

# SETTING STANDARDS OF ENGINEERING EXCELLENCE

Successful turbomachinery engineering involves a number of factors: experience, creativity, the correct tools, checks and reviews, and a disciplined approach. Since many of our projects are highly engineered, we have strived at RMS to build strength in all of these areas. Our staff includes Product Managers for each type of large turbomachinery: centrifugal compressors, steam turbines, axial compressors, hot gas expanders, power turbines and gas turbines – with literally decades of specific machinery design engineering experience, averaging over 25 years. We have invested in the finest engineering tools in our core areas: FEA, CFD, 2D and 3D CAD, and performance modeling software for each type of compressor and turbine.



By Robert J Klova, PE

We have long standing partnerships with specialists in all support fields: rotor dynamics, aerodynamics, controls, testing and instrumentation – specialists that we have worked with for decades. Backing our engineers is a group of CAD designers with the same level of specific machinery experience that is probably unmatched in the industry.

Having the best engineering and the best tools does not ensure success without the systems and disciplines to minimize errors in both the engineering and manufacturing phases. Our critical design decisions are guided by a robust and continuously growing body of RMS engineering and drafting standards. Each job is controlled by a Quality Manufacturing Plan, which lays out the specific QC steps required for each component and assembly. We have implemented procedures for double checks on reverse engineering inspections. All manufacturing drawings must pass an engineering review process. Every engineered project is to be checked through a series of formal Design Reviews. Wherever possible, each project incorporates one or more design validation tests.

These resources and this level of control are not put in place overnight, but rather through years of working toward the same goal: meeting the requirements of each job and doing it right the first time. As a final point, RMS has established itself as a leader in the turbomachinery aftermarket through a process of continuous improvement. Each job is subject to a close-out review that seeks to implement any lessons learned to improve the way we execute the next project. We would be pleased to make that YOUR project!

# **RMS POWER SOLUTIONS**

#### By Paul Poley



The RMS Power Solutions shop, during the second quarter has managed very well to stay active with continuous improvements and meet the production requirements at the same time.

The current theme of jobs is steam turbine rebuilds and re-rates in the assembly area and centrifugal compressor rotor inspections and reconditioning in the rotor area. However, there continues to be a generous variety of tasks that keep us busy as well. Our machining area has taken on more responsibility in the manufacturing of support tooling. We also took on a large stud removal job the work on schedule and at a major cost savings to the project.

and were able to complete the work on schedule and at a major cost savings to the project .

We now have our climate controlled inspection room complete and active. It is proving to be a valued addition to our shop operation by providing the much needed space to perform inspections and allow our inspector to manage the precision tooling in a very organized manner.

Our assembly cells are taking better definition and are better served with the addition of a couple of jib cranes. The work bench and storage fixtures in each area are improved and make the job a little easier and more effective.

One of our next major improvements will be the addition of more heavy pallet racking for improved component storage.

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exhibit!!

API 687 Rotor Repair Course RMS Bethlehem October 31– November 4

See page 2 for details

# ROTATING MACHINERY SERVICES. INC.

## TURBOMACHINERY RULES OF THUMB

#### Vibration - Common Causes

Resonance - Each part of a machine has a resonant frequency that may be excited by a

Unbalance - Most common cause of vibration. Frequency is I per running speed. Amplitude of vibration is steady and proportional to unbalance.

Bent Shaft - Predominantly I 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). Amplitude of vibration is radial and unsteady.

Looseness – Mechanical looseness will result in a vibration with a frequency 2 times the running speed. Amplitude is proportional to looseness.

# STEAM TURBINE TRIP & THROTTLE VALVE

The T&T valve, as it is often referred to on industrial turbines, is located upstream of the steam chest and often mounted directly to it. Its main function is stopping the steam flow to the turbine to discontinue operation in emergency situations. It may also be referred to as the emergency stop valve or trip valve with some distinction in the ability of the valve to act as a throttling device. Apart from its emergency

function, it is also often used to start the turbine by manually opening it to slowly admit steam to the turbine and bring rpm up to minimum governor speed, as well as execute solo trip testing runs. These functions are growing less popular, however, with the proliferation of more sophisticated electronic governing systems capable of ramping a turbine from stopped, through slow roll, warm up and critical speed(s) to operating and trip speeds using the governor valve system.

The valve plug, once opened and latched, can be rapidly closed through a heavy duty spring attached to the spindle. Latching in the open position is typically maintained by an oil operated cylinder which responds to loss of oil pressure by releasing the latch and allowing the valve to shut. Closing time is on the order of less than 1/2 second. Loss of oil pressure to the latching cylinder is accomplished through a dump valve circuit that responds to events such as low lube oil pressure, over speed, rotor axial position change and high vibration as well as manual tripping.

T&T valves see harsh operating conditions. The valves are subject to high temperatures & pressures and to deposition. They are the leading causes of accidents, often during over-speed testing events. While some improvements are being made, like automated partial stroking of the valves, the entire trip system should be tested on occasion. Current generation T&T valves are designed to be exercised regularly without affecting train speed or process parameters, but many older models are not configured to permit, or to reliably execute, partial stroking. Because exercising is critical to detecting problems and to avoiding critical failures on demand, consideration should be given to upgrading or replacing valves not suitably designed or equipped.

# Throttle Trip

Installed T&T valves should be sent back to the manufacturers for teardown inspection and reconditioning at each major turnaround. The repair centers will disassemble and clean valves, recut or relap seats, and recondition and reassemble the units with new gaskets, packing, washers, springs, etc., as necessary. Valves will also be hydro-tested and operationally tested.

#### API 687 SEMINAR AT RMS—OCTOBER 31 - NOVEMBER 4, 2011 By Kathy Ehasz

Rotating Machinery Services will host the API 687 Rotor Repair Course at our Bethlehem, Pa office on October 31 - November 4, 2011. The API Rotor Repair Course, based on API standard 687, covers the minimum requirements for the inspection and repair of rotating equipment rotors, bearings and couplings used in the petroleum, chemical and gas industry services.

RMS engineer Tony Rubino contributed to the writing of the API 687 standard. For more information on the API 687 course, please visit the API website at www.api-u.org/rotorrepair.html.





**By Sydney Gross** 

**By Neal Wikert** 

# **RMS MANUFACTURES REPLACEMENT VANE CARRIER**

RMS has completed the manufacture, assembly and installation of a Sulzer AC-12-53 axial compressor stator vane carrier. The compressor features a "casing within a casing" design where the outer casing is the pressure vessel and the inner casing (i.e., stator vane carrier) contains the assembled flow path stationary compo-Use of a vane carrier can reduce turnaround time since all of the flow path components can be nents.

Due to a process upset, the customer's vane carrier had become distorted and airfoil tip clearances had to be increased to permit compressor assembly. The loss in compressor capacity due to the increased tip clearance and airfoil damage was estimated to be approximately 6%.

facility. The vane carrier was fit verified to the rotor in the shop using a special fixture and arbor to ensure

factured with machining allowance at the inlet and discharge outer casing fit locations since the fit dimensions were not known. RMS included additional machining allowance at the fits to accommodate modifications to the outer casing to correct for material loss due to corrosion and other damage that has occurred over time.

The vane carrier was installed during the turnaround using the RMS provided arbor and engineering supervision. The outer casing was found to need significant rework at not only the fits but to also correct misalignment at the seal boxes. While the outer casing was reworked, the vane carrier fits were final-machined. The vane carrier was installed into the outer casing without incident and all clearances were within specification. The refinery process has not yet been brought to full rate but preliminary indications are that design

Since the refinery operator's spares were used in building the compressor during the turnaround, RMS manufactured replacement blades, vanes and spacers.

# SAFETY INITIATIVES

Rotating Machinery Services' safety committee has been busy the past few months, but not because of incident or loss. Some of the recent safety related activities include:

- A representative from RMS attended a seminar at the local community college held in conjunction by the college, OSHA, Center for Business and Industry and the Lehigh Valley Safety Committee. The seminar covered PPE usage and the latest safety products available.
- We conducted a sound level and audio dosimetry survey on site. This survey will compliment the hearing conservation program already in effect at RMS.
- We are currently working on safety certification for our safety committee.
- In addition to our safety assessment, RMS continues to develop job safety assessments (JSA's) for common jobs and tasks conducted on site as our shop expands. This helps assess potential hazards, and ways to avoid them on specific duties.
- We continue to have our weekly "toolbox talks" to perpetuate a mindset of accident awareness and prevention to shop employees.
- We have installed an electronic message board with safety tips and reminders in the shop of safety awareness.

RMS remains an accident, incident, and loss free business for 12 years running because of the company's commitment to the health and safety of its employees. We operate on 100 percent safety policy compliance requirement and are constantly reviewing policies to conform to the best practices of our field to protect our employees and prevent any form of loss.

swapped by changing two major units: the vane carrier and the rotor.

RMS manufactured a replacement vane carrier and installed the vanes into the carrier at RMS' Bethlehem fault free assembly in the field. The vane carrier was manu-

flow has been reestablished.

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By Tony Rubino, PE



# ROTATING MACHINERY SERVICES. INC.

# **RMS WELCOMES OUR NEWEST TEAM MEMBERS**



**Timothy W. Coull Design Engineer** 

Tim graduated with Highest Honors from Lehigh University with a B.S in Mechanical Engineering in 2008, and a Masters in Mechanical Engineering in 2010 with a focus in energy. While at Lehigh, he held various project engineering and leadership positions with Engineers Without Borders, developing a potable water system for a community in Honduras.

#### **Corey M. Jones Design Engineer**



Corey recently graduated from Lehigh University with a Master's in Mechanical Engineering, With previous design engineering experience through a series of internships at Fender Musical Instruments, Corey is looking forward to his chosen career path in turbomachinery engineering and is excited for the opportunity to learn under some of the most knowledgeable experts in the area.

Both Tim and Corey are excited to start their career at Rotating Machinery Services, Inc.

**Kevin Murphy** Sr. Buyer



Kevin has thirty years of experience in supply chain management of turbomachinery including material procurement, production control, material, scheduling, expediting and project coordination.

Previous positions with Ingersoll-Rand, Air Products and Chemicals, CONMEC Inc. and GE Energy. Was sourcing liaison in production meetings and attained Six Sigma green belt certification.



#### **Brad Dennis** Drafting / 3D Design

Brad brings to RMS seventeen years of experience in inspection, layout and design drafting of various types of turbomachinery and related packaging. He also has experience in heavy industrial machinery design, transportation equipment, and consumer products. Brad is experienced with ProEngineer, SolidWorks, and Unigraphics 3D solid modeling packages. Previously held positions at GE Energy, CONMEC Inc, Dana Corporation, and RPA Engineering Consultants.

Brad served eight years in the U.S. Navy Reserve as an Information Systems Technician. As part of a Naval Construction Battalion he was responsible for the units computers and communications equipment. Brad was deployed in 2006 to the Irag/Kuwait border in support of Operation Iragi Freedom.



#### Eva G. Diaz **Office Receptionist**

Eva is a recent graduate of Northampton Community College with an Associate degree in Business Management. She is currently pursuing her Bachelors degree in Accounting. Eva brings with her 7 years experience in Customer Service and 2 years of Travel experience. She looks forward to growing with RMS while learning about the turbomachinery industry.

# CONGRATULATIONS TO OUR STAFF MEMBERS

We'd like to congratulation our fellow employees on their recent additions to their families. We wish them the best of luck!

Sydney and Kathi Gross welcomed their daughter Hayden Elizabeth to their family on April 8th. Hayden has 4 older brothers, Colin, Arran, Sam and Keegan.

Barry and Ann Ruch welcomed their first grandchild Adrianna into their family on March 1st.

Neal and Pat Wikert welcomed their 4th grandchild into the family on April 29th. Tanner Kast. Tanner has an older sister, Kaylee.

Carl and Gertrude Hess welcomed their 10th grandchild Katelynn into their family on May 6th.





Hayden Gross





Tanner Kast

Katelynn Hes

# VOLUME 7, ISSUE 2

# PARTIAL ARC SHOCK RESPONSE

In order to increase the part-load power output and efficiency from the first stage of blades in a steam turbine, the steam is often admitted in a "partial arc". That is, steam flow through the nozzles is limited to an arc of less than 360 degrees. In this way, high steam velocities can be achieved under both full-load and part-load conditions, thus enabling the blades to operate at optimum or near-optimum aerodynamic conditions. Unfortunately, this is one case where what is good for aerodynamic efficiency is not good for blade reliability. This is because as the blades pass into and out of the arc of admission, they experience sudden and complete loading and unloading.

This sudden application and removal of load increases the dynamic load on the blades, which in most cases is limited to the nozzle wake perturbations, by a factor of about 10. Furthermore, depending on the natural frequencies of the packeted blade modes, the shock loads can be multiplied by the blade modes being in resonance with the blade-to-blade load applications. Of course, while all this is going on, the blades are also being subjected to the typical nozzle passing loads.

The effect of packeted blade frequencies and mode shapes on partial arc response can be demonstrated analytically using dynamic response modeling. In this case we will examine a packet of 5 blades. For simplicity, the blades and

shroud will be built using "beam" elements. With beam elements, the blade and shroud cross-section properties (area and moments of inertia) are defined for specific intervals. The ends of the intervals are located and linked by nodes. The blade and shroud model can be seen in Figure 1.

In the analyses, the blades are loaded sequentially at intervals based on the assumed rotor speed. The blades remain loaded through the arc of admission. Finally, the blades are unloaded sequentially as they leave the arc of admission.

One of the key factors in determining the response of a group of blades to the sudden load application is how many blade vibration cycles occur as the blade progresses one blade pitch (cycled per blade pitch). This can best be visualized for the case of one cycle per blade pitch for the first tangential mode. As the first blade enters the arc of admission it is immediately deflected. The shroud passes the deflection to the remaining blades in the packet. At this point we should probably point out that any sudden application of load excites all of the blade modes of vibration to some extent (this is what happens during an impact vibration test). Therefore, if the first tangential mode is excited, and the frequency of excitation corresponds with the blades progressing one blade pitch, then as the second blade is loaded it already wants to move in the direction of the applied load. This can increase response significantly.

The effect of the above can be seen in Figure 2, which is a plot of the response of the 5-blade beam model in terms of cycles per blade pitch. (For this plot, only tangential loads were applied.)

# **DO WHAT YOU SAY!**

How many times have you heard that statement? Do you practice it, or is the statement only applicable for the "other guy".

For the Project Manager, we have to deal with this on a daily basis. For a variety of reasons, dates are missed. Some reasons are understandable and others are not. Everyone must honor his or her commitments for a project to run smoothly.

If you purchase a refrigerator for your home that is scheduled by the supplier to be delivered between I and 3 pm, on a specific day, don't you expect it to happen? Of course! Especially, if you have to schedule time off from work to accept the delivery. If the delivery doesn't happen, I'll bet the retail store hears about it in record time! Plus you may not want to do business with them again.

We all have to make our commitments; from the refrigerator delivery to the centrifugal compressor, from the supplier to the final shipment.

Here at RMS we work very hard to fulfill all of our promises and meet our customer's expectations of delivery and quality work. We are here for you, Mr. Customer! And we aim to make our promises.

# By William Sullivan, PE



ELEMENTS

3.0

#### Figure I (Node Numbers Turned on for Visibility)



Shock Amplification for 5 Blades per Packet



**By Glenn Gaddis** 

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ANS

urement process.

Page 6

**QUALITY CONTROL** 

skill of the operator, the environment, the condition of the item being measured and other effects. Even if a resolution to distinguish between the values.

When measurements are taken we generally assume that some exact or "true value" exists based on how the item being measured is defined. When the results are reported, we can specify a range of values that

tainty. The uncertainty is the best estimate of how far a measured value might be from the "true value." The art of estimating this uncertainty is error analysis.

One of the elements of measurement uncertainty is temperature variation. Due to their different coefficients of thermal expansion, different materials used in the manufacture of parts for turbo machinery vary widely in their response to temperature variation. When parts and measuring instruments are given sufficient time to acclimate to an environment in which temperature fluctuations are controlled within +/- 2 degrees Fahrenheit of standard temperature (68 degrees Fahrenheit), this element of measurement uncertainty is neutralized.

To address the issue of the effect of temperature on the measurement process, RMS has commissioned a climate controlled inspection room.

# SARAH GOBER: MASTER OF THE PIANO

As engineers, our search for technical excellence and achievement can sometimes hinder our artistic pursuits. Fortunately, for the Gober family, our daughter Sarah keeps us focused on the arts. Sarah recently achieved major milestones in her life long passion, playing the piano.

Sarah's schedule in April and May was hectic. In April, after months of preparation, she performed her Senior Piano Recital at West Chester University with her proud family, friends, fellow students and faculty in attendance. Her recital was a beautiful and flawless one hour performance of works by Bach, Haydn, Ravel, Schoenberg, and Shchedrin. One week later, Sarah graduated Magna cum Laude with a degree in Piano Performance. Two days after graduation, she traveled to China for a 2 week Masters Piano class at Guzhou University that included tours of Shanghai and Beijing. Quite a month for our talented Sarah ! The next step on her classical mystery tour will be to attend Temple University in the Fall to pursue a Masters Degree in Piano Accompanying and Opera Coaching.

Sarah's musical resume has grown vastly since she began playing piano in the 2<sup>rd</sup> grade. At Freedom High School, she was the lead pianist for the Patriot and Concert Choirs for 4 years and the Les Chanteurs Honors Choir for 3 years. She was selected twice for Northampton County Chorus, sang in Carnegie Hall with the Metropolitan Opera Company, played in the orchestra for 5 theatre company plays, and traveled on a 7 day / 3 city choral tour of Italy, all while graduating from the Honors program earning the Lamp of Knowledge for achieving straight A's for all 4 years of high school.

At West Chester University, Sarah's resume continued to grow while carrying a full academic workload and working as a church pianist on Sundays. A few of her accomplishments included Section Leader in the Concert Choir for 2 years, accompanied over 40 student and faculty singers and instrumentalists for auditions and recitals, participated in 4 Gilbert & Sullivan Society operettas (3 on the piano / 1 acting and singing), was pianist for 2 university operas, and won the Jacob's Music Steinway Scholarship in her senior year.

Brava Sarah ! We are very proud of you !

# ROTATING MACHINERY SERVICES. INC.

#### Our objective is to ensure that our measurement processes have adequate resolution and are both precise and accurate.

Among the operating procedures in place or in process at RMS are those governing measuring instrument

No measurement is exact. Several variables must be defined for a complete characterization of any measurement process: the accuracy and precision of the measuring instrument, the measurement procedure, the quantity were to be measured several times, in the same way and in the same circumstances, a different measured value would in general be obtained each time, assuming that the measuring system has sufficient

# the "true value" is expected to fall within. The most common way to show the range of values is: measurement = best estimate $\pm$ uncer-







By Bob Dehart, ASQ CQT





By Dave Gober

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# **CENTRIFUGAL COMPRESSORS**

RMS has recently purchased and implemented the use of CompAero. CompAero is a centrifugal and axial compressor design and analysis software suite of tools developed by Ron Aungier. Refer to <u>www.turbo-aero.com</u> for more information about Ron Aungier and CompAero.

CompAero gives RMS additional capabilities to assist in the aerodynamic performance audits of existing compressors as well as the design of new stages for the rerate of existing compressors. The CompAero suite of tools provides for preliminary stage sizing, ID meanline analysis, 2D blade to blade flow analysis and a quasi-3D inviscid flow analysis of the stages. There are additional modules for vaneless and vended diffuser design. CompAero can be used for the design and analysis of open, closed, 2D and 3D centrifugal impellers.

There is a built in ideal/non-ideal fluid equation of state for the calculation of real gas properties that is used seamlessly by the various calculation tools within the CompAero software suite.

CompAero allows for the modeling of single section, multi-section and multi-body compressors with inlet / discharge losses, inter-coolers, and liquid knockout between sections.

RMS utilizes the latest AnsysCFX computational fluid dynamics software for additional modeling and optimization capability.

A project we are currently working on is to back-engineer the performance of an existing flow path and design a new discharge volute for that compressor. We are using CompAero in conjunction with dimensional inspections of the flow path and customer process data to provide an aerodynamic model to reverse engineer the performance of this compressor and provide updated performance curves that reflect the current process conditions of this compressor. The existing flow path is being married to a new casing for which a new discharge volute will be provided for. We are using CFD modeling of the purposed volute design to ensure the exit flange conditions are fully understood. Figure I and 2 are the volute design CFD mesh from AnsysCFX and first pass performance data from CompAero.



Figure I – AnsysCFX mesh of the discharge volute.



Figure 2A – CompAero Output, Overall Machine





**By Bob Huffman** 



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# **RMS POWER SOLUTIONS**

An industry leader in inspection, assembly & balancing of Turbomachinery

## CAVANDIULIDAS

· 10,000 sq. ft. machinery assembly bay

- 10,000 sq. ft. rotor assembly bay
- Climate controlled inspection room
- 40,000 [b and 17,500 [b Schenck@ balancing machine with latest controls

· 62,000 lb total crane capacity