Minutes
Electrical Power Working Group
Friday, July 16, 1999
Dallas/Ft. Worth Marriott Hotel
Irving, Texas

Chairmen: Bob Luther; Lex Products Corp.; Principal; Producer
Ken Vannice; NSI Corporation (Leviton Manufacturing Co., Inc.); Principal; Producer

Recording secretary: Karl G. Ruling, ESTA

Members attending: (All joined at this meeting.)
Tim Bachman; Barbizon Light (Barbizon Companies); Principal; User
Mitch Hefter; Rosco/Entertainment Technology;; Principal; Producer
Robert Barbagallo; Proximo Inc.; Principal; General interest
Paul F. Mardon; Pulsar Ltd.; Principal; Producer
Eckart Steffens; SOUNDLIGHT (VPLT); Principal; General interest
Brian Dowd; TMB Associates; Alternate; Producer
Tim Cox; PLASA; PLASA; Principal; General interest
Edwin S. Kramer; IATSE, Local 1; Principal; User
Doug Kraus; Advanced Devices, Inc.; Principal; Producer
Jose J. Flores; Kino Flo, Inc.; Principal; Producer
R. Bruce Prochal; I.A.T.S.E. Local 728; Principal; User
Louis Bradfield; Bally's Las Vegas (Louis Bradfield); Individual; User
Mitchell Stein; Leviton Manufacturing Co., Inc.; Alternate; Producer
Andy Topinka; Technical Group Services, Inc.; Principal; General interest

Note: The names in parenthesis indicate the organization represented, if different from the company affiliation.

1. Opening remarks

Ken Vannice called the meeting to order at 8:00. Vannice announced that normally we will close door at the meeting's start. Today was an exception and the door would be left open today to be more welcoming. Vannice introduced himself, Bob Luther and Karl Ruling. He described the reason for the working group.

2. Attendance and membership

2.1. Introduction of those present

Vannice asked the members of the group to introduce themselves and to give a brief description the person's interest, qualifications, and committment to attend meetings and respond to letter ballots.

A vividly colored attendance sheet was circulated.

2.2. Requirements for membership

Ken Vannice read Section V of our Policies and Procedures document, and read in detail the procedures for joining. Vannice also discussed the participation requirement. According to the P&P, the working group must meet at least once a year, but not more than six. Vannice told the group where the meetings are traditionally held and when: January at the D/FW Marriott, March or April at the USITT Conference, June or July at the D/FW Marriott, and October or November at LDI.

Vannice announced that the penalty for non-attendance will be a change of voting status to Observer. At the beginning of the third consecutive meeting missed by both a principal and his alternate, the principal and alternate (if there is one) will be changed to observer.

2.3. Processing of new membership requests

Vannice and Luther recessed the meeting while they sorted out the membership applications and processed them. Then informed the group as to what interest and voting categories they had been assigned. (These interest and voting category assignments are noted in the membership list at the end of these minutes.)

3. Call for Patents

Read by Ken Vannice:

> "ESTA intends to publish no standard that contains protected intellectual property, unless that property can be licensed by anyone for a reasonable fee. ESTA uses a process of open patent disclosure to implement this intent. ESTA does not conduct patent searches and does not warrant that its standards contain no protected intellectual property.
>
> "In keeping with the open disclosure policy, I ask if anyone present wishes to notify the working group of the existence of a patent or copyright that might protect material in a standard being developed by the working group. You need not be the holder of the patent or copyright in order to notify the working group of its existence."

Mitch Hefter mentioned his company's Low-Harm Mode, which is a patented technology. It may become an issue if standards or recommended practices are drafted that describe a process similar to Low-Harm Mode. Hefter doesn't know his company's position on licensing it.

Vannice also read the Anti-Trust Statement

> "The ESTA Board of Directors, the Technical Standards Committee, and the leadership of this Working Group will reject or nullify any actions that restrain trade. Anyone who feels that an action restraining trade is being or has been taken is requested to bring the matter to the attention of the chair immediately. Anyone who feels that actions in restraint of trade have been taken and not properly annulled is requested to notify the TSC chair or ESTA president immediately.

"ESTA legal counsel has informed us that any member of this working group may be found individually liable for any action that restrains trade taken by this working group. An individual convicted of a violation of the Sherman Act may be fined as much as $100,000 and be imprisoned for up to three years. An easy to read pamphlet describing restraint of trade is available from the Technical Standards Committee."

No actions in restraint of trade were reported.

4. Approval of Agenda

Vannice asked if there was anything new that needed to be added. No one offered anything.

Tim Bachman moved that we accept the agenda. The motion was seconded. Unanimous by a show of hands.

5. New business

5.1 Vision and Mission Statements

Bob Luther presented a first draft of the mission and vision statements. In discussion it was decided that a little bit of editing was needed. When the editing was finished, Eddie Kramer moved that the amended document be accepted as an interim vision and mission statement. This was seconded, and unanimously approved. The interim vision and mission statements are:

<u>Vision</u>

The field of Entertainment is an area where copious amounts of electrical power are used, usually in close proximity to the general public. The Electrical Power Working Group recognizes that electrical power needs to be treated with the utmost respect, particularly given the unique characteristics of our market.

Our vision is an Entertainment Industry where all aspect of the distribution and use of electrical power can be accomplished in a safe, economical, and efficient manner, with no risk to employees or the general public, and without limiting creative options.

<u>Mission</u>

It is our mission to listen to our membership regarding the use of electrical power and to identify areas that represent a safety concern or an encumbrance on efficient production. Wherever possible, we will address these areas by developing standards for equipment, components, or safe practices that eliminate the concern.

5.2. New Task Groups

Bob Luther distributed Rose Brand post-it-type notes to solicit ideas for projects from the group.

Bob Luther and Ken Vannice reviewed the notes and sorted them into general groups.

Luther noted that there were a lot of cabling issues identified and a few power quality issues. Among the hot cabling issues were multi-cable pin-outs, two-fers in Canada, American National Standards for pin connectors, and standardization of 50-amp twist locks. Other electrical power concerns were dimmer performance criteria, including quiet and silent dimming, load circuit multiplexing, safe practices in regard to outdoor water issues, grounding practices, and GFI and RCD use in stage environments.

Bachman moved that we form a task group to identify topics that would be included in recommended practices for cabling and connector use in the Entertainment Industry. The topics may be publishable as small publications rather than as an omnibus document. Hefter seconded the motion. Unanimous.

Hefter moved that Bachman head the task group. Kramer seconded. Unanimous.

Tim Bachman's Cabling Issues Task Group:

R. Bruce Prochal
Louis Bradfield
Mitch Stein
Eddie Kramer
Doug Kraus
Brian Dowd
Bob Barbagallo
Bob Luther
Mitch Hefter

This group will deal with what had been items 5.2.1 and 5.2.2 on the agenda, which were HMI cable configurations and single-pole separable connector conventions respectively Thus, these items were not discussed separately.

5.2.3. Current-harmonics induced on power lines

Ken Vannice gave his report, pointing out the significance of the three documents, "Report to ESTA on Harmonics," "DRAFT - IMPLICATIONS FOR LIGHTING- REVISION of IEC61000-3-2," and " United States National Committee -Powerline Harmonics Position Paper" (These are appended to the end of these minutes). Vannice asked for help in devising a position for the October USCCEMC meeting.

Vannice identified these important questions relative to our industry and harmonics control:

- The size of our power consumption compared to the general consumption.
- The actual harmonic distortion produced by our equipment at the point of common coupling.

Vannice listed these other possible projects related to power line harmonics:

- Determining the costs of mitigation. These costs could shrink the market or limit the use of dimmers in some markets.
- Recommended practices for installing loads so that problems are as few as possible.
- Investigating the harmonics produced by arc sources and ballasts, moving lights, etc.

Eddie moved that the working group approve the work Ken Vannice has done in representing our industry to the USCCEMC and thank him for his efforts. The motion was seconded. Unanimous by show of hands.

Mitch Hefter moved that we form a task group to provide additional information for the draft discussion document to be used by the USCCEMC. Kramer seconded.Unanimous by voice vote. No abstentions.

Andy Topinka moved that Ken Vannice shall be the task group head. The motion was seconded. Unanimous approval by show of hands.

Ken Vannice's Harmonics Task Group:

- Andy Topinka
- Colin Waters (Put forth by Brian Dowd per Collin's instructions)
- Jose Flores
- Tim Cox

6. Other business

None.

7. Schedule for future meetings

Vannice announced that the next meeting would be November 19th, 7:00 to 11:00 p.m., in Orlando, Florida at the Peabody Hotel.

8. Adjournment

Mitch Hefter moved the meeting adjourn. The motion was seconded. Unanimous. Vannice declared the meeting adjourned at 11:59.

Report to ESTA on Harmonics
By
Ken Vannice
June 27, 1999

I attended the second Power Harmonics Workshop held on May 6&7, 1999, at the Sheraton BWI. The purpose of the Workshop was to produce a "position paper" on harmonics from the US, and hopefully the North American, viewpoint. After two days of hard work the attached document was produced by consensus. It has been endorsed by the US National Committee Executive Committee and has been formally distributed to the Canadian and Mexican National Committees. Hopefully these committees will also endorse the document making it a North American position. Canada was represented in the formation of this progressive document at the Workshop.

The USNC Powerline Harmonics Position Paper, USCCEMC 99-01, is not a standard, but a philosophy. It exists to be used by all representatives of the US, and hopefully North America, as the guiding philosophy in their deliberations on the various national and international standards-making technical committees, working groups, task groups, etc.

During the course of the above process it occurred to me that while we were pursuing the issue of harmonics driven by issues around SCR dimmers, the issue really needed to be addressed in all areas of the entertainment industry. Furthermore, since the subject matter is so large, we need to ride the "coat tails" of other, more mainstream, industries where we can, and conserve our energies for those areas that are different. To that end I offer the following comments:

- Computerized consoles, computers and other ITE equipment – follow the lead of IBM, HP, etc.
- Professional audio and video equipment – follow the lead of the National Systems Contractors Assoc., Harman, etc.
- Lighting equipment excluding moving lights – follow the lead of GE, MagneTek, etc.
- Moving lights – potential problem area if someone does not step forward.
- Motorized rigging – no one from the motor control industry participated in the Workshop. I have suggested to Tom Young that maybe the rigging segment of our industry should be paying attention to this issue.
- Dimming equipment – our current major thrust.

At the Workshop we received a copy of IEC 61000-3-2 marked up with the current (as of Workshop time) proposed changes. Some of the more pertinent changes are paraphrased as follows:

- *Special (custom) equipment not in compliance may be installed if acceptable to the supply authorities (utilities)* was limited to that connected to the low-voltage supply in accordance with Technical Report IEC 61000-3-4. Furthermore, IEC 61000-3-4 will eventually be made an International Standard.
- *Motor driven equipment with phase angle control directly on the mains, domestic equipment with symmetrical control directly on the mains for a short time, and equipment with asymmetrical controls directly on the mains* were added to Class A. *Equipment not included in Classes B thru D* (the catch-all group) is no longer Class A. This is because Class D has been changed from *equipment with special waveforms and power less than or equal to 600W,* to *all other apparatus.* Since Class D no longer includes special waveforms the curve identifying the special waveform has been deleted.
- The Control Methods section was deleted in favor of the following:

  Asymmetrical controls and half-wave rectification directly on the mains may only be used where (1) they are the only practical solution to detect unsafe conditions, (2) input power is less than 100W, or (3) the appliance is portable and intended for use for short periods of time.
- Measurement methods have been completely revised.

- The tag to the Harmonic Current Limits section temporarily exempting professional equipment greater than 1kW was deleted in favor of the following exemptions:
    1. *Equipment, other than lighting equipment, rated 75W or less (to be eventually changed to 50W).*
    2. *Professional equipment rated greater than 1kW.*
    3. *Symmetrically controlled heaters rated less than or equal to 200W.*
    4. *Independent dimmers rated less than or equal to 1kW.*

The next Harmonics Workshop is scheduled for October 1999; and its purpose is to begin to detail what are acceptable limits in line with our position paper. As I stated before I have chosen to work with Ed Yandek of GE. He is the representative to the US contingent on harmonics from the lighting industry. He has started a draft of the lighting industry's position, copy attached. It contains big blank spaces reserved for our industry to be filled in by us, hopefully before next October. We have a lot of work to do.

There is another new group being formed "Product Industries Initiative on Low-Frequency Emissions". This group is predominately manufacturer's and their trade associations. ESTA was invited. Karl was on vacation and I could not change my schedule. I sent our regrets and indicated our interest. I have been talking with some of its forming members. Its purpose is to create a strategy for change. Part of the strategy appears to be to raise money to do studies in a manner similar to those the utilities have already done. They will probably be asking ESTA for donations. We may need to keep our money for the studies we will need to do in our own industry.

Ending on a positive note, many IEC meetings were recently held in San Diego. I do not yet have details but the reports I do have indicate a major shift in positions.

DRAFT- NOT AN OFFICIAL POSITION
FOR DISCUSSION ONLY

IMPLICATIONS FOR LIGHTING- REVISION of IEC61000-3-2

Introduction

IEC 61000-3-2 currently becomes enforceable in Europe on January 1, 2001 under CENELEC and the EMC Directive. Many aspects of this standard remain controversial including how measurements are made, how products are categorized versus their relative impact to utility systems, and what the specific limits are for various products.

Due to ongoing criticism of this standard, and due to the fact that it only covers 230V/50Hz systems, SC77A WG1 initiated an effort begin a complete revision of IEC 61000-3-2 (See 77A/242/NP).

This revision seeks to improve the standard by making it simpler to understand and apply, be truly international by extending its scope to include North American and Japanese line voltages and frequencies, and by revisiting the basis for determining harmonic limits, product categories, exemptions, and measurements. Task Force 5A has the overall responsibility for the revision, and Task Force 5B has the specific responsibility to consider the North American and Japanese distribution systems, impedance implications, environment, and how this would interplay with limits for products in these regions of the world. While the objective is that there be no unnecessary differences in limits globally, this may not be possible given the very significant differences in electrical distribution systems, network design, systems impedances, and connection practices—all of which will continue to be different.

This following is a “lighting-only” discussion of the implications of this revision and seeks to initiate a position from which we could form a consensus for limits for lighting products that could eventually be incorporated into a US position.

Existing IEC 61000-3-2

The existing standard assumes that all lighting products should have harmonic limits. Thus, it would apply limits to extremely low wattages as well as very high wattages, regardless of the environment in which the products are used and regardless of the potential for impact to the utility or the local user/customer. Although factors such as usage, environment, and impact were supposedly taken into account in determining which products should be covered (have limits) and what those limits should be, the fact of the matter is that the process was driven by European utility representatives who strongly believed that most products should have stringent limits regardless of the consequences to the end user, product manufacturer, and products themselves. This resulted in a standard that was both Euro-centric in approach and biased towards utility objectives. Thus, almost no lighting product, no matter how low in wattage, would be exempted for complying with harmonic limits. In addition, the limits are sufficiently stringent to require the application of expensive active power factor correction, which has additional implications on thermal management, performance, physical size, and product market penetration.

Lighting harmonic limits are the strictest for any product category, despite the fact that other mass volume products are known to consume more energy and produce greater harmonic emissions than lighting loads.

The Case for Some Harmonic Limits

Non-linear loads are increasing dramatically. Utilities argue that they must "do something" before the aggregate effects of harmonic distortion become so severe that customers experience operational problems, service outages occur, and utility equipment is damaged. Scenarios can be constructed, especially via models, that purportedly justify such concern- if not today, then at some point in the future as more linear loads are converted to non-linear. Surveys of utilities, both formal and informal, find that isolated incidents involving harmonics do occur, especially in concentrated industrial locations. It is harder to find evidence of widespread issues in commercial locations and there is really no evidence of issues in residential locations today.

However, one legitimate role for standards is to develop requirements, using a consensus and transparent process, to avoid problems before they develop. Indeed, industry sectors often develop their own requirements just for this purpose- to avoid problems for customers and manufacturers alike, and to ensure compatibility of operation and interaction with the larger system within a premise.

The debate centers around which products should be limited, what the limits should be, and when they should be applied. Conversely, which products should be excluded or exempted from limits. The current version of 61000-3-2 unfairly places very stringent limits indiscriminately across virtually all lighting products without considering the environments and without using an approach that would set some limits, evaluate, and then determine if more stringent limits are actually needed.. In addition, the apportionment of responsibility for system compatibility, which is really a shared responsibility between product and utility, has been totally pushed towards the product manufacturer without regard for product or utility infrastructure life cycle considerations or the implications of such a "hidden tax" on consumers, commercial/industrial customers, and building owners/managers..

Recent work by industry indicates that harmonic current issues, although potentially real, are often mitigated naturally within the operating systems, especially at the premises level. Furthermore, rationales used to develop the existing limits did not sufficiently address the nature of aggregate product interactions and their beneficial effects. Central mitigation in concentrated locations is another real option. Many products have been developed- with more emerging- that seek to offer harmonic mitigation for problem locations. These include transformers specially designed to cancel and reduce harmonic currents as well as electronic systems that measure harmonic content and automatically inject cancelling currents. Such transformers are only nominally more expensive then their non-mitigating counterparts. Electronic approaches, while expensive today, were not even readily available 5 years ago, and provide the promise of eventual local, cost effective mitigation even at the residence level. Wiring practices, especially for large commercial buildings in North America, have evolved to manage harmonic issues that can impact neutral conductors and on-premise transformers. Utilities routinely apply point of common coupling (PPC) compatibility limits for voltage distortion with commercial and industrial customers that cause unreasonable disturbances to utilities or other local users. It is appropriate that the limits contained in 61000-3-2 be re-evaluated in light of current practice and known systemic solutions that have proven effective in the intervening years since the initial work on this standard was begun.

A Reasoned Approach

Given that gradually the level of harmonic currents will rise in utility systems, and given that as they do, compatibility levels will be exceeded with some resultant level of customer dis-satisfaction and system disturbance, what is the best overall approach?

Since there is no accurate ability to predict the rate of increase nor how, when, or where the compatibility levels will be exceeded, or even the specific local or aggregate impact when they are exceeded, what seems to make sense is a gradual approach that seeks to reduce potential impact in environments that are **most likely** to encounter problems. Establishing a set of limits for certain selected products by key environment is a way to begin a process that can then be continued if and when data indicates that problems are being encountered. There is no credible argument that can be made that does not accept a “phased-in” approach. Product trends are sufficiently gradual to allow time to monitor, assess, and respond with newer, stricter requirements if needed. Many lighting products, in particular, undergo upgrades and replacement on a regular basis. Some, such as screw in CFLs, have relatively short lifetimes, so the future generations can replace existing ones automatically with improved harmonic emissions if the need arised.

What is not a reasoned approach is to require all products to immediately incorporate stringent, new limits regardless of the proven need, impact to manufacturers, impact to product cost and performance, and impact to customers/users themselves. It is also unreasonable to put the full burden of system compatibility with individual products, especially for those that are replaced on a fairly short time frame, ie, several years. It must be accepted, since practices already exist as well as vendors, that central control and mitigation is perfectly acceptable expectation for some environments. This still puts most of the burden on the manufacturer and end user but does allow limits to be based on some shared responsibility. It should also be accepted that utilities bear a responsibility to transition to new technologies in a phased in manner and to periodically upgrade their immunity to reasonable levels of harmonic disturbance. System compatibility is about both disturbance and immunity- and an assumption that both must be ultimately considered and implemented for the best overall solution- which is the one that results in a generally fair and reasonable cost (if not always the total lowest cost) to society.

Strawman for Consideration- Guiding Principles

This strawman seeks to build a lighting-oriented set of harmonic limits that is admittedly North American focused but that could potentially work for most industrialized locations, especially since it is a phased-in approach. It also seeks to use the environment as its first screen, realizing that some products may potentially overlap into other secondary environments, but that the potential disturbance impact when this occurs will not be significant.

Without consideration for the environment as a first screen, it soon becomes apparent that all products become over-designed for the worst case situation, which is not reasonable. This approach assumes that the cost learning curve for harmonic mitigation will continue to improve, so that in the future, it may become more easy to embed some low harmonic, low THD performance without significantly adding to cost or possibly reducing performance as well if and when data indicates more stringent measures need to be taken.

This approach is based on the following Principles-

General Principles

1. Harmonic limits for some products in some environments are justified when considered as part of a systemic approach to minimizing potential disturbance and customer dis-satisfaction.

2. Central premise mitigation should be a natural part of good facility practice and should be expected in commercial and industrial buildings. Both utilities and manufactures have an obligation to engage in the development of educational information on such solutions.

3. Utilities should upgrade their immunity to harmonic currents (Vthd transfer function) as they naturally change out equipment, particulalry transformers, where such mitigation is possible. (This may not be possible at all distribution levels in all international systems.)

4. Harmonic limits, where established, can and should be based on an assumption that product, premise, and utility mitigation and immunity will all be employed depending upon the application environment.

5. The level and nature of limit (be it PF, THD, harmonic limit by order) should be based on product classification by application environment and the ability to cause a compatibility issue in the relatively near future (impact on the environment).

6. Manufacturers should declare the market application environment for which the product is intended. Limits should then be applied as appropriate by the manufacturer based on this declaration. Cross-over miss-application will represent a small issue with little potential for general system disturbance.

7. Limits enacted should be reviewed every 5 years to determine if they are still adequate. Any proposed tightening of the limits must be based on field data from the application environment that is of concern. Initial limits should be considered to be in a trial use phase for the initial 5 year period. At the end of the trial use period, product sectors and utilities should convene to present experiences, new data, and to discuss if adjustments to either limits or covered products are prudent. During this period, utilities, in particular, should instrument consumer, commercial, and industrial regions of their systems at PCCs, substations, and any levels where they anticipate a concern. Only in this way can we attempt to correlate any increasing levels of harmonic emission with field or customer problems that may be reported during the 5 year period. We may

also find that in the intervening 5 year period that product technology, consumer trends, and emerging mitigation technologies may take us somewhere we had not predicted.

Basis for a Rationale

The application of limits should be proportional to the potential impact covered products may have on the local network and utility. “Lighting” equipment covers thousands of products, many of which will have little real potential negative impact. As a result in some cases no limits are applied (products are purposely not covered.) In other cases only a power factor limit is applied since experience indicates that has been sufficient. In other cases both power factor and THD are specified.

Some lighting products are sold predominantly through commercial channels and are unlikely to ever find application in a residence. Hard wired ballasts fo4 240, 277, and 480V operation are good examples of products that are quite naturally limited to commercial and industrial environments. Others could conceivably work in multiple environments but in practice are limited by cost and/or channels of distribution. The later is true even for Europe where the common product voltage is 230V for both residential and commercial products. Residenial customers are still unlikely to purchase and install most commercial products regardless of the fact that the line voltage is the same for both environments.

Other industries should be free to define categories and environments that make sense for their industry, but most product sectors will probably want to consider both aspects when setting limits. While a simple standard is the goal, it must be workable and practical for each product sector, or it will not be embraced. The alternative would be for each product sector to write its own standard to agreed upon over-arching principles. Lighting products cover a wide range of technologies, input powers, applications, physical dimensions, and performance levels- a “one size fits all” approach is inconsistent and not practical. Limits for different product sectors should ultimately be equivalent when the potential for disturbance impact is the same between such products, or where exemptions for similar disturbance and usage factors are granted.

Commercial Environment- General Lighting

Commercial lighting is overwhelmingly energy efficient, being predominantly a mix of fluorescent and HID discharge lamps for indoor area lighting with halogen and incandescent used primarily for retail display lighting. Incandescent is still used where ambiance is important or where precision dimming is required, such as in many restaurants and ball rooms. The majority of fluorescent commercial lighting is operated from ballasts that will meet ANSI C82.11, where THD is required to be less than 32%. In addition, practice is that the vast majority of such ballasts will also operate with power factors greater than the traditional 0.9. Many newer electronic ballasts have power factors that approach or even exceed 0.95. Some very low THD electronic lighting systems are in the 10-15% range with many in the 20% range. Existing magnetic designs are relatively linear but exhibit phase angle displacement of voltage and current unless capacitor corrected, which is typically done within the ballast. Electronic ballasts, which can display current waveforms typically associated with capacitor-diode bridge power supplies either use passive inductors to mitigate harmonic content, or, in come cases, use active power factor correction.

The majority of compact fluorescent lamps (CFLs) are of the plug-in type and are used with dedicated hard wired fixtures and ballasts. Some screw-in CFLs are used, particularly in the hotel/motel industry, where there is an attempt to replace incandescent lamps to reduce energy costs. Where such screw-in CFLs are used they are predominantly low power factor, although some limited number of high power factor units are sold. (These are usually part of a utility incentive program where the utility specifies the power factor.) Compact fluorescent lamps achieve their best overall performance in dedicated luminaires. As a result, the trend is heavily in favor of installing plug-in lamps with high power factor, low THD electronic ballasts as opposed to installing replacement screw-in CFLs with low PF, high THD.

The primary harmonic focus for lighting loads in commercial applications should be where the largest concentrated loads exist. In the US, these are hard wired ballast systems for 120 and 277 volts AC. Some estimates show that approximately 40% or more of ballasts being sold today are for 277 volt applications. A large segment of both the existing and electromagnetic and electronic technologies are coupled directly at the 480V level within commercial structures. This may have very favorable implications for harmonic current immunity as an inherent benefit of US wiring and installation practice. (This is one example of very different practices between the USA and Europe. European commercial systems may be less immune in this respect.)

General lighting products for commercial use represent the most significant potential for interaction with the system since much of the load is already non-linear (electronic) and regulatory pressure to save energy are likely to mandate more use of electronic lighting over the next 5 year period. Such products by their very nature are concentrated loads within commercial facilities. The lighting industry has recognized for decades that the commercial environment benefits from on-board power factor correction. With the advent of electronic ballasts in the late 1980's, the industry also voluntarily developed a maximum THD level that is incorporated in an American National Standard for electronic fluorescent ballasts. Commercial user/specifiers are aware of power factor and THD and already expect a certain minimum level of performance. Certain industry standards and practices already exist and have proven effective in avoiding any issues in this environment. Initial limits should be based on what has proven to be effective.

Fluorescent electronic ballasts for commercial use should have line current THD requirements since lighting can represent 30-40% of the load of many office buildings. Other types of products, such as phase controlled dimmers, should be exempted since the impact is low and the cost to comply would be excessive for such limited impact on the environment.

Commercial environments includes offices, retail stores, schools, institutions (libraries, government building), health care, hotel & motel, and restaurants.

Stage & Studio Environment- Specialty Lighting

Individual specialty lighting products for stage and studio should be for exempted for dimming systems but should be required to implement premises solutions if compatibility levels are exceeded at the point of common coupling (PCC). Stage and studio operation is intermittent in some cases and in all cases is localized by the nature of the application, which makes it ideal for central mitigation if needed. Other general lighting (such as for office areas) would typically be specified to use commercial fluorescent lighting. In the case of very large sports factilities, such as stadiums or arenas, HID is typically employed due to the need for very high lighting levels. PCC requirements for Vthd will require that such lighting systems employ high power factor and reasonably low THDs, both of which are readily available from manufacturers.

Stage and Studio environments include theaters, arenas, stadiums, concert halls, television studios, movie sound stages, that are fixed in location.

Industrial Lighting & Roadway Lighting Environment

Lighting for industrial sites and roadway represent less potential for interaction with the system since lighting is a proportionally small load at an industrial site and is a widely distributed load (not concentrated) for roadway and street lighting. Roadway lighting is largely controlled by municipalities and utilities, and should be the subject of special dialogue between those parties if issues develop. Industrial and roadway lighting is dominated by HID sources which are largely core and coil ballasts. These systems are often corrected to high power factor via capacitors, but not in all cases, especially where space within
some fixtures is very limited.

Industrial and Roadway use includes: Factories, warehouses, treatment facilities, mills, street and roadway lighting.

Residential Environment- General Environment

Residential lighting is predominantly incandescent, which has an almost ideal linear load characteristic. A relatively small number of compact fluorescent lamps are sold into residences, but the current penetration rate is much less than one CFL per household. This market is extremely cost/price sensitive, hence the relatively small penetration of more efficient (but more costly) sources. Dedicated fluorescent fixtures, both CFL and linear, are relegated to certain areas/applications in homes (some laundry, kitchen, bath, and work rooms) but still represent a very small percentage of the total connected load of a residence. Field data indicates that the harmonics from such applications are readily diluted with other loads, and cancellation/attenuation effects are also found as CFLs interact in aggregate with other loads.

As non-linear loads in residences grow over time, it is reasonable to expect some limits to be applied to this environment on a product basis. However, since residential loads are, by definition, distributed, aggregate effects will include some natural mitigation. Products below a specified power level should have no power factor or THD limits. Above a certain power level it ma be reasonable to require at least a power factor limit and a maximum THD limit to ensure that emerging new, lower cost technologies do not create additional disturbance as product proliferation increases. Even European based field studies in residential areas with hundreds of CFLs have not found aggregate harmonic effects to be troublesome, probably as a result of the natural mitigation that has been observed in the US as well. Indiscriminately requiring such products to implement strict harmonic controls, such as active power factor correction, will add significant cost, significantly increase the user price, and greatly reduce consumer product penetration. Cost increases of 50 cents to one dollar are typical with a resultant 4X multiplier to arrive at a final end user acquisition cost. This can raise the end user cost $2-$4, which has heavy impact on a product that is being targeted (before PF and harmonic controls) in the $10-$15 range. In addition, such products are severely constrained by size and thermal management tradeoffs. Adding active PF correction has an adverse impact on product size and power dissipation, which, in turn, reduce product acceptance since larger products fit less places and added dissipation elevates internal component temperatures, which reduces reliability and product life. Some products can manage increased thermals via heat sinking. Integral (one piece) CFLs can only manage thermals via initial efficiency and overall ballast surface area.

The majority of linear fluorescent tube luminaires (which are the most dominant type of fluorescent lighting found in residences today) use a low power factor magnetic ballast. While PF is low, THD is reasonably low as well. Even with low displacement power factor, the current demand is still less than would be required with linear incandescent lamp. The market dynamics drive such products to low cost alternatives. If limits are placed on these products the consumers will revert to less energy efficient products that will increase connected load. This would create a greater demand for power at a time when the US and other countries are trying to implement treaty obligations aimed at reducing green house gas emissions from fossil fuel power plants in order to achieve global climate change committments.

Phase control dimmers are often found in homes, but since they tend to be set at low levels when used, and since cancellation occurs due to the fact that aggregate units are rarely set to the same phase angle, these products have been exempted from coverage in IEC 61000-3-2. This is reasonable given the liklihood of disturbance impact, but such consideration and rationale should also be extended to similarly low impact non-linear loads in residences. Whereas incandescent phase control dimmers can readily operate lamps at hundreds of watts, other loads should at least be exempted below a certain lower nominal power threshold of 75 watts. Below this wattage the addition of PF and harmonic controls adds considerable cost burden, particularly since such products are replaced on a relatively frequent basis. It is similarly unfair to require that consumers pay a “harmonic tax” every time they replace such products.

Residential use includes: Private homes, condominiums, and apartments.

Control at the Point of Common Coupling

For commercial and industrial environments, utilities and manufacturers alike should support a strategy that requires facilities to meet compatibility limits at the interface to the utility, ie, the point of common coupling (PCC). This represents a reasonable way for utilities to minimize potential disturbance to their networks since any anticipated connection must not result in a Vthd that is higher than that set by the utility. Looking backwards into the premise, the utility should not be concerned with the specifics of harmonics within the premise as long as the PCC compatibility limit is not exceeded. Within the premise the effects of harmonics are the province of the building owner/operator, the tenants/occupants, and the manufacturers of equipment connected within the building.

If a given premise cannot meet the compatibility limits, then building owners/operators must seek additional help with internally mitigating harmonic emissions within the structure. This may mean a range of options, all of which are viable, as long as the Vthd is decreased to a suitable value. Some building managers may choose to mitigate in a manner that does not investigate individual product options. Others may choose to look at which product are responsible for generating the most harmonic currents or contributing the most Vthd. Such investigations and remediations, if needed, will eventually drive manufacturers of products and solutions to meet the demands of their customers such that excursions above the Vthd level are minimized. If evidence indicates that products must incorporate active power factor correction in order to routinely enable future premises to achieve PCC compatibility, then products will be developed to meet that need and the standard can be revised to include those requirements.

In Europe, it may not be as easy to get at the true PCC due to differences in connection practice, but it should be possible to come reasonably close. Although European systems do not typically employ transformers at the PCC as do many US and Canadian installations, Vthd levels at the PCC may still be measured closest to the premise of concern. If they are exceeded, it may take additional investigation within adjacent premises to ensure that the right premise is identified for corrective action, but it is still nonetheless possible to identify the premise needing corrective action.

Residences do not lend themselves as readily to PCC control at this time, but that day may not be far off. One can envision reasonable cost solid state harmonic cancellation devices either on residences or on distribution system poles. Some utilities are exploring cost effective means to monitor and bill customers for harmonic content and or PF at the meter interface. When such capability becomes practical this will drive customers to seek out and demand products with low THD or high PF and will result in economic incentives at all levels of the supply chain to produce such products.

Strawman THD and Power Factor Requirements for Lighting

The following charts describe key product/application environments and as well as strawman limit requirements. Environments, covered products, and limit requirements are meant to initiate discussion and are not meant to imply any industry agreement or position at this time. This document is intended to facilitate the development of a US/North American position on this subject that may also form the basis for both national and international requirements for lighting.

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April 28, 1999

GENERAL LIGHTING
COMMERCIAL ENVIRONMENT

Covered Lighting Products	Manufacturer's Rated Input Power (Watts) at Nominal Line Voltage	Power Factor Requirement	Line Current THD (fundamental) Requirement
Indoor, Hard wired ballasts for General Lighting Applications: Tubular Fluorescent, Plug-in CFL, & HID sources	All wattages	0.9 or greater	Less than 32%
Indoor, Hard wired ballasts for task lighting, down lighting, modular office furniture: Tubular Fluorescent, Plug-in CFL, & HID sources	All wattages	0.9 or greater	Less than 32%
Indoor, Hard wired halogen power supplies and halogen power converters for track lighting	All wattages	0.9 or greater	Less than 32%

Point of Common Coupling
Maximum Vthd = 5%
Notes

1. For dimmable or other multiple light level systems, the PF and THD requirements are tested at full rated power and at nominal rated line voltage.
2. All products are tested with lamp loads specified by the manufacturer and at nominal rated line voltage.
3. Point of Common Coupling (PCC) is the point of consumer- utility interface. See IEEE Std 519- 1992
4. Commercial environments include: Offices, retail stores, schools, institutions, health care factilities, hotel & motel, and restaurants.

SPECIALTY LIGHTING
STAGE & STUDIO
ENVIRONMENT

Covered Lighting Products	Manufacturer's Rated Input Power (Watts) at Nominal Line Voltage	Power Factor Requirement	Line Current THD (fundamental) Requirement
Incandescent & Halogen lighting systems, including phase controlled dimming systems, follow-spots, and other stage & studio lighting	All	None	None

Point of Common Coupling
Maximum Vthd = 5%

Notes:
1. For dimmable or multiple light level systems, the PF and THD requirements are tested at full rated power and at nominal line voltage.
2. All products are tested with lamp loads specified by the manufacturer and at nominal rated line voltage.
3. Point of Common Couping (PCC) is the point of consumer- utility interface. See IEEE Std 519- 1992
4. In multiple use facilities, the PCC for Stage & Studio environments may be considered to be at the interface of the Stage & Studio connection to the internal building mains if the utility PCC is shared.

INDUSTRIAL & ROADWAY LIGHTING
INDUSTRIAL & ROADWAY ENVIRONMENT

Covered Lighting Products	Manufacturer's Rated Input Power (Watts) at Nominal Line Voltage	Power Factor Requirement	Line Current THD (fundamental) Requirement
Indoor, Hard Wired Ballasts for General Lighting Applications:	175W and less	0.5 or greater	Less than 32%
Tubular Fluorescent, HID sources	Above 175W	0.9 or greater	Less than 32%
Outdoor, Hard Wired Ballasts for Roadway and Street Lighting: HID sources	All	0.5 or greater	Less than 32%

Point of Common Coupling
Maximum Vthd = 5% (10% if dedicated) to the industrial site

Notes:
1. For dimmable or other multiple light level systems, the PF and THD requirements are tested at full rated power and at nominal rated line voltage.
2. All products are tested with lamp loads specified by the manufacturer and at nominal rated line voltage.
3. Point of Common Coupling (PCC) is the point of consumer-utility interface. See IEEE Std 519- 1992
4. Utility may be responsible for street lighting in some municipalities and own both sides of the interface connection.

RESIDENTIAL LIGHTING ENVIRONMENT

Covered Lighting Products	Manufacturer's Rated Input Power (Watts) at Nominal Line Voltage	Power Factor Requirement	Line Current THD (fundamental) Requirement
Indoor, Medium Screw CFLs and Indoor, Portable Luminaires	Power ≤ 35 watts 35 watts < Power ≤ 60 watts 60 watts < Power ≤ 100 watts Power > watts	0.5 or greater 0.8 or greater 0.9 or greater 0.95 or greater	Less than 200% Less than 80% Less than 50% Less than 32%
Indoor, Hard wired ballasts and power supplies for all lighting applications: Fluorescent, HID, and Halogen sources	Power ≤ 75 watts Power > 75 watts	0.5 or greater 0.9 or greater	Less than 200% Less than 32%

Point of Common Coupling
Note applicable at this time.

Notes:
1. For dimmable or other multiple light level systems, the PF and THD requirements are tested at full rated power and at nominal line voltage.
2. All products are tested with lamp loads specified by the manufacturer and at nominal rated line voltage.
3. Point of Common Coupling (PCC) is the point of consumer-utility interface. See IEEE Std 519- 1992
4. Portable Luminaires are connected to the supply via line cord and plug
5. Hard wired ballasts and luminaires are connected to the supply via direct connection- ie, are considered permanently installed.

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1 Introduction

Loads connected to electricity supply systems may be broadly categorized as either linear or nonlinear. Until quite recently, the vast majority of loads have been linear. Examples include induction motors and incandescent lamps. Linear loads may exhibit high or low power factor, but in either case draw current only at the powerline fundamental frequency. In contrast, nonlinear loads such as rectifiers or switchmode power converters also draw significant current at harmonic frequencies. Harmonic currents flowing through electric power supply systems cause voltage distortion. Voltage distortion caused by growing penetration of nonlinear loads has in many cases been accommodated without serious consequences, but in other cases mitigation steps have been required to avoid compromised power quality.

Control of lower order powerline harmonic emissions from nonlinear loads is a serious issue that requires cooperation between utilities, equipment manufacturers, premises owners, and end users. Utilities desire to prevent problems by restricting emissions from products and/or utility customers connected to the public supply network. Equipment manufacturers desire to keep overall product costs low for the consumer and prefer supply system modifications or local mitigation when required. End users want low cost, high performance, and trouble free operation.

Different approaches are under consideration. One approach, typified by IEEE Standard 519, seeks to control emissions at the interface between facilities and the public distribution system. Another approach, typified by IEC/EN 61000-3-2, focuses primarily on controlling emissions at the product level. Utilities and manufacturers need to agree on the existing level of concern, the potential for future problems, and the most effective methods of controlling harmonic emissions.

This position paper is a direct result of the efforts to reach mutual understanding and consensus between electric utilities and equipment manufacturers. The United States offers the following guiding principles for consideration as a way forward that can be the accepted international approach for managing harmonic emissions. These guiding principles would then be used to develop detailed strategies and requirements for both residential and commercial applications and for specific product sectors.

2 Guiding Principles for Harmonic Limits

2.1 Minimum overall cost to society

All costs associated with harmonic emissions are ultimately born by consumers. Emission control requirements, including guidelines and standards, should strive to minimize the overall cost to society while providing both needed flexibility for product design freedom and the ability for utilities to maintain acceptable electric power quality.

This generally necessitates a sharing of mitigation responsibilities. Minimum cost to society best serves the interest of all parties even when one party bears a larger portion of the cost. Minimum cost to society maximizes the benefit for all provided that neither the power distribution network, installation premises, nor the product designs are constrained for satisfying other important customer requirements (e.g., minimum size, weight, component recycling, electric supply quality, etc.)

2.2 Minimal regulatory interference with free market mechanisms

Regulations should promote free market mechanisms and promote free trade. They should not create trade or market barriers.

2.3 Equal opportunity for all affected parties

All affected parties must have equal opportunity to participate in the establishment of the limits.

2.4 Limits based on objective data

Any decision to limit emissions and selection of limit values must follow from proper use of objective data. Factors that should be considered include power level, actual or expected market volume, usage patterns, efficiency, and emission properties.

Electric utility and building electric power network properties must also be considered. These properties include but are not limited to system impedance, network topologies, attenuation, cancellation, and dilution.

Application of limits is appropriate in two situations:

1. Statistically valid field data documents the existence of voltage distortion problems that may be attributed to harmonic emissions from identifiable product classes.

2. Models that correlate with statistically valid field data predict future problems for electric supply quality if identifiable product classes are deployed in the system.

2.5 Simple compliance test methods are preferred

Simple tests are less expensive and promote enhanced reproducibility and repeatability. Simple tests are also easier to verify and provide a lower total cost to society. Simple tests allow more flexibility, innovation, and creativity in product design while satisfying all compatibility objectives

2.6 Targeted application

Harmonic limitations on products should consider the power consumption, duty cycle and the quantity of those products that will be connected to the supply system. Low power products and products with only a small quantity of units in service may not need any limits. Requirements should begin for products whose power consumption and expected quantity in service reach levels at which problems are reasonably anticipated via statistically valid field data establishing a definitive trend. More stringent requirements may need to apply to products with greater impact.

The anticipated conversion of higher power loads from linear to electronic control is likely to convert these loads from linear to nonlinear and poses a larger threat to supply systems. Setting appropriate limits today for higher impact products will prevent unacceptable future designs without the burden of redesigning existing products. Further, harmonic control for some of the larger power loads may have an acceptable cost/price premium when compared to very low power, very low cost products.

2.7 Gradual implementation

Initial requirements should reflect the fact that present problems on utility grids due to distributed harmonic sources in residential and commercial are minimal. Some products have been present for many years, and they operate without significant negative impact on the electric power supply system. These products should be exempted from initial requirements. Examples might include selected consumer electronics, small appliances, information technology equipment, and some lighting products.

Requirements should also consider the fact that some products become obsolete in a very few years. It is not necessary to redesign existing products with inherently short product life cycles. Requirements for short life cycle products can be adjusted as needed in the future.

3 Rationale and Areas of Mutual Understanding

3.1 Utility supply voltages are presently within compatibility limits

Measurements around the world have shown the supply voltage distortion at the point of common coupling is below levels of immediate concern. Some studies show a slow increase in distortion, however the levels are still acceptable. The utility supply system has generally been able to accept the present amount of nonlinear loads without widespread, significant problems. Most problems to date have only been with highly concentrated, high power nonlinear loads and have been mitigated with local solutions.

3.2 Nonlinear load currents can cause problems

Nonlinear loads of sufficient size and quantity can cause problems in electric supply systems. The severity of problems depends upon the local and regional supply characteristics, the size of the loads, the quantity of these loads, and how the loads interact with each other (factors like harmonic cancellation, attenuation, and dilution).

Utilities are clearly concerned about future problems from increased concentrations of nonlinear loads that will result from the growing proliferation of electronic equipment. Experience shows that higher concentrations of nonlinear loads tend to increase the number and severity of supply problems. Problems from high concentration of nonlinear loads in industrial systems are well documented. In the U.S., information technology manufacturers under the guidance of the Information Technology Industry Council (ITIC) recognized localized potential problems at the installation facility level. Since 1988, information technology manufacturers have held workshops and issued guidelines to inform their customers about proper building facility wiring requirements to accommodate these types of nonlinear loads. The National Electrical Code guidelines address building wiring requirements for nonlinear loads.

3.3 Interaction between loads needs adequate consideration

In general, it is known that that emissions from nonlinear loads do not add directly. Higher order harmonics are much less likely to be additive than lower order harmonics. Cancellation by selection of transformer connections is a common strategy in U. S. industrial loads. Hence, simulation model parameters must adequately account for cancellation and attenuation between loads.

For example, distributed nonlinear loads in residential and some commercial installations account for a small percentage of today's total load. Market research shows that about 80% of the total residential load is linear. Linear loads absorb harmonic currents from localized nonlinear loads in a way that tends to reduce voltage distortion below levels that would be expected if these effects are not considered. This is one reason why supply systems have not experienced widespread problems from distributed nonlinear loads.

3.4 Harmonic limits should reflect product impact on the power distribution system

A survey of U.S. based Edison Electric Institute member utilities shows greater concern for larger loads and support for more stringent THD limits at higher power levels. Some loads are insignificant when compared to the total load, and the same survey shows little concern for low power loads. This fact should influence the development of limits and may affect certain product industries more than others.

3.5 Harmonic control at the customer-utility interface is effective for industrial and large commercial loads

U. S. utilities have good experience with IEEE 519 Recommended Practice for industrial and large commercial loads. These customers understand harmonics and can deal with them internally. IEEE 519 allows these users to implement a variety of local harmonic control strategies. Building owners have demonstrated a willingness to use special wiring techniques for concentrations of information technology equipment. Acceptance of National Electrical Code wiring requirements reflects this willingness. Industrial supply designs often include phase shifting designs for harmonic cancellation.

3.6 Growth of distributed residential and commercial nonlinear loads is a greater concern

Residential and small commercial customers are generally unable to understand harmonics. They are less able and less likely to take responsibility to solve harmonic emission problems. Thus, product harmonic limits for these markets may be more important, especially for high power, high volume products.

3.7 Some product industries with high load concentrations already have effective voluntary limits

The lighting industry in the U.S. voluntarily developed and implemented harmonic limits for commercial electronic ballasts. These limits have been instrumental in the development of electronic ballast technologies that require no more harmonic current than the traditional magnetic ballast technology. In fact, many, modern electronic ballasts have lower emissions than the ANSI C82.11 standard and have lower emissions thantraditional magnetic ballasts. Lighting accounts for nearly 50% of commercial energy use, and these limits have effectively prevented problems. It may even be possible that conversion to electronic ballasts will slightly reduce harmonic levels on distribution systems.

The electric vehicle battery charging industry is working in cooperation with utilities to establish harmonic limits. Also, other product manufacturers are adopting low harmonic, high power factor designs for non-regulatory business reasons. For example, some manufacturers choose high power factor designs to deliver maximum available power to a load when restricted by power cord ratings, fuse limitations, or circuit breaker size.

3.8 Simplified method for specification of limits and compliance testing

Either of the following two methods should be sufficient to address product emission limits when required.

1. The first method uses combined limits on power factor and Total Harmonic Distortion (THD). This method of specifying limits allows adequate differentiation between true power factor and harmonic emissions.

2. The second method uses combined limits on individual low order harmonics and THD. Individual limits may only be necessary for harmonic orders up to 15 and would be set to prevent unacceptably high emissions at any single frequency. This method allows one or more individual harmonic emissions to exceed expected levels provided the THD limit is met.

Several otherwise adequate power factor correction circuits fail because they slightly exceed one or a few individual limits. For example, some of the high power factor electronic ballast designs may fail on an individual harmonic limit even though field experience has shown they do not cause problems. More flexibility is needed. It should not be necessary to satisfy precise, individual harmonic current limits out to the 39 th harmonic.

3.9 Overly complex requirements prohibit acceptable solutions without adequate justification

Some existing and proposed harmonic standards and tests inappropriately constrain equipment designs and impose unnecessary costs. This prevents otherwise satisfactory designs from ever reaching the market.

3.10 Local harmonic current control is preferred

High reactance in medium and high voltage (MV, HV) systems makes it very difficult to supply harmonic currents over long distances and through step-down transformers. Further, maintenance of high power factor in these systems creates a variety of resonance conditions that are difficult to manage. Thus, it is generally more practical to control harmonic currents within local environments such as individual building wiring systems or within products. One method for local harmonic control utilizes passive and/or active harmonic filters. These filters may be placed at the point of common coupling or distributed throughout the low voltage wiring systems. Another method is phase displacement by special transformer winding connections in building wiring systems. It is also possible to control harmonics by using products or product systems with low emissions.

4 Conclusion

By cooperation between standards bodies, equipment manufacturers and electric power suppliers, it should be possible to reach a consensus on control of powerline harmonics that makes sense both economically and technically. A stable and clean power system is in everyone's best interest; however, that objective should not be achieved by the application of harmonic limits on products where there is little or no valid field data for supporting them. Unless a consensus is reached based on data and reasonable compromise, an unjustified economic burden on the consumer is likely to be the result.

5 References

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Working group membership at the end of the meeting:

Name	Company	Parent co./ org representd	Voting Status	Interest cat.
Andre Broucke	ADB - TTV Technologies	Siemens	O	P
Doug Kraus	Advanced Devices, Inc.	Advanced Devices, Inc.	P	P
Bud Toly	Advanced Devices, Inc.	Advanced Devices, Inc.	A	P
Louis Bradfield	Bally's Las Vegas	Louis Bradfield	I	U
Tim Bachman	Barbizon Light	Barbizon Companies	P	U
Ron Dahlquist	Dadco	Dadco	P	
R. Bruce Prochal	I.A.T.S.E. Local 728	I.A.T.S.E. Local 728	P	U
Edwin S. Kramer	IATSE, Local 1	I.A.T.S.E. Local 1	P	U
Jose J. Flores	Kino Flo, Inc.	Kino Flo, Inc.	P	P
Mitchell Stein	Leviton Manufacturing Co., Inc.	Leviton Manufacturing Co., Inc.	A	P
Bob Luther	Lex Products Corp.	Lex Products Corp.	P	P
Ken Vannice	NSI Corporation	Leviton Manufacturing Co., Inc.	P	P
Tim Cox	PLASA	PLASA	P	G
Steve Terry	PRG Lighting Division	PRG	P	U
George Sabbi	PRG Lighting Group	PRG	O	U
Robert Barbagallo	Proximo Inc.	Proximo Inc.	P	G

Name	Company	Parent co./ org representd	Voting Status	Interest cat.
Paul F. Mardon	Pulsar Ltd.	Pulsar Ltd.	P	P
Mitch Hefter	Rosco/ Entertainment Technology	Rosco Laboratories	P	P
Eckart Steffens	SOUNDLIGHT	VPLT (SOUNDLIGHT)	P	G
Andy Topinka	Technical Group Services, Inc.	Technical Group Services, Inc.	P	G
Colin Waters	TMB Associates	TMB Associates	P	P
Brian Dowd	TMB Associates (NJ)	TMB Associates	A	P
Richard Wolpert	Union Connector Company	Union Connector Company	P	P
Bruce Whitehead	Whitehead Engineering Services	Whitehead Engineering Services	O	G
Peter Brooks	Zero 88 Ltd.	Zero 88 Ltd.	O	P

Voting Status

P Principal voting representative for a company or organization
A Alternate voting representative for a company or organization
I Individual representing no organization other than himself or herself
O Observer; non-voting

Interest Categories

P Producer (manufacturer) of electrical power devices or products
U User of electrical power devices
G General interest in electrical power devices