U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL
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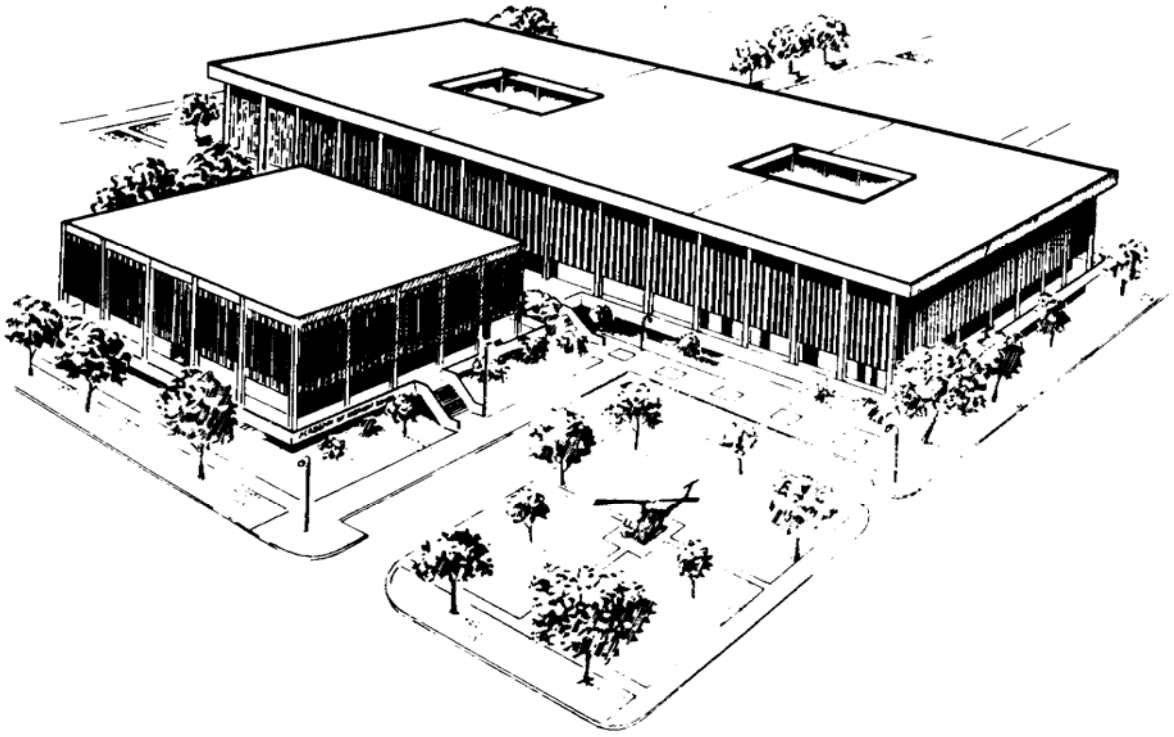

ELECTRICAL SAFETY

SUBCOURSE MD0356 EDITION 100

DEVELOPMENT

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the Academy of Health Sciences and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

ADMINISTRATION

Students who desire credit hours for this correspondence subcourse must enroll in the subcourse. Application for enrollment should be made at the Internet website: http://www.atrrs.army.mil. You can access the course catalog in the upper right corner. Enter School Code 555 for medical correspondence courses. Copy down the course number and title. To apply for enrollment, return to the main ATRRS screen and scroll down the right side for ATRRS Channels. Click on SELF DEVELOPMENT to open the application; then follow the on-screen instructions.

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CLARIFICATION OF TERMINOLOGY

When used in this publication, words such as "he," "him," "his," and "men" 'are intended to include both the masculine and feminine genders, unless specifically stated otherwise or when obvious in context.

USE OF PROPRIETARY NAMES

The initial letters of the names of some products may be capitalized in this subcourse. Such names are proprietary names, that is, brand names or trademarks. Proprietary names have been used in this subcourse only to make it a more effective learning aid. The use of any name, proprietary or otherwise, should not be interpreted as endorsement, deprecation, or criticism of a product; nor should such use be considered to interpret the validity of proprietary rights in a name, whether it is registered or not.

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CORRESPONDENCE COURSE OF
THE U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL

SUBCOURSE MD0356

ELECTRICAL SAFETY

INTRODUCTION

As a Medical Equipment Repairer, it is your job to ensure that medical equipment is safe to operate for both patients and equipment operators. One way that you accomplish this crucial objective is to perform electrical safety tests on new equipment before you use it for the first time and whenever equipment is repaired. You also perform safety tests on a regular basis according to the schedule established at the medical treatment facility.

Subcourse Components:

This subcourse consists of 2 lessons. The lessons are:

Lesson 1 Principles of Operating the Safety Analyzer.

Lesson 2, Performing Electrical Safety Tests.

Here are some suggestions that may be helpful to you in completing this subcourse:

--Read and study each lesson carefully.

--Complete the subcourse lesson by lesson. After completing each lesson, work the exercises at the end of the lesson, marking your answers in this booklet.

--After completing each set of lesson exercises, compare your answers with those on the solution sheet that follows the exercises. If you have answered an exercise incorrectly, check the reference cited after the answer on the solution sheet to determine why your response was not the correct one.

Credit Awarded:

Upon successful completion of the examination for this subcourse, you will be awarded 5 credit hours.

To receive credit hours, you must be officially enrolled and complete an examination furnished by the Nonresident Instruction Branch at Fort Sam Houston, Texas.

You can enroll by going to the web site http://atrrs.army.mil and enrolling under "Self Development" (School Code 555).

A listing of correspondence courses and subcourses available through the Nonresident Instruction Section is found in Chapter 4 of DA Pamphlet 350-59, Army Correspondence Course Program Catalog. The DA PAM is available at the following website: http://www.usapa.army.mil/pdffiles/p350-59.pdf.

LESSON ASSIGNMENT

LESSON 1	Principles of Operating the Safety Analyzer.
TEXT ASSIGNMENT	Paragraphs 1-1 through 1-4.
LESSON OBJECTIVES	After completing this lesson, you should be able to:
	1-1. Identify what the safety analyzer measures.
	1-2. Identify the specifications.
	1-3. Identify how to use the controls, indicators, and connectors.
SUGGESTION	After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 1

PRINCIPLES OF OPERATING THE SAFETY ANALYZER

1-1. GENERAL

The National Fire Code in the National Fire Protection Act (NFPA 99) requires that you perform electrical safety tests to ensure that medical equipment used for patients meets the specific safety standards. For this lesson, leakage current, resistance voltage, and other measurement limits have been established. However, the final authority for standards is the current NFPA 99.

a. **Testing the Patient Environment and Patient-Care-Related Electrical Equipment**. You use the Model 232 safety analyzer to make measurements which determine if the patient environment and patient-care-related electrical equipment meet safety standards. A patient environment is a space occupied by a patient and extending 6 feet beyond the vicinity and 7 feet 6 inches vertically above the floor. Patient-care-related electrical equipment is electrical equipment intended to be used for diagnostic, therapeutic, or monitoring purposes in a patient environment. Equipment found in the patient environment includes, but is not limited to the following:

(1) X-ray equipment.

(2) Electrocardiograph (ECG).

(3) Dental X-ray equipment.

(4) Dental equipment.

(5) Clinical equipment.

(6) Laboratory equipment.

(7) Ward equipment.

(8) Operating room equipment.

(9) Central material supply equipment.

b. **Types of Environmental Tests**. These environmental tests include the measurement of power system voltages, voltage gradient/grounding differential in millivolts (mv), and intergrounding resistances in milliohms (mOhms).

c. **Types of Equipment Safety Tests**. Additionally, the Model 232, when connected to the specified power source and ECG, is capable of making the following measurements by activating the appropriate switches and without changing terminal connections:

(1) Line voltage of the alternating current (ac) power line at the test receptacle three ways: neutral to hot, neutral to ground, and hot to ground.

(2) Leakage current from the chassis of an ECG to ground; from each patient electrode individually to ground; and from all patient electrodes in common to ground with the electrical power supply to the ECG normal and reversed, and grounded and ungrounded.

(3) Leakage current between the right arm and left arm; right arm and right leg; and between left arm and right leg.

(4) Leakage current through all patient electrodes in common to ground when applied by a 120/230 volts (v) alternating current (vac) power supply internal to the tester.

(5) Ground resistance test for portable equipment having a power cord. Measurements are made of the ground resistance between the chassis of the equipment and the ground pin. This test verifies that the unit under test (UUT) is properly grounded.

(6) Ground resistance test for hard-wired equipment.

(7) Case leakage current test for portable equipment.

(8) Case leakage current test for electrocardiographs.

1-2. SPECIFICATIONS

a. **Meter.** The safety analyzer displays measurements on a 3 1/2 digit light emitting diode (led) display. Overrange is indicated by a flashing 1999. The appropriate range is selected automatically with the units of measure shown on the mode switch. During resistance measurements, a separate led illuminates when the current source has been activated.

b. **Current.** There are two current ranges: 0-199.9 microamperes (µa) and 0-1999µa. Measurements are made through an AAMI load. Accuracy is one percent of full scale. Measurements are root-mean-square (rms) and can be ac plus direct current (dc). With the DC ONLY switch depressed, only the dc component of the signal is measured.

c. **Resistance.** There are four resistance ranges: 0-199.9mOhms, 0-1999mOhms, 0-19.99ohms, and 0-199.9ohms. Accuracy is one percent of full scale. Resistance is measured by monitoring the voltage across the UUT when the dc current is passed through it. The four-terminal measurement method is used for the mOhms ranges, and the two terminal method is used for the ohm ranges. Both mOhms and ohms are autoranging.

d. **Voltage.** There are four voltage ranges: 0-199.9mv, 0-1999mv, 0-199.9v, and 0-500v. Readings are root-mean-square (rms) ac+dc or dc only. Accuracy is one percent of full scale. The AAMI load is used for these tests. Both mv and volts are autoranging.

e. **Advancement of Medical Instrumentation Load.** The simulated patient load is recommended by the Association for the Advancement of Medical Instrumentation (AAMI), Safe Current Limits Standard (ANSI/AAMI ESI-1985) (revision of ANSI/AAMI SCL-12/78). The AAMI load aids in determining the actual voltage or unit shocks to the patient. If there is no load, there is no current. Figure 1-1 shows the load. The result is a frequency response which is flat to the 1 kiloHertz (kHz), then rolls off at 20 decibel (dB) per decade, and levels off at 1 megaHertz (mHz) attenuated by the 40dB. The measurement circuit adds an additional roll off at approximately 3dB at 1mHz. Measurement of accuracy is one percent of range from 40Hz to 1000Hz, 2.5 percent of range from 1kHz to 100kHz, and 5 percent of range from 100kHz to 1mHz.

f. **Test Receptacle.** This supplies power to the UUT. It supplies 120vac at 15a maximum or 6a at 230v (50/60Hz). Front panel toggle switches select power ON/OFF, NORMAL/REVERSE POLARITY, OPEN/CLOSED GROUND to the equipment under test.

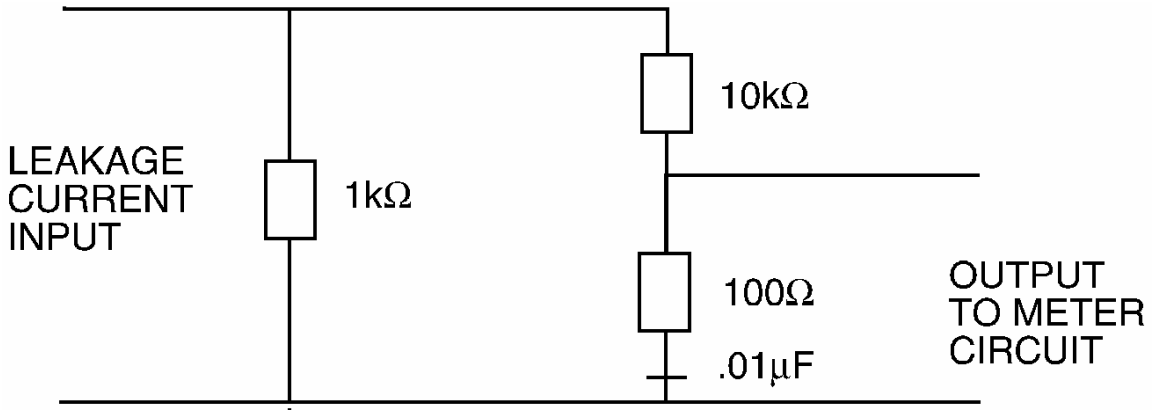


Figure 1-1. AAMI load diagram.

g. **Test Lead Jacks.** These are standard banana jacks. Two are for the meter input and two are for the current source. These are arranged to allow connection of a set of Kelvin cables which you may leave connected for all tests without damaging the analyzer. The current source is only connected internally for resistance measurements, so it will not interfere with leakage current measurements even though the cables are connected to the current source jacks. For two terminal resistance measurements, the current source is internally connected to the external meter jacks instead of current jacks. All the test lead jacks are protected against the accidental application of line voltage.

h. **Electrocardiograph Binding Posts.** Five universal binding posts accept 3.2 millimeters (mm) or 4mm pins or disposable snap ECG electrodes.

i. **Power Requirements.** The power requirements are 117vac at 15a 50-60Hz or 230vac at 6a 50-60Hz. A detachable hospital power cord is supplied. The unit by itself uses very little power (<100ma). The 15a rating is for equipment under test plugged into the test receptacle. See paragraph 1-4 for instructions for setting line voltage.

1-3. CONTROLS, INDICATORS, AND CONNECTORS

Figure 1-2 shows front and top panel controls, indicators, and connectors of the 232M. Use this figure to locate those items that are described in the following paragraphs.

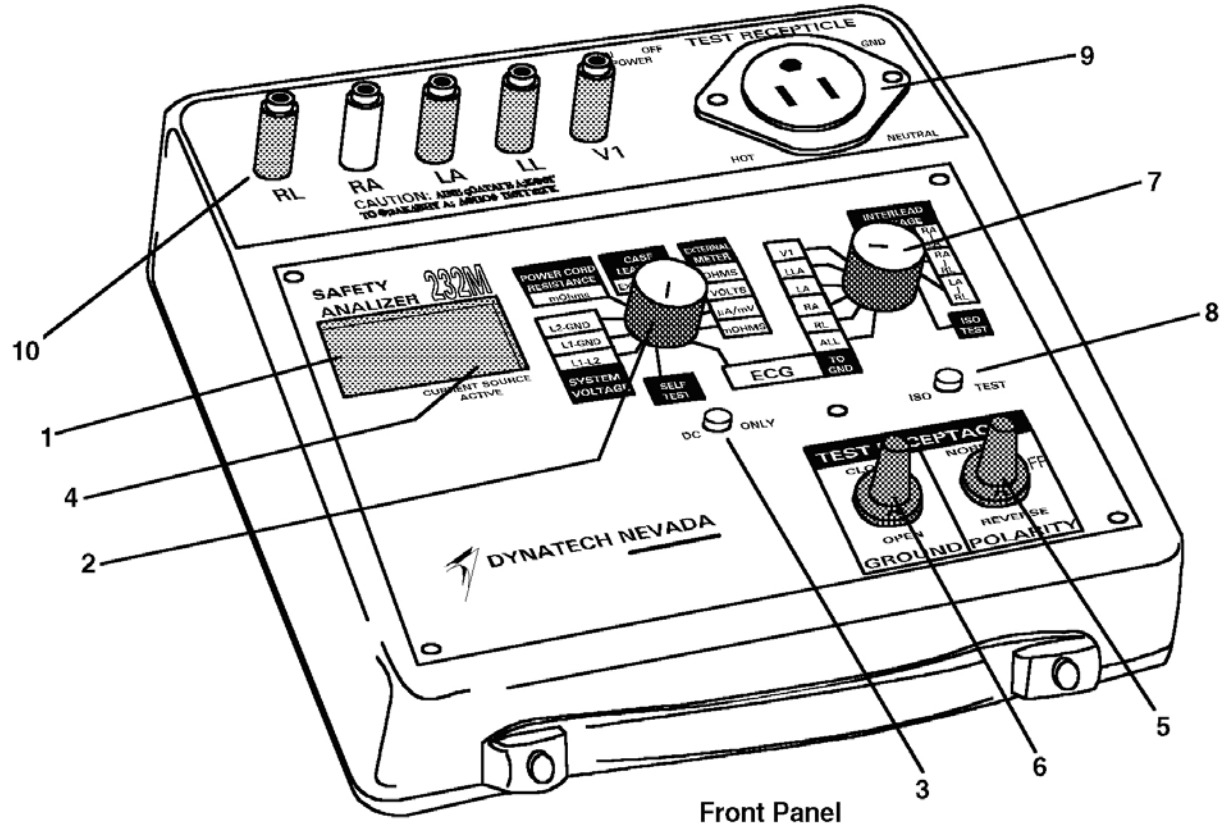


Figure 1-2. Safety analyzer front panel.

a. **Front Panel Controls and Indicators.**

(1) Display. A 3 1/2 digit led display that indicates the results of the measurements being made. Decimal points are placed automatically, and the units of measurement are shown on the mode switch (number 1).

(2) Mode switch. Sets the type of measurement to be made. The last position of the mode switch, ECG, enables the ECG selector switch (number 7). This allows you to make measurements for the ECG patient lead and isolation leakage current.

(3) DC ONLY switch. Changes the measurement mode from ac+dc to dc only (number 3).

(4) Current source active led. Illuminates indicating the current source is internally connected to the test lead jacks during ground resistance measurements (number 4).

(5) Polarity switch. Selects normal or reverse polarity of the hot and neutral lines to the test receptacle. This is a three position switch. In the center position, the switch shuts off power to the test receptacle (number 5).

(6) Ground switch. A momentary switch to open the ground connection to the test receptacle (number 6).

(7) Electrocardiograph selector switch. Sets the ECG lead test to be made. The mode switch must be in the ECG position to activate these measurement selections (number 7).

(8) ISO test. Connects the line voltage to the ECG binding posts (number 8).

CAUTION: This voltage is 120/230vac, and it is limited to 1ma. Do not touch the UUT, patient leads, or safety analyzer during this test since line voltage is applied to the ECG binding posts.

PATIENT SAFETY PRECAUTION

Since the test method injects potentially hazardous current levels into the ECG and the related power system, do not conduct tests in an occupied patient location or while the patient is connected to a related power system branch circuit.

b. **Top Panel Connectors.**

(1) Test receptacle. Provides operating voltage to the UUT (number 9).

(2) Electrocardiograph binding posts. Accepts all styles of electrocardiograph connectors (disposable snaps, 3.2mm pins, and 4mm pins) (number 10).

c. **Rear Panel Connectors and Controls.** Refer to figure 1-3 for an illustration of the rear panel.

(1) Power switch. Turns on the safety analyzer and supplies power to the test receptacle (number 11).

(2) Power cord receptacle. Receptacle for power cord plug (number 12).

NOTE: Remove the power cord when storing the unit in the carrying case.

(3) Fuse holder. 15a 3AG slow blow fuse. This fuse protects the instrument and the safety analyzer (number 13).

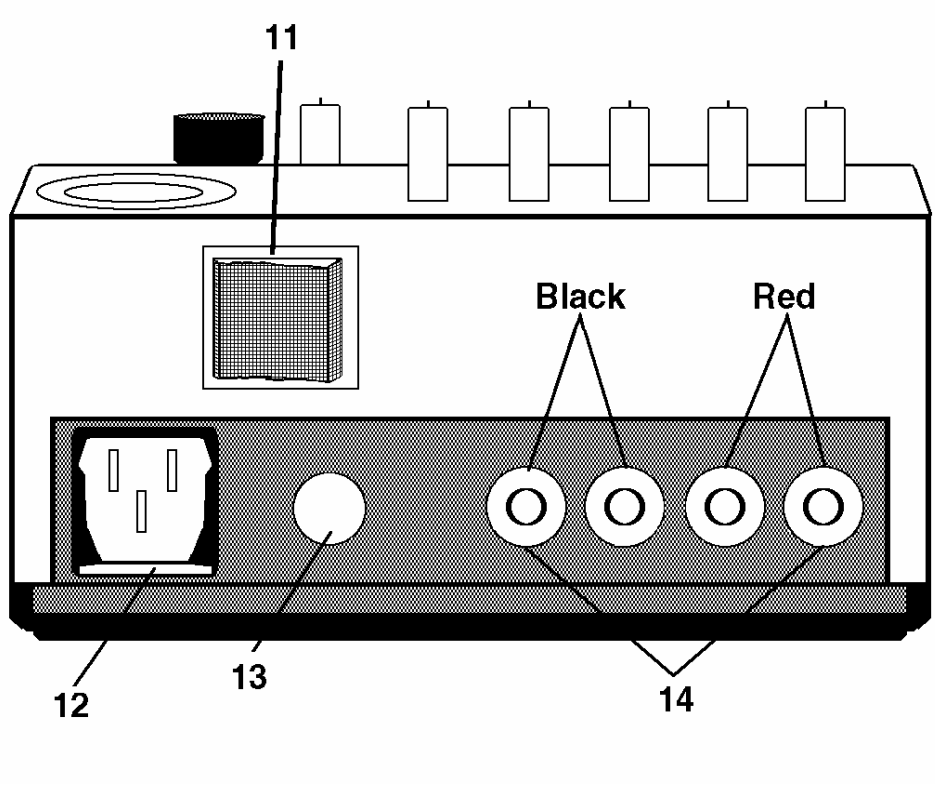


Figure 1-3. Safety analyzer rear panel.

(4) Test lead jacks. Connects to test leads, called Kelvin cables, to make ground resistance or leakage current measurements. The Kelvin cables may be left connected for all measurements (number 14).

(a) Current source. The current source for measuring ground power cord resistance is internally connected when the mode switch is in the mOhms measuring positions.

(b) External meter. The metering circuit is internally connected when the mode switch is in one of the four positions requiring external connections. The current source is connected here in the measuring position for testing hardwired equipment.

1-4. LINE VOLTAGE

a. **Set Line Voltage.** The 232M may be operated on 110vac or 230vac. To set the line voltage, set the jumpers on the transformers T1 and T2. Refer to figure 1-4.

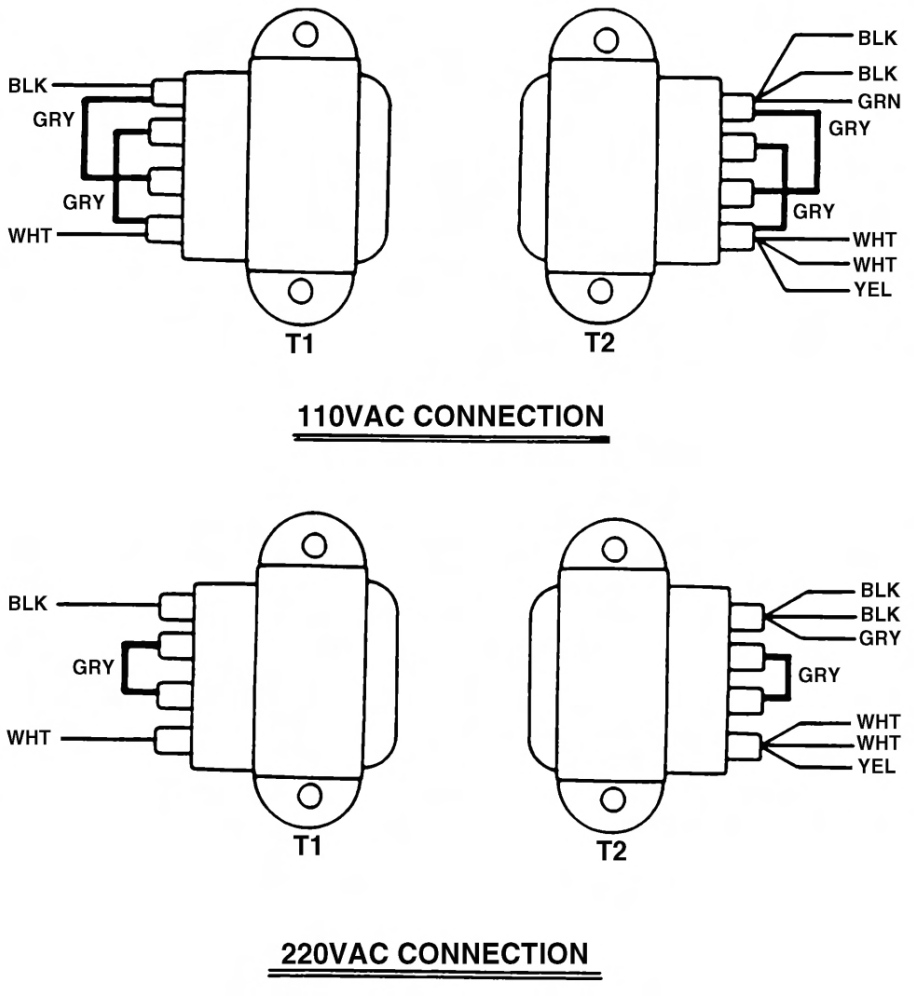
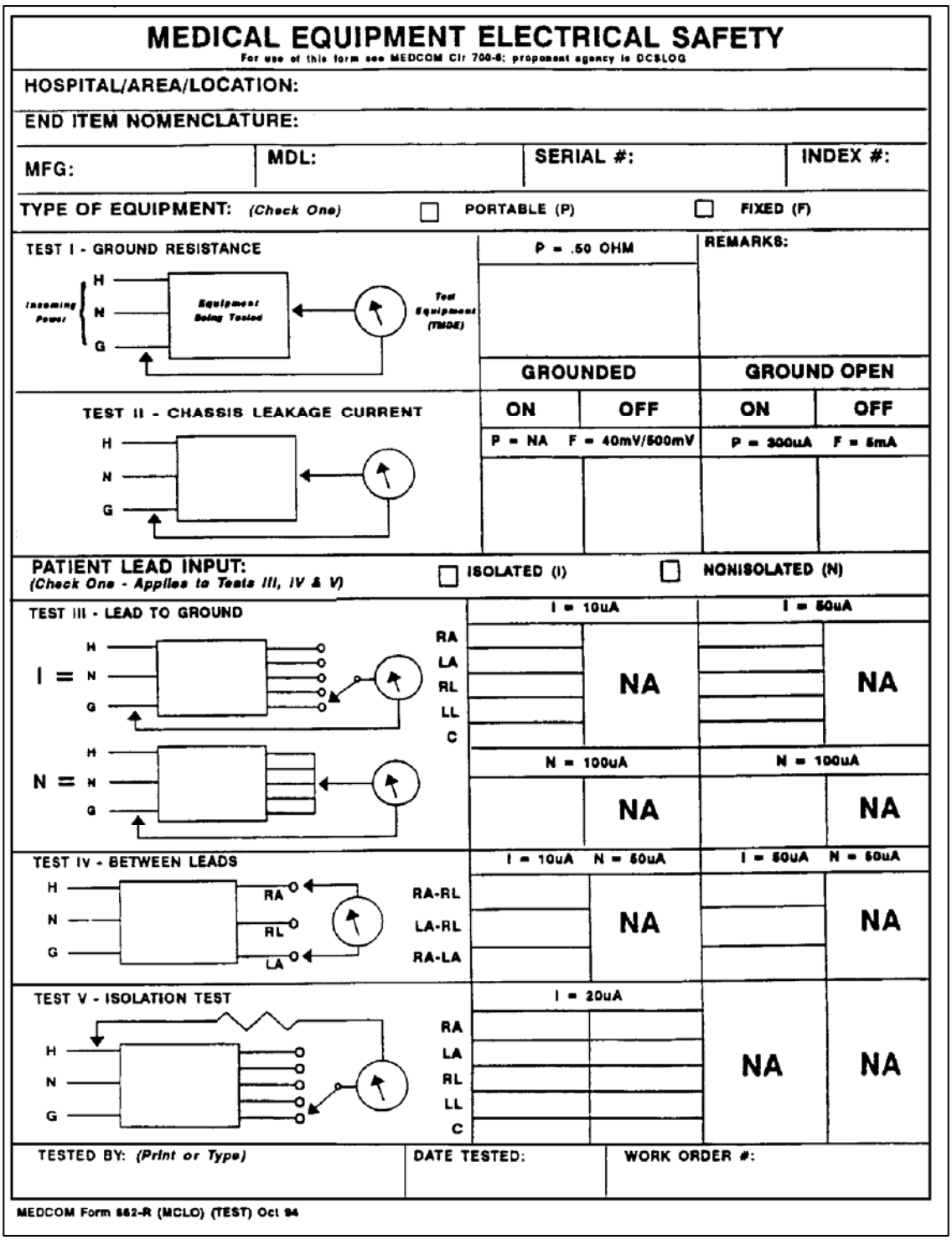


Figure 1-4. Transformer wiring.

b. **MEDCOM Form 662-R**. Refer to figures 1-5 and 1-6. Use MEDCOM Form 662-R to post the results of your tests when the UUT fails the safety testing. Note that you select the isolation current limit resistor under MAXIMUM LIMITS.



MEDICAL EQUIPMENT ELECTRICAL SAFETY

For use of this form see MEDCOM Cir 700-8; proponent agency is DCSLOG

HOSPITAL/AREA/LOCATION:

END ITEM NOMENCLATURE:

MFG: | MDL: | SERIAL #: | INDEX #:

TYPE OF EQUIPMENT: (Check One) ☐ PORTABLE (P) ☐ FIXED (F)

TEST I - GROUND RESISTANCE

Incoming Power: H, N, G — Equipment Being Tested — Test Equipment (TMDE)

P = .50 OHM | REMARKS:

	GROUNDED	GROUND OPEN

TEST II - CHASSIS LEAKAGE CURRENT

H, N, G

ON	OFF	ON	OFF
P = NA	F = 40mV/500mV	P = 300uA	F = 5mA

PATIENT LEAD INPUT: (Check One - Applies to Tests III, IV & V) ☐ ISOLATED (I) ☐ NONISOLATED (N)

TEST III - LEAD TO GROUND

I = H, N, G — N = H, N, G

RA, LA, RL, LL, C

I = 10uA		I = 50uA	
	NA		NA
N = 100uA		N = 100uA	
	NA		NA

TEST IV - BETWEEN LEADS

H, N, G — RA, RL, LA

RA-RL, LA-RL, RA-LA

I = 10uA N = 50uA		I = 50uA N = 50uA	
	NA		NA

TEST V - ISOLATION TEST

H, N, G

RA, LA, RL, LL, C

I = 20uA			
		NA	NA

TESTED BY: (Print or Type) | DATE TESTED: | WORK ORDER #:

MEDCOM Form 662-R (MCLO) (TEST) Oct 94

Figure 1-5. DA Form 662-R.

INSTRUCTIONS FOR COMPLETING

GENERAL

HOSPITAL/AREA/LOCATION: Self explanatory.

END ITEM NOMENCLATURE: Self explanatory.

MFG: The manufacturer of the end item.

MDL: The model number of the end item. Use the manufacturer's generic model identification rather than a catalog number.

Figure 1-6. Instructions for use with DA Form 662-R

Continue with Exercises

EXERCISES, LESSON 1

INSTRUCTIONS: Answer the following items by completing the statement or by writing the answer in the space provided at the end of the item.

After you have completed all of these items, turn to "Solutions to Exercises" at the end of the lesson and check your answers with the solutions.

SITUATION: You are identifying the purpose of the controls and indicators. Use this situation and Figure 1-2 to answer questions 1 through 3.

1. Identify the part of the system analyzer that shows the results of measurements.

   a. 1.

   b. 2.

   c. 6.

   d. 7.

2. Identify the part of the system analyzer that you must set before you perform checks on the ECG.

   a. 2.

   b. 6.

   c. 7.

   d. 11.

3. On what part of the safety analyzer is the power switch located?

   a. Top panel.

   b. Side panel.

   c. Front panel.

   d. Rear panel.

SITUATION: You are performing electrical safety tests on medical equipment. Use this situation to answer questions 4 and 5.

4. The ISO test connector is used when testing:

   a. Dental equipment.

   b. Clinical equipment.

   c. The ECG.

   d. Any UUT.

5. The test receptacle supplies power to the UUT. At 120vac, it supplies a maximum of:

   a. 5a.

   b. 10a.

   c. 15a.

   d. 20a.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 1

1. a (para 1-3a(1))
2. a (para 1-3a(2))
3. d (para 1-3c(1))
4. c (para 1-3a(8))
5. c (para 1-2f)

End of Lesson 1

LESSON ASSIGNMENT

LESSON 2	Performing Electrical Safety Tests.
TEXT ASSIGNMENT	Paragraphs 2-1 through 2-4.
LESSON OBJECTIVES	After completing this lesson, you should be able to:
	2-1. Check the safety analyzer.
	2-2. Check the system voltage.
	2-3. Check the power cord ground resistance.
	2-4. Check the case leakage current.
	2-5. Check leakage to ground current (ECG).
	2-6. Check interlead leakage current (ECG).
	2-7. Perform isolation test (ECG).
	2-8. Perform external tests.
	2-9. Perform power down procedures.
SUGGESTION	After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 2

PERFORMING ELECTRICAL SAFETY TESTS

2-1. SAFETY

Ensure that you observe the following safety precautions when performing the required safety checks:

a. Do not conduct tests in an occupied patient location or while the patient is connected to a related power system branch circuit.

b. If the safety analyzer fails the start-up and self test, do not continue. Stop immediately. Obtain another analyzer and turn in the defective analyzer for repair.

c. If the system-voltage test fails, contact the Directorate of Engineering and Housing or other appropriate authority to repair the power system.

d. Avoid contacting the UUT during any test.

e. Do not run tests on the power line ground system with electrically sensitive patients present unless you take steps to isolate them from all connections to any equipment which in turn is connected to the power line under test.

2-2. REQUIRED TOOLS AND EQUIPMENT

You will use the following tools and equipment to perform electrical safety checks.

a. Safety Analyzer Model 232M.

b. Unit to be tested.

c. Medical Repairman's Tool Kit, NSN 5180-00-611-7923.

d. Medical Repairman's Tool Kit, NSN 5180-00-611-7924.

2-3. TEST PROCEDURES

In Lesson 1, you learned operational procedures for the safety analyzer. You also learned the specifications. In this lesson, you will learn how to perform the electrical safety tests.

a. **Perform Start up and Self Test on the 232M.** Perform the following steps:

(1) Ensure that no equipment is plugged into the test receptacle before plugging in the unit or turning on the power.

(2) Plug in the analyzer and turn it on.

(3) Set the mode switch to SELF TEST.

(4) The display should read 1000 +/-20, and the current source active lamp should be on.

b. **Check the Power Supply System Voltage.** Refer to figure 2-1 for acceptable voltage readings. Perform the following steps:

POWER SYSTEM VAC	**L-1--L-2**	**L1-GND**	**L2-GND**
120vac (isolated)	120vac ± 20%	45-55% of L1-L2	45-55% of L1-L2
120vac (nonisolated)	120vac ± 10%	5% of K1-L2	120vac ± 10%

Figure 2-1. Acceptable measured voltage readings.

(1) Set the mode switch to L1-L2. The display should now read line voltage ± 10 percent.

(2) Set the mode switch to L1-GND. The display should read no more than 5 percent of L1-L2 (line voltage) on the grounded power system. For a properly balanced isolated system, the reading should be about the same as the L2-GND reading.

(3) Set the mode switch to L2-GND. This should read about the same as the L1-L2 reading for a grounded system. For an isolated system, it should read about the same as the L1-GND.

(4) If the receptacle is wired backwards (reverse polarity), L1-GND instead of L2-GND will be about equal to L1-L2. If the ground is open, L1-GND and L2-GND will both be zero volts.

NOTE: Contact the Directorate of Engineering or other appropriate authority to repair the power system if it fails the power system voltage test.

c. **Check the Power Cord Ground Resistance of the Unit Under Test.** Refer to figure 2-2. Perform the following steps:

NOTE: This procedure does not apply to equipment that is hardwired to the power such as x-ray or sterilizing equipment. For this equipment, you must use the external ground resistance testing procedure. See paragraph e below for external testing procedures.

CONDITION	PORTABLE EQUIPMENT	FIXED EQUIPMENT	ISOLATED	NON ISOLATED
Power off (grounded)	300µa	5.0ma	10µa	100µa
Power off (grounded lifted)	300µa	5.0ma	50µa	100µa
Power on (grounded)	300µa	5.0ma	10µa	100µa
ISO test for patient leads	Lead to lead	Lead to lead	20µa	
Maximum ground resistance	0.50 ohm	0.50 ohm		

Figure 2-2. Sample of maximum acceptable leakage current measured with normal polarity.

(1) Set the mode switch to power cord resistance.

(2) Set the test receptacle polarity to the center position (OFF).

(3) Plug the UUT into the test receptacle on top of the Model 232M.

(4) Connect the dual banana plug end of a Kelvin cable to the two red rear panel jacks.

(5) Connect the alligator clip of the Kelvin cable to a grounded point on the case of the UUT.

(6) The current source active lamp lights up to indicate that the current source is connected to the test lead jacks. The display reads the ground resistance in mOhms from the test receptacle ground pin of the safety analyzer to the case of the UUT. Refer to figure 2-2 for an example of acceptable resistance measurements. Because the standards change, always refer to the current NFPA 99 in your work situation.

d. **Check the Case Leakage Current.** Refer to figure 2-3. Perform the following steps.

(1) Set the mode switch to CASE LEAKAGE.

(2) Connect a Kelvin cable to the red rear panel jacks. Current is disabled in this mode so you can leave the cable connected for both resistance and leakage current tests.

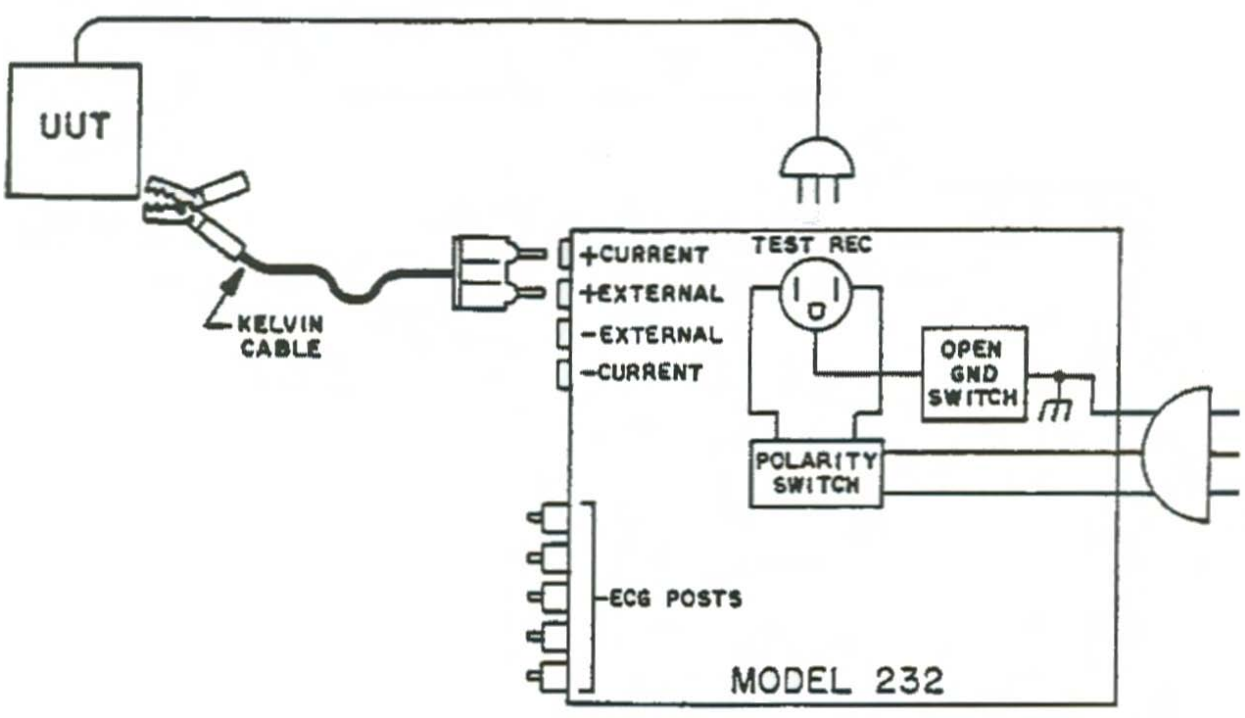


Figure 2-3. Connections for testing power cord ground resistance and case leakage current.

(3) Connect the alligator clip of the Kelvin cable to a grounded point on the case of the UUT. If you leave the clip in place after making the ground resistance measurement, you can be sure that you have the clip on a grounded point of the case. Make measurements for all of the following conditions with normal polarity selected.

(a) UUT power off, grounded.

(b) UUT power off, ground open.

(c) UUT power on, grounded.

(d) UUT power on, ground open.

NOTE: Refer to figure 2-2 for a sample of leakage current limits.

e. **External Test Procedures.** External testing procedures involve testing ground continuity with a volt/ohm meter. You perform external tests on hardwired equipment. The following paragraphs describe the procedures to follow for external tests.

(1) External meter, ohms. Refer to figure 2-4. Set the mode switch to EXT METER, OHMS. In this mode, the current source and measurement circuits are both connected to the rear panel jacks. Connect the red probe to the red EXT jack and the black probe to the black EXT jack. Connect the resistance to be measured between the probes. Be sure the current source active lamp comes on when the connections are all made. This is a two terminal measurement. You can also perform this test with the Kelvin cables as shown in figure 2-5.

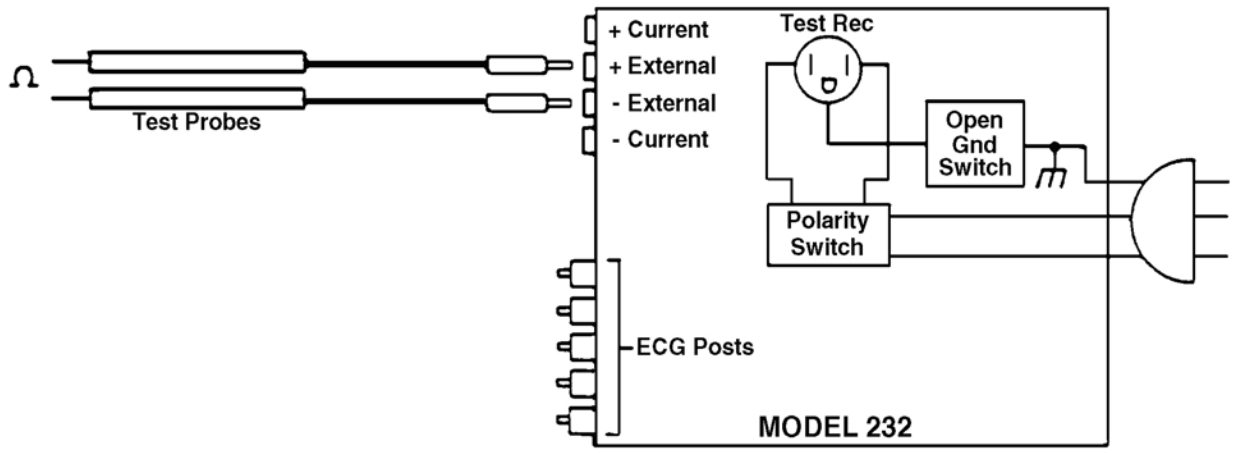


Figure 2-4. External meter connections except mOhms.

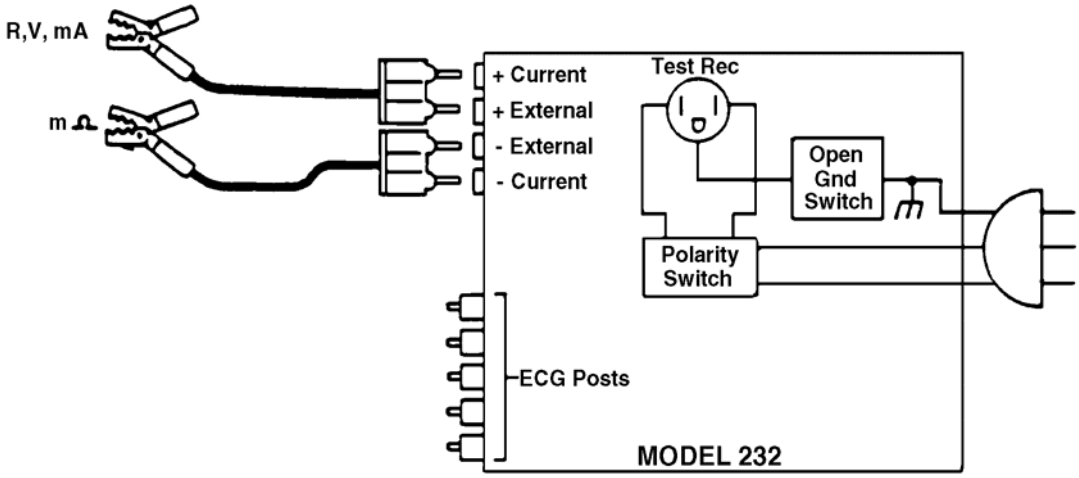


Figure 2-5. External meter connections for mOhms.

(2) External meter, volts. Refer to figures 2-4 and 2-5. Set the mode switch to EXT METER, VOLTS. Connect a Kelvin cable to the red jacks on the rear panel or a single test lead to the red EXT jack and the other cable to the black jacks. A voltage of up to 500 can now be measured between the cables. The input impedance is 1mOhm, and the AAMI load is connected.

(3) External meter, µa/mv. Refer to figures 2-4 and 2-5. Set the mode switch to EXT METER, µA/mv. Connect a Kelvin cable to the red jacks on the rear panel or a single test lead to the red EXT jack and the other cable to the black jacks or black EXT. A current of up to 2000µa or a voltage up to 2000mv can now be measured between the cables. The AAMI load is connected which may load down voltage measurements where the impedance of the voltage source is high.

(4) External meter, mOhms. Refer to figure 2-5. Set the mode switch to EXT METER, mOHMS. In this mode, the current source and measurement circuits are both connected to the rear panel jacks. Connect one Kelvin cable to the red jacks and the other cable to the black jacks. Connect the resistance to be measured between the alligator clips. Be sure the current source active lamp lights up when the connections are made. This is a four terminal technique used to accurately measure low value resistances such as less than 2µ. This is also the only measurement requiring two Kelvin cables.

f. **Power Down.** At the completion of the tests, perform the following steps:

(1) Turn off the UUT.

(2) Turn off the safety analyzer.

(3) Set the polarity switch to OFF.

(4) Disconnect the UUT from the test receptacle.

(5) Unplug the safety analyzer.

NOTE: When not in use, store the safety analyzer in the storage case provided.

NOTE: If the UUT fails any safety test, document the measurements on the appropriate form. Ensure that the equipment is tagged and turned in for repair according to your shop's standing operating procedures (SOP).

2-4. ELECTROCARDIOGRAPH TESTS

In addition to the tests above, include the following three tests when you check the ECG.

NOTE: You do not perform external tests on the ECG.

a. **Check the Patient Lead Leakage Current to Ground.** Refer to figure 2-6. Perform the following steps:

(1) Set the mode switch to ECG.

(2) Connect the patient leads to the ECG binding posts on the top panel of the safety analyzer.

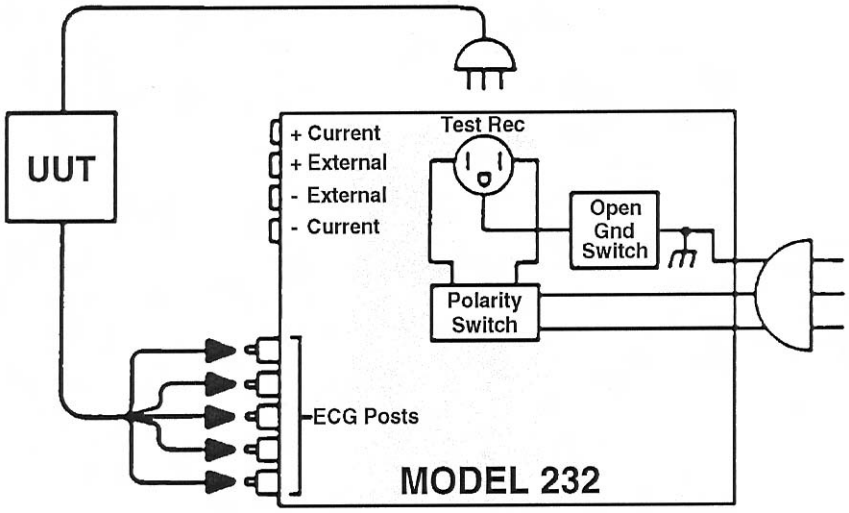


Figure 2-6. Electrocardiograph patient lead test connections.

(3) Set the ECG selector switch to ALL. Set the corresponding switch of the UUT to the same position. Measure the leakage current from all leads to ground. Make patient lead current leakage measurements for the following conditions with normal polarity selected.

(a) UUT power off, grounded.

(b) UUT power off, ground open.

(c) UUT power on, grounded.

(d) UUT power on, ground open.

(4) The next five switch positions measure the leakage current of individual leads to ground.

b. **Check Interlead Leakage Current.** Refer to figure 2-6. Perform the following steps:

(1) Set the mode switch to ECG.

(2) Set the ECG switch to RA-LA. If possible, set the corresponding switch of the UUT to the same position.

(3) Measure the leakage current between leads for the following conditions with normal polarity selected:

(a) UUT power off, grounded.

(b) UUT power off, ground open.

(c) UUT power on, grounded.

(d) UUT power on, ground open.

(4) Perform steps (1) and (2) for the other interlead positions (RA-RL and LA-RL). Ensure that you change ECG switch positions for both the safety analyzer and the UUT.

c. **Perform Isolation Test.** Refer to figure 2-2. Perform the following steps.

(1) Set the switch to ISO TEST.

(2) Depress the ISO TEST button. This test measures the leakage current that would result if line voltage is applied to the ECG terminals. Refer to paragraph 2-3f for power down procedures.

CAUTION: Depressing the ISO TEST button applies line voltage to the ECG posts. The current is internally limited to 1ma.

NOTE: During the isolation test, select only the properly wired test receptacle condition (normal polarity and closed ground).

NOTE: If the UUT fails any safety test, document the measurements on the appropriate form. Ensure that the equipment is tagged and turned in for repair according to your shop's standing operating procedures (SOP). Refer to figure 2-2 for a sample of leakage current limits.

Continue with Exercises

EXERCISES, LESSON 2

INSTRUCTIONS: Answer the following items by completing the statement or by writing the answer in the space provided at the end of the item.

After you have completed all of these items, turn to "Solutions to Exercises" at the end of the lesson and check your answers with the solutions.

1. Before conducting the safety analyzer start up and self test, ensure that:

   a. No equipment is plugged into the unit.

   b. The UUT is plugged into the safety analyzer.

   c. Power for the safety analyzer is on.

   d. The display reads 1000 ± 20.

2. Which of the following tests is performed only on the ECG?

   a. Power supply system voltage.

   b. External meter, ohms test.

   c. External meter, volts test.

   d. External meter, µa/mv test.

3. To perform the patient lead leakage current to ground test, set the ECG selector switch to:

   a. ALL.

   b. CASE LEAKAGE.

   c. L1-GND.

   d. RA-LA, RA-RL, and LA-RL.

4. To check the system voltage, you set the mode switch to L1-L2. The display should read line voltage:

   a. ±2 percent.

   b. ±5 percent.

   c. ±10 percent.

   d. ±15 percent.

5. Which test do you perform to measure leakage current that would result if line voltage is applied to the ECG patient lead?

   a. Interlead leakage current.

   b. Isolation test.

   c. Leakage to ground current.

   d. Case leakage current.

6. You are checking the system voltage. The ground is open. What will your reading be for L1-GND and L2-GND?

   a. 10v.

   b. 5v.

   c. 2v.

   d. 0v.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 2

1. a (para 2-3a(1))
2. a (paras 2-4 NOTE, 2-3e)
3. a (para 2-4a(3))
4. c (para 2-3b(1))
5. b (para 2-4c(2))
6. d (para 2-3b(4))

End of Lesson 2