Compressor & Driver Selection Strategies

Gas Electric Partnership Conference
February 8-9th 2017 Houston, TX

Agenda

- Overview Compressor, Driver and Control Technologies
- Tips to specify Rotating Machinery Correctly
- Common Selection Criteria
- Compressor Application Charts

ROUNDTABLE:

- Host:
- **Chris Kapp**
- Dr.Rotating LLC

Mitchell Mauch	Kinder Morgan
GeJuan Coles	Williams
Gus Posada	Boardwalk
Arnold Eisenstein	Universal Pegasus

In the Future, far, far away compressors work perfectly ?

Maybe not...

Common types and sub-types of Drivers

Engines
- Diesel, **Gas** or CNG/LNG

Gas Turbines
- **aero-derivative** / **industrial**

Electric Motors
- **fix speed motor**
- synchronous / induction / permanent magnet
- **variable frequency drives**

Gears: **helical**/ fluid couplings /**mechanical variable speed drives**

Multi Drives, Generators, Expansion & Steam Turbines…………….

Common types and sub-types of Compressors

Reciprocating

- Vertical, V ,W types, membrane & **horizontally opposed**

Rotary Screw

- dry and oil flooded

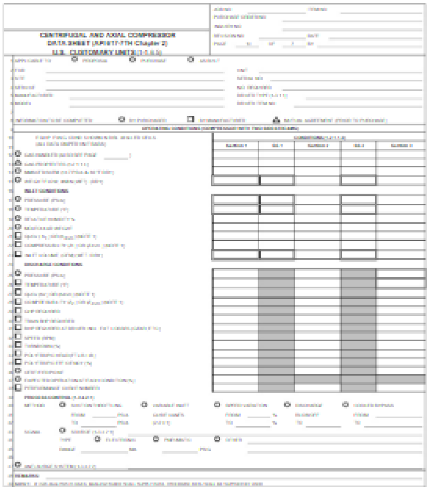
Centrifugals (radial)

- Centrifugal **pipeliners** (axial inlet / radial inlet)
- Beam style or in-line centrifugals
- **hermetically sealed motor centrifugals** (beam style)
- Integrally geared centrifugals
- axial / radials
- axials

Specify Rotating Machinery Correctly

Use API Style Data Sheets – 617/618

- Great check list to remind you to put in everything
  You only need the first pages for the basics


CENTRIFUGAL AND AXIAL COMPRESSOR
DATA SHEET (API 617-7TH Chapter 2)
U.S. CUSTOMARY UNITS

Detail <u>ALL</u> Operating Points

- Correct equipment selection considers part load and controls
  Requires a full understanding of all operating conditions.
- Have a good understanding of current and future demand.
- *(just because you don't know what it is, don't assume it doesn't exist)*
- Use detailed gas analysis instead of just standard gravity
  (important for correct performance and material selection)

Integration of the Compressor Train

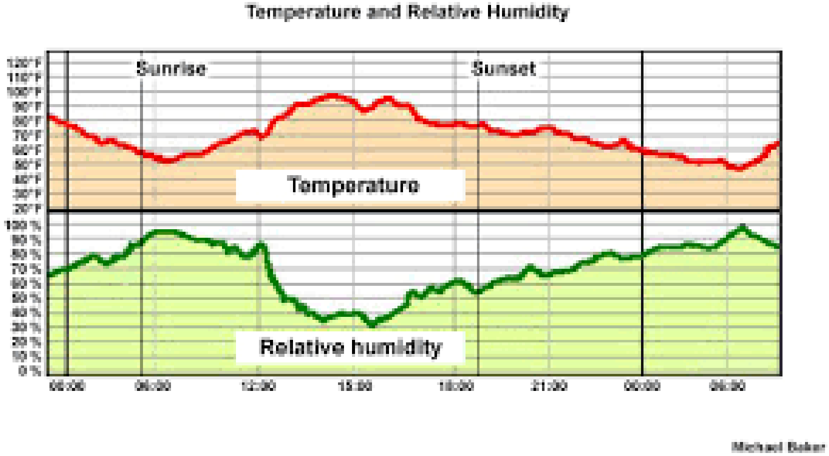
Certain types of drivers and compressors
naturally go together . (i.e. similar speeds)

Consider using a manufacturer who has experience
integrating similar, referenced equipment for
similar duties'"
Give me your latest technology with 20 years experience"

Specify Rotating Machinery Correctly

Don’t Oversize (or Undersize) Equipment

Ambient conditions maximum versus design temperatures.
If you always design for max then your equipment is running in inefficient part load even for normal operations.



Understand your Process

Are you operating with typical pipeline resistance curves
multiple side-streams in and out ?
or working a gas storage cavern ? Or a combination……?

Don’t <u>design</u> the equipment for the OEM

Describe <u>all</u> the operating points and their importance but let the OEM determine their internal design point themselves.

Common Selection Considerations

- **OPEX** (Fuel / Electricity)
- What rate contracts do I get ?
- What supply contract conditions ?, i.e. demand charges
- Compressor and drive train efficiency

- **CAPEX** (train + installed cost incl. foundations/ehouse etc.)

- **RELIABILITY** (equipment or station) (scheduled maintenance)
- Backup compressors ? Spare substations and electrical feeds?

- **AVAILABILITY** (unscheduled / scheduled maintenance)
- Minimum thresh hold 90, 95, 97 % or higher ?
- Local and quick technical and parts support
- Long Term Service agreements for critical installations ?
- Standardization of fleet equipment ?
- Parts inventory

Criteria are not listed in order of importance

Common Selection Considerations

- **MAINTEX** (Scheduled / Overhauls / Modernization)
- Cost and frequency of scheduled maintenance
- Major overhaul costs
- Cost to upgrade from obsolesce (i.e. electronics)
- Operator personnel familiar with technology

- **FOOTPRINT**
- Important for brown field sites: incl. train, station & periphery

- **TECHNOLOGY & COMPATIBILITY**
- Vibrations, pulsations, valve issues ?
- High Speeds vs Slow Speeds ?
- Reciprocating and centrifugal technology working in parallel ?
- Unequal size horsepower in one station ? Parallel operations ?
- Will electronic equipment be supported in 20 years ?
- Risk mitigation adopting unfamiliar types of technology

*Approaches vary by specific operators and projects

Common Selection Considerations

- **STATION, PIPE & WIRE**
- Station cost vs Pipe looping ~$5M/mile, right of way extra*
- High Voltage lines can also be very expensive ~$1.25M/mile*
- Does the operator have to purchase substation & auxiliaries ?
- upgrades vs horsepower replacement at up and downstream stations
  High pressure pipe hydraulics reduces HP requirements.

- **CONTROLS / OPERABILITY**
- How do I start-up ?
- Automatic, remote step-less control often desired.
- What range is required ? Important on gas drives: CO_x, NO_x
- Block out speeds or ranges?
- Be able to re-aero up to 25% for future growth ?

- **EMISSIONS / PERMITTING**
- PPM and absolute tons/year, emissions offsets ?
- BACT
- Government questions use of SCR, waste heat recovery evaporative cooling, combined cycle drives
- Replace smaller, dirty units with cleaner larger units
- Limit Blowdowns, methane emissions
- Air/Noise dispersion

*Broad estimates, may vary strongly by project

What are the most important criteria ?

- **<u>"It Depends"</u>**

- Customer surveys suggest that availability is critical (not just reliability) but operators struggle to quantify this.

- Operational costs are important but once again difficult to measure and quantify.

- Project specific details may "trump" pure technical preferences.

A dialogue is very important between operators and providers what an optimum solution cold be. Requires real engineering and economic reviews

Axial and Axial/Radial Compressor

Mainly air and nitrogen

Mainly e-motor drive (but also turbines)

Good volume and pressure control

Excellent efficiencies

Low pressure capability only

High cost

P/P
PSIG
Bar

4000
360

2000
180

1000
90

500
45

Radial-Axials

Axials

20,000
34,000

100,000
170000

Actual Volume
CFM
m3/h

Compressor ranges are indicative only and vary by range and actual experience from OEM to OEM. ,please consult an OEM for a specific design and references.
Images taken from Wikipedia are typical only and not meant to recommend a specific OEM.

Oil Flooded Rotary Screw

Fuel Gas Boosting

Upstream boosting at low pressures

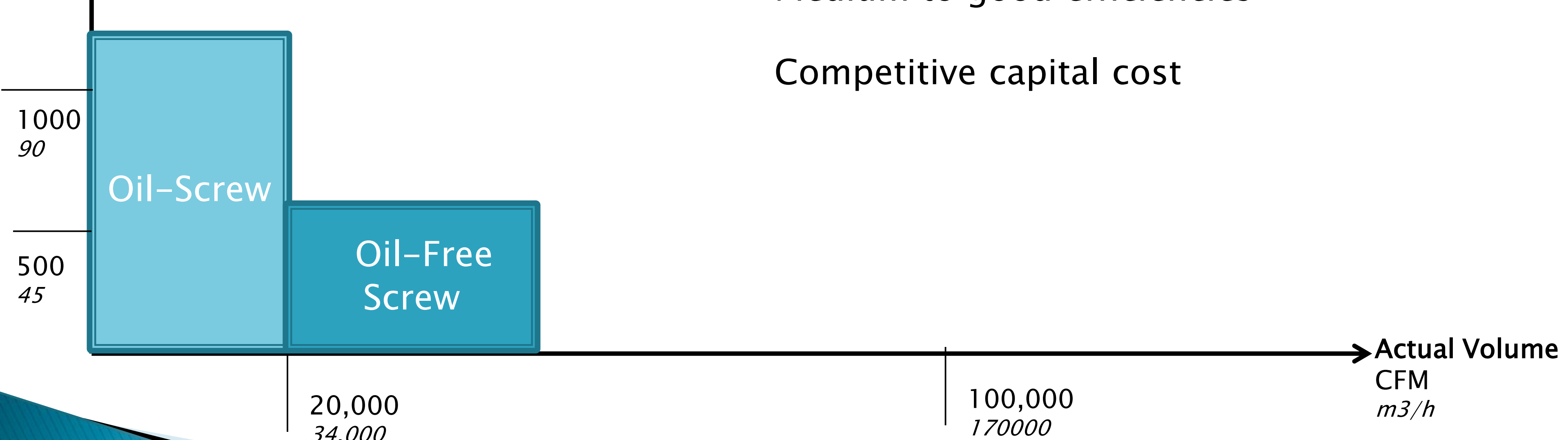
Good volume control with discharge slide valve.

VFD and engine drives are popular

However constant pressure ratio !

Medium to good efficiencies

Competitive capital cost



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P/P
PSIG
Bar

Single Stage Integrally Geared Compressor

Single stage pressure ratio up to 2
One or more stages can be used as an expander
Low and medium suction pressure
References up- and downstream
Fixed speed electric drive only
Inlet Guide vanes for maximum turndown.
Good efficiency
Competitive cost

Multi Stage Integrally Geared Compressor

Pressure ratios up to 15!
API 617 Part 3 designs available
Low and medium suction pressures
High discharge pressures up to 1600 PSIG
References LNG and and CO2 reinjection
Fix speed electric drive
Guide vanes provide maximum turndown
High efficiency (with limited intercooling)
Competitive cost

4000 *360*
2000 *180*
1000 *90*
500 *45*

20,000 *34,000*
100,000 *170000*
Actual Volume CFM *m3/h*

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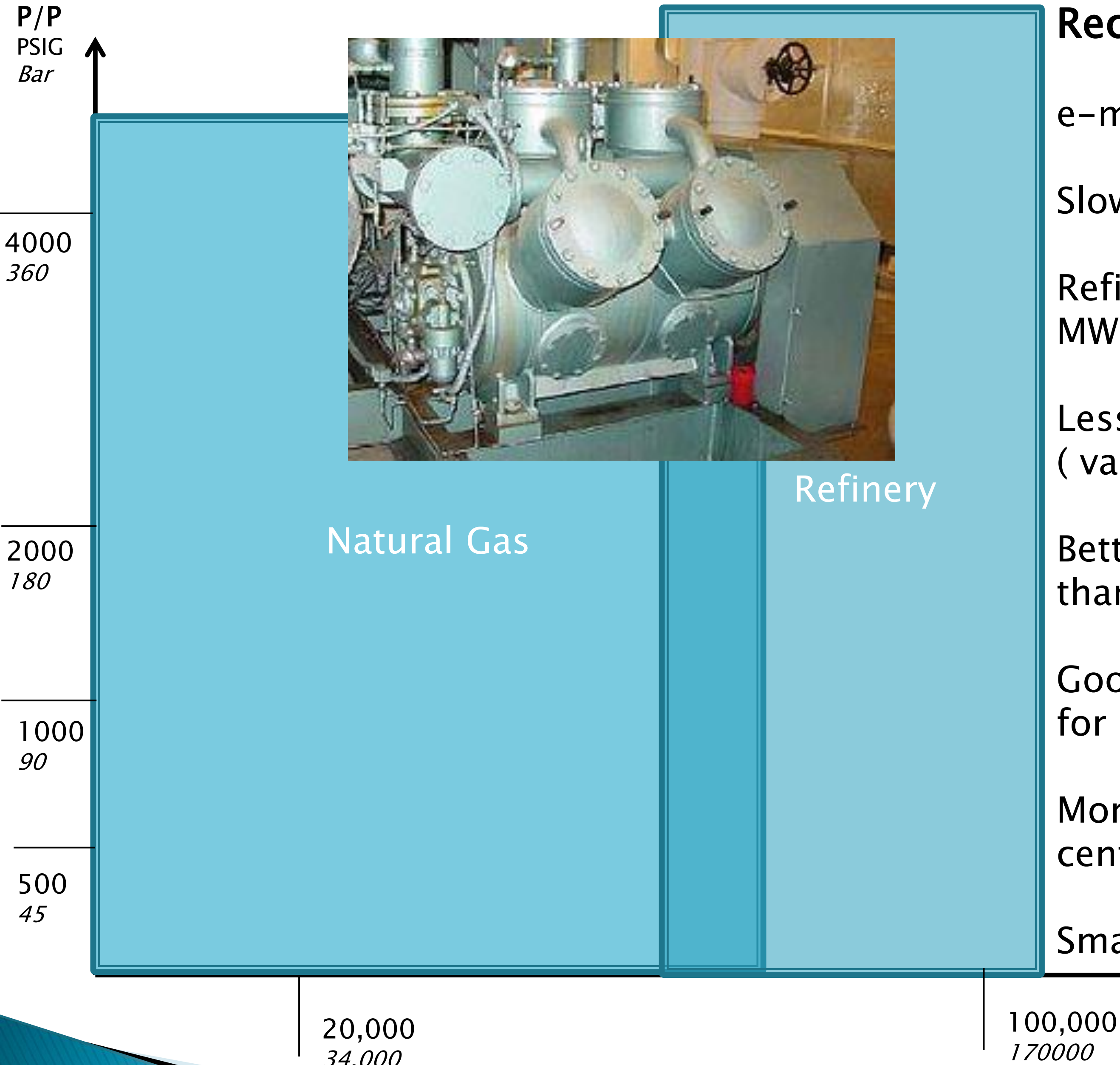
Reciprocating Compressors



e-motor and gas engine drive

Slow & "high" speeds available

Refinery experience up to 34 MW

Less flexible flow control, (valves- manual controls)

Better pressure ratio capability than centrifugals

Good efficiencies (watch out for inter-stage losses)

More wear parts than centrifugals

Small units good cost

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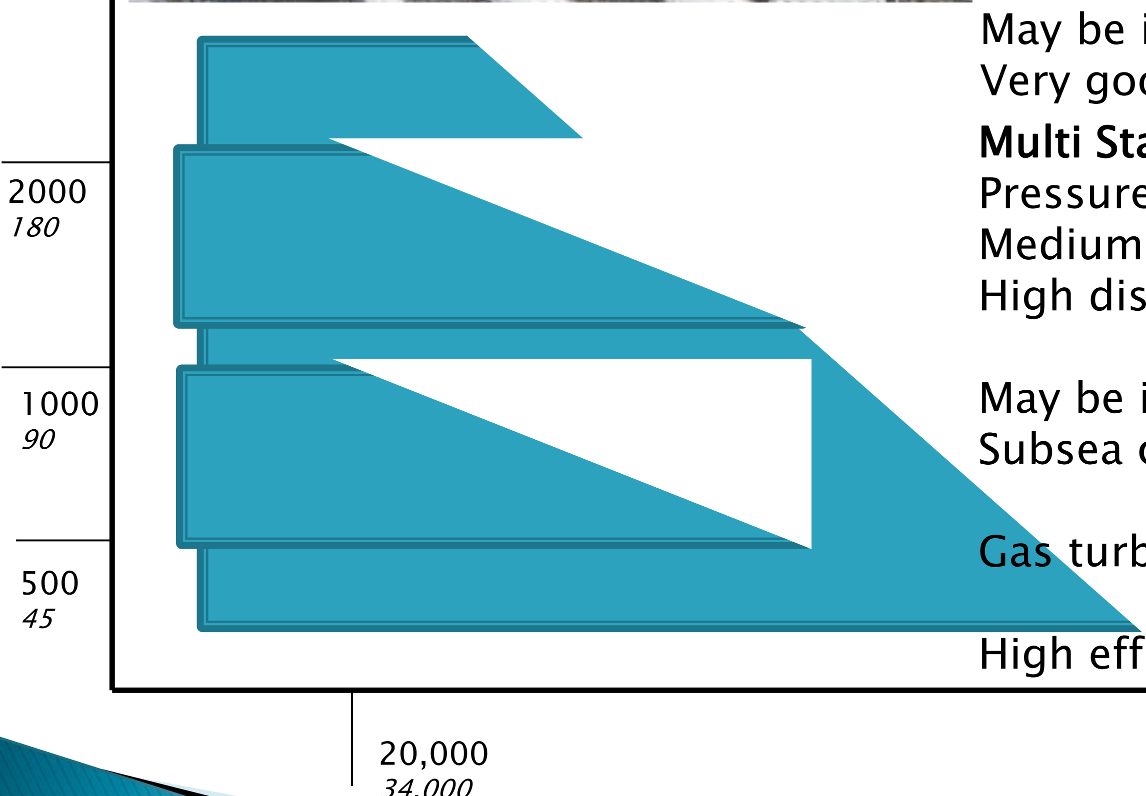

Single Stage Pipeline Compressor

Single stage pressure ratio up to 1.8

Medium and high suction pressure

Well established midstream

Gas turbine, mechanical and electric drives
May be integrated with e-motor
Very good efficiency, very good turndown

Multi Stage Pipeliner Compressor

Pressure ratios up to 5-6 per casing
Medium and high suction pressures
High discharge pressures above 3250 PSIG

May be integrated with e-motor
Subsea compressor is a derivative

Gas turbines, electric and mechanical drives

High efficiency

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Now to the Round Table

Christean Kapp
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Marybeth McBain
Kinder Morgan

Marybeth McBain works as a senior pipeline engineer in Kinder Morgan's gas compression engineering group. In this role, she specializes in recommending gas compression for new pipeline projects and reviewing operational needs for compression improvement and horsepower augmentation projects.

Marybeth previously worked for Apache Corporation as a facility engineer and for Southwest Research Institute in San Antonio, Texas. She has been awarded four patents in pulsation control technologies. Marybeth has published over a dozen technical papers ranging from reciprocating and centrifugal compressors, gas monetization, LNG turbomachinery and pulsation / vibration control.

She holds a bachelor's mechanical engineering degree from UT Austin and a masters degree from Georgia Tech.

Mitchell Mauch
Kinder Morgan

Mitchell has 36 years of experience in engineering design and project management of compression facilities for several major gas transmission companies including; Tennessee Gas Pipeline, ANR Pipeline, Kern-River Pipeline and he is currently employed by Kinder Morgan Inc. as staff compression engineer in the KMI Engineering and Technical Services group located in Houston Texas.

Mitchell has been directly involved in the design and construction of over 500,000 horsepower of pipeline compression. The horsepower was installed at major transmission compression stations all across the United States. His experience includes both reciprocating and centrifugal compressors as well as electric motors, gas turbines and reciprocating engines.

Mitchell has a bachelor of science from Texas Tech University and is a licensed professional engineer.

Ge'Juan Cole Williams

Ge'Juan Cole, P.E., is a Senior Project Developer at Williams Gas Pipeline. With over 14 years of experience in the oil and gas industry, he has held various positions in operations, project engineering, project management, and planning primarily focused on installing compression facilities on the Transco natural gas pipeline system. In his current role, he is responsible for leading multifunctional teams in the development of market expansion opportunities to build critical large scale pipeline transmission infrastructure necessary to meet the growing global demand for natural gas. Ge'Juan earned a BS in Mechanical Engineering from Georgia Tech, a BS in Mathematics from Morehouse College, and an M.B.A in Global Leadership from the University of Houston. He is also licensed by the Texas Board of Professional Engineers.

Arnold Eisenstein
Universal Ensco

Arnold Eisenstein has served as Project Director, for Universal Pegasus since 2013. In this capacity, Arnold is responsible for technical oversight of assigned compression and pipeline projects.

Arnold began his pipeline career as a consultant to Aramco in the 1980s, joined Enron's Group Technical Services in 1990 and has served in a number of key leadership positions with Enron Engineering and Construction including Director of Compression Projects (worldwide 1990) and Project Director and Project Manager for Major expansions. At Universal Ensco, Arnold has participated in major projects for Net Midstream – Agua Dulce Compressor Station (100 KHP electric compression) and currently assisting with the design of the VCP stations for Spectra Energy.

Arnold earned a Bachelor of Science degree in Engineering from Texas A&M.

Gus Posada