Technologies to Enhance Operation of the Existing Natural Gas Compression Infrastructure

Quarterly Technical Progress Report

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ABSTRACT

This report documents work performed in the first quarter of the project entitled: *Technologies to Enhance Operation of the Existing Natural Gas Compression Infrastructure*. The project objective is to develop and substantiate methods for operating integral engine/compressors in gas pipeline service, which reduce fuel consumption, increase capacity, and enhance mechanical integrity. The report describes the following work: preparation and submission of the Research Management Plan; preparation and submission of the Technology Status Assessment; attendance at the Project Kick-Off meeting at DOE-NETL; formation of the Industry Advisory Committee (IAC) for the project; preparation of the Test Plan; acquisition and assembly of the data acquisition system (DAS).

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1. INTRODUCTION

This report documents work performed in the first quarter (October through December 2002) of the project entitled: *Technologies to Enhance Operation of the Existing Natural Gas Compression Infrastructure*.

The project objective is to develop and substantiate methods for operating integral engine/compressors in gas pipeline service, which reduce fuel consumption, increase capacity, and enhance mechanical integrity.

The project has been structured in three phases – the first to last eighteen (18) months, with nine (9) tasks. These tasks are as follows:

1. **Research Management Plan:** To define a work breakdown structure and supporting narrative that addresses the overall project objectives.
2. **Technology Status Assessment:** To describe current and competing technologies for pipeline compression, with strengths and weaknesses.
3. **Industry Advisory Committee (IAC):** To interact with industry advisors and their suppliers and, thereby, focus the work and help transfer knowledge into practice.
4. **Test Plan:** To develop a test plan which addresses project objectives, and which will serve as a basis for tests to be performed at various industry sites.
5. **Data Acquisition System (DAS):** To develop a data system which will support project objectives and acquire all needed data with appropriate format, data rates, and display.
6. **Test Program:** To perform tests on a representative series of engine/compressors; gather data to develop required relationships for efficiency, capacity, and mechanical integrity.
7. **Data Analysis:** To relate power cylinder standard deviation, balancing process, and compressor cylinder operation to fuel flow, compression efficiency, and crankshaft strain through models.
8. **Methods for Optimized Operation:** To apply the models and develop optimized methods for balancing and operating engine/compressors.
9. **Program Management:** To perform planning, administrative, and technical direction functions to achieve project objectives; to communicate with and report to the DOE and other co-funding organizations.

So far, progress has been made under Tasks 1 through 5 and Task 9, and is discussed in the subsequent sections of this quarterly report.

2. EXECUTIVE SUMMARY

Southwest Research Institute®'s (SwRI®) Research Management Plan for the project has been prepared and submitted to DOE for review. This constitutes the bulk of the work under project Task 1.

A Technology Status Assessment document is in the final stages of review and editorial revision prior to submission to DOE-NETL for review. This constitutes the bulk of the work under project Task 2.

An Industry Advisory Committee (IAC) has been formed and a first meeting has been scheduled for January 14, 2003. This activity falls under project Task 3.

The project Test Plan has been drafted and is in the process of internal review. This constitutes the bulk of work under Task 4. It will be reviewed with the Industry Advisory Committee at the planned January meeting, and revised as needed.

The Project Manager and Senior Project Engineer for the project attended a Project Kick-Off meeting at NETL in Morgantown, December 5, 2002, and presented plans for the project for review and discussion. This falls under Task 9: Program Management.

Assembly of the data acquisition hardware is complete, and the adaptation of SwRI's software to the specific needs of this project is well advanced. Checkout with transducers will start in January 2003. The data acquisition system represents work under Task 5.

The following report discusses each of these items of progress in more detail.

3. EXPERIMENTAL

As described in the Test Plan, the following data channels which will be acquired simultaneously and processed as part of the testing:

- Compressor cylinder dynamic pressure - used for compressor horsepower and flow determination (Sensotec piezo-restrictive transducer).
- Engine dynamic cylinder pressure - used for engine horsepower determination, engine balance, and engine statistics (Kistler quartz piezoelectric transducer).
- Engine intake and exhaust dynamic pressure measurements - used to correlate acoustic dynamic effects to engine statistics (Kistler piezo-restrictive transducer (water-cooled)).
- Torsional vibrations (IRV) - used as a surrogate for mechanical integrity (BEI 512 pulse encoder).
- Bearing centerline vibration measurements - used as a surrogate for mechanical integrity (PCB velocimeters).
- Crankshaft dynamic strain - acquired using SwRI's Strain Data Capture Module (SDCM). Used as a direct measurement of shaft loading, and used to provide link between engine statistical quantities (PFP), and crankshaft fatigue damage [Ref. 1].
- Engine fuel flow - used to document overall engine efficiency (AGA3 method using Emerson Flobas 103).
- Suction header and discharge header pressures and temperatures - used for installation efficiency determination (Sensotec piezo-restrictive transducer).
- Engine exhaust NO_X O_2 levels - used for input into an engine performance model (NGK fast-response transducer).
- Compressor rod load - used for both mechanical integrity and loading optimization (strain gage-based; bridged to cancel bending.)

4. RESULTS AND DISCUSSION

RESEARCH MANAGEMENT PLAN (TASK 1)

This plan first describes SwRI's process for management of technical projects on behalf of clients to meet technical objectives within cost and schedule constraints. It then defines the current project objectives, budget, schedule, and work plan, including individual task responsibilities. This Research Management Plan was submitted to DOE for review at the start of December 2002.

TECHNOLOGY STATUS ASSESSMENT (TASK 2)

The Technology Status Assessment document defines the new technologies to be applied or developed under the project. These are:

- The Strain Data Capture Module (SDCM)
- Rod Load Monitoring (RLM)
- Alternative Power Cylinder Balancing Methodologies
- Cylinder Loading Control
- Speed Control
- Operational Optimization

This five-page document is in the final stages of internal review and editorial revision prior to submission to DOE-NETL for review in early January. It describes each technology briefly with illustrative photographs, where appropriate; it identifies competing technologies; it identifies the benefits of the new technology in comparison to the competing technology.

INDUSTRY ADVISORY COMMITTEE (TASK 3)

An Industry Advisory Committee (IAC) has been formed and a first meeting has been scheduled for January 14, 2003. At present, committee representatives have been invited from those operating companies who have offered test sites. In addition, the project champion from GMRC/PRCI and the DOE project manager are members. As of the end of December, four out of five invitees have accepted, and the fifth is expected to formally accept soon. The site for the first meeting will be at El Paso Corporation's offices in Houston at 9 Greenway Plaza.

PROJECT TEST PLAN (TASK 4)

The Project Test Plan has been drafted and is in the process of internal review. This constitutes the bulk of work under Task 4. It will be transmitted to the Industry Advisory Committee (IAC) members and reviewed at the planned January 14, 2003 meeting. This review includes selection of candidate engine/compressor models and test sites. Data to support this analysis was obtained from an industry database of engines and compressors in gas transmission service, supported by PRCI. Tables 1 and 2 were obtained by appropriate sorting of the database to show the top ten (10) engine models in terms of number installed (Table 1) and in terms of horsepower installed (Table 2). These rankings will be one input guiding the choice of engine.

Table 1. High Count Engines in Gas Transmission – Sorted by Number
(from 1998 Coerr Database)

Model	Sum of Rated HP	Count	Cumulative			Comments
GMW	708336	336	336	Top 6 by HP or #	Top 10 by HP or #	Just GMW - No GMWA & GMWC
KVG	330918	296	632		Top 10 by HP or #	
TLA	672085	280	912	Top 6 by HP or #	Top 10 by HP or #	
GMV	270489	269	1181		Top 10 by HP or #	Just GMV - No GMVB & GMVH
KVS	441455	233	1414	Top 6 by HP or #	Top 10 by HP or #	
HBA	372414	223	1637	Top 6 by HP or #	Top 10 by HP or #	
GMVH	302242	179	1816		Top 10 by HP or #	
TCV	872106	155	1971		Top 10 by HP or #	Includes TCV thru TCVD
L-7042	154528	150	2121			Small High-Speed Waukesha
BA	207271	140	2261			Old & Small

Table 2. High Count Engines in Gas Transmission – Sorted by Horsepower
(from 1998 Coerr Database)

Model	Sum of Rated HP	Count	Cumulative HP			Comments
TCV	872106	155	872106		Top 10 by HP or #	High HP
GMW	708336	336	1580442	Top 6 by HP or #	Top 10 by HP or #	
TLA	672085	280	2252527	Top 6 by HP or #	Top 10 by HP or #	
KVS	441455	233	2693982	Top 6 by HP or #	Top 10 by HP or #	
HBA	372414	223	3066396	Top 6 by HP or #	Top 10 by HP or #	
V-250	335450	93	3401846			
KVG	330918	296	3732764		Top 10 by HP or #	
W-330	315656	56	4048420			High HP; Recent
GMVH	302242	179	4350662		Top 10 by HP or #	
GMV	270489	269	4621151		Top 10 by HP or #	
Note: If we total all GMV, GMVB, GMVC thru GMVS, we get 962,510 HP and 721 units.						
Note: If we total all GMW, GMWA thru GMWS, we get 1,189,736 HP and 511 units.						

PROJECT KICK-OFF MEETING

The Project Manager and Senior Project Engineer for the project attended a Project Kick-Off meeting at NETL in Morgantown, December 5, 2002. At this kick-off meeting, they presented plans for the project for review and discussion to DOE staff, and to contractors for other projects undertaking a similar function. This material addressed the technologies to be applied and developed, which include the Strain Data Capture Module (SDCM), the Rod Load Monitor (RLM), alternative balancing methods, concurrent dynamic pressure measurement from all cylinders and cylinder ends, methods for control of speed and load step for each compressor cylinder end, and alternative balancing methods.

DATA ACQUISITION SYSTEM (TASK 5)

Figures 1 and 2 show photographs of the Data Acquisition System (DAS). The system comprises an industrially hardened computer, a flat screen for display, and a separate box with connectors to which cables from individual sensors are connected. The DAS box has analog-to-digital converters of appropriate speed for over 50 different channels.

Figure 1. Front View of Data Acquisition System (DAS)

Figure 2. Rear View of Data Acquisition System (DAS)

To supplement the DAS, SwRI (as part of its capital equipment) has purchased a set of pressure transducers which will enable concurrent real-time dynamic pressure measurement in all the engine and compressor cylinders of most integral engine compressors.

The individual power cylinder transducers (up to 10) will be connected to a box with connectors on the deck near the cylinders. A single cable from this box will carry the signals from all the power cylinder transducers to the main data acquisition box. A similar approach will be used for the compressor cylinders. In this way, the complexity of the cabling and system checkout is minimized. Signals from rod load monitors, from other system pressures, and from temperature sensors will be acquired by the DAS, concurrently, and a database of the sensor values throughout the test will be created by the DAS.

The assembly of data acquisition hardware is complete, and the adaptation of SwRI's software to the specific needs of this project is well advanced. Checkout and calibration with transducers will start in January 2003.

5. CONCLUSIONS

The project is proceeding according to the Research Management Plan. The Technology Status document, the Research Management Plan, the Test Plan, and three Monthly Highlight reports have been submitted. Program plans have been presented at a Kickoff meeting at NETL in Morgantown. The transducers and data acquisition system have been procured, assembled, and calibration is planned for January. Data acquisition and analysis software is being adapted. The first meeting of the Industry Advisory Committee is planned for January 14, 2003. Site selection is anticipated in late January, and a preliminary site visit should occur in early February.

6. REFERENCES

1. Harris, R.E., Edlund, C.E., Smalley, A.J., and Weilbacher, G., "Dynamic Crank Web Strain Measurements for Reciprocating Compressors," presented at the GMRC Gas Machinery Conference (GMC), October 2-4, 2000, Colorado Springs, Colorado.

7. LIST OF ACRONYMS AND ABBREVIATIONS

02	Oxygen Molecule
AGA	American Gas Association
BEI	Manufacturer's Trade Name
DAS	Data Acquisition System
DOE	U.S. Department of Energy
GMRC	Gas Machinery Research Council
IAC	Industry Advisory Committee
IRV	Instantaneous Rotational Velocity
NETL	National Energy Technology Laboratory
NGK	Manufacturer's Trade Name
NO_X	Oxides of Nitrogen
PCB	Manufacturer's Trade Name
PFP	Peak-Firing Pressure
PRCI	PRC International
RLM	Rod Load Monitoring
SDCM	Strain Data Capture Module
SwRI®	Southwest Research Institute®