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MRC NEWSLETTER

Maintenance & Reliability Center
The University of Tennessee
"where industry & academia meet"

Editor
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Call For Papers - MARCON 2008

May 5-8, 2008 (presentations May 7-8) **Knoxville Marriott, Knoxville, TN**

Like previous MARCON conferences, **MARCON 2008** will be a forum for all – practitioners, specialists, educators, students, and managers – to exchange information on new emerging technologies as well as on tried and proven methods and techniques in the area of maintenance and reliability engineering. Cutting edge research topics, case studies of real applications and the latest thinking in the managerial/financial aspects of the maintenance & reliability field come together in this multi-track, highly informative conference. **You are invited to provide a 300 – 500 word abstract for consideration by the Technical Review Committee for presentation at MARCON 2008.**

Submission Requirements:

- 300—500 word abstract
- Clear, descriptive title
- Author's name, e-mail address, phone & FAX number, company affiliation
- Agreement to attend and present the paper if selected
- Electronically sent to MRC by November 2, 2007

Critical Dates:

November 2, 2007	**Abstracts Due**
December 14, 2007	**Authors Notified of Selection**
April 4, 2008	**Manuscripts/Presentation Slides Due**
May 7-8, 2008	**Presentations at MARCON**

Inside this issue:

Abstracts should be transmitted electronically to kkallstr@utk.edu. Successful authors will be sent manuscript and presentation preparation guidelines when notified of selection. Final manuscripts and presentation slides must be submitted electronically.

MARCON 2008 should prove to be greatly beneficial for your business, featuring keynote addresses and workshops centered around bridging classic reliability and industrial maintenance. We welcome manuscripts that correspond to this theme as well as additional topics pertaining to the field of maintenance and reliability.

Speakers receive complimentary conference attendance (1 per paper)

Director's Corner

The Fall Season is Underway

Tom Byerley
MRC Director

Once again the UT campus has come alive with an influx of students for the Fall semester. It's always an exciting time of the year with new students hopelessly wandering around looking for various buildings, new faculty members searching for unfamiliar classrooms, student organizations vying for attention and even a tiny bit of enthusiasm about a sport we call football.

In the midst of all this, we on the MRC staff are continuing our never-ending quest to support our MRC members, our faculty cohorts, and our MRE students in whatever ways possible. We have had a good summer with 21 of our students in MRC intern positions with several of our member companies. The interns are all back on campus, and judging from the reports I have seen to date, have had outstanding experiences this past summer. We are now starting the recruiting process for the 2008 MRC interns and look forward to working with several of you in placing interns for next summer.

We have just completed the Residential School we run in conjunction with our UT-Monash Graduate Studies Program. We had 12 students here in Knoxville August 25 – 27 to meet with the Monash faculty and some of their fellow students. Seven of the attendees are in the final stages of earning their Master's Degrees and presented their preliminary project work to the total group. Hopefully, some of them will also be presenting their projects at MARCON 2008.

And speaking of MARCON 2008, we are already very active on making it even Bigger and Better. We are partnering with the folks at Reliabilityweb.com again and they are definitely planning a larger expo area with more exhibitors. Kim has sent the "Call for Papers" out and we are preparing to sort through the selection process to bring you the high quality program of presentations you have grown accustomed to. In addition, this year's conference will be co-located with the *Plant Engineering and Maintenance Show*. So mark your calendars now for next May 5-8 and plan to be here for MARCON 2008!

Throw in preparations for our Fall members' meeting, pursuit of a few research proposals, and handling a good deal of day-to-day administrative and business support activities and you have the recipe for a busy and fulfilling summer and fall. It has been, and is, that way for us.

I hope you all have also had a great summer – and are looking forward to fall and the rest of this year.

Tom

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Increasing Productivity and Asset Life with Infrared Windows

By: Jennifer Daugherty, Sarah Newberry, and Casey Schewe
(Arnold Engineering Development Center, Arnold AFB)

The Arnold Engineering Development Center (AEDC), at Arnold Air Force Base, Tennessee, has focused efforts toward an improved infrared program. As equipment ages, the need for improving inspections and making work more effective becomes imperative. Infrared (IR) inspection of electrical equipment allows equipment health to be determined and teardown intervals to be driven more by condition, with a maximum time limit. Infrared windows reduce lockout/tag out requirements and make infrared on high-voltage electrical components economical and easy to schedule. This paper discusses a case study on installation of over 50 separate IR thermography windows in electrical equipment cabinets and discusses lessons learned. The goal of the infrared program is to detect impending failures, improve equipment health, and decrease lost test time. Infrared windows reduce man-hours required to perform infrared inspections, they increase safety of the inspections, and, by reducing the hours required to perform the inspections, they allow us to perform the infrared inspections more frequently.

AEDC is the largest ground flight simulation test complex in the world. AEDC is the world's premier flight simulation test facility, can simulate flight conditions from sea level up to 300 miles and from subsonic velocities to Mach 20. AEDC has motors of up to 83,000 hp and pumps up to 50,000 gpm. The Engine Test Facility has compressors with flow rates of 1,000,000 cfm. Protecting the equipment to prevent lost test time is imperative. AEDC has performed Predictive Maintenance (PM) and Reliability-Centered Maintenance (RCM) for over 20 years. An established and mature vibration and oil analysis program has been instrumental in ensuring equipment reliability for key pieces of rotating equipment. To improve equipment health assessment and reduce the cost to maintain equipment, AEDC is improving the infrared program that assesses electrical and mechanical equipment. Installation of infrared windows and a major effort to establish a good electrical predictive maintenance program have been focused goals for the next step in improving maintenance and reliability of equipment. This paper discusses the implementation of infrared windows and lessons learned during installation of electrical equipment of up to 13.8 kV.

Infrared thermography of high-voltage equipment historically has been a costly and lengthy process. Without windows, thermography required extensive outages and time-consuming lockout/tag out (LOTO) procedures. Most of our electrical cabinets are bolted cabinets; very few are hinged doors. The first step to perform infrared inspection of a bolted, high or medium-voltage electrical cabinet was to lock out the system, in some cases taking down multiple 13.8 kV transformers. Next, the bolted doors would be removed and the area roped off. The locks would be removed, and the equipment would be reenergized. When the equipment was in a steady state, non-changing condition, infrared image data would be collected with an IR camera. At the completion of the infrared imaging, another electrical outage and LOTO were required to bolt the cabinet doors back on. The equipment could then be reenergized and returned to normal service. Infrared in the Propulsion Wind Tunnel Facility took over 100 locks to safeguard the 13.8 kV breakers for the two 83,000-hp motors and two 60,000-hp motors. In June, 2006, AEDC began the installation of infrared windows. With infrared windows we are able to perform this job safely without opening cabinets and performing the extensive LOTO process. Fifty plus infrared windows have been installed to cover all the accessible, critical, electrical connections. This includes capacitor banks, potential transformers, switchgear, incoming lines, unit subs, and other electrical equipment. Image capture for this equipment with windows, located all over the plant, takes two people one to two days. Reporting takes one person one day. This is a vast improvement over the multi-day LOTO method previously used. As the benefits of IR imaging were realized and the cost to attain the data was reduced, AEDC began to schedule and perform the inspection on a quarterly basis, when before it was generally the practice to perform this inspection only once every two to three years. The installation cost of the windows was almost the same as that to perform one route of infrared imaging without the windows installed, so the payback was almost immediate.

An aerial view of the AEDC

An additional driver of the use of IR windows is safety. Infrared window installation in many areas is driven by the need to comply with safety guidelines such as the National Fire Protection Agency NFPA70.E, regarding arc flash and arc blast. NFPA70.E increased the rated minimum safe distance to equipment when it is energized, resulting in new arc flash boundary calculations to assess personal protective equipment needs. In several instances, IR image data was collected with critical cabinets open before the implementation of NFPA70.E, but now the new calculations have established the safe distance boundary is beyond the wall of the facility or another piece of equipment. In these cases, windows are a logical risk mitigation.

Many lessons have been learned with installation and use of over 50 IR thermography windows. Accurate temperature determination from IR images is sensitive to the radiation loss through the windows, termed transmission loss. The transmission loss was much greater than expected, and it varied by infrared window lot and manufacturer. Early AEDC testing of windows was done using windows bought from one manufacturer and in one lot. It was later found that transmission losses varied enough from lot to lot that transmission loss variation needed to be considered. In addition, testing results indicated the transmission losses were large enough that all low-emissivity (E) targets required painting to increase the emissivity and to ensure detection of hot spots. One industry practice is to place stickers on the equipment, but a hot plate is capable of melting and peeling the stickers. AEDC selected a technique to paint a target with red polyurethane coat paint, Glyptol. This is the same coating used in motor windings and provides a good emissivity target, and it is proven safe in high-heat electrical applications. The paint emissivity tested in the high 90 percent range. Some IR thermography cameras provide input of the transmission losses. For those that do not, the transmission losses need to be accounted for to enable accurate temperature indications. We have written detailed work instructions for the IR thermography technicians. The work instructions for taking infrared through a window have emissivity tables that account for transmission loss. While corrections for the angle of viewing and resultant view factors can be estimated with theory, tests in the lab showed the transmission loss at a high viewing angle was too great. If viewing angle becomes too great for some equipment, additional windows are required for sufficient accuracy. For instance, incoming lines for switchgear in one plant required two 3-in. windows. Some cabinets, once opened, required changing the location of the window because of partitions or shields. This revealed a new concern. When windows are relocated to sides or backs of cabinets, worker handrails or other safety devices are required to ensure worker safety. Some cabinets have equipment too close to the cabinet door to allow for minimum focus distance on the camera, and in these cases windows are not useful.

As the IR thermography program matures, we will establish routes and ensure that all windows are properly labeled. A list of the windows and a baseline copy of the reference image needs to be provided with the work order issued to IR thermography technicians. For example, some equipment will have a window where an image of the A and B phase is captured and another window where an image of the B and C phase is captured. It is desirable to develop the IR program to a state where a baseline and two cycles of images exist. It is beneficial to keep images, even if no problems are found, to record a baseline image of normal operation; this enables contrast as equipment degrades and simplifies assessment of equipment degradation.

Collecting IR images through windows requires more skill and knowledge of the factors that influence accuracy. Technicians should be given adequate training to ensure that accurate data is collected.   AEDC fully calibrates and characterizes the IR cameras annually. In addition, on the day of use, each camera is checked against a known temperature source.

Imaging through infrared windows is difficult, but it provides a path toward safer operations and early detection of problems. A good high-voltage electrical infrared program is more difficult without infrared windows. In many cases infrared imaging without windows is cost prohibitive, primarily because of the extensive lockout/tag out process and compliance with NFPA70.E regulations. AEDC's infrared program has augmented oil and vibration programs, and routes for infrared are being established. No one predictive technology is the best for all applications. For example, ultrasound technology complements the infrared program. Ultrasound can be used to detect equipment problems and has been used to select equipment where window-enabled IR thermography could be suitable. In establishing an infrared program AEDC had to further develop the ultrasound program to be able to provide accurate asset health evaluation.

Up-front planning and evaluation is critical to a successful program. Presently AEDC is installing infrared windows on only the most critical assets and on assets where safety is a concern. This method is not foolproof. To ensure asset health and employee safety, infrared windows are necessary for high and some medium-voltage equipment. Imaging through infrared windows, while not perfect, has greatly enhanced safety and the timely collection of electrical equipment condition. In addition, the installation cost is little more than one infrared route with extensive lockout/tag out. Infrared imaging of high-voltage cabinets can be performed more often and more safely at lower cost with windows, and the result is improved asset health evaluation and equipment uptime. However, there are a few things to keep in mind. Most installations require more infrared windows than originally expected. Direct line of sight and a high-emissivity targets like polyurethane red coat are critical to accurate anomaly detection. Digital pictures taken while the cabinet is open are a help and should be a part of the baseline development for a good PM program. Detailed planning of installation of infrared windows can lead to an effective infrared program for high-voltage equipment.

In summary, the key lessons learned from our work include these: paint high-E targets on parts of interest; ensure very close to direct line of sight; taking images normal to the surface is best; and account for transmission loss of the windows to ensure accurate detection of temperature and problems.

UT & MRC Join Forces with Interested Companies to Work Towards "Best-in-Class"

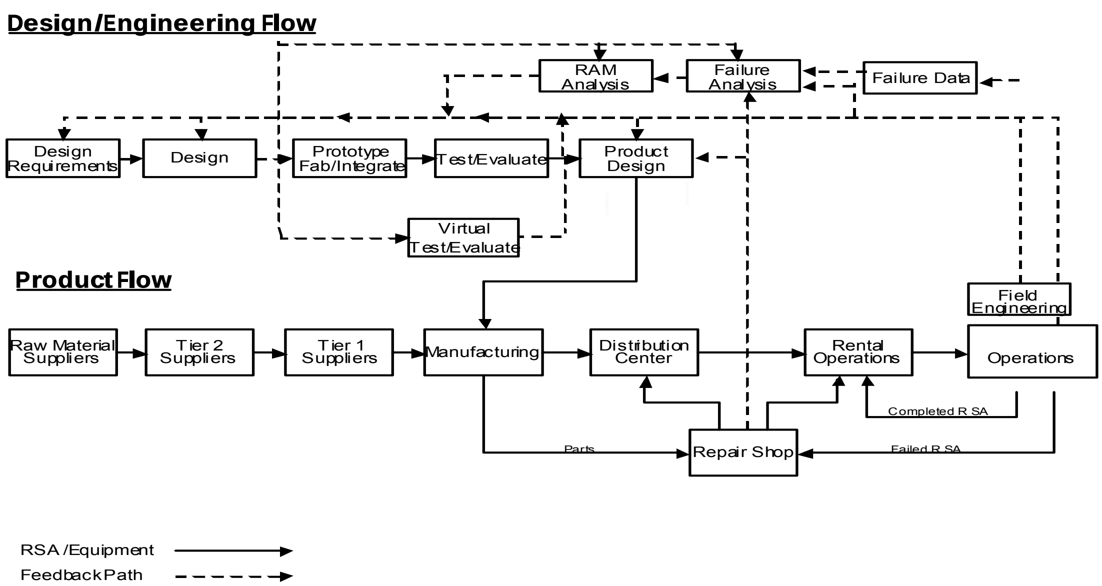
By: Duane Dunlap, MRC Consultant

The University of Tennessee College of Engineering and the MRC have recently been combining forces to pursue reliability and maintenance projects with interested companies. At the request of several companies, teams composed of UT faculty members, graduate students and MRC personnel have visited various industrial sites and have offered ideas for improvement towards the goal of "best-in-class". UT faculty members are interested in developing useful research projects and the companies are interested in reliability and maintenance improvements and associated cost reductions. Working together, they make an unbeatable team covering all of the bases.

The process includes pre-work, site visits and follow-up reports with observations, recommendations, and (often) proposals for appropriate research projects to assist the site. Prior to the visit, contact personnel are identified and pertinent information is exchanged concerning organization/personnel charts, process flow charts and key operating, engineering and maintenance personnel. All visits have had upper management support with a key manager identified as a sponsor for the visit. To date, UT teams have visited 16 company sites.

To gather information, the UT Team takes a systematic view of the process following the appropriate steps in the Design/Engineering flow and Product flow model shown below. Site tours and interviews with plant personnel and company management are the most important sources of information. Generally, a sub-team composed of mechanical, electrical and nuclear engineering faculty follows the Design/Engineering Flow; and, industrial and mechanical engineering faculty follow the Product Flow.

Example No. 1



While visiting the plant site, the UT Team utilizes the interviews and observations to focus on the following:

- Personnel safety rules, protective equipment and injury rates
- Use of quality tools
- Use of reliability tools
- Documentation of maintenance procedures, schedules and machine histories
- Use of drawings/CAD tools
- Instrument calibration
- Testing and re-testing
- Supplier delivery, parts and documentation
- Inventory
- Maintenance spare parts
- Housekeeping/Cleanliness
- General morale
- Visual factory

The findings of the UT visits to date are, in a word, “disappointing”. Most sites were unaware of reliability and maintenance “best practices” utilized by other companies and did not have a formal process for designing reliability into their products. Feedback from operations in the field to design was often erratic and inaccurate. Few suppliers of critical product components used statistically-based tools such as SPC or other quality tools. Training and certification of personnel struggled to keep up with the high turnover rate of key employees. Most managers were unaware of reliability and maintenance processes and principles and there was no corporate sponsor for these concepts.

At the conclusion of each visit, the UT Team reviewed the findings and made suggestions to management. The first and most important suggestion was to get involved with the reliability and maintenance community. Many companies pursuing reliability and maintenance principles in organizations such as MRC or SMRP are proud of their progress and willing to share their experiences on the path to best-in-class. Traveling this path alone can be both time consuming and expensive.

Other suggestions/needs from the UT teams that are most representative of the many sites visited are as follows:

Training

1. Reliability Overview
2. Lean Flow Training
3. Reliability Centered Maintenance
4. Lean Maintenance
5. Root Cause Analysis Training

Duane Dunlap

Design Engineering Flow

1. Enhancement of CAE Tools to Move Towards Virtual Prototyping
2. Transforming Data into Information via Statistical Analysis and Data Mining
3. Improved Modeling of Product Dynamics
4. Design for Reliability
5. On-Line Monitoring, Diagnostics and Prognostics

Product Flow

1. Improving Asset Reliability Based on Proactive Quality Systems
2. Designing State of the Art Repair and Maintenance Facilities
3. Integrated Supplier Development to Develop Reliable Suppliers
4. Analysis of Maintenance Policy to Enhance Asset Availability
5. Reliability as Measured by Assembly Fit Problems

MRC Intern Testimonials

Our MRC intern program was a great success again this year, with 21 interns placed at 6 companies. In the January issue of the newsletter, we included excerpts of a note from a very happy intern employer. This time we thought we would give the interns an opportunity to recount their experiences.

WILLIAM F. ROHR - SENIOR, MECHANICAL ENGINEERING (DUPONT - BORDERLAND, TX)

Spending a summer interning at Borderland offered a unique experience. The plant was under construction during the summer. The operations team was training and working on the infrastructure for the plant. Also, tests where being performed on installed equipment. Throughout the summer I was able to actively participate in some of the work and observed a large part of it.

I spent the bulk of my time at Borderland working with the documents and Excel. I worked to help create an instrument list that will be used in loop checks while testing the equipment. I worked to produce a gasket list for Borderland. I combined and edited documents to make contractor safety guide lines. I participated in several training sessions: safety harness, SHE, intern training, and others. I worked on the Iris testing of the acid coolers. I was involved in the interview process when the team was looking for a maintenance supervisor. Overall, I got to experience what it is like building a plant and laying the ground work needed to start it.

One of the most interesting things I got to witness was the high performance work system. This management system allows the operators to take ownership of the plant and their careers. I found it interesting to see how much they where all actively involved in the process of getting the plant ready for day to day operation; whether it is involvement with the community, work hours, commissioning, maintenance, safety, etc., they all were actively involved in the decision making for the plant.

Before working at Borderland, I did not realize that some plants are built using modular sections. This reduces cost by taking the work to the contractors, instead of the contractors to the work. The steel structure of the plant is built and then broken into pieces. The pieces are then shipped to the site, to be put together like huge Lego blocks. It was interesting to see the plant being built.

This internship was a valuable experience for both me and DuPont. I learned a lot and got to experience a large variety of the work that goes into building a plant. Everybody was very busy this summer with all the work that goes into setting up the plant, so having an intern around helped to relieve the work load. The MRC internship program is great for both the students and the companies.

Shaan Mohammed - Junior, Mechanical Engineering (Michelin North America - Spartanburg, SC)

This past summer I had the opportunity to work with Michelin North America at the Spartanburg US-3 facility. The US-3 facility is responsible for making the heavy truck tires for North and South America, as well as military tires for the armed forces. While at Michelin I worked alongside two other interning students under the guidance of Charles Cureton and Cindy Pendley, two of Michelin's Reliability Engineers.

When I first arrived at Michelin I was both excited and apprehensive about what the summer would have in store. It was my first internship in my degree related field and I wasn't sure what to expect. However, after meeting the people I would be working with and learning about the projects I would be working on, I became more comfortable and really enjoyed what I was doing.

During the summer, I worked on bottleneck equipment—finding causes of downtime and then researching and developing proposals as to how to reduce or eliminate the problem from occurring again. I worked with the two other interns in the designing of prototypes to test new ideas on different pieces of equipment and then aided in the implementation of those ideas. We studied critical parts of the plant and developed maintenance routes and plans that would better aid in the reliability of those areas. These studies often involved hands-on use of tools such as thermography, ultrasonics, RCFA, oil analysis and various computer software. We had the opportunity to work side by side with maintenance on inspections and repairs to get a first hand look at what kind of work was involved. Working in the plant was also a great experience for developing communication skills, as there were many different people we had to interact with.

We were each assigned a piece of equipment as well as an area in the plant to focus on. We were to look at the data that had been reported to maintenance and pick a few problems to work on. The machine I was assigned to had problems with rubber jams, and the vacuum that was used to remove debris. To work on these problems I spent many hours watching the operations of the machine as well as just watching the operators and their routines. On one specific day I had the opportunity to watch a rubber jam occur. After doing a root cause failure analysis, I determined that the jam was due to another piece of equipment that was in bad repair - a reel that was used to wind up the finished product. The reels were broken causing operators in one area of the plant to perform makeshift repairs in order to get the reels to work with their machines. However, their repairs did not work when the reels were transferred to other machines in the process, and resulted in the rubber jams experienced on my machine. My solution was to talk with the managers of that area and have them inform their operators of the damage that can result from make-shift repairs. I also talked with the maintenance personnel responsible for repairing those reels and developed a new method of marking the broken reels as well as a route to pick them up. I also suggested switching to a newly designed reel that was more durable and less prone to failure.

The vacuum portion of the machine was a piece of equipment that was combined with brushes in the removing of a by-product build up from parts of the machine. The problem with the vacuum was that it was not collecting the by-product like it should and was allowing the brushes to make a mess in the floor. After some calculations and meetings with the vendors it was determined that the system in place was inadequate and a new system is currently in development.

Aside from our individual projects we were given some projects to work on as a group. One project we worked on was developing a maintenance plan for part of the plant that was seen as a bottleneck in the production process. To develop this plan we spent many weeks in the area recording data from the bearings and motors using ultrasonics and thermography. After the inspection of two failed motors we determined that a build-up of a sulfur by-product was clogging the cooling system for the motors causing them to over-heat and the windings to fail. To solve this problem we developed a filter that could be placed over the back of the motor, trapping the by-product before it entered the motor. The filters were not only easy to inspect but they were easy to maintain and replace as well. After the study, we then compiled all of our data and information into reports and suggested a maintenance plan that would better predict and prevent failures.

Another project that was given to us unexpectedly was a problem that was occurring with a metal detector. The detector was used in the scanning of the rubber to ensure that no metal was making it into the tires or machinery. The problem was that the detector was having false readings and rubber jams which were causing lots of downtime throughout the plant. After running some tests and speaking with the operators we hypothesized that a static shock given off by the detector may have been the problem for the false readings. To solve this we developed a series of static bars that could be placed on the detector to safely discharge the static. The rubber jam was an inconvenience and safety hazard to the operator due to the nature in which the rubber was removed after the jam. To eliminate this problem we redesigned an end plate that would stop the rubber from going underneath the belt. After a follow up of the plate and static bars we determined that while the static bars did eliminate shock, they did not help with the false readings. Some more investigating found the problem to be a procedural error in the way the rubber was placed through the detector.

We also visited two motor vendors where we were able to see how a motor was assembled and repaired as well as learn some very useful information that later aided us in our projects. Another field trip led us to Laurens Test Track, a 3300 acre facility where Michelin tests tires. At the track the engineers design and perform tests on tires far beyond what any tire would experience under normal driving. The facility also has a car corral well stocked with everything from Corvettes, Mustangs, BMW M3s, minivans, trucks, semi's, to a 600+ hp Camaro used for testing drag tires. The trip to the track was informational because it gave us a look at the other end of the industry. We got to see first hand the results of the quality and performance that go into Michelin's tires.

This past summer has been very useful to me in understanding the field in which I am getting my degree. I received lots of hands on training and experience that I feel to be crucial in my goal towards a degree in Mechanical Engineering as well as my future career search.

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MRC 2007/2008 Calendar of Events

October 7-10	SMRP Annual Conference (Louisville, KY)
October 22-23	SMRP Executive Summit (Houston, TX)
November 2	MARCON Abstracts Due
December 4-7	International Maintenance Conference (Daytona Beach, FL)
January 15	UT-Monash Applications Due
May 5-8	MARCON & Plant Engineering and Maintenance Show (Knoxville, TN)

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