BIRKET ENGINEERING NEWS

Electrical & Software Control Systems for Safe Rides & Shows Since 1984

Spring 2005

ATTRACTION SAFETY

Birket Engineering, Inc., 2004 Thank You

She had my heart a spinnin', just like a Tilt-A-Whirl' the country song says. A flat ride's excitement, however, is not extreme enough to describe the thrills available in the business of ride and show development.

After a white-knuckle ride down the 9/11 accelerator plunge, the industry can finally perhaps feel the blood re-enter its head and hands, and maybe relax its grip long enough to take in the view. Maybe just for a moment, before the unknown around the next corner. For Birket Engineering, Inc., we thankfully acknowledge a great year.

2004 Control System Projects for a Ride or Show

- LIM-launch roller coaster, controls design & installation, Orlando
- LIM-launch roller coaster, controls design & installation, Los Angeles
- 3D show, controls installation, Orlando
- Broadway show, controls modifications, New York
- Lagoon show, controls modifications, Osaka
- Theater show, controls modifications, Orlando
- Major stunt show, life-safety and flame system controls design & installation, Orlando
- 4D Show, controls assembly, Orlando
- Outdoor show, safety analysis, Las Vegas
- Water ride, animation controls upgrade, Orlando
- Operator interfaces, assembly, Orlando
- 3D show, controls installation, Hong Kong
- Fireworks show, controls design & installation, Hong Kong
- Stunt show, controls modification, Las Vegas

2004 Lighting Projects

- Strobe-Brik installation, Star Trek: The Experience
- Strobe-Brik installation, three thrill rides, Los Angeles
- Strobe-Brik installation, thrill ride, Orlando
- Strobe-Brik installation, architectural icon, Hong Kong
- Strobe-Brik installation, Hard Rock Vegas
- Strobe-Brik installation, Argosy Casino, Kansas City
- Strobe-Brik installation, Tangerine Lounge, Las Vegas
- Strobe-Brik installation, H.L. Hunley Experience
- Strobe-Brik installation, BraviSEAmo!, Tokyo DisneySea
- Outdoor spectacular, lighting control enhancement prototype design/build, Orlando
- Strobe-Brik installation, lagoon show, Osaka

Confidentiality agreements require that many of our projects go unnamed.

For more information see www.birket.com.

How to follow NFPA 1126 - Use of Pyrotechnics before a Proximate Audience - and get hurt anyway

by David Crater PE, LumenEssence

Imagine standing on your mark, waiting for your cue when, at the expected moment, there is a blinding flash, a deafening roar, and then… nothing. Or maybe it just gives you a scare and provides a story for later. In either case, an unintended pyro ignition can be bad news for actors, for pyrotechnicians, for system designers and for all involved. Aren't there rules or standards to prevent pyrotechnic tragedies? There are, but you can't always count on them to keep you safe, even when they are well intentioned.

The National Fire Protection Association (NFPA) has aided in the safe presentation of pyrotechnics since 1978 by publishing and administering two standards for pyrotechnics: NFPA 1123 - Code for Fireworks Display, and NFPA 1126 - Standard for the Use of Pyrotechnics before a Proximate Audience. System designers and industry professionals contribute their expertise in a consensus process to regularly update these standards to reflect continually evolving technologies, products and practices.

Any standards process inevitably lags behind current practice by some amount. It takes time to poll members, present issues, invite discussion, and arrive at and publish a final standard. Due to this lag shortcomings in the standards may be identified and may persist for some time before being corrected in a future revision. As a result, an unsafe system may still comply with applicable standards. Experience with the design and use of electric match ignition systems has identified just such a potentially hazardous fault mode which can occur in systems compliant with NFPA 1123 and NFPA 1126.

What is the Problem?

The fault mode in question is characterized by unintended ignition of a shell or other pyrotechnic device connected to an electric firing system. The cause of these ignitions is multiple undetected ground faults in the electric match firing circuitry. Typically, but not always, these faults are in the wiring from the firing system modules to the electric matches. Unfortunately, although both NFPA 1123 and 1126 address the topic of electric firing systems, neither

(NFPA 1126 continued next page)

This Issue

This newsletter is provided by Birket Engineering, Inc. as a communications device to current and future customers and friends.

Every control system must be evaluated and designed with consider-ation for the details of the specific application.

Information in this newsletter is not meant to be an engineering or professional opinion.

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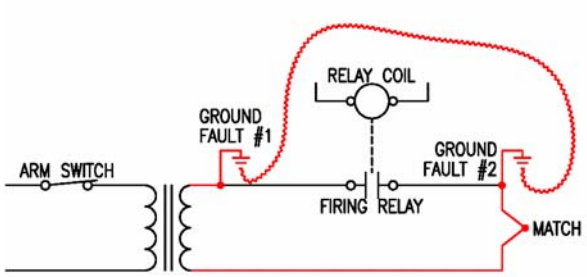
(NFPA 1126, continued from page 1)

standard contains requirements that would prevent these potentially serious faults. Any unintended ignition of pyrotechnics can be hazardous, but, if while in the vicinity of pyrotechnics, actors or other personnel involved in a presentation rely on the firing system to prevent ignitions, an unintended ignition could cause serious injury or worse.

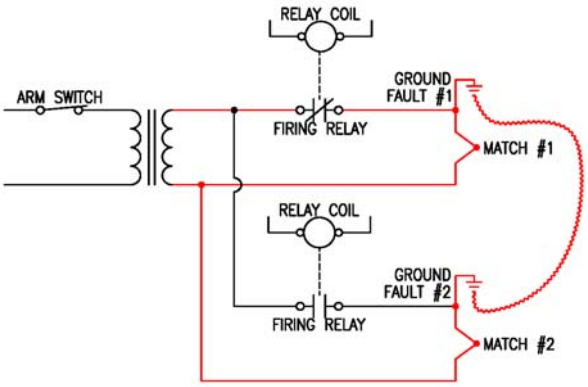
How Ground Faults Cause Unintended Ignition

Just as the hazard we are examining is characterized as an unintended ignition, ground faults are an unintended connection of a portion of a circuit to ground, or earth, or any other conductive structure, surface or material. When this happens, and it can and does easily happen, electrical current flows where it isn't supposed to. If two ground faults happen, electrical current can flow from the point of one fault to the other, with possible nasty consequences.



CIRCUIT 1. ONE MATCH FAULT

Circuit 1 shows how two ground faults can cause an unintended ignition in a single electric match system by allowing current to flow from one ground fault to another, bypassing the firing relay contact intended to prevent ignition until commanded closed.



CIRCUIT 2. TWO MATCH FAULT

Circuit 2 shows how two ground faults can cause an unintended ignition in a multiple match system.

Bad Luck or Inevitable?

What are the chances of a system developing the necessary two ground faults at the right place at the right time to cause an unintended ignition? As it turns out, the chances are high that this condition can develop. Ground faults can be easily caused by abrasion of insulated wire on exposed metal surfaces, corners, or concrete. The widespread use of inexpensive "zip" cord and temporary wiring in fireworks displays contributes to the hazard.

Faults that are acceptable in a system governed by NFPA 1123, where personnel are cleared from the firing and fallout areas before ignition, can become hazards in a system operating under NFPA 1126. Many pyrotechnicians have personally witnessed misfires and unintended ignitions that go unexplained partly because they are transient conditions and partly because temporary systems are dismantled, making diagnosis impossible.

In a permanent installation, or even limited engagement system, there is far greater opportunity for the development of faults; traffic between and during shows increases wear on system components and produces faults; degradation over time inevitably leads to faults; entropy prevails. The standard of care in the effects industry includes the statement that

> "A fault that can go undetected must be assumed to have already occurred."

The reason for this statement is that over time faults will accumulate in a system. Although a system may work perfectly when installed, as the faults accumulate eventually two or more faults combine to produce a hazardous or tragic event. In the history of engineering failures, it is most often these multiple fault scenarios that are responsible for tragedies.

Prevention

If we accept the fact that ground faults can cause unintended ignition, as has been demonstrated convincingly in tests and by cooperating spontaneous ground faults in pyrotechnic installations, what can be done to prevent this hazard?

What about isolation?

Isolation sounds like a good way to prevent unintended ignition. In fact, isolation is mentioned in both NFPA 1123 and 1126. In NFPA 1126 (2001), paragraph 6.3.2 states:

> "Power sources used for firing pyrotechnic devices shall be restricted to batteries or isolated power supplies used for firing purposes only."

NFPA 1123 has a similar paragraph. Both further state that a transformer is an acceptable means of isolation. Transformers are commonly used in electrical systems for their ability to provide isolation between subsystems. However, in neither standard is there any reference to the purpose for using power source isolation or transformers. Interestingly, we have already proved the case that isolation doesn't work in preventing unintended ignition due to ground faults.

Look back at Circuit 1 and Circuit 2. Each circuit represents the power source as a transformer-isolated source. Isolation didn't help; the offending ground

(Continued next page)

Do you have a controls question on a specific ride or show application? Birket Engineering, Inc. invites inquiries. We are fortunate to have a wealth of experience and talent from which to draw to address your need.

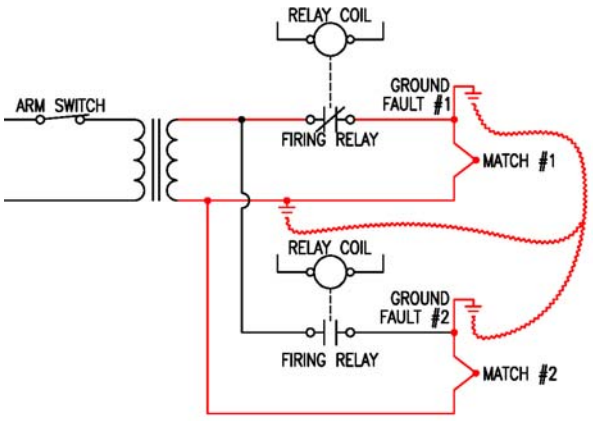
(Continued from page 2)

faults occur after the isolation. In fact, an argument can be made that a non-isolated, grounded power source would be safer, but that would distract us from the problem of the niggling ground faults. Isolation does have some possible benefits as to reliability, induced currents, and protection from shoot-through of high voltages, but these are complex scenarios that still don't support a conclusion that isolation is always the best approach to ignition source design.

Finally, there is the problem that unless we monitor to insure the continued integrity of the isolation, we can't count on it to be there when we need it. For our current concern we have to conclude that ignition power source isolation has no beneficial effect on system safety as regards ground faults.

What about grounding?

Grounding is frequently cited as an essential component of safe and reliable electrical system design. Can grounding solve the problem of unintended ignition due to ground faults? It could, if we carefully controlled every wire size, length, power supply size, match ignition current, fuse, etc.



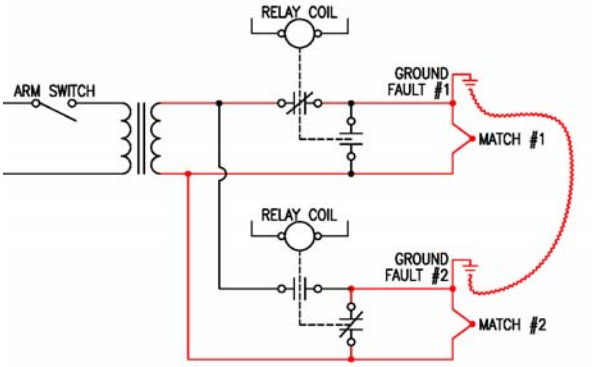
CIRCUIT 3. TWO MATCH FAULT-GROUNDED SUPPLY

Circuit 3 shows the same two-match fault as Circuit 2 but with one side of the firing system grounded. Ideally, all the current would go from Ground Fault #1 over to the system ground, bypassing Match #1 and Match #2. In practice however, the current will split among all available paths with some passing through Match #1, some through Match #2 and some straight to the system ground. This reduces the probability of an unintended ignition and increases the probability of a misfire (Match #1 may not fire when commanded) but cannot be relied upon to make the system safe.

Usually, grounded systems rely on the ground fault to produce a high enough current to trip a circuit protective device such as a fuse or circuit breaker, preventing all further current flow (in our case, stopping some portion of the show). Grounding does have other benefits relating to reduction of shock potential, dissipation of induced currents, and ease of troubleshooting and diagnostic self-tests. It does not however, solve our ground fault problem.

What about Shunts?

Shunting the match should prevent any current from passing through the shunted match. But, typical electric match resistance is 1.6 Ω. In practice, a few feet of wire, a few terminations, and a relay contact can easily approach 1.6 Ω. Because of this, the shunt is not perfect and the current is split between the shunt and the match.



CIRCUIT 4. UNINTENTIONAL IGNITION OF A SHUNTED MATCH

Circuit 4 shows an example of a shunted match receiving current due to ground faults. Once again, the precaution improves performance, but is not an adequate guarantee of safety.

What about GFCIs?

Aren't they designed to detect and protect against ground faults? Interestingly, GFCI stands for Ground Fault Circuit Interrupter, and sounds like the right animal for us. GFCIs detect "missing" current by comparing the current in both legs of the power source circuit; if the two currents aren't equal some must have been "lost" to another path, usually a ground fault. On detecting this condition GFCIs interrupt the circuit (once again stopping some portion of the show). The first limitation of a GFCI is that it cannot do its job if it is installed before an isolation transformer. The second limitation is that in order to perform this detection GFCIs require a ground connection and this connection must be after any isolation device, contrary to the current code's requirement. In theory this will solve our problem.

In practice, large distributed systems with many matches frequently have many low current ground faults or leakage paths. If the sum of all leakage paths approaches the current for a single match, the GFCI cannot distinguish between multiple harmless leaks or a single significant leak. This defeats the GFCI and results in nuisance tripping.

Design of a safe system

Fortunately for system designers, pyrotechnicians, and other personnel needing protection from unintended ignition, there is a viable solution to achieve a safe electric firing system. Ironically, the solution is described in NFPA 1126, but only in the

(NFPA 1126 continued next page)

Top 20 best-attended theme parks in 2004, with attendance:

1. *WDW Magic Kingdom, 15.2M*
2. *Disneyland, 13.4M*
3. *Tokyo Disneyland, 13.2M*
4. *Tokyo Disney Sea, 12.2M*
5. *Disneyland Paris, 10.2M*
6. *Universal Studios Japan, 9.9M*
7. *WDW EPCOT, 9.4M*
8. *WDW Disney-MGM Studios, 8.3M*
9. *Lotte World, 8M*
10. *WDW Animal Kingdom, 7.8M*
11. *Everland, 7.5M*
12. *Universal Studios Florida, 6.7M*
13. *Universal's Islands of Adventure, 6.3M*
14. *Blackpool Pleasure Beach, 6.2M*
15. *Disney's California Adventure, 5.6M*
16. *Sea World Florida, 5.6M*
17. *Yokohama Hakkeijima Sea Paradise, 5.1M*
18. *Universal Studios Hollywood, 5M*
19. *Adventuredome at Circus Circus, 4.4M*
20. *Tivoli Gardens, 4.2M*

Source: Amusement Business

(NFPA 1126 continued from page 3)

appendix where it is relegated to "informational" status instead of the "requirement" status accorded the body of the standard. Paragraph A.6.3.3 states:

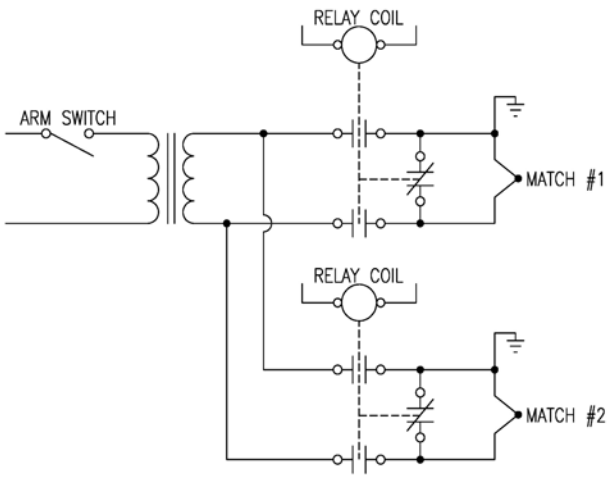
> "Firing circuit design should be such that neither igniter lead is electrically connected to the firing power source until ignition is intended. It should not be permitted to wire one side of multiple match terminals together, then to switch current to the other terminal of the igniter."

Another item from the appendix introduces another widely used (but not required!) safety element. Paragraph A.6.3 states in part:

> **"**Electromagnetic induced currents in firing circuit wiring can be reduced by utilizing one or more of the following methods: … (4) Shunting near the electric match"

Finally, the body of the standard states clearly in paragraph 6.3.3 that:

> "All firing systems shall be designed to ensure against accidental firing by providing at least a two-step interlock in which no firing power can be applied to any firing circuit unless the operator intentionally does both of the following: (1) Enables or arms the firing system and (2) Deliberately applies firing power"



CIRCUIT 5. SAFE FIRING CIRCUIT

Circuit 5 shows a design incorporating all of the above requirements and recommendations as well as the previously discussed, but dubious, power source isolation. The features of this design include: separate arming switch, supply isolation, individual firing command control of each match circuit, dual-leg match isolation, and match shunts.

The essential feature of this design is the use of dual contacts to interrupt both sides of the match leads. This is what prevents those pesky ground faults from rendering the ignition system unsafe. (Note that while the schematic and text suppose the use of a relay, interruption of both sides of the match lead can equally well be accomplished by a solid state device such as a FET.)

For details of a hazard experience resulting from a pair of ground faults in a pyro system that met the requirements of the NFPA 1126 standard, see www.birket.com/safety/tipyrostory.htm.

Understanding Standards

Standards are not a substitute for common sense or engineering analysis. Even the NFPA recognizes this. In the "Important Notice About This Document" in NFPA 1126 it states:

> "..the NFPA … does not … verify the accuracy of any information or the soundness of any judgments contained in its codes and standards."

And:

> "Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances."

Standards can be an obstacle to good system design. Ideally, standards are a mechanism for lay individuals to benefit from the experience of acknowledged experts (the standards' authors) without having to understand the underlying technical details. When a standard omits requirements to address known unsafe conditions, such as our ground faults, a false sense of security is created which can lead to tragedy. Similarly, standards can impede improved system designs; as we have seen, the requirement in NFPA 1123 and 1126 for "isolated" power sources is of questionable value and may prevent superior designs that could benefit from the use of grounded distribution systems. It may be difficult or impossible to obtain a variance from the authority having jurisdiction to allow the use of such an improved design.

The NFPA developed two pyrotechnic standards to serve the needs of two types of pyrotechnic presenters. For a special events pyrotechnic systems engineer NFPA 1123 is typically the applicable standard. It dictates mostly sound practices which can be demonstrated to be safe because, and only because, the entire firing field and fallout area will be cleared of personnel before bringing the ignition power source anywhere near the ignition system. For these events there are two overriding principles:

(1) The show MUST go on; given the special event nature of many shows, anything that would delay or interrupt the show seriously diminishes the event. Minor flaws (such as unintended second ignitions or misfires) are not significant.

(2) The primary safety tactic: Clear the entire firing field and fallout area of personnel before bringing the ignition power source anywhere near the ignition system.

For a show systems engineer dealing with personnel in proximity to hazardous effects, NFPA 1126 is typically applicable but falls below the required standard of care with regard to the prevention of unintended ignition. To implement only the requirements of NFPA 1126 would be negligent because such a system IS NOT SAFE when

(NFPA 1126 continued next page)

TIMOTHY D SWIETER

Tim at a recent project opening

TIM SWIETER, THE INTERVIEW. Birket Engineering, Inc. (BEI): So, Tim, I notice your full name, Timothy D. Sweiter is used in the banner of this article. **Tim Swieter (TS):** I like to use my full name, but most of my friends call me Tim. I only let cute girls call me Timmy. At some point, my website www.timothydswieter.com will be placed on-line; it will be there that you can discover what the 'D' means. **BEI:** What brings you to Birket Engineering? **TS:** When I was young I took many family trips to Walt Disney World, which is how I learned about the Imagineers. I have wanted to work in the entertainment industry since the third grade. I have a passionate interest in creating entertainment experiences - controls, lights, audio, artistic, video, operation, acting, producing, film, special effects, etc. I started living my dream by working here at Birket just before I graduated from college. **BEI:** Do you have a favorite type of project? **TS:** My favorite projects to work on are roller coasters, just because I want to be one of the first to ride! It is a great challenge to make sure the ride control system is safe. I like all sorts of attractions and entertainment - I'm sort of a connoisseur. **BEI:** What do you think of Orlando? **TS:** The first five or six months that I lived in Orlando I spent more time at the project site than anywhere else in Orlando. **BEI:** I understand you know Brendan Frasier. **TS:** We went on one of my favorite coasters when I saw him last, but that is a different story. **BEI:** What are you working on now? What are your goals? **TS:** Right now I am working on a fireworks control system for a Hong Kong park. One of my goals is to become one of the best professionals in the industry. I want to have a great understanding of all aspects of entertainment engineering and business. I have passed the Fundamentals of Engineering test, the first one in a series of two to get the Professional Engineering license. I like to visit the area theme parks as a guest in my spare time. I also have many hobbies and home projects that keep me occupied when I am not at work.

For more information contact Tim at tims@birket.com.

The Stats on Tim

Favorite Drink
Fresh (Florida) Orange Juice

Favorite Food
BBQ (Choctaw Willy's) or Pizza (but not together)

Favorite Noise
The sound of people screaming on a rollercoaster

Ride/Show Engineer, Birket Engineering, FL, 2003-present
Fireworks Control System Design, Orlando, for Hong Kong park.
Animation Control System Rehab, Orlando, FL.
Ride Integration team member, LIM-launch coaster project, Los Angeles, CA.
Ride Integration team member, LIM-launch coaster project, Orlando, FL.

Bachelor of Science in Electrical Engineering, 2003
Kettering University, Michigan

(NFPA 1126 continued from page 4)

personnel are in proximity to the effects. For these types of shows two different overriding principles apply:

(1) The safety of persons is PARAMOUNT; all potentially hazardous effects systems, including pyro, must be designed in a manner which does not allow undetected faults to cause a hazardous condition.

(2) A hazardous condition must be remedied even if it causes delay or forfeiture of all or portions of the show.

The Next Steps

After all is said and done there are two implications for NFPA 1126. First, electric match ignition systems that rely on single pole firing relays are not safe for use in situations where personnel are in proximity to the effects after the ignition power source is present in the system. The standard already recognizes this issue as indicated by the inclusion of paragraph A.6.3.3 wherein dual-leg match isolation is recommended. Hopefully, as the standards committee and industry professionals become aware of the potential for harm if this recommendation is not followed, the standard will be revised to require this practice.

Second, isolation of ignition sources as described in NFPA 1123 (2000) and 1126 (2001) is inadequately described. The benefits of isolation, if any, need to be described and coordinated with provisions for designs with grounded distribution systems. This will allow designers to continue to improve the safety of electric ignition systems.

Glenn Birket PE is a member of the NFPA Technical Committee for Special Effects which is responsible for NFPA 1126 and NFPA 160. During 1126's recent revision cycle, Mr. Birket proposed a revision to eliminate the requirement for isolated power supplies and to add a requirement that both sides of the match circuit be broken.

As this newsletter goes to print, final votes of the members of the Committee are being tabulated. It appears that the 2005 edition of NFPA will not include the requirement for isolated power supplies. The committee however declined to consider the requirement for breaking the connection to both sides of the match circuit, but agreed that the matter should be considered further during the next revision cycle.

Contact Glenn at glennb@birket.com.

Author David Crater PE is a principal with LumenEssence, providing consulting and turn-key design for show systems. LumenEssence has designed numerous systems for controlling all aspects of show systems including pyrotechnics, flames, mechanics, audio, video and film effects with installations at major (and minor) attractions worldwide. He can be contacted at: mail@LumenEssence.com.

Birket Engineering, Inc. *provides electrical and computer engineering services for entertainment and industrial automation.*

For information on Birket Engineering, see ***www.birket.com*** *or contact Steve at (407) 290-2000 x126 or steve.birket@birket.com. Fax to (407) 654-2150, or write to Birket Engineering, Inc., 568 W. Silver Star Ext., Ocoee, FL, 34761.*

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***Gilbert Rosario**, BSET*
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***Ed Sabis**, CMA*
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***Tim Swieter**, BSEE*
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***Luke Zagurski**, AST*
Design

Birket Engineering Adds Florida Limited Energy Contractors' Licensure

Effective October 27, 2004, Birket Engineering, Inc. is licensed as a Specialty Electrical Contractor (ES12000256) by the State of Florida, and is certified as a Limited Energy Systems Specialist. Many code authorities require permitting and contractor's licensure in order for a systems provider to install equipment in their jurisdiction. From the Florida Electrical Contractors' Licensing Board - Rule 61G6-7.001 Specialty Electrical Contractors (4) Limited Energy System Specialty:

> *The scope of certification of a limited energy systems specialty contractor includes the installation, repair, fabrication, erection, alteration, addition to, or design of electrical wiring, fixtures, appliances, thermostats, apparatus, raceways, conduit, and fiber optics or any part thereof not to exceed 77 volts, when those items are for the purpose of transmitting data, proprietary video (satellite systems which are not part of a community antenna television, cable television, or radio distribution system), radio frequency, central vacuum, or electric locks, data distribution networks, home theater systems, surround sound systems, public address systems or telephone systems. (a) The scope of certification is limited to electrical circuits and equipment governed by the applicable provisions of Articles 725 (Class 2 and 3 circuits only), 770, 800, 810, and 820 of the National Electric Code.*

Birket Engineering, Inc. maintains its State of Florida Engineering Business license (PE0036753) also.

For more information see www.birket.com.

Strobe-Brik™ System Receives CE Marking

Birket Engineering, Inc. received notices of conformity for our Strobe-Brik controller and strobes on November 24, 2004, allowing the CE marking to be applied. Certificates of Conformity to Low Voltage Directive 73/23/EEC and EC Council Directive 89/336/EEC for Electromagnetic Compatibility (EMC) were received from TUV Rheinland. The system was found to conform with Safety Standard EN 60204-1:2001 and EMC Standards EN 55103-1:1996, EN55103-2:1996, EN 61000-3-2:2000, and EN 61000-3-3:1995+A1.

The CE marking is a European marking of conformity indicating that a product complies with the essential requirements of the applicable European laws or Directives with respect to safety, health, environment and consumer protection. Generally, this conformity to the applicable directives is done through self-declaration.

The CE marking is required on products in the 18 countries of the European Economic Area (EEA) to facilitate trade between the member countries. The manufacturer or his authorized representative established in the EEA is responsible for affixing the CE marking to his product. The CE marking provides a means for a manufacturer to demonstrate that his product complies with a common set of laws required by all of the countries in the EEA to allow free movement of trade within the EEA countries.

The CE marking makes possible an installation of three Brik-32S systems planned for January 2005 in Paris. Site labeling of the system to UL standards for North American installations is also available.

For more information see www.birket.com.

BIRKET ENGINEERING, INC. WORK IN PROGRESS

Current Projects

- Control systems for three new domestic stunt shows.
- A fireworks control system for an Asian theme park.
- Controls for flying automation in a new Broadway show.
- Strobe-Brik™ systems for a thrill ride in a European park and two Orlando shows.
- Installation support for a new Asian theme park.
- Filter controllers for Pall Corporation.
- Controls upgrades for an Orlando attraction.
- Upgrades for an Asian lagoon show.

For more information see www.birket.com.

Another beautiful day in Orlando, developing electrical and software systems for the world's finest attractions.