Advantages of Couple-Free Compression Technology and Flexible Cylinders

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Reciprocating Compression , GE Oil & Gas

Imagination at work

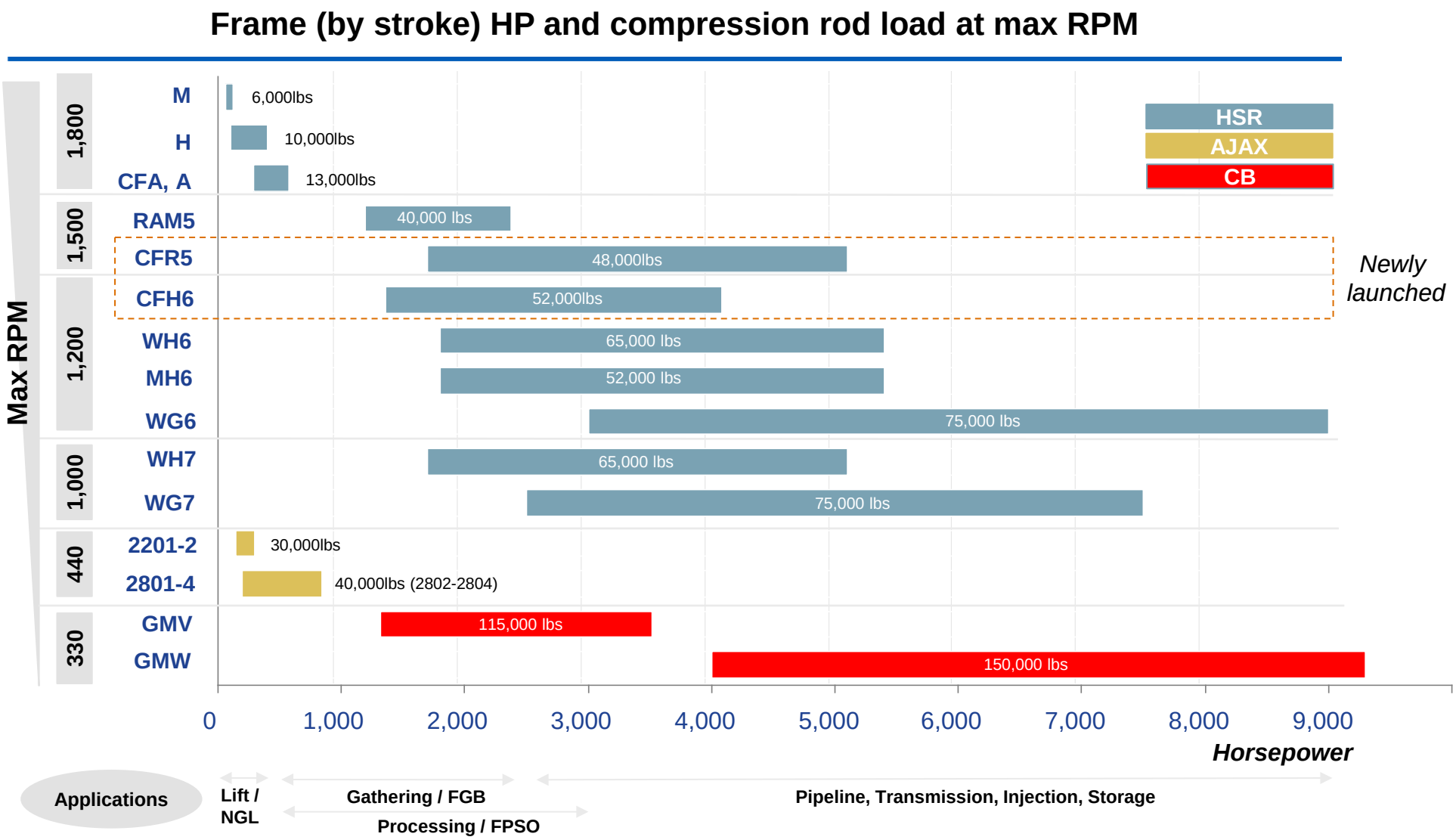
180 years and counting

And we’re setting the stage for the next 180

- 800+ employees, 7 global sites, headquarters in Houston
- Manufacturer of gas engines and compressors
- Product names in our portfolio include Ajax™, Cooper-Bessemer™, High-Speed Reciprocating Compressors (Formerly Gemini ™& Superior™) & API618 Reciprocating Compressors
- Our roots go back to 1833; GE Oil & Gas acquired Gemini Compressors in 1999; Cameron Compression in 2014
- Gas lift, Gas gathering & injection , Station boosting , Gas storage , Transmission, Processing, Fuel gas boosting




GE Reciprocating Compression with 14 commercially available compressor models



Note: RPMs and HP displayed are max

Couple-Free Frame Summary

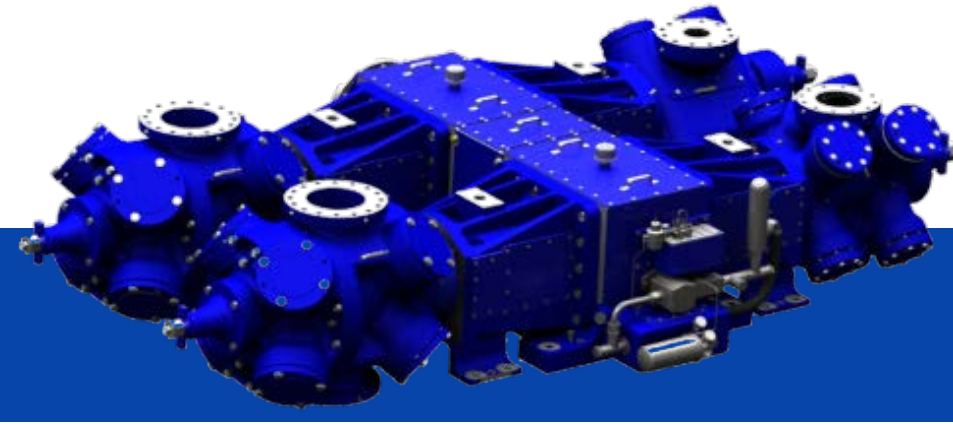
GE's Couple-Free Frame Benefits

Matching capability of 1400 RPM engines and 1200 RPM Waukesha™ VHP™

Lower-vibration couple-free crankshaft design

Reduces wear-related maintenance costs & minimizes cost for skid/foundation installation

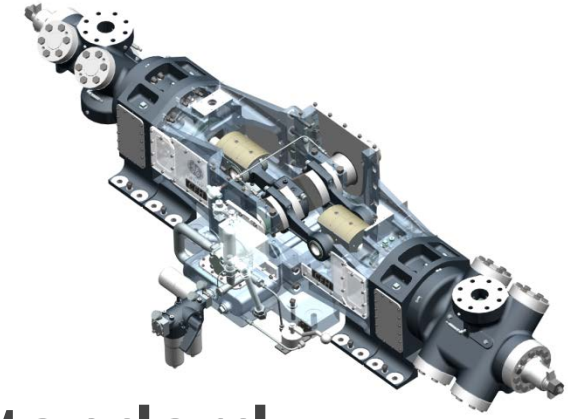
Well-proven frame designs built to last: robust rod load of 48,000 - 52,000 pounds



The CFH/CFR frame is an ideal solution for our industry: reliable, durable & flexible.

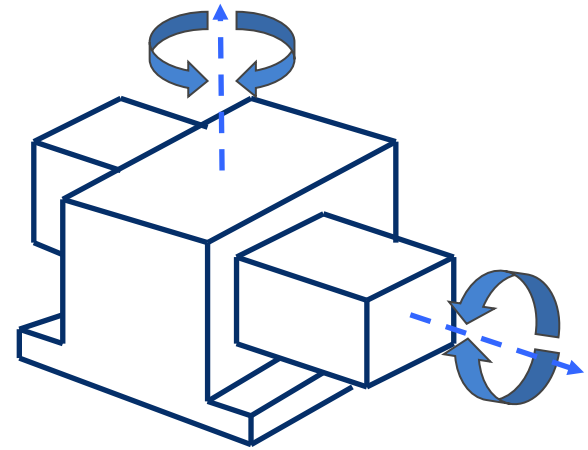
Couple free technology

- Opposing throws w/ common centerline
- Eliminates dynamic moments (the largest forcing function of mechanical vibration)



Couple-Free

Standard



Primary Couples [KPI-Ft]

Horizontal:	**0**
Vertical:	**0**

Vs.

Horizontal:	**typ. 20 – 30**
Vertical:	**typ. 15 – 35**

Product technical specification

Two configurations:

1. CFR at 1500 RPM
2. CFH at 1200 RPM

	CFR		CFH	
Number of Throws	2	4	2	4
Maximum Power (hp)	1700	3400	1360	2720
Max RPM	1500		1200	
Stroke (inches)	5		6	
Piston road diameter (in.)	2.25		2.5	
Net Rod Load (lbs)	48000		52000	

Summary of the Technical Key Features

- ✓ **Opposing throw with common centerline:**

  Reduced mechanical vibrations, packaging & foundation costs as well, while increasing the mechanical compressor reliability and package portability

- ✓ **Low crankshaft axis, reduced width, central cross tie bar:**

  Increased frame strength, increased MNF, reduced vibration moment arm

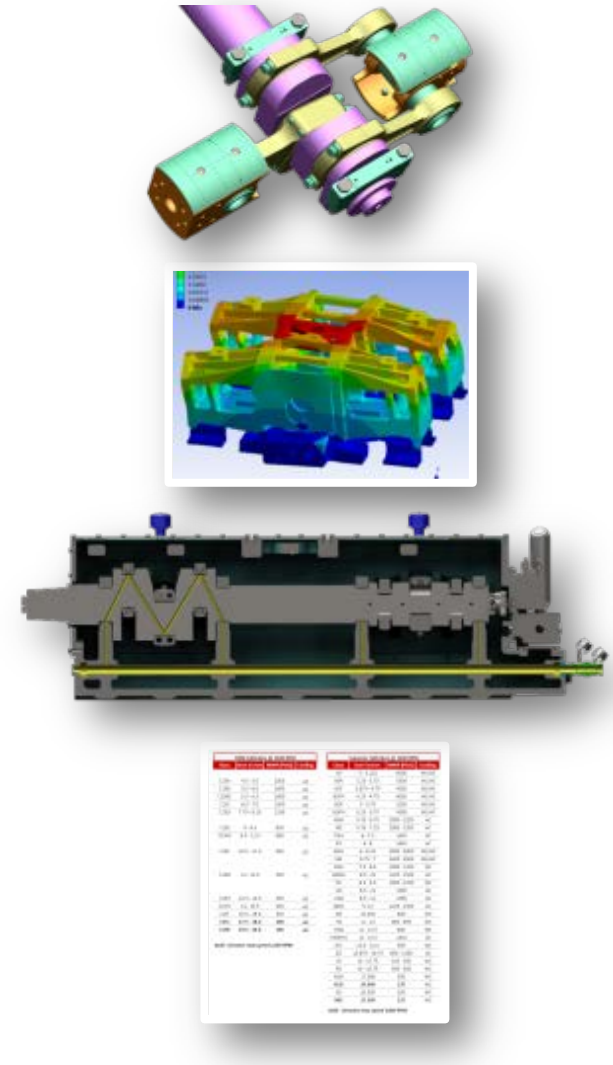
- ✓ **New Leak-Free Oil Design:**

  Oil header and oil passages integral in the frame casting and fully contained. Environmentally friendly and simple.

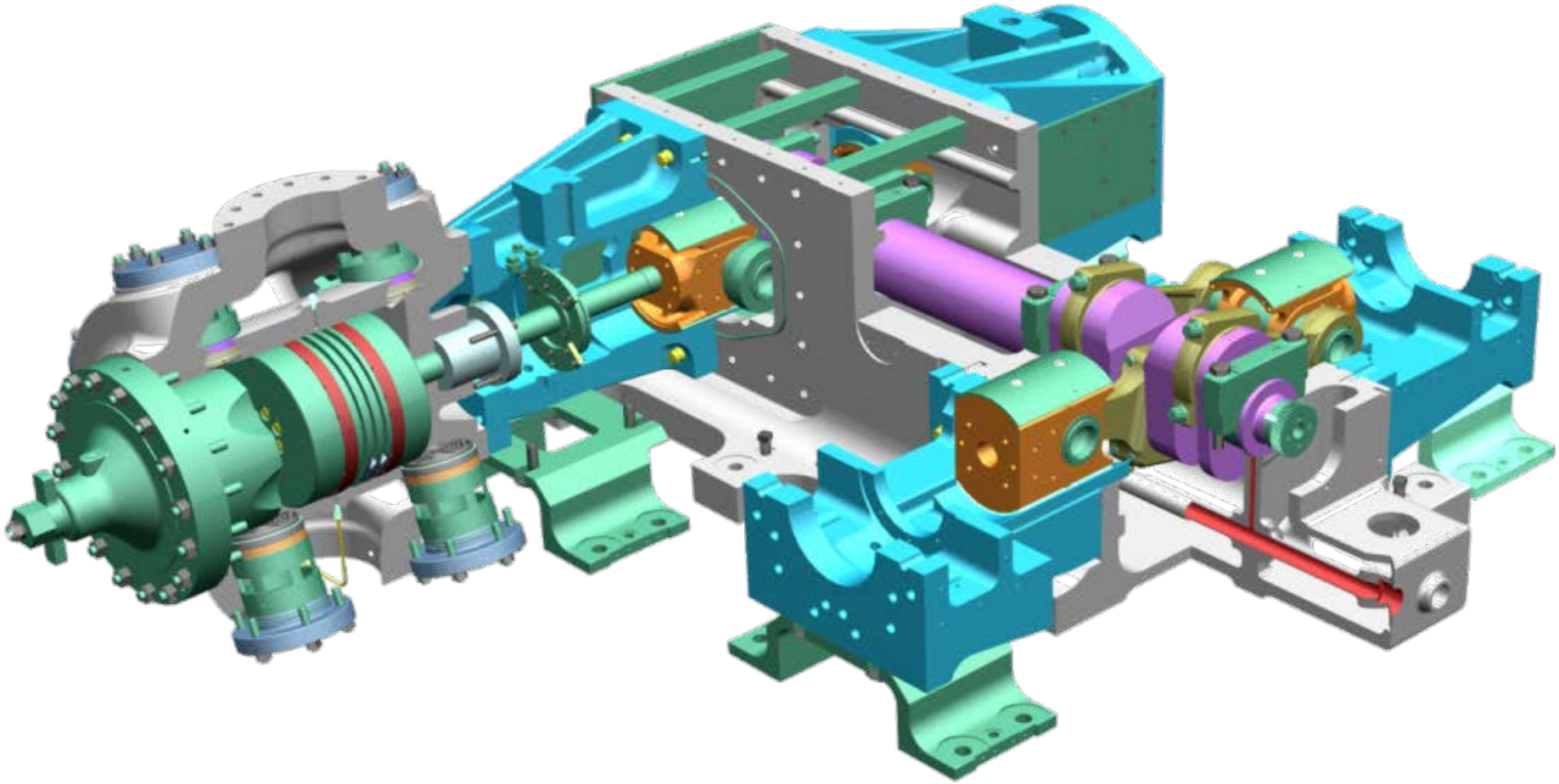
- ✓ **Compatibility with several cylinders:**

  ~45 classes, 144 cylinders

- ✓ **Designed for maximum serviceability**
- ✓ **Compact design and lower weight**



4 throw frame, sectioned view



FlexFlow

FlexFlow allows end users to optimize equipment for varying operating conditions

FlexFlow compressor offering aimed at gathering / transmission applications

- Utilizes MH/WH/WG frames operating at 1200 RPM, paired with easily exchanged cylinder liners
- Driven by engine (e.g. Waukesha™ 7042/7044) with 1400+ HP, allowing for flow expansion

As operating conditions change, only liners (not full cylinders) need to be exchanged to upgrade a compressor to meet new site requirements

- e.g. a customer built a compression station – the flow can later be increased or decreased by ~25%[1] by only changing liners and pistons

FlexFlow allows end users to maximize Revenue and reduce Capex as conditions vary

- Optimizing equipment increases flow (and utilizes full engine capacity), maximizing Revenue
- Avoiding expensive equipment upgrades reduces required Capex, increasing Op Profit

Maximize your bottom line with FlexFlow

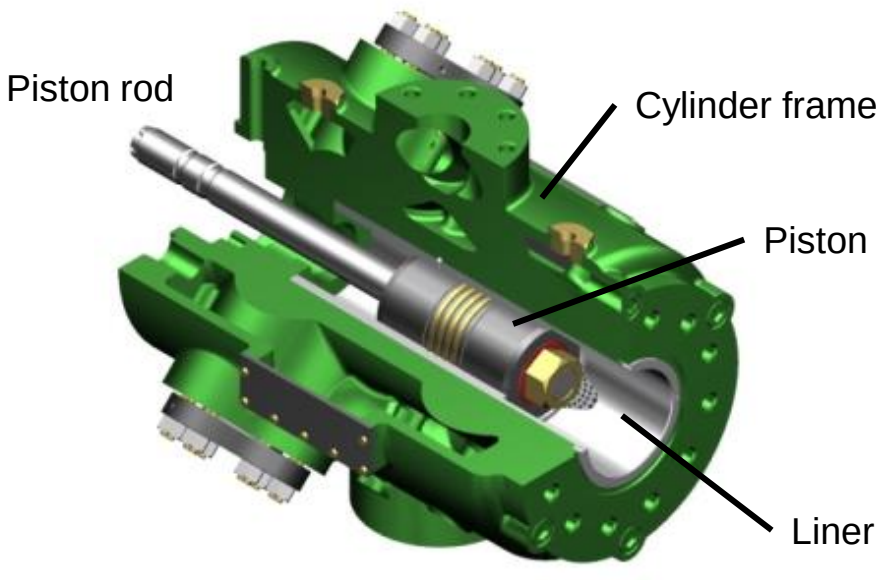
1. Exact flow range dependent on equipment and site conditions

Cylinder liners at heart of FlexFlow technology. Liners significantly more cost effective to swap than full cylinders

Key to FlexFlow technology are liners that can easily be swapped

FlexFlow cylinders (shown below) can "flex" up/down in diameter using liners

- For example, a 14.5 in cylinder can be used as a 14 or 15 in cylinder with different liners



FlexFlow cylinders significantly reduce inventory & labor costs

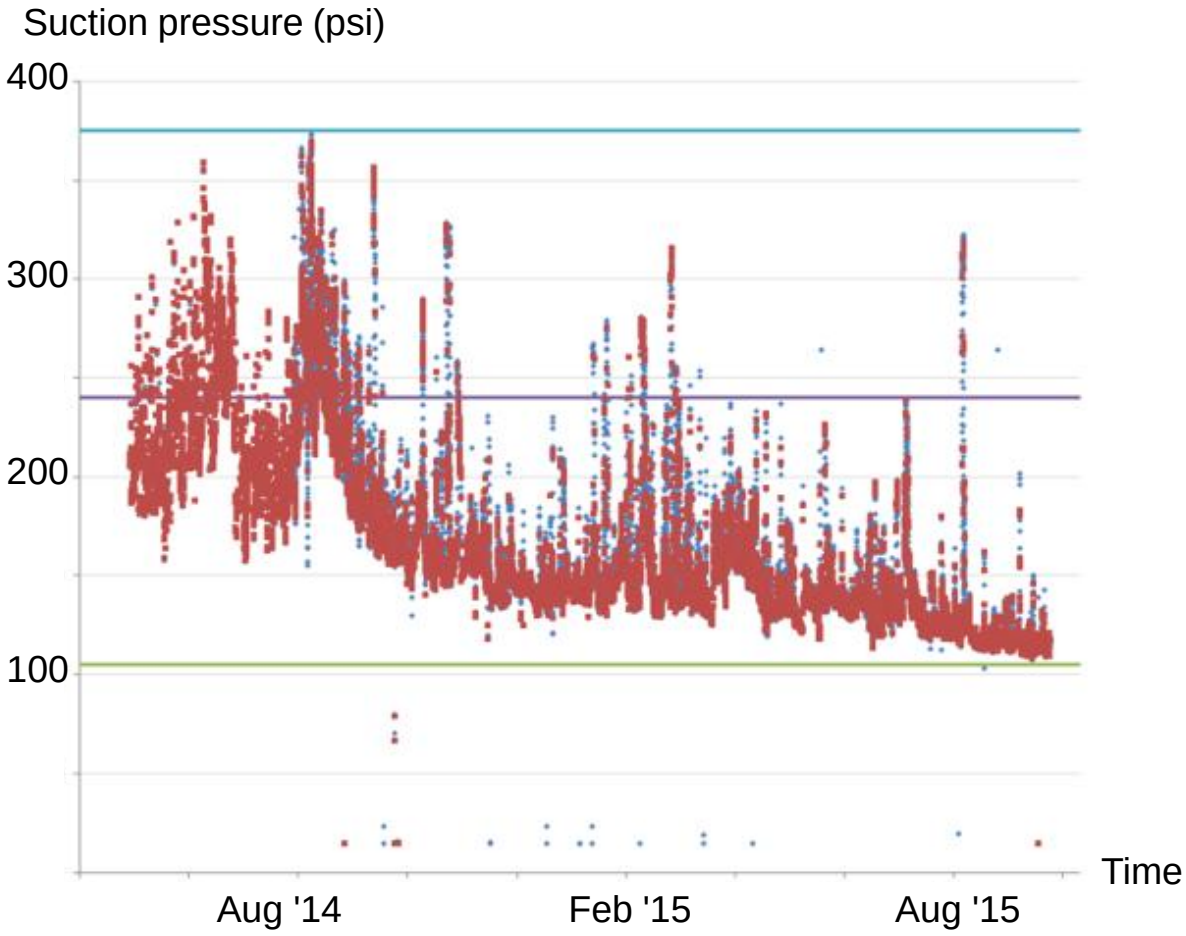
e.g. flexing up first stage of compressor to 15 in diameter

	Traditional full cylinder replacement	FlexFlow cylinder replacement
Required equipment in inventory	• 15" cylinder • 15" piston rod assembly	• 15" liner • 15" piston halves • 15" ring carrier • 15" rings • SuperNut
Total equipment cost	~$100K	**~$15K** (15% of traditional cost)
Estimated labor	~8 hrs	**~4 hrs** (50% of traditional labor)

Note: Cost & labor calculations available upon request
Source: GE analysis

Illustrative example: customer experienced 42% decline in suction pressure over 12M as old wells depleted

Suction pressure of actual gas gathering station



Source: Performance data from actual gas gathering station

Description

Customer gathering station showing decline in suction pressure since '14

- 42% decline in average suction pressure of gathering station from June '14 to June '15

Traditionally, new wells are drilled as old ones deplete to keep average suction pressure constant

In current market environment, drilling activity is scarce

- Results in declining gas supply & suction pressure
- Increases need for equipment flexibility to adjust to varying operating conditions

Wellhead/ gathering example

FlexFlow compressor allows 100% utilization of engine as suction pressure declines, maximizing flow

	Traditional cylinders			FlexFlow cylinders			
	Traditional cylinder diameter fixed, underutilizing engine			**FlexFlow cylinder diameter can vary to optimize equipment**			**FlexFlow advantage**
Declining suction pressure (psig)	**Cylinder diameter (in)**	**Required power (HP)**	**Resulting flow (MMSCFD)**	**Cylinder diameter (in)**	**Required power (HP)**	**Resulting flow (MMSCFD)**	**Additional flow (MMSCFD / %)**
80	15	1500	**~10**	15	1500	**~10**	**-**
40	15	1000	**~6**	15.5	1500	**~8**	**~2 (33%)**
20	15	800	**~4**	16.5	1500	**~6**	**~2 (50%)**

As suction pressure declines...

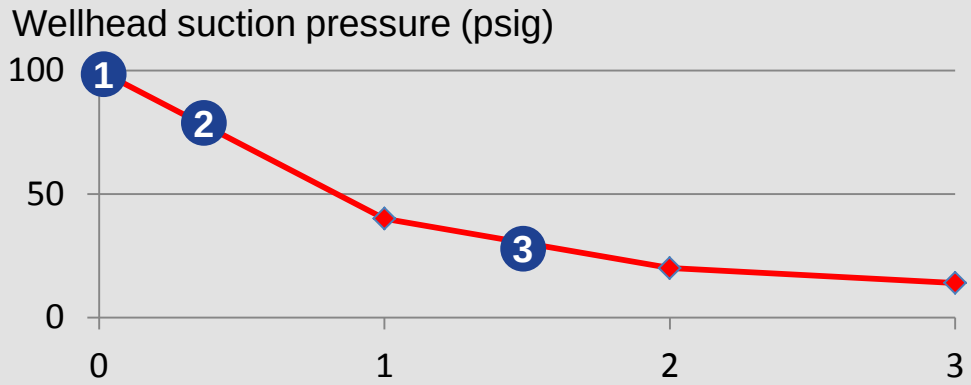
- Traditional cylinders do not have liners and cannot adjust diameter
- Therefore, decreased engine capacity (HP) is required
- By underutilizing engine, flow decreases significantly and revenue & operating Profit fall

- FlexFlow cylinders can be adjusted via liners as suction pressure declines
- Increasing cylinder diameter ensures engine is fully utilized
- Higher flow (compared to traditional cylinders) is maintained, maximizing revenue

Source: GE analysis

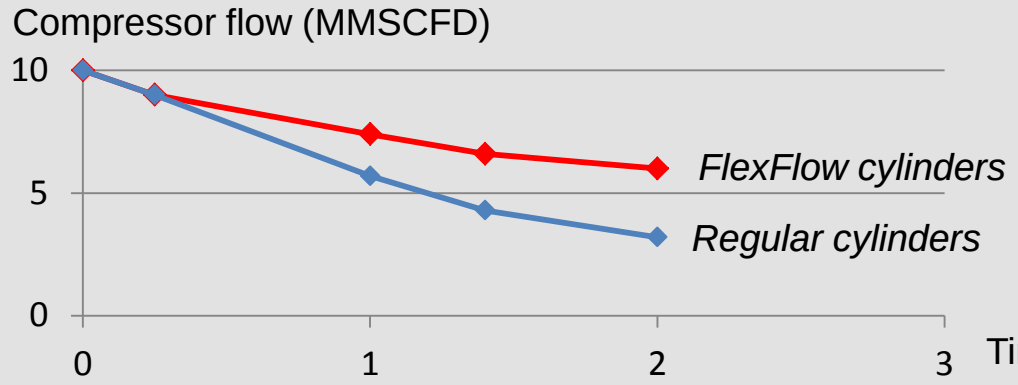
$~3M impact on revenue over first two years from additional gas flow due to FlexFlow technology

Within first two years of wellhead pressure decline, FlexFlow cylinders can be adjusted twice



1. **Initial cylinder setup at 100 psi**
   - 1st stage diameter at 15"
2. **First cylinder swap at 80 psi**
   - 1st stage diameter at 15.5"
3. **Second cylinder swap at 30 psi**
   - 1st stage diameter at 16.5"

FlexFlow compressor achieves higher flow, resulting in ~$3M in additional revenue



- By optimizing cylinder setup as wellhead conditions decline, FlexFlow compressor achieves higher flow
- Over initial two years, additional flow yields significant increase in revenue, ~$2.8M

Note: Example describes 3-stage compressor setup, only 1st stage cylinder liners are adjusted; Source: GE analysis

Transmission station example

FlexFlow allows transmission stations to increase flow without adding new packages

	Initial installation: use smaller cylinders, less HP	Flex Flow expansion: expand station when more flow required	FlexFlow advantage
Sample operating conditions	*Suction pressure: 20 psi* *Discharge pressure: 850 psi*		-
Desired flow (MMSCFD)	**~32**	**~48**	*Increase flow 50%*
Station setup	**4x packages** (~8 MMSCFD each)	**4x packages** (~12 MMSCFD each)	*No need to add additional packages*
Cylinder configuration	**2 x 19” / 11.5” / 8”** (additionally unloaded using spacers/VVCP)	**2 x 21” / 13.75” / 9.75”**	*Simple cylinder upgrade due to same X, Y, Z flange locations (more details on next page)*
Required HP	**~1500 HP** (per compressor)	**~2500 HP** (per compressor)	*Utilize excess HP of existing engines or "swing" new larger-HP engine*

Note: Calculation done for sample conditions – other operating parameters applicable for FlexFlow technology, detailed calculations available
Source: GE analysis

Transmission station example

FlexFlow significantly reduces Capex required to upgrade equipment and increase station capacity

Estimated cost to upgrade station – traditional vs. FlexFlow

Cost metric	**Traditional:** Requires adding full new package	**FlexFlow:** Only upgrade cylinders
Equipment	Full package, ~$1.5M	4x new cylinders, ~$0.3M (may require engine upgrade unless excess capacity installed initially)
Infrastructure	New concrete base/piping, ~$0.1M	-
Labor	New package installation, 240 hrs	Cylinder installation, 32 hrs
Total cost	**~$1.6M** 240 hrs of labor	**~$0.3M** 32 hrs of labor

FlexFlow upgrade cost less than 20% cost of adding new package to transmission station

Source: GE analysis

FlexFlow cylinders available with same X, Y, Z flange locations – allowing for easy cylinder exchanges

Available cylinders for Superior WG by diameter:

1st stage

21”	20.5"	20”	19”	19.5"	18.5"	18"	17.5"	17"	16.5"

2nd stage

13¾"	13.5"	13”	12¾"	12.5"	12"	11¾"	11.5"

3rd stage

9 ¾"	9.5"	9 ¼"	9"	8 ¾"	8.5"	8"

Legend:

Same cylinder body & XYZ flanges

Same XYZ flanges

Technical specification of WG	
Stroke (in)	7.00
RPM	Up to 1000
Piston Rod Size (in)	2.750
BHP/Throw	1250
Crosshead Bushing	71.79 in^2
Main/Crank Pin Bearing	107.4 in^2
Crankshaft Diameter (in)	8.000
Crankshaft Material	ASTM A668 Class L
Crankshaft Tensile (psi)	110,000
Gas Rod Load (lbs)	75,000

For more information, please contact:

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