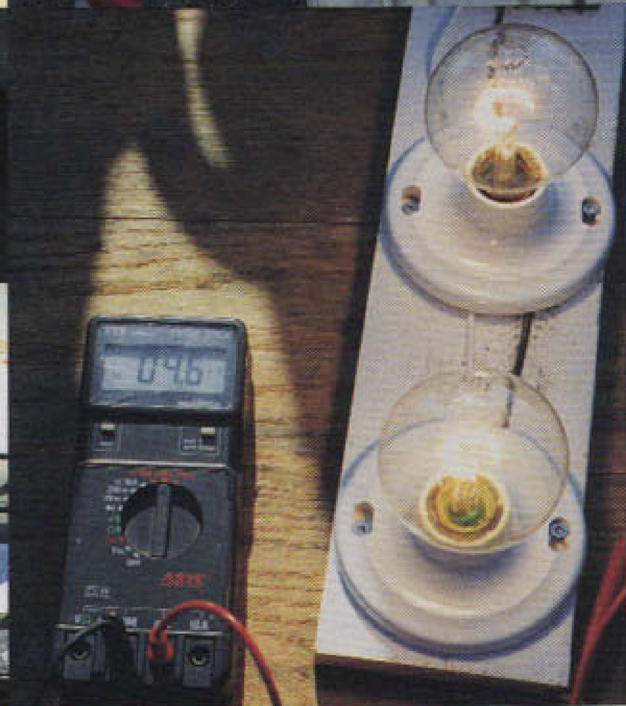
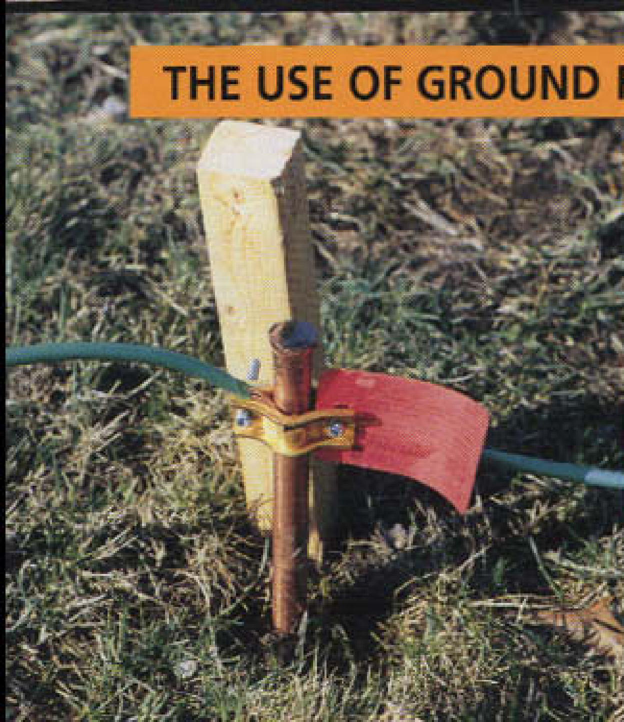
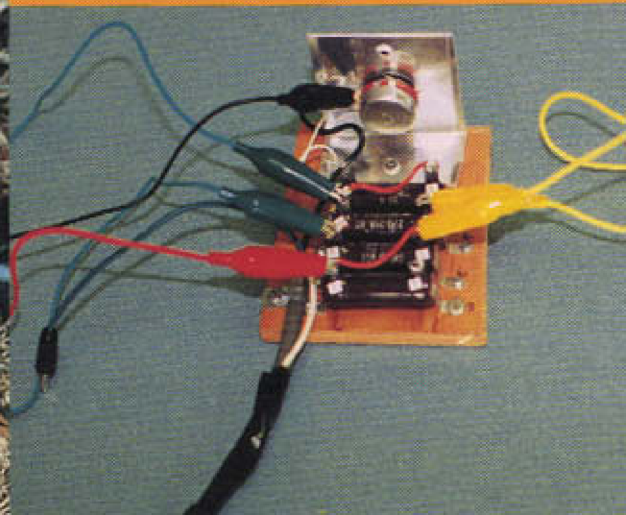
CONSTRUCTION SAFETY



THE USE OF GROUND FAULT CIRCUIT INTERRUPTERS ON PORTABLE GENERATORS





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The Use of Ground Fault Circuit Interrupters on Portable Generators

by

Francis Hardy, *Project Coordinator, CSAO*

Purpose

This report analyzes the results of tests recently conducted by the Construction Safety Association of Ontario (CSAO) The purpose is to determine the protection provided by ground fault circuit interrupters (GFCIs) on portable generators and to provide guidelines for their effective use

Background

Portable generators have been used extensively in construction wherever electricity from the local utility is not available or impractical to obtain Civil, mechanical, and electrical projects have all used portable generators to supply power to equipment such as drills, saws, and pumps

Some types of equipment in construction such as welding machines and lighting equipment have built-in generators Generators are used in all weather and are operated on all types of surfaces

Questions surrounding portable generators, grounding* requirements, neutral connections, the use of GFCIs, and relevant health and safety regulations have caused many debates in the industry

Before exploring these questions, three basic facts must be understood

1) Most new portable generators today are equipped with grounding lugs, though most manufacturers concede that grounding is seldom done in the field
2) Some people believe that a grounded electrical system is safer than an ungrounded system, while others believe the opposite
3) The difference of opinion on grounding is reflected in manufacturers' designs for portable generators ,resulting in either a bonded-neutral or a floating-neutral electrical system

Because of the potential hazards in working with electric tools especially under wet conditions, various jurisdictions have established requirements for ground fault protection Some safety regulations require that personnel use GFCIs when working in a wet environment, whatever the source of electric power

What fuels the argument over GFCIs is that some people believe that GFCIs will function regardless of the grounding arrangement of the power source, while others believe the opposite

In this report grounding or grounded refers to earth ground

Finally, although there are separate safety standards for grounding, generators, and GFCIs, none addresses the use of the three together and none addresses the problems and scenarios found in construction To compound the issue, public understanding of electricity and its hazards is minimal

To understand this report, some basic knowledge of electricity is needed Since the nature of electricity is not easy to grasp for the average person, the report has taken the liberty of presenting basic concepts in their simplest form

Electricity and Grounding

Current, voltage, resistance

Electricity always travels in a circuit or a loop When the circuit is broken, so is the flow of electricity To visualize electricity, many of its characteristics can be compared to water Like water, electricity flows This flow is called current, measured by amperes The power needed to push the flow through the circuit is voltage

Electricity encounters friction in the form of electrical resistance, measured by ohms The bigger the diameter of the electrical wire, the smaller the resistance The smaller the diameter of the wire, the higher the resistance The higher the resistance, the bigger the pressure or voltage needed to push the same current the same distance

When electrical current is given alternate paths to travel, most of the current will follow the path of least resistance In an electrical circuit, electricity primarily flows through material with the least resistance Most metals have low resistance to electricity and make excellent conductors Water also conducts electricity Human bodies, made of 90% water, are good conductors, especially when the skin is wet

Circuits

Electrical current travels from a power source (such as a generator), passes through a load (such as a drill), and returns to the power source to complete a circuit (Figure 1)

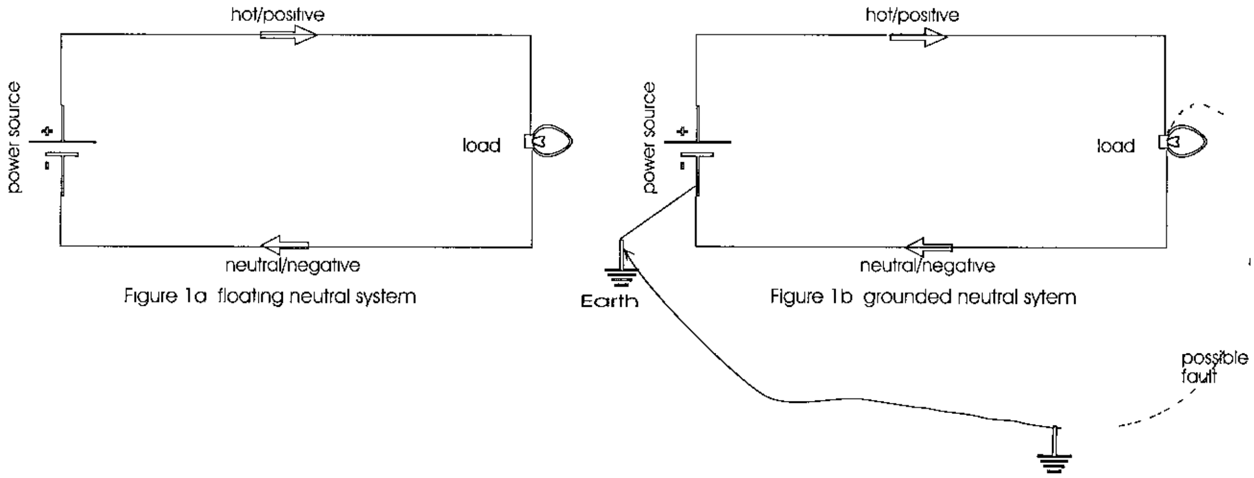


Figure 1

The part of the circuit going out from the power source to the load is called the hot or "positive" side The part of the circuit returning from the load to the power source is called the neutral or "negative" side Ideally, the current going out from the power source (hot) should be equal to the current returning (neutral) For obvious reasons, it is preferable that current travels only through electrical wires or other suitable conductors

Grounding

In a grounded electrical system, the neutral is intentionally connected to ground, making the ground an alternate part of the electrical circuit The grounded circuit can therefore be completed by electricity going either from the source to the load (through the positive side) and back to the power source (through the negative side) or from the source through the positive side to ground (negative side) and back to the power source

Faults

An electrical fault can be compared to a leak in a water hose A fault occurs when current partially leaks out of the intended path or circuit, using another path to return to the power source As a result the current flow at the hot side is not the same as the current flow at the neutral side

Common causes of current leaks are frayed electrical cords, poorly insulated tools or cords, and defective tools

There are two types of faults

1) **Current leaking directly from hot to neutral** - When the current leak is severe enough that there is no effective resistance, it produces a short circuit In such a case, circuit breakers or fuses in the circuit will trip or blow, de-energizing the circuit

2) **Current leaking to ground** - This is called a ground fault In a grounded system the current leak completes the circuit by going back to ground

Ground fault can be deadly Electrocution can occur when a worker holds a faulty tool and the current returns to ground or when a worker touches the hot side of the load A prime example is an aluminum ladder contacting an overhead powerline – one of the most common causes of electrocution in construction The fault returns current to ground using the ladder and the worker as a conductor

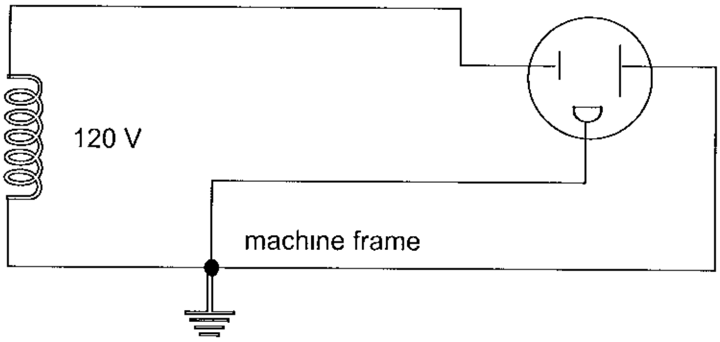
In an ungrounded system, the neutral is not bonded (or grounded) and is often called "floating " In a true ungrounded or floating system, the circuit is isolated from ground For this reason, the current has no tendency to go to ground to complete the circuit, unless the system becomes grounded by having more than one fault in the circuit

Thus a worker using a floating-neutral system could be electrocuted when there are two faults in the electrical system – one occurring on the positive side, the other on the negative

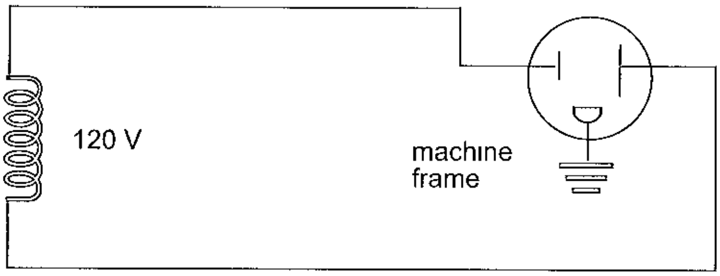
GFCIs and Portable Generators

GFCIs function by comparing current flow on the hot side with current flow on the neutral side In a faulty circuit, leaking current creates an imbalance between the flow going out (hot side) and the flow returning (neutral side) When the imbalance (measured in milliamperes or thousandths of an ampere) exceeds the allowable level, the GFCI trips, shutting off current

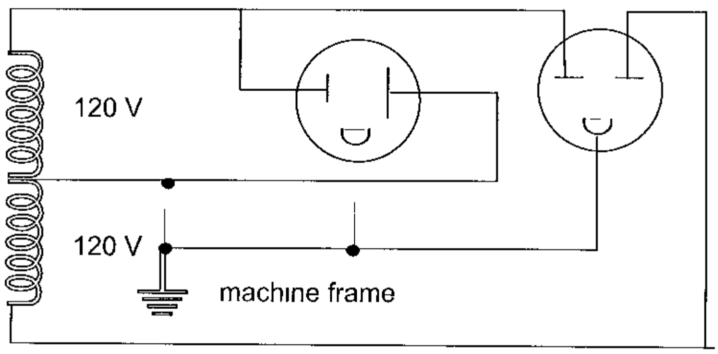
For portable generators, there are two different philosophies of safety design to guard against electrocution Some manufacturers believe it is safest not to bond the generator winding to the frame The generator is left ungrounded or "floating-neutral ' Other manufacturers bond the generator winding to the frame, making the generator "bonded-neutral "



For power > 5kW, two wire circuit, bonded-neutral system



For power < 5kW, Voltage < 150 V
two-wire circuit, floating-neutral system



For 3 wire-circuit, bonded-neutral system

Figure 2

The Canadian Standards Association (CSA) has two standards for generators: CAN/CSA-C22.2 No. 100-95, Motors and Generators, and CAN/CSA-C22.2 No.145-M1986 (reaffirmed 1992), *Motors and Generators for Use in Hazardous Locations.*

CSA has also issued a Technical Information Letter No. D-19 (10 March 1992) addressing overcurrent protection for ungrounded circuits and grounding of 2-wire and 3-wire circuits in arc welding equipment and generators.

This document permits three grounding methods, depending on power output and voltage. The wiring configurations are illustrated in Figure 2. A requirement for portable generators using GFCIs is mentioned in CAN/CSA-C22.2 No.100-95. Clause 11.3.2.(c) states that "generators equipped with GFCIs shall have the neutral bonded to the frame."

CSAO Tests

Conditions

The Construction Safety Association of Ontario (CSAO) conducted a series of tests to determine the effectiveness of GFCIs used on portable generators in typical construction scenarios.

The tests focused on the most common type of generators found in construction – namely, portable generators that can be handled and moved by one or two workers.

Larger portable generators exist, but their operation is based on established grounding that meets the requirements of the electrical code. Grounding and GFCIs are not an issue for these generators.

The following are the most likely locations for portable generators in construction:

1) **wet ground** - including ground, grass, and mud

2) **dry surfaces** - including sand, rock, concrete slab, and pavement

3) **isolated** - including floorbeds of utility vehicles, wooden pallets, barges, and docks.

In addition to different surfaces, the CSAO tests had to cover variable grounding conditions. These were

1) proper ground

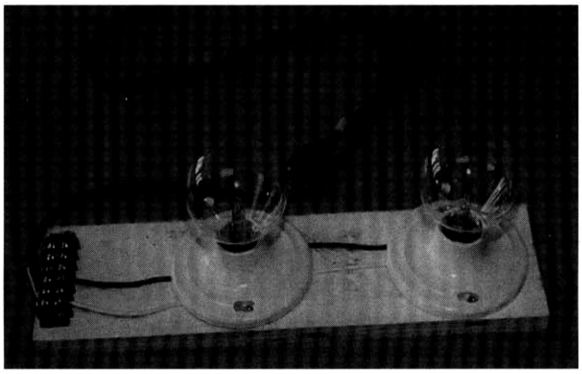
2) ground with some resistance

3) no ground.

Apparatus

Load

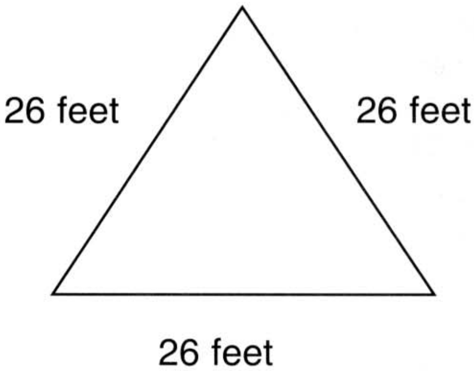
The load consisted of two 150-watt light bulbs connected in series (Photograph 1).



Photograph 1

Grounding

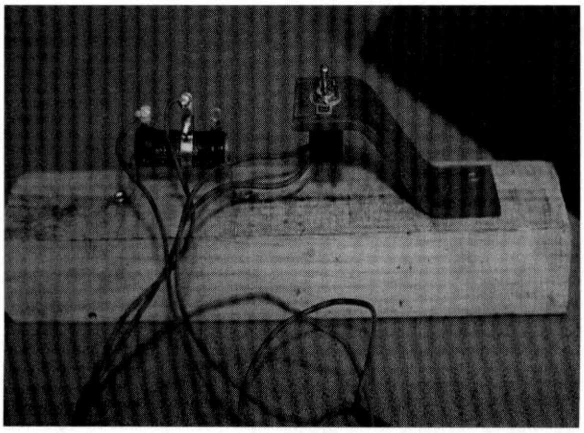
Ground Rods
Three 10-foot copper ground rods were driven at 26 feet apart in a triangular configuration. Two ground rods are connected by one Φ (AWG) wire. The wires are secured to the ground rods by means of 1/2" to 1" brass clamps (Photograph 2).



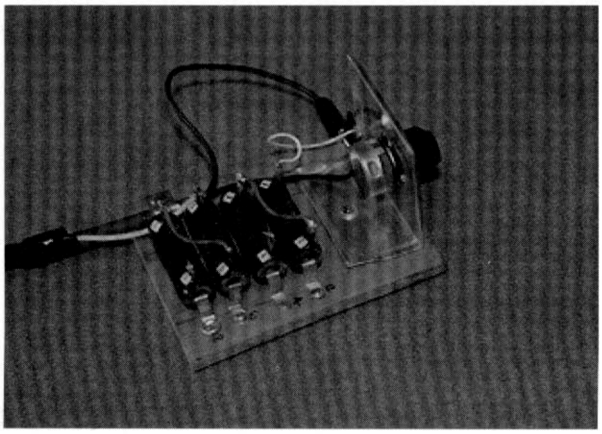
Photograph 2

Resistor for Grounding Unit
The grounding unit shown in Photograph 3 is made up with one 2-kOhm IRC variable resistor set to give 1.2 kOhm resistance. The resistor can be switched on and off by means of a toggle switch. Each end of the wire is connected to a battery clamp.

Rheostat or Variable Resistance Unit
The rheostat is used to simulate current leak to ground (ground fault) – Figure 3 and Photograph 4. This unit is composed of a 2 Amp PEC 10-kOhm adjustable rheostat and four 15-kOhm Ohmite resistors.



Photograph 3



Photograph 4

Multimeter
Two multimeters were used In the first series of tests, an ITT Metrix MX20 with an accuracy of ± 0 1 mA was used This meter was calibrated prior to testing The second series of tests used a Beckman Tech 300, with an accuracy of ± 0 1mA

Ground Fault Circuit Interrupters
Two types of GFCIs were used extension cord type and receptacle type All GFCIs were tested for their trip level one day before tests were conducted The extension cord types were Windmere Corporation Model Number ESP-06, Class A, 120 volts, 60 Hertz, 15 amps, the receptacle types were Leviton, Model Number DDFT-A, 125 volts, 60 Hertz, 15 amps Both models were designed to trip under 5 milliamps

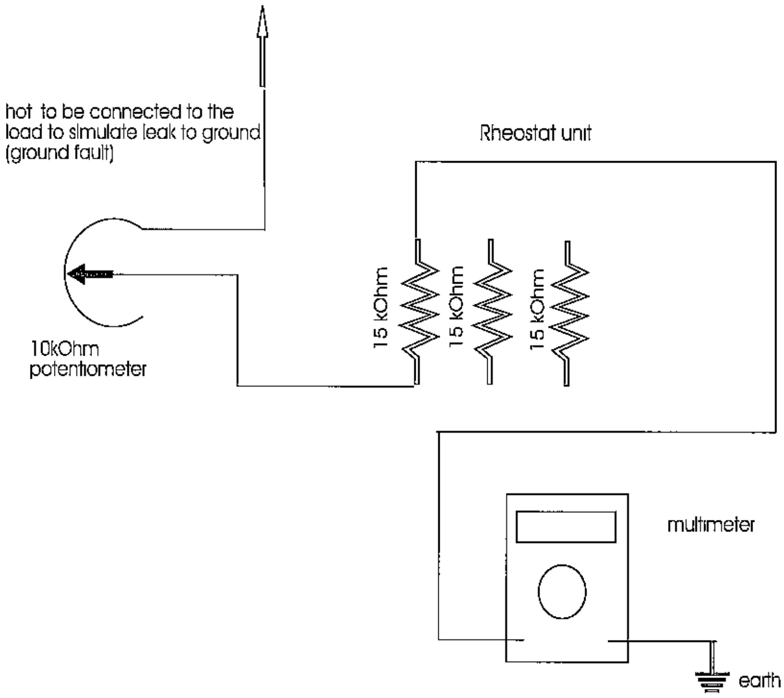


Figure 3

Generators
Two generators were used in the tests The first series of tests used a Kubota AE 3500 rated at 25 amps for 120 volts (AC) and 10 amps for 12 volts (DC), with output of 3000 watts The Kubota generator has a two-wire circuit that comes from the manufacturer with the coil winding bonded to the frame

The second series of tests used a Coleman 1700 rated at 11 amps for 120 volts (AC) and 15 amps for 12 volts (DC), with output of 1350 watts The Coleman generator was also bonded to the frame

Procedure

Duration
The first series of tests was two hours in duration, while the second series, done on a different day, took less than an hour Soil and weather conditions were similar for each test

First series

In the first series of tests, two types of neutral wiring connection were tested bonded-neutral and floating-neutral

To convert the generator from a bonded-neutral to a floating-neutral circuit, the bond from the generator winding to the frame was disconnected

Four rubber mounts were used to isolate the generator winding from the frame, making the generator floating-neutral

Figure 4 shows the flowchart of testing procedures

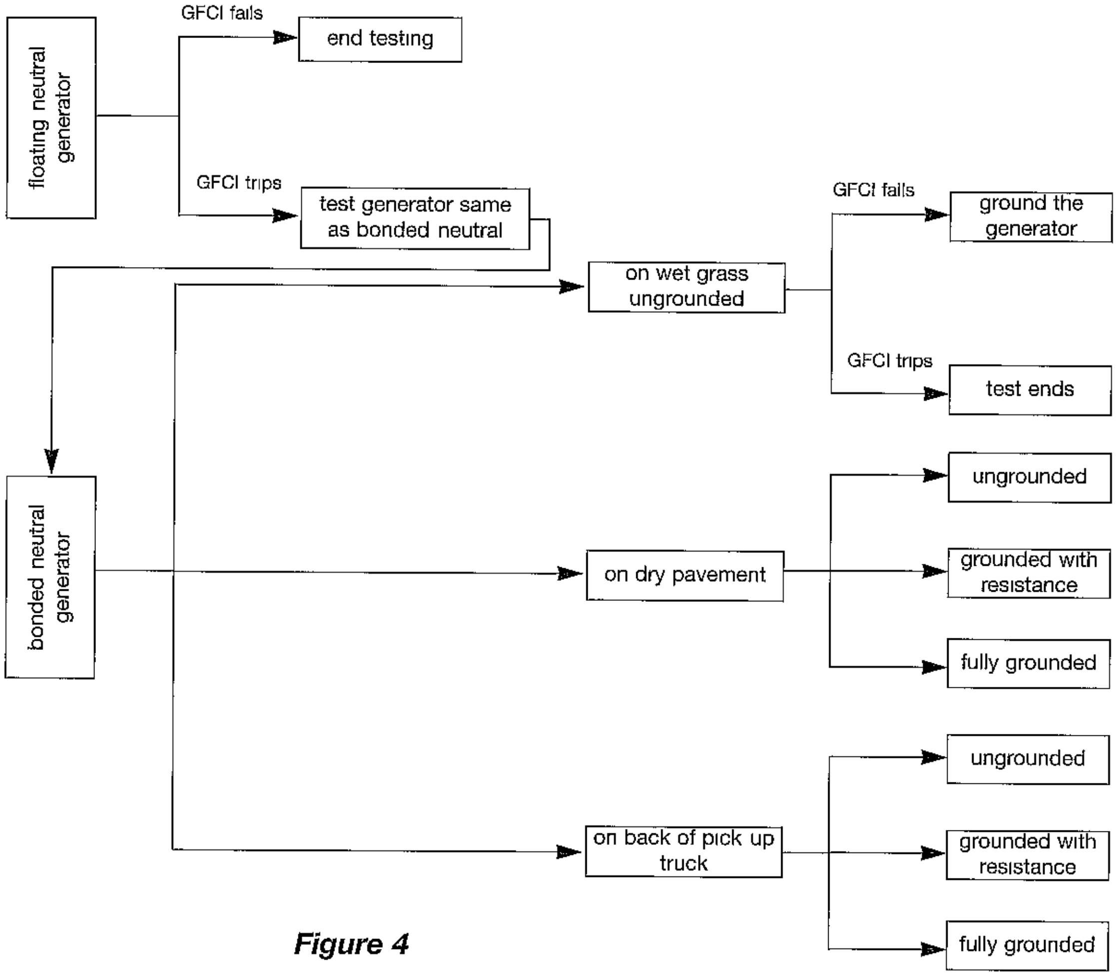


Figure 4

The floating-neutral generator was tested first, sitting on wet grass To achieve wet ground conditions, the ground was hosed with water for 5 minutes before testing Since the test was conducted in spring, the ground was already relatively wet

The floating neutral generator was never grounded since there was no connection from the generator winding to the frame and ground (Figure 5) If the test with the floating-neutral generator failed to trip the GFCI, no further testing with floating-neutral generators would be done

However, if the GFCI tripped in the initial set-up, testing on the floating-neutral generator would continue with tests similar to those for the bonded-neutral generator

The bonded-neutral generator was tested on three surfaces wet grass, dry pavement, and the back of a utility vehicle

Tests conducted with the generator sitting on dry pavement and in the back of a utility vehicle had the generator connected to three grounding conditions (Figures 6, 7, and 8)

Placing current on the load was done by pushing the reset button on the GFCI The current leak was produced by connecting a parallel circuit to the hot wire at the terminal block and directing it to ground via the unit of resistors and the multimeter

In all tests, current leak started below the 5 mA level and was increased by reducing resistance in the rheostat The starting resistance level was established by trial and error As can be seen in the test results, the initial resistance level had to be adjusted in some instances

Second series

The purpose of the second series of tests was to determine (a) whether a floating-neutral circuit can inadvertently become a grounded circuit by having a positive and neutral fault in the circuit, and (b) the correct placement of the GFCI in the circuit, if the floating-neutral circuit can become grounded by two faults

All tests were conducted with the generator sitting on dry pavement Two electrical cords were tested Both were 10 metres long One had no defects, the other included several splices and exposed wires covered by electrical tape

All tests were done with the electrical cord running across wet ground Trials were also done with wires in the defective cord bare, in contact with wet ground, and covered with moist dirt (Figure 9)

Summary of Test Results

First series

a) Floating-neutral generator (Figure 5)

A ground leak of 0 6 mA was detected on the multimeter as electrical power from the floating-neutral generator was switched on No change on the multimeter was observed when the leak to ground was increased by reducing resistance in the rheostat Current still flowed as the ground leak was set at full Since the GFCI failed to trip in this test, further testing with floating-neutral generators was terminated

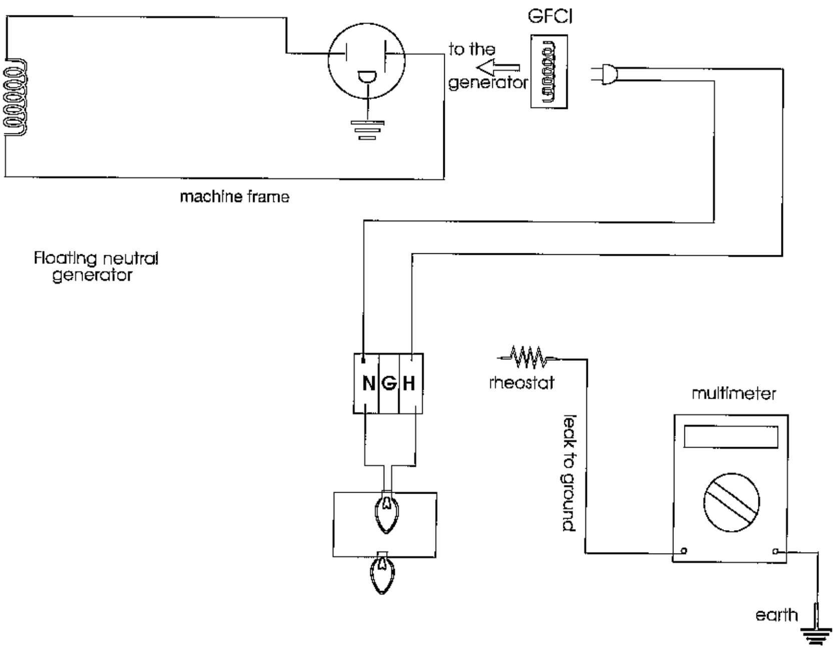


Figure 5

b) Bonded-neutral generator

Wet grass (Figure 6)

With the bonded-neutral generator sitting on wet ground and electrical power switched on, a starting ground leak of 4 6 mA was detected, tripping the GFCI immediately The initial resistance at the rheostat was set at 15 kOhms When the initial resistance was reset at 22 kOhms, a starting leak of 4 3 mA was registered The GFCI tripped at 4 6 mA as resistance was gradually reduced at the rheostat

Dry pavement (Figure 6)

The generator was placed on dry pavement ungrounded The reading on the multimeter was 0 1 mA when power was switched on As the leak to ground was increased by minimizing the resistance at the rheostat (Figure 8), no change in the multimeter was detected

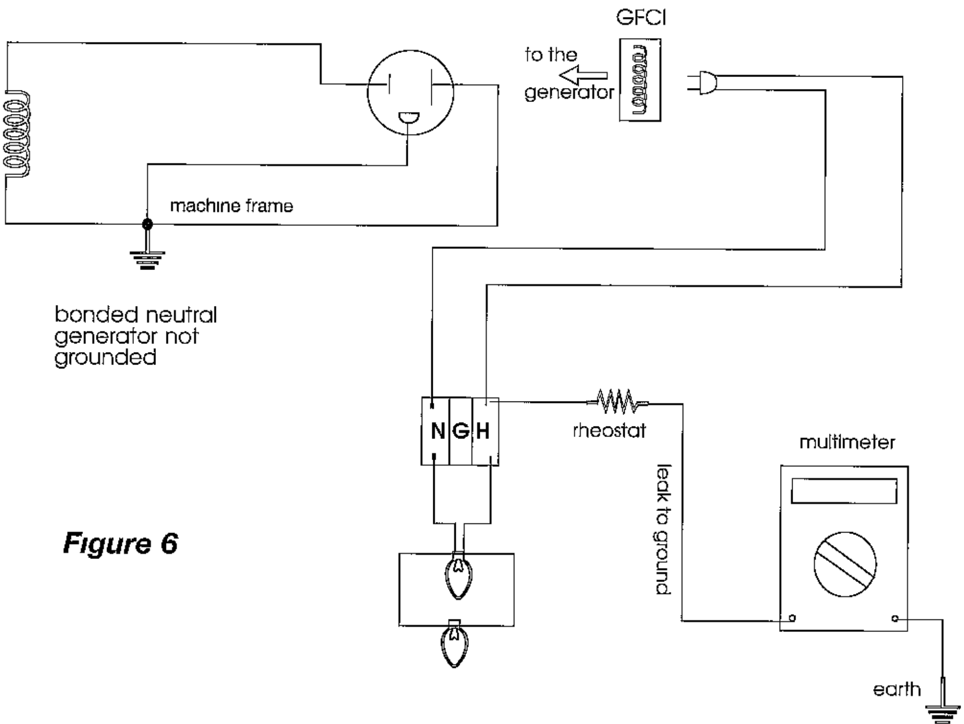


Figure 6

When the generator was grounded by connecting it to the ground rod with 1 2 kOhm resistance, the multimeter registered a 4 2 mA ground when the power was turned on Initial resistance at the rheostat was set at the 22 5 kOhm level The GFCI eventually tripped at 4 6 mA

The second test tripped the GFCI at 4 7 mA The test was repeated using grounding with no resistance (Figure 7) The test was done three times with the GFCI tripping at 4 9 mA, 4 8 mA, and 4 8 mA Initial resistance at the rheostat was set at 22 5 kOhm, 15 kOhm, and 15 kOhm respectively

Next, the generator was grounded by connecting the grounding cable to a 12-inch long rusted screwdriver

Initial resistance at the rheostat was 15 kOhm Two tests tripped the GFCI at 4 5 mA and 4 6 mA The same test was done with a 6-inch long steel reinforcing bar set in moist ground The GFCI tripped at 4 8 mA Then the generator was moved to another spot and was grounded by means of the same rusted screwdriver but in a sloped area No current leak to ground was read at the multimeter, even when the resistance at the rheostat was set at a minimum The GFCI did not trip in this scenario

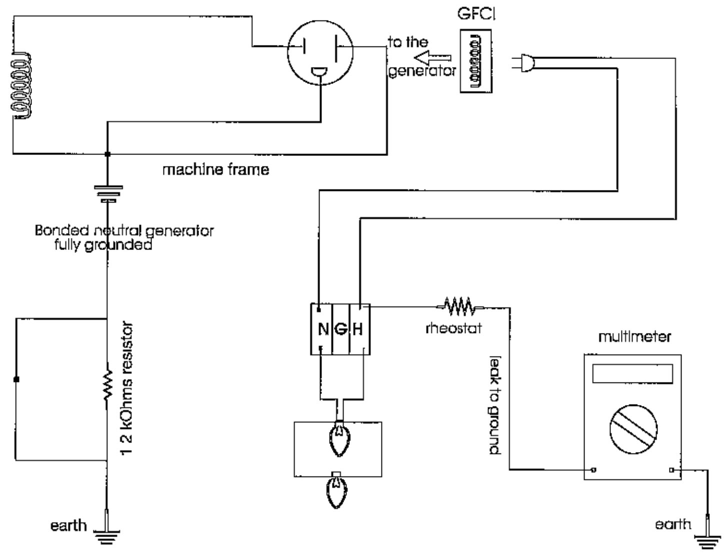


Figure 7

In the back of a utility vehicle

First, the generator was placed in the back of a utility vehicle ungrounded (Figure 6) Current was leaked to ground with initial resistance at the rheostat of 15 kOhms No ground leak was detected and no change was registered when the resistance to ground was minimized

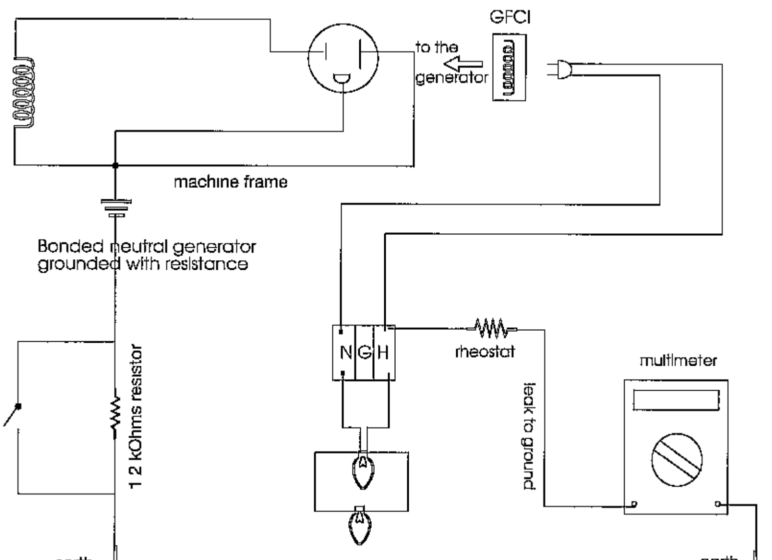


Figure 8

The generator was then grounded by connecting the ground wire to a screwdriver inserted in wet ground The resistance in the ground wires was 1 2 kOhms The GFCI responded by tripping at 4 8 mA When the generator was grounded to a ground rod (Figure 8) the GFCI tripped at 4 8 mA In addition to these tests, the test button on the GFCI was tested on the generator with floating-neutral and bonded-neutral wiring In both cases, the test button worked without fail

Second series (Figure 9)

The generator was connected to an extension cord with no defect The GFCI was plugged directly to the generator with only a positive fault The resulting leak to ground was detected at 0 1 mA

Next, the defective extension cord was tested The stripped wires were covered by electrical tape and the GFCI was plugged directly to the generator The leak to ground was 0 18 mA When the bare wire was exposed, the leak to ground increased to 2 8 mA

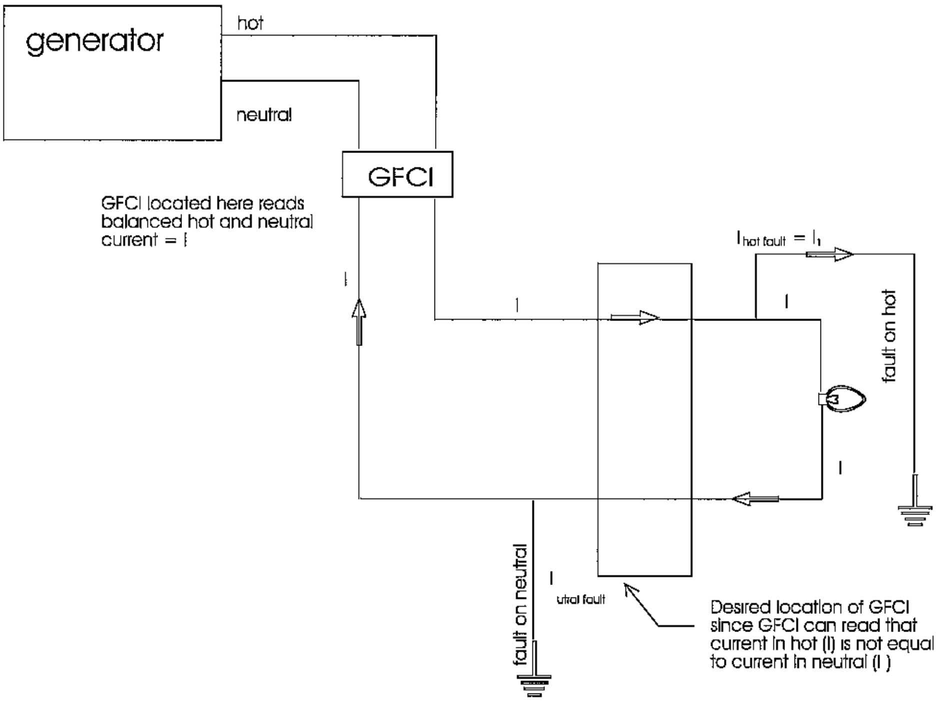


Figure 9

The next test had the bare wire covered by moist dirt, with the GFCI plugged directly to the generator This condition simulates a defective cord being dragged through mud The initial leak to ground was found at 10 mA, with the GFCI not tripping When the resistance in the rheostat was reduced as low as it possibly could, the reading reached 18 mA and still the GFCI did not trip

The GFCI was now relocated next to the load The reading at the multimeter reached 5 5 mA before tripping the GFCI

First and second series test results are included in the appendix to this report

Analysis

It is clear that when generators of the floating-neutral or bonded-neutral type sit on dry surfaces in dry environments, they behave similarly In both cases, the GFCIs failed to trip In addition, the reading of little or no current on the multimeter indicated that there was not enough electricity leaking to ground to constitute a hazard In both cases, the GFCI did not trip when there was only one ground fault in the system

When effective grounding was established, GFCIs performed as expected Testing also proved that wet surfaces can create grounding for bonded-neutral generators When a bonded-neutral generator was placed on wet ground, the GFCI tripped under the prescribed current leakage

However, testing also showed that grounding can vary from one place to another, even when both are relatively close In one test, a variation in ground elevation yielded different results When the screwdriver was inserted in wet ground, the GFCI tripped When the screwdriver was moved 100 feet to a slope that had better drainage, the GFCI did not trip

The second series of tests showed that the placement of the GFCI in the circuit is critical to a floating-neutral system (Figure 9)

When the GFCI was plugged directly to the generator, the GFCI failed to detect any imbalance in the current As a result, it did not trip even when the current leak reached a higher than acceptable level When the GFCI was placed at the tool, however, it tripped at the prescribed level

Conclusions

Since the GFCI test button functioned regardless of the generator's grounding property, GFCI test buttons cannot and should not be used to test the effectiveness of GFCIs as personnel protection or the grounding of portable generators The test button should only be used to test GFCIs **after** grounding has been established

Portable generators *with established ground* must be treated the same way as any grounded utility system Workers must be protected by GFCIs to prevent electrocution by ground fault Ground should be established and verified only by competent workers trained to do so and using specialized instruments

Generators with established ground allow a GFCI mounted at the generator outlet to work effectively When there is a current leak, the current goes to ground to complete the circuit This creates an imbalance, causing the GFCI to trip When generators with established ground are being used, GFCIs should be located *closest to the generator,* protecting all workers from ground faults, not just the generator user

Construction people complain that GFCIs trip unnecessarily, especially with extension cords As a result, personnel often consider GFCIs a nuisance and don't use them But GFCIs trip for a reason These trips should be treated as a warning that there is a ground fault in the system When a GFCI trips, tools, cords, and plugs should be inspected for defects and, where necessary, replaced before work continues

When the electrical system does not have reference to ground, GFCIs mounted on the generator do not work With one fault, not enough current leaks to ground to be considered a hazard

Thus, in a floating-neutral circuit, workers are not endangered by electrocution from current going to ground *as long as there is only ONE fault in the system*

However, with two faults in the system, one on the neutral and one on the hot side, it is possible that the floating-neutral system can become grounded In that case, workers without properly located GFCIs can be electrocuted Two faults can be produced by a defective generator, poorly insulated or defective extension cord, defective tool, or defective plug, to name just a few causes Other conditions such as wet ground, rain, or high humidity can increase the risk that the electrical system will become grounded

Testing showed that in a two-fault system, the placement of the GFCI is critical The GFCI must be placed between the two faults in order to function Since the likely locations for faults are tool cord, tool plug, and extension cord, the GFCI should be placed *closest to the tool*

Last but not least, the hazards of electrocution can be minimized by using only double-insulated tools in good working order and well-insulated cords

APPENDIX
TEST DATA

GFCIs used in Tests

GFCI number	Type	Trip Level 1st [mA]	Trip Level 2nd [mA]	Trip Level Average
1	extension cord	4.9	4.9	4 9
2	extension cord	4.8	4.8	4.8
3	extension cord	4.9	4.9	4.9
4	extension cord	4 8	4.8	4 8
5	extension cord	5.0	5.0	5.0
6	extension cord	4.9	4.9	4.9
7	receptacle	4 9	4.9	4 9
8	receptacle	4.7	4.7	4.7
9	receptacle	4.3	4.3	4.3
10	receptacle	4.5	4.5	4 5
11	receptacle	4.5	4.5	4.5
12	receptacle	4.5	4 5	4.5
13	receptacle	4.3	4.3	4.3
14	receptacle	4 3	4.4	4.4

First Series of Tests

Generator's wiring configuration			Floating-neutral
Surface the generator is sitting on			wet grass
Grounding of generator			none
GFCI used & trip level			#6 - 4 9 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	0 6 mA max; did not trip.		
Comment	GFCI did not trip – no second reading.		

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			wet grass
Grounding of generator			none
GFCI used & trip level			#4 4.8 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	4 6 mA	4 6 mA	4 6 mA
Comment	Initial resistance was increased on second test to 22 5 kOhm		

First Series Continued

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			none
GFCI used & trip level			#7 - 4.9 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
none	0 mA		
Comment	GFCI did not trip		

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			grounded with 1.2 kOhm resistance
GFC used & trip level			#7 - 4.9 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
22.5 kOhm	4.6 mA	4.7 mA	4.65 mA
Comment			

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			fully grounded
GFCI used & trip level			#1 - 4.9 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
22.5 kOhm	4.9 mA	4.8 mA	4.83 mA*
Comment	*Initial resistance on second test was 15 kOhm; third test was performed with the GFCI tripping at 4.8 mA.		

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			screwdriver in wet ground
GFCI used & trip level			#8 - 4.7 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	4.5 mA	4.6 mA	4.55 mA
Comment			

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			screwdriver in dry ground
GFCI used & trip level			#1 - 4.9 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	0 mA		
Comment	GFCI did not trip.		

First Series Continued

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			half-inch reinforcing bar in semi-dry ground
GFCI used & trip level			#7 - 4.9 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	4.8 mA	4.8 mA	4.8 mA
Comment			

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			back of utility truck (half-ton pick-up)
Grounding of generator			none
GFCI used & trip level			#2 - 4.8 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	0 mA		
Comment	GFCI did not trip.		

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			back of utility truck (half-ton pick-up)
Grounding of generator			grounded with screw-driver in wet ground
GFCI used & trip level			#2 - 4.8 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	4.8 mA	4.8 mA	4.8 mA
Comment			

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			back of utility truck (half-ton pick-up)
Grounding of generator			grounded with 1.2 kOhm resistance
GFCI used & trip level			#5 - 5.0 mA
Initial Resistance	*1st trip level*	*2nd trip level*	*Average trip level*
15 kOhm	4.8 mA	4.8 mA	4.8 mA
Comment			

Second Series of Tests

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			none
Electrical system			floating-neutral
GFCI used & trip level			#6 - 4.9 mA
Location of GFCI			at the generator
Condition & location of electrical extension cord			defects insulated, cord on wet grass
Initial Resistance	*max. meter reading*	*max. meter reading*	*Average trip level*
15 kOhm	0.7 mA		
Comment	Did not trip – no significant leak to trip GFCI.		

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			none
Electrical system			floating-neutral
GFCI used & trip level			#6 - 4.9 mA
Location of GFCI			at the generator
Condition & location of electrical extension cord			wires bare, sitting in water
Initial Resistance	*max. meter reading*	*max. meter reading*	*Average trip level*
15 kOhm	2.5 mA	2.8 mA	2.65 mA
Comment	Did not trip – no significant leak to trip GFCI.		

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			none
Electrical system			floating-neutral
GFCI used & trip level			#6 - 4.9 mA
Location of GFCI			at the generator
Condition & location of electrical extension cord			wires bare, in moist dirt
Initial Resistance	*max. meter reading*	*max. meter reading*	*Average trip level*
15 kOhm	10 mA	10 mA	10 mA
Comment	Did not trip; GFCI did not read the fault.		

Second Series Continued

Generator's wiring configuration			Bonded-neutral
Surface the generator is sitting on			dry pavement
Grounding of generator			none
Electrical system			floating-neutral
GFCI used & trip level			#6 - 4.9 mA
Location of GFCI			at the load
Condition & location of electrical extension cord			wires bare, sitting in water
Initial Resistance	*max. meter reading*	*max. meter reading*	*Average trip level*
15 kOhm	5.5 mA	5.3 mA	5.4 mA
Comment	GFCI tripped; GFCI was located between the two faults.		

REFERENCES

1 Canadian Standards Association, *CSA Standard C22 2 No 100-95, Motors and Generators Industrial Products* Canadian Standards Association, Rexdale Ontario, 1995 page 41

2 Canadian Standards Association *CSA Standard C22 2 No 144-M91 Ground Fault Circuit Interrupters Industrial Products,* Canadian Standards Association, Rexdale, Ontario, October 1991

3 Canadian Standards Association *CSA Standard C22.2 No 145-M1986 (reaffirmed 1992), Motors and Generators for Use in Hazardous Locations, Industrial Products* Canadian Standards Association Rexdale, Ontario, 1986

4 John H Watt (editor) *American Electrician's Handbook,* Ninth Edition McGraw-Hill, New York 1970, pages 8-90

5 Lal Bahra, *Certification Notice, Technical Information Letter No D-19, Power Supplies and Process Control/Motors and Controls,* Canadian Standards Association, Rexdale Ontario 1992, page 3

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