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The Product Safety Newsletter

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What's Inside

Chairman's Message

I recently had the opportunity to make a career change of sorts. After nearly twenty years practicing product safety and related disciplines in the information technology (IT) industry, I'm now plying my trade in the semiconductor process equipment sector. In researching the industry prior to the move and from my experiences in the business so far, I've noticed some interesting contrasts in product safety practices between IT and semiconductor equipment worth sharing.

First, however, some caveats. I realize that IT is a huge business serving a huge global market, much larger than the semiconductor business, and that this difference in size and maturity accounts for some of the differences. However, if one looks back on IT twenty years ago and realize how little has changed in some ways, the contrasts are quite legitimate. Additionally, my observations arise from my initial exposure to the industry and may be affected by future experience.

Key characteristic include:

The products involve a variety of significant risks.

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The Product Safety Newsletter

The Product Safety Newsletter is published bimonthly by the Product Safety Technical Committee of the IEEE EMC Society.

Opinions expressed in this newsletter are those of the authors and do not necessarily represent the opinions of the Technical Committee or its members. Indeed, there may be and often are substantial disagreements with some of the opinions expressed by the authors.

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PSN Subscriptions,
Dave McChesney
1865 Farndon Avenue
Los Altos, CA 94024
fax: (408) 296 3256

Comments and questions about the newsletter may be addressed to:
The Product Safety Newsletter,
Roger Volgstadt (Loc. 55-53)
c/o Tandem Computers
10300 North Tantau Avenue
Cupertino, CA 95014
Fax No. (408) 285 2553

Editor: Roger Volgstadt
News Editor: David Edmunds
Activities Editor: John Reynolds
Page Layout: Ken Warwick
Subscriptions: Dave McChesney
Institutional Listings: Ervin Gomez

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IEC 479-1 Effects of Current Passing Through the Human Body

a review by Peter E. Perkins, PE

The human body impedance is reasonably well known in the region of mains voltages commonly used in equipment. The break points between the perception reaction through to fibrillation are given for both AC and DC currents. Knowledge of these values in setting requirements for equipment will provide for equipment design that is safe and effective in the hands of the user. From the information given on the effects of electric current causing reaction and the body impedance data we see that safe voltages are in the region of 50 volts or less.

The electrical model for body impedance is simple; the threshold effect of current are more complex. The body is a fairly simple mechanism. The skin resistance is high while the body fluids are low impedance. Although there is sound statistical evidence for the body impedance, there is less data for the hazardous portions of the time current curves developed for both AC and DC currents. Obviously, there are few volunteers for shocks that can cause severe damage or death.

Important characteristics of the body are:
1) Values for the total impedance of the human body are known; it is about 1000 ohms or so for mains voltages.

Although the early work of the US researcher Dalziel is foundational, the primary data for the recent work comes from European research. Some of it is done by Dr. Biegelmeier of the Austrian ÖVE, who as the chairman of IEC TC64/WG4, guided the committee responsible for IEC 479.

2) The variation of impedance through various body paths is well described; a variation of a factor of 2X or so. The effects of frequency and length of current flow are also described. Dr. Biegelmeier himself has been a principle subject of some of the data presented.

3) Time vs. current graphs clearly show the effects of current reactions over several order of magnitude changes in body current or current duration. The body can withstand quite large currents - on the order of a few hundred milliamperes - for up to a few hundred milliseconds.

4) For DC, the physiological effects are not as severe - by a factor of 3X or almost 4X - and the let-go boundary is not well defined.

The DC current traditionally allowed, expecting no reaction, has been 2mA which is substantially higher than the corresponding 0.5 mA allowed for AC currents.

Having good information on the effects of current on the body is the key to setting requirements for residual current from electrical equipment. Electric shock, an insidious hazard, sneaks up on the user. It can be fatal. You never know until you touch the leaky equipment that it is going to give you a shock.

Generally people are alert for hazards that exist around them and try to avoid any that they can. Since we do not have an electric field sensor mechanism

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Working Voltages, Spacings Req'd by CSA C22.2 Nos. 234 and 950

by Lal Bahra, P. Eng.
Canadian Standards Association

Working voltage is understood and measured differently by product safety engineers, certification personnel and standard writers. Some consider the line voltage to be the working voltage while others measure the highest voltage between any two points in the primary and base the clearances and creepage distances on this highest voltage.

The instrumentation used for measurements at higher frequencies may not be suitable for the frequency of the circuit under consideration. Some manufacturers may not have proper test equipment for the high frequency measurements. This article tries to clarify all of the above.

What is Working Voltage?

Working voltage is defined as the highest voltage to which insulation under consideration is, or can be, subjected when equipment is operating at its rated voltage under conditions of normal use. Clause 1.2.9.6 in both CSA Standards C22.2 No 234 and C22.2 No 950 gives definition of the working voltage. Clause 2.2.7 in both standards explains various conditions for determining the working voltage.

For dc, the peak value of superimposed ripple must be included.

Non-recurring transients shall be disregarded.

Insulation in equipment being evaluated may be solid insulating material, fixed clearances through air and creepage distances over surface or a combination of clearances and creepage distances.

When determining the working voltage for creepage distances, the voltage of an ELV or SELV circuit must be taken into account, but such voltages are disregarded when determining the working voltage for clearances and electric strength test voltages.

Breakdown through air (clearance) is dependent upon the maximum value (peak) of the voltage. A reduced clearance may result in flashover when a transient voltage occurs. Repetitive peaks are taken into account by Table 3(a) of Standard C22.2 No 950. Creepage distance must not be less than the air clearance. Creepage is a surface phenomenon that is dependent upon voltage stress developed over a long period of time (compared to a transient). Creepage distance is therefore dependent upon the dc or rms value of voltage and is not affected by voltage transients or voltage peaks of short time duration.

When making a working voltage measurement, all unearthed parts and unearthed transformer windings may be connected to earth and to each other in a manner that will result in the highest working voltage. The earthing connection must be made in a fashion that maintains the normal operation of the unit.

Where double or reinforced insulation is used, the basic or supplementary insulation shall be assumed to be shorted (one at a time) in order to determine the working voltage across the supplementary or basic insulation respectively. Also, between transformer windings, a short circuit of basic or supplementary insulation shall be assumed to occur at a point which will result in the highest working voltage across the

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News and Notes

by Dave Edmunds
fax: (716) 422-6449

Speculations on the European Ergonomic Standard, ISO 9241

While there is some variation in the national laws being drafted to cover the EEC Directive 90-270, most countries are simply taking the directive verbatim. However, the text for standards such as ISO 9241 is not being added to these laws. Great Britain is the only country to date to directly tie their health and safety laws to ISO 9241. For most countries, references to ISO 9241 will be indirect, with future versions of the Directive expected to reference the Standard as one of the ways to comply.

It appears that ISO 9241 will be mandated as a health and safety standard, not as a product standard. This allows some countries to institute additional standards in this area that are stricter then the ISO standard. A class taught in the US by a German safety agency suggested that the CE mark associated with CEN will not replace the GS mark. The CE mark will indicate that a product has passed the minimum health and safety requirements. However, having a GS mark would mean it has met a higher quality standard. The teachers of the class predicted that Germany would revise ZH1 to make it more rigid than 9241.

There also appears to be some relationship between having a GS mark and disability insurance for companies in Germany. If the products (such as computer terminals) in a company have GS marks, the company is covered by disability insurance in the event of health hazards such as repetitive strain injury. If a company has products without the GS mark, it may have to pay employees directly if an equipment related disability occurs.

This seems to indicate that, while meeting ISO 9241 will be necessary to sell products in Europe, it may not be sufficient.

Bellcore document, TA-NWT-001089

Be aware of a new Bellcore document, TA-NWT-001089, Issue 2. As a Technical Advisory, this document provides a view into how the Bellcore standard for "Electromagnetic Compatibility and Electrical Safety Generic Criteria for Network Telecommunications Equipment" may change.

The proposed standard includes requirements for ESD, Electromagnetic Emissions, Electromagnetic Immunity, Lightning and AC Power Faults, Steady State Power Induction, DC Potential Difference, Electrical Safety, Corrosion, and Bonding and Grounding.

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Technically Speaking

WORKING VOLTAGE, ELECTRIC STRENGTH, AND SPACINGS

For the purposes of safety, what is "working voltage," and what is its relevance to the safety of the equipment?

SOME DEFINITIONS.

Here are some definitions of "working voltage":

IEC 950, First Edition, Sub-clause 1.2.9.6:
EN 60950, First Edition, Sub-clause 1.2.9.6:
IEC 950, Second Edition, Sub-clause 1.2.9.6:
UL 1950, First Edition, Sub-clause 1.2.9.6:
CSA 950, First Edition, Sub-clause 1.2.9.6:

"Working voltage: The highest voltage to which the insulation under consideration is, or can be, subjected when the equipment is operating at its rated voltage under conditions of normal use."

28A(Central Office)29, Sub-clause 3.5:
(Revision of IEC 664, including IEC 664A)

"The highest RMS value of the AC or DC voltage which may occur (locally) across an insulation of equipment supplied at rated voltage, transients being disregarded, in open circuit conditions or under normal operating conditions."

IEC 742, First Edition:

"Working voltage denotes the highest r.m.s. voltage which may occur across any insulation system at rated input volts, phase angle and transients being neglected, in no-load conditions or during normal operation.

"When considering the insulation system between windings not intended to be connected together, the working voltage is considered to be the highest voltage occurring on any of these windings.

"Attention is drawn to the fact that the working voltage to earth of the input may be different from the apparent value on single-phase systems with no neutral line and on three-phase systems with no earthed neutral when star connected, or when delta connection is used. The output voltage of a transformer may be artificially raised with respect to earth by conditions which occur in an appliance or equipment."

IEC 335, Second Edition, Sub-clause 2.2:

"Working voltage denotes the maximum voltage to which the part under consideration can be subjected when the appliance is operating at its rated voltage and under normal conditions of use.

"Normal conditions of use include changes of voltage within the appliance imposed by likely oc-

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Area Activities

by John Reynolds
Area Activities Editor
381 Los Pinos Way
San Jose, CA 95123-5118
fax: 415-962-9439
e-mail: reynolds@esd.sgi.com

I am making progress in contacting the various area groups and am excited about this new column. Most of the local chapters are on Summer break until September, so there is not much to report on right now.

I will be working to make better and more frequent contact with the local groups. Please don't wait to hear from me! Please call or write or fax and let me know about your members and officers. I'd also like to know about your planned speakers and topics.

So far I have information on the Santa Clara Valley PSTC and the Seattle Area PSTC. As more information becomes available I will be featuring other groups as well. Remember, don't wait to be contacted. Send me your plans for this next year and who the officers are.

Seattle Area Activities:
The meetings of the Seattle Area PSTC are from September through May @ 7:00 pm on the Wednesday following the 3rd Tuesday of each month. Location is by announcement.

For information about meeting details and to get on the mailing list contact Walt Hart, (206) 356-5177

Santa Clara Valley Activities:
The meetings of the Santa Clara Valley Area PSTC are from September through June on the 4th Tuesday of the month. Dinner before the meetings is at Carlos Murphy's @ (5:00 pm social and 5:30 pm dinner) located at 10741 N. Wolfe road, Cupertino, CA. Reservations* required for dinner but not for the presentation. The meetings are held at 7:15 pm at Apple Computer building Valley Green 6, 20705 Valley Green Drive, Cupertino, CA.

For information about meeting details and to get on the mailing list contact Mike Campi, (408) 434-4084. For dinner reservations, contact Murlin Marks (408) 434-4084

Their June meeting featured a presentation on "The Present State of Research on the Physiological Effects of Electro-Magnetic Radiation" by Dr. Dan Weinberg, Ph.D.

I am updating the Officers of the PSCT section on Page 2. If you have any corrections, please contact me. ❑

European Community Requirements for Info Tech Equipment

by Ercell Bryant

Regulatory agency requirements are changing drastically in the European Community (EC). New Directives are being issued and existing Directives are being revised on a daily basis. By December 31, 1995 manufacturers of Information Technology Equipment (ITE) may be required to comply with 8 or more standards. The regulations driving these new standards are the European Community Directives issued by the Commission for the European Community (CEC). As standards development is taking longer than anticipated, the effective date of most Directives effecting Information Technology Equipment are being postponed until the end 1995.

EC Directives are divided into two types, Directives issued before May 7, 1985 and New or Global Approach Directives issued after May 7, 1985. The early Directives, such as the Low Voltage Directive, issued in 1974, state the general requirements for compliance however they do not specify how a manufacturer certifies to compliance. An amendment currently being considered by the CEC will correct this discrepancy and allow for the placement of the "CE" marking on ITE. The New Approach Directives, issued after May 7, 1985, give specific requirements for compliance and how the manufacturer certifies a product as complying to the directives. The method of complying with the New Approach Directives has been standardized by developing a certification process setup as standard Modules A thru H.

When a product complies with all applicable New Approach Directives, the manufacturer may apply the "CE" marking to the product. Each Directive stipulates how the "CE" marking is applied and what information must be provided with the mark. An amendment to all directives specifying the use of the "CE" marking in being considered by the CEC. This amendment will standardize the requirements for applying the "CE" marking.

This article will endeavor to list the current EC Directives effecting ITE and the standards that have been or are being developed in order to comply with each directive.

Low Voltage Directive – 72/23/EEC

This directive was the first directive issued effecting ITE. It was the driving force in the development of IEC 950 which started the world wide ITE standards harmonization effort. The CEC issued a Commission Communication of 15 December 1981 clarifying the requirements of the Low Voltage Directive. This Directive currently does not allow the "CE" marking to be placed on ITE. An amendment currently being considered by the CEC will correct this discrepancy and will require the "CE" marking on ITE by December 31, 1994. Compliance with the following standard meets the requirements of this Directive.

EN 60950 – ITE Safety Standard

This standard covers ITE and Telecommunication equipment and is IEC 950 with EC deviations incorporated.

EMC Directive – 89/336/EEC
Revision – 92/31/EEC

New Approach Directive – Requires Module A, Module B with D or E or Module H for compliance.

This Directive as amended sets up an interim period where a product can comply with existing Member State standards Law until December 31, 1995, or comply with the directive. Germany is the only Member State with a law in place by the deadline set by the Directive. The EC standards developed or being developed for this directive are:

EN 50082–1 – Generic immunity standard
Compliance with this standard will meet the immunity requirements of the Directive until the ITE immunity standard is adopted by the Member States. Products will then have to be retested to the ITE immunity standard.

prEN 55024 – ITE Immunity Standard
This is a draft standard and is expected to be adopted by the Member States. Sections 1, 5, 6 and 7 are still in committee and are not available for distribution.

- –1 ??
- –2 Electrostatic Discharge.
- –3 Radiated RF.
- –4 Conducted RF.
- –5 Surge Voltage.
- –6 Continuous Wave Voltage.
- –7 Mains Voltage Interruptions.

EN 55022 – ITE Radiated and Conducted Emissions.
Compliance with this standard meets the radiated and conducted requirements of the Directive.

VDE 0871 – ITE Radiated and Conducted Emissions.
Germany is expected to keep VDE 0871 until the 1995 deadline.

Telecommunication Directive – 86/361/EEC
Revision – 91/263/EEC
New Approach Directive – Requires Module B with C or D or Module H for compliance.
ITE which calculates data intended to be transmitted on the telecommunication line whether directly or indirectly connected to the telecommunication line must comply with this Directive. Two methods of compliance are based on EN 29 000 registration. The EC standard developed for this directive is:

EN 41003 – Telecommunication Safety Standard.
This standard was originally intended to be withdrawn when the telecommunication safety requirements were incorporated in the ITE safety standard EN 60950. However the CEC has determined that there is still a need for this standard.

EN 60950 – ITE Safety Standard 2nd edition
This standard will meet the intent of the directive for ITE with Telecommunications included in place of EN 41003.

Due to the incompatibility of the telecommunication equipment in the EC Member States, all Analog Telecommunication equipment must be approved by the PTT of each Member State that equipment is to be installed in.

Safety and Health of Workers – 89/391/EEC
Ergonomics for VDT Directive – 90/270/EEC
New Approach Directive – Establishes minimum requirements for equipment, environment and operator/computer interface.

This directive states that workstations put into operation after 12–31–92 must comply and all existing workstations must comply within four years (12–31–96). No method of compliance is stated in this directive and no standard has been adopted to date.

ISO 9241 – Ergonomic Requirements of VDT
This standard is intended to consist of 19 sections. Each section of this standard is expected to be adopted by CENELEC as an EN standard when complete. The proposed subject for each section is listed below.

–1 General Introduction.
–2 Task Requirements.
–3 Visual Display Requirements.
–4 Keyboards and Other Input Devices.
–5 VDT Work Place Design.
–6 VDT Work Environment.
–7 VDT Surfaces and Filters.
–8 Use of Color and Graphics.
–9 Non Keyboard Input Devices.
–10 Dialogue Interfaces.
–11 Meth for Eval and Test Software Usability.
–12 Coding and Formatting.
–13 Terminology.
–14 thru –19 are not defined.

EN 29000 – Quality Assurance Series (ISO 9000)
This series of standards were developed to maintain a consistent level of product quality being shipped across Member State borders. Registration to these quality standards can allow manufacturers to reduce or eliminate the requirement of having products tested by a Notified Body (see Fig. 1). The EN 29000 series quality standards are optional, however the US State Department feels that non–compliance to these standards could become a non–tariff trade barrier for US companies trying to import products into Europe. Although Sweden is not a Member State of the EC these Swedish standards are becoming the defacto international standard for evaluation of VDTs for ELF and VLF emissions. An ANSI committee is currently developing a US standard for VDT and is using the Swedish standard as a guide line. All VDT slated for international markets should comply with these standards.

MPR 8: – Test Methods for VDT. Ergonomics, ELF & VLF Emissions

MPR 10: – Requirements for VDT. Ergonomics, ELF & VLF Emissions ❑

News and Notes
Continued From page 5

Bellcore is asking for comments on the document up until September 15, 1993.

The following three articles were obtained from IEEE Spectrum dated August, 1993:

Cellular Safety

Given the public's concern about the potential hazards of RF emissions from cellular telephones and communications centers, manufacturers and operators of cellular equipment will probably find it wise to measure the radiation associated with their products and facilities--to fix it if it is too high, or to brag about it if it is low. To help them with those measurements, General Microwave Corp. has developed its Raham family of radiation hazard meters.

Further details are available from General Microwave Corp., 5500 New Horizons Blvd., Amityville, NY 11701; 516-226-8900.

Safety and Health Standards

Here's a provocative trivia question: how many standards relating to safety and health have been approved and published by the American National Standards Institute (ANSI)? The answer is 1230, and all of them are listed in ANSI's new 1993 Safety and Health Catalog, which is available free of charge in single quantities.

The catalog lists standards by subject and ANSI designation numbers and titles. It also has an index.

Speaking of standards, World Standards Day will be celebrated on October 14, 1993, and a paper competition will be held as part of the celebration. Jointly sponsored by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) as well as ANSI, the compe-

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Voltage Markings For More Than One Country

by Lal Bahra, P. Eng.
Canadian Standards Association

From the point of view of voltage markings that are acceptable to the regulatory authorities its very straight forward for a manufacturer who wants to supply electrical products in the domestic market. Standards of each country specify what voltage systems are being used and their tolerances (i.e. voltage variation limits and frequencies).

In Canada, for example, the preferred voltage levels are specified in Standard CAN3C235-83, Preferred Voltage Levels for AC systems 0 to 50,000V. Table 2 of this standard defines the voltage variation limits for various systems. For a 120V system, the nominal range (normal operating conditions) specified is 108 to 125V and extreme voltage range (extreme operating conditions) specified is from 104 to 127V. Manufacturer may mark any single voltage from 108 to 125V (eg. 110V). Single voltages outside the low end of the nominal range cannot be marked but may be included as part of the nominal range of voltages (i.e. 100V cannot appear but will be acceptable if the marking is shown as 100-110V). On the upper end of the nominal range, for cord connected equipment, the maximum marked voltage is restricted by the rating of the attachment plug which is generally the upper limit of the nominal range.

Similarly, if equipment is suitable for both 120V and 240V systems, 120/240V or 100-120/200-240V marking is acceptable with appropriate abnormal tests being performed and caution markings applied.

The above approach does not help a manufacturer who wants to market a product worldwide with a single nameplate having a set of voltage markings which is acceptable to all electrical regulatory authorities. Also, a user may purchase a portable appliance such as a shaver or video camera and travel from one country to another where the system voltage is not the same as the voltage at which the equipment was tested in the first place.

To require manufacturers of such equipment to mark their products only with those voltages that are acceptable in Canada or identify such Canadian voltages separately, can be looked upon as being trade restrictive.

Rather than restricting voltage markings to meet standards of one country, it is desirable to have markings that comply with the requirements of more than one country and conduct tests to assure that the equipment does not cause any hazard when operated at various marked voltages, mismatched configurations, over or under voltages and frequency variations. For example, if a unit is marked with voltage markings of 90-250V, then it can be connected to a 100V (Japan), 120V (North America), 127V (Tahiti), 220V (with a neutral in Europe), 240V (120V - 120V in North America), 120/208V and 240/417V systems.

Leakage current, temperature rises, overcurrent protection requirements, input current, and insulation stresses etc. will be different in each case and all these factors must be taken into account when units which are marked as such are evaluated for compliance with the applicable standard.

Cord connected equipment provided with an attachment plug may be marked to indicate the voltage which is suitable if the plug is used in another country, where the same plug configuration is used, but at a different voltage. For example, cord-connected equipment with an attachment plug having a 1-15P configuration and marked 125V, may be used in Japan where the voltage on the receptacle (having the same configuration) into which it will be plugged is rated only 100V.

For specific applications, the NEMA 6-15R configuration for 250V receptacles may be used for supplying 208V (rather than 250V) single-phase power. Also NEMA 14-30R receptacle (for 125/250V, 3-wire plus ground) may be used for 125/208V systems. All these are special cases which can be dealt with, if it is known at the time of evaluation that they will be used for a different application.

Similarly, "cord connected" equipment that is marked 100/110/120/130V, where the main power transformer integral to the equipment is provided with 100V, 110V, 120V and 130V taps must be tested for all possible combinations.

Voltages such as 110V and 120V fall within the nominal voltage range of a 120V system. With the 110V tap connected, normal temperature test must be conducted at 125V. Because 100V is outside the nominal range of the 120V system, a normal temperature test must be conducted at 100V and an abnormal temperature test conducted at 125V. Similarly 130V is outside the nominal range of a 120V system, and the normal temperature test must therefore be conducted at 130V and an abnormal temperature test conducted at 108V (especially for motor operated equipment). Manufacturer must provide proper installation and operating instructions.

For permanently connected equipment, testing may be done only for Canadian voltages even though additional voltage markings may appear, as long as there are markings to indicate that the unit was certified by CSA for the voltages for which tests were conducted.

CSA recently published a Technical Information Letter (T.I.L.) No K-12, Voltage Markings Outside the Range of Nominal System Voltages, which was announced to the industry under Miscellaneous Products, Informs No 3. The TIL allows voltage markings which were not previously permitted, as long as it can be demonstrated by normal and abnormal tests that the equipment is not going to create any hazard and there is a need for such markings. Manufacturers can now apply a single nameplate which will cover not only Canadian voltages but other voltages which are required to appear on products that are supplied to other countries. Also, manufacturers of products from other countries who intend to export their products to Canada may use a common nameplate having voltage markings for more than one country. ❑

Chariman's Message
Continued From page 1

In addition to sharing the risks that form the basis of IT equipment safety standards, semiconductor process equipment such as plasma etch systems utilize extremely dangerous (lethal) gases and high levels of RF energy. All must be precisely applied and controlled (under computer control) both to assure the quality of the etched wafers and to reduce safety risks to acceptable levels.

Product safety is customer driven. The prevailing domestic product safety standard, SEMI S2, was initially developed by a key industry customer as a supplier standard. It was adopted as an industry standard about four or five years and already is in its third edition (the revision process works quickly). Even today, customers have greater influence on standards development than the suppliers or any other interest group segments and, as a body, customers (SEMATECH) wield considerable power.

The S2 standard is very broad in its orientation. Unlike IEC 950, UL 478, etc., there are almost no specific detailed requirements or test procedures. Standards are prescriptive only in the general sense, and sound safety engineering practice across a multitude of disciplines and systems-type risk assessments are essential.

The third party approval sector is not yet a major influence. Although established third party certifiers are entering the market, there does not seem to be preeminent widely recognized and established players with industry-wide influence, at least at the present time. There is considerable opportunity for third parties, if for no other reason than to lessen the impact of redundant assessments required by different customers.

These observations raise several questions, including:
Have we lost track of our final customers' expectations regarding safety? How many of you have regular, pro-active contact with final customers on their safety needs and requirements?

Have we created such a huge global standards infrastructure that we and our customers are now serving it rather than it serving us? Speaking of customers (and I'm referring to the final customers), where are they in the standards making process?

Have we lost track of our understanding of technical causation justifying IT safety standards and practice? That is to say, can each of us give technical/scientific justification for the specific requirements we use while having sound basis for ignoring what we don't investigate? Have we institutionalized the "whats" and forgotten the "whys"? ❑

Technically Speaking
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currences such as the operation of a circuit breaker or the failure of a lamp.

“When deducing the working voltage, the effect of possible transient voltages on the supply mains is ignored.”

IEC 65,
IEC 348,
IEC 601-1,
IEC 1010.
"Working voltage” is not defined in these standards.

WORKING VOLTAGE.
Except for IEC 335, we can conclude that working voltage is the voltage, exclusive of transient overvoltages, across an insulation under normal operating conditions.

From a safety point of view, the only insulations with which we are concerned are basic, supplementary, and reinforced. Therefore, working voltage (exclusive of transient overvoltages) is the voltage across basic, supplementary, or reinforced insulation under normal operating conditions.

Failure of a safety insulation could lead to an injury. Our objective is to prevent failure of basic, supplementary, or reinforced insulation due to normal operating conditions.

Insulation is presumed to fail if the voltage applied to it exceeds its electric strength.

This discussion addresses how working voltage is used to predict the value of voltage applied to the insulation and how to determine that the insulation has electric strength greater than the applied voltage.

Thus, we can be assured that safety insulation will not fail as a result of the voltage applied to it.

ELECTRIC STRENGTH.

Let's first examine the relationship between working voltage and electric strength (hi-pot) voltage.

I like to think of the world as having two kinds of circuits.

The first kind of circuit is widely distributed and has many different loads, many of which are inductive or otherwise naturally generate and inject transient overvoltages into the circuit. Mains circuits are common examples of this kind of circuit. It is a normal condition that mains circuits have transient overvoltages.

Because transient overvoltages are normal in this kind of circuit, insulations used in the circuit must have an electric strength equal to or greater than the highest expected transient overvoltage for the circuit. One rule-of-thumb relating electric strength to mains voltage (i.e., working voltage) is the traditional 2V + 1000, where V is the rated (working) mains voltage.

For many years, 2V + 1000 was the standard formula for determining the electric strength voltage for insulations. Recent safety standards based on IEC 664 use tables to determine the electric strength voltage for any value of working voltage.

Note that, while transient overvoltages are normal conditions of mains circuits, the value of working voltage does not include such overvoltages. Instead, for mains circuits, the working voltage is the rated value of the mains voltage.

Using both the formula and IEC 664, we find that the required electric strength for mains working voltage of up to 250 volts is about 1500 volts.

The second kind of circuit is of limited distribution, has a limited number of highly controlled loads, and is suitably isolated from the mains circuits such that it has virtually no transient overvoltages. Equipment secondary dc circuits are examples of this kind of circuit. It is an abnormal condition that secondary dc circuits have transient overvoltages.

Insulations used in the second kind of circuit must have an electric strength equal to or greater than the highest working voltage for that circuit.

Consequently, an insulation with an electric strength greater than 1500 volts would be suitable for use in a mains circuit with rated (working) voltage up to 250 volts.

That same insulation would also be suitable for use in a dc secondary circuit with a nominal (working) voltage up to 1500 volts.

Working voltage is the basis for determining the electric strength (hi-pot) voltage required of a basic, supplementary, or reinforced insulation.

SPACINGS.

Now let's examine the relationship between working voltage and spacings between conductors of the working voltage.

Electric strength is directly proportional to the distance through the insulating medium: the greater the distance, the greater the electric strength.

The electric strength of most insulating media are rated in volts/distance. Therefore, spacings (distance through the insulating media) are an indirect measure of the electric strength of the insulating media.

(The volts/distance parameter also depends on the shape of the electric field in the insulating medium. The maximum volts/distance occurs with a "homogeneous" field, while the minimum volts/distance occurs with the worst-case "inhomogeneous" field.)

Commonly, safety standards publish tables working voltage and distances in air (clearances). So, working voltage is used to determine the clearance distance.

However, the clearance distance values in many of those tables are very much greater than the volts/distance value for air for the working voltage. Likewise, the clearance distance values are also greater than the volts/distance value for the transient overvoltage or hi-pot voltage.

So, while the working voltage is indeed used to determine the clearance distance from a table in the standard, often there is no physical or mathematical relationship between the clearance distance value and either the working voltage or the transient overvoltage or the hi-pot voltage.

Many safety standards have no requirements for distance through solid insulation. The hi-pot test is the only mechanism by which the solid insulation is evaluated and determined as not likely to fail. This is okay as almost any and every solid insulation of any usable thickness will have an electric strength greater than 3000 volts. According to one wag, even Mr. Whipple's squeezingly soft Charmin has an electric strength greater than 3000 volts.

Some safety standards publish minimum values of distance for solid insulation, regardless of the volts/distance characteristics of the insulation. As with clearance distances, such values have no relationship to applied voltage.

The interface between a solid insulating medium and atmospheric air insulating medium is a special case. Within the safety trade, this is commonly referred to as "creepage" distance. An example of this interface is the emergence of leads from the case of the optocoupler into the air.

This interface is of special concern because it is often subject to deposition of a third, uncontrolled material (i.e. pollution of the surface of the solid insulation). Therefore, the authors of safety standards have published various schemes by which the interface must have a greater dimension than is required for a pure air insulation. This greater dimension supposedly accounts for the lesser volts/distance value of the "foreign" material (as if we already knew the electric strength of the "foreign" material).

However, the failure of the interface (creepage) due to the accumulation of pollution is a long-term failure mechanism. Consequently, the electric strength of the interface (creepage) is based on working voltage rather than transient overvoltage. Therefore, when the working voltage is very much less than the transient overvoltage (as in a mains circuit application), the creepage distances requirements are much less than the clearance distances requirements. Similarly, when working voltage and transient overvoltages are equal, the creepage distances requirements are much greater than the clearance distances requirements.

Obviously, the greater of the two distances, creepage or clearance, takes precedence as the requirement for the interface (creepage) distance.

A construction of two conductors in air is also subject to pollution. In this case the pollution accumulates directly on the conductors, thus effectively reducing the distance in air (clearance) between the two conductors. This concern is principally directed at very small values of clearance (i.e., electric strength values less than 1500 volts rms) where the pollution could completely bridge the air gap.

Working voltage is the basis for determining creepage distances of a basic, supplementary, or reinforced insulation.

Transient overvoltage is the basis for determining the distance through air (clearance) and the distance through solid insulation for basic, supplementary, or reinforced insulation. Working voltage is the basis for determining electric strength sufficient to withstand normally-occurring transient overvoltages.

Recall that distance through insulation is an indirect measure of the electric strength of that insulation. Note that common safety standards independently specify hi-pot voltage (electric strength) and spacings (which determine electric strength). Any correspondence between the hi-pot voltage and the spacings is purely coincidental. Typically, safety standards require spacings such that the electric strength is very much greater than the hi-pot voltage.

However, IEC Publication 664 is an attempt to create correspondence between the hi-pot voltage and the distance through insulation.

CONCLUSION.

From working voltage, we determine the value of the hi-pot test voltage, a direct measure of electric strength. From working voltage, we determine the minimum values of spacing, an indirect measure of electric strength. Therefore, working voltage is the basis for determining the minimum electric strength of insulations. ❑

IEC 479-1

Continued From page 3

that checks the potential of devices before we contact them, we're exposed to electric shock when it is unexpected.

People reluctantly grab a doorknob when they know that they will experience that high voltage, low current shock that occasionally comes after walking across a rug and charging up one's self. (We quickly learn to grab the knob hard and fast to dissipate the current rapidly over a large area. Unfortunately, this is the wrong technique if hazardous currents exist.)

We don't have to imagine incidents; you may know of the man who was killed after he climbed a protective fence to attach the high voltage distribution lines to his auto battery to recharge the battery and restart his car.

A sound understanding of the basics, the impedance of the human body and the effects of AC and DC current, are the base for providing reasonable protection from electric shock. The impedance of the body is a series of RC elements, the higher impedance skin on each end with the lower impedance salty body in the middle. The statistical values of impedance are a function of voltage and also a function of the body path (hand to hand, hand to back, etc.). Relating the current effects to threshold values for perception, reaction, let-go and fibrillation is the focus of this standard. Something is known of the vulnerable period of the heart; the heart current factor (electric field strength in the heart) for various current paths is also discussed.

Normally, the higher skin impedances are adequate for providing an impedance to the current for voltages below 50 volts or so. At higher voltages, the internal impedance of the body is the more dominant factor. An impedance of 650 ohms or so is the lower asymtotic value for 95% of the adult population at higher voltages.

This detailed information is aimed at those that are providing reasonable protection against electric shock. This is for both the practicing equipment designers or their product safety engineers plus those setting requirements for electric shock protection in standards.

The first line of defense against shock protection is found in the design of equipment. This protection is evaluated in the safety review of the product. Protection mechanisms are classed in just a few ways; the implementation of these is varied in practice. Assessment of the execution is the role of the product safety review of the product.

Proper design against electric shock is key; providing protection during installation or later following practices to avoid shock all increase the risk of shock itself. Equipment is usually designed to provide electric shock protection under normal use conditions plus under single fault conditions.

We examine two specific areas; body impedance and effects of AC or DC current. The body is more tolerant of DC currents for any of the response modes. Increasing the understanding of designers will get the equipment design to bring provision for protection into the design at an early stage. Upgrading the understanding of those setting standards will result in reasonable limits being set.

The designer makes choices from the very beginning of the design process. These affect not only the leakage current that will be available in the design but will also limit choices later in the process if the leakage current is more than is desired or allowed. A shoddily designed product will not provide the necessary protection against electric shock under all long term conditions of use and misuse. A thorough safety evaluation will ferret this out. The designer has the keys to success in providing shock proof equipment in their hands right from the beginning of the project. Every project leader is responsible for providing safe equipment.

There is considerable specific information contained in the standard; not all of it is covered here in detail. Body impedance is a function of the applied voltage and varies enough from person to person that a statistical distribution must be used and the lowest impedance segment of the population protected.

The goal is to show what information is already available on these effects from IEC 479. This information needs to be used along with an under standing of the conditions under which leakage current might be experienced to set limits values. It is quite intriguing that the body, which is electrically quite simple, has such complex threshold responses to electric current.

The current work of the TC64/WG4 committee is to extend the data to higher frequencies, which is needed in the equipment committees as high frequency, high power designs are developed. The switch mode power supplies found today are moving from a hundred kilohertz toward a megahertz. The leakage currents from this type equipment is more easily carried to accessible parts, it is also less dangerous - until high frequency burn issues come in.

This is an explanation of one of the three IEC requirements that complete their development of protection from electric shock. The IEC has a series of standards that discuss protection against electric shock; including classification of equipment (IEC 364-4-41), effects of current on the human body (IEC 479-1) and measurement of touch current (IEC 990). A comprehensive under standing of all three standards provides a complete picture on the subject. ❑

News and Notes
Continued From page 10

tition has as its theme, "Standards: A Strategic Investment."

The deadline for submitting papers illustrating how critical standardization is to competitiveness was August 15. The author of the winning paper will receive a plaque and an award of $ 2500. Contact: American National Standards Institute, 11 West 42nd St., New York, NY 10036. For information about the paper competition, phone the Standards Engineering Society at 513-223-2410. To request a copy of the Safety and Health Catalog, phone ANSI at 212-642-4900.

Faults and Failures: The worm turns
At least 30 people have been electrocuted over the past 20 years by a simple, commercially available electric appliance--a probe used to harvest earthworms for live fishing bait.

The device consists of a metal rod connected to the hot side of household electricity. The circuit is completed by inserting the rod into the earth. The shocked worms rise to the surface, where they can by easily collected.

Citing the deaths and the inherent danger of the probes, the U.S. Consumer Product Safety Commission (CPSC), Washington, DC, recently announced the recall of the only current commercial version--the Worm Getter, manufactured by the now defunct Handy Marketing Co. of Grand Rapids, MI. While no deaths or injuries have been attributed to Worm Getters, the devices are functionally equivalent to the lethal units, according to the announcement by the CPSC. The commission is especially concerned about home-made probes built by ingenious fisherman. They usually lack the most rudimentary safety fea-

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Working Voltages
Continued From page 4

other insulation.

For insulation between two transformer windings, the highest voltage between any two points in the two windings shall be used. The windings shall be connected to their external sources as intended for correct operation.

Minimum Working Voltage of a Circuit
The minimum working voltage shall be the nominal supply voltage for the purpose of determining clearances, creepage distances and electric strength test voltages between any point in the primary circuit and any grounded or floating metal part, or to a secondary circuit.

There are many reasons for this. For example, reversed line and neutral connections may be caused by a miswired convenience outlet or by a power supply connector in which polarization is not provided.

For practical purposes, when determining accessibility and clearances etc. in a switching power supply , a neutral is treated like a phase conductor. A positive (+) dc rail and a negative (-) dc rail are practically at line potential with respect to earth. The waveform of + or - dc rails with respect to earth, as viewed on an oscilloscope, will be as shown in Figure 1. (For L, N system only).

Although the base of a switching transistor may appear to be operating at only a few volts with respect to a - dc rail, it is actually operating at close to line potential with respect to earth (see example illustrated in Figure 1).

Working Voltage Between Primary and Secondary circuits
When determining the creepage distance between a

point in the primary circuit and a point in a secondary circuit, the voltage between any two points must be taken into account rather than the highest primary circuit voltage that may occur between two points in the primary circuit. For example, between the collector of a switching transistor and - dc rail, the voltage difference could be up to a maximum of twice the voltage between the + dc rail and the - dc rail, but this voltage difference should not be used in determining the creepage distance between points in the primary and secondary circuits. The intent of these measurements is to find the actual voltage to which the insulation system is subjected. For creepage distances between collector and secondary, or any other point in primary to secondary, the true rms voltage between these points must be used.

For clearances, the additional clearances of Table 3(a) of Standards C22.2 No 234 and C22.2 No 950, based on the maximum repetitive peak voltage, must be added to the clearances shown in Table 3 of the Standards.

For clearances and creepage distances in secondary circuits that are not connected to earth, or which are not isolated from the primary by an earthed metal screen, minimum clearances for installation category II (i.e. Table 3 clearances) shall be used. This means that even for double insulated secondaries, Table 3 clearances shall be used unless the secondaries are connected to earth by a capacitor (approx. 0.1µF).

Measuring Instrument:
Where the rms value of voltage is measured, the measuring instrument must be a true rms type that is capable of giving a true rms reading for both sinusoidal and non-sinusoidal waveforms and one that is suitable for the high frequency of the switching power supply. Typical CSA practice is to use an instrument having a frequency band width of at least 5 times the switching frequency. Also, the memory of an oscilloscope or voltage meter, for purpose of storing the voltage wave form must be of sufficient size to store minimum 3 cycles of the input voltage waveform superimposed with the switching waveform to give a reasonably accurate value. The crest factor of the measuring instrument is most important.

The maximum peak measuring capability of a meter is equal to its maximum range multiplied by the crest factor. If, for example, the maximum range of a voltmeter is 250V and the crest factor is 3, the voltmeter will measure peak voltages accurately up to 750V. If the peak voltage happens to be 1000V, such a voltmeter will not give a correct value.

Fig 1 - Typical Waveforms for a Single Transistor Switching Circuit:
This figure illustrates a typical single transistor switching circuit. Al represents the rms voltage between the collector of the switching transistor and earth (basic). A2 represents the rms voltage between the switching transistor collector on a secondary circuit having one side connected to earth to establish a reference (basic, if secondary is earthed in actual practice, otherwise reinforced or double insulation is used). A3 represents the rms voltage between the + dc rail and the secondary having one side earthed (again to establish a reference).

B1 represents the + dc rail voltage and may be viewed on the oscilloscope as indicated above (see Fig 1). B2 is the - dc rail voltage and may also be viewed on the oscilloscope (see Figure 1). B3 is the voltage between the + dc rail and collector of the switching transistor. In this particular example the collector voltage with respect to earth may reach a value which is twice the voltage between the two rails when the transistor switches off. B4 is a measure of the peak voltage of the collector in addition to Al, to be used in determining the additional clearance specified in Table 3(a) of CSA Standards C22.2 No 234 and

C22.2 No 950.

This figure also illustrates the waveforms of the + and - dc rail voltages with respect to earth. Even though the potential between the + and - dc rails is a dc voltage with some ripple, the potential between either rail to earth is not a pure dc voltage. It is almost the ac line voltage shifted by a dc bias.

For dual switching transistor designs, the maximum line voltage may be used. ❑

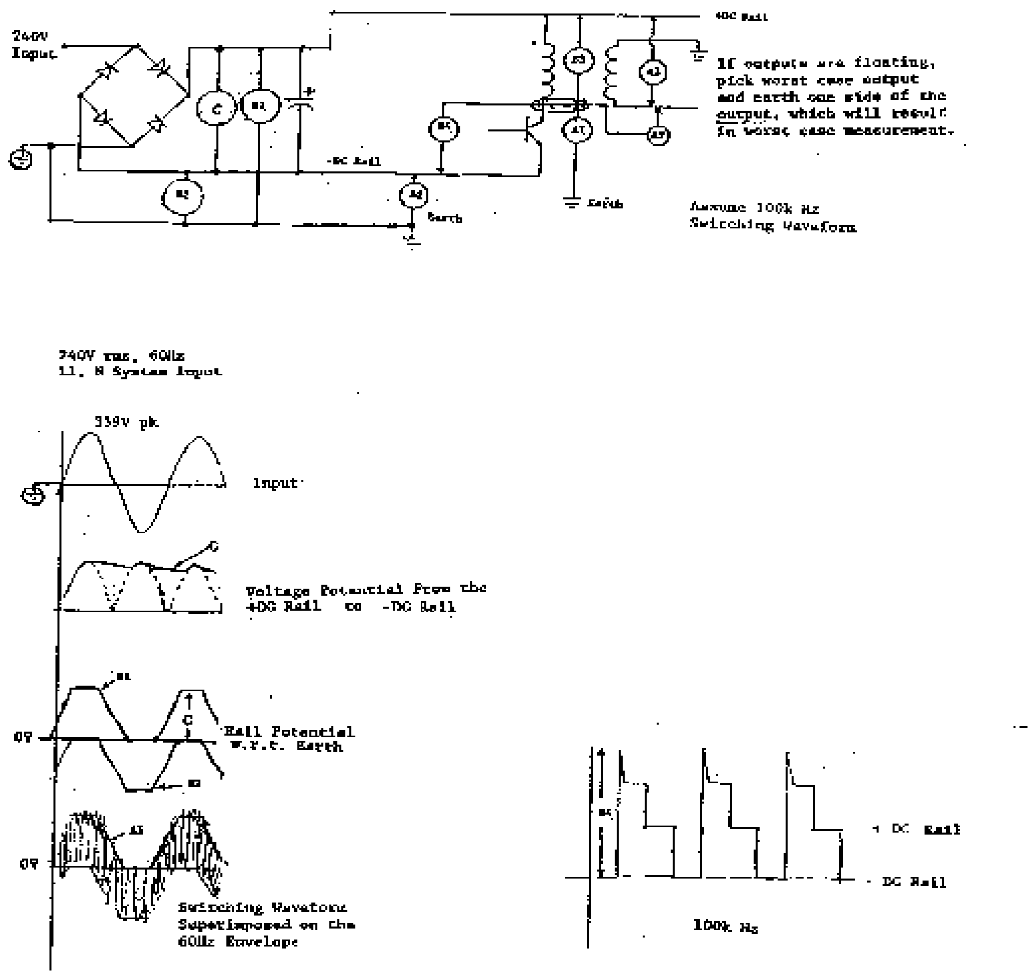

FIGURE 1
TYPICAL WAVEFORMS FOR A SINGLE TRANSISTOR SWITCHING POWER SUPPLY
AS VIEWED ON AN OSCILLOSCOPE

Continued From page 18

tures, and some have even been found to have no insulating handles. These units are the cause of many of the reported deaths.

The very simplicity of the probe--it is fundamentally just an extremely low-resistance path between 120 V and ground--is what makes it so dangerous. In normal operation several amperes of current can flow. . But current levels of only a few milliamperes can be fatal to human beings. Children are especially vulnerable and, in fact, form most of the fatalities reported to the commission. The resistance of the person's contact with the ground is also a big factor. The type of shoes worn and the wetness of the soil can make a life-or-death difference.

Designers of the Worm Getter probe attempted to make the product safe by shielding a user from contact with its metal parts. They covered the shaft's upper section with a thin transparent plastic sleeve and its lower portion with a hard plastic sheath that retracts when the probe is pushed into the ground. A cap at the end of the shaft covers the probe tip. Under normal use, though, the cap would be removed. And there is nothing to prevent a user from manually retracting the sheath and grasping the rod.

The operating principle of the worm probe makes it hard to provide safeguards. Two common safety precautions are completely ineffective. Reducing the voltage could make the probes safe for humans but it also makes them safe for the worms, which apparently remain unmoved by the lower currents. Fuses also will not work. Household fuses and circuit breakers are usually rated at 10 to 20 Amps, many times the fatal level. A lower-rated fuse would only blow before the probe could be effective. The same reasons make the use of a ground-fault circuit interrupters ineffective. The worm probes themselves are ground faults.

This is not the first time that the commission has ruled against worm probes. In 1991, after a lengthy court battle, the commission ordered P&M Enterprises, to halt the manufacture and sale of its Worm Gett'rs. By the time the ban could be enforced, P&M Enterprises was bankrupt, so no recall could be ordered.

Handy Marketing is out of business, too. So six retailers who sold the Worm Getter have agreed to carry out the recall.

About 30,000 of the P&M Worm Gett'r probes have been sold since 1983. Handy Marketing manufactured more than 80,000 of its probes from 1980 on. The cost ranged from $8 to $28, depending on the model. Tim Jones worries that the probes could be around for a while, and result in more deaths.

Although the CPSC recognizes the inherent danger of these products, it does not have any authority for premarket clearance. Each new product is examined as it comes on the market, and only then banned if found dangerous.

"The idea for worm probes has been around for 50 years" said Jones. And it's an idea that doesn't die easily." One enterprising individual was selling instructions for making the probes, according to Jones. The commission ordered him to stop and to send warnings to those who had purchased the instructions.

The 30 deaths due to the probes are a tiny fraction of deaths from electric current, which number more than 700 per year in the U.S. But with a device so simple that it can be made at home, the blame must lie, at least in part, with popular ignorance of the hazards of household electricity. ❏

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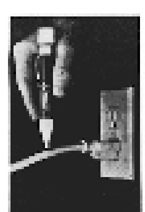

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