WHITE PAPER

Rethinking the Stage Pin Connector

Recent improvements could offer users longer connector life and help optimize production success

HUBBELL®
Wiring Device-Kellems

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Recent improvements such as resilient housings, greater temperature performance, superior mateability, lower price point and better aesthetics could offer users longer connector life and help optimize production success

The venerable stage pin—with its flat, low profile and basic design—has been the standard connector type for powering high intensity theatrical lighting equipment on North American stage and studio sets for decades. These familiar workhorses are invariably deployed by the dozens or even hundreds—with both male and female sides—all around nearly every TV, film or stage production, effectively powering the brightest and most essential fixtures, and helping to transform the darkest and most challenging locations into optimally lit scenes.

But while stage pin connectors have been deemed irreplaceable by the entertainment industry at large, they are certainly not without their flaws. Indeed, many industry veterans might observe that stage pins have a bit of a checkered past, with a plentiful assortment of good, bad and ugly along the way. While they have been preeminently successful in performing one task—helping deliver power to lights in remote locations—lighting technicians know painfully well that they also traditionally display a number of inherent design problems that can and do continually lead to issues on set and the need for stat replacements.

Stage pin design stages and usability issues

The housings of stage pin connectors have traditionally been made from thermoset phenolic material, an older type of plastic that is irreversibly hardened in manufacturing and requires each individual unit to be physically machined from large chunks of hard, permanently temperature "set" solid material, like sculpting wood or stone. Thermoset materials are often contrasted with thermoplastic materials which can be melted and re-melted at high temperatures—a couple of hundred to upwards of thousands of degrees Fahrenheit depending on the material—and so can be produced in custom molds or through an extrusion technique where the soft material is pushed through a die. This characteristic allows thermoplastic products to be made faster and in larger quantities, and makes thermoset products, which are more labor intensive and less flexible to produce, often higher in cost.

In addition to being generally more costly, thermoset materials often tend to form products with an arcane "old fashioned" look that many find out of synch with modern aesthetics—a fact which has been of particular note in an industry in which good looks, elegance and leading edge appearances are especially important, and the sleeker modern look of thermoplastic products are often deemed preferable. But even more vexing from a practical standpoint, thermoset materials are often less robust and resilient than thermoplastics, with a layered construction and

brittleness that leaves them prone to cracking, flaking, peeling and chipping on impact. In the case of thermoset stage pin connectors, this tendency often leads to damage in use on set, where the stage pins, solid and weighty for their size themselves and attached to heavy 50 or 100 foot cables, are often thrown on and off of trucks, carts, ladders and dollies; tossed across the stage; dragged across the pavement; kicked off of high catwalks; driven over by cars and trucks; and otherwise are generally handled roughly in everyday use and often meet the ground hard. So it's no surprise that thermoset stage pin housings often quickly show superficial or ultimately more impactful signs of damage.

Speaking of the threat of damage, many electrical techs often comment on the relative vulnerability of the brass pins in traditional stage pin connector designs. These are the "pins" that give pin connectors their name—three thin brass rods (originally only two before a longer ground pin was added to the design for additional safety) that stick out of the housing about an inch and a half. They are in many ways analogous to the familiar three prongs in the "Edison" or NEMA connectors of a microwave or similar familiar household product, but their length, need for frequent and forceful mating/unmating, and more robust handling patterns leave them far more vulnerable to bending, twisting, misalignment, chipping, wear and other issues. The danger in use is that damage to the pins will lead to imperfect mating connections, and imperfect mating connections will lead to heat build-up—possibly extreme—that can damage connectors and objects around them and even ultimately cause failure.

The mateability tolerance of male and female pins are carefully controlled by such organizations as the American National Standards Institute (ANSI E1.24), the Entertainment Services and Technology Association (ESTA), and United States Institute for Theatre Technology (USITT), which have established standards for consistent intermateability connections among all brands. With the high quality engineering capabilities demonstrated by most all manufacturers today, deviance is unlikely to be an issue out of the box. This can quickly—very quickly—change with hard use, however, as users are well aware.

Further, there is another interface in stage pins connectors where damage in use can cause intense heat build up—at the connection points were the live wires meet the wiring terminals inside the housing. Pulling and yanking cable at the point of connection can loosen wires, as can hard impacts of any kind. Further, these points are also vulnerable to over-tightening and under-tightening in installation.

Many users report that staying on top of these threats to their stage pin inventory is an ongoing battle, and the onus is on users, studios and rental companies to be on the lookout for damaged

pins and loose connections, and move to repair or swap these damaged stage pins out as soon as possible.

Efforts to upgrade

As noted, in spite of its many perceived limitations, the stage pin has been an integral tool for stage and screen productions, continually, for decades. Indeed, perhaps counterintuitively, over the years any attempts at developing dramatically improved engineering redesigns, such as building in retracting or moving pins or pin locks, have often not gotten much past the prototype phase or not sold well, meeting resistance for reasons perhaps including a fear of a need for related equipment changes, increased costs, added complexity, unfamiliarity, maintenance changes, or other issues, leading to their not being well received by the industry at large.

However, over the years there was at least one targeted improvement to stage pin connector design that was embraced by the entertainment industry, at least at first, with a modern thermoplastic material replacing the venerable thermoset material, bringing down the cost and improving the mechanical performance of the housing. These thermoplastic stage pin connectors were well-received, to the point that users began to routinely replace their thermoset stage pins with thermoplastic stage pins as the former failed, so that the two co-existed in large part along any set. Indeed, according to veteran perceptions, thermoplastic versions began, over time, to overtake thermoset versions by usage.

This situation changed quickly however, as it was soon discovered or perceived that, at least on some stage pins, the thermoplastic material specified in these products evidently did not display adequate temperature performance in light of the way that some stage pins were used. The result was that, unlike past experience with thermoset materials, which could smolder and smell but inherently are unlikely to re-melt, the housings of some thermoplastic stage pins were melting, charring or even burning in use, causing damage to sets and failure and downtime in some cases.

According to industry veterans, the backlash from the industry in many cases was swift and severe; since there was no certain way to determine which thermoplastic pins were made with good performing thermoplastic material and which made with potentially vulnerable thermoplastic material, some users moved to err on the side of caution and ensure that all thermoplastic stage pins were removed, replaced with the old, otherwise inferior thermoset products and subsequently “banned forever” from some productions.

While this was clearly an effective decisive move to alleviate a short term threat, over the years, vestiges of ongoing prejudice shunning “all” thermoplastic stage pin connectors could also be

causing some productions to miss out on potential advantages while continuing to embrace what many in the industry consider an otherwise outdated, costly, unaesthetic and mechanically vulnerable thermoset design. Indeed, since the early thermoplastic missteps, a number of manufacturers have made valid, proven upgrades in materials, features and performance to stage pin connectors that are worthy of consideration. Of additional note, these specific strategic modifications tended to be made in a measured fashion, to avoid any dramatic redesign that would increase costs or impact design of related products.

Key features of an optimal stage pin connector

In the mind of every electrical technician, shop repair specialist, stage hand, lighting director and anyone else whose livelihood involves the need for the ongoing problem-free functioning of these ubiquitous devices, there is an "optimum" performing stage pin—one that provides all the robust performance characteristics desired with little threat of heat damage, and all delivered at an attractive price point.

Based on stage pin connector manufacturing and entertainment industry experience, as well as numerous discussions with professionals who we serve in the entertainment industry, let's take a look at some of these commonly desired stage pin features, and how they might be obtained.

A stage pin housing that stands up to impact AND stands up to high heat

One of the major complaints from users regarding thermoset stage pin connectors is how easily the protective housing can be cracked or damaged in use. Once this happens, it is easier for live internal wiring to be jarred loose, where it can become dangerously exposed to users or cause heat build-up that can cause damage to the connector.

In the manufacturer's selection of materials, there is often a trade-off to find the best mix of properties for the particular application. While thermoset materials—with their brittleness and tendency to crack—are often considered below optimum in mechanical durability for a product that will experience extremely hard use, they do display good resistance to heat and will not melt under any likely circumstance. While, in theory, stage pin connectors "shouldn't" ever heat up significantly, the practical reality of pushed amperage and damaged pins or wiring causing heat build-up will ensure that, in the real world, temperature exposures will likely become higher.

Thermoplastic materials can provide outstanding mechanical stability as well as high temperature resistance, but each material has a temperature at which it will melt or "reflow." Clearly, in designing a thermoplastic stage pin, manufacturers should specify a mechanically resistant

thermoplastic that also has a reflow temperature beyond what is likely to be experienced by a stage pin in the field even under adverse conditions. The right material must be selected for the outer housing to deliver the proper balance of mechanical and temperature performance.

To provide an example with which the authors are familiar, Hubbell's new line of stage pin connectors are constructed of a high impact, high temperature nylon. Due to the sensitivities of the marketplace as described above, Hubbell's lab subjected the product to "torture testing" to ensure adherence to not only UL498 for stage pins and the more stringent UL1682 that is required not for stage pins but for hardier pin and sleeve devices, but also to some more "creative" extreme situations. For example, the specs require that the product run at fully rated current (100 Amps in this case) for four days without demonstrating a temperature rise of more than 30°C. When the Hubbell devices performed handily, a new longer term test was established which operated them at rated current for eight hours per day for 25 straight days; again the temperature delta remained under 30°C.

Then the team began further torture testing to see at what levels of out-of-spec usage one might expect to see any temperature related issues with the connectors. Amperage was increased to 120, 140, 160 and finally 180, and the stage pins continued operating without temperature rises high enough to cause issue. The decision was made to purposefully damage the pins to see at what stage a heavily compromised product would begin to display a temperature rise. It took exposure to a corrosive salt fog for five days, heavy manual damage to the pins with a channel grips pliers and then sending an overrated current of 160 Amps to the 100 Amp pin to make the temperature rise to a level that would be likely to cause issue.

Of note, it is important to realize that any male/female stage pin combination is only as good as its weaker link. For example, if the male end is a brand that uses a highly heat resistant thermoplastic and the female end is not, under an extremely high current load the female end can melt and fail, causing intense nearby temperatures and failure to the stage pin system, even though, theoretically, the male end could continue to operate. This is true even if that end shows visible burn marks from the intense heat of the failing connector it is attached to. The message is, on set, the entire production's stage pin network can be compromised even by a single faulty pin, causing a downtime situation. Care should be taken to make sure every stage pin, male and female alike, has the properties desired and is in good operating order—the production depends on it.

Of course, the mechanical side of the equation is important also, and should be evaluated. In the case of the Hubbell stage pin connector, a cold impact torture test was performed for surety. Under this UL1682 lab test, more stringent than what is required by UL for stage pins, male

and female stage pins were first “conditioned” in a cold chamber at sub-freezing temperatures of -25°C for six hours to create a debilitated state below operational norms. These heavily compromised connectors were then tethered to a length of cable and dropped to the floor from a height of 30 inches eight times, turning the pin at different angles each time to impact different edges and sides. No wiring was exposed or damage incurred during the procedure.

A stage pin connector strategically engineered to mitigate heat generating events

In an electrical device there are two points of potential heat generation. The first is where the male and female pins mate. If that meeting is not tight, with even small airgaps between the connection points, electrical resistance occurs, a phenomenon which quickly creates heat.

The second point is where the live wires are attached to the device at the screws or other termination points. A loose connection here can likewise cause temperature to escalate.

In traditional connectors, the pins are “out there” all the time, and as they inevitably get worn and dinged and bent in use, they will begin to mate with less than their manufactured tolerance, forming airgaps. By industry standards, manufacturers work to counter this phenomenon by splitting the male pins so they can be readily “stretched” with a flat head screwdriver or more specialized tool, and/or putting springs or similar structures inside the female connector to simulate tighter tolerances as the male pin degrades. In more modern designs, manufacturers add innovative protections that also reduce the dissemination of heat from the pins without the need to change any related materials or add significant cost or complexity to the component. In the case of the Hubbell stage pin, for example, a proprietary, high temperature, gray colored thermoplastic sleeve has been developed that is wrapped internally around each pin. Of note, this thermoplastic is formulated to have even higher temperature tolerance/melt point than the thermoplastic used on the housing. This robust sleeve provides some degree of dimensional stability and mechanical protection to be sure; however, its main purpose is to help ensure that as pins get slightly bent or damaged in use, which, based on the reality of their deployment, they almost certainly will, and therefore begin to mate less completely and start to generate heat, that that heat will be contained safely inside the sleeve and will be less likely to impact the wiring, housing or other components—or any objects or people in the adjacent environment.

A point of fascination to our designers at Hubbell is that, in addition to effectively meeting its intended purpose, this innovation has also provided an unexpected and unintended benefit that was actually first brought to our attention by users who experienced it and discovered its value. As the thermoplastic sleeve material does its job to contain the runaway heat generated by damaged pins, the gray begins to darken a little bit. This has allowed proactive, savvy studio

maintenance people to use this coloration as a guide to flag connectors with damaged, heat generating pins—enabling them to keep an eye on them well before there is any functional issue to be concerned about.

Additionally, since damage to pins can occur during hasty mating and unmating, when stage hands must do hundreds of these in a hurried time frame, manufacturers work to construct the brass pins to be as robust as possible to begin with. Hubbell subjected their stage pins to a torture test of mating and unmating to ensure mechanical and electrical efficacy. Using a robotic arm for safety, the pins were first subjected to the UL 1682 test for pin and sleeve devices, with 50 mating cycles performed quickly at 150% of rated current (150 Amps in this case). When no pitting, welding or burning of contacts was observed, Hubbell lab technicians raised the mechanical torture stakes considerably—with 2000 matings and unmatings under non-current conditions. No significant wear or damage to pins was observed.

Contemporary stage pin connector designs are also targeting the other key reason for temperature runaway—improper or loosening connection at the termination screws. This can be done in a number of ways.

Terminations are the point where the live wire brings the power to the connector. In most cases, the ends of the wires are stripped and the copper manually connected to the interior of the connector by means of the two screws on each of the three pins. Typically, the screws are loosened, the wire wrapped around or under the barrel of each one, and then the screw is tightened down to a specified torque. Under-tightening—which can cause the wire to jiggle out, and overtightening—which can cause the wire to break and pull off the screw—are common situations which can lead to loosened screws or wires and overheating over time. In addition, even if all six screws are torqued perfectly, the continuous cycles of heating and cooling causes thermal expansion which leads to loosening over time, as does the constant motion and stress of the set up/tear down of the connectors.

One innovative way to alleviate these situations is to make it easier to optimize the perfect wiring termination in the first place—indeed, this was a top point on the “wish lists” of electrical technicians and stage hands. They admit that the tendency is to tighten “to the max” but they correctly fear that overtightening might lead to issues so they “hold back.” Meanwhile, their equipment or workflow rarely allows them to formally calibrate to the exact torque, so “doing it by feel” is the order of the day. In response, Hubbell was one manufacturer that rethought the thread pitch count of the screws, with finer threading that allows them to be torqued to far greater values without detrimental effect, so technicians can do their thing, cranking down as hard as they like and not “guess” at the proper torque. In addition, the contacts can be removed, wired

outside the device and then easily snapped back into place enmasse for optimum flexibility and accuracy.

Another way that wiring is often compromised in a working stage pin is by a snagging or strong pulling on the cable attached to the pin—if the stress of the connection falls at the vulnerable electrical contact point, it can easily be loosened, causing a heating situation, or even yanked out and disconnected altogether, causing the lighting to instantly lose power on the set. Innovative stage pin manufacturers today build in some kind of strain relief capability. Hubbell's adjustable clamping mechanism, for example, clamps down securely on the cable jacket and moves the connecting point to the entry of the housing, keeping the strain point far from the vital termination points, while accommodating a broad range of cable diameters. While the UL498 listing standard for Stage Pin products requires a 30 pound static pull test, the Hubbell stage pin was subjected to a much more strenuous 150 pound pull for a full minute, with no out-of-spec conditions occurring. This is a vital capability for stage pins today, so be sure to ask your stage pin manufacturer about their design strategy in this regard.

A stage pin that's easier and faster to handle throughout the production

Faster load-ins and load-outs save time and money, and while stage pins might be only one small aspect of a production, there are usually a lot of them deployed—so a few minutes or seconds saved on each one, a little less muscle expended on each one, or a little less weight to haul around on each one can, all told, add up to big advantages.

Customer-focused stage pin manufacturers are listening, and modern designs take ergonomics and overall workability into account in their designs. Thermoplastics are infinitely moldable, and allow designers to form the housing into nearly any shape, as opposed to thermosets which mostly demand machining into non-ergonomic, hard to hold, block-like constructions. Manufacturers take advantage of this capability on behalf of their customers by creating connector shapes that allow "hand-holds" for better gripping and easier joining or disconnection of the dozens or hundreds of stage pin sets dispersed throughout every modern set. Since the strong back and forth "wiggling" of the stage pins required to separate them—over hundreds of times—can take quite a toll on the wrists and hands, this feature is much appreciated by stage hands, and often facilitates faster set ups and tear downs. Thermoplastics also allow for the creation of a product that is noticeably lighter in weight, so carrying a trunk full of them from place to place can be a dramatically less laborious experience for stage hands used to dealing with thermoset pins.

Conclusion

With all of their flaws, stage pins have been an integral part of stage and screen sets for decades, and their familiarity and huge installed base ensures that they will likely continue to be the "go to" connector for high intensity lighting for the foreseeable future.

However, this does not mean that users are necessarily "stuck" with the traditional limitations of thermoset or older, temperature-sensitive thermoplastic pins. Innovative manufacturers have not only long since alleviated the unfortunate thermoplastic melting issues that occurred briefly for a short time years ago, but also alleviated many traditional design flaws—improving mechanical resistance, temperature resistance, ergonomic performance, pricing issues, aesthetic issues, maintenance issues and more—making, for many users, a timely reconsideration of their stage pin fleet potentially advantageous. Users might want to consult with their manufacturers, rental companies or other trusted suppliers to scan the market for what is currently available, and consider a cost/benefit analysis to see if it would be of benefit to begin swapping out existing stage pins, and at what rate. Further, for producers outside of North America who may like the flat profile of the stage pin but avoided them due to their inherent historical design flaws, a re-evaluation may be in order. Today's stage pins may offer overall advantages over round, bulky Edison plugs or pin and sleeve designs in some stage applications, and may make increasing sense to consider in some applications. In all cases, Hubbell, a full line connector manufacturer, stands ready to offer expert advice to any operator.

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