RaneNote 121

RAP – Remote AC Power: An Idea Long Overdue

- **Hum Suppression**
- **Safety Agencies**
- **Performance Comparison**

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INTRODUCTION

RAP is an acronym standing for **R**emote **A**C **P**ower. RAP means remote power supplies. It means two pieces, where before you had one. RAP simply takes the transformer from inside the box and puts it outside the box. Call it a remote power supply. Call it an AC adapter. Call it a desktop power supply. Call it an external power supply. Call it a three-letter word: Call it RAP.

The idea for RAP grew out of the recognition that power supplies for truly professional audio signal processing equipment should be remote. They should not be in the same box with audio. Fifty years ago we got off on the wrong foot and have been stumbling about ever since. Everyday we pay the price for beginning wrong and not fixing it. The aim of professional audio products should be maximum performance, not maximum convenience. Maximum performance should be what separates professional audio products from consumer audio products. Yet the very best consumer products offer remote power supplies for that last percent of perfection, while most mainstream professional audio products do not. Only the top-of-the-line mixing consoles recognize power supplies must be remote to get maximum performance.

To make remote power supplies more palatable to the end-user, there should be an international standard specifying the voltages, connectors and wiring. All signal processing equipment would then have the same power jack and run off the same voltages. And instead of several remote power supplies, one central unit power supply would run everything through flexible cabling. Eventually, power supplies would become accessories, just like cables are today. In 1988, Rane took the first steps to make this a reality.

Due to Rane's efforts, members of the pro audio industry has been meeting and discussing such a standard since April, 1988. Later that year, the Audio Engineering Society (AES) created a Working Group to draft a standard. This Note discusses progress of the Working Group and presents Rane's decision to proceed with remote power supplies for most of its product line.*

BACKGROUND

In 1986 Rane began incorporating provisions for optional remote powering of its products[1]. Next, Rane called upon the professional audio industry to recognize the merits of remote power supplies, and to seek ways to standardize them[2,3]. RAP represents what we learned these past years.

Before getting into the details of RAP, we should discuss the need for remote power. Two quite different factors: performance and safety, dominate the case for remote power supplies.

PERFORMANCE

That audio products improve without hum sources in the box is self-evident; yet, a little review of the basics cannot hurt.

Hum Basics

The main ingredient of internal power supplies is the transformer used to step the AC line voltage down to usable levels for audio. This transformer operates by converting electrical energy into a magnetic field used to regenerate electrical energy at lower levels. The magnetic field is a strong source of either 50 Hz or 60 Hz hum. (50 Hz hum fields are much worse, which explains why the same audio products are quieter in 60 Hz countries.) Rich in odd-order harmonics, this field easily induces hum into sensitive audio lines (discrete or printed circuit) unless extreme (read, expensive) measures are taken to reduce this phenomenon.

Hum Suppression

Common techniques include using special copper bands around the transformer, installing special mu-metal shielding cans over the transformer, or going to expensive toroidal designs to reduce the spread of the magnetic field. All adding significantly to product costs.

If not contained, these hum field components leak into otherwise pristine audio to reappear as audible hum within the noise floor. Since these components are periodic, the ear is excellent at picking out and focusing on their repetitive nature within the noise. All high-gain microphone preamp stages, all summing nodes, and all high impedance points along the audio path are vulnerable to magnetic field induced hum.

Hidden Hum

Experienced audio designers learn many techniques to reduce these effects and get very impressive performance specifications. And experienced audio marketing people learn many equally valuable techniques to *hide* whatever small residual effects remain after being released to production.

Such as specifying the noise of graphic equalizers with all the sliders set flat. For it is when the sliders are in use that the equalizer is vulnerable to picking up radiated hum components from the transformer, not when set flat. (Which is why Rane also specifies its equalizers with the sliders positioned at their extremes.)

Tricks like using A-weighting to roll-off the hum components before measuring noise. Things like specifying mic stages with input referred noise (Equivalent Input Noise), instead of total output noise. Things like specifying compressors, limiters, and gates with all dynamics turned off.

These things account for why one product *sounds* quieter than another, yet they have identical noise specs. The difference is one has hum components mixed with the noise and the other does not. The ear syncs into the repetitive nature of the hum and finds it much more objectionable than random noise of equal magnitude.

Ho Hum

You must understand that this discussion concerns very *small* amounts of hum. What my old boss used to describe as "picking fly droppings out of pepper."

Making good better, and making excellent superlative — that is what remote power supplies are all about. Improving already excellent products is the goal, not fixing unacceptable designs. Nothing short of absolute perfection is acceptable. Power supply transformers are a major detraction from that goal. So, you get rid of them. You move them outside the box.

SAFETY

"Protecting" public safety has become very big business, with hundreds of millions of dollars at stake. (In 1994, Underwriters Laboratories grossed $281 million in revenue and posted $17.1 million in profits[5].) Safety agencies have a job to do, but they also have a job to protect. As a result, we see more mandatory safety agency compliance, not less. In the US, the number of audio contracting jobs *requiring* UL listing grows at an alarming rate. Outside the US, it's become a weapon.

Safety compliance, in its essence, is not really very difficult. Any safety agency's main concern in electrical products is shock hazard. Shock hazard is confined to safety concerns of the line (mains) connected AC primary circuits. Remove the AC primary circuits from the box and you remove the shock hazard. Remove the shock hazard and you remove the need for compliance. That is the essence of RAP.

UL, NRTL and JAIL

In the United States, failure to have products listed by a "Nationally Recognized Testing Laboratory" (NRTL) is a crime in some jurisdictions — a **crime,** not a civil matter, but a **criminal** matter. On the federal level it is OSHA (Occupational Safety and Health Administration) that most directly affects audio makers. Congress gave OSHA exclusive jurisdiction to ensure the health and safety of workers *wherever* they may work — private industry, private schools, private churches, private recording studios, etc. In 1981, the agency adopted regulations requiring all equipment that uses electricity to be listed. OSHA Regulations, Section 1910.399, state "Electronic equipment is acceptable … if it is … listed … by a Nationally Recognized Testing Laboratory …." Use of equipment in the work place that is not "acceptable" is a violation of federal law and subjects the user to a broad range of penalties[4]. Very powerful lobbying.

**See Note on last page.*

Canadian Standards Association (CSA)

In Canada, nearly all Provinces require equipment to be CSA certified. The Saskatchewan restrictions are typical. They totally ban the sale or use of equipment not CSA certified. Penalties include fines, recalls, or imprisonment. And in Europe, things are really beginning to boil.

Harmonization's Ugly Side

Now that the European Communities (EC, i.e., Common Market) harmonization is in effect, many people forget that the whole reason for harmonization is to create one large European market. A market with few *internal* walls, but with very strong *external* walls. Where possible, the aim of harmonization is to make it easier for EC members, and harder for outsiders, namely the United States and Japan, to sell products *within* the EC. The lesson here, is don't confuse a "common market" with a free market.

Low Voltage Directive

Sometimes making it easier for one must make it easier for the other. An example is the *1973* (this is not a misprint; it's an indicator of just how long harmonization efforts have been going on) "Low Voltage Directive" that unified the product safety standards for electronic products throughout the 12 member EC (Great Britain, France, West Germany, Belgium, Netherlands, Luxembourg, Spain, Portugal, Italy, Greece, Denmark and Ireland). The Low Voltage Directive, designated 73/23/EEC, acknowledged that the product safety requirements of some governments of the EC had become "repressive" and had to be eliminated[5].

Among the repressive requirements was the need for equipment to receive the national mark of each country to be sold. Also, the standards would no longer be drafted by the individual countries, but would be chosen by the Common Market itself. This resulted in one common safety document (EN60065 for audio products), and all members of the EC must accept each other's safety marks. So, for example, VDE works in Great Britain, and DEMKO works in Luxembourg, etc.

To U.S. manufacturers, this means that compliance in one country, means compliance in all countries of the EC, plus Switzerland and Norway. (Expect other countries to agree to the common product safety code as harmonization spreads.) That is one side of the coin — the good side. The other side of the coin is that compliance with the requirements established by IEC 65 (now referred to as EN60065) is mandatory for all products entering into EU after 1/1/97.

Punitive Safety, or No Pay, No Play

Mandatory safety agency compliance too often becomes a de facto trade barrier preventing otherwise high quality products from being used or available to customers or contractors. For example, in the United States if UL is required, only Japanese and a few US and foreign products qualify. They are the only ones who can afford the UL process. Small companies simply do not have the resources to get compliance with multiple agencies (UL, CSA, VDE, etc.) for multiple products. For example, in Rane's case, for, say 30 products, this would entail over 90 separate filings and compliance records. The cost would amount to more than $350,000 and the total time required would approach 10 years!

And that is not the bad news. The really bad news is that, too often, these safety agencies have conflicting requirements. What satisfies UL will not satisfy CSA, and so on, so you must build *separate* products for each safety agency. The limited resources of most audio companies, and the total available sales volume in most foreign countries simply does not allow building separate products.

Only the largest audio companies (read, mostly Japanese) can afford to do business in this manner. Many smaller American audio companies will be forced to withdraw from international markets, and try to survive on what non-UL business exists in the US.

Bleak? You bet it is.

Compliance Exemption

Enter remote power supplies, to save the day.

Remote power supplies may represent the survival of the small entrepreneurial audio company in America and elsewhere. *By using remote power supplies, and sizing them correctly, all products powered by them become as exempt as possible from safety agency compliance.* Only the remote power supply itself must comply with each safety agency. With proper design, the number of products requiring compliance reduces to 2 or 3. This is manageable by any audio company.

The hedging ("…as exempt as possible…") recognizes the reality that any government agency can require safety agency markings on anything they so choose. Even if something runs off a 9 V battery, they can argue it could be a fire hazard and demand compliance. There are never any guarantees when dealing with governments. But the use of approved remote power supplies makes compliance simple, fast and economical.

REMOTE POWER SUPPLIES

Beginning in 1989, improving performance and providing instant safety agency compliance caused Rane to adopt remote power supplies for all new products, and to convert many existing products. Instead of waiting for the AES to agree on a standard, Rane chose to move ahead and provide their customers with all the benefits of remote power.

AC Power

Today Rane uses RAP for remote power. This differs from what was described in the now discontinued *Rane Note 118,* "Remote Power System," and sold as the RS 10, Remote Power Supply. RAP is remote **AC** power; the RS 10 is remote **DC** power — big difference.

Rane's early efforts in remote power supplies centered on DC systems. Most of Note 118 is still valid, and RS 10 based systems work perfectly; but, we have learned DC's limitations. We have learned there are easier ways. Ways that allow more freedom in mixing manufacturers and different wiring techniques for complex professional audio systems. Our work in chairing the AES Working Group and our own experience taught us the superiority of distributed AC systems over DC systems regarding ground loops.

Adopting AC is similar to simply removing the existing power transformers from within the units and collecting them together remotely in a common box. This box may contain one transformer, like our RS 1, or it may contain 5 transformers with 10 separate secondaries, like our RAP 10. If each power transformer has isolated secondary windings, then each unit powered has its own isolated ground system.

RAP supplies also allow us to use simple AC doubling techniques for generating higher voltage levels when required, without having to resort to expensive DC-to-DC converters. And adopting AC makes for simpler, more cost-effective external supplies.

Voltage Level

The AES Working Group's choice of voltage level occurred after a study of international safety regulations for professional audio products. A cross section of countries investigated found the maximum voltage permitted before requiring safety compliance. Table 1 shows the results of this study.

At least half the countries studied feel that a risk of shock occurs with exposure to greater than 42.4 volts peak (30 volts RMS). The other half defines shock hazards at lower voltages. And there are obvious contradictions. For instance, Table 1 shows that while Italy and the U.K. are members of the EC and legally bound to the tenets of Low Voltage Directive 73/

Table 1. Maximum voltage levels allowing greatest exemption from safety codes.

Country	Vpeak	VACrms	Comments
U.S.A. (UL)	42.4	30	Class 2
Canada (CSA)	42.4	30	Class 2
Japan (JET)	42.4	30	
Swiss (SVE)	42.4	30	
W. Germany (VDE)	42.4	30	VDE SELV Definition EC Member
Australia (SECV)	70.7	50	
Italy (IMQ)	100	34	EC Member
Denmark (DEMKO)	50	35.4	EC Member
Finland (FEMKO)	42.2	29.8	
Norway (NEMKO)	42	29.7	
Sweden (SEMKO)	35	25	
U.K. (BSI)	34	24	BS415 (IEC 65) EC Member
Dir 73/23/EEC	75	50	Low Voltage Directive
IEC 65*	34	24	CENELEC** Safety Standard Covering Audio

* IEC 65, entitled "Safety Requirements for Mains Operated Electronic and Related Apparatus for Household and Similar General Use, is the approved Harmonization Document (HD 195 S3).

** CENELEC is the European Committee for Electrotechnical Standardization. (1989 Data)

23/EEC, they differ widely on the required voltage for compliance. And look at the differences between the Directive and IEC 65. The Working Group decided upon two remote power supply voltages. One, aimed at low voltage products, would be 9 VAC RMS. The other would be the best compromise for worldwide acceptance. Therefore, since Europe was more restrictive than the United States, it would decide the voltage level. Further investigation revealed that IEC 65 was the controlling harmonization document, and that any disagreements between IEC 65 and any EC member country must be resolved. All of which boiled down to 24 VAC RMS being the maximum voltage allowable in any product for the greatest exemption from worldwide safety codes.

Based on this input, the final voltage level picked by Rane was 18 VAC RMS. This allows worst case high AC line conditions, combined with light load situations, never to let the voltage level exceed 24 VAC. This voltage level is low by professional audio standards and required a complementary decision that all Rane RAP products incorporate regulated voltage doublers to create the necessary headroom demanded by our products.

All Rane RAP products qualify worldwide as Safety Extra Low Voltage (SELV) units. They pose no shock hazard at all.

Connector

Once you accept the need for RAP, the hardest and most controversial aspect becomes connector choice. The AES Working Group favors, and Rane uses, telephone style modular connectors.

Three problems head the list of what is wrong with the connectors in use today (mostly barrel and mini-phone jacks):

1. They do not lock.
2. They are prone to shorting (either during the act of plugging them in, or just by having them dangle and touch something).
3. There is no interchangeability between manufacturers adapters

After a painstaking search, Rane concluded the modular series developed by AT&T was the best choice. These connectors offer the following advantages:

1. Keyed and locking design.
2. Pins fully protected against accidental short circuits.
3. Small size.
4. Inherently strain relieved.
5. Very economical.
6. Multi-sourced from many manufacturers.
7. Extremely reliable.
8. Field repairable.

All currently used connectors fail the first two critical criteria. Alternative proposals tended to fail 1, 3 and 5. Only the modular connector satisfied *all* these requirements. On reliability, AMP Corporation applications engineers agree that the telephone modular connector is one of the most tested and approved connectors ever developed. When AT&T develops and approves something for consumer use, it is reliable.

Addressing the obvious question of potential telephone/audio equipment wiring mix-ups was a major concern of RAP. In the end, simply using red mod jacks, with a special RAP logo (Fig. 1) silkscreened around them, reduced all telephone confusion. Further precautions dictated a wiring convention (Fig. 2) that prevents potential damage resulting from inadvertent telephone equipment hook-up.

Selecting the 6-pin connector for the 18 VAC designs (and the 4-pin handset connector for 9 VAC use), further improved the power handling, performance and reliability. Using the 6-pin version allowed parallel pins and wiring for each side of the transformer and center-tap lead. Figure 2 shows this arrangement.

Addressing the Negatives

Remote power supplies have been around for a long time; long enough to have earned a bad reputation. Most complaints boil down to these:

The remote power supply unit must plug directly into the wall or an outlet strip. Doing so, covers up other AC outlets, preventing their use.

The connecting cable is too short to reach the unit from where you want to put the outlet strip.

There is no way to mount the power supply securely so it will not become disconnected or damaged.

Rane's RAP supplies address each of these complaints in a simple and straightforward way: Rane's units are a desktop design, with a 6 foot AC mains line cord out one side, and a 6 foot low voltage cable out the other. And each power supply comes complete with integral mounting ears.

Now you are free to mount a RAP supply almost anywhere you want to, without covering any AC outlets. Typically, RAP supplies securely mount to the side or bottom of the equipment rack. This makes for a neat, out of the way location with all wiring bundled and tied. Larger installations get even easier by using the RAP 10 Remote Power Supply to eliminate several individual RAP units altogether.

Terry Pennington, Rane's MIS Director, refers to the RAP supply as "the fat spot in the line cord." Looked at from this view point, it's no big deal. You mount it once, and forget it.

Hum Avoidance

Mounting RAP supplies requires common sense. Since they are nothing but a hum producing transformer, mount them far away from sensitive high gain inputs. Locate them near AC outlet strips, or power amplifiers (another source of large hum fields), or together off in a corner. Avoid putting them near microphone inputs, mixers, and other small signal processing devices. Mount them as far away from audio lines as possible. No need to get paranoid about it, just use common sense.

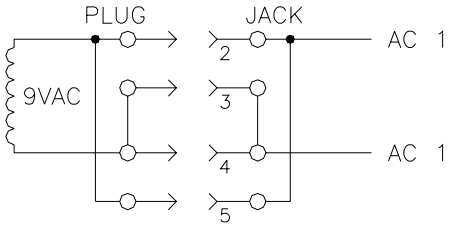
(a) RAP–4 Logo

(b) RAP–6 Logo

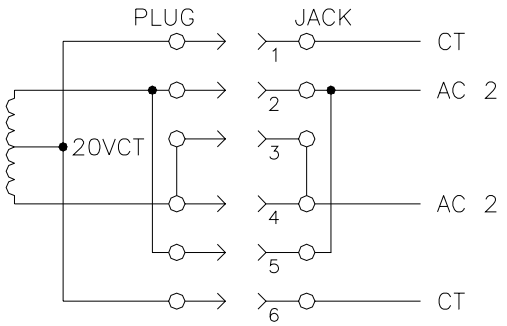
Figure 1. RAP Logos

PERFORMANCE COMPARISON

Converting an existing product to a RAP product results in varying performance improvements. Some products benefit more than others. Performance improvement stems from the lack of hum fields within the unit. Removal of these hum fields improves the noise and distortion performance of RAP products. The improvement in distortion results from the reduction of the noise floor. Since distortion is measured as total harmonic distortion plus noise (THD+N), reducing noise also reduces distortion. Most other parameters of RAP products remain as before.



(a) RAP–4 9VAC wiring.



(b) RAP–6 20VAC W/CT wiring.

Figure 2. RAP Wiring Convention

RAP graphic equalizers benefit most in their cut noise performance. Flat and boost figures remain about the same. It is always annoying to experience an increase in noise when using sliders to cut the signal. Intuition says if you are reducing levels through the equalizer, the noise should reduce, not increase. Well, most equalizers exhibit a degrading noise performance with increased cutting of their sliders. Partially, this is due to the antenna effect produced by having all sliders tied together along the front panel. This forms a loop-antenna of sorts, and moving the sliders from their center-detent positions allows them to pick-up magnetic hum produced by the transformer. Hum picked-up from boosting usually gets masked by the larger signal level. Hum picked-up when cutting stands out from the reduced signal level. RAP graphic equalizers do not suffer from the malady.

As an example of this phenomenon, let's examine the GE 30 before and after RAP conversion (see Table 2). For proper perspective, remember the GE 30 is a leader the world over among active graphic equalizers for noise. It is among the quietest active equalizers ever designed. Against this background, the performance advantages provided by RAP are startling. Performance of this magnitude was previously only possible from passive equalizers.

As expected, we see a couple of dB improvement in the flat settings. The 4 dB increase in signal-to-noise for full boost and maximum gain is good, but nothing compared to the full cut improvement. The RAP GE 30 is over 15 dB quieter when used in the Cut Mode. We think that's worth a little inconvenience in mounting an outboard power supply.

Another dramatic improvement happened with the RAPping of the HC 6 Headphone Console. This box demanded the extra current of a model RS 2 remote supply. The signal-to-noise ratio improved by 16 dB in Channel 1! The rest of the Channels improved by 6 dB or better. Simply because the transformer was located next to Channel 1. Now all Channels are equally quiet.

Some dramatic improvements do not show up on the data sheet. An example is the SM 26B. The Mono Outputs of the SM 26B have always been quiet (96 dB re +4 dBu), but the Mix Outputs have always had a tendency to pick up transformer and AC line hum. Over the years we have improved this by adding a metal shield can to the transformer and routing the signal path differently, but it has always been a fight. And when used in 50 Hz countries, it is always worse. Still very quiet, but not as quiet as we would have liked. Then we converted it to RAP. Now the Mix Outputs exhibit at least 95 dB signal-to-noise ratio for unity gain settings, and over 82 dB with all controls set for maximum gain. These figures are at least 6 dB better than without the outboard power supply.

Some products show no measurable improvement at all. This is the case with the DC 24. It was so extraordinarily quiet before, that no further improvement is practical.

The AC 22 and AC 23 Active Crossovers are similar, with one exception. The exception is the 230 VAC, 50 Hz units. In these units the overall noise is down about 10 dB for the Ch. 1 Low Output. Not surprisingly, this is the output closest to the power transformer. All other outputs show little improvement. Again, over the years we had to add transformer shielding with other separate shields to hold performance.

Now, all cans and shields are gone and the low noise performance is repeatable, predictable and the lowest we have ever measured.

RAP, RAP, RAPPING UPON MY DOOR

So there you have it: RAP, an idea long overdue. The only price is having to mount a small power supply using the supplied hardware. The benefits range from being essential to the recording studio producing digital recordings; to being absolute to the commercial sound installer, who is no longer prevented from using Rane because of National or local safety codes.

Here's to the "fat spot in the line cord" — a small inconvenience, a large benefit.

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DISSOLUTION OF AES WORKING GROUP ON POWER SUPPLY INTERFACING*

The AES Working Group grew out of an ad hoc committee started by Bob French (Ashly) and Jim Furman (Furman) at the April 1988 NSCA Expo in Reno, with representatives from ART, Ashly, Furman, Rane and Symetrix attending. During the summer of 1988, research was carried out to determine the maximum voltage level allowable to power commercial audio products (country-by-country) before requiring compliance with safety agency codes.

AES Working Group Formed

The results of this study made it clear that all audio products would benefit from remote power supplies – both in performance and safety. In August 1988, the ad hoc committee agreed to form an AES Working Group on remote power supply standardization. The first meeting was held during the November 1988 AES Conference in Los Angeles. By that time, over 20 companies were on the mailing list, expressing interest in standardizing remote power supplies. Representatives attending the November 1988 meeting were from ART, Ashly, Crown, dbx, Furman, Korg, Lexicon, Rane, and Shure.

At this meeting, a formal proposal was handed out for study and discussion. Over the next several months, revisions were made to this report, loosely referred to as the RAP (Remote AC Power) proposal.

A revised version circulated in February 1989 to official representatives of 25 companies for comment, solicited only one response. A draft proposal was then drawn up and submitted to the AESSC (AES Standards Committee) in July 1989. Along with the proposal, went the results of balloting all interested parties. Of 23 companies responding, 16 companies (70%) favored the proposal, while seven companies (30%) rejected the proposal.

Draft Proposal Summary

Remote power voltage would be alternating current (AC). There would be two levels: level 1 would be 9 VAC single-ended, and level 2 would be 20 VAC with center-tap connections.

The connectors would be telephone style modular plugs. Level 1 would use the 4-pin handset modular plug (AMP no. 641334, or equal) with parallel pins and wire for each side of the 9 VAC supply. Level 2 would use the 6-pin RJ-12 modular plug (AMP no. 641337, or equal) with parallel pins and wire for all three connections of the 20 VAC with center-tap supply. An alternate proposal would use the offset version of the 6-pin plug to prevent telephone miswiring. All connector plugs and matching jacks would be color-coded red.

All plug and jack wiring was specified (as much as possible) to prevent any damage to or from any telephone equipment inadvertently miswired into these connectors.

A unique identifying logo was specified to be silk-screened around the red modular jack as a further preventive measure against any possible telephone confusion.

Disagreements With Draft Proposal

Of the seven companies disagreeing with the proposal, two were against the voltage and five were against the connector.

The two companies voting against the voltage wanted DC instead of AC. They believed a ground loop free system of distributed DC was possible and superior to the proposed distributed AC system.

The five companies voting against the modular connector proposal all voiced reservations that many companies voting for it also shared. The most obvious one was confusion with telephone equipment. They did not feel that the offset latch plug, red color, and unique logo were sufficient to prevent confusion.

The second concern was with the reliability of the plastic latching tab. Many felt it could be broken off too easily, and that the entire plug was too vulnerable to breakage.

Further concern was expressed by the lack of readily available 6-pin crimping tools and connectors, particularly if the offset latch version were adopted. It was pointed out this issue becomes even more acute outside the United States.

And last, reservations were stated regarding the current handling capability of modular plugs, especially over long distances. Even though the modular pin carries a 2 amps/pin UL rating, it restricts wire size to 26 AWG. And two 26 AWG conductors in parallel only allows 1.5 amps maximum.

Yet after 18 months of discussion, no one presented an alternative connector proposal better suited than the modular plug.

AES Working Group Dissolved

The AESSC rejected the proposal for *Journal* draft publication because four of the seven companies disagreeing were large companies. After a poorly attended meeting during the October 1989 AES Conference in New York, the AESSC Executive Committee dissolved the Working Group on the grounds of insufficient interest.

* Condensed from the original article appearing in the *J. Audio Eng. Soc*., Vol. 39, No. 4, April 1991, pp. 275-276.