**FACILITIES INSTRUCTIONS,**
**STANDARDS, AND TECHNIQUES**
**VOLUME 5-13**

# FAULT PROTECTION FOR PORTABLE AND VEHICLE-MOUNTED GENERATORS AND WELDERS

# PERSONNEL SAFETY

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***The Appearance of the Internet Version of This Manual May Differ From the Original, but the Contents Do Not***

**UNITED STATES DEPARTMENT OF THE INTERIOR**
**BUREAU OF RECLAMATION**
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## PURPOSE

The purpose of this volume is to advise personnel at all facilities of the danger posed by ungrounded and non-GFCI (ground fault circuit interrupter) protected circuits on portable and vehicle-mounted generators and welders.

Personnel at many Reclamation facilities use portable and vehicle-mounted generators and welders in the conduct of maintenance and construction. Because of the design of this equipment, as permitted by the National Electric Code (NEC), some 120-volt a-c circuits powering receptacles are not fully protected for all fault conditions.

***Unless these circuits are modified, they pose a risk to personnel in the event of a fault in both conductors or in the event of wiring errors where the neutral and grounding conductor are reversed. Circuit modification is recommended as outlined below.***

## BACKGROUND

The National Electric Code (NEC) 1996 states in Section 305-6 that all 125-volt, single-phase, 15- and 20-ampere receptacle outlets that are not a part of the permanent wiring of the building or structure and that are in use by personnel shall have GFCI protection for personnel.

**EXCEPTION**: Receptacles on a 2-wire, single-phase, portable or vehicle-mounted generator rated not more than 5 kilowatts, where the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces.

Portable describes equipment that is easily carried from one location to another (see 1996 National Electric Code Handbook, section 250-6). A vehicle-mounted generator is not defined, but is obviously any generator on a trailer, truck, skid, or any other vehicle.

The above exception applies to many portable and vehicle-mounted generators in use in Reclamation facilities maintenance programs. Generator manufacturers who meet the criteria for the exception are not required to include GFCI protection, and many do not as a matter of cost savings. ***However, this practice does reduce personnel safety in the events described above.***

These unmodified generators are deceptive because they give the appearance of safely grounded systems when, in fact, they are not. The receptacle accepts a 3-pin plug, including the grounding pin, but the grounding pin is connected only to the generator frame and not to the generator winding (neutral).

When a 3-pin grounded tool or extension cord is plugged into a 3-hole receptacle, the user ***expects*** it to be grounded like any other receptacle, giving a false sense of security.

This unsafe arrangement also applies to 120-volt receptacles available on some welders.

Note that NEC exceptions only apply to 2-wire, 120-volt generators and not to 3-wire 120/240-volt generators, which do not meet the exception requirements in NEC Article 305-6. Therefore, 3-wire 120/240 volt generators ***must*** have neutral grounding and GFCI protection.

***Simply installing a GFCI will not ensure a safe system.*** A GFCI will not operate reliably if one side of the winding is not grounded to the generator frame because fault current has no path back to the winding to complete the circuit. On the other hand, simply grounding one side of the winding without also adding GFCI is inadequate. Although grounding the winding would increase the probability that the circuit breaker would trip on a ground fault, current levels would still be too high to protect personnel. A combination of grounding the winding and adding a GFCI is necessary.

## RISK AND DEFICIENCIES

The risk to personnel is illustrated in figures 1 and 2. Figure 1 depicts an actual fatal accident at an industrial facility. Figure 2 shows what would happen in the event of two faults one at the generator and one at the tool.

The deficiencies in these generators/welders are:

1. The neutral of the generator winding is neither grounded to the generator frame nor to the grounding pin of the receptacle. This deficiency makes operation of the protective device (breaker or fuse) unreliable because fault current has no definite path.

2. The receptacle is not GFCI. A ground fault cannot be detected and cleared properly to protect personnel.

***The hazard posed to personnel from these non-grounded and non-GFCI protected systems is unacceptable and should be corrected.***

## CORRECTIVE ACTIONS

The following corrective actions should be taken immediately to ensure a safe system:

1. Inspect all portable and vehicle-mounted generators (and welders) to determine:

   A. Whether the generator winding is grounded to the generator frame.
   B. Whether the grounding pin of the receptacle is grounded to the generator frame or the winding neutral.

   Steps A and B may be easily checked by placing an ohmmeter across the ground and neutral pin of the 120-volt receptacle while the generator is ***not*** running. The ohmmeter will indicate open if the neutral is not grounded.

   C. Whether the 120-volt receptacle(s) are GFCI.

2. Ground the generator winding to the generator frame as needed by connecting a jumper between the neutral connection and ground connection at any convenient point inside the wiring compartment. The jumper should be the same size as the other conductors on the receptacle, normally No. 14 American Wire Gauge.

3. Replace the 120-volt receptacle(s) with GFCI receptacles as needed.

4. Retest with the ohmmeter as in step No. 1 above with the generator not running.

5. Before starting the generator, test between the hot and ground pins of the receptacle with an ohmmeter to ensure that a ground fault has not been inadvertently created.

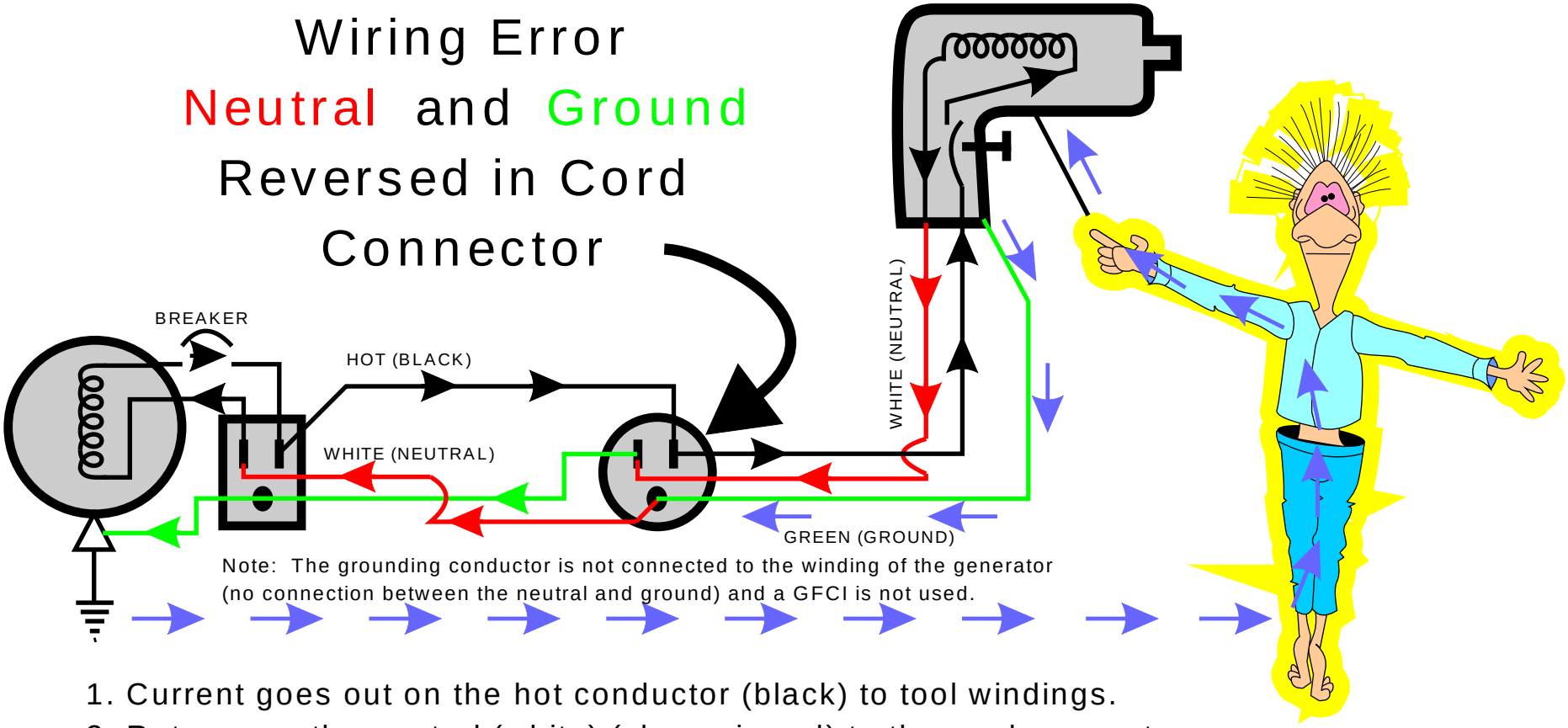
6. Start the generator engine and test between the hot and neutral pins for proper voltage with a voltmeter.

7. With the generator running, test the operation of the GFCI by pressing the test button. Perform this test each time the generator is started. A spare GFCI should be kept on hand in case of failure.

Figure 3 shows the recommended wiring. Note that the generator winding is connected to the grounding conductor, which provides a path for fault current from any load all the way to the generator winding. A GFCI is also shown, which provides proper ground fault protection for workers.

**NOTE:** If the excitation winding of a welder is the same winding that supplies the 120-volt receptacles, the generator will not work properly if one side of the winding is grounded. In this case, the receptacles should be removed and blocked off so they cannot be used. Normally, this situation only occurs on the older 3-wire 120/240-volt welders.

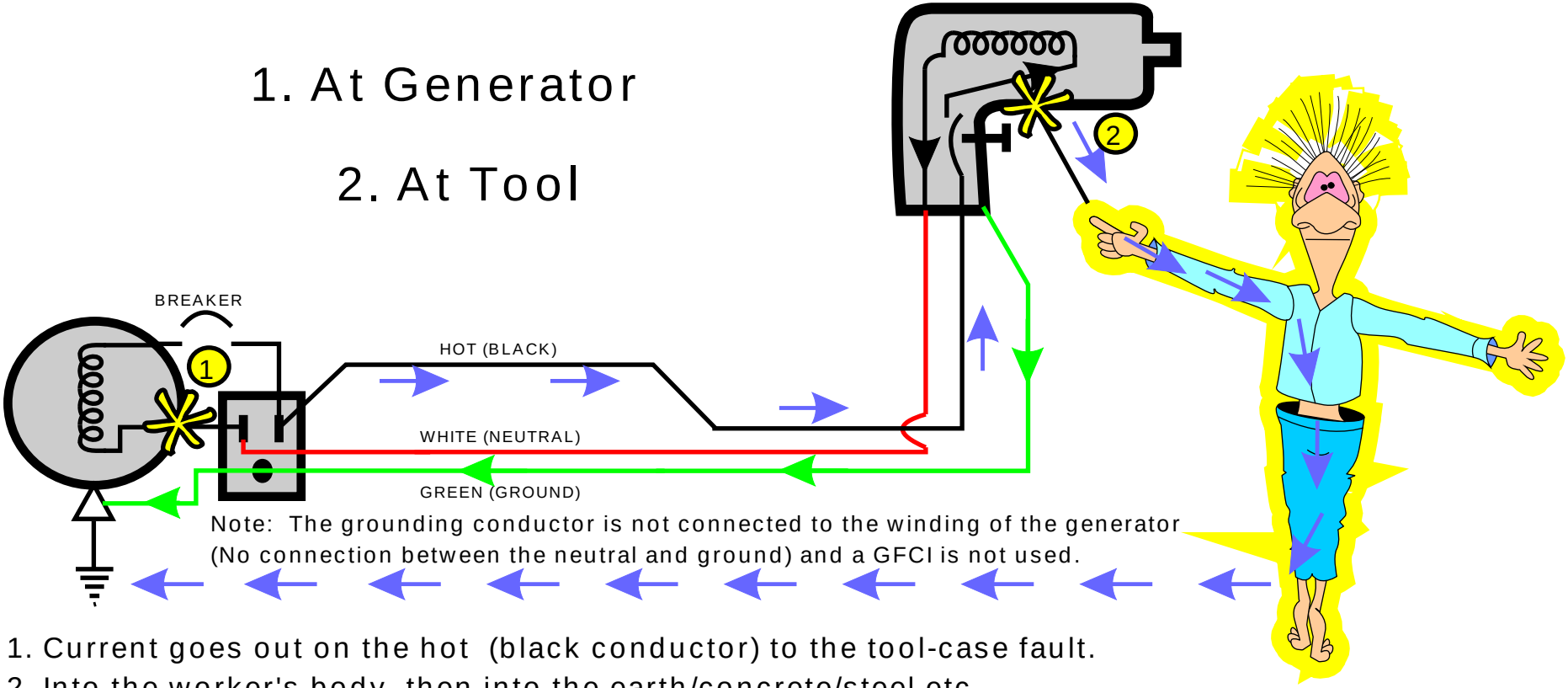
# Industrial Fatality on Floating System




1. Current goes out on the hot conductor (black) to tool windings.
2. Returns on the neutral (white) (shown in red) to the cord connector.
3. Transfers to the grounding conductor from the receptacle and goes to the generator frame and into the earth/concrete/steel etc.
4. Through earth, through the victim, to the tool case, to the tool ground wire.
5. To the cord connector and transfers to the neutral, and from the receptacle back to the generator winding.
6. Worker is connected across the generator winding.

Figure 1. - Depiction of a fatal accident attributable to inadequate ground fault circuit interruption and improper wiring.

# Two Fault Hazard

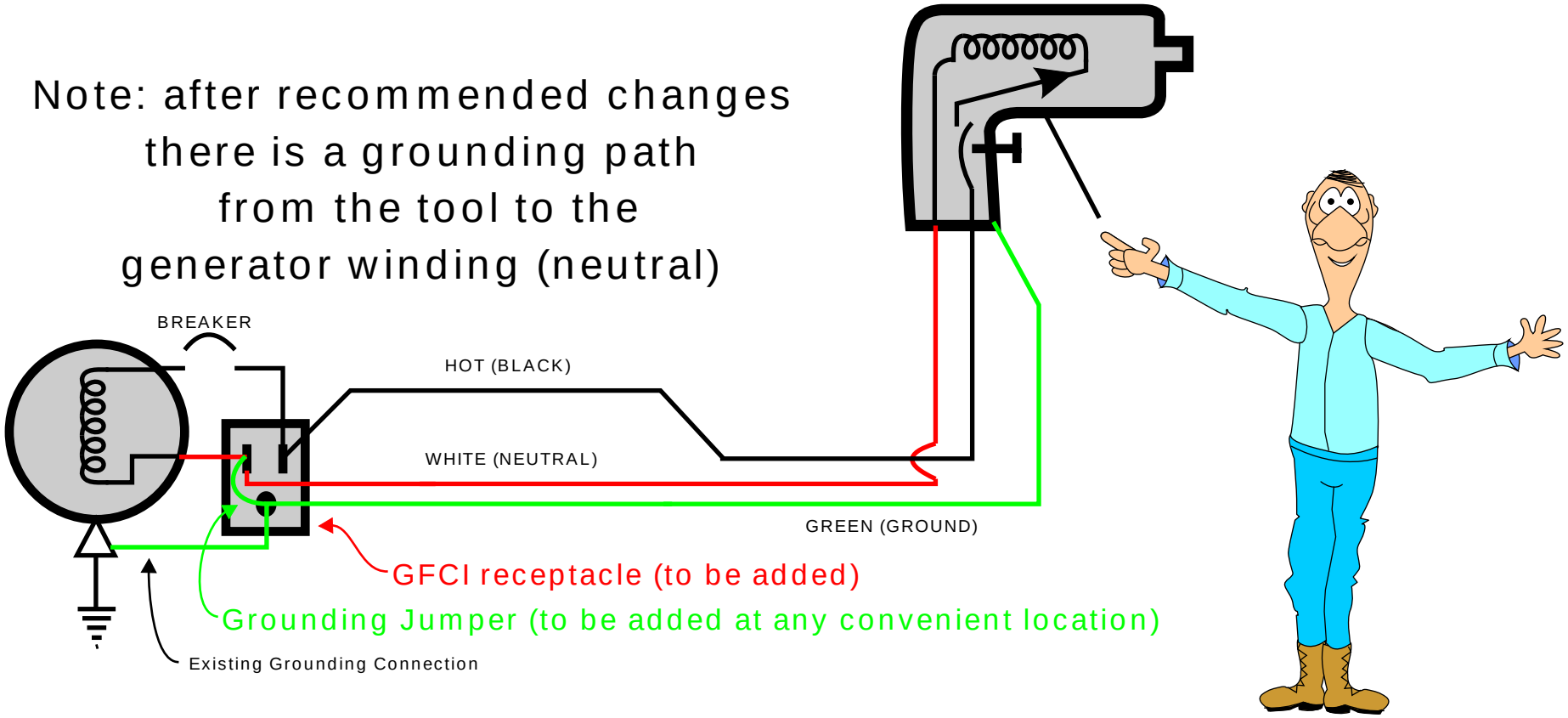



1. Current goes out on the hot (black conductor) to the tool-case fault.
2. Into the worker's body, then into the earth/concrete/steel etc.
3. Current enters the generator frame and goes back to the generator winding through fault no.1. Current also travels on the ground wire, if it is in good condition.
4. Note that the worker is connected across the tool winding, and is parallel to the grounding conductor.
5. **The breaker may work in this case but the worker is exposed to electrical shock until the breaker operates because no GFCI is used.**
6. **If either of the faults is high resistance the current will not be high enough to open the breaker. However, the current will be high enoughif the grounding conductor is faulty (the grounding pin broken or bad connection). It takes only about 75ma (.075 amps) to cause ventricular fibrillation.**

Figure 2. - Results attributable to two faults - one at the generator and one at the tool.

# Recommended Wiring Arrangement

Note: after recommended changes there is a grounding path from the tool to the generator winding (neutral)




1. If a fault develops at the tool or in the cord, the GFCI will open the circuit and the worker will be protected.

2. The GFCI opens at 5 to 7 ma; far below the current level that could harm the worker.

Figure 3. - Recommended ground fault circuit interrupter and proper grounding.

## MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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