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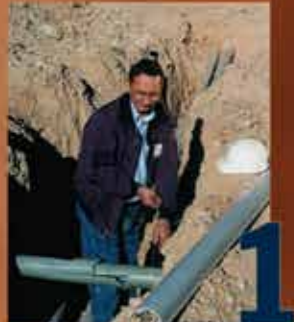
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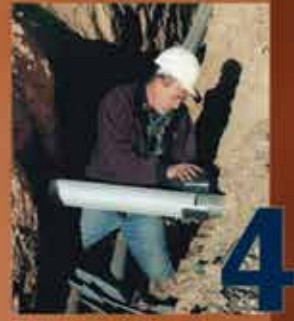
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## PUBLISHER

Glen Hobson  
205-441-5591  
[glen@tipsmag.net](mailto:glen@tipsmag.net)

## ADMINISTRATIVE DIRECTOR

Steven Hobson  
[steven@tipsmag.net](mailto:steven@tipsmag.net)

## EDITOR

Brandon Greenhill  
[brandon@handfmedia.net](mailto:brandon@handfmedia.net)

## CREATIVE/ WEB DIRECTOR

Jacklyn Greenhill  
[jacklyn@handfmedia.net](mailto:jacklyn@handfmedia.net)

P.O. Box 1568 • Pelham, AL 35124  
Phone: 205-441-5591 • Fax: 205-624-2181  
[www.theutilitysource.net](http://www.theutilitysource.net)  
[info@theutilitysource.net](mailto:info@theutilitysource.net)



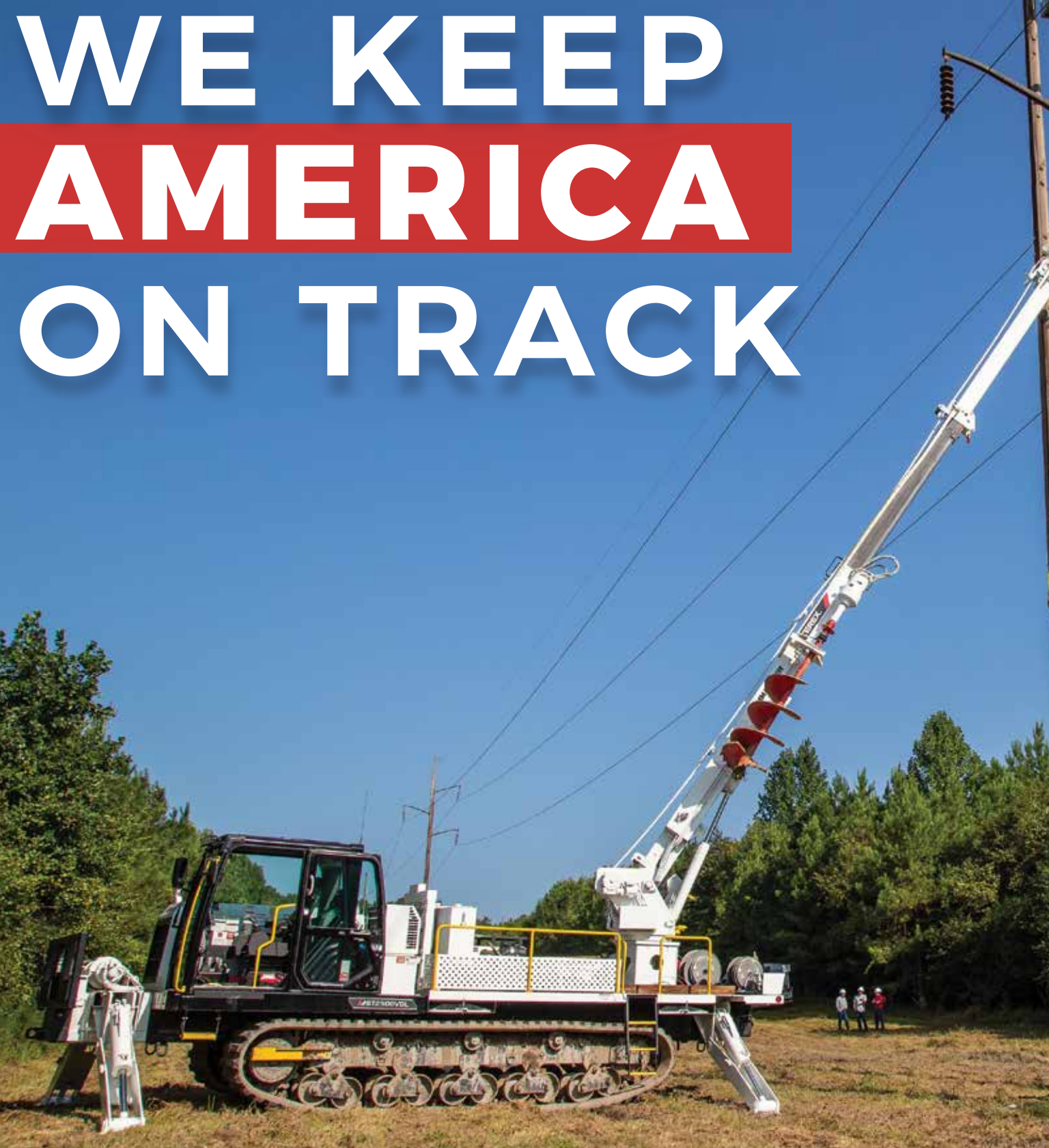
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# Preventing Thermal Runaway Before It Begins

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*In Li-ion Battery Energy Storage Systems, off-gas detection up to 30 minutes before dangerous thermal runaway events enables action to deter potentially catastrophic cascading failure*

Utility, industrial, commercial, and government facilities are increasingly turning to Battery Energy Storage Systems (BESSs) in a variety of sizes and power outputs for reliable back-up power, to avoid peak demand charges and to store energy generated by renewable power systems for use at a later time. The market is expected to exceed more than US \$9 billion by 2024 at a compound annual growth rate of 34%, according to a Market Research Engine report.

Given the expected growth in this sector, coupled with the fact that most BESSs are designed by interconnecting a series of Lithium-ion (Li-ion) batteries, the industry is continuing to focus attention on measures designed to all-but-eliminate any potential for dangerous thermal runaway conditions.

Thermal runaway occurs when excess heat caused by defects, mechanical failures from damage or improper operation of the system creates a reaction that further increases the temperature. If left unchecked by built-in system protections or the Battery Management System (BMS), this process can continue to drive up temperature and pressure until the battery cell ruptures, which can cause fires in affected and adjacent cells.

Fortunately, early detection systems have been developed that can now detect a unique pre-cursor event to thermal runaway – an off-gassing in the battery cell that occurs up to 30 minutes prior to a cascading failure. This distinctive and recognizable early warning sign enables the problem to be mitigated or the system shut down before thermal runaway can even begin.



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Although virtually all quality BMS equipment monitors temperature and other variables to prevent thermal runaway by triggering protections before temperatures change in an unplanned way, the early detection of off-gassing provides a critical additional layer of protection for the entire system, the facility and even personnel.

“There are hundreds, if not thousands of [BESS] systems already deployed where single cell failure could result in loss of the system. So, the ability to detect cell failure before it results in thermal runaway – and stop it – could literally save the system, adjacent property, and human lives,” says Nick Warner, an internationally recognized expert in energy storage safety, testing and technology. Warner is Principal Engineer and founder of Warner Energy Storage Solutions, and co-founder of Energy Storage Response Group.

#### *Early detection*

The early detection of thermal runaway relies on four sequential stages of Li-ion battery failure, according to Steve Cummings, director of the sensors business unit at Nexceris, a developer of gas sensors and monitors. The company worked with the U.S. Navy a decade ago to develop an off-gassing detection technology for Li-ion BESSs that would later be commercialized in a product called Li-ion Tamer, compatible with all Li-ion chemistries.

“A Li-ion battery cell first begins to fail when it is subjected to an abuse factor like heat, over-voltage, etc.,” says Cummings. “The second step is off-gassing. The third step is smoke, and the fourth step is fire. But smoke and fire often occur almost simultaneously. So, by the time smoke is detected, thermal runaway has typically already begun.”

Off-gassing usually occurs due to a breakdown of a Li-ion battery cell electrolyte, as a result of

pressure buildup. Later, temperature increases, smoke is emitted and then fire breaks out.

To enable off-gassing detection at the earliest stage of a battery event after the initial abuse, the Li-ion Tamer system offers a battery off-gas monitor and sensor network designed specifically for lithium ion batteries.

Because the system can detect off-gassing at the ppm-level concentration range, it can detect individual cell failures without contacting the cells. This enables action to prevent thermal runaway and its spread to adjacent cells as soon as a single battery cell begins to fail.

“Early detection could help prevent thermal runaway before it starts, particularly those related to failure of the active primary control system,” says Warner of Warner Energy Storage Solutions. “When I was involved with testing the Li-ion Tamer system, the earliest detection of imminent failure was 12 minutes before it occurred. For some of the most common failure modes, I’ve found that it offers the earliest possible warning of imminent failure and I consider it a best practice technique.”

When working with Tier 1 providers, it is typical to have a well-integrated BMS with enough sensors to properly monitor various aspects of Li-ion usage, including the state of charge of individual cells and temperature in the system. However, this may not be the case when dealing with Tier 2 or 3 providers that sell batteries only and leave the BMS to the Engineering, Procurement, Construction (EPC) contractor.

“[Lower end, offshore] battery manufacturers have generally gone from monitoring every small cell group to having one thermocouple run an entire module, monitoring dozens of cells,” says Warner.



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“As a result, the Battery Management System is completely dependent on a voltage indication to detect any problems with the cells, he adds. “But in many cases, voltage is not the perfect indicator of something potentially going wrong in the cell.”

Even in the case of qualified Tier 1 battery suppliers, Warner recommends having an independent, redundant system like Li-ion Tamer. In the same way that seatbelts and airbags combined can reduce the risk of injury in a car crash, such an approach can help a qualified EPC integrate additional complementary safety measures into a safer, more comprehensive solution.

Warner notes that the detection system’s sensitivity to Li-ion electrolyte off-gassing is much greater than traditional sensors for other kinds of gas monitoring.

“Most sensors that detect gases are either looking for a generic hydrocarbon gas or generic level of gas, and are only detecting at one physical location,” says Warner. “The value of a Li-ion Tamer sensor is that it is specifically looking for the gas that is emitted from Li-ion batteries. It is incredibly sensitive and able to detect it at much lower levels than any other sensor.”

Another advantage of such an advanced Li-ion specific system is that it is designed to function as a network of sensors, which enhances its effectiveness in Li-ion off-gas detection. “Because it also allows multiple sensors to be deployed, it is much more effective at detecting gas as it disperses through the container. So, when off-gassing occurs, it is detected immediately and an alarm is sent.”

According to Warner, the Li-ion specific system is also more cost effective than traditional fixed gas sensors.

“Typical fixed gas sensors are usually intended to have two or three installed and cost from \$1,500 to \$4,000 each,” says Warner. “But they only measure at a certain point. If you want to extend that, you would need to buy and install 10 to 20. Then you would need to activate each individually to control the system, which adds to the cost.”

Because of the benefits of Li-ion BESSs, along with Li-ion specific off-gas detection systems, a growing number of facilities are installing them together.

As an example, Northern Reliability, Inc. (NRI) of Waterbury, VT was selected by the Palo Alto, CA-based Electric Power Research Institute (EPRI) to design and build two transportable microgrid BESSs for the U.S. Navy.

EPRI’s \$2M contract with NRI was finalized in August 2019. The project is funded in part through the California Energy Commission’s Electric Program Investment Charge (EPIC) program, and the Department of Defense’s Environmental Security Technology Certification.

Microgrids are small electrical systems that can operate both independently and together with the larger local electrical grid. Microgrids are being increasingly deployed at critical, nonmilitary facilities such as hospitals, fire stations, and airports to provide uninterrupted power during local electric utility outages.

The microgrid in the project will use solar energy and the BESS, along with Navy site generation, to provide emergency backup for blackout recovery, disaster recovery and weather/fire storm response.

Each NRI BESS is lithium-ion based and can deliver 250kW of power on demand. The two microgrid BESSs will go through testing at the Port Hueneme



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Naval Base in Ventura County, CA. They will then go through testing and operational use at a Naval Surface Warfare Center-Port Hueneme division data center in Southern California.

"For our military, mobile microgrids with energy storage offer a readily available, quiet power and energy reserve for military decision makers to use during day-to-day operations," says Jay Bellows, NRI's President & CEO. "This solution provides customers with reliable power, keeps our troops safer, enables operational flexibility, and provides the effective integration of modern-day renewable resources with legacy assets like backup diesel generators, wherever needed."

Based on EPRI's recommendation, NRI integrated the Navy-approved off-gas detection system into the unit's system supervisory controller as a redundant safety solution and on-board fire protection/suppression system.

"With Lithium batteries being installed all over the world, improving safety is always something that we take seriously. Even though we use the highest quality battery modules on the market today, we will always take additional steps to make sure we have as many levels of protection as possible," says Bellows.

For more info, contact Nexceris: (614) 842-6606; visit <https://nexceris.com>; or write to Nexceris at 404 Enterprise Drive, Lewis Center, OH 43035, USA.

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## Terex Utilities Focuses on Innovation for Mission Critical Equipment at Utility and Truck Equipment Shows

Earlier this month, Terex Utilities attended the National Rural Electric TechAdvantage conference in New Orleans and the NTEA Work Truck Show in Indianapolis.

"Both of these shows bring together key electric utility stakeholders and give us the opportunity to catch up on industry trends as well as engage to understand their safety, fleet and operational challenges," said Joe Caywood, Director of Marketing.

At TechAdvantage, Terex Utilities featured a Hi-Ranger LTM40 aerial device, a Commander C4047 digger derrick and a table-top demo showing our Positive Attachment Lanyard warning device or "PAL in a Bucket" option. PAL is a unique innovation for aerial devices which aids operators to follow their safe work practices. It provides audio and visual warnings when controls are engaged, and the lanyard has not been attached to the lanyard anchor in the bucket. An Optima TC55 aerial device was displayed with an innovative self-contained plug-in electric hybrid option at the 20th Anniversary Work Truck Show.

The LTM40 aerial device has an articulating and telescopic boom design with material handling capabilities. Several features make this ideal for use as a 'trouble truck.' No CDL license is required and it sets up easily in traffic because there's no street-side overhang. The Commander C4047 digger derrick is built for distribution work. "Our digger derricks are known for productivity, reliable design, and work zone capacity," said Gary Rice, Regional Sales Manager who attended Tech Advantage. "Overall, customer attendees provided positive feedback on the equipment and new innovations such as PAL and appreciated the overall quality of our product."

"Terex continues to focus on product innovation and reliable parts and service to support dependable electric delivery," said Caywood. "We recognize that the work electric utilities do is mission critical to the infrastructure of our country. Terex relies on a U.S.-based supply chain, underscoring our ability to respond to customer demand for equipment, parts & service."



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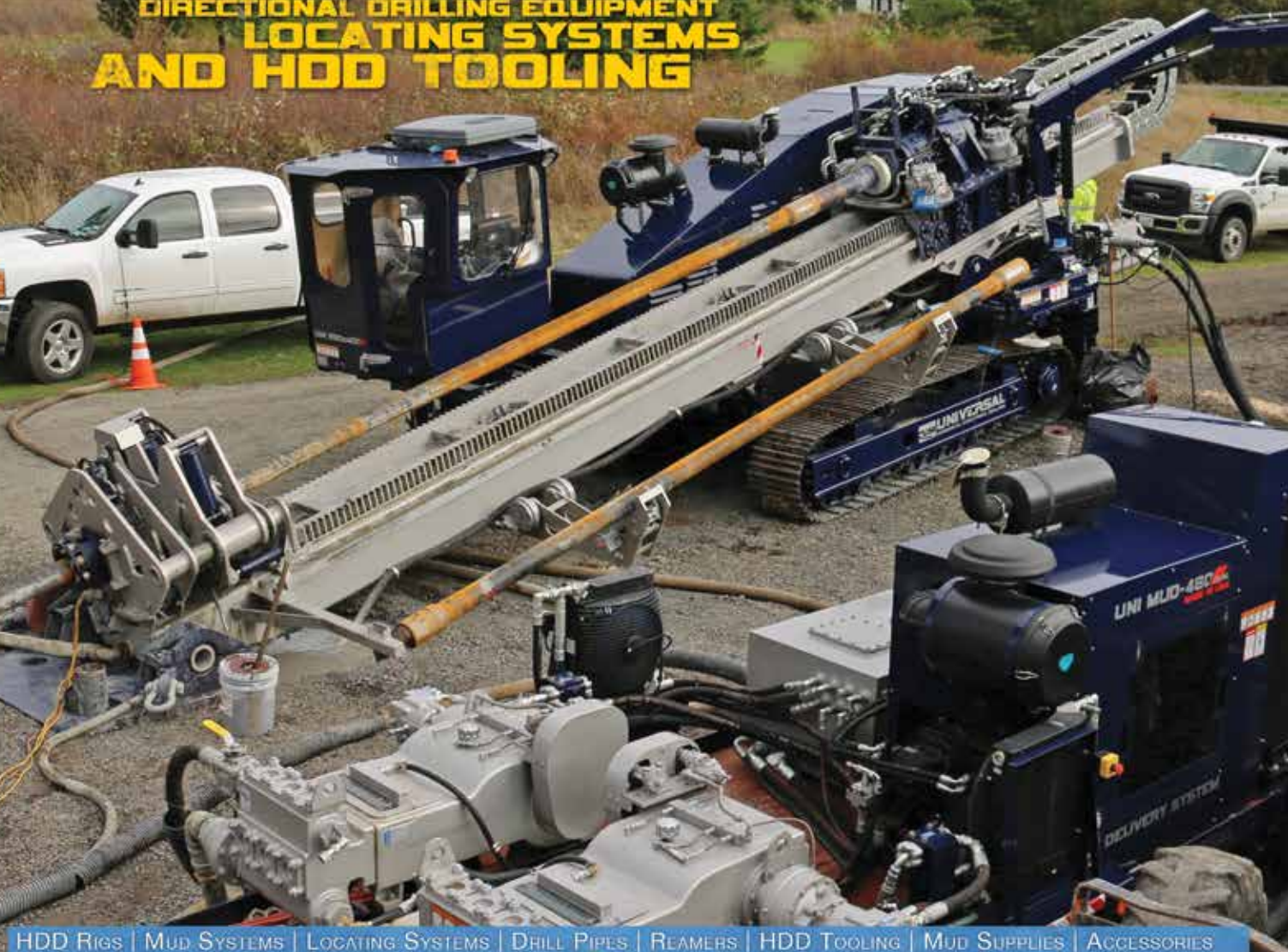


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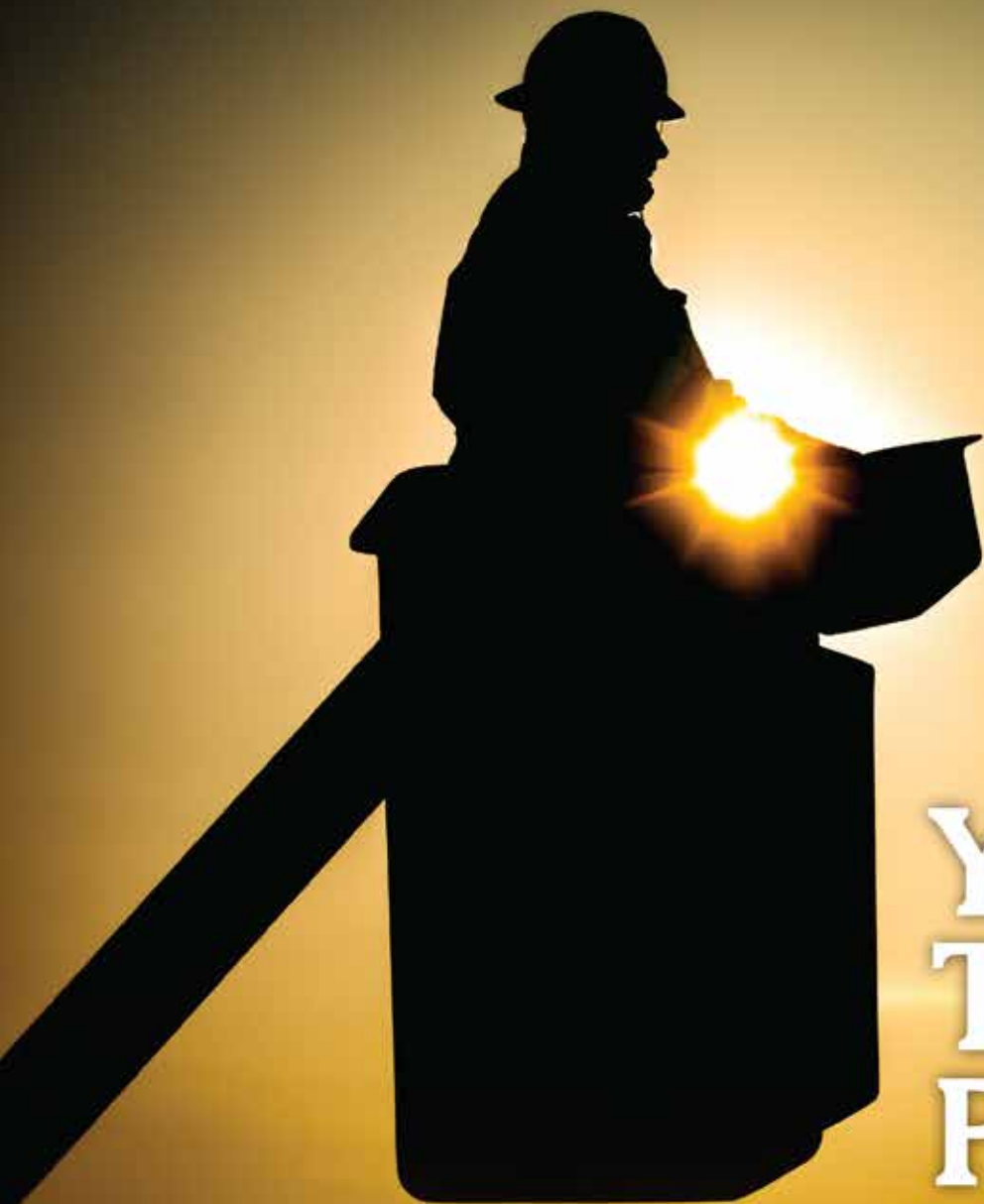
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- Made of water-resistant 1680d ballistic weave materials for durability
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"With the wide range of Klein Tools products that our customers use, we wanted to make sure they had a hands free carrying option with lots of organization and a workstation with light that makes finding your tools quick and easy," said Linda Rolfe, senior project manager at Klein Tools. "The Tool Station Backpack gives users the ability to take their tools on the go, set up a temporary work station anywhere, and to illuminate their work areas with the removable magnetic worklight."

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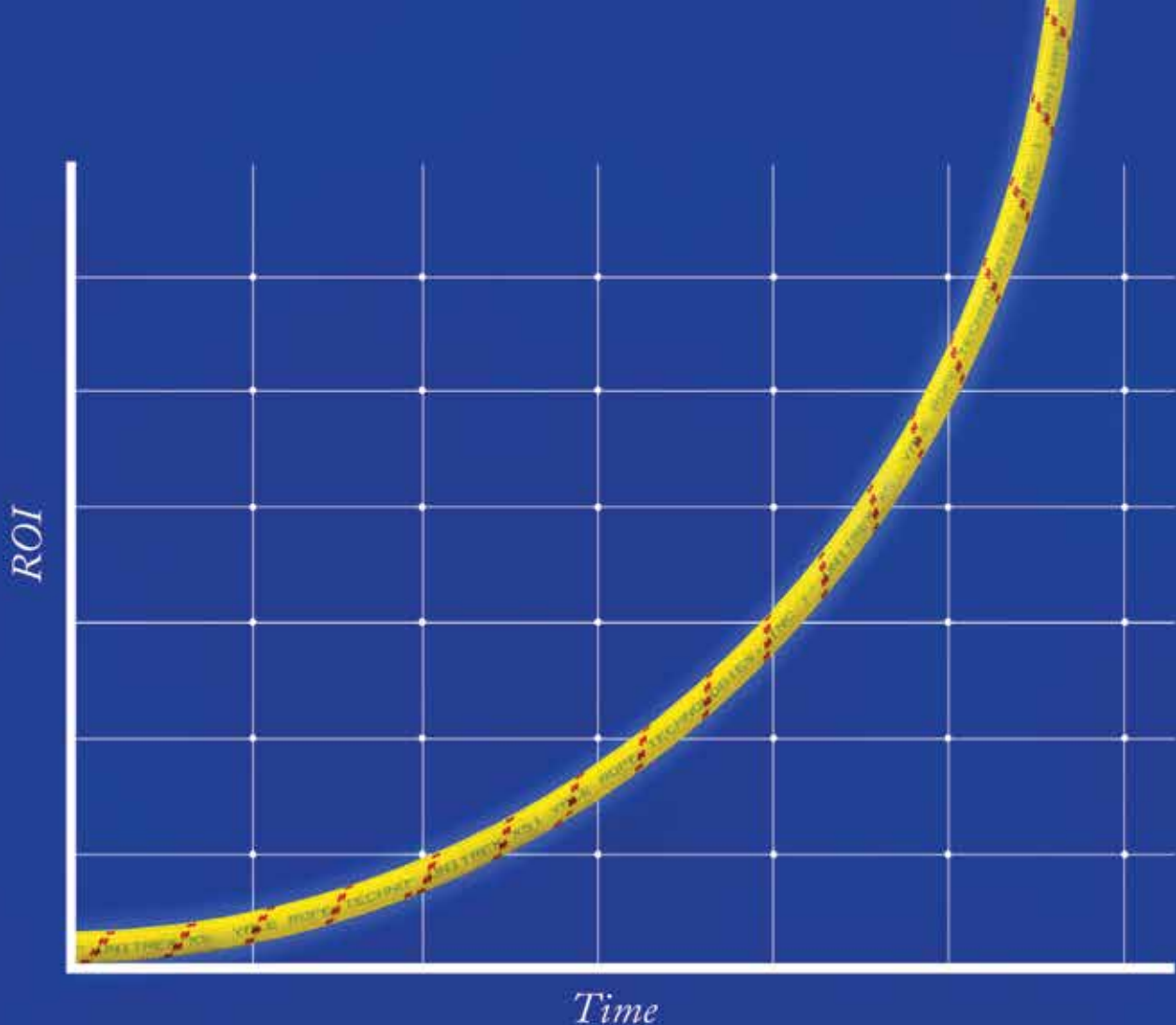
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