GROUNDING/BONDING

Previous issues of *ITEM* have nearly always contained articles on grounding and/or bonding. For instance, our 1976 issue contains a fine article on bonding prepared by Hugh Denny of Georgia Tech's Engineering Experiment Station. Mr. Denny also prepared an excellent article titled "Grounding of Electronic Systems" which appeared in our 1975 issue. The 1974 issue contained an article titled "Facility Grounding" which was assembled by our staff writers from a government report. This article discussed basic ground planes, earth grounding, measurements and the use of various ground conductors.

In 1976, the U.S. Department of Transportation, Federal Aviation Administration, issued a number of publications on grounding, bonding and shielding. These were prepared under contract by the Engineering Experiment Station, Georgia Institute of Technology, and are available to the public through the National Technical Information Service, Springfield, VA 22151. They are listed as follows:

Grounding, Bonding & Shielding Practices and Procedures for Electronic Equipments and Facilities. Volume I, Fundamental Procedures. Final Report, December 1975. Report No. FAA-RD-75-215, I.

Grounding, Bonding & Shielding Practices and Procedures for Electronic Equipments and Facilities. Volume II, Procedures for Facilities and Equipments. Final Report, December, 1975. Report No. FAA-RD-75-215, II.

Grounding, Bonding & Shielding Practices and Procedures for Electronic Equipments and Facilities. Volume III, Economic Considerations and Program Management. Final Report, December 1975. Report No. FAA-RD-75-215, III.

Survey of Grounding, Bonding and Shielding Practices. Final Report, April 1976. Report No. FAA-RD-76-68.

Grounding, Bonding and Shielding Bibliography 1930 to 1971. Final Report, January 1976. Report No. FAA-RD-76-145.

Grounding, Bonding and Shielding Bibliography 1971 to 1975. Final Report, September 1976. Report No. FAA-RD-76-177.

For our 1977 edition of *ITEM*, the editors have decided to excerpt a number of references on grounding and bonding from the last two reports listed above. Although these documents do not contain all of the published works on this subject, they do present a good list of references, some of which should be of interest to most of our readers. Obviously omitted were *ITEM* articles, some government reports, and several books on the subject. We did not go back beyond 1970 in our own extraction because of considerable redundancy and anticipated difficulty in obtaining copies of these documents.

Behavior of Conductive Epoxy for Shielding and Bonding; Alfred W. Dimarzio - Frequency Technology, Aug./Sept. 1970, pp. 18-23.

The application of conductive epoxies for interference control purposes is widespread. The performance of these epoxies is known only in general terms and is often clouded by use with other materials such as gaskets.
The investigation presented analyzes the epoxy as a means to bond covers onto compartmentized modules and afford intercompartmental shielding with no loss of packaging density due to fasteners. Secondly, the epoxy's bulk resistivity is analyzed versus frequency (0.15 to 60 MHz) and compared to other techniques used to achieve high frequency bonds. Lastly, a hypothesis is presented for optimum bond configuration and proposed application of a conductive epoxy.
The test sample was an epoxy-amine electrically conductive adhesive.
"A silver filled, two component, thermosetting resin system which when properly catalyzed and cured will produce an electrically conductive material for use as electrical contacts, terminations and adhesive."

High Voltage Lightning Grounding Device; V. S. Peterson and R. G. Hoffman, Lewis Research Center, 2100 Brookpark Rd., Cleveland OH 44135 - NASA Technical Brief, May 1971, Brief 71-10137.

This article describes a transient grounding device to be used in preventing lightning-induced high voltage transients from reaching the inputs or outputs of solid state instruments and control systems. Also described is the necessary modification of terminal blocks for the insertion of the transient grounding device in wire termination cabinets commonly used in large facilities.

The transient grounding device was successfully tested at 10 KV and 10 joule strike levels; the highest energy level that can be present in this type of wire terminal block, before the transient arcs over the block and finds its own path to earth.
The device is described and the circuit diagram is given. The elements required for constructing the device are: three gas filled spark gaps, two ferrite core chokes and a zener diode.

Electrical Grounding Bracket; Technology Utilization Officer, Ames Research Center, Moffett Field CA 94035 - NASA Technical Briefs, 1972, Brief 72-10045.

The brief describes a specially shaped bracket which fits around a typical multiple-pin connector and supports a grounding bar to which shield ground wires can be fastened. It is simply a rigidly supported, rounded strip of metal onto which may be soldered the shieldground leads of the sheilded wires leading to the connector pins.

The electrical grounding bracket simplifies solder operations and the dressing of shield terminations. Because each shieldground lead can be soldered independently to the bracket, it is a simple matter to alter the writing configuration of the connector or to remove or add shielded wires. The bracket also permits addition or deletion of a ground circuit without disturbing the remaining ground wires, and the grounding bracket may itself be unfastened from the connector for electrical tests.

Earthing Practice Overseas; W. L. Leicester - Elec. Times (GB), Vol. 161, No. 16, p. 33-36 (20 April 1972).

The need to protect electricity users from shock hazard is the determining factor for a country's earthing philosophy and this philosophy must be an extension of the approach adopted by the electricity supply companies. For this reason the types of electricity supplies available must be considered.

A Note on Grounded Thermocouple Circuits; R. P. Benedict, R. J. Russo, (Westinghouse Electric Corp., Lester PA, USA) - Trans. ASME Ser. D (USA), Vol. 94, No. 2, p. 377-380 (June 1972).

Basic circuits involving the thermocouple as a temperature-sensing device have been described and analyzed in the literature. However, relatively little has been written on the thermocouple as part of an overall instrument circuit wherein external electrical effects are important. After reviewing the more important electrical effects which are extraneous to the basic thermocouple circuit, the problem of multiple grounds in a thermocouple proper is considered in some detail. Experiment and analysis indicate that serious errors in temperature measurement can result from the use of improper grounds in thermocouple circuits.

Grounding of Large Electrical Installations in Limited Area of High Earth Resistivity; S. N. Roy (U. P. State Electricity Board, Dehradun, India) - J. Inst. Engr. (India), Electr. Engr. Div., Vol. 52, pt. EL-6, No. 12, p. 308-14 (August 1972).

Grounding of large electrical installations in limited areas of high earth resistivity poses special problems. Recommended low values of ground resistance are difficult to achieve for such cases. However, the installation can be made safe by limiting the potential gradients and by adopting special means. Design of a grounding mat and determination of step and touch potentials encountered involve lengthy calculations or a computer program by way of varying the depth of burial, spacing and number of parallel paths of the grounding conductor. With a few sets of calculations given in this paper, the length of conductor required to limit dangerous potential gradients is represented graphically with respect to the above variants giving the required information at a glance and making the designing processes simpler.

Ground Connector for Conduit: A. R. Norden, Oz Electrical Mfg. Co., Inc., patent USA 3706959, 8 April 1971 - published 19 Dec 1972, US 132462.

A grounding device is disclosed wherein a bushing is adapted to be threaded onto an end of conduit extending through a wall of a housing and a grounding lug is secured on the periphery of the bushing. The lug has a resilient C-shaped wire clamping portion and resilient wings extending from opposite ends thereof formed so as to provide spring tensioned connections to the periphery of the bushing. The wings have teeth adapted to make grounding connections with the wall of an enclosure or box upon threading of the bushing onto conduit extending through the enclosure, additionally providing anti-turning means to prevent the lug from rotating on its mounting screw.

Neutral Grounding and the Prevention of Neutral Instability; J. B. Johnson, J. R. Stevenson (General Electric Co., Schenectady, NY, USA) - IEEE Transactions Power Apparatus and Systems (USA), Vol. PAS-92, No. 1, pp. 341-345 (Jan. - Feb. 1973).

Investigative results from a systems-in-miniature setup are presented concerning the stability of Y-connected potential transformers, and the effect of potential transformers as generator neutral grounding devices. Included is the influence of a resistance burden on the neutral grounding transformer.

Electrical Power Systems Neutral Grounding Practice to Minimize Downtime; K. J. Owen - 59th annual meeting 1973 of the Technical Section of the Canadian Pulp and paper Assoc., Montreal Canada, 23-26 January 1973 (Montreal, Canada: Canadian Pulp & paper Assoc., 1973) pp. 1-8.

The philosophies used in the past to determine the merits of operating power systems in a grounded or ungrounded neutral mode are considered no longer completely valid, due to the advent in recent years of monitoring devices, highly sensitive to very small deviations in normal phase-ground conditions. It is the intent then to review these philosophies and propose a particular approach—namely high resistance grounds to the function of the neutral that retains the advantages and reduces the disadvantages of past power system operation, still leaving the operator of the power system the option of selecting the mode of operation; that is, to trip or annunciate only when phase-ground relationship becomes abnormal. It is also proposed that this concept will minimize both the rate of and elapsed down times.

A Review of Lightning Protection and Grounding Practices; G. W. Walsh (General Electric Co., Schenectady NY, USA) - IEEE Trans. Ind. Appl. (USA), Vol. IA-9, No. 2, pp. 133-148 (March-April 1973).

Guides are presented to facilitate proper economic lightning protection of industrial power system component arrangements. Basic concepts of the traveling wave nature of lightning are included to enhance understanding of protective practices as they have developed and emphasizing the need for carful adherence to approved practices in critical areas. The grounding treatment is very brief, being limited to the most salient considerations of equipment grounding in relation to the overall lightning protective system and the ground fault protective system. The paper is referenced throughout to current industry standards, application guides, and codes.

Trends and Practices in Grounding and Fault Protection Using Static Devices; R. O. D. Whitt (Westinghouse Corp., Beaver, Pa., USA) - IEEE Trans. Ind. Appl (USA), Vol. IA-9, No. 2, pp. 149-157 (March-April 1973).

Grounded and ungrounded systems are in general use in both commercial and industrial distribution systems. This paper briefly identifies the types of systems in use in each category and lists some of the main advantages and disadvantages of each. The need for adequate protection has been recognized by the 1971 Electrical Code (national). This recognition is being complemented by Underwriters Laboratories with the introduction of appropriate standards. With the passing of the Occupational Safety and Health Act of 1970, more emphasis than ever before will be placed on adherence to the preceding code and standards. This paper reviews the various methods of detecting ground faults using static devices and describes some of the equipment available for those applications.

Utility Grounding Practices; H. M. Smith, General Electric Cablevision Corp., San Antonio TX, USA - Cablecasting-Cable TV Engr., Vol. 9, No. 2, pp. 6-10, July-Aug. 1973.

This article discusses the principles and safety regulations of earthing techniques. The author describes the optimum methods and some of the problems involved.

A Review of Lightning Protection and Grounding Practice; G. W. Walsh (General Electric Co., Schenectady NY) - 1973 8th Annual Meeting of the IEEE Industry Applications Society, Milwaukee, Wisconsin, 8-11 October 1973 (New York, USA. IEEE 1973), pp. 465-480.

Guides are presented to facilitate proper economic lightning protection of industrial power system component arrangements. Basic concepts of the traveling wave nature of lightning are included to enhance understanding of protective practices as they have developed and emphasize the need for careful adherence to approved practices in critical areas. The grounding treatment is very brief, being limited to the most salient considerations of equipment grounding in relation to the overall lightning protective system and the ground fault protective system. The paper is referenced throughout to current industry standards, application guides, and codes.

Impulse Characteristics of Horizontally-buried Straight Conductors used as Grounding Electrode; B. Thapar, R. P. Nagar (Punjab Engr. College, Chandigarh, India) - J. Inst. Engr. (India) Elec. Engr. Div., Vol. 54, Pt. EL1, pp. 11-15 (Oct. 1973).

To predict the impulse behavior of grounding electrodes, it is necessary to evaluate the effect of the various factors controlling the impulse characteristics. In this paper an analytical method is developed to determine the effect of those factors and to evaluate the impulse grounding impedance of a single horizontal conductor subjected to impulse currents. It is shown that the impulse grounding impedance of a straight horizontal electrode does not change if the length of the conductor is increased beyond its effective length, which depends upon the resistivity of the soil and the time-to-peak of the applied impulse current. An equivalent lumped π network is defined to represent the single horizontal grounding conductor.

Study of Relative Effectiveness of Conduits and Grounding Conductors in Reducing Potential Differences in a Patient's Room Produced by Fault Currents; G. N. Webb, D. Gordon (Johns Hopkins Hospital, Baltimore, Maryland) - Proceedings of the 26th Annual Conference on Engineering in Medicine and Biology, Minneapolis, Minn., USA, 30 Sept. 4 Oct. 1973 (Arlington VA, USA: Alliance for Engineering in Medicine and Biology 1973), pp. 241.

Modelling of Potential Distribution Around a Grounding Electrode; D. Mukhedkar, Y. Gervais, F. Dawalibi, Ecole Polytech., Montreal, Canada - IEEE Trans. Power Apparatus and Systems, Vol. PAS-92, No. 5, pp. 1455-1459, Sept. - Oct. 1973.

A twin layer model is used for experimental determination of the potential distribution around and near different ground electrodes. An attempt is made to study the effect of local top layer discontinuities on potential distribution in a twin layer model.

Sneak Ground Currents in A-C Power Sytems; L. Yenraque - Electrical Construction and Maintenance, Vol. 72, No. 11, pp. 80 (Nov. 1973).

Sneak currents in A.C. power systems are those currents that flow in the grounding conductor for no apparent reason. Regardless of the size of the system, ground currents will be present to some extent, whether measureable or not, contributing to malfunctioning of sensitive equipment and nuisance tripping of ground fault protective devices. In this paper suggestions of possible methods to aid attenuation and control these ground currents are given.

Ground Electrode Resistance Measurements in Non-uniform Soils; F. Dawalibi, D. Mukhedkar (Shawinigan Engng. Co. Ltd., Montreal, Quebec, Canada) - IEEE Transactions Power Apparatus and Sytems (USA), Vol. PAS-93, No. 1, pp. 109-115 (Jan. - Feb. 1974).

Ground electrode resistance measurements are usually done by fall of potential method. The potential probe position (0.618 rule) has been calculated for homogeneous soil. Theoretical computation and experimental verification of the potential probe position in non-homogeneous soil is presented. The experimental work was carried out on a twin layer laboratory model.

Grounding for Industrial and Commercial Distribution Systems; A. A. Regotti, H. W. Wargo (Westinghouse Electric Corp., Pittsburgh PA, USA) - Westinghouse Eng. (USA), Vol. 34, No. 2, pp. 41-45 (April 1974).

Phase to ground faults are the most common kind in distribution systems. Therefore, the kind of system grounding used (if any) and the ground-fault protection applied are important. They should be carefully chosen to fit the particular application.

Equipment Grounding for Reliable Ground Fault Protection in Electrical Systems Below 600 Volts; R. B. West (Monsanto Co., St. Louis MO, USA) - 1973 Industrial and Commercial Power Systems Technical Conference, Atlanta GA, USA, 13-16 May 1973), pp. 48-63.

Equipment grounding is one of the most important, but least understood, requirements for reliable ground fault protection. This paper defines the basic objectives of equipment grounding and analyzes the role of equipment grounding conductors in providing ground fault protection for electrical systems below 600 volts.

An Earth Fault Monitor for "Floating" Control Systems; W. Meier (Siemens A G, Erlange, Germany) - Siemens Rev. (Germany), Vol. 41, No. 5, pp. 233-236 (May 1974).

Floating systems are becoming more and more popular in the electronic control field. However, such systems cannot operate reliably unless an earth fault monitor is installed to monitor them for earth faults and if necessary, give immediate warning of such faults. The earth fault monitor EA-2 operates on the principle of differential current measurement. The monitor, which is connected to earth via a high resistance, sends out a pulsating search current, which produces a voltage drop across a resistor, the magnitude of the voltage drop varying with the magnitude of the earth-fault resistance.

Earthing System Devices - Electrical Equipment (GB), Vol. 13, No. 6, pp. 30-31, 33, 35 (June 1974).

Since at some time or other most electrical installations will suffer, at least occasionally, from leakage currents, lightning strikes, static buildup or short circuits these abnormal conditions have to be catered for. This means that most systems have to have an effective and reliable earthing arrangement. Indeed it does not take long, reading accident investigation reports, to discover that the omission or failure of an earthing system can and has resulted in loss of supply for some lengthy periods, fire and subsequent equipment damage and even loss of life. Several devices for making earthing systems including the thermoweld electrical connection process are discussed.

Earthproving for Portable Plant; A. Wright (A. Reyrolle & Co. Ltd., Hebburn, England) - Elect. Times (GB), No. 4291, p. 12 (25 July 1974).

Examines the main requirements of protection of portable and trans-portable equipment and illustrates how, typically, it is achieved in practice. A typical earth proving unit connected to a portable appliance which monitors impedance of the earth loop and disconnects the appliance should this impedance exceed a pre-determined value is described. It also rapidly disconnects the appliance should an earth fault appear. Main advantage of this protection is, that it does not depend upon sensing current flowing through an operator in contact with the appliance.

Guarded Double Insulation--A Technique for Reducing the Shock Hazard of Grounded Electrical Systems; N. L. Kusters, M. P. MacMartin (Nat. Res. Council Canada, Ottawa, Ontario) - Fifth Canadian Medical and Biological Engineering Conference--Digest of papers, Montreal, Quebec, Canada, 3-6 Sept. 1974 (Montreal Quebec, Canada: Univ. Montreal 1974), pp. 16/5a-5b.

Describes a technique, making use of both guarding and double insulation, which reduces the shock hazard of electromedical apparatus. The technique is suitable for use in treatment areas where both the patient and the electrical supply system are connected to ground. The addition of a guarded, double-insulated power input circuit to each piece of electromedical equipment prevents current from flooding from the power source to the grounding circuit, and makes an equipotential ground possible in a patient area.

Ground Fault Tests on a High Resistance Grounded 13.8KV Electrical Distribution System of a Modern Large Chemical Plant (Arcing); L. B. McClung, B. W. Whittington (Union Carbide Corp., South Charleston, WV, USA) - IEEE Trans. Ind., Appl. (USA), Vol. IA-10, No. 5, pp. 601-617 (Sept. - Oct. 1974).

Actual ground fault tests were conducted to determine the behavior of low magnitude arcing ground faults in a closed air-filled 13.8KV terminal chamber. Ground current magnitudes between 10 and 50A were allowed to flow under various ground fault conditions. At higher ground fault current levels the ionization of the air-filled chamber progresses at a rapid rate, and the arc is sustained or phase to phase faulting quickly occurs. The practical consideration appears to be that if ground fault current can be limited to 10A or less then initial ground faults will either clear themselves or create solid ground paths. This can allow the system to operate until an orderly shutdown procedure can be initiated.

Earth Loop Testing and p.m.e. Systems; S. R. Freeman - Electr. Times (GB), No. 4301, p. 15 (10 Oct. 1974).

Outlines the development of protective devices since 1930's. Discusses the importance of installing sensitive current balance trips. Questions some aspects of protective multiple earthing; e.g., the hazards in the events of breakage of the neutral connection. Suggests that a regular test of p.m.e. installations with a line-earth tester is needed. Outlines the development of a universal tester with combined test facilities.

Conductive Gasket; J. A. French, S. P. Kleczkowski, J. A. Kornfeld, M. Trynoski (IBM, New York, USA) - IBM Tech. Disclosure Bull. (USA) Vol. 27, No. 5, p. 1304 (Oct. 1974).

The gasket is a flexible, carbon filled silicone compound moulded into a U-shape and fastened to one side of a cover or frame with clips or adhesive. When the gasket is squeezed between the cover and frame, electrical and mechanical contact occurs despite very low closure forces.

Isolating Power Supply Lines Avoids Problems with Earthing; E. B. Piercy, M. J. Scott (Taylor Instrument Co., Europe, Ltd., London, England - Control & Instrum. (GB), Vol. 6, No. 10, pp. 50-51 (Nov. 1974).

The authors take a postive look at the "common negative" approach for connection of electrical power supplies.

Grounding and Safety; D. J. Hatch, M. M. B. Raber (Health Scis. Centre, Winnipeg, Man., Canada) - IEEE Trans. Biomed. Engr. (USA) Vol. BME-22, No. 1, pp. 62-65 (Jan. 1975).

Several basic facts about the effects of steel conduits in a.c. power systems are reviewed to show that the geometry of a grounding path may have a greater impact on its effectiveness as a ground return path than its d.c. resistance. Data are presented on the effect of 1/2" E.M.T. conduit and No. 10 conductors in tests simulating regular room wiring under ground fault conditions. It is shown that an internal grounding conductor tied to the conduit produces the lowest practical limit to voltage differences in the ground circuit; additional grounding paths external to the conduit make little appreciable difference to the voltage rise due to a fault current. A separate grounding conductor external to the conduit, when used by itself, produces a much larger voltage rise than the conduit system.