GMC*2006*

October 2-4 – Oklahoma City, Oklahoma

Air Regulatory Update

Jim McCarthy-Innovative Environmental Solutions

This annual session on air regulatory issues will cover the status, content, and potential impact of new U.S. EPA and State air regulations affecting gas industry facilities. The course material will include: review of recent final rules, including the Turbine NSPS; key State NOx Rules to address the 8-hour ozone and fine particulate standards; implementation issues with existing rules; and, key 2006 IC engine rule proposals, including the NSPS, MACT standard for engines 500 horsepower and smaller, and air toxic rules for area sources (small facilities).

ARCT & GMRC Pulsation Control Project

Buddy Broerman-Southwest Research Institute

Southwest Research Institute has developed and is currently evaluating new concepts in acoustic design technology that could help mitigate resonant piping pulsations and could, in some cases, eliminate the need for orifices at the compressor connection. This paper presents the results of development work conducted as part of the Advanced Reciprocating Compressor Technology (ARCT) project jointly funded by GMRC and Industry.

Assessing the Impact of Pressure Pulses in Exhaust Manifolds During Blowdown Process on In-Cylinder Distribution Using T-RECS

Kirby Chapman-Kansas State University National Gas Machinery Laboratory

In an internal combustion engine, both the two-stroke and the four-stroke variety, the ejection of exhaust gases from the cylinder is termed as blowdown. In a two-stroke engine, during blowdown the in-cylinder gases which are at a pressure higher than the exhaust manifold pressure rush out of the exhaust port into the manifold, resulting in a high-pressure wave propagating through the manifold. In a multi-cylinder engine where the exhaust ports of each cylinder are connected to the manifold, the high pressure pulses in the manifold will impact the in-cylinder performance of the cylinders downstream of the first cylinder. This impact was investigated using the Turbocharger Reciprocating Engine Computer Simulation (T-RECS), a zero-dimensional cycle simulation tool developed at the National Gas Machinery Laboratory (NGML). The manifold pressure distributions were generated using the NGML developed Virtual Pipeline Simulation Tool (VPST), which is a one-dimensional pipe flow simulation software package. The analysis assumed that at any given instant the exhaust port of only one cylinder is open while the exhaust ports of all other cylinders remain closed. The results showed that the in-cylinder pressure distributions could become significantly altered under the influence of the exhaust manifold pressure pulses. The knowledge gained would help in utilizing the pressure pulses more effectively in tuning the exhaust manifold.

Basic Thermodynamics of Reciprocating Compression

Greg Phillippi – Ariel Corporation

This short course is intended to provide the attendee a review of the basic thermodynamic principles of compression utilizing a reciprocating compressor. This will include discussions of the pressure-volume diagram, volumetric efficiency capacity, and adiabatic valve loss and friction horsepower. In addition, the topics of varying conditions, gas analysis, temperature, pulsation, staging and end deactivation horsepower are reviewed.

A Case Study of the Application of State-of-the-Art Modeling Techniques to Successfully Turbocharge a Not-so-State-of-the-Art Engine

Greg Beshouri-Advanced Engine Technology Corp./Kirby Chapman-Kansas State University National Gas Machinery Laboratory/Jonathan Goss-El Paso Pipeline Group

Through a variety of projects, the Pipeline Research Council International (PRCI) and its member companies have sponsored research and analysis of engine modeling, turbocharger modeling and the modeling of the interaction between the engine and turbocharger. The K-State NGML and AETC collaborated on the continual refinement of these techniques over the last 10 years in support of a number of engine upgrades. Recently, Tennessee Gas Pipeline came to both parties with a particularly challenging problem: pure turbocharging of a pump scavenged Worthington LTC without making any modifications to major iron such as the lines, pistons or heads. As an indicator of the challenge, significantly funded attempts to turbocharge the engine had not succeeded. When the conversion was attempted with modifications to the cylinders and pistons, the degradation in performance due to loss of compression ratio and scavenging efficiency was unacceptable. A sound and robust engineering approach to upgrade this low BMEP engine was implemented. The prior engineering tools were upgraded to more accurately simulate the blowdown event. This offered a much better estimate of energy available to the turbocharger which defines its ability to self sustain. Based on this and previously developed dimensionless analysis methods, the team developed a comprehensive turbocharger specification. Using that specification, the turbocharger provider developed a special design and then optimized it at the NGML to meet that specification. With the precisely matched turbocharger self-sustaining in the field at a relatively low boost pressure, the turbocharged engine system achieved an emissions limit margin with acceptable combustion stability throughout the operating range.

Case Study of the Installation & Performance of a Large Horsepower, High-Speed, Gas Engine Driven, Separable Compressor at AGL Jefferson Island

Gary Mueller-Caterpillar, Inc./Jim Pitts-AGL Resources

In order to provide for flexible operations with an increase in the demand for natural gas storage, AGL Resources needed to expand the throughput of their Jefferson Island Hub & Storage facility. Of the options available, AGL elected to use a high-speed, reciprocating, separable compressor driven by an 8,000 bhp 4-cycle, lean-burn natural gas engine. This case study will review the project requirements and the design considerations for the installation of the major equipment and process piping. Unlike most other previous large horsepower, separable engine/compressor installations, the engine and compressor were directly mounted to the foundation at the Jefferson Island site. In addition to installation design, this paper will present how actual performance compared to the targeted performance of the engine-compressor system from the perspectives of power, efficiency, emissions, and vibration. Lessons learned during the design, installation, commissioning, and from day-to-day operations will be shared.

A Comparative Study of Performance & Efficiency of High-Speed Compressor Valves

James Trent-El Paso Corp.; Diana Grauer-National Gas Machinery Laboratory KSU

Reciprocating compressor efficiency is heavily dependent the performance of the suction and discharge compressor valves. Performance and endurance tests in the past have been conducted to explore the performance of several types of compressor valves. The majority of these studies have been conducted on slow speed reciprocating compressors; therefore, a need exists for an updated study on higher speed, variable frequency compressors. A variable speed reciprocating compressor unit has been selected by El Paso Pipeline Group's Plant Services department to conduct a performance and endurance test on six compressor valves from five OEM and aftermarket valve manufacturers. The valves tested were two plate type valves and four poppet valves. The compressor valves were tested over a compression ratio of 1.15 to 1.30 for 3000 unit operating hours. The compressor efficiencies, calculated using the Benedict-Webb-Rubin (BWR) equation of state, ranged from 65% at a compression ratio of 1.15 to 82% at 1.28. Efficiency data was supplemented with pressure-volume cards captured using a multi-channel data acquisition system. The data shows that percent valve loss, at a rated horsepower and speed of 1000 RPM, varied from 16% at a compression ratio of 1.28 to 29% at 1.19. At a minimum speed of 800 RPM, valve loss varied from 12% at a compression ratio of 1.28 to 19% at 1.19. Results of the performance and endurance test will be presented without disclosing the valve manufacturer, but will demonstrate that valve selection can have a significant impact on overall compressor efficiency. The valve manufacturers who allowed their valves to be analyzed will be notified of which data corresponds to their valve make, allowing them to assess their relative performance among the group.

Compressor Cylinder Lubrication Systems: Design, Components, Operation & Reliability

Clinten D. Lingel-Ariel Corporation

A compressor lubrication system is a hydraulic system that injects a specified amount of lubricant into the cylinder and packing. This enables the piston and piston rod to travel on an oil film to optimize the life of the packing and piston rings. The lubricant type, the lubrication system, the cylinders, and the seal rings are all an integral part of total compressor lubrication. Premature wear of pickings, piston rings, or cylinders is an indication of improper lubrication. This paper will identify the components necessary to build a proper lubrication system and how to monitor the system to ensure it is working correctly. It will also identify the proper viscosity of oil necessary to build a sufficient oil film as well as some design and field issues with current lubrication system components.

Development & Field Verification Testing of an Oxidizing Converter & a Compatible Lube Oil for Two-Stroke, Lean-Burn Gas Engines

Bruce Chrisman-Cameron Compression Systems/Glen Sharkowicz-ExxonMobil Lubricants & Petroleum Specialties

Because of the increasing emphasis on achieving low exhaust emissions for stationary gas engines, an oxidizing converter was developed for Ajax two-stroke lean burn (2SLB) engines in 2004. A few months prior to the effective compliance date for the ICE MACT rules which require large reductions in the formaldehyde levels for engines rated at $\geq$500 BHP, these converters were placed into service with two 710 BHP engines at a gas compression plant in Colorado. To assure continuous compliance with the emissions regulations, it was guaranteed that the CO removal efficiency with the original catalyst elements would not fall below 60% during the first six months of operation. Oxidizing converters have been proven highly effective for many years for four-stroke stationary engines. However, previous efforts to establish successful use of oxidizing converters for 2SLB engines had not produced adequate long term emissions removal efficiencies. There are several challenges associated with the use of converters on 2SLB engines which include: catalyst fouling from the products of combustion of the force fed cylinder oil, relatively low exhaust temperatures, and occasional rapid pressure fluctuations in the exhaust system. After confirming successful emissions removal efficiencies during a 500-hour R&D lab test, two of these converters were placed into service in the field. This paper focuses on the subsequent monitoring of the field performance during the first two years of operation and on several improvements which were implemented to enhance the commercial viability for the converters. These improvements include two major advancements to this technology: (1) The development of a catalyst box that can be retrofitted to existing exhaust silencers. (2) The formulation of a lube oil that avoids catalyst fouling and which can be successfully used for cylinder and crankcase lubrication.

Development of a Guideline for Field Testing of Gas Turbines & Centrifugal Compressors

Klaus Brun & Marybeth Nored-Southwest Research Institute/Rainer Kurz-Solar Turbines Inc.

Field testing is often conducted to verify the performance of centrifugal compressors and gas turbines at site conditions. The challenge in field testing is to obtain accurate and representative performance results from data that is measured under difficult conditions and varying site-specific requirements. Under a program funded by GMRC, Southwest Research institute has developed a comprehensive field test guideline for field testing of centrifugal gas compressor and gas turbines. This guideline recommends best practices for testing of gas turbine power and efficiency and centrifugal compressor power, head, flow and efficiency. Guidelines are based on recommendations from industry experts, existing public domain literature, and analysis of instrumentation, data acquisition, observed uncertainties, and performance calculation methods. It is anticipated that the guideline would become a reference that is widely acceptable for most OEMs and gas turbine users. This paper discusses the critical issues of the field test guideline, including pretest planning, test instrumentation, test setup and the determination of test uncertainty. The use of test uncertainty to assess the quality (and validity) of the field test results is also discussed. The paper presents the recommendations on ideal versus non-ideal installations and the impact of installations on test uncertainty. Equations of state, instrument installation best practices, pre-test requirements, and data interpretation are also discussed. A widely accepted field test guideline will assure that field test performance results and associated uncertainties are clear, well defined, and fairly interpreted.

Development of a Semi-Active Compressor Plate Valve

Klaus Brun & Ryan Gernentz-Southwest Research Institute/John Platt-BP

Reducing valve plate impact velocity can greatly increase the life of a valve. A new valve concept, developed under a GMRC program and co-funded by BP creates a soft landing at both the valve seat on closing and at the valve guard on opening using electromagnetic damping. The concept is to replace or augment the valve springs with an electromagnetic coil that senses position and provides an opposing force prior to impact. This concept is referred to as a "semi-active electromagnetic plate valve" because it is still activated by gas pressure and only controlled prior to impact; i.e., it does not require sensors for pressure or crank shaft angle and still functions as a passive valve if the coil or coil-control is disabled. This new valve concept was initially tested using a shock tube and then a 250 hp reciprocating compressor. During this testing, a valve element was coupled to a 1000W coil to provide a variable reaction force. A controller sensed the onset of a high velocity impact and provided proportional opposing electromagnetic damping to the plate just prior to the plate impact, thus reducing impact velocities. The reaction force applied by the coil was able to measurably reduce the impact velocities of the valve plate by 60-90%. The reduction in impact velocities would result in a relative high cycle fatigue life gain of 3 to 11 times that of a standard valve plate. This paper discusses the semi-active valve design, bench-scale testing, prototype design and planned field trials. Design options and kinematic motion analysis is also discussed.

Effective Use of Expansion Joints in Gas Transmission Systems

Michael Cabrera-Expansion Joint Systems, Inc.

There are a multitude of problems that can occur when expansion joints are not used properly, or at all, in gas transmission compressor stations. These problems occur at two major locations in the pump station: the inlet and outlet of the reciprocating engine or gas turbine used to rotate a pump and the piping networks that transmit low and high pressure air between equipment at the station. Most designs incorporate some types of expansion joints, but quite often they are not used properly or are missing where needed. This paper is written to alleviate the headaches and shed light on the mysteries of system failure because of poor use of expansion joints. We will show several examples of ideal systems and work backwards into a real-life piping system to show how proper use of guides and anchors will reduce the amount of expansion joints needed. We will also explain how to select the correct materials for the metal bellows to combat corrosion while still performing well during cycling at high temperatures. We will discuss the use of internal flow liners in the expansion joint to stop flow-induced vibration. There will be a section showing how multi-ply bellows are used to greatly increase the cycle life of expansion joints that must isolate vibration of the pump or engine. The concept of pressure thrust on high-pressure systems will be described and design techniques to control the pressure thrust through proper anchoring or the use of pressure balanced expansion joins will be explained. Specific site examples using pressure balanced joints will be used for this. Finally, a redundant ply option for high-pressure critical-service expansion joints will be introduced to increase the reliability of the joints and act as a warning system for future bellows failure.

Emissions Reduction & Horsepower Re-rate: A Case Study

Gerry Creel-El Paso Corp./Dustin Malicke & Fred Basin-Hoerbiger Engineering Services

In 2003, the El Paso Corporation Southern Natural Gas facility located near White Castle, Louisiana was required to propose a plan for reducing the station NOx emissions for 80%. There were 10 units located at the facility, three of which were low horsepower (550 hp each) engines. The remaining seven engines were comprised of 3 GMVA-8, 1 GMVA-10, 2 GMVC-10 and 1 GMVH-12. The project scope required retirement of the three smaller engines and uprating of the 7 remaining engines to maintain the FERC permitted station horsepower. This had to be accomplished while achieving the required NOx reduction. As part of the project, all centrifugal blowers were removed from the GMVA and GMVC series machines and new ABB turbochargers were installed. The GMVH received turbocharger modifications to enhanced air delivery. The turbocharger changes required replacement or installation of new unit level charge air cooling systems, cooling water control systems, and cooling system capacity modification. Enhanced mixing technologies and automatic balancing were employed to achieve the desired emissions performance and re-rate of the unit horsepower. Other systems modified during the course of the project included free air and exhaust, lubrication and compressor cylinders. The project concluded successfully in 2005 resulting in improvement in fuel economy and reduction in maintenance all while reducing the emissions. This paper brings the details of a "real" project and the operation results to those who may be faced with similar opportunities.

Gas Pipeline Black Powder: Who Should Know or Care?

Richard Baldwin-Southwest Research Institute

Although a substance in many gas pipelines called "Black Powder" is known and understood by many as an old problem, there are others who are discovering it as a new problem or at least a problem that was previously a nuisance that has now made major impacts on pipeline integrity and operations and maintenance costs. This paper presents an overview of what black powder is, where it comes from, and more importantly, who should know about it and whose responsibility it is to control it. There are two areas of primary importance to address in dealing with the problem. First, the influence that gas tariff agreements have upon the corrosion potential of the gas brought into a pipeline, based on prior GMRC funded research, and secondly the approaches companies should take to control it.

Impact of the Mounting Design on Temperature Exposure of Combustion Pressure Sensors on Large Bore Gas Engines

Thomas Walter-Kistler Instrumente AG/John Millot & Greg Beshouri-Advanced Engine Technology/Paul Odneal-Kistler Instrument Corp.

For investigating the typical temperature exposure of combustion pressure sensors on a large bore gas engine, pressure sensors were equipped with thermocouple washers and temperature measurements over a period of one year were recorded. This paper will give a report about this project and will cover the measured temperatures of the sensors, the operational conditions of the engine, the resulting effects on the sensors, and recommendations for improved sensor installation and sensor life time. Finally, the paper will lay out a methodology for qualifying the design of sensor mountings for large bore engines to minimize high temperature excursions and maximize sensor life. This paper continues the presentation given by Kistler at GMC2005 and targets engine technology providers as well as engine operators.

Impurities in the Gas Stream

Fred Mueller-Mueller Environmental Design, Inc.

This paper describes how iron sulfides are formed in the pipeline, methods to minimize its production, and improved technology for its removal and remediation.

Inertia Unbalance Forces & Couples

Dan Hannon-Ariel Corporation

This paper describes, in non-mathematical terms, the nature of unbalance in reciprocating compressors and presents an opinion on how reported magnitudes might be useful for foundation or skid design.

Interstage Pressure Calculation Derivation

Manny Angulo-ACTT div. of CECO

This paper presents a set of equations used to determine the interstage pressure for reciprocating compressor units with two stages. It begins with the basic assumption that the flow through each stage should be equal and concludes with an equation set for determining the interstage pressure. Along the way, several factors will be discussed such as variable compressibility, including pressure losses in the equations and interactive solution methods.

Introduction to Rotordynamics

Ken Atkins, Jim Tison & Troy Feese-EDI

Rotordynamic analyses of turbo-machinery are performed to identify potential problems before manufacture, thus preventing costly project delays and downtime. Machinery engineers need to understand the types of analyses that can be performed to evaluate proposed designs. This short course describes the types of rotordynamic analyses that are routinely performed for major equipment (turbines, motors, gearboxes, compressors, pumps, etc.). Typical analysis results are presented along with guidelines for their interpretation.

Investigation of Engine Air Balance

Ford Phillips & Ralph Harris-Southwest Research Institute/Gary Bourn & Randy Raymer-El Paso Corp.

This paper represents continued results from an investigation into the causes and correction of inlet imbalance to power cylinders of a two-stroke integral compressor engine. The project was funded by the Department of Energy's (DOE) Office of Fossil Energy as part of their Natural Gas Infrastructure Reliability Program. Co-funding for this project is provided by GMRC, EL Paso Corp., Cooper Compression, Southern Star Central Gas Pipeline, and Optimum Power Technology. A laboratory GMVH-6 turbocharged engine was used to provide engine data and conduct prototype testing. This paper describes testing and analysis of cylinder-to-cylinder variations. A prototype exhaust manifold retrofit, derived during the conceptual design phase, was constructed and tested for validation. The prototype exhaust retrofit is a side branch absorber designed to attenuate pulsations affecting scavenging. Initial testing indicated increased airflow and scavenging efficiency.

Knock Characterization Using Ionization Detection

Jessica Adair, Mark Woolston & Ed VanDyne-Woodward Governor Co./Jeff Barrett-Apple Valley Design

Knock constrains engine performance and efficiency. Severe knock is potentially damaging to the engine. Traditionally, knock has been detected with either a piezoelectric transducer or an accelerometer. However, knock can also be detected with an ionization probe. For a piezoelectric transducer, knock is characterized by ringing on the combustion pressure signal where the amplitude of the ringing indicates knock intensity. This classical ring of knock can also be detected on an ion curve. Similarly, the amplitude of the ringing on the ion curve also indicates knock intensity. Ionization can detect knock on a cycle-by-cycle basis, but technical difficulties have forced most ionization systems to use heavy averaging and/or filtering, destroying the classic ring signature of knock. However, certain ionization sensing ignition systems are able to accomplish robust ionization sensing without resorting to excessive filtering or averaging. In these systems, characteristic knock ring frequencies are preserved. This preservation provides the ability to offer closed loop knock control. The unique nature of the knock detection on the ion curve is the key to easy calibration on an engine. Once calibrated, a percentage of light knock can be used with closed loop control of the timing to avoid heavy knock. This control can extend the performance and efficiency of an engine by allowing the engine to further approach the knock limit without damaging the engine.

Measure Seven Times, Cut Once: A Systematic Method of Troubleshooting Engine & Compressor Problems

Randy Anderson-ACTT div. of CECO

Engines, compressors, ignition systems and controls sometimes experience unusual problems. Rather than replacing parts until the problem goes away, how can you systematically troubleshoot the problem and eliminate frustration and downtime? 1. Identifying change. 2. Building a time line. 3. Determining what is odd, unique or unusual (as opposed to similar equipment). 4. Gathering accurate data (measure everything, assume nothing). 5. Sticking to the facts (putting the I in eyewitness). 6. Assessing the type of failure (i.e., infant mortality). 7. Test before and after the fix.

Mounting Separable Compressors for Pipeline Service

Anthony J. Smalley-Tony Smalley Consultants, Inc./Robert J. McKee & Joe Pantermuehl, Southwest Research Institute

This paper summarizes guidelines under development as part of a GMRC research effort, with wide industry co-funding, for mounting medium and high speed reciprocating compressors in pipeline service. It explains the need for these guidelines, and uses relevant photographs, diagrams, and data, for illustration. The guidelines take mounting to include support of compressor, driver, cylinders, crosshead guide, bottles, and other appurtenances; and cover skid, mat/foundation, anchor bolts, chocks, washers, grout, and other support structures. The paper lists sources of influential forces (static and dynamic); discusses the interplay between pulsation control, vibration control, and mounting; and identifies the important role of specific design analyses. The paper includes issues to consider when choosing between skid and block mounting for higher horsepower compression systems. The guidelines and the paper have the pipeline end user as their primary audience, but make clear the importance of a team approach, with effective communication, involving all stakeholders (suppliers, agents, sub-contractors, service providers, and interested parties within the end user organization). Such teamwork greatly increases the probability that an installation meets all expectations for integrity, reliability, safety, capacity, and efficiency. The guidelines detail the due diligence which the end user must exert during procurement, installation, and commissioning, to ensure team effectiveness and a satisfactory installation.

New Developments in the Application of Online Reciprocating Engine & Compressor Pressure Monitoring Systems

Bruce Howerton & Noah Dixon-Williams Gas Pipeline/Al Krawczak-Windrock, Inc.

Williams Gas Pipeline-Transco System operates 41 compressor stations from South Texas to New Jersey. By the end of 2006, 121 out of a total of 307 reciprocating engine-driven compressors in those stations will be monitored locally and remotely through an advanced continuous pressure monitoring and diagnostic system. This continuous pressure monitoring (CPM) system utilizes crankshaft-referenced dynamic pressure measurement and advanced automated software analysis of power cylinders and compressor cylinder ends to accurately detect malfunctions, provide easily understood diagnostic messaging, and enable unit-to-unit economic performance comparisons over the Williams Gas Pipeline wide area network. Since first presented at this conference in 2003, this paper will examine new developments in the applied hardware and software technology enabling analysis of engine/compressor data now on an exception basis or only as required by indication from the systems automated diagnostics. Originally a secondary benefit of high pressure fuel injection retrofits to reduce emissions, CPM systems are now justified and installed for their added value alone in monitoring the mechanical condition, performance and operating costs of units without high pressure fuel injection systems.

Optimizing Compressor Design for Complex Reciprocating Compressor Installations

Derrick Derksen-Beta Machinery Analysis, Ltd.

Compressors in applications such as mainline transmission and gas storage are required to operate across a wide range of suction pressures, discharge pressures and capacities. These applications require multiple compressor units, which create different operating scenarios and pulsation effects in the system. An optimum design for these applications poses several challenges for the pulsation study including identifying conditions that represent the limiting cases for each attribute. Because of the complexity of these systems it is difficult to know what operating condition will govern. The limiting operating conditions for pulsation, unbalanced forces, pressure drop, and total horsepower will generally be different. The designer is faced with the challenge of comparing various attributes: across many operating conditions, for multiple units, and for alternative designs. With new tools, designers can now simulate can now simulate and compare results for many units and operating conditions. This paper describes methods of condensing the results in for the form of a series of "profile" graphical presentations. These simple but effective presentations make the situation clear for the designer, supporting rapid and, even more importantly, accurate design decisions. The graphs provide practical tools to explain the tradeoffs clearly to the end user, enabling the end user to become part of the decision on design tradeoffs.

Performance Control of Reciprocating Compressors: Devices for Managing Load & Flow

Chad Brahler, Norm Shade & Dwayne Hickman – ACI Services

This short course aims to provide attendees with the knowledge to fundamentally understand the various types of unloading and capacity control devices, the ability to decipher product claims, and the skills to identify methods and equipment used to modify unit performance relative to their needs and budgets. Useful, and unbiased, comparisons between the various performance control devices are detailed via provided quick-reference charts. Additional information provided includes diagrams, pictures, and schematics, advantages and disadvantages, performance considerations, operational limitations, and practical applicability. Upon course completion, attendees will be able to identify best possible means to achieve optimum performance control for both current and new units. Furthermore, participants will gain valuable knowledge that can be readily implemented when considering the full economics of real costs versus return on investments.

Performance Improvement to Existing Air-Cooled Heat Exchangers

Robert Giammaruti-Hudson Products Corporation

Many older air-cooled heat exchangers currently in operation today are not performing to their original specified design points due to several factors such as age, poor design, and high process cooling rates, to name a few. Fortunately, there are several options at your disposal to get more out of what you have without the need for brand new air-coolers. This paper will outline a step-by-step method by which an end user can systematically improve the heat transfer performance of his existing equipment without, in most cases, spending a lot of money.

Pipeline Compressor Packing Leakage

Craig Martin-C. Lee Cook

Operators of pipeline compressor expect their packing to deliver low leakage rates as well as long run times. Over the years, several packing arrangements and technologies have been proposed and/or utilized to achieve these goals. One particular arrangement that has been considered is the use of a side-loaded seal ring on the pressure side of the vent in the packing case. The idea behind this is that the sealing capabilities of this ring should effectively restrict gas from leaking out of the packing vent. While this arrangement may in fact reduce packing leakage for a time, field experience has demonstrated that it may lead to other packing problems. Typically, side-loaded rings are designed to seal at low pressures. This makes them effective vent rings, where they seal between atmosphere and the packing vent. However, these seals were not intended to be used under high pressure. Locating a side-loaded ring on the pressure side of the vent can have a detrimental effect on the packing material and reduce the life of the ring set.

Reciprocating Compressor Performance Measurement & Condition Analysis

Warren Laible-Windrock, Inc.

The objective of this course is to discuss the use of portable and stationary test equipment to determine the performance characteristics and the mechanical condition of reciprocating compressors. The course is designed for engineers and technicians who work with compressor maintenance reliability and optimization. The course will include a review of reciprocating compressor theory; potential reciprocating compressor faults; performance prediction (horsepower, volumetric efficiency, temperature, capacity, etc.); modern performance measurement equipment (encoders, transducers, signal processors, displays and data storage); compressor performance measurement (RPM, IIIP, VE, losses, temperature, clearance volumes, compression efficiency); discussion of mechanical condition analysis techniques, and a comparison of portable and continuous monitoring.

Reciprocating Compressor Performance: Seeing the Big Picture

Dwayne Hickman-ACI Services, Inc.

Compressor performance tools are often used to size units and determine safe operating maps. Today's performance specialists, such as Applications/Engineering, Packagers/OEMs, Operators/Supervisors, Automation/Control, Gas Control/Dispatch, and consultants, require tools that provide them with valuable information well beyond simple sizing and performance maps. Data from different types of calculated performance (point reports, tabular reports, various types of performance curves, contour plots, and 3D surfaces) will be used for technical studies and to generate important reports. This short course will focus on methodologies and tools available to achieve specific goals and not on how to use any particular performance tool. As such, familiarity with any particular software package is not required for his course. (A general knowledge of reciprocating compressors would be beneficial but is also not required.) By effectively using today's modern compressor performance tools, attendees will be able to better meet the demands of their jobs and to better serve the needs of their customers by promptly generating informative reports. Providers of performance can now achieve results in mere minutes for that which may otherwise have taken hours, days or weeks. Reports that can cover entire ranges of pressures, temperatures, speeds and load steps provide to end-users an insight that is simply not available from simple point-performance reports.

Review of Greenhouse Gas Programs, Policies & Legislation

Fiji George-El Paso Corp.

Over the past few years, there have been numerous legislation/bills discussed or introduced in Congress. In addition, several state or regional entities have discussed or introduced mandatory programs. The presentation provides an overview of these bills and state programs. Specifically, the presentation will review proposals from Senators Bingaman and Feinstein, the Udall-Petri bill, Sense of Congress proposal and programs like DOE's 1605(b), California Climate Action Registry (CCAR), EPA Climate Leaders and Chicago Climate Exchange (CCX).

Suggestions for Career Enhancement

James R. Hutton-CECO

Jim Hutton, author of "How to Sell Technical Equipment and Services", has learned many things about salesmanship in his 50 years in the energy equipment business and will pass this knowledge on to others who can benefit from his experience.

The Surprising Influence of Bearing (and Compressor Drive) Type on Compressor Station Economics: How Certain New Technologies Provide Significant Life Cycle Cost Advantages & Represent a Strategic (Real) Option

Michael Swann-Waukesha Magnetic Bearings/Ramkumar Wallooppillai-El Paso Corp.

The successful demonstration of new technologies for Active Magnetic Bearings and Electric Motor Drive in recent natural gas pipeline applications with a good reliability and availability record have led the industry to take a fresh look at the financial case for these technologies. This paper describes a modern day basis for comparing the costs and benefits of electric motor drive with magnetic bearings in centrifugal compressors with the conventional technologies of gas turbine drive and fluid film bearings. Life cycle cost analyses using Monte Carlo simulation of future operating expenses are employed during the compressor station planning stages to allow Net Present Value (NPV) comparisons of competing technologies. Case studies are provided for examples typical of the US pipeline industry.

Technology Update on Prime Movers & Compressors Used in Natural Gas Compression Service

William A. Couch & Thomas W. Burgett – El Paso Pipeline Group

This short course will outline the evolution of gas compression equipment in North America beginning with the slow-speed horizontal integral engines up through the modern high-speed separable gas engines and compressors. Additionally, we will outline the evolution of gas turbines and centrifugal compressors from the introduction of the GE Frame 3 gas turbines in the early 50's to the latest industrial and aero-derivative gas turbines and centrifugal compressors. Along with this compression equipment overview, we will also discs outside forces and internal changes that have changed the face of our industry, including environmental requirements, deregulation of the gas industry, reduction in the "take or pay" contracts, increased throughput, availability of repair parts and major components, OEM orphaned engines, and increased fuel costs.

Test & Evaluation of a Continuous Combustion Pressure Monitoring System for High-Speed Four-Stroke Engines

David Jetelina-Windrock/Jim McCraw-BP/Bill Ashton-PCB

This paper will present the results of the first large-scale application of dynamic pressure sensor monitoring on high speed 4-stroke engines in the Gas Industry. Currently, 10 units are being retrofitted with these systems. The paper will describe the innovative way the sensors are installed, special mounting considerations and calibration techniques. The monitoring system architecture and networking infrastructure will also be presented along with a discussion of how the combustion data can be used to enhance engine operations in the Gas Industry.

Turbine Inlet Ice Related Failures & Predicting Inlet Ice Formation

David Maas & Nathan McCown-El Paso Corp.

Ice ingestion has caused damage and subsequent failures of a Solar Mars 100 turbine on two separate occasions. Understanding this phenomenon and the required ambient conditions is key to preventing ice related failures in the future. This paper investigates the required ambient temperature and relative humidity for inlet ice formation.

Understanding & Applying Ion Sense for the Detection of Misfire, Detonation & Combustion Instability & for Engine Balance

Greg Beshouri & Mark Richter-Advanced Engine Technology Corp./Bo Nilson-Almstedt-Mecel/Michael Duffy, Altronic,Inc.

Combining information on flame initiation, flame propagation, air/fuel ratio and load, Ion Sense offers a new paradigm for monitoring and analyzing in-cylinder combustion processes. This short course will first familiarize the attendees with the hardware used to measure Ion Sense. It will then review the Ion Sense derived parameters that can be used to determine knock, misfire, combustion instability and imbalance. The course will next explore future applications of Ion Sense for rich burn engines and for closed loop control of air/fuel ratio and emissions monitoring. Finally, the course will review the results of industry funded Factory Acceptance Tests of the prototype production hardware.

Universal Efficiency Definition for Reciprocating & Centrifugal Compressors

Rainer Kurz-Solar Turbines Inc./Klaus Brun & Ralph Harris, Southwest Research Institute

Reciprocating compressors and centrifugal compressors use different definitions of compressor efficiency. This paper will provide guidelines for a true comparison (including valve losses, pulsation dampener losses, losses due to pulsation, station accessory losses), as well as a universal efficiency definition for both types of machines based on the requirements the ultimate user is really interested in. Further, the impact of actual pipeline conditions on the change of efficiency at different loads, using different means of control, is evaluated. Test data for either type of compressor is provided.

The Value of Compressor Efficiency

Ralph Harris-Southwest Research Institute/Randy Raymer & Tim Canton-El Paso Pipeline Group

This short course will cover compressor efficiency (components of losses, irreversible losses, cylinder valves, orifices-static & dynamic, installation-manifold losses, piping arrangements, performance measurements-cylinder versus "line to line") and value analysis (review cost analysis & introduce "value" analysis, calculate the compressor efficiency "Value" potential, compare BTU/BHP-hr to KwH) and will include three case studies (low speed vs. high speed gas fired, low speed gas fired vs. high speed electric, and high speed vs. high speed valve change out).

Visible Flame Imaging of Pre-chamber Combustion in a Large Bore Natural Gas Engine

Justin Lisowski, Daniel Olsen & Azer Yalin-Colorado State University Engines & Energy Conversion Laboratory

Precombustion chambers (prechambers) are an enabling technology to facilitate reliable ignition of natural gas engines operating with ultra-lean mixtures. Previous testing indicates that at ultra-lean mixtures, emissions from the prechamber may contribute a significant fraction of engine-out emissions formation in the prechamber as well as in the main chamber. In an effort to support prechamber development, an optical head was manufactured for use on the Cooper-Bessemer GMV engine at the Colorado State University Engines & Energy Conversion Laboratory. A high-speed camera was used to image the prechamber flame jet propelled into the main chamber and the ensuing main chamber combustion. Post processing the video can determine the flame penetration depth into the main chamber, flame development time, and the character of main chamber combustion.

Who Moved My Knowledge?

Rich Schoonover-Enginuity, LLC

The natural gas industry, whether gathering, midstream, transmission or local distribution, faces many challenges in today's market place. Growing demand, increasing price, an aging infrastructure and a rapidly retiring workforce, among other pressures, are all converging to form an operating environment not previously experienced by this or many other industries. As daunting as the challenges are in and of themselves, the combined impact on operations will serve to redefine how the natural gas industry operates in the future. Meeting these complex challenges requires new thought processes and approaches to capture, facilitate and deploy the unique knowledge inherent in the industry's workforce. Training is but one step in the devolution of knowledge. Ensuring that knowledge is kept whole, further developed and readily deployed requires imbedding the necessary tools throughout the industry's operating infrastructure from end-devices to intuitive, interactive user interfaces. The tools to capture and deploy knowledge exist today as in no other time in history. Deployment, however, requires a paradigm shift in the way that knowledge is viewed. Gone are the days of power in knowledge; we now operate n a world wrought with acute economic pressures where the true power comes in the sharing, facilitation and expansion of knowledge. This paper will explore the potential impact of increasing demand, an aging infrastructure and demographics on the knowledge equation within the natural gas industry. Specifically, the paper will offer ideas and suggested guidelines to help facilitate the transition to a knowledge based infrastructure.

Working Sideways: Using Emissions Modeling & Controls to Solve Operational Problems (A Case Study)

Todd Rose-Questar Pipeline Co./Gavin Goolsbee & Hans Mathews-Hoerbiger Engineering Services/Randy Anderson-ACTT div. of CECO

Questar Pipeline Company operates 5 KVSR units at their storage facility in eastern Utah. These units have proven to be a handful operationally with frequent and substantial failure of power side components, including not only the common scored cylinder, stuck ring and wrist pin failure but also broken cylinder bolts, cracked heads and damaged blocks. An investigation noted that there were issues with oil and water temperature control, air manifold temperature control, a complete lack of any air manifold pressure control and frequent detonation. A basic site evaluation and mapping program were undertaken to determine the operational state of the existing installation. The result of this study showed that the engines needed more air, a way to control the air during off-peak operation and a control strategy that treated the unit as one larger inter-related system. An installation was designed that insured the units were operated with ample operational margin. The solution included turbocharger upgrades, an air bypass valve, new high energy ignition systems, a re-design of the cooling system loops and controls upgrades ensure optimum performance throughout the operating envelope.