c. Immediately after removal of the victim from the power-carrying object, administer artificial respiration, as described in Subsection 3-21, Resuscitation and Artificial Respiration.

3-3 SHIPBOARD UNGROUNDED ELECTRICAL DISTRIBUTION SYSTEMS ARE DEADLY

The following article appeared in the Naval Sea Systems Command Technical News, of March 1970, Volume 19, Number 3, NAVSEA 0900 -LP-OOO-2060, and was written by G.C. Janzen of the Naval Sea Systems Command.

For reasons given in the following paragraphs, all electrical systems can be potential killers. Shipboard '(ungrounded" electrical systeme are actually capacitively grounded to the extent that lethal currente can flow through a persons body if a live conductor is touched while in contact with ship's ground. The capacitance which causes this electrical ground leakage current to flow is inherent in the design of equipment and cable, and can not be eliminated by practical technical means. All personnel should be aware of the potential hazards; those who work on electrical equipment or systeme should be completely knowledgeable of the hazards, precautions, first-aid techniques, and theory of electric shock.

3-3.1 REASON FOR USING AN UNGROUNDED SYSTEM

Ungrounded electrical distribution systems of both 450 and 120 volts AC are provided on naval ships to achieve maximum system reliability and continuity of electrical power under combat conditions. If one line of the distribution system is grounded, due to battle damage or deterioration of system insulation resistance, the circuit protective devices (circuit breakers, fusee, etc.) will not de-energize the circuit having the ground and electrical power will continue to be delivered to vital load equipment without further damage to the system. Frequent and proper use of the system ground detectors provided on the ship-service switchboards and certain power panels will allow maintenance personnel to locate the ground and make repairs to remove the ground from the systems as operating conditions permit. The primary advantage of an ungrounded system is that power can be maintained to a piece of vital load equipment (such as fire control equipment) during a battle condition, even when a ground occurs on one line of the electrical circuit supplying power to the equipment. If the system was designed as a grounded system, the abovementioned ground on one power line would result in immediate tripping of the circuit protective devices, possible de-energizing a piece of vital equipment when it is most needed.

3-3.2 MISCONCEPTIONS OF A SHIPBOARD UNGROUNDED SYSTEM

Many personnel believe that since the electrical syetem is supposed to be ungrounded, it is possible to touch one bare conductor without danger, since there will be no electrical path for current to flow and, therefore, no electrical shock hazard. This can be a very deadly belief. The misconception arises when we consider the question; what is an ungrounded system? How do we measure or determine that an electrical system is ungrounded? How much electrical current does it take to kill a person? For purposes of discussion, a perfectly ungrounded single-phase, two-wire distribution system is shown in Figure 3-1. The system consists of a generator, distribution cable, and load equipment.

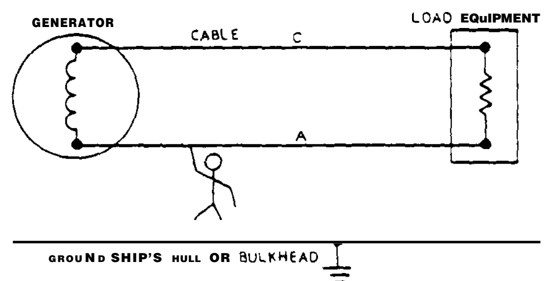

Figure 3-1. Perfect Ungrounded System

By a perfect ungrounded system we mean one in which the insulation is perfect on all cables, switchboard, circuit breakers, generators, and load equipment; that no Radio Frequency Interference (RFI) filter capacitors are connected from ground to any of the conductors, and that none of the system's equipment or cables have any inherent capacitance-to-ground. If all these conditions were met, there would not be a path for electrical current to flow to ground from any of the system conductors. Figure 3-1 shows that if a person touches a live conductor at point A while standing on the deck or ground at point B, there is no completed path for current to flow from conductor A to conductor C through the persons body, and thus there is no danger for electrical shock. However, shipboard electrical power distribution systems do not and can not meet the above definition of a perfect ungrounded system. If we examine a typical shipboard “real” ungrounded system (see Figure 3-2) there are additional factors which must be considered, some of which are not visible.

These additional factors can be grouped into two categories: resistance and capacitance. The resistance consists of $\mathbf{R_g}$ which is the generator insulation resistance, $\mathbf{R_c}$ which is the electric cable insulation resistance, and R_l which is the load insulation resistance. These resistances, when combined in parallel, form the insulation resistance of the system. Insulation resistance is periodically measured by the crew using a 500 volt DC megger. The reading obtained is an indication of the integrity or quality of the insulation. These resistors, ($\mathbf{R_g}$, R_c, R_l) can not be seen as physical components, but are representative of small current paths through equipment and cable electrical insulation. The values of these resistances are measured in ohms; the higher the resistance, the better the system insulation and consequently, less current flow between conductor and ground. Typical values would be,

$\mathbf{R_g}$ = 500,000 ohms*
R_c = 50,000 ohms* for large system
R_l = 1,000,000 ohms* or greater

The capacitance, shown in Figure 3-2 consists of $\mathbf{C_g}$ which is the capacitance of the generator to ground, C_c which is the capacitance of the distribution cable to ground, and C_l which is the capacitance of the load equipment to ground. As mentioned before, these capacitances can not be seen, since they are not actually physical components, but are inherent in the design of electrical equipment and cable. As an example, if we consider an electrical conductor surrounded by insulation, mounted on a metal bulkhead, we have two pieces of metal separated by an insulating material. Then, since on shipboard systems a potential difference (voltage) will exist between the conductor and the metal bulkhead or ground, we have established, in effect, a capacitor as shown in Figure 3-3.

The value of the capacitance thus generated between the conductor and ground is determined by the radius of the conductor, the distance between the conductor and the bulkhead, the dielectric constant of the material between the two, and the length of the cable. Similar capacitance exists between the generator winding and ground, and between various pieces of load equipment and ground. Since capacitors ideally have an infinite impedance to DC current, their presence can not be detected by a megger or insulation resistance test.

* These values are typical of a large operating system but can vary widely depending on the size of the ship and the number of electrical circuits connected together.

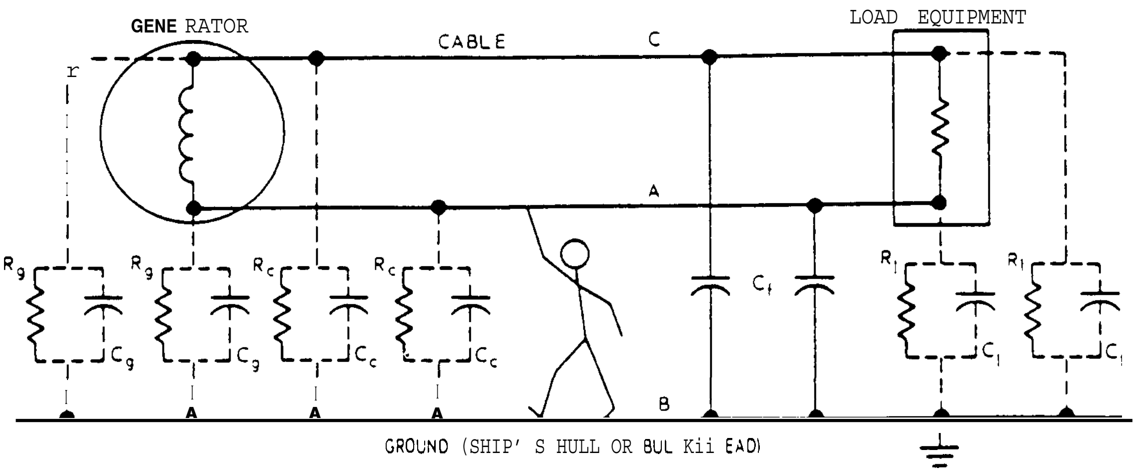

Figure 3-2. Typical Shipboard “Real” Ungrounded System

Figure 3-2. Typical Shipboard “Real” Ungrounded System

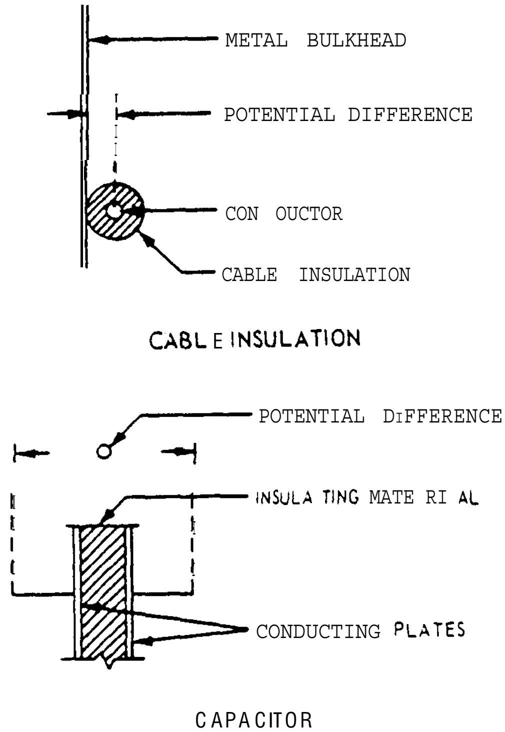

Figure 3-3. Capacitance of Cables

In addition to the non-visible system capacitance, typical shipboard electrical systems contain Radio Frequency Interference (RFI) filters which contain capacitors (C_f) connected from the conductors to ground. These filters may be a part of the load equipment or mounted separately, and are used to reduce interference to communications equipment. The impedance of this capacitance to electrical current flow, also measured in ohms, is determined by the relation:

X_c = Capacitive Reactance in Ohms

$$= \frac{1}{2\pi\,(\text{Frequency})(\text{Capacitance in Farads})}$$

Typical values of X_c are:

X_g = 26,000 ohms* (C_g = 0.1 pF/phase)

X_c = 1,060 ohms* (C_c = 2.5 pF/phase)

X_f = 53 ohms* (C_f = 50 pF/phase)

X_l = Very high unless equipment contains filter capacitors

If we re-examine Figure 3-2, we will notice that the capacitances (C_g, C_c, C_f, C_l) are in parallel with the system insulation resistances (R_g, R_c, R_l), and form an additional path for electrical current flow from the conductors to ground (ship's hull or bulkhead). Therefore, if a person accidentally touches a conductor at point A, current will flow through the body to ground at point B and back through the system resistances and capacitances to the other conductor at point C, thus completing the electrical circuit, and presenting a serious shock hazard.

3-3.3 RESISTANCE VERSUS CAPACITANCE

If we were to megger the system of Figure 3-2, and obtain a system value of insulation resistance of approximately 50,000 ohms, we would conclude rightly that no low resistance grounds exist on the system and wrongly that the system is "perfect" ungrounded system. Perhaps, we have forgotten the system capacitance which exists is parallel with the resistance. If we look at the typical values of system capacitances given above, we will see that if the system contains many RFI filters, the capacitive reactance of the system to ground may be as low as 50 ohms, while, even without these filter% the inherent capacitance of generators and distribution cable would result in a capacitive reactance of approximately 1,000 ohms. What does this mean to the person who is careless and touches a live electrical conductor? Figure 3-4 shows a simplified circuit assuming no RFI filters are connected to the system. If we assume a person's body resistance of 600 ohms, possible under work conditions when hands are wet from sweat, and combine the total system insulation resistance (R) in parallel with the system capacitive reactance (XC) we obtain the system impedance (Z) to ground, as in the following formula:

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* Data obtained from measurements made on the CVA-20 in 1955.

\# Data obtained from measurements made on the CG-10 and CG-12 in 1969.

$$Z = \frac{(R)(X_c)}{\sqrt{R^2+X^2_c}} = \frac{(50{,}000)(1{,}000)}{\sqrt{(50{,}000)^2+(1{,}000)^2}}$$

= Approximately 1,000 ohms

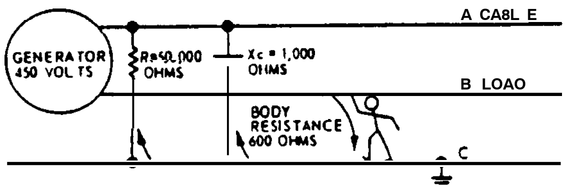

Figure 3-4. Ground (Ship's Hull or Bulkhead)

If the person touches conductor B, the current will flow through the body (600 ohms) to **ground,** then through the system impedance Z (1,000) ohms, and back to conductor A completing the electrical circuit. The total opposition to this current flow is the square root of the quantity 10002 + 600^2, or 1166 ohms. The amount of shock current which would flow is given by Ohm's Law;

$$I_s = \frac{450 \text{ volts}}{Z_T} = \frac{450 \text{ volts}}{1166 \text{ ohms}} = .386 \text{ amps}$$

How much current does it take to kill a person? The following general guidelines are taken from NAVSEA 0900-LP-007-9010 "Electric Shock-Its Causes and Its Prevention".

a. At 1.0 mA, shock is felt.

b. At 10 mA, a person may be unable to let go.

c. At 100 mA, shock is fatal if **it** lasts for one second or more.

Thus, even if no RFI filters were connected to the system, even if a megger test showed the system to be ungrounded, a current of almost **four** times the current required to kill a person would flow through the body, and death would result. The aforementioned system capacitance (C_g, C_c, C_1) can not be eliminated since it results from inherent laws of electrical theory associated with the practical design of electrical equipment and cable. This condition existed on all previous ships constructed with AC distribution systems, exists on all present ships, and will exist on all future ships. However, unlike the system insulation resistance, the system capacitance will not change with time (unless equipments containing capacitors connected to ground are added) since it is a function of equipment and cable design. Therefore, no need exists to periodically measure capacitance as we measure the insulation resistance.

The addition or elimination of RFI filter capacitors connected to the system makes no difference from a safety standpoint. It only makes no difference from a safety standpoint. It only takes so much current to kill you, and there is more than enough without RFI filters. Remember:

a. Never touch a live conductor of an electrical circuit, "ungrounded" or grounded.

b. High system insulation readings from a megger test do not make the system safe to touch–nothing does.

c. Insulation resistance tests are made to ensure that the system will operate properly, not to make the system safe.

d. Know and follow the electrical safety instructions contained in Naval Ships Technical Manual Chapter 300.

3-3.4 ISOLATED RECEPTACLE CIRCUITS

To reduce the inherent hazard of these leakage currents on receptacle circuits where portable tools or applicants are plugged in and out, and personnel are more likely to receive an electric shock, isolated receptacle circuits are installed on all new-construction ships. These circuits are individually isolated from the main power distribution **system** by transformers and each circuit is limited to 1,500 feet in length to reduce the capacitance to an acceptable level. This design is intended to limit ground leakage currents to 10 mA which produces a non-lethal shock. To maintain this low level of leakage current and provide personnel safety, it is extremely important that the isolated receptacle circuits be maintained free of all resistance grounds.

Ships already in the fleet were provided information for installation of either fixed or portable isolation transformers in the receptacle circuits in 1960.

The use of isolated receptacle circuits, and equipment design improvements, have materially reduced the hazards encountered when using portable tools and appliances. However, the best safety device is respect for the deadly hazards present in all electrical systems, grounded or ungrounded, low or high-voltage, AC or DC; for they all are potential killers of the careless or the inexperienced. Each crewmember should be familiar with the electrical safety precautions contained in the following publications.

a. Naval Ships Technical Manual, NAVSEA S9086-KC-5TM-000/CH-300 RI Chapter 300

b. Electric Shock-Its Causes and Its Prevention, NAVSEA 0900-LP-007-9010 (formerly NAVSHIPS 250, 660-42)

3-4 GENERAL SAFETY PRECAUTIONS AND POLICIES

Electronic equipment in the Fleet today has become exceedingly complex and sophisticated. It includes such areas as radars, sonars, radios, power amplifiers, antennas, satellite communications and navigation equipment, electronic warfare equipment, missile and fire control equipment, computers and associated control equipments.

Safety from the viewpoint of the technician requires a full appreciation of the various factors and hazards involved in the maintenance of these equipments. Adequate safety features, such as the use of suitable enclosures, provision for grounding, protective interlocks, etc., are required for electronic equipments. Electronic installations require similar protective features or additional features such as the installation of approved insulating deck covering on deck areas adjacent to electronic equipments.

Regardless of efforts made during design and installation, however, safety depends on the user being continually aware of hazards and being alert to guard against them.

Personnel must always remember that the removal of a unit or part from the normal location and the energizing of the unit or part, while it is outside the normal enclosure, removes the protective features such as interlocks, grounds and enclosures. Since these safety features then no longer exists, special precautions and safety measures must be taken.

Some of these basic, but vital safety precautions pertaining to the proper handling of electronic equipment circuits, are compiled in this subsection. These safety precautions, together with those contained in equipment technical manuals and Maintenance Requirement Cards, comprise a nucleus for the promulgation of detailed instructions for accident-free installation, maintenance, and operation of electronic equipment and facilities ashore and afloat.

3-4.1 INTENTIONAL SHOCKS ARE FORBIDDEN

Intentionally taking a shock at any voltage is always dangerous and is STRICTLY FORBIDDEN. Whenever is becomes necessary to check a circuit to see if it is alive, a test lamp, a voltmeter, or some other appropriate indicating device shall be used. The indicating device employed shall be suitable for obtaining the desired check without jeopardizing personnel, and if necessary, it should be used in conjunction with authorized safety devices. (See subsection 3-19, Safety Equipment.) Never implicitly trust insulation material: treat all wiring as though it were bare of insulation. Insulating material has failed before and may fail again-be on the alert!

3-4.2 NEVER WORK ALONE

Never work on electronic equipment by yourself; have another person (safety observer) qualified in first aid for electrical shock present at all times. The safety observer should also know which circuits and switches control the equipment, and should be given instructions to pull the switch immediately if anything unforeseen happens.

3-4.3 AUTHORIZED PERSONNEL ONLY

Because of the danger of fire, damage to material, and injury to personnel, no person should be assigned to operate, repair, or adjust any electronic equipment unless that person has demonstrated a practical knowledge of its operation and repair and of all applicable safety regulations, and then only when duly authorized by the head of department having cognizance over such equipment.

3-4,4 ENERGIZED ELECTRONIC EQUIPMENT

Personnel should not reach within or enter energized electronic equipment enclosures for the purpose of servicing or adjusting except when such servicing or adjusting is prescribed by official applicable technical manuals (instruction books) and then only with the immediate assistance of another person capable of rendering adequate aid in the event of an emergency. Personnel shall be warned to exercise extreme caution when reaching into the enclosures of equipment having internal exposed high voltage points. The metal shielding shell of some capacitors, kylstrons, cathode-ray tubes, and other components are at high potentials above ground.