Compressor & Driver Selection Strategies

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25+ years Turbomachinery experience with Demag-Delaval (now Siemens), Rolls-Royce (now Siemens), Siemens (proper), Hoerbiger in general management, application engineering, product as well as project management and technical field support. Member of API taskforces 618/688.

Currently President and General Manager of CompMaster, a provider of new and refurbished reciprocating and screw compressor packages in Houston.

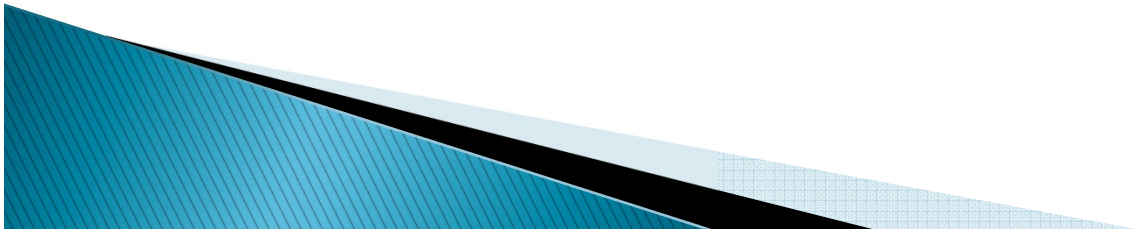
Global Experience with Pipelines: Kindermorgan, PG&E, FGT, SNG, TransCanada, PDVSA, Petrobras, GAIL, Ruhrgas, CNPC etc.

Master's Degree of Aerospace Engineering & Science at RWTH Aachen(D) & NIT Trondheim(N)

Agenda

- Top Tips to specify Rotating Machinery Correctly
- Common Pipeline Project Selection Questions & Criteria
- Compression Technology Application Charts

This presentation was compiled interviewing experts from Boardwalk, Williams, Energy Transfer, Centerpoint, Kinder Morgan and Universal Pegasus, however the opinion expressed in this presentation is that of the author.



Avoid Basic Specification Mistakes

Detail ALL Operating Points and Scope

Have a good understanding of current & future demand.

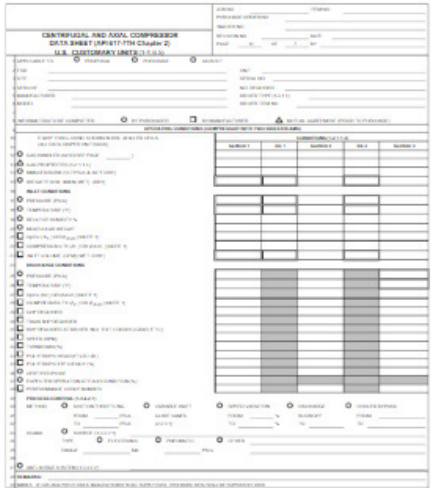
(determines sizing and control philosophy, big $$$$)

Use detailed gas analysis instead of just standard gravity

(important for correct performance and reliability)

Use API Style Data Sheets – 617/618/619

(internationally understood with all major OEMs)



Don't Design the equipment for the OEM,

Involve OEMs up front in suggesting options and alternatives for best results. A very high level of technology & expertise is required.

Engineering is the art of compromise.

Specify Rotating Machinery Correctly

Don't Oversize (or Undersize) Equipment EASIER SAID THAN DONE

If your Turbine/Engine is oversized you increase your fuel burn at part load dramatically.

A slight oversizing enhances production availability and allows catch-up

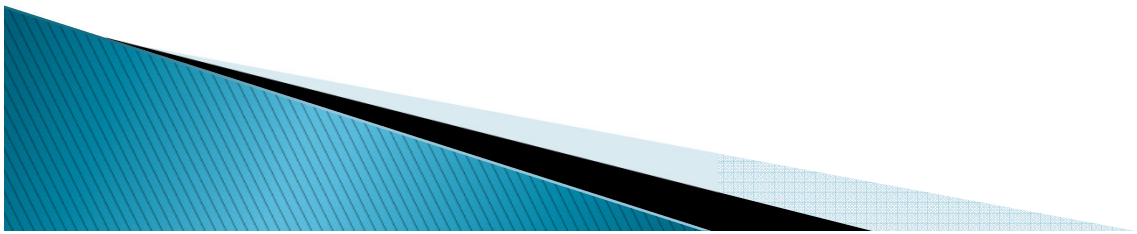
However you may find emissions limits at part load that reduce your operational flexibility.

A flow control system is required to operate at part load – often overlooked.

Have a clear idea of what backup compression is required

On the other side if the compressor is too small you wasted a multi million dollar investment.

Set your Priorities, make it a conscious decision.



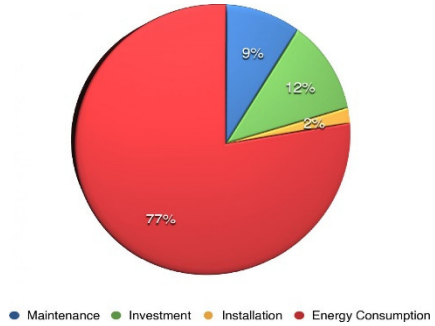
Common Selection Considerations

1. CAPEX (compressor train + installed cost incl. foundations/ehouse etc.)

2. OPEX (Fuel / Electricity)

- What rate contracts do I get ? what electrical demand charges ?
- Calculate Compressor & Driver peak & part load fuel costs

Fuel is the MAJORITY of YOUR OPERATING COST



3. EQUIPMENT RELIABILITY (including scheduled maintenance)

- Mainly driven by quality of machine design.
- Backup compressors ? Spare substations and electrical feed
- Your upstream and downstream pipeline stations may be the backup!

4. AVAILABILITY (unscheduled & scheduled maintenance)

- Threshold 98 % or even higher. Does this supports the gas supply contract?
- Quick technical and parts support is as critical as equipment reliability

Common Selection Considerations

5. MAINTEX (Maintenance / Overhauls / Training)

- Cost and frequency of scheduled maintenance
- Emission regulations drive engine/turbine overhaul costs up!
- Operator personnel must be familiar with technology

6. FOOTPRINT

- Important for brown field sites: incl. train, station & periphery
- electric driven compressor stations require a large station footprint !
- exhaust noise concerns push station boundary out for engines/turbines

7. COMPRESSOR TECHNOLOGY & COMPATIBILITY

- High Speed vs Slow Speed Integral Reciprocating Compressors?
  (cost vs reliability) High speeds replacing slow speeds despite revamps
- Reciprocating and Centrifugal technology working in parallel ?
- Unequal size horsepower in one station ? Parallel/Series Operations ?

*Approaches vary by specific operators and projects

Common Selection Considerations

8. STATION, PIPE & WIRE

- Pipe looping ~$5M/mile, $12-20M/Station? right of way extra*
- High voltage lines also cost money ~$1.25M/mile*
- Will the operator purchase or lease substation & auxiliaries ?
- High pressure hydraulics reduces compressor HP dramatically, pipe cost ↑

9. CONTROLS & OPERABILITY

- How do I start-up ? Not a trivial question.
- Automatic step-less or variable speed flow control often desired
- OEMs may block technically speed or load ranges, a real issue for operations

10. EMISSIONS & SAFETY

- How does the permit work: PPM, tons/year, emissions offsets ?
- What level of BACT(best available current technology) do I have to use
- Be prepared to argue your case for Catalytic Reduction, Waste Heat Recovery evaporative cooling, combined cycle drive when permitting.
- Limit blowdowns for lower methane emissions
- Station Noise limits
- HAZOP Studies

*Broad estimates, may vary strongly by project

CONCLUSION: It Depends on your Situation

Operator survey suggest that AVAILABILITY is critical *Loss of production can be 10-100 thousands of dollars per day or worse*

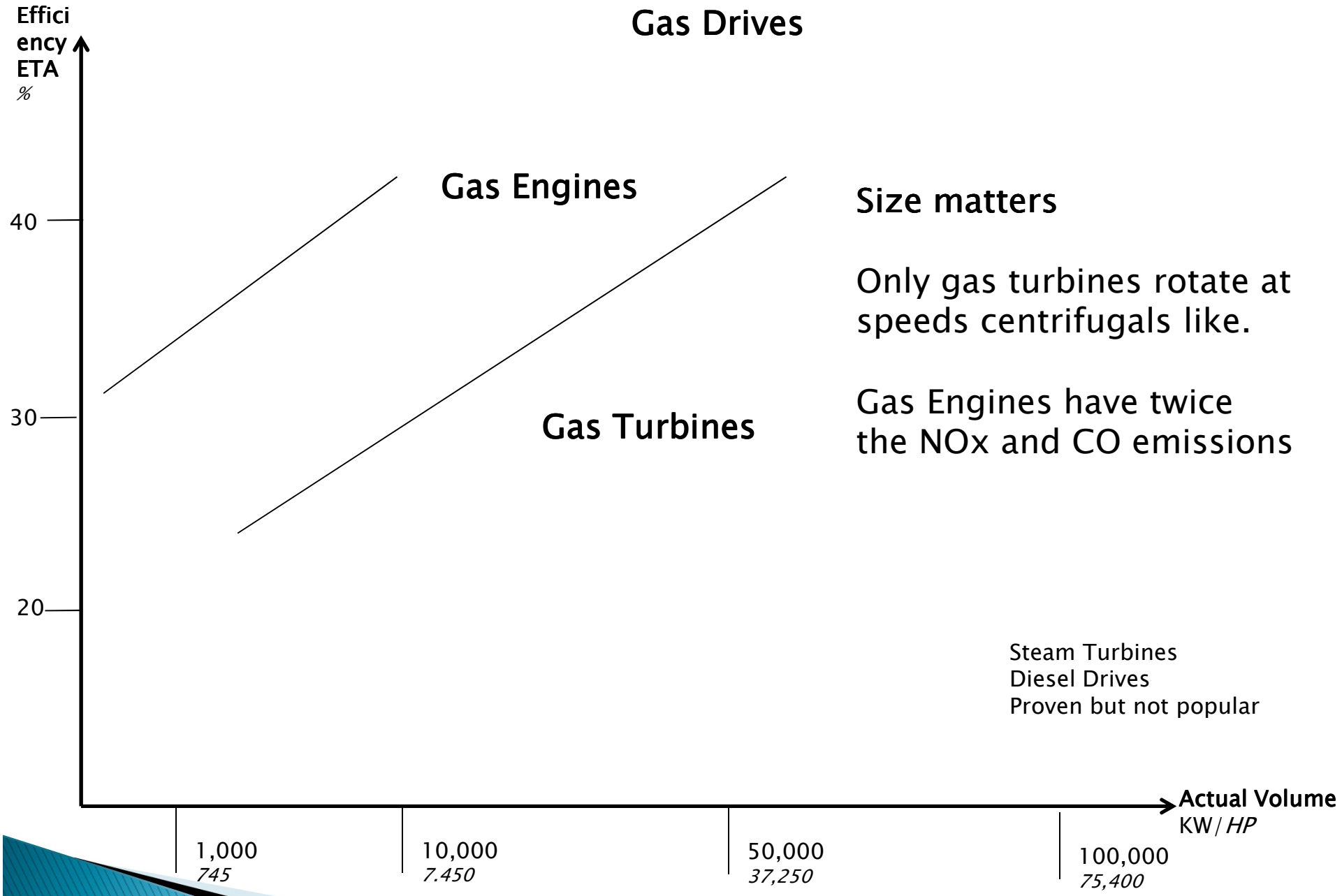
You really don't want to take this phone call

- DELIVERY and RISK are other key drivers to a compressor project.

- ALREADY a hot topic is Digitalization…… Remote operations and condition based monitoring and maintenance. But O&G is behind.

- ANOTHER hot topic is Renewable Energy. How do we manage very flexible operation and energy storage ?

Gas Drives



Size matters

Only gas turbines rotate at speeds centrifugals like.

Gas Engines have twice the NOx and CO emissions

Steam Turbines
Diesel Drives
Proven but not popular

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.

Electric Drives

P/P
PSIG
Bar

Variable Frequency Electric Drives

Mechanical Variable Speed
Very High Reliability

Dual Drive, Ultimate Fuel Type Flexibility

Actual Volume
KW / *HP*

1,000
745

10,000
7.450

50,000
37,250

100,000
75,400

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Oil Flooded Rotary Screw

Fuel Gas Boosting

Upstream boosting at low pressures

Volume control with discharge slide valve.

VFD e-motor and engine drives are popular

However constant pressure ratio !

Medium to good efficiencies

Competitive capital cost

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Single Stage Integrally Geared Compressor

Single stage pressure ratio up to 2
Low and medium suction pressure
References Fuel Gas Boosting and others
Fixed speed electric drive,
Inlet Guide vanes for maximum turndown.
Very 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 CO2 reinjection
Fix speed electric drive
Inlet Guide vanes for maximum turndown
Very Good efficiency
Competitive cost

P/P
PSIG
Bar

4000
360

2000
180

1000
90

500
45

Actual Volume
CFM
m3/h

20,000
34,000

100,000
170000

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Reciprocating Compressors

Refinery

Natural Gas

Diaphragm

Ajax Integral

P/P
PSIG
Bar

4000
360

2000
180

1000
90

500
45

20,000
34,000

100,000
170000

Actual Volume
CFM
m3/h

e-motor and gas engine drive

High Speed Experience up to 9,000 HP

Slow Speed Experience up to 50,000 HP!!!

Less flexible flow control, (valves- manual controls)

Better pressure ratio capability than centrifugals

Good efficiencies (but watch out for high inter-stage losses)

Higher maintenance cost

Less reliable than centrifugals

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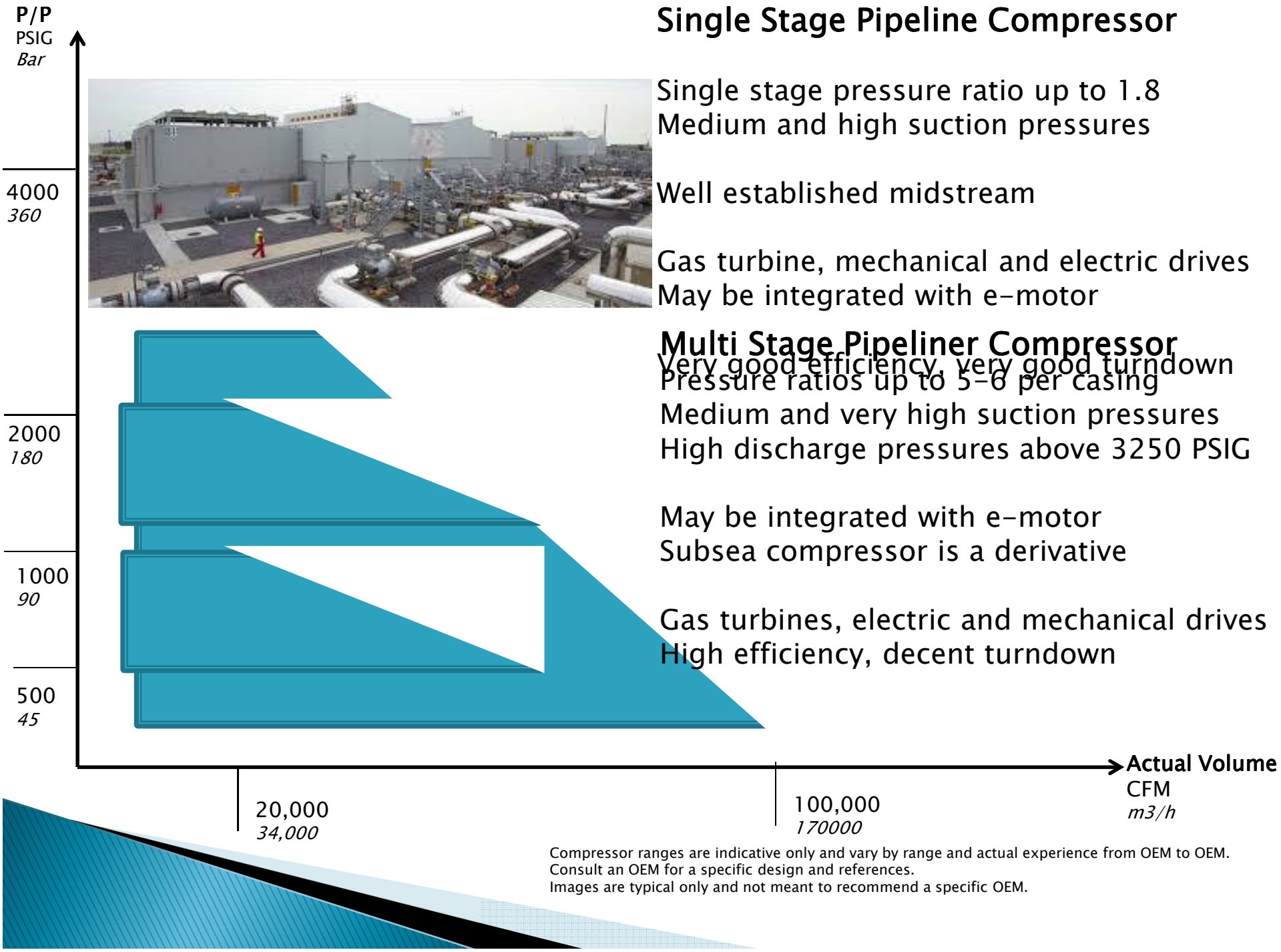

Single Stage Pipeline Compressor

Single stage pressure ratio up to 1.8
Medium and high suction pressures

Well established midstream

Gas turbine, mechanical and electric drives
May be integrated with e-motor

Multi Stage Pipeliner Compressor

Very good efficiency, very good turndown
Pressure ratios up to 5-6 per casing
Medium and very 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, decent turndown

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Questions ?

See you soon :
Gas Electric Partnership Conference
January 31-February 1, 2018
CenterPoint Energy Tower, 1111 Louisiana St

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In the Future, Far, Far away
Do Compressors work perfectly ?

Maybe not…