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Presentation to Research Forum

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2005 R&D Program

Projects	GMRC	Industry	In-Kind	DOE	Total
Surge (4th yr)	$50K				$50K
Integrals(3rd yr)	$25K	$25K		$150K	$200K
Air Balance, 1/4 yr	$1.25K	$25K	$46.8K	$37.5K	$110.5K
ARCT	$162.5K	$187.5K		$650K	$1000K
Admin.	$30K				$30K
Total	$268.75K	$237.5K	$46.8K	$837.5K	$1390.5K
GMRC Contract	**$506.25K**				

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Direct Surge Control

The technology for detection of incipient surge and control to prevent it in certain combustion turbines has been developed in past years. The scope of work for 2005 includes identifying and selecting a company to be the application contractor, transferring the technology, and demonstrating a commercially supplied direct surge control system.

Preliminary discussions have been held with potential commercialization suppliers.

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Enhance Operations of Existing Integral Engine/Compressor Infrastructure

This is the third year of a program to develop and evaluate a number of technologies for balancing, operation, and control of integral reciprocating engine/compressors in pipeline gas transmission service. Develop and substantiate methods for operations by reducing fuel consumption, increasing capacity, and enhancing mechanical integrity.

Four candidate sites have been identified for Phase III.

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Manifold Design for Controlling Engine Air Balance

This is the second year of a program to improve the cylinder-to-cylinder balance of trapped air mass and air/fuel ratio in an integral two-stroke compressor engine. New manifold designs will be investigated, along with the contribution to air imbalance from component geometry.

Conceptual designs have been derived for simulation. Initial concepts include an acoustically isolated exhaust manifold and timed exhaust manifold.

ARCT

Advanced Reciprocating Compression Technology (ARCT) Program

Year 1 Project Plan

Objective

- 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 are 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.

ARCT Approach

- The ARCT program duration is five years with three sequential phases.
- Each phase will increase the technology maturity from proof of concept to prototype to demonstration of the next generation of compression technology.
- Program budget is $5 million over 5 years at $1 million per year. Cost share of 65% DOE and 35% GMRC & Member Companies.

Work Breakdown Structure

- Phase 1. Proof of Concept
  - (Year 1 @ $1 million)
- Phase 2. Prototype Development
  - (Year 2 & 3 @ $2 million)
- Phase 3. Demonstration & Commercialization
  - (Year 4 & 5 @ $2 million)

Phase 1- Proof of Concept

- Task 1.1 Project Management
- Task 1.2 Advanced Pulsation Control
- Task 1.3 Advanced Capacity Control
- Task 1.4 Advanced Valves
- Task 1.5 Advanced Sensors & Automation
- Task 1.6 System Integration & Optimization
- Task 1.7 Evaluation of Technologies for Phase 2 Continuation

Advanced Pulsation Control

- Develop advanced pulsation control technology that reduces flow pulsations, reduces vibrations, improves reliability and reduces parasitic pressure losses over the full compressor-operating envelope.
- Proof of concept for a range of advanced pulsation control technologies shall be investigated and the most feasible concepts identified.

Pulsation Control Concepts

- Infinite length cylinder nozzle (perforated nozzle projection)
- Variable volume SBA (Side Branch Absorber)
- Damped SBA (with orifice)
- Multi-frequency SBA (more than one volume in a single bottle)
- Tapered nozzles
- Pockets on each filter bottle volume (variable volume filter bottle)
- Higher order filters
- Multiple hole orifices
- Active pulsation damping devices (variable orifice beta)
- Multi-hole orifice with a gate valve (active damping device)

Advanced Capacity Control

- Develop advanced capacity control techniques that are active, robust, continuously variable, and efficient.
- To support these technologies, an accurate capacity measurement technology shall be investigated.

The Purpose of Capacity Control

- To control the load (torque and horsepower) in a compressor:
  - To achieve full utilization
  - To prevent overloads
- To control the throughput of gas:
  - To meet the flow demands (nominations)
  - To maintain deliverability

Capacity Control Concepts

- Variable speed (automatic transmission) with single drive
- Variable speed with multiple drive
- Improved valve deactivation
- Variable stroke compressor
- Temperature control for suction gas
- Pocket in piston clearance volume
- Large effective clearance volume
- Piston bypass or bleed gas
- Piston deactivation

Selected from preliminary ranking (applies to the first four items)

Variable Stroke Compressor Concepts

- Linear Electric Motor Compressor
- Hydraulic Drive Compressor
- Crankless Engine Compressor
- Phased Pistons
- Piston Deactivation

Linear Electric Motor Compressor:
A Piston Driven by Electro-Magnets in a Non-Magnetic Cylinder -No Crank, No Rods, and Infinite Control of Stroke

Advanced Valves

- Develop technologies for robust, efficient, and low leak valves.
- Valve operating parameters shall be analyzed to optimize the performance of current compressor valve designs.
- Advanced valve technology shall be developed with sealing element motion control to achieve increased capacity, enhanced flow control, and improved valve life.

Valve Ideas

- **Electromagnetic plate valve: Use a plate mounted on shaft, sense and control plate motion with electromagnet.**
- **Screw/cam thread rotary valve: Rotating slotted, plate valve that moves on a screw thread or cam, with or without torsional spring.**
- **Combo electromagnetic rotary valve: Rotating plate valve controlled by standard motor. Valve position controlled by cam profile.**
- **Slider valve: Curved plate mounted on cylinder, slides open and closed.**
- **Reinforced valve: Design valve material or geometry to withstand higher impact forces in areas of high frequency impact.**
- **Improved springs: Spring research aimed at improving spring reliability and extending range of operating conditions.**
- **Self-damping valve: Return air flow to seating side of valve to improve valve damping and long-term reliability.**
- **Micro flapper valve: Valve uses multiple small flappers to control opening or closing of gas flow passage area.**
- **Rotary valve: Moves two plates rotationally to align open slots on both plates.**
- **Valve in piston: Valve installed in piston to allow gas flow through open area of piston to port on cylinder side.**
- **Removable guard: Remove existing guard in order to increase flow area.**

Advanced Sensor & Automation

- Develop advanced sensor, measurement, and automation technology, which will enhance intelligent compression, specifically self-diagnostics, adaptive operation, reliability, and flexible operations.
- Develop technology in the area of instrumentation and measurement systems needed to support the prior tasks.

Automation Issues

- Traditional
  - Unit control, local, remote
  - Valve control, lockouts
  - Key sensors (pressure, temperature, position, speed, flow)
  - Hard wiring issues…potential for RF replacement?
    - Security concerns
- ARCT development and project needs
  - Advanced measurements for technology development and evaluation
    - Capacity control, torque control, system performance optimization, active component control
  - Unique sensor development enhancing system operation, diagnostics, health

Critical ARTC Measurement Needs

- Accurate In Cylinder Pressure Measurements
- Accurate Unit Flow Measurements
- Accurate Cylinder HP measurements (independent of pressure measurements perhaps for valve performance determination)
- Local measurement/control systems for active components

Ideas for "Sensor" Development

- Field Deployable RLM system for cylinder evaluation and load control development.
- High capacity crank strain monitoring system for alignment degradation evaluation (possibly continuous).
- Internal component temperature sensors (self-powered, RF transmitted).
- Continuous shaft torque measurement for HP and load determination on separable units.
- Real-time liquid sensor.
- Cylinder pressure probe compatible with existing Kiene valve systems for HP and diagnostics.

System Integration & Optimization

- Develop and integrate technologies that optimize compression system efficiency, reliability, and capacity at both the unit and station level.
- The focus is on integration of single compressors into compressor station operational strategies and station optimization.

System Integration and Optimization

- Compressor Mounting
- Unit and Station Optimization
- Technology Integration
- Unit and Station Operation

Plan for Mounting Research

- Develop a Best Practice Design Guideline for Compressor Mounting
  - This guideline will provide industry with recommendations for:
    - Deciding when skid and block mounting are appropriate
    - Designing skids and blocks for compressor and driver dynamic loads
- Approach
    - Review of previous studies
    - Define unresolved problems or issues
    - Define controlling analytic parameters
    - Determine engineering and economic analyses that should be performed
    - Conduct at least four example analyses
    - Develop a draft decision matrix
    - Develop draft guidelines

Optimization Overview

- The focus of the ARCT Project Optimization is on compressor packages and stations using these packages.
- Typical Optimization Parameters
  - Fuel/power consumption
  - Fuel/power costs
  - Emissions
  - Unit horsepower/torque
  - Startup/shutdown costs
  - Maintenance costs
- Optimization for a unit may be different than optimizing for the station but is a good starting point.
- Optimization is for a required flow and pressure ratio

Optimization Methods

- Current Methods are for Steady-State Conditions
  - Optimizing for a Transient Condition is Different
- Heuristic Methods –Rules of Thumb
  - Most commonly used by station operators and gas control.
- Mixed Integer Linear Programming (MILP)
  - A simple math model with fuel linearly related to flow and unrealistically simple assumptions about the compressors.
  - Integer because compressor are on or off (not deteriorated).
- Mixed Integer Non-Linear Programming (MINLP)
  - Removes the overly simple assumptions and the fixed linear relationship between fuel and throughput but becomes mathematically complex for multiple compressor units.

Unit and Station Optimization

- Pipeline optimization is not in the scope of work.
- Optimization methods for individual compressors will be developed as Advanced Reciprocating Compressor Technology is developed.
- An Optimization Tool for Stations is Needed.
- Potential Option is an automatic tool for station optimization in which the operator:
  - Enters the rating and character of each compressor,
  - Enters the condition of each compressor and driver,
  - Enters the required operating conditions, and
  - Obtains quantified recommendations for starting and operating compressors at his/her station.

System Integration Summary

- Compressor Mounting
  - Develop a guideline for compressor mounting.
- Unit and Station Optimization
  - Develop a unit optimization tool.
  - Develop a tool for station optimization considering station characteristics, current unit conditions, operating requirements, and unit flexibility.
- Technology Integration
  - Delay this task until later in the project when ARCT is ready to be integrated into station operations.

Phase 2 – Prototype Development for ARCT

- Prototype hardware for the most feasible concepts identified in Phase 1 shall be built, tested, and actual performance documented.
- It is anticipated that a number of cycles of modification, retest, and documentation shall be conducted during Phase 2.
- Provide summary evaluation of all technologies developed and tested under Phase 2 indicating level of success and level of future potential for continuation into Phase 3.

Phase 3 – Demonstration & Commercialization of ARCT

- Next generation technologies identified in Phase 2 shall be demonstrated.
- These next generation technologies shall be brought to a maturity that can be transferred to a commercialization partner.
- Commercialization partner shall be selected and agreements negotiated to assure that viable products and/or services are commercially available to pipeline owner companies.

PSC Process

- Project Champion – PSC Chairman
- Each Task – PSC Technical Advisors
- PSC Supervision of ARCT program
  - Submit for Review and Input
  - Submit Monthly Status Reports
  - Regular Review Meetings
- Address Intellectual Property & Patent Issues
- Lead Commercialization & Selecting Applications Contractor process