ROTATING MACHINERY SERVICES, INC.

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THE FINISH LINE

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RMS EXPANSION FINISHES IN TIME FOR INFLUX OF EXPANDERS

By RMS Project Team

We are happy to report the expansion of our shop and offices completed just in time for the expansion of the RMS expander fleet.

The following types of equipment are presently in our shop for inspections, repairs, replacement, redesign and turnaround support: E-138, EX38, (2) FEX-97, FEX-107, EX48, FEX-142.

The FEX-142 is the largest expander in operation in the world. After an unplanned outage the machinery was brought to RMS for inspection and repair.

The level of experience and expertise at RMS to support all types of expanders is un-rivaled in the industry. When we are planning and executing projects, the level of expertise and in house resources allows us to take the project from conception to the finish line with outstanding results.

Upon completion of the new expansion also comes the opportunity to increase our capabilities to better serve our customers. The new shop has a 35 ton crane and 26 foot vertical lift allowing us to handle and work on bigger equipment. With the addition of new equipment, staff and a renewed need to provide a superior product to our customers, we continue to grow and provide you with the best service in the industry.

What's Inside

RMS IMPORTANT NUMBERS

HOUSTON SALES OFFICE:
Kurt Diekroeger
281-340-8520 (O)
713-898-1015 (C)

David Cummings
281-340-2056 (O)
832-444-0592 (C)

TENNESSEE SALES OFFICE:
Mike Spangler
865-981-9831 (O)
484-896-8438 (C)

BETHLEHEM MAIN OFFICE:
Bill Velekei
484-821-0702 (O)
484-896-8569 (C)

RULES OF THUMB - TURBOMACHINERY

By Neal Wikert

H2S Service:

Alloy Steel / 410 SS / 17-4PH: All three materials are acceptable at different strength levels. Low alloy steels like 4330 could be used to HRC 22 max (UTS app. 113 ksi max), 410 stainless steel can be used up to HRC 25 (UTS app. 126 ksi) and 17-4PH can be used up to 33 HRC (UTS app. 140 ksi). These limits are outlined in NACE MR0175. Corrosion resistance is in the same order. 17-4PH is the material of choice is there is any chance of H2S reacting to form H2SO4, or any other corrosive byproduct, in a particular stage(s).

Impeller manufacturing notes:

Double Temper weld procedure for H2S service:

1600F normalize w/ oil quench

First temper: 1225F +/-15 F

Second Temper: 1175 to 1200F

Impeller Repair Notes:

Impeller Bore Repair

API687: Welding and thermal spraying are the only accepted methods. Chrome or nickel plating is strictly forbidden due to the difference in thermal growth coefficients. Thermal spray coatings have recommended finished thickness limits as follows:

- 7-25 mils for high velocity fuel processes and
- 3-10 mils for combustion processes

Vibration - Common Causes

Unbalance – Most common cause of vibration. Frequency is 1 per running speed.

Bent Shaft – Predominantly 1 per running speed, sometimes 2 times. It is accompanied by a high axial vibration component.

Bearings, Sleeve – Excessive clearance will result in vibration with a frequency of 1 times running speed.

Misalignment – Will result in a vibration with a frequency that can be 1, 2, or 3 times running speed. It is accompanied by a high axial vibration and may be as high as 1.5 times the vertical or horizontal readings.

Oil Whip – May occur in lightly loaded sleeve bearings. The frequency of vibration is sub synchronous (below running speed).

FINAL COUNTDOWN TO "MISSION COMPLETE"

By Barry Ruch

With the new office addition having reached completion, three departments have relocated into the new North wing. The three groups affected are Purchasing, Drafting, and Project Management. This move of people will more effectively create a stream-lined work flow. With communication between these departments occurring on a daily basis, it made sense to locate these people into a closer proximity, as our 'vision' had foreseen it.

As we've now populated all of the first floor outside (window) offices of the new addition, this in turn has created office openings in our South facing 'Engineering Alley' for additional engineers and support personnel. The past six months have produced a beautiful work atmosphere that has tied in seamlessly to our existing main office.

It's an exciting time and we all look forward to being able to be the best we can and serve our customers at a higher, more proficient level.

EMERGENCY NITRIC ACID EXPANDER SERVICE FIXES CHRONIC VIBRATION PROBLEM

By Scott MacFarlane

Rotating Machinery Services, Inc. was recently contracted to install a spare Ingersoll-Rand E520 Expander on an emergency breakdown for a Northeastern US nitric acid plant. RMS' support in the breakdown repairs for the Nitric Acid Train began in late May, following a failure of the operating expander. A cross-sectional view of the expander can be seen in Figure 1.

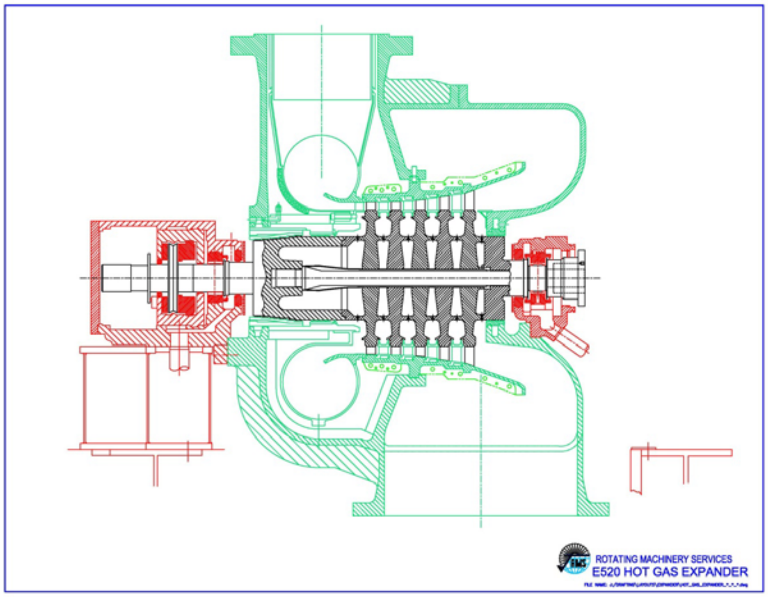
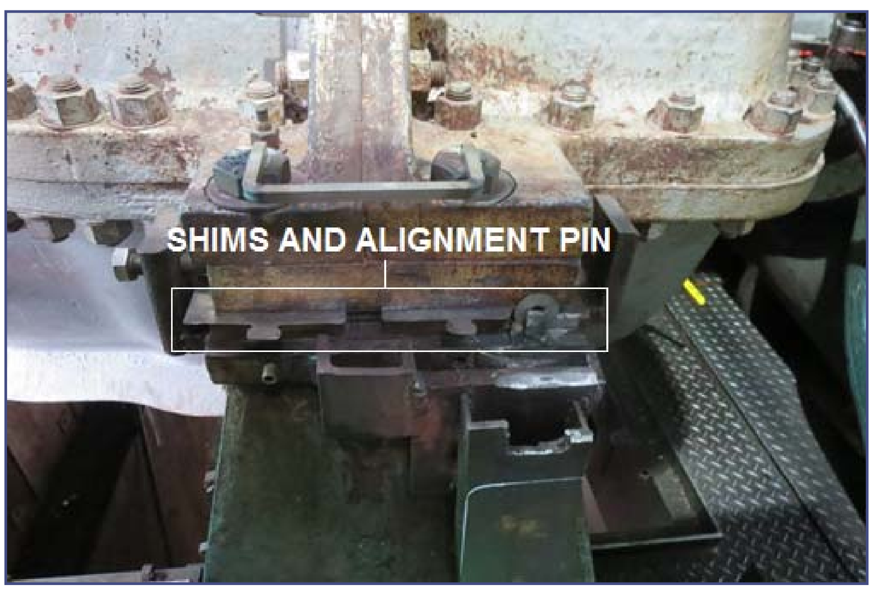


Figure 1

The spare E520 Expander had been sitting idle without repairs for approximately 2 years following a multiyear service run. During that run, the spare expander experienced high and unstable shaft vibrations in the range of 2-3 mils. RMS was tasked with the re-installation and alignment of this machine to the remainder of the Nitric Acid Train, which consists of two centrifugal compressor bodies and a steam turbine. The customer requested two 12 hour shifts for around-the-clock assistance of the installation.

Based on extensive experience with the IR E520 Expander, RMS has developed cold alignment settings that account for the machines' thermally predicted operating position. Using the RMS alignment chart, accounting for the position of the mating centrifugal compressor, RMS was able to shim the expander and machine new alignment pin holes on the pedestals to set the expander in its optimum position. Photograph 1 shows the emergency shims additions and the alignment pin.

Coupling and aligning wasn't the only task RMS was going to complete though. RMS proposed bearing modifications to tackle the vibration issue as well. While RMS has optimized sleeve and tilt-pad bearing retrofits for nitric acid expanders, a complete bearing change-out was not possible on the tight turn-around schedule. Instead, RMS modified the existing bearings for more stable operation.



Photograph 1

After 3 days of installation, RMS successfully turned the expander back over to the customer within their expected deadline. The train was tested following the turn over, using the steam turbine for power, and displayed a maximum vibration level of 0.98 mils at 5000 RPMs.

Once the tests were concluded the train was brought up to its operating speed with the expander showing a maximum vibration level at the journals of 1.06 mils, which is the best this machine has seen in operation.

LESS IS MORE: IMPELLER FITS TO SHAFTS

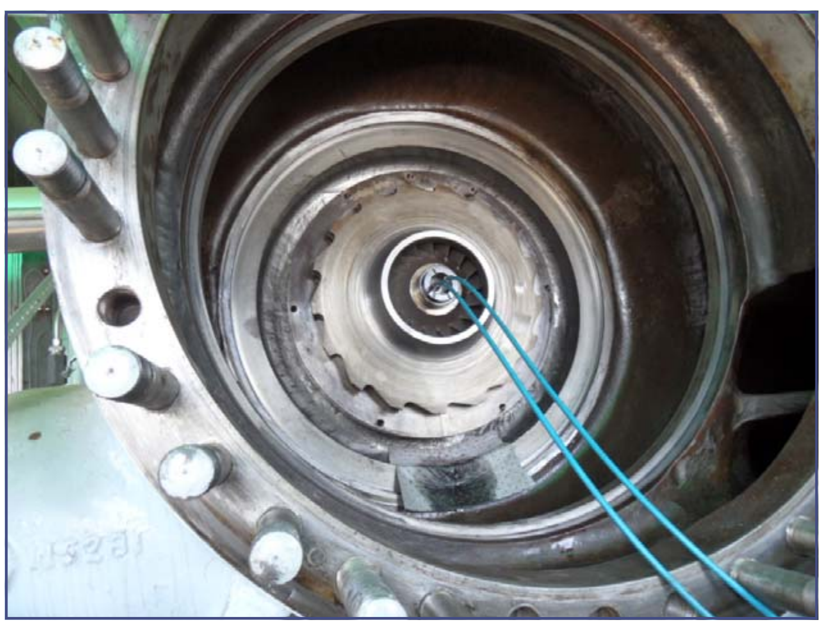
By Marc Rubino

The proper assembly of impellers onto shafts is crucial to reliable centrifugal compressor rotor operation. Just like their human designers, these turbomachinery components are subjected to numerous, diverse stresses throughout their lifetimes. For instance, there are contact pressures that arise in bores from assembly, centrifugal loading due to rotor rotation, blade bending stresses due to gas loading and cover deflection, and axial stresses from stage pressure differentials and thermal gradients. Interference fits between the impeller and shaft permit efficient torque and power transmission. Sometimes, though, impellers are mounted to the shaft with excessive fit, causing costly difficulties in the overhaul shop.

To meet service requirements, impellers are mounted to the rotor shaft with interference fits commonly known as shrink. The undersized bore, or disc inner diameter, relative to the shaft creates contact pressure and a means of transmitting torque, and is often designed with single or double keyways. Keys are usually considered to be redundant contingency torque transmission features. Consequently, all impellers require elastic deformation to facilitate assembly to the shaft. This is achieved by soaking the impeller with heat (torch, oven, induction) or hydraulic pressure. Hydraulically mounted impellers are found exclusively on overhung type rotors, while thermally mounted impellers are the standard for between-bearing rotors. In both methods, the bore is typically dilated approximately 0.005" larger than the shaft diameter prior to installation. After cooling or relief of oil pressure, an interference contact pressure develops between the shaft and impeller. This stress must be analyzed by the designer prior to rotor assembly. RMS generally designs wheels with fits up to 1.5 mil/in of diameter for impellers having tip speeds less than 1000 ft/s. Other manufacturers have been found to use heavy class fits up to 3.0 mil/in, particularly on vintage rotors, which make rotor disassembly problematic. Ultimately, the impeller fit to the shaft must maintain suitable contact at operating and trip speeds while maintaining adequate fatigue life.

In addition to the interference specified, the bore geometry can vary widely. In RMS's service experience, it seems different OEMs favor different strategies for design. The most common styles for U.S. manufacturers are "straight-thru" and "differential" bores. A straight-thru bore has a single diameter for the entirety of the hub length. The straight bore design maximizes the surface area of the bore-to-shaft interference fit and theoretically reduces the fit needed. In contrast, the differential bore has a torque fit band that is axially longer and radially tighter than the centering, or alignment, fit band. They are separated axially in the bore by a machined relief. The differential style facilitates manufacturing and assembly by shortening the length of the torque transmitting fit, and reduces overall operational bore stresses. Other fit styles include supporting rings, polygonal, and integrally coupled.

RMS recently had to redesign the fit of a 1970s vintage impeller to a new shaft for an overhung type rotor assembly. Due to the heavy shrink fit, the impeller and shaft could not be separated. The fit was so great that a combination of heating the impeller, submerging the shaft in liquid nitrogen, and a hydraulic jack failed to disassemble the rotor. Fortunately, the shaft required replacement per contract anyway, and the rotor was destructively disassembled. Consequently, an existing fit was unable to be quantitatively identified. Regardless, RMS dimensionally inspected the impeller with a portable CMM for profile dimensions. A 2-D axisymmetric finite element model was created with the dimensions and weight from the existing impeller. RMS also measured impeller hardness and chemistry to properly identify material elastic properties. With the provided OEM compressor operating conditions data sheet,



LESS IS MORE: IMPELLER FITS TO SHAFTS *(Con't)*

RMS was able to estimate gas horsepower and calculate a suitable impeller fit and stress versus power transmission capability. As a result, the new shaft taper size was specified to define the redesigned impeller to shaft fit that provided adequate torque transmission capability and substantial margin from yielding. This rotor overhaul is just another instance in which RMS demonstrates the experience and analytical tools needed to redesign your vintage equipment to ensure safe and reliable operation.

ANALYTICAL UPDATE

By William Sullivan, P.E.

Over the last year, the analytical capabilities of Rotating Machinery Services (RMS) have increased significantly. The most significant change probably is the addition of a full-time aerodynamicist, Ryan Montero. Ryan has earned B.S. (Cum Laude) and M.S. degrees in Aerospace Engineering from Virginia Polytechnic Institute and State University. Having Ryan on board gives RMS considerably more flexibility in aerodynamic design and optimization including computational fluid dynamics (CFD) analyses.

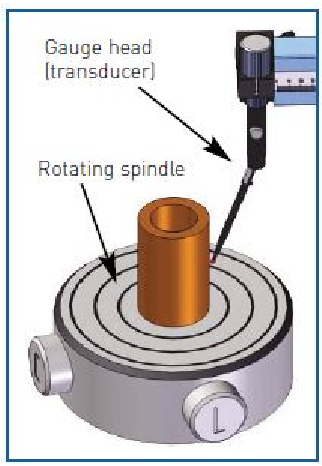
Another significant addition is Chris Sykora who specializes in structural analysis and soon will be leading the RMS analytical group as I move to a more part time role. Chris has earned a B.S in Aerospace Engineering from the Pennsylvania State University and a M.S in Mechanical Engineering from the University of Cincinnati. Chris comes to RMS from GE Aviation, a subsidiary General Electric, where he worked on large and small jet, turboprop and turboshaft engines. The addition of Chris to the analytical team increases our solid model to analysis capabilities while maintaining our expertise in turbomachinery engineering. My continued involvement will provide continuity to better ensure a smooth transition as Chris comes up to speed on the specific requirements of industrial turbomachinery.

QUALITY CONTROL - MEASURING PART GEOMETRY

By Bob DeHart ASQ

Measuring work piece geometry which involves more complex comparisons of part shape to an ideal shape using the geometry gauge or roundness checking instrument.

The geometry of circular work piece features is too complex to assess with conventional dimensional gauging equipment, regardless of their level of accuracy. Two nominally round work pieces may exhibit identical effective maximum and minimum diameters, and yet, the parts have very different functional attributes. Depending upon the application, one of these parts might be acceptable and the other not.



The capabilities of a geometry gage are required to measure geometric parameters and perform complex form analyses such as roundness, concentricity, circular runout, circular flatness, perpendicularity, plane runout, top and bottom face runout, circular parallelism, and coaxiality.

Parts are placed on a rotating spindle and brought into contact with a gauge head. The gauge head is coupled with an electronic amplifier capable of resolutions under one ten thousandth of an inch.

Measurement resolutions of this degree are essential when assembling rotors, the features and components of which may have tolerances of two ten thousandths of an inch.

RMS TOTAL TEAM EFFORT SAVES DR61 POWER TURBINE USER MONTHS OF DOWN TIME

By Robert J. Klova, P.E.

In April, a North American Dresser-Rand DR61 power turbine user experienced an unexpected turbine failure. Rotating Machinery Services was called in to get the turbine back on-line as quickly as possible. On an emergency breakdown basis, RMS manufactured a replacement for the failed part, mobilized a field crew, performed a shop repair and overhaul of their rotor, and reinstalled it in less than three weeks' time. The DR61 was restarted successfully at very low vibration levels. It took a complete team effort on RMS' part – field service, purchasing, shop and engineering, working closely with the customer's experienced maintenance team.

The problem was caused by a heat shield that came free from its mounting point behind the second stage disk, heavily rubbing the disk and blades, and destroying the heat shield. The customer needed a new heat shield in the shortest possible timeframe. With our strong supplier relationships, RMS' seasoned Purchasing department was able to source a new Inconel 600 fabricated heat shield in one weeks' time.

This would have been just in time to reassemble the power turbine – but that was not to be. Inspection of the removed rotor by RMS' on-site engineer revealed that the blade lockwire tabs were rubbed so heavily that blade fixity in the disk could not be guaranteed. RMS recommended a partial shop overhaul of the rotor, including the repair and use of second stage blades from a damaged rotor stored on-site. Based upon site inspection of both rotors, RMS put together a plan and estimate to perform a four day repair in our shop, working around the clock.

The rotor was completed in the promised eight shifts, and shipped back to the field, in spite of several unanticipated findings. Primary among these was the extensive work required to remove the rub damage from, and save, the Waspaloy second stage disk – an expensive and long-lead part. Hardness readings revealed a softening of the disk material along nearly the entire disk aft surface. Without experienced engineering review, and working hand-in-hand with skilled shop personnel to carefully remove material and monitor hardness levels, this disk would not have been suitable for re-use. A company with less experience at dealing with this type of damage might have declared this disk scrap, or returned it to service in an unfit condition.

After repairs and assembly, the rotor was precision balanced by RMS specialists, each with over 30 years of experience. The end result is that the rotor was re-assembled into the power turbine, and started with 0.6 mils of vibration at both ends. Most helpful in the field efforts was a highly experienced customer maintenance group, whom worked very closely with the RMS field crew.

As a follow-up, RMS has developed an innovative mechanical repair for the damaged second stage blades, which should save our customer the high cost of replacing a row of superalloy turbine blades.

PERFORMANCE EFFECTS OF INCIDENCE

By Scott MacFarlane

Steam turbines are designed to perform at specified steam pressures, temperatures, flows and rotor speeds throughout their lifecycle. However, in real life applications they are more frequently than not operating at off-design conditions. A primary example of this is the reapplication of surplus turbines. The same holds true for the individual stages of blades within the steam turbine. Most blades are designed to perform at an optimum level, which occurs when the inlet flow angle is close to the blade's inlet angle. When these angles are off, the resulting flow entering the stage of blades is considered off incidence. Incidence is defined as the difference between the inlet blade angle and the inlet flow angle. These angles are measured with respect to the tangential plane at the leading edge shown as 0° in Figure 1.

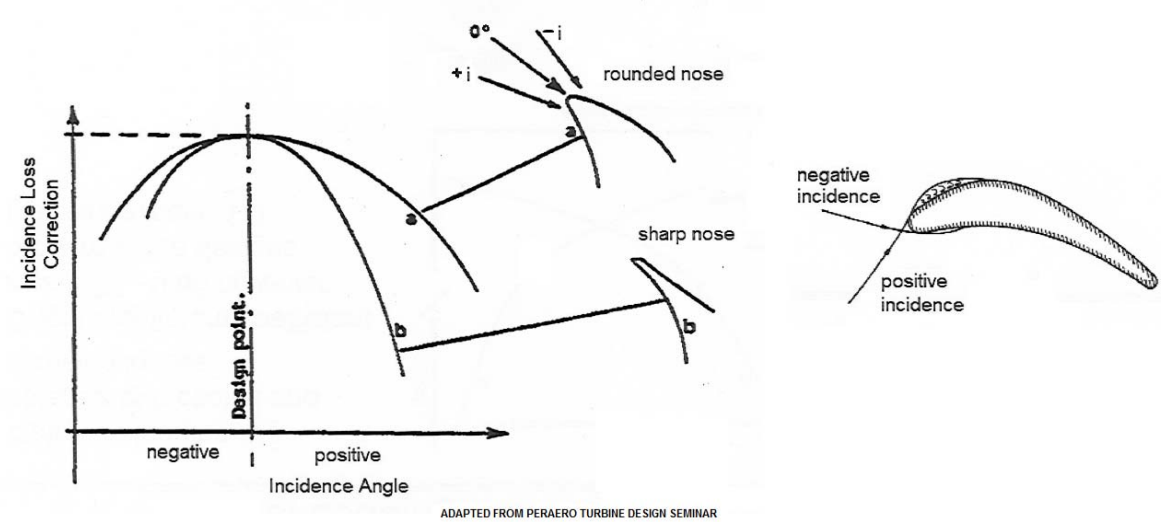


Figure 1

Off-incidence can occur when the turbine is required to operate at common off design conditions such as idling, variable speed and varying loading. The effects of off-incidence on the total loss vary with different blade profiles and geometry. Off-incidence losses are highly affected by the leading edge geometry. The nose shape will determine the extent of flow separation with respect to the incident angle, which can also be seen in Figure 1. A negative incidence angle is more desirable due to the minimized amount of flow separation from the blade. A positive incidence angle causes increased blade loading which results in a thicker boundary layer on the suction side and greater separation.

Reaction style blade profiles are designed with the ability to withstand a wider range of incidence without negatively effecting losses. This is due to the flow acceleration through the stages. The variation of profile losses against the angle of incidence range for impulse and reaction turbine blades can be seen in Figure 2.

When deciding to operate an existing or reapplied turbine at off design conditions, consideration should be given to the possible performance penalty of off-incidence from a mismatched flow path.

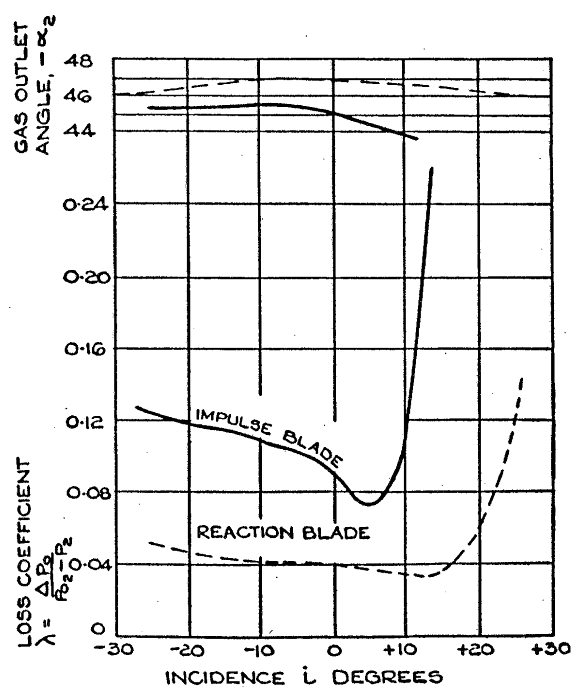


Figure 2

SAFE WORDS - BREAKING THE SILENCE!

By Tom Edwards

Imagine that a co-worker just fell off of an upside down five gallon plastic bucket that he was standing on to tighten a bolt on casing flange. He was hurt pretty bad during the fall when the back of his head struck a valve stem on the way down before his head bounced off the concrete pad. He has a deep gash behind his right ear and is bleeding heavily. You are watching the EMTs provide first aid and taking vitals on him as he fades in and out of consciousness. The ambulance arrives, they package him up and you hear the on-the-scene EMT tell the Emergency Dispatcher that they need to have the trauma team ready to meet the ambulance when it arrives at the local hospital.

While all this is happening, it starts to sink in that, just before the accident, you saw him using the bucket this way. **You knew what he was doing was unsafe, but chose not to say anything to him**. You just walked by on your way to your work station, rationalizing in your head one or more of the reasons below as to why you did not approach him.

It's not my responsibility.

I was too busy.

I worried that he or my peers might think I wasn't "cool" or "macho".

Other people do the job that way.

I didn't want a confrontation.

I didn't want to get involved.

I didn't know what the fix was for his unsafe act.

I saw someone do it before and they didn't get hurt.

I wasn't comfortable in approaching him about his unsafe behavior.

Now think for a minute and ask yourself this question:

Are any of above good reasons not to approach someone and stop an unsafe act that might get them hurt?

NEW EMPLOYEES

By Kathy Ehasz

Rotating Machinery Services would like to welcome our newest additions to the RMS Team!

ERIC DUNLAP
SENIOR ENGINEER

Eric graduated from Cornell University with a B.S. in Mechanical Engineering in 2011. He previously worked as a Mechanical Engineer at Air Products. His experiences at Air Products include Pressure Systems Design and Engineering for large scale Air Separation Plants and Manufacturing and Test Engineering for Cryogenic Expanders and Compressors.

Eric joins us as a Senior Engineer focused on Expanders.

CHRISTOPHER SYKORA
SENIOR STRUCTURAL ANALYST

Chris brings with him seven (7) years of engineering experience in the mechanical analysis, design, manufacture, and testing of aerospace and turbomachinery equipment. Currently specializing in structural analysis at Rotating Machinery Services, Inc. He previously held positions at GE Aviation and the US Air Force SEEK EAGLE Office. His major accomplishments at GE included structural analysis of advanced programs exhaust systems, preliminary design of afterburner liners, durability improvement exhaust flap & seal designs for F110 & F101 aircraft engines for F-16, F-15, & B-1 aircraft, and mechanical & aerodynamic rig testing of advanced ceramic matrix composites. Chris completed an internship designing web-based training material on aircraft stores separation design & analysis for the SEEK EAGLE office. Chris graduated from University of Cincinnati with M.S. in Mechanical Engineering (2011) and the Pennsylvania State University with B.S. in Aerospace Engineering (2007). He is experienced in ANSYS, NASTRAN, NX 7.5, Solidworks, MATLab, and Six Sigma Green Belt certified.

WILLIAM “BILL” VELEKEI
NORTHEAST REGIONAL SALES MANAGER

Bill joins us with thirty-six years of turbomachinery experience in manufacturing, field service, sales and management of axial compressors, centrifugal compressors, expanders, steam turbines, gas turbines, axi compressors and large industrial valves.

Bill will be responsible for covering the turbomachinery needs of our customers in Maine, Vermont, New Hampshire, Massachusetts, New York, Connecticut, Rhode Island, Pennsylvania, New Jersey and Delaware.

POWER RECOVERY TRAIN (PRT) ROUND TABLE IN NOVEMBER 2014

Rotating Machinery Services will be hosting a Power Recovery Train Round Table in November 2014. A welcome reception will be held on Wednesday, November 12, 2014. The Round Table will be held on Thursday, November 13 and Friday, November 14. If you are interested in attending please contact Don Shafer or Kathy Ehasz at 484-821-0702.

If you have a topic, question or problem area for the Round Table, please email Don Shafer at dshafer@rotatingmachinery.com.

There are only a few seats left, please RSVP as soon as possible!

ROTATING MACHINERY SERVICES, INC.

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43rd TURBOMACHINERY SYMPOSIUM

BOOTH 1811

We at Rotating Machinery Services, Inc. are excited to see everyone again this year at the 43rd Turbomachinery Symposium in Houston, Texas, September 23—- 25. If this is your first time attending, please stop by our booth. We always enjoy meeting new people and making new friends.

We will be located at Booth 1811 and have so much to share with you all! Let us fill you in on what's going on here at RMS…..new faces, new expansion, new projects….and so much more!

In appreciation of our customers, we will be hosting a hospitality social at the House of Blues on Monday evening, September 22nd from 6 pm - 10 pm! So start the week off right and come on over!!

It is just a short walking distance from the Hilton Americas. We will be in the Bronze Peacock Room. Entertainment will be provided by YELBA, Latin Fire. So come on over and dress comfortably!!

Good Food, Good Friends and Good Fun!!!