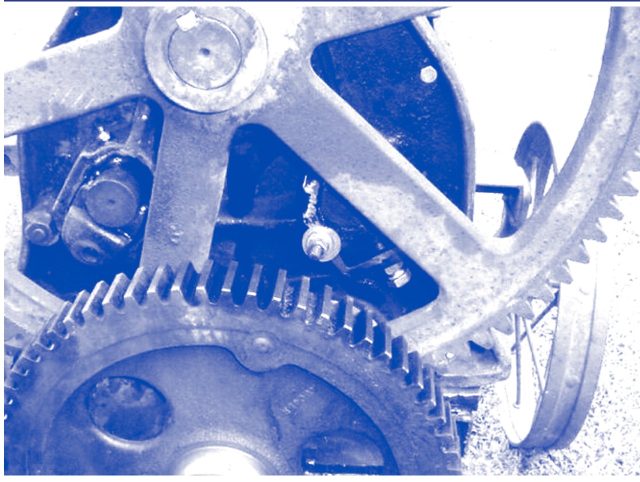
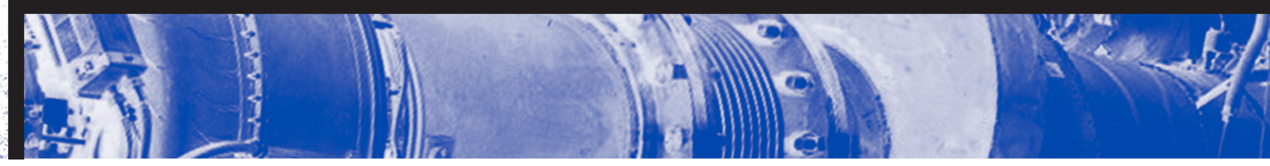
First Quarter 2005

Gas Machinery
Journal





Industry Calendar

March 6-9
10th Annual Suppliers Expo and Conference
Gas Compressor Association
Galveston
www.gascompressor.org

March 14-16
GPA Annual Convention
Gas Processors Association
San Antonio
www.gasprocessors.com

April 4-8
Applied Principles Of Engines And Compressors
GMRC
Colorado Springs, Colo.
www.gmrc.org

April 19-20
API Annual Pipeline Conference
American Petroleum Institute
Austin, Texas
Web site: www.api.org

May 2-5
Offshore Technology Conference
Houston
Web site: www.otcnet.org

May 17-18
Foundation Design and Repair
GMRC
Oklahoma City
www.gmrc.org

May 19
The Bolted Joint
GMRC
Oklahoma City, Oklahoma
www.gmrc.org

June 6-10
Applied Principles of High-Speed Engines And Compressors
GMRC
San Antonio
www.gmrc.org

July 18-21
Transmission Conference with Exhibits
Southern Gas Association
Albuquerque
www.southerngas.org

July 26-28
Engine Analyzer And Reliability Workshop
GMRC
Nashville
www.gmrc.org

-see 2005 Industry Calendar, p. 8

GMRC AWARDED DOE CONTRACT

On October 3, 2004, the U.S. Department of Energy announced that they have awarded a five-year $5 million research contract to the Gas Machinery Research Council (GMRC) for an Advanced Reciprocating Compression Technology (ARCT) Program.

The GMRC Project Supervisory Committee met January 25-26 to begin planning for the ARCT program.

The objective of the ARCT program is to develop the next generation of reciprocating compressor technology to enhance the efficiency, reliability, and integrity of pipeline operations through improved compression. The suite of technologies developed by this program is aimed at providing pipeline operators with improved affordable choices for new compression as well as innovative products that can be retrofitted to existing machines to substantially improve the current infrastructure.

Danny Deffenbaugh, SwRI®, leads discussion on the ARCT program.

Advanced concepts for ARCT include intelligent compression technology that monitors operational conditions and automatically adjusts internal geometry to tune performance over the full-extended operational range, thereby optimizing performance and minimizing life-shortening machine vibration.

Advanced pulsation control will monitor vibration frequency and magnitude at critical locations as operational speed varies and shift the filter cut-off frequency or damping to lower magnitude.

Advanced valve concepts are passive, active or semi-active. Passive concepts will focus on reducing the high parasitic pressure loss of current designs.

Advanced capacity control concept is to control flow rate and load in concert with the pulsation control and valve control.

Advanced sensors and automation is to implement self-powering sensors with wireless data transmission to provide the "intelligence" required for the advanced concepts proposed.

Bill Elston, Compressor Systems, Inc.

All of this advanced technology will be integrated into an optimized compressor package and optimized station operational strategy. The program will culminate in an overall system demonstration of the next generation of reciprocating compression.

DOE will provide 65% of the funding for ARCT with the remaining 35% funded by GMRC and its member companies. The first year of the program is being co-funded by El Paso Corporation, BP, Ariel Corporation, Caterpillar and Compressor Systems, Inc. The program will be managed by GMRC's Project Supervisory Committee under the leadership of Don Crusan, Columbia Gas Transmission, PSC Chairman. Southwest Research Institute (SwRI) in San Antonio is the research contractor.

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GMRC Offers Leading-Edge Technical Training In 2005

Technical training ranging from field troubleshooting of gas machinery to understanding the most complex machines in the industry is available throughout the year from the Gas Machinery Research Council. The latest advances in technology will be detailed, along with proven basics that have been successful over the years.

Most classes also qualify for professional education credits.

Top experts in the field will present the information that attendees can use immediately to enhance their value in the organization. Student will learn what they need to know to keep their company's fleet of compression equipment operating at its peak of efficiency, reliability and safety.

For more information about any of these courses or others that may be announced during the year, please visit the GMRC web site at www.gmrc.org, or contact GMRC Vice President Marsha Short at 972/620-4024.

Applied Principles Of Engines and Compressors

April 4 - 8 – Sheraton Hotel
Colorado Springs, Colo.

This engine fundamentals class provides a solid foundation to anyone involved in the operation of prime movers. Although the principles described by instructor Randy Anderson of Anderson Consulting, Testing and Training/CECO are simple and easy to understand, the class is both stimulating and challenging.

Upon completion, students will have a basic understanding of the equipment configuration and operation and will be capable of simple troubleshooting and problem recognition for their gas compression equipment.

Course content includes engine fundamentals, crankcase lubrication systems, combustion theory, exhaust emissions and engine balance.

Twenty-eight Professional Development Hours will be given to each participant at the end of the workshop.

Class begins each day at 8 a.m. and ends at 5 p.m. Monday through Thursday, and 8 a.m. until noon on Friday.

Foundation Design and Repair

May 17-18 - Holiday Inn North
Oklahoma City

Instructors Bob Rowan of Robt. L. Rowan & Associates Inc. and Pete Harrell of Southwest Research Institute will give those responsible for reciprocating compressor design and installation the knowledge, tools, and practice needed to apply the latest compressor mounting and foundation design and repair techniques to help maintain machines reliability.

Class will cover foundation design based on American Concrete Institute Committee 351 guidelines, components of the foundation, how the foundation reacts to compressor loads, and tools for condition assessment.

Registration for the Foundation Design Class also includes the Bolted Joint Class on Thursday morning.

Ten Professional Development Hours will be given to each student at the end of the workshop.

The workshop begins at 1 p.m. Tuesday and ends at 5 p.m. Wednesday's class is from 8 a.m. through 5 p.m., and the session on Thursday session is from 8 a.m. through noon.

The Bolted Joint

May 19 - Holiday Inn North
Oklahoma City

This course is intended for engineers, reliability and maintenance technicians, and construction technicians who routinely make up or close bolted joints. Instructor Peter Harrell will describe pipe joints, man-ways, inspection ports, and other structural members joined by bolts or by nuts on studs. The workshop begins at 8 a.m. and ends at noon.

Course content include basic properties of the bolted joint, design of the bolted joint, and design and selection of threaded fasteners.

Three Professional Development Hours will be given to each participant at the end of the Workshop.

Applied Principles of High-Speed Engines and Compressors

June 6-10 - Hyatt Regency Riverwalk
San Antonio

Instructor Randy Anderson will focus his presentation on high-speed engines and reciprocating compressor fundamentals.

This class provides a solid foundation to any employee involved in the operation and maintenance of high-speed reciprocating engines and separable reciprocating compressors. Information is intended for equipment operators, maintenance personnel, supervisors, engineers, gas controllers and other personnel responsible for high-speed reciprocating compression equipment.

Participants will also have the opportunity to tour several labs at Southwest Research Institute.

The class will cover 4-stroke cycle theory and operation; mechanical linkages; engine packages; horsepower, torque and brake specific fuel consumption; emissions formation theory and control technologies; compressor horsepower, pressure-volume curves and rod load, and compressor valves.

The workshop begins each day at 8 a.m. and ends at 5 p.m. Monday through Thursday and at noon on Friday.

Twenty-eight Professional Development Hours will be given to each participant at the end of the course.

Compressor Station Design

July 12-14 - Sheraton Hotel
Colorado Springs, Colorado

This 2-day workshop will give engineers and senior design professionals information on how to design and integrate all the various parts of a compressor station into an effective and efficient system. It will provide practical knowledge on how to design a new compressor station or evaluate the design on an existing compressor station.

Course Content includes Plot Plan Layout, Horsepower, Gas Cleaning, Yard Piping, Fuel Gas Piping, Division & Classification, Ventilation, Gas & Fire Detection, Foundation, Air, Heating, Electrical Loads, Generators, Wire & Conduit, Lighting Systems, Tankage, Power & Power Gas Systems, Cooling Water System, Major Equipment, Automation, Exhaust, Air Intake, and Cathodic Protection.

The instructor is Chuck Law from Alliance Engineering.

A certificate indicating 16 Professional Development Hours will be given to each participant at the end of the Workshop.

The workshop begins at 8:00 a.m. and ends at 5:00 p.m. Tuesday and Wednesday and 8:00 a.m. through 12:00 noon on Thursday.

Engine Analyzer and Reliability Workshop

July 26-28 - DoubleTree Hotel
Nashville, Tenn.

The GMRC Engine Analyzer and Reliability Workshop is designed to meet the needs of analysts and engineers who are involved in predictive and preventive maintenance programs throughout the natural gas industry.

The Workshop Committee includes Keith Schafer, Columbia Gas Transmission; Brad Goodwin, CenterPoint Energy; David O'Kelly, Columbia Gas Transmission; Gary B. Smith, Tennessee Gas Pipeline; Ed Gerzina, Dominion East Ohio Gas Co.; Jerry R. Lewis, El Paso Corp.; and Randy Anderson, ACTT, div. of CECO

Classes that range from basic to advanced will allow the analysts and engineers to take home information that is useful now. Segments are included that will allow attendees to present their problems, challenges, and solutions to their peers.

The course will include ignition analysis, primary and secondary; power cylinder analysis; turbocharger vibration analysis; start-to-finish emission testing; compressor calculations; and how to interpret oil analysis reports

Eighteen Professional Development Hours will be given to each participant at the end of the Workshop.

The workshop begins each day at 8 a.m. and ends at 5 p.m.

Combustion Characteristics

*Aug. 15-19 - University Park Holiday Inn**
Fort Collins, Colo.

Combustion Characteristics is a comprehensive problem-solving class covering the effects of operating conditions and control adjustments on engine combustion. Instructor Randy Anderson will also cover issues affecting the development and use of horsepower performance curves.

The class will feature in-depth discussions of combustion characteristics including peak firing pressure, MEP, exhaust temperatures, turbocharger speed, brake specific fuel consumption, and NO_x and CO emissions on various engines.

Other topics will include effects of changes in air/fuel ratio, ignition timing, fuel composition, torque, speed, and certain mechanical problems on the engine's combustion characteristics.

Participants will have the opportunity to tour the Engine & Energy Conversion Lab at Colorado State University.

Twenty-eight Professional Development Hours will be given to each participant at

The workshop begins at 8 a.m. and ends at 5 p.m. Monday through Thursday and 8\ a.m. through noon on Friday.

**Note: Effective May 1, the University Park Holiday Inn will become the Fort Collins Hilton.*

Introduction To Gas Turbines And Centrifugal Gas Compressors

Sept. 8-9 - Hyatt Regency
New Orleans

This two-day class is a unique opportunity to learn from the experts how to apply and operate gas turbines and gas compressors as well as to interact and network with others in the field of turbomachinery applications. Instructors are Rainer Kurz and Miller Robison, both of Solar Turbines Inc.

In addition to the theoretical presentations, case studies will be presented by the instructors in an interactive forum. Students will also be able to participate in a round table discussion concerning the latest trends and ask questions of interest that can be submitted in advance of the seminar.

Topics include gas turbine and gas compressor components; gas turbine and gas compressor applications; performance maps and what to do with them; gas turbine & gas compressor testing; and maintenance.

Twelve Professional Development Hours will be given to each participant at the end of the course.

Engine Emissions Stack Testing And Analyzer Workshop

Oct. 11-13 - Holiday Inn North
Oklahoma City

Co-sponsored by SGA and GMRC, this workshop provides an understanding of and familiarity with emissions testing through live demonstrations, hands-on inspection of equipment, and lectures and group discussions of actual field testing experiences.

Topics to be covered include the processes and equipment for EPA stack testing methods and protocols; function and design of portable analyzer equipment; factors affecting accuracy and outcome of testing and other calculations and flow measurements required; state and federal requirements in lieu of Title V enhanced monitoring and record keeping and reporting requirements; evaluation of emissions reduction technology for internal combustion and turbine engines.

The workshop also features a portable analyzer field test session at the Cooper Ajax facility.

Instructors will include Bruce Chrisman, Cooper Compression/Ajax; Jon Tice, El Paso Corp.; Charles Ely, ACTT, div. of CECO; Rich Schoonover, Enginuity; Michael Callegari, Williams Gas Pipeline; Jeff Thomason, Cubix Corp.; Quinn Bierman, Air Hygiene Inc.; Drew Wilson and Jerry Jeffers, ECOM America, Ltd.; and Craig McKim, Testo, Inc.

Fourteen Professional Development Hours will be given to each participant at the end of the Workshop.

The workshop begins each day at 8 a.m. and ends at 5 p.m. Tuesday and Wednesday, and at noon on Thursday.

Controlling Pulsations In Compressor and Piping Systems

Oct. 18-20 - Southwest Research Institute,
San Antonio

Material for this class has been specifically tailored to match today's engineering environment where performance and cost effectiveness are as important in plant design as safety and reliability.

While technically a short course for engineers, practical experience and common sense have proven to be the most important prerequisites. Instructors include the GMRC Design Facility staff at Southwest Research Institute. All sessions are held at SwRI.

The course begins at 1:30 p.m. on Tuesday and ends at noon on Thursday.

Although this short course has been oriented to the design and layout of new facilities, the material presented will also assist in the solution of existing plant problems. The detailed and practical sessions will present the skills and know-how necessary for controlling acoustical and mechanical forces in compressors, pumps and piping systems.

Topics will include compression technology and pulsation problems; fundamentals of piping acoustics; prediction and control of vibration and stress; effect of pulsations on compressor performance; and pulsations in centrifugal compressor systems

Twelve Professional Development Hours will be given to each participant at the end of the course.

San Juan College Program Specializes In Compression Technology

Located in the prolific natural gas fields of northern New Mexico, San Juan College provides the gas machinery industry with highly trained employees through its Natural Gas Compression Program
·

The community college in Farmington began the Natural Gas Compression Program in August 2002 after professionals in the local compression industry asked the college to implement the program.

San Juan College has a reputation for starting new programs that fill the employment needs of the local industry. Most of the major producers of natural gas in the United States are represented in Farmington; which makes it the perfect site for this effort.

Billy Hancock, far right, and students from San Juan College.

Billy Hancock is the instructor for the program. "This type of program is perfect for the type of students we have in school," Hancock said. "They tend to be a little older than the average college student, and more focused on learning."

San Juan College initiated a national search to find an individual who had compression experience as well as training/teaching experience to develop the program. They hired Hancock from Hanover Compression Co., where he had eight years seniority with POI and Hanover. Hancock has a BS in mathematics from New Mexico State University and taught high school math, computer science, and physical science for eight years.

The program provides an education that will last these students for a lifetime, Hancock said. "I tell prospective students that they can do anything they want with this type of education," he said. "Whether they want to stay in this area and settle down, or go out and see the world, they have the education that will allow them to do what they want with their life."

The Natural Gas Compression Program is a six-month certificate program designed to provide the graduate with the basic foundation in the fundamentals of natural gas compression.

The program has earned a reputation for developing well-trained graduates, ready for employment in the natural gas industry. Several companies have indicated an interest in hiring graduates and sponsoring new students into the program.

"This indicates an acceptance that the program is providing students with the necessary foundation highly needed in the natural gas industry," Hancock said. "This has been proven by the fact of each graduate has been employed directly from the class, and that several companies have hired more than one graduate."

To help with the startup of this program several organizations provided donations; The Gas Compressor Association helped purchase three rolling A-frame hoists. These allow the students to lift and roll the engines and compressors being overhauled.The state Department of Labor provided help in purchasing tools for the tool room, and the Navajo Nation also helped to supply much of the hand tools used by the students.

Additional donations are always helpful, Hancock said. Engines, compressors, tools and parts would be welcome, and should qualify as a charitable contribution, he said.

Graduation Rate

Since its inception, 26 students, including two women, have graduated with certificates from the program.

Of these graduates, there has been 100% placement upon graduation. Some of the students have gone to work with some of the major compression companies and others have obtained employment with energy producers.

The companies and the number of graduates they employ include:

· CSI – 5 students
· Hanover – 5 students
· XTO Energy – 3 students
· Stewart and Stevenson – 2 students
· Cooper – 2 student
· Compressco – 1 student
· Twin Stars – 1 student
· Henry Production – 1 student
· JW Power – 1 student·
· Richardson Production – 1 student
· Cordillera Energy – 1 student

There are eight students in the class that will graduate in the first week of April. Their ages range from 18 to 37.

Curriculum

The course work is structured to last six months.

"We try to give them a good mix of theory and actual field practice with equipment," Hancock said. "We want them to be able to work with any type of equipment and understand how it works."

Students also work for three weeks with a sponsoring compression company under a cooperative education agreement.

Subject areas include:

· Week 1-5: Engine Theory and Overhaul
· Week 6-9: Engine Preventive Maintenance
· Week 10-13: Compressor Theory and Overhaul
· Week 14-17: Compressor Preventive Maintenance
· Week 18-20: Cooperative Work Experience/On the Job Training
· Week 21-22: Electrical/Electronic Systems
· Week 23-24: Instrumentation/Control Theory

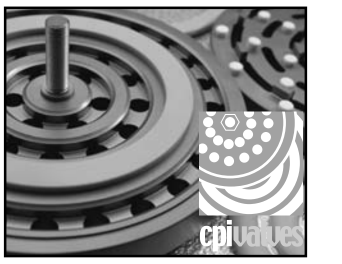
Long-Term Growth

San Juan College considers the needs of the industry for the short-term; as well as long-term growth. The projections of demand for natural gas indicate that there are and will be a substantial demand for natural gas technicians in the future.

The natural gas industry must look at the feasibility of helping to sponsor this growth if the demands for trained technicians are at a level that can be considered critical.

Two years of the program have provided the gas machinery industry the proof that San Juan College has developed a viable program conducive for the training of local workers aiming to gain a place in a very rewarding industry.

For more information about the Compression Technology Program at San Juan College, please contact Billy Hancock at 505-320-9812 or visit the school's web site at www.sanjuancollege.edu.



CPI Radiused Disc Compressor Valves

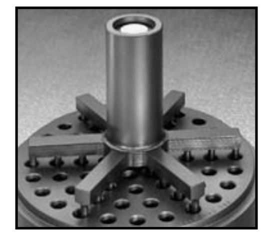
CPI valves are capable of operating in a wide range of applications reaching temperatures of up to 390°F/200°C, pressures in excess of 6000psi/400 bar, and are suitable for sour gas applications.

- Streamlined flow provides free passage of entrained solids and liquids
- Flow increase due to optimum sealing
- Conformability with seat
- Durable thermoplastic discs prevent seat damage and wear
- Simple internal design is easy to service
- Suitable for lubricated or non-lubricated conditions
- Increased savings on power consumption

CPI valvealert™ Valve Monitoring System

The CPI valve**alert**™ system is a revolutionary non-intrusive reciprocating compressor valve monitoring and analysis system. It is available as an innovative handheld or on-line option, supported by its own unique software. CPI valve**alert**™ provides operators with the technology to identify problems before they occur – simply and affordably.

- Non intrusive - no drilling into cylinders or valve covers
- Low cost - easily justifiable within budgets
- Simple to use - no special training or expertise required to interpret data.

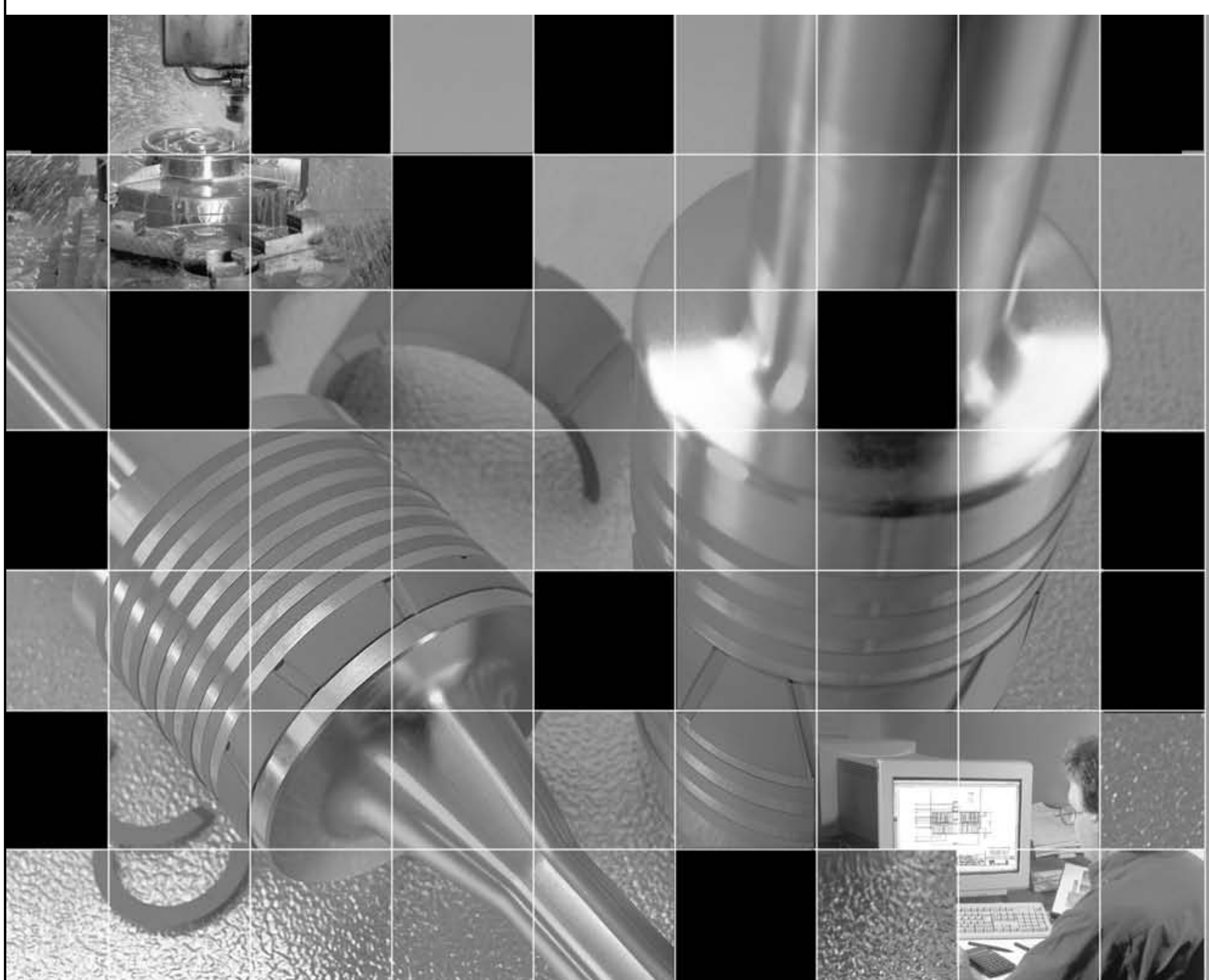


Valve Unloaders

CPI valves can be provided with finger-type, plug-type, or other suction valve unloaders.

Valve Actuators

Quality valve unloader actuators are designed specifically for each application.



What can you **EXPECT** when you're looking for **MORE** reliable compressor performance **FROM** the professionals at **CPI**?

CPI – Compressor Products International – is recognized as a world leader in providing world-class products and services for the increased reliability and performance of reciprocating piston compressors used throughout the oil, gas, petrochemical and air separation industries.

- Application specific solutions
- Innovative products
- Revolutionary technology
- Technical expertise
- Engineering support
- Reconditioning services
- Worldwide facilities

EXPECT products and services that ensure your **SUCCESS**!

Contact our new Houston, TX facility for additional information on any of our products or services. Or visit our website to learn more – www.compressor-products.com

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RG17 0QP England
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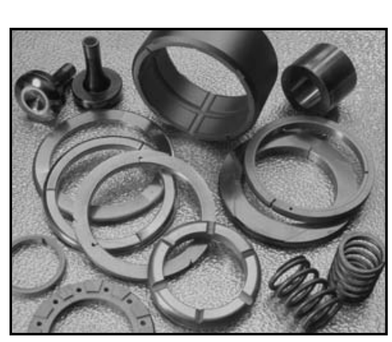
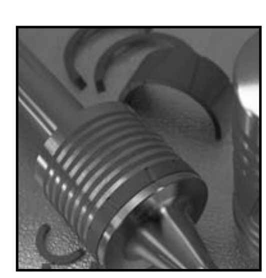
CPI Special Polymer Alloy™ Materials

CPI's range of proprietary Special Polymer Alloy™ materials are used in lubricated or non-lubricated conditions and have provided improved performance and extended compressor life in countless applications around the world.



Hyper Compressor Components

Packings and rings are designed and manufactured specifically for the high standards of quality and precision demanded by hyper compressors.



Piston and Rider Rings

CPI manufactures a comprehensive range of piston and rider rings for the vast majority of reciprocating compressor applications, provided in CPI's Special Polymer Alloys™ and other non-metallic materials.

Packings and Packing Cases

Main gas, intermediate and oil wiper packings, as well as packing cases in various materials from cast iron to high grade alloy steels.

The Power of Design

SwRI® engineers develop a low-cost centrifugal gas turbine

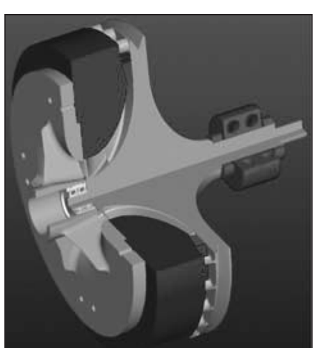
Approximately 50,000 industrial gas turbines are in use throughout the world, and they are gaining in market share against reciprocating engines and steam turbines. However, they tend to be technically complex and hard to maintain. A team of engineers at Southwest Research Institute® has designed a novel gas turbine engine, whose turbine disk is shown here, that is intended to be simple to maintain and inexpensive to operate.

By Klaus Brun, Ph.D. and Robert J. McKee

Excerpted from Winter 2004 *Technology Today*®. Reprinted by permission of Southwest Research Institute®.

Approximately 50,000 industrial gas turbines are in use throughout the world, and these machines are steadily gaining market share against reciprocating engines and steam turbines in all industries. Gas turbines generally require less maintenance, have a higher availability, and can provide higher efficiency than reciprocating engines and steam turbines.

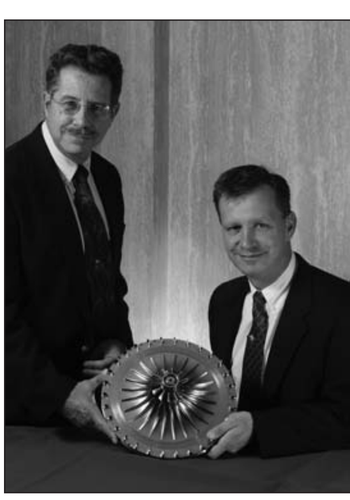
Industrial gas turbines are commonly used in applications where high power-to-weight ratio, low emissions and high availability requirements prohibit the use of reciprocating engines, despite their lower cost. In the oil and gas industry, small industrial gas turbines are used for pipeline compression, oil pumping, water injection, gas lift and offshore platform power generation — all applications where efficiency is of secondary concern to low weight and high reliability.



This computer image illustrates the final assembled gas turbine. A functioning prototype of the SwRI® gas turbine will be available for demonstration in late 2005.

Most modern industrial gas turbines are technically complex machines consisting of multiple rotating parts, bearings, seals, lubricating oil systems and sophisticated electronic controls. They are so technically sophisticated that most users cannot perform basic repairs and maintenance.

Industry is demanding simple, low-cost gas turbines that can function under very rugged environmental conditions, are easy to repair or replace, can be operated by untrained staff and can be moved easily. At present there are few gas turbine products commercially available that satisfactorily meet these market requirements. To meet this growing demand, engineers at Southwest Research Institute® (SwRI®) have developed a novel, prototype centrifugal gas turbine using internal research funding.



Dr. Klaus Brun (right) is a principal engineer in the Mechanical and Fluids Engineering Department in SwRI®'s Mechanical and Materials Engineering Division. Brun is experienced in performance prediction, off-design function, degradation, uncertainty diagnostics and root cause failure analysis of gas turbines, combined cycle plants, centrifugal compressors, steam turbines and pumps. Robert J. McKee is also a principal engineer in the Mechanical and Fluids Engineering Department. McKee's expertise includes fluid dynamic analysis, centrifugal compressors and pumps, gas turbines, industrial fluid handling systems and flow meters.

Turbine basics

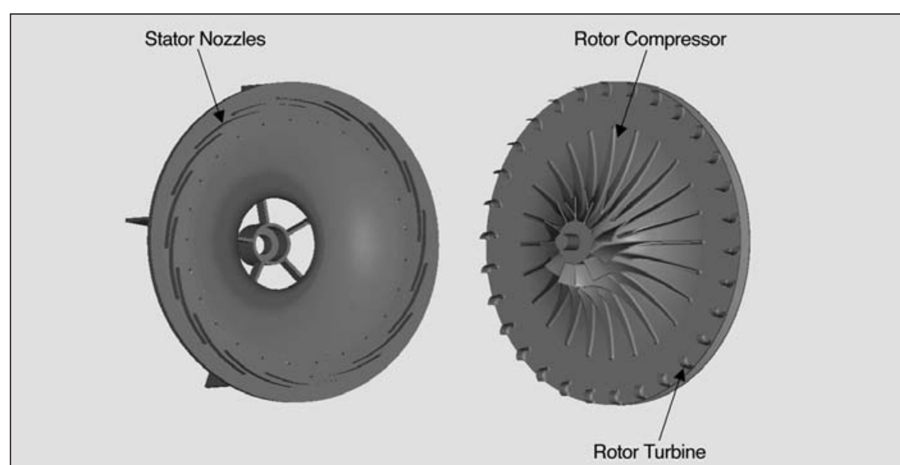
Currently, most gas turbines use an axial flow compressor and an axial flow turbine. This design is a direct evolution of the jet engine and clearly provides the highest aerodynamic efficiency. However, the axial design does not typically provide the lowest weight, smallest dimensions or greatest ease of maintenance.

Simple, open-cycle gas turbines consist of three principal components: a compressor, a combustor and a turbine mounted on a single rotating shaft. The compressor ingests and compresses ambient air, the combustor heats this air by fuel combustion and the turbine expands the resulting hot air to drive a shaft that generates mechanical output power. The SwRI®-designed centrifugal gas turbine is based on this simple, open cycle.

The fundamental difference between the SwRI® centrifugal gas turbine and conventional gas turbines is that the compressor and turbine section are installed on the same side of the rotating wheel, while the combustor and nozzle are mounted on the stationary shroud. Thus, the entire gas turbine assembly consists of only two relatively easy-to-manufacture components: the rotating compressor turbine wheel, which is directly coupled to the generator/starter motor, and the combustor shroud, which holds the utility line connections. Unlike conventional gas turbines, no flow turning is required. Because the SwRI® design incorporates only one rotating part, costs of manufacture, maintenance, repair and replacement are low.

Prototype development

The objective of the SwRI® internal research project is to develop a 50-kilowatt centrifugal gas turbine design that can achieve simple cycle efficiency greater than 16 percent while maintaining rotordynamic and mechanical integrity and stability. During the last year, SwRI® engineers designed the gas turbine's compressor, turbine and nozzle using in-house and commercial engineering codes, and built a prototype machine. The final hardware prototype was machined from Inconel® super-alloy using a five-axis milling machine.



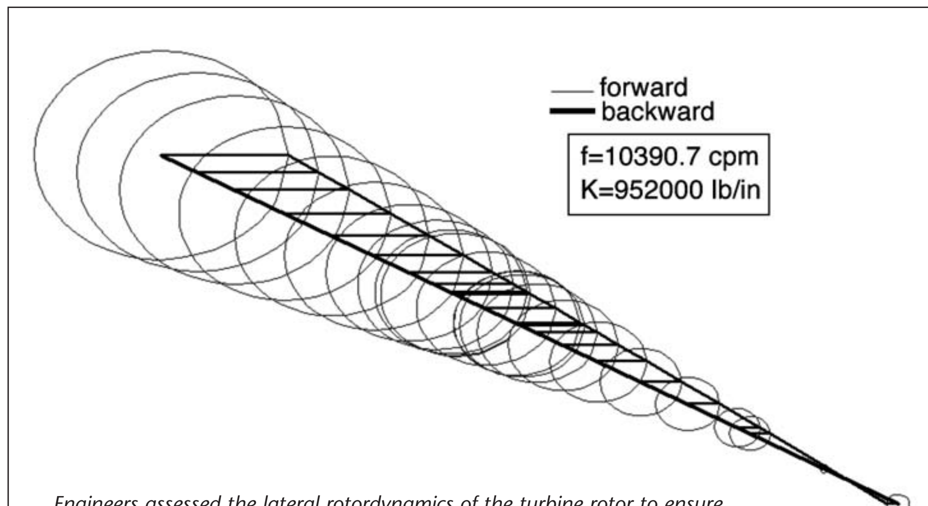
Both SwRI®-developed and commercial engineering codes were used to design the turbine engine's key components as shown in these compressor, turbine and nozzle designs.

A one-dimensional gas turbine thermodynamic cycle design code was written to predict the gas turbine performance and to serve as a preliminary design validation tool. For the compressor performance, the code uses empirical, characteristic-flow curves and a highly radial flow compressor design. For the turbine analysis, a high-impulse turbine design and experimental data were used.

A finite element stress analysis was performed to evaluate the maximum allowable rotational speed of the proposed centrifugal gas turbine. This design includes a 20-percent safety margin on speed to protect the machine from sudden overspeed excursions or operational upsets. Various possible rotor geometry options were evaluated. To maintain structural integrity and durability, the speed of the operational prototype is limited to less than 32,000 revolutions per minute (rpm).

A combustion system design must be appropriate to the unique radial-flow system. The system must stabi-

-see "Power of Design," next page



Engineers assessed the lateral rotordynamics of the turbine rotor to ensure that the turbine would run well at all expected operating speeds.

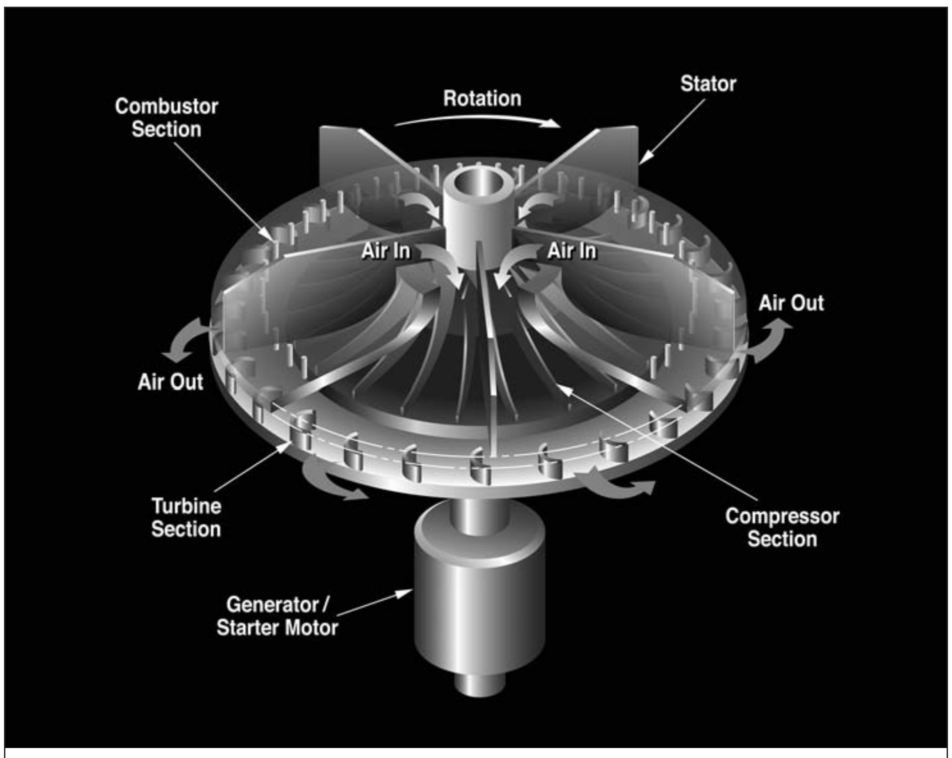
Power of Design

-contd from page 6

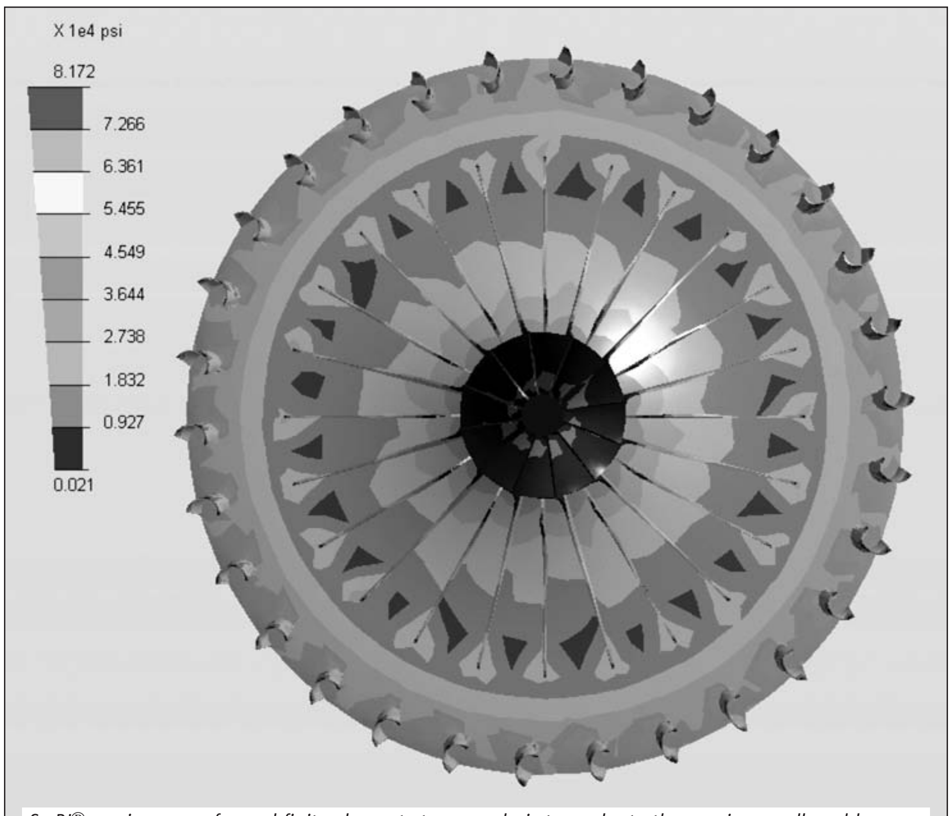
lize the flame while allowing for cooling of the walls and dilution of the combustion gases to achieve a temperature that is compatible with the turbine inlet. The combustor development phase will be initiated in early 2005.

Further development

Completion of gas turbine hardware fabrication and final installation are under way. A rapid prototype of both the rotor and stator were also built and are being used for promotional activities. For prototype testing, the gas turbine will be mounted on a high-speed test rig driven by a 200-hp electric motor with a dynamic brake rather than being directly coupled with a high-frequency AC motor/generator. This will allow SwRI® to test a wide range of prototype models rather than being limited to a single speed and load. In this rig, the AC motor/generator is coupled via an 11/1 rpm gearbox to the centrifugal gas turbine, and the gas turbine is fully supported on inboard and outboard high-speed bearings. A functioning prototype of the SwRI® gas turbine will be available for demonstration by late 2005.



This conceptual drawing shows the simplicity of the SwRI®-designed gas turbine. The turbine has only one rotating part and is easy to maintain and repair.



SwRI® engineers performed finite element stress analysis to evaluate the maximum allowable speed of the gas turbine. The design includes a 20-percent safety margin on speed to protect the machine from sudden over-speed excursions.

Applications

The SwRI® gas turbine is compact, light and portable. These features make the SwRI® gas turbine an ideal candidate for applications including military battlefield, oil production flare gas, and on-ship auxiliary power unit generation. Other possible applications include nanotechnology gas turbines, distributed power generation, combined heat and power, and hydrogen power generation.

SwRI® has applied for and received patent protection for its centrifugal gas turbine design. Discussions are under way with a number of turbomachinery manufacturers to commercialize the SwRI® gas turbine prototype.

The Need To Test Large-Bore Engine Turbochargers

By Dr. Kirby S. Chapman & Sandra J. Chapman
The National Gas Machinery Laboratory
Kansas State University

Turbochargers typically are removed from service on a company-specific schedule and are shipped to a turbocharger overhaul facility. The substantial cost associated with turbocharger removal and overhaul, as well as costs associated with failure in the field after re-installation illustrate the compelling need to ensure that a rebuilt turbocharger meets operational needs before return to service.

Post-overhaul turbocharger performance tests at Kansas State University's National Gas Machinery Laboratory can verify that the turbocharger is mechanically sound and will perform as expected when installed on the engine. The operator also may acquire complete compressor and turbine performance maps that can be used to determine whether a turbocharger can provide sufficient air flow through an engine to meet mandated pollutant emission levels.

Ultimately, this information may help operators avoid needless and costly turbocharger replacement.

The NGML Industry Advisory Committee worked with the staff at the National Gas Machinery Laboratory to develop guidelines that determine when and to what extent a turbocharger should be tested based on the cost and benefits of various scenarios.

The five scenarios include a typical turbocharger overhaul, three types of turbocharger retrofits; and turbocharger technical development activities.

Each scenario is assigned a risk from low to high that is based upon the cost to the operating company if the unit fails in the field. From that risk exposure, the committee determined the necessity of a test; the type of test that should be conducted; and which turbocharger in a series of like models should be tested.

Table 1: Turbocharger Scenarios.

Assessment	Scenarios: Typical Overhaul	Match Parts for Rebuild	Replacement In Kind	Retrofit Vetting	Technical Development
Risk if Not Tested?	Low	Medium	High	High	High
Necessity?	Arguable	Necessary	Necessary	Necessary	Necessary
Test Type Needed?	Mechanical	Full Map	Load-Line	Load-Line	Full Map
Test which Turbo?	All Rebuilds	Lead Turbo	All Rebuilds	Lead Turbo	All Turbos

For example, in the case where third-party manufactured parts are installed for a rebuild, the lead turbocharger should be fully tested to ensure compliance with that of OEM parts.

The consensus of the NGML Advisory Committee was that Scenarios 2 through 5 required testing. In some scenarios only the first turbocharger of a specific build needs to be tested, whereas in other scenarios all turbochargers should be tested.

At first glance, the typical overhaul does not require a post-overhaul mechanical test. The risk is low if a test is not performed and a failure occurs in the field.

Turbocharger failures either happen quickly, or over a period of time. After an overhaul, some failures are easy to identify, such as surge or the engine will not operate due to low air flow. Other turbocharger mechanical problems may remain hidden for a longer period, much like a cancer.

In the experience of the NGML, mechanical failures primarily have been caused by abnormal vibration from imbalance, bearing problems or looseness; oil flow or pressure not within specifications; and cracks in the housing that result in oil or water leaks.

Information on how often overhauled turbochargers fail in the field is anecdotal at best as no statistical analysis has been conducted. However, of the mechanical tests conducted at the NGML on high-profile units in the last seven years, approximately 25% have failed on the first test.

While arguable whether these tests are indicative of the industry as a whole, this indicates the potential number of hidden mechanical problems on overhauled turbochargers that are re-installed in the field.

When these problems finally surface in operation, whether by catastrophic failure or through analysis, an unplanned and often costly overhaul is required to correct the problem.

Regardless of how the hidden problem is ultimately detected, a percentage of untested turbochargers will have significantly shorter time-between-overhaul intervals. For high profile turbochargers upon which critical operations rely – such as nuclear, Coast Guard, and main line gas compression – this is not an acceptable risk.

Table 2: Field Failure Cost Analysis.

Item	Scenario: Conservative	Typical
Shipping	$6,000	$7,500
Labor	$1,000	$1,000
Other costs[1]	$8,000	$18,500
Total cost	**$15,000**	**$27,000**

[1] Other costs include the cost of an overhaul if it is out of warranty, crane rental, lost throughput, etc.

To determine whether a mechanical turbocharger test is cost effective on a typical overhaul, the NGML Advisory Committee identified the direct costs associated with a turbocharger field failure and compared that to the cost of a mechanical turbocharger test.

Table 2 illustrates two scenarios of direct costs incurred once a turbocharger mechanical problem is detected in the field.

A conservative estimate of the cost to remove a turbocharger from service and ship it for overhaul is $6,000. The labor to remove the turbocharger and prepare it for shipping was estimated at $1,000. Other costs represent the cost of the overhaul as well as additional costs such as crane rental, lost throughput, etc.

For the conservative scenario, $8,000 was established for the additional costs as shown in Table 2. The $15,000 total cost represents a conservative estimate to remove, repair, and reinstall a failed turbocharger. The right column in Table 2 shows what the NGML Advisory Committee felt were more typical direct costs to overhaul a failed turbocharger of $27,000.

A $3,000 turbocharger mechanical test at the NGML provides the assurance that the turbocharger will be free of mechanical problems before the warranty period starts and before it is placed in service.

To compare the cost of a $3,000 mechanical test to that of costs incurred should a field failure occur, the question arises as to how many field units suffer from pre-mature failure that could have been prevented with mechanical tests.

If the NGML historical percentage of 25% of the overhauled units contain mechanical problems is cor-

- see "Need to Test" next page

2005 Industry Calendar, cont'd.

- cont'd from p. 1

August 8-10
Offshore Gas Operations Conference with Exhibits
Southern Gas Association
Lafayette, La.
www.southerngas.org

August 15-19
Combustion Characteristics
GMRC
Fort Collins, Colo.
www.gmrc.org

September 8-9
Introduction To Gas Turbines and Centrifugal Gas Compressors
GMRC
New Orleans
www.gmrc.org

October 3-5
Gas Machinery Conference
GMRC
Covington, Ky.
www.gmrc.org

October 11-13
Engine Emissions Stack Testing and Analyzer Workshop
GMRC
Oklahoma City
www.gmrc.org

October 18-20
Controlling Pulsations In Compressor And Piping Systems
GMRC
San Antonio
www.gmrc.org

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GMJournal and **GMC Today** focus on the development, design, operation and maintenance of gas machinery used in the compression of natural gas and other applications in the energy industry.

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Gas Machinery Journal
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972-475-7880

Need to Test Large-Bore Engine Turbochargers

- cont'd from p.6

rect, then one in four turbochargers are placed in the field with mechanical deficiencies.

By performing mechanical tests on all four turbochargers for a total cost of $12,000, then the operator can avoid the $15,000 or higher cost of a field failure. This represents a savings of $750 to $3,750 per turbocharger.

Lowering the percentage of turbochargers released to the field that have unidentified mechanical problems to 20%, or one in five turbochargers, then the breakeven point is reached for the conservative total cost scenario.

Here, the cost of five mechanical tests equals the conservative $15,000 cost of a field failure for one in five turbochargers. The savings per turbocharger for the typical scenario, however, is $2,400 per turbocharger.

While the percentage of premature overhauls on turbochargers has not been formally studied, a well-experienced operator will be able to determine a reasonable percentage of premature turbocharger field failures.

A similar financial analysis can then be conducted at a company level to determine if all overhauled turbochargers should be mechanically tested or if such testing should be limited to high profile units.

In the absence of costly well-documented quality assurance programs within turbocharger overhaul facilities, a mechanical turbocharger test after an overhaul may in many cases be a cost-effective mean to assure the operator that the overhaul meets specifications before it is placed in the field.

Field Monitoring

As of early 2005, field turbochargers do not contain sufficient instrumentation to determine and trend turbocharger performance. While several past NGML research projects pertained to developing the ability to monitor and trend turbocharger performance in a laboratory setting, that information is now being modified for field settings.

A turbocharger performance monitoring system for a field turbocharger entered the prototyping state in early 2005. This monitoring system will calculate, normalize, and trend turbocharger performance over time. Using this data, engine operators will have the ability to determine whether a turbocharger will provide sufficient air to meet engine emission requirements in the coming months.

The installation of this monitoring system is expected to be a simple process.

After an overhaul, the monitoring system can be installed, validated, and calibrated for field conditions at the NGML. The cost of a test then provides two benefits: verification that the turbocharger is mechanically sound and can satisfy the design conditions; and a means to calibrate and certify that the installed turbocharger monitoring system will provide performance-based maintenance scheduling information for future turbocharger overhauls.

Because this monitoring system is at the heart of the entire engine system, additional control and diagnostic packages can easily and inexpensively be added to the system.

Match Point Tests

A match point test requires special consideration.

This case typically falls under the scenario where an engine is undergoing an upgrade to meet emissions. The air requirement typically includes a very specific turbocharger specification. The turbocharger specification includes the required turbocharger compressor discharge pressure, and the turbocharger turbine inlet pressure and temperature.

As there are several potential risk factors when upgrading an engine, the match point test is viewed as low-cost insurance to make sure that the turbocharger will operate as expected when installed on the engine.

The match point test verifies that the turbocharger will operate as a complete system, as opposed to verifying compressor performance only. The acceptable means to accomplish the match point test is to literally dial-in the design conditions at the turbine inlet (pressure and temperature), and load the compressor to its design discharge pressure and air flow rate. If the turbocharger can operate at this point as a system, then it will operate at this point on the engine.

If any of the design parameters cannot be achieved, then the turbocharger will most likely not reach the design conditions on the engine.

Testing Needs

There are several scenarios under which a turbocharger should be tested. These include the use of third party parts in place of OEM parts, modification of blades, diffusers, and nozzle rings, and retrofitting a turbocharger to a given engine system.

In almost all cases, a mechanical and/or performance test is cost-effective. Historical data also suggests that tests following a typical overhaul for a high profile turbocharger are cost-effective.

When the decision is made to test a turbocharger, the test procedure and facility must satisfy a minimum standard to ensure that the test results indicate the true mechanical integrity and performance capabilities of the turbocharger.

Instrumentation must be installed according to accepted standards, and that instrumentation must be calibrated on a schedule that is justifiable and traceable to the National Institute of Standards and Technology.

Finally, the end-user should ensure that the reporting requirements are sufficient enough so that the data can be referenced later in the life of the turbocharger.

GMC 2004 Sets Record Attendance

A record crowd (below) turned out to enjoy lunch and hear the special presentation "Making Good Things Happen: A Challenge to Excellence" by Bryan Townsend (right) on the opening day of the GMC 2004. Six hundred attendees and more than 70 spouses resulted in standing room only in the short courses and plenty of opportunities to learn and share from colleagues and friends.

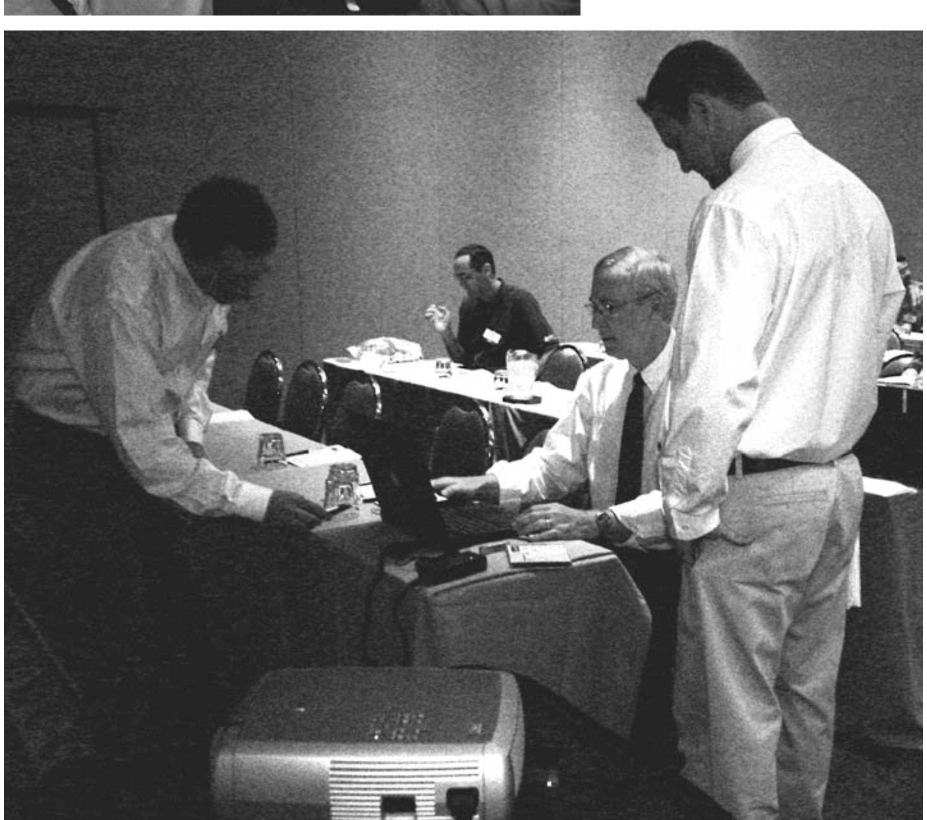
GMRC would like to extend a huge THANK YOU to all of you - attendees, speakers and sponsors for making this our biggest and best year ever!

DOE Research Review

The DOE Technical Review of ongoing research projects co-funded by industry and DOE was well attended on Sunday afternoon.

Left - the crowd at the DOE Research Review on Sunday afternoon.

Below - Rodney Anderson and Richard Baker from the DOE and Gary Bourn from SwRI prepare for the DOE Research Review.



Winston A. Johnson of El Paso Pipeline honored with first GMRC Distinguished Service Award

Winston A. Johnson, II, Senior Vice President of Engineering for El Paso Pipeline Group, has been named the recipient of the first GMRC Distinguished Service Award. This award was presented to Mr. Johnson for his years of dedication to the growth and success of GMRC and its research program. He has been a champion of research programs in the industry and has served as Chairman of the Board for both GMRC and PRCI.

Mr. Johnson assumed his present role at El Paso in 1996 and provides engineering support to ANR Pipeline, El Paso Natural Gas, Colorado Interstate Gas, Southern Natural Gas, and Tennessee Gas Pipeline for onshore and offshore facilities. He began his career in 1972 at El Paso Natural Gas Company in the machinery and piping section of Central Engineering, where he designed the installation of new compressor facilities and the modification of existing facilities.

He earned his master's degree in mechanical engineering at New Mexico State University and is a registered professional engineer in the State of Texas. He served with the United States Army in Vietnam.

GMRC *is a financially self-sufficient, not-for-profit corporation that provides focused, cost-effective research, technology and training for the global marketplace in the rapidly changing natural gas, oil and petrochemical industries. Founded in 1952, GMRC maintains its office in Dallas, Texas.*

Bob Rajeski (left) president of Cooper Compression, and Kirby Chapman (right), Director of Kansas State's NGML are excited about their alliance for cooperative efforts in engineering research and commercialization potential for Ajax engine compressors, Superior compressors and legacy Cooper products.

Bob Rajeski emphasized Cooper's present and future strategies in a recent interview. "We are focused on growth initiatives and comprehensive solutions to our customers' needs by continuing to search for alliances, partnerships and acquisitions both internationally and domestically," he said.

Leaves cover the courtyard of the hotel after five inches of hail fell on Tuesday night.

GMC 2005 Set For Cincinnati Area

The greatest collection of gas machinery talent and technology in one spot will come to the Greater Cincinnati area this fall. The Gas Machinery Conference 2005 is set for Oct. 3 through 5 at the Northern Kentucky Convention Center in Covington, Ky., just across the Ohio River from downtown Cincinnati.

Abstracts for papers to be considered for presentation at the GMC must be in the GMRC offices in Dallas no later than March 4.

The GMC Planning Committee will accept papers for the Conference based on the informative abstract. All abstracts will be evaluated on the information supplied. This information should be a synopsis of the paper and should be very specific.

Preference will be given to papers that involve or are presented by users.

Abstract may be presented for a technical paper presentation (45 minutes), a short course (3 hours), or a new technology update (10 minutes). All papers must be free of unnecessary commercialism.

Papers submitted must be related to gas compression machinery. The committee will give preference to papers that:

- Present a properly constructed informative abstract as opposed to a descriptive abstract.
- Are pertinent to current gas compression machinery issues.
- Discuss new, innovative, and/or successful technologies, processes or methodologies
- Present the results of scientific studies (may be in support of technologies, process or methodologies)
- Case studies involving gas compression machinery and related issues.

GMC 2005 Planning Committee

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Jon K. Tice, *Vice Chairman*	El Paso Corp.
Donald E. Crusan	Columbia Gas Transmission
Hans Mathews	Hoerbiger Service, Inc.
Curt Pedersen	ANR Pipeline
Greg Phillippi	Ariel Corporation
Rainer Kurz	Solar Turbines Incorporated
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Gene McClendon	Cooper Compression, Ajax Division
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Kirby Chapman, Ph.D., *Advisor*	Kansas State University
Eric Thomas, *ex officio member*	Southern Natural Gas
Marsha Short, *GMRC Staff Liaison*	Gas Machinery Research Council

Emeritus Members

Lewis E. Bishop, Jr.	ExxonMobil (retired)
Davis Conkling	ChevronTexaco (retired)
Randy Raymer	El Paso Corp.

Above: The team at the Hyatt prepare for **Ariel's Monday Night Reception**. *They gave us a true Albuquerque Welcome!*

Our hosts, at left, Ariel President and CEO Karen Wright with Ariel Vice President of Sales John Mowery

Thanks to **Hoerbiger** *for a fabulous Tuesday breakfast! Below, pictured left to right are Brian Stewart, Steve Jackson, Johannes Wunderlich, Tom Thomas, Bret Hightower, Kathy Boutin and Dave Belser.*

Thanks to **Dresser Rand** *for the bestt Monday Night Football Party yet! The KC Chiefs made our K-State students' night by beating Baltimore!*

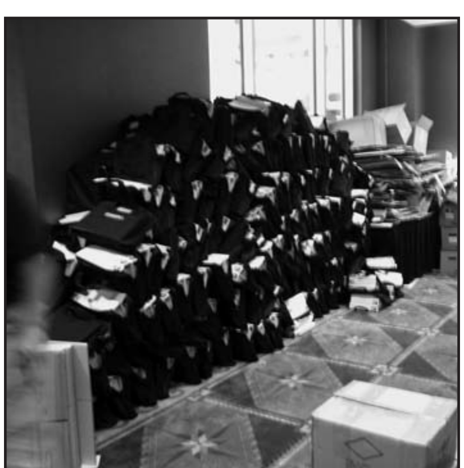
At Right, **The Siemens Group** *welcomed the GMC attendees in style with a lavish buffet and open bar. Thank you Siemens!*

KSU Students keep the GMC Runnng

These K-State students are among the group which did an outstanding job facilitating the meetings, short courses and registration at the GMC 2004.
For information regarding interviewing any of these students, please contact **Sandra Chapman**, **schap@ksu.edu**


Damian Kuiper

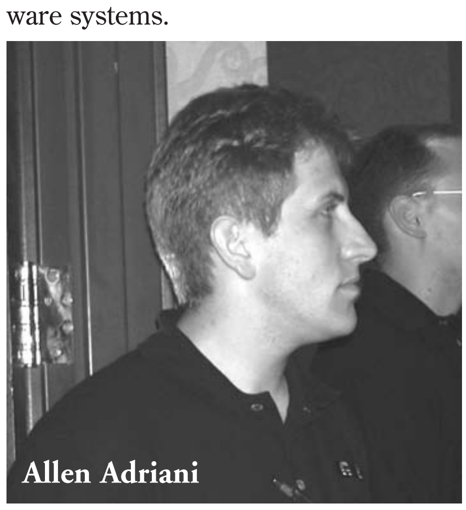
Damian Kuiper, B.S. Mechanical Engineering, M.S.M.E. Emphasis: Turbomachinery & Computational Fluid Dynamics, *Graduation date: December 2004.* Damian is currently at the National Gas Machinery Laboratory where he is serving as a Graduate Research Assistant. His Thesis project: "Fluid Dynamic Analysis of Turbo Machinery with Computational Real Time Results," is complemented by his Graduate Research project: "Quantifying a Cost Effective Efficiency Increase using Turbocharger Tip Seals." Damian has developed and designed devices which have demonstrated improved turbocharger efficiency and are capable of increasing combustion engine air manifold pressure. He has had four published industry articles in the last two years and was a speaker at the 2004 GMC Conference (Numerical and Experimental Investigation of Performance Losses in a Clark Turbocharger Compressor)


K-State students spent all Sunday morning assembling registration packages. This pile represents 1/2 of the materials for this year's record-setting number of conference attendees!


Eric and Heath work the registration table and welcome conference attendees.


Andrew Lindgren

Andrew Lindgren, B.S. Manufacturing Systems Engineering, *Graduation date: Spring 2005. Awarded Associate of Science in 2001.* Andrew has recently spent two summer internships as a Manufacturing Engineer with Eaton Corporation in the Fluid Power Division. While there, he engineered a programmable 4-spindle nut runner system. Since 2002, he has held the positions of both Research Assistant and Lab Technician for the National Gas Machinery Laboratory where he designed and implemented a modular turbine exhaust system for a turbo charger test cell. In addition, he is a Supervisor over turbocharger receiving, installation, and removal, and oversees manufacturing, operation, maintenance and supply. He also assists students in learning machine shop practices; basic foundry principles, welding skills, mill operation, lathe operation and inspection management. He has experience with various computer software systems.


Allen Adriani

Allen Adriani is currently specializing in mechanical engineering fields of Thermodynamics and Fluids Dynamics at Kansas State University. Allen completed his undergraduate studies at the University of New Haven, receiving a Bachelor's of science degree in Mechanical Engineering in the spring of 2001. While studying for his Bachelors degree, he received two undergraduate fellowships awarded by the NASA Connecticut Space Grant College Consortium. He served as the president of the student ASME section at the University of New Haven and was awarded the ASME a Student Achievement Award. With Allen's hands on experience and capability of combining textbook knowledge has enabled him to build an internal combustion engine test cell at KSU. Allen is planning to use this test cell to apply different emission control strategies to large bore engines. Allen plans to graduate in August of 2005.


Eric Figge

Eric Figge, B.S. Mechanical Engineering (Physics Minor), A.S. Mechanical Engineering Technology, *Graduation Date: December 2005.* Eric is currently a Senior Technical Advisor at KSU in the National Gas Machinery Laboratory. While working toward two degrees, Eric manages and supervises other student employees, coordinates, logs and performs laboratory calibration, designs mechanical and plumbing systems, designs, implements and troubleshoots electrical and control systems, operates the turbocharger test cell, maintains a 3,000 hp gas turbine and axial compressor package and, on top of all that, he also maintains the laboratory computer systems. He is so hard-working, we couldn't get him to stop long enough to take a picture.


Christopher Bret Grier

Christopher Bret Grier, B.S. Mechanical Engineering, *Graduation date May 2005.* Bret is currently a Senior Undergraduate Research Assistant, at the NGML where he has assumed a leadership role with the turbocharger test cell horsepower upgrade, conducted 3-D static structural analysis for the turbocharger test cell frame using finite element analysis with modal and solid state analysis, conducted vibration analysis of rotating equipment, fabricated large test cell transitions and machine base fabrication, provided troubleshooting during testing, and calibrated control data acquisition instrumentation. He also has experience as a Teaching Assistant in Thermodynamics at KSU, and as the Chief On-Site Mechanic, Utility Contractors in Wichita KS where he maintained all on-site machines and equipment for the Victoria, KS site that supported a 14 mile I-70 construction project. In addition, he is no stranger to fast-pace and high pressure - having served as a Sauté Cook during his undergraduate studies. In college, he has ohoned his leadership skills as the Phi Gamma Delta Fraternity Philanthropy Chair, and as a member of the Judicial Board.


Diana Grauer

Diana Grauer, Mechanical and Nuclear Engineering Major, *Graduation Date: December 2006.* With graduation two short years away, Diana is looking for an internship to help her better prepare for a future in the Engineering field. She is currently the Research Coordinator for the NGML, assisting the research director in his efforts. She has completed an internship at the Kiewitt Industrial Company where she was responsible for document control, piping take-offs, quantity tracking, scheduling and cost analysis. Project work for Kiewitt includes design, installation, inspection and quality control for small bore piping design. Diana has served as the President of both the Mechanical and Nuclear Engineering Student Advisory Council and Mechanical and Nuclear Engineering Women. She also coordinated the Mechanical and Engineering Newsletter.


Heath Mireles

Heath Mireles, B.S. Mechanical Engineering, *Graduation Date: May 2006.* Heath is currently the NGML's Lab Assistant Researcher, a position he has held for two consecutive school terms. He spent this past summer in Alaska as a Reservoir Engineer Intern for BP Exploration where he performed an Enhanced Oil Recovery (EOR) Reconciliation study in Prudhoe Bay and developed a program for Pad Engineers to use in calculating recovery due to EOR. He also discovered trends in injector/producer communication and performance that led to the formation of new conformance/performance mapping in the area. His 2003 summer internship was with BP's Amoco Production Company as a Production Engineer Intern. While there, he learned the basics of offshore well work through field visits, developed a successful gas lift re-design for an offshore well, wrote three well work procedures and identified future production opportunities in the Gulf of Mexico Shelf.