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OUR MINDEN FACILITY

orbit

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A Technical Publication for Advancing the Practice of Operating Asset Condition Monitoring, Diagnostics, and Performance Optimization

OUR MINDEN FACILITY

...an inside look

Editor's Notepad

Gary Swift
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Orbit Magazine
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Greetings, and welcome to *Orbit!*

In the January issue, we included a timeline of Bently Nevada milestones from 1953 to 2002. This issue builds on that historical background by focusing on the current state of our Manufacturing facility here in Minden, Nevada, USA (cover photo). Since 2002, GE has continued to invest in our high-tech plant, and it is nice to have the chance to "toot our own horn" just a bit.

Our Plant Manager, Jim Flemming, contributed our feature article, and several of our other managers created additional articles that describe how their organizations support our Manufacturing team. I enjoyed the chance to learn more about the Minden facility, and the dedicated employees who work here!

The historic Minden Wool Warehouse was modernized and renamed "Building D" by Don Bently. It housed Software Engineers and most of the "Bently Rotor Dynamics Research Corporation" (BRDRC) team until our new facility was ready for occupancy in 2000.

In July, we will expand our horizons outward and take a look at some of the interesting activities in the India region. Our business has been "global" for many years, and I look forward to learning more about our operations around the world.

Cheers!
Gary

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ADRE* Quick Configuration

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For years the Bently Nevada team has been recognized for doing one thing very well: Creating powerful solutions for machinery diagnostics. With the introduction of the ADRE Quick Configuration software, we've transformed one of the most powerful diagnostic tools on the market into one of the easiest tools to use.

ADRE is an advanced tool designed to handle the toughest problems. In 2012, the ADRE team was given a challenge: Make the ADRE 408 easier to configure. So easy, in fact, that a user with little experience could pick one up and use it with very little training. Challenge accepted! And so, the ADRE Quick Configuration software was born.

The ADRE Quick Configuration software simplifies the configuration of your ADRE 408 into three fast, easy, intuitive steps:

1. **Arrange the cards on your ADRE 408**
2. **Sketch out a machine train**
3. **Connect the Sensors**

Arrange the cards

Before doing anything else, the software asks a simple question: what does the back of the ADRE 408 look like? To answer this question, the user can drag cards from the ADRE Quick Configuration palette onto the interactive 408 back-panel until the diagram matches the existing hardware (Figure 1). By default, the software assumes the ADRE408 has three sampler cards and a single Keyphasor* card. If the default configuration matches the 408, this step can be skipped altogether as it is already done!

FIGURE 1: The first page of the ADRE Quick Configuration software, showing an ADRE 408 with 3 sampler cards and a single Keyphasor card

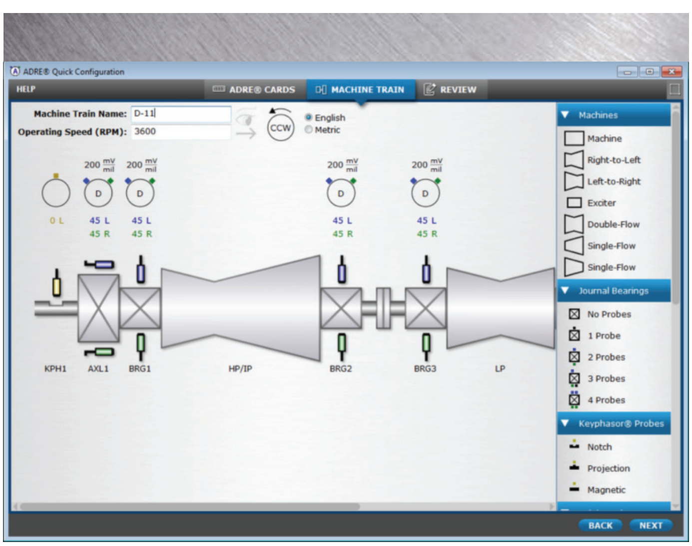

FIGURE 2: The second page of the ADRE Quick configuration software, showing a GE D-11 steam turbine created by dragging parts from the palette on the right

Sketch the machine train

Because the software uses a block diagramming standard that is recognized worldwide, anyone who can draw a machine train as a diagram already knows how to configure an ADRE 408—even if they've never touched one before. Simply drag and drop large machine components, bearings, couplings, and Keyphasor probes from the palette onto the interactive machine train diagram.

By convention, the diagram is composed from left to right starting with the outboard end of the prime-mover, through every component of the machine train, and ending with the furthest bearing of the driven machine (driver to driven machine). Individual parts of the machine train can be added in any order, and may be rearranged with a simple click and drag. If a bearing with probes is added, the probes appear as part of the diagram, and may be modified in-place. The most common settings are presented and changed in one place: the interactive machine train diagram (Figure 2).

Plug it in

Here's where the magic happens. The software does all the tedious work. Sensor pairs from the machine train are assigned to cards on the 408 in order from left to right (driver to driven machine), followed by individual channels from left to right. The last page of the software summarizes the new database that will be created (Figure 3), and shows how the ADRE 408 connects to the sensors on the machine train. Clicking FINISH opens the fully configured database in ADRE SXP software (Figure 4).

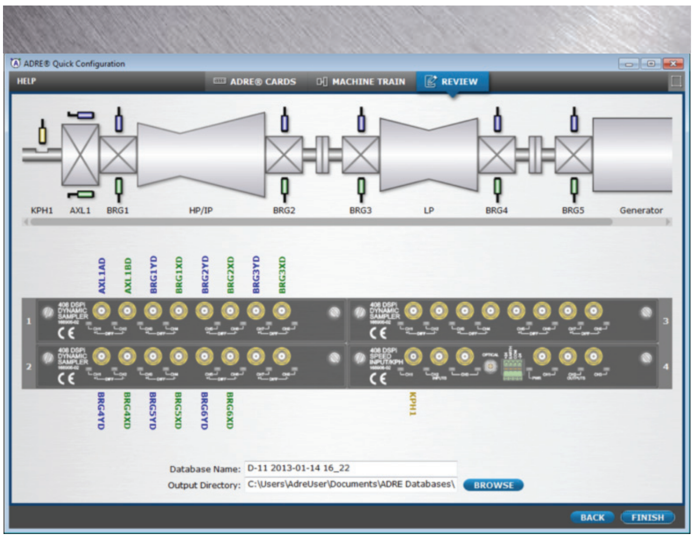

FIGURE 3: The last page of the ADRE Quick configuration software, showing how the ADRE 408 connects to a GE D-11 steam turbine.

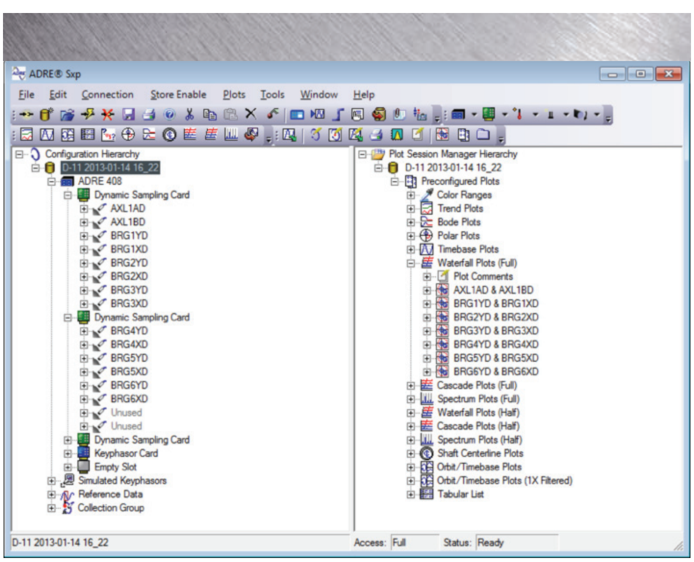

FIGURE 4: ADRE SXP software displaying a database generated for a GE D-11 steam turbine using the ADRE Quick Configuration software

The end result is a database tailor-made to match a specific ADRE 408 and machine train. Data collection rates are calculated based on the speed of the machine train and preconfigured plots are generated for each channel based on established Bently Nevada best practices. The ADRE Quick configuration software configures databases that are ready to collect data for most common scenarios. The generated database can be used to collect and display data immediately after its creation.

Simplicity is now the standard. The ADRE Quick Configuration software allows a basic user to take advantage of all the power that an ADRE 408 has to offer, without the learning curve. For the experienced user, the ADRE Quick Configuration software saves time and energy—making a powerful tool easy and accessible to more users.

The ADRE Quick Configuration software is immediately available for download for customers with a current Technical Support Agreement (TSA), and will be part of the standard offering for all new ADRE sales. ■

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35 YEARS

Steve Barnes, June Delorey & Patty Vick. Not shown: Reidar Wahl

Celebrating Our Experience

This issue focuses on our Minden manufacturing plant, with mini-articles on a few of the organizations that support the operations of the facility. It is impressive to realize that most of the employees in these photos have many years working with the Bently Nevada* product line right here in Minden – although those with the longest service spent much of their earlier time in other buildings around town before our new facility was completed and open for business back in 2000. ■

Note: If it seems that this issue is more "Minden-focused" than usual, it is. But don't worry. In future issues, we will highlight our operations in other regions around the globe. – Editor

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30 YEARS

Steve Brush is our only representative of the 30-year group who was available to attend the photo session. Not shown: Wang-Min Anderson, Aleta Haglund & Brent Tessmann

25 YEARS

Steve Hadley, Larry Auchoberry, Patrick Ezekiel.
Not shown: John Lowry, Robert Rath & Delores Schreiber

20 YEARS

Eric Butterfield, Tom Kalb, Lorri Williams, Mark Dieter & Jennie Hamiter. Not shown: John Hunter

15 YEARS

The 15-year group filled several steps on our main stairway. Back row, left to right: Brian Bowlds, Juan Moralez, Doug Eckery. Second row: Kevin Rollings, Tony Ward, Hans Van Der Poel, Jerry Williams, Skip Ferguson. Third row: John Kelley, Matt Kalb, Alice Mcintire, Merly Wright. Front row: Chris Higginbotham, Brian Wood, Devanee Schaeffer, Trini Cansino. Not shown: Laurie Abbott, Stuart Campbell, RJ Carlson, Michael Davis, Chris Kirby, Raymond Mc Tier & Gregory Schaeffer.

10 YEARS

Libby Oakden, Leigh Ann Gardner, Matt Beier & Chad Cox.
Not shown: Brian Huang & Adam Rogers.

2013 Ascent* Software and SCOUT Firmware Released

All Bently Nevada customers with these products are eligible for this update at no cost.

This is consistent with GE's Bently Nevada 5 year Product Support for the SCOUT portable data collector, along with our commitment to ongoing Customer Support at no annual charge. Notable enhancements and additions in this release are listed here:

- Probe referenced Orbit plots with Keyphasor pulses marked on time waveforms
- Selectable spectrum peak hiding to enable focus on more subtle indications
- View spectra in dB units to support motor current signature analysis
- SCOUT140, Cross Channel Spectrum for Operating Deflection Shape (ODS) analysis
- SCOUT140, Modal impact testing with Frequency Response Function (FRF) and Coherence calculations
- SCOUT140 Universal File Format (UFF) Export, which allows Export to Compatible Applications
- SCOUT140 80 KHz Fmax and 12,800 line spectrum resolution

The latest versions of Ascent software and SCOUT firmware are available for self-service installation from the Downloads section of the BNTechSupport.com portal. ■

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China Holds New Engineer Training Class

New engineers from left to right. Front row: Roy Guo, Sophie Wang, Maggie Yang, Xining Zhu, Cai Jiang, Qi Wang, Derek Su, Geoff Jiang, Amos Sun, Hongxiang Qiu, Bo Zhang, Alice Chen, Fuquan Liu. Back row: Frank Zhang (Bently Nevada China Engineering Manager), Paul Lindsay, Graham McMillian & Nigel Leigh (Instructors), Phoenix Zhu, Edwin Chen, Yaming Cheng, Jacky Zhu, Ren Zheng, Curtis Hoffman (Instructor), Sean Jee, Max Liu, Guanqun Yu, Jian Wang, Jun Chen & Xiaobo Fu.

Our Bently Nevada Technology team recently held a training seminar in Shanghai, China, for a group of new engineers. The class included participants from electrical, mechanical and computer science disciplines, and was facilitated by Curtis Hoffman & Paul Lindsay from the USA and Graham McMillian & Nigel Leigh from New Zealand.

The new engineers learned fundamental concepts of our transducer systems and were introduced to the permanently-installed and portable monitoring systems in our product line. The seminar included discussion on a wide variety of subjects, including the key topics summarized here.

- Bently Nevada history, with a description of our Customers and their expectations.
- GE culture, including acronyms, communications, and organizations that engineers work with closely as part of their normal job functions.
- Established processes and resources for applications such as Change Management, Customer Issue Resolution, Design for Manufacturability, Independent Design Review, Intellectual Property & Patent protection and Hazardous Area Approvals.
- Demonstration of various hardware and software products, including our RK4 Rotor Kit, 1900/65A General Purpose Equipment Monitor, SCOUT Portable Vibration Analyzer, 3500 monitoring & protection system, and System 1* software. ■

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"THE TRAINING SEMINAR WAS VERY BENEFICIAL TO OUR CHINA ENGINEERING TEAM. IT HELPED OUR NEW ENGINEERS TO ALIGN THEMSELVES CLOSELY WITH THE BENTLY NEVADA TECHNICAL TEAM STRATEGY, SO THAT THEY CAN BETTER SUPPORT OUR GLOBAL NPI (NEW PRODUCT INTRODUCTION) ACTIVITIES, AND MORE EFFECTIVELY SUPPORT OUR CUSTOMERS IN THE CHINA REGION."

—FRANK ZHANG, BENTLY NEVADA CHINA ENGINEERING MANAGER

"OUR CHINA ENGINEERING TEAM IS CRITICAL TO OUR GLOBAL STRATEGY AND WILL SUPPORT THE REGION WITH WORLD CLASS EXPERTISE. WE HAVE AN EXTREMELY TALENTED GROUP AND WE WILL CONTINUE TO INVEST TO ENSURE OUR STRONG GE BENTLY NEVADA TECHNOLOGY LEGACY AND GLOBAL BEST PRACTICES ARE THE FOUNDATION FOR OUR LOCAL TEAMS."

—ERIC BUTTERFIELD, BENTLY NEVADA ENGINEERING MANAGER

Training Schedule Update

The training schedule in our JAN 2013 issue did not include courses in the Middle East, Africa & Turkey, and it had a few mistakes in the Netherlands and UK schedules. For closure, we are including the updated information here. Since schedules are subject to change, your best source of up-to-date information is always our online training website: **http://ge-energy.turnstilesystems.com**

MIDDLE EAST, AFRICA & TURKEY

COURSE TITLE	LENGTH (DAYS)	LOCATION	COUNTRY	START DATE
3500 System Operation & Maintenance	3	Manama	Bahrain	18-Feb-13
Machinery Diagnostics	5	Manama	Bahrain	10-Mar-13
3500 System Operation & Maintenance	3	Manama	Bahrain	15-Sep-13
Machinery Fundamentals & Applied Diagnostics	5	Manama	Bahrain	27-Oct-13
System 1* Fundamentals	3	Doha	Qatar	3-Feb-13
3500 System Operation & Maintenance	3	Doha	Qatar	21-Apr-13
Machinery Diagnostics	5	Doha	Qatar	5-May-13
System 1 Fundamentals	3	Doha	Qatar	8-Sep-13
3500 System Operation & Maintenance	3	Doha	Qatar	10-Nov-13
ADRE* 408 Sxp	3	Doha	Qatar	17-Nov-13
Mobius Institute** CAT I (Course & Exam)	4	Abu Dhabi	UAE	17-Mar-13
Mobius Institute CAT II (Course & Exam)	4	Abu Dhabi	UAE	9-Jun-13
Mobius Institute CAT I (Course & Exam)	4	Abu Dhabi	UAE	6-Oct-13
Mobius Institute CAT III (Course & Exam)	5	Abu Dhabi	UAE	3-Nov-13
System 1 Fundamentals	3	Kuwait	Kuwait	1-Sep-13
Machinery Diagnostics	5	Kuwait	Kuwait	8-Sep-13
System 1 Fundamentals	3	Khobar	Saudi	9-Mar-13
3500 System Operation & Maintenance	3	Khobar	Saudi	4-May-13
Machinery Diagnostics	5	Khobar	Saudi	1-Jun-13
System 1 Fundamentals	3	Yanbu	Saudi	20-Apr-13
3500 System Operation & Maintenance	3	Yanbu	Saudi	7-Sep-13
Machinery Fundamentals & Applied Diagnostics	5	Khobar	Saudi	9-Nov-13
Advanced Machinery Dynamics	5	Dubai	UAE	16-Jun-13
Machinery Fundamentals & Applied Diagnostics	5	Cairo	Egypt	27-Oct-13

3500 System Operation & Maintenance	3	Istanbul	Turkey	4-Mar-13
Machinery Diagnostics	5	Istanbul	Turkey	10-Jun-13
System 1 Fundamentals	3	Istanbul	Turkey	12-Sep-13
System 1 Fundamentals	3	Midrand	South Africa	8-Apr-13
3500 System Operation & Maintenance	3	Midrand	South Africa	15-Jul-13
Machinery Diagnostics	5	Midrand	South Africa	9-Sep-13
Machinery Diagnostics	5	Algier	Algeria	21-Apr-13
System 1 Fundamentals	3	Algier	Algeria	6-Oct-13
3500 System Operation & Maintenance	3	Algier	Algeria	9-Sep-13
Machinery Diagnostics	5	Port Harcourt	Nigeria	8-Jul-13
System 1 Fundamentals	3	Port Harcourt	Nigeria	21-Oct-13
3500 System Operation & Maintenance	3	Port Harcourt	Nigeria	18-Nov-13

Note: Middle East, Africa & Turkey courses are presented in English.

NORWAY

COURSE TITLE	LENGTH (DAYS)	DATES	LOCATION	LANGUAGE
3500 Operation and Maintenance	3	26-28 Feb 2013	Bergen	Norwegian
System 1 Fundamentals	3	12-14 Mar 2013	Bergen	Norwegian
3500 Operation and Maintenance	3	18-20 Sep 2013	TBD	Norwegian
System 1 Fundamentals	3	01-03 Oct 2013	TBD	Norwegian
Machinery Diagnostics (Vibrasjonsanalyse)	5	14-18 Oct 2013	TBD	English
Basic Thermodynamic Machine Performance	3	29-31 Oct 201	TBD	English
Advanced Thermodynamic Machine Performance	2	26-27 Nov 2013	TBD	English
Fundamentals of Vibration and Transducer Operation	2	TBD	TBD	Norwegian
ADRE 408	3	TBD	TBD	Norwegian
Trendmaster PRO	3	TBD	TBD	Norwegian
Basic Vibration Analysis	3	TBD	TBD	Norwegian
Reciprocating Compressors Condition Monitoring & Diagnostics	3	TBD	TBD	English
Leveraging Decision Support	3	TBD	TBD	English
Machinery Fundamentals – Applied Diagnostics	5	TBD	TBD	English

Note: TBD = Dates To Be Determined. Location for these courses will be in either Bergen or Stavanger, Norway.

UK

COURSE TITLE	LENGTH (DAYS)	DATES	LOCATION
Vibration (Transducer) Fundamentals	2	18-19 Feb 2013	Warrington
3500 System Operation & Maintenance	3	20-22 Feb 2013	Warrington
System 1 Fundamentals	3	26-28 Feb 2013	Warrington
ADRE 408 Fundamentals	3	12-14 March 2013	Warrington
Machinery Diagnostics with System 1	5	18-22 March 2013	Warrington
Reciprocating Compressor Monitoring & Diagnostics	3	21-23 May 2013	Warrington
Vibration (Transducer) Fundamentals	2	24-25 June 2013	Warrington
3500 System Operation & Maintenance	3	26-28 June 2013	Warrington
System 1 Fundamentals	3	2-4 July 2013	Warrington
ADRE 408 Fundamentals	3	8-10 Oct 2013	Warrington
Machinery Diagnostics with System	5	14-18 Oct 2013	Warrington
Vibration (Transducer) Fundamentals	2	11-12 Nov 2013	Glasgow
3500 System Operation & Maintenance	3	13-15 Nov 2013	Glasgow
System 1 Fundamentals	3	19-21 Nov 2013	Glasgow
Advanced Machinery Diagnostics	5	TBD	TBD

Note: All UK courses are presented in English.

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OUR MIN

An inside look at Bently Nevada* Manufacturing

Jim Flemming
Bently Nevada Plant Manager
james.flemming@ge.com

When Don Bently moved his fledgling company from his Berkeley garage to Minden in the mid-1960s, the entire operation fit into a single empty building at the airport. As the business grew over the decades, it spread out to fill a dozen or so buildings in the local area, with the manufacturing plant moving from the airport to a historic brick creamery building "downtown." In 2000, the business consolidated into a single newly-constructed facility, which remains the home of our main manufacturing plant and other headquarters functions.

As the electronics state-of-the-art evolved over the years, Bently Nevada manufacturing processes evolved right along with it – starting with hand-wired circuits, then moving to hand-soldered through-hole boards, automated wave-soldered Printed Wire Boards (PWBs), and finally to the modern paste-soldered double-sided surface mount Printed Circuit Boards (PCBs) that represent the current technology.

DEN PLANT

ABOVE: Our main manufacturing plant fills the entire ground floor of our facility in Minden, Nevada, USA

Continuing Investment

After acquiring the Bently Nevada business in 2002, GE continued to invest in our infrastructure, allowing us to constantly improve our tools and processes. Most recently, this includes the ongoing construction of a Printed Circuit Board Assembly (PCBA) Prototyping Center. Rei Wahl describes this new line in an article on page 22 of this issue.

Our Focus

- Workplace Safety: We take employee safety very seriously, and are a certified Volunteer Protection Program (VPP) "Star" facility. Our EHS team helps tremendously with improving the ergonomics of the tasks that our employees perform – increasing the effectiveness of our processes while at the same time preventing worker injuries.
- Product Quality: Our business is certified ISO-9000/9001, which means that we have a Quality Management System that is tightly integrated with our engineering design and manufacturing processes. Our employees are empowered to "stop the line" without negative repercussions if they ever suspect the occurrence of a product quality issue.
- Regulatory Compliance: Our EHS team also helps us to comply with all required environmental regulations, so that we handle hazardous materials properly. We are also working toward full compliance with future requirements, such as the lead-free solder requirements of the Removal of Hazardous Substances (RoHS) regulations.
- Modern Production Techniques: In addition to embracing state-of-the-art manufacturing techniques, we also apply "Lean Six Sigma" concepts to eliminate wasteful processes and make our plant more effective. By making the right decisions, we can actually improve product quality while at the same time speeding up our processes and keeping costs down.

Now that I have shared an overview of our organization and our goals, some of our key team members will describe how their work centers fit into the big picture of our plant operations.

Shop Operations

> FABRICATION & FINAL ASSEMBLY <

"Fabrication converts raw materials such as sheet metal and solid bar stock into transducer housings, rack modules, probe sleeves and other important components for our product line, using modern CNC milling and machining tools for most of our work. Some of our fabricated products require welding, while others need specific finishing operations, such as anodizing, graining, or screen-printing. Final Assembly combines tested PCBAs with cables, connectors, housings, and other required components to produce the finished product. Our 3500 System is a perfect example of this collaboration."

—Deb Epps

> PRINTED CIRCUIT BOARD ASSEMBLY (PCBA) <

"Our department is made up of assemblers, specialists, and electronics technicians. These employees perform a range of operations including assembly, machine operation, and electronic testing. Printed circuit boards are built up with components using precision machines and skilled hands before being electronically tested for operation and functionality. The final modules are built up into assemblies that are then delivered to stock or shipped directly to a customer (if built for a specific order). We ensure each module is built and tested with the customer in mind."

—Kyle Francis

> MATERIALS <

"The Materials team manages the flow of material all the way from our suppliers to our customers. The purchasing team orders materials from our suppliers, the receiving team processes materials into the plant, the stockroom team stores and distributes materials to the production centers, and finally, the shipping and logistics teams package and process the shipments to distribute to our customers worldwide. Encompassing all of this is the planning team, who manages the production schedule to ensure we receive and process the orders to meet our customer's expectations."

—Derrick Olson

> TRANSDUCERS <

"Our team manufactures and tests proximity probes, Proximitor* sensors and cables. These products are the modern evolution of Don Bently's original "distance detector" products from the mid-1950s. They remain the heart of our business, even today. Probe assembly is a very specialized operation that combines precise microscopic operations, while Proximitor assembly is where we integrate PCBAs with housings, potting compound and connectors to form finished products. Transducers applied to the customer's machinery produce the signals that our monitoring systems process to provide protection and condition monitoring for our customer's most critical assets."

—Brooke Woellner

> LEAN SIX SIGMA PROCESSES <

"Our use of lean-six sigma is about driving a change culture. The Bently Nevada team has developed a sustained culture around improvement and problem solving. We use "Lean Action Workout" projects to collaborate and implement solutions to identified improvement opportunities within our supply chain. Our goal is to eliminate waste from our operations while improving the value we are providing customers. This culture of change drives cross-functional teams to improve: quality, safety, timeliness, data systems, environmental awareness, and efficiency throughout our operations. Lean-six sigma is our tool for ensuring future customer satisfaction."

—Jonathan Bridgers

> LONG RANGE PLANNING

"While the Materials team is focused on maintaining the scheduling that is needed for our day-to-day manufacturing operations, I am looking ahead with a longer view to translate what raw materials will be required for products we will be selling in the next 9 to 12 months. Understanding historical selling patterns, our applications, and the economic environment is critical to forecast accuracy and providing the transparency required to efficiently plan our future production."

—Karen Stoffer

The Minden Manufacturing team is well-known across the GE Oil & Gas business for having a true passion for Quality and Safety excellence. This is one of the key characteristics that impressed me the most when I joined the Bently Nevada team in 2011. The team always views quality through the customers' eyes and is willing to stop the production line, even over what others would consider a minor cosmetic 'non-issue'. Every Minden employee delivers upon Safety and Quality projects every single year. This creates an environment where the quality of our products improves continuously.

— Ernest Carey
Global Supply Chain Manager

Engineering

> MANUFACTURING <

"Right from the beginning, our Manufacturing Engineers work closely with the design engineers in our Technology team to ensure the manufacturability of our new products. We develop the processes and procedures that are used for manufacturing the production parts, including automating key manufacturing operations. One example of this is the transducer potting operation, which is now done more quickly and consistently than when it was a manual process."

—Curt Hooper

> TEST <

"Test Engineers develop the testing procedures that we use to ensure product quality. Most of our testing is automated, which improves consistency and reduces the time needed to perform the tests. We are constantly developing new test fixtures, processes and procedures in order to improve the quality of our testing to ensure that our products will meet specifications and perform as advertised."

—Michael Arthurs

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CUSTOM PRODUCTS

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THE BENTLY NEVADA* ASSET CONDITION MONITORING PRODUCT LINE HAS EVOLVED OVER SEVERAL DECADES TO ACCOMMODATE A WIDE VARIETY OF APPLICATIONS.

These include installations with harsh environmental conditions such as corrosive chemicals and high temperatures. Still, it sometimes happens that a specific application may be outside the capabilities of our portfolio of standard condition monitoring and protection products.

In such a situation, it may be appropriate to create a "custom" modified product that can meet the unique requirements of the installation. A few of the most commonly-requested special capabilities for our probes and Proximitor* sensors include those listed here:

- Extreme environmental temperatures (very hot or unusually cold)
- Extended linear range for proximity measurement
- Non-standard target material (our standard calibration target is AISI-4140 steel)
- Presence of especially corrosive chemical agents (Figure 1)

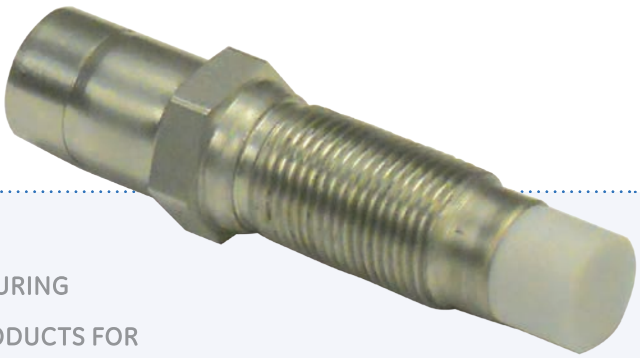
Special capabilities can also be incorporated into our monitoring instruments. These include changes such as modifying the monitor to work with a non-standard sensor, or incorporating non-standard signal filtering in the monitor hardware.

The Process

There are many different resources that you can use to help select appropriate standard (or custom) products for your condition monitoring & protection needs. Your local Bently Nevada Sales & Services contacts (including Field Application Engineers) are available to help with advice, as are our Customer Care Representatives. You can also download "datasheets," (officially known as Specification and Ordering Information documents) which include descriptive details of our standard products.

EXAMPLE: The 3300 XL datasheet is available for download at this link: **http://www.ge-mcs.com/download/sensors-and-transducers/141194_CDA_000.pdf**

Datasheets include specification information such as allowable ranges for ambient temperature and power supply voltages, proximity target material used for calibration, effects of magnetic fields, probe tip and case



CUSTOM ENGINEERING AND MANUFACTURING SERVICES CAN DELIVER SPECIALIZED PRODUCTS FOR UNIQUE AND CHALLENGING REQUIREMENTS SUCH AS UNUSUAL TRANSDUCER MOUNTING LOCATIONS, EXTREME ENVIRONMENTS, UNIQUE SIGNAL PROCESSING NEEDS, AND INTERFACES TO NON-STANDARD SIGNALS.

FIGURE 1: Example of a custom ceramic-tipped proximity probe that was engineered to accommodate a specified chemical environment.

material, allowable connector torque, and integrated and differential scale factors. They also include descriptions of part numbers and “dash options” (Reference 1), such as overall probe case length, probe case thread pitch, cable length, and available mounting brackets.

STEP 1

If you suspect that you may need custom modification of a standard product, the preferred way to start the process is to contact our Technical Support organization: **www.bntechsupport.com**

Our Tech Support team will review your needs, and if they are outside of the options for our standard products, they will check with existing “Mods” to determine whether the custom product modification that you need may already have been created. If it has, it is a simple matter to order the product with the required part number mod information.

STEP 2

If the needed mod does not exist, you have the option of requesting that we start the engineering design and manufacturing processes required to actually develop it. Our team will investigate all potential avenues for modifications knowing that you have unique requirements. If the required modification is safe and manufacturable, we provide a quotation that includes lead time and cost. The vast majority of non-standard requests can be fulfilled by our Custom Products team at only a nominal additional cost.

STEP 3

If you decide to purchase the modification, our Custom Products Engineering team will do the design work, and will coordinate obtaining agency approvals if needed. Our Manufacturing Engineers will ensure the manufacturability and extensive testing of the modified part. The specifications of the custom product will be logged and made available to the Tech Support team for future reference. ■

References

1. Orbit Vol.33 No. 1, JAN 2013, Swift, Gary, Part Numbers and Options

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ENVIRONMENTAL HEALTH & SAFETY (EHS) SUPPORT

Julie Abbott
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DALE VERTATSCHITSCH AND JULIE ABBOTT: step outside for some Minden fresh air on a pleasant January afternoon.

Safety has always been the top Bently Nevada priority. Just as our condition monitoring and protection systems enhance site safety for our industrial customers, our EHS program supports Manufacturing by ensuring a safe working environment in our own plant. To demonstrate our commitment, we have made the extra effort to become certified by the U.S. Occupational Safety and Health Administration (OSHA) certified as a Volunteer Protection Program (VPP) "Star" site.

VPP sites are committed to effective employee protection that goes beyond the requirements of OSHA standards, to more effectively identify, evaluate, prevent, and control occupational hazards to prevent employee injuries and illnesses. As a result, the average VPP worksite has a lost workday incidence rate at least 50 percent below the average of its industry (Reference 1).

Our EHS program focuses on the environment and the safety and health of all employees, customers and visitors.

As a VPP Star certified facility we work closely with other area businesses to help them achieve VPP Star certification. Not only do we have a chance to share our best practices with local industries but we are able to enhance our program by leveraging their EHS practices.

A key factor to the strong EHS culture at our facility is the employee engagement and management support. Our site has an employee-run safety team. The Minden Safety Team (MST) is team is made up of over 60 employees from across the business. This team supports the annual safety at home fair, an ergonomics team, chemical management, housekeeping audits, EHS communication, first responders and health and wellness programs. Management provides resources and support for all of the initiatives taken on by the MST.

EHS integrated with Manufacturing and Technology

EHS works closely with both manufacturing and technology to successfully drive business goals. It is imperative that all product designs are reviewed to ensure they meet industry safety and environmental requirements. Once a design is reviewed, technology and EHS work closely with the manufacturing team to help develop a strong manufacturing process. Air quality compliance, ergonomics, machine guarding and chemical exposures are only a few pieces of EHS that technology and manufacturing review during the product design phase.

In the field, the EHS function works closely with service technicians, field engineers and the customer to execute on EHS. Employees who work at customer locations are encouraged to "Stop Work" if they feel there is an unsafe condition or environmental concern. The EHS function will then work with the employee and customer to identify an appropriate solution.

Continuous improvement and customer satisfaction are other key element of the EHS program. EHS supports quality and engineering to help address any customer questions or concerns. EHS is integrated with the lean manufacturing concepts across the business. Identifying ways to eliminate waste, reduce cycle time and reduce cost of quality tend to have a positive impact on EHS goals. Various projects over the years have incorporated lean tools to eliminate chemical exposures, reduce hazardous waste, improve controls for permitted processes and reduce ergonomic concerns.

Summary

Our goal is to have every employee go home healthy at the end of every workday, to be a strong environmental citizen in our community and support our customer's needs.

"Maintaining a strong EHS culture and VPP Certification is no accident! I'm proud of the Minden EHS team, along with the employee-led MST dedication of continuously improving the site's safety and environmental processes. Our programs have served as "best practice" models for other GE facilities throughout the Measurement & Control business, and even for other western Nevada businesses that are not a part of GE."

—*Barry Hollis*
GE Measurement & Control North America EHS Manager

References

1. OSHA FactSheet, U.S. Department of Labor, 8/2009.

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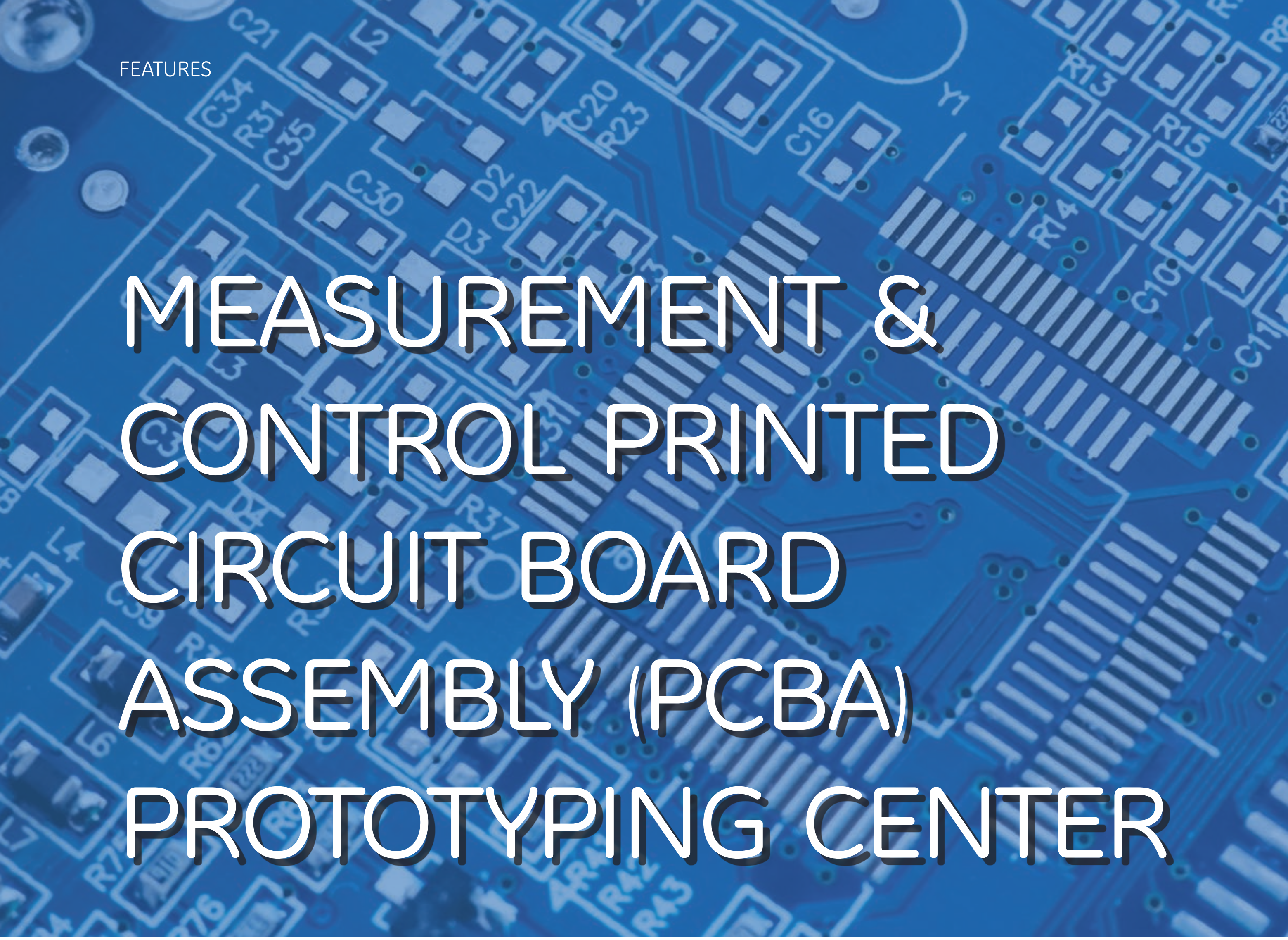

MEASUREMENT & CONTROL PRINTED CIRCUIT BOARD ASSEMBLY (PCBA) PROTOTYPING CENTER

Reidar Wahl
PCBA Prototyping Center Leader
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ELECTRONICS IS A CORE PART of our portfolio for the Bently Nevada* product line, as well as for every GE Measurement & Control business. Operational Excellence in electronics is a critical priority for our continued growth, and we are excited about the recent significant investment in this area. We are installing another state-of-the-art PCBA assembly line in our Minden, Nevada facility, building on in-house infrastructure and process expertise. This will allow for a dedicated line that builds high quality, rapid turn-around prototypes for the development of new products.

"THE PCBA PROTOTYPING CENTER REPRESENTS A HUGE INVESTMENT IN THE MEASUREMENT & CONTROL BUSINESS. THE FACT THAT THIS INVESTMENT IS BEING MADE IN MINDEN, NEVADA IS A VERY STRONG TESTAMENT TO THE MANUFACTURING EXPERTISE THAT THE MINDEN TEAM POSSESSES. EVERY SINGLE MINDEN EMPLOYEE CAN BE EXTREMELY PROUD THAT THEY GET TO TAKE PART IN LEVERAGING THEIR EXPERTISE BEYOND THE BENTLY NEVADA PRODUCT LINE AND HAVING A POSITIVE IMPACT ON MANY PRODUCT LINES ACROSS THE BROADER MEASUREMENT & CONTROL BUSINESS."

— ERNEST CAREY
GLOBAL SUPPLY CHAIN MANAGER

Our new PCBA prototype line (still under construction) will resemble one of our existing lines shown in this example.

Designing and building reliable electronics requires tremendous product, process and application expertise. The PCBA prototyping center will serve as a focal point for our global electronics knowledge, leveraging what we do well into a more consistent process while allowing for continuous improvements. This facility will provide manufacturable and testable prototype and pilot boards, as well as transitioning the build and test to production either in-house or at suppliers. The key to success is to share our expertise early in the process – bringing our experts together for "up-front" collaboration that will help the entire process to proceed more smoothly and minimizing unexpected surprises.

At the time of this writing, our Facilities, Manufacturing, Test, and Machine Maintenance teams are working together to install, align, test, program, and commission the production machines in our new PCBA line. Since we haven't mentioned the Machine Maintenance team in other articles in this issue, this is a good time for team manager Greg Marenco to describe what his people do in our Minden manufacturing facility.

Minden Machine Maintenance Team

Keeping the manufacturing equipment at a high-tech facility functioning to the highest standards requires a team of highly skilled, trained and dedicated technicians working behind the scenes. The Minden Machine Maintenance team fits this mold. Our team of twelve technicians and one manufacturing associate is responsible for maintaining all production equipment; over 600 assets, which includes home-grown fixtures, complex CNC lathes and mills, robotic systems, and leading edge technology surface mount equipment.

In addition to the necessary electronics degree and strong mechanical skills, the team members attend multiple machine specific training schools to further their understanding of both machine operations and processes. We employ current condition monitoring technologies, including oil sampling, thermal imaging, and power analysis in performance of these tasks. We routinely support two shifts of production along with continuous on-call duties for third shift and weekend coverage when needed. To accomplish our tasks effectively, we track all of the equipment with Computerized Maintenance Management (CMM) software for both preventive maintenance schedules and equipment repairs to build a solid machine history and operational cost. This has allowed us to go from primarily reactive maintenance to 68% preventive tasks and 32% other maintenance type tasks. ■

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GE Energy
GE Energy
GE Energy
CHILLED WATER RETURN
CHILLED WATER SUPPLY

MINDEN FACILITIES SUPPORT

Our modern facility in Minden, Nevada, USA is exemplary within GE for its "green" energy efficiency, as well as for extensive backup capabilities that ensure the quality of service to our manufacturing plant. The building was designed with such foresight that there was little room for improvement when GE's company-wide greenhouse gas reduction goals were introduced as part of the ecomagination* initiative back in 2005. As an example, every motor that is rated greater than 10 hp (7.5 kW) is powered by a Variable Frequency Drive (VFD) in order to reduce electrical demand during part-load operation.

Like any small city, our building – which accommodates more than 700 GE employees – needs a dedicated maintenance crew to "keep the lights on" and to ensure that the entire required utility infrastructure remains in good health. Our Facility Maintenance team is responsible for all of the systems that support the occupants of our building, starting with the Bently Nevada** manufacturing plant that fills most of the ground floor. The second floor houses office spaces, conference rooms, cafeteria, fitness center, health & wellness center, data center, Customer Application Center and Remote Monitoring Center (Reference 1), while the third-floor mezzanine contains HVAC infrastructure such as air handlers.

Minden Facilities employees take a quick break to gather in the "Central Plant" for a team photo. **LEFT TO RIGHT:** Darren Bradbury, Chad Blankenship, Jeremy Litka, Jose Hernandez, Steve Smith, Ken Forbes, Dennis DeLange, David Cruz, Monica Arthurs, Mark Ortiz, Rod Smith, Becky Pappenfort, Christian Funk. **INSET PHOTO:** Rod Salas.

Christian Funk
Bently Nevada Facilities
Maintenance Manager
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HISTORIC SNAPSHOT: shows our facility at the time of occupancy in 2000 (Bently Nevada became a GE business two years later). Brickwork in front of the building came from the ranch buildings originally located on this property, and large grassy areas with picnic benches allow our employees to eat lunch outside when the weather is nice.

Unique Features

In addition to all of the normal functions (elevators, fire detection & suppression, lighting, network, parking, sanitation, storm drains, ventilation, etc.) our building incorporates some interesting and uncommon capabilities that improve safety, conserve energy, and allow us to function effectively during unusual conditions.

- **Central Vacuum System:** For efficient removal of personnel safety hazards such as sharp cable clippings from manufacturing work centers.
- **Compressed Air System:** Uses variable speed screw compressors to meet demand without wasting energy.
- **Electrical Power Distribution:** Includes two, 2 MW diesel generators to provide Closed-Transition (CT) transfer to backup power when the offsite grid is not available. We also use modular electrical distribution stanchions in the manufacturing plant, which accommodate efficient reconfiguration as machines and work centers are moved to optimize production processes as part of Lean Manufacturing initiatives. In most cases, the modular design eliminates the need for "hot work permits" and Lock-Out-Tag-Out (LOTO) procedures.
- **Heating, Ventilation & Air Conditioning (HVAC):** Employs economizing with both water and air systems in order to efficiently maintain habitable conditions in the building. An extensive CO_2 monitoring system ensures that occupants always receive enough fresh air, while oxygen sensors monitor for the possibility of leakage from the liquid nitrogen system.
- **Lighting:** Our building incorporates clerestories (high windows above eye-level) that reduce the need for traditional long-tube fluorescent fixtures. We also use energy-efficient compact fluorescent fixtures where appropriate, and have upgraded some of the lighting to modern LEDs. When spaces are unoccupied, motion sensors detect that they are empty and turn off the lights.
- **Liquid Nitrogen Storage & Distribution:** Allows us to perform in-house environmental testing of our products using special chambers in the manufacturing plant and the engineering lab.
- **Propane Storage & Distribution:** Used as a backup heating source if natural gas is not available. Also provides a clean, safe fuel for forklifts used in the plant.
- **Security System:** Incorporates a network of "pan-tilt-zoom" video cameras at key locations with digital storage for surveillance. Most doors use card readers to control access automatically, while non-equipped doors use appropriate administrative procedures to control access.
- **Tahoe Studios:** Provides the capability to produce our own videos for internal and external communications.

Interesting Facility Facts

Construction of our Minden facility started in November of 1998, and was completed after 16 months. The building was occupied in February 2000, when it became an efficient centralized "home" that took the place of about a dozen separate buildings scattered around the Minden area. The building floor space is approximately 286,000 square feet. This equates to about 3 American-style football fields per floor.

Materials

6,000 cubic yards of concrete were used during construction. Reinforced for heavy machinery, the first floor weighs approximately 9 million pounds, while the lighter second floor weighs approximately 3.8 million pounds. Enough carpet was used in the building to carpet ~120 modern single family homes. There are more than 200 miles of telephone and network cable in the building. There is enough Category 5e (computer) cable to run from Minden, Nevada to San Francisco, California.

Disaster Preparedness

We work closely with local government and law enforcement agencies to coordinate our communications, planning, and responses for various possible scenarios. We also monitor the weather closely, and when lightning strikes have been identified within a specified distance of the site, we prepare the backup generators for automatic loading if needed.

EARTHQUAKE:

The facility is designed and constructed to a seismic Zone 4 requirement plus a 25% additional margin. This significantly exceeds local codes for earthquakes. The building can withstand an earthquake corresponding to approximately 8.0 on the Richter scale with minimal damage. Constructing to this specification added about 400 tons (800,000 lbs.) of steel to the project.

FIRE:

The building is constructed of all non-flammable materials, and incorporates an extensive fire detection and suppression system. Flammable materials are kept in closed containers and are stored in appropriately-rated steel cabinets.

FLOOD:

The building is sited above the 500-year flood plain, at an elevation 80 feet higher than the previous headquarters' location in downtown Minden.

UTILITY DISRUPTION:

With a disruption of offsite power, the building is able to operate continuously without interruption, using our backup diesel generators. If the natural gas supply is interrupted, we can use our propane storage tank to supply our heating needs in cold weather. And if the domestic water supply is unavailable, we have the ability to pump water from a local well.

Note: Our backup generating capability allowed us to continue production during a severe wind storm late in 2003 that knocked out power to the Carson Valley for several days.

Amenities

BENTLY ADVENTURES:

Provides an outdoor recreational service to our employees. Coordinates group events and checks out and maintains equipment for camping, climbing, bicycling, hiking, kayaking, skiing, snowboarding, snowshoeing and even white water rafting.

CAFETERIA:

Serves breakfast and lunch, and supports "backshift" operations when needed. It has been recognized as a benchmark for other GE operations for quality of service and healthy menu options.

CONFERENCE CENTER:

Incorporates folding walls that allow it to be divided into 4 individual rooms, one large room capable of accommodating 300 plus people, or other variations. All configurations incorporate support for Audio Visual (AV) presentations.

FITNESS CENTER:

Our Fitness Center is a modern gym staffed with professional trainers and equipped with a variety of exercise equipment. It is available to all employees and their spouses.

HEALTH & WELLNESS CENTER:

Our Health & Wellness Center is staffed with a Nurse Practitioner and Nurse Manager for our employees and their families. In addition to providing routine medical services, the qualified staff provides first aid if needed, trains our First Responders, and coordinates events such as flu shot clinics and blood donation drives.

If all of this sounds too good to be true, stop in for a visit the next time you're in western Nevada and see for yourself!

References

1. Orbit Vol. 32 No. 3, JUL 2012. "Minden Customer Application Center (CAC) Grand Opening."

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PACKAGED SYSTEMS SUPPORT

Our Packaged Systems team is the part of our Manufacturing organization that provides industrial enclosure solutions for Bently Nevada* machinery protection instruments and associated network hardware. Designs are specifically focused on ease of field wiring termination, protecting personnel from accidental contact with the enclosed electrical instruments, and protecting the instruments against specified environmental conditions. Each enclosure is supplied with a comprehensive drawing package.

Completed systems ready for shipping to customers. Painted steel cabinets are standard and stainless steel cabinets are optional for use in corrosive environments. Purged cabinets are available for use in Hazardous Areas.

Brent Tuohy
Bently Nevada Packaged Systems Manager
brent.tuohy@ge.com

Delivery, Installation and commissioning of our packaged systems are performed by our Global Project Services team, while design, assembly, and testing are accomplished at Bently Nevada facilities in several locations around the world.

Multi-lingual placard illustrates the global nature of our Packaged Systems support

Standard Equipment & Options

- Modular cabinets with industry-standard dimensions and 4 removable eye-bolt lifting lugs. Optional plinth (base).
- Solid or viewing front door and solid rear access door. Solid rear wall available for cabinets installed with back to wall.
- Outlet filter and inlet fan installed in rear door. Interior lamp.
- DIN-mount circuit breakers supplied:
  — One for each 3500 System Power Supply.
  — One for each electrical component.
  — One for the auxiliary outlet.
- Cable guide rings and wire duct for routing cable.
- DIN-mount Compression Style Termination Blocks for Power, Transducer Signal, recorder, and relay outputs.
- Utility Power outlet (with safety ground).
- Print pocket, A4 and A3 sizes available.
- Standard cabinet color, light gray.
- Two copper bus bars (earth and signal common), as shown in Figures 1 & 2.
- UL or CE rated wire for all wiring.
- 120 VAC, or 230 VAC, 50/60 Hz operation.
- Internal wires labeled with from/ to tagging on both ends.
- Field-cable entry through removable gland plates in bottom of enclosure (optional cable entry through top cover also available).
- Ring-tongue type wire lugs used for 3500 power supply wiring; ferrules used for all other wiring.

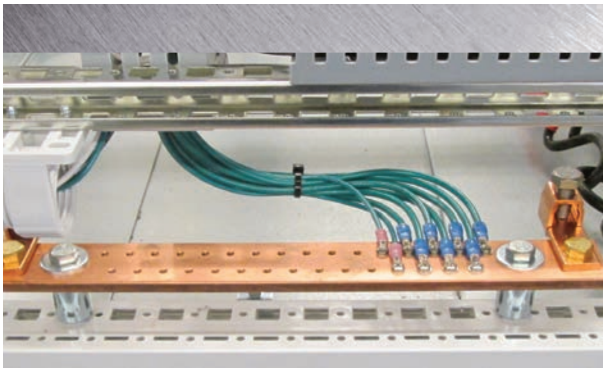

FIGURE 1: Standard Cabinet Safety Ground Bus shown during assembly (copper bar is bonded to cabinet chassis).

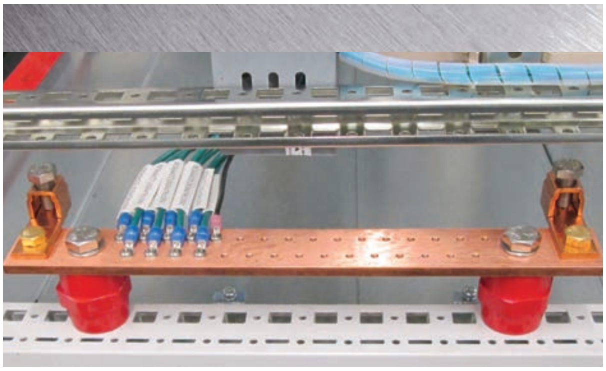

FIGURE 2: Standard Cabinet Instrument Ground Bus shown during assembly (copper bar is isolated from cabinet chassis with standoff insulators).

Standard Test & Validation

All Packaged Systems with installed instruments are tested and verified before leaving the factory as follows:

- All hardware including monitors, monitor options, power supplies, tagging, etc., is inspected to the enclosure list of materials.
- A power-off point-to-point continuity check of all wiring is performed.
- AC voltage wiring is tested at 1480 VAC for one minute (high-pot) wire-to-wire and wire-to-chassis.
- Installed equipment is mechanically inspected and power is applied for component functional check.

In Closing

If you are simply installing one of our new monitoring systems in an existing instrument panel to replace an obsolete system that is being removed, you might not need one of our packaged systems. But if you are installing a new system, it is worth considering the benefits of our integrated packages.

Note: Special testing requirements (such as optional Factory Acceptance Testing with customer representative present) can be accommodated upon request.

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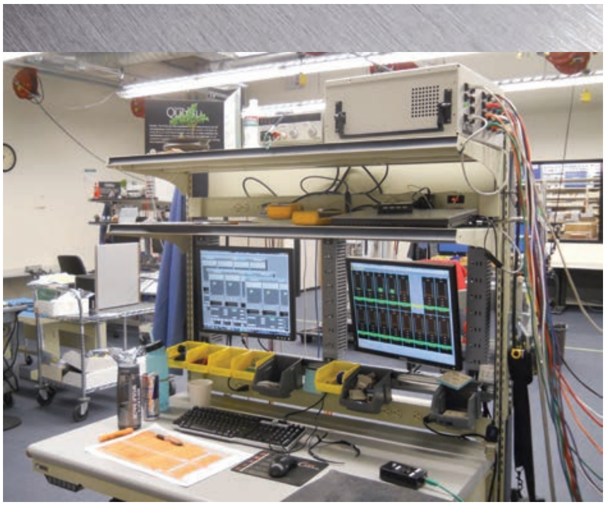
Projects Quality Coordinator Pam Litka shrinks tubing over wiring labels.



Automated processes ensure consistent, high-quality verification testing.

"ONE LESSER KNOWN FACT ABOUT THE BENTLY NEVADA MANUFACTURING TEAM IS HOW GLOBAL OUR OPERATIONS HAVE GROWN TO BE. THE ADDITION OF COMMTEST BROUGHT AN IMPRESSIVE FLOW PRODUCTION LINE THAT PRODUCES THE COMMTEST PRODUCT LINE IN CHRISTCHURCH, NEW ZEALAND. WE ALSO HAVE CABINET ASSEMBLY AND FACTORY ACCEPTANCE TEST SITES GLOBALLY THAT GIVE OUR CUSTOMERS A LOCAL OPTION FOR WORKING CLOSELY WITH OUR WORLD CLASS MANUFACTURING TEAM FOR THEIR CABINET PROJECTS. THESE GLOBAL SITES INCLUDE CAMPINAS BRAZIL, BAHRAIN, FOT HUNGARY, SINGAPORE, PUNE INDIA AND A START UP NEAR SEOUL SOUTH KOREA. THE BENTLY NEVADA MANUFACTURING TEAM PRIDES ITSELF IN MAINTAINING THE MINDEN STANDARDS FOR QUALITY GLOBALLY."

—ERNEST CAREY, GLOBAL SUPPLY CHAIN MANAGER

Manufacturing Technician Scott Smith performs power-off point-to-point continuity check.

PRODUCT QUALITY SUPPORT

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Rand Croxall
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Our Quality team works closely with our Manufacturing team in Minden. In addition to ongoing administration of our Quality Management System (QMS), and performing Root Cause Analysis (RCA) for identified problems, we issue Life Cycle Notification (LCN) and Technical Information Letter (TIL) documents to help you manage your installed Bently Nevada* condition monitoring & protection systems.

LCNs include important information about older products that are becoming obsolete, while TILs describe identified potential problems with our products, with recommended actions for resolution. You can sign up to be notified of applicable LCN and TIL documents by registering with our Technical Support team at the following link: **http://www.bntechsupport.com/**

Life Cycle Notification

Our Product Life Cycle Management Program is intended to help you proactively plan the ongoing operation and maintenance of your Bently Nevada products by providing information on the availability of parts and support. Notices are issued at life cycle milestones to inform you of changes and to provide recommendations on how to move forward. These notifications are typically issued several months before transitioning from one phase to the next, as reminders to purchase new systems, spare parts or repairs as needed.

phase 1 PRODUCT RELEASE: Product is released for sale with full support including ongoing enhancements, custom modifications, new spare parts, and full repair capabilities.

phase 2 MATURE PRODUCT: Same as Phase 1 except that no new enhancements are planned. Custom modifications are still available, but discouraged.

phase 3 SPARES ONLY: Product is no longer available for new installations and no new custom modifications are available. New spare parts (including those for existing custom modifications) are still available, and repair and support are provided as in Phases 1 and 2.

phase 4 LIMITED SUPPORT: New spare parts are no longer available and support is limited to repair, exchange, or remanufacture (subject to component availability).

phase 5 OBSOLETE: The product has no or limited support and is not recommended for continued use in a machinery protection application.

Customers are advised to migrate to an appropriate replacement product with the assistance of their GE sales professional specializing in Bently Nevada Asset Condition Monitoring.

"AT BENTLY, QUALITY IS FOUNDATIONAL TO WHAT WE DO EVERY DAY. IT IS AT THE CORE OF OUR BELIEFS AND DRIVES US TO PROVIDE WORLD CLASS PRODUCTS TO OUR CUSTOMERS."

— LEANNE PEDUZZI, MEASUREMENT & CONTROL QUALITY LEADER, GE OIL & GAS

Technical Information Letter

Our Technical Information Program is intended to help you maintain reliable operation and maintenance of your Bently Nevada products by providing information on any identified problems and the appropriate technical solutions for them. For consistency, TIL documents follow an established format that includes the following sections:

Application: Describes the specified product and installation application. Includes references for Hazardous Area approvals or other certifications.

Purpose: Provides a brief high-level overview of the reason for writing the TIL, including any applicable cautionary statements or possible consequences of not implementing recommendations.

Compliance Category: Summarizes the priorities of action needed to address an identified problem.

- O – Optional: Identifies changes that may be beneficial tot some, but not necessarily all, operators. Accomplishment is at customer's discretion.
- M – Maintenance: Identifies maintenance guidelines or best practices for reliable equipment operation.
- C - Compliance Required: Identifies the need for action to correct a condition that, if left uncorrected, may result in reduced equipment reliability or efficiency. Compliance may be required within a specific operating time.
- A – Alert: Failure to comply with the TIL could result in equipment damage or facility damage. Compliance is mandated within a specific operating time.
- S – Safety: Failure to comply with this TIL could result in personal injury. Compliance is mandated within a specific operating time.

Timing Code: Describes appropriate scheduling and plant conditions for implementing any recommended corrective actions.

1 Prior to Unit Startup / Prior to Continued Operation (forced outage condition)

2 At First Opportunity (next shutdown)

3 Prior to Operation of Affected System

4 At First Exposure of Component

5 At Scheduled Component Part Repair or Replacement

6 Next Scheduled Outage

7 Optional

Background Discussion: Provides overview of how the issue in question may affect the customer's plant operation. Describes how the issue was discovered, and associated RCA that was performed to determine the contributing factors.

Recommendations: Lists specific step-by-step actions that the customer, GE or vendor should perform to resolve the issue. Explains the benefits of following the recommendations, and how to verify that the TIL is "completed."

Planning Information: Includes useful information about the required technician skills, replacement parts, special tooling, reference documents and scope of work for implementing the TIL recommendations.

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제한구역
허가자 외 출입금지
GS

Gas Turbine Generator Loose Component Detected Using Vibration Analysis

Daekyoung Cho
GS Caltex Corporation
Rotating Equipment
Reliability Team

The events described in this case history occurred at the Refinery that is owned and operated by GS Caltex. Located in Yeosu, Republic of Korea, this Refinery has a refining capacity of 775MBPD and was built in 1969. The plant has 3 similar gas turbine generators that operate in parallel. The machine described in this article is the #2 Co-Gen unit, 116K550.

The machine described in this case history is a GE heavy duty (Frame 6B) gas turbine in power and high pressure steam generation service. As shown in Figure 1, the gas turbine drives a 60 Hz synchronous AC generator through a speed-decreasing load gearbox. The loose component that was detected using vibration analysis was located at the gas turbine output shaft to load gear coupling.

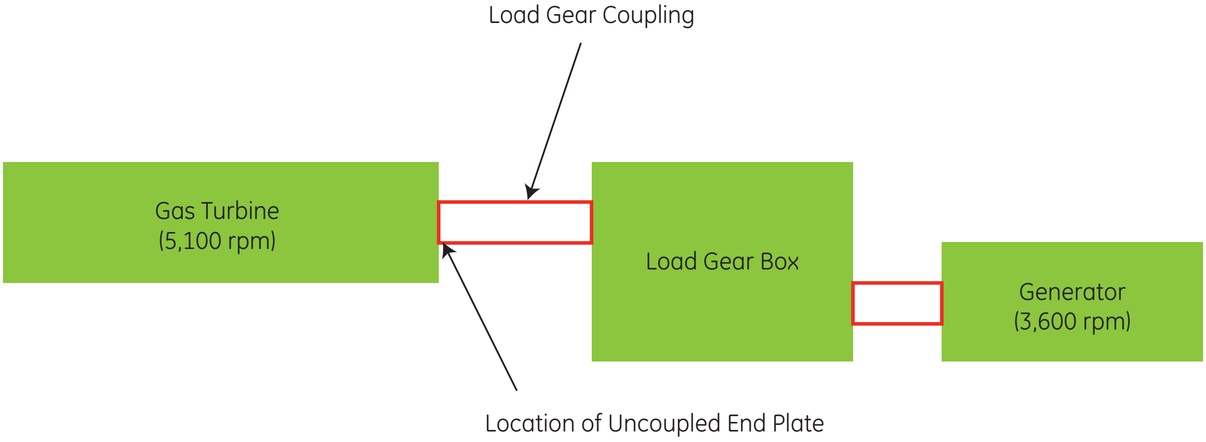


FIGURE 1: Simplified block diagram of machine train

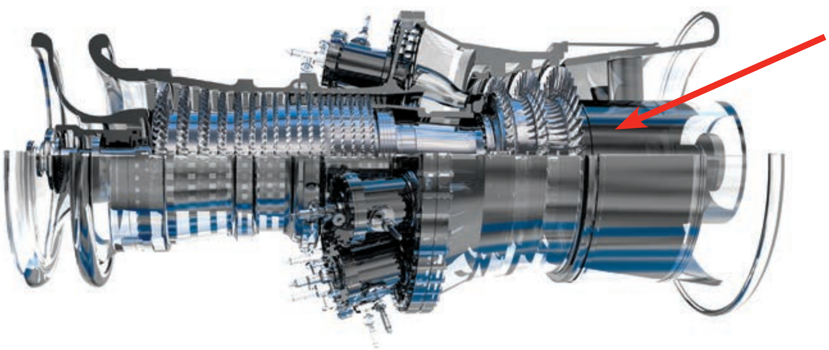


FIGURE 2: Cutaway drawing of a GE MS6001 gas turbine. Arrow points to location of loose component described in this case history.

Gas Turbine Details

The 116K550 gas turbine is a single shaft GE MS6001B model, with Mark V control system. It runs on either liquid (Heating Oil / Diesel) or Gas (C4 Raffinate) fuel. Combustors are cannular reverse flow design, and rated speed is 5105 rpm. Rated at 34.7 MW output, the gas turbine was originally installed in 1996 (Figure 2).

Operation & Maintenance History

Operation and maintenance history of the gas turbine is summarized chronologically in Figure 3. Major details are listed from 17 Apr 1996 when the gas turbine first started its operation up to the moment when the turbine tripped due to high vibration in no.1 bearing, as described in this article. Statistical data is listed here:

- Total Fired Hours: 58,176 hours
- Total Starts Counter: 382
- Total Fired Starts Counter: 176
- Emergency Trips Counter: 92

YEAR	MAJOR EVENTS
April 1996	First Fired Date
May 2001	Hot Gas Path Inspection
May 2005	Major Inspection
April 2007	No.1 Bearing Vibration High High Trip

FIGURE 3: Gas Turbine Operation & Maintenance History

Long-Term Operating Trends – *June through December, 2005*

The trend plot in Figure 4 shows vibration trends for about 6 months before the major inspection in 2005. The dashed red line indicates that maximum vibration level was below 6.0mm/s during normal operation. Periodic inspection results were normal, and there was nothing significant to report until the last event.

Long-Term Operating Trends – *January through December, 2006*

The trend plot in Figure 5 shows data for the same monitored parameters as in Figure 4, only for the following year. Once again, these parameters indicate that the gas turbine operated normally during this time period following the major inspection in 2005.

Short-Term Operating Trends – *March 2, 2007*

During a period of normal operation, vibration at the number 1 bearing (compressor inlet end of gas turbine rotor) and number 2 bearing (between the gas turbine and load gear) suddenly doubled – from 8 mm/s to 16 mm/s – and triggered a high vibration alarm. Note: The Vibration Alarm Set Point is 12.7 mm/s, and the Trip Set Point is 25.4 mm/s. (Figure 6).

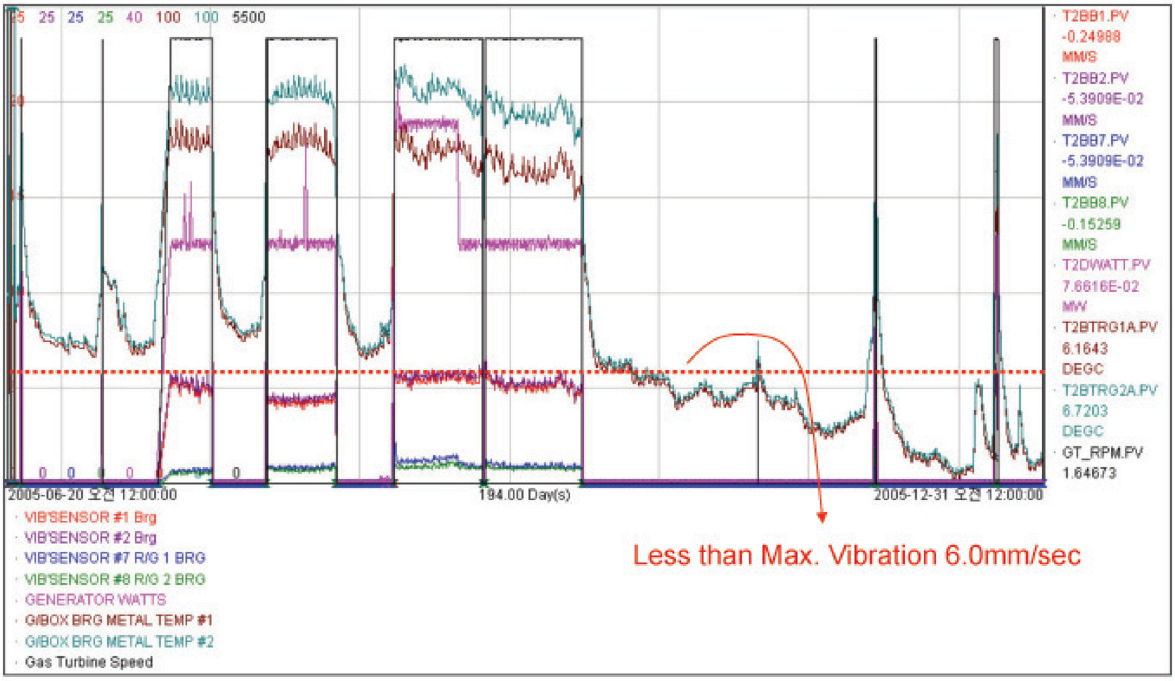


FIGURE 4: Operating trends from June through December, 2005 (194 days, total), after major inspections were completed in May, 2005.

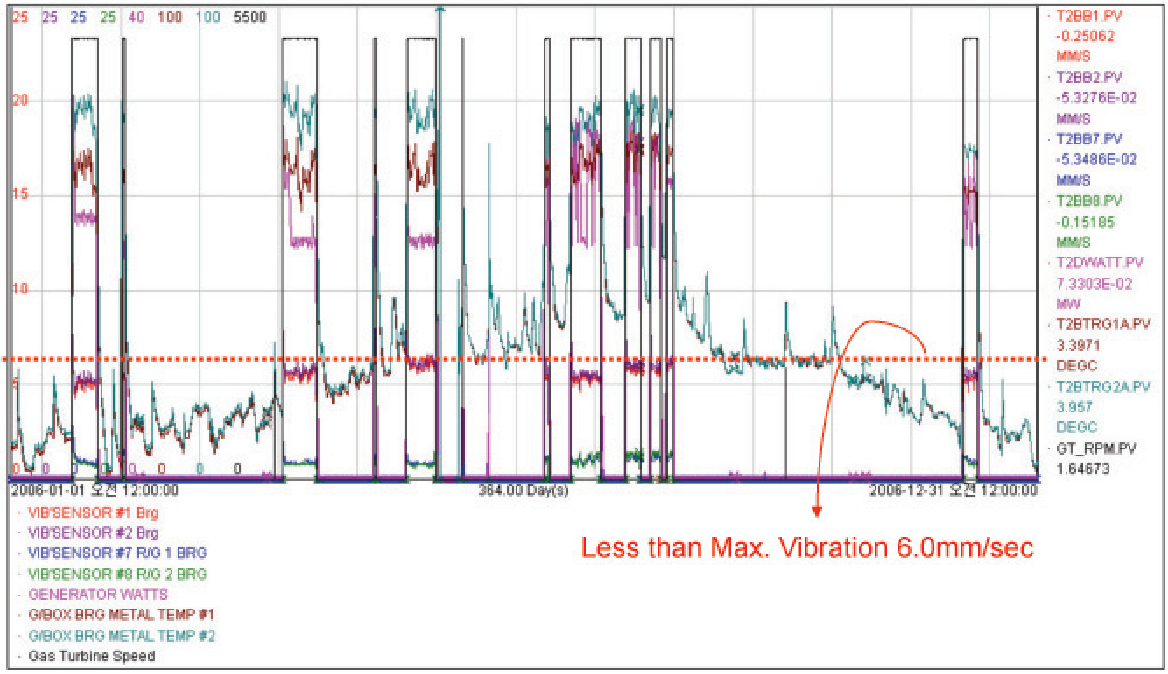


FIGURE 5: Operating trends in 2006.

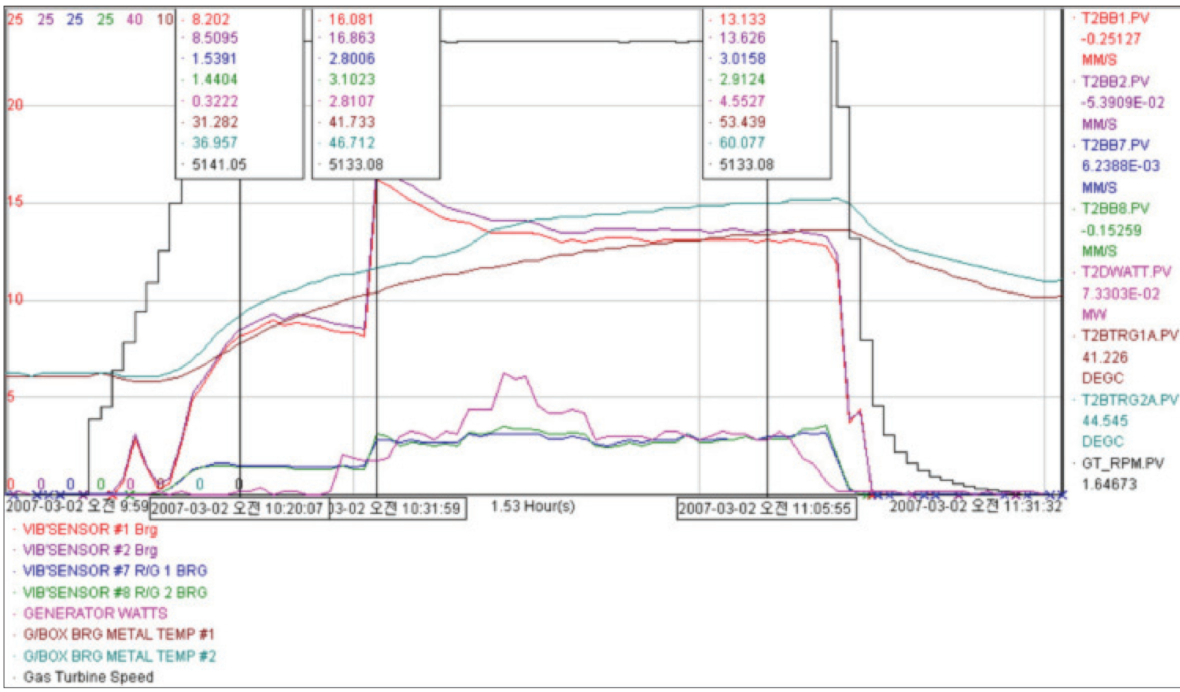


FIGURE 6: This short-term plot shows operating trends for a period of approximately two hours on March 2, 2007. The blue curve indicates a sharp increase in vibration at the number 1 and 2 bearings. The black RPM curve indicates that the gas turbine was shut down after about 40 minutes of operation at vibration that was higher than normal, but below the trip setpoint.

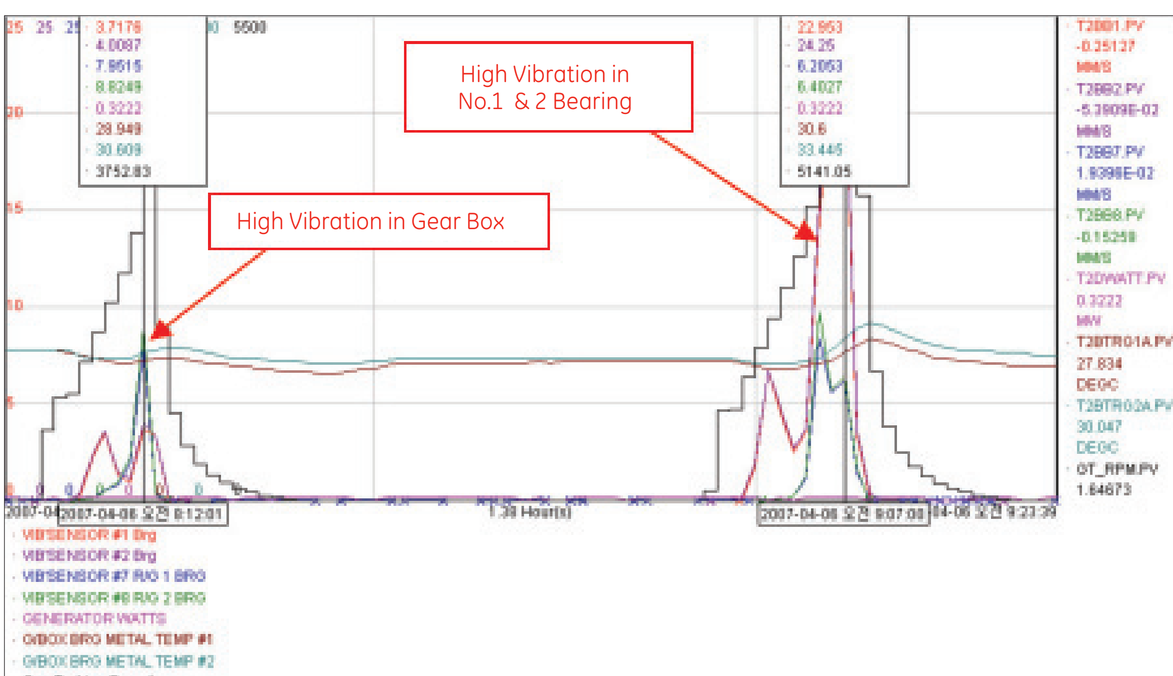


FIGURE 7: This plot shows trends for just under an hour and a half on April 6, 2007. The first trip occurred due to high vibration at the gearbox. The second trip occurred due to high vibration at the gas turbine number 1 & 2 bearing after a restart following extended slow-roll operation.

Short-Term Operating Trends – *April 6, 2007*

About a month later, the turbine tripped during normal operation due to high vibration at the gear box. Bowing of turbine rotor was suspected as the cause of high vibration – which increased to the trip setpoint while speed was being raised during a startup. The gas turbine was placed into slow-roll (via racheting drive) for about an hour in an attempt to straighten the suspected rotor bow before attempting restart. However, immediately following the restart, the turbine tripped again. This time, the trip was caused by high vibration at the number 1 & 2 bearing, rather than at the gearbox (Figure 7).

Investigation Details

The frequency of gas turbine vibration was analyzed after the increase in vibration amplitude was detected. The increase was observed to be a 1X vibration component, which corresponds to synchronous speed of the gas turbine rotor. Such a vibration response is often produced by unbalance force caused by a bowed rotor.

On June 20, 2007, a test was performed to resolve any potential rotor bow issues. (No.3 CO-Gen train was operated instead of No.2 CO-Gen since April, 2007). A portable vibration data gathering and analysis tool (ADRE*) was installed during this test because this machine didn't have an on-line vibration analysis tool.

The rotor was first warmed up for 30 to 60 minutes at the cranking speed (which is 20% of normal operating RPM) and then tested in its normal operating mode. However, high vibration continued to exist following the thorough rotor warm up, which indicated that a bowed rotor might not be the problem.

After the gas turbine rotor was warmed up, direct (unfiltered) and 1X-filtered components of vibration were measured and plotted during a startup from 10:38:25 to 10:51:10. The upper left plot in Figure 8 shows the vibration response at the #1 bearing case. Vibration amplitude increased up to 10 mm/s as the speed passed through a resonance at about 1800 rpm, and then fell to roughly 5 mm/s as machine speed continued to increase. However, as the speed passed through 3000 rpm, vibration amplitude again increased, ramping up to about 16 mm/s as speed approached 4000 rpm.

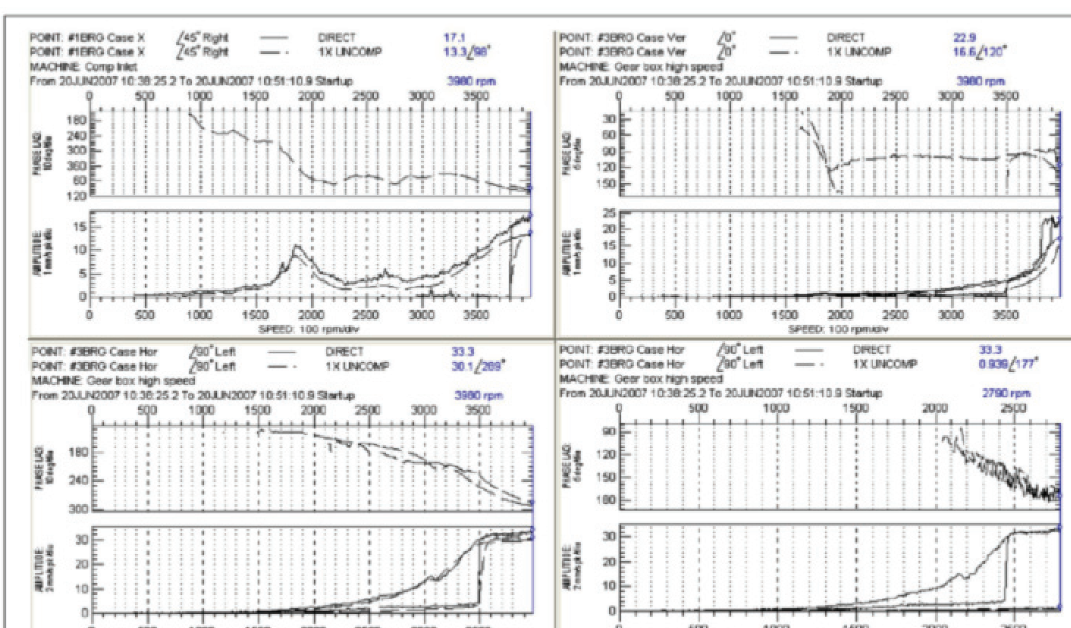


FIGURE 8: Bode plots show vibration amplitude and phase vs. running speed for Bearing #1 (gas turbine compressor end) and Bearing #3 (gearbox high speed shaft).

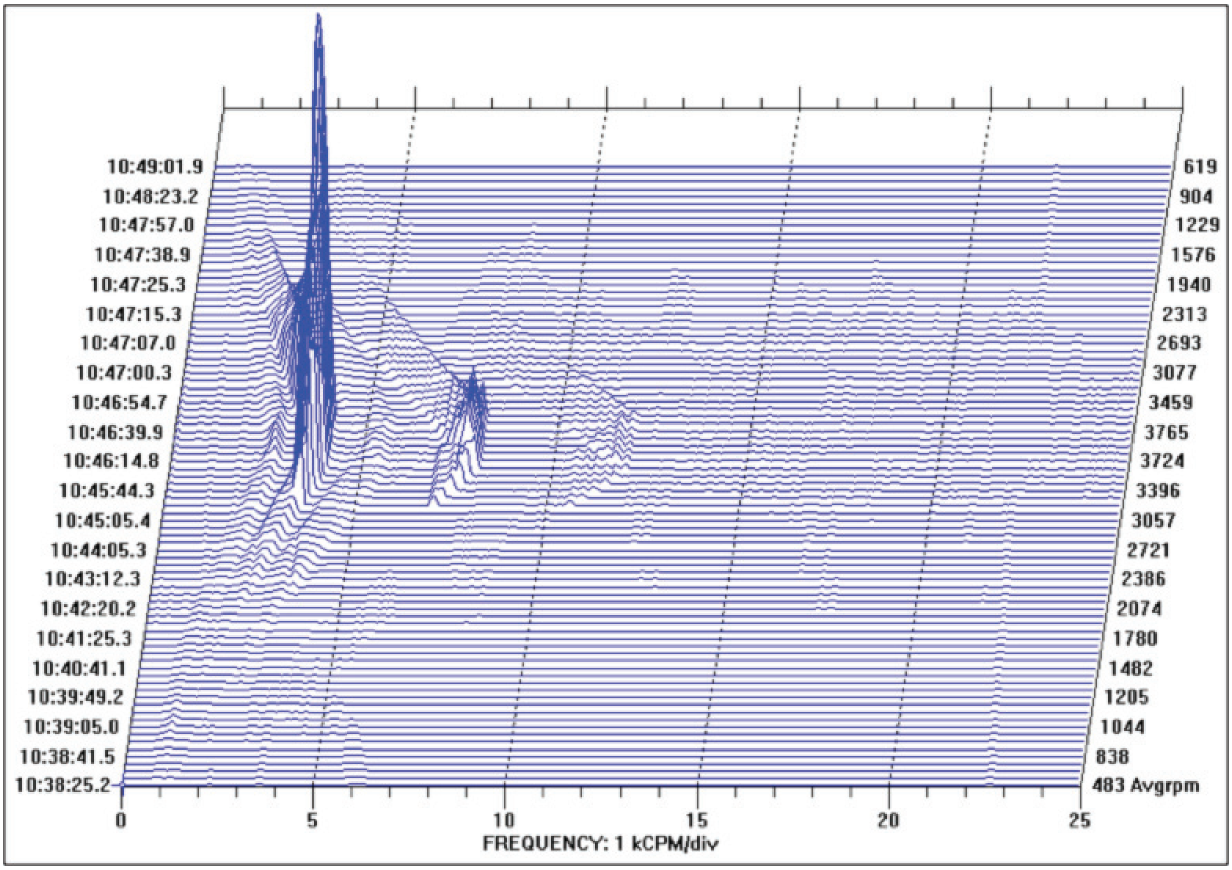


FIGURE 9: This waterfall plot shows vibration amplitude measured at the gearbox high speed shaft, bearing #3.

The upper right plot shows vibration response at the vertical sensor on the bearing #3 and the gearbox high speed shaft. The bottom two plots both show vibration data from the horizontal sensors on bearing #3. Both of these sensors showed unusually high vibration amplitudes as machine speed increased, with the vertical sensor reaching about 22 mm/s, and the horizontal sensor reaching just over 30 mm/s.

The waterfall plot in Figure 9 shows that amplitudes for synchronous (1X) vibration and its second harmonic (2X) both increase with machine speed. A synchronous (1X) vibration was dominant and increased suddenly at 3396 ~ 3724rpm.

Both vertical and horizontal vibration increased but the vibration trend in Figure 10 shows that there was a time difference and rising pattern difference between the vertical and horizontal vibration measurements. For horizontal vibration, amplitude increased from 4 mm/s to 30 mm/s with a sudden step, but amplitude of the vertical vibration increased from 1 mm/s to 4 mm/s at the same time as the sudden increase of horizontal vibration and then it trended up to 24 mm/s over a period of about 30 seconds.

This difference in horizontal and vertical vibration patterns can also be seen in the direct orbit (Figure 11). Vibration in the Y direction (horizontal) increased suddenly when the rotor speed increased from 3440rpm to 3520rpm. However, in the X direction, (vertical) vibration did not initially increase as much as it did in the Y direction. Then, vertical vibration increased while horizontal vibration remained at almost same level. Observe that the orbit shape was not round.

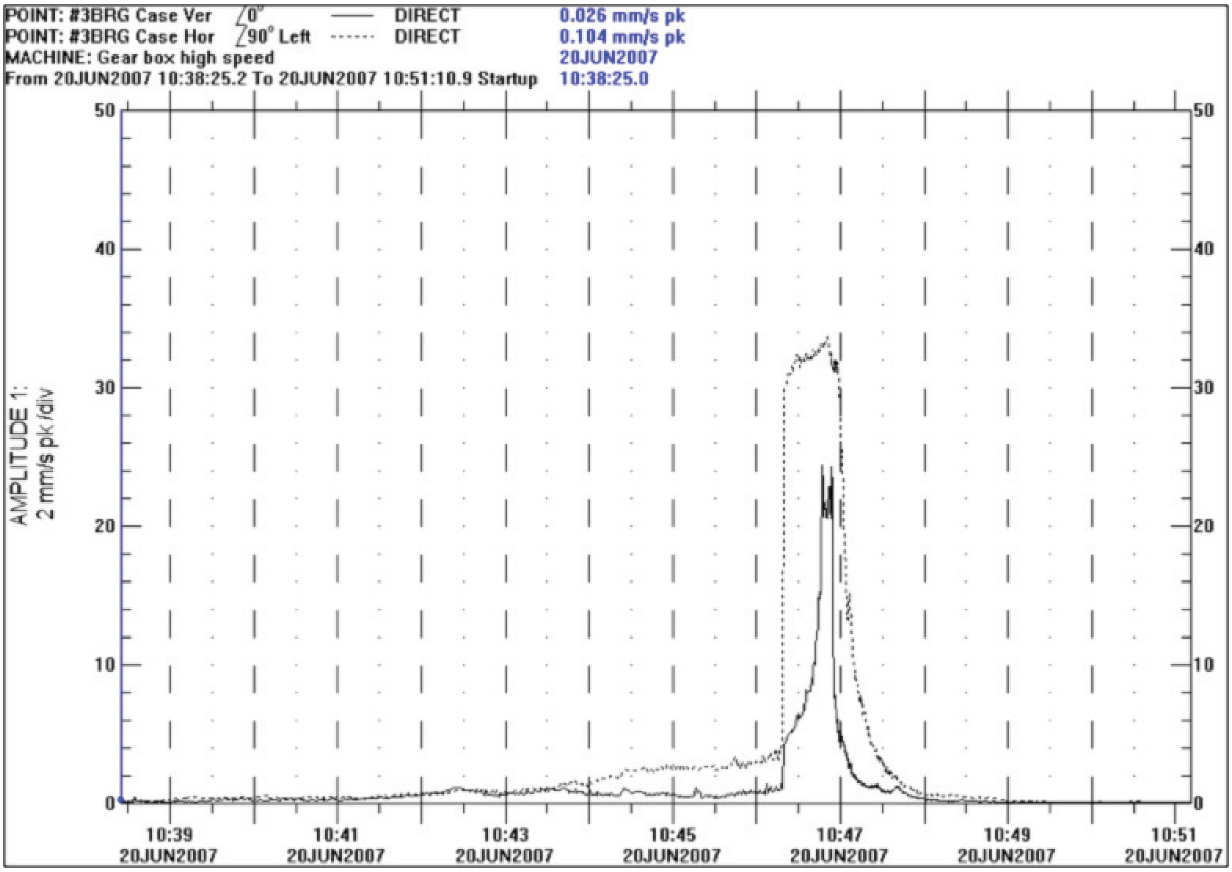


FIGURE 10: This graph shows vertical and horizontal vibration trend at the gearbox high speed shaft, bearing #3.

IN ADDITION TO THE VIBRATION SYMPTOMS,

we detected an abnormal sound at the load coupling area when the turbine was tripped and coasting down. Based on the correlation between these symptoms, we made the decision to inspect the inside of the load coupling.

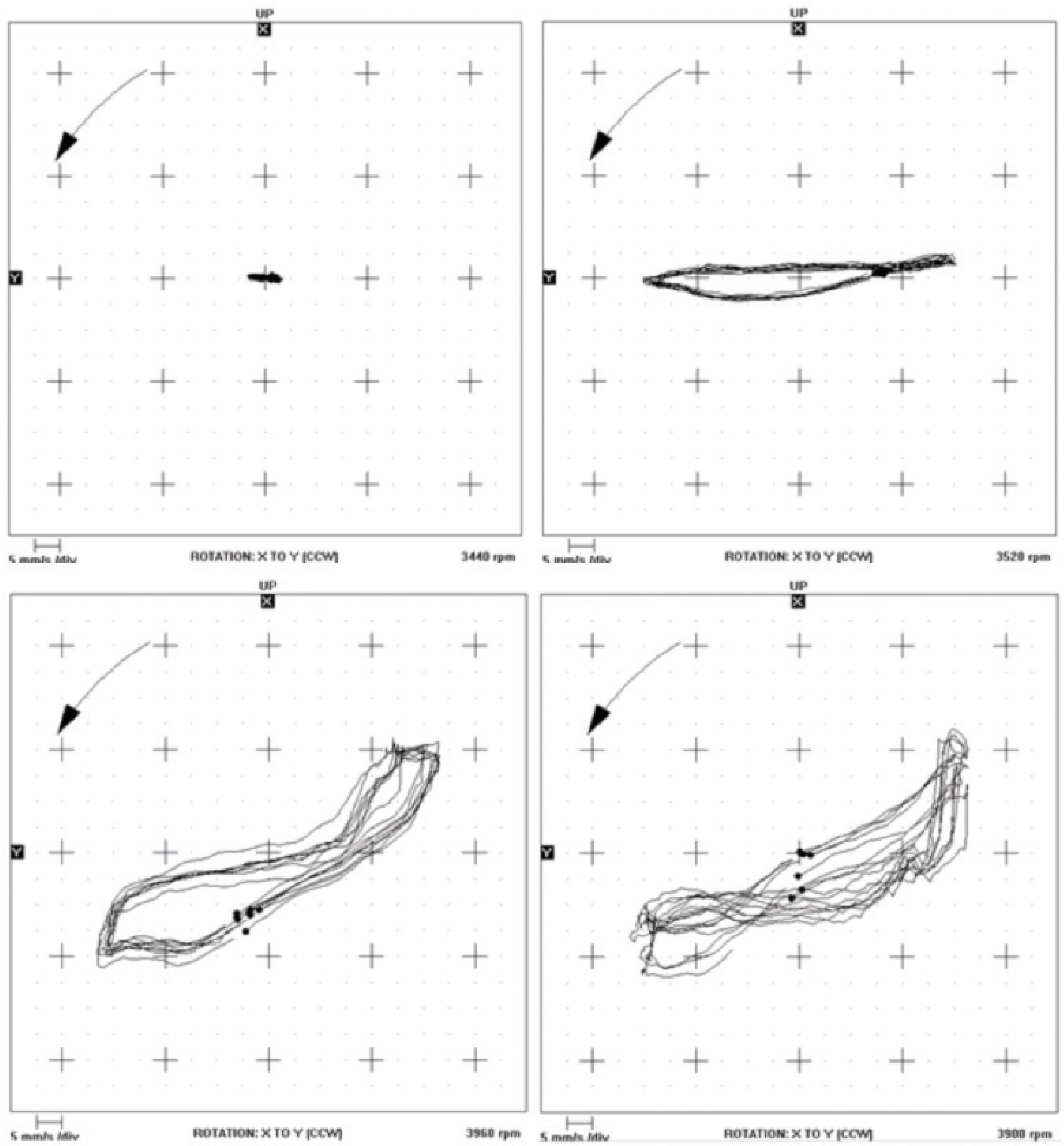


FIGURE 11: These plots show the direct (unfiltered) orbit at the gearbox high speed shaft, bearing #3.

Because the dominant frequency of the sudden vibration increase was synchronous (1X) and the rising pattern of vertical and horizontal vibration was different, we suspected the presence of a loose part, which caused a mass unbalance that was able to move to a different location. In addition to these vibration symptoms, we detected an abnormal sound at the load coupling area when the turbine was trip and coast down. Based on the correlation between these symptoms, we made the decision to inspect the inside of the load coupling.

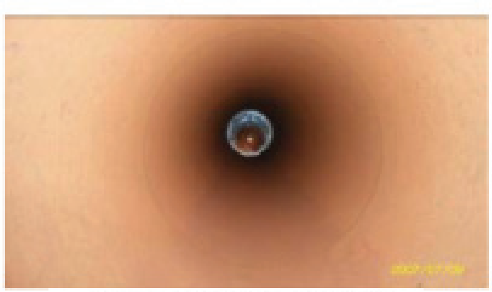
Rotor Inspection Results & Corrective Actions

Following the operational test, a visual inspection of the inside of the load coupling was performed. As indicated in Figure 2, the end plate is installed at the junction of the turbine output shaft and the load coupling. This plate is installed to prevent the escape of hot gas from the inside of the hollow turbine shaft.

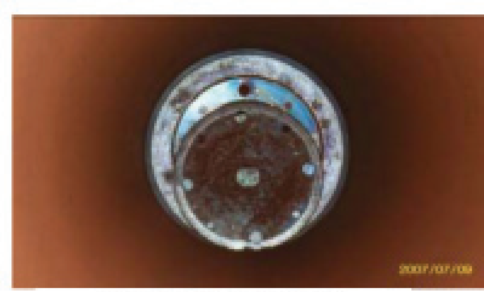
The visual inspection revealed that the end plate in the rotor load coupling was disconnected and resting on the lower inside surface of the tubular shaft (Figure 12, A & B). This uncoupled end plate was free to move around the inside of the load coupling, where it would have contributed to the changing unbalance conditions that were observed. Note: The mass of the end plate is about 2 kg, which would have generated enough rotating force to show up as increased 1X vibration.

The conclusion of the inspection results was that the end plate fasteners had not been adequately tightened by maintenance personnel the last time the plate was installed during the Major Inspection in 2005. It was surmised that the inadequately tightened fasteners finally vibrated loose on March 2, 2007, allowing the end plate to become uncoupled and cause the observed step increase in vibration.

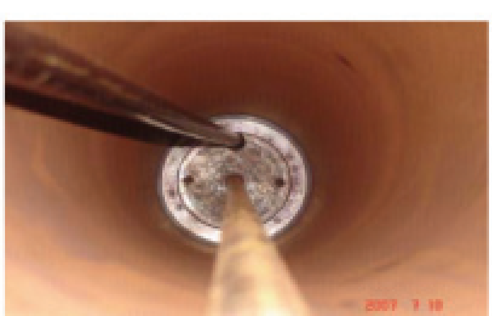
The uncoupled end plate was reinstalled using appropriate extension tools, and correct fastener tightness was verified (Figure 12, C & D). In order to prevent a similar problem from recurring, a new installation verification process was added to the maintenance procedure, to ensure that this step is not overlooked during future maintenance activities.



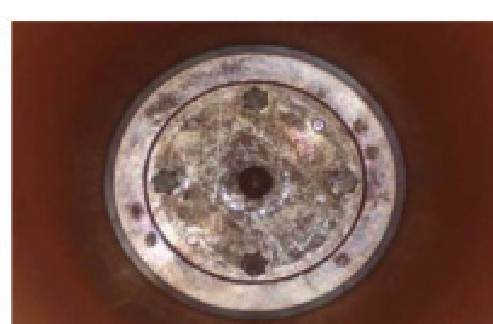
A. Inside Load Gear Coupling



B. End Plate Uncoupled



C. End Plate Being Tightened



D. End Plate Completely Assembled

FIGURE 12: Photos taken inside the load gear coupling show the uncoupled end plate (A & B) the long extension tools used to reinstall the plate (C) and the correctly-installed plate (D).

Post-Maintenance Test Results

The gas turbine was started up three times in sequence after the load coupling end plate was reinstalled. The results show that the gas turbine now operates normally, with no increased vibration levels. Figure 13 shows the operating trend of monitored parameters after the end plate was reinstalled. Instead of tripping on a maximum vibration amplitude of 25.4 mm/s, as occurred on April 6, 2007, the gas turbine operated very smoothly, with maximum vibration levels below 8.0 mm/s. ■

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BECAUSE THE DOMINANT FREQUENCY OF THE SUDDEN VIBRATION INCREASE WAS SYNCHRONOUS (1X) AND THE RISING PATTERN OF VERTICAL AND HORIZONTAL VIBRATION WAS DIFFERENT, WE SUSPECTED THE PRESENCE OF A LOOSE PART, WHICH CAUSED A MASS UNBALANCE THAT WAS ABLE TO MOVE TO A DIFFERENT LOCATION.

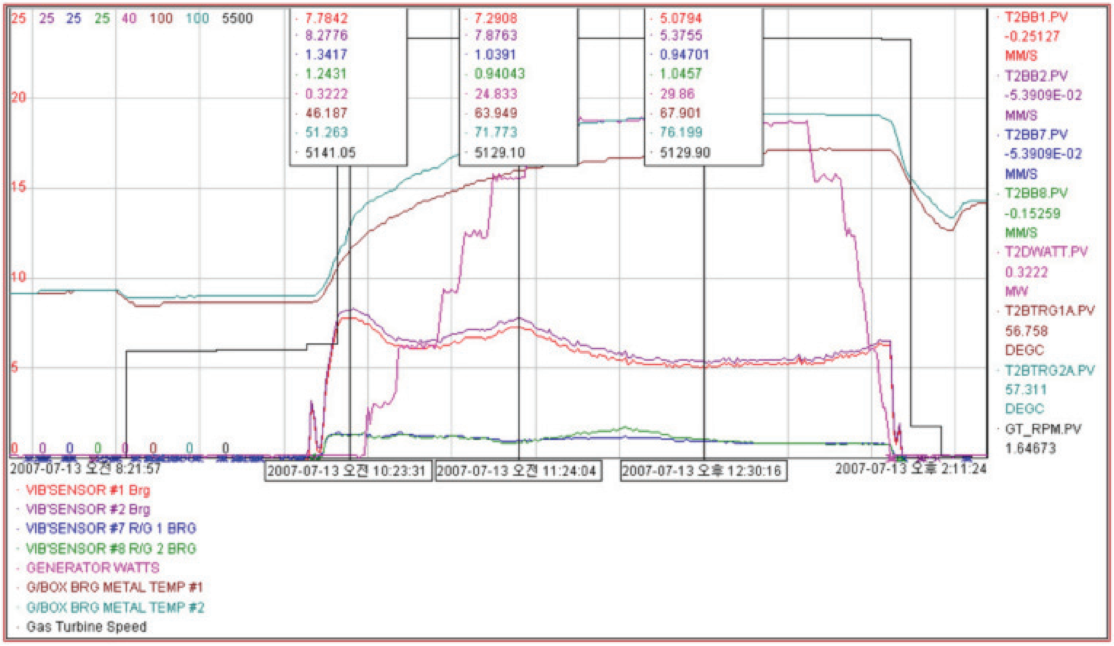

FIGURE 13: Operating trends following reinstallation of the end plate.

How to Use the 3500 Import Feature for ADRE* Sxp Software

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Field Application Engineer
derek.prinsloo@ge.com
(Written on behalf of John Kingham)

PICTURE THIS:

you need to collect data on a turbine driven compressor set with a gearbox, but you don't know a lot about it.

- Are the proximity probes 8mm or 5mm?
- Are they mounted 45° Left & Right or 30°/60°?
- What types of accelerometers are on the gearbox?
- What are the full scale ranges for everything?
- What are the zero voltages for the thrust probes?

CUE THE "BIG SIGH"...

Thankfully you just upgraded to version 2.80 of the ADRE Sxp software and you're good friends with the instrument tech! Today's Tip will discuss using the new 3500 Rack Configuration Import feature to save you a LOT of time.

3500 Rack Configuration Importer

In the past, getting your hands on the 3500 rack configuration file was only half the battle. Granted, it answered a lot of questions – but it still required a lot of switching between the 3500 software (Figure 1) and the ADRE software – if you even had it installed on your ADRE laptop – and digging into each channel of each card one at a time. It was very nearly a finger sprain issue with all the right-clicks, left clicks and Alt-Tabs! And even then, you ran the risk of missing something...

BREAKING NEWS!

Version 2.90 of the ADRE Sxp software incorporates an updated version of the Rack Configuration Import feature described in this article. Two new key features are included:

- Automatically configured plots for imported channels.
- Interactive graphical 3500 to ADRE channel mapping diagram.

Stay tuned for more information in the JUL 2013 issue!

FIGURE 1: 3500 rack configuration software screen

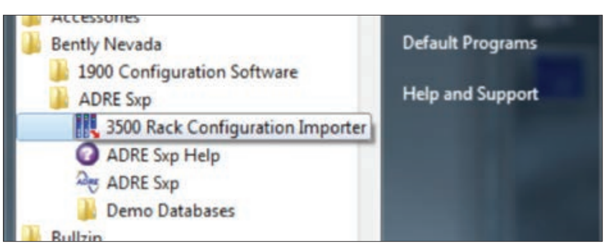


FIGURE 2: Accessing the rack configuration import tool from the Windows Start menu

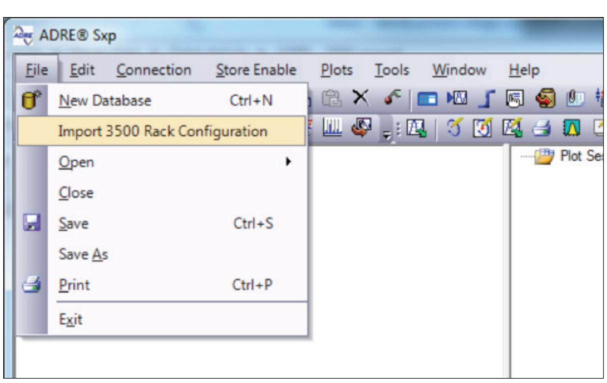


FIGURE 3: Accessing the rack configuration import tool from the Sxp software

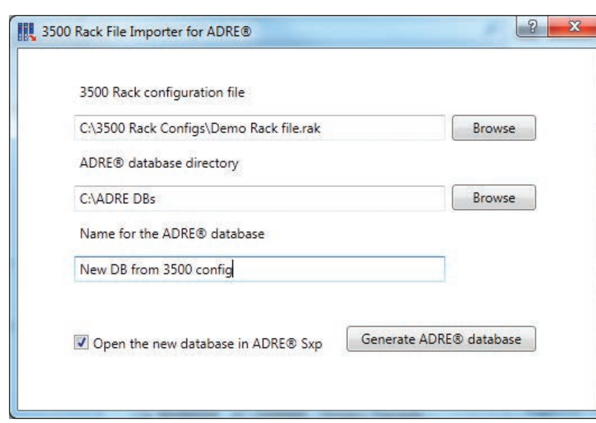


FIGURE 4: 3500 Rack File Importer window

Assuming that you already have the rack configuration file, there are now two ways to accurately import that data into the latest version of ADRE software. The first way is via the Windows Start button. Point to **All Programs, Bently Nevada, ADRE Sxp** and select **3500 Rack Configuration Importer** (Figure 2).

Alternatively, if you already have your ADRE Sxp software open, you can select **Import 3500 Rack Configuration** from the File menu (Figure 3).

With either method, the next few steps will be the same. You'll see a new Rack File Importer window pop up with three boxes for you to complete (Figure 4).

- In the "3500 Rack configuration file" box, browse to where you saved the 3500 rack configuration file (*.rak) and select it.
- In the "ADRE database directory" box, define where you would like the resulting ADRE database to be saved.
- And finally, give that new database a name!

Click **Generate ADRE database** and you are now ready to collect data! If you go through this process from the Windows Start button, the ADRE Sxp software will start and the new database will be loaded (if you left the check box selected). If you go through this process from the Sxp software, switch from the Importer tool to Sxp and you will see your database ready & waiting.

Hooray, this has been the shortest Orbit article ever! Well, maybe not. I'm still going to walk you through some of the advantages of using this tool – but how easy was that?!

OK, what does this do for me?

Expanding the hierarchy under the new database, you'll see that all the tag names have been brought in from the 3500 rack configuration file, along with a handy guide as to which slot and channel they're associated with (Figure 5).

Right-clicking on the "ADRE 408" level of the hierarchy and selecting **Configure** from the shortcut menu lets us dig even deeper into the benefits of this new tool. First up is the Keyphasor configuration (Figure 6). A couple of notes here:

- While the probe orientations are brought in from the 3500 rack config, the Max RPMs and Shaft Rotation Directions are not. *Update them now.*

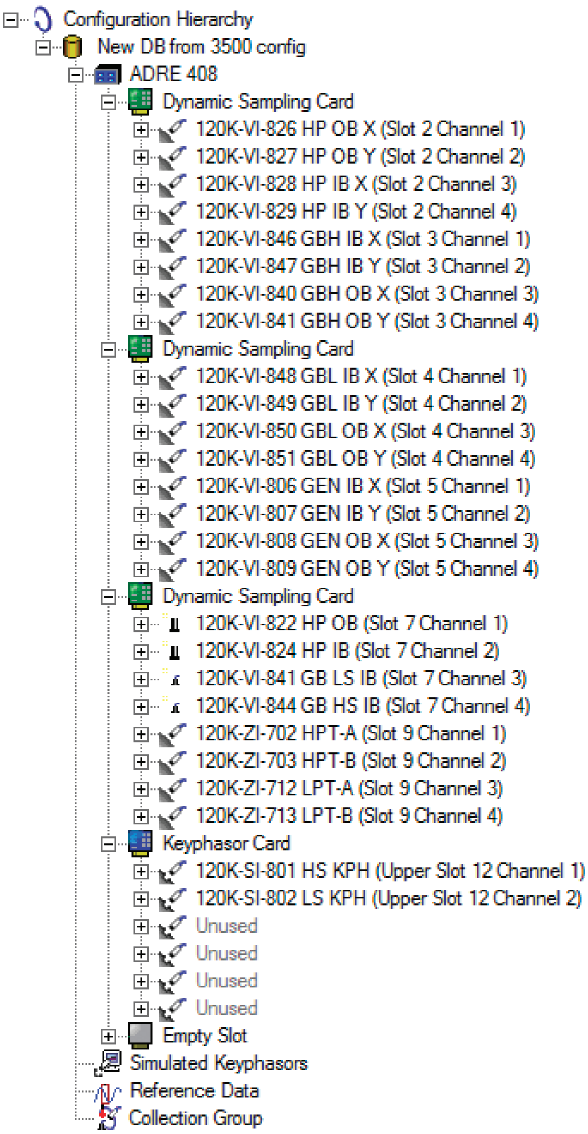


FIGURE 5: The ADRE database hierarchy is already configured!

- While the long channel names are very descriptive, the "Input Source" descriptions have less information. For example, in the "Input Source" column, all you can really tell is whether it is from Channel 1 or 2. Modifying these names slightly will make life a little easier elsewhere (when configuring the other input channels, for example).

Once the Keyphasor is sorted out, click **OK** and head onwards to the rest of the channel configurations! As is evident from the screenshots in Figure 7, re-naming the Keyphasor channels helps to make life a little easier at this step. In the General tab, you can see the following information:

- All channel names and Keyphasor associations are already configured. However, if you'd like to have the points labeled with "Machine Name" components, you'll have to add that now.
- As with the Keyphasor, while the transducer orientations are already configured, the Shaft Rotation direction is not a parameter stored in the 3500 config – so you'll have to set it here.

In the Transducer tab (Figure 8), you can see the following information:

- All transducer types and their associated Full Scale ranges, Scale Factors, etc. are already configured.
- Even the 'Zero' voltages for the thrust position probes are brought in from the 3500 configuration.
- By default, the Wide (120 RPM) Bandwidth Filter is selected. If you'd prefer another setting or want to Auto Switch, you'll need to change that here.

As you might expect, since the 3500 rack doesn't permit "nX variables", there is nothing to import on the Variables tab. Of course, all of the usual options are still available to you there. In the Waveforms tab, the import has done a couple of things (Figure 9):

- Two sets of waveforms collection settings are established for each channel:
  — One synchronous waveform: Sample Rate = 128 (per revolution)
  — One asynchronous waveform: 1000 Hz frequency span & 800 spectral lines

Note: If the Max RPM values are adjusted in the Keyphasor configuration window, you may have more or fewer Sample Rate options available to you in the Synchronous samples than are shown in this example.

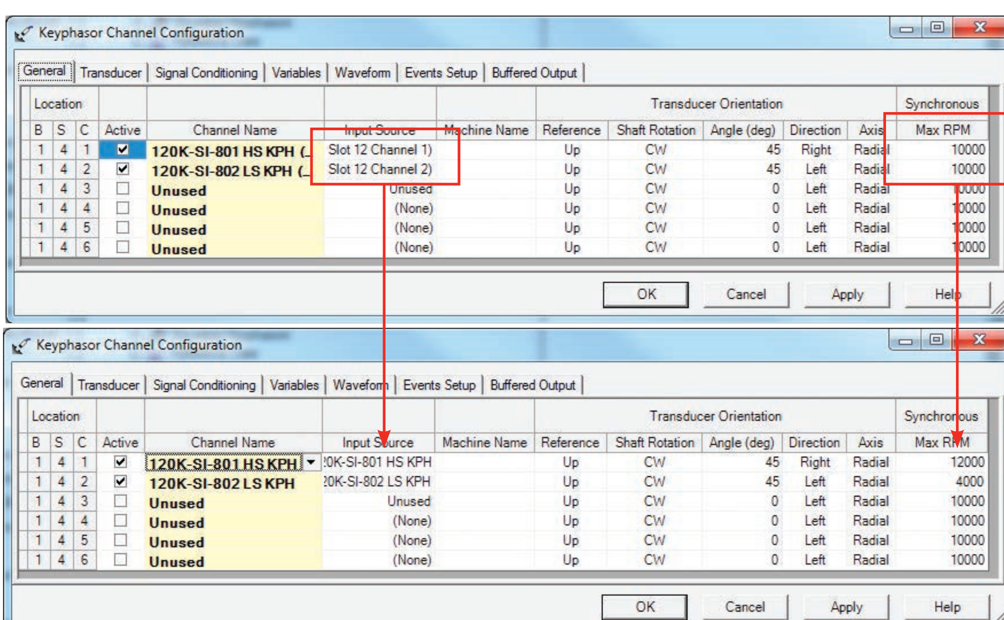
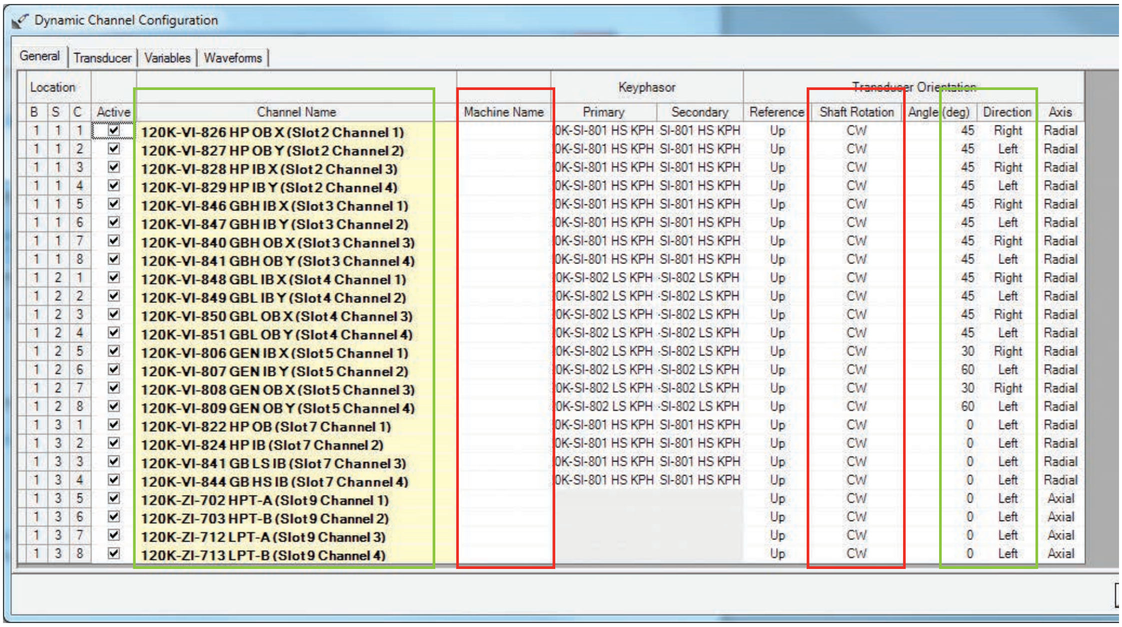


FIGURE 6: Modify Keyphasor Input Source names and Max RPM values as needed.

"ASSUMING THAT YOU ALREADY HAVE THE RACK CONFIGURATION FILE, THERE ARE NOW TWO WAYS TO ACCURATELY IMPORT THAT DATA INTO THE LATEST VERSION OF ADRE SOFTWARE."

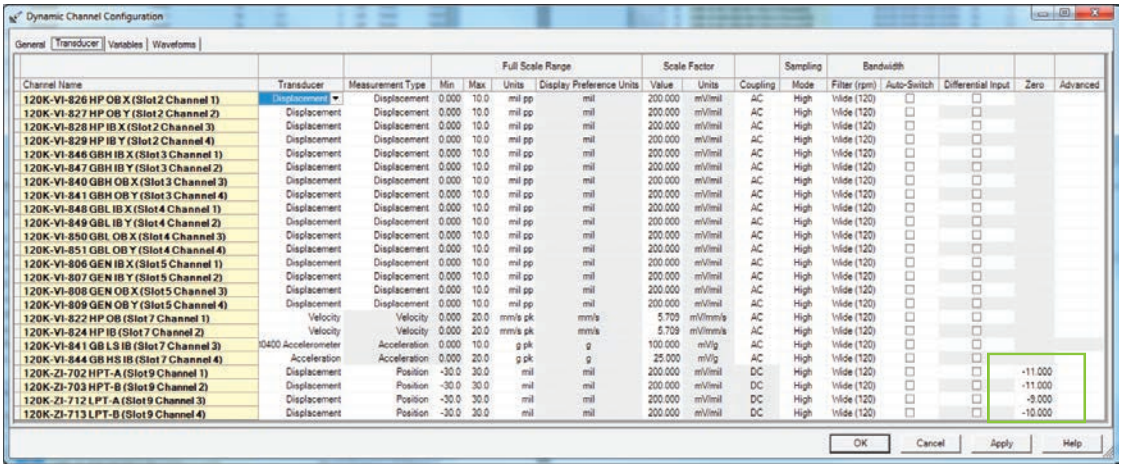


Dynamic Channel Configuration

General | Transducer | Variables | Waveforms

Location						Keyphasor		Transducer Orientation				
B	S	C	Active	Channel Name	Machine Name	Primary	Secondary	Reference	Shaft Rotation	Angle (deg)	Direction	Axis
1	1	1	☑	120K-VI-826 HP OB X (Slot 2 Channel 1)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Right	Radial
1	1	2	☑	120K-VI-827 HP OB Y (Slot 2 Channel 2)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Left	Radial
1	1	3	☑	120K-VI-828 HP IB X (Slot 2 Channel 3)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Right	Radial
1	1	4	☑	120K-VI-829 HP IB Y (Slot 2 Channel 4)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Left	Radial
1	1	5	☑	120K-VI-846 GBH IB X (Slot 3 Channel 1)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Right	Radial
1	1	6	☑	120K-VI-847 GBH IB Y (Slot 3 Channel 2)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Left	Radial
1	1	7	☑	120K-VI-840 GBH OB X (Slot 3 Channel 3)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Right	Radial
1	1	8	☑	120K-VI-841 GBH OB Y (Slot 3 Channel 4)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	45	Left	Radial
1	2	1	☑	120K-VI-848 GBL IB X (Slot 4 Channel 1)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	45	Right	Radial
1	2	2	☑	120K-VI-849 GBL IB Y (Slot 4 Channel 2)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	45	Left	Radial
1	2	3	☑	120K-VI-850 GBL OB X (Slot 4 Channel 3)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	45	Right	Radial
1	2	4	☑	120K-VI-851 GBL OB Y (Slot 4 Channel 4)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	45	Left	Radial
1	2	5	☑	120K-VI-806 GEN IB X (Slot 5 Channel 1)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	30	Right	Radial
1	2	6	☑	120K-VI-807 GEN IB Y (Slot 5 Channel 2)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	60	Left	Radial
1	2	7	☑	120K-VI-808 GEN OB X (Slot 5 Channel 3)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	30	Right	Radial
1	2	8	☑	120K-VI-809 GEN OB Y (Slot 5 Channel 4)		0K-SI-802 LS KPH	SI-802 LS KPH	Up	CW	60	Left	Radial
1	3	1	☑	120K-VI-822 HP OB (Slot 7 Channel 1)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	0	Left	Radial
1	3	2	☑	120K-VI-824 HP IB (Slot 7 Channel 2)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	0	Left	Radial
1	3	3	☑	120K-VI-841 GB LS IB (Slot 7 Channel 3)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	0	Left	Radial
1	3	4	☑	120K-VI-844 GB HS IB (Slot 7 Channel 4)		0K-SI-801 HS KPH	SI-801 HS KPH	Up	CW	0	Left	Radial
1	3	5	☑	120K-ZI-702 HPT-A (Slot 9 Channel 1)				Up	CW	0	Left	Axial
1	3	6	☑	120K-ZI-703 HPT-B (Slot 9 Channel 2)				Up	CW	0	Left	Axial
1	3	7	☑	120K-ZI-712 LPT-A (Slot 9 Channel 3)				Up	CW	0	Left	Axial
1	3	8	☑	120K-ZI-713 LPT-B (Slot 9 Channel 4)				Up	CW	0	Left	Axial

FIGURE 7: Dynamic Channel Configuration window. Observe that the Channel Name and Transducer Orientation columns are pre-populated (outlined in green) while the Machine Name and Shaft Rotation columns are blank until you add this information (outlined in red).



Dynamic Channel Configuration

General | Transducer | Variables | Waveforms

			Full Scale Range				Scale Factor			Sampling	Bandwidth				
Channel Name	Transducer	Measurement Type	Min	Max	Units	Display Preference Units	Value	Units	Coupling	Mode	Filter (rpm)	Auto-Switch	Differential Input	Zero	Advanced
120K-VI-826 HP OB X (Slot 2 Channel 1)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-827 HP OB Y (Slot 2 Channel 2)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-828 HP IB X (Slot 2 Channel 3)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-829 HP IB Y (Slot 2 Channel 4)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-846 GBH IB X (Slot 3 Channel 1)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-847 GBH IB Y (Slot 3 Channel 2)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-840 GBH OB X (Slot 3 Channel 3)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-841 GBH OB Y (Slot 3 Channel 4)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-848 GBL IB X (Slot 4 Channel 1)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-849 GBL IB Y (Slot 4 Channel 2)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-850 GBL OB X (Slot 4 Channel 3)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-851 GBL OB Y (Slot 4 Channel 4)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-806 GEN IB X (Slot 5 Channel 1)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-807 GEN IB Y (Slot 5 Channel 2)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-808 GEN OB X (Slot 5 Channel 3)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-809 GEN OB Y (Slot 5 Channel 4)	Displacement	Displacement	0.000	10.0	mil pp	mil	200.000	mV/mil	AC	High	Wide (120)	☐	☐		
120K-VI-822 HP OB (Slot 7 Channel 1)	Velocity	Velocity	0.000	20.0	mm/s pk	mm/s	5.709	mV/mm/s	AC	High	Wide (120)	☐	☐		
120K-VI-824 HP IB (Slot 7 Channel 2)	Velocity	Velocity	0.000	20.0	mm/s pk	mm/s	5.709	mV/mm/s	AC	High	Wide (120)	☐	☐		
120K-VI-841 GB LS IB (Slot 7 Channel 3)	0400 Accelerometer	Acceleration	0.000	10.0	g pk	g	100.000	mV/g	AC	High	Wide (120)	☐	☐		
120K-VI-844 GB HS IB (Slot 7 Channel 4)	Acceleration	Acceleration	0.000	20.0	g pk	g	25.000	mV/g	AC	High	Wide (120)	☐	☐		
120K-ZI-702 HPT-A (Slot 9 Channel 1)	Displacement	Position	-30.0	30.0	mil	mil	200.000	mV/mil	DC	High	Wide (120)	☐	☐	-11.000	
120K-ZI-703 HPT-B (Slot 9 Channel 2)	Displacement	Position	-30.0	30.0	mil	mil	200.000	mV/mil	DC	High	Wide (120)	☐	☐	-11.000	
120K-ZI-712 LPT-A (Slot 9 Channel 3)	Displacement	Position	-30.0	30.0	mil	mil	200.000	mV/mil	DC	High	Wide (120)	☐	☐	-9.000	
120K-ZI-713 LPT-B (Slot 9 Channel 4)	Displacement	Position	-30.0	30.0	mil	mil	200.000	mV/mil	DC	High	Wide (120)	☐	☐	-10.000	

OK | Cancel | Apply | Help

FIGURE 8: Channel configuration settings shown in the Transducer tab. Observe that thrust position zero voltages have been imported automatically (circled in green)

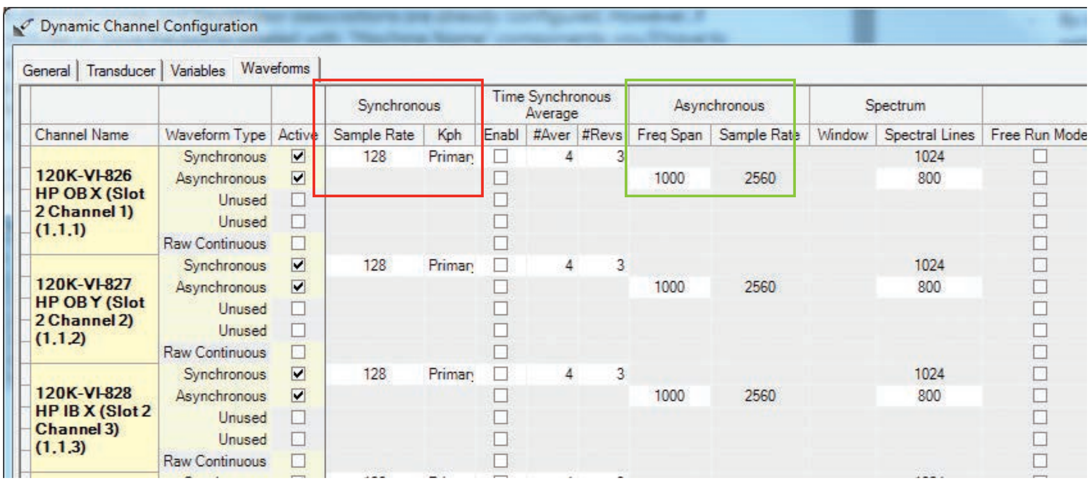


FIGURE 9: Channel configuration settings as shown in the Waveforms tab

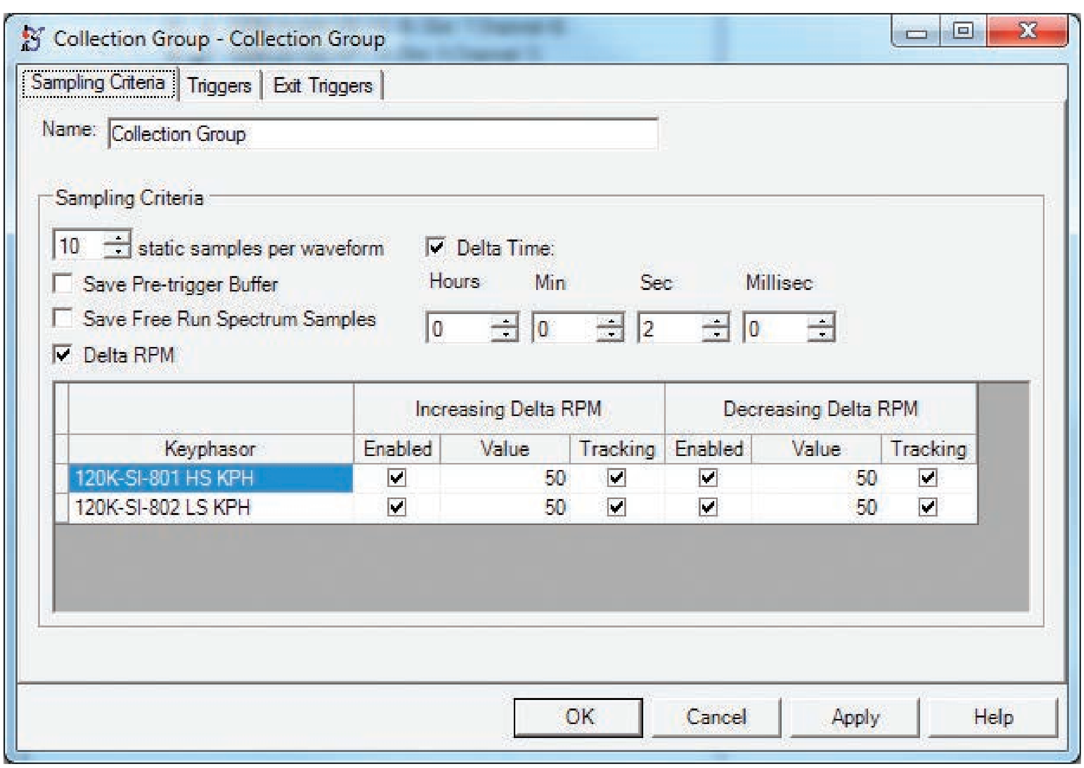


FIGURE 10: Collection Group configuration dialog, showing Sampling Criteria settings

The remainder of the channel configuration will be set up as per the usual defaults (Figure 10):

- ±50 RPM Delta RPM sampling
- 2 second Delta Time sampling
- 10 static samples per waveform sample
- No triggers set

I hope that using the new 3500 Rack Configuration Importer tool saves you a lot of time, eliminates nearly all the guesswork and generally makes your life easier in the field. See you the next time the KPH rolls around!

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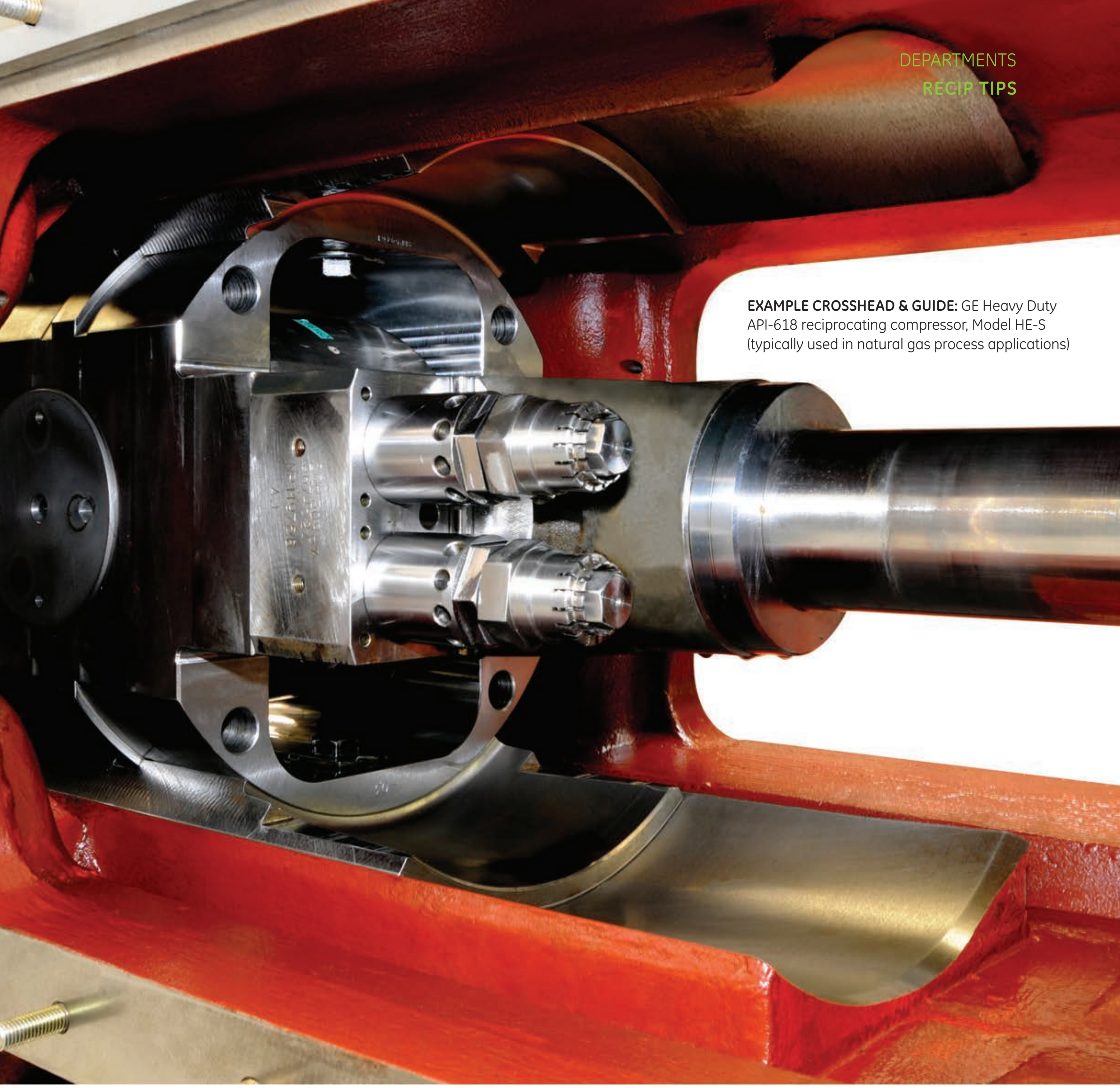

EXAMPLE CROSSHEAD & GUIDE: GE Heavy Duty API-618 reciprocating compressor, Model HE-S (typically used in natural gas process applications)

Vibration Analysis for Reciprocating Compressors (Part 2)

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In Part 1 of this series (Reference 1), we described the characteristics of vibration on reciprocating compressor components and how the resulting vibration patterns measured on compressor frame, crosshead guides and cylinders represent the response to the inherent forces acting on those components.

For monitoring and protection, we described the key locations to monitor and the required characteristics of a monitoring system, transducers and signal processing to enable accurate monitoring of the vibration while minimizing false alarms. For diagnostics, we indicated that, due to the diverse forces acting at compressor components, vibration analysis presents unique interpretation challenges and requires an approach that is specific to reciprocating machines. This approach is substantially different from the one used for analyzing vibration on purely rotating machinery, where a harmonized approach has been established in industry over the decades.

In recent years, the critical role of reciprocating compressors has been recognized, along with the need to obtain higher reliability and availability from these machines. This has required developing the same predictive maintenance approach that has been applied to critical turbomachinery for a long time.

The main challenge of reciprocating compressor vibration analysis is the difficulty in effectively associating a malfunction to a specific vibration pattern in order to obtain an early failure diagnostic. However, the use of advanced transducers and signal processing technologies has allowed the development of online diagnostic techniques that facilitate associating vibration with additional measured dynamic parameters such as rod load. These new analytic capabilities are proving to be of great value in component malfunction identification.

Since most of the typical catastrophic failures on reciprocating compressor involve the running gear and cylinder components, crosshead guide vibration is the primary recommended measurement for monitoring and protection of highly critical reciprocating compressors.

Measuring vibration at the crosshead guide (Figure 1) allows the detection of vibration "peaks" that can be associated with the structural response to impulsive events. Conditions that increase this excitation are generated by developing faults such as loose rod nuts, loose bolts, excessive crosshead slipper clearance and worn pins, as well as liquid in the process gas. These faults can be detected at early stages of development using crosshead impact monitoring, thus allowing appropriate countermeasures and avoiding potential catastrophic consequences.

The purpose of this article is to describe the correlation between vibration patterns measured on the compressor components and the associated events occurring at those components. These events can be identified by correlation with another essential measurement – cylinder pressure.

Diagnostic Methodology – Correlation of Vibration and Force

If we consider the typical signal from an accelerometer located on the crosshead guide of an API 618 type compressor, the measurement will appear as a series of apparently disconnected peaks in the crank angle domain (Figure 2).

Synchronized dynamic cylinder pressure measurement is the key to providing correlation of these vibration impulse peaks, leading to the more accurate identification of malfunctions. While cylinder pressure measurement has long been recognized as being essential for cylinder performance evaluation (for example, through pressure vs. volume "PV" diagram analysis) and diagnosis of malfunctions on valves, the ability to correlate events in the crosshead vibration signal with known events in the pressure and rod load curves has proven to have great value in enabling the diagnosis of mechanical malfunctions, such as components looseness. To better understand how this correlation provides insight into reciprocating compressor condition, the next section explains how the cylinder pressure curve, combined with machine kinematic data, results in the rod load force curves for the running gear.

Rod Load Monitoring

Alternating forces due to masses in reciprocating motion and varying gas pressures in the cylinder place the piston rod under both tensile and compressive forces. The combination of the gas loads and inertia loads evaluated at the crosshead pin in the direction of piston motion is the "combined rod load" as defined in API-618 5th edition (Reference 2) and it varies continuously throughout the revolution. This article will use the definitions of terms as described in Reference 1.

Note: For more details on rod load definitions and calculations, as well as an explanation of how the Bently Nevada* 3500 monitoring system calculates them, see the 'Recip Tips' article in Orbit Vol.28 No.1 2008 (Reference 3).

Dynamic cylinder pressure measurement provides the basis for rod load monitoring; the blue line in Figure 3 shows the gas rod load for an operating cylinder on a typical process compressor with double-acting cylinders. This measurement is calculated in a 3500 monitoring system by multiplying the pressure measurement at each ½ degree of revolution by the active area of each piston face. The resultant curve in System 1* software is the sum of these forces.

The inertia forces must be added to the gas forces to obtain the combined load at the crosshead pin. The red line in Figure 3 shows the inertia force as calculated by the 3500 system from the compressor moving masses (piston assembly, rod and crosshead assembly), dimensions and speed. The sum of the inertia and gas force results in the combined rod load curve shown as the green line in Figure 3.

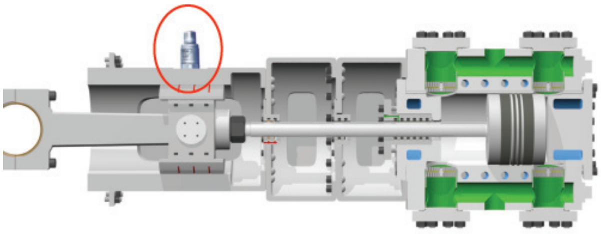

FIGURE 1: Recommended location of accelerometer measurement on crosshead guide

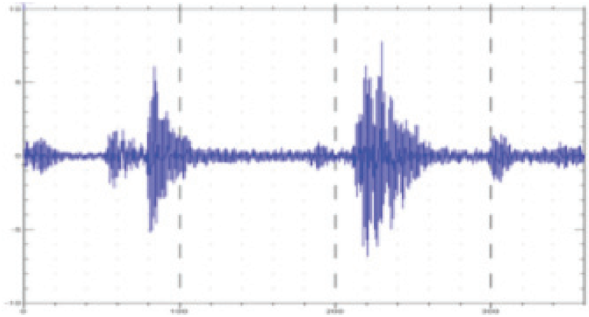

FIGURE 2: Example plot of acceleration impulses vs. crank angle, measured at crosshead guide

RECIPROCATING MACHINERY VIBRATION IS INTRINSICALLY DIFFERENT FROM PURELY ROTATING TURBOMACHINERY; THEREFORE MANY CONSIDERATIONS NEED TO BE TAKEN FOR AN EFFECTIVE ANALYSIS.

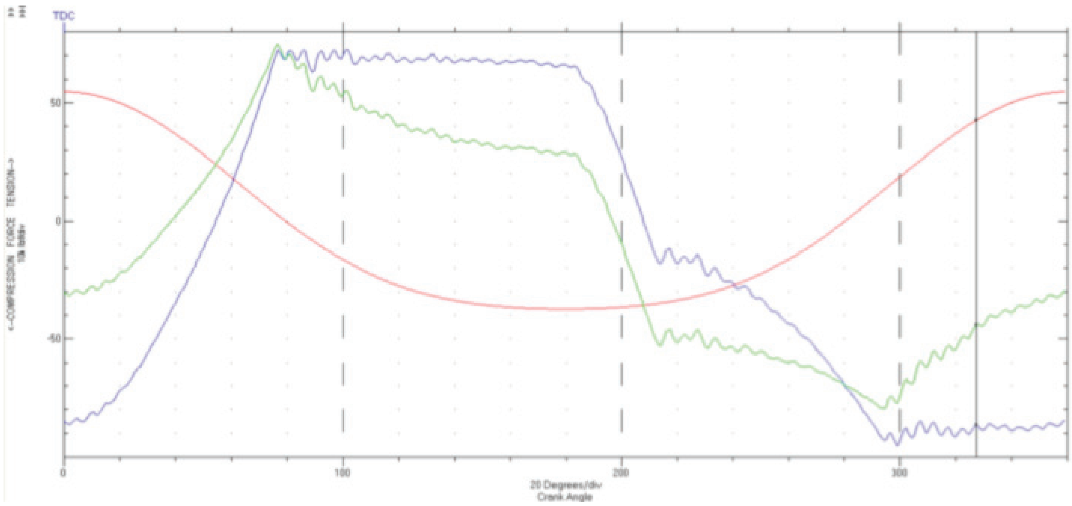

FIGURE 3: Gas force (blue), inertia force (red) and combined force (green) vs. crank angle generated by 3500 system and System 1 software. Scale of the x-axis starts at 0 degrees (Top Dead Center for the monitored cylinder) and goes through one full rotation of the crankshaft, ending at 360 degrees.

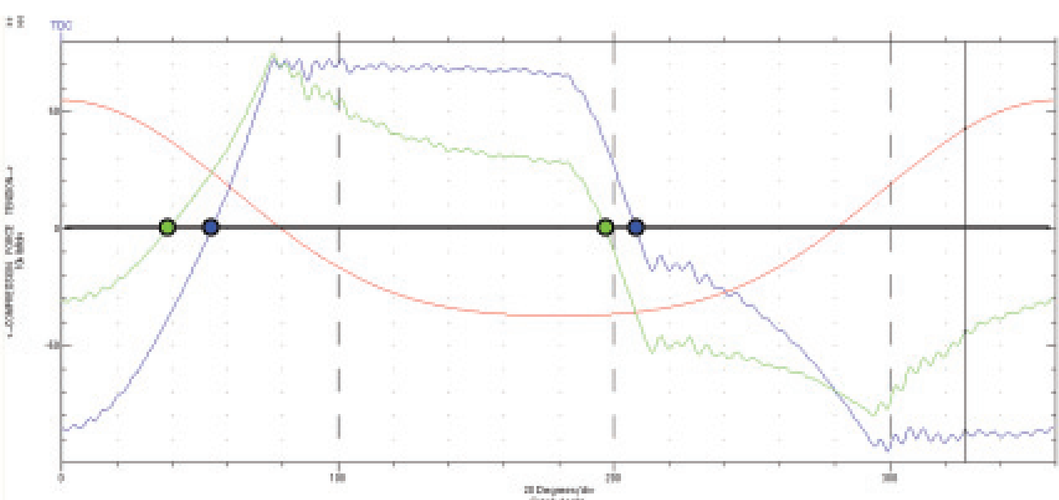

FIGURE 4: Gas force (blue) and combined force (green) reversal points

Online rod load monitoring provides great value in assessing machine stress by continuous calculation of maximum rod load (tension), maximum rod load (compression) as well as rod load reversal values for each revolution.

The Bently Nevada 3500 monitoring system has the unique capability of continuous rod load calculation from cylinder pressures and compressor design data configured directly in the 3500 hardware, allowing online monitoring of the peak rod forces (compression and tension) for each cycle.

Rapidly-developing catastrophic damage to crosshead pin and small end bearing can occur when rod load reversal is absent or significantly reduced – which reduces vital lubrication to these surfaces. Therefore, rod load reversal must also be calculated and monitored directly by the protection system to allow reliable and prompt alarming when needed. The 3500/77 monitor provides this output directly as a protection parameter without need of external computer calculations that would prevent the reliable use of these values for machinery protection.

At the same time, rod load curves are a key element for loose component diagnostics in System 1 software, enabling localization of knocks and impacts.

Loose Component Identification Using Rod Load Curves

The concept behind the diagnostic methodology is that impacts measured by a vibration transducer originate in the component that experiences a change in direction of force. If an impulse event can be correlated with a force change on a particular component, then the fault very often lies with that specific component.

As shown by the green dots in Figure 4, the combined rod load forces at the crosshead pin transitions from compression (below the horizontal line at zero load) to tension (above the zero line), and vice-versa twice during each revolution. During these load reversals, the crosshead pin moves from one side of the bushing to the other. When excessive clearance develops between the crosshead pin and bushing, a rapid build-up of velocity must be absorbed by the bushing, resulting in a knock at the point where the combined rod load crosses the neutral axis. Therefore, knocks that occur near the point of combined rod load reversal typically indicate looseness or problems within the crosshead assembly.

In the case of a loose piston to rod connection, or piston ring slap, the situation is different. Knocks caused by these malfunctions are not influenced by the reciprocating mass force so the knock occurs at gas load reversal points (shown by the blue dots on Figure 4) rather than at combined load reversal points.

Diagnostic tools in System 1 software automate these analytic principles to provide real-time identification of loose components in the monitored compressor. Using an advanced technology called Dynamic Segmental Waveform Analysis, System 1 Impulse/Impact Rulepak logic processes the pressure and force waveforms, then determines the location of each potential impact event and stores the corresponding crank angle (Reference 4).

This algorithm accounts for compressor load changes (for example by means of clearance pocket unloaders). The degrees of crank angle at which the zero-force crossings occur are dynamically tracked and stored. A band in the associated crosshead acceleration waveforms is then established. Since these bands follow, or track, the condition of the cylinder, they may be referred to as "tracking bands."

The evaluation algorithm then establishes alarm levels within each associated vibration waveform band based on the impact event location.

For example, Figure 5 shows normal (uncolored), yellow, and red threshold band alarms for acceleration at the gas load reversal points. If the impulse event amplitudes in all bands move into the yellow region, the system generates a piston-looseness "Alert" alarm. If all impulse event amplitudes move into the red region, the system generates a piston-looseness "Danger" alarm.

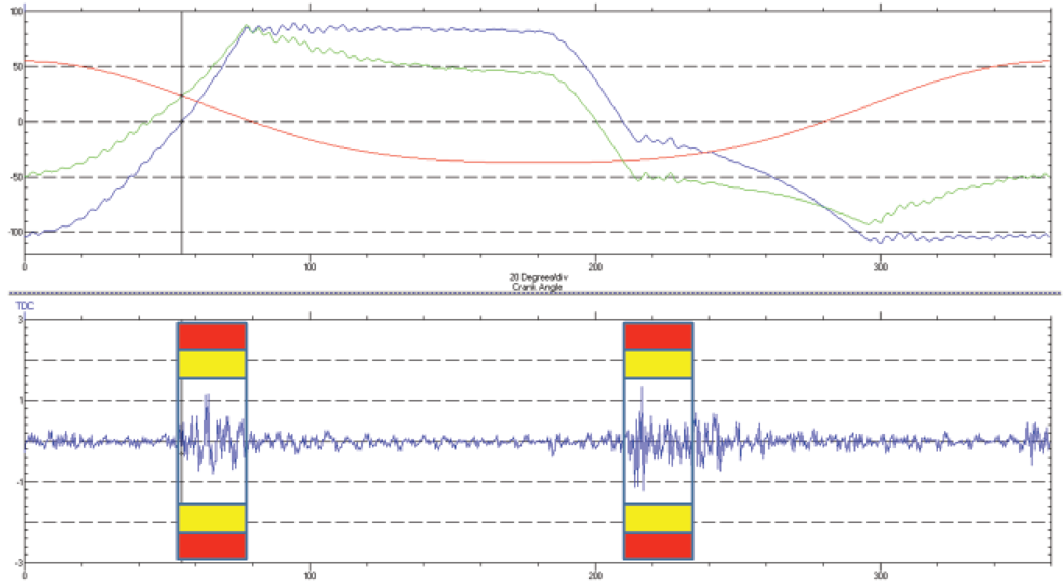

FIGURE 5: Rod Load Forces, crosshead acceleration and tracking bands

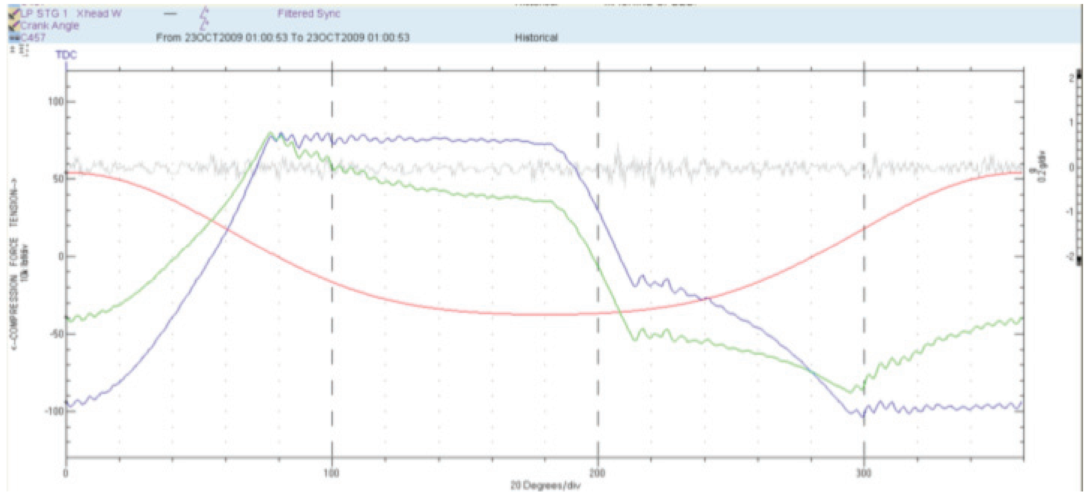

FIGURE 6: 23OCT 2009: Rod load curves (red, green, blue) and filtered crosshead acceleration (gray) before the diagnostic alarm was triggered

The algorithm processes piston rod vibration measurements in the same way, as supporting evidence for the detection of a loose piston assembly.

When highly critical compressors are part of an equipment health management program that is supported by an online monitoring and diagnostic system, a huge amount of data is generated. Since it would be impractical to review ALL of this data, automated diagnosis provides great value by facilitating rapid and positive failure identification.

EXAMPLE: Piston Looseness Detection

The plots in Figures 6 through 8 show the progression of vibration peaks at the first stage crosshead of a large hydrogen compressor. Red, blue and green rod load curves are shown as before, while crosshead vibration waveforms are shown as a light gray overlay. During normal conditions (Figure 6), these vibration amplitudes were less than 0.5 g pk.

The System 1 Rulepak first identified the looseness event, issuing an “Alert – Piston Looseness” alarm when the overall value was about 0.8 g pk (Figure 7). The vibration was visible in the filtered waveform and increased over time up to 1.2 g pk when the software raised a “Danger – Piston Looseness” alarm.

Finally, exactly one month after the first software alarm, the value exceeded 2 g pk, the threshold for protection system Alert (Figure 8). At this point – following four weeks of continuous operation - the decision was made to shut down the compressor for inspection. The inspection revealed that a broken roll pin that retains the piston in position broke and allowed the piston nut to loosen, resulting in a piston knock. The nut continued to loosen to the point where a 6 mm gap existed between the nut and the piston.

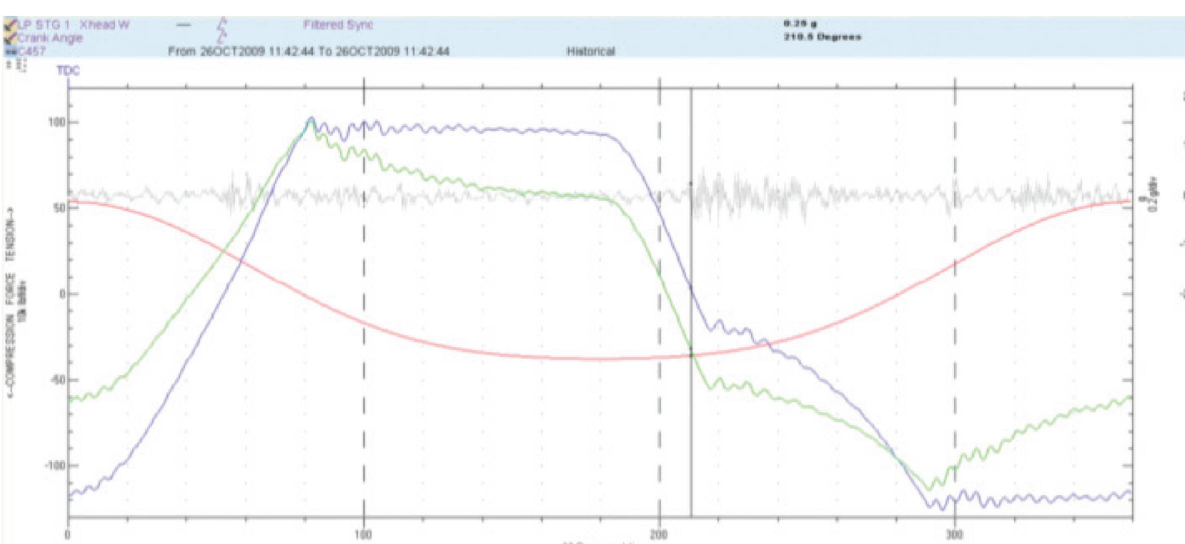

FIGURE 7: 26OCT2009: System 1 software alarm was raised: Alert - Piston Looseness.

Conclusions

Reciprocating machinery vibration is intrinsically different from purely rotating turbomachinery; therefore many considerations need to be taken for an effective analysis.

While velocity measurements on a reciprocating compressor are intended to measure malfunctions such as overloading, foundation degradation and unbalanced forces transmitted to the frame, accelerometers should be used to measure impacts on the crosshead guide and related malfunctions. These two measurements work together complementing each other to create a more complete picture of the machine condition.

Since loose connections between components in reciprocating compressor running gear can cause damage, diagnostic methodologies such as on-line load-tracking vibration analysis have been developed to identify these malfunctions.

The key advantage with this technique is that it is not dependent on load conditions, gas or process changes, nor in relying on comparison with historical patterns that for a typical reciprocating compressor may result in an unmanageable amount of data.

Early identification of looseness allows the prevention of not only catastrophic failures, but also of unscheduled downtime and loss of production, while automated fault diagnostic facilitates plant personnel in pinpointing the specific malfunction.

Specific References

1. Vibration Analysis for Reciprocating Compressors (Part 1), Orbit Vol.32 No.2, APR 2012.
2. API Standard 618, Fifth Edition, "Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services", American Petroleum Institute, 2007.
3. Rod Load Calculations and Definitions for Reciprocating Compressor Monitoring, Orbit Vol.28 No.1 2008
4. Rossi G., "Dynamic Segmental Waveform Analysis Detects Mechanical Looseness in Reciprocating Compressors", Reciprocating compressor – operational reliability seminar, IMechE, London 2011.

General References

Howard, B.F., "Loose Piston Detection for Reciprocating Compressors", Compressor Tech Two, April 2009.

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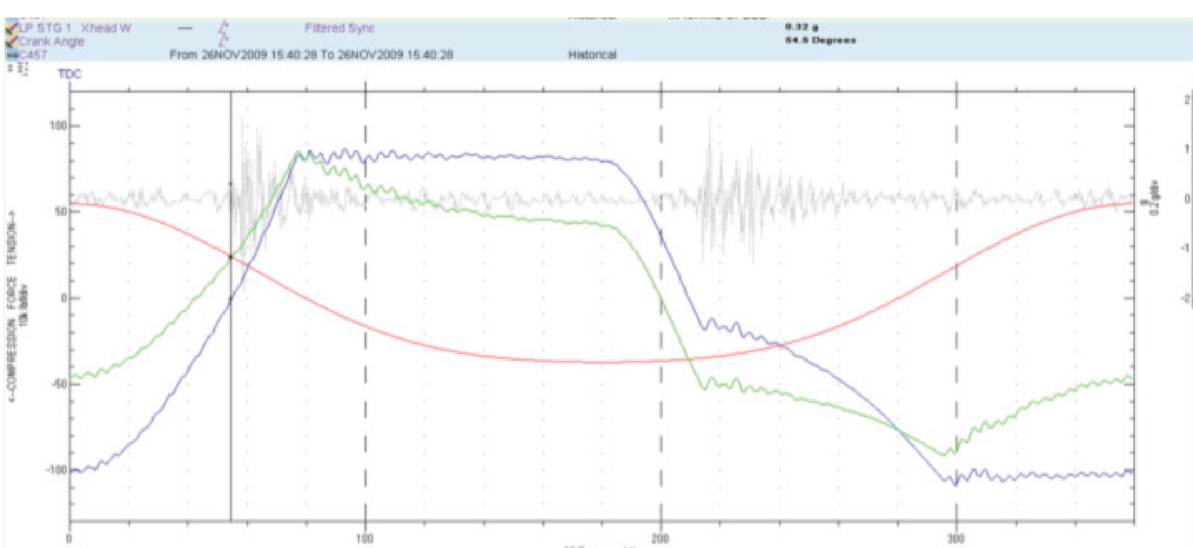

FIGURE 8: 26NOV2009: the 3500 system issued an Alert protection alarm, and the machine was shut down for inspection.

Using the System 1* Journal Editor

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Dear System 1 User,

In this issue, we'll show you a convenient way to store important operating history or any manually entered information for any component in your Enterprise, using the Journal Editor. Journal entries are saved in the configuration database for the selected Enterprise.

Sincerely,
Your FAE Team

Tip Applicability

SYSTEM 1 VERSIONS

Applies to all versions

SYSTEM 1 FEATURES

Applies to System 1 Tools

RECOMMENDED USER LEVEL

Applies to all User levels

The Journal Editor tool provides a convenient method for saving log entries, notes and other useful pieces of information about the monitored assets in your Enterprise. For this mini-article, we will summarize the process into a few simple steps. First of all, it is important to recognize a situation where it would be beneficial to make a new journal entry or to refer to an existing entry. Some examples of these needs are listed here:

- To add written comments about any item in your Enterprise
- To view specific history or background information about specific components, machines, areas, plants, etc.
- For benchmarking process changes, inspections, or other procedures
- To notify others concerning the status of a procedure or the results of testing

Note: Availability of the Journal Editor feature depends on your profile configuration. If it is not available, contact your system administrator to request this feature.

Your goal should be to preserve important information or instructions that will assist other System 1 users. Here are a few examples of types of information that have proven to be useful:

- Operator Observations
- Scheduled Maintenance
- Current testing or Procedures in progress
- Particular points, variables, machines to 'keep an eye on'
- Replacement of Consumable Parts
- Performance Test Results
- Unexpected Process Transients

A Simple Process

1 To access the Journal Editor, rightclick on a highlighted Enterprise component, and select **Journal Editor** from the shortcut menu. In this example (Figure 1), the dialog box will list and display any existing entries that were made for the component named "Ethylene Building."

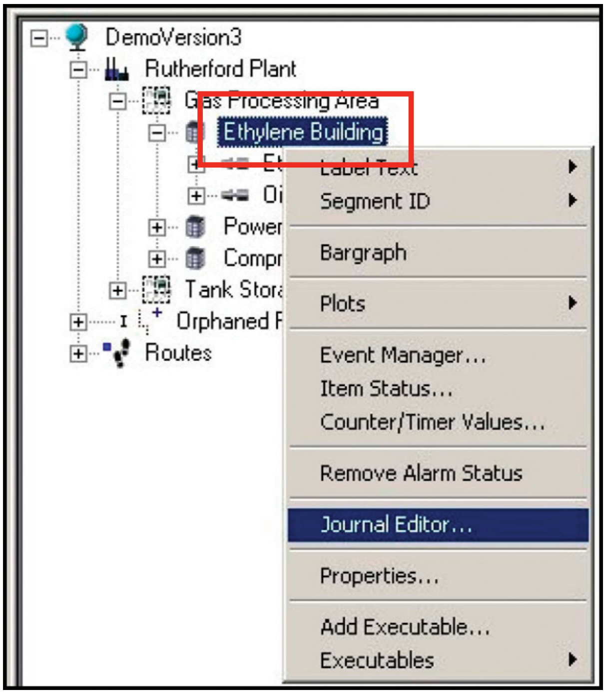

FIGURE 1: Opening the Journal Editor for a selected Enterprise component

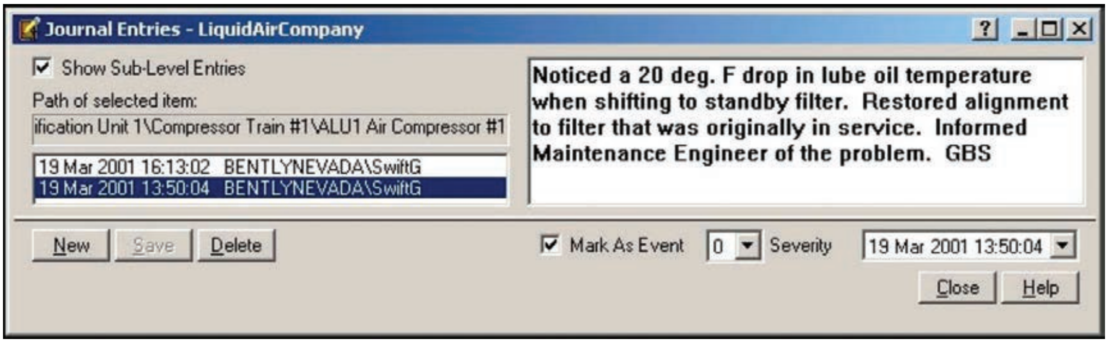

FIGURE 2: This example shows a journal entry that a plant operator made for the lube oil system on Air Compressor #1.

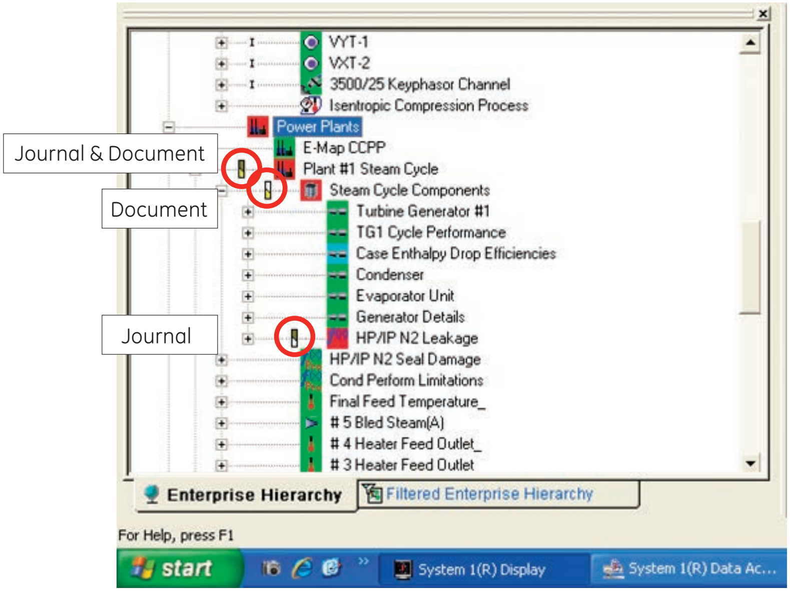

FIGURE 3: Icons show whether any components in the hierarchy have an associated document or journal entry (or both).

2 In this example (Figure 2), the ALU1 Air Compressor #1 has been selected from the Enterprise Hierarchy. Existing entries for the compressor are shown by date and time in the list on the left side of the dialog. To add a new entry, click New, type your comments into the text box on the right side of the dialog and click **Save**. Your Journal Entry will then be available for other users who select the compressor in System 1 Display.

3 In the Enterprise and Instrument hierarchy of Display (and Configuration) it is useful to know whether a node in the hierarchy (tree) has a journal entry or document associated with it. The Journal Editor and Docuview symbols show you which components have a Journal entry, a Docuview entry or both. In Figure 3, three of the hierarchy nodes have either a document or a journal entry (or both) associated with them

Note: Docuview will be discussed in another tip, but the procedure is very similar to using the Journal Editor. Docuview will create links that let you attach any file to a component in the hierarchy.

4 Journal Entries may be viewed as a group by selecting the highest level in the enterprise for which you want to see the Journal Entries. Right click and select Journal Editor from the shortcut menu. When the Journal Editor screen opens, mark the check box for "Show Sub-Level Entries" as shown in Figure 4.

5 Finally, Journal Entries may also be shown in Report Form by selecting **Reports** in the Tools menu (Figure 5).

6 Select "Journal & Inspection Reports" from the Report Type list in the Report tab (Figure 6). Then use the Interval tab to specify the date range for the report. Finally, click **Print** to produce a summary report of journal entries listed by hierarchy node (Figure 7).

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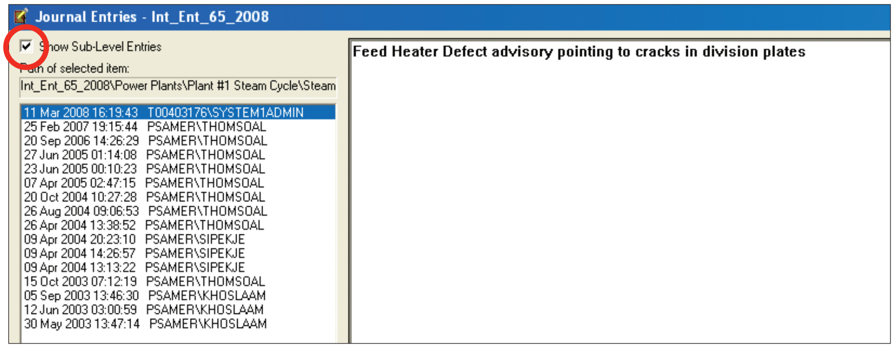


FIGURE 4: Displaying a list of journal entries for all of the sublevels below the selected hierarchy node.

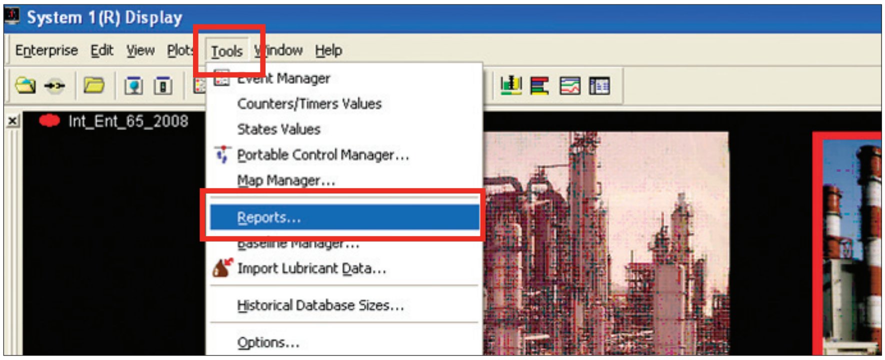


FIGURE 5: Opening the Reports dialog for your enterprise

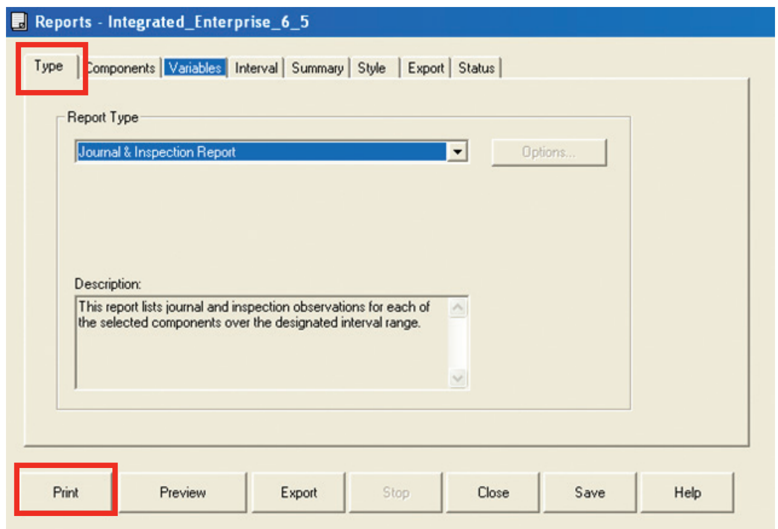
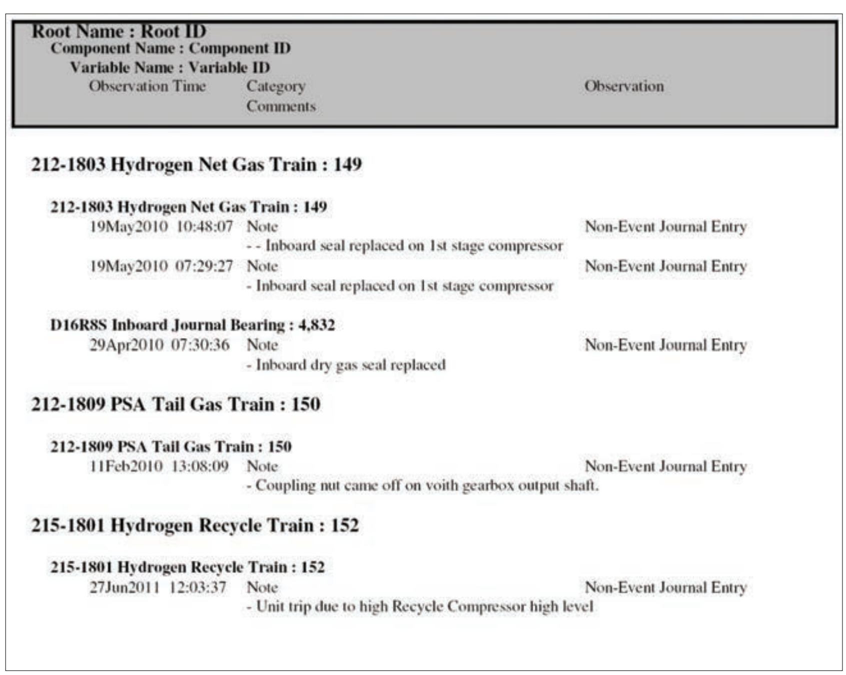


FIGURE 6: Selecting Report Type.



Root Name : Root ID
Component Name : Component ID
Variable Name : Variable ID
Observation Time   Category   Observation
Comments

212-1803 Hydrogen Net Gas Train : 149

212-1803 Hydrogen Net Gas Train : 149
19May2010 10:48:07 Note Non-Event Journal Entry
- - Inboard seal replaced on 1st stage compressor
19May2010 07:29:27 Note Non-Event Journal Entry
- Inboard seal replaced on 1st stage compressor

D16R8S Inboard Journal Bearing : 4,832
29Apr2010 07:30:36 Note Non-Event Journal Entry
- Inboard dry gas seal replaced

212-1809 PSA Tail Gas Train : 150

212-1809 PSA Tail Gas Train : 150
11Feb2010 13:08:09 Note Non-Event Journal Entry
- Coupling nut came off on voith gearbox output shaft.

215-1801 Hydrogen Recycle Train : 152

215-1801 Hydrogen Recycle Train : 152
27Jun2011 12:03:37 Note Non-Event Journal Entry
- Unit trip due to high Recycle Compressor high level

FIGURE 7: Example Inspection Report printed for 212-1803 Hydrogen Net Gas Train. The notations that are listed by component come from the historic Journal entries that have been saved for these components.

Find Our Videos Online

ABOUT GE'S BENTLY NEVADA video is a perfect complement to this issue, showing several scenes of people working in our Minden manufacturing facility. It also includes a statement from Plant Manager, Jim Flemming, on the importance of our employees, who are passionate about providing high quality products and service to our customers:

http://www.youtube.com/watch?v=-S6XvK3VeX8

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http://www.youtube.com/bentlynevadainfo

About GE's Bently Nevada

Coming Attractions

In the JUL 2013 issue, we will broaden our global scope outward from Minden, shining the Orbit spotlight on our team in India. You are cordially invited to join us on the "voyage."

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