ROTATING MACHINERY SERVICES, INC.

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April—June 2012

THE FINISH LINE

PHONE 484-821-0702 FAX 484-821-0710 WWW.ROTATINGMACHINERY.COM

POWER RECOVERY TRAIN (PRT) ROUND TABLE

Rotating Machinery Services will be hosting a Power Recovery Train Round Table on October 30 and October 31, 2012. A Welcome Reception will be held for attendees on Monday evening, October 29, 2012 at 6 pm – 8 pm at the Marriott Courtyard Hotel, 2220 Emrick Blvd, Bethlehem, Pa.

The FCC Expander Discussion Group is geared towards expander end users and is headed by a moderator supported by 3 to 4 experts from the key Expander manufacturers. Various topics addressing the operation, maintenance and technology of FCC Expanders are discussed. This forum allows the end users to pose questions to the experts and share problems and experiences they have encountered with other end users.

A general overview of topics to be discussion are:

- Process and PRT Overview
- Expander Reliability Overview
- Axial Compressor Theory of Operation
- Motor / Generator and Steam Turbine Overview
- Field Service / Technical Advisor Support during outage

For more detailed information on the Topics of Discussion, attending, or discounted hotel rates, please contact:

> Don Shafer, Expander Senior Product Engineer - dshafer@rotatingmachinery.com
> Kathy Ehasz, Manager - Marketing/Engineering Support - kehasz@rotatingmachinery.com
> or contact the Main Office at 484-821-0702.

PRT Attendee packets are also available on our website at www.RotatingMachinery.com. If you plan on attending, please send in your RSVP form as early as possible to reserve your spot. Seating is limited. We look forward to seeing you there!

RMS WELCOMES REMUS CREEL - SALES ENGINEER

Remus Creel is responsible for RMS sales in Louisiana and Arkansas. He has forty-seven years of Turbo Machinery experience with new equipment and aftermarket sales. His service background extends to centrifugal, axial, screw and reciprocating compressors as well as turbines. Further knowledge includes FCCU and nitric acid hot gas power recovery expanders, lube and seal oil consoles and other auxiliary systems.

Before joining RMS, Remus retired from Ingersoll-Rand and Dresser-Rand, where he held positions as application engineer, product marketing engineer, sales engineer, sales manager and project development manager. He also served on Dresser-Rand's Quality Steering Committee as a Client Alliance Manager.

Remus received his bachelor's degree in Mechanical Engineering from North Carolina State University, and currently lives with his wife in Baton Rouge, LA.

You can contact Remus at 225-939-4680 or email at rcreel@rotatingmachinery.com.

What's Inside

Come Join Us...

41st TURBOMACHINERY SYMPOSIUM

SEPTEMBER 24—27, 2012

George R, Brown Convention Center Houston, TX

BOOTH 740

STOP BY TO SAY HI, LET US TELL YOU WHAT IS NEW AT RMS, AND MEET OUR STAFF OF EXPERTS!

RULES OF THUMB—LUBRICANTS, SEALANTS AND O-RINGS

By Neal Wikert

LUBRICANTS

Bolt lubricants

For high temperature machines:

1. FEL-PRO Heavy Duty Anti Seize – used to be C-102.
2. Milk of Magnesia is a good choice for high temperature fasteners.
3. Anti Seize – N- 5000 Nuclear Grade – Nickel based – Contains only trace sulfides and chlorides which at high temperatures would tend to allow corrosion and fretting which result in galling during disassembly. (safe, but not as effective as the above two choices)

SEALANTS

Permatex "Ultra Blue" - Oil resistant RTV. Not high temperature.

Permatex Aviation Form-A-Gasket Sealant Liquid 3H – Gasket sealant, non-hardening, used on metal-to-metal joints

Dow Corning 3120RTV, Red - Joint sealant for centrifugal compressors. Check temperature capability prior to use on equipment.

GE RTV60 – High temp RTV. Uses a catalyst – Used on Axial Compressor horizontal splits. Can be used on LP steam turbine joints. Can be used with GE SS4004 Primer for improved adhesion.

Turbo R - Joint sealant for steam turbines horizontal joint.

Triple Boiled Linseed Oil – Successfully used on steam turbine joints.

Tite-Seal – Joint sealant for steam turbines.

"Silver Seal" – Some (limited experience) success on high temperature horizontal joints.

Temp-Tite – Steam turbine joint sealant. Comes in string form (sealed in can).

STEAM TURBINE WATER DROPLET EROSION

By Sydney Gross

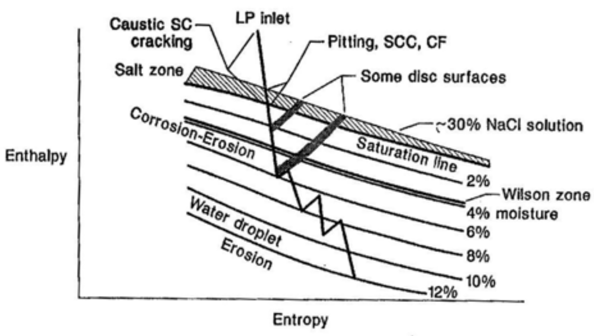
When there is no need in the plant for the steam after it passes through a turbine, a condensing turbine is often preferred over a back pressure turbine. Condensing turbines operate with an exhaust vacuum or pressure below atmospheric. A surface condenser is typically used to maintain exhaust vacuum and can achieve pressures as low as 1 ½ inches of Mercury absolute (3/4 psia). This results in significantly more power per pound of steam than if the turbine exhausted to atmosphere. However, it comes at a price with larger, more expensive turbines and the increased maintenance concerns associated with the formation of water droplets in the last turbine stages.

In large generation units where the effects of moisture on efficiency can be very costly, a great deal of research and development has been devoted to removing moisture and delaying the onset of condensation. But in the process environment where reliability and maintenance concerns supersede relatively small gains in efficiency, the bigger issue is water droplet erosion and component life.

Water droplet erosion occurs when condensate droplets repeatedly strike the rotating blades at relatively high velocity causing spalling of the surface metal. Erosion is most severe at the leading edge tip because the relatively massive droplets are centrifugated outward and their inertia won't allow them to turn around the leading edge obstacle with the vapor. I have been asked on several occasions the recommended maximum moisture content at which to design or operate a turbine with respect to droplet erosion. The Mollier diagram on Page 3 shows that at around 10% moisture, water droplet erosion becomes evident. ***Con't on Page 3***

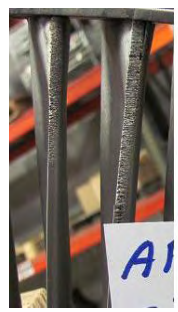
STEAM TURBINE WATER DROPLET EROSION Con't

This is usually in the last stage of rotor blades but may also occur in the next to last or L-1 stage. Erosion becomes severe when moisture levels increase beyond the 12% region.



(Turbine Steam, Chemistry, and Corrosion, Palo Alto, CA, Electric Power Research Institute, August 1994, TR-103738)

The most common solution to this problem in industrial turbines is to attach a Stellite shield to the leading edge of the blade by brazing. The desirable wear properties of Stellite delay the erosion process and extend the run time of the blades. In more severe cases a solid Stellite bar nose can be welded to the blade leading edge to further extend blade life. The photos on the right show last stage blades that have experienced moderate erosion. They were fitted with Stellite shields that have been eroded near the tips.



NITROGEN PRESERVATION SYSTEMS FOR ROTOR CANISTERS **By Marc Rubino**

In the turbomachinery industry, it is critical to protect and maintain spare rotors to ensure the capability of immediate installation. All components including the shaft, turbine disks or compressor impellers, the thrust collar, any sleeves, etc. are subject to damage when stored in an area without environmental control. Due to the immense capital invested in rotors, it is necessary to provide a robust and secure storage structure. The structure would ideally provide adequate support for the rotor's static weight, sufficient protection from foreign contaminants such as dust, the minimization of rusting agents, and a rigid exoskeleton to prevent trauma to the rotor.

Due to the many advantages, rotors are frequently stored in fabricated steel canisters. These containers provide significant protection during either shipping or storage. They are also constructed to enable the container to be stowed vertically. As a result, the risk of rotor bowing is prevented that would otherwise occur during long-term horizontal storage. In the horizontal position, the rotor would sag and detrimentally affect API level rotor balance.

Although these containers are closed structures, there is still potential for contamination from outside air including dust and humidity. Consequently, the steel rotor parts would be in the presence of moisture and react with oxygen causing material corrosion. To combat rust and debris, rotors are often coated with preservatives. Depending on storage time, preservatives can range from WD-40 to LPS Labs' corrosion inhibitors to Cosmoline.

Due to the gelatinous nature of heavier preservatives, they are difficult and time-consuming to remove from rotors. **The premier solution, then, for rotor preservation is a nitrogen purge system**. Nitrogen functions as an excellent alternative to physical coatings as removal is not required prior to operation. Accordingly, rotor canisters are frequently equipped with a nitrogen purge system. ***Con't Page 4***

NITROGEN PRESERVATION SYSTEMS FOR ROTOR CANISTERS *Con't*

As the name implies, the system purges atmospheric air and replaces the volume of sealed rotor containers with commercially pure nitrogen. The rotors are then suited for long-term storage without excessive surface preservation.

RMS was recently contracted to perform inspections for two rotors, a steam turbine and centrifugal compressor, for an oil refinery in Canada. An additional aspect of the work scope was to retrofit the accompanying storage containers for each rotor with a nitrogen purge system. Both canisters were first modified by welding on custom support brackets and clamping saddles for the nitrogen tanks. An expanded metal mesh cage was also welded on by RMS staff to protect and maintain visibility of the dual pressure gauge regulator on the nitrogen tanks. Both rotor containers were then sandblasted and painted with a corrosion resistant epoxy. After installing all hoses, fittings, valves, and gages, both containers were pressurized with nitrogen to 5 psig to test for gas leakage. After passing leakage tests, the rotors were placed back into the containers and readied for shipment. In summary, both rotor containers were successfully modified with nitrogen purge systems with rigid, yet aesthetically pleasing construction and avoided the recurring cost of off-site storage.

SOLIDWORKS ADDS NEW DIMENSION TO RMS CAPABILITIES **By Barry Ruch**

An exciting new addition brought into RMS this Spring has been the installation of SolidWorks, a three dimensional computer aided design package. Prior to this, the RMS Drafting and Engineering departments had been using Auto-Cad as our primary drafting tool, along with Pro-Engineer for complex 3-D modeling.

These two packages have provided the necessary support for over fourteen years here at RMS and have fulfilled every challenge thrown at them. With expected productivity improvements, and an observed shift to SolidWorks by our suppliers, along with increased supplier requests for model geometry, the decision was made to implement this state-of-the-art software.

To start off, we've established the "3-D Tech Team". The team consists of three Design Engineers experienced in SolidWorks along with two Senior draftsmen to facilitate the transition to the 3-D technology world. With a lesson plan formatted and scheduled "classroom" interaction dates established, the learning process kicked off on May 29th. With this now in process, we have also implemented lesson sessions that started June 2nd and continuing for four weeks to mesh Faro Arm 3-D measuring techniques with SolidWorks 3-D model creation.

As always, the main objective at Rotating Machinery Services is to provide our customers the best service we can. One way we do this is to stay in tune with the most current methods by which we reverse engineer equipment and design new components, ensuring the best deliverable product we can.

CENTRIFUGAL COMPRESSORS

By Robert Huffman

This edition's newsletter will be the start of some technical articles to discuss specific features / topics of centrifugal compressors. I've experienced recently where some customers have an influx of new talent into their organizations that have not had specific exposure to the details of a centrifugal compressor. So this month's newsletter will be the first of a series to help provide basic understanding of centrifugal compressors. We will start with an overview of what components are within a centrifugal compressor, focusing on the flow path of the machine. Subsequent articles will discuss general compressor performance theory, compressor curves and how each component within the flow path influences the compressor's range, head and efficiency.

The basic compressor stage has an inlet section, an impeller, a diffuser and depending upon the location of the stage within the machine either a return channel or an exit section to the discharge flange. The exit section can either be a volute or a collector. Refer to figures 1 and 2 for cross section views of a typical compressor stage.

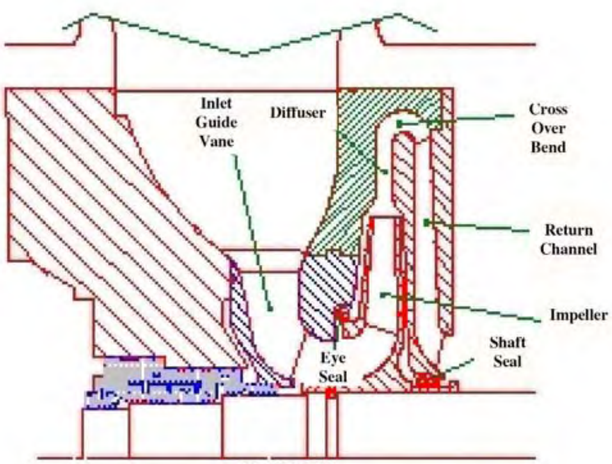


FIGURE 1

Let's start with a typical multistage compressor, we'll first list the typical components and then in future articles come back and talk about each one in some more detail. The first stage in the machine may or may not have an inlet guide vane before the impeller. The next component will be the impeller, followed by the diffuser, the cross over bend, and finally the return channel. There is an impeller eye seal and a shaft seal at the back of the impeller. Each stage will follow this component stack up until you get to the last stage within the machine. Typically the last stage impeller exits into a diffuser and from the diffuser the flow passes into either a discharge volute or discharge collector and then on out of the compressor discharge flange. This last stage impeller has an eye seal but instead of a shaft seal behind the impeller, there is a balance piston seal. Now let's go back and talk about the specific purpose of each components.

Inlet Guide Vane: Regardless of its location within the compressor, the inlet guide vane (IGV) is there as the name suggests, guiding the flow into the inlet of the next component. Specifically what it does is to ensure that a prescribed velocity profile is present going into the next component. In another article we will come back to this subject in more detail to discuss the Euler Turbomachinery equation, but in short the work input to a gas from a compressor stage is a function of the change in tangential velocity from the inlet to the outlet. It is important for the compressor designer to ensure that the inlet velocity profile is known to ensure that the stage design meets the target output. The IGV acts to ensure that the velocity profile is known. Most machines are designed to have a tangential velocity component of zero magnitude, but some designers have used the IGV to impart tangential velocity into the flow. There are also machines that have variable IGV's, that is the IGV can be rotated while the machine is in operation. ***Con't on Page 6***

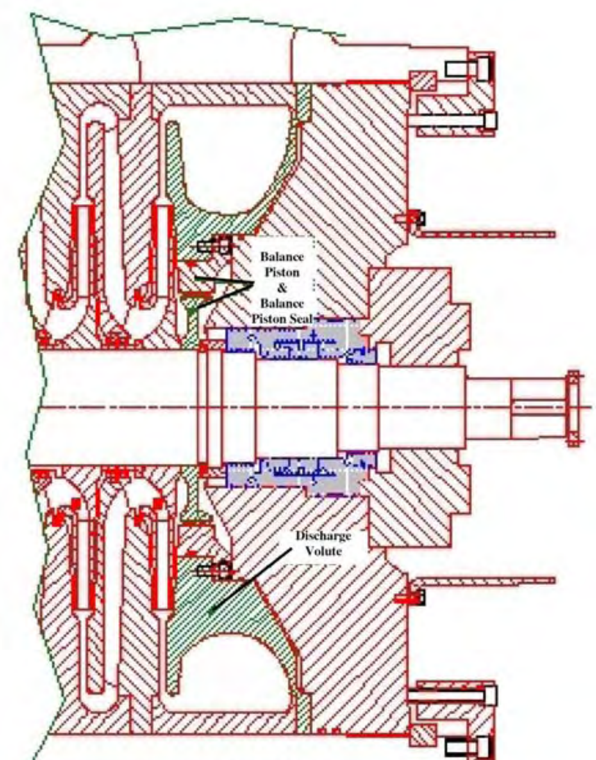


FIGURE 2

CENTRIFUGAL COMPRESSORS *Con't*

This is typically only seen at the first stage of the compressor due to mechanical constraints and complexity of using variable IGV's at stages

other than the first stage. Variable IGV's are also typically found on fixed speed compressors vs. variable speed compressors. Speed changes have a greater effect on compressor output than IGV rotation changes. Further discussion of this will occur in future articles, but the key takeaway is that the IGV is there to ensure a known velocity profile going into the impeller.

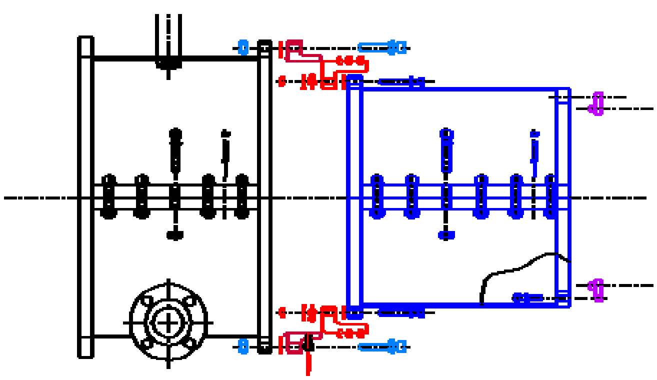
Impeller: There are various designs of impellers; open, closed, radial, mixed flow, 2D and 3D.

Depending upon the specific gas being handled, the flow rate, target pressure ratio of the compressor, the number of stages present, and cost vs. efficiency goals will determine the type of impeller required. Further details of these areas will be in the future but for now the takeaway is that the impeller imparts work into the gas to increase the gas kinetic energy. The things that affect the work input, or energy added to the gas, include the impeller blade exit diameter, impeller blade mean inlet diameter, the impeller blade exit angle, the inlet flow tangential velocity and the shaft speed. Most industrial multistage impellers will be a covered impeller of either 2D or 3D blade design. The flow leaving the impeller will have a large velocity component in the tangential direction. Open impellers are typically not used in multistage compressors where the impellers are mounted on a single shaft. There are a few multistage machine types where the first stage is of an open wheel design but they are not that common. It is not uncommon for integrally geared compressors to have open impellers for all stages. Open impellers are typically used when higher pressure ratio's per stage are needed; the impeller can with stand a higher tip speed than a closed impeller. Without the cover, the stresses are reduced significantly so the impeller can be spun faster before the same stress limits of a closed impeller are met. Impeller discharge pressure is a direct function of the tip speed of the impeller, so the faster I can spin an impeller the more pressure I can develop. Open impeller stage efficiency is in part governed by the leakage of the gas over the top of the impeller blade; therefore control of this clearance is critical to maintaining good stage efficiency. With a multistage compressor with all the impellers on a single shaft, it has proven difficult in practice to ensure all stages are at the correct clearance during rotor installation due to tolerance stack up and to control hot running clearances in operation. Closed impellers do not suffer from the shroud tip leakage loss and so in general typically achieve better efficiency but at lower discharge pressure when compared to an open impeller of the same diameter. The next newsletter article will continue on with discussion of the diffuser, cross over and return channel sections of the compressor.

COUPLING GUARDS

By Anthony Rubino, PE

Coupling guards are a persistent maintenance annoyance prone to oil leakage unless perfectly assembled. This newsletter highlighted a previous RMS coupling guard project utilizing a bellows element to accommodate thermal growth while providing superior leakage avoidance. A recent RMS project addressed a coupling guard that had to be repaired during a turnaround since there was insufficient time to manufacture new. The existing guard utilized a rubber sheet as a diaphragm to accommodate the axial thermal growth. The rubber diaphragm design, while conceptually attractive, was problematic in practice due to assembly difficulties and propensity to leakage. To eliminate the diaphragm, RMS developed a module which utilized the overlapping sleeves concept and three o-rings.



COUPLING GUARD ASSEMBLY

The design also included a leak off port as a contingency in the event some oil leaked past the first two o-rings. The module was easier to install and could be bench assembled prior to installation where the rubber diaphragm had to be assembled in situ.

During the turnaround, the existing guard was shipped to RMS for inspection, rework and fit up of the module modification which were completed in less than a week.

EMPLOYEE HIGHLIGHTED: TIM COULL

AS A TOUGH MUDDER, I PLEDGE…

By Tim Coull

…I understand that Tough Mudder is not a race but a challenge.
…I put teamwork and camaraderie before my course time.
…I do not whine – kids whine.
…I help my fellow Mudders complete the course.
…I overcome all fears.

Each Tough Mudder recites this pledge before embarking on the 12.5-mile, 26-obstacle, water-logged, mountainous, muddy, electro-shock-inducing, team-building, confidence-boosting adventure course designed to show you what you're really made of in body, mind, and soul. This is what it takes to be a Tough Mudder:

Body – Obviously if you're going to partake in such an event and still expect to function with any kind of proficiency in the foreseeable future, you have to be prepared to deal with the distance, terrain, and obstacles and be ready to take on the challenge.

Mind – Though Tough Mudder events are very physical in nature, some of the biggest tests and greatest takeaway lessons are psychological. Like letting go of the wish that you might find a way to not be freezing after the ice bath. Or putting your head down and dealing with the fact that every joint in your body hurts after the electro-shocks. Or forgetting about your time and accepting that neither you, nor your fellow Mudders, can possibly make it over that wall without someone giving you a boost.

Soul – In addition to benefitting physically and mentally, participants also benefit spiritually by serving a higher cause. In all, Tough Mudder participants have raised over $3-million for the Wounded Warrior Project and the uniformed military personnel giving motivation throughout the course serve as a reminder for what the race is all about. This higher calling is what drives a Tough Mudder to help his participants up the slick quarter-pipe – so we can all shake a serviceman or woman's hand at the top.

As it was in the event, so it is here at RMS. In order to execute a quality aftermarket turbomachinery project, you need to be technically fit for the job. In this business, you need to take up any challenge in the face of discoveries, turnarounds, and emergency shutdowns. At the end of the day, providing exceptional service to make a customer happy is what drives the business. This is what it takes to be a Tough Mudder in Turbo-Machinery. Also, RMS shows its true Mudder spirit in recognizing the importance of service beyond self by sponsoring its employees in this event and others like it for a greater cause. To pay it forward, Tough Mudder donated additional funds for each participant who received a Tough Mohawk on race day, and I am proud to say that I showed my own Mudder spirit and made that contribution.

ROTORS OF SPRING

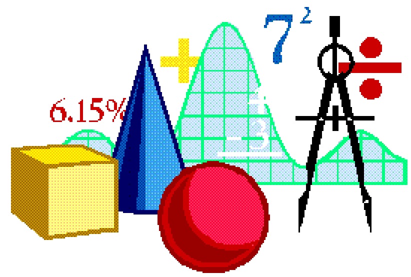
By Glenn Gaddis

For those of us that have been in this business for a few years, we all know that Election Year can frequently present challenges. With that said, RMS has been fortunate to capture a significant number of orders for Rotors. Specifically Axial, Centrifugal, and Steam Turbine.

RMS's new customers in 2012 have provided us with several rotor orders and the remaining by existing customers that are pleased with the work provided by RMS. Customers are satisfied to the extent that we recently had a rotor arrive in our shop for repair that was unannounced. It's nice to know that we have customers that completely trust the work we do here at RMS. We have also received orders for replacement Axial Stator Vanes, Expander blades, and Steam Turbine overhauls to name a few. The customers are out and they are finding RMS!

QUALITY CONTROL

By Bob Dehart ASQ CQT



The transformation of reverse engineering capability is underway with collaborative efforts to propel the propagation of new techniques while maintaining existing, proven processes.

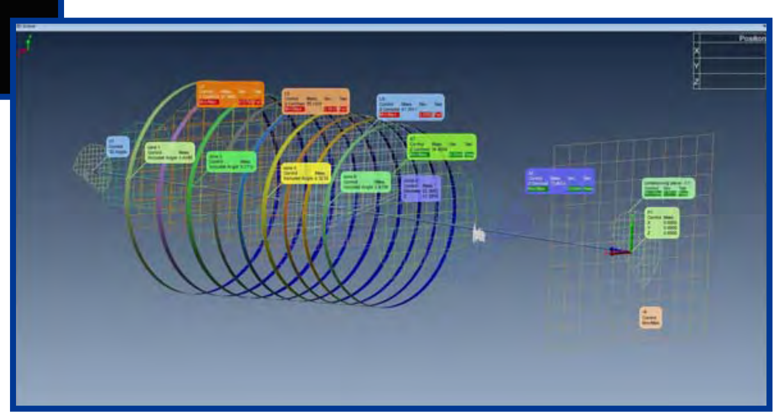
The effort is being facilitated by the acquisition of measuring instruments and the implementation of software for gathering data. The goal is the distillation of that data for the purpose of revealing its most effective use.

All measuring instruments are entered into a database which allows for the maintenance of the inventory in accordance with the calibration operating procedure. In essence, the purpose of the procedure is to standardize and streamline best practices and prevent continuous re-invention.

The procedure specifies, for the purpose of ensuring accuracy, that the instruments are recalled for calibration at intervals based on historical data. It specifies the precise environmental conditions under which calibration must take place and it specifies the required documentation. The documentation must include the lineage of traceability to standards maintained by NIST the National Institute of Standards and Technology.

Calibration accuracy is the backbone of the measurement process. It reduces the possibility of rejecting something that should have been accepted or accepting something that should have been rejected. A measuring process currently under investigation is the capturing of blade tip laterals and diameters on axial compressor rotors. Traditional methods can be time consuming and subject to inaccuracies because of the orientation and condition of the blades. The leading edge may be angled from base to tip in the direction of flow making the precise position of the tangent point challenging to locate. The proposed method uses a portable co-ordinate measuring machine and single point probing. Considerations must include the orientation of the blade tip relative to the spherical probe. The method establishes a co-ordinate system with a vector thru the centers of the rotor journals as the Z axis. The x, y and z co-ordinates of all points subsequently taken will be relative to the established co-ordinate system. Five points are taken on a sample of four blades, one sample at each of the four quadrant locations.

Left: Blade tip probing. The blade profile is generated by scanning a cross section of the blade.



Right: The point data is used to determine the minimum z value, the range of the z values and, using the x and y values, determine the polar coordinates and the range of the radii of the points.

Rotor blade tip lateral and diameter inspection using the Faro portable co-ordinate measuring machine.

Shop Capabilities

RMS Power Solutions is an industry leader performing inspection, repair, overhaul and field service on a full range of critical rotating equipment including centrifugal compressors, axial compressors, steam turbines, power turbines and hot gas expanders for the refining and power generation industries. We currently operate a 20,000 square foot shop which includes rotor assembly and balance, unit assembly, and machining capabilities. We take pride in our ability to refurbish turbomachinery to a condition that ensures long term trouble free operation for our customers.

Our assemblers, inspectors, machinists and field service supervisors have an average of 25 years of experience in their respective field and take great pride in our facility and our ability to handle our customer's property with the greatest efficiency and attention to detail. We are affiliated with highly respected millwright service organizations throughout the country and supply RMS field supervision for each crew to ensure proper execution of every project.

Our latest addition to our shop includes a 52" swing 240" between centers engine lathe. Our continuously expanding range of capabilities includes:

GENERAL FACILITY

- Machinery assembly bay
- Rotor repair bay
- Three overhead cranes with capacities up to 25 tons
- The full range of lifting, moving, and storage equipment

ROTOR SPECIFIC

- 40,000 lb Schenck® balancing machine
- 17,000 lb Schenck® balancing machine
- Latest Schenck® electronic controls and software
- Two rotor runout stands
- Two rotor assembly pits
- Bracker automatic steam turbine blade tenon peening stand

MACHINING

- Constantly expanding range of machine tools to support assembly and component repairs

WELDING

- TIG welding capability, up to 250 amp
- MIG welding capability

QUALITY CONTROL

- Climate controlled, state of the art inspection room
- Coordinate measuring machine
- Granite Tables
- Full NDT inspection capability
- Full range of inspection measuring tools including OD micrometers up to 60"

CLEANING

- Grit and Glass bead blasting
- Solvent cleaning





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RMS

PRODUCT LINES:

AXIAL COMPRESSORS • CENTRIFUGAL COMPRESSORS • EXPANDERS • GAS TURBINES • POWER TURBINES • STEAM TURBINES

SUPERALLOY DISKS...When Needed

By Robert J. Klova, PE

Rotating **M**achinery **S**ervices, Inc. recently supplied superalloy disks to two major North American natural gas companies, as part of complete power turbine rotor overhauls. The complexity of these disks showcase RMS's reverse engineering, manufacturing, and quality control methods. They were manufactured from contoured forgings. A rigorous inspection program included forging chemical and mechanical certification, ultrasonic inspection, overall and firtree slot dimensional inspections, go/no-go gaging, blade fit-up checks, and final die-penetrant inspections. Both rotors are now in successful operation.

Replacement of both disks was required because their useful life limit was reached. Often however, using remaining life analysis techniques pioneered by RMS personnel, we are able to extend the useful life of power turbine disks beyond their rated operating lives, which is typically 100,000 hours. RMS has been able to certify disks for operation up to 200,000 hours.