Ufer grounding

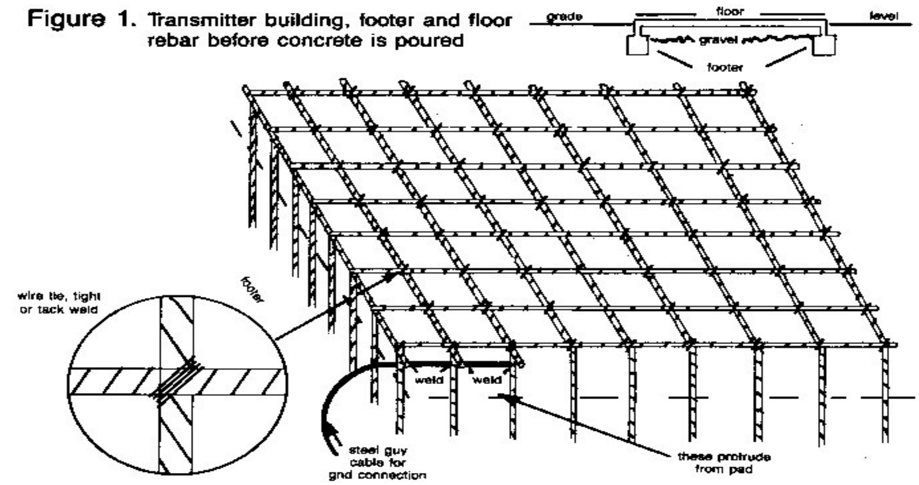

Figure 1. Transmitter building, footer and floor rebar before concrete is poured

"Concrete Encased Electrode Grounding" by the NEC (National Electrical Code) 250-52 (A)(3) in 2005, is in many states the primary source of "Earth" ground in "all" remodel and new building construction concrete foundations. The present method was "Ground Rods" which one rod at best will give you 25 ohms resistance or a additional ground rod must be added for 25 ohms maximum (NEC 250-56). The "Concrete Encased Electrode" will give you 5 ohms or less resistance and a better "Resonant Frequency" in a grounded transmission or reception device.

Ufer Ground - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/Ufer_ground

During World War II, a retired Vice President of Underwriters Laboratories, Herbert G. Ufer, developed it for the U.S. Army. Igloo shaped bomb storage vaults were being built, and possible static and lightning induced detonation problems were of concern. Ground conductivity was poor, and to be effective enough, ground rods would have to be driven several hundred feet. After much research and testing Mr. Ufer advised the Army to make connection to the steel bar that would internally reinforce the concrete foundation. He had determined that concrete was more conductive than all but the best soil, and that this improved semiconducting characteristic would enhance surface area contact with the surrounding soil. The wire ties normally used would be extra secure, and attention would be given to bonding or welding the lattice- type network together. The Army adopted the idea, and built the vaults as specified.

After construction ground resistance tests were made. No measurement exceeded five ohms. This value was considered extremely low for the local soil conductivity. Later tests confirmed stability. Mr. Ufer went on to develop the concept of concrete encased grounding electrodes. Many of his findings are detailed in IEEE Transactions paper # 63-1505. His system has since been used by the military and High Tec laboratories ever since.

Wardencluffe Tower -
The Wardenclyffe tower had a shaft sunk 120 ft into the ground, and below that it is said there are 16 iron pipes laid end to end for an additional 300 feet. At this depth (420 feet), Tesla determined that telluric currents (ELF) could easily be transceived from one station to another, at any point on Earth.

TODAY -
These "Concrete Encased" grounding rings have been used for years incorporated in the construction of all "Circular or Cyclic Partial Accelerators" or "Gizmos" I call rings are made like a tire enter tube, the rubber concrete with re-enforced steel re-bar with the electronic equipment inside the tube. These concrete tubes are usually buried except for a portion of the top to be moistened by rain or water if needed to maintain 1-5 ohms resistance.

--
mail: anne@therp.nl
tel: +31 (0)20 3093093
mob: +31 (0) 642324577
web: therp.nl
skype: therp.nl

Ufer ground
From Wikipedia, the free encyclopedia

The Ufer Ground is an electrical earth grounding method developed during World War II. It uses a concrete-encased electrode to improve grounding in dry areas. The technique is used in construction of concrete foundations.

Contents

1 History
2 Construction
3 External links
4 References

History

During World War II, the U.S. Army required a grounding system for bomb storage vaults near Tucson and Flagstaff, Arizona. Conventional grounding systems did not work well in this location since the desert terrain had no water table and very little rainfall. The extremely dry soil conditions would have required hundreds of feet of copper rods to be inserted into the ground in order to create a low enough impedance ground to protect the buildings from lightning strikes.

In 1942, Herbert G. Ufer was a consultant working for the U.S. Army. Ufer was given the task of finding a lower cost and more practical alternative to traditional copper rod grounds for these dry locations. Ufer discovered that concrete had better conductivity than most types of soil. Ufer then developed a grounding scheme based on encasing the grounding conductors in concrete. This method proved to be very effective, and was implemented throughout the Arizona test site.

After the war, Ufer continued to test his grounding method, and his results were published in a paper presented at the IEEE Western Appliance Technical Conference in 1963.[1] The use of concrete enclosed grounding conductors was added to the U.S. National Electrical Code (NEC) in 1968. It was not required to be used if a water pipe or other grounding electrode was present. In 1978, the NEC required rebar to be used as a grounding electrode if present. The NEC refers to this type of ground as a "Concrete Encased Electrode" (CEE) instead of using the name Ufer ground.

Over the years, the term "Ufer Ground" has become synonymous with the use of any type of concrete enclosed grounding conductor, whether it conforms to Ufer's original grounding scheme or not.[2]

Construction

Concrete is naturally basic (has high pH). Ufer observed this meant that it had a ready supply of ions and so provides a better electrical ground than almost any type of soil. Ufer also found that the soil around the concrete became "doped", and its subsequent rise in pH caused the overall impedance of the soil itself to be reduced.[3] The concrete enclosure also increases the surface area of the connection between the grounding conductor and the surrounding soil, which also helps to reduce the overall impedance of the connection.

Ufer's original grounding scheme used copper encased in concrete. However, the high pH of concrete often causes the copper to chip and flake. For this reason, steel is often used instead of copper.

When homes are built on concrete slabs, it is common practice to bring one end of the rebar up out of the concrete at a convenient location to make an easy connection point for the grounding electrode.[4]

Ufer grounds, when present, are preferred over the use of grounding rods. In some areas (like Des Moines, Iowa) Ufer grounds are required for all residential and commercial buildings.[5] The conductivity of the soil usually determines if Ufer grounds are required in any particular area.

A Ufer ground of specified minimum dimensions is recognized by the U.S. National Electrical Code as a grounding electrode.[6] The grounding conductors must have sufficient cover by the concrete to prevent damage when dissipating high-current lightning strikes.[7]

A disadvantage of Ufer grounds is that the moisture in the concrete can flash into steam during a lightning strike or similar high energy fault condition. This can crack the surrounding concrete and damage the building foundation.[8]

External links

- The "Ufer" Ground
- A new look at the Ufer ground system

References

"Electrical Grounding and Bonding" By J. Philip Simmons
"Nfpa's Dictionary of Electrical Terms" By H. Brooke Stauffer
"Investigation and Testing of Footing-type Grounding Electrodes for Electrical Installations" H.G. Ufer, November 4, 1963
"Electrical Wiring Residential: Based on the 2005 National Electric Code" By Ray C. Mullin
"Ufer Grounding System" Permit and Development Center, City of Des Moines Community Development
NEC rule 250.52(3)
Jerry C. Whitaker (1998), AC power systems handbook, CRC Press, pp. 385–387, ISBN 0-8493-7414-6
"Electrical Overstress/Electrostatic Discharge Symposium Volume 22" By ESD Association, Institute of Electrical and Electronics Engineers

The "*Ufer*" Ground

The term "Ufer" grounding is named after a consultant working for the US Army during World War II. The technique Mr. Ufer came up with was necessary because the site needing grounding had no underground water table and little rainfall. The desert site was a series of bomb storage vaults in the area of Flagstaff, Arizona.

The principle of the Ufer ground is simple, it is very effective and inexpensive to install during new construction. The Ufer ground takes advantage of concrete's properties to good advantage. Concrete absorbs moisture quickly and looses moisture very slowly. The mineral properties of concrete (lime and others) and their inherent pH means concrete has a supply of ions to conduct current. The soil around concrete becomes "doped" by the concrete, as a result, the pH of the soil rises and reduces what would normally be 1000 ohm meter soil conditions (hard to get a good ground). The moisture present, (concrete gives up moisture very slowly), in combination with the "doped" soil, make a good conductor for electrical energy or lightning currents.

Ufer techniques are used in building footers, concrete floors, radio and television towers, tower guy wire anchors, light poles, etc. Copper wire does not function well as a "Ufer" ground due to the pH factor of concrete (+7pH is common). The use of steel reinforcement as a "Ufer" ground works well and concrete does not chip or flake as has been found with copper. The use of copper wire tied to the reinforcement rods outside the concrete shows none of these problems.

The minimum rebar necessary to avoid concrete problems depends on:

1. The type of concrete, its content, density, resistivity, pH factor, etc.
2. Amount of concrete surface area in contact with the soil.
3. Soil resistivity and ground water content.

4. Size and length of the reinforcement rod, wire, or plate.
5. Size of the lighting strike current.

The following chart shows the conductivity of lightning current per foot of Rebar (reinforcement rod). Only the outside Rebar can be counted. Rebar in the center of the footer or foundation does not count in this calculation. In a trench footer only the rebar in the sides and bottom of the footer can be counted.

Rebar Diameter In Inches	Surge Amperes Per Foot
.375	3400
.500	4500
.625	5500
.750	6400
1.000	8150

Mr. Ufer did not know what he had found until he experimented with various lengths of wire in concrete. Today's informed engineer benefits from Mr. Ufer's discovery and will tie in the bars of steel reinforcement in a building or other foundation to the building electrical ground. When bonded to the electrical ground, building steel, etc., the buildings reinforced floor and foundation become part of the building grounding system. The result is a much improved grounding system with a very low overall resistance to earth reference.

If Ufer grounding alone was enough, the manufacturers of ground rods would go out of business. But a Ufer ground alone it is not adequate. Few buildings, even those under construction today are built to take advantage of the Ufer ground. It is common to see the use of "Ufer grounding" in military installations, computer rooms, and other structures with very specific grounding specifications. It is not common in most industrial plants, office buildings and homes. More common today is grounding to national and local electrical codes. This will involve one or more driven ground rods connected (bonded) to the neutral wire of the electrical service entrance. The purpose of this bond is what is known as life safety ground. It is used for many other things but the code required life safety ground is why it is there to begin with.

Ground rods come in many forms, but the most common used in electrical service grounding are galvanized steel ground rods. Please remember, the best day a ground rod will normally see (resistivity) is the day it is installed. Corrosion, glazing, etc., all are factors that lessen the effectiveness of ground rods.

Ground rods in general are divided into one of the following sizes; 1/2",5/8",3/4" and 1". They come in steel with stainless, galvanized or copper cladding and can be solid stainless or mild (unclad) steel. They can be purchased in unthreaded or threaded sections that vary in length. The most common lengths are 8′ and 10′.

Some will have a pointed end, others will be threaded and can be coupled together to form longer rods when driven.

The effectiveness of a 1" ground rod over the 1/2" ground rod is minimal when resistance readings are taken. The larger rods are chosen for more difficult soil conditions. Clay or rocky conditions often dictate the use of power drivers, similar to an impact driver used by mechanics when working on your automobile. They are typically electric or pneumatic. The power drivers when used with the heavy 1" ground rods will drive in most soils.

A 1" copper clad rod when compared to a 1/2" copper clad rod in the same soil conditions will yield about a 23% improvement is performance. The surface area of the 1/2" rod is 1.57 compared to the 1" rod at 3.14 (3.14 x .5 = 1.57 and 3.14 x 1 = 3.14). So, for double the surface area, you only get about 23% improvement in performance.

The cladding of ground rods is to protect the steel from rusting. Most think the cladding, (copper on a steel rod) is for the increase in conductivity of the rod. It does aid in conduction, but the main purpose of the cladding is to keep the rod from rusting away. Not all clad ground rods are the same and it is important the clad rod have a reasonably thick cladding. High quality industrial quality copper clad steel ground rods may cost a little more but they are worth the small extra cost.

When a ground rod is driven into rocky soil, it can scratch off the cladding and the rod will rust. Rust is not conductive when dry, in fact it is a good insulator. When it is wet it is still not as conductive as the copper on the rod. Soil pH can be tested and that should determine the type of rod used. In high pH soil conditions only high quality clad rods should be used. If the soil is extremely acidic, stainless rods are the best choice.

One of the most popular ground rods is the galvanized (hot dipped zinc) steel ground rod. This rod is used with copper and aluminum conductors to form the service entrance ground in most buildings and homes. This is a poor choice for ground restivity over time. The joint between the ground rod and conductor are made above or below the surface of the ground and in most cases subject to constant moisture. Under the best of conditions the joint between two dissimilar materials will result in corrosion and increased resistance over time.

When dissimilar materials are joined, electrolysis occurs. If Aluminum is used with copper that is not tinned the aluminum will pit to the copper leaving less surface area for contact and the connection could come loose and even allow arcing. Any sharp blow or impact could cause the connection to be broken. When installing in the soil it is not recommended tinned wire be used. Tin, lead, zinc and aluminum are all more anodic than copper and they will sacrifice (disappear) in the soil. When the connection is made above the surface of the soil in the electrical distribution panel tinned wire is acceptable.

Another treatment for joint corrosion problems is using a joint compound to prevent moisture bridging between the metals. The more popular compounds are copper or graphite particles imbedded in a grease compound. Using similar material is a better solution as even joint compounds can loose their effectiveness if not maintained but their use is preferable to a dry joint. Joint compounds work by imbedding particles into the metals to form a virgin junction of low resistance void of air when they are placed under pressure. The act of tightening the clamp on the conductor and rod provide this pressure.

The problem of dissimilar material is not found in copper clad steel rods. Of all the reasonably priced choices, the copper clad steel rod with a copper conductor is your best choice. If money were no object a gold conductor, and ground rod would be ideal, but hardly economically practical.

The effective performance of ground rods is reduced by soil conditions, lightning currents, physical damage, corrosion, etc., and should be checked for resistance on a regular basis. Just because your ground was good last year it does not mean it is today. Have it checked by the fall of potential testing method.

A driven rod, when compared to a back filled rod, is much better. The density of undisturbed soil is much higher than even compacted soil. The connection of the soil is the key to the rod performance.

Installing ground rods is not difficult but proper procedures must be followed and the resulting rod(s) should be checked for performance. Testing for resistance by the fall of potential method is the only way to be sure what looks good is good, a low resistance ground.

This information in Microsoft Word 97 format is availiable for download (37.5kb)

substation grounding

Just how important is substation reliability? Fast clearing of faults, made possible by good grounding, improves the overall safety and reliability of an electrical system. Therefore, substation reliability must be as "built-in" as possible because of the high available fault current levels present and unlikely occurrence of follow-up grounding inspections.

The following 11 basic tips, if put into practice, will enhance your substation grounding system.

Tip 1: Size conductors for anticipated faults

Conductors must be large enough to handle any anticipated faults without fusing (melting). Table 1, which is derived from IEEE 80-1986, IEEE Guide for Safety in AC Substation Grounding, lists the maximum allowable fault current (in kA) for various conductor sizes and fault durations. Fig. 1 shows maximum-allowable-fault-current-versus-time performance curves for the same conductor sizes listed in Table 1.

Failure to use proper fault time in design calculations creates a high risk of melted conductors. For example, a 4/0 AWG conductor can withstand 42,700A for 0.5 sec before fusing. However, this same conductor can withstand only 13,500A for 5 sec. IEEE 80 suggests using 3.0 sec for small substations. This time is equal to the short-time rating of most switchgear.

Tip 2: Select the right connector

The connections between conductors and the main grid, and between the grid and ground rods, are as important as the conductors themselves in maintaining a permanent low-resistance path to ground. You must consider the type of bond the connection creates with the conductor or ground rod and temperature limits.

The most frequently used grounding connections are mechanical pressure-type (bolted, compression, and wedge) and exothermically welded. Pressure-type connections produce a mechanical bond between conductor and connector. This connection either holds the conductors in place or squeezes them together, providing surface-to-surface contact with the exposed strands. The exothermic process fuses the conductor ends together to form a molecular bond between all strands of the conductor.

Temperature limits are important considerations. How effectively a connection carries current indicates how well it will maintain low resistance. IEEE 80 rates the maximum allowable temperature limits for both pressure-type and welded connections. IEEE 837 gives additional information.

Tip 3: Pay attention to ground rod length, number, placement, and spacing

The length, number, and placement of ground rods affect the resistivity of the path to earth ground. Each doubling of ground rod length reduces resistivity 45%, if you're working with uniform soil conditions. Usually, soil conditions are not uniform, so it's vital to obtain accurate resistivity data by measuring ground rod resistivity with appropriate instruments.

For maximum efficiency, rods should be placed no closer together than the length of the rod. Normally, this is 10 ft. Each rod forms an electromagnetic shell around it, and when the rods are too close, the shells actually interfere with each other.

For economic reasons, there's a limit to the maximum distance between rods. Normally, this is 20 ft. At more than 20 ft, the cost of real estate and additional conductor needed to connect the rods is not economically attractive. Four interconnected rods on 100-ft centers will reduce resistivity 94% over one rod but require at least 400 ft of conductor. On the other hand, four rods placed 20 ft apart will reduce resistivity 81% over one rod and use only 80 ft of conductor. Additionally, the 20-ft spacing uses only 4% of the real estate consumed by the 100-ft spacing.

Tip 4: Prepare the soil

Soil conductivity is an important consideration in substation design. The lower the resistivity, the easier it is to get a good ground. In areas where soil conductivity is low or where dry weather can change soil conductivity, consider using a ground-enhancement material. Another option, especially in areas where deep frost occurs, is to use deep-driven rods.

Tip 5: Eliminate step and touch potential

Limiting step and touch potential to safe values in your substation is vital to employee safety. Step potential is the voltage difference between a person's feet and is caused by the dissipation gradient of a fault entering the earth. Just 30 in. away from the entry point, voltage usually will have been reduced by 50%. For example, a 1000A fault in a 5-ohm grounding system will enter the earth at 5000V. So, 30 in. away, less than the distance of a normal step, a fatal potential of 2500V will exist. This is shown in Fig. 2.

Touch potential represents the same basic hazard, except the potential exists between the person's hand and his or her feet. However, since the likely current path runs through the arm and heart region instead of through the lower extremities, the danger of injury or death is even greater.

In both situations, the potential essentially can be eliminated by an equipotential wire mesh safety mat installed just below ground level, as shown in Fig. 3. Connected to the main ground grid and any switches or equipment a worker might touch, an equipotential mesh will equalize the voltage along the worker's path and between the equipment and his or her feet. With the voltage difference (potential) thus essentially eliminated, the hazard to personnel is virtually eliminated as well.

An equipotential wire mesh safety mat is usually fabricated from #6 or #8 AWG copper or copper-clad wire to form a 24 x 24-in. or 24 x 48-in. mesh. Many other mesh sizes are available. To ensure continuity across the mesh, all wire crossings are brazed with a 35% silver alloy. Interconnections between sections of mesh, and between the mesh and the main grounding grid, should be made so as to provide a permanent low-resistance high-integrity connection.

Tip 6: Ground the foundation

Because it's nearly impossible to isolate a metal structure from its foundation, the use of "Ufer" grounds has significantly increased in recent years. Ufer grounds utilize the concrete foundation of a structure plus building steel as a grounding electrode. Even if the anchor bolts are not directly connected to the reinforcing bars (rebar), their close proximity and the semi-conductive nature of concrete will provide an electrical path. Two additional facts need to be considered in Ufer grounding.

A high fault current (lightning surge or heavy ground fault) can turn moisture in the concrete to steam. This steam, attempting to expand to 1800 times its original volume, produces forces that may crack or otherwise damage the concrete. In an actual installation, a major utility used only the footers for grounding electrodes on a 765kV line. Later inspection found 90 foundations with fractures, some severe.

The presence of even a small amount of DC current will ca use corrosion of the re bar. Because corroded steel expands to more than two times its original volume, this expansion creates extremely large forces on the concrete. Although AC leakage will not cause corrosion, the earth will rectify a small percentage of the AC to DC. In situations where the anchor bolts are not bonded to the rebar, concrete can disintegrate in the current path.

To reduce concrete damage, you can limit the short duration current or provide a metallic path from the rebar through the concrete to an external electrode. That external electrode must be sized and connected to protect the concrete's integrity.

Proper design of Ufer grounds, as shown in Fig. 4, provides for connections between all steel members in the foundation and one or more metallic paths to an external ground rod or main ground grid. This gives faults a low-resistance path through the concrete to the earth.

Tip 7: Ground the fence

Utilities vary in their fence-grounding specifications, with most specifying that each gate post and corner post, plus every second or third line post, be grounded. All gates should be bonded to the gate posts using flexible jumpers. All gate posts should be interconnected. In the gate swing area, an equipotential wire mesh safety mat can further reduce hazards from step and touch potentials when opening or closing the gate.

Some substation designs require fence grounding to be isolated from the main ground grid; others require it to be tied into the grid. Tying the fence ground into the main ground grid, as shown in Fig. 5, will reduce both grid resistance and grid voltage rise. A word of caution here: Internal and perimeter gradients must be kept within safe limits because the fence is also at full potential rise. This can be accomplished by extending the mesh with a buried perimeter conductor that is 3 ft or 4 ft outside the fence and bonding the fence and the conductor together at close intervals.

Tip 8: Ground all disconnect switch handles

To protect the switch operator in case of a fault, place a safety mat on or under the earth's surface at all switch handles. There are four types of safety mats.

- A steel grate or plate on supporting insulators. This works only if the operator can be kept completely isolated on the grate. Therefore, insulators must be kept clean. Any vegetation in the vicinity should be cut or eliminated completely.
- A steel grate on the surface, permanently attached to the grounded structure. This arrangement has the operator standing directly on the grate.
- Bare conductor buried (in a coil or zigzag pattern) under the handle area and bonded to the grounded structure.
- Prefabricated equipotential wire mesh safety mat buried under the handle area and bonded to the grounded structure, as in Fig 6 (on page 46). This is likely to be the least expensive choice.

In all but the first arrangement, both the switch operating handle and the personnel safety grate (or mat) should be exothermically welded to structural steel, thus ensuring nearly zero voltage drop.

Tip 9: Ground all surge arrestors

Surge arrestors pass surge energy ("spikes") to ground. To transfer current at minimum voltage drop (which provides maximum protection), each surge arrestor groundlead should have a short direct path to earth and should be free of sharp bends.

To use transformer tanks or structures as the grounding path, you must ensure that multiple paths to ground are both available and secure (this includes making effective connections). Whenever there is any question about the adequacy of these paths, use a separate copper conductor between the arrestor and the ground terminal (or main grounding grid). Because steel structures (due to their mass) have a lower impedance than a separate copper conductor, connect any separate conductor to the structure near the arrestor.

Tip 10: Bond and ground all cable trays

The NEC in Art. 318 details the requirements for cable trays, which cannot be treated the same as conduit. All metallic tray sections must be bonded together because mechanical splice plates do not provide an adequate path for fault currents. Therefore, the bonding jumpers (either the welded type used on steel trays or the lug type) must be placed across each spliced joint. If a metallic tray comes with a continuous grounding conductor, the conductor can be bonded inside or outside the tray. When cable tray covers are used, they should be bonded to the tray with a flexible conductor. The trays themselves should be bonded to the building steel (usually at every other column) and to all conduits containing conductors common to the cable tray system.

Tip 11: Pay attention to temporary grounding

When personnel work on high-voltage electric structures or equipment, any conductive bodies should be grounded. The usual grounding method is to attach a flexible insulated copper cable with a ground clamp or lug on each end, as shown in Fig. 7. These flexible jumpers require continual inspection and maintenance.

For cable connections to clamps, welded terminations (either a welded plain stud or a threaded silicon bronze stud welded to the conductor end) will provide a secure, permanent connection. The electrician solidly ties the clamp or lug to ground, then attaches the other clamp to the cable being grounded. The selection of the right ground for the first step is critical, as the following two incidents illustrate.

Case History No. 1
A utility company ran a series of tests to determine the effectiveness of grounding jumpers. Using a 20,000A short circuit, it discovered clamping directly to the tower structure was ineffective in that the high contact resistance between the clamp and the structure surface caused the clamp to be blown off.

Case History No. 2

A firm tested a stainless steel stud that projected through a hole in a structure; it was secured with a washer and nut on each side. The testers attached a clamp the stud, then subjected it to a 20,000V test. The short circuit caused the stud to burn off at the structure.

A solution to the high-resistance structure attachment involves welding a copper stud to the structure. Attaching a ground clamp to this copper stud provides a low-resistance contact. A special note: The stud must have an enlarged end located away from the structure, because a fault would tend to move the jumper toward this end of the stud. Fig. 8 shows some common studs, which should be welded or bolted to steel surfaces and fabricated to fit specifications.