# Why Positive Power Ground in Telephone Subscriber Loops?

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Supplementary Note for EETS8302

Many students and other people in the telephone industry have asked for further information regarding use of positive battery ground in telephone outside plant (subscriber loops, etc.) and its relationship to corrosion. This note gives some supplementary information on this topic. First, remember that earth or soil is a moderately good electrical conductor, particularly when it is wet with water. When the water in the soil contains dissolved minerals such as ocean salt (NaCl) or various other soluble minerals that are naturally present in rocks, it is even more conductive than pure water. Completely dry soil is a poor conductor. One of the major historical improvements in telephone systems in the late 19$^{th}$ century was the replacement of single-wire service (using the earth for current return) by a "subscriber loop" consisting of a pair of insulated wires to carry the current from the central office to the subscriber on one wire and return the current via the other wire.

**Different Reasons for Grounding in Different Systems:** There are three different categories of "reasons" for connecting the earth or ground to one of the terminals of the power supply in non-telephone systems:

1) In automobiles and other vehicles having a metal frame, the frame (called the ground in vehicle jargon) is used as one of the conductors to save the weight and cost of using a complete loop of insulated wire. The frame of the vehicle is not truly electrically connected to the earth in most vehicles, since the rubber tires electrically insulate the frame from the earth. In all modern 12 volt vehicle electrical systems, the negative terminal of the battery is "grounded" to the metal frame (a situation often described as "negative ground"). Considering various older vehicles made before approximately 1960 and using 6 volt batteries, most had negative ground but a few had positive ground instead. In vehicular applications, the problem of accelerated corrosion that is so important for telephone outside plant wiring is usually not a factor. The insulation color codes used for vehicle power wiring are also different than in telephone wiring. In a vehicle the positive power wire has red insulation and the negative wire (often connected to the frame) has black insulation. Some vehicles do not use the frame as a conductor. In some vehicles, the frame is totally or partially made of electrically non-conductive materials such as reinforced plastics. In some vehicles used for geophysical measurements or other research purposes, the magnetic field produced by current flow through the metal frame is undesirable when other magnetic field measurements are to be made in that vehicle.

2) For alternating current public electric power systems, one of the power wires is intentionally connected to the earth. The reason for this has no relationship to corrosion issues, but is part of the safety protection system. In North American power wiring one of the power wires is designated as the "neutral" wire. The insulation on the neutral wire is typically white. At the point where the power wiring enters the user's building (the "service entrance") this white neutral wire is grounded (connected to a copper spike driven into the earth, or connected to an underground metal cold water pipe). The "hot" wire(s) that are *not* grounded have black (or sometimes red) insulation. An extra wire, having green insulation, that does not normally carry electric current, is included in the power wiring cable together with the black and white insulated wires. The green wires are also connected to the earth at the service entrance. On a modern North

American 110 volt power socket there are three openings, two are straight slots and one is round. They are connected respectively to the “hot” wire (typically black insulation) at the shorter slot, the “neutral” wire (typically white insulation) at the longer straight slot, and a third opening connected to the green wire. This last green wire connects to the round opening And thus to the round extra-long prong on the power plug.

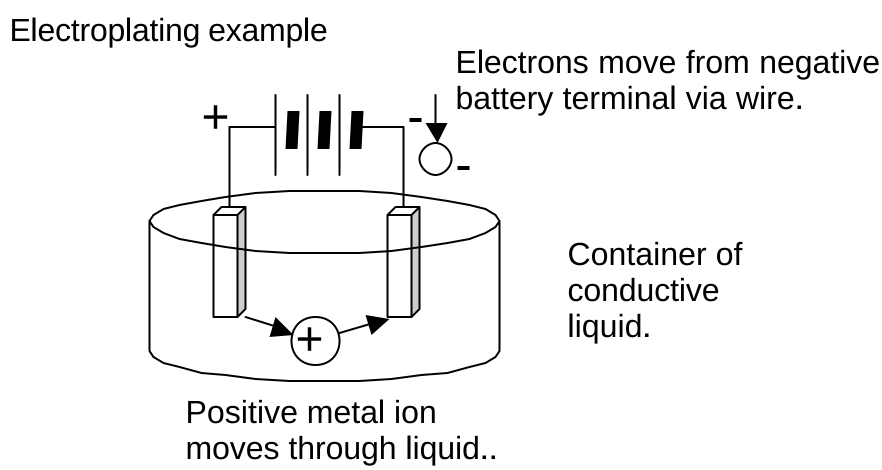
In older North American electric power wiring that did not have this extra green wire, a dangerous fault could occur without being detected until too late. A “hot” wire with damaged insulation could touch the conductive cover or housing of an electrical device such as a toaster. The toaster would work and make toast, but if a person touched the metal housing he or she could become part of a current path to the earth, therefore receiving a bad electric shock. Modern wiring prevents this shock. The metal housing parts of a modern toaster with a three-prong plug are connected to the long round prong. When you plug in the faulty toaster, the electric current will return to the earth via the green wire in the toaster cord and the green wire inside wiring from the outlet back to the grounding point at the service entrance. If this current is large, it will cause a fuse or circuit breaker to turn off the power on that circuit. Even when the current in the green wire is very small (just a few milliamperes) the installation of Ground Fault Circuit Interrupter (GFCI) on that power circuit protects you by disconnecting the electric power. The GFCI detects when the current returning in the white wire is smaller than the current emerging from the black wire, and shuts off the power. Electric power sockets installed in locations near water or where the possibility of electric shock is high (kitchens, bathrooms, outdoor locations) require a GFCI because a person can act as part of the current flow path to the earth. Incidentally, because alternating current is used in public power systems, we cannot describe either wire as “positive” or “negative.”

3) In most types of electronic equipment the negative terminal of the dc power supply is intentionally connected to the metal frame or housing of the electronic equipment. The frame is also connected to the earth or ground (sometimes using the green wire in the power cord). A power supply typically uses a transformer and various electronic rectifiers and filters to convert 110 volt alternating current power into a direct current at a constant voltage (typically 5 volts) needed by the electronic equipment. It would be more descriptive to call this device a “power converter” instead of a power supply. In these applications, the reason for connecting the negative voltage to the frame or housing and grounding it is partly like the reason in a vehicle: the frame carries current instead of using additional insulated wires. Another reason is that the grounding of the housing helps to shield the electronic devices inside from electromagnetic waves (radio and television signals or electromagnetic waves arising from electrical equipment in the vicinity such as the motor that operates an elevator). Incidentally, in some *very* few older types of electronic equipment (using so-called PNP transistors) the positive terminal of the power supply was connected to the frame, housing and earth.

In contrast to the three cases described above, the reason for grounding the positive terminal of the power supply battery in telephone outside plant wiring is to minimize the amount of corrosion on the copper wire. Corrosion effects related to the grounding of the battery would not occur if the insulation around the wire were perfect (no leakage current whatever) and bare (non-insulated) parts of the wire were never exposed to moisture or chemically reactive molecules in the air. It would also be nice, to absolutely prevent corrosion if the insulation around each wire was a perfect barrier to the passage of metal atoms or ions. If this ideal situation were to exist, then we could ground either terminal of the battery and not worry about corrosion. If absolutely all of the current flows from the + to the - pole of the battery only via the telephone wires (and through the telephone set), then we would not be concerned about the current removing or placing (electroplating) copper atoms off of or onto the wires. No current would leak through the insulation and return to the other battery terminal via the conductive earth. That would be nice but this desirable situation is not practically possible.

Plastic insulation used today is much better -- lower leakage current -- than paper pulp or silk or cotton fiber insulation used in the past. But even with very good insulation, corrosion can be accelerated because the insulation is not perfect and some "leakage" current gets through the insulation and some metal or oxygen molecules can move through imperfections in the insulation. The leakage current is typically only in the range of 1 to 10 microamperes, but over a long time it could cause some serious changes in the wire diameter if we made the wrong design choice regarding battery grounding.

**Electroplating:** If we connect the terminals of a dc battery to two pieces of metal and then place them in a conductive liquid, like water with a little bit of acid or a soluble mineral added to it, electric current will flow through the liquid. Furthermore, positive metal ions (atoms with one or more electron removed) will move through the liquid from the positive terminal to the negative terminal. If the positive terminal in the liquid is gold and the negative terminal is a "base" metal like lead, gold atoms will coat the base metal. When the gold ions reach the surface of the negative terminal in the liquid, electrons from the negative terminal of the battery will meet these positive ions and electrically neutralize them.




***De*-Electroplating Removes Surface Metal Atoms:** When leakage current flows from one wire to another via microscopic passages through the insulation and via wet earth or via a very moist atmosphere, positive metal ions (atoms with one electron removed) leave the positive wire and move by an available path through the wet earth toward the negative wire or negative voltage nearby objects. If we made the wrong design choice and grounded the negative battery terminal, then all the wet earth in the vicinity of the positive wire would be a convenient nearby place for these positive ions to go. We would then continuously "de-plate" copper atoms (the reverse of the process of electroplating) off of the negative wire and deposit them in the earth. We would also electro-plate some copper and some copper oxide and/or copper carbonate onto the negative wire. Copper oxide and carbonate form because the atmosphere provides oxygen and carbon dioxide that lead to these chemical products. The dangerous situation occurs because the positive copper wire in this situation is continually getting thinner and thinner, so its electrical resistance is increasing and it may eventually break due to mechanical stress.

Incidentally, the verdigris coating that forms on copper or its alloys (brass, bronze, etc.), composed of copper oxide and copper carbonate, is called verdigris from the Latin words "verdi" (green) and "gris" (grey), which describes the approximate color of this material.

If we ground the positive battery terminal, then even when the earth is wet, the earth is at a positive voltage just like the positive (tip wire or green insulation) wire. Therefore, there is little or no voltage difference between that + wire and the + voltage earth, and there is much less leakage current and much less "de-plating" of the wire. There may still be some copper plating or a build up of copper oxide or copper carbonate onto the negative (ring or red insulation) wire if it is physically close to the wet earth or in a wet corrosive atmosphere.

If we have made a secure metal-to-metal contact of the wire to a screw terminal (or a type-66 stake-down electrical connection block that cuts through the insulation with two tin-plated metal prongs and grips the copper wire), with no gaps between the wire and the metal terminal, there should not be a problem with corrosion forming between the wire and terminal. If we made a loose "sloppy" connection, then there will probably be a problem with corrosion forming in the gap between the negative wire and the terminal (but not so much corrosion forming on the positive wire). In that case we would need to occasionally clean the wire and re-connect it, a definite maintenance problem.

**Regarding a Grounding Stake in the Earth:** If we intentionally put an un-insulated wire near the positive grounding stake, and connected that wire to the negative battery terminal, then after a long time the grounding stake would get measurably thinner. However, with a leakage current of 1 microampere, if every electron charge amount were to be carried via a copper ion, only $6x10^{13}$ copper atoms come off of the stake each second. That is a volume of approx $6x10^{-11}$ cubic meters. For a stake that is 50 centimeters long and 25 mm diameter (one inch diameter) the diameter would shrink by about 1 millimeter per year. The nearby negative wire would get surface corrosion on it in a somewhat thicker layer since it would get carbonate and oxide as well as copper.

It would take a long time to remove enough copper from the ground stake to require replacement, and this only happens in this example because we do a silly thing for the sake of explanation -- namely putting a negative un-insulated wire from the battery near to the stake in wet earth.

Removing a similar volume of copper from a thin telephone wire would be much more serious because the wire is very thin (24 AWG copper wire, a commonly used telephone wire, is only 0.511 mm diameter to begin with). We could eat away (de-electroplate) most of the copper wire in a year or two with only a microampere of leakage current. This problem does not occur if we keep the wire dry and at the same voltage as the surrounding wet earth, and don't intentionally put any negative voltage bare wires into the wet earth near the positive wire.

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