemplates packages being stacked, have been converted to the metric system by applying the test to packages up to 5000 kg rather than 10,000 lb and by adopting the IAEA load value of 1300 kg/m^2 (1.85 lb/in^2) rather than the previous 2 lb/in^2. The IAEA regulations do not specify an upper limit for weight. However, such stacking is not contemplated for packages such as spent fuel casks, and thus the test will not be applied to packages greater than 5000 kg.

13. *Appendix B—Hypothetical accident conditions.* As in Appendix A for normal transport conditions, the ambient temperature and internal pressure are specified for the package entering the test sequence. Paragraph (c), describing the thermal test, will be revised for clarity and will require consideration of convective heat input when significant. When the main body of a package is surrounded by and directly exposed to fire, the convective heat input is small compared to radiant heat input. However, some packages are protected partially or wholly by a radiation shield through which air and combustion gases may circulate. In such cases, convective heat input may be significant and must be included since the test is intended to simulate realistic fire conditions with respect to expected total heat input.

A requirement will be added that artificial cooling shall not be applied and that any combustion of materials of construction shall be allowed to proceed until natural termination. The IAEA regulations permit artificial cooling after 3 hours. However, 3 hours may be inadequate for control of fire even in populated areas. Also, unrecognized smoldering may continue for a much longer time.

Proposed paragraph (e) adds an accident test condition of immersion in 15 m of water, since some harbors have such depth and a package might be dropped overboard during handling. Immersion to a greater depth within the United States could occur in one of the Great Lakes, but such occurrence is very improbable.

14. *Appendix C—Determination of A_1 and A_2.* A few of the radioisotopes listed in Appendix C of the present Part 71 have been omitted from the table of A_1 and A_2 values in proposed Part 71, because these radioisotopes have seldom if ever been shipped in recent years. However, the proposed Appendix C provides procedures for determining the A_1 and A_2 values for any radioisotope. A new entry has been included for the radionuclide lead-201 a medical isotope, in response to a petition currently pending before NRC.

15. *Appendix D—Requirements for special form radioactive material.* The qualification tests for special-form radioactive material in proposed Appendix D have been modified, primarily by adding a bending test, providing more detailed instructions for the immersion or leaching procedure, and changing the maximum loss by leaching to 0.05 microcurie in each of two determinations rather than the present 0.005% for a single determination. Long, slender objects are more likely to suffer bending under rough handling or accident conditions than are short or spherical objects; hence, a minimum length of 10 cm and a minimum length-to-width ratio of 10 have been selected for application of the bending test. The proposed leaching test specified by the IAEA regulations has been selected as suitable and should yield uniform results. An absolute amount leached is better related to the hazard than is a fixed percentage. Although 0.05 microcurie is much smaller than any of the A_2 quantities, in this case it is specified as a measure of the indispersibility and is equivalent to the maximum permissible non-fixed surface contamination on an area of 50 cm^2 of a package surface.

Existing regulations require that "special form radioactive material" have either (1) no dimension less than 0.5 mm or (2) at least one dimension greater than 5 mm. It is now proposed that special form radioactive material must have at least one dimension not less than 5 mm. The first option has been removed because of the possible difficulty of identifying, for safe handling, an object as small as 0.5 mm in every dimension.

16. *Miscellaneous.* Several changes and additions that experience indicates will be useful are proposed in the requirements for exemption of fissile material from the provisions of Part 71 and in the specifications for packages of fissile material that are generally licensed. Criticality studies showed that these proposed modifications satisfy the requirements for avoidance of criticality. The IAEA regulations also include some examples of specific packages that the IAEA considers to satisfy criticality requirements but nevertheless to require approval by the competent authority before use. These examples are not included in the proposed revision of 10 CFR Part 71.

The metric system, as represented by the International System of Units (SI), has been incorporated in the proposed regulation. Rounded-off values of equivalents for the English system are given in parentheses, except in a few cases where the conversion seems unnecessary or inappropriate.

The Commission has determined that neither the Council of Environmental Quality guidelines, 40 CFR Part 1500, nor the NRC regulations in 10 CFR Part 51, "Licensing and Regulatory Policy and Procedures for Environmental Quality," require the NRC to prepare an environmental impact statement for the proposed revision of 10 CFR Part 71. Concurrently with the publication of this notice of proposed rule making the Commission is making available in its Public Document Room at 1717 H Street, NW., Washington, D.C., an "Environmental Impact Assessment of Changes to Radioactive Material Transport Regulations," to support the negative declaration required by 10 CFR Part 51.

The Commission has determined that no significant changes are being made in the reporting requirements of 10 CFR Part 71, so no GAO clearance is required.

Interested persons are invited to submit written comments and suggestions on the proposal and/or the supporting value/impact analysis to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch. Copies of the value/impact analysis supporting the rule are available for public inspection at the Commission's Public Document Room at 1717 H Street, N.W., Washington, D.C. Single copies of the value/impact analysis may be obtained on request from: Mr. Donald R. Hopkins, Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Telephone: 301-443-5946.

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and section 553 of title 5 of the United States Code, notice is hereby given that adoption of the following revision to 10 CFR Part 71 in its entirety is contemplated.

PART 71—PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL

Subpart A—General Provisions

Authority: The provisions of this Part 71 issued under secs. 53, 63, 81, 161, 182, 183, 68 Stat. 930, 933, 935, 948, 953, 954, as amended; 42 U.S.C. 2073, 2093, 2111, 2201, 2232, 2233, unless otherwise noted. For the purposes of sec. 223, 68 Stat. 958, as amended; 42 U.S.C. 2273, sections 71.61–71.63 issued under sec. 161o, 68 Stat. 950, as amended; 42 U.S.C. 2201(o). Secs. 202, 206, Pub. L. 93–438, 88 Stat. 1244, 1246; 42 U.S.C. 5842, 5846.

Subpart A—General Provisions

§ 71.1 Purpose.

(a) This part establishes: (1) Requirements for packaging, preparation for shipment, and transportation of licensed material; and (2) procedures and standards for approval by the Nuclear Regulatory Commission of packaging and shipping procedures for fissile material (uranium-233, uranium-235, plutonium-238, plutonium-239, or plutonium-241) and for quantities of other licensed material in excess of type A quantities, as defined in § 71.4(s).

(b) The packaging and transport of these materials are also subject to other parts of this chapter and to the regulations of other agencies having jurisdiction over means of transport. The requirements of this part are in addition to, and not in substitution for, other requirements.

§ 71.2 Scope.

The regulations in this part apply to any licensee authorized by specific license issued by the Commission to receive, possess, use, or transfer licensed materials, if the licensee delivers such materials to a carrier for transport or transports such material outside the confines of his facility, plant or other authorized place of use. No provision of this part shall be construed to authorize possession of licensed material.

§ 71.3 Requirement for license.

No licensee subject to the regulations in this part shall (a) deliver any licensed materials to a carrier for transport or (b) transport licensed material except as authorized in a general license or a specific license issued by the Commission, or as exempted in this part.

§ 71.4 Definitions.

As used in this part:

(a) "A_1 or A_2" means the maximum activity of special form or normal form radioactive material, respectively, permitted in Type A package. These values are listed in Appendix C, Table C-1, for many radionuclides. Rules given in Appendix C may be used to derive A_1 and A_2 values for individual radionuclides and for mixtures.

(b) "Close reflection by water" means immediate contact by water of sufficient thickness for maximum reflection of neutrons.

(c) "Containment system" means the components of the packaging intended to retain the radioactive material during transport.

(d) "Fissile classification" means classification of a package or shipment

of fissile materials according to the controls needed to provide nuclear criticality safety during transportation as follows:

(1) *Fissile Class I:* Packages which may be transported in unlimited numbers and in any arrangement, and which require no nuclear criticality safety controls during transportation. A transport index is not assigned for purposes of nuclear criticality safety but may be required because of external radiation levels.

(2) *Fissile Class II:* Packages which may be transported together in any arrangement but, for criticality control, in numbers which do not exceed an aggregate transport index of 50. Such shipments require no other nuclear criticality safety control by the shipper during transportation. Individual packages may have a transport index not less than 0.1 and not more than 10.

(3) *Fissile Class III:* Shipments of packages which do not meet the requirements of Fissile Classes I or II and which are controlled in transportation by special arrangements between the shipper and the carrier to provide nuclear criticality safety.

(e) "Fissile material" and "fissile radionuclides": "Fissile material" means any material consisting of or containing one or more of the fissile radionuclides, which shall be taken as uranium-233, uranium-235, plutonium-238, plutonium-239, and plutonium-241. Unirradiated natural and depleted uranium are not considered to be fissile materials.

(f) "Full load" (also referred to as "sole use" and "exclusive use" in IAEA and DOT regulations) means any shipment:

(1) From a single consignor having the exclusive use of a transport vehicle or of an aircraft, or of a hold or compartment of an inland watercraft, or of a hold, compartment, or defined deck area of a seagoing vessel; and

(2) For which all initial, intermediate, and final loading and unloading is carried out by or under the supervision of the consignor, consignee, or the designated agent of either party.

(g) "Low-level solid radioactive material (LLS)"[1] means any of the following:

(1) Solids (e.g., consolidated wastes, activated materials) in which:

(i) The activity under normal transport conditions is, and remains, distributed throughout a solid or a collection of solid objects, or is, and remains, uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic);

(ii) The activity is, and remains, insoluble so that, even under loss of packaging, the loss of radioactive material per package resulting from the effects of wind, rain, etc., and from total immersion in water is limited to less than 0.1 A_2 in a period of one week; and

(iii) The estimated activity averaged throughout the material does not exceed 2×10^{-3} A_2/g.

(2) Objects of non-radioactive material contaminated with radioactive material, provided that the radioactive contamination is in a non-readily dispersible form and the level of contamination averaged over 1 m^2 (or the area of the surface if it is less than 1 m^2) does not exceed 20 μCi/cm^2, of which no more than 2 μCi/cm^2 may be alpha emitters other than natural or depleted uranium or natural thorium.

(h) "Low specific activity material (LSA)"[2] means any of the following:

(1) Uranium or thorium ores and physical or chemical concentrates of those ores.

(2) Natural or depleted uranium or natural thorium.

(3) Tritium oxide in aqueous solutions, provided the concentration does not exceed 10 Ci/liter.

(4) Materials in which the activity, under normal transport conditions, is, and remains, uniformly distributed and in which the average estimated specific activity does not exceed 10^{-4} A_2/g.

(5) Materials in which the activity is uniformly distributed and which, if reduced to the minimum volume under conditions likely to be encountered in transport, such as dissolution in water with subsequent recrystallization, precipitation, evaporation, combustion, abrasion, etc., would have an average estimated specific activity of no more than 10^{-4} A_2/g.

(6) Objects of non-radioactive material contaminated with radioactive material, provided the non-fixed surface contamination does not exceed ten times the values given in § 71.54(b), Table VI, and the contaminated object or the contamination on the object, if reduced to the miminum volume under conditions likely to be encountered in transport, such as dissolution in water with subsequent recrystallization, precipitation, evaporation, combustion, abrasion, etc., would have an average estimated specific activity of no more than 10^{-4} A_2/g.

(7) Objects of non-radioactive material contaminated with radioactive material, provided that the radioactive contamination is in a non-readily dispersible form and the level of contamination averaged over 1 m^2 (or the area of the surface if it is less than 1 m^2) does not exceed 1 μCi/cm^2, of which no more than 0.1 μCi/cm^2 may be alpha emitters other than natural or depleted uranium or natural thorium.

(i) "Maximum normal operating pressure" means the maximum gauge pressure that would develop in the containment system in a period of one year under the normal condition of transport specified in paragraph (1) of Appendix A, in the absence of venting, external cooling by an ancillary system, or operational controls during transport.

(j) "Normal form radioactive material" means radioactive material which has not been demonstrated to satisfy the requirements for "special form" radioactive material.

(k) "Optimum interspersed hydrogenous moderation" means the presence of hydrogenous material between components of the packaging to such an extent that the maximum nuclear reactivity results.

(l) "Package" means the packaging together with its radioactive contents as presented for transport.

(1) "Fissile material package" means a fissile material packaging together with its fissile contents.

(2) "Type A package" means a Type A packaging together with its radioactive contents.

(3) "Type B package" means a Type B packaging together with its radioactive contents. The two classifications of Type B package are as follows:

(i) "Type B(M) package," which may be subject to special conditions of shipment or storage; or

(ii) "Type B(U) package" which has the special design and performance features described in § 71.34 and which requires no special conditions of shipment or storage.

(m) "Packaging" means the assembly of components necessary to ensure compliance with the packaging requirements of this part. It may, in particular, consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or for absorbing mechanical shocks. The vehicle, tie-down system, and auxiliary equipment may form an integral part of the packaging.

(n) "Radioactive material" means any material, or combination of materials, having a specific activity greater than 0.002 microcuries per gram (μCi/g).

(o) "Special form radioactive material" means radioactive material which meets the requirements of Appendix D.

[1] Packaging requirements for LLS are set forth in 49 CFR Part 127.

[2] Packaging requirements for LSA are set forth in 49 CFR Part 127.

(p) "Specific activity" of a radionuclide means the activity of the radionuclides per unit mass of that nuclide. The specific activity of a material in which the radionuclides are essentially uniformly distributed is the activity per unit mass of the material.

(q) "Stress intensity" means twice the maximum shear stress and is equal to the largest algebraic difference between any two of the three principal stresses at a point.

(r) "Transport index" means the dimensionless number (rounded up to the first decimal place) placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation, and determined as follows:

(1) The number expressing the maximum radiation level in millirem per hour at 1 meter from the external surface of [illegible] package; or

(2) For [illegible] Class II packages, the number [illegible]ing the maximum radiatio[illegible]n millirem per hour at 1 meter from the external surface of the package, or the number obtained by dividing 50 by the number of such packages which may be transported together per shipment as determined under § 71.35(c), whichever number is larger.

(s) "Type A quantity" means a quantity of radioactive material, the aggregate radioactivity of which does not exceed A_1 for special form radioactive material or A_2 for normal form radioactive material, where A_1 and A_2 are given in Appendix C to this part or may be determined by procedures described therein.

(t) "Type B quantity" means a quantity of radioactive material greater than a Type A quantity.

(u) "Uranium—natural, depleted, enriched"

(1) "Natural uranium" means uranium with the naturally occurring distribution of uranium isotopes (approximately 99.28% uranium-238, 0.72% uranium-235).

(2) "Depleted uranium" means uranium containing less than 0.72% uranium-235.

(3) "Enriched uranium" means uranium containing more than 0.72% uranium-235, with the remainder being uranium-238.

§ 71.5 Transportation of licensed material.

(a) No licensee shall transport any licensed material outside of the confines of his plant or other place of use, or deliver any licensed material to a carrier for transport, unless the licensee complies with the applicable requirements of the regulations of the Department of Transportation in 49 CFR Parts 127 and 170–189, and the U.S. Postal Service in 39 CFR Parts 14 and 15, and in addition complies with the requirements of this Part, insofar as such regulations relate to the packaging of byproduct, source, or special nuclear material, marking and labeling of the packages, loading and storage of packages, placarding of the transportation vehicle, monitoring requirements and accident reporting.

(b) When Department of Transportation regulations are not applicable to shipments of licensed material by rail, highway, or water because the shipment or the transportation of the shipment is not in interstate or foreign commerce, or to shipments of licensed material by air because the shipment is not transported in civil aircraft, the licensee shall conform to the standards and requirements of the Department of Transportation, specified in paragraph (a) of this section, to the same extent as if the shipment or transportation were in interstate or foreign commerce or in civil aircraft. Any requests for modifications, waivers, or exemptions from those requirements, and any notifications referred to in those requirements shall be filed with or made to the Nuclear Regulatory Commission.

(c) Paragraph (a) of this section shall not apply to the transportation of licensed material or to the delivery of licensed material to a carrier for transport, where such transportation is subject to the regulations of the Department of Transportation or the U.S. Postal Service.

Exemptions

§ 71.6 Specific exemptions.

On application of any interested person or on its own initiative, the Commission may grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not endanger life or property or the common defense and security.

§ 71.7 Exemption of physicians.

Physicians, as defined in § 35.3(b) of this chapter, are exempt from § 71.5 with respect to the transport of licensed material for use in the practice of medicine.

§ 71.8 Exemption for low level materials.

A licensee is exempt from all the requirements of this part other than § 71.5 for the following shipments:

(a) Shipments of licensed material having a specific activity not greater than 0.002 microcurie/gram; and

(b) Packages or shipments of low specific activity or low level solid radioactive material as defined in § 71.4, provided the fissile material exemption standards of § 71.9 are satisfied; and

(c) Packages each of which contains no more than a Type A quantity of radioactive material as defined in § 71.4, provided the fissile material exemption standards of § 71.9 are satisfied.

§ 71.9 Exemption for fissile material.

A licensee is exempt from the requirements of § 71.35 to the extent that he transports or delivers to a carrier for transport:

(a) Packages containing individually not more than 15 grams of fissile radionuclides. When material is transported in bulk, the quantity limitations apply to the vehicle, inland waterway craft or part of a seagoing vessel; or

(b) Packages containing homogeneous hydrogenous solutions or mixtures satisfying the conditions listed in Table I of this part. When material is transported in bulk, the quantity limitations apply to the vehicle, inland waterway craft, or part of a seagoing vessel; or

Table I.—*Limitations on Homogeneous Hydrogenous Solutions or Mixtures for Exemptions From § 71.35 in Accordance with § 71.9(c)*

Parameters	Uranium-235 only	Any other fissile radionuclide (including mixtures)
Minimun H/X [1]	5200	5200
Maximum concentration of fissile radionuclides in solution or mixture, g/1	5	5
Maximum mass of fissile radionuclides in package, g	800 [2]	500

[1] Where H/X is the ratio of the number of hydrogen atoms to the number of atoms of fissile nuclide.

[2] Total mass of plutonium and uranium-233 shall not exceed 1% of the mass of uranium-235.

(c) Packages containing uranium enriched in uranium-235 to a maximum of 1% by weight, and with a total plutonium and uranium-233 content of up to 1% of the mass of uranium-235, provided that the fissile radionuclides are distributed homogeneously throughout the material. In addition, if uranium-235 is present in metallic or

oxide form, it shall not form a lattice arrangement within the package: or

(d) Packages containing any fissile material, provided they do not contain more than 5 grams of fissile radionuclides in any 10-liter volume, and provided the material is in packages which will maintain the limitations of fissile radionuclide distribution during normal transport: or

(e) Packages containing individually not more than one kilogram of plutonium, of which not more than 20% by mass may consist of plutonium-239, plutonium-241, or any combination of those radionuclides: or

(f) Packages containing liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2% by weight, and with total plutonium and uranium-233 not more than 0.1% of the mass of uranium-235.

General Licenses

§ 71.11 General license for shipment of fissile material.

A general license is hereby issued, to persons holding specific licenses issued pursuant to this chapter, to deliver fissile material to a carrier for transport, without complying with the package standards of Subpart C of this part, provided that:

(a) The material is shipped as Fissile Class II packages with the following limitations:

(1) Each package shall contain no more than a Type A quantity of radioactive material, as defined in § 71.4; and

(2) No package contains more than:

(i) 40 grams of uranium-235; or

(ii) 30 grams of uranium-233; or

(iii) 25 grams of plutonium, except that for encapsulated plutonium-beryllium neutron sources the maximum amount of plutonium may be 400 grams or A_1 (curies) whichever is the smaller mass; or

(iv) A combination of uranium-235, uranium-233 and plutonium in which the sum of the ratios of the amount of each radionuclide to the corresponding maximum amounts in paragraphs (i), (ii) and (iii) does not exceed unity; and

(3) Each package containing more than 15 grams of fissile radionuclides is labeled with a transport index (T.I.) not less than the number given by the following equation, where the package contains x grams of uranium-235, y grams of uranium-233 and z grams of plutonium:

$$\text{Minimum T.I.} = (0.40x + 0.67y + z)\left(1 - \frac{15}{x + y + z}\right)$$

except that for a package in which the only fissible material is an encapsulated plutonium-beryllium source, the transport index based on criticality considerations may be taken as 0.026 times the number of grams of plutonium in excess of 15 grams. In all cases the transport index shall be rounded up to one decimal place, and shall not exceed 10.0; or

(b) The material is shipped as Fissile Class II packages with the following limitations:

(1) Each package shall contain no more than a Type A quantity of radioactive material as defined in § 71.4; and

(2) Beryllium and hydrogenous material enriched in deuterium shall not be present; and

(3) The total mass of graphite present shall not exceed 150 times the total mass of uranium-235 plus plutonium; and

(4) Substances having a higher hydrogen density than water, e.g. some hydrocarbon oils, shall not be present, except that polyethylene may be used for packing or wrapping; and

(5) Uranium-233 shall not be present, and the amount of plutonium shall not exceed 1% of the amount of uranium-235; and

(6) The amount of uranium-235 shall be limited as follows:

(i) If the fissile radionuclides are not uniformly distributed, the maximum amount of uranium-235 per package shall not exceed the value given in Table II of this part; or

(ii) If the fissile radionuclides are distributed uniformly and cannot form a lattice arrangement within the packaging, the maximum amount of uranium-235 per package shall not exceed the value given in Table III of this part; and

(7) The transport index of each package based on criticality considerations shall be taken as 10 times the number of grams of uranium-235 in the package divided by the maximum allowable number of grams per package in accordance with Table II or Table III of this section as applicable; or

(c) The material is shipped as Fissile Class III packages with the following limitations:

(1) Each single package shall contain no more than a Type A quantity of radioactive material, as defined in § 71.4, nor more than 400 grams total of plutonium-238, plutonium-239, and plutonium-241 encapsulated as plutonium-beryllium neutron sources, and

(2) The fissile radionuclide content of the shipment shall not exceed:

(i) 500 grams of uranium-235; or

(ii) 300 grams total of uranium-233, plutonium-238, plutonium-239 and plutonium-241; or

(iii) A total quantity of uranium-233, uranium-235, and plutonium such that the sum of the ratios of the quanity of each radionuclide to the quanity specified in paragraphs (2)(i) and (2)(ii) of this paragraph exceeds unity; or

(iv) 2500 grams of plutonium-238 plutonium-239, and plutonium-241 encapsulated as plutonium-beryllium neutron sources; and

(3) Shipment of these packages shall be made only under procedures specifically authorized by the Department of Transportation pursuant to 49 CFR 127.507 of its regulations, so as to prevent loading, transport or storage of these packages with other fissile Class II or Fissile Class III packages:

(d) The material is shipped as Fissile Class III packages under the following conditions:

(1) Each package shall contain no more than a Type A quantity of radioactive material, as defined in § 71.4(s); and

(2) The packages are currently approved as Fissile Class II packages and the number of packages in any one consignment does not exceed twice the number which may be transported together as specified in the Fissile Class II approval; and

Table II.—*Permissible Mass of Uranium-235 per Fissile Class II Package Applicable to § 71.11(b)(6)(i) (Nonuniform Distribution)*

Uranium enrichment in weight per cent of uranium-235 not exceeding—	Permissible maximum grams of uranium-235 per package
20	42
15	45
11	48
10	51
9.5	52
9	54
8.5	55
8	57
7.5	59
7	60
6.5	62
6	65
5.5	68
5	72
4.5	76
4	80
3.5	88
3	100
2.5	120
2	164
1.5	272
1.35	320
1	680
0.92	1200

Table III.—*Permissible Mass of Uranium-235 per Fissile Class II Package Applicable to § 71.11(b)(6)(ii) (Uniform Distribution)*

Uranium enrichment in weight percent of uranium-235 not exceeding—	Permissible maximum grams of uranium-235 per package
4	84
3.5	92
3	112
2.5	148
2	240
1.5	560
1.35	800

Table IV.—*Permissible Mass of Uranium-235 per Fissile Class III Consignment Applicable to § 71.11(e)(6)(i) (Nonuniform Distribution)*

Uranium enrichment in weight percent of uranium-235 not exceeding—	Permissible maximum grams of uranium-235 per consignment
20	520
15	560
11	600
10	640
9.5	655
9	675
8.5	690
8	710
7.5	730
7	750
6.5	780
6	810
5.5	850
5	900
4.5	950
4	1000
3.5	1100
3	1250
2.5	1500
2	2050
1.5	3400
1.35	4000
1	8500
0.92	15000

Table V.—*Permissible Mass of Uranium-235 per Fissile Class III Consignment Applicable to § 71.11(e)(6)(ii) (Uniform Distribution)*

Uranium enrichment in weight percent of uranium-235 not exceeding—	Permissible maximum grams of uranium-235 per consignment
4	1050
3.5	1150
3	1400
2.5	1800
2	3000
1.5	7000
1.35	10000

(3) Shipment of these packages shall be made only under procedures specifically authorized by the Department of Transportation pursuant to 49 CFR 127.507 of its regulations, so as to prevent loading, transport or storage of these packages with other Fissile Class II or Fissile Class III packages; or

(e) The material is shipped as Fissile Class III packages with the following limitations:

(1) Each package shall contain no more than a Type A quantity of radioactive material, as defined in § 71.4(s); and

(2) The packaging shall not incorporate lead shielding exceeding 5cm in thickness, nor tungsten nor uranium shielding; and

(3) Beryllium and hydrogenous material enriched in deuterium shall not be present; and

(4) The total mass of graphite present must not exceed 150 times the total mass of uranium-235 and plutonium; and

(5) Substances having a higher hydrogen density than water, e.g. some hydrocarbon oils, shall not be present, except that polyethylene may be used for packing or wrapping; and

(6) For fissile contents containing no uranium-233 and less than 1% total plutonium:

(i) If the fissile radionuclides are not uniformly distributed, the maximum amount of uranium-235 per consignment shall not exceed the value given in Table IV of this part; or

(ii) If the fissile radionuclides are distributed uniformly and cannot form a lattice arrangement within the packaging, the maximum amount of uranium-235 per consignment shall not exceed the value given in Table V of this part; and

(7) For fissile contents containing uranium-233 or more than 1% plutonium, the total mass of fissile material per consignment shall be such that the sum of the number of grams of uranium-235 divided by 400, the number of grams of plutonium divided by 225, and the number of grams of uranium-233 divided by 250, does not exceed unity [5], and

(8) The transport shall be direct to the consignee without any intermediate transit storage.

(9) Shipment of these packages shall be made only under procedures specifically authorized by the Department of Transportation pursuant to 49 CFR 127.507 of its regulations, so as to prevent loading, transport or storage of these packages with other Fissile Class II or Fissile Class III packages.

§ 71.12 General license for shipment in approved packages.

A general license is hereby issued, to persons holding a general or specific license issued pursuant to this chapter, to transport or to deliver to a carrier for transport licensed material as follows, provided the licensee has a quality assurance program approved by the Commission as satisfying the provisions of § 71.51:

(a) In a specification container for fissile material as specified in 49 CFR 127.117, or for a Type B quantity of radioactive material as specified in 49 CFR 127.115 of the regulations of the Department of Transportation, 49 CFR part 127; or

(b) In a package for which a license, certificate of compliance or other approval has been issued by the Office of Nuclear Material Safety and Safeguards of the Commission, provided that:

(1) The person using a package pursuant to the general license provided by this paragraph:

(i) Has a copy of the specific license, certificate of compliance, or other approval of the package and all documents referred to in the license, certificate, or other approval, as applicable;

(ii) Complies with the terms and conditions of the license, certificate, or other approval, as applicable, and the applicable requirements of this part; and

(iii) Prior to the licensee's first use of the package submits in writing to the Director of the Commission's Office of Nuclear Material Safety and Safeguards, his name and license number, the name and license or certificate number of the person to whom the package approval has been issued, and the package identification number specified in the package approval.

(2) The package approval authorizes use of the package under general license provided in this paragraph.

(c) In a package which meets the pertinent requirements in the 1973 regulations of the International Atomic Energy Agency and the use of which has been approved in a foreign national competent authority certificate which has been revalidated by the Department of Transportation, but only for import or export of radioactive material and only provided that the person using a package pursuant to the general license provided by this paragraph:

(1) Has and complies with the applicable certificate, the revalidation, and the documents referenced in the certificate; and

(2) Complies with the applicable requirements of Subpart D of this part, and with the Department of Transportation regulations in 49 CFR Parts 127, 175, and 176.

§ 71.13 Communications.

All communications concerning the regulations in this part should be addressed to the Director, Office of Nuclear Material Safety and Safeguards, Nuclear Regulatory Commission, Washington, D.C. 20555, or may be

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[5] grams uranium-235 ÷ 400 grams + grams plutonium ÷ 225 grams + grams uranium-233 ÷ 250 grams < 1.

delivered in person at the Commission offices at 1717 H Street, NW., Washington, D.C., or its offices at 7915 Eastern Avenue, Silver Spring, Maryland.

§ 71.14 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding on the Commission.

§ 71.15 Additional requirements.

The Commission may by rule, regulation, or order impose upon any licensee such requirements, in addition to those established in this part, as it deems necessary or appropriate to protect health or to minimize danger to life or property.

Subpart B.—Application for Package Approval

§ 71.21 Contents of application.

An application for an approval under this part shall include, for each proposed packaging design and method of transport, the following information in addition to any other information required:

(a) A package description as required by § 71.22;

(b) A package evaluation as required by § 71.23;

(c) A quality assurance program description as required by § 71.24;

(d) In case of fissile material, an identification of the proposed fissile class.

§ 71.22 Package description.

The application shall include a description of the proposed package in sufficient detail to identify the package accurately and to provide a sufficient basis for evaluation of the packaging. The description should include:

(a) With respect to the packaging:

(1) Classification as Type B(U), Type B(M) or fissile material packaging.

(2) Gross weight;

(3) Model number;

(4) Specific materials of construction, weights, dimensions, and fabrication methods of:

(i) Receptacles, identifying the containment system;

(ii) Materials specifically as nonfissile neutron absorbers or moderators;

(iii) Internal and external structures supporting or protecting receptacles;

(iv) Valves, sampling ports, lifting devices, and tiedown devices;

(v) Structural and mechanical means for the transfer and dissipation of heat; and

(5) Indentification and volumes of any coolants and of receptacles containing coolant.

(b) With respect to the contents of the package:

(1) Identification and maximum radioactivity of radioactive constituents;

(2) Identification and maximum quantities of fissile constituents;

(3) Chemical and physical form;

(4) Extent of reflection, the amount and identity of nonfissile materials used as neutron absorbers or moderators and the atomic ratio of moderator to fissile constituents;

(5) Maximum weight; and

(6) Maximum amount of decay heat.

§ 71.23 Package evaluation.

The applicant shall:

(a) Demonstrate that the package satisfies the standards specified in Subpart C;

(b) For a Fissile Class II package, ascertain and specify the number of similar packages which may be transported together in accordance with § 71.35(c); and

(c) For a Fissile Class III shipment, and for a Type B(M) package, describe any proposed special controls and precautions to be exercised during transport, loading, unloading, and handling, and in the event of accident or delay.

§ 71.24 Quality assurance.

(a) The applicant shall describe his quality assurance program to be applied to the design, fabrication, assembly, testing, maintenance, repair, modification and use of the proposed packaging.

(b) The applicant shall identify any established codes and standards proposed for use in package design, fabrication, assembly, testing, maintenance and use. In the absence of such codes and standards, the applicant shall describe the basis and rationale used to formulate the package quality assurance program.

(c) The applicant shall identify any specific provisions to be contained in his quality assurance program which are applicable to the particular package design under consideration, including a description of his leak testing procedures.

§ 71.25 Additional information.

The Commission may at any time require further information in order to enable it to determine whether a license, certificate of compliance, or other approval should be granted, denied, modified, suspended, or revoked.

Subpart C.—Package Standards

§ 71.31 Demonstration of compliance.

(a) The effect of the transport environment on the integrity of a package of radioactive material shall be evaluated as follows:

(1) The ability of a package to withstand conditions likely to occur in normal transport shall be assessed by subjecting a sample package or scale model, by test or other assessment, to the normal conditions of transport as specified in Appendix A; and

(2) The effect on a package of conditions likely to occur in an accident shall be assessed by subjecting a sample package or scale model, by test or other assessment, to the hypothetical accident conditions as specified in Appendix B.

(b) Taking into account the type of vehicle, method of securing or attaching the package, and controls to be exercised by the shipper, the Commission may permit the shipment to be evaluated together with the transporting vehicle for the purpose of one or more tests.

(c) Except with respect to Type B(U) packages, normal conditions of transport and hypothetical accident conditions different from those specified in Appendix A and Appendix B may be approved by the Commission of the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

§ 71.32 Standards for all packages.

(a) Any lifting attachments on the package, when used in the intended manner, with an appropriate safety factor to cover abrupt lifting, shall not impose unsafe stresses on the structure of the package, and shall be so designed that failure under excessive load would not impair the ability of the package to meet other requirements of this Subpart. Attachments or other features on the outer surface of the packaging which could be used to lift the package shall be removable or otherwise rendered inoperable for transport, or shall be designed with strength equivalent to that required for lifting attachments.

(b) The smallest overall dimension of the pacakge shall not be less than 10 cm (4 in.).

(c) The outside of the package shall incorporate a feature, such as a seal, which is not readily breakable, and which, while intact, will be evidence that the package has not been illicitly opened.

(d) Each package shall include a containment system securely closed by a positive fastening device which cannot be opened unintentionally.

(e) Each tie-down device which is a structural part of the package shall be so designed that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this subpart.

(f) Packages shall be of such materials and construction that there will be no significant chemical, galvanic or other reaction among the packaging components, or between the packaging components and the package contents, including possible reaction resulting from inleakage of water to the maximum credible extent.

(g) All package valves through which the radioactive contents could otherwise escape shall be protected against unauthorized operation and, except for pressure relief valves, shall be provided with an enclosure to retain any leakage.

(h) Packages shall be so designed, constructed and prepared for shipment that under normal conditions of transport specified in Appendix A there will be no loss or dispersal of radioactive contents, as demonstrated to a sensitivity of 10^{-6} A_2 per hour by NRC approved test procedures, no significant increase in the maximum radiation level at the external surface of the package, and no substantial reduction in the effectiveness of the packaging.

§ 71.33 Additional requirements for Type B(M) packages

A Type B(M) package, in addition to satisfying the requirements of § 71.32, shall be so designed and constructed that under the hypothetical accident conditions of Appendix B:

(a) The escape of radioactive material other than krypton-85 would not exceed a total amount A_2 in one week, and for krypton-85 the escape would not exceed 10,000 curies in one week.

(b) The external radiation dose rate would not exceed one rem per hour at one meter from the external surface of the package.

§ 71.34 Additional requirements for Type B(U) packages

A Type B(U) package, in addition to satisfying the requirements of § 71.32, shall satisfy the following requirements:

(a) The package shall be so designed and constructed that under the hupothetical accident conditions of Appendix B:

(1) The escape of radioactive material would not exceed an amount 10^{-3} A_2 in one week.

(2) The external radiation dose rate would not exceed one rem per hour at one meter from the external surface of the package.

(b) Compliance with the permitted activity release limits shall depend neither upon filters nor upon a mechanical cooling system.

(c) The package shall not incorporate a feature which is intended to allow continuous venting during transport.

(d) The package shall not include a pressure relief system which would allow the release of radioactive material to the environment under the conditions of the test specified in Appendix A and Appendix B.

(e) The package shall have a maximum normal operating pressure not exceeding 690 kilopascal (100 psi) gauge.

(f) The containment system shall be capable of withstanding the thermal test in Appendix B without experiencing a stress intensity greater than the minimum yield strength at the maximum temperature it would be expected to reach. For the purpose of this determination, the stress intensity shall be considered to result from the sum of membrane stresses and bending stresses caused by pressure, thermal gradients, and differential thermal expansions.

(g) The containment system shall be capable of withstanding at least 1.5 times the maximum normal operating pressure without experiencing a stress intensity greater than either 75 percent of the minimum yield strength or 40 percent of the ultimate strength at the maximum expected operating temparature. For the purpose of this determination, the stress intensity shall be considered to result from the sum of membrane stresses and bending stresses caused by pressure.

§ 71.35 Standards for fissile material packages.

(a) *General requirements.* Fissile material packages which are not exempt by § 71.9 or § 71.11 shall satisfy the following requirements:

(1) A package used for the shipment of fissile material shall be designed and constructed in accordance with § 71.32, and when so required by the total amount of radioactive material, also in accordance with § 71.33 or § 71.34:

(2) Except as otherwise provided by § 71.35(a)(5) with respect to leakage, a package used for the shipment of fissil material shall be so designed and constructed and its contents so limited that it would be subcritical if water were to leak into the containment system or liquid contents were to leak out of the containment system such that under the following conditions, maximum reactivity of the fissile material would be attained:

(i) In the most reactive credible configuration consistent with the chemical and physical form of the material;

(ii) Moderated by water to the most reactive credible extent; and

(iii) Fully reflected on all sides by water.

(3) A package used for the shipment of fissile material shall be so designed and constructed and its contents so limited that under the normal conditions of transport specified in Appendix A:

(i) The contents would be subcritical;

(ii) The geometric form of the package contents would not be substantially altered;

(iii) There would be no leakage of water into the containment system unless, in the evaluation of undamaged package under §§ 71.35(b), (c)(1)(i), and (d)(1), it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form of the material; and

(iv) There will be no substantial reduction in the effectiveness of the packaging, including no more than 5 percent reduction in the total effective volume of the packaging on which nuclear safety is assessed, no more than 5 percent reduction in the effective spacing between the fissile contents and the outer surface of the packaging, and no occurrence of an aperture in the outer surface of the packaging large enough to permit the entry of a 10 cm (4 in.) cube.

(4) A package used for the shipment of fissile material shall be so designed and constructed and its contents so limited that under the hypothetical accident conditions specified in Appendix B the package would be subcritical. For this determination it shall be assumed that:

(i) The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents;

(ii) Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents; and

(iii) There is reflection by water on all sides and as close as is consistent with the damaged condition of the package.

(5) The Commission may approve exceptions to the requirements of this section with regard to assumed inleakage or outleakage provided the package incorporates special design features such that no single packaging error would permit leakage and provided appropriate measures are

taken before each shipment to verify the leaktightness of the containment system.

(b) *Specific standards for a Fissile Class I package.* A Fissile Class I package shall be so designed and constructed and its contents so limited that:

(1) Any number of such undamaged packages would be subcritical in any arrangement, and with optimum interspersed hydrogenous moderation in packaging, in which case the greater amount may be assumed for this determination: and

(2) Two hundred fifty (250) such packages would be subcritical in any arrangement, if each package were subjected to the hypothetical accident conditions specified in Appendix B and if the geometry, moderation and water reflection were then as described in paragraphs (a)(4) and (e) of this section.

(c) *Specific standards for a Fissile Class II package.* (1) A Fissile Class II package shall be designed and constructed and its contents so limited, and the number of such packages which may be transported together so limited, that:

(i) Five times that number of such undamaged packages would be subcritical in any arrangement if closely reflected by water: and

(ii) Twice that number of such packages would be subcritical in any arrangement if each package were subjected to the hypothetical accident conditions specified in Appendix B and if the geometry, moderation and water reflection were then as described in paragraphs (a)(4) and (e) of this section.

(2) The transport index with respect to criticality control for each Fissile Class II package shall be calculated by dividing the number 50 by the number of such Fissile Class II packages which may be transported together as determined under the limitations of paragraph (c)(1) of this section. The transport index so determined shall not exceed 10 and shall be rounded up to the first decimal place.

(d) *Specific standards for a Fissile Class III package.* A package for Fissile Class III shipment shall be so designed and constructed and its contents so limited, and the number of packages in a Fissile Class III shipment shall be so limited, that:

(1) The undamaged shipment would be subcritical with an identical shipment in contact with it and with the two shipments closely reflected on all sides by water: and

(2) The shipment would be subcritical if each package were subjected to the hypothetical accident conditions specified in Appendix B and if the geometry, moderation and water reflection were then as described in paragraphs (a)(3) and (e) of this section.

(e) *Evaluation of an array of packages of fissile material.* The effect of the transport environment on the nuclear safety of an array of packages of fissile material under hypothetical accident conditions shall be evaluated on the basis that each package in the array is subjected to the hypothetical accident conditions specified in Appendix B and that the geometry, moderation and water reflection of the damaged packages correspond to the maximum credible reactivity consistent with the design of the packaging, the nature of the contents, and the conditions of shipment. In the case of a Fissile Class III shipment, the Commission may, taking into account controls to be exercised by the shipper, permit the shipment to be evaluated as a whole rather than as individual packages, either with or without the transporting vehicles, for the purpose of one or more tests.

§ 71.36 Special requirements for plutonium shipments.

(a) Notwithstanding the exemption in § 71.9, plutonium in excess of twenty (20) curies per package shall be shipped as a solid.

(b) Plutonium in excess of twenty (20) curies per package shall be packaged in a separate inner container placed within outer packaging that meets the requirements of Subpart C for packaging of material in normal form. The separate inner container shall not release plutonium, as demonstrated to a sensitivity of $10^{-6}A_2$ per hour by NRC approved test procedures, when the entire package is subjected to the normal test conditions specified in Appendix A. When the entire package is subjected to the hypothetical accident conditions specified in Appendix B, the separate inner container shall restrict the loss of plutonium to not more than A_2 in one week for B(M) packages, and to not more than $10^{-3}A_2$ in one week for B(U) packages. Solid plutonium in the following forms is exempt from the requirements of this paragraph:

(i) Reactor fuel elements;

(ii) Metal or metal alloy; and

(iii) Other plutonium bearing solids that the Commission determines should be exempt from the requirements of this section.

§ 71.37 Previously approved packages.

Notwithstanding any other provisions of this subpart, a package, the design of which has been approved by the Commission by the issuance of a certificate of compliance on or before (the effective date of these amendments), shall be deemed to comply with the package standards of §§ 71.31, 71.32, 71.33, and 71.35, provided that fabrication of the package is satisfactorily completed, as demonstrated by the application of its model number in accordance with § 71.53(c), by (date two years after effective date of these amendments) or by the expiration date of the package design approval, whichever is later.

Subpart D.—Operating Controls and Procedures

§ 71.51 Establishment and maintenance of a quality assurance program.

(a) The licensee shall establish, maintain and execute a quality assurance program satisfying each of the applicable criteria specified in Appendix E, "Quality Assurance Requirements," and satisfying any specific provisions which are applicable to the licensee's activities including procurement of packaging. The description of the quality assurance program shall include a discussion of which requirements of Appendix E are applicable and how they will be satisfied.[7] A description of that program shall be filed with the Director, Office of Nuclear Material Safety and Safeguards, Nuclear Regulatory Commission, Washington, D.C. 20555. If a licensee has filed such a description by January 1, 1979, the continued use of his existing quality assurance program is authorized until the acceptability of the program has been finally determined by the Commission.

(b) The provisions of this paragraph deal with packages which have been approved for use in accordance with this part prior to January 1, 1979, and which have been designed in accordance with the provisions of this part in effect at the time of application for package approval. Notwithstanding the provisions of paragraph (a) of this section, such packages shall be deemed to have been designed in accordance with a quality assurance program which satisfies the provisions of paragraph (a) of this section.

(c) The provisions of this paragraph deal with packages which have been approved for use in accordance with this part prior to January 1, 1979, have been at least partially fabricated prior to that date, and for which the fabrication is in accordance with the provisions of this part in effect at the time of

[7] The pertinent requirements of Appendix E should be applied in a graded approach, i.e., applied to an extent consistent with their importance to safety as described in Section 2 of Appendix E.

application for approval of package design. Notwithstanding the provisions of paragraph (a) of this section, such packages shall be deemed to have been fabricated and assembled in accordance with a quality assurance program which satisfies the provisions of paragraph (a) of this section.

(d) A Commission-approved quality assurance program which satisfies the applicable criteria of Appendix B of Part 50 of this chapter and which is established, maintained, and executed with regard to transport packages shall be deemed to satisfy the requirements of paragraph (a) of this section.

§ 71.52 Assumptions as to unknown properties.

When the isotopic abundance, mass, concentration, degree of irradiation, degree of moderation, or other pertinent property of fissile material in any package is not known, the licensee shall package the fissile material as if the unknown properties have such credible values as will cause the maximum nuclear reactivity.

§ 71.53 Preliminary determinations.

Prior to the first use of any packaging for the shipment of licensed material:

(a) The licensee shall ascertain that there are no cracks, pinholes, uncontrolled voids or other defects which could significantly reduce the effectiveness of the packaging;

(b) Where the maximum normal operating pressure will exceed 34.3 kilopascal (5 psi) gauge, the licensee shall test the containment system at an internal pressure at least 50% higher than the maximum normal operating pressure to ensure compliance with design requirements for integrity and leaktightness; and

(c) The packaging shall be conspicuously and durably marked with its model number, gross weight, and a package identification number assigned by the Nuclear Regulatory Commission. Prior to applying the model number, the licensee shall determine that the packaging has been fabricated in accordance with the design approved by the Commission.

§ 71.54 Routine determinations.

(a) Prior to each shipment of licensed material, the licensee shall ascertain that the package with its contents satisfies the applicable requirements of this part and of the license, including determinations that:

(1) The package is proper for the contents to be shipped.

(2) The package is in unimpaired physical condition except for superficial marks, dents, etc;

(3) Each closure device of the packaging, including any required gasket, is properly installed and secured and free of defects;

(4) Any system for containing liquid is adequately leaktight and has adequate space or other specified provision for expansion of such liquid;

(5) Any pressure relief device is operable and set in accordance with written procedures;

(6) The package has been loaded and closed in accordance with written procedures;

(7) For fissile material, any moderator or neutron absorber, if required, is present and in proper condition;

(b) *External radiation level.*—Prior to each shipment of licensed material, the licensee shall ascertain that, when the package is subjected to the normal conditions of transport specified in Appendix A:

(1) Except as provided in (2), no radiation level will exceed 200 millirem per hour on the accessible external surface of the package and the transport index will not exceed 10, and

(2) For packages shipped as full load by rail, highway or water, no radiation level will exceed either:

(i) 1000 millirem per hour on the accessible external surface of the package;

(ii) 200 millirem per hour on the external surface of the vehicle, including the upper and lower surfaces, or, in the case of an open vehicle, on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load, and on the lower external surface of the vehicle;

(iii) 10 millirem per hour at 2 m (6.6 feet) from the external surface of the vehicle, including the upper and lower surfaces, or in the case of an open vehicle, 2 m (6.6 feet) from the vertical planes projected from the outer edges of the vehicle and the upper surface of the load; or

(iv) Two millirem per hour in any normally occupied position of the vehicle, unless persons occupying such positions are provided with special health supervision and personnel monitoring devices and training in accordance with 10 CFR 19.12.

(c) *Surface temperatures.*—Prior to each shipment of licensed material, the licensee shall ascertain that, if the package were in still air at 38°C (100° F) and in the shade, the temperature of any readily accessible surface of the package would not exceed the following applicable limit:

(1) 50°C (122°F) for a package in a consignment less than full load, or

(2) 82°C (180°F) for a package in a full load consignment.

(d) *External radioactive contamination.*—Prior to each shipment of licensed material, the licensee shall ascertain that the level of nonfixed (removable) radioactive contamination on all external surfaces of each package is as low as practicable, and, when the package is subjected to the normal conditions of transport specified in Appendix A:

(1) Except as provided in (2), no level will exceed the levels in Table VI of this part when averaged over any 300 cm² area of the package surface; and

Table VI.—*Maximum Permissible Levels of Non-fixed Radioactive Contamination*

Contaminant	Maximum permissible level	
	μCi/cm²	dpm/cm²
Beta-gamma emitting radionuclides; all radionuclides with half-lives less than ten days; nautural uranium; natural thorium; uranium-235; uranium-238; thorium-232; thorium-228 and thorium-230 when contained in ores or physical concentrates	10^{-4}	220
All other alpha emitting radionuclides	10^{-5}	22

(2) For packages shipped as full load by rail or highway, no level will exceed either the levels in Table VI of this part at the time of shipment or ten times those levels at any time during transport, when averaged over any 300 cm² area of the package surface.

§ 71.55 Opening instructions.

Prior to delivery of a package to a carrier for transport, the licensee shall ensure that any special instructions needed to safely open the package have been sent to or otherwise made available to the consignee.

§ 71.61 Reports.

The licensee shall report to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, within 30 days any instance in which there is significant reduction in the effectiveness of any authorized packaging during use.

§ 71.62 Records.

(a) Each licensee shall maintain for a period of 2 years after shipment a record of each shipment of fissile material or of a Type B quantity of radioactive material, showing, where applicable:

(1) Identification of the packaging by model number;

(2) Details of any significant defects in the packaging, with the means employed to repair the defects and prevent their recurrence;

(3) Volume and identification of coolant;

(4) Type and quantity of licensed material in each package, and the total quantity of each shipment;

(5) For each item of irradiated fissile material:

(i) Identification by model number and/or serial number;

(ii) Irradiation and decay history to the extent appropriate to demonstrate that its nuclear and thermal characteristics comply with license conditions; and

(iii) Any abnormal or unusual condition relevant to radiation safety.

(6) Date of the shipment;

(7) For Fissile Class III and for Type B(M) packages, any special controls exercised;

(8) Name and address of the transferee;

(9) Address to which the shipment was made; and

(10) Results of the determinations required by § 71.54.

(b) The licensee shall make available to the Commission for inspection, upon reasonable notice, all records required by this part.

(c) The licensee shall maintain, during the life of the packaging to which they pertain, sufficient quality assurance records to furnish documentary evidence of the quality of packaging components which have safety significance and of services affecting such quality, including records of the results of the determinations required by § 71.53, and of monitoring, inspection and auditing of work performance during the design, fabrication, assembly, testing, modification, maintenance and repair of the packaging.

§ 71.63 Inspection and tests.

(a) The licensee shall permit the Commission at all reasonable times to inspect the licensed material, packaging, and premises and facilities in which the licensed material or packaging are used, produced, tested, stored or shipped.

(b) The licensee shall perform, and permit the Commission to perform, such tests as the Commission deems necessary or appropriate for the administration of the regulations in this chapter.

(c) The licensee shall notify the Director, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, at least 45 days prior to fabrication of a package to be used for the shipment, in that package, of radioactive material having a decay heat load in excess of 5 kW or with a maximum normal operating pressure in excess of 103 kilopascal (15 psig).

§ 71.64 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Atomic Energy Act of 1954, as amended, (the Act) or Title II of the Energy Reorganization Act of 1974, as amended, or any regulation or order issued thereunder. A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of sections 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act, or section 206 of the Energy Reorganization Act of 1974, as amended, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime, and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

Appendix A—Normal Conditions of Transport

Evaluation of each package design under normal conditions of transport shall include a determination of the effect on that design of the conditions and tests listed in this appendix. Separate specimens may be used for the free drop test, the compression test and the penetration test provided that each specimen is subjected to the water spray test before being subjected to any of the other tests.

With respect to the initial conditions for the tests in this appendix, except for the water immersion tests, the demonstration of compliance shall be based on the assumption that the ambient temperature preceding and following the tests remains constant at that value between −29° C (−29° F) and +38° C (100° F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system shall be considered to be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature considered to precede and follow the tests is more unfavorable.

Normal Conditions of Transport

(1) Heat—An ambient temperature of 54° C (130° F) in still air, and daily average solar radiation of 450 watts/m² with a daily maximum of 900 watts/m².

(2) Cold—An ambient temperature of −40° C (−40° F) in still air and shade.

(3) Reduced external pressure—An external pressure of 24.5 kilopascal (3.5 psia).

(4) Increased external pressure—An external pressure of 172 kilopascal (25 psi) gauge.

(5) Vibration—Vibration normally incident to transport.

(6) Water spray—A water spray that simulates exposure to rainfall of approximately 5 cm (2 in.) per hour for at least one hour.

(7) Free drop—Between 1½ and 2½ hours after the conclusion of the water spray test, a free drop through the distance specified below, onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected. For Fissile Class II packages, the free drop shall be preceded by a free drop from a height of 0.3 m (1 ft.) on each corner or, in the case of a cylindrical Fissile Class II package, onto each of the quarters of each rim.

Package Mass (kg)	Package Mass (pounds)	Free Drop Distance (m)	Free Drop Distance (ft)
5,000 or less	11,000	1.2	4
5,000 to 10,000	11,000 to 22,000	0.9	3
10,000 to 15,000	22,000 to 33,000	0.6	2
more than 15,000	33,000	0.3	1

(8) Corner drop—A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft.) onto a flat essentially unyielding horizontal surface. This test applies only to fiberboard or wood rectangular packages not exceeding 50 kg (110 pounds) and fiberboard or wood cylindrical packages not exceeding 100 kg (220 pounds).

(9) Compression—The package shall be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The load shall be the greater of the following:

(i) The equivalent of 5 times the weight of the package;

(ii) The equivalent of 12.75 kilopascal (1.85 lb/in²) multiplied by the vertically projected area of the package.

(10) Penetration—Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1¼ in) diameter and 6 kg (13 lb) mass, dropped from a height of 1 m (40 in) onto the exposed surface of the package which is expected to be most vulnerable to puncture. The long axis of the cylinder shall be perpendicular to the package surface.

Appendix B—Hypothetical Accident Conditions

The hypothetical accident conditions in paragraphs (a) through (d) are to be applied sequentially, in the order indicated, to determine their cumulative effect on a package or array of packages. A separate specimen may be used for the water immersion conditions specified in paragraph (e).

With respect to the initial conditions for the tests of this appendix, except for the

water immersion tests, the demonstration of compliance shall be based on the assumption that the ambient temperature preceding and following the tests remains constant at that value between −29°C (−20°F) and +38°C (100°F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system shall be considered to be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature assumed to precede and follow the tests is more unfavorable.

(a) *Free Drop*—A free drop of the specimen through a distance of 9 m (30 ft) onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

(b) *Puncture*—A free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding horizontal surface. The bar shall be 15 cm (6 in) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (¼ in) and of such a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar shall be vertical.

(c) *Thermal*—Exposure of the whole specimen for not less than 30 minutes to a heat flux not less than that of a radiation environment of 800°C (1472°F) with an emissivity coefficient of at least 0.9. For purposes of calculation, the surface absorptivity shall be either that value which the package may be expected to possess if exposed to a fire or 0.8, whichever is greater. In addition, when significant, convective heat input shall be included on the basis of still ambient air at 800°C (1472°F). Artificial cooling shall not be applied after cessation of external heat input, and any combustion of materials of construction shall be allowed to proceed until it terminates naturally. The effects of solar radiation can be neglected prior to and during the test but insolation as specified in paragraph (a)(1) of Appendix A shall be assumed for the period following the 30 minute exposure to fire conditions.

(d) *Immersion—fissile material*—For fissile material in those cases where water inleakage has not been assumed for criticality analysis, the specimen shall be immersed under a head of water of at least 0.9 m (3 ft) for a period of not less than eight hours and in the attitude for which maximum leakage is expected. For this test an ambient temperature of 38°C (100°F) is not required.

(e) *Immersion—all packages*—Either the damaged specimen or a separate undamaged specimen shall be immersed under a head of water of at least 15 m (49 ft) for a period of not less than eight hours. For test purposes, an external pressure of water of 147 kilopascal (21 psi) gauge will be considered to meet these conditions.

APPENDIX C—DETERMINATION OF A_1 AND A_2

I. *Single radionuclides.*—(1) For single radionuclides of known identity, the value of A_1 and A_2 are given in Table C-1. The values of A_1 and A_2 are also applicable for radionuclides contained in (α, n) or (γ, n) neutron sources.

(2) For any single radionuclide whose identity is known, but which is not listed in Table C-1, the values of A_1 and A_2 shall be determined according to the following procedure:

(a) If the radionuclide emits only one type of radiation, A_1 shall be determined according to the rules in paragraphs (i), (ii), (iii) and (iv) of this paragraph. For radionuclides emitting different kinds of radiation, A_1 shall be the most restrictive value of those determined for each individual radiation. However, in both cases A_1 shall be restricted to a maximum of 1000 Ci. If a parent nuclide decays into a shorter lived daughter, of a half-life not greater than 10 days, A_1 shall be calculated for both the parent and the daughter, and the more limiting of the two values shall be assigned to the parent nuclide.

(i) For gamma emitters, A_1 is determined by the expression:

$A_1 = 9/\ \ $ curies

where is the gamma-ray constant, corresponding to the dose in R/h at 1 m per Ci; the number 9 results from the choice of 1 rem/h at a distance of 3 m as the reference dose-equivalent rate.

(ii) For X-ray emitters, A_1 is determined by the atomic number of the nuclide:

for $Z \leq 55$—$A_1 = 1000$ Ci
for $Z > 55$—$A_1 = 200$ Ci

where Z is the atomic number of the nuclide.

(iii) For beta emitters, A_1 is determined by the maximum beta energy (E_{max}) according to Table C-2;

(iv) For alpha emitters A_1 is determined by the expression:

$A_1 = 1000\ A_3$

Where A_3 is the value listed in Table C-3;

(b) A_2 shall be the more restrictive of the following two values:

(i) The corresponding A_1; and

(ii) The value A_3 obtained from Table C-3.

(3) For any single radionuclide whose identity is unknown, the value of A_1 shall be taken to be 2 Ci and the value of A_2 shall be taken to be 0.002 Ci. However, if the atomic number of the radionuclide is known to be less than 82, the value of A_1 shall be taken to be 10 Ci and the value of A_2 shall be taken to be 0.4 Ci.

II. *Mixtures of radionuclides, including radioactive decay chains.*—(1) For mixed fission products the following activity limits may be assumed, if a detailed analysis of the mixture is not carried out:

$A_1 = 10$ Ci
$A_2 = 0.4$ Ci

(2) A single radioactive decay chain in which the radionuclides are present in their naturally occurring proportions and in which no daughter nuclide has a half-life either longer than 10 days or longer than that of the parent nuclide shall be considered a single radionuclide. The activity to be taken into account and the A_1 or A_2 value to be applied shall be those corresponding to the parent nuclide of that chain. However, in the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than 10 days or greater than that of the parent nuclide, the parent and such daughter nuclides shall be considered as mixtures of different nuclides.

(3) In the case of a mixture of different radionuclides, where the identity and activity of each radionuclide are known, the permissible activity of each radionuclide R_1, R_2 . . . R_n shall be such that $F_1 + F_2 + \ldots F_n$ is not greater than unity, where

$$F_1 = \frac{\text{Total activity of } R_1}{A_i(R_1)}$$

$$F_2 = \frac{\text{Total activity of } R_2}{A_i(R_2)}$$

$$F_n = \frac{\text{Total activity of } R_n}{A_i(R_n)}$$

$A_i(R_1, R_2 \ldots R_n)$ is the value of A_1 or A_2 as appropriate for the nuclide R_1, R_2 . . . R_n.

(4) When the identity of each radionuclide is known but the individual activities of some of the radionuclides are not known, the formula given in paragraph (3) shall be applied to establish the values of A_1 or A_2 as appropriate. All the radionuclides whose individual activities are not known (their total activity will, however, be known) shall be classed in a single group and the most restrictive value of A_1 and A_2 applicable to any one of them shall be used as the value of A_1 or A_2 in the denominator of the fraction.

(5) Where the identity of each radionuclide is known but the individual activity of none of the radionuclides is known, the most restrictive value of A_1 or A_2 applicable to any one of the radionuclides present shall be adopted as the applicable value.

(6) When the identity of none of the nuclides is known, the value of A_1 shall be taken to be 2 Ci and the value of A_2 shall be taken to be 0.002 Ci. However, if alpha emitters are known to be absent, the value of A_2 shall be taken to be 0.4 Ci.

Table C-1.—*A, and ;Values for Radionuclides* [1]

Symbol of radionuclide	Element and atomic number	A1(Ci)	A2(Ci)
^{227}Ac	Actinium (89)	1000	0.003
^{228}Ac		10	4
^{105}Ag	Silver (47)	40	40
^{110m}Ag		7	7
^{111}Ag		100	100
^{241}Am	Americium (95)	8	0.008
^{243}Am		8	0.008
^{37}Ar (compressed or uncompressed)	Argon (18)	1000	1000
^{41}Ar (uncompressed)		20	20
^{41}Ar (compressed)		1	1
^{73}As	Arsenic (33)	1000	400
^{74}		20	20
^{76}As		10	10
^{77}As		300	300
^{211}At	Astatine (85)	200	7
^{193}Au	Gold (79)	200	200
^{196}Au		30	30
^{198}Au		40	40
^{199}Au		200	200
^{131}Ba	Barium (56)	40	40
^{133}Ba		40	10
^{7}Be	Beryllium (4)	300	300
^{206}Bi	Bismuth (83)	5	5
^{207}Bi		10	10
^{210}Bi (RaE)		100	4
^{212}Bi		6	6
^{249}Bk	Berkelium (97)	1000	1
^{82}Br	Bromine (35)	6	6
^{14}C	Carbon (6)	1000	100
^{45}Ca	Calcium (20)	1000	40
^{47}Ca		20	20
^{109}Cd	Cadmium (48)	1000	70
^{115m}CD		30	30
^{115}Cd		80	80
^{139}Ce	Cerium (58)	100	100
^{141}Ce		300	200
^{143}Ce		60	60
^{144}Ce		10	7
^{249}Cf	California (98)	2	0.002
^{250}Cf		7	0.007
^{252}Cf		2	0.009
^{36}Cl	Chlorine (17)	300	30
^{38}Cl		10	10
^{242}Cm	Curium (96)	200	0.2
^{243}Cm		9	0.009
^{244}Cm		10	0.01
^{245}Cm		6	0.006
^{246}Cm		6	0.006
^{56}Co	Cobalt (27)	5	5
^{57}Co		90	90
^{58m}Co		1000	1000
^{58}Co		20	20
^{60}Co		7	7
^{51}Cr	Chromium (24)	600	600
^{131}Cs	Cesium (55)	1000	1000
^{134m}Cs		1000	1000
^{134}Cs		10	10
^{135}Cs		1000	1000
^{136}Cs		7	7
^{137}Cs		30	20
^{64}Cu	Copper (29)	80	80
^{165}Cy	Dysprosium (66)	100	100
^{166}Dy		1000	200
^{169}Er	Erbium (68)	1000	300
^{171}Er		50	50
^{152m}Eu	Eurpium (63)	30	30
^{152}Eu		20	20
^{154}Eu		10	5
^{155}Eu		400	90
^{18}F	Fluorine (9)	20	20
^{52}Fe	Iron (26)	6	6
^{55}Fe		1000	1000
^{59}Fe		10	10
^{72}Ga	Gallium (31)	7	7
^{153}Gd	Gadolinium (64)	200	100
^{159}Gd		300	300
^{71}Ge	Germanium (32)	1000	1000
^{3}H	Hydrogen (1) see T-Tritium		
^{181}Hf	Hafnium (72)	30	30
^{197m}Hg	Mercury (80)	200	200
^{197}Hg		200	200
^{203}Hg		80	80
^{166}Ho	Holmium (67)	30	30
^{125}I	Iodine (53)	1000	70
^{126}I		40	10
^{129}I		1000	2
^{131}I		40	10
^{132}I		7	7
^{133}I		30	30

Table C-1.—*A_1 and $_2$Values for Radionuclides* [1]—Continued

Symbol of radionuclide	Element and atomic number	A1(Ci)	A2(Ci)
^{134}I		8	8
^{135}I		10	10
^{113m}In	Indium (49)	60	60
^{114m}In		30	20
^{115m}In		100	100
^{190}Ir	Indium (77)	10	10
^{192}Ir		20	20
^{194}Ir		10	10
^{42}K	Potassium (19)	10	10
^{85m}Kr (uncompressed)	Krypton (36)	100	100
^{85m}Kr (compressed)		3	3
^{85}Kr (uncompressed)		1000	1000
^{85}Kr (compressed)		5	5
^{87}Kr (uncompressed)		20	20
^{87}Kr (compressed)		0.6	0.6
^{140}La	Lanthanum (57)	30	30
LLS	Low level solid radioactive material—see § 71.4(g).		
LSA	Low specific activity material—see § 71.4(h)		
^{177}Lu	Lutetium (71)	300	300
MFP	Mixed fission products	10	0.4
^{28}Mg	Magnesium (12)	6	6
^{52}Mn	Manganese (25)	5	5
^{54}Mn		20	20
^{56}Mn		5	5
^{99}Mo	Molybdenum (42)	100	100
^{22}Na	Sodium (11)	8	8
^{24}Na		5	5
^{93m}Nb	Niobium (41)	1000	200
^{95}Nb		20	20
^{97}Nb		20	20
^{147}Nd	Neodymium (60)	100	100
^{149}Nd		30	30
^{59}Ni	Nickel (28)	1000	900
^{63}Ni		1000	100
^{65}Ni		10	10
^{237}Np	Neptunium (93)	5	0.005
^{239}Np		200	200
^{185}Os	Osmium (76)	20	20
^{191}Os		600	400
^{191m}Os		200	200
^{193}Os		100	100
^{32}P	Phosphorus (15)	30	30
^{230}Pa	Protoactinium (91)	20	0.8
^{231}Pa		2	0.002
^{233}Pa		100	100
^{201}Pb	Lead (82)	20	20
^{210}Pb		100	0.2
^{212}Pb		6	5
^{103}Pd	Palladium (46)	1000	700
^{109}Pd		100	100
^{147}Pm	Promethium (61)	1000	80
^{149}Pm		100	100
^{210}Po	Polonium (84)	200	0.2
^{142}Pr	Praseodymium (59)	10	10
^{143}Pr		300	200
^{191}Pt	Platinum (78)	100	100
^{193}Pt		200	200
^{193m}Pt		300	300
^{197}Pt		300	300
^{238}Pu	Plutonium (94)	3	0.003
^{239}Pu		2	0.002
^{240}Pu		2	0.002
^{241}Pu		1000	0.1
^{242}Pu		3	0.003
^{223}Ra	Radium (88)	50	0.2
^{224}Ra		6	0.5
^{226}Ra		10	0.05
^{228}Ra		10	0.05
^{86}Rb	Rubidium (37)	30	30
^{87}Rb		Unlimited	Unlimited
Rb (natural)		Unlimited	Unlimited
^{186}Re	Rhenium (75)	100	100
^{187}Re		Unlimited	Unlimited
^{188}Re		10	10
Re (natural)		Unlimited	Unlimited
^{103m}Rh	Rhodium (45)	1000	1000
^{105}Rh		200	200
^{222}Rn	Radon (86)	10	2
^{97}Ru	Ruthenium (44)	80	80
^{103}Ru		30	30
^{105}Ru		20	20
^{106}Ru		10	7
^{35}S	Sulphur (16)	1000	300
^{122}Sb	Antimony (51)	30	30
^{124}Sb		5	5
^{125}Sb		40	30
^{46}Sc	Scandium (21)	8	8
^{47}Sc		200	200

Table C-1.—A_1 and A_2 Values for Radionuclides [1]—Continued

Symbol of radionuclide	Element and atomic number	A1(Ci)	A2(Ci)
^{48}Sc		5	5
^{75}Se	Selenium (34)	40	40
^{31}Si	Silicon (14)	100	100
^{147}Am	Samarium (62)	Unlimited	Unlimited
^{151}Sm		1000	90
^{153}Sm		300	300
^{113}Sn	Tin (50)	60	60
^{125}Sn		10	10
^{85m}Sr	Strontium (38)	80	80
^{85}Sr		30	30
^{87m}Sr		50	50
^{89}Sr		100	40
^{90}Sr		10	0.4
^{91}Sr		10	10
^{92}Sr		10	10
T (Uncompressed)	Tritium (1)	1000	1000
T (compressed)		1000	1000
T (activated luminous paint		1000	1000
T (adsorbed on solid carrier)		1000	1000
T (tritiated water)		1000	1000
T (other forms)		20	20
^{182}Ta	Tantalum (73)	20	20
^{160}Tb	Terbium (65)	20	20
^{96m}Tc	Technetium (43)	1000	1000
^{96}Tc		6	6
^{97m}Tc		1000	200
^{97}Tc		1000	100
^{99m}Tc		100	100
^{99}Tc		1000	80
^{125m}Te	Tellurium (52)	1000	100
^{127m}Te		300	40
^{127}Te		300	300
^{129m}Te		30	30
^{129}Te		100	100
^{131m}Te		10	10
^{132}Te		7	7
^{227}Th	Thorium (90)	200	0.2
^{228}Th		6	0.008
^{230}Th		3	0.003
^{231}Th		1000	1000
^{232}Th		Unlimited	Unlimited
^{234}Th		10	10
Th (natural)		Unlimited	Unlimited
Th (irradiated) [2]			
^{200}Tl	Thallium (81)	20	20
^{201}T		200	200
^{202}Tl		40	40
^{204}Tl		300	30
^{170}Tm	Thulium (69)	300	40
^{171}Tm		1000	100
^{230}U	Uranium (92)	100	0.1
^{232}U		30	0.03
^{233}U		100	0.1
^{234}U		100	0.1
^{235}U		100	0.2
^{236}U		200	0.2
^{238}U		Unlimited	Unlimited
U (natural)		Unlimited	Unlimited
U (enriched) < 20%		Unlimited	Unlimited
U (enriched) 20% or greater		100	0.1
U (depleted)		Unlimited	Unlimited
U (irradiated) [2]			
^{48}V	Vanadium (23)	6	6
^{181}W	Tungsten (74)	200	100
^{185}W		1000	100
^{187}W		40	40
^{131m}Xe (compressed)	Xenon (54)	10	10
^{131m}Xe (uncompressed)		100	100
^{133}Xe (uncompressed)		1000	1000
^{133}Xe (compressed)		5	5
^{135}Xe (uncompressed)		70	70
^{135}Xe (compressed)		2	2
^{90}Y	Yttrium (39)	10	10
^{91m}Y		30	30
^{91}Y		30	30
^{92}Y		10	10
^{93}Y		10	10
^{175}Yb	Ytterbium (70)	400	400
^{65}Zn	Zinc (30)	30	30
^{69m}Zn		40	40
^{69}Zn		300	300
^{93}Zr	Zirconium (40)	1000	200
^{95}Zr		20	20
^{97}Zr		20	20

[1] In Table C-1, "uncompressed gas" means at a pressure not exceeding ambient atmospheric pressure at the time the containment system is closed. A gas which has escaped from a package is considered to be uncompressed.

[2] The values for A1 and A2 must be calculated in accordance with the procedure specified in Appendix C, paragraph II(3), taking into account the activity of the fission products and of the uranium-233 in addition to that of the thorium.

Table C-1.—*A_1 and A_2 Values for Radionuclides* [1]—Continued

Symbol of radionuclide	Element and atomic number	A1(Ci)	A2(Ci)

[1] The values for A1 and A2 must be calculated in accordance with the procedure specified in Appendix C, paragraph II(3), taking into account the activity of the fission products and plutonium isotopes in addition to that of the uranium.

Table C-2.—*Relationship Between A^1 and E^{max} for Beta Emitters*

E^{max} (MeV)	A^1 (Ci)
<0.5	1000
0.5–<1.0	300
1.0–<1.5	100
1.5–<2.0	30
<>2.0	10

Table C-3—*Relationship Between A^3 and the Atomic Number of the Radionuclide*

Atomic No.	A^3		
	Half-life less than 1,000 days	Half-life 1000 days to 10^6 years	Half-life greater than 10^6 years
1 to 81	3 Ci	.05 Ci	3 Ci
82 and above	.002 Ci	.002 Ci	3 Ci

Appendix D—Requirements for Special Form Radioactive Material

(a) *General.* (1) Special form radioactive material must either be an indispersible solid or be contained in a sealed capsule which can be opened only by destructive means.

(2) The solid material or capsule shall have at least one dimension not less than 5mm.

(3) The qualification tests for special form are the impact test, the percussion test, the bending test, and the heat test.

(4) Specimens (solid radioactive material or capsules) to be tested shall be prepared as normally presented for transport. The radioactive material shall be duplicated as closely as practicable.

(5) A different specimen may be used for each of the tests.

(6) The specimen shall not break or shatter when subjected to the impact, percussion or bending tests.

(7) The specimen shall not melt or disperse when subjected to the heat test.

(8) After each test, a leaching assessment shall be performed on the specimen by a method no less sensitive than the methods given in paragraph (c) of this appendix.

(b) *Test methods.* (1) Impact test: the specimen shall fall onto a flat, horizontal, essentially unyielding surface from a height of 9 m (30 ft).

(2) *Percussion test:* the specimen shall be placed on a sheet of lead which is supported by a smooth solid surface and struck by the flat face of a steel billet so as to produce an impact equivalent to that resulting from a free fall of 1.4 kg (3 lb.) through 1 m (40 in.). The flat face of the billet shall be 25 mm (1 in.) in diameter with the edges rounded to a radius of 3 mm (0.12 in.) ±0.3 mm (0.012 in.). The lead, of hardness number 3.5 to 4.5 on the Vickers scale and not more than 25 mm (1 in.) thick, shall cover an area greater than that covered by the specimen. A fresh surface of lead shall be used for each impact. The billet shall strike the specimen so as to cause maximum damage.

(3) *Bending test:* the test is applicable only to long, slender sources with both a minimum length of 10 cm (4 in.) and a length to minimum with ratio not less than 10. The specimen shall be rigidly clamped in a horizontal position so that one half of its length protrudes from the face of the clamp. The orientation of the specimen shall be such that the specimen will suffer maximum damage when its free end is struck by the flat face of a steel billet. The billet shall strike the specimen so as to produce an impact equivalent to that resulting from a free verticle fall of 1.4 kg (3 lb.) through 1 m. The flat face of the billet shall be 25 mm (1 in.) in diameter with the edges rounded off to a radius of 3 mm (0.12 in.) ±0.3 mm (0.012 in.).

(4) *Heat test:* the specimen shall be heated in air to a temperature of not less than 800° C (1472° F) and held at that temperature for a period of 10 minutes and shall then be allowed to cool.

(c) Leaching assessment procedures.

(1) For indispersible solid material:

(i) The specimen shall be immersed for 7 days in water at ambient temperature. The water shall have a pH of 6–8 and a maximum conductivity of 10 μmho/cm at 20° C (68° F).

(ii) The water with specimen shall then be heated to a temperature of 50°±5° C (122°±9° F) and maintained at this temperature for 4 hours.

(iii) The activity of the water shall then be determined.

(iv) The specimen shall then be stored for at least 7 days in still air of humidity not less than 90% at 30° C (86° F).

(v) The specimen shall then be immersed in water of the same specification as in (i) above the water with specimen heated to 50°±5° C (122°±9° F) and maintained at this temperature for 4 hours.

(vi) The activity of the water shall then be determined.

(vii) The activity determined in paragraphs (c)(1)(iii) and (vi) shall not exceed 0.05 μCi.

(2) For encapsulated material:

(i) The specimen shall be immersed in water at ambient temperature. The water shall have a pH of 6–8 with a maximum conductivity of 10 μmho/cm. The water and specimen shall be heated to a temperature of 50°±5° C (122°±9° F) and maintained at this temperature for 4 hours.

(ii) The activity of the water shall then be determined.

(iii) The specimen shall then be stored for at least 7 days in still air at a temperature not less than 30° C (86° F).

(iv) Repeat paragraph (c)(2)(i) of this appendix.

(v) The activity of the water shall then be determined.

(vi) The activities determined in paragraphs (c)(2)(ii) and (v) shall not exceed 0.05 μCi.

Appendix E—Quality Assurance Requirements

This appendix describes quality assurance requirements applying to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of components of packaging which are significant to safety. As used in this appendix, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a system or component will perform satisfactorily in service. Qualify assurance includes quality control, which comprises those quality assurance actions related to control of the physical characteristics and quality of the material or component to predetermined requirements.

1. *Organization.*—The licensee [11] shall be responsible for the establishment and execution of the quality assurance program. The licensee may delegate to others, such as contractors, agents, or consultants, the work of establishing and executing the quality assurance program, or any part thereof, but shall retain responsibility therefor. The authority and duties of persons and organizations performing activities affecting the safety-related functions of structures, systems, and components shall be clearly

[11] While the term "licensee" is used in these criteria, the requirements are applicable to whatever design, fabrication, assembly and testing of the package is accomplished with respect to a package prior to the time a package approval is issued.

established and delineated in writing. These activities include both the performing functions of attaining quality objectives and the quality assurance functions. The quality assurance functions are those of (a) assuring that an appropriate quality assurance program is established and effectively executed and (b) verifying, such as by checking, auditing, and inspection, that activities affecting the safety-related functions have been correctly performed. The persons and organizations performing quality assurance functions shall have sufficient authority and organizational freedom to identify quality problems; to initiate, recommend or provide solutions; and to verify implementation of solutions. Such persons and organizations performing quality assurance functions shall report to a management level such that this required authority and organizational freedom, including sufficient independence from cost and schedule when opposed to safety considerations, are provided. Because of the many variables involved, such as the number of personnel, the type of activity being performed, and the location or locations where activities are performed, the organizational structure for executing the quality assurance program may take various forms provided that the persons and organizations assigned the quality assurance functions have this required authority and organizational freedom. Irrespective of the organizational structure, the individual(s) assigned the responsibility for assuring effective execution of any portion of the quality assurance program at any location where activities subject to this Appendix are being performed shall have direct access to such levels of management as may be necessary to perform this function.

2. *Quality Assurance Program.* The licensee shall establish at the earliest practicable time, consistent with the schedule for accomplishing the activities, a quality assurance program which complies with the requirements of this appendix. The quality assurance program shall be documented by written procedures or instructions, and shall be carried out in accordance with those procedures throughout the period during which packaging is used. The licensee shall identify the material and components to be covered by the quality assurance program and the major organizations participating in the program, together with the designed functions of these organizations. The quality assurance program shall provide control over activities affecting the quality of the identified materials and components to an extent consistent with their importance to safety, and as necessary to assure conformance to the approved design of each individual package used for the shipment of radioactive material. Activities affecting quality shall be accomplished under suitably controlled conditions. Controlled conditions include the use of appropriate equipment; suitable environmental conditions for accomplishing the activity, such as adequate cleanness; and assurance that all prerequisites for the given activity have been satisfied. The program shall take into account the need for special controls, processes, test equipment, tools and skills to attain the required quality, and the need for verification of quality by inspection and test.

The licensee shall base the requirements and procedures of his quality assurance program on the following considerations concerning the complexity and proposed use of the package and its components:

(1) The importance of malfunction or failure of the item to safety;

(2) The design and fabrication complexity or uniqueness of the item;

(3) The need for special controls and surveillance over processes and equipment;

(4) The degree to which functional compliance can be demonstrated by inspection or test; and

(5) The quality history and degree of standardization of the item.

The program shall provide for indoctrination and training of personnel performing activities affecting quality as necessary to assure that suitable proficiency is achieved and maintained. The licensee shall review the status and adequacy of the quality assurance program at established intervals. Management of other organizations participating in the quality assurance program shall regularly review the status and adequacy of that part of the quality assurance program which they are executing.

3. *Design Control.*—Measures shall be established to assure that applicable regulatory requirements and the package design, as specified in the license, for those materials and components to which this appendix applies, are correctly translated into specifications, drawings, procedures and instructions. These measures shall include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from such standards are controlled. Measures shall be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of the materials, parts, and components of the packaging.

Measures shall be established for the identification and control of design interfaces and for coordination among participating design organizations. These measures shall include the establishment of written procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces. The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. The verifying or checking process shall be performed by individuals or groups other than those who performed the original design, but who may be from the same organization. Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualification testing of a prototype or sample unit under the most adverse design conditions. Design control measures shall be applied to items such as the following: criticality physics, radiation shielding, stress, thermal, hydraulic, and accident analyses; compatibility of materials; accessibility for inservice inspection, maintenance and repair; features to facilitate decontamination; and delineation of acceptance criteria for inspections and tests.

Design changes, including field changes, shall be subject to design control measures commensurate with those applied to the original design. Changes in the conditions specified in the package approval require Commission approval.

4. *Procurement Document Control.*—Measures shall be established to assure that applicable requirements of this part which are necessary to assure adequate quality are suitably included or referenced in the documents for procurement of material, equipment, and services, whether purchased by the licensee or by his contractors or subcontractors. To the extent necessary, the licensee shall require contractors or subcontractors to provide a quality assurance program consistent with the pertinent provisions of this part.

5. *Instructions, Procedures and Drawings.*—Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings. These shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

6. *Document Control.*—Measures shall be established to control the issuance of documents, such as instructions, procedures, and drawings, including changes thereto, which prescribe all activities affecting quality. These measures shall assure that documents, including changes, are reviewed for adequacy and approved for release by authorized personnel and are distributed and used at the location where the prescribed activity is performed. Changes to documents shall be reviewed and approved by the same organizations that performed the original review and approval unless the applicant designates another organization.

7. *Control of Purchased Material, Equipment, and Services.*—Measures shall be established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery. Documentary evidence that material and equipment conform to the procurement specifications shall be available prior to installation or use of such material and equipment. This documentary evidence shall be retained by or be available to the licensee and shall be sufficient to identify the specific requirements met by the purchased material and equipment. The effectiveness of the control of quality by contractors and subcontractors

shall be assessed by the licensee or designee at intervals consistent with the importance, complexity and quantity of the product or services.

8. *Identification and Control of Materials, Parts and Components.*—Measures shall be established for the identification and control of materials, parts, and components. These measures shall assure that identification of the item is maintained by heat number, part number, or other appropriate means, either on the item or on records traceable to the item, as required throughout fabrication, installation, and use of the item. These identification and control measures shall be designed to prevent the use of incorrect or defective materials, parts and components.

9. *Control of Special Processes.*—Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

10. *Inspection.*—A program for inspection of activities affecting quality shall be established and executed by or for the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity. Such inspection shall be performed by individuals other than those who perform the activity being inspected. Examinations, measurements, or tests of material or products processed shall be performed for each work operation where necessary to assure quality. If inspection of processed material or products is impossible or disadvantageous, indirect control by monitoring processing methods, equipment, and personnel shall be provided. Both inspection and process monitoring shall be provided when quality control is inadequate without both. If mandatory inspection hold points, which require witnessing or inspecting by the licensee's designated representative and beyond which work shall not proceed without the consent of its designated representative, are required, the specific hold points shall be indicated in appropriate documents.

11. *Test Control.*—A test program shall be established to assure that all testing required to demonstrate that the packaging components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements of this part and the requirements and acceptance limits contained in the package approval. The procedures shall include provisions for assuring that all prerequisites for the given test have been met, that adequate test instrumentation is available and used, and that the test is performed under suitable environmental conditions. Test results shall be documented and evaluated to assure that test requirements have been satisfied.

12. *Control of Measuring and Test Equipment.*—Measures shall be established to assure that tools, gages, instruments, and other measuring and testing devices used in activities affecting quality are properly controlled, calibrated, and adjusted at specified times to maintain accuracy within necessary limits.

13. *Handling, Storage and Shipping.*—Measures shall be established to control the handling, storage, shipping, cleaning and preservation of materials and equipment to be used in packaging in accordance with instructions to prevent damage or deterioration. When necessary for particular products, special protective environments, such as inert gas atmosphere, specific moisture content levels and temperature levels shall be specified and provided.

14. *Inspection, Test and Operating Status.*—Measures shall be established to indicate, by the use of markings such as stamps, tags, labels, routing cards, or other suitable means the status of inspections and tests performed upon individual items of the packaging. These measures shall provide for the identification of items which have satisfactorily passed required inspections and tests, where necessary to preclude inadvertent by-passing of such inspections and tests.

Measures shall also be established for indicating the operating status of components of the packaging, such as tagging valves and switches, to prevent inadvertent operation.

15. *Nonconforming Materials, Parts, or Components.*—Measures shall be established to control materials, parts, or components which do not conform to requirements in order to prevent their inadvertent use or installation. These measures shall include, as appropriate, procedures for identification, documentation, segregation, disposition, and notification to affected organizations. Nonconforming items shall be reviewed and accepted, rejected, repaired or reworked in accordance with documented procedures.

16. *Corrective Action.*—Measures shall be established to assure that conditions adverse to quality, such as deficiencies, deviations, defective material and equipment, and nonconformances, are promptly identified and corrected. In the case of a significant condition adverse to quality, the measures shall assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management.

17. *Quality Assurance Records.*—Sufficient written records shall be maintained to furnish evidence of ativities affecting quality. The records shall include the following: design records, records of use and the results of reviews, inspections, tests audits, monitoring of work performance, and materials analyses. The records shall also include closely-related data such as qualifications of personnel, procedures, and equipment. Inspection and test records shall, as a minimum, identify the inspector or data recorder, the type of observation, the results, the acceptability, and the action taken in connection with any deficiencies noted. Records shall be identifiable and retrievable. Consistent with applicable regulatory requirements, the licensee shall establish requirements concerning record retention, such as duration, location, and assigned responsibility.

18. *Audits.*—A comprehensive system of planned and periodic audits shall be carried out to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program. The audits shall be performed in accordance with the written procedures or check lists by appropriately trained personnel not having direct responsibilities in the areas being audited. Audited results shall be documented and reviewed by management having responsibility in the area audited. Followup action, including re-audit of deficient areas, shall be taken where indicated.

Dated at Washington, D.C. this 7th day of August, 1979.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,

Secretary of the Commission.

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PART 170

FEES FOR FACILITIES AND MATERIALS LICENSES AND OTHER REGULATORY SERVICES UNDER THE ATOMIC ENERGY ACT OF 1954, AS AMENDED★

GENERAL PROVISIONS

Sec.

SCHEDULE OF FEES

ENFORCEMENT

AUTHORITY: The provisions of this Part 170 issued under sec. 501, 65 Stat. 290; 31 U.S.C. 483a; sec. 161, 68 Stat. 948; 42 U.S.C. 2201. Sec. 201(f), Pub. L. 93-438, 88 Stat. 1243; 42 U.S.C. 5841.

GENERAL PROVISIONS

§ 170.1 Purpose.

The regulations in this part set out fees charged for licensing services rendered by the Nuclear Regulatory Commission, as authorized under Title V of the Independent Offices Appropriation Act of 1952 (65 Stat. 290; 31 U.S.C. 483a) and provisions regarding their payment.

§ 170.2 Scope.

43 FR 7210

Except for persons who apply for or hold the permits, licenses, or approvals exempted in § 170.11, the regulations in this part apply to a person who is an applicant for, or holder of, a specific byproduct material license issued pursuant to Parts 30 and 32-35 of this chapter, a specific source material license issued pursuant to Part 40 of this chapter, a specific special nuclear material license issued pursuant to Part 70 of this chapter, a specific approval of spent fuel casks and shipping containers issued pursuant to Part 71 of this chapter, a specific request for approval of sealed sources and devices containing byproduct material, source material, or special nuclear material, or a production or utilization facility construction permit and operating license issued pursuant to Part 50 of this chapter, to routine safety and safeguards inspections of a licensed person, to a person who applies for approval of a reference standardized design of a nuclear steam supply system or balance of plant, for review of a facility site prior to the submission of an application for a construction permit, for review of a standardized spent fuel facility design, and for a special project review which the Commission completes or makes whether or not in conjunction with a license application on file or which may be filed.

43 FR 7210

§ 170.3 Definitions.

As used in this part:

33 FR 10923

(a) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material.

(b) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government.

(c) "Materials license" means a byproduct material license issued pursuant to Part 30 of this chapter, or a source material license issued pursuant to Part 40 of this chapter, or a special nuclear material license issued pursuant to Part 70 of this chapter.

(d) "Nuclear reactor" means an apparatus, other than an atomic weapon, designed or used to sustain nuclear fission in a self-supporting chain reaction.

(e) "Other production or utilization facility" means a facility other than a nuclear reactor licensed by the Commission under the authority of section 103 or 104 of the Atomic Energy Act of 1954, as amended (the Act), and pursuant to the provisions of Part 50 of this chapter.

33 FR 10923

(f) "Power reactor" means a nuclear reactor designed to produce electrical or heat energy licensed by the Commission under the authority of section 103 or subsection 104b of the Act and pursuant to the provisions of §§ 50.21(b) or 50.22 of this chapter.

(g) "Production facility" means:

(1) Any nuclear reactor designed or used primarily for the formation of plutonium or uranium-233; or

(2) Any facility designed or used for the separation of the isotopes of uranium or the isotopes of plutonium, except laboratory scale facilities designed or used for experimental or analytical purposes only; or

40 FR 8774

(3) Any facility designed or used for the processing of irradiated materials containing special nuclear material, except:

(i) laboratory scale facilities designed or used for experimental or analytical purposes;

(ii) facilities in which the only special nuclear materials contained in the irradiated material to be processed are uranium enriched in the isotope U^{235} and plutonium produced by the irradiation, if the material processed contains not more than 10^{-6} grams of plutonium per gram of U^{235} and has fission product activity not in excess of 0.25 millicuries of fission products per gram of U^{235}; and

(iii) facilities in which processing is conducted pursuant to a license issued under Parts 30 and 70 of this chapter, or equivalent regulations of an Agreement State, for the receipt, possession, use, and transfer of irradiated special nuclear material, which authorizes the processing of the irradiated material on a batch basis for the separation of selected fis-

*Amended 43 FR 7210.

40 FR 8774

sion products and limits the process batch to not more than 100 grams of uranium enriched in the isotope 235 and nto more than 15 grams of any other special nuclear material.

33 FR 10923

(h) "Research reactor" means a nuclear reactor licensed by the Commission under the authority of subsection 104c of the Act and pursuant to the provisions of § 50.21(c) of this chapter for operation at a thermal power level of 10 megawatts or less, and which is not a testing facility as defined by paragraph (m) of this section.

(i) "Sealed source" means any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material.

(j) "Source material" means:

(1) Uranium or thorium, or any combination thereof, in any physical or chemical form; or

(2) Ores which contain by weight one-twentieth of one percent (0.05%) or more of (i) uranium, (ii) thorium, or (iii) any combination thereof. Source material does not include special nuclear material.

(k) "Special nuclear material" means:

(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material but does not include source material; or

(2) any material artificially enriched by any of the foregoing, but does not include source material.

38 FR 30261

(l) "Manufacturing license" means a license pursuant to Appendix M of Part 50 of this chapter to manufacture a nuclear power reactor(s) to be operated at sites not identified in the license application.

33 FR 11587

(m) "Testing facility" means a nuclear reactor licensed by the Commission under the authority of subsection 104c of the Act and pursuant to the provisions of § 50.21(c) of this chapter for operation at:

(1) A thermal power level in excess of 10 megawatts; or

(2) A thermal power level in excess of 1 megawatt, if the reactor is to contain:

(i) A circulating loop through the core in which the applicant proposes to conduct fuel experiments; or

(ii) A liquid fuel loading; or

(iii) An experimental facility in the core in excess of 16 square inches in cross-section.

(n) "Utilization facility" means any nuclear reactor other than one designed or used primarily for the formation of plutonium or U^{233} and any other equipment or device determined by rule of the Commission to be a utilization facility within the purview of subsection 11cc of the Act.

(o) [Deleted 43 FR 7210.]

36 FR 145

(p) "Human use" means the internal or external administration of byproduct, source, or special nuclear material, or the radiation therefrom, to human beings.

43 FR 7210

(q) "Nuclear Steam Supply System" consists of the reactor core, reactor coolant system, and related auxiliary systems including the emergency core cooling system; decay heat removal system; and chemical volume and control system.

(r) "Balance of plant" consists of the remaining systems, components, and structures that comprise a complete nuclear power plant and are not included in the nuclear steam supply system.

(s) "Special projects" means those projects submitted to the Commission for review and for which specific fees are not prescribed in this chapter. Examples of special projects include, but are not limited to, topical reports, early site reviews, waste solidification facilities, fuel reprocessing facilities, and amendment or renewal of standardized reference design approvals.

(t) "Routine inspection" means an inspection performed at frequencies or during a certain period of time prescribed by the Commission for purposes of reviewing a licensee's authorized activities to assure that they are being conducted in accordance with regulatory or statutory requirements and that associated facilities and equipment are being operated in a safe manner.

(u) "Duplicate unit" means one of a limited number of the same kind of units which are to be constructed within a limited time span and subject to review at the same time by the staff.

(v) "Replicate unit" means a unit based on the reuse of a plant design, previously reviewed and approved for construction by the same utility or by another utility as part of another construction permit application.

(w) "Reference systems concept" means a concept that involves the review of an entire facility design or major fraction of a facility design outside of the context of a license application. The standard design would be referenced in subsequent license applications.

(x) "Advanced reactor" means any nuclear reactor concept other than light water reactors and high temperature gas cooled reactors.

33 FR 11587

§ 170.4 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

40 FR 8774

§ 170.5 Communications.

All communications concerning the regulations in this part should be addressed to the Executive Director for Operation, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications may be delivered in person at the Commission's offices at 1717 H Street NW, Washington, DC on or at 7920 Norfolk Ave., Bethesda, MD

33 FR 11587

§ 170.11 Exemptions.

43 FR 7210

(a) No application fees, license fees, amendment fees, renewal fees, approval fees, or inspection fees shall be required for:

33 FR 11587

(1) A license authorizing the export only of a production or utilization facility.

(2) A license authorizing the export only or import only of byproduct material, source material or special nuclear material.

(3) A license authorizing the receipt, ownership, possession, use or production of byproduct material, source material, or special nuclear material incidental to the operation of a production or utilization facility licensed under Part 50 of this chapter, including a license under Part 70 of this chapter, authorizing possession and storage only of special nuclear material at the site of a nuclear reactor for use as fuel in operation of the nuclear reactor or at the site of a spent fuel processing plant for processing at the plant.

(4) A construction permit or license applied for by, or issued to, a nonprofit educational institution for a production facility or utilization facility, other than a power reactor, to be used for teaching, training, or medical purposes, or for byproduct material, source material, or special nuclear material to be used for teaching, training, or medical purposes, or in connection with a facility, other than a power reactor, used for teaching, training, or medical purposes.

37 FR 24028

(5) A construction permit or license applied for by, or issued to, a Government agency, except for a utilization facility designed to produce electrical or heat energy pursuant to section 103 or 104b of the Atomic Energy Act of 1954, as amended.

(6) [Deleted 38 FR 18443.]

(7) [Deleted 38 FR 18443.]

(8) A license authorizing the use of source material as shielding only in devices and containers, provided, however, that all other licensed byproduct material, source material, or special nuclear material in the device or container will be subject to the fees prescribed in § 170.31.

(9) A license for possession and use of byproduct material, source material, or special nuclear material applied for by, or issued to, an agency of a State or any political subdivision thereof, except for licenses which authorize distribution of byproduct material, source material, or special nuclear material, or products containing byproduct material, source material, or special nuclear material, or licenses authorizing services to any person other than an agency or political subdivision of the State.

(10) Activities of the Commission undertaken, pursuant to Part 75 of this chapter, solely for the purpose of implementation of the US/IAEA Safeguards Agreement.

(b) (1) The Commission may, upon application by an interested person, or upon its own initiative, grant such exemptions from the requirements of this part as it determines are authorized by law and are otherwise in the public interest. (2) Applications for exemption under this paragraph may include activities such as, but not limited to, the use of licensed materials for educational or noncommercial public displays or scientific collections. (3) [Deleted 43 FR 7210.]

§ 170.12 Payment of fees.

(a) *Application Fees.* Each application for which a fee is prescribed shall be accompanied by a remittance in the full amount of the fee. No application will be accepted for filing or processed prior to payment of the full amount specified. Applications for which no remittance is received may be returned to the applicant. All application fees will be charged irrespective of the Commission's disposition of the application or a withdrawal of the application.

(b) *License Fees.* Fees for construction permits, operating licenses, manufacturing licenses, and materials licenses, are payable upon notification by the Commission when the review of the project is completed.

(c) *Amendment Fees.* The appropriate amendment fee shall accompany the application for amendment when filed with the Commission. Where applicable, the applicant shall provide a proposed determination of the amendment class and state the basis therefor as part of the amendment request and shall remit the fee corresponding to this determination with the application for amendment. The Commission will examine the amendment fee and will, where applicable, refund any overcharges or bill the applicant for the additional amendment fee.

(d) *Renewal Fees.* The appropriate renewal fee shall accompany the renewal application when filed with the Commission.

(e) *Approval Fees.* Fees for spent fuel cask and shipping container approvals, standardized spent fuel facility design approvals, and construction approvals are payable upon notification by the Commission when the review of the project is completed. Fees for facility reference standardized design approvals will be paid in five (5) installments based on payment of 20 percent of the approval fee (see footnote 3 § 170.21) as each of the first five (5) units of the approved design are referenced in an application(s) filed by a utility or utilities.

(f) *Special Project Fees.* Fees for special projects are payable upon notification by the Commission when the review of the project is completed.

(g) *Inspection Fees.* Inspection fees are payable upon notification by the Commission.

(h) *Method of Payment.* Fee payments shall be by check, draft, or money order made payable to the U.S. Nuclear Regulatory Commission.

§ 170.21 Schedule of fees for production and utilization facilities, review of reference standardized designs, and special projects.

(a) Applicants for construction permits, manufacturing licenses, operating licenses, and approvals of reference standardized facilities designs, shall pay the fees set forth in the table below.

(b) Applicants for special project reviews shall pay fees as separately determined by the Commission.

SCHEDULE OF FACILITY FEES

Facility categories	Types of fees	Fee
A. Power reactors:		
1. Custom	Application—Construction permit	$125,000
	Construction permit—First unit	944,000
	Construction permit—Concurrent unit	174,000
	Operating license—First unit	1,024,500
	Operating license—Concurrent unit	302,500
2. Standardized design—duplicate unit	Application—Construction permit	125,000
	Construction permit—First unit	944,000
	Construction permit—Concurrent unit	174,000
	Construction permit—First identical unit additional site(s)	757,100
	Operating license—First unit	1,024,500
	Operating license—Concurrent unit	300,200
	Operating license—First identical unit additional site(s)	712,000
3. Standardized design—replicate unit	Application—Construction permit	125,000
	Construction permit—First unit	811,600
	Construction permit—Concurrent unit	164,200
	Construction permit—First identical unit additional site(s)	725,900
	Operating license—First unit	914,400
	Operating license—Concurrent unit	293,900
	Operating license—First identical unit additional site(s)	691,500
4. Standardized design—Reference systems concept:		
a. Utility referencing a standardized nuclear steam supply system and custom balance of plant for both CP and OL stages.	Application—Construction permit	125,000
	Construction permit—First unit	853,600
	Construction permit—Concurrent unit	162,500
	Construction permit—First identical unit additional site(s)	725,900
	Operating license—First unit	934,100
	Operating license—Concurrent unit	292,100
	Operating license—First identical unit additional site(s)	669,200
b. Utility referencing a standardized nuclear steam supply system and standardized balance of plant for both the CP and OL stages.	Application—Construction permit	125,000
	Construction permit—First unit	721,800
	Construction permit—Concurrent unit	162,500
	Construction permit—First identical unit additional site(s)	725,900
	Operating license—First unit	829,100
	Operating license—Concurrent unit	292,100
	Operating license—First identical unit additional site(s)	669,200
5. Manufacturing license concept:		
a. Vendor—review of preliminary design.	Application	125,000
	Manufacturing license	1,477,500
b. Vendor—review of final design.	Final design amendment	448,100
c. Utility referencing a manufacturing license.	Application—Construction permit	125,000
	Construction permit—First unit	730,000
	Construction permit—Concurrent unit	41,500
	Operating license—First unit	1,001,200
	Operating license—Concurrent unit	221,000
6. Advanced reactors	Application—Construction permit	125,000
	Construction permit	1,781,300
	Operating license	1,954,900
B. Standard reference design review:		
1. Vendor—Standardized nuclear steam supply system:		

(Continued)

(Continued) SCHEDULE OF FACILITY FEES

Facility categories	Types of fees	Fee[3]
a. Review of preliminary reference design.	Application	50,000
	Approval	412,100
b. Review of final reference design.	Application	50,000
	Approval	483,400
2. Architect-engineer—Standardized balance of plant:		
a. Review of preliminary reference design.	Application	50,000
	Approval	412,100
b. Review of final reference design.	Application	50,000
	Approval	501,200
C. Test facility:[3]	Application—Construction permit	5,000
	Construction permit	67,200
	Operating license	100,300
D. Research reactor:[3]	Application—Constructic… permit	5,000
	Construction permit	34,900
	Operating license	55,000
E. Uranium enrichment plants:[3]	Application—Construction permit	125,000
	Construction permit	388,400
	Operating license	457,200
F. Special projects and reviews[4]		

[1] Where a partial fee for a power reactor operating license has been paid prior to the effective date of this amendment, the amount paid shall be deducted from the fee prescribed by this amendment and the difference will be due when the operating license for 100 pct power is issued.

[2] *Concurrent unit.* A concurrent unit is defined as a power reactor of the same design at a single power station that was subject to concurrent licensing review.

[3] When review of the permit, license, approval, or amendment is complete, the expenditures for professional manpower and appropriate support services will be determined and the resultant fee assessed, but in no event will the fee exceed that shown in the schedule of facility fees. When one application for a preliminary design approval or final design approval contains more than one design, the additional approvals are subject to a maximum fee which is the sum of the application fee and approval fee.

[4] Charge will be separately determined by the Commission taking into account the professional manpower required to conduct the review multiplied by the applicable cost per man-year, plus any appropriate support services costs incurred. Where a fee has been paid for a facility early site review, the charge will be deducted from the fee for a construction permit issued for that site. A separate charge will not be assessed for a site review where the person requesting the review has an application for a construction permit on file for the same site, except where the application is withdrawn by the applicant or denied by the Commission. The maximum fee for review of a topical report shall not exceed $20,000.

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§ 170.22 Schedule of fees for facility license amendments.

SCHEDULE OF AMENDMENT FEES FOR REACTOR FACILITY PERMITS, LICENSES, AND OTHER APPROVALS REQUIRED BY THE LICENSE OR COMMISSION REGULATIONS

Class of Amendment[1]	Fee[2]	
	Power reactors	Test and research reactors
CLASS I: Amendments that are a duplicate of an amendment for a second essentially identical unit at the same site, where both proposed amendments are received, processed, and issued at the same time	$400	——
CLASS II: Amendments that are pro forma, administrative in nature, or have no safety or environmental significance	1,200	$600
CLASS III: Amendments, exemptions, or required approvals that involve a single environmental, safety, or other issue, have acceptability for the issue clearly identified by an NRC position, or are deemed not to involve a significant hazards consideration	4,000	2,000
CLASS IV: Amendments, exemptions, or required approvals that involve a complex issue or more than one environmental, safety, or other issue, or several changes of the class III type incorporated into the proposed amendment, or involve a significant hazards consideration, or require an extensive environmental impact appraisal, or result from dismantling or license termination orders	12,300	4,000
CLASS V: Amendments, exemptions, or required approvals that require evaluation of several complex issues, or involve review by the ACRS, or require an environmental impact statement	25,800	12,000
CLASS VI: Amendments, exemptions, or required approvals that require evaluation of a new Safety Analysis Report and rewrite of the facility license (including technical specifications), such as may be required for a license renewal	45,900	30,000

[1] At the time the application is filed, the licensee or applicant shall provide a proposed determination of amendment class and state the basis therefor as part of the amendment or modification request and shall remit the fee corresponding to thi· determination. The Commission will evaluate the proposed amendment class determination and inform the …censee or applicant if reclassification is required. Reclassification that changes the class of amendment will result in the refund of over-charges to the licensee or applicant or billing the licensee or applicant for additional fees.

[2] License amendments or approvals resulting from Commission Orders issued pursuant to 10 CFR 2.204, and amendments resulting in an initial increase in power to 100 percent of the initial design power level are not subject to these fees, except as provided in footnote 1 to § 170.21. Class I, II, or III amendments which result from a written Commission request for the application may be exempt from fees when the amendment is to simplify or clarify license or technical specifications; the amendment has only minor safety significance, and is issued for the convenience of the Commission.

§ 170.23 Schedule of fees for routine health, safety and environmental inspections of facilities.

SCHEDULE OF FACILITY ROUTINE HEALTH, SAFETY AND ENVIRONMENTAL INSPECTION FEES[1]

Category	Fee[1]	Maximum frequency[2]
(1) Power reactor:		
First unit	$75,700 per year	Continuous.
Additional units at same site[3]	$60,400 per year	Do.
(2) Test reactor	$4,500 per inspection	2 per year.
(3) Research reactor	$4,200 per inspection	1 every 2 years.
(4) Other production or utilization facility[4]	$42,100 per year	Continuous.
(5) Production or utilization facility licensed for possession but not operation.	$650 per year	1 per year.

[1] Routine inspections are safety, environmental, and health physics inspections performed at specified frequencies for purposes of reviewing a licensed program to assure that the authorized activities are being conducted in accordance with the Atomic Energy Act of 1954, as amended, Commission regulations, and the terms and conditions of the license.

[2] The frequency shown in the schedule is the maximum number of routine inspections for which a fee will be assessed.

[3] A reduced fee will be charged when the inspection of an additional unit at the same site is conducted concurrently with the first unit.

[4] Fee is applicable for a fuel reprocessing facility and for a uranium enrichment facility.

§ 170.24 Schedule of fees for routine safeguards inspections of facilities

SCHEDULE OF FACILITY ROUTINE SAFEGUARDS INSPECTION FEES

Category	Fee	Maximum frequency[1]
(1) Power reactor:		
First unit	$11,800 per year	2 per year.
Additional unit at same site[2]	$9,500 per year	Do.
(2) Test reactor (fuel of high strategic importance)	$6,500 per inspection	1 per year.
(3) Research reactor (fuel of moderate strategic importance).	$1,300 per inspection	1 every 2 years.
(4) Other production or utilization facility[3]	$35,700 per year	3 per year.

[1] The frequency shown in the schedule is the maximum number of safeguards inspections for which a fee will be assessed. Power reactors and other production and utilization facilities will be assessed the yearly inspection fee shown in the above table.

[2] A reduced fee will be charged when the inspection of additional unit(s) at the same site is conducted concurrently with the first unit.

[3] Fee is applicable for a fuel reprocessing facility and for a uranium enrichment facility.

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§ 170.31 Schedule of fees for materials licenses and other regulatory services.

Applicants for materials licenses and other regulatory services and holders of materials licenses shall pay the following fees.

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES

Category of materials licenses	Type of fee[1]	Fee
1. *Special nuclear material:*[2]		
A. Licenses for possession and use of 5 kg or more of contained uranium 235 in uranium enriched to 20 pct or more, or 2 kg or more of uranium 233, for fuel processing and fabrication.[3]	Application	$14,000
	New license	122,600
	Renewal	78,800
	Amendment:[4]	
	Major—Safety and environmental	34,600
	Major—Safeguards	8,300
	Minor—Safety and environmental	1,400
	Minor—Safeguards	3,500
	Administrative	150
B. Licenses for possession and use of 5 kg or more of contained uranium 235 in uranium enriched to less than 20 pct, for fuel processing and fabrication.[3]	Application	12,000
	New license	112,800
	Renewal	71,300
	Amendment:[4]	
	Major—Safety and environmental	34,600
	Major—Safeguards	6,900
	Minor—Safety and environmental	1,400
	Minor—Safeguards	3,500
	Administrative	150
C. Licenses for possession and use of 2 kg or more of plutonium for fuel processing and fabrication.[3]	Application for construction approval	50,000
	Construction approval	480,300
	License fee	241,900
	Renewal	170,800
	Amendment:[4]	
	Major—Safety and environmental	75,000
	Major—Safeguards	13,600
	Minor—Safety and environmental	1,400
	Minor—Safeguards	6,200
	Administrative	150

See footnotes at end of table.

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee	Fee
D. Licenses for possession and use of 5 kg or more of contained uranium 235 in unsealed form, or 2 kg or more of uranium 233 in unsealed form for activities other than fuel processing and fabrication.	Application	3,000
	New license	31,600
	Renewal	18,000
	Amendment:	
	Safety and environmental	1,400
	Safeguards	2,800
	Administrative	150
E. Licenses for possession and use of quantities of plutonium of 2 kg or more in unsealed form for activities other than fuel processing and fabrication.	Application	6,000
	New license	58,300
	Renewal	38,100
	Amendment:	
	Safety and environmental	1,400
	Safeguards	6,900
	Administrative	150
F. Licenses for possession and use of 200 g but less than 2 kg of plutonium in unsealed form.	Application	5,000
	New license	42,100
	Renewal	29,800
	Amendment:	
	Safety and environmental	1,400
	Safeguards	4,800
	Administrative	150
G. Licenses for possession and use of 350 g but less than 5 kg of contained uranium 235 in unsealed form, or 200 g but less than 2 kg of uranium 233 in unsealed form.	Application	2,000
	New license	18,800
	Renewal	11,100
	Amendment:	
	Safety and environmental	1,400
	Safeguards	2,800
	Administrative	150
H. Licenses for receipt and storage of spent fuel: (1) License application for a storage facility of custom design requiring a full design review:		
(a) Storage facility to be located at a new site.	Application	$35,000
	New license	290,000
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(b) Storage facility to be located at the site of an existing nuclear facility.	Application	25,000
	New license	209,100
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(2) License application for a storage facility which references an approved standardized design:		
(a) Storage facility to be located at a new site.	Application	25,000
	New license	226,600
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(b) Storage facility to be located at the site of an existing nuclear facility.	Application	15,000
	New license	130,000
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(3) License application for a storage facility of duplicate design—design which is identical to a previously licensed detail design:		
(a) Storage facility to be located at a new site.	Application	15,000
	New license	159,200
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(b) Storage facility to be located at the site of an existing nuclear facility.	Application	10,000
	New License	73,500
	Renewal	32,000

See footnotes at end of table.

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SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee	Fee
	Amendment:	
	Major—Safety and environmental	58,500
	Major—Safeguards	4,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
I. Licenses for possession and use of special nuclear material in sealed sources contained in devices used in industrial measuring systems.	Application—New license	110
	Renewal	110
	Amendment	40
J. All other special nuclear material licenses, except licenses authorizing special nuclear material in unsealed form in combination that would constitute a critical quantity as defined in § 150.11 of Part 150 which shall pay the same rate as Category 1C and special nuclear material for use in power generation which shall pay the fee in Category 10.	Application—New license	460
	Renewal	460
	Amendment	110
2. Source material:		
A. Licenses for possession and use of source material in milling operations, except in in situ leaching and heap-leaching operations.	Application	11,000
	New license	96,700
	Renewal	100,800
	Amendment:	
	Major—Safety and environmental	20,800
	Minor—Safety and environmental	3,500
	Administrative	150
B. Licenses for processing and recovery of source material in in situ leaching operations or heap-leaching operations.	Production scale activity:	
	Application	7,000
	New license	59,500
	Research and development scale activity:	
	Application	2,000
	New license	21,800
	Renewal	17,200
	Amendment:	
	Major—Safety and environmental	4,200
	Minor—Safety and environmental	760
	Administrative	150
C. Licenses for refining uranium mill concentrates to uranium hexafluoride.	Application	11,000
	New license	96,700
	Renewal	45,800
	Amendment:	
	Major—Safety and environmental	20,800
	Minor—Safety and environmental	3,500
	Administrative	150
D. All other source material licenses	Application—New license	140
	Renewal	70
	Amendment	40
3. Byproduct material:		
A. Licenses for possession and use of byproduct material issued pursuant to Parts 30 and 33 of this chapter for processing or manufacturing of items containing byproduct material for commercial distribution, except byproduct material for use in power generation which shall pay the fee in category 10.	Application—New license	460
	Renewal	460
	Amendment	110
B. Licenses issued pursuant to § 32.72 of this chapter authorizing the processing or manufacture and distribution of radiopharmaceuticals containing byproduct material.	Application—New license	190
	Renewal	150
	Amendment	40
C. Licenses for byproduct material issued pursuant to Part 34 of this chapter for industrial radiography operations performed in shielded radiography installation(s) or permanently designated area(s) at the address(es) listed in the license.	Application—New license	190
	Renewal	150
	Amendment	40
D. Licenses for byproduct material issued pursuant to Part 34 of this chapter for industrial radiography operations performed in a shielded radiography installation(s) and at multiple temporary locations at the address(es) shown in the licenses or at temporary jobsites of the licensee in the field.	Application—New license	460
	Renewal	460
	Amendment	110
E. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is not removed from its shield (self-shielded units).	Application—New license	190
	Renewal	150
	Amendment	40
F. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is exposed for irradiation purposes.	Application—New license	460
	Renewal	460
	Amendment	110

See footnotes at end of table.

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SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee [1]	Fee
G. Licenses issued pursuant to Subpart B of Part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons generally licensed under Parts 31 or 35 of this chapter, except specific licenses authorizing redistribution of items which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons generally licensed under Parts 31 or 35 of this chapter.	Application—New license	460
	Renewal	370
	Amendment	230
H. Licenses issued pursuant to Subpart A of Part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons exempt from the licensing requirements of Part 30 of this chapter, except: (1) §§ 32.11 and 32.18 of this chapter, (2) specific licenses authorizing redistribution of items and quantities which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons exempt from the licensing requirements of Part 30 of this chapter, and (3) specific licenses which authorize distribution of timepieces, hands, and dials.	Application—New license	950
	Renewal	370
	Amendment	230
I. Licenses issued pursuant to § 32.18 of this chapter to distribute quantities of byproduct material to persons exempt from the licensing requirements of Part 30 of this chapter.	Application—New license	190
	Renewal	150
	Amendment	40
J. Licenses issued pursuant to § 32.14 of this chapter to distribute timepieces, hands, and dials containing hydrogen 3 or promethium 147 to persons exempt from the licensing requirements of Part 30 of this chapter.	Application—New license	190
	Renewal	150
	Amendment	40
K. Licenses for possession and use of byproduct material for research and development, except those licenses covered by categories 3A or 3B, and licenses covered by categories 7B or 7C authorizing medical research.	Application—New license	190
	Renewal	150
	Amendment	40
L. All other specific byproduct material licenses, except those in categories 4A through 10A.	Application—New license	110
	Renewal	110
	Amendment	40
4. Waste disposal:		
A. Licenses specifically authorizing the receipt of waste byproduct material, source material, or special nuclear material, from other persons for the purpose of commercial disposal by land or sea burial by the licensee.	Application	32,000
	New license	291,100
	Renewal	96,500
	Amendment:	
	Major-Safety and environmental	197,700
	Minor—Safety and environmental	890
	Administrative	150
B. Licenses specifically authorizing the receipt of waste byproduct material, source material, or special nuclear material from other persons for the purpose of packaging the material. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.	Application—New license	1,100
	Renewal	370
	Amendment:	
	Safety and environmental	370
	Administrative	150
C. Licenses specifically authorizing the receipt of prepackaged waste byproduct material, source material, or special nuclear material from other persons. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.	Application—New license	190
	Renewal	150
	Amendment	40
5. Well logging and well surveys and tracer studies: A. Licenses for possession and use of special nuclear material and/or byproduct material for well logging, well surveys, and tracer studies.	Application—New license	460
	Renewal	460
	Amendment	110
6. Nuclear laundries: A. Licenses for commercial collection and laundry of items contaminated with byproduct material, source material, or special nuclear material.	Application—New license	460
	Renewal	460
	Amendment	110

See footnotes at end of table.

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SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee	Fee
7. Human use of byproduct material, source material, or special nuclear material:		
A. Licenses issued pursuant to Parts 30, 40, and 70 of this chapter for human use of byproduct material, source material, or special nuclear material in sealed sources contained in teletherapy devices.	Application—New license	300
	Renewal	270
	Amendment	40
B. Licenses issued pursuant to Parts 30, 40, and 70 of this chapter to medical institutions, or two or more physicians on a single license, for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	Application—New license	190
	Renewal	150
	Amendment	40
C. Licenses issued pursuant to Parts 30, 40, and 70 of this chapter to an individual physician for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	Application—New license	190
	Renewal	150
	Amendment	40
8. Civil defense: A. Licenses for possession and use of byproduct material, source material, or special nuclear material for civil defense activities.	Application—New license	190
	Renewal	150
	Amendment	40
9. Device, product, or sealed source safety evaluation:		
A. Safety evaluation of devices or products containing byproduct material, source material, or special nuclear material, except reactor fuel devices and devices or products distributed to general licensees or persons exempt from the requirements for a license pursuant to Parts 30, 40, and 70 of this chapter.	Application—Evaluation	570
B. Safety evaluation of sealed sources containing byproduct material, source material, or special nuclear material, except: (1) Reactor fuel, (2) sealed sources distributed to general licensees or persons exempt from the requirements for a license pursuant to Parts 30, 40, and 70 of this chapter, and (3) power sources covered by category 10.	do	110
10. Power source: A. Licenses for the manufacture and distribution of encapsulated byproduct material or special nuclear material wherein the decay energy of said material is used as a source of power, except reactor fuel.	Application—New license	1,900
	Renewal	460
	Amendment	460
11. Transportation of radioactive material:		
A. Evaluation of spent fuel cask for greater than 20 kW decay heat.	Application	8,000
	Approval	75,100
	Amendments:	
	Major	6,900
	Minor	3,500
	Administrative	150
	Renewal	150
B. Evaluation of spent fuel cask for less than 20 kW decay heat; air shipping package for plutonium; high-level waste casks; and packages containing radioactive material greater than 2,000 times the type A quantity.	Application	7,000
	Approval	62,200
	Amendments:	
	Major	5,500
	Minor	2,800
	Administrative	150
	Renewal	150
C. Evaluation of fissile packages containing greater than type A quantities of radioactive material; packages containing radioactive material less than 2,000 times the type A quantity	Application	1,000
	Approval	12,800
	Amendments:	
	Major	3,500
	Minor	590
	Administrative	150
	Renewal	150
D. Evaluation of fissile packages containing less than type A quantities of radioactive material; packages containing radioactive material less than 200 times the type A quantity.	Application	700
	Approval	6,200
	Amendments:	
	Major	1,400
	Minor	350
	Administrative	150
	Renewal	150
E. Evaluation of packages containing radioactive material less than 20 times the type A quantity.	Application	200
	Approval	1,200
	Amendments:	
	Major	350
	Minor	150
	Renewal	150

See footnotes at end of table.

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee [1]	Fee
12. Review of standardized spent fuel facility design. [5]	Application	12,000
	Approval [4]	107,200
13. Special projects [8]		

[1] *Types of fees.* Separate charges as shown in the schedule will be assessed for applications for new licenses and approvals, issuance of new licenses and approvals, and amendments and renewals to existing licenses and approvals. The following guidelines apply to these charges:

(a) *Application fees.* Applications for materials licenses and approvals shall be accompanied by the prescribed application fee for each category, except that applications for licenses covering more than one fee category of special nuclear material (excluding category 1H) to be used at the same location, shall be accompanied by the prescribed application fee for the highest fee category. Where a license or approval has expired, the full application fee for each category shall be due, except for licenses covering more than one fee category of special nuclear material (excluding category 1H) for use at the same location, in which case the application fee for the highest category would apply.

(b) *License/approval fees.* New licenses and approvals issued in fee categories 1A through 1H, 2A, 2B, 2C, 4A, 11A through 11E, and category 12, shall pay the license or approval fee for each category, as determined by the Commission when the review of the application or project is completed (see footnote 4), except that a license covering more than one fee category of special nuclear material in categories 1A through 1G shall pay a license fee for the highest fee category assigned to the license.

(c) *Renewal fees.* Applications for renewal of materials licenses and approvals shall be accompanied by the prescribed fee for each category, except that applications for renewal covering more than one fee category of special nuclear material (excluding category 1H) to be used at the same location, shall be accompanied by the prescribed renewal fee for the highest fee category. When the review of an application for renewal is complete for licenses in fee categories 1A through 1H, 2A, 2B, 2C, and 4A, the Commission will examine the renewal fee in accordance with footnote 4, and will refund any overcharges of the renewal fee, if applicable.

(d) *Amendment fees.* Applications for amendments shall be accompanied by the prescribed amendment fee(s). At the time an application for amendment is filed for licenses and approvals in fee categories 1A through 1H, 2A, 2B, 2C, 4A, 11A, 11B, 11C, 11D, and 11E, the licensee or applicant shall provide an initial determination of the amendment class and state the basis therefor as part of the amendment or approval request, and shall remit the fee corresponding to that determination; however, when review of the amendment or approval is complete, the Commission will examine the amendment fee in accordance with footnote 4, if applicable, and will refund any overcharges to the licensee or applicant, or bill the licensee or applicant for the additional amendment fee. Amendments which result from written NRC requests may be exempted from these fees at the discretion of the Commission when the amendment is issued for the convenience of the NRC.

An application for amendment to a license or approval classified in more than one fee category shall be accompanied by the prescribed amendment fee for the category affected by the amendment, unless the amendment is applicable to two or more fee categories, in which case the amendment fee for the highest fee category would apply. An application for amendment to a materials license or approval that would place the license or approval in a higher fee category or add a new category shall be accompanied by the prescribed application fee for the new category, except for applications for amendments increasing the scope of a licensed program from fee categories 1F to 1E, 1G to 1D, 3C to 3D, and 7C to 7B, in which cases the amendment fee for the higher fee category would apply. An application for amendment reducing the scope of a licensee's program shall pay the amendment fee of the fee category assigned to the license at the time the application is filed. Applications to terminate licenses shall not be subject to fees.

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[2] Licensees paying fees under categories 1A through 1H are not subject to fees under categories 1I and 1J for sealed sources authorized in the same license. Applicants for new licenses or renewal of existing licenses that cover both byproduct material and special nuclear material in sealed sources for use in gauging devices will pay the appropriate application or renewal fee for fee category 1I only.

[3] A major amendment is defined as one requiring evaluation of many aspects of licensed activities where the proposed action could present a potential risk to the public's health and safety. A minor amendment is defined as one where safety, environmental, or safeguards considerations may be easily resolved. An administrative amendment is defined as an amendment that is pro forma, routine in nature, or has no safety, environmental, or safeguards significance.

[4] When the review of an application is complete, the expenditures for professional manpower and appropriate support services will be determined and the resultant fee assessed, but in no event will the fee exceed that shown in the schedule of fees for materials licenses and other regulatory services. All administrative amendments are based on fixed charges.

[5] Fees would be applicable only in those instances where a site safety and environmental review has been performed and documented by the Commission for the site at which the storage facility is to be located.

[6] Fee is applicable to a license authorizing either production scale activity or research and development scale activity.

[7] A type A quantity is defined in § 71.4(q) of 10 CFR Part 71.

[8] Charge will be separately determined by the Commission taking into account the professional manpower required to conduct the review multiplied by the applicable cost per man-year, plus any appropriate support services costs incurred.

§ 170.32 Schedule of fees for health and safety, and safeguards inspections for materials licenses.

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES

Category of materials licenses	Type of fee	Fee	Maximum frequency
1. Special nuclear material:			
A. Licenses for possession and use of five (5) kg or more of contained uranium 235 in uranium enriched to 20 pct or more, or two (2) kg or more of uranium 233, for fuel processing and fabrication.	Health and safety	35,300	3 per year.
	Safeguards	10,300	Do.
B. licenses for possession and use of five (5) kg or more of contained uranium 235 in uranium enriched to	Health and safety	5,300	Do.
	Safeguards	10,300	1 per year.

See footnote at end of table.

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
less than 20 pct. for fuel processing and fabrication.			
C. Licenses for possession and use of two (2) kg or more of plutonium for fuel processing and fabrication.	Health and safety Safeguards	4,600. 11,700	4 per year 3 per year.
D. Licenses for possession and use of five (5) kg or more of contained uranium 235 in unsealed form, or two (2) kg or more of uranium 233 in unsealed form for activities other than fuel processing and fabrication.	Health and safety Safeguards	4,900 7,600	1 per year. 2 per year.
E. Licenses for possession and use of quantities of plutonium of two (2) kg or more in unsealed form for activities other than fuel processing and fabrication.	Health and safety Safeguards	780 5,400	1 per year. 2 per year.
F. Licenses for possession and use of 200 g but less than two (2) kg of plutonium in unsealed form.	Health and safety Safeguards	780 2,300	1 per year. Do.
G. Licenses for possession and use of 350 g but less than five (5) kg of contained uranium 235 in unsealed form, or 200 g but less than two (2) kg of uranium 233 in unsealed form.	Health and safety Safeguards	780 4,000	1 every 2 years. 1 per year.
H. Licenses for receipt and storage of spent fuel:			
(1) License application for a storage facility of custom design requiring a full design review:			
(a) Storage facility to be located at a new site.	Health and safety Safeguards	780 2,900	Do. 2 per year.
(b) Storage facility to be located at the site of an existing nuclear facility.	Health and safety Safeguards	780 2,900	1 per year. 2 per year.
(2) License application for a storage facility which references an approved standardized design:			
(a) Storage facility to be located at a new site.	Health and safety Safeguards	780 2,900	1 per year. 2 per year.
(b) Storage facility to be located at the site of an existing nuclear facility.	Health and safety Safeguards	780 2,900	1 per year. 2 per year.
(3) License application for a storage facility of duplicate design—design which is identical to a previously licensed detail design:			
(a) Storage facility to be located at a new site.	Health and safety Safeguards	780 2,900	1 per year. 2 per year.
(b) Storage facility to be located at the site of an existing nuclear facility.	Health and safety Safeguards	780 2,900	1 per year. 2 per year.
I. Licenses for possession and use of special nuclear material in sealed sources contained in devices used in industrial measuring systems.	Health and safety	330	1 every 3 years.
J. All other special nuclear material licenses, except licenses authorizing special nuclear material in unsealed form in combination that would constitute a critical quantity as defined in § 150.11 of part 150 which shall pay the same rate as category 1C and special nuclear material for use in power generation which shall pay the fee in category 10.	do	780	1 per year.
2. Source material:			
A. Licenses for possession and use of source material in milling operations, except in in-situ leaching and heap-leaching operations.	do	1,800	Do.
B. Licenses for processing and recovery of source material in in-situ leaching operations or heap-leaching operations.	do	1,800	Do.
C. Licenses for refining uranium mill concentrates to uranium hexafluoride.	do	1,800	Do.
D. All other source material licenses	do	460	1 every 2 years.
3. Byproduct material:			
A. Licenses for possession and use of byproduct material issued pursuant to parts 30 and 33 of this chapter for processing or manufacturing of items containing byproduct material for commercial distribution, except byproduct material for use in power generation which shall pay the fee in Category 10[5].	Health & Safety[4] Large program Small program	 1,500 780	 1 per year. Do.
B. Licenses issued pursuant to § 32.72 of this chapter authorizing the processing or manufacture and distri-	Health & Safety	650	1 every 3 years.

See footnote at end of table.

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SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[a]	Fee[b]	Maximum frequency[c]
bution of radio-pharmaceuticals containing byproduct material.			
C. Licenses for byproduct material issued pursuant to part 34 of this chapter for industrial radiography operations performed in a shielded radiography installation(s) or permanently designated area(s) at the address(es) listed in the license[a].	do	720	1 per year.
D. Licenses for byproduct material issued pursuant to part 34 of this chapter for industrial radiography operations performed in a shielded radiograph installation(s) and at multiple temporary locations at the address(es) shown in the license or at temporary jobsites of the licensee in the field[a].	do	980	Do.
E. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is not removed from its shield (Self-shielded units).	do	390	1 every 5 years.
F. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is exposed for irradiation purposes.	Health and safety	390	1 every 3 years.
G. Licenses issued pursuant to Subpart B of part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons generally licensed under parts 31 or 35 of this chapter, except specific licenses authorizing redistribution of items which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons generally licensed under parts 31 or 35 of this chapter.	do	390	Do.
H. Licenses issued pursuant to Subpart A of part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons exempt from the licensing requirements of part 30 of this chapter, except (1) §§ 32.11 and 32.18 of this chapter, (2) specific licenses authorizing redistribution of items and quantities which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons exempt from the licensing requirements of part 30 of this chapter, and (3) specific licenses which authorize distribution of timepieces, hands and dials.	do	390	Do.
I. Licenses issued pursuant to § 32.18 of this chapter to distribute quantities of byproduct material to persons exempt from the licensing requirements of part 30 of this chapter.	do	390	Do.
J. Licenses issued pursuant to § 32.14 of this chapter to distribute timepieces, hands, and dials, containing hydrogen 3 or promethium 147 to persons exempt from the licensing requirements of part 30 of this chapter.	do	390	Do.
K. Licenses for possession and use of byproduct material for research and development, except those licenses covered by categories 3A or 3B, and licenses covered by categories 7B or 7C authorizing medical research.	do	390	Do.
L. All other specific byproduct material licenses, except those in categories 4A through 10A.	do	390	1 every 5 years.
4. Waste disposal:			
A. Licenses specifically authorizing the receipt of waste byproduct material, source material, or special nuclear material, from other persons for the purpose of commercial disposal by land or sea burial by the licensee.	do	980	1 per year.
B. Licenses specifically authorizing the receipt of waste byproduct ma-	Health & Safety	680	1 every 3 years.

See footnotes at end of table.

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SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
terial, source material, or special nuclear material, from other persons for the purpose of packaging the material. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.			
C. Licenses specifically authorizing the receipt of prepackaged waste byproduct material, source material, or special nuclear material, from other persons. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.	...do...	650	Do.
5. Well logging and well surveys and tracer studies:			
A. Licenses for possession and use of special nuclear material and/or byproduct material for well logging, well surveys, and tracer studies.	...do...	520	Do.
6. Nuclear laundries:			
A. Licenses for commercial collection and laundry of items contaminated with byproduct material, source material, or special nuclear material.	...do...	590	Do.
7. Human use of byproduct material, source material, or special nuclear material:			
A. Licenses issued pursuant to parts 30, 40, and 70 of this chapter for human use of byproduct material, source material, or special nuclear material in sealed sources contained in teletherapy devices.	...do...	460	1 every 2 years.
B. Licenses issued pursuant to parts 30, 40, and 70 of this chapter to medical institutions, or two or more physicians on a single license, for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	...do...	460	1 every 3 years.
C. Licenses issued pursuant to parts 30, 40, and 70 of this chapter to an individual physician for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	...do...	330	Do.
8. Civil defense:			
A. Licenses for possession and use of byproduct material, source material, or special nuclear material for civil defense activities.	...do...	700	1 every 10 years.
9. Device, product, or sealed source safety evaluation:			
A. Safety evaluation of devices or products containing byproduct material, source material, or special nuclear material, except reactor fuel devices and devices or products distributed to general licensees or persons exempt from the requirements for a license pursuant to parts 30, 40, and 70 of this chapter.	Not applicable...	...	No inspections conducted.
B. Safety evaluation of sealed sources containing byproduct material, source material, or special nuclear material, except (1) reactor fuel, (2) sealed sources distributed to general licensees or persons exempt from the requirements for a license pursuant to parts 30, 40, and 70 of this chapter, and (3) power sources covered by category 10.	Not applicable...	...	No inspections conducted.
10. Power sources:			
A. Licenses for the manufacture and distribution of encapsulated byproduct material or special nuclear material wherein the decay energy of said material is used as a source of power, except reactor fuel.	Health and safety...	780	1 per year.
11. Transportation of radioactive material:			
A. Evaluation of spent fuel cask for greater than 20 kW decay heat.	Not applicable...	...	No inspections conducted.
B. Evaluation of spent fuel cask for less than 20 kW decay heat; air shipping package for plutonium; high-level waste casks; and packages containing radioactive material	...do...	...	Do.

See footnotes at end of table.

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
greater than 2,000 times the type A quantity.			
C. Evaluation of fissile packages containing greater than type A quantities of radioactive material; packages containing radioactive material less than 2,000 times the type A quantity.	do		Do.
D. Evaluation of fissile packages containing less than type A quantities of radioactive material; packages containing radioactive material less than 200 times the type A quantity.	do		Do.
E. Evaluation of packages containing radioactive material less than 20 times the type A quantity.	do		Do.
12. Review of standardized spent fuel facility design.	do		Do.

[1] *Types of Fees*—Separate charges as shown in this schedule will be assessed for each routine inspection which is performed.

[2] Inspection fees are due upon receipt of notice from the Commission. The inspection fee for licenses covering more than one fee category will be charged only for the highest fee category assigned the license, if the inspection of the entire license is done at the same time. Where a licensee holds more than one materials license at a single location, a fee equal to the highest fee category covered by the licenses will be assessed, if the inspections are conducted at the same time.

[3] The frequency shown in the schedule is the maximum number of each type of inspection for which a fee will be assessed.

[4] Where a license authorizes shielded radiographic installations or manufacturing installations at more than one address, a separate fee will be assessed for inspection of each location, provided, however, that if the multiple installations are inspected during a single visit a single inspection fee will be assessed.

[5] For inspection purposes, large and small programs in Category 3A are defined as follows: A. *Large Programs*—Those licensees handling or processing loose or unsealed material for the manufacture of tagged compounds or products such as sealed sources and distribution of same to others. *Small Programs*—Those licensees who are processors of "finished products," such as previously tagged compounds and sealed sources for introduction into products or repackaging for sale to others.

§ 170.41 **Failure by applicant or licensee to pay prescribed fees.**

In any case where the Commission finds that an applicant or a licensee has failed to pay a prescribed fee required in this part, the Commission will not process any application and may suspend or revoke any license or approval involved or may issue an order with respect to licensed activities as the Commission determines to be appropriate or necessary in order to carry out the provisions of this part, Parts 30, 40, 50, 70, and 71 of this chapter, and of the Act.

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

NOTICE TO EMPLOYEES

Standards for Protection Against Radiation

In Title 25 of its Rules and Regulations, The Pennsylvania Department of Environmental Resources has established standards for your protection against radiation hazards.

YOUR EMPLOYER'S RESPONSIBILITY

Your employer is required to -

1. Apply these Department of Environmental Resources regulations and any conditions of his radioactive materials license to all work involving radiation sources.

2. Post or otherwise make available to you a copy of the regulations, licenses, and operating procedures which apply to work you are engaged in, and explain their provisions to you.

YOUR RESPONSIBILITY AS A WORKER

You should familiarize yourself with these provisions of the regulations and operating procedures which apply to the work you are engaged in. You should observe their provisions for your own protection and protection of your co-workers.

WHAT IS COVERED BY THESE REGULATIONS

1. Limits on exposure to radiation and radioactive materials in restricted and unrestricted areas;
2. Measures to be taken after accidental exposure;
3. Personnel monitoring, surveys and equipment;
4. Caution signs, labels, and safety interlock equipment;
5. Exposure records and reports; and
6. Related matters.

REPORTS ON YOUR RADIATION EXPOSURE HISTORY

1. The Department of Environmental Resources regulations require that your employer give you a written report if you receive an exposure in excess of any applicable limit as set forth in the regulations or the license. The basic limits for exposure to employees are set forth in Chapter 227 of the regulations. This chapter specifies limits on exposure to radiation and exposure to concentrations of radioactive material in air.

2. If you work where personnel monitoring is required pursuant to Chapter 227:

   (a) Your employer must give you a written report of your radiation exposure upon the termination of your employment if you request it, and

   (b) Your employer must advise you annually of your exposure if you request it.

INSPECTIONS

All activities involving radiation are subject to inspection by representives of the Pennsylvania Department of Environmental Resources.

INQUIRIES

Inquiries dealing with matters outlined above can be sent to the Bureau of Radiation Protection, Pennsylvania Department of Environmental Resources, P. O. Box 2063, Harrisburg, Pennsylvania 17120. Telephone 717-787-3720.

POSTING REQUIREMENT

Copies of this notice must be posted in a sufficient number of places in every establishment where activities covered by the regulations are conducted to permit employees working in or frequenting any portion of a restricted area to observe a copy on the way to or from their place of employment.

IN-HOUSE TRAINING SEMINAR
NUCLEAR SURFACE MOISTURE-DENSITY GAUGE
SEMINAR QUIZ

Name:______________________________ Date:______________________________

1. At what temperature should you turn on the display heater? (3400 series)
   a. 32°C
   b. 32°F
   c. Whenever the numbers are displayed in the reverse order
   d. Whenever the display reads heat
   e. None of the above

2. Moisture measurements with the 3400 are made only with the source rod in the backscatter position?

   True _______ False _______

3. From the time BAT is first shown on the gauge display panel; the gauge may be used for about 8 hours until the gauge shuts down automatically. What is the minimum amount of time required to bring the power pack to full capacity? (3400 series)

   a. 6
   b. 12
   c. 8
   d. 14
   e. Batteries are totally ruined and cannot be charged.

4. If the gauge is stolen or damaged with the source rod exposed the following agencies should be notified?

   a. County Sheriff
   b. Department of Environmental Resources Bureau of Radiation Protection
   c. U.S. Nuclear Regulatory Commission
   d. State Police
   e. Civil Defense
   f. Company Safety Officer

5. Gauge shielding is provided by encasing the sources in:

   a. Copper-zinc alloy
   b. Tungsten
   c. Stainless steel
   d. Americium-241 and beryllium
   e. Other

6. The Troxler gauges must be at least 300 feet from another gauge in order for them to function properly?

   True _______ False _______

7. A density test cannot be accurately conducted in any other mode except for the direct transmission mode?

   True _______ False _______

8. Whenever the source rod is removed it must be kept in the vertical position with a "Yellow II" lable displayed on a nearby wall?

True _______ False _______

9. An error code of 76 is displayed on the Troxler 3411-B gauge; this means that the sources within the gauge is about to reach critical mass?

True _______ False _______

10. What time mode should the gauge be switched to whenever the material being tested is frozen soil?

a. 4 minutes
b. 1 minute
c. 15 seconds
d. Cannot be tested

11. The properties of one of the sub-atomic particles allows it's use in the determination of density:

a. Neutron
b. Alpha Particle
c. Beta Particle
d. Photon (Gamma Ray)

12. Radiation intensity decreases with distance from the source. This decrease is a function of the source of the distance (D^2). Moving five times further away from the square decreases intensity by a factor of:

a. 25
b. 2
c. 50
d. 100

13. Briefly define the units Curie & Rem.

Which of these two units applies to the "impact" on the human body?

14. According to law, the maximum allowable whole body exposure is 1,250 mrem. (milli-rems) over a 13 week period. The law further allows an exposure of 3 Rems (=3000 milli-rems) if the cummulative life-time exposure limit as defined by:

[5 x (N-18)] Rem (where N = age in years)

has not been reached. Assume a 22 year old individual with a cummulative exposure of 17.2 rem. Can he be exposed to a 13 week dose of 3 rem? Why?

15. According to the operating manual for the 3400-B series Troxler, the total surface radiation is 15.0 mrem/hr. If the operator were to sit on the troxler for 1.2 hours per for a 5 day work week, (a) what percent of allowable "whole-body" exposure limit would be reached? (Note: "whole-body" limit is 96 mrem per week)

(b) if the operator worked at a distance of 1 meter (total exposure = 0.15 mrem/hr) from the 3400-B troxler for a period of 4 hours a day for a 5 day week, what percent of the "whole-body" limit would be reached?

16. When selecting a testing site on asphalt, what should you be looking for?

17. Name four types of material where a density correction factor will be possibly needed?

a.
b.
c.
d.

18. Referring to 3411-B model when should a statistical stability and drift test be run?

19. Name two times on a project where you would be required to bring soil samples to the lab for oven drying?

a.

b.

20. When using the 2400 model, in a trench, what is the minimum width where no moisture correction is needed?

21. Referring to question 20, what is the minimum width for the 3411-B model?

22. If the material is too coarse to drive a rod through, can a test be taken? If yes how?

23. What is a control strip?

24. If a moisture correction factor is needed for the 2400 model, how many samples must be oven dried?

25. Referring to question 24, how many samples are required for the 3411-B model?