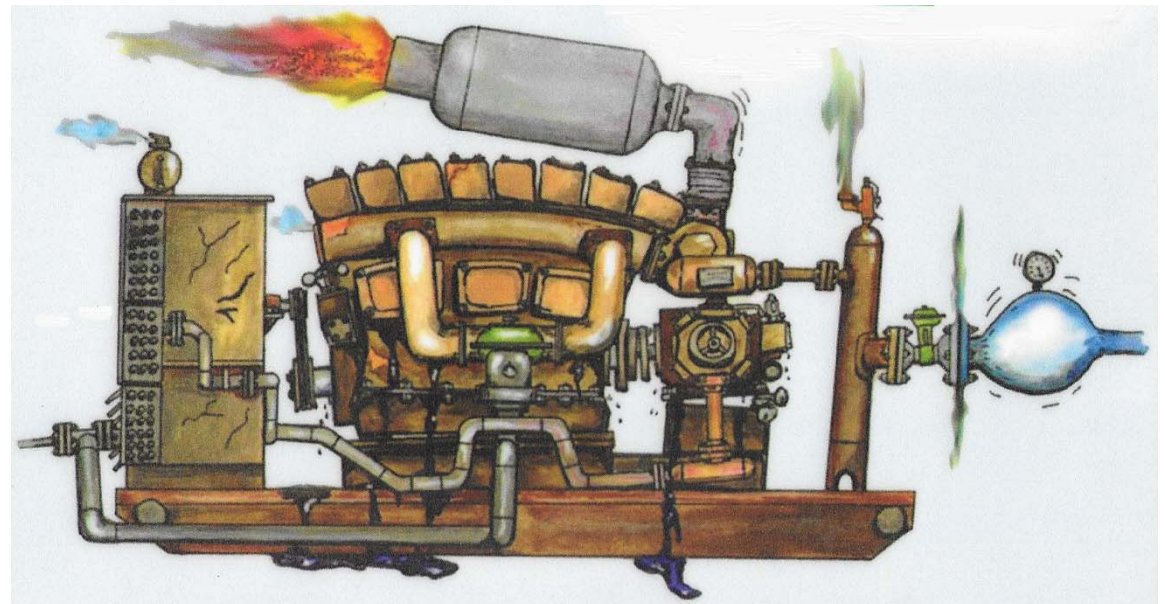


GMRC High Speed Compressor Package Guideline Project

GCA Overview

**ACI Services Inc.
W. Norm Shade, PE
April 24, 2017**



Why do we need this?

Industry experience is aging rapidly. Downturns accelerate the losses.

New people often don't know what they don't know.

There are no adequate specifications in existence.

- **API 618 is for slow-speed hydrogen-based process and refinery compressors**
- **API 11-P is incomplete, obsolete and no longer supported.**
- **ISO-13631 is incomplete in several key areas, and it can't be supported by U.S. companies anymore.**
- **GMRC Guidelines pertain to larger, pipeline gas compressors.**
- **GCA Guidelines are very limited in scope.**

Previous Guidelines:

- ***GMRC Guideline for High-Speed Compressor Packages for Natural Gas Transmission & Storage Applications***
 - Developed in 2011-2013; released in 2013.
 - Thus Guideline is currently being updated – completion estimated July 31, 2017
- ***GMRC Guideline and Recommended Practice for Control of Torsional Vibrations in Direct-Driven Separable Reciprocating Compressors***
 - Developed in 2013-2015; released in 2015.

New Guideline:

- ***Field Gas Compressor Package Guideline***
 - 2016 phase gathered lists of needs, issues and best practices.
 - Results were summarized in detailed report Sept. 30, 2016 that included the preliminary outline for the new Guideline.
 - **Current Phase** is the actual Guideline development: ***GMRC Guideline for High-Speed Compressor Packages for Field Gas Applications***
 - Collaborative effort with Gas Compressor Association.

Project Oversight Team

End Users:

Anadarko: Gary Bourn; William Charanza
Atmos: Josh Shaver
DCP Midstream: Hap Schadler
Enable Midstream: JT Boswell
EQT: Oscar Smith
Hess: Reuben Gates
Kinder Morgan: Christine Scrivner
National Fuel Gas: Terry Kreuz
Occidental: Mark Noall
Williams/Access Midstream: Rod Moreland

Packagers & Contract Compression Companies:

Archrock: Joe Voskuhl
Bidell: Scott Oltrogge
CSI Compressco: Chuck Kirk, Rod Guidry; Mike Kinney
Enerflex: Daren George; Stephen Kovach; Brian Peavy
Exterran: David Frier; Eric Taylor
Gas Drive Global: Alasdair Robinson
Great Plains: Terry McBride
JW Power: John Dutton; Joe Avila*; Mark Davis
NGSG: Dale Williams
Propak: Ron Delisle; Ron Ferguson
SEC EP: Kathy Norris; Jonathon Lee
Valerus: Brett Gill, Jack Smith

Equipment Manufacturers:

Alfa Laval/ACE: Misty Ingle
Ariel: Dave McCoy; Bryan Marlow
Caterpillar: Ken Hall
Cummins: Gary Farr; Cary McFarden
EADS/AXH: Rick Grapengator
Frick: David Seiler
GE/Waukesha: Victor Gharakhanian; Chris Kipp
Keltech: Ed Sobiexi
Miratech: Jeff Brown
Sullair: Steven Mueller

Engineering Companies:

ACI: Norm Shade* (leader); Kristen Gilcher*
Beta: Gary Maxwell, Josh Haff, Kelly Eberle
BCE: Mark Adkins*
SNC-Lavalin: Prashant Gijavanekar
Tech Transfer: Geoff Anderson

Other Data Resources:

Baldor/ABB: Alex DallaPozza
GE Energy: Brandon Bishop

39 companies

55 people

*** Work Team Leaders**

2016 Phase– Established basis and background material for new *Field Gas Compressor Package Guideline*

- Examined recent & current problems with high-speed upstream reciprocating (and screw) compressors.
- Identified past and current best practices.
- Identify opportunities/needs/benefits of a new guideline for package selection, integration, design installation, commissioning, and operation.
- Coordinated with the Gas Compressor Association (GCA), which will use the installation, commissioning and operation section(s) as their standard.
- 66 page Summary Report (@right).
- Proposal for finishing development and writing of the new Guideline.
- GMRC approved Guideline development.

HIGH-SPEED COMPRESSOR PACKAGE GUIDELINE
FOR FIELD GAS (UPSTREAM) APPLICATIONS

Survey of Problems, Solutions, Best Practices
& Technology Gaps

RELEASE 1.0

September 30, 2016

Gas Machinery Research Council

ACI Services Inc.



2016 Phase– End User Survey Participants

<u>Compressor End Users</u>		9 companies	
<u>Company</u>	<u>Representative(s)</u>	<u>Recip Survey</u>	<u>Screw Survey</u>
Anadarko Petroleum Corp.	William Charanza Gary Bourn	Received	NA
Atmos Energy	Josh Shaver	Received	Received
DCP Midstream	Hap Schadler	Received	Received
Enogex	J T Boswell	Received	Received
Energy Transfer	Jon Lee	Received	NA
EQT	Oscar Smith	Received	NA
National Fuel Gas	Terry Kreuz	Received	NA
Occidental Petroleum	Mark Noall	Received	NA
Williams/Access Midstream	Rod Moreland Scott Schubring	Received	NA



2016 Phase– Compressor Rental Fleet Survey Participants

<u>Compressor Rental Fleets</u>		6 companies	
<u>Company</u>	<u>Representative(s)</u>	<u>Recip Survey</u>	<u>Screw Survey</u>
Archrock	Joe Voskuhl	Received	NA
CSI Compressco	Chuck Kirk Rod Guidry Mike Kinney	Received	Received
Exterran	David Frier Eric Taylor	Restricted	Restricted
Great Plains Gas Compression	Terry McBride	Received	Received
JW Power	Joe Avila John Dutton	Received	Received
Natural Gas Compr. Systems	Dale Williams	Received	Received



2016 Phase– Compressor Packager Survey Participants

<u>Compressor Packagers</u>		10 companies	
<u>Company</u>	<u>Representative(s)</u>	<u>Recip Survey</u>	<u>Screw Survey</u>
Bidell	Scott Oltrogge	Promised	Promised
CSI Compressco	Chuck Kirk Rod Guidry Mike Kinney	Received	Received
Enerflex	Daren George	Received	Received
Exterran	David Frier Eric Taylor	Restricted	Restricted
Great Plains Gas Compression	Terry McBride	Received	Received
JW Power	Joe Avila John Dutton	Received	Received
Natural Gas Compression Systems	Dale Williams	Received	Received
Propak	Ron Delisle	Received	NA
SEC Energy Produces & Serv.	Jon Lee Kathy Norris	Received	NA
Valerus	Jack Smith Brett Gill	Promised	Promised

2016 Phase– Package Component Manufacturer Survey Participants

<u>Manufacturers</u>		10 companies		
<u>Company</u>	<u>Representative(s)</u>	<u>Compressor Survey</u>	<u>Engine Survey</u>	<u>Other Survey</u>
Alfa Laval ACE	Misty Stanton	NA	NA	Received
Ariel Corporation	Dave McCoy Bryan Marlow	Received	NA	NA
AXH/Eads	Rick Grapengator	NA	NA	Received
Caterpillar	Ken Hall	NA	Received	NA
Cummins	Gary Farr Cary McFarden	NA	Received	NA
GE/Waukesha	Victor Gharakanian Chris Kipp	NA	Received	NA
Gas Drive Global	Alasdair Robinson	NA	Received	NA
Frick	David Seiler	Received	NA	NA
Miratech	Jeff Brown	NA	NA	Received
Sullair	Steven Mueller	Received	NA	NA



2016 Phase– Compressor Packager Survey Participants

<u>Engineering Companies</u>		3 companies	
<u>Company</u>	<u>Representative(s)</u>	<u>Recip Survey</u>	<u>Screw Survey</u>
ACI Services	Norm Shade Kristen Gilcher	Received	Received
Beta Machinery Analysis (Wood Group)	Gary Maxwell Joshua Haff Kelly Eberle	Received	Received
Tech Transfer	Geoff Anderson	Received	NA

2016 Phase– Site Visits

<u>End User</u>	<u>Location</u>	<u>Compressor</u>	<u>Driver</u>	<u>No. of Units</u>
Chesapeake Energy	Spring Ridge South Gathering Station, Shreveport, LA	JGC/4	Caterpillar G3606TALE	5
Enable Midstream	S. Canadian Gathering Station, El Reno OK	Ariel JGK/4	900 rpm Toshiba motor	3
Enable Midstream	S. Canadian Gas Plant, El Reno, OK	Ariel JGC/4	900 rpm Toshiba motor	4
		Ariel JGK/4	1200 rpm Toshiba motor	2
		Ariel JGN/2	1200 rpm Toshiba motor	2
Enable Midstream (USA Comp. rental)	S. Canadian Gas Plant, El Reno, OK	Ariel JGT/4	Caterpillar G3508	1
Enable Midstream	Greenfield Gathering Station, Greenfield, OK	Ariel JGT/4	Caterpillar G3516	4
Mark West	Gas Plant Waynesburg, PA	Ariel JGH/4	1200 rpm Toshiba motor	4
Restricted	Gathering Station (confidential), WV	Ariel JGD/4	Waukesha P9390	1
Restricted	Gathering Station Bradford Co. PA	Ariel JGT/4	Caterpillar G3516B	5
National Fuel Gas	Bowen Gathering Station Kane, PA	Ariel JGT/4	Caterpillar G3516LE	1
		Ariel JGK/4	Caterpillar G3606LE	2
Williston Basin Int. PL	Glen Ulin Gas Boosting Station Glen Ulin, ND	Superior W74	Superior 12SGTB	2

10 sites; 36 packaged compressor units

Reciprocating Compressor Survey Summaries

- Advantages
- Disadvantages
- Problems Originating in the Quoting Stage
- All Problems
- Solutions Shared
- Suggested Changes & New Features

Screw Compressor Survey Summaries (Unique Issues Only)

- Advantages
- Disadvantages
- Problems Originating in the Quoting Stage
- All Problems
- Solutions Shared
- Suggested Changes & New Features

2016 Phase Findings: Key Issues

- Should there be different guidelines for small vs. medium-sized units? Maybe 50 to 400 & >400 to ≤2000?
- Cooler sizing – worst case; position, louvre control, variable fan drives
- Access: Safety, work platforms, lifting aids, access, portable crane access
- Guidance on site prep & installation
- Gravel pad specifications (content, compaction, size, grade level, etc.)
- Define what application information is needed (explain importance - tutorial)
- Shipping and storage guidelines
- Should there be basic minimum requirements (and selected optional requirements) to level the playing field for quoting
- Remote monitoring guidance

2016 Phase Findings: Key Issues (continued)

- Controls & diagnostics
- Sizing philosophy/capacity control/more efficient utilization
- Precautions with engine dry exhaust manifolds
- Fuel conditioning requirements/guidance
- Sour gas package guidelines
- Inlet filter/separator specifications & guidance for preliminary sizing for quotes
- Preliminary bottle sizing & guidance for quotes
- Minimal requirements for engineering studies (pulsation, vibration, torsional)
- Engine derating and parasitic loads; recommended margin
- Define and call attention to best practices throughout (but don't over-ride engine and compressor manufacturer's requirements).

2016 Phase Findings: Key Issues (continued)

- Include unique requirements of units for gas plants (parked for now)
- Leak and drip prevention and containment, cleanliness, etc.
- Cold weather considerations
- Different guidelines for rental vs. built for sale (preserve interests of rental fleets and avoid making millions of HP obsolete)
- Specifications: How much is enough?

Phase III - Guideline Table of Contents & Status

- 1. Scope and Introduction Initial Draft available for review**
 - 1.1 Introduction & Background
 - 1.2 Management Components for a High-Speed Compressor Design Project
 - 1.3 Considerations and Design Practices
 - 1.4 Statutory Requirements

- 2. Project Management and Schedule Initial Draft available for review**
 - 2.1 Project Manager
 - 2.2 Inspector
 - 2.3 Installation & Commissioning Coordinator
 - 2.4 Schedule

- 3. Compressor System Selection & Specification Draft to be completed by April 30**

- 4. Driver and Coupling Initial Draft available for review**
 - 4.1 Engine Selection and Specification
 - 4.2 Electric Motor Selection and Specification
 - 4.3 Coupling Selection and Specification

- 5. Capacity Control & Automation Design Draft to be completed by April 30**

- 6. Cooler Selection and Specification Initial Draft available for review**
 - 6.1 Typical Package Cooler Configurations
 - 6.1.1 Fan Draft
 - 6.1.2 Horizontal Inlet / Horizontal Discharge
 - 6.1.3 Single Fan Horizontal Inlet / Vertical Discharge
 - 6.1.4 Multiple Fan Horizontal Inlet / Vertical Discharge
 - 6.2 Application Considerations
 - 6.3 Specification Recommendations



Phase III - Guideline Table of Contents & Status

7. Gas Filtration and Separation **Initial Draft available for review**

7.1 Introduction

7.1.1 Liquid Formation and Accumulation

7.1.2 Principles of Separation

7.1.3 Principles of Filtration

7.2 Basic Requirements for Inlet Separators

7.2.1 Design and Construction

7.2.2 Inlet Separator Specification and Preliminary Sizing Guidelines

7.2.2.1 Required Specification Data

7.2.2.2 Recommended Efficiency and Preliminary Sizing

7.2.2.3 Recommended Separator Location and Features

7.3 Basic Requirements for Inlet Filters

7.3.1 Gas Filter Specification and Preliminary Sizing Guidelines

7.4 Pulsation Bottle and Suction Piping Considerations

7.5 Basic Requirements for Engine Fuel Gas Conditioning

7.6 Basic Requirements for Screw Compressor Discharge Separators and Filters

7.7 Gas Separator and Filter Monitoring and Control Guidelines



Phase III - Guideline Table of Contents & Status

8. Skid and Foundation *Initial Draft available for review*

- 8.1 Introduction
- 8.2 Owner Responsibilities and Project Management Considerations
 - 8.2.1 Responsibilities
 - 8.2.2 Milestones and Timing in Skid and Foundation Design
- 8.3 Summary of Foundation and Skid Design Requirements
 - 8.3.1 Skid and Foundation Performance Criteria
 - 8.3.2 Foundation Design
 - 8.3.2.1 Reinforced Concrete Block Foundation Design Considerations
 - 8.3.2.2 Driven Pile Foundation Design Considerations
 - 8.3.2.3 Screw Pile Foundation Design Considerations
 - 8.3.2.4 Caliche or Gravel Pad Design Considerations
 - 8.3.3 Foundation Static Design Requirements
 - 8.3.4 Foundation Dynamic Design Requirements
 - 8.3.5 Soil Analysis
 - 8.3.5.1 Bore Holes
 - 8.3.5.2 Geotechnical Testing Scope
 - 8.3.5.3 Geotechnical Soils Report
 - 8.3.5.4 Crosshole Seismic Testing Scope
 - 8.3.5.5 Crosshole Seismic Soils Report
 - 8.3.5.6 Soil Loading and Settlement
 - 8.3.6 Skid Design and Construction

9. Pulsation and Vibration Analysis and Control *Draft to be completed by April 30*



Phase III - Guideline Table of Contents & Status

10. Vessels, Piping and Package / Building Design & Assembly **Initial Draft available for review.**

- 10.1 Engine Fuel Conditioning
 - 10.1.1 Engine Fuel Properties
 - 10.1.2 Engine Fuel Treatment Considerations
- 10.2 Sour Gas Considerations
 - 10.2.1 H₂S Service Addendum
 - 10.2.2 CO₂ Service Addendum
- 10.3 Scrubbers and Condensate, Slug and Gas Liquid Considerations
 - 10.3.1 Scrubber Mounting
- 10.4 Pulsation Bottle Design and Fabrication
 - 10.4.1 Pulsation Bottle Design
 - 10.4.2 Pulsation Bottle Fabrication
- 10.5 Pressure Safety Valves (PSV)
 - 10.5.1 Pressure Safety Valve Mounting
 - 10.5.2 Pressure Safety Valve Vent Line Mounting
- 10.6 Equipment Accessibility and Maintainability
- 10.7 Buildings and Enclosures
 - 10.7.1 Building/Enclosure Types
 - 10.7.2 Skid Layout Considerations and Coordination with Building Enclosure
 - 10.7.3 Design Criteria and Permitting
 - 10.7.4 Ventilation and Heating
 - 10.7.5 Gas Detection
 - 10.7.6 Fire Detection
 - 10.7.7 Electrical
 - 10.7.8 Materials
- 10.8 Cold Weather Considerations
- 10.9 Noise Avoidance and Control
 - 10.9.1 Engine Exhaust Silencing
 - 10.9.2 Cooler Noise Control



Phase III - Guideline Table of Contents & Status

10. Vessels, Piping and Package / Building Design & Assembly (continued) **Initial Draft available for review.**

- 10.10 Compressor Distance Piece and Other Vents and Drains
 - 10.10.1 Packing and Distance Piece Vents and Drains
- 10.11 Installations With Flexible Hose
- 10.12 Engine Intake Air and Exhaust Systems
 - 10.12.1 Intake Air Systems
 - 10.12.2 Exhaust System Mounted on Cooler
 - 10.12.3 Intake Air and Exhaust Systems for Packages In Buildings Or Enclosures
- 10.13 Liquid Cooling Systems
- 10.14 Engine Starting Systems
- 10.15 Equipment Mounting and Alignment Considerations
- 10.16 Process Piping
- 10.17 Auxiliary Piping and Tubing
- 10.18 Conduit and Wiring
- 10.19 Mounting of Instrumentation and Control Devices
- 10.20 Skid, Equipment and Building Layout



Phase III - Guideline Table of Contents & Status

- 11. Instrumentation and Control** **Initial Draft available for review**
 - 11.1 Unit Control System
 - 11.2 Packaged Compressor System Instrumentation & Monitoring Requirements
 - 11.2.1 Minimum Reciprocating Compressor Instrumentation
 - 11.2.2 Minimum Rotary Screw Compressor Instrumentation
 - 11.2.3 Minimum Reciprocating Engine Driver Instrumentation
 - 11.2.4 Minimum Electric Motor Driven Instrumentation
 - 11.2.5 Air-Cooled Heat Exchanger Instrumentation and Control
 - 11.2.6 Other On-Skid Instrumentation
 - 11.3 Special Considerations
 - 11.3.1 Sour Gas Applications
 - 11.3.2 Heavy (Rich) Gas Applications
 - 11.4 Alarms and Shutdowns
 - 11.4.1 Basic Requirements
 - 11.4.2 Emergency Shutdown Systems
 - 11.5 Additional Instrumentation Guidelines and Recommended Practices
 - 11.5.1 Pressure Transmitters
 - 11.5.2 Pressure Gauges
 - 11.5.3 Temperature Instruments
 - 11.5.4 Level Switches
 - 11.5.5 Vibration Switches and Transmitters
 - 11.5.6 Solenoid Valves



Phase III - Guideline Table of Contents & Status

12. Equipment Safety, Accessibility and Maintainability Considerations Initial Draft available for review

- 12.1 Platforms, Walkways and Stairways
 - 12.1.1 Engine and Compressor Access
 - 12.1.2 Cooler Access
- 12.2 Engine Intake and Exhaust Mounting
- 12.3 Skid Deck and Access Covers
- 12.4 Auxiliary Systems and Piping
- 12.5 Electrical, Conduit and Wiring Systems
 - 12.5.1 Rigid Galvanized Steel Conduit
 - 12.5.2 Cable Trays
 - 12.5.3 Plug and Play Cables
 - 12.5.4 Armored Marine or Shipboard Cable
 - 12.5.5 Cable and Wire Size Selection
 - 12.5.6 Batteries
- 12.6 Maintenance Accessibility
 - 12.6.1 Machine Guards
 - 12.6.2 Coolant Systems
 - 12.6.3 Fluid Supply Fill Points



13. Inspection and Testing Draft to be completed by April 30

14. Site Considerations Draft to be completed by April 30

15. Commissioning Draft to be completed by April 30

16. Operation and Maintenance Considerations Draft to be completed by April 30

Phase III - Guideline Table of Contents & Status

17. Appendices Draft partially available for review; to be completed by May 15

A Data Sheets and Checklists

- A.1 Data Required for Inlet Separator and Filter Sizing
- A.2 Recommended Reciprocating Compressor Instrumentation
- A.3 Recommended Rotary Screw Compressor Instrumentation
- A.4 Recommended Engine Instrumentation
- A.5 Recommended Electric Motor Driver Instrumentation
- A.6 Recommended Balance of Package Instrumentation
- A.7 Minimum Required Compressor Package Alarms and Shutdowns
- A.8 Recommended Project Sequence and Schedule For A High-Speed Compressor Package

B Recommended Computational Procedures

- B.1 Simplified Methods for Preliminary Sizing of Inlet Separators

C Informative Reference Material

- C.1 Typical Package Start-Up Control Logic
- C.2 Typical Package Shut-Down Control Logic
- C.3 Typical Compressor P&ID – Cover Sheet & Legend
- C.4 Typical Compressor P&ID - Motor-Driven Rotary Screw
- C.5 Typical Compressor P&ID – Motor-Driven Reciprocating
- C.6 Typical Compressor P&ID – Engine-Driven Reciprocating
- C.7 Coordination and Project Management Guidelines for Successful Screw Pile Installations
- C.8 Gravel Pad Specification – Rental Fleet Example
- C.9 Gravel Pad Specification – End User Example 1
- C.10 Gravel Pad Specification – End User Example 2
- C.11 Gravel Pad Specification – End User Example 3
- C.12 Cementitious Grout Leveling Layer on Gravel Pad

D References



Designing for Safety is an Important Aspect in the Guideline

SLIP, TRIP & FALL HAZARDS IN THE FIELD GAS COMPRESSION INDUSTRY



Joe Avila, HSE Supervisor, JWPC

Schedule History & Remaining Steps

Aggressive Schedule – want to be ready for the market recovery!

Prefer a collaborative process if sufficient timely participation.

- Launched Work Teams & Process – Nov. 30/Dec. 1, 2016
 - Reviewed needs and recommend section content
 - Made sure key issues are addressed where applicable
 - Developed content, or portions of content, where practical
 - Wrote draft sections of guideline (where skill sets and interest apply)
- Face-to-Face Work Day (San Antonio) – Jan. 23, 2017
- Issued Draft & Final Guideline Sections for review by Guidance Team
 - Sections 7, 11 – draft Feb. 28; final **April 30**
 - Sections 5, 8, 9 – draft Mar. 15; final **May 10**
 - Sections 10, 12, 14 – draft Apr. 15; final **May 15**
 - Sections 13, 15, 16 – draft Apr. 30; final **May 15**
 - Sections 3, 4, 6 – draft May 1; final **May 19**
 - Sections 1, 2 – draft April 1; final **April 30**
- Face-to-face Review Meeting (Dallas) – May 15
- Issue Final Field Gas Guideline to legal for review – Jun. 30
- Issue Guideline to GMRC for Review and Approval – Aug. 1



Questions / Comments?



- **Work product is greatly anticipated within the industry**
- **API Officials are very interested in using this and the other GMRC Guidelines as the basis for a new API spec to replace the old API-11P spec.**