LAKEHEAD TESTING LABORATORY, INC

OPERATING AND EMERGENCY PROCEDURES

FOR

TECHNICIANS USING

SOIL MOISTURE/DENSITY GUAGES

MANUAL NO. _____ ASSIGNED TO _____

INDEX

LAKEHEAD TESTING OPERATION MANUAL FOR MOISTURE/DENSITY GAUGES

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LAKEHEAD TESTING OPERATION MANUAL FOR MOISTURE/DENSITY GAUGES

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I. GENERAL OPERATING AND EMERGENCY PROCEDURES:

A. OPERATING PROCEDURES:

1. Only authorized personnel who have completed either the Troxler Electronic Labs, Inc Training Course, or a similar manufacturer's training course, or our Company Training Course will be permitted to use these Soil Moisture/Density Gauges. Operators should follow standard operating procedures, report unsafe conditions and if in doubt about the use of the gauge, ask his radiological safety officer.

2. A film badge supplied by R. S. Landauer, Jr & Company, Glenwood, Illinois, will be worn at all times whenever operating or transporting these gauges.

3. Each such film badge, which is sensitive to both gamma and neutron radiation, will be assigned to and worn by only one person.

4. Keep all unauthorized persons out of the operating area, that is, a distance of 5 meters or 15'. The general public must not be unnecessarily exposed to radiation.

5. While exposure dose levels are within limits for radiation workers, never expose yourself to the bare source unless absolutely necessary to clean or maintain the equipment. Follow cleaning and maintenance procedures.

6. Keep the source in the "SAFE" or stored position when not in use.

7. Maintain security of the instrument at all times. The source lock should be in place when not in use, and the instrument should be secured in the vehicle when transported. When stored, the area should be locked and posted. 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.

8. Whenever the gauge is stored in the lab or at a field site, it must be kept in a locked storage room, and the room must be posted with a sign - "CAUTION-RADIOACTIVE MATERIALS". The sign should have a yellow background and the three-bladed radiation symbol and lettering in red or magenta.

B. EMERGENCY PROCEDURES:

1. This section covers the course of action to be taken in case of accident involving a Soil Moisture/Density Gauge.

2. If the gauge is damaged at a field location because of being hit by construction equipment or similar occurrence, immediately restrict the area of the gauge for at least 10'.

3. Stop all vehicles which may have collided with the gauge and which could possibly have radiation contamination on tires, cleats, or tracks. DO NOT WALK THROUGH THE AREA AND DO NOT MOVE THE GAUGE OR ANY GAUGE PARTS UNTIL DAMAGE HAS BEEN ASSESSED.

4. If assistance is needed, call one of the following for help or instructions:

Robert Christen	Lab Phone:	628-2295	Home Phone:	626-1496
Gary Wirtz		628-2295		722-0142

5. If the gauge has been broken open and there is a possiblity of spreading radioactive contamination, the operator should "freeze" or secure the site, stopping the vehicle that damaged the machine, etc., and should send somebody to call one of the persons listed above. The gauge should not be moved until authorized personnel with a survey meter determine the extent of possible source damage and take charge. Personnel should not be allowed to walk through the damaged area in event of contamination.

6. If for any reason, no one can be contacted for help, call the State Health Department or the Region III office of the Nuclear Regulatory Commission.

   Minnesota State Department of Health 612-378-1150

   U S Nuclear Regulatory Commission - Region III
   Office of Inspection and Enforcement
   799 Roosevelt Road - Glen Ellyn, Illinois 60137

   Phone: 312-790-5500 (day, night, holidays)

7. If the gauge has not been broken open, retract the source back into the shielded head and return the gauge to the laboratory.

8. If source cannot be returned to the "SHIELDED" position, place shielding material around it such as packing it in a container of soil for protection. Return instrument to the laboratory.

9. If Soil Moisture/Density Gauge must be sent to the manufacturer for repairs, call Troxler Electronic Labs or other manufacturers for shipping instructions.

10. If Soil Moisture/Density Gauge is lost or stolen, call laboratory for instructions immediately. If no one can be contacted, then the State Health Department and the Region III office of the NRC must be contacted immediately.

C. TRANSPORTING SOIL MOISTURE/DENSITY GAUGE:

1. The gauge should be kept in its shipping case when transporting it to a field site.

2. The shipping case containing the gauge shall be tied down or restrained when transporting it in a vehicle so that it will not be thrown out or lost in case of accident.

3. Current regulations do not require the vehicle to be placarded with the

diamond-shaped signs required for other classes of radioactive materials.

4. Always keep vehicle locked whenever a source is in the vehicle.

5. If vehicle is used for storage of the gauge, it must be locked and posted with a "CAUTION-RADIOACTIVE MATERIALS" sign.

D. PROCEDURE FOR REMOVAL AND SHIELDED STORAGE OF SOURCE ROAD ASSEMBLY

1. Only qualified individuals who are knowledgeable in removal and shielded storage of source rod assemblies will perform this procedure.

2. Any individual performing this procedure must wear a film badge.

3. Secure the area by roping it off to prevent access by unathorized personnel.

4. The source rod assembly must be physically watched at all times by the individual performing this procedure.

5. 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.

6. Depress the trigger and lift the source rod out of the gauge shield.

7. Keeping the source rod tip away from the body, immediately place it in the shielded storage.

8. Perform required cleaning and/or maintenance.

9. Replace source rod assembly including rod cap and roll pin.

E. RECORDS

The following records will be maintained and kept available for authorized inspectors:

1. Film badge reports showing radiation dosage to individuals using the Soil Moisture/Density Gauges.

2. Leak test reports on source(s) used in these gauges.

3. Necessary maintenance, service, and calibration of these gauges.

4. Records covering shipment of these gauges with their sources by public transportation.

5. Quarterly inventory of gauges with sources showing location of sources in our possession.

6. Utilization logs showing when equipment was used and to whom assigned.

II. LEAK TESTING MOISTURE/DENSITY GAUGES:

A. PROCEDURE: (See also Section VIII-G)

1. All radioactive sources must be leak tested every six months.

2. Only qualified individuals who are knowledgeable in leak testing sources will perform this test.

3. Any individual performing leak tests must wear a film badge.

4. Using an LT-1 Kit supplied by ICN, wipe the control rod containing the radioactive source using the following procedure:

   a. Lay gauge on its side with bottom plate facing away from you.

   b. Dissolve Alconox powder supplied with kit in 10 ml of water.

   c. Push source rod out of gauge 4".

   d. Standing behind the gauge, quickly wipe the end of the source rod with swab moistened in Alconox solution. Wipe around the weld area near the end of the rod and use both swabs on single source gauges.

   e. Retract source into shielded head.

   f. Remove scaler assembly of the 3400 series Troxler Gauges.

      1) Take second moistened swab and wipe the surface of the yellow and magenta label in the gauge cavity, or use both swabs on both sources.

      2) Replace scaler assembly.

   g. Allow swabs to dry before sealing them in the plastic bag.

   h. Survey swabs by holding them against survey meter.

   i. If no reading is obtained, send smears into laboratory to the attention of the Radiation Safety Officer. We will forward them to ICN for analysis.

   j. If reading on survey meter exeeds 0.5 MR/HR on the low range, DO NOT SEND BY MAIL. Call Radiation Safety Officer for instructions. We will contact ICN for shipping instructions

   k. Include following information with leak test smears:

      1) Brand name of Soil Density/Moisture Gauge.

      2) Model and serial number of gauge

      3) Type of source.

      4) Serial number of source(s).

      5) Activity of source(s) in millicuries.

6) Date of leak test.

7) Name of person performing leak test.

5. Smears are evaluated by ICN and results reported to the Duluth lab.

6. If radioactive contamination exceeds 0.005 microcuries, we are immediately notified by ICN, and the equipment will be withdrawn from service.

7. If the leak test results are satisfactory, the test reports are filed in the Duluth Office and kept available for audit by authorized individuals.

III. TRANSPORTING AND SHIPPING MOISTURE/DENSITY GAUGES:

A. PREPARATION OF MOISTURE/DENSITY GAUGES FOR SHIPMENT:

1. Insure that the radioactive source in the gauge is in the "Shielded" position and the gauge is locked.

2. Place the gauge in its shipping case and secure lock with lead seals to insure that the package has not been opened or tampered with.

3. Include any necessary papers or information with the gauge such as a current copy of the leak test on the source(s), instruction manual for gauge, etc.

4. Follow instructions in Twin City Testing and Engineering Laboratory, Inc, procedure 5-G-12, "Procedure for the perparation of Soil Moisture/Density Gauge Sources for Shipment."

5. These instructions are intended for the shipment and transport of gauges whether by common carrier, company truck or personal vehicle.

6. A bill of lading must be in the driver's compartment whenever transporting a Soil Moisture/Density Gauge to a project site. An example of the straight bill of lading form is in procedure 5-G-12.

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SUBJECT: * PROCEDURE FOR THE PREPARATION OF SOIL MOISTURE/DENSITY GAUGE SOURCES FOR SHIPMENT -RECEIPT OF PACKAGES CONTAINING SOIL MOISTURE/DENSITY GAUGE SOURCES

1.0 SCOPE

1.1 This procedure outlines the requirements for preparing shipments of Soil Moisture/Density gauges containing radioactive sources.

*1.2 This procedure also outlines the requirements for receiving packages containing radioactive sources.

*1.3 The requirements for packages, labels, marking and shipper certification papers are outlined in this procedure for compliance with applicable regulations.

*1.4 Shipment of these gauges with radioactive sources may be made by commercial truck, air freight, company vehicle or private vehicle.

2.0 APPLICABLE REFERENCES

*2.1 Title 49 - Code of Federal Regulations "Transportation" = Parts 172, 173, 175 and 177

*2.2 Title 10 - Code of Federal Regulations - Part 71 "Packaging and Transportation of Radioactive Material".

3.0 GENERAL REQUIREMENTS

3.1 Personnel

3.1.1 The individual assigned to package this material shall be familiar with this procedure and regulations referenced by this procedure.

3.1.2 The Radiation Safety Officer or his designate shall inspect the package, verify it is properly labelled and marked, and sign the necessary shipping papers.

3.2 Type of Package

3.2.1 Soil Moisture/Density gauges containing radioactive sources shall be shipped in a Type A package.

3.2.2 A Type A package must meet the requirements of DOT Specifications 7A outlined in Section 173.465 of the DOT Specifications.

3.2.3 A DOT Specification 7A package must withstand normal conditions of transport without loss or dispersal of the radioactive contents.

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3.0 GENERAL REQUIREMENTS (cont)

3.2.4 Typical DOT 7A packages may include steel drums, wood cases or boxes, or a fiberglass case such as the ones supplied with our Troxler Model 3400 series Troxler Gauges.

3.3 Labels

3.3.1 There shall be at least two diamond-shaped labels on opposite vertical sides of the package depending upon the radiation levels from the package.

3.3.2 One of the labels shall be placed adjacent to the name of the contents.

3.3.3 The type of labels placed on the package shall be one the following types depending upon the radiation levels measured:

Type of Label	Maximum Surface Reading, mr/hr	*Maximum Reading at 1 meter (39 3/8") mr/hr
 Radioactive White I	0.5	0
 Radioactive Yellow II	50	1.0
 Radioactive Yellow III	200	10

CONTROL NO. 78627

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3.0 GENERAL REQUIREMENTS (CONT.)	3.3.4	The usual radiation levels from a package containing a Soil Mositure/Density Gauge would require a Yellow II label.
	3.4	Markings
	3.4.1	Each case containing a Soil Moisture/Density Gauge must have the notation, "DOT 7A" package.
	3.4.2	If the weight of the package is over 110 pounds (50 kilograms), the gross weight shall appear on the outside of the package.
	3.4.3	The name and shipping address of the consignee shall appear on the outside of the package.
	3.5	Shipping Papers and Certification
	3.5.1	Shipping papers, whether truck Bill of Lading or the red and white striped "Shipper's Certification for Radioactive Materials" used for air shipments, shall be legibly printed or typed in English.
4.0 PREPARATION OF SHIPMENTS	4.1	Shipments by Public Highway
	4.1.1	Packaging
	*4.1.1.1	Insure that the package meets the requirements of Paragraph 3.2 of General Requirements for a DOT 7A package.
	4.1.1.2	Make sure the package is properly secured, that is, locked, bolted and lead seals are in place.
	4.1.2	Labels
	4.1.2.1	Make sure that the package has the proper type labels on the outside of the case, for example, Yellow II labels.
	4.1.3	Markings
	4.1.3.1	Make sure that the package has legible markings as described in Paragraph 3.4.

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4.0 PREPARATION OF SHIPMENTS (CONT.)

4.1.4 Shipping Papers and Certification

*4.1.4.1 Use the Bill of Lading form shown in Example 1 for shipment by commercial truck, company vehicle or private vehicle.

4.1.4.2 The following information must appear on this Bill of Lading in this order:

*4.1.4.2.1 Name, Class of Material and emergency response number - Radioactive Material Special Form - n.o.s. - (not otherwise specified) - UN2974.

4.1.4.2.2 Number of Units and Container Type - left column - enter number of packages - 1 and A for Type "A" package.

4.1.4.2.3 Mark "X" in red-bordered column HM - this indicates item is Hazardous Material.

4.1.4.2.4 Name of Radionuclide - for example $Ra^{226}Be$ or Am^{241} Be/Cs^{137}.

4.1.4.2.5 Quantity of Radioactive Material - number of curies on date of shipment.

4.1.4.2.6 Category of Labels Applied - state whether White I or Yellow II labels applied to package.

*4.1.4.2.7 Transport Index - radiation level 1 meter from surface of package. This number must also appear on the Yellow II labels.

4.1.4.2.8 State the US NRC Approval Number - DOT 7A

*4.1.4.2.9 Serial Number of Source(s)

4.1.4.2.10 Check item "Placards Tendered" at bottom of page. If shipment bears Yellow III labels, vehicle must be placarded. If truck driver was offered placards, check "YES". If not, so indicate. Vehicles are not required to be placarded when carrying Yellow II label material.

4.1.4.2.11 Sign the certificate at bottom of page directly under "Placards Tendered" stating package was prepared according to applicable regulations of the Department of Transportation.

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4.0 PREPARATION OF SHIPMENTS (CONT.)

4.2 Shipments by Air

4.2.1 Shipments of radioactive sources for industrial radiography must be shipped by CARGO-ONLY AIRCRAFT.

4.2.2 Packaging

4.2.2.1 The same packaging requirements apply to air shipments as those mentioned in 3.2 and 4.1.1 of this procedure.

4.2.3 Labels

4.2.3.1 The same labels must be affixed to the package as those mentioned in 3.3 and 4.1.2 of this procedure.

4.2.3.2 In addition, the orange and black label with the wording "DANGER-PELIGRO" - "Do Not Load in Passenger Aircraft" shall be affixed to each package shipped by air.

4.2.4 Markings

4.2.4.1 The same marking requirements apply as those in 3.4 and 4.1.3 of this procedure.

4.2.5 Shipping Papers and Certification

*4.2.5.1 2400 Series Troxlers with Lead Shielded Gauge

*4.2.5.1.1 Use the"Shipper's Certification for Radioactive Materials" form with the red-striped border.

*4.2.5.1.2 This form shall be filled out as follows as shown in Example 2:

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4.0 PREPARATION OF SHIPMENTS (CONT.)

*4.2.5.1.2.1 Place "X" in square marked Cargo-Only Aircraft.

*4.2.5.1.2.2 Under column "Proper Shipping Name" - enter Radioactive Material n.o.s. (not otherwise specified) and emergency response number - UN2974.

*4.2.5.1.2.3 Under column "Radionuclide" - enter $Ra^{226}Be$ or Am^{241} Be/Cs^{137}.

*4.2.5.1.2.4 Under column "Group" - enter I for Ra^{226} and I/III for Am^{241} Be/Cs^{137}.

*4.2.5.1.2.5 Under column "Form" - enter Special Form.

*4.2.5.1.2.6 Under column "Activity" - enter strength of source in curies on date shipped.

*4.2.5.1.2.7 Under column "Number of Packages" - fill in number in shipment.

*4.2.5.1.2.8 Under column "Category" - enter type of labels applied to package, that is, White I, Yellow II or Yellow III.

*4.2.5.1.2.9 Under column "Transport Index" - enter index which is radiation level 1 meter from any surface on package.

*4.2.5.1.2.10 Under column "Type" - enter type "A" for type of packaging used for these sources.

*4.2.5.1.2.11 Do not make entries in center of page regarding fissile materials. These sources do not fall into this class of radioactivity.

*4.2.5.1.2.12 Fill in name and address of shipper and print name of individual preparing shipment. Individual should sign certification in lower right corner of certificate.

*4.2.5.2 <u>3400 Series Troxler with Uranium Shielded Gauge</u>

*4.2.5.2.1 Fill out the "Shipper's Certification for Radioactive Materials" form as shown in Example 3:

*4.2.5.2.1.1 Place "X" in square marked Cargo-Only Aircraft.

*4.2.5.2.1.2 Under column "Proper Shipping Name" - enter Radioactive Material n.o.s. (not otherwise specified) and emergency response number - UN 2974, on the first line (source designation).

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4.0 PREPARATION OF SHIPMENTS (CONT.)

*4.2.5.2.1.3 On the second line under "Proper Shipping Name", enter Radioactive Material, Article Manufactured from Depleted Uranium - UN 2909.

*4.2.5.2.1.4 Under column "Radionuclide" - enter Am^{241} Be/Cs^{137} on the first line (source description).

*4.2.5.2.1.5 On the second line under "Radionuclide" - enter Depleted $Uranium^{238}$.

*4.2.5.2.1.6 Under column "Group" - enter I/III for $Am^{241}Be/Cs^{137}$ on the first line.

*4.2.5.2.1.7 On the second line under "Group", enter III for depleted U^{238}.

*4.2.5.2.1.8 Under column "Form" - enter Special Form, on the first line.

*4.2.5.2.1.9 On the second line under "Form", enter Solid Metal.

*4.2.5.2.1.10 Under column "Activity" - enter strength of source in curies or millicuries on date shipped on the first line.

*4.2.5.2.1.11 On the second line under "Activity", enter 0.005 curies (activity of Uranium shielding in gauge).

*4.2.5.2.1.12 Under column "Number of Packages" - fill in number in shipment on same line as shielding description.

*4.2.5.2.1.13 Under column "Category" - enter type of labels applied to package, that is, White I, Yellow II or Yellow III on same line as shielding description.

*4.2.5.2.1.14 Under column "Transport Index" - enter index which is radiation level 1 meter from any surface on package on same line as shielding material.

*4.2.5.2.1.15 Under column "Type" - enter Type "A" for type of packaging used for these sources on same line as shielding material.

*4.2.5.2.1.16 Do not make entries in center of page regarding fissile materials. These sources do not fall into this class of radioactivity.

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4.0	PREPARATION OF SHIPMENTS (CONT.)	*4.2.5.2.1.17	Fill in name and address of shipper and print name of individual preparing shipment. Individual should sign certification in lower right corner of certificate.
*5.0	RECEIVING PACKAGES CONTAINING SOIL MOISTURE/DENSITY GAUGES	*5.1	The individual performing the receipt inspection shall wear a film badge.
		*5.2	The receipt inspection shall be done as soon as practical after receipt of the package, but in no case more than three hours during the day shift nor 18 hours if received after normal working hours.
		*5.3	Inspect the package for any signs of damage or tampering.
		*5.4	Make sure the lead seals are intact.
		*5.5	Normally, radiation level readings at the surface of the package and at one meter away are not required for a Type A package. However, if the package is damaged, contact the Radiation Safety Officer for advice. Radiation level readings may have to be taken to ensure the source did not come out of the shield.
		*5.6	If the radiation levels exceed the allowable limits of 200 mr/hr at the surface of the package and/or 10 mr/hr at one meter from the surface, notify the Radiation Safety Office or your Supervisor immediately.
		*5.7	A report will have to be made to the Regional Office of the NRC and the delivering carrier.
		*5.8	The results of the receipt inspection shall be kept on Twin City Testing and Engineering Laboratory, Inc Form N900.
*6.0	RECORDS	*6.1	Records covering the shipment of these Soil Moisture/Density sources shall be kept on file for audit by authorized parties.
		6.2	Shipment records will be the responsibility of the Radiation Safety Officer or his designate.

STRAIGHT BILL OF LADING

ORIGINAL—NOT NEGOTIABLE

Shipper No. _____

Carrier No. _____

NAME OF TRUCKING COMPANY (Name of Carrier) (SCAC)

Date DATE OF SHIPMENT

TO:
Consignee
On Collect on Delivery shipments, the letters "COD" must appear before consignee's name & or as otherwise provided in Item 430, Sec. 1.

Street

Destination Zip Code

FROM:
Shipper Twin City Testing and Engineering Laboratory, Inc

Street Address of office making shipment

Origin

Route

Vehicle Number

No. of Units & Container Type	HM	DESCRIPTION AND CLASSIFICATION (Proper Shipping Name, Class and Identification Number per 172.101, 172.202, 172.203	UN# or NA#	TOTAL QUANTITY (Weight, Volume, Gallons, etc.)	WEIGHT (Subject to Correction)	RATE	CHARGES (For Carrier Use Only)
1-B	X	Radioactive Material - Special Form	UN 2974				
		n.o.s. (Not otherwise specified)					
		Name of Radionuclide - $Ra^{226}Be$ (old 2400 series troxler)					
		or $Am^{241}Be/Cs^{137}$ (Modified 2400 troxler & 3400 series troxler)					
		Quantity of material - millicuries on date of shipment (this information on plate riveted to gauge)					
		Category of labels applied - usually Yellow II labels					
		Transport Index - this information on plate affixed to shipping case of gauge					
		USNRC Approval Number - DOT 7A Package					
		Serial Number of Source(s)					
		PLACARDS TENDERED: YES ☐ NO ☒ XX					

EXAMPLE 1

REMIT COD TO ADDRESS

COD Amt: $

COD FEE PREPAID ☐ COLLECT ☐ $

TOTAL CHARGES $

FREIGHT CHARGES
FREIGHT PREPAID (except when box at right is checked) ☐ Check box if charges are to be collect

Note—Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding
$ _____ per _____

This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.
Sign Here Signature

Subject to Section 7 of the conditions, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

(Signature of Consignor)

RECEIVED, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading, the property described above in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated above which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed as to each carrier of all or any of said property over all or any portion of said route to destination and as to each party at any time interested in all or any said property, that every service to be performed hereunder shall be subject to all the bill of lading terms and conditions in the governing classification on the date of shipment.

Shipper hereby certifies that he is familiar with all the bill of lading terms and conditions in the governing classification and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

CARRIER

PER

DATE

PER

Permanent post-office address of shipper

STYLE F65-47 LABELMASTER CHICAGO, IL. 60626

(Provide at least two copies to the airline)

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.

[X] 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 Material n.o.s. UN 2974 (Information required for	$Ra^{226}Be$ or $Am^{241}Be/Cs^{137}$	I Lead Shielded 2400	Special Form	Refer to data plate on gauge Series Gauges)	1	Usually II Yellow	Refer to plate on shipping case Usually 0.5	A

ADDITIONAL INFORMATION REQUIRED FOR FISSILE MATERIALS ONLY

EXEMPTED FROM THE ADDITIONAL REQUIREMENTS FOR FISSILE MATERIALS SPECIFIED IN 7.1. OF PART 2 OF THE IATA RESTRICTED ARTICLES REGULATIONS [ ]
NAMES, PLUS QUANTITY IN GRAMS, OR CONCENTRATION OR ENRICHMENT IN U235: LEAVE BLANK

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 [ ]

LEAVE BLANK

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	Name and title of person signing Certification
Twin City Testing and Engineering Laboratory, Inc Address of office making shipment	Type or print name and title of individual preparing shipment 2
Date Date of Shipment EXAMPLE	Signature of the Shipper (see WARNING above) Individual sign here

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

*To be completed by the issuing carrier

(Provide at least two copies to the airline)

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 Material n.o.s. - UN 2974	$Am^{241}Be$ Cs^{137}	I III	Special Form	Refer to info plate on gauge				
Radioactive Material Article Manufactured from Depleted Uranium UN 2909 (Information required for spent Uranium Series Guages)	Depleted U^{238}	III	Solid Metal	0.005 curies shielded	1 3400	Usually II - Yellow	Refer to info plate on shipping case-Usually 0.5	A

ADDITIONAL INFORMATION REQUIRED FOR FISSILE MATERIALS ONLY

EXEMPTED FROM THE ADDITIONAL REQUIREMENTS FOR FISSILE MATERIALS SPECIFIED IN 7.1. OF PART 2 OF THE IATA RESTRICTED ARTICLES REGULATIONS ☐
NAMES, PLUS QUANTITY IN GRAMS, OR CONCENTRATION OR ENRICHMENT IN U235: LEAVE BLANK

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 ☐

LEAVE BLANK

Special Handling Information EXAMPLE 3

LEAVE BLANK

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	Name and title of person signing Certification
Twin City Testing and Engineering Laboratory, Inc Address of office making shipment	Type or print name of individual preparing shipment
Date Date of Shipment	Signature of the Shipper (see WARNING above) Individual sign here

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

*This box optional for completion by issuing carrier

twin city testing

SHIPPING/RECEIPT INSPECTION

OF

EXPOSURE DEVICES, SOURCE CHANGERS, GAUGES AND SHIPPING CONTAINERS

USED TO TRANSPORT RADIOACTIVE SOURCES

A. Date of Inspection: _____

B. Location of Inspection: _____

C. Type of Shipping Container/Package: ☐ Type A ☐ Type B

☐ Exposure Device ☐ Source Changer ☐ Gauge

☐ Other _____

D. Type of Overpack or Case:

☐ Steel Case ☐ Wood Case ☐ Fiberglass Container

☐ None Used ☐ Other _____

E. Shipper: _____

F. Consignee: _____

Delivering Carrier: _____

H. Radiation Survey of Package (Before Opening)
(Required of Type B Quantities - Radiography Sources)

1. Radiation level at surface (highest reading) of package - _____ mr/hr
2. Radiation level at 3 ft. (same as Transport Index) from Surface _____ mr/hr
3. Survey Meter Used - Make/Model _____ Serial Number _____

I. Type of Source _____ Source S/N _____

J. Inspection of Package:

1. Lead seals intact through lock or container fasteners Yes____ No____
2. Any evidence of tampering during shipment Yes____ No____
3. Any visible damage to container or contents Yes____ No____
4. If Yes - describe damage _____

_____

5. Is equipment - exposure device or gauge in operating order Yes____ No____

Inspection Performed BY: _____

Title: _____

N900(81-A)

CONTROL NO. 78627

INDEX

IV. OPERATION OF MODEL 2400 TROXLER M/D GAUGES

A. CONTROL FUNCTIONS AND OPERATIONS (See Figure IV-2)

1. 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.

2. 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.

3. FUNCTION - The three position switch selects the proper logic for MOISTURE or DENSITY measurements. The center of 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.

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

5. 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.

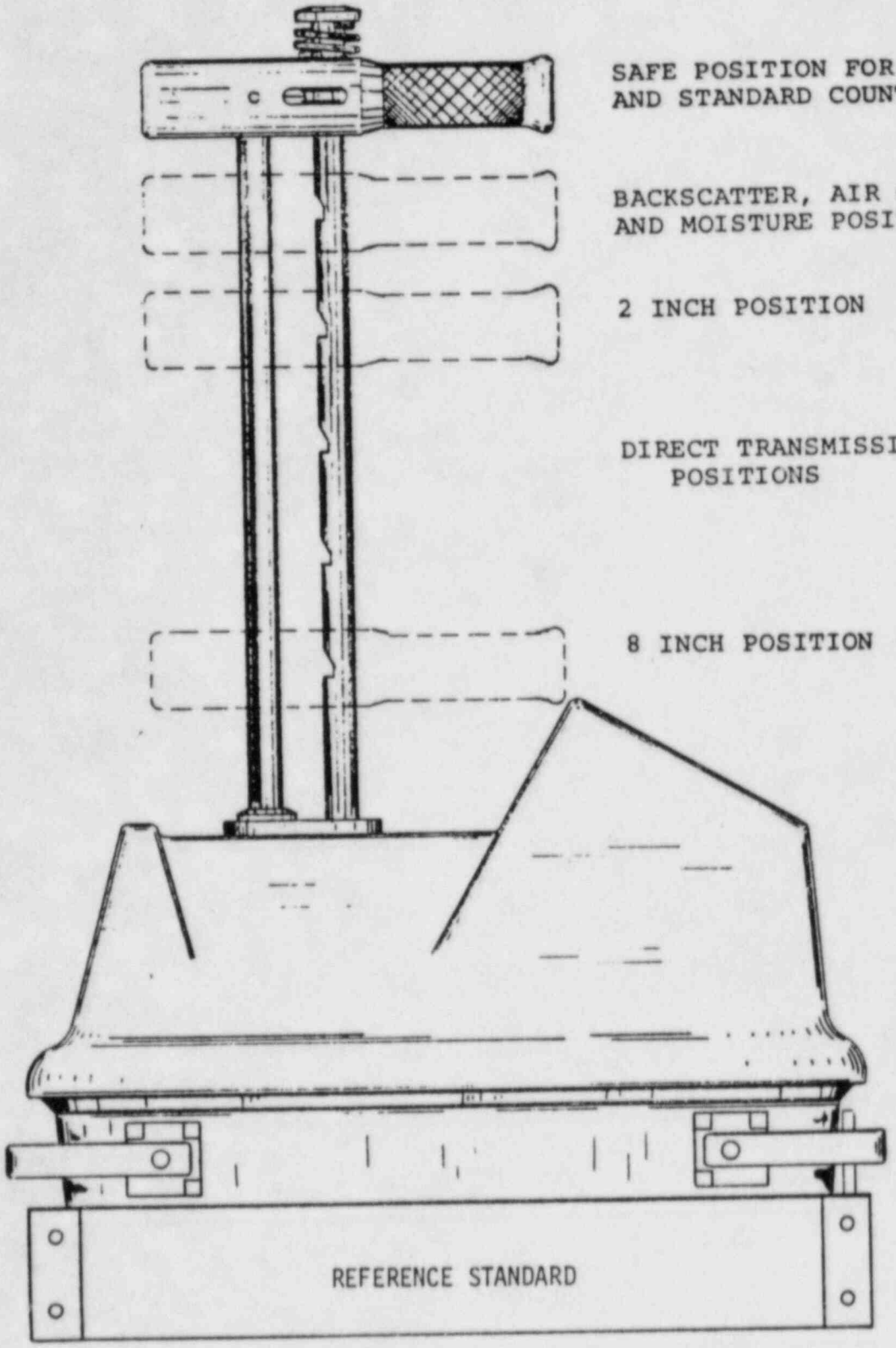
6. READ - Under normal conditions, the digital indicators are not illuminated in order to conserve power. This pushbutton applies voltage to the indicators and may be pressed at any time without affecting the accumulator operation or data storage. The power consumption is very high so use should be limited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

7. 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.

8. 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.

9. 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 operations, and a decimal point may be considered to exist to the right of the last digit.

2400 MODELS



CONTROL NO. 7862

FIGURE IV-1

INDEX ROD POSITIONS
AND
REFERENCE STANDARD ORIENTATION

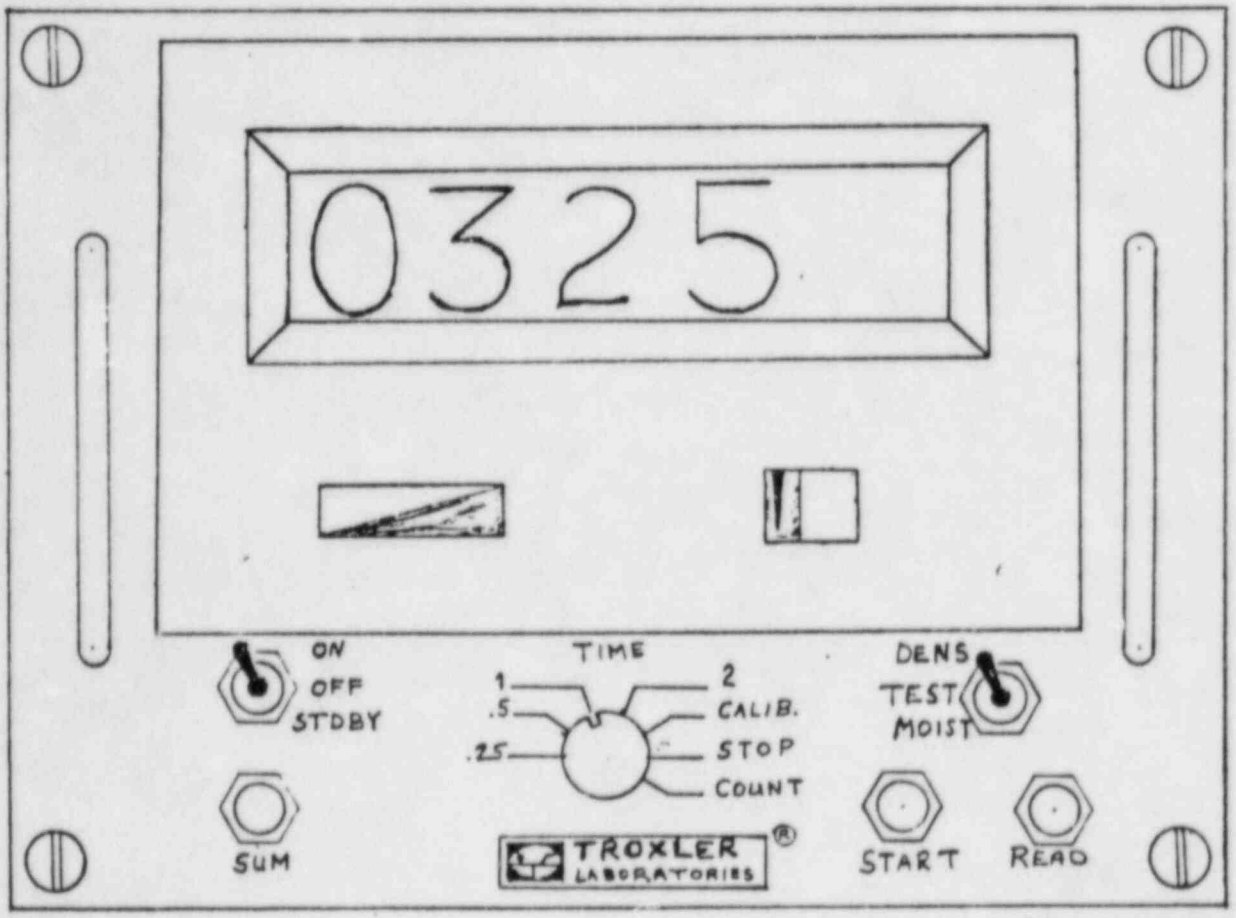


FIGURE IV-2

TROXLER 2400 SERIES FRONT PANEL

Drawn By Sid Meidee

Twin City Testing

Rochester, MN

10. 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. Always insure that the gauge lock is removed before taking any standard counts. 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 IV-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.

11. 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.

B. 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.

1. 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 IV-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.

2. 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 defects 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 be recorded.

3. 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. A second attempt to acquire usable standard counts is permissible. A log should be kept of the gauge standard counts.

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

C. SITE PREPARATION:

1. 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.

2. 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.

3. 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.

4. 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.

D. 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. Determine a count ratio by dividing 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.

E. BACKSCATTER DENSITY MEASUREMENTS:

With the gauge on the site as covered in paragraph D 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.

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 throught 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. OTHER PROCEDURES:

1. 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 long 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 build up of asphalt.

2. AIR GAP DENSITY MEASUREMENTS

After taking the backscatter density count as in paragraph E 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

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.

I. FIELD CALIBRATION AND CORRECTIONS

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.

1. 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.

2. 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 is 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 3.

3. 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.

4. 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:

$$\text{Correction Factor (CF)} = \text{Std Count}_{\text{Trench}} - \text{Std Count}_{\text{Surface}}$$

Count ratios are then calculated by:

$$CR = \frac{(\text{Meas Count}_{\text{Trench}} - CF)}{\text{Std Count}_{\text{Surface}}}$$

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 or other large vertical structures.

J. MAINTENANCE AND SERVICE

1. BATTERY 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 volts, 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.

2. PERIODIC MAINTENANCE

a. Routine cleaning of the gauge exterior with compressed air and a damp cloth will help maintain the appearance and finish.

b. 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.

1. Make sure the source rod handle is in the storage position.

2. Orient the gauge so that the bottom is facing away from the person performing the work.

3. Place a mirror in front of the gauge bottom so as to afford an indirect view of the work being performed.

4. Remove the four retaining screws and lift off the access plate.

5. Clean the pocket containing the sliding shield and spring with a stiff brush and compressed air.

6. Lubricate the shield using a dry lubricant.

7. Replace the access plate and put the four retaining screws back in place.

8. Place the gauge upright and use a light oil sparingly on the source and index rod.

c. When the gauge is used on hot asphalt mix, any accumulation of asphalt on the bottom surface should be removed with a suitable solvent.

d. 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.

e. 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.

f. If, for any reason, it is necessary to remove the source rod from the unit for maintenance, place the source in or behind some shielding such as concrete block, concrete, or steel column etc. Keep 5' from source with shielding between the source and yourself.

g. When maintenance is complete, replace source rod assembly as quickly as possible keeping the end of the source rod as far from the body as possible.

3. SERVICE

a. 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.

b. 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.

K. CHECKOUT AND TROUBLESHOOTING PROCEDURES

1. CHECKOUT PROCEDURE

a. 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' from other nuclear gauges. The floor under the standard should be concrete or other material of at least 100 pcf density.

b. 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.

c. Repeat b 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.

d. Set the TIME switch to CALIB and press START. The display shall indicate 3276, and the counting period should be 4 minutes.

e. 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.

f. If the above tests are completed and agree with the requirements, the scaler modules is operative, and the checkout can proceed. If the conditions are not met, refer to TROUBLESHOOTING HINTS.

g. Place the FUNCTION switch to DENS and the TIME switch to 1. Press START and after 1 min, press READ and record the display reading. Repeat this function until a total of 10 density standard counts have been recorded. Compute the RMS standard deviation (Refer to INSTRUCTION MANUAL). Using the average of the 10 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.

h. Repeat Paragraph 7g above with the FUNCTION switch on MOIST. This procedure tests the short term stability of the moisture system.

i. 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 requirements have been met, the system may be used for field measurements, but should be taken out of service for repair as soon as possible.

j. 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 successive. 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.

k. If all the conditions above are met, the system may be continued in service. If the conditions are not met, refer to TROUBLESHOOTING HINTS.

2. 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 and repair or adjust. 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.

a. BATTERY INDICATOR does not deflect when the POWER switch is placed to ON or STDBY.

1. Replace DC fuse.
2. Recharge/replace battery pack.
3. Defective battery saver on pre-amp circuit board.

b. Battery will not charge.

1. Replace AC fuse.
2. Recharge/replace battery pack.
3. Replace battery pack.

c. Battery will not hold charge.

1. Replace battery pack.

d. With POWER ON, BATTERY INDICATOR deflects to white area but digital indicators do not light when READ is depressed.

1. Replace Indicator Power Supply.

e. All Numbers of the indicators light when READ is depressed.

1. Replace Logic Power Supply.

f. Any single digit fails to light.

1. Replace the Decoder-Indicator Board Assembly.

g. Performing the test procedure listed under paragraph B of this section does not produce the proper sets of numbers.

1. Replace the defective indicator if only one digit of each number set is wrong.
2. Replace the Accumulator Board if more than one digit of each set is wrong.
3. 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.

4. Replace the Input and Clock Board if the number sets are correct but the time period is wrong.
5. Replace the Accumulator Board if the time period if four minutes but the number indicated for the CALIB function is incorrect.

h. Timing period restart and cycle without pressing the START or SUM pushbuttons.

1. Replace the Time Base Divider Board.

i. GATE INDICATOR deflects to red when START is depressed but indicators do not count.

1. Replace Input and Clock Board.
2. Replace Accumulator Board.
3. Replace Time Base Divider Board.

j. Indicators do not reset when START is depressed.

1. Replace the Time Base Divider Board if all digits fail to reset to zeros.
2. 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 the difficulties are experienced in MOISTURE and DENSITY functions.

k. System fails to count on MOISTURE and DENSITY functions.

1. Replace H.V. Supply Board.
2. Replace Input and Clock Board.

l. System fails to count on MOISTURE but DENSITY standard count is normal.

1. Replace Preamplifier Board.
2. Replace Input and Clock Board.

m. System fails to count on DENSITY but MOISTURE standard count is normal.

1. Replace Preamplifier Board.
2. Replace Input and Clock Board.

n. MOISTURE standard count is normal but DENSITY standard count is erratic and high or reduced to approximately 1/3 or 2/3 of normal.

1. Replace one or more G.M. Detectors.
2. Replace Preamplifier Board.

o. DENSITY standard count is normal but MOISTURE standard count is high and erratic or reduced to 1/2 of normal.

1. Replace on BF-3 Detector.
2. Replace Preamplifier Board.

p. A series of DENSITY counts do not meet statistical tests.

1. Replace H.V. Supply
2. Replace G.M Detectors.

q. A series of MOISTURE counts do not meet statistical tests.

1. Replace H.V. Supply.
2. Replace BF-3 Detectors.
3. Replace Preamplifier Board.

r. Day to day abnormal changes or long term drift in the DENSITY standard count.

1. Replace Input and Clock Board.
2. Replace H.V. Supply.
3. Replace one or more G.M. Detectors.
4. Replace Preamplifier Board.

s. Day to day abnormal changes or long term drift in the MOISTURE standard count.

1. Replace Input and Clock Board.
2. Replace H.V. Supply.
3. Replace Preamplifier Board.
4. Replace BF-3 Detectors.

INDEX

V. OPERATION OF MODEL 3401 AND 3401-B TROXLER M/D GAUGES

A. CONTROL FUNCTIONS AND OPERATIONS

1. MODEL 3401

a. Remove the Reference Standard from the transport container and place it on a high density surface, i.e. compacted soil, concrete or asphalt surface, in an area at least five feet from any vertical structure and 30 or more feet from another nuclear gauge.

b. Remove the instrument and place it on the Reference Standard as shown in Figure V-1, with the scaler end of the gauge facing the metal plate on the Reference Standard. The instrument must be firmly seated within the raised edges and pushed against the metal plate. Remove the lock from the trigger and place the POWER switch in the ON position and TIME on SLOW.

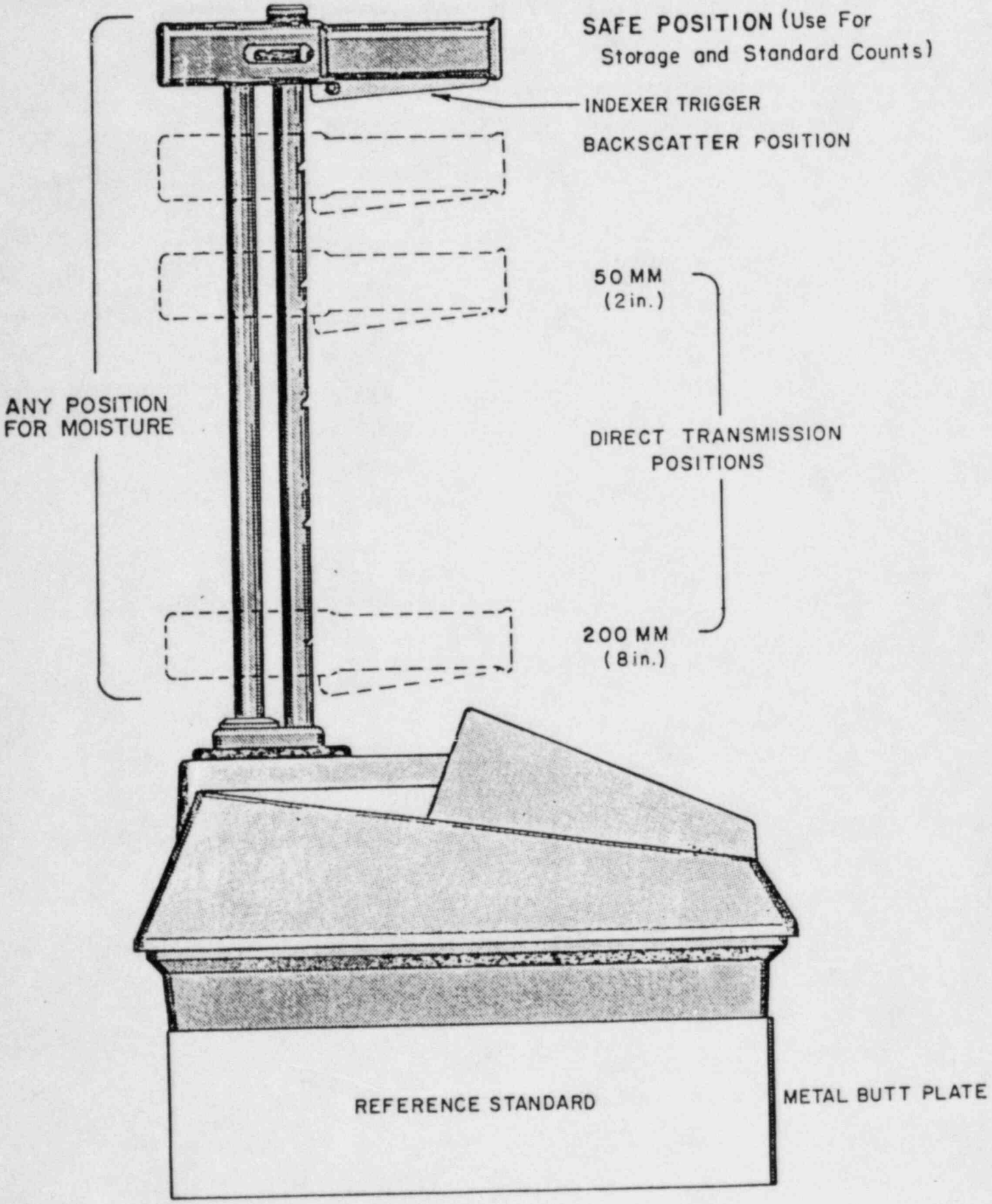
c. Refer to Figure V-1 and note the various positions of the handle assembly. The position used for transport is the safe or shielded position and is also used to obtain the standard counts, i.e MS (Moisture Standard) and DS (Density Standard). These counts will always be taken with the TIME switch in the SLOW position. The next positions are various direct transmission positions for depths as stamped on the index rod.

d. Refer to Figure V-2 or the front panel of the instrument and note that there are two horizontal rows of four keys. The bottom row controls the accumulation of data and the top two controls the display of data.

e. Assuming 10 minutes have elapsed since powering the instrument, depress the key labeled STD. These keys are pressure sensitive and require a light touch. Use your fingertip, NOT the point of a pencil or other sharp object! Observe that the notation ERR appears in the upper left corner of the display. The notation BAT will appear below ERR if the instrument batteries are in need of a recharge.

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 count which appears is the density standard count and will 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 also decrease at a rate of 2% per year from the date of calibration due to decay of cesium-137. Depress MS. The displayed count is the moisture standard count and will be withing 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 will not decrease with time. Both standard counts may change with



Reference Standard Orientation
Figure V-1

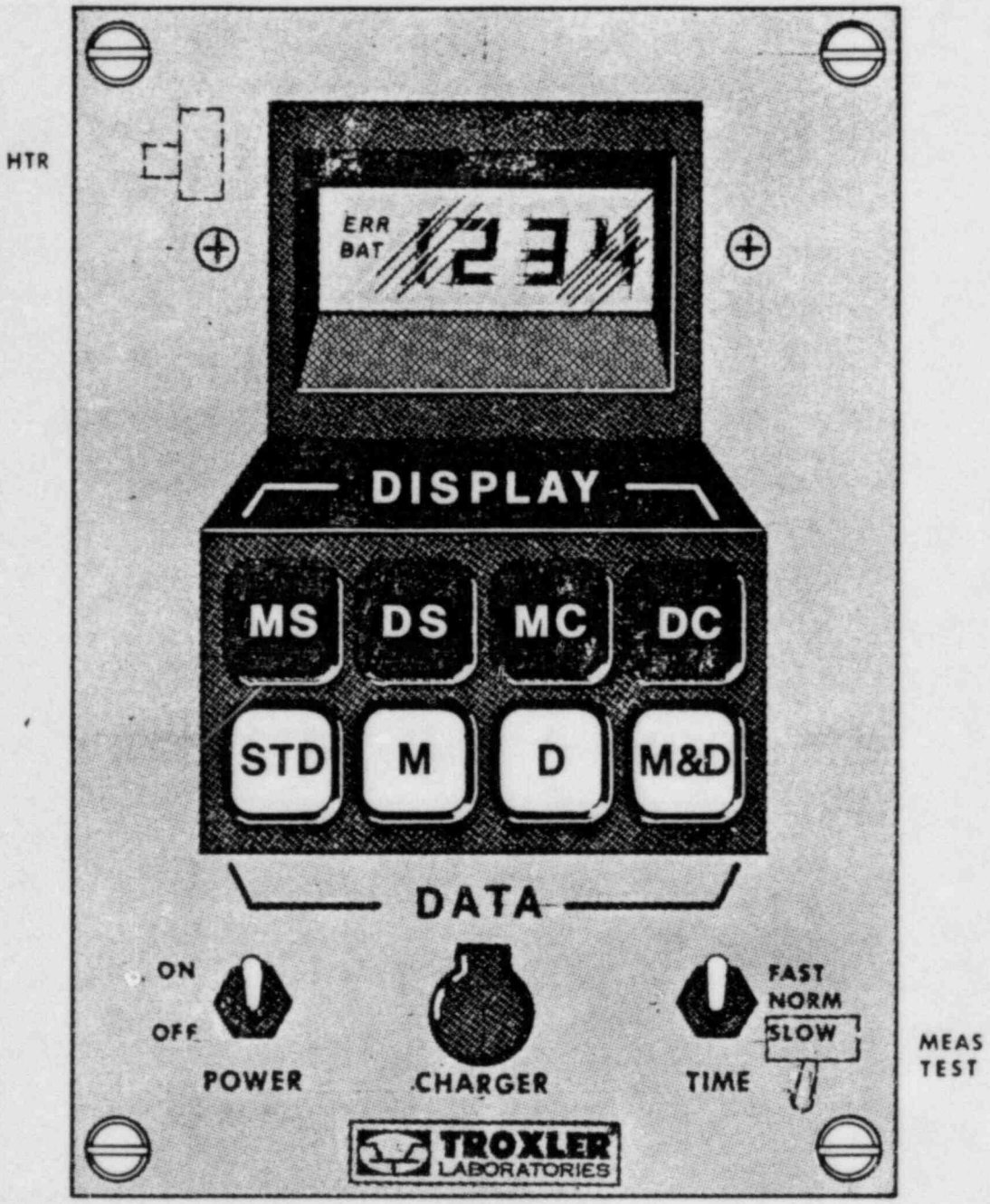


FIGURE V-2

3401 FRONT PANEL

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 on the gauges 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. Place TIME on NORM and depress M & D noting 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 can be displayed at any time by depressing MS and DS. The will remain until the instrument is switched OFF or until other sets of standard counts are accumulated.

j. 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. When driving the rod into the soil, base material or hot asphalt, remember that you are driving a steel pin with a lot of force. This pin may 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 in strongly advised. The hole for the source rod should always be at least two inches deeper than the depth of measurement.

k. 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 0.5 PCF increments and mental interpolation will allow a quick determination to within 0.25 PCF. This represents 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 in PCF will 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 and the moisture content in percent obtained by dividing the moisture content in PCF 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 take care of the different time period), but there will be a statistical difference in the results. The short 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 can be noted by referring to Section II-A-1 in the instruction manual.

l. Note that the values obtained for moisture are uncorrected for hydrogen and will be in error. Section F-2 will discuss the methods of correcting these values.

m. Use of Display Heater

The liquid crystal display (LCD) used in this instrument has definite temmperature 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 temperatures 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 alleviated by turning the face of the gauge away from direct sunlight or otherwise shading the display.

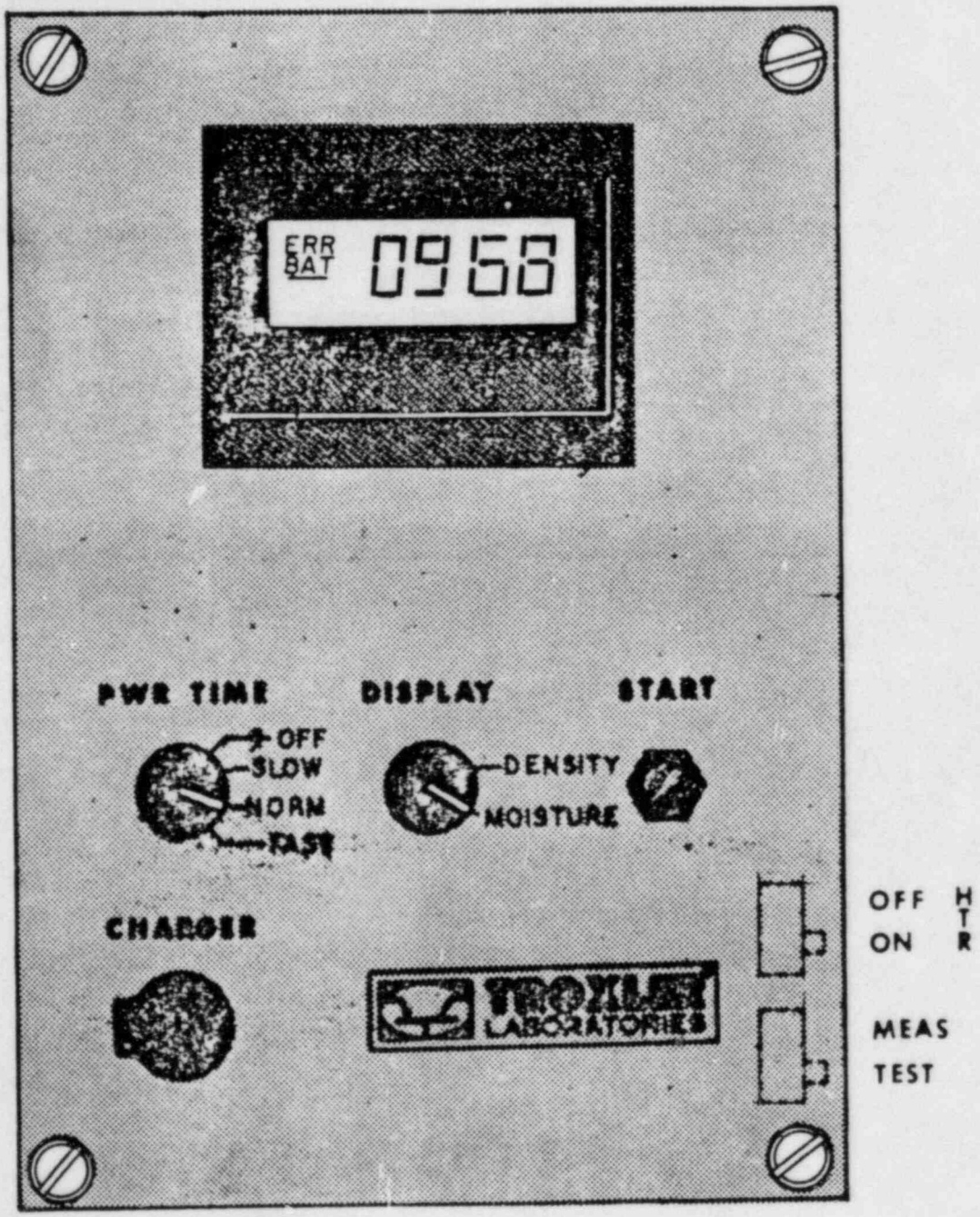
Around 0°C (32°F) the display will require several seconds to change numbers and at -10°C (15°F) a minute or more will be required. Under these low temperature conditions, which seldom occur, some external heat is required to warm the liquid.

There is a 0.5 watt heater attached to the display which will allow use at ambient temperatures down to -10°C (15°F) with little or no delay. The switch controlling this heater is located behind the module panel on the top side of the circuit board. It is reached by removing the module. When switched on, a HTR symbol will appear on the display to remind the operator of the power being consumed. It is also turned off by the normal switch and low-battery shutdown circuits.

Under full-time use, the instrument can only be operated for about two weeks per battery charge instead of the usual 6-8 weeks.

2. MODEL 3401-B

The front panel modules are different between the 3401-B and 3401, but it also requires some calculations by the operator. A step-by-step procedure for the use of the 3401-B gauge follows. Refer to Figure V-3 as needed.



3401-B Front Panel Controls
Figure V-3

a. Place the gauge on the reference standard adhering to the precautions outlined in the standard count 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 V-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 (which is two inches) deeper than the depth of the 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 in the instruction manual.

k. Note that the value obtained for moisture is uncorrected for chemically bound hydrogen and may be in error. Section F-2 will discuss the methods of correcting this value.

B. DAILY STANDARD COUNTS

The calibration of these instruments is made in terms of a ratio to a count made on a Reference Standard, which is supplied with the instrument. For this reason, measurements made with the instruments can be no more accurate than the accuracy of the reference counts. The operator should therefore use care to establish a set of reference 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 use to determine when a defect may be occurring either in the procedure or the instrument.

In general, a sudden shift of more than 1% density standard count or 2% 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 well away from any building or other large structure and not closer than thirty feet to another nuclear gauge. The surface can be asphalt or concrete paving, compacted aggregate, or similar surface with not more than 15 PCF moisture. Sites not to be used are truck beds or tailgates, table tops or similar structures of low mass.

1. Standard Counts With Model 3401

a. Switch the gauge power ON and position the instrument on the Reference Standard as shown in Figure V-1. Make certain that the standard is clean and does not have soil or other material in the seating area which would prevent good surface contace with the gauge base. The base should be firmly seated within the raised edges of the standard and firmly pulled against the metal butt plate on the end of the standard.

b. 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.

c. Place the TIME switch on SLOW and press STD. After 4 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, but they will remain in the memory unless the power is switched OFF.

d. If the counts deviate more than the values previously stated from prior standard counts , check for gauge seating and positioning before taking another set.

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 for a complete stability check as explained in Section IX-B-3 of the instruction manual.

2. Standard Counts With Model 3401-B

a. Turn the PWR/TIME switch to the SLOW position and locate the instrument on th Reference STandard as shown in Figure V-1.

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

c. 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.

d. 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.

e. 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.

f. If an instability 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 then 25 for the density or 12 for the moisture, the gauge should be returned to the laboratory and a complete stability check run as explained in Section VIII-E of the appropriate instruction manual.

C. 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 of test to be performed.

1. Embankment or Subgrade

Using the scraper plate supplied with the instrument, carefully scrape the 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 by 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.

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.

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 at least 50 mm (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 particularly 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.

D. FIELD MEASUREMENTS, MOISTURE AND DENSITY

1. Measurement with Model 3401

With the gauge properly seated on the prepared site, place TIME on NORM and depress M & D. 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. Read and record these count rates.

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 and depress D to accumulate the count rate data. It would only be necessary to depress DC to read and record the density count rate.

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.

2. Measurement with 3401-B

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 material 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.

E. CALCULATION OF DRY DENSITY AND PERCENT MOISTURE

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 F-2.

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.

F. CORRECTIONS AND CALIBRATIONS

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.

1. Density Correction

Only on a very few occasions will it be necessary to correct the wet density measurement. This will probably occur with materials 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.

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 conient 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:

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

where:

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

The correction factor can now be obtained by taking the differences 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 moisure 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.

3. Trench Corrections

When a nuclear moisture-density gauge is operated close to trench walls or 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 Series was designed to minimize these effects.

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 placed in the center of the trench. For trenches with a width down to 0.6 meters (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). If needed, the procedure for obtaining and using the moisture offset value is as follows:

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

a. Obtain the daily standard counts following the steps outlined in previous sections. 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 away from the trench.

b. 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.

c. Determine the moisture offset value by subtracting the moisture standard count (a above), from the Moisture count obtained in the trench (b above). 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 worksheet.

d. 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.

G. OTHER PROCEDURES

1. 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 general requirement of 98% of Marshall density specifications. This is particularly true when the backscatter geometry is used. With a Marshall density of 140 PCF, the passing limit would be 137.2 PCF, but assuming a true density of 140 PCF, the gauge could indicate as low as 136-137 PCF based on the total expected error of 3-4 PCF. This can be overcome by correcting the calibration to account for the composition error and good site preparation to reduce the surface roughness error. By doing this, the expected error can be reduced to 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 several 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 procedure involves the selection of a 400 square yard section on which the material will be installed. Compaction is accomplished with conventional rollers and density measurements made between passes with nuclear equipment. 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 then established as 98% of the control section density. Tests are run on 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 material has occurred or after 10 test sections have been approved.

This description is a brief summary and detailed information may be obtained from the Virginia Highway Department or Highway Research Council.

2. 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.

Several procedures have been devised using the moisture detecting capability of the nuclear moisture-density 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 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 V-4.

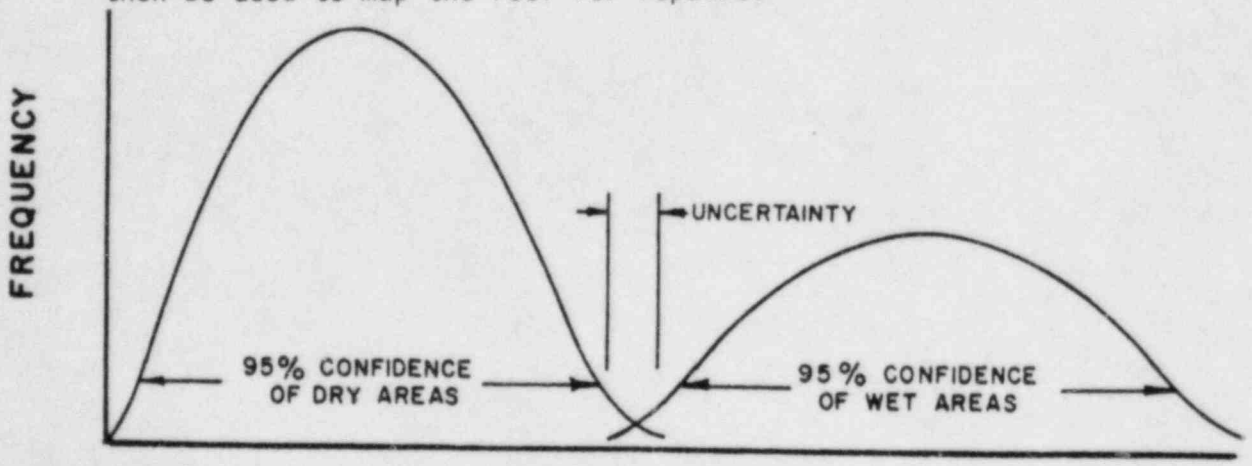
With this type of distribution, the 95% confidence limits can be established for a normal distribution.

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 on Figure V-4.

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.



Frequency Histogram of Roof Moisture
Figure V-4

H. PERIODIC MAINTENANCE AND SERVICE

1. 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 recharges to the amount required to bring the battery up to a full-charge level.

The 3401 gauge has a power consumption of 100 milliwatts. The 3411 has an average power consumption of 120 milliwatts assuming an average of four-site measurements per hour of use. If the display heater is used continuously, these values increase to approximately 800 milliwatts.

Since the battery stores approximately 40 watts, the 3401 will operate for 350 hours and the 3411 for 300 hours before requiring a full-recharge or approximately 50 hours if the display heater is in use. 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 or four hours of heater use.

Since the heater will seldom be in use full-time, the lower limits of battery life will not normally apply. Where possible, the instrument should be stored inside a heated space during nights when the temperature is likely to drop below 5°C (40°F). This will eliminate the long waiting period for the display to get to a reasonable operating temperature.

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 charge will allow use of the gauge for many hours.

2. Cleaning and Lubrication

The source rod in the 3400 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 bottom of the center post of the gauge. These bearings will require little or no service, unless the gauge is overhauled.

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 wreck 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 same tool, 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 will 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 wipe 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, it may 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. 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 the parts and handle. 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 <u>light</u> 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 <u>unscrewing</u> the cap, if necessary. These holes <u>must be in alignment</u> 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 the outer surfaces of the instrument.

3. 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 case will dry if it is stored in a warm, dry room with the electronic module removed.

4. Front Panel Module Removal

Unscrew the front panel and lift the module from the opening. There is a cable connecting the module to the base assembly. Disconnect the base end of the cable, noting the relative position of the connector and receptacle. The red wire side of the connector is positioned towards the center post of the gauge.

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. If the connector is rotated 180 degrees, no damage will occur but the gauge cannot be turned on. If the connector is plugged in with the pins offset by one or more rows, the battery fuses will burn out and prevent other damage. The fuses may be replaced with a Bussman Type GMW, two ampere fuse.

5. 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 A-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 five feet from all personnel.

The procedure is the same as noted in Paragraph 2 above, 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 Paragraph 2.

6. Service

The 3400 series utilizes a high degree of circuit integration into custom packages and 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 without recalibration other than establishing a new set of standard counts.

Due to the degree of large-scale integration, it is recommended that no

field repairs be considered other than replacement of the liquid crystal display, which is a plug-in device. The factory has an exchange program for the modules, or the units can be repaired and returned. The compactness and small circuit board runs require specialized equipment for fault location and replacement.

I. CHECKOUT AND TROUBLESHOOTING PROCEDURES

1. Checkout Procedures

There are several procedures which can be used to verify proper operation of the instrument. The user may elect to periodically run these procedures to verify proper operation or use them when improper operation is suspected. If trouble is known to exist, refer to the section on troubleshooting.

a. Timer Accuracy

The crystal controlled oscillator, which generates the measurement times and performs certain other data queuing, is too accurate to be checked with a watch. Fortunately, if it fails, it either quits entirely, or jumps to another frequency. This error is obvious.

b. Divider Accuracy

To check the divider accuracy, loosen the four thumbscrews and lift the front panel module out of the base. On the lower right side there is a toggle switch on the 3401 or a slide switch on the 3401-B. This switch is labeled TEST-MEASURE. Please the switch in TEST and replace the panel

Place TIME on FAST and depress STD (for 3401-B place the PWR/TIME switch on FAST and depress START). At the end of 0.25 minutes, 8192 should be stored in the MS, DS, MC and DC registers of the 3401 and in both the moisture and density registers of the 3401-B. Place TIME on NORM and repeat. At the end of one minute, 8192 should again be stored in the registers. Place TIME on SLOW and repeat for the same indication at the end of four minutes.

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

c. Liquid Crystal Display

See Section A-1-M for instructions and explanation of the liquid crystal display and the display heater.

2. Troubleshooting Hints

The 3401 instruments, while complex, can generally be repaired in the field by isolating problems to one or two modules by the process of elimination.

a. Instrument fails to display when power is turned on.

1. Batteries are discharged below cut-off voltage. Plugging in the charger will turn on the instrument.

2. 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.

b. Charger lamps come on, but unit still does not indicate a turned-on condition.

1. Replace Battery Monitor Module.
2. Replace Front Panel Module.

c. Instrument turns on but will not indicate counting condition when MEASURE is attempted.

1. Replace H.V. Module.
2. Replace Front Panel Module.*

d. Instrument counts moisture, but not density.

1. Replace Density Module.
2. Replace Front Panel Module.*
3. Replace GM Tubes. (Model 3401-B)

e. Instrument counts density but not moisture.

1. Replace Moisture Module.
2. Replace Front Panel Module.*
3. Replace He-3 Tube. (Model 3401-B)

f. Instrument counts moisture and density, but is erratic and will not meet stability test.

1. Replace Density or Moisture Module as required.
2. Replace detectors as required.

g. Instrument counts moisture correctly, but density count is about half the normal value.

1. Replace the defective GM Tube. (Model 3401-B)

h. All other failures require replacement of Front Panel Module.

*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.

INDEX

VI. OPERATION OF MODEL 3411 & 3411-B TROXLER M/D GAUGES

A. CONTROL FUNCTIONS AND OPERATIONS

1. 3411 Control Functions and Operations

a. Remove the Reference Standard from the transport container and place it on a high-density surface, i.e. compacted soils, concrete or asphalt surface in an area at least five feet from any vertical structure and 30 or more feet from another nuclear gauge.

b. Remove the instrument and place it on the Reference Standard as shown in Figure VI-1 with the scaler end of the gauge facing the metal plate on the Reference Standard. The instrument must be firmly seated within the raised edges and pushed against the metal plate. Remove the lock from the trigger and place the POWER switch in the ON position and TIME on SLOW.

c. Refer to Figure VI-1 and note the various positions of the handle assembly. The position used for transport is the safe or shielded position and is also used to obtain the standard counts, i.e., MS (Moisture Standard) and DS (Density Standard). These counts will always be taken with TIME switch in the SLOW position. The next positions are the various direct transmission positions for depths as stamped on the index rod.

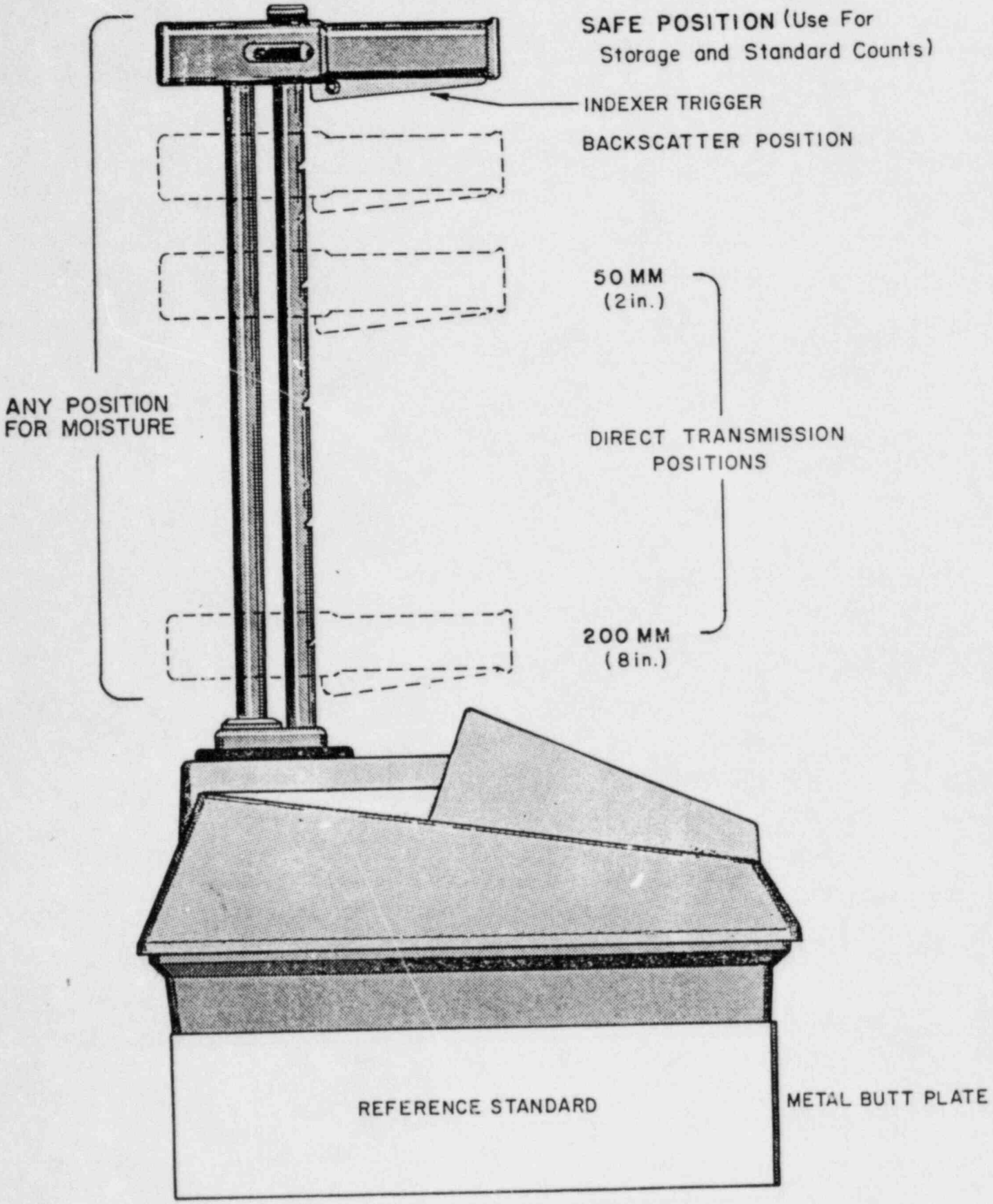
d. Refer to Figure VI-2 or the front panel of the instrument and note that there are three horizontal rows of keys. The bottom row consists of two keys which control the accumulation of data. The middle row of four keys controls the display of accumulated data, and the top row of four keys controls the data processor.

The row of thumbwheel switches across the bottom of the panel may be accessed by sliding the cover downward. The switch on the left controls the data processor to allow it access to the proper set of calibration constants for the particular mode of density, i.e., backscatter (BS), 2" direct transmission (2), etc.

The next three switches allow the setting of a constant to correct for chemically bound hydrogen other than water. The first switch designates the sign (+ or -) of the constant, and the next two designate the magnitude.

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

e. Assuming 10 minutes have elapsed since powering the instrument, depress the key labeled STANDARD, and while holding it down, momentarily depress MEASURE and release STANDARD. Use your fingertip, NOT the point of a pencil or other sharp object! The two keys are interlocked to prevent accidental initiation of a standard count. Observe the notation ERR appears in the upper left corner of the display. The notation BAT will appear below ERR if the instrument batteries are in need of a recharge.



Reference Standard Orientation
Figure VI-1

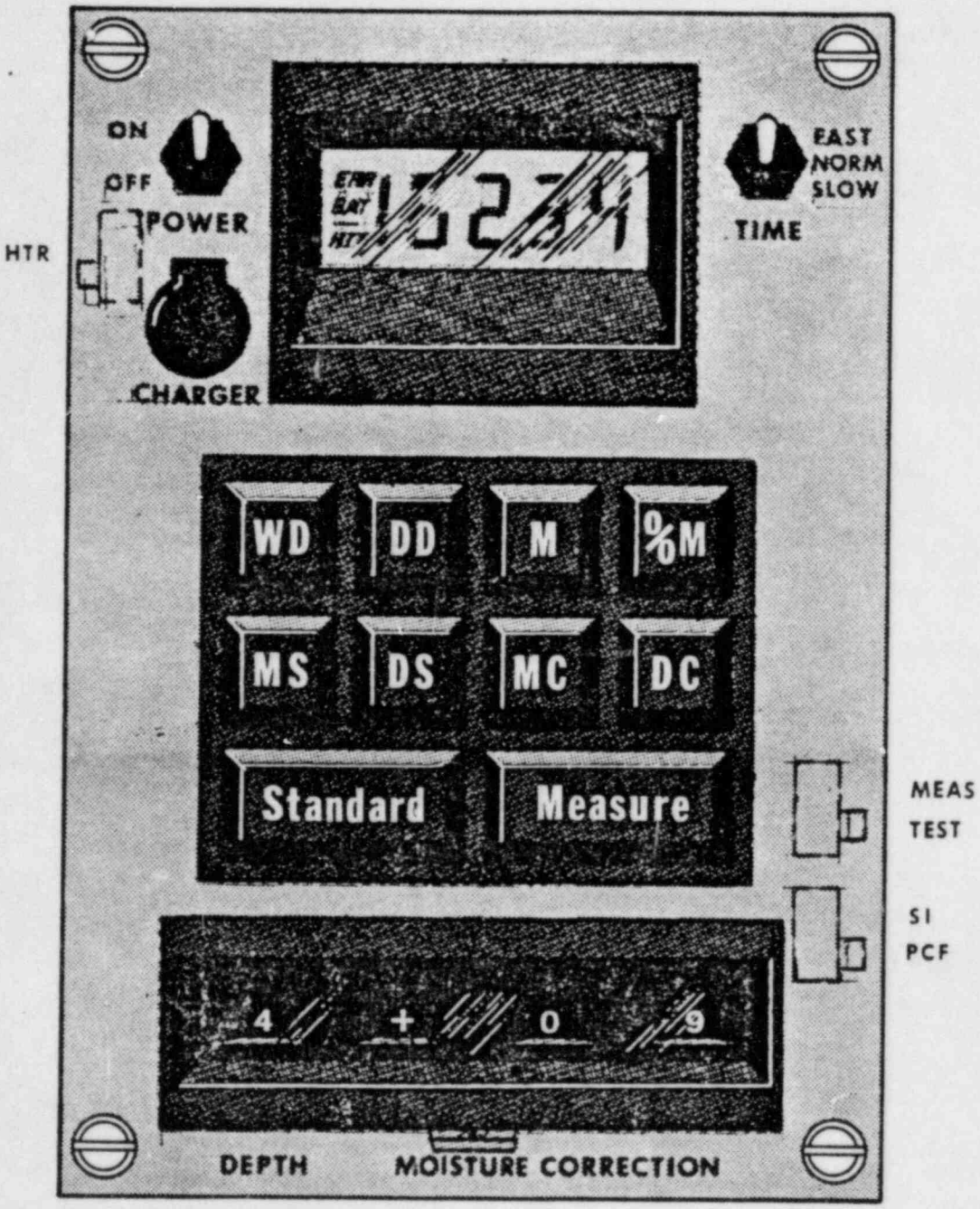


FIGURE VI-2

3411 FRONT PANEL

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 count which appears is the density standard count and will 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 also decrease at a rate of 2% per year from the date of calibration, due to decay of Cesium-137.

   Depress MS. The displayed count is the moisture standard count and will 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 will not 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 on the gauges 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. Place TIME of NORM and depress MEASURE, noting 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 can be displayed at any time by depressing MS and DS. They will remain until the instrument is switched OFF or untill other sets of standard counts are accumulated.

j. 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. When driving the rod into soil, base material or hot asphalt, remember that you are driving a steel pin with a lot of force. This pin may 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. The hole for the source rod should always be at least two inches deeper than the depth of measurement.

k. The data can now be processed to obtain the desired parameters.

First, set the DEPTH switch on BS and the MOISTURE CORRECTION on +00. Depress WD. In approximately 6 seconds the value of wet density will appear in the display in PCF. Depress DD and the value of Dry Density will appear in the display in PCF. Depress DD and the value of dry density will appear. Repeat for M (Moisture content in PCF) and % M (percent Moisture). If the measurement was made on concrete or asphalt, the moisture content obtained in PCF will be quite low and represents the water equivalency of the hydration of the concrete or the hydrogen content of the asphalt mix.

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 take care of the different time period) but there will be a statistical difference in the results. The short 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 can be noted by referring to the instruction manual.

l. Note that the values obtained for moisture are uncorrected for hydrogen and will be in error. In fact, the computation could have produced a negative moisture content which is obviously in error. The NEG symbol may appear below the BAT symbol. Section E will discuss the methods of correcting these values.

m. In the event a processing error occurs, such as attempting to process data with a zero in the MS or DS registers, and ERR will appear. An ERR during a data process indicates that the processor is attempting an impossible computation. This situation is cleared by depressing any one of the display keys (MS, DS, MC, DC). One should read these counts to determine the cause of the error and reaccumulate the erroneous data.

n. Use of Display Heater

The liquid crystal display (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 temperatures other portions of thesystem 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 alleviated 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, some external heat is required to warm the liquid.

There is a 0.5 watt heater attached to the display which will allow use at ambient temperatures down to -10°C (15°F) with little or no delay. The switch controlling this heater is located behind the module panel on the top side of the circuit board. It is reached by removing the module. When switched on, a HTR symbol will appear on the display to remind the operator of the power being consumed. It is also turned off by the normal power switch and low-battery shutdown circuits. Under full time use, the instrument can only be operated for about two weeks per battery charge instead of the usual 6-8 weeks.

2. 3411-B OLD MODEL CONTROL FUNCTIONS AND OPERATION

a. Remove the Reference Standard from the transport container and place it on a high-density surface, i.e. compacted soil, concrete or asphalt surface in an area at least five feet from any vertical structure and 30 or more feet from another nuclear gauge.

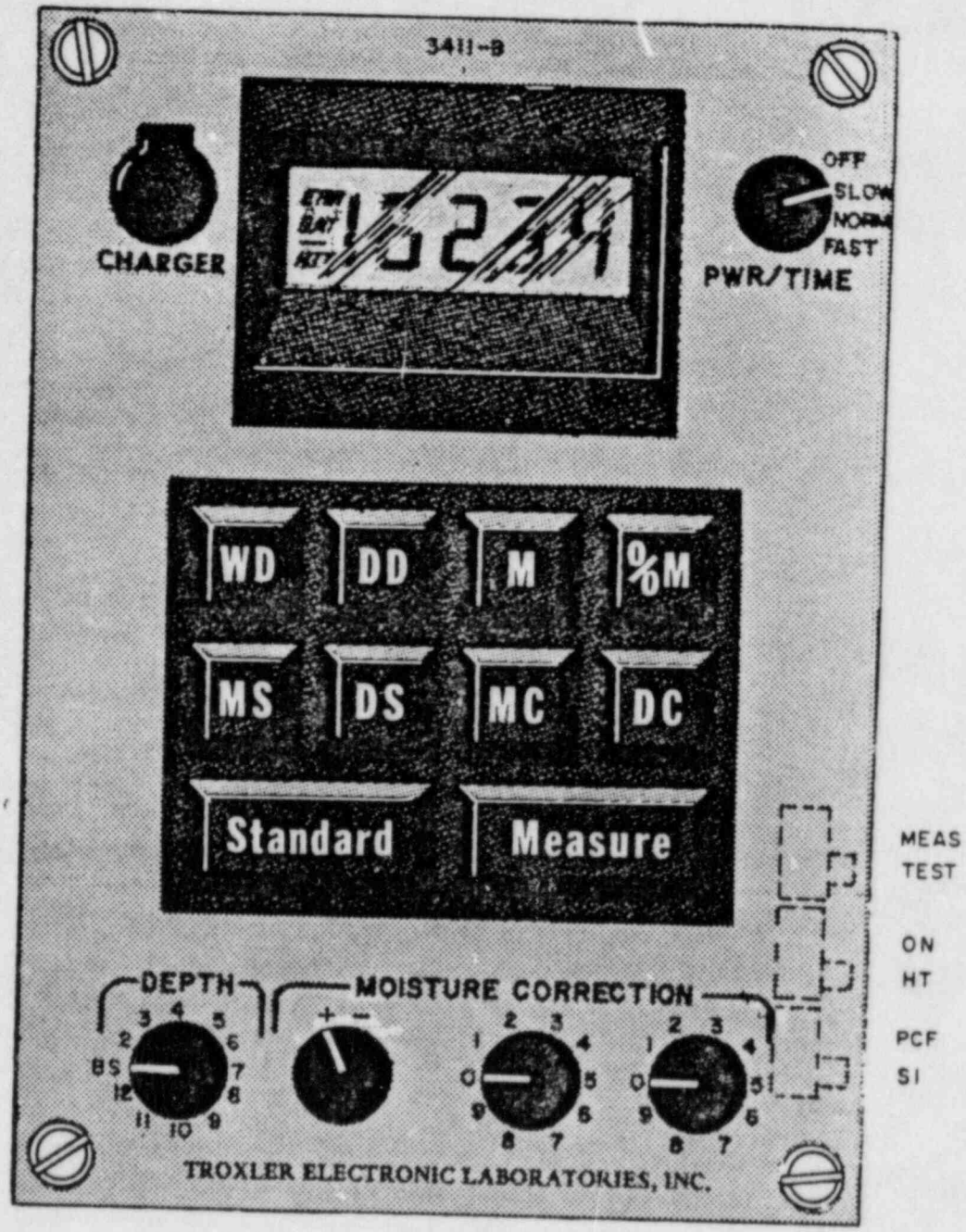
b. Remove the instrument and place it on the Reference Standard as shown in Figure VI-1 with the scaler end of the gauge facing the metal plate on the Reference Standard. The instrument must be firmly seated within the raised edges and pushed against the metal plate. Remove the lock from the trigger and turn the PWR/TIME switch to the SLOW position.

c. Refer to Figure VI-1 and note the various positions of the handle assembly. The position used for transport is the safe or shielded position and is also used to obtain the standard counts, i.e. MS (Moisture Standard) and DS (Density Standard). These counts will always be taken the PWR/TIME switch in the SLOW position. The next positions are the various direct transmission positions for depths as stamped on the index rod.

d. Refer to Figure VI-3 or the front panel of the instrument and note that there are three hoizontal rows of keys. The bottom row consists of two keys which control the accumulation of data. The middle row of four keys controls the display of accumulation of data. The middle row of four keys controls the display of accumulated data, and the top row of four keys determine what function is to be computed by the data processor.

The rotary 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 row of rotary switches across the bottom of the panel are for operator inputs to the data processor. The switch on the left determines the proper set of calibration constants for the particular mode of density, i.e., (BS) backscatter, (2) 2" direct transmission, etc.



3411-B FRONT PANEL (OLD MODEL)

Figure VI-3

The next three allow the setting of a constant to correct for chemically bound hydrogen other than water. The first switch designates the sign (+ or -) of the constant, and the next two designate the magnitude.

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

e. Assuming 10 minutes have elapsed since powering the instrument, a set of standard counts can be accumulated. This is accomplished by:

1) Depressing and holding down the key labeled STANDARD.
2) Depressing the MEASURE key and then releasing it
3) Releasing the STANDARD key.

Use your fingertip, NOT the point of a pencil or other sharp object! The STANDARD and 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. The notation BAT will appear below ERR if the instrument batteries are in need of a recharge.

f. Depress MS or DS. Assuming that the ERR notation still appears, one can watch the accumulation of the standard counts. The 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 count which appears is the density standard count and will 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 also decrease at a rate of 2% per year from the date of calibration, due to decay of Cesium-137.

Depress MS. The displayed count is the moisture standard count and will 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 will not 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, noting 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 can be displayed at any time by depressing MS and DS. They will remain until the instrument is switched OFF or until other sets of standard counts are accumulated.

j. 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 two 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 A LOT OF FORCE. THIS PIN MAY 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 (mg/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 reached by removing the module. Refer to Figure VI-3 for the exact location of the switch.

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

First, set the DEPTH switch on BS and MOISTURE CORRECTION on +00. Depress WD. In approximately 1 second, the value of 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 will be quite low and represent the water equivalency of the hydration of the concrete or the hydrogen content of the asphalt mix.

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 take care of the different time period) but there will be a statistical difference in the results. The short 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 can be noted by referring to section II-A-1 in the instruction manual.

l. Note that the values obtained for moisture are uncorrected for hydrogen and may be in error. In fact, the computation could have produced a

negative moisture content which is obviously in error. The (-) symbol is located below the BAT symbol. Section E 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 the possible causes is in section VI-H.e. 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 are 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 be inhibited.

n. Use of Display Heater

The liquid crystal display (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 temperatures 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 eventually elevate its internal temperature to the point of blacking out. This can be alleviated 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, 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. The switch controlling this heater is located behind the module panel on the component side of the circuit board. It is reached by removing the module. 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.

3. NEW MODEL 3411-B CONTROL FUNCTIONS AND OPERATIONS

The Data Processor Module used in the model 3411-B gauge contains a uP (Microprocessor) as its key component. The uP 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 VI-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 G-1 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 occurred.

   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 G-6 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 corresponds to accumulate periods of 4, 1, or 0.25 minutes, respectively.

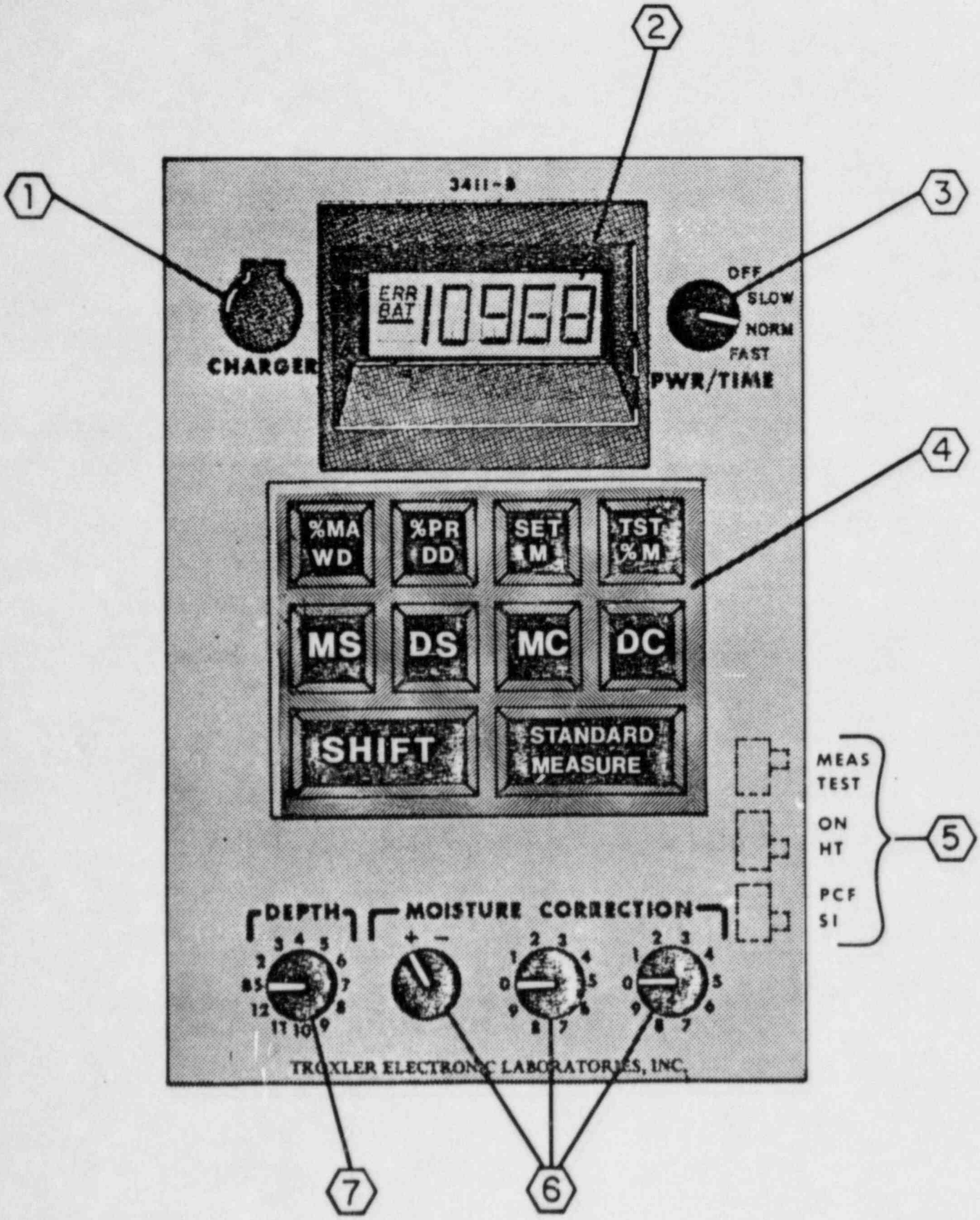
4. The keyboard is color coded for ease of use. Five keys are "dual function". The large, yellow SHIFT key determines which mode the dual funtion keys are in. The functions labeled in yellow (STANDARD, % MA, % PR, SET, and TST) are valid only when the SHIFT key is depressed. The functions labeled in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

   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 % Marshall and % of Proctor. The SET key is used to read or change the value of the established standard density. (See Sec. 3-b-13.) for a detailed description of the Marshall and Proctor functions.)

   The TST key is used to initiate the self-test routines. Section H-2 describes these routines.



3411-B Front Panel Controls for New Model
Figure VI-4

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 H-2 for a full description.

   HRT - This switch was on early units and is used to turn on a display heater if needed. See section G-6 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 chemically bound hydrogen. The method for determining the moisture correction value is covered in Section E-2.

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

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

1. Place the gauge on the reference standard, adhering to the precautions outlined in section VI-B. 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).

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

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

4. 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 fingertip, 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.

5. 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.

6. 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-231 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.

7. 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.

8. 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 the 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.

9. 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 hole to the proper depth. The hole for the source rod should always be at least 50 mm (2 inches) deeper than 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.

10. The 3411-B can display computed results in either PCF or SI (kg/m^3). the SI/PCF switch that allows the operator the 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 VI-4 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 represent 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 now 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 of the instruction manual.

11. Note that the values obtained for moisture are uncorrected for chemically bound hydrogen and may be in error. Section E-2 will discuss the methods of correcting these values.

12. 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 H-2.

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 calculations will still be inhibited.

13. 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 performed by the % MA and % PR keys are shown below.

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

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

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 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 present 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 voids were present. The equation would be:

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

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

B. DAILY STANDARD COUNTS AND 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 use 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 VI-1. 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 3411 models, they will be discussed separately.

1. DAILY STANDARD COUNTS WITH MODEL 3411

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.

Place the TIME switch on SLOW, depress and hold STANDARD while momentarily depressing MEASURE: release STANDARD. These keys are interlocked to prevent accidently erasing the memory. 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, but they will remain in the memory unless the power is switched OFF.

If the count deviates more than the values previously stated from prior standard counts, check for gauge seating and positioning before taking another se

If an instability is suspected, four or five sets may be run in the field. I 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 the instruction manual.

2. DAILY STANDARD COUNTS WITH 3411-B OLD MODEL

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.

A set of standard counts can now be accumulated. This is accomplished by:

1) Depressing and holding down the key labeled STANDARD
2) Depressing the MEASURE key and then releasing it.
3) Releasing the STANDARD key.

The STANDARD and 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, but they will remain in the memory unless the power is switched OFF.

If the counts deviate more than the values previously stated from prior standard counts, check for gauge seating and positioning before taking another set.

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 the instruction manual.

3. DAILY STANDARD COUNT WITH 3411-B NEW MODEL

Turn the PWR/TIME switch to the SLOW position and locate the instrument on the Reference Standard as shown in Figure VI-1.

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 SHIFT key
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 abnoramilty in gauge operation or procedure.

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

C. 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.

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 otherwide 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.

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

3. ASPHALT PAVING

When using a nuclear instrument for compaction control of asphalt paving, the Control Strip Method outlined under section F is recommended; however, there may be a time when direct density measurements are desired. If the compacted lift 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 particularly 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 acomplishing 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.

D. FIELD MEASUREMENTS AND DATA CONVERSION

1. MEASUREMENT WITH MODEL 3411

With the gauge properly seated on the prepared site, place 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 and DS will display the standard counts which were previously taken and stored.

Open the clear window over the DEPTH and MOISTURE correction switched. Set DEPTH to the same depth which was used to take the measurement, set the sign switch to "+" and the 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 is was shipped outside the US, it should be set up to display in

SI Units (gm/cm^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 left side there is a slide switch labeled SI and PCF. Place the switch in the desired mode. Replace the electronic assembly. (See Figure VI-2).

Wet Density (WD), Dry Density (DD), Moisture Content (M) and Percent Moisture (% M) can now be computed and displayed by depressing the desired key. The moisture content has not been corrected for soil hydrogen, so DD, M and % M may be in error. Subsecton E of this section explains the procedure for correction. 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. This is not recommended on soils where the higher precision of the longer period is needed to obtain accurate moistures.

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.

2. MEASUREMENT WITH OLD MODEL 3411-B

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 and DS will display the standard count which were previously taken and stored.

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 withing the U S it is set up to display in U S Customary Units (PCF). If it was shipped outside th 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. Put it in the desired mode. Replace the assembly. (See Figure VI-3).

Wet Density (WD), Dry Density (DD), Moisture Content (M) and Percent Moisture (% M) can now be computed and displayed by depressing the desired key. The moisture count has not been corrected for soil hydrogen, therefore, DD, M and % M may be in error. Subsection E of this section explains the procedure for correction. 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. This is not recommended on soils where the higher precision of the longer period is needed to obtain accurate moistures.

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

3. MEASUREMENT WITH 3411-B NEW MODEL

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.

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 is 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. (See Figure VI-4).

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 E-2 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 sec. 3-b-13, 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 and % PR.

E. CORRECTIONS AND CALIBRATIONS

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 tests acceptable to the user.

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 Models. 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 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.

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 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 which 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 on the 3411-B 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 minimum recommended sample size is 500 g (one 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.

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

3. TRENCH CORRECTIONS

When a nuclear moisture-density gauge is operated close to trench walls or 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 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 meters (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 placed in the center of the trench. For trenches with a width down to 0.6 meters (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 3400 Series have identical bases, their susceptibility to sidewall reflection is the same. Therefore, the procedure for obtaining the moisture offset value is similar. In the 3411's, the processor will automatically offset each moisture measure count once a correction has been entered. The procedure follows.

It is necessary to determine the increase in the moisture count due to the hydrogen 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.

a) Obtain the daily standard counts following the steps previously outlined. 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 away from the trench.

b) 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 on the new model 3411-B's, as this would destroy the standard counts taken previously.

c) Subtract the number in MS from number in MC. This difference should then be set on the MOISTURE CORRECTION switches. (See section on moisture correction.) This value is preset as a negative number into the moisture count register (MC) on new model 3411-B's 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 it is changed by entry of a new offset, a new set of standard counts are taken, or 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.

F. OTHER PROCEDURES USING MOISTURE DENSITY GAUGES

1. 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 or (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 meters (2800 Square yards) 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.

2. ROOF MOISTURE MEASUREMENTS

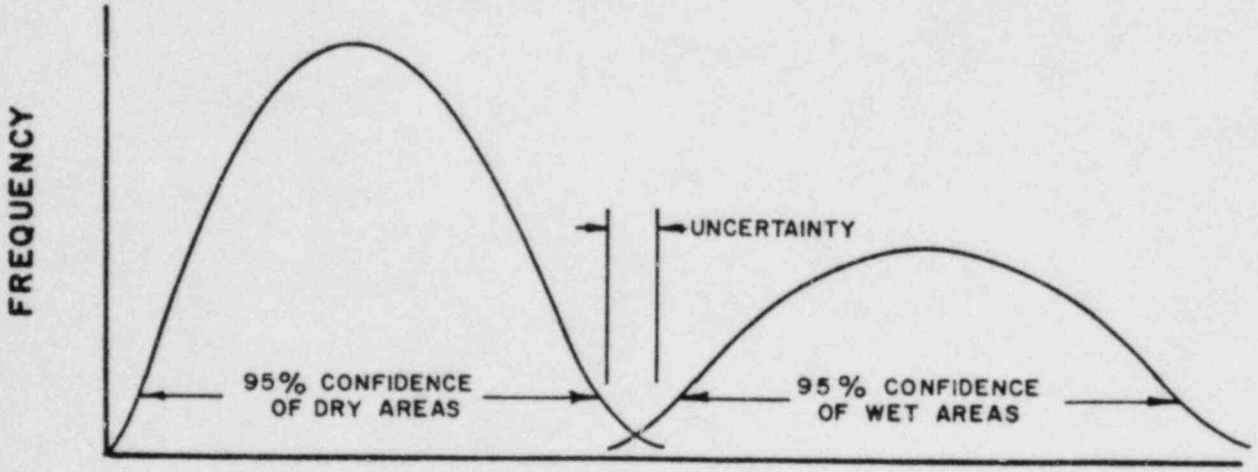
A 3 x 3 meter (10 x 10 foot) grid is laid out on the roof and on a drawing of the roof. Nuclear moisture counts are then taken at the grid intersections. A frequency histogram is next plotted on all of the data points and used to separate the wet and dry areas. A typical bimodal histogram is shown in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

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

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.



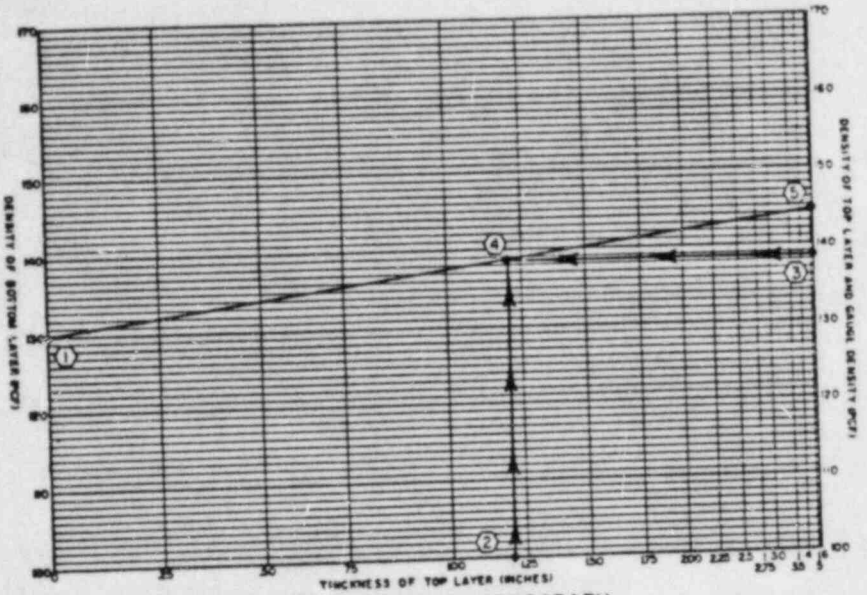
CONTROL NO. 78627 **THERMAL NEUTRON COUNT**

Frequency Histogram of Roof Moisture

Figure VI-5

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.

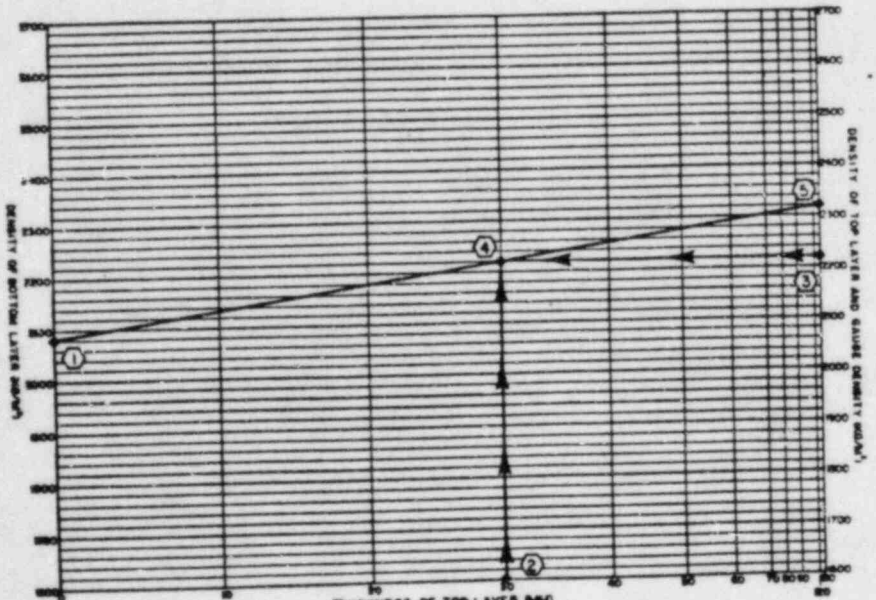


THIN LIFT OVERLAY NOMOGRAPH

FIGURE VI-5

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.



THIN LIFT OVERLAY NOMOGRAPH

FIGURE VI-6

3. 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 tests 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.

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

Fig. VI-5&6 are examples of nomographs for SI and U S Customary Units. Blank nomographs, suitable for reproduction, are included in the appendix of the operators manual.

G. PERIODIC MAINTENANCE AND SERVICE

1. 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 milliwatts 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 BAT 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 nor 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.

2. 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 bottom of the bearings. The bearings will require little or no service, unless the gauge is overhauled or excess soils 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 soils 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 5 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.

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.

3. 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.

4. 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.

5. 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 VI-G.2, 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 the same section.

6. 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 VI-1 for a 3411 and Figure VI-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 temperatures, 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 alleviated 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.

7. SERVICE

The 3411-B Series utilizes a high degree of integrated 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 without recalibration other than establishing a new set of standard counts.

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.

H. CHECK OUT PROCEDURES

1. CHECKOUT PROCEDURES FOR MODEL 3411

There are several procedures which can be used to verify proper operation of the instrument. The user may elect to periodically run these procedures to verify proper operaton or use them when improper operation is suspected. If trouble is known to exist, refer to the section on troubleshooting.

a. Oscillator and Timer

The crystal controlled oscillator, which generates the measurement times and performs certain other data queuing, is too accurate to be checked with a watch. Fortunately, if it fails, it either quits entirely or jumps to another frequency. This error is obvious.

b. Divider Accuracy

To check the divider accuracy, loosen the four thumbscrews and lift the electronic package out of the base. On the lower right side there is a toggle switch on the 3401 or a slide switch on the 3411. This switch is labeled TEST-MEASURE. Place the switch in TEST and replace the panel.

Place TIME on FAST and depress STD (for 3411, press and hold STANDARD while momentarily depressing MEASURE). At the end of 0.25 minutes, 8192 should be stored in the MS, DS, MC and DC registers. Place TIME on NORM and repeat. At the end of one minute, 8192 should again be stored in the registers. Place TIME on SLOW and repeat for the same indication at the end of four minutes.

c. 3411 Processor Check

If the requirements of paragraph b above have been completed, place the DEPTH switch on BS and the MOISTURE CORRECTION on +00. With 8192 stored in all registers, processing results for WD, DD, M and % M should yield the results listed on the PROCESS DATA CHECK SHEET supplied with the instrument. Repeat the test with MOISTURE CORRECTION set to +99 and -99.

Repeat the test for all positions of the DEPTH selector. If the proper

results are obtained, the processor operation is correct.

2. CHECK OUT PROCEDURES FOR 3411-B

a. Microprocessor

The 3411-B contains a uP (Microprocessor) which controls the majority of the instrument's functions. The uP, in conjunction with its crystal oscillator, provides the time standard for the accumulation cycle. The uP 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 uP must be operational before any test can be performed. Fortunately, if the uP fails, it normally fails catastrophically. If the display indicates four zeros when the instrument is turned on, the uP is probably working normally.

b. Oscillator and Prescalers

As mentioned in the first paragraph, the uP 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 VI-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. For new models, depress the SHIFT key and while holding the SHIFT key down depress the STANDARD/MEASURE key. For old models, depress the STANDARD key and, while holding that key down, depress the MEASURE key. At the end of 0.25 minutes, a 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.

c. 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, th % 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 on new models. While holding the SHIFT key down, depress the STANDARD/MEASURE key. On older models, depress the STANDARD key and, while holding this key down, depess the 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 positions and +99 and -99 values of MOISTURE CORRECTION.

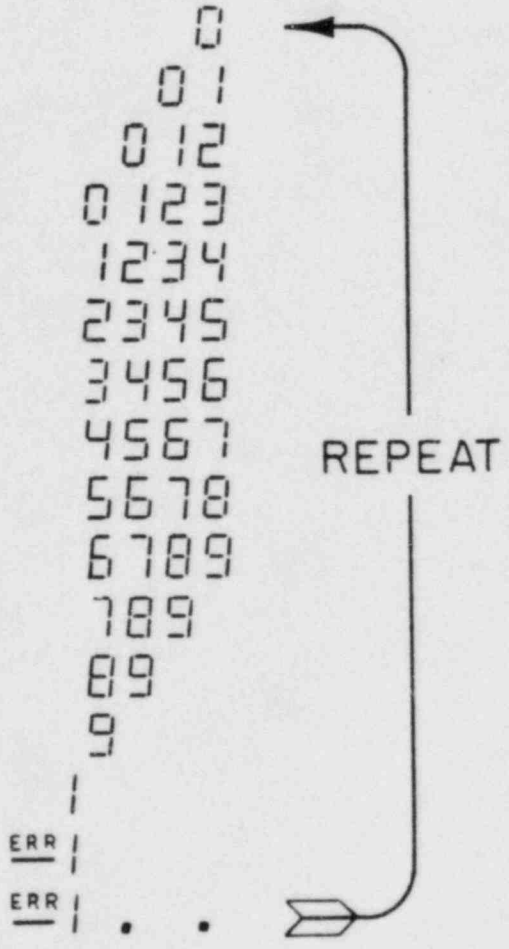
If the proper results are obtained, the processor operation is correct.

d. Self-test Routines

If the uP 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 down and, while holding this down, depress the TST key. Each repeated depression of the SHIFT and TST keys, indexes to the next test. To return the instrument of the normal mode of operation, depress the SHIFT key and while holding it 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.

1) Display Test

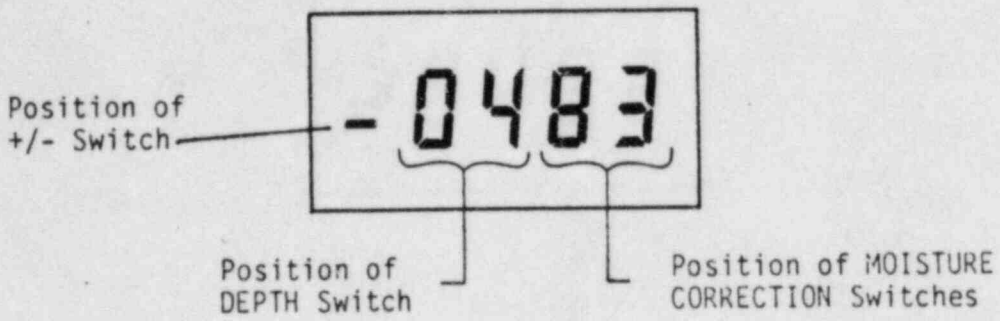
This routine produces a cyclic number sequence that ripples across the display. The exact sequence is shown in Figure VI-7. By watching each digit "count up", you can verify that the LCD (Liquid Crystal Display) and its associated electronics are operating properly.



Display Test Sequence
Figure VI-7

2) Rotary Switch Test

Assuming that the display test above is correct, this routine can be used to verify that the uP is reading the rotary switches correctly. The uP reads the rotary switches and indicates the switch position via the display. The display format is shown in Figure VI-8. 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 VI-8

3) 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 VI-9 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, they keyboard or associated circuits are defective.

11	12	13	14
21	22	23	24
31		32	

KEY CODES FOR KEYBOARD TEST ROUTINE

FIGURE VI-9

e. Error Codes

If the uP 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 VI-H 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 uP 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	uP tried to evaluate the log of a negative number	Uncalibrated depth selected by DEPTH switch
30	uP attempted to divide by zero	No standard counts in the MS or DS registers
31	Negative overflow in division	Incorrect depth selected by DEPTH switch.
		Standard or measure counts aren't 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

3. TROUBLESHOOTING HINTS

The 3411-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 or 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 an on condition.

   a) Replace Battery Monitor Module.
   b) Replace Front Panel Module.

3. Instrument turns on, but won't 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 won't meet stability test.

   a) Replace Density or Moisture Module as required.
   b) Replace detectors as required.

7. Instrument counts moisture correctly, but density count is about half the normal value.

   a) Replace the defective GM tube.

8. All other failures require replacement of Front Panel Module.

   * 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.

INDEX

VIII OPERATION OF TROXLER ROOF MOISTURE GAUGE MODEL 3216

A. 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. If required by your license or organizational procedures, wear a film badge or other dose measurement device when using or transporting the instrument.

3. 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.

4. Keep all unauthorized persons out of the operating area. A suggested distance is 3 meters (10 feet). The general public must not be unecessarily exposed to radiation.

5. Maintain security of the instrument at all times. The instrument should be kept in 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.

6. Every user organization has standard operating procedures; the operator should follow those procedures and report any that he feels are unsafe.

7. Insure that the gauge has had leak tests performed at the proper intervals, as required by your Radioactive Materials License.

8. If you have any doubts about use of the instrument, ASK. Your Radiological Safety Officer has the answer or can obtain one.

B. CONTROL FUNCTIONS AND OPERATIONS

Refer to the front panel of the instrument and note there is a rotary switch labeled POWER/TIME and a pushbutton label START. The POWER/TIME switch controls power to the gauge and also selects the duration of the accumulation (counting) period. Turn the POWER/TIME switch to 7.5 SEC.

The ERR symbol will appear in the upper left corner of display indicating the gauge is accumulating data. Since the gauge "powers-up" in the counting condition, this initial count is invalid and must be disregarded.

If the batteries are in need of a recharge, the BAT symbol will appear below the ERR symbol.

There are two START buttons on the gauge. One is located on the front panel and a remote START is located on the gauge handle. These switches are connected in parallel and either can be used.

Press one of the START switches and then observe the ERR notation appears in the display. At the end of the accumulation period, the ERR symbol will disappear and the gauge will emit a brief "beep". If this were an actual test, the number displayed should be recorded and another count could be started.

The RATEMETER located on the top of the cover is useful for fast visual indication of count rate. You can see the effect of this meter by raising and lowering the gauge over a hydrogenous material (use the 3216 shipping case). This meter is not calibrated and therefore should only be used as a quick indication of count rates. It should also be noted that the RATEMETER has a logarithmic response. This gives greater sensitivity at the low end of the scale.

The CHARGER connector is used with either of the battery chargers supplied with the unit. When the batteries are receiving a charge, the indicator light adjacent the connector will light.

C. TEST FUNCTIONS

There are two tests that can be performed if defective operation is suspected. The first and easiest test is to let the gauge count a hydrogenous material which produces a known count rate. A concrete floor covered with asbestos tile will produce a count of approximately 25. A count taken with the gauge placed in its shipping case will produce a count rate of approximately 9.

The second test involves removing the top cover and substitute a test signal of known rate in place of the moisture modules. See Section F-4 on page VIII-5 for disassembly instructions and switch location, respectively.

After the cover has been removed, slide the TEST/MEASURE switch to TEST. Placing the POWER/TIME switch on any of the time positions and pressing the START button should result in a count of 38 ± 3.

If the scaler accumulates the correct count for the three time positions, you can be reasonably confident the scaler is functioning correctly.

D. FIELD MEASUREMENTS

While the 3216 can be used for accumulating data on any hydrogenous (hydrogen containing) material, it is designed specifically for performing roof moisture surveys. For this reason, the section will be limited to roof moisture considerations.

The procedure provides a nondestructive means of tracing wet sections of a built-up roof to determine damaged areas before or after a leak has penetrated the roof structure. It will greatly reduce the maintenance costs due to the ability of defining areas needing repairs instead of the usual total replacement.

The procedure requires a statistical analysis of data collected during a roof survey. The analysis will indicate which sections of the roof have an elevated count rate indicative of water penetration. Only relative moisture levels can be determined unless the gauge is calibrated for the particular roof. The

zero moisture count rate will vary widely due to the quantity of organic material, asphalt thickness, etc. The slope of the calibration will vary due to changes in thickness. If absolute quantities of moisture content are required, several core samples will have to be cut from the roof material and used for calibration purposes.

Roof moisture surveys can be divided into two main functions: 1) data collection, 2) data reduction and analysis. The data collection process is described in Section E below. Data reduction and analysis can be either done manually or with computer aided graphics.

E. DATA COLLECTION

The result of the data collection process is to be a gridded drawing of the roof with moisture measurements recorded at the grid intersections. With this goal in mind, the suggested method is shown below:

1. Select Grid Size

The grid size determines the total number of data points, data collection time, and resolution. There is no hard and fast rule for determining the optimum size. Below is a table that illustrates the effects of various grid sizes.

100' x 200' ROOF

Grid Size	Roof Plan Size	# of Data Points	Data Collection Time in Hrs (*) 7.5 SEC Mode	15 SEC Mode
3' x 3'	33 x 66	2178	7.6	12.1
5' x 5'	20 x 40	800	2.8	4.4
6' x 6'	16 x 33	528	1.8	2.9
10' x 10'	10 x 20	200	0.7	1.1

(*) Assumes 5 Sec between measurements

2. Layout Grid on Roof

The grid pattern (at the selected size) must be layed out on the roof. Paint, strings, marked ropes, or other methods can be used to define the grid intersections on the roof.

One popular method is to use two marked ropes, placed parallel on opposite sides of the roof. A third marked rope is stretched between the two parallel ropes. A spray paint can is then used to spot the roof at each marking on the rope.

3. Drawing of Roof Plan

Make a scaled drawing of the top view of the roof. Note on this drawing all roof structures (drains, heating and air conditioning units, ventilation shafts, etc.)

If there are no roof structures or other details that indicate the building orientation, then note on the drawing the North orientation.

Any roof structures that you wish to be included on the plot must also be shown on the roof plan.

4. Collect Measurement Data

Set the POWER/TIME switch to the desired accumulation time period. Use the gauge to make a measurement count at each grid intersection. Record this count on the roof plan at the correct position.

5. Cut Core Samples

Nuclear gauges register relative hydrogen levels. If absolute moisture levels are needed, it is necessary to correlate count rates and actual moisture levels. This is normally done via core samples.

The core samples should be chosen to include as wide a range of count rates as possible. The roof plan count rate data will be useful in choosing where to cut core samples. If a limited number of core samples are to be cut, then they should be made at sites (determined from the count data) that indicate a transition from dry to wet.

F. PERIODIC MAINTENANCE

1. Battery Charging

Numerous factors (charge rate, discharge rate, temperature during charge/discharge, number of charge/discharge cycles, self-discharge, age of cells, and etc.) affect the ability of nickle-cadmium batteries to accept a charge and then deliver this power to a load. It is therefore difficult to specify operating time per battery recharge.

The 3216 instrument typically has a power consumption of less than 100 milliwatts. Since the battery stores approximately 14 watts, the 3216 will operate for 130 hours before requiring a full recharge. Assuming an 8 hour day, the 3216 should operate for approximately two weeks between recharging. 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 using th AC charger will be 16 hours or overnight for a full charge.

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.

Using the above figures, one hour of recharge from the AC charger will replace approximately 8 hours of usage.

The DC charger cable will operate while plugged into a cigarette lighter receptacle of a 12 volt negative ground vehicle system. No damage will occur, but no charging will be possible in 6 volt or positive ground systems. The DC charger is intended for emergency use when required.

With the vehicle engine in operation, use of the DC charger cable should be limited to a maximum of a two hour period. With the vehicle engine not in operation, use of the DC charger cable should be limited to a maximum of seven hours. Charging periods longer than those stated could damage the battery packs. A one hour charge will allow use of the gauge for about ten hours.

2. Cleaning

The surfaces of this instrument are corrosion resistant; however, the surfaces should be kept clean by wiping with a damp (not wet) cloth after use.

3. Interior Condensation

Under some climatic conditions, changes in atmospheric pressure will cause some flow of moist air in and out of the case since the instrument is not pressure sealed. This can result in the formation of water inside the case due to condensation. This could cause erratic operation or even failure. This can be prevented by storage in a warm, dry area when the instrument is not in use.

If condensation does occur, the instrument can be dried out by storage overnight in a dry warm area with the cover removed.

4. Gauge Disassembly

To disassemble the 3216 gauge, remove the six phillips head screws connecting the yellow top cover and the gauge base. Carefully lift the top cover up and lay it upside down beside the gauge base. You now have access to the gauge modules and battery packs.

* * * CAUTION * * *

This gauge generates HIGH VOLTAGE (1 kv) which can cause severe shock. Before removal or insertion of any modules, the unit must be turned off and the HIGH VOLTAGE DISCHARGE button pressed for 3-5 seconds.

Also when measuring the HIGH VOLTAGE, be certain the measuring instrument and probes are rated for at least 1000 volts DC.

The HIGH VOLTAGE DISCHARGE switch is located on baseboard printed circuit between the two modules on the left side of the unit.

To disconnect the top cover from the gauge base, unplug either end of the flat cable by grasping the connector firmly and pulling upward.

If you are going to perform a leak test, the entire electronic assembly can be removed by lifting upward on the electronic assembly mounting plate. It is not necessary to disconnect the cables since they are long enough to allow the assembly to be placed on the right hand side of the base.

Perform the reverse process to reassemble the gauge.

G. LEAK TEST PROCEDURE

State and Federal laws require that the radioactive source be leak tested every six months and records maintained of the results. Personnel safety must be considered and leak tests performed to eliminate possible radiotoxicity hazards. Refer to Section II in the beginning of this manual for a description of our leak test procedure.

Remove the top cover and the electronic assembly as described in Section VIII F-4. After the electronic assembly has been placed beside the gauge, the source holder can be seen attached to the bottom of the gauge base. The top of the source holder is covered with a yellow "radioactive material" label.

Wet the swabs with the Alconox solution. Wipe the visible edges of the yellow label with the swabs. Reassemble the unit, dry the swabs and place in the plastic bag. Proceed with the leak test as described in Section II.

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 certificate will be sent to the owner, and charges for the service will be included with other repair charges.