Instructions for the preparation and use of

CHANCE®

New and Improved Protective Grounding-Set Tester

Catalog No. C403-3220

U.S. Patent 5,811,979

WARNING

Select actual work-site values for system-fault current, fault duration and permissible maximum-worker-body current before attempting to set grounding jumper acceptable limits.

Failure to select actual system-fault current, fault duration and permissible maximum-worker-body current may result in personal injury or death.

These instructions do not claim to cover all details or variations in equipment, nor to provide for all possible conditions to be met with concerning installation, operation, or maintenance of this equipment. If further information is desired or if particular problems are encountered which are not sufficiently covered in this guide, contact A. B. Chance Company.

NOTE:
Because Hubbell has a policy of continuous product improvement, we reserve the right to change design and specifications without notice.

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POWER SYSTEMS, INC.

P403-3222 Rev. E 2/08

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FUNCTIONAL DESCRIPTION

The PROTECTIVE GROUNDING SET TESTER uses a 5 volt direct current (dc) source to measure resistances in grounding sets. Output current through the grounding set is limited to a maximum of 10 amps by an internal current limiting resistor. The tester switches the 5 volt power supply on, makes a measurement, and switches the power off again for a minimum of 500 milliseconds.

The tester uses a 4 wire resistance measurement approach to obtain accurate resistance measurements. The measurement system is auto ranging to give +/-1% accurate resistance measure from 1 μΩ* to 6.5 Ω.

FEATURE DESCRIPTION

The following list of features are referenced with number 1 - 19, and the location of the feature is shown on Figure 1.

1. <u>Test Probes</u>
   Probes are used in troubleshooting mode to locate high resistance area of the ground set.

2. <u>Instructional Video P403-3223</u>
   Shows how to use the Protective Ground Set Tester. The videotape is **not** a substitute for this Instruction Manual. Thoroughly read and understand these instructions before using the Tester.

3. <u>Fixed Input Connections</u>
   When the ‘INPUT SELECT’ switch is in the fixed position. The resistance measurement shown will be the value of resistance from one fixed connection through the ground set to the other fixed connection.

4. <u>Power Entry Module</u>
   Includes 105 - 260V (47-70 Hz) input, main power switch which illuminates when power to the tester is on, and a fuse holder compartment.

5. <u>Preset Resistance Threshold</u>
   This number, shown on the display, is the pass/fail resistance threshold used to light the pass or fail LEDs. There is a different resistance threshold for each cable size. The ‘<’ symbol displayed means less than. For example, when ‘<3.333’ (mΩ**) is displayed, it means that a ground set resistance which is less than 3.333 mΩ** will light the pass LED.

6. <u>Measured Ground Set Resistance</u>
   When the ‘INPUT SELECT SWITCH’ is in the ‘FIXED’ position. The value shown will be the resistance measured from one fixed connection (3) through the ground set to the other fixed connection (3). When the ‘INPUT SELECT SWITCH’ is in the ‘PROBE’ position. The value shown will be the resistance measured between the probe contact points.

7. <u>Selected Cable Size</u>
   Indicates size of cable under test. This must be changed for each new size cable used.

*1 μΩ (1 micro ohm) = 0.000001 ohm
** mΩ (milli ohm) = 0.001ohm

8. <u>Continuous Test Switch</u>
When switched to the 'ON' position, the ground set tester will continuously make measurements at the rate of 1 per second. When switched to the 'OFF' position, the ground set tester will hold the last measurement made.

9. <u>Fail LED (Red)</u>
This LED will light whenever the last measurement is greater than the preset resistance threshold. It will also turn off to indicate a new measurement is being made.

10. <u>Cable Size Switch</u>
Used to select the size of cable to be tested. (#2, 1/0, 2/0, 4/0)

11. <u>Pass LED (Green)</u>
This LED will light whenever the last measurement is less than the preset resistance threshold. It will also turn off to indicate a new measurement is being made.

12. <u>Power Cord</u>
For connection to AC power supply.

13. <u>Probe Input</u>
When the 'INPUT SELECT' switch is in the 'PROBE' position, the resistance measurement shown will be the value of resistance between probe contact points.

14. <u>Input Select Switch</u>
Allows selection of measurement input between the probes or the fixed connections to the ground set.

15. <u>Single Test Switch</u>
Causes the Ground set tester to make a single resistance measurement and hold the value.

16. <u>Attachment Studs</u>
These copper studs are threaded into the fixed connection (3), and the ground set clamps can then be attached to the studs.

17. <u>Elbow adapter</u>
Used to adapt ground set with grounding elbow to threaded fixed connection. 15kV elbow adapter (C403-3449) is available as an option.

18. <u>Grounded Parking Stand Adapter</u>
Used to adapt ground set with grounded parking stand to threaded fixed connection. Parking stand adapter (T403-3159) is available as an option.

19. <u>Self Test Cable</u>
Used for testing the functionality of the Protective Ground Set Tester.

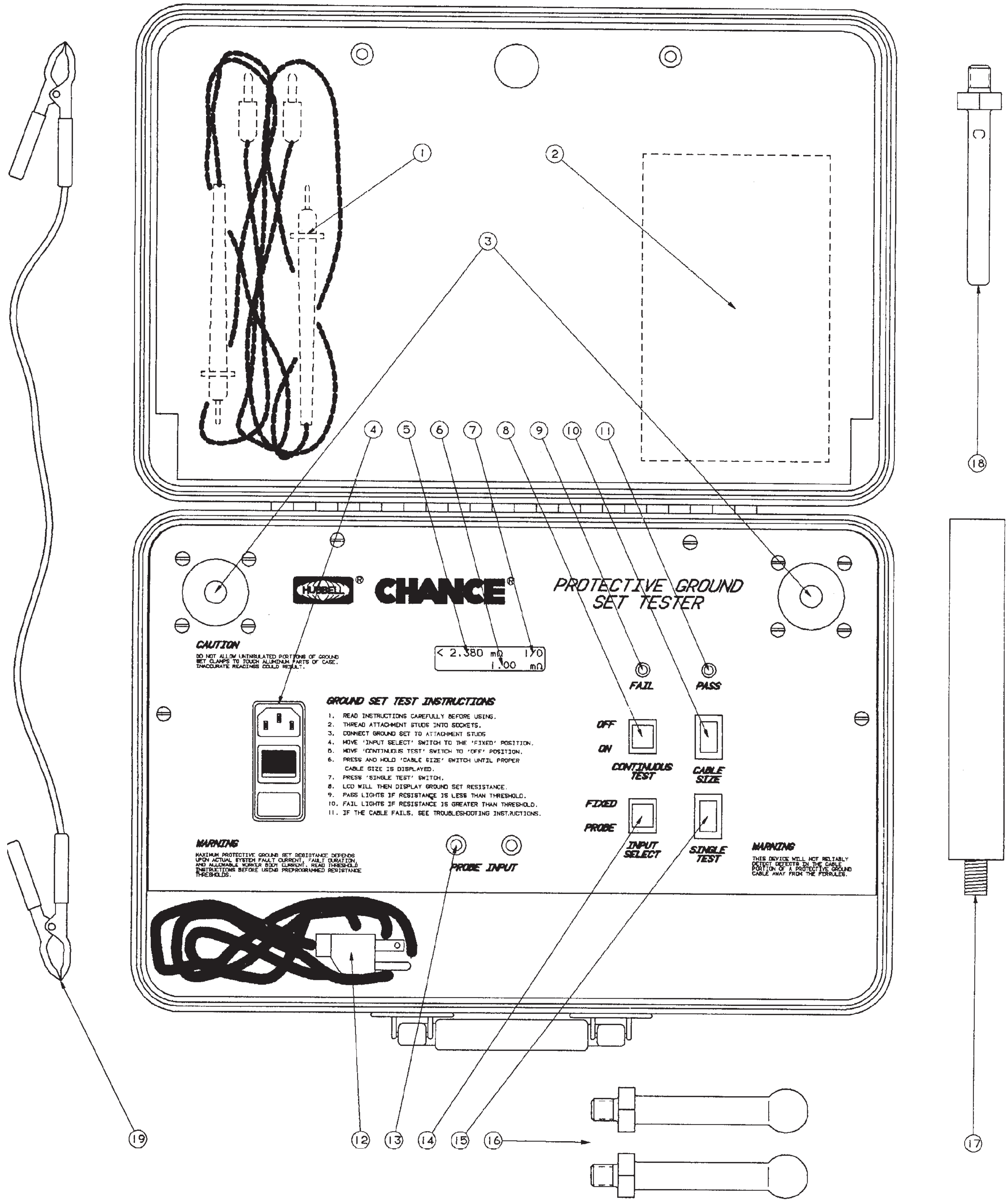

Figure 1: Front Panel of Protective Ground Set Tester Showing Feature Location

SELF TEST PROCEDURE

The operation of the Protective Ground Set Tester can be verified using the Self Test Cable included with the tester. It is not designed to test accuracy.

1. Place the tester on a table of convenient height and plug it into an AC outlet, 110 or 220 VAC, as appropriate.

2. Thread the attachment studs into fixed connection inputs.

3. Securely connect Self Test Cable to the attachment studs.

4. Turn on the unit. The power switch will illuminate when the power is on.

5. Place the ‘INPUT SELECT’ switch in the ‘FIXED’ position.

6. Place the ‘CONTINUOUS TEST’ switch in the ‘OFF’ position.

7. Press the ‘SINGLE TEST’ switch.

8. The display will show the measured resistance of the self test cable on line 2 of the display. The resistance measured should be between 3.0 and 7.5 mΩ**. If the measured resistance is outside these values, retighten the ball studs and check to make sure that the self test cable has good electrical connections. After retest, if the measured resistance is still not between 3.0 and 7.5 mΩ**, discontinue use of the tester. The Self Test Cable is not designed with tight tolerances for accuracy testing.

Note that the thresholds and pass/fail LEDs will function during the self test but do not pertain to the self test.

**mΩ (milliohm) = 0.001 ohm

THRESHOLD PROGRAMMING

1. Threshold Derivation
   The resistance threshold (R_{THR}) is calculated by dividing the voltage allowed across the man (V_{MAN}) by the maximum current (I_{MAX}) the protective ground set can withstand for 15 cycles. Table 1 shows the preset values used for four sizes of cable. The ground set tester comes from the factory with (R_{THR}) based upon (V_{MAN}) = 100V.

CABLE SIZE	15 CYCLE CURRENT WITHSTAND CAPABILITY*
#2	14500 A
1/0	21000 A
2/0	27000 A
4/0	43000 A

* ASTM F855 standard specifications for temporary grounding systems.

Table 1: Withstand Current Capability of Various Cable Size

$$R_{THR} = \frac{V_{MAN}}{I_{MAX}}$$

I_{MAX} = MAXIMUM CURRENT WITHSTAND CAPABILITY
V_{MAN} = VOLTAGE ALLOWABLE ACROSS THE MAN
R_{THR} = MAXIMUM RESISTANCE ALLOWED FOR GROUND SET

CAUTION

The above method gives a suitable resistance threshold as long as available system fault current is below 15 cycle current withstand capability. See Appendix A for detailed theory of threshold determination.

WARNING

It may be necessary to reprogram the threshold level if the preset level does not fit the utility conditions. The Safety Department of the using utility MUST select actual work-site values for system-fault current, fault duration and permissible maximum-worker-body current before attempting to set grounding jumper acceptable limits to assure against personal injury, death or property damage. See appendix A.

Failure to select actual system-fault current, fault duration and permissible maximum-worker-body current may result in personal injury or death.

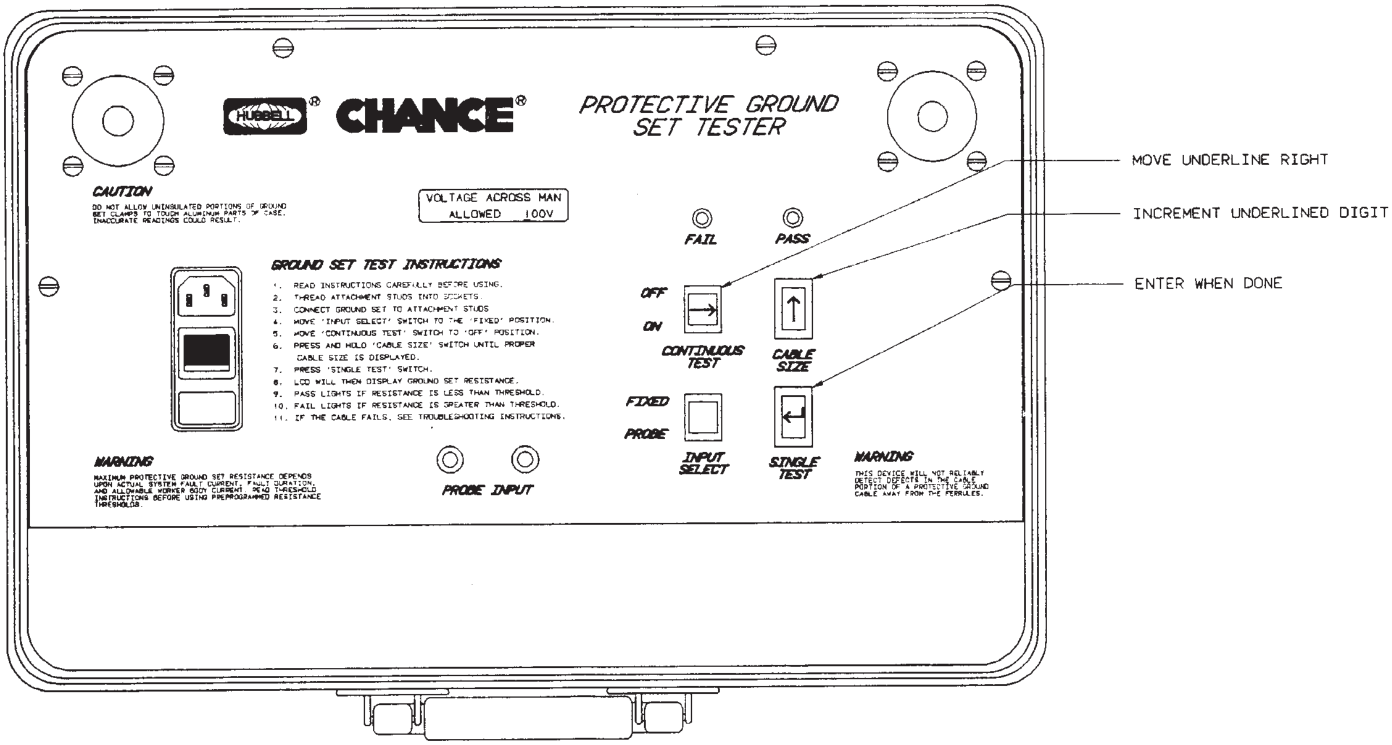

Figure 2: Template of Switches When Changing the Threshold

2. <u>Changing the Threshold</u>

1) Turn off the Ground Set Tester.

2) Place the ‘CONTINUOUS TEST’ switch in the ‘OFF’ position.

3) Hold down the ‘CABLE SIZE’ and the ‘SINGLE TEST’ switches simultaneously. Power up the unit. The display should read ‘THRESHOLD CHANGE MODE’. Release the two switches. After three seconds, the display switches to ‘VOLTAGE ACROSS MAN ALLOWED <u>1</u>00V’.

4) Refer to Figure 2. The voltage displayed on the second line will be the voltage across the man used to calculate the maximum values for the thresholds. This voltage can be adjusted using the ‘CABLE SIZE’ and the ‘CONTINUOUS TEST’ switches as described in 5 & 7.

5) Select and underline the number to be changed by using the ‘CONTINUOUS TEST’ switch.

6) Use the ‘CABLE SIZE’ switch to change the number of the voltage that is underlined. The number will increase to 9 and then change back to 0. The number on the left will change between 0 and 2.

7) When the desired voltage is displayed, press the ‘SINGLE TEST’ switch. If you enter an incorrect voltage, start again from Step 1.

TEST SETUP

Figure 3 shows the test setup required to test a protective ground set. The protective ground set under test must always be connected between the fixed connection connections regardless of the mode of testing. The ground set carries the test current from one fixed input to the other during testing. Without the ground set, the resulting open circuit prevents the resistance measurement. If the ground set is left unconnected and the ‘INPUT SELECT’ is in the ‘FIXED’ position, the display will read ‘OVER RANGE’ after a test. If the ground set is left unconnected and the ‘INPUT SELECT’ is in the ‘PROBE’ position, the display will be erratic. The erratic display is unpredictable and does not indicate resistance.

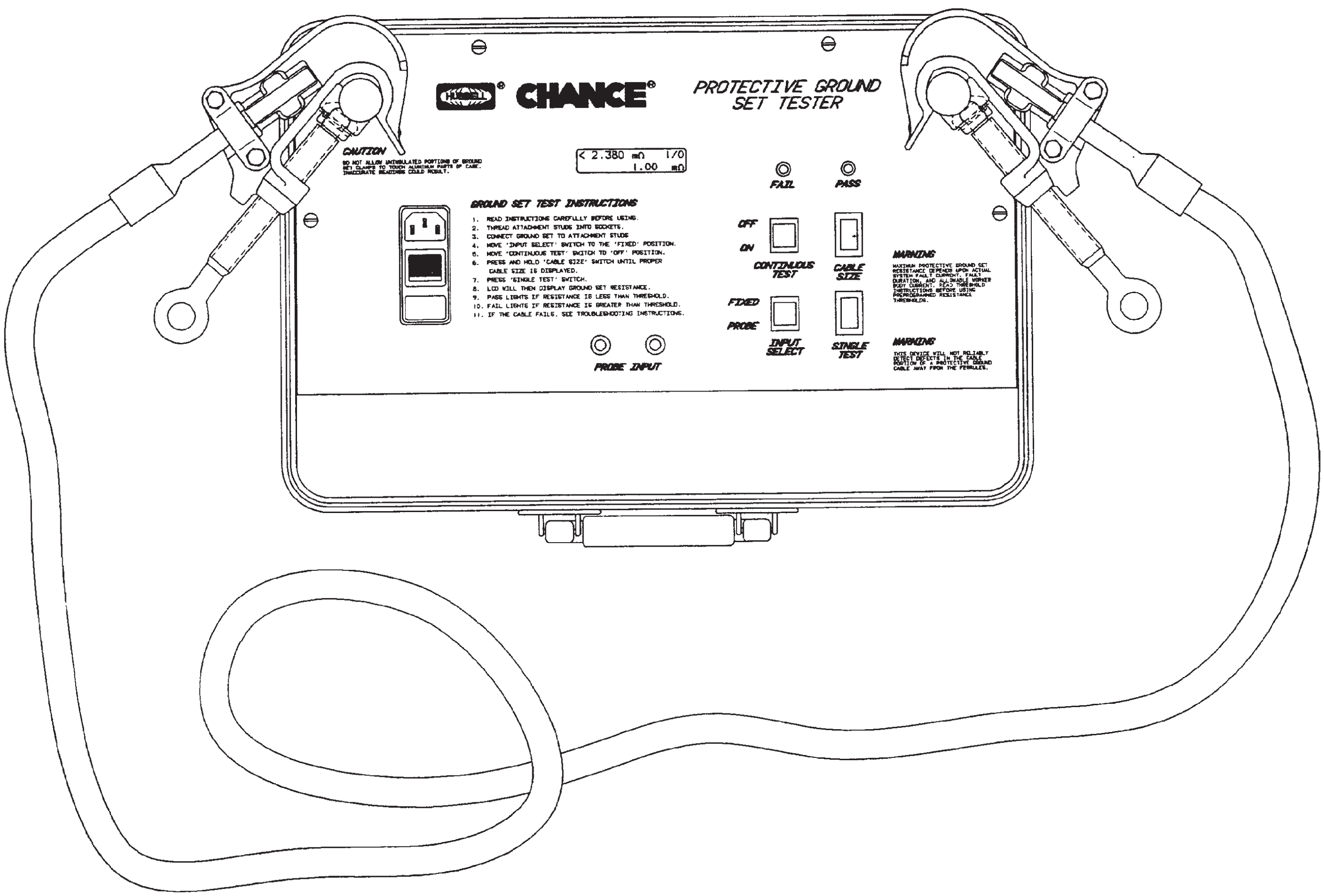

Figure 3: Ground Set Testing Setup

GROUND SET TEST PROCEDURE

Use the Self Test Procedure to verify operation of the Ground Set Tester before testing Ground Sets.

1. Place the tester on a table of convenient height and plug it into a nominal 120/240V AC outlet.

2. Thread the attachment studs into the fixed connection inputs.

3. Securely connect the Grounding Set to be tested to the attachment studs. A low resistance connection must be maintained while testing the ground set. (Figure 3 shows typical test setup.)

4. Turn on the unit. The power switch will illuminate when the power is on.

5. Use the 'CABLE SIZE' switch to select the cable size being tested. The cable size is displayed at the end of the first line of the display.

6. Place the 'INPUT SELECT' in the 'FIXED' position.

7. Place the 'CONTINUOUS TEST' switch in the 'OFF' position.

8. Press the 'SINGLE TEST' switch.

9. The display will show the measured resistance between fixed connections on line 2 of the display in mΩ.** When used in fixed mode the resistance displayed includes the contact resistance of the connection studs to the ground set. The red light will illuminate if the ground set resistance is above the preset threshold shown on line 1 of the display (see notice below). The green light will illuminate if the ground set resistance is below the preset threshold. NOTE: Ground sets to be used in parallel with the worker must pass the preset threshold resistance. Ground sets not used in parallel with the worker must meet the expected resistance for the cable size and length. Refer to Section "EXPECT-ED GROUND SET RESISTANCE" for Ground Sets not covered by preset threshold.

**mΩ (milli ohm) = 0.001 ohm

WARNING

Chance protective ground set tester is not designed nor recommended for detecting cable flaws. Problems with the cable, away from the ferrule exit area, are often intermittent in nature.

NOTICE

If the ground set fails (red light) there are two possibilities.

1. **The ground set has a problem. Use probes to identify the high resistance section. See section GROUND SET TROUBLESHOOTING WITH PROBES.**

2. **Cable is improperly sized for the application (AWG or length). See Appendix A for maximum resistance determination.**

GROUND SET TROUBLESHOOTING WITH PROBES

The following sections describe how to use the probes in troubleshooting a ground set. Using the probes in this mode, the high resistance areas of the ground set can be identified.

1. Place the tester on a table of convenient height and plug it into a nominal 120/240V AC outlet.
2. Thread the attachment studs into the fixed connection inputs.
3. Connect the Grounding Set to be tested to the attachment studs. A low resistance connection must be maintained while testing the ground set. Figure 3 shows typical test setup.
4. Turn on the unit. The power switch will illuminate when the power is on.
5. Use the 'CABLE SIZE' switch to select the cable size being tested. The cable size is displayed at the end of the first line of the display.
6. Place the 'INPUT SELECT' in the 'PROBE' position.
7. Place the 'CONTINUOUS TEST' switch in the 'ON' position. This causes the ground set tester to repeatedly make measurements at a rate of about 1 per second.
8. In this mode the display will show the resistance across the part(s) of the ground set to which the probes are connected. Start from one end of the ground set. Take resistance readings between attachment stud and clamp body, clamp body to cable ferrule and cable ferrule to cable 12 inches from ferrule exit. Repeat test on opposite end.
9. The display will show the measured resistance from one probe to the other when contacting the ground set (on line 2 of the display in mΩ). The red light will illuminate if the ground set resistance is above the preset threshold shown on line 1 of the display. The green light will illuminate if the ground set resistance is below the preset threshold.

⚠ WARNING

Chance protective ground set tester is not designed nor recommended for detecting cable flaws. Problems with the cable, away from the ferrule exit area, are often intermittent in nature.

EXPECTED GROUND SET RESISTANCE

The resistance through a Ground Set will be equal to the resistance of the cable itself and the resistance of the cable clamps and connections to the cable. The resistance of the cable is found by multiplying the resistance per foot by the number of feet of the cable. Table 2 supplies the resistance per foot for various cable sizes. The cable clamps and connections should be less than 1 mΩ. Since there are 2 clamps 2 mΩ must be added for the clamps and connections.

For example, the expected resistance for a 32 foot 1/0 Ground Set will be less than

$$32\text{ ft} * \frac{0.098\text{m}\Omega}{\text{ft}} + 2\text{ m}\Omega = 5.136\text{ m}\Omega^{**}$$

CABLE SIZE	4/0	3/0	2/0	1/0	#1	#2
mΩ** PER FOOT [11]	0.049 mΩ	0.062 mΩ	0.078 mΩ	0.098 mΩ	0.123 mΩ	0.156 mΩ

Table 2: Resistance per foot for various sizes of grounding cable

** mΩ (milliohm) = 0.001 ohm

ERROR MESSAGES

CALIBRATE ERROR

The calibration factors have been corrupted. New calibration factors must be generated. Return to factory for repair.

COP ERROR

Computer Operating Properly Error has occurred. A problem has occurred with the power supply, its connections or an electronics failure. Return to factory for repair.

WARNING

It is the responsibility of the user to establish and maintain a maximum resistance threshold for the protective ground set to provide a safe working environment.

APPENDIX A: THEORY OF RESISTANCE THRESHOLD DETERMINATION

Although substantial research has been conducted to determine the reaction of the human body to various levels of current, no single value can be given as a safe level for all situations. Research has determined that the body's reaction is dependent upon the time duration as well as the magnitude of the current flow [1], [2], [8]. Other variables to consider are: the protective grounding method employed [3], the fault current available [4], the assumed body resistance of the protected worker [1], [5] along with his weight [3] and the level of protection being sought by the user. Ultimately the safety department of the using utility must give due consideration to the variables which affect the degree of worker safety which that utility desires to achieve. Values of each variable may differ from utility to utility, or even from work site to work site. Once the variables are defined, the equations discussed below can be used to establish a maximum resistance value for protective grounds issued to workers for use in a predefined area.

For example, a nearly equipotential zone can be created by placing a protective ground in parallel with the worker at the work site [4]. The allowable resistance of the protective ground can be higher for low values of available fault current than for very large values. Also, fast backup circuit protective devices remove the body current quicker, allowing a somewhat higher body current to flow and still achieve a level of protection. Many standards and reference literature use 1,000 ohms as the worker's body resistance [3]. While this may be not be totally correct, it provides a basis for calculations.

Charles Dalziel, a noted researcher, has published charts which are widely used in the utility industry today [1], [2], [3], [4]. He determined statistically that the average perception current, the least current detectable by the body, to be 1.2 milliamperes and the average let-go threshold to be 9 milliamperes [1], [6]. He further determined that 99.5% of those receiving shocks will not go into heart fibrillation if the shock current, for a specified duration, is below the value calculated by Equation 1. [1], [3], [9]:

$$I = K/(\sqrt{t}) \qquad \text{Eq. 1}$$

Where:

- I = Current flowing through body's chest cavity, in milliamperes
- t = Duration of current flow, in seconds
- K = A constant related to the electric shock energy
  - 116 for a 110 lb. man or,
  - 157 for a 154 lb. man or,
  - 165 for a 165 lb. man

Possible ventricular fibrillation thresholds, with time dependency, may occur above:

0.03 second shock 1,000 milliamperes
3.00 second shock 100 milliamperes

Figure 1 illustrates a parallel protective grounding scheme is used [4], [10], the current flow through the worker is:

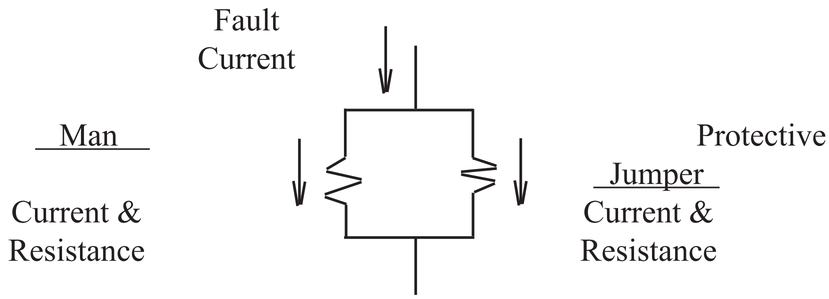

Figure 1

$I_m = I_f \cdot [R_j/(R_j + R_m)]$ Eq. 2

Where:

I_m = Current through the man, in amperes
I_f = Available fault current at the work site, in amperes
R_j = Resistance of the parallel jumper, in ohms
R_m = Resistance of the worker, in ohms

Equation 2 can be rearranged to calculate the maximum jumper resistance, for a given set of conditions.

$R_j = R_m \cdot [I_m / (I_f - I_m)]$ Eq. 3

Example 1:

Assume: R_m = 1,000 ohms K = 157
I_f = 1,000 Amp. t = .25 Sec.

I_{max} = 314 milliamperes, fibrillation threshold (from Eq. 1)

With 3:1 safety margin:

R_j = 100 milliohms for any parallel protective ground length (Eq. 3 divided by 3)

Some utilities, in order to provide a margin of safety in the assumptions used, for their own circumstances, may desire to limit the maximum voltage drop across the worker to 100 V. If this is the desired approach, equation 4 provides the limiting body current value.

$I_m = V_m / R_m$ Eq. 4

For the same worker as defined in Example 1

I_m = 100 V. / 1,000 ohm = 100 milliamperes (from Eq. 4)

R_j = 100 milliohm, for any parallel protective ground length.
(from Eq. 3)

For each multiple increase in current either the maximum calculated protective ground resistance must be divided by the multiple or a new calculation must be made, to reduce the protective resistance accordingly. For multiples of the 1,000 Amp. fault current given above:

Fault Current	Multiplier	Maximum Resistance
2,000	2	50 milliohms
5,000	5	20 milliohms
10,000	10	10 milliohms

Results of calculations illustrating the body current level, below which 99.5% of the affected workers will not experience heart fibrillation, is shown in Chart 1 and Graph 1. This chart is based upon C.F. Dalziel's research and widely used industry values. Calculations were made using equation 1, with the variable being time duration of current flow. Chart 2 and Graph 2 illustrate the maximum allowable resistance of the protective ground, based upon the constraint that the maximum voltage drop across the man will never exceed 100 volts, at fault current level below the selected value. Equations 3 and 4 were used, the variable being the fault current available. These charts and graphs are presented for information only.

The appropriate department of the using utility MUST define the method and level of protection they wish to use. The values for the variables can then be defined for that utility. See the sample calculation on page 16.

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[10] King, C.C., TECHNICAL CONSIDERATIONS IN PROTECTIVE GROUNDING AND JUMPERING, A.B. Chance Co. bulletin no. 9-8001 (Rev. 1-84 CCG 5M)

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SAMPLE DEVELOPMENT OF CHART

WARNING

The following is only for illustrative purposes. Actual fault current, fault duration and permissible maximum worker current MUST be determined for the specific power system on which the grounding sets are to be used.

Failure to select actual system fault currents, fault durations and permissible maximum worker current may result in personal injury and death.

Assumptions:

Workers weight and body resistance = 165 lbs. and 1,000 ohms

Maximum available fault current, at using locations = 12,000 Amp. RMS

Back up breakers maximum operation time = 20 cycles (.333 sec.)

Utility's Accepted level of safety:

$V_{\text{worker max}}$ = 100 Volts

$I_{\text{worker max}}$ = 0.100 ampere = 100 milliampere (from Eq. 4)

Maximum parallel jumper resistance allowed: (from Eq. 3)

R_j = 1,000 ohms X (.1 Amp. / (12,000 Amp. - 0.1 Amp.)) = 8.3 milliohm

As check on margin of safety (from Eq. 1)

$I_{\text{fibrillation threshold}} = 165 / \sqrt{.33}$ sec. = 288 milliamp

The 8.3 milliohm value represents the maximum value of protective ground resistance allowed. This value should be clearly printed on an appropriate size paper and placed in the lid of the tester, under the protective cover provided. This value now represents the maximum safe level of resistance for any protective ground to be placed in parallel with a worker in the previously defined work areas.

Chart 1

99.5% of Workers Will Not Experience Heart Fibrillation At Currents & Durations Below:
(Based Upon C.F. Dalziel's Research)

Assume: 154 Lb. Man @ 1,000 ohm resistance

time (cycles)	Iman (mA)	Maximum Jumper Resistance (mohm) @ Available Fault Current		
		1000	5000	10000
2	860	861	172	86
3	702	703	140	70
4	608	608	122	61
5	544	544	109	54
6	496	497	99	50
7	460	460	92	46
8	430	430	86	43
9	405	406	81	41
10	385	385	77	38
11	367	367	73	37
12	351	351	70	35
13	337	337	67	34
14	325	325	65	33
15	314	314	63	31
16	304	304	61	30
17	295	295	59	29
18	287	287	57	29
19	279	279	56	28
20	272	272	54	27
21	265	265	53	27
22	259	259	52	26
23	254	254	51	25
24	248	248	50	25
25	243	243	49	24
26	239	239	48	24
27	234	234	47	23
28	230	230	46	23
29	226	226	45	23
30	222	222	44	22

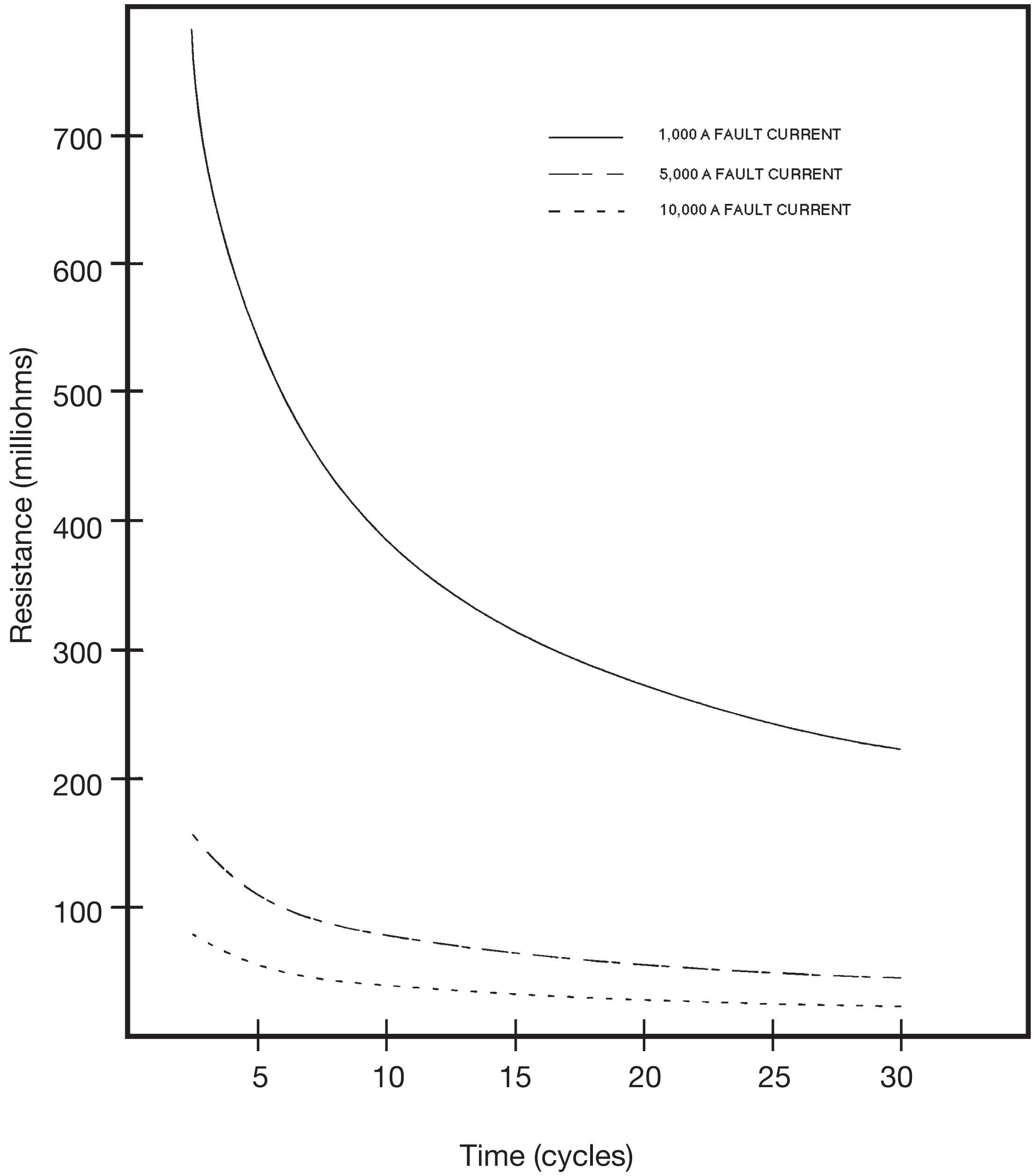
Chart 2

The Maximum Voltage across the man will be limited to 100V AC if the maximum jumper resistance is limited to the value associated with the selected maximum fault current available

Maximum Ifault (Amp.)	Rj Maximum (Milliohm)
2000	50.0
4000	25.0
6000	16.7
8000	12.5
10000	10.0
12000	8.3
14000	7.1
16000	6.3
18000	5.6
20000	5.0
22000	4.5
24000	4.2
26000	3.8
28000	3.6
30000	3.3
32000	3.1
34000	2.9
36000	2.8
38000	2.6
40000	2.5

Maximum Protective Ground Resistance

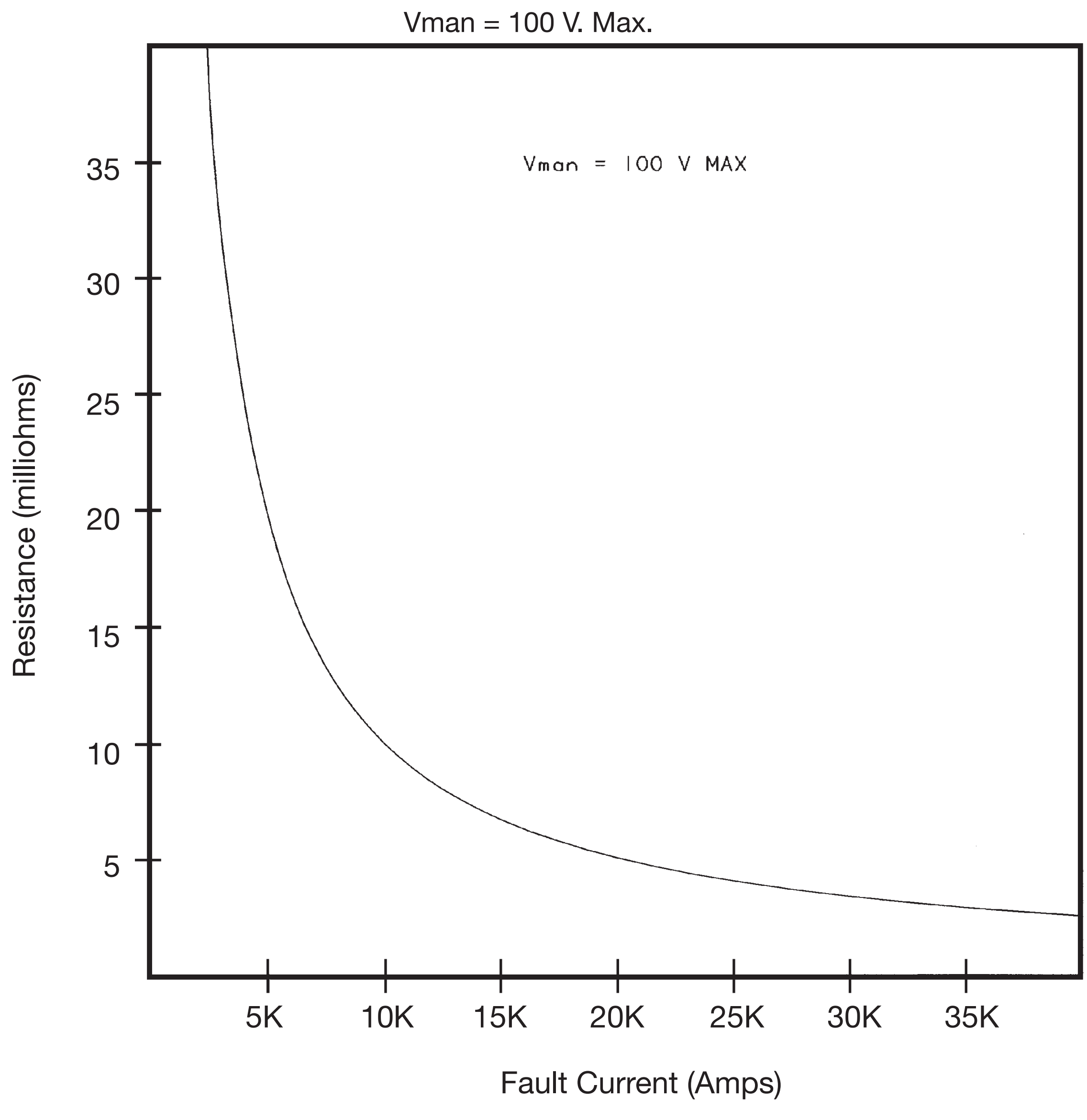
(From Dalziel's Equation)



Graph 1

This chart is based upon C.F. Dalziel's research and widely used industry values. Calculations were made using equation 1 with the variable being time duration of current flow.

Maximum Protective Ground Resistance



Graph 2

This chart represents the maximum allowable resistance of the protective ground, based upon the constraint that the maximum voltage drop across the man will never exceed 100 volts, at any fault current level. Equations 3 & 4 were used, the variable was the fault current level.

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