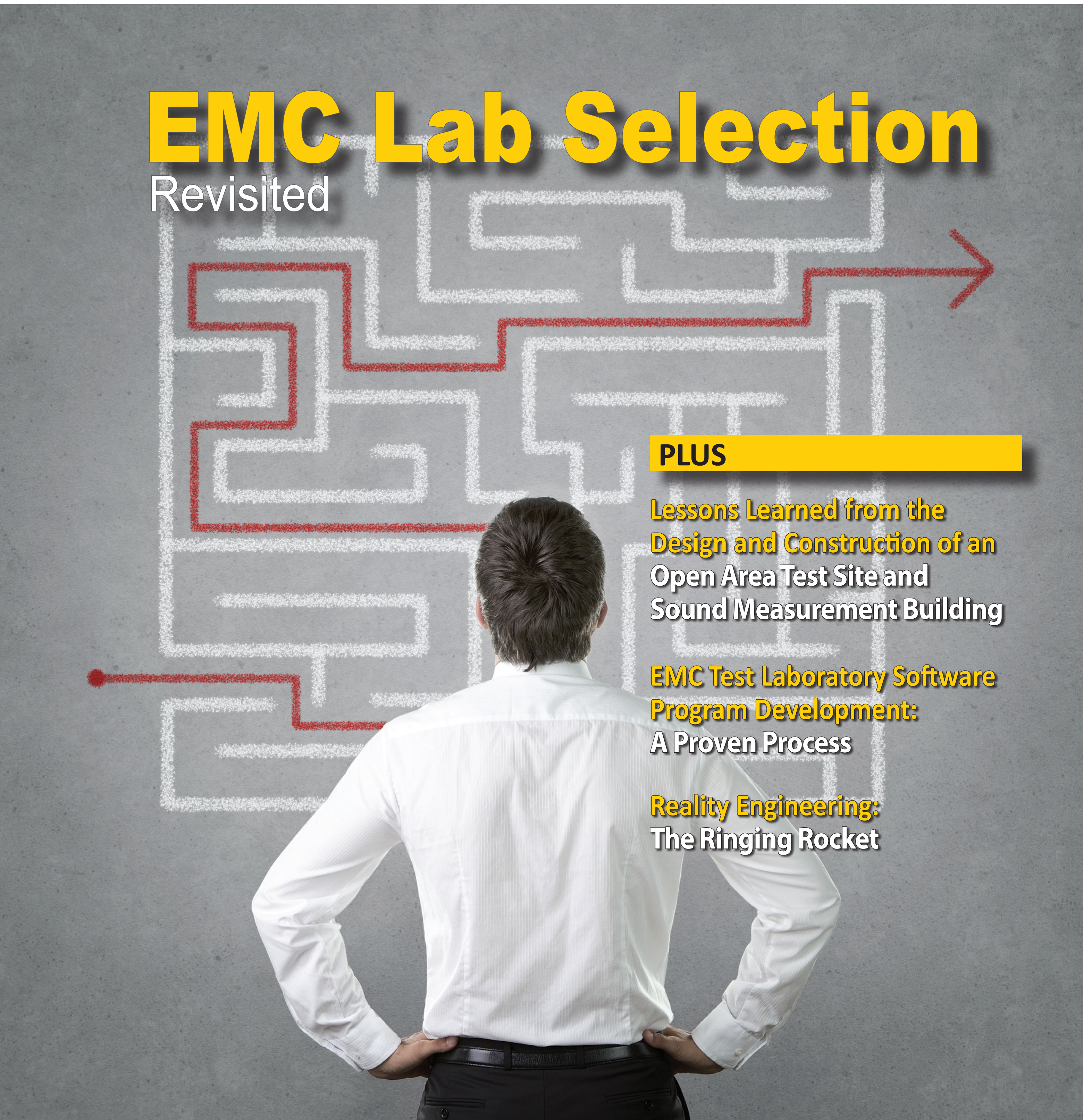
OCTOBER 2013

IN COMPLIANCE™

THE COMPLIANCE INFORMATION RESOURCE FOR ELECTRICAL ENGINEERS



EMC Lab Selection Revisited

PLUS

Lessons Learned from the Design and Construction of an Open Area Test Site and Sound Measurement Building

EMC Test Laboratory Software Program Development: A Proven Process

Reality Engineering: The Ringing Rocket

GOT GAIN?

improve your overall system sensitivity

Preamplifiers
20 MHz - 40 GHz
8 Models

Low-Loss Cables
DC - 40 GHz
4 Models

Like milk and cookies, preamplifiers go together with high-frequency low-loss cables. As frequency requirements increase, so do the losses encountered in antennas, cables and test instrumentation. Our preamplifiers provide the necessary gain to overcome these losses. The signal level at the receiver must be high enough to produce useful data. A.H. Systems has both preamplifiers and low-loss cables to match all antennas to 2, 4, 7, 18, 26.5 and 40 GHz. Our custom length low-loss cables match these frequencies and can be assembled and delivered in 2 days. Why wait when you can have it all now.

Preamplifiers... And Cables too.

Innovation Quality Performance

Phone: (818)998-0223 ♦ Fax (818)998-6892
http://www.AHSystems.com

A.H. Systems


Our expertise takes you to the top.
EMC solutions from Rohde & Schwarz.
We provide everything you need for development, precompliance and compliance measurements to ensure successful EMC certification.
Exceptionally fast EMI test receivers
Efficient diagnostic tools for detecting EMI
EMC software packages for interactive and fully automatic measurements
Wide range of accessories for performing EMI measurements
Compact and modular broadband amplifiers
RF shielded chambers
Complete EMC test systems
For more information, visit:
www.rohde-schwarz.com/ad/emc
ROHDE & SCHWARZ

IN COMPLIANCE

In Compliance Magazine
ISSN 1948-8254 (print)
ISSN 1948-8262 (online)
is published by

Same Page Publishing Inc.
531 King Street, Suite 5
Littleton, MA 01460-1279
tel: (978) 486-4684
fax: (978) 486-4691

editorial staff

editor/publisher Lorie Nichols
lorie.nichols@incompliancemag.com
(978) 873-7777

production director Erin Feeney
erin.feeney@incompliancemag.com
(978) 873-7756

publishing staff

director of sales Sharon Smith
sharon.smith@incompliancemag.com
(978) 873-7722

national sales manager Shellie Johnson
shellie.johnson@incompliancemag.com
(404) 991-8695

marketing communications specialist Heather Stehman
heather.stehman@incompliancemag.com
(978) 873-7710

marketing communications strategist Ashleigh O'Connor
ashleigh.oconnor@incompliancemag.com
(978) 873-7788

circulation manager Alexis Harrington
alexis.harrington@incompliancemag.com
(978) 873-7745

subscriptions

In Compliance Magazine subscriptions are free to qualified subscribers in North America.

Subscriptions outside North America are $129 for 12 issues.
The digital edition is free.

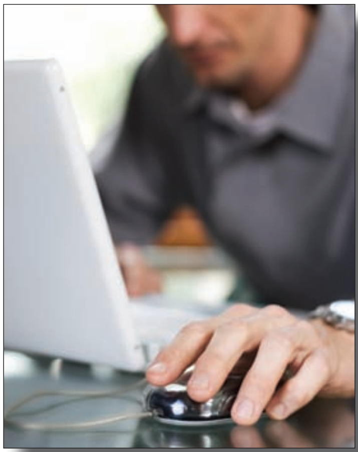
Please contact our circulation department at circulation@incompliancemag.com

advertising

For information about advertising contact:
Sharon Smith at 978-873-7722
sharon.smith@incompliancemag.com

CONTENTS

October 2013
Volume 4 ● Number 10



Remembering Dr. Ralph M. Showers

August 7, 1918 - September 8, 2013

Dr. Ralph Showers (1918 - 2013)

Ralph M. Showers, Ph.D., Emeritus Professor of Electrical Engineering, University of Pennsylvania, had an esteemed career dedicated to improving electronics communications by controlling electronic interference (electromagnetic interference). He was both a national and international technical leader whose contributions have had tremendous impact on standardization in the field of Electromagnetic Compatibility (EMC) Engineering.

Dr. Showers had shown outstanding long-term commitment to the voluntary standards process. He served as vice president of the U. S. National Committee (USNC) of the International Electrotechnical Commission (IEC), as a member of its Executive Committee. He served as the Technical Advisor for the USNC for Technical Advisory Groups (TAGs) for IEC Technical Committee (TC) 1 – Terminology, IEC TC 77 (Electromagnetic Compatibility), and the International Special Committee on Radio Interference (CISPR).

He served as the Chairman of the ANSI-Accredited Standards Committee C63

In 2007, at the IEEE EMC Symposium in Honolulu, Hawaii, Daniel D. Hoolihan, chair of the EMCS History Committee, interviewed seven founders and pioneers in the industry. He asked them all to tell a "war story" from their EMC careers. This is Ralph's war story.

This is not a war story, I just want to tell you something about the early days of standardization that you may not know about. I want to start back in the early days. I want to reference American Standards Committee C63, which was started before World War II; I am not sure what the origination date of that committee was. About the time I got into it was around 1950; it had just reinitiated work after World War II because the work had been interrupted during the war. One of the first projects it undertook was Instrumentation for Measuring Interference. I think basically it prescribed what became known as the first instrument for measuring interference. It was one of the original instruments, other instruments were made shortly thereafter but I think it was the cornerstone of our measurement of interference. It had a quasi-peak detector in it with time constants that were different than the ones that are used now. It was restricted in frequency range up to 30 megahertz, which almost everything was at that point. It was the standard.

I wanted to say something about the organization of C63. At the time it was organized, and I think the C in C63 meant coordination, I am not sure if that is correct, but its primary function was to coordinate work in the EMC field among various organizational members of ANSI and other organizations and including the military incidentally. It was sponsored by three organizations that you all know about. One was IRE, the other was AIEE, the other was NEMA.

By the time I got into it, NEMA was providing the Secretary, who was John Clark at the time. John Clark worked for NEMA and they provided the Secretary at that time. At the time I got into it, the Chairman of the committee I think was a fellow by the name of Tucker from Bell Labs. He retired from that position shortly thereafter. Believe it or not the next chairman was Bill Pakala who was in the heavy equipment area, high voltage equipment area of Westinghouse. Which is interesting, because at the moment you say, "Why was heavy equipment of concern?" Well, apparently one of the main problems they were dealing with was radio interference produced by high voltage lines and high voltage equipment. One of their cornerstone standards was NEMA 107. That was a standard procedure for measuring interference from power lines. The objective of the measurements was to control the radio interference that was generated by high voltage equipment. All the equipment that went out the door was measured for radiation, radiated interference in that frequency range up to 30 MHz. So that was the primary function of that particular equipment.

About the time I got interested in that, I had already been working on EMC for over 35 years! He was a Founder of the Institute of Radio Engineers (IRE) Professional Group on Radio Frequency Interference in 1957 which became the EMC Society of the Institute of Electrical and Electronics Engineers (IEEE). He was awarded the EMC Society's Hall of Fame Award in 2007 at the Society's 50th Anniversary Celebration in Hawaii.

Since the 1940s, he was active in research on measurement of electrical noise, weapons systems communications, aerospace microwave technology, space shuttle radio frequency experiments, stabilization of cable radiation characteristics, and cable coupling models. Among his many accomplishments, he worked for NASA, the U. S. Navy, the U. S. Army, and IBM and supervised ten PhD dissertations and 38 master theses. He authored and contributed to numerous articles in his field, as well as presented at many seminars and technical symposiums.

He received many prestigious awards over the course of his career including the 2011 Elihu Thomson Electrotechnology Medal, the IEEE Fellow Award, the IEEE Steinmetz Award, the EMC Society Richard R. Stoddart Award, and many others.

He was a registered professional engineer in Pennsylvania, a life member of the IEEE, and an honorary life member of the USNC. ■

with Leonard Thomas. One of the projects they were working on was what eventually turned out to be C63.4, which is Methods of Measurement. They had the instrument now, then they moved on to methods of measurement and I think that the number of the document was C63.4, the same as the main document we have today. Bill Pakala served as chair of that committee for many years, finally I succeeded him. By that time, what I wanted to really mention was, the military got interested in C63 and our first project was standard JNI225, this was the military standard for measuring interference from all kinds of equipment. I think that happened before the organization of EMC Society or its predecessor. You might ask the question as to why the predecessors did all their organizational work in New York City. The point I want to make is all the major sponsoring organizations were headquartered in New York City. The American National Standards Institute, of which C63 was a member, was a committee headquartered in New York. So was IRE; so was NEMA and so was AIEE. Also, as you've heard from Tony Zimbalatti, there were quite a few people in the New York area who were practicing and solving EMC problems. The New York Naval Shipyard was one that was very active at that time in EMC. They produced a lot of problems and reports for what went on there. So, it was quite natural that the efforts in organizing the EMC society really came out of some efforts of individuals in New York City. Of which, many people in the founders came from this area. I think that is what I wanted to say.

There is a lot of detail that one could go on and try to indicate some of the things that happened. I said this the other day, I gave a speech at a conference and a fellow was there from GE and he really came to me and he said, "Let's set up a committee on radio-interference and IRE."

That committee was the predecessor to the present SD COM, Standards Development Committee in the Society. ■

Dr. Ralph Showers

interview courtesy of
IEEE EMC Society History Committee from video and oral interview of Dr. Showers in
Hawaii in 2007

Daniel D.Hoolihan, Chair
EMCS History Committee

News in Compliance

FCC News

FCC Levies $2 Million Fine Against Business Owner for Junk Faxes

The U.S. Federal Communications Commission (FCC) has ordered a business owner to pay more than $2 million for repeatedly delivering unsolicited advertisements via fax to consumers in violation of federal law.

Issued in May 2013, the Commission's Forfeiture Order levies a penalty of $2,187,000 against Tim Gibbons, the owner of United Employee Benefits Group (UEBG) and related entities, for delivering 196 unsolicited fax advertisements to 156 individual consumers. The Forfeiture Order follows repeated efforts by the Commission over a nearly three year period to stop the flow of junk faxes from Gibbon's companies, including a Citation issued in October 2010, and two separate Notices of Apparent Liability for Forfeiture issued in February and September 2012.

The only response from either Gibbons or his companies to these enforcement efforts was a request to the FCC from an attorney representing Gibbons for an extension of time to respond to the February 2012 Notice of Apparent Liability. The Commission granted the extension, but was later notified that Gibbons did not plan to submit a formal response to the Notice.

The Telephone Consumer Protection Act of 1991 makes it "unlawful for any person within the United States…to use any telephone facsimile machine, computer, or other device, to send, to a telephone facsimile machine, an unsolicited advertisement," without prior authorization of the recipient.

In this case, the Commission cited Gibbons for willful and repeated violations of its regulations, levying $16,000 in fines for each of the 196 apparent violations, for a total of $2,187,000.

The complete text of the Commission's Forfeiture Order against Gibbons is available at incompliancemag.com/news/1310_01.

> The FCC has ordered a business to pay a fine of more than $2 million for repeatedly delivering unsolicited fax advertisements. The FCC has also proposed a fine of more than $200,000 against a company for operating unlicensed radio transmitters.

Commission Proposes Fine for Interference

The U.S. Federal Communications Commission (FCC) has proposed a fine of more than $200,000 against a Rhode Island company for operating unlicensed radio transmitters that created interference with critical weather radar systems near some of the nation's busiest airports.

Up To 1000 Watts* Of Class A Power From 80-1000 MHz But There's More...

Our enhanced "W" Series solid state RF amplifiers continue to deliver the performance customers demand. Linear Class A output power over the entire instantaneous frequency range, great harmonic rejection, and the best gain flatness and noise figure in the industry. These are all key features, but the ability to operate without foldback into poorly matched loads is paramount in most Radiated Immunity applications.

They're also extremely energy-efficient and have lower acoustic noise than our competition and previous versions which saves on both your wallet and your hearing. They are also much smaller and lighter which enables you to place them in size-constrained areas. These features along with our new easy-to-use touch-screen panels and numerous control interfaces makes your choice simple. And as always, AR provides the best service and support in the industry.
It just doesn't get any better than that.

To learn more, visit us at www.arworld.us/wSeries, or for technical support, call 800-933-8181.

**Higher Power Levels Coming Soon!*

ISO 9001:2008 Certified

rf/microwave instrumentation

Other ar divisions: modular rf • receiver systems • ar europe

USA 215-723-8181. For an applications engineer, call 800-933-8181.
In Europe, call ar United Kingdom +44 1908 282766 • ar France +33 147 917530 • ar Deutschland +49 6101 80270-0 • ar Benelux +31 172 423000

www.arworld.us

News in Compliance

FCC News

In a Notice of Apparent Liability for Forfeiture issued in August 2013, the FCC cited Towerstream Corporation of Middletown, RI for repeat instances in 2012 of interference with terminal Doppler weather radar (TDWR) systems operated by the Federal Aviation Administration near major airports around the country, including John F. Kennedy International Airport in New York, Miami International Airport, and the Fort Lauderdale-Hollywood International Airport. According to the findings from investigations by the Commission's Enforcement Bureau, the instances of interference were created by Unlicensed National Information Infrastructure (U-NII) transmission devices operated by Towerstream on leased rooftop locations near these airports.

U-NII devices are subject to operation within specific spectrum bands and must not create harmful interference. The Commission's Enforcement Bureau had notified Towerstream of similar interference issues at these and other major airports in 2009, and had received pledges of compliance from the company. The FCC characterized the most recent instances of interferences as examples of repeated or willful violations of its rules, and cited Towerstream for its "blatant disregard for Commission authority and the consequent harm to public safety."

The complete text of the Commission's Notice of Apparent Liability in connection with Towerstream is available at incompliancemag.com/news/1310_02.

Commission Adjusts Maximum Forfeiture Penalties to Reflect Inflation

The U.S. Federal Communications Commission (FCC) has issued an Order adjusting its maximum civil monetary penalties to reflect economic inflation.

Under the Federal Civil Penalties Inflation Adjustment Act of 1990, all federal agencies are required to adjust their maximum civil monetary penalties at least once every four years to reflect the impact of inflation. The FCC's Order details the procedures and formulas used to determine new maximum forfeiture penalties applicable under the Communications Act as amended. The new maximum forfeiture penalties are detailed in the Order's Appendix.

The FCC's last forfeiture adjustment Order was issued in June 2008. The new maximum forfeiture limits are applicable only to forfeitures issued after August 30, 2013.

The complete text of the Commission's Order adjusting forfeiture penalties to reflect inflation is available at incompliancemag.com/news/1310_03.

Commission Proposes Budget for Fiscal Year 2014

The U.S. Federal Communications Commission (FCC) has submitted to Congress a request for an appropriation of just over $359 million for the 2014 fiscal year, which begins October 1, 2013.

The Commission's appropriation request is detailed in its *Fiscal Year 2014 Budget Estimates*, a 132 page document submitted to Congress in April 2013. The Commission's *Budget Estimates* document includes a wealth of additional information about the Commission, its operations and its strategic goals for the coming fiscal year.

The Commission's proposed 2014 appropriation represents a 3.6% increase over the nearly $347 million requested for fiscal year 2013. However, the Commission projects that its requested appropriation will be offset by the nearly $455 million it expects to collect in regulatory fees and auction proceeds. As a frame of reference, the Commission projected collections of nearly $300 million in fiscal year 2006, and about $185 million in fiscal year 2000.

The Commission also projects that it will employ the equivalent of 1821 full-time staffers during the 2014 fiscal year, up from 1776 in fiscal year 2013.

The FCC has adjusted its maximum penalties to reflect economic inflation to meet requirements of revising the penalties at least every four years. The FCC has also proposed its budget for the fiscal year of 2014.

News

The complete text of the Commission's *Fiscal Year 2014 Budget Estimates* is available at incompliancemag.com/news/1310_04.

Commission Modifies Part 15 Rules for Wireless Services

The U.S. Federal Communications Commission (FCC) has modified its rules applicable to unlicensed communications equipment operating in the 57-64 GHz band.

In a Report and Order issued in August 2013, the Commission increased the power limits for outdoor directional antennas operating between fixed points. In order to avoid potential interference to other users, the rule changes have also tied the maximum permitted power to the precision of an antenna's beam.

According to the Commission, these changes will permit outdoor transmission devices to provide high-capacity communication links over distances as great as one mile and at data rates of 7 GB per second, thereby enhancing the utility of broadband devices operating in the 57-64 GHz band. The changes will also broaden the use of unlicensed spectrum as a relatively low-cost, high-capacity short-range signal backhaul alternative for wireless broadband networks.

The complete text of the Commission's Report and Order is available at incompliancemag.com/news/1310_05.

News in Compliance

CPSC News

LED Bulbs Recalled Due to Shock Hazard

Philips Lighting of Somerset, NJ has recalled 99,000 of its Endura and Ambient-brand LED dimmable light bulbs manufactured in China.

The company reports that a lead wire in the bulb's housing may have an improper fitting, which can electrify the entire lamp and pose a shock hazard to consumers. Philips has not received any reports of injuries or other incidents associated with the defective bulbs, but has initiated the recall to prevent future incidents.

The recalled LED bulbs were sold at The Home Depot and other grocery and home center stores nationwide, through Amazon.com and other online retailers, and through electrical distributors from the period from October 2012 through May 2013 for between $15 and $30 each.

Additional information regarding this recall is available at incompliancemag.com/news/1310_06.

Consumers Reminded to Shop Safely for Replacement Batteries

The U.S. Consumer Product Safety Commission (CPSC) and the industry trade group CTIA-The Wireless Association are warning consumers to "shop safely" when choosing replacement batteries for mobile devices.

The CPSC's/CTIA's recommendations to consumers include using only those batteries and battery chargers that are compatible with their devices, such as those recommended by the device manufacturer or an authorized wireless carrier. Consumers are urged to contact the original equipment manufacturer if they are unsure about the compatibility of a battery or charger with their mobile device.

The CPSC/CTIA's notice comes in the wake of recent news reports of certain models of smartphones exploding or catching fire when connected to incompatible batteries and chargers. The CPSC says that 61 separate consumer reports related to wireless mobile devices and their accessories have been posted to the CPSC's SafeProducts.gov web site since its launch in 2011.

The CPSC's/CTIA's complete list of recommendations regarding the safe use of mobile devices, replacement batteries and chargers is available at incompliancemag.com/news/1310_07.

You Can't Make This Stuff Up

17th Century Pocket Calculator for Sale

One of four surviving 17th Century "pocket" calculating machines is scheduled to be auctioned at Christie's in London this coming October.

Invented in the late 1600s by Rene Grillet, a French inventor and watchmaker, the paper and wood box measures about five and half inches by nearly 13 inches, and features 24 separate dials embedded in the box lid. According to the Reuters report, the calculator was capable of performing addition, subtraction, multiplication and division using the so-called "Napier's bones" logarithm.

However, there's little chance that the calculating machine would be confused with today's smart mobile devices or even the advanced scientific calculators of the 1970s and 1980s, since the pocket calculator required users to "carry the 10s" when computing multiple numbers.

Christie's has estimated that the antique pocket calculator will sell for between 70,000 and 100,000 pounds (about $108,000 to $155,000 U.S.) at auction.

Is a Digital Autopsy in Your Future?

A Malaysian entrepreneur believes that today's digital technologies could soon replace the traditional (some would say gruesome) post-mortem examinations of human bodies.

According to a recent report from the Reuters News Service, Matt Chandran expects to open the first of 18 planned digital autopsy facilities in Great Britain beginning this October. The digital autopsy procedure would utilize Chandran's proprietary iGene 3D imaging software, and would replace the scalpel with a digital scanner and the autopsy bed with a touchscreen surface. Not only is the digital autopsy cleaner and less gruesome, but the results of the digital examination can be reviewed after the procedure by other experts without having to reopen the body.

At one point in the 1950s, pathologists in the U.S. and Europe performed autopsies on more than 60% of those who died. The percentage of autopsies has declined to about 20% of all deaths, but there are still an estimated 7 million autopsies performed each year in Great Britain alone, according to the Reuters report.

European Union News

EU Commission Releases 2013 Mid-Year RAPEX Summary Statistics on Unsafe Consumer Products

The Commission of the European Union (EU) has released statistics on notices of unsafe consumer products that have been processed through the EU's rapid information system (RAPEX) for the period from January 1 through June 30, 2013.

According to the Commission's report, 783 notifications of products posing a serious risk to health and safety were processed through the RAPEX system during the first half of 2013. This represents an overall 20% decrease in the 976 notifications received over the same period in 2012, although notifications during the April-June period were roughly equal with the April-June 2012 period.

Of the notifications processed through the RAPEX system during the period as presenting a serious risk to consumers, 194 (25%) were related to clothing, textiles and fashion items, with an additional 176 (22%) related to toys, and 78 (10%) related to electrical appliances. There were also 68 notifications related to motor vehicles (9%), and 7 notifications (>1%) related to childcare articles and children's equipment. Regarding the country of origin identified in connection with products posing a serious safety risk, more than half of all notifications (60%) were related to products originating from China, including Hong Kong. 15% of unsafe products originated in EU Member States, while 8% failed to identify any country of origin.

To view the complete text of the EU Commission's 2013 mid-year report on RAPEX statistics, go to incompliancemag.com/news/1310_08.

Charging by Walking

Walking on an insulative floor covering produces a predictable charge

BY NIELS JONASSEN, sponsored by the ESD Association

There are very few cases in which it is possible to quantitatively describe an electrostatic charging process (i.e., the rate at which the voltage of an insulated conductive system or insulator field increases).

INTRODUCTION

Associate Professor Neils Jonassen authored a bi-monthly static column that appeared in *Compliance Engineering Magazine*. The series explored charging, ionization, explosions, and other ESD related topics. The ESD Association, working with *In Compliance Magazine* is re-publishing this series as the articles offer timeless insight into the field of electrostatics.

Professor Jonassen was a member of the ESD Association from 1983-2006. He received the ESD Association *Outstanding Contribution Award* in 1989 and authored technical papers, books and technical reports. He is remembered for his contributions to the understanding of Electrostatic control, and in his memory we reprise “Mr. Static”.

~ The ESD Association

Two important examples where this is possible, however, are the flow of a liquid such as gasoline into an insulated container or, of more interest in the electronics world, walking on an insulative floor covering—the most common way people are charged.

As explained in a previous column titled “Is Static Electricity Static?” (*In Compliance Magazine*, September 2013) the charging of a person by walking can be described by assuming that the contact and friction between the person’s shoe soles and the floor separates a charge, Δq, for each step. If the step rate is n steps per unit of time, this corresponds to a charging current of

$$i_c = n\Delta q \qquad (1)$$

The current will charge the person in such a way that the voltage, V, will initially increase at a mean rate of

$$\frac{\Delta V}{\Delta t} = \frac{n\Delta q}{C} \qquad (2)$$

where C is the person’s capacitance. The increase in voltage, ΔV, by the first step will be

$$\Delta V = \frac{\Delta q}{C} \qquad (3)$$

The voltage will cause a decay current, i_d, through the resistance, R, from the person to ground:

$$i_d = \frac{V}{R} \qquad (4)$$

And the voltage will reach its maximum value, V_m, when $i_c = i_d$ or

$$V_m = Rn\Delta q \qquad (5)$$

If the highest acceptable body voltage is V_{accep}, then the grounding resistance must fulfill the condition

$$R \le \frac{V_{accep}}{n \cdot \Delta q_{max}} \qquad (6)$$

where Δq_{max} is the maximum value of the charge separated per step.

In the column cited, the maximum value of Δq_{max} was estimated as

$$\Delta q_{max} = \varepsilon_0 E_b A \qquad (7)$$

where ε_0 (the permittivity of air) = $8.85 \cdot 10^{-12}$ F·m^{-1}, E_b (the breakdown field strength in air between plane electrodes) » $3 \cdot 10^6$ V·m^{-1}, and A (the area of the shoe sole) » 150 cm^2 (see Figure 1).

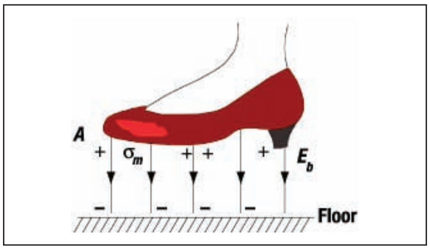
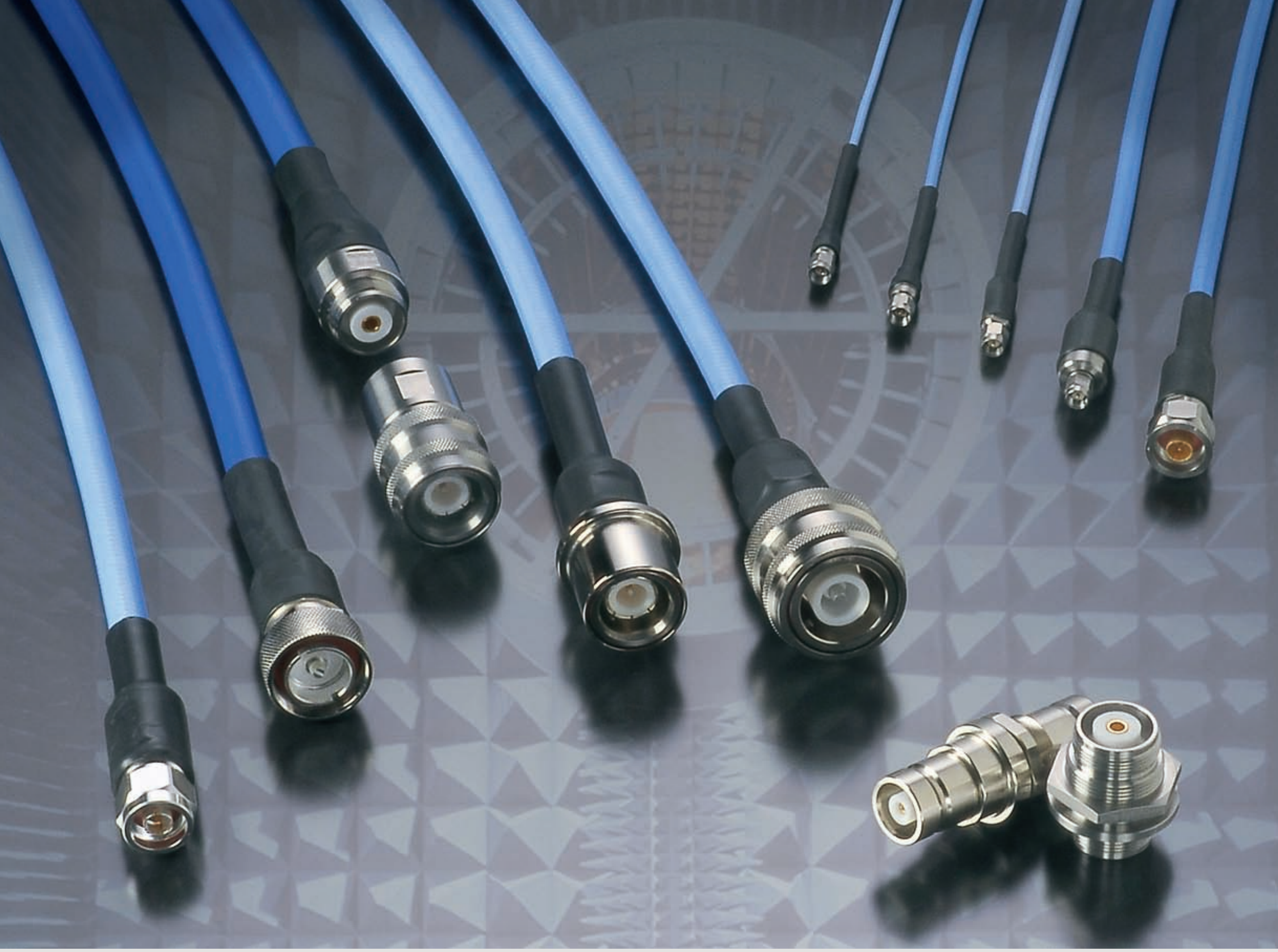


Figure 1: Charge separation between shoe and floor



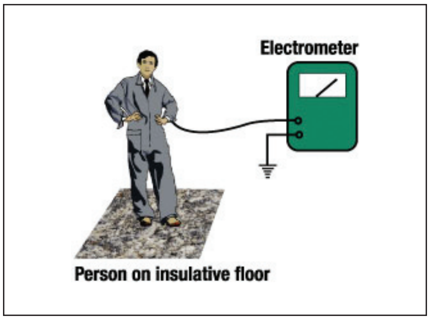


Figure 2: Measurement of body voltage

Introducing these values into Equation 5, we find that

$$\Delta q_{max} \text{ » } 4 \cdot 10^{-7}\ C \qquad (8)$$

which corresponds to a charging current of

$$i_{c,max} = n \cdot Dq_{max} = 8 \cdot 10^{-7}\ A \text{ » } 10^{-6}\ A \qquad (9)$$

assuming a rate of 2 steps/sec. Therefore, if $V_{accep} = 100$ V, then R = 100 MΩ. Note that the values for an acceptable floor resistance derived from Equations 6 and 9 are conservative. It is highly unlikely that the whole area of the shoe sole would be charged to the breakdown level and that no neutralizing discharge would occur when lifting the foot.

Equation 3 indicates the expected increase in voltage at the first step to be

$$\Delta V = \frac{4 \cdot 10^{-7}}{100 \cdot 10^{-12}} = 4\ kV \qquad (10)$$

assuming a capacitance of 100 pF for one foot. To find more realistic values for Δq and ΔV, a series of measurements of the body voltage on a highly insulative floor covering (vinyl tiles) were taken. The body resistance to ground was measured to 10^{11} Ω, varying over the floor from 0.5 to $1.5 \cdot 10^{11}$ Ω. The body capacitance was 160 pF for both feet and 100 pF for one foot.

The experimental setup is shown in Figure 2. The person is connected to an electrometer, which can be run as a charge meter (high capacitance) or as a static voltmeter (low capacitance). With the meter in the charge-measuring mode, the charge for a single step was determined. As the average of 10 determinations, the value was found to be

$$\Delta q = 3 \cdot 10^{-8}\ C \qquad (11)$$

with a standard deviation on a single determination of $0.5 \cdot 10^{-8}$ C. According to Equation 3, this corresponds to a voltage increase for the first step of With a rate of 2 steps/sec, Equation 5 indicates an expected maximum voltage of

$$\Delta V = \frac{3 \cdot 10^{-8}}{100 \cdot 10^{-12}} = 300\ V \qquad (12)$$

With a rate of 2 steps/sec, Equation 5 indicates an expected maximum voltage of

$$V_m = Rn\Delta q = 10^{11} \cdot 2 \cdot 3 \cdot 10^{-8} = 6\ kV \qquad (13)$$

Figure 3 shows the body voltage as a function of time. It appears that the voltage reaches a maximum of about 3.5 kV after approximately 15 seconds. The reason a person doesn't reach the predicted maximum value of 6 kV from Equation 13 can be found in the decay curve starting at 21 seconds. At that moment, the person stands still and allows the charge to be neutralized through the effective grounding resistance. An analysis of the curve shows that the initial decay corresponds to a resistance of approximately $2 \cdot 10^{10}$ Ω and concludes with a value close to 10^{11} Ω. This must mean that the resistance (or rather, the resistivity) of the floor (and sole) material decreases with increasing voltage (or rather, field strength). The direct measurement of the person's resistance was taken at a voltage of approximately 300 V, and the measured resistance will therefore be higher than the effective resistance at the maximum voltage.

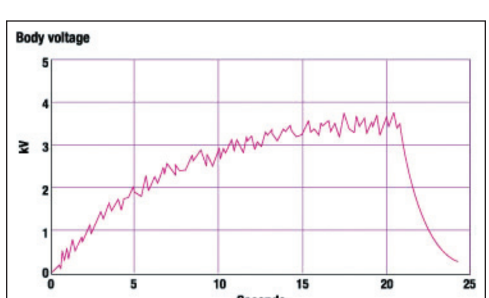


Figure 3: Body voltage of person walking on an insulative floor

The value of V_m predicted by Equation 5 appears to provide a safe upper limit for the body voltage when walking on a floor characterized by a resistance R. One problem, however, remains. According to Equation 3, the voltage developed by a single (the first) step seems to be independent of the decay resistance. Further, the value of 300 V, as predicted by Equation 12, could be a problem in many scenarios involving electrostatic discharge. It should also be stressed that Equation 3 does not account for the unavoidable decay during the time it takes to lift the foot from the floor and separate the charge Δq. If this time is Δt, then the voltage ΔV at the end of Δt can be written as

$$\Delta V = \frac{\Delta q}{C} \cdot \frac{RC}{\Delta t}\left(1 - e^{-\frac{\Delta t}{RC}}\right) \qquad (14)$$

If we assume Δt ~ 0.1 second, C (one foot) = 100 pF, n = 2 steps/sec, and $\Delta q = 3 \cdot 10^{-8}$ C, we can find ΔV (Equation 14) and V_m (Equation 5) as functions of the decay resistance R (see Figure 4). It appears that for low values of R, ΔV is higher than V_m. For instance, at $R = 10^9$ Ω (1 GΩ) the mean maximum voltage is $V_m = 60$ V, and the one-step voltage is

The upper limit of the voltage to which a person walking across an insulative floor may be charged can be predicted with reasonable accuracy by measuring the person's total resistance to ground. And again, at relatively low resistances the body voltage after one step shows up as a voltage spike higher than the mean body voltage integrated over several steps.

$\Delta V = 180$ V. It may seem peculiar that the body voltage after one step (rather, at the end of the first foot lift) can be higher than the mean body voltage after many seconds. The reason is that the voltage decays in the time between the lifting of one foot and the lifting of the other foot. Assuming $\Delta t = 0.1$ second and $n = 2$ steps/sec, this decay time is approximately 0.4 second (i.e., four times as long as the charging time).

The curves show that $\Delta V = V_m = 270$ V at $R = 4.5 \cdot 10^9\ \Omega$. The implication of the results plotted in Figure 4 is that at resistances lower than approximately 4.5 GΩ, the voltage spikes connected with a single step are the primary concern, and at higher resistances the equilibrium voltage integrated over many steps is the dominating factor.

CONCLUSION

The upper limit of the voltage to which a person walking across an insulative floor may be charged can be predicted with reasonable accuracy by measuring the person's total resistance to ground. And again, at relatively low resistances (< ca. 4.5 GΩ) the body voltage after one step shows up as a voltage spike higher than the mean body voltage integrated over several steps.

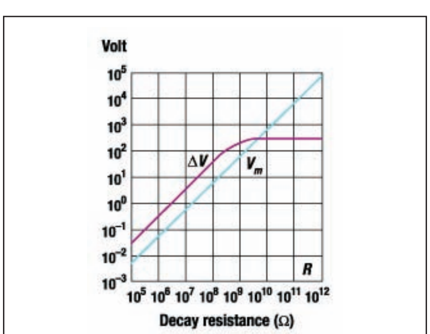


Figure 4: Maximum voltage, V_m, and one-step voltage, ΔV, as a function of the decay resistance, R

(the author)

NIELS JONASSEN, MSC, DSC,

worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. After retiring, he divided his time among the laboratory, his home, and Thailand, writing on static electricity topics and pursuing cooking classes.

Mr. Jonassen passed away in 2006.

ON Your Mark

OSHA's New Safety Sign Ruling and Its Impact on Workplace Safety

BY GEOFFREY PECKHAM

In this column, we'll discuss OSHA's newly implemented update to rules on safety signage in the workplace – and how it's raising the bar on safety communication.

In the last *On Your Mark* column, we shared news on a regulation change for workplace safety slated for the Occupational Safety and Health Administration's (OSHA) 2013 regulatory agenda. As of September 11, 2013[1], OSHA's rule update to incorporate the current ANSI Z535 (2011) safety sign and tag standards into its safety regulations is now in effect. No longer merely an anticipated agenda item, this rule change is now real, and it's a game-changer for product and safety engineers responsible for protecting people from harm.

Prior to this fall, OSHA's safety sign and tag regulations referenced outdated, 1967 and 1968 standards; now, OSHA's safety sign and tag regulations integrate the latest state-of-the-art warnings technology as defined by the most recent (2011) version of the ANSI safety sign and tag standards. This seemingly small change is an incredibly significant action that will advance safety in the United States; the newer standards give nearly all industries the tools they need to create effective safety communication in the workplace.

The question that's likely on your mind is, "What are the compliance and liability implications of this OSHA change for my organization?" First, it's important to note that this new OSHA safety sign rule allows employers to continue to use the old safety signs and tags if they want to do so. Changing to the new ANSI Z535 standards-compliant signs and tags is not mandatory even though the older signs and tags are based on a 1941-era standard. The consensus of the safety, engineering, risk management and insurance professionals that I've spoken to since OSHA's intention to change their regulations was announced in January is, "Why would you want to stick with the old? There is too much at stake not to change." The common understanding here is that companies who have a strong commitment to workplace safety and an aversion to litigation will eagerly adopt the OSHA 2013-sanctioned ANSI Z535-2011 standards. Here's why:

- **More Effective, Uniform Safety Communication**

One of the primary reasons OSHA made this change is that it allows those responsible for environmental and facility safety to take advantage of the substantially more advanced ANSI Z535 warnings technology that product manufacturers have been using for their product safety labels for the past two decades. The goal of achieving more effective safety communication in the workplace is furthered when you understand that the new signs and tags are part of a national uniform system for hazard recognition. Soon the safety signs and tags people see in their workplace will match the ANSI Z535-formatted product safety labels they see in their daily lives on machinery, component parts, tools, and consumer products. And this is significant because intelligently-designed ANSI Z535 signs, tags and labels represent a completely higher level of safety communication technology. Most often they include graphical symbols to communicate across language barriers, specific color-coding to bring added noticeability, precise formatting that corresponds with modern risk assessment methodologies and more substantial content to satisfy today's expectation for more substantive warnings that tell not only what the hazard is, but how to avoid it.

- **Reducing the Risk of Litigation**

The 2011 ANSI Z535 standards represent best practices for visually communicating safety messages. As a product design engineer, you know

1 At the time of writing, the OSHA regulation update was expected to be announced and to go into effect on September 11, 2013.

Examples of old OSHA-style safety signs (left) beside the corresponding new OSHA 2013/ANSI Z535-2011 safety signs (right). (New designs ©Clarion Safety Systems.)

the vital role your product's warnings play to both make your products safe and lessen your company's product liability exposure. For decades the *ANSI Z535.4 Standard for Product Safety Signs and Labels* has set the bar for product safety labeling and almost all product safety engineers responsible for labeling use it. In a similar way, the OSHA rule change that just occurred makes the *ANSI Z535.2 Standard for Environmental and Facility Safety Signs* and the *ANSI Z535.5 Standard for Temporary Safety Tags and Barricade Tapes* the best practice documents that both your industry and the U.S. court system will look to as defining state-of-the-art for safety communication in the workplace. Not using safety signs and tags in compliance with the 2011 ANSI Z535 design principles will open companies up to allegations of "failure to warn" and "inadequate warnings" when accidents occur.

This second point is critical because the legal theory of the *duty to warn* is evolving. It first began in the area of product liability law which found that manufactures have a duty to warn of potential hazards associated with the foreseeable use and misuse of their products. In the past several years, we've seen the legal theory of the duty to warn expand beyond products and into workplaces and public areas. For example, there have been multiple lawsuits based on the lack of warnings by people who have been injured after diving into shallow pools – with many million dollar settlements or verdicts. Major settlements have also occurred when visitors, subcontractors, temporary workers and maintenance employees have been injured in someone else's facility. And there is a shift going on in many states' laws regarding workers' compensation, allowing injured employees (or their families, if the employees are killed) to sue their employers. The new OSHA-endorsed ANSI Z535 safety signage gives organizations a risk reduction tool they can use to provide adequate warnings so accidents are prevented, number one. Second, if an accident does occur, the new signs, labels and tags will provide the organization with a litigation defense tool that should help to lessen liability.

The OSHA rule change's "raising of the bar" in safety signage is a direct reflection of our society's increasing expectation for accurate risk communication. When safety is not communicated properly, accidents happen, lives can be lost, and a company's reputation can be destroyed. Failing to reduce risk, when possible, is not an option. Too much is at stake. This new development should have the attention of your safety and legal/risk management decision-makers. Now is the time to bring the same high level of attention you've given to product safety labeling and focus it on using the latest best practice safety signs, labels, and tags in your facility. As compliance and safety professionals, we all share a common goal of creating safer products and safer work environments to help prevent accidents and injuries. Adopting the new OSHA rule change that embraces the ANSI Z535 standards for your workplace will help your organization to accomplish this worthy objective.

For more information about OSHA/ANSI safety signs, labels and tags, visit www.clarionsafety.com.

(the author)

GEOFFREY PECKHAM

is CEO of Clarion Safety Systems and chair of both the ANSI Z535 Committee and the U.S. Technical Advisory Group to ISO Technical Committee 145-Graphical Symbols. Over the past two decades he has played a pivotal role in the harmonization of U.S. and international standards dealing with safety signs, colors, formats and symbols. This article is courtesy of Clarion Safety Systems ©2013. All rights reserved.

REALITY Engineering

The Ringing Rocket

BY MIKE VIOLETTE

As a hired hand on a launch vehicle project some years back, my task was to examine, specify, calculate, test, analyze and predict all issues that had something to do with RF in general and EMC in particular. It wasn't ROCKET SCIENCE...

GIMBALS & GIMBALLING

Ships' compasses are mounted on **gimbals**, fixtures that allow the needle to stay steady against the pitching and rolling of surging seas. Sailors know that a steady compass helps to steer a true course.

In rocketry, the nozzles are "gimbaled," providing positive control of the thrust from the business end of a rocket engine and assuring that the rocket stays on-course. Rocketeers know that an unsteady nozzle can ruin your whole day.

In many designs, the hydraulically-operated gimbal system takes control inputs from the on-board flight computer to steer the vehicle along its proper trajectory. The hydraulic system is charged with enough juice to get the vehicle to altitude. If the gimbaling gets out of whack, it's mission over.

Getting a rocket to space takes a whole lot of things going right. But unknown factors can grab hold…and things go wrong.

HIRED HANDS

Speaking of rockets, as a hired hand on a launch vehicle project some years back, my task was to examine, specify, calculate, test, analyze and predict all issues that had something to do with RF in general and EMC in particular. The project was a privately run, but partially supported by the same organization who put an Apollo LEM down gently in the soft dust of the Sea of Tranquility. As it would turn out, our ending did not go so well, our vehicle landing—not-so-softly—in the chilly waters of the Atlantic.

Frank called one day and said there was a space-task and would I be interested? I've always been a fan of space projects. Frank said that there wasn't any kind of SOW or RFP for this project, so he advised to "Bid a hundred hours and see what happens." With baby number two needing diapers and shoes, I bit and I bid it. Soon enough, I was on-board.

The launch vehicle was of relatively simple design (if anything that breaks through the atmosphere can be "simple") with a modest mission: launch a couple of science projects into low Earth orbit (LEO). The experiments were designed to collect some data in the stratosphere and drop back to Earth by parachute for retrieval and analysis.

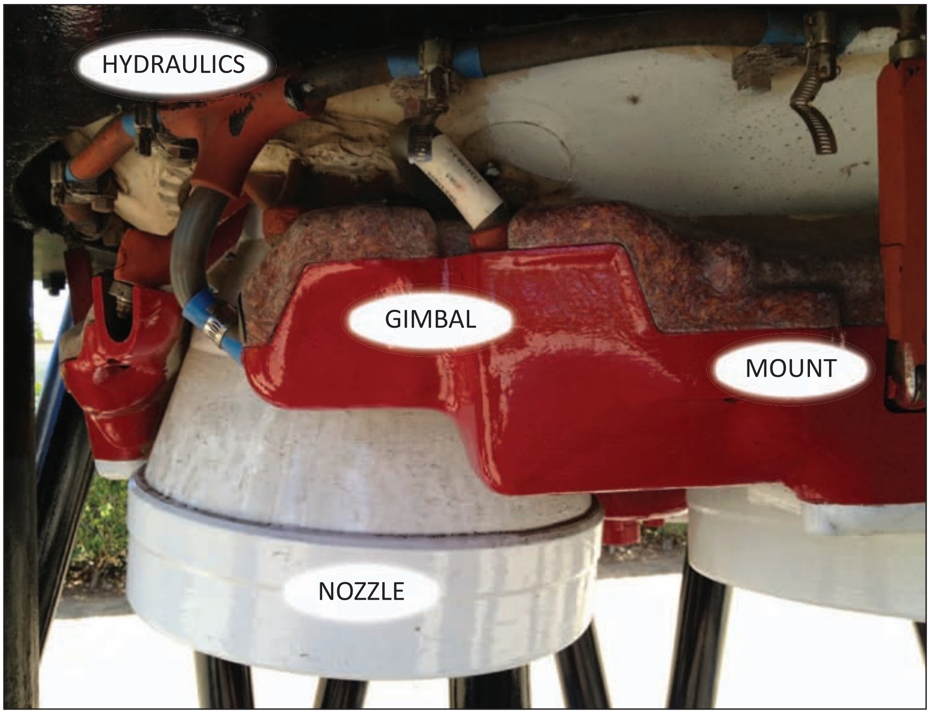
We hired hands out-numbered the employees by a good margin, much like a myriad of other operations scattered about in non-descript office buildings around the various fountains of money around the Capital Beltway. My office mate Steve, also a hired hand, was in charge of the telemetry and had been on similar programs before. He took me under his wing, so to speak, and guided me to the right meetings and interpreted the corporate culture for me.

Steve and I both contracted with Jack, a distant voice that grumbled in my phone (I still have yet to meet him). Jack had a dozen or so guys on this project and he took a piece of each of us, extolling the virtues of working lots of hours "charge as many hours as you can, Mike. Fifty, sixty a week is no problem." Sure Jack, no problem.

As the telemetry guy, Steve's job was to collect data on the rocket during ascent. The vehicle was wired with dozens of accelerometers, strain gauges, temperature sensors and the like. Data from these sensors flowed back to ground control to monitor the progress of the rocket (and to inform design modifications on the next vehicle—if there was to be a next). If something were truly to go awry during flight—like if it was out of control—a big red button in the control room would be pressed, fast.

Settling back in his chair, hands behind his head, Steve swiveled in my direction and said "One of the first things you have to do is to get to know George." George was the project lead, which meant that he was in charge of herding the cats.

I wandered over to George's office, knocked and entered slowly and looked around. The four walls of his office were lined with large sheets of paper covered with project diagrams, milestones, sticky notes, red stars and yellow highlighting. George was head-down in a pile of papers, scratching away furiously. "Have a seat." He motioned to a chair that was stacked with thick spiral-bound design review documents. I sat those on the floor and took the chair.



George started reeling off a list of priorities. I jotted them down as quickly as I could. "Mike, we've *got* to get a ground diagram worked up! We absolutely must! And the antennas, take a look at the antennas! Are they a problem? Also, get a hold of Vivek and ask him about the ordnance; he'll know. Burt can help you with the

REALITY Engineering

GSE—just get to him before noon. And shielding! Is the wire shielding good enough? Hank can give you the wiring diagrams. Here, take a look at this." He handed me a legal pad-sized paper with a hundred lines, interconnecting numbered boxes: IMU, FC, BATT1, BATT2, COMM, DWNLNK, TLM. "This is my shot at the ground diagram. What do you think?"

I took the paper. "Yeah, good" was all I could muster. George returned to scribbling something on a sticky note, stood up and put it up onto the web of lines on the wall.

"OK. See you at the meeting tomorrow morning. I want a report on everything." He stood, turned his attention to the diagram on the wall, tapping his chin with his pen.

Time to go and get started.

ANTENNA WHISPERER

One of the first tasks was to analyze the potential cross-coupling between the various antennas on the craft. There was the telemetry downlink, a communications connection to the TDRSS[1] constellation (a collection of transmitters orbiting about the planet for space-ground-communications) and the all-important "self-destruct" receive antenna for the worst-case scenario that the lift-off needed to be aborted by the range safety officer. The analysis involved calculations of margins, based on output powers and antenna patterns. Some of the antennas were moved, just to be on the safe side.

ALL THE WRITE SPECS

Another task was the generation of EMC testing and performance specifications. We favored the NASA General Environmental Verification Specification (GEVS) which was developed for the Space Shuttle program. The only non-cookie cutter activity was to determine tailored requirements for RS03 (radiated susceptibility) levels. I needed information on the launch site and for this I went to Burt, who was managing the ground operations and Ground Support Equipment (GSE). Burt was helpful, although he had a funny habit of pounding three mai-tais at lunch at the local Chinese restaurant. I'm not sure how he was able to function in the afternoon, so, as George suggested, I always caught him first thing in the morning.

"There's a big radar down there at the launch site." Burt told me one morning, sipping coffee (I suppose) from his mug, which may as well have been attached to his right hand. "It's operating at around 2 GHz, if I recall correctly. It's kind of close to our launch pad, so heads-up!"

Got it. I marked 2 GHz on a spreadsheet, FREQ: 2GHz. LEVEL: TBD.

EXPLOSIVES ON-BOARD!

Another task was to analyze safety margins for the dozen pieces of ordnance on the craft to make sure they wouldn't go off inadvertently—an ill-timed explosion being a bad thing. There were two kinds of these devices: Explosive bolts were designed to blow at a certain altitude to cleave the aerodynamic structure (the fairing), which would separate out and away from the craft. It would be bad form for these bolts to blow early, say, on the launch pad because of a nearby RF source (like a pesky radar). The second kind there were the self-destruct charges that were designed to destroy the vehicle if it went off-course.

This kind of analysis is often referred to as a HERO[2] analysis which is ironic, because if you "blow it," you won't be a hero. The basic analyses was not heavy on Maxwell, but a general wag at how much coupled energy would find its way into the wiring and (potentially) induce a triggering voltage across the pins. End game: use a triple-shielded cable and good connector and bond the heck out of the thing. Should be OK, but everybody likes calculations, so I put together something with a bunch of dBs to shore up the argument.

HOW TO GROUND A ROCKET

The other part of the job involved "grounding," George's favorite topic. I know how some perfectly sane engineers get worked up about ground (Run! Hide! Ground Loops!), but developing ground concept on a flying thing is not all that difficult, once you realize you can't trail a long wire out the back of the thing and that's not how "ground" works anyway. The avionics packages on the rocket were a collection of metal boxes places around the core of the rocket's fuselage, which was non-conductive composite. The solution for "ground" was really to create an "equipotential structure." This would also serve as the mechanical mounting for the avionics and other electronics.

All the boxes were mounted to a six-sided panel arrangement: flight computer, radios, power distribution, batteries and telemetry subsystems were arranged according to function and the interconnection hierarchy. To minimize the generation of errant voltages across the structure, we selected a thick, heavy printed circuit board material: double-sided un-etched fiberglass + copper. To bond the boxes, some sort of non-oxidizing goo was slathered on the footprint of each of the boxes. This "ground plane" structure was beneficial to overall system performance because all the interconnect cables were staked tightly

1 TDRSS Tracking and Data Relay Satellite System

2 Hazards of Electromagnetic Radiation to Ordnance

to the plane, minimizing coupling/ radiating loops. Each of the six panels was bonded along the edge to its neighbor.

FIVE OUT OF FIVE ENGINEERS RECOMMEND TESTING

Tests of the avionics were performed during development to see if there were any real issues. A lot of these tests were informal, bench-level and incremental. The only hairy part of that task (one of those: 'Why did I take this job?' moments) was when I flipped on my power amplifier and blew a main breaker, crashing the avionics exercise mid-test. After a searing glare from the Chief Scientist and an angry "If you broke it, Violette, you're going to pay for it!" we reset the breaker, the test resumed and the whole business re-booted without hiccup (I moved my amp to another circuit, of course).

Eventually, functionality was beat into the works, we ran some system-level EMC tests and the payload was moved to the launch site to be bolted onto the launch vehicle.

FAT BOY AT 2 GIGS

The radar was indeed close, about 600 meters from our launch pad. Hoo-boy. I took some measurements and found peak levels around 300 V/m. Ouch. I rechecked the HERO analysis and decided there were sufficient margins, but what about the other systems? Navigation? Communication? We never tested at levels this high. I reported back the measurements and a note of caution 'See if they can at least turn the radar off during launch.' It was the last time I touched the project.

A FEW HERTZ HURTS

Steve called me about eighteen months later.

"Hi Mike. Did you hear about the rocket?" Sometimes a question is posed in a certain way, with the answer embedded in the question.

I said 'no'. (I think I whispered my reply, actually.)

"She splashed." He let that sink in a moment.

Wow. I thought about the radar, testing, all the design reviews, the guesses. The entire sweep of the project rushed by. What happened? EMI?

Steve laughed "No no. You're off the hook."

Phew. What happened then?

Steve explained. "We run a 'tap test' on the rocket once it's on the pad."

Tap test? The last tap test I ran was in college.

"Yeah, a tap test checks for vehicle resonances. Technicians whack the thing all over. The accelerometers record the structure response and any resonances, or ringing."

OK. And?

"Turns out the vehicle was resonant at a few hertz, but it was overlooked. As the vehicle lifted off, the thing rang like a bell. The gimbaling system tried to compensate, commanding the nozzles like crazy." He paused. "The hydraulics were exhausted at less than a minute and with no control, the thing heeled over, split apart and the rocket tumbled into the ocean."

Damn.

Steve continued. "It's hindsight, but all we needed was a simple filter in the software to reject the structure resonance. " He let that soak in and added, more quietly. "The range destruct system didn't even work because all of the antennas were ripped away when the fairing blew off." He repeated. "We needed a filter in the software." He sighed. "Live and learn, I guess."

Live and learn indeed. The reality is that to put something above the atmosphere, safely and in the right spot, so many things need to go right. That's why it's called 'Rocket Science.'

(the author)

MIKE VIOLETTE
remembers the first Moon walk (the same night the cat had a litter under the living room couch), *Space Food Sticks,* drinking *Tang* and the awesome *Saturn V,* The King of All Launch Vehicles. He can be reached at mikev@wll.com.

Compliance Worldwide, Inc.

Test Locally, Sell Globally and Launch Your Products Around the World!

FCC - Wireless - Telecom - CE Marking - International Approvals - Product Safety

Compliance Worldwide is an independent regulatory compliance testing laboratory founded in 1996. We provide testing and certification services for domestic and international markets. We are A2LA Accredited under ISO Guide 17025-2005 and provide EMC, EMI/RFI, CE Marking, Product Safety, Wireless and Wireline Telecommunications Testing and FCC/Industry Canada approval Liaison Services for manufacturers of Electronic Equipment.

Our testing expertise and core technologies we serve include ITE, Audio/Video, Consumer, Telecommunications, Laboratory, Medical, Security and Wireless products. We work with organizations around the world and also cater to very specific product categories, such as, Automotive Radar, Ground Penetrating Radar, Ultra Wideband (UWB), DECT (UPCS - Un-licensed PCS), Cellular / PCS / LTE (AWS) 4G Amplifiers, 802.11 b/g/a/n Access Points and Client Devices, 802.15.4 Zigbee, 802.15 Bluetooth, and VoIP.

We continue to grow and expand, with the completed upgrade to our anechoic chamber we can measure 9 kHz to 40 GHz in an ambient and reflection free environment. The addition of a second OATS site is now complete and has doubled our daily capacity for wireless/emissions testing. We also added a 3 Meter ground penetrating radar (GPR) Test Site to the rear of our enclosed 10 Meter site. Our continued success over the last 17 years can also be measured by our innovation to better serve our clients. Over the last decade we have developed one of the fastest radiated emission pre-scanning capabilities in the country, providing excellent correlation to final measurements made on our 10 Meter OATS. We offer reliable and repeatable data, meaning you can debug your product quickly, saving time and money for your company. Today, customers want maximum flexibility and seamless solutions. Whether you are a start-up or Fortune 500 company, now more than ever, demand for quicker time-to-market continues to grow. We offer a timely lab schedule with options the same day the inquiry is made, and our veteran engineers work closely with you throughout the entire testing process and are always available for consultation.

At Compliance Worldwide, our success is driven by our people and their commitment to excellence. We fully understand our customer's challenges with global compliance. We think from the client's perspective and work as a team to ensure total customer satisfaction and support. This has always been our driving force and will continue to set us apart from our competitors. ■

Compliance Worldwide

Compliance Worldwide, Inc.
357 Main Street
Sandown, NH 03873

Tel: (603) 887-3903
Fax: (603) 887-6445
sales@ComplianceWorldwide.com
www.ComplianceWorldwide.com

Year company was founded: 1996

Number of employees: 10

Number of facilities: 1 - 5000 square feet, includes two open area test sites, 3 meter compact semi anechoic chamber and two ground-planes.

Get Your Products to Markets on Time With TÜV Rheinland's Efficient Compliance Solutions

TÜV Rheinland is a leading global independent test provider with a history dating back more than 140 years. The Group employs 17,000 people in 65 countries on all continents.

In its role as a neutral third party, TÜV Rheinland tests technical systems, products and services, supports projects and designs processes for companies on the basis of recognized standards and statutory requirements. In addition, the experts train people in a wide range of careers and industries.

In the US, TÜV Rheinland has locations from coast to coast, including the newest laboratory in Irvine, Calif., and offers services for practically all business sectors.

The testing and certification programs include EMC, product safety, ZigBee® Alliance and market access (International Approvals) certifications for Smart Grid, medical, lighting (including LED luminaries), Information Technologies and electrical equipment. Corporate Social Responsibility (CSR) audits and programs are also available.

Lighting

TÜV Rheinland tests and certifies all types of lighting products according to the U.S., Canada and global requirements – from product safety and international approvals to EMC. The products include LED equipment for use in luminaires, portable luminaires, self-ballasted lamps, low-voltage lighting systems, low-voltage landscape lighting, LED drivers, and dimmers/controllers.

ZigBee®

As an official ZigBee Alliance testing body, TÜV Rheinland is extensively involved in developing ZigBee tests, specifications and methods. TÜV Rheinland helps manufacturers get their ZigBee-compliant platforms and ZigBee application profile products certified.

Smart Grid

TÜV Rheinland's Smart Grid test lab in Pleasanton, Calif., tests many new methodologies and techniques for electric meter reading, wireless communications, data analytics and powerline and cyber security according to mandatory thresholds of performance.

The company's ZigBee and Wi-Fi Alliance certification marks, along with safety, ANSI and FCC test suites, are just part of testing the company provides to support manufacturers and utilities providing Smart Grid technologies. As a member of the SunSpec Alliance, TÜV Rheinland is also focused on the interoperability of the inverter industry adhering to SSA 2.0 specification.

International Approvals

For the eighth consecutive year, TÜV Rheinland has been named the top certificate issuing body in the CB Scheme, issuing 19% of all certificates in 2012. The company offers seamless solutions for access to world markets with timely and accurate product certification management.

Consolidating all of your testing needs with one partner eliminates the inconvenience of managing multiple laboratories, streamlines logistics, simplifies documentation and results in a faster, more efficient and cost-effective compliance strategy. ■

TÜV Rheinland's new laboratory in Irvine, Calif., offers manufacturers, retailers and service providers a variety of testing and certification programs.

TÜVRheinland®
Precisely Right.

TUV Rheinland of North America, Inc.
Precisely Right
1300 Massachusetts Ave, Suite 103
Boxborough, MA 01719

Tel: 1-TUV-RHEINLAND
Fax: 978-266-9992
info@tuv.com
www.tuv.com/us

Year Founded: 1872

EMC Lab Selection – Revisited

BY DANIEL HOOLIHAN

Designers and manufacturers of electronic products are frequently faced with the question: "How do I find a high-quality EMC testing laboratory where I can confidently test my products?"

The emphasis of the great majority of design and/or manufacturing entities is on obtaining (1) quality preliminary testing of EMC characteristics to refine the design of their products and (2) quality final design testing of their product for regulatory approvals. The final design, of course, is what gets manufactured and released to the general population for their use in daily life. This article is intended to aid designers and manufacturers in finding and utilizing high-quality EMC testing laboratories.

INTERNAL AND EXTERNAL EMC LABS

If the designer/manufacturer is part of a large organization, they most likely will have an internal EMC lab that they can approach and schedule time for a preliminary or final (qualification) test of their product. However, if the internal EMC lab is tightly-scheduled; the project manager may be invited to look outside the company for an external source of EMC lab expertise in order to meet his/her project schedule. In the ideal case, the project manager may have the opportunity to investigate several competing labs and solicit bids from the same.

If the designer/manufacturer is not part of a large organization, then the project manager for the development project is immediately put into the position of soliciting bids and information from external EMC labs.

FIRST IMPRESSIONS

When soliciting bids from external EMC testing labs, first impressions are significant. If the EMC testing lab does not return phone calls, that is an indication of a lack of interest in new

business or a lack of an organizational structure to respond to customer inquiries. Either way, you may want to seek another EMC testing lab.

If the lab returns your phone call, then the next step is to ask for a bid to do certain tests that will allow you to verify your design or qualify it for shipment to customers. The EMC tests needed for your commercial product will, in general, consist of both emission and immunity tests. These tests will encompass United States emission requirements, European Union and International emission requirements, and European Union and International immunity requirements.

Once the bids are received and compared, you are ready to make an on-site visit to the potential EMC lab. Again, the first visit to the EMC lab is critical for both you and the lab. First impressions of the lab are just as important as the first phone-call impression. The first impression of the lab consists of both a "gut check" and an "intellectual check."

The gut check is a feeling about the lab and its people. If you don't feel right about the lab personnel nor the lab's facilities or equipment; you might surmise that your "uneasy feeling" is based on a deeper issue you will uncover when you use the lab.

The intellectual check is more of a "technical checklist" concept where you either have a mental checklist or a written checklist on specific administrative or technical items that you want to investigate. These items could include test equipment, calibration of the test equipment, test facilities, and sample test reports.

GEOGRAPHICAL PROXIMITY

Most EMC testing labs used by designers/manufacturers are geographically situated in close proximity to a concentration of intended users. This should allow for an easy inspection of the lab. The EMC lab should be proud to show you their lab and to discuss their capabilities. They should also have an open-door policy that allows their customers to observe the testing of their products through the entire battery of EMC tests.

Most EMC testing labs used by designers/manufacturers are geographically situated in close proximity to a concentration of intended users. This should allow for an easy inspection of the lab.

A lab that is geographically close to its customers also allows engineers and technicians who designed and developed the product the freedom to troubleshoot the product easily if it fails one of the EMC tests during preliminary testing. That is, they can readily make modifications to the products because the electrical engineers, mechanical engineers, and power-supply engineers are close at hand. An EMC lab that is distant from the design center makes it more difficult (telephone consulting), more time-consuming (extra travel time), and more costly (travel costs).

If the lab is geographically close, the first visit leaves you with a positive impression, and the financial bid is in the acceptable range, then, it is time to check on some of the other attributes that a high-performing EMC lab will possess.

ACCREDITATION

One of the key qualities that a high-performing EMC testing lab will possess is that it will be an "Accredited Laboratory." In the United States we have three accreditation bodies that are recognized by the United States Federal Communications Commission (FCC) for EMC testing, the American Association for Laboratory Accreditation (A2LA), the United States Department of Commerce's National Institute of Standards and Technology (NIST), National Voluntary Laboratory Accreditation Program (NVLAP), and ACLASS (an ANSI-ASQ National Accreditation Board Company). A2LA and ACLASS are private organizations while NVLAP is part of the United States Government. It should be noted that there are other qualified accreditation bodies outside of the United States that can accredit labs internationally. In some cases, EMC testing labs in countries other than the USA will ask to be accredited by one of the three United States accreditation bodies. The International Laboratory Accreditation Cooperation (ILAC) is the international-body that designates accreditation bodies around the world and assures they are meeting standard accreditation requirements.

Accreditation bodies will assess EMC testing labs to the requirements of *ISO/IEC 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.* The latest version of this standard is dated 2005. It superseded the first edition of 17025 which was released in 1999 (it replaced ISO/IEC Guide 25 and European Norm 45001).

Laboratory accreditation has been incorporated into the laws of the United States by the Federal Communications Commission (FCC). The Commission allows a large number of electronic products that are tested in accredited EMC testing labs to be placed on the market with no further government approval for EMC criteria. The specific process using accredited EMC testing labs is called the Declaration of Conformity (DoC) by the FCC. It is preceded by a Manufacturer's Declaration of Conformity or a Self Declaration of Conformity before the official declaration based on testing in an accredited EMC testing lab.

Declaration of Conformities can apply to such digital devices as Class B personal computers, Class B computer peripherals, citizens band (CB) receivers, television-interface devices, and consumer Industrial, Scientific, and Medical (ISM) equipment. The DoC concept has allowed products to be marketed more quickly and aided in improving our quality of life while at the same time protecting licensed communications services in the United States.

INTERNATIONAL RAMIFICATIONS

Because the laboratory accreditation process is built around an international standard, this allows products to potentially flow more smoothly in the world trade arena. This is accomplished by the EMC lab being accredited for appropriate test methods, by the EMC lab writing a test report that complies with ISO/IEC 17025 report requirements, and by the EMC lab properly using the accreditation body's symbol and logo on the test report.

The accreditation body's mark on the test report signifies that the testing was done in an accredited lab and that the tests performed by the lab were within the scope of its accreditation. (Note – the test report must indicate in the body of the report if tests were performed that were not on the testing lab's scope of accreditation). This sends a clear signal to any country importing the product that it is in compliance with the stated requirements.

Often times, this means that the product will be cleared quickly through customs and be place on the market. Without the mark on the test report, the product could be destroyed, returned to the country of origin (originating manufacturer), or retested in an accredited laboratory in the country where the product is to be marketed.

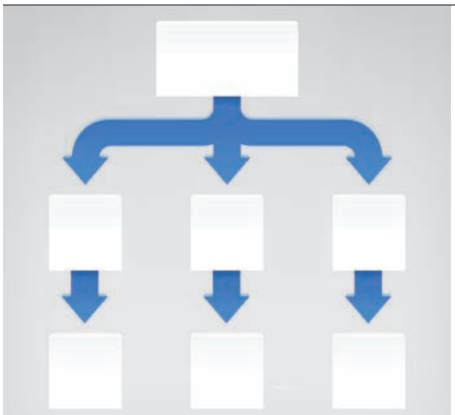
ISO/IEC 17025 – MANAGEMENT REQUIREMENTS

The international standard on criteria for testing labs is *ISO/IEC 17025* which includes both Management Requirements and Technical Requirements. The Management Requirements are very similar to those found in *ISO 9001:2008 – Quality Management System – Requirements.*

The Management Requirements in ISO/IEC 17025 encompass the following areas:

1. Organization
2. Management System
3. Document Control
4. Review of Requests. Tenders, and Contracts
5. Subcontracting of Tests (and Calibrations)
6. Purchasing Services and Supplies
7. Service to the Customer
8. Complaints
9. Control of Nonconforming Testing (and/or Calibration) Work
10. Improvement
11. Corrective Action
12. Preventive Action
13. Control of Records
14. Internal Audits
15. Management Reviews

The organization of the EMC testing lab is its management structure (for example, who is the president of the lab and who has key areas of responsibility under the president such as quality control). It is also the organizational entity that can be held legally responsible for the actions of the EMC testing lab. A potential user of the EMC lab should look at the organizational structure and be comfortable with the organizational chart and with the qualifications of the individuals filling the key slots.



The organization of the EMC testing lab is its management structure. A potential user of the EMC lab should look at the organizational structure and be comfortable with the organizational chart and with the qualifications of the individuals filling the key slots.

The EMC labs management system must be appropriate to the scope of the EMC activities offered. The management system must be documented; it shall have detailed policies, procedures, programs, and specific work instructions sufficient to assure a high-quality test effort on a consistent basis. The management system must be in written form; it can be available in hard-copy format or stored on a server in a soft-copy format.

The document control portion of the Management Requirements can be checked by looking at the EMC testing labs quality manual and by examining some representative documents. The key element is that the lab should demonstrate a process that is under control; that is, a process in which all documents are identifiable and controllable.

The fourth Management Requirement is Review of Requests, Tenders, and Contracts and it is very important for a potential user of the lab. This requirement will encourage the lab to review your request for a test and establish a contract between the lab user and the lab. The contract should specify the requests of the lab user and it should allow for amendments to the contract assuming agreement by both parties.

For testing labs, the Management Requirement that is stated as Subcontracting of Tests and Calibrations should be read as Subcontracting of Tests. That is, because ISO/IEC 17025 is written for both testing labs and calibration labs, the testing lab must read the requirements as stated for a testing lab and not as stated for a calibration lab (For example, calibration labs would read the Management Requirement as Subcontracting of Calibrations.) An accredited testing lab may subcontract some of its tests to another accredited testing lab due to a temporary lack of test equipment or other similar legitimate reasons. In general, a long-term subcontract relationship is not allowed since an accredited testing lab shall have the capability to perform the tests on its scope of accreditation.

For an EMC testing lab, the management requirement Purchasing of Services and Supplies - which are critical to the operation of the lab - is most often focused on its purchase of calibration services. The calibration of the EMC testing labs equipment is a key factor in making proper measurements that are traceable to fundamental national and international standards. A user of the EMC testing lab should feel confident that the calibration labs being used by the EMC testing lab are accredited for calibration services.

Service to the Customer is that aspect of the EMC testing labs operation that makes a user feel comfortable about the lab. For example, the user should be allowed to observe the labs performance in testing their products. Excellent communications between the customer and the EMC lab is also consistent with this area of the Management Requirements.

If you, as a customer, complain to the EMC testing lab, how does the lab react? Do they investigate the complaint and make changes? Or do they ignore your complaint and continue on with the approach that this is the way we always do this test. A high-quality lab will respond to customer complaints and, if warranted, make appropriate changes in their procedures after a thorough investigation.

Control of Nonconforming Testing is that area of the Management Requirements that addresses mistakes made by the EMC lab in its testing service. Does the lab offer to redo the test that was done incorrectly for no additional charge? A user of the lab should familiarize himself with the testing labs philosophy in this area.

The next area of Management Requirements is Improvement. The EMC testing lab should have a continual improvement philosophy consistent with Quality Assurance theory and practice. One location that this emphasis on Improvement can be illustrated is in the EMC testing labs Quality Policy Statement which should be prominently displayed in the lab and it should be clearly understood by the employees of the lab.

The next part of the management requirements; Corrective Action is closely related to Complaints and Improvements. This part of the Management Requirements addresses the actions the lab takes to satisfy Customer Complaints. When a user identifies a problem, it is essential that the lab institute a root cause analysis and follow their logical trouble-shooting to a solution to the problem.

A fair question for a potential user to ask the EMC lab is "What corrective actions have been taken in the past to satisfy customer requirements?"

Preventive Action is more difficult for a potential user of the EMC testing lab to identify. It involves the continuous improvement aspect of the ISO/IEC 17025 standard. One example of a Preventive Action situation is a lab that has calibration complaints on antennas in the frequency range below 1 GHz should also look at potential calibration problems on antennas above 1 GHz as a preventive measure.

The next management requirement is Control of Records. In the context of ISO/IEC 17025, the records can be either a quality record or a technical record. Quality records include reports from internal audits, minutes of management reviews, records of corrective actions, and records of preventive actions. Technical records include accumulations of data and information which result from carrying out tests and which indicate whether specified quality or process parameters are achieved. They may include forms, contracts, work sheets, work books, check sheets, work notes, control graphs, external and internal test reports, customers notes, customers papers, and customers feedback. The records should include the identity of personnel responsible for the performance of tests and checking of the test results. How does the lab protect and control its records? What evidence do you see that the lab has its records held securely and in a manner to maintain confidentiality? Your test results will become part of the record-keeping system; make sure your privacy and confidentiality are protected.

Every EMC testing lab should perform an internal audit at least yearly. This is a semi-formal audit done by member of the lab and it is intended to review the operations of the lab including both management and technical requirements. The lab should have a record of its past internal audits and a plan and schedule for future audits.

Management Reviews are intended to be performed by upper management of the lab. There are 11 specific areas that shall be reviewed in Management Review. They include: (1) the suitability of policies and procedures, (2) reports from management and supervisory personnel, (3) the outcome of recent internal audits, (4) corrective and preventive actions, (5) assessments by external bodies, (6) the results of inter-laboratory comparisons of proficiency tests, (7) changes in the volume and type of work, (8) customer feedback, (9) complaints, (10) recommendations for improvements, and (11) other relevant factors such as quality control activities, resources, and staff training. The Minutes of the Management Reviews should reflect the above eleven items. The Management Reviews should be done annually.

Every EMC testing lab should perform an internal audit at least yearly. This is a semi-formal audit done by member of the lab and it is intended to review the operations of the lab including both management and technical requirements.

ISO/IEC 17025 – TECHNICAL REQUIREMENTS

The Technical Requirements section of ISO/IEC 17025 is what differentiates it from the ISO 9001 Standard. An EMC testing laboratory can meet ISO 9001 and still not be in full compliance with ISO/IEC 17025 unless it also meets the Technical Requirements. On the other hand, a lab that is accredited to ISO/IEC 17025 can be considered to be in compliance with ISO 9001 and its management requirements.

The ISO/IEC 17025 Technical Requirements are:

1. General
2. Personnel
3. Accommodation and Environmental Conditions
4. Test (and Calibration) Methods and Method Validation
5. Equipment
6. Measurement Traceability
7. Sampling
8. Handling of Test (and Calibration) Items
9. Assuring the Quality of Test (and Calibration) Results
10. Reporting the Results

General is the first section of the Technical Requirements. It is basically a listing of the requirements in the technical requirements portion of ISO/IEC 17025 plus a comment on the total uncertainty of measurement.

Personnel is the next section of the Technical Requirements. People make a testing laboratory successful. An EMC testing lab provides an engineering service, and a service business must be people-oriented. So as a customer of a lab you should feel comfortable with the technical personnel you are going to be spending 8-hours a day with on your testing needs. You should check their technical qualifications (engineering degrees, technical associate degrees, years of experience in EMC, personnel certificates from iNARTE and other similar personnel certification bodies). On-going education is also important. Do you see the individuals from the EMC lab attending local meetings of the IEEE EMC Society? Are the technical personnel actively attending workshops and seminars on EMC. Test results on your product are a function of the technical training of the technical personnel coupled with excellent test equipment and test facilities. The customer of the lab should make sure the lab personnel have had adequate training and that they are keeping up to date on the latest changes in EMC standards, EMC design, EMC test equipment, and similar pertinent EMC areas.

An EMC testing lab relies heavily on its laboratory facilities. So, the technical requirement titled Accommodation and Environmental Conditions is a key aspect of a testing laboratory. For example, does the lab have both 50 Hz and 60 Hz power available? Does it have a variety of voltages for alternating current available? Make sure that the lab has a power source for alternating current that will satisfy your product design. You will also want to see a separation of emission and immunity testing activities so that the immunity testing does not adversely affect the radiated and conducted emission profiles of the product. Does the lab have the capability to test for radiated emission at a 10-meter antenna distance? As mentioned earlier in this article, good housekeeping can be an indication of the quality of the lab. Look for a well-maintained lab and the lab results will usually reflect a high-quality lab.

A testing lab should read the next Technical Requirement as Test Methods and Method Validation. (Again, calibration labs would read the requirement as Calibration Methods and Method Validation). It is important to ask the lab about their Scope of Test Methods. How many tests do they have the capability to run?

The test methods should be documented including frequency ranges and amplitudes of various tests. The testing lab should have a verification process for each test method so that the lab knows the test equipment is operating properly for the test on the customers product. This verification is a system check that assures the EMC Test equipment and the corresponding test method are both in synchronization. This verification process can be combined with intermediate checks and daily checks of test equipment to assure a repeatable and reproducible test of the customers products.

Equipment for EMC testing labs is expensive especially for large semi-anechoic (SAC) and fully-anechoic chambers (FAC). As a potential user of the EMC lab, you may want to ask for a list of the labs EMC test equipment as well as a description of the labs test facilities. Once you arrive at the lab, you should double-check the calibration status of the labs test equipment. Each piece of equipment that is being used for the testing should have a calibration tag on it with a current in-calibration status indicated on the tag. High-quality test equipment will help assure a high-quality testing experience.

The next technical criterion for an ISO/IEC 17025 accredited lab is Measurement Traceability which is closely associated with the labs test equipment. A calibrated piece of test equipment has to be traceable to the International system of Units through a direct path to a National Metrology Institute. In the United States, the National Metrology Institute is the National Institute of Standard and Technology (NIST). The best way to do this is to assure that the calibration labs used by the testing lab are accredited to ISO/IEC 17025. This assures that the calibration labs measurement standards and measurement instruments are linked to relevant primary standards through an unbroken chain of calibrations.

Sampling is an important aspect of the technical characteristics of a testing lab. However, for most independent testing labs they will test products brought to the lab not knowing what sampling plan, if any, was followed by the customer in selecting the product to be tested. Internal EMC labs sometimes have more input to a sampling plan of manufactured products and their selection for occasional testing of their companys manufactured products.

Handling of Test Items is the eighth technical requirement of the ISO/IEC 17025 standard. This deals with how test items are delivered to the EMC lab for testing; are they hand-carried, delivered by a company truck, delivered by a common carrier such as UPS, Federal Express, etc. This topic also covers identity of the products while they are in the lab, security and confidentiality of the products while they are in the lab, and, finally, the shipment of the test items back to the customer.

Assuring the quality of test results is usually combined with intermediate checks and daily checks. The EMC lab may also participate in inter-lab proficiency testing and other techniques for checking and verifying the quality of the labs test results.

The last part of the Technical Requirements is the Test Report or as ISO/IEC 17025 refers to it: Reporting the Results. A prospective user of a test lab should ask to see a test report template for the lab. The test report should comply with the requirements of Clause 5.10 (Reporting the Results) of ISO/IEC 17025.

SUMMARY

Look for laboratory accreditation to ISO/IEC 17025 as a first step in finding a high-quality EMC testing lab. However, it should be noted that even accredited testing labs can make mistakes.

It is important to check the scope of tests for an accredited lab to make sure the scope of tests encompasses the tests required for the customers product.

An accredited lab that is qualified to perform the necessary scope of tests will provide the customer a complete test report that will ease the acceptance of the product in national and international markets.

In general, you will be satisfied with accredited EMC labs because there is a higher probability of a successful test using calibrated and high-quality test equipment. This should allow easy marketing of your product relative to EMC requirements.

(the author)

DANIEL D. HOOLIHAN

is the Founder and Principal of Hoolihan EMC Consulting. He is Chair of the ANSI-ASC C63 Committee on EMC. He is a Past-President of the EMC Society of the IEEE and is presently serving on the Board of Directors. He is presently an assessor for the NIST NVLAP EMC and Telecom Lab Accreditation program. For further information, contact Dan at danhoolihanemc@aol.com or 651-213-0966.

Lessons Learned from the Design and Construction of an Open Area Test Site (OATS) and Sound Measurement Building

BY JAMES K. MARTIN, SCOTT PANSING, AND ANDREW BELLAMY

How do you construct a building without metallic components of any kind? When you are engineers charged with overseeing the design and construction of an Open Area Test Site (OATS) for your company, you find out very quickly how to build a structurally sound facility while still keeping the area free of reflective materials.

The company we work for designs and manufactures Uninterruptible Power Supply (UPS) systems and associated components to support the power availability requirements of data centers and other critical electronic equipment. UPS systems, electrical bypass cabinets, large battery systems, electrical distribution systems and monitoring systems contain microprocessors with high speed switches, and most also contain high current power switches. Both switch types radiate electromagnetic fields and conduct high frequency noise that may potentially exceed the limits for radiated and conducted emissions as defined in the FCC Code of Federal Regulations, Title 47, Part 15.

Due to our tight product development and product release schedules and cost, it became a matter of both pragmatism and economics to build our own test facility. Here's what the experience was like, and what we learned.

THE PRESENTING PROBLEM

For years, in order to verify the compliance of our products with FCC standards governing electromagnetic interference (EMI), we sent our products to third-party labs. Although these labs are reputable and efficient for many test requirements, we struggled with using these facilities for some of our larger power systems products or products that were on a time-sensitive schedule. The reasons were as follows:

1. *Power requirements:* Our largest unit exceeds 1 Million Volt Amps (MVA). We do not necessarily test at the maximum current, but the startup inrush needs to be taken into consideration. Most outside labs do not have the capacity available to test our units without a rented generator.

2. *Turntable size:* Our units can be large and heavy, with the 1 MVA uninterruptible power supply weighing 20,000 pounds. The typical outside lab turntable cannot accommodate a product this large, or the weight of the forklift required to move the product onto the table.

Left hand page: **Ground plane, turntable and mast**

3. *Sound measurements:* Another portion of our testing includes measuring the audible noise that a product creates. For acoustical noise testing, the challenges of physical size and supplied power that exist with EMI and electromagnetic compatibility (EMC) testing still apply, only now with the additional requirements of the appropriate ambient environment and room construction.

CONSIDERING THE OPTIONS FOR A TEST FACILITY

First we had to determine which type of facility of the two kinds available was best to perform the radiated and conducted emissions testing in our particular circumstances.

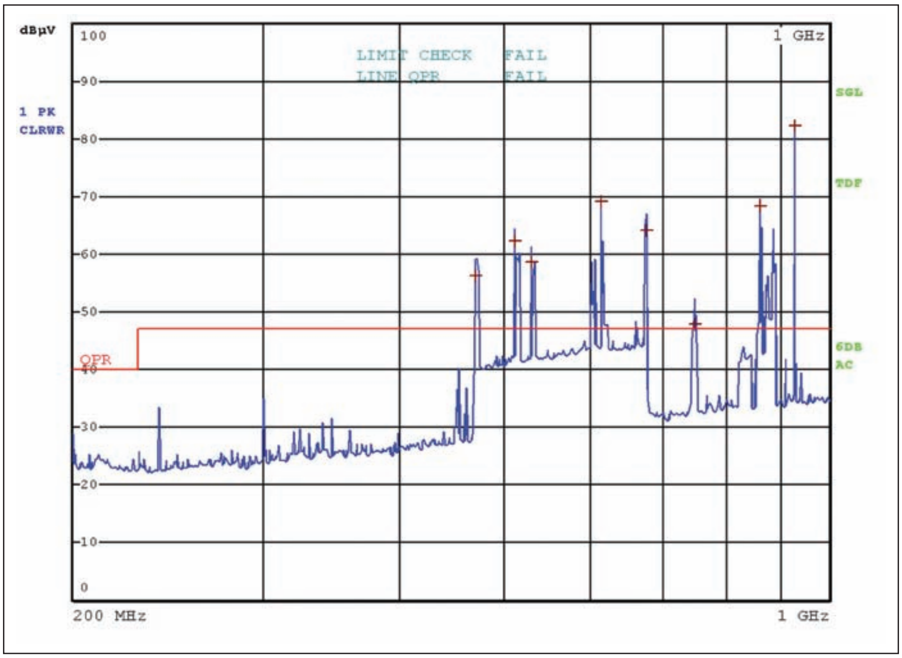
1. Semi-Anechoic Chamber (SAC), which allows measurement of equipment emissions by eliminating all external noises via ferrite absorber tiles placed around the room; or

2. Open Area Test Site (OATS), which allows measurement of equipment emissions by removing all reflective and absorptive surfaces within a greater-than-ten-meter area.

The SAC, though extremely efficient, had cost estimates for a ten-meter chamber reaching beyond several million dollars. The OATS facility, with a cost under one million dollars (including instrumentation) was much more financially feasible.

By definition, an OATS facility is not actually a building. The ideal OATS is a flat piece of land, free of obstructions, away from any and all external signals, with a perfectly reflective surface. But because our test site would be in an industrial complex next to a small airport, a structure would have to be placed around the reflective ground plane of the OATS, making it less open than the ideal but still approximating ideal conditions. We understood that what we were proposing was a Modified-Open Area Test Site (M-OATS); but during the preliminary discussions with the engineers and contractors involved, the term OATS caught on. This abbreviation was used throughout the project to minimize confusion.

It is not common to construct a building using non-metallic material.



Typical ambient noise sweep graph

Ground plane assembly

Our challenge became striking a balance between keeping the area free of reflective materials for EMC testing and making the framework structurally sound.

Some of the same issues that gave us a challenge at the outside labs came into play in our design and build. Ambient signals are abundant near an airport within a city near a larger metropolitan area. Broadcast TV, AM and FM radio, wireless towers, family radio, air traffic control, emergency dispatchers and now, broadband high definition TV (HDTV), are consuming larger portions of the RF spectrum and can readily be detected by antenna at our location.

Due to these ambient emissions, a careful site survey was conducted prior to site selection, wherein we measured the direction and amplitude of the ambient signal spectrum. After reviewing the data, we positioned the building such that, during testing, the receive antenna would be facing away from the highest ambient source(s), attenuating those signals as much as possible.

We also knew wires and conduits were going to be a problem in testing. We had to keep metal of any type to a minimum anywhere close to the receive antenna, an area that comically came to be called the "cone of silence." This term was used to help explain to individuals such as the architect and the building contractor that the three-dimensional space around the test area had to be kept clear of metallic objects of any size from the ground plane to the height of the trusses. As we explain below, this was easier said than done.

TOP 10 LIST: NOT YOUR USUAL CONSTRUCTION ISSUES

Our customers expect conditioned, uninterrupted power with ratings up to 8 MVA for multi-module systems, and up to 1.1 MVA for single-module systems. We chose 1.5 MVA as the test rating point, with the expectation of expanding capacity in the near future, when the power feed will be increased. The building size and specifications were based on these requirements. As we proceeded, we had to deal with a laundry list of issues and considerations, among which included:

1. The planned building height entailed submitting plans to the local building authority for approval.
2. Since the facility is located next to an airport, the FAA needed to know and approve the building height. This was a lengthy process.
3. To limit metallic content, outlets had to be located either outside the "cone of silence" or in the floor below the ground plane.
4. Framing was nonmetallic, and minimal fasteners were used to reduce RF reflections. The wall and ceiling consisted of Structural Insulated Panels (SIP). Drywall was placed over the SIP for fire code compliance and will accommodate more reverberant sound measurements that will be used in the next development phase of the building.
5. Due to the prohibitive cost of a restroom, we decided not to install one in favor of using the main building's facility.
6. Our turntable was designed to lift 36,000 pounds and accommodate a unit up to 18 feet wide. Rotation could not be electrical.
7. Again, to limit metallic content above the ground plane, ambient lighting had to be installed in the floor as opposed to above ground.
8. Due to cost and potentially increased reflections, heating and cooling of the OATS became

Best Practices Note: To make code approval a smoother process, talk to the local inspector and discuss the goals of your project.

a concern. Because of the structurally insulated panels, the building has a high insulating rating and, therefore, heating of the building would come from the lighting in the floor (with additional heat provided by the natural heat losses of the product itself being tested.) Cooling of the control room was achieved by installation of a small air conditioning unit, below grade and away from the "cone of silence."

9. Reflective fire extinguishers had to be positioned outside of the "cone of silence," but still within easy access, if needed.
10. The electromagnetic field (EMF) associated with flights taking off and landing at the local airport had to be identified in order to keep these distinct from our own measurements.

Best Practices Note: To make code approval a smoother process, talk to the local inspector and discuss the goals of your project. Getting input on the front end will ensure that issues are addressed early in the design and build, and they can give you expert insight. They will also appreciate not being blindsided during inspection. Likewise, assume that the architect and turntable manufacturers will not be familiar with EMC testing, and educate them at the outset to ensure that their deliverables are in line with your needs and expectations.

Floor construction showing turntable and foundation

Best Practices Note: In order to operate with maximum efficiency, we experimented with LED light fixtures to illuminate some of the rooms in the OATS building.

MAKING SURE WE STOOD UP TO SCRUTINY

In order to accept EMI measurements inside of the OATS, the site had to be validated in a process called Normalized Site Attenuation (NSA) testing. As described in ANSI C63.4-2003, this process is intended to ensure that the reflective/absorptive losses at the site are comparable to the standard's theoretical values. Essentially, it was our task to ensure that the OATS we had spent so much time developing, from design to construction, met the standard requirements in order to actually be utilized.

Using Log-Periodic and Biconical antennas, we performed a volumetric test on the ten-meter area between the turntable and the future location of the receive antenna mast. In the NSA test, a signal was injected into a transmit antenna and then received, over the air and across the OATS ground plane, by another antenna. The received signals were measured on an EMI receiver and the difference between the transmitted and received decibel values documented. We then compared this number to a theoretical value in the standard. To validate the site, in accordance with the ANSI standard, the documented value had to be within +/-4dB of the theoretical value.

This NSA test was performed for four transmit antenna positions around the perimeter of the turntable (and one in the center). In the instances of the leftmost and rightmost positions, the inside edge of the antenna remained outside the planned volume of our largest product to be tested. This would ensure that reliable data would be gathered when testing, no matter the product size, so long as it was placed within the tested volume. In all, when considering the repositioning of the transmit antenna, the adjusted height of the transmit antenna (per ANSI C63.4-2003), and the adjustment of the receive antenna between heights of one meter to four meters, some six hundred measurements were made over the course of an entire work week.

The results were generally similar to the theoretical values. But there were some points in the building that required modification in order to meet NSA expectations. Exit signs on the side entrance of the building had to be replaced with the phosphorescent variety; this required removing the wiring and conduit previously in place. Copper brushes were sought to better connect the turntable to the ground plane, electrically speaking. With each alteration, the decibel measurements better aligned with the theoretical values.

Some changes have taken place since NSA testing, including the addition of an air cooling/condenser system in the control room, switchgear conduit, indicator lights, and an Emergency Power Off (EPO) push button above the ground plane. With continual improvements and additions to the facility, validation of the site will need to be performed on an annual basis to guarantee continued confidence in the building.

Best Practices Note: In order to operate with maximum efficiency, we experimented with LED light fixtures *to illuminate some of the rooms in the OATS building. The LED lights required a voltage transformer to convert 120 VAC to the lower LED voltage. The transformer radiated noise exceeding tolerances to allow for compliance testing, so LED technology is not recommended for an OATS test facility.*

With validation of the OATS facility completed, along with the removal of known radiated EMI sources, numerous UPS and ancillary products have made their way through the doors of the building. Over the last two years, radiated and conducted EMI testing has been performed on many products, ranging from 1 MVA UPSs to 120 VAC printed circuit boards. In each case, testing proceeded with relatively few problems related to the test setup itself, while offering reliable, supportable data.

In order to validate the tests in the OATS facility, we retested equipment that was previously tested in third-party labs. The radiated EMI results were comparable with those taken in a separate semi-anechoic chamber for one product, and data retrieved from conducted EMI testing for another matched the results taken on a previously constructed ground plane (from which data had been shown to be similar to that of a third-party laboratory). After all of the hard work involved, it was gratifying to see the OATS facility operational, in use, and producing verifiable, satisfactory data.

WHAT IS NEXT IN THE OATS STORY?

Since the validation process, we have modified the OATS by either adding or removing elements that we considered after the preliminary work.

Even the inclusion of safety items that must be kept on premises requires evaluation for their radio frequency interaction. Along with annual evaluations, scrutinizing normal everyday items and their locations has become a matter of routine, while still following the local fire and building codes.

Testing must be monitored and controlled by qualified personnel,

Completed interior test cell

which requires further education for the EMI/EMC compliance technicians and engineers. In-house training and outside courses are provided for the EMI/EMC technicians and engineers. The new facility requires a different set of procedures than typical test facilities; technicians need to study and understand everything from setup to standards to ensure proper operation and maintenance of the site. This will continue to be an ongoing requirement, but will allow the OATS to grow and be a cornerstone in testing.

BUDGET

A development team included members from our design group, an architect, a construction contractor, and our own facility engineers which worked with a nine-month timeline. Testing instrumentation was included in the budget. Some existing equipment, such as spectrum analyzers and antennas, were already being utilized onsite and could easily be moved into the OATS facility but we also wanted equipment with increased scope, sensitivity, automation, networking features, and enhanced user interface. With the budget provided, we estimated a return on investment of 1.8 years vs. outsourcing the testing of our equipment for EMC. This does not include the benefit of faster time to market.

WHAT WOULD WE HAVE DONE DIFFERENTLY, IF OUR BUDGET HAD BEEN LARGER?

1. Installed an even larger turntable.

2. Allotted for more power to the unit under test.

3. Cleared an even greater area surrounding the OATS – our NSA measurements were decent enough but unexplained reflections still occurred on the far side of the turntable nearest a sizable wooded area.

4. Installed an HVAC system – though the temperature is typically within reason, there can be extremes in January and August when the facility is no longer "user friendly."

5. Provided increased storage capacity for equipment, tools and components – most of the initially designed storage space came to be consumed by power feed switchgear. An additional area for storage would have increased efficiency and saved time in gathering tools/components.

6. Placed ancillary equipment below grade (ground plane) – most of our equipment resides beyond the measurement ellipse and has not proven to be an issue; however, placing it below grade would have helped reduce any unrecognized reflections and may have helped in creating more precise NSA measurements.

7. Utilized more fiberglass than wood – wood begins to develop reflective properties at higher frequencies and thus we are open to measurement concerns as we go beyond 1 GHz. This could require more frequent NSA surveys to verify compliance.

There are many challenges presented when developing and designing an OATS, specifically one with such extraordinary power and spacing requirements. In addition to EMC-related needs, there are architectural requirements, city and county codes and regulations, and personal budgets which must be taken into account. Our task was slightly unique considering our product line and also our location inside of a very active RF transmission area but we overcame these obstacles and constructed a reliable test site. Since the building was completed, we have run numerous tests on several different products with results comparable to those of an established, qualified third-party laboratory. In all, the success of our OATS depended upon advance planning, proactive approaches to known issues, communication with outside parties, inclusive team meetings, and a commitment to designing a facility without abandoning quality or efficiency.

(the authors)

JAMES K. MARTIN P.E.
has worked for thirty-two years as a UPS designer at Emerson Network Power / Liebert in Delaware, Ohio. He holds a BSEET in Electronic Engineering through Franklin University and a BSEE in Power Systems through The Ohio State University. Additionally, he has worked as a consulting engineer during his lengthy career. He can be reached at jim.martin@emerson.com.

SCOTT PANSING
began his career as an Industrial Electrician and received his Associate Degree through CPI in Columbus, Ohio. He has spent twenty years in the electrical, electronic and automation industry, having worked within the EMC/EMI field for the past eight years at Emerson Network Power in Delaware, Ohio. He can be reached at scott.pansing@emerson.com.

ANDREW BELLAMY
has seven years' experience in the power electronics industry, four years specifically related to electromagnetic compatibility while employed with Emerson Network Power in Delaware, Ohio. He has an Associate Degree in Electronic Engineering through North Central State College, is a graduate of Global EMC University, and is certified as an iNARTE EMC Technician. He can be reached at andrew.bellamy@emerson.com.

EMC Test Laboratory Software Program Development: A Proven Process

An EMC test engineer's primary responsibility includes creating test plans, procedures, analyzing test data, generating test reports, and mitigating noncompliance challenges. Many times the EMC engineer must assume the role of a software test engineer and create test programs necessary to meet the project objectives. The EMC engineer may or may not have the intrinsic knowledge to create test programs while meeting laboratory requirements (i.e. ISO-17025[1]). In addition, Laboratory accreditation auditors require the laboratories to provide evidence their test software has been verified and validated[2]. This article was written to give EMC test personnel guidance in creating their test programs, while verifying and validating their test software within the development cycle in order to expedite test throughput and meet laboratory requirements.

BY JACK MCFADDEN

I have been in the testing field for over twenty five years. I started in the Department of Defense (DOD) world. I gained experience in the automotive industry and fine-tuned my skills through a mixture of the DOD, automotive and commercial industries. I learned to create test programs through necessity, not desire. For the majority of my career I worked within an organization's internal laboratory. Our true software test engineers were focused on production. I had tremendous difficulty enlisting their support. Our senior management had this strange idea. They believed the software engineers' time was best spent where we received a positive return. So the internal testing laboratories were left to fend for themselves. The result was that I learned to create test programs on my own. Naturally, I made just about every mistake you could imagine along the way, but I grew and learned from them. I know and understand there can be a difference in what you intend for the computer to do versus what the computer actually does and that the measure of a competent test software engineer is his or her ability in creating test programs that perform what he or she intends. I have struggled over the years with getting the system to do what I needed it to do rather than what I inadvertently told it to do. This article is designed to improve your probability of developing successful test programs. It can help you teach your test system and instruments to behave themselves.

TEST PROGRAM DEVELOPMENT METHODS

When I began designing test programs I used the classic design approach which is commonly called the Waterfall[3] Method as illustrated in Figure 1. The Waterfall Method starts with the requirements, moves straight into design, then implementation, followed by verification and ends in maintenance. Its biggest drawback is the lack of feedback. You have completed the majority of the development process before you can verify the test program. This can lead to costly errors as you try to navigate back upstream. I knew there was a better way. So I spent some time researching. I found other development methods. I learned how I could reduce risk and increase my probability of first time success. The software development process I prefer is called the Revised "V" Cycle[3]. It was developed in the 1980s. The Revised "V" Cycle was an evolution of the "V" Cycle and the "V" Cycle was the evolution of the Waterfall Method. The Revised "V" Cycle embeds feedback into every phase of the development process. This feedback enables the design to be modified in the program early within the development cycle. I found it is far easier and less costly to correct issues in the very beginning of the development process. Early fault detection also reduces your pain as the project heads downstream. So the old adage *test early, test often* is critical to developing a useable program. The Revised "V" Cycle process is shown in the following figure. If you want more information regarding the different software development methods please visit: http://www.aiglu.org/aiglu_documentations/agile-introduction.

As shown in Figure 2, the Revised "V" Cycle component phases are

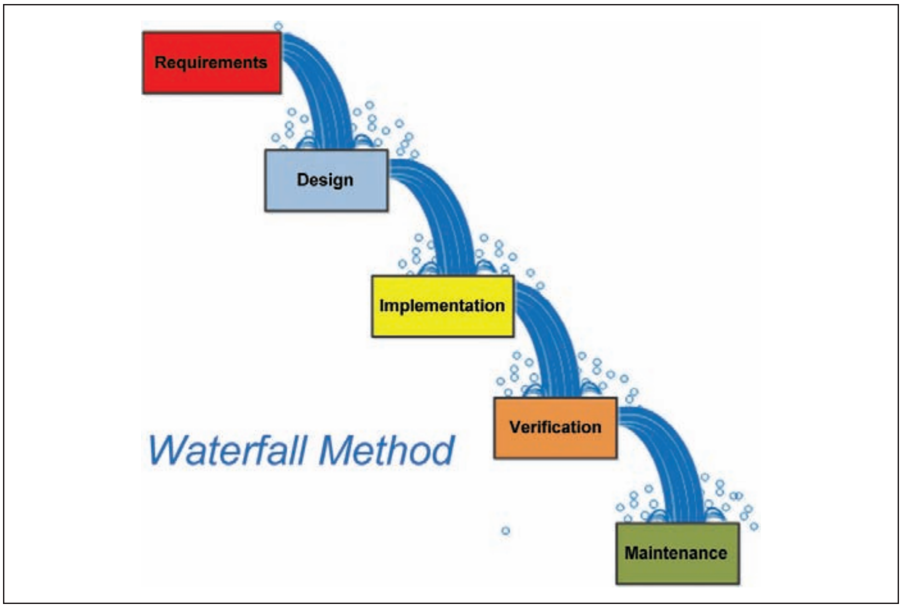


Figure 1: Illustration of step down waterfall method.

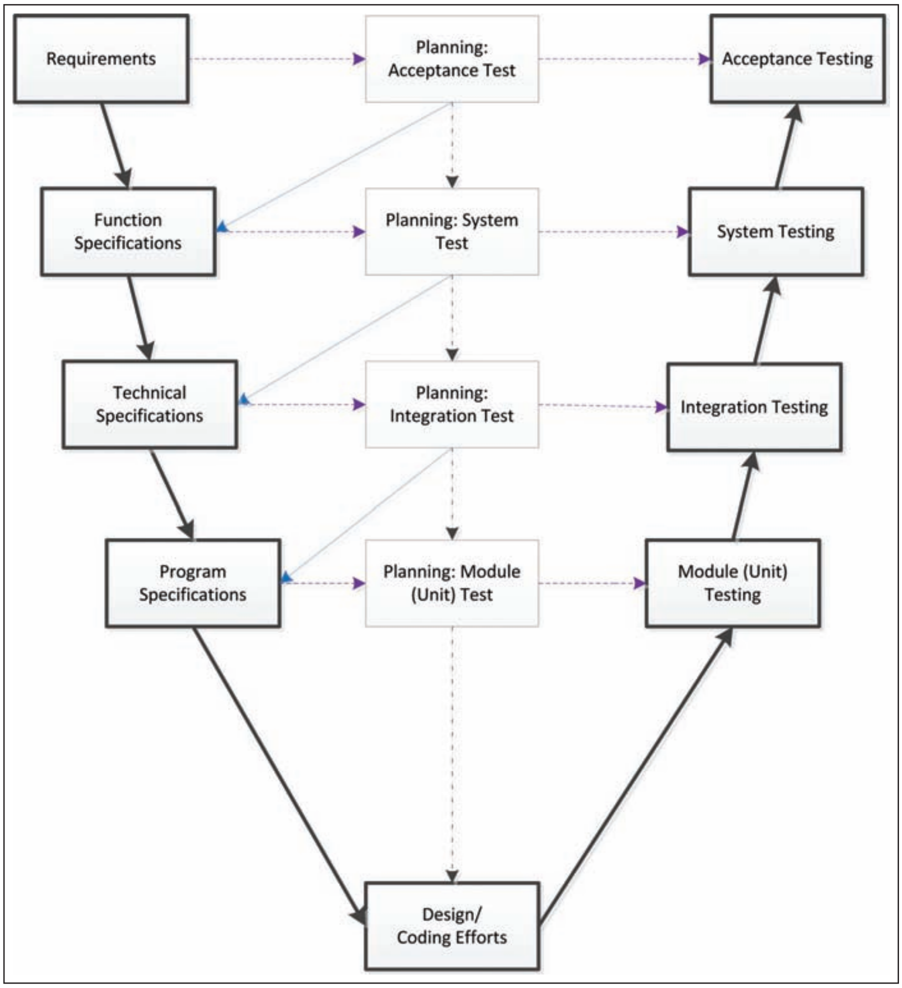
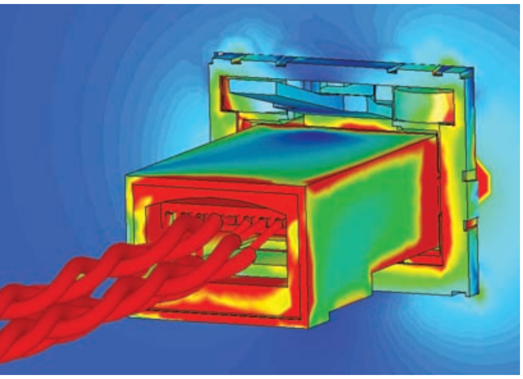


Figure 2: Revised "V" Cycle software development process showing interdependence of component phases.



interdependent on each other. You start with the requirements, specification (function and technical) as well as the program specifications while beginning the Planning: Acceptance, System, Integration and Module phases. You move from one phase into another while feeding back the information you discovered during the previous phase.

PROGRAM DEVELOPMENT PROCESS (PDP)

As you can see, the test program development is a process. There are specific tasks that are repeated over and over. Understanding the process enables you to break it down into its discrete components and standardize them. Standardizing the process benefits everyone involved. The standardized process objective is development method tools that reduce risk. For example, if you develop a process that is dependent on highly skilled personnel, your process could be impacted if the highly skilled personnel had a bad day. Unintentional errors could be injected into the process which could invalidate the results and end up costing you time and money. Creating standardized processes can help decrease the potential errors or at the very least identify them and implement corrective action. The test program development process[4] I use is shown in Figure 3.

PDP - Test Requirements

The first step is to understand your requirements. The test standard has specific rules. The standard rules are clear. They are the "shall" statements found within the standards. The test specimen must comply with specified limits, whether below an emission predetermined level or for immunity, above a certain level. As an example, I am using the MIL-STD-461F[5], Radiated Emissions (RE)102.

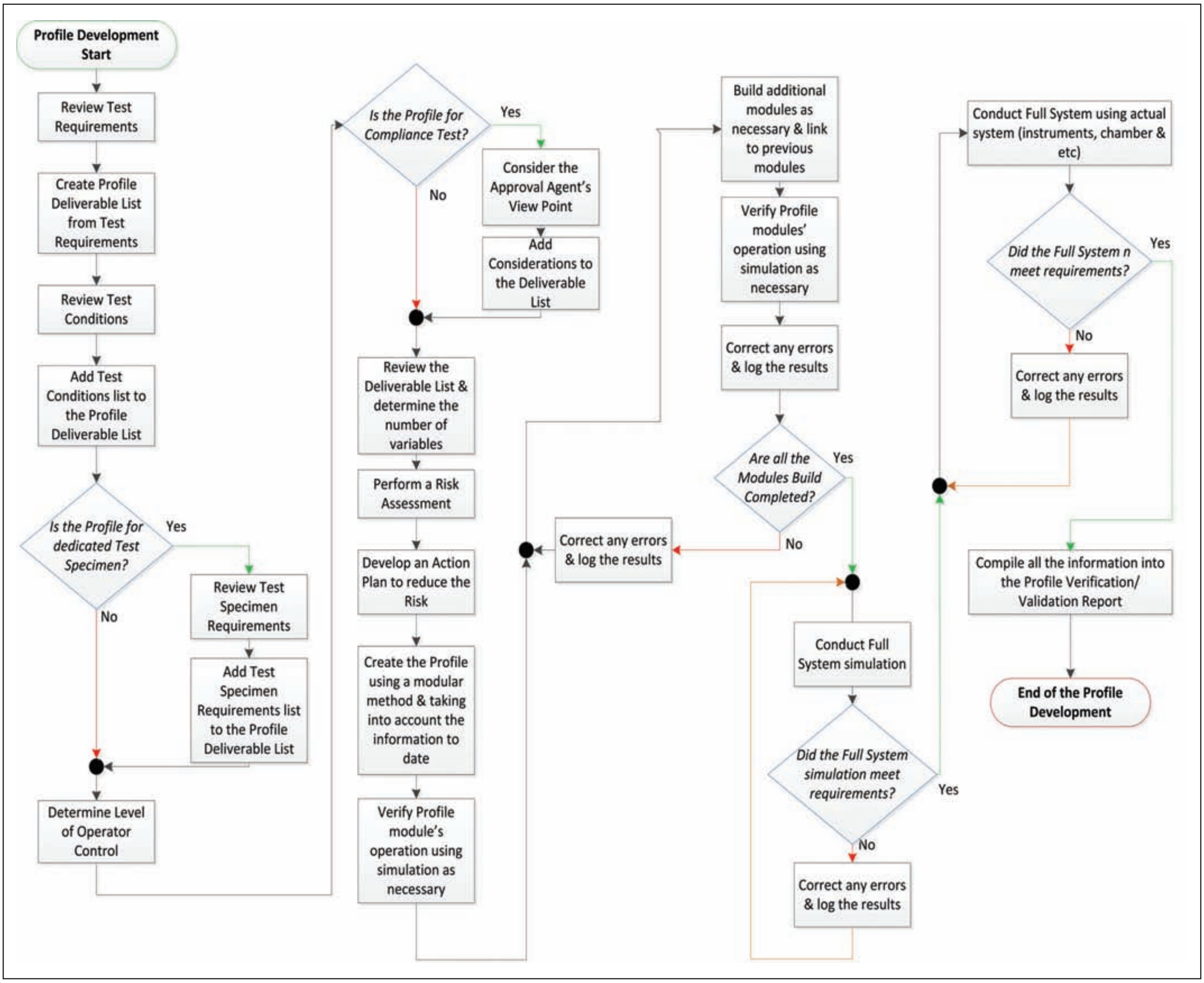


Figure 3: Flowchart showing software program development process used by the author.

Nemko

ONE WORLD ○ OUR APPROVAL

ONE Nemko

Nemko is celebrating our 80th anniversary by launching a new strategy with expanded services as well as an enhanced logo as the symbolic image of our significant global presence.

One world – our approval

Companies around the world trust Nemko to assess their products, systems, installations and personnel for conformity with relevant standards and regulations.

Since 1933, we have ensured that our customers comply with requirements everywhere in the world. Our services include pre-compliance, product testing, international approvals, and product and system certifications.

Through our offices, laboratories and extensive partner network in Asia, North and South America, Europe, Middle East and Africa we are committed to being a strategic partner to serve our customers in a reliable, efficient and open manner.

We combine local presence with global knowledge and expertise, reducing your time to market through:

- Pre-compliance
- Product testing
- Product and system certification
- International approval

- West Coast Operations, San Diego, CA 760-444-3500
- North Mid West Operations, Salt Lake City, UT 801-972-6146
- South Mid West Operations, Dallas, TX 972-436-9600
- East Coast Representation, Tampa, FL 813-528-1261
- North East Coast Representation, Boston, MA 978-973-7126
- Nemko Canada, Ottawa, ON 613-737-9680 and Montreal, QC

nemko.com

The test requirement information is described in Table 1 and Figure 4. I will use the term equipment under test (EUT) for the test specimen when discussing the MIL-STD example since the MIL-STD uses EUT as the definition of test specimen.

Initially, you might argue the requirement is actually the "EUT Active Limit" as shown in Figure 4. This is partially true. The final objective is to measure the EUT emissions. The EUT emissions must be lower than the applicable limit for the EUT to comply with the MIL-STD; however, the test laboratory is required to prove their test system and ambient conditions are capable of making the final (EUT Active) measurements. It is the requirement of the laboratory. It needs to be addressed in the beginning of the

Item Description		Requirements	Tolerance
Equipment Under Test (EUT) Active Limit		The peak corrected levels shall not exceed levels shown in Test Requirements Graph.	±3 dB
Ambient Limit		-6 dB below EUT Active Limits, Test Requirements Graph. Results are to be included within the test report if Active Mode results exceed Limits.	
System Check	Continuity	Verify signal path using a calibrated signal at low, medium and high frequencies of a rod monopole and a calibrated signal at the highest frequencies of the remaining antennas. The rod system verification use a 10 pf capacitive network within the signal path as described within MIL-STD-461F. This 10 pf capacitive network cannot be a commercial product.	
	Stub Radiator	Verify antenna (signal) path's integrity at each of the antenna's highest frequency.	

Table 1: MIL-STD-461F, RE102 Test Requirements

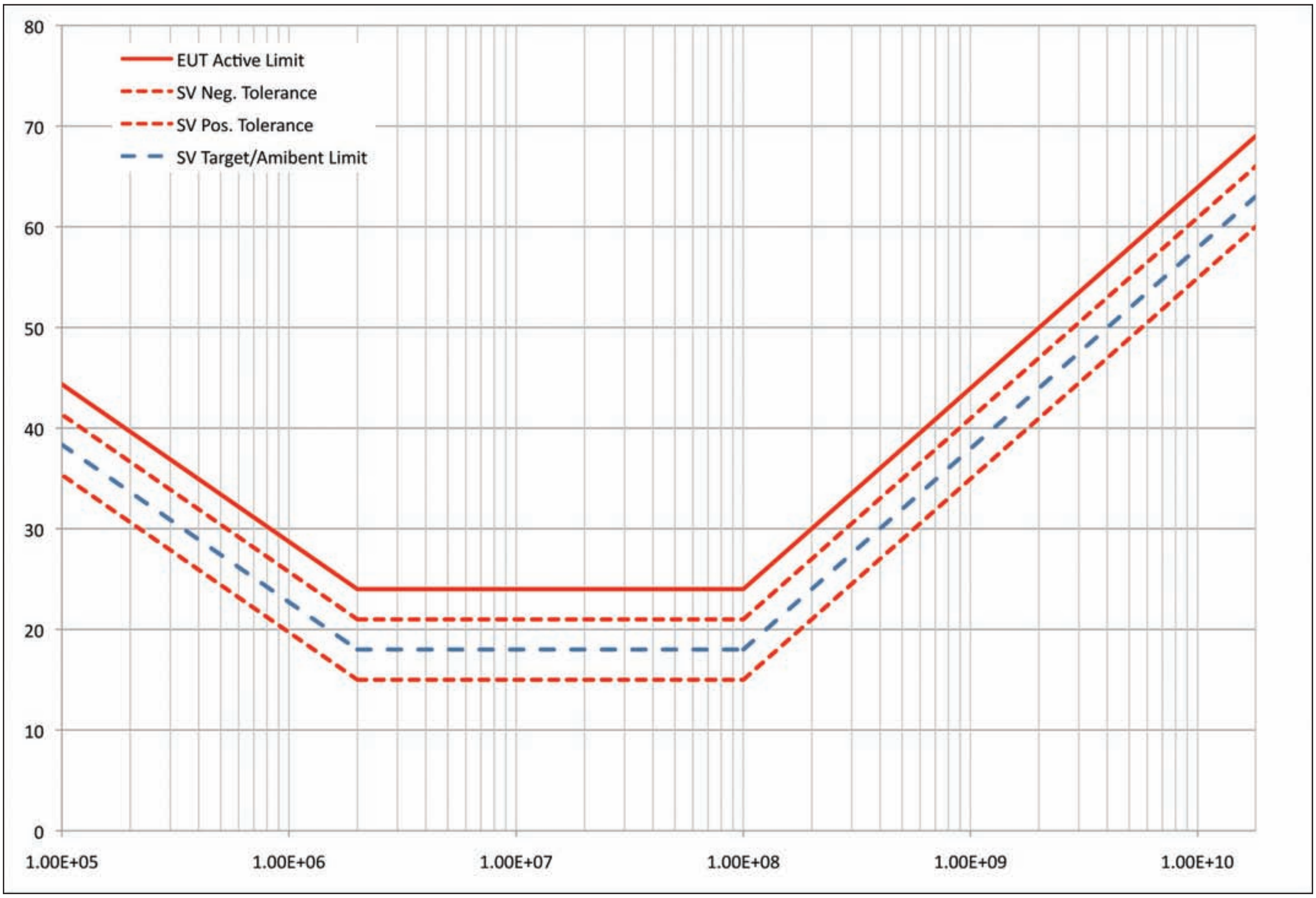


Figure 4: MIL-STD-461F, RE102 Test Requirements Graph

test program development. If you are satisfied that you have considered the test requirements, I highly recommend documenting them within a deliverable list in order to ensure they are not missed.

PDP - Test Conditions

This moves us to the next step of the process. What are the test conditions? Test conditions are the "should" statements within the standard. These are the test parameters necessary to meet the standard, but there is an element of choice within the standard parameters.

Test conditions answer the following questions: How fast should the frequency sweep be made? What is the frequency resolution, etc.? Table 2 continues the MIL-STD-461F, RE102 example.

Note the antenna beamwidth is more of a test setup condition. It typically does not enter the test program arena unless you are one of the fortunate laboratories that possess a remote positioner. If you have a remote positioner, this should be included within your test program. If you do not have a remote positioner, then you need to decide if you are going to provide guidance to test personnel on the correct test setup or not. The information you gathered should be entered into your deliverable list.

PDP – EUT Monitoring Requirements

This brings us to the next step in the process. It is the first decision block within the flowchart. It is regarding where the EUT operation monitoring duties fall. There are times when the actual EUT is monitored independently from the test program. There are other times when the EUT's operation is integrated within the test program. As shown in Table 3 (page 54), you need to determine if the test program has EUT monitoring requirements. At this point I will go back to the MIL-STD-461F, RE102 example. You should answer the following questions: Does the test program need to accommodate the monitoring of the EUT operation? If you are required to monitor the EUT, then how are you to measure and record the EUT's performance? How susceptible is the monitoring and support equipment? What is the monitoring and support equipment's emanation levels? If

Test Condition I.D.	Test Condition Requirement			Units
Test Standard	MIL-STD-461F			n/a
Test Type	Emissions			n/a
Measurement Instrument	Receiver			n/a
Detector/Measurement Method	Peak			n/a
Frequency Accuracy	2			%
Sweep Method	Single Sweep			each
Measurement Tolerance	±3			dB
Resolution Bandwidth	Frequency Range		Min. Duration seconds	Min. Number of Data Points
	Start	Stop		
1 kHz	10 kHz	150 kHz	4.2	280
10 kHz	150 kHz	30 MHz	89.55	5970
100 kHz	30 MHz	1 GHz	291	19400
1 MHz	1 GHz	18 GHz	510	34000
Video Bandwidth	Maximum available			
Antenna Beamwidth Requirements				
Active Monopole Rod	Multiple position required if test boundary exceeds 3 meters			
Biconical				
Large Double Ridged Horn 69 x 94.5 cm opening	EUT width plus 35 cm of cable harness			
Small Double Ridged Horn 24.2 x 13.6 cm opening	EUT width plus 7 cm of cable harness			

Table 2: MIL-STD-461F, RE102 Test Conditions

you don't know the emission and immunity characteristics of the EUT monitoring/support equipment, you may find yourself generating more work than necessary during actual testing. You also need to understand what the acceptable tolerance of the EUT is. In other words, when does the EUT operation go from an acceptable condition to an unacceptable condition? For example, if you are testing a video product, when does its normal operation cease and it becomes susceptible? Is it when there are little transparent disturbance horizontal/ vertical lines observed on the video, but it otherwise remains legible, or is it when you can no longer read the print or understand the graphics? You must be extremely careful if the EUT susceptibility is defined with "any deviation" as then any EUT normal variation could be interpreted as a susceptibility response. The MIL-STD covers this by stating words to the effect that EUT susceptibility response is any deviation greater than the specified parameters found within the product specification. Once you know the answers, you should record them into the deliverable list which ends this part of the process. This discussion is summarized in Table 3, EUT Monitoring Characteristics.

PDP – Test Personnel

The next item to consider is your test personnel. What type of control will you give your test personnel during testing? If you have test personnel with an expert skill level, you might consider relaxing the number of prompts and controls for the test program. If your test personnel have a novice skill level, then you might want stricter controls and more operator prompts guiding the test personnel throughout the course of the test sequence(s). The evaluation of test personnel and control level is shown in Table 4. It is far safer to develop a test program with the novice in mind than the expert. After you

EUT Monitoring	Applicable	Not Applicable
EUT Acceptance Criteria	Product specification allowable tolerance	
EUT Susceptibility Criteria	How to determine if the EUT is susceptible?	
EUT Support Equipment Susceptibility	How susceptible or immune is the EUT support equipment?	
	What is the EUT monitoring/support equipment contribution to the ambient conditions?	
EUT Monitoring Method	Integrated within test program	Independent of test program

Table 3: EUT Monitoring Characteristics

Test Personnel	Novice	Nominal	Expert
Test Control Level	High	Medium	Low

Table 4: Evaluation of Test Personnel and Control Level

Test Level	Pre-compliance (Evaluation, R&D)	Compliance (Qualification)

Table 5: Determining the Test Level for the Program

Item I.D. No.	Risk Description	Item I.D. No.	Risk Description
1	Incorrect frequency range	2	Incorrect resolution bandwidth
3	Incorrect sweep time	4	Incorrect number of data points/steps
5	Incorrect video bandwidth	6	Incorrect detector
7	Missing/incorrect data plots	8	Incorrect equations
9	Incorrect/missing transducer factors	10	Incorrect/missing data arrays
11	Incorrect switch settings	12	Incorrect limit
13	Incorrect instrument drivers	14	Incorrect instrument addressed
15	Incorrect pre-selector settings	16	Incorrect preamplifier settings

Table 6: Possible Causes of Errors in MIL-STD-461F, RE102 Test Program

know your answer, you should record it into the deliverable list.

PDP – Test Type

This moves us into the next phase of planning action. What is the test type? Is it compliance testing, pre-compliance, or research and development (R&D)? The requirements for compliance testing are the most severe while pre-compliance and R&D can be less stringent depending on the objective. For example, you could reduce the system checks for a pre-compliance evaluation or reduce the frequency range to a specific area of interest. Either way, as shown in Table 5, the test program needs to account for the test type and again it is far easier to go with the most stringent level than reduce the scope and increase the test scope at a later date and time.

PDP- Risk Analysis

You have almost completed the fact gathering of the process. There is one other item to consider then it is time to analyze the information you compiled. This is one of the most important phases of this process. You know what you need. It is covered in your deliverables list. Now you have to understand what can stop you from achieving your objective. I have experienced many times a test program failure due to an unaccounted for or incorrectly set variable. So this is the time to determine how many different variables you need to accommodate and control. The more variables there are, the greater the chance for error. After identifying the potential error causes it is time to conduct a risk assessment. The results of a risk assessment[1, 2 & 3] should include a corrective action for any score determined to be a medium to high risk.

Going back to the MIL-STD-461F, RE102 example, I have determined sixteen possible test program error causes and listed them in Table 6.

The next step is to create the risk assessment scoring. There is a risk scoring method described within the Software Quality Engineer's (SQE) training manual[6]. If you do not have access to the SQE training manual then I recommend using a standard risk assessment process: identify the risk, ascertain the risk score, summarize the risk characteristics, and create corrective actions in order to reduce the risk score, assign resources and create a risk analysis database for tracking purposes. Table 7 reflects the end result of the risk assessment from the MIL-STD-461F, RE102 example.

Item I.D. No.	Description	Likelihood of Occurrence	Severity/ Impact	Score	Correction Action
1	Incorrect frequency range	Medium	High	High	SR & PS
2	Incorrect resolution bandwidth	Medium	High	High	SR & PS
3	Incorrect sweep time	Medium	High	High	SR & PS
4	Incorrect number of data points/steps	Medium	Low	Medium	SR & PS
5	Incorrect video bandwidth	Medium	Low	Medium	SR & PS
6	Incorrect detector	Low	High	Medium	SR & PS
7	Missing/incorrect data plots	Low	High	Medium	SR & PS
8	Incorrect equations	Medium	High	High	SR & PS
9	Incorrect/missing transducer factors	Medium	High	High	SR, PS & PE
10	Incorrect/missing data arrays	Medium	High	High	SR & PS
11	Incorrect switch settings	Low	High	Medium	SR & PE
12	Incorrect limit	Low	High	Medium	SR & PS
13	Incorrect instrument drivers	Low	High	Medium	SR & PE
14	Incorrect instrument addressed	Low	High	Medium	SR & PE
15	Incorrect pre-selector settings	Low	High	Medium	SR & PE
16	Incorrect preamplifier settings	Low	High	Medium	SR & PE

Legend:

SR	Static Review
PS	Performing program operation using Simulator (if available – if not available, use PE)
PE	Performing program operation using actual Equipment (system and acceptance testing)

Table 7: End Result of the Risk Assessment from the MIL-STD-461, RE102 Test Program

Test Type	Test Condition	Description		Results
V/V Modular	Modular testing discretely verifies individual program components			
	Zero Fault	Limit Select	Limit Calculations	
	Intentional Fault(s)			
	Zero Fault		Frequency Range Calculations	
	Intentional Fault(s)			
	Zero Fault	Instruments	Select Instrument Drivers	
	Intentional Fault(s)			
	Zero Fault		Instrument Addresses	
	Intentional Fault(s)		Instrument Addresses	
	Zero Fault	Transducers	Loading Transducer Correction Factors (antennas, signal path, preamplifiers and etc.)	
	Intentional Fault(s)			
	Zero Fault	System Check Sweep	Resolution Bandwidth	
			Video Bandwidth	
	Zero Fault	System Check Sweep	Frequency Resolution	
			Sweep Time	
			Detector Setting	
			Number of Data Points	
			Calculations	
			Switch Settings	
	Zero Fault	Ambient Sweep	Pre-selector Settings	
			Receiver Settings	
			Preamplifier Settings	
			Resolution Bandwidth	
			Video Bandwidth	
			Frequency Resolution	
			Sweep Time	
			Detector Setting	
			Number of Data Points	
			Calculations	
			Switch Settings	
	Zero Fault	Test Active Sweep	Pre-selector Settings	
			Receiver Settings	
			Preamplifier Settings	
			Resolution Bandwidth	
			Video Bandwidth	
			Frequency Resolution	
			Sweep Time	

Test Type	Test Condition	Description		Results
V/V Modular	Zero Fault	Test Active Sweep	Detector Setting	
			Number of Data Points	
			Calculations	
			Switch Settings	
			Pre-selector Settings	
			Receiver Settings	
			Preamplifier Settings	
	Zero Fault	Report	Labeling	
	Intentional Fault(s)			
	Zero Fault		Generation	
	Intentional Fault(s)			
	Zero Fault		Data Plots and Tables	
V/V System Integration using simulation	Integration checks the full operation (transducers, instruments, calculations, report and etc.) of specific actions			
	Zero Fault	System Check, calibrated signal source(s)		
	Intentional Fault(s)			
	Zero Fault	Ambient Sweep, known test conditions		
	Intentional Fault(s)			
	Zero Fault	Test Active Sweep, known test conditions		
	Intentional Fault(s)			
V/V System Testing using actual instruments	System tests the full operation (transducers, instruments, calculations, report and etc.) of specific actions			
	Zero Fault	System Check, calibrated signal source(s)		
	Intentional Fault(s)			
	Zero Fault	Ambient Sweep, known test conditions		
	Intentional Fault(s)			
	Zero Fault	Test Active Sweep, known test conditions		
	Intentional Fault(s)			
V/V Acceptance Testing	Acceptance tests full operation (transducers, instruments, calculations, report and etc.) of specific actions and usually enlists third party operation/witness			
	Zero Fault	System Check, calibrated signal source(s)		
	Intentional Fault(s)			
	Zero Fault	Ambient Sweep, known test conditions		
	Intentional Fault(s)			
	Zero Fault	Test Active Sweep, known test conditions		
	Intentional Fault(s)			

Table 8: The Verification/Validation Phase for a MIL-STD-461F, RE102 Test

Adherence to a test laboratory development software process described will generate evidence needed for internal and external quality audits and provide greater confidence that your test programs are doing what you intended them to do. The result is expedited test throughput while meeting laboratory requirements.

PDP – Functional Modules Building and Links

The results of the process so far have generated a deliverables list and risk assessment table/database. It is time to start building the program using the information you have created. I highly recommend building the test program using a modular method and running the modules operation at specific stages in order to keep to the adage: *test early, test often*. Using the MIL-STD-461F, RE102 example, you can break the test program into discrete components: limit select, instruments configuration, transducer correction factors, system check, ambient sweep, test sweep, report labeling, and report generation. If you record the results of the modular build testing, you are building documentation you can use for your test program verification/validation report. You continue this process until all modules have been created, debugged and linked. After you have completed this phase you move from code creation to testing (verification/validation). Please note, debugging is part of the development process. It does not start the verification/validation process[3].

I recommend generating a test case table where you enact the entire operation of the test program[2 & 3]. You build into the test case both zero user fault conditions and intentional user fault conditions then observe how the test program responds to the conditions. User fault conditions are actions where the user could enter or generate unintentional errors. Here are a few fault examples: The user could incorrectly select the limit. The user could load the wrong transducer corrections factors. The user could load an incorrect instrument driver. Where the operator or user does not have input, I recommend using zero fault conditions only. I see little value injecting errors into the system where or when there is little probability of that error occurring during actual operation. The intent is to find and eliminate potential errors. It is not to embed them into the system.

PDP – Verification/Validation (V/V)

Start the verification/validation phase at the lowest level (modular) then increase the scope until you have a full system acceptance test. If the test

The standards/documents mentioned in this article include:

I.D. Number	Title	Rev.	Date
1	ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories, International Organization for Standardization (ISO)	2	2005
2	Software Validation in Accredited Laboratories, A Practical Guide, Gregory D. Gogates, Fasor Inc. ftp://ftp.fasor.com/pub/iso25/validation/adequate_for_use.pdf	n/a	07 June 2010
3	Software Training and Consulting (SQE Training) Testing, Development, Management Requirements and Security	V4.1	2004-2011
4	ETS-Lindgren's TILE Profile Development Process, J. McFaddenhttp://support.ets-lindgren.com/TILE	n/a	2012
5	MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, Department of Defense Interface Standard	F	10 December 2007
6	Description of the SWEBOK Knowledge Area Software Engineering Process (Version 0.9), Khaled El Emam, National Research Council of Canada, Institute for Information Technology NRC, Canada	0.9	2001

results indicate a fault, then corrective action should be performed immediately prior to moving to the next phase.
As always, record the results to build evidence for your verification/validation report. An MIL-STD-461F, RE102 example is shown in Table 8.

CONCLUSION

The article followed a software development process using the Revised "V" Cycle. Adherence to a test laboratory development software process[2] described will generate evidence needed for internal and external quality audits and provide greater confidence that your test programs are doing what you intended them to do. The result is expedited test throughput while meeting laboratory requirements.

ACKNOWLEDGEMENT

The author would like to recognize and thank David R. Guzman of RFTek for his helpful review of this article.

REFERENCES

More information on software quality engineering can be found at

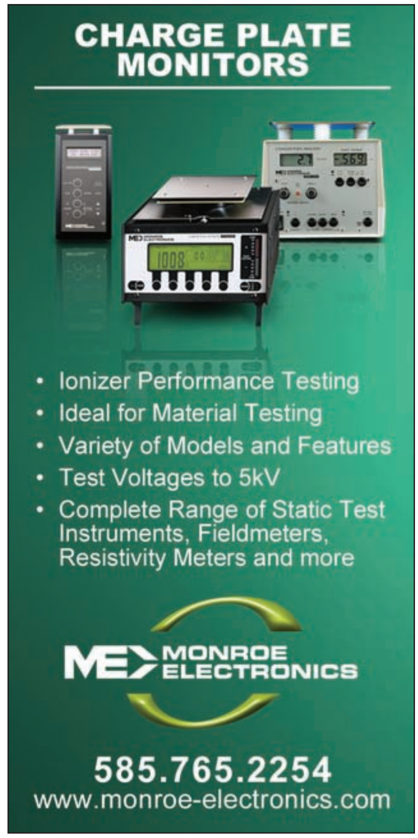
- American Society for Quality
  www.asq.org
- American Software Test Qualification Board, Inc.
  www.astqb.org
- Society Quality Engineering
  www.sqe.org
- ETS-Lindgren TILE Support
  https://support.ets-lindgren.com/TILE/

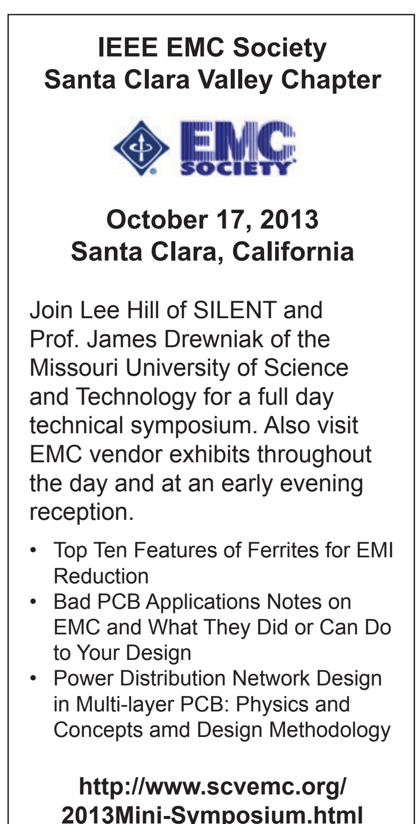
(the author)

JACK MCFADDEN
is an EMC Systems Engineer with ETS-Lindgren in Cedar Park, Texas. His responsibilities include EMC test system design and integration.
Prior to joining ETS-Lindgren, he worked for Wyle Laboratories where he was a Senior Project Engineeer. Mr. McFadden is an iNARTE certified EMC engineer as well as an iNARTE certified EMC technician with over 25 years experience in EMC test systems and software development. He is a certified tester foundation level (CTFL) per the American Software Testing Qualifications Board, Inc. (ASTQB). He may be reached at Jack.McFadden@ets-lindgren.com.

PRODUCT Showcase

Your Source for Product and Service Solutions





Testing Laboratory Service Directory

Accelerated Stress Testing

Cascade TEK - Oregon
Cascade TEK - Colorado
Compliance Management Group
Core Compliance Testing
CSZ Testing - Michigan
CSZ Testing - Ohio
CSZ Testing Services
Dayton T. Brown, Inc.
DNB Engineering, Inc.
Elite Electronic Engineering
EMC Testing Laboratories, Inc.
Flextronics
Garwood Laboratories Inc. SC
Global EMC Inc.
Hermon Laboratories
IQS, a Division of CMG
Keystone Compliance
MET Laboratories
NTS - Corporate HQ
NTS Fullerton
NTS LAX
NTS Northeast
NTS Plano
NTS Santa Clarita
NTS Tempe
NTS Tinton Falls
Professional Testing
QAI Laboratories
Retlif Testing Laboratories
Test Site Services Inc
Trace Laboratories, Inc.
TÜV SÜD America Inc.

Acoustical Testing

Compliance Worldwide, Inc.
Core Compliance Testing
Dayton T. Brown, Inc.
DNB Engineering, Inc.
Ergonomics, Inc.
ETS-Lindgren
Flextronics
Garwood Laboratories Inc. SC
IQS, a Division of CMG
MET Laboratories
NCEE Labs
NTS Fullerton
NTS LAX
NTS Northeast
NTS Plano
NTS Santa Clarita
NTS Tempe
NTS Tinton Falls
Professional Testing
Pulver Laboratories Inc.
Retlif Testing Laboratories

BSMI Compliant Certification Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Atlas Compliance & Engineering
Compliance & More, Inc
Compliance Management Group
Compliance Worldwide, Inc.
Core Compliance Testing
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electro Magnetic Test, Inc.
EMC Integrity Inc.
EMCplus LLC
G&M Compliance, Inc.
Nemko USA - SouthEast
Northwest EMC Inc. - Minnesota
Northwest EMC Inc.- California
Northwest EMC Inc.- Washington
Northwest EMC, Inc. - Oregon
NTS Fremont
SGS Consumer Testing Services
SIEMIC
Test Site Services Inc
TUV Rheinland of North America

CB Test Report

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Compliance & More, Inc
CSA Group
CSIA, LLC
Curtis-Straus (Bureau Veritas)
DNB Engineering, Inc.
Electro Magnetic Test, Inc.
EMCplus LLC
G&M Compliance, Inc.
Hermon Laboratories
MET Laboratories
Nemko USA - SouthEast
NTS Fremont
NTS Newark
O'Brien Compliance Management
Professional Testing
QAI Laboratories
SGS Consumer Testing Services
SIEMIC
Test Site Services Inc
TUV Rheinland of North America
UL LLC

CE Marking

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
American Certification Body, Inc.
Atlas Compliance & Engineering
CertifiGroup Inc
CKC Laboratories, Inc.
Compatible Electronics, Inc.
Compliance & More, Inc
Compliance Management Group
Compliance Worldwide, Inc.
Core Compliance Testing
CSA Group
CSIA, LLC
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electro Magnetic Test, Inc.
Electronics Test Centre
Electronics Test Centre - Airdrie
Elite Electronic Engineering
EMC Integrity Inc.
EMC Testing Laboratories, Inc.
EMCC DR. RASEK

EMCplus LLC
Ergonomics, Inc.
F2 Labs
G&M Compliance, Inc.
Garwood Laboratories
Garwood Laboratories Inc. SC
Global EMC Inc.
Green Mtn. Electromagnetics
H.B. Compliance Solutions
HCT Co., Ltd.
Hermon Laboratories
International Certification Services, Inc.
Intertek
Keystone Compliance
LabTest Certification Inc.
Lewis Bass International
LS Research
MET Laboratories
Montrose Compliance Services
NCEE Labs
Nemko Canada
Nemko USA - SouthEast
Northwest EMC Inc. - Minnesota
Northwest EMC Inc.- California
Northwest EMC Inc.- Washington
Northwest EMC, Inc. - Oregon
NTS Fremont
NTS Fullerton
NTS Newark
NTS Northeast
NTS Rockford
O'Brien Compliance Management
Product Safety Consulting
Professional Testing
Pulver Laboratories Inc.
QAI Laboratories
Radiometrics Midwest Corp.
Retlif Testing Laboratories
Rhein Tech Laboratories, Inc.
SGS Consumer Testing Services
SIEMIC
Test Site Services Inc
Thermo Fisher Scientific
Timco Engineering, Inc.
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC

China Compulsory Certification (CCC)

American Certification Body, Inc.
Compliance & More, Inc
CSA Group
CSIA, LLC
D.L.S. Electronic Systems, Inc.
Electro Magnetic Test, Inc.
EMC Integrity Inc.
EMCplus LLC
G&M Compliance, Inc.
Garwood Laboratories
Garwood Laboratories Inc. SC
Go Global Compliance Inc.
HCT Co., Ltd.
Nemko Canada
Nemko USA - SouthEast
RTF Compliance
SGS Consumer Testing Services
SIEMIC
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC

Electrical Safety Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
American Certification Body, Inc.
CASE Forensics
CertifiGroup Inc
Compliance Management Group
Core Compliance Testing
CSA Group
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electro Magnetic Test, Inc.
Elite Electronic Engineering
EMCC DR. RASEK
eti Conformity Services
F2 Labs
G&M Compliance, Inc.
Global EMC Inc.
Green Mtn. Electromagnetics
HCT Co., Ltd.
Hermon Laboratories
High Voltage Maintenance
Intertek
LabTest Certification Inc.
Lewis Bass International
MET Laboratories
NCEE Labs
Nemko Canada
Nemko USA - SouthEast
NTS Fremont
NTS Fullerton
NTS Tinton Falls
Product Safety Consulting
Professional Testing
Pulver Laboratories Inc.
QAI Laboratories
Retlif Testing Laboratories
Rhein Tech Laboratories, Inc.
SGS Consumer Testing Services
Test Site Services Inc
TestingPartners.com
Trace Laboratories, Inc.
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC
Ultratech EMC Lab

EMC Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Alion Science and Technology
Amber Precision Instruments, Inc.
American Certification Body, Inc.
Americor Electronics Ltd.
Atlas Compliance & Engineering
CKC Laboratories, Inc.
Compatible Electronics, Inc.
Compliance & More, Inc
Compliance Management Group
Compliance Worldwide, Inc.
Core Compliance Testing
CSIA, LLC
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.

continues on next page

Testing Laboratory Service Directory

EMC Testing *continued*

Dayton T. Brown, Inc.
Electro Magnetic Test, Inc.
Electronics Test Centre
Electronics Test Centre - Airdrie
Elite Electronic Engineering
EMC Compliance
EMC Integrity Inc.
EMC Testing Laboratories, Inc.
EMCC DR. RASEK
EMCplus LLC
eti Conformity Services
F2 Labs
Flextronics
G&M Compliance, Inc.
Garwood Laboratories
Garwood Laboratories Inc. SC
General Dynamics C4 Systems
Global EMC Inc.
Green Mtn. Electromagnetics
H.B. Compliance Solutions
HCT Co., Ltd.
Hermon Laboratories
International Certification Services, Inc.
Intertek
Jacobs Technology
Keystone Compliance
L-3 Communications Cincinnati
LabTest Certification Inc.
LCR Electronics, Inc.
Lewis Bass International
LS Research
MET Laboratories
Microwave Vision Group
Montrose Compliance Services
NCEE Labs
Nemko Canada
Nemko USA - SouthEast
NexTek, Inc.
Northwest EMC Inc. - Minnesota
Northwest EMC Inc.- California
Northwest EMC Inc.- Washington
Northwest EMC, Inc. - Oregon
NTS - Corporate HQ
NTS Europe GmbH
NTS Fremont
NTS Fullerton
NTS Newark
NTS Northeast
NTS Plano
NTS Rockford
NTS Tempe
NTS Tinton Falls
Professional Testing
Pulver Laboratories Inc.
QAI Laboratories
Qualtest Inc.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
RF Exposure Lab
Rhein Tech Laboratories, Inc.
SGS Consumer Testing Services
SIEMIC
Southwest Research Institute
Test Site Services Inc
TestingPartners.com
Thermo Fisher Scientific
Timco Engineering, Inc.
Trace Laboratories, Inc.
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC
Ultratech EMC Lab
Yazaki Testing Center

Energy Efficiency Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
CSA Group
CSIA, LLC
G&M Compliance, Inc.
Hermon Laboratories
Intertek
MET Laboratories
Nemko USA - SouthEast
Pulver Laboratories Inc.
Rhein Tech Laboratories, Inc.
SGS Consumer Testing Services
SIEMIC
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC
UL Verification Services

Environmental Simulation Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Cascade TEK - Oregon
Cascade TEK - Colorado
Compliance Management Group
Core Compliance Testing
CSZ Testing - Michigan
CSZ Testing - Ohio
CSZ Testing Services
Curtis-Straus (Bureau Veritas)
Dayton T. Brown, Inc.
DNB Engineering, Inc.
Electronics Test Centre - Airdrie
Elite Electronic Engineering
EMCC DR. RASEK
Flextronics
Garwood Laboratories
Garwood Laboratories Inc. SC
Global EMC Inc.
Hermon Laboratories
Intertek
Keystone Compliance
L-3 Communications Cincinnati
MET Laboratories
NCEE Labs
Nemko USA - SouthEast
NTS Europe GmbH
NTS Fullerton
NTS LAX
NTS Northeast
NTS Plano
NTS Santa Clarita
NTS Tempe
NTS Tinton Falls
Professional Testing
Qualtest Inc.
Retlif Testing Laboratories
Trace Laboratories, Inc.
TÜV SÜD America Inc.
Yazaki Testing Center

EuP Directive Compliance

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Curtis-Straus (Bureau Veritas)
Hermon Laboratories
Intertek
Nemko USA - SouthEast
TUV Rheinland of North America
UL Verification Services

GOST R certification

CSIA, LLC
DNB Engineering, Inc.
Electro Magnetic Test, Inc.
EMC Integrity Inc.
G&M Compliance, Inc.
Global EMC Inc.
Go Global Compliance Inc.
Hermon Laboratories
Keystone Compliance
Nemko Canada
Nemko USA - SouthEast
Northwest EMC Inc. - Minnesota
Northwest EMC Inc.- California
Northwest EMC Inc.- Washington
Northwest EMC, Inc. - Oregon
Professional Testing
TestingPartners.com

Green Energy Compliance

CertifiGroup Inc
CSA Group
Intertek
TUV Rheinland of North America
UL LLC

GS Mark Certification

Compliance & More, Inc
Curtis-Straus (Bureau Veritas)
Electro Magnetic Test, Inc.
EMCplus LLC
Global EMC Inc.
Intertek
Nemko Canada
Nemko USA - SouthEast
TUV Rheinland of North America
UL LLC

Halogen Testing

Product Safety Consulting
RTF Compliance
SGS Consumer Testing Services

Lithium-Ion Battery Testing

Cascade TEK - Oregon
Cascade TEK - Colorado
CASE Forensics
CSZ Testing - Michigan
CSZ Testing - Ohio
Dayton T. Brown, Inc.
DNB Engineering, Inc.
Elite Electronic Engineering
Garwood Laboratories
Garwood Laboratories Inc. SC
Intertek
Nemko USA - SouthEast
Product Safety Consulting
SGS Consumer Testing Services
Timco Engineering, Inc.
TUV Rheinland of North America
TÜV SÜD America Inc.

Marine Electronics Testing

Cascade TEK - Oregon
Cascade TEK - Colorado
Compliance Management Group
Compliance Worldwide, Inc.
Core Compliance Testing
Curtis-Straus (Bureau Veritas)
Dayton T. Brown, Inc.
Electro Magnetic Test, Inc.
EMC Testing Laboratories, Inc.
Garwood Laboratories
Garwood Laboratories Inc. SC
Green Mtn. Electromagnetics
Nemko USA - SouthEast
NTS Northeast
Professional Testing
QAI Laboratories
Qualtest Inc.
Retlif Testing Laboratories
Test Site Services Inc
Trace Laboratories, Inc.

Nationally Recognized Testing Laboratory (NRTL)

CSA Group
Curtis-Straus (Bureau Veritas)
Go Global Compliance Inc.
Intertek
MET Laboratories
NTS - Corporate HQ
NTS Europe GmbH
NTS Fullerton
NTS Northeast
NTS Tempe
NTS Tinton Falls
Product Safety Consulting
Qualtest Inc.
SGS Consumer Testing Services
TUV Rheinland of North America
TÜV SÜD America Inc.

Network Equipment Building System (NEBS) Testing

Cascade TEK - Oregon
Cascade TEK - Colorado
Compliance Management Group
CSZ Testing - Michigan
CSZ Testing - Ohio
Curtis-Straus (Bureau Veritas)
Dayton T. Brown, Inc.
Electro Magnetic Test, Inc.
Flextronics
Garwood Laboratories
Garwood Laboratories Inc. SC
MET Laboratories

continues on next page

Testing Laboratory Service Directory

Network Equipment Building System (NEBS) Testing *continued*

NTS - Corporate HQ
NTS Europe GmbH
NTS Fremont
NTS Fullerton
NTS Newark
NTS Northeast
NTS Plano
NTS Tempe
NTS Tinton Falls
Southwest Research Institute
Thermo Fisher Scientific
UL LLC

Product Pre-Compliance Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Atlas Compliance & Engineering
Cascade TEK - Colorado
CASE Forensics
CertifiGroup Inc
CKC Laboratories, Inc.
Compatible Electronics, Inc.
Compliance & More, Inc
Compliance Management Group
Compliance Worldwide, Inc.
Core Compliance Testing
CSA Group
CSIA, LLC
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.
Dayton T. Brown, Inc.
Electro Magnetic Test, Inc.
Electronics Test Centre - Airdrie
Elite Electronic Engineering
EMC Integrity Inc.
EMCC DR. RASEK
EMCplus LLC
Ergonomics, Inc.
eti Conformity Services
F2 Labs
Flextronics
Garwood Laboratories
Garwood Laboratories Inc. SC
Global EMC Inc.
H.B. Compliance Solutions
Hermon Laboratories
International Certification Services, Inc.
Keystone Compliance
L-3 Communications Cincinnati
LCR Electronics, Inc.
Lewis Bass International
LS Research
Montrose Compliance Services
NCEE Labs
Nemko Canada
Northwest EMC Inc. - Minnesota
Northwest EMC Inc.- California
Northwest EMC Inc.- Washington
Northwest EMC, Inc. - Oregon
NTS Fremont
NTS Plano
NTS Rockford
O'Brien Compliance Management
Parker Hannifin, Chomerics Div
Product Safety Consulting
Professional Testing
Pulver Laboratories Inc.
Qualtest Inc.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
RF Exposure Lab
Rhein Tech Laboratories, Inc.
SGS Consumer Testing Services
Stephen Halperin & Associates
Test Site Services Inc
TestingPartners.com
Timco Engineering, Inc.
Trace Laboratories, Inc.
TUV Rheinland of North America
UL Verification Services
Ultratech EMC Lab
Wyatt Technical Services LLC

Product Safety Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Cascade TEK - Colorado
CASE Forensics
CertifiGroup Inc
CKC Laboratories, Inc.
Compatible Electronics, Inc.
Compliance & More, Inc
Core Compliance Testing
CSA Group
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.
Dayton T. Brown, Inc.
DNB Engineering, Inc.
ED&D Inc.
Electro Magnetic Test, Inc.
Electronics Test Centre
Elite Electronic Engineering
EMC Testing Laboratories, Inc.
EMCC DR. RASEK
EMCplus LLC
Ergonomics, Inc.
eti Conformity Services
F2 Labs
Flextronics
G&M Compliance, Inc.
Garwood Laboratories
Garwood Laboratories Inc. SC
Global EMC Inc.
Green Mtn. Electromagnetics
H.B. Compliance Solutions
HCT Co., Ltd.
Hermon Laboratories
High Voltage Maintenance
Intertek
Keystone Compliance
LabTest Certification Inc.
Lewis Bass International
MET Laboratories
Montrose Compliance Services
NCEE Labs
Nemko USA - SouthEast
NTS - Corporate HQ
NTS Fremont
NTS Fullerton
NTS Newark
NTS Northeast
NTS Pittsfield
NTS Plano

NTS Tempe
NTS Tinton Falls
O'Brien Compliance Management
Product Safety Consulting
Professional Testing
Pulver Laboratories Inc.
QAI Laboratories
SGS Consumer Testing Services
SIEMIC
Test Site Services Inc
TestingPartners.com
Trace Laboratories, Inc.
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC

Radio Performance & Functionality Testing

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Compliance Worldwide, Inc.
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.
Dayton T. Brown, Inc.
Electro Magnetic Test, Inc.
Elite Electronic Engineering
Flextronics
Garwood Laboratories
Garwood Laboratories Inc. SC
Green Mtn. Electromagnetics
H.B. Compliance Solutions
Hermon Laboratories
Intertek
Keystone Compliance
LS Research
Microwave Vision Group
Nemko USA - SouthEast
NTS Fremont
Professional Testing
QAI Laboratories
RF Exposure Lab
Rhein Tech Laboratories, Inc.
SGS Consumer Testing Services
SIEMIC
Ultratech EMC Lab

RoHS Directive Compliance

Alberi EcoTech
G&M Compliance, Inc.
Garwood Laboratories
Intertek
Nemko Canada
Product Safety Consulting
Professional Testing
Pulver Laboratories Inc.
QAI Laboratories
RTF Compliance
SGS Consumer Testing Services
TestingPartners.com
Trace Laboratories, Inc.
TUV Rheinland of North America
UL LLC

Standards Council of Canada Certification Body

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Compliance Management Group
CSA Group
Curtis-Straus (Bureau Veritas)
Electronics Test Centre
Intertek
LabTest Certification Inc.
MET Laboratories
Nemko USA - SouthEast
Northwest EMC Inc. - Minnesota
Northwest EMC, Inc. - Oregon
NTS Fremont
Retlif Testing Laboratories
SGS Consumer Testing Services
SIEMIC
TUV Rheinland of North America
TÜV SÜD America Inc.
UL LLC

Telecommunication Certification Approval

ACS - Atlanta, GA
ACS - Boca Raton, FL
ACS - Melbourne, FL
Compatible Electronics, Inc.
CSIA, LLC
Curtis-Straus (Bureau Veritas)
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electro Magnetic Test, Inc.
Elite Electronic Engineering
G&M Compliance, Inc.
Garwood Laboratories
Garwood Laboratories Inc. SC
Go Global Compliance Inc.
H.B. Compliance Solutions
Hermon Laboratories
Intertek
MET Laboratories
Microwave Vision Group
Nemko Canada
Nemko USA - SouthEast
Northwest EMC Inc. - Minnesota
Northwest EMC Inc.- California
Northwest EMC, Inc. - Oregon
NTS - Corporate HQ
NTS Fremont
NTS Northeast
Professional Testing
QAI Laboratories
Retlif Testing Laboratories
SGS Consumer Testing Services
SIEMIC
Test Site Services Inc
TestingPartners.com
Thermo Fisher Scientific
Timco Engineering, Inc.
TUV Rheinland of North America
UL LLC
Ultratech EMC Lab

Testing Laboratory Company Directory

ACS - Atlanta, GA
5015 B.U. Bowman Drive
Buford, GA 30518 USA
tel: 770-831-8048
www.acstestlab.com

ACS - Boca Raton, FL
3998 FAU Boulevard, Suite 310
Boca Raton, FL 33431 USA
tel: 561-961-5585
www.acstestlab.com

ACS - Melbourne, FL
284 West Drive, Suite B
Melbourne, FL 32904 USA
tel: 321-951-1710
www.acstestlab.com

Alberi EcoTech
6130 Elton Avenue #370
Las Vegas, NV 89107 USA
tel: 702-677-6923
www.AlberiEcoTech.com

Alion Science and Technology
20 Clipper Road
West Conshohocken, PA 19428 USA
tel: 610-825-1960
rb.alionscience.com

Amber Precision Instruments, Inc.
746 San Aleso Avenue
Sunnyvale, CA 94085 USA
tel: 408-752-0199 x102
www.amberpi.com

American Certification Body, Inc.
6731 Whittier Avenue, Suite C110
McLean, VA 22101 USA
tel: 703-847-4700
www.acbcert.com

Americor Electronics Ltd.
675 S Lively Boulevard
Elk Grove Village, IL 60007 USA
tel: 800-830-5337
www.americor-usa.com

Atlas Compliance & Engineering
1792 Little Orchard Street
San Jose, CA 95125 USA
tel: 866-573-9742
www.atlasce.com

Cascade TEK - Oregon
5245 NE Elam Young Parkway
Hillsboro, OR 97124 USA
tel: 888-835-9250
www.cascadetek.com/
product-testing-services

Cascade TEK - Colorado
1530 Vista View Drive
Longmont, CO 80504 USA
tel: 888-835-9250
www.cascadetek.com/
product-testing-services

CASE Forensics
4636 N Williams Avenue
Portland, OR 97217 USA
tel: 877-736-1106
www.case4n6.com

CertifiGroup Inc
901 Sheldon Drive
Cary, NC 27513 USA
tel: 800-422-1651
www.CertifiGroup.com

CKC Laboratories, Inc.
5046 Sierra Pines Drive
Mariposa, CA 95338 USA
tel: 800-500-4362
www.ckc.com

Compatible Electronics, Inc.
114 Olinda Drive
Brea, CA 92823 USA
tel: 650-417-EMC1 (3621)
www.celectronics.com

Compliance & More, Inc
1076 Deer Clover Way
Castle Rock, CO 80108 USA
tel: 303-663-3396
compliance-more.com

Compliance Management Group
202 Forest Street
Marlborough, MA 1752 USA
tel: 508-281-5985
www.cmgcorp.net

Compliance Worldwide

Compliance Worldwide, Inc.
357 Main Street
Sandown, NH 3873 USA
tel: 603-887-3903
www.cw-inc.com

Core Compliance Testing
79 River Road
Hudson, NH 3051 USA
tel: 603 889-5545
www.corecompliancetesting.com

CSA Group
8501 E Pleasant Valley Road
Cleveland, OH 44131-5516 USA
tel: 866-463-1785
csagroup.org

CSIA, LLC
61535 SW Hwy 97 Suite 9635
Bend, OR 97702 USA
tel: 503-489-8006
www.csiassoc.com

CSZ Testing - Michigan
44461 Phoenix Drive
Sterling Heights, MI 48314 USA
tel: 586-997-3589
www.csztesting.com

CSZ Testing - Ohio
11901 Mosteller Road
Cincinnati, OH 45241 USA
tel: 513-793-7774
www.csztesting.com

CSZ Testing Services
11901 Mosteller Road
Cincinnati, OH 45241 USA
tel: 513-793-7774
www.csztesting.com

Curtis-Straus (Bureau Veritas)
One Distribution Center Circle, Suite 1
Littleton, MA 1460 USA
tel: 877-277-8880
www.bureauveritas.com/ee

D.L.S. Electronic Systems, Inc.
1250 Peterson Drive
Wheeling, IL 60090 USA
tel: 847-537-6400
www.dlsemc.com

Dayton T. Brown, Inc.
1195 Church Street
Bohemia, NY 11716 USA
tel: 800-TEST-456
www.dtbtest.com

DNB Engineering, Inc.
3535 W. Commonwealth Avenue
Fullerton, CA 92835 USA
tel: 714-870-7781
www.dnbenginc.com

ED&D Inc.
901 Sheldon Drive
Cary, NC 27513 USA
tel: 800-806-6236
www.ProductSafeT.com

Electro Magnetic Test, Inc.
1547 Plymouth Street
Mountain View, CA 94043 USA
tel: 650-965-4000
www.emtlabs.com

ELECTRONICS TEST CENTRE

Electronics Test Centre
302 Legget Drive
Kanata, ON K2K 1Y5 Canada
tel: 613-599-6800
www.etc-mpb.com

Electronics Test Centre - Airdrie
27 East Lake Hill
Airdrie, AB T4A 2K3 Canada
tel: 403-912-0037
www.etc-mpb.com

Elite Electronic Engineering
1516 Centre Circle
Downers Grove, IL 60515 USA
tel: 800-ELITE-11
www.elitetest.com

EMC Compliance
P.O. Box 14161
Huntsville, AL 35815-0161 USA
tel: 256-650-5261
www.emccompliance.com

EMC Integrity Inc.
1736 Vista View Drive
Longmont, CO 80504 USA
tel: 888-423-6275
www.emcintegrity.com

EMC Testing Laboratories, Inc.
2100 Brandon Trail
Alpharetta, GA 30004 USA
tel: 770-475-8819
emctesting.com

EMCC DR. RASEK
Moggast, Boelwiese 4 - 8
Ebermannstadt, 91320 Germany
tel: 49-9194-9016
www.emcc.de

EMCplus LLC
1076 Deer Clover Way
Castle Rock, CO 80108 USA
tel: 303-663-3396
emcplus.com

Ergonomics, Inc.
324 Second Street Pike Unit 3
Southampton, PA 18966 USA
tel: 800-862-0102
www.ergonomicsusa.com

eti Conformity Services
8760 Orion Place, Suite 110
Columbus, OH 43240 USA
tel: 877-468-6384
www.eticonformity.com

Testing Laboratory Company Directory

Enabling Your Success™
ETS-LINDGREN™
An ESCO Technologies Company

ETS-Lindgren

1301 Arrow Point Drive
Cedar Park, TX 78613 USA
tel: 512-531-6400
www.ets-lindgren.com

F2 Labs

26501 Ridge Road
Damascus, MD 20872 USA
tel: 877-405-1580
www.f2labs.com

Flextronics

21 Richardson Side Road
Ottawa, ON K4A 3H6 Canada
tel: 613-895-2053
www.flexdvc.com

G&M Compliance, Inc.

154 South Cypress Street
Orange, CA 92866 USA
tel: 714-628-1020
www.gmcompliance.com

Garwood Laboratories

7829 Industry Avenue
Pico Rivera, CA 90660 USA
tel: 888-427-4111
www.garwoodlabs.com

Garwood Laboratories Inc. SC

143 Calle Iglesia
San Clemente, CA 92672 USA
tel: 888-427-4111
www.garwoodlabs.com/gsc/index.html

General Dynamics C4 Systems

8201 E McDowell Road
Scottsdale, AZ 85257 USA
tel: 480-441-5321
www.gdc4s.com

Global EMC Inc.

11 Gordon Collins Drive, PO Box 581
Gormley, ON L0H 1G0 Canada
tel: 888-441-7337
www.globalemclabs.com

Go Global Compliance Inc.

4454 Crabapple Court
Tracy, CA 95377 USA
tel: 408-416-3772
www.goglobalcompliance.com

Green Mtn. Electromagnetics

219 Blake Roy Road
Middlebury, VT 5753 USA
tel: 802-388-3390
www.gmelectro.com

H.B. Compliance Solutions

5005 S. Ash Avenue, Suite # A-10
Tempe, AZ 85282 USA
tel: 480-684-2969
www.hbcompliance.com

HCT Co., Ltd.

105-1 Jangam-ri, Majang-myeon
Icheon, Gyeonggi 467-811
South Korea
tel: 82-31-645-6454
www.hct.co.kr

Hermon Laboratories

66 Hatachana St
Binyamina, 30500 Israel
tel: -6267433
www.hermonlabs.com

High Voltage Maintenance

5100 Energy Drive
Dayton, OH 45414 USA
tel: 866-486-8326
www.hvmcorp.com

International Certification Services, Inc.

1100 Falcon Avenue
Glencoe, MN 55336 USA
tel: 888-286-6888
www.icsi-us.com

Intertek

70 Codman Hill Road
Boxborough, MA 1719 USA
tel: 800-WORLDLAB
intertek.com

IQS, a Division of CMG

257 Simarano Drive
Marlborough, MA 1752 USA
tel: 508-460-1400
www.iqscorp.com

Jacobs Technology

3300 General Motors Road
MC-483-340-145
Milford, MI 48380 USA
tel: 248-676-1101

Keystone Compliance

131 Columbus Inner Belt
New Castle, PA 16101 USA
tel: 724-657-9940
www.keystonecompliance.com

L-3 Communications Cincinnati

7500 Innovation Way
Mason, OH 45040 USA
tel: 800-543-8220
www.cinele.com/environmental.html

LabTest Certification Inc.

3133 - 20800 Westminster Hwy
Richmond, BC V6V2W3 Canada
tel: 604-247-0444
www.labtestcert.com

LCR Electronics, Inc.

9 South Forest Avenue
Norristown, PA 19401 USA
tel: 800-527-4362
www.lcr-inc.com

Lewis Bass International

1250 Ames Avenue
Milpitas, CA 95035 USA
tel: 408-942-8000
www.lewisbass.com

LS Research

W66 N220 Commerce Court
Cedarburg, WI 53012 USA
tel: 262-375-4400
www.lsr.com

MET Laboratories

914 W. Patapsco
Baltimore, MD 21230 USA
tel: 410-354-3300
www.metlabs.com

Microwave Vision Group

2105 Barrett Park Dr, Suite 104
Kennesaw, GA 19044 USA
tel: 678-797-9172
www.microwavevision.com

Montrose Compliance Services

2353 Mission Glen Drive
Santa Clara, CA 95051-1214 USA
tel: 408-247-5715
www.montrosecompliance.com

NCEE Labs

4740 Discovery Drive
Lincoln, NE 68521 USA
tel: 888-567-6860
www.nceelabs.com

Nemko Canada

303 River Road
Ottawa, ON K1V 1H2 Canada
tel: 613-737-9680
www.nemko.com

Nemko USA - SouthEast

Tampa Sales Office
Tampa, FL 33511 USA
tel: 813-662-4606
www.nemko.com

NexTek, Inc.

2 Park Drive, Building #1
Westford, MA 1886 USA
tel: 978-486-0582
www.nexteklightning.com

Northwest EMC Inc. - Minnesota

9349 W Broadway Ave.
Brooklyn Park, MN 55445 USA
tel: 888-364-2378
www.nwemc.com

Northwest EMC Inc.- California

41 Tesla Avenue
Irvine, CA 92618 USA
tel: 888-364-2378
www.nwemc.com

Northwest EMC Inc.- Washington

19201 120th Avenue NE Suite 104
Bothell, WA 98011 USA
tel: 888-364-2378
www.nwemc.com

Northwest EMC, Inc. - Oregon

22975 NW Evergreen Parkway
Suite 400
Hillsboro, OR 97124 USA
tel: 888-364-2378
www.nwemc.com

NTS - Corporate HQ

24007 Ventura Boulevard
Calabasas, CA 91302 USA
tel: 800-270-2516
www.nts.com

NTS Europe GmbH

Hofmannstr. 50
Munich, D-81379 Germany
tel: 49 89 787475 160
www.nts.com/locations/europe

NTS Fremont

41039 Boyce Road
Fremont, CA 94538 USA
tel: 877-245-7800
www.nts.com

NTS Fullerton

1536 East Valencia Drive
Fullerton, CA 92831 USA
tel: 800-677-2687
www.nts.com

NTS LAX

5320 West 104th Street
Los Angeles, CA 90045 USA
tel: 800-559-3202
www.nts.com/locations/los_angeles

NTS Newark

38995 Cherry Street
Newark, CA 94560 United States
tel: 877-245-7800
www.nts.com

Testing Laboratory Company Directory

NTS Northeast

1146 Massachusetts Avenue
Boxborough, MA 2109 USA
tel: 800-723-2687
www.nts.com

NTS Pittsfield

10 Downing Industrial Parkway
Pittsfield, MA 01201-3890 United States
tel: 800-270-2516
www.nts.com

NTS Plano

1701 East Plano Parkway, Suite 150
Plano, TX 75074 USA
tel: 877-717-2687
www.nts.com

NTS Rockford

3761 South Central Avenue
Rockford, IL 61102 USA
tel: 800-270-2516
www.nts.com

NTS Santa Clarita

20970 Centre Pointe Parkway
Santa Clarita, CA 91350 USA
tel: 800-270-2516
www.nts.com

NTS Tempe

1155 West 23rd Street, Suite 11A
Tempe, AZ 85282 USA
tel: 480-966-5517
www.nts.com

NTS Tinton Falls

36 Gilbert Street South
Tinton Falls, NJ 7724 USA
tel: 732-936-0800
www.nts.com

O'Brien Compliance Management

12 Stedman Street
Chelmsford, MA 1824 USA
tel: 978-970-0525
www.obcompman.com

Parker Hannifin, Chomerics Div

77 Dragon Court
Woburn, MA 1801 USA
tel: 781-935-4850
www.chomerics.com

Product Safety Consulting

605 Country Club Drive
Bensenville, IL 60106 USA
tel: 877-804-3066
www.productsafetyinc.com

Professional Testing

1601 North A.W. Grimes Boulevard
Suite B
Round Rock, TX 78665 USA
tel: 800-695-1077
www.ptitest.com

Pulver Laboratories Inc.

320 North Santa Cruz Avenue
Los Gatos, CA 95030-7243 USA
tel: 800-635-3050
www.PulverLabs.com

QAI Laboratories

Suite 200, 834 80th Street SW
Everett, WA 98203 USA
tel: 888-540-4024
www.qai.org

Qualtest Inc.

5325 Old Winter Garden Road
Orlando, FL 32811 USA
tel: 407-313-4230
www.qualtest.com

Radiometrics Midwest Corp.

12 East Devonwood
Romeoville, IL 60446 USA
tel: 815-293-0772
www.radiomet.com

Retlif Testing Laboratories

795 Marconi Avenue
Ronkonkoma, NY 11779 USA
tel: 631-737-1500 x111
www.retlif.com

RF Exposure Lab

802 N. Twin Oaks Valley Road
Suite 105
San Marcos, CA 92069 USA
tel: 760-471-2100
www.rfexposurelab.com

Rhein Tech Laboratories, Inc.

360 Herndon Parkway, Suite 1400
Herndon, VA 20170 USA
tel: 703-689-0368
www.rheintech.com/

RTF Compliance

22431 Antonio Parkway #B160-698
Rancho Santa Margarita, CA 92688 USA
tel: 949-813-6095
www.rtfcomp.com

SGS Consumer Testing Services

620 Old Peachtree Road, Suite 100
Suwanee, GA 30024 USA
tel: 800-777-TEST (8378)
www.us.sgs.com/cts

SIEMIC

775 Montague Expressway
Milpitas, CA 95035 USA
tel: 408-526-1188
www.siemic.com

Southwest Research Institute

6220 Culebra Road, P.O. Drawer 28510
San Antonio, TX 78228-0510 USA
tel: 210-522-2122
www.swri.org

Stephen Halperin & Associates

1072 Tower Lane
Bensenville, IL 60106 USA
tel: 630-238-8883
www.halperinassoc.com

Test Site Services Inc

30 Birch Street
Milford, MA 1757 USA
tel: 508-962-1662
www.testsiteservices.com

TestingPartners.com

8440 East Washington Street #207
Chagrin Falls, OH 44023 USA
tel: 862-243-2329
www.testingpartners.com

Thermo Fisher Scientific

200 Research Drive
Wilmington, MA 1887 USA
tel: 978-275-0800 x2302
www.thermo.com/esd

Timco Engineering, Inc.

849 N.W. State Road 45
Newberry, FL 32669 USA
www.timcoengr.com

Trace Laboratories, Inc.

5 North Park Drive
Hunt Valley, MD 21030 USA
tel: 410-584-9099
www.tracelabs.com

TUV Rheinland of North America

1300 Massachusetts Avenue
Boxborough, MA 1719 USA
tel: 1-TUV-RHEINLAND
www.us.tuv.com

TÜV SÜD America Inc.

10 Centennial Drive
Peabody, MA 1960 USA
tel: 800-888-0123
www.TUVamerica.com

UL LLC

333 Pfingsten Road
Northbrook, IL 60062 USA
tel:
www.UL.com

UL Verification Services

25, South HuanShi Avenue
Nansha District
Guangzhou, 511453 China
tel: 86 20 28667188
www.ul.com/verification

Ultratech EMC Lab

3000 Bristol Circle
Oakville, ON L6H 6G4 Canada
tel: 905-829-1570
www.ultratech-labs.com

Wyatt Technical Services LLC

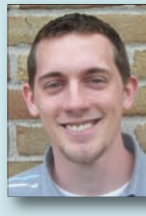
56 Aspen Drive
Woodland Park, CO 80863 USA
tel: 877-443-9275
www.emc-seminars.com

Yazaki Testing Center

6800 N. Haggerty Road
Canton, MI 48187 USA
tel: 734-983-6012
www.yazakiemc.com

(Authors)

ANDREW BELLAMY
has seven years' experience in the power electronics industry, four years specifically related to electromagnetic compatibility while employed with Emerson Network Power in Delaware, Ohio. For more about Andrew, please visit page 45.



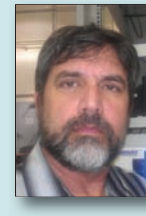
DANIEL D. HOOLIHAN

is the Founder and Principal of Hoolihan EMC Consulting. He is Chair of the ANSI-ASC C63 Committee on EMC. He is a Past-President of the EMC Society of the IEEE and is presently serving on the Board of Directors. For more about Dan, please visit page 37.

NIELS JONASSEN, MSC, DSC,
worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate.
Mr. Jonassen passed away in 2006.
For Mr. Jonassen's full bio, please see page 17.

JAMES K. MARTIN P.E.
has worked for thirty-two years as a UPS designer at Emerson Network Power / Liebert in Delaware, Ohio. He holds a BSEET in Electronic Engineering through Franklin University and a BSEE in Power Systems through The Ohio State University. For more about James, please visit page 45.

JACK MCFADDEN
is an EMC Systems Engineer with ETS-Lindgren in Cedar Park, Texas. His responsibilities include EMC test system design and integration. Prior to joining ETS-Lindgren, he worked for Wyle Laboratories where he was a Senior Project Engineeer. For more about Jack, please visit page 59.



SCOTT PANSING
began his career as an Industrial Electrician and received his Associate Degree through CPI in Columbus, Ohio. He has spent twenty years in the electrical, electronic and automation industry, having worked within the EMC/EMI field for the past eight years. For more about Scott, please visit page 45.

GEOFFREY PECKHAM
is CEO of Clarion Safety Systems and chair of both the ANSI Z535 Committee and the U.S. Technical Advisory Group to ISO Technical Committee 145- Graphical Symbols. For more about Geoff, please visit page 21.

MIKE VIOLETTE
remembers the first Moon walk (the same night the cat had a litter under the living room couch), *Space Food Sticks,* drinking *Tang* and the awesome *Saturn V,* The King of All Launch Vehicles. He can be reached at mikev@wll.com.

We wish to thank our community of knowledgeable authors, indeed, experts in their field - who come together to bring you each issue of *In Compliance*. Their contributions of informative articles continue to move technology forward.

(Advertisers)

Antennas and Pre-Amps are Calibrated as a Unit

Accurate Antenna Factors, Less Uncertainty

Mismatches Mislead

Losses occur between antennas and pre-amps due to impedance mismatches. These mismatch losses are not accounted for in the supplied antenna factor (AF) data because the antenna was not calibrated with the pre-amp, and the pre-amp gain was not measured with the antenna. The result is misleading AF data that increases measurement uncertainty.

Mated and Calibrated

ETS-Lindgren solves the problem by matching our most popular antennas with our new pre-amps and calibrating them as a single unit. All combinations are designed with quality components that provide flat gain across the frequency range, and good signal-to-noise ratios. Find out more at the URL below.

Enabling Your Success™

ETS·LINDGREN™
An **ESCO Technologies** Company

www.ets-lindgren.com/emcantennas

Phone +1.512.531.6400 • info@ets-lindgren.com
Offices in the US, Brazil, Germany, Finland, UK, France, India, Japan, Singapore, China, Taiwan