



# Cooper-Bessemer Overhauls Best Practices

**3 April 2018**

© 2017 Baker Hughes, a GE company, LLC - All rights reserved.

© 2017 Baker Hughes, a GE company, LLC - All rights reserved.



The background is a vibrant blue digital landscape. A large sphere with a wireframe grid is on the left. A bright light source on the right creates a lens flare and illuminates the scene. Swirling blue lines and binary code (0s and 1s) are scattered throughout, giving a sense of high-tech energy and data flow.

We invent smarter ways  
to bring energy to the world.



# Fullstream

**Rely on cutting-edge technology, digital solutions, and expert service across every segment**

## Upstream

Evaluation

Drilling

Completion

Production & optimization

## Midstream

Pipeline & storage

LNG

## Downstream

Refinery

Petrochemical & fertilizer

Industrial power & processing

**Digital**

# Reciprocating Compression

BHGE's Reciprocating Compression business is a leading provider of engines, compression equipment and services, focused on gas compression at or near the point of use. Reciprocating Compression's product portfolio includes highly efficient industrial reciprocating engines generating up to 12,500 bhp of power each for numerous energy producers globally.

**Our heritage and our people provide  
a strong foundation for future  
success**





# Reciprocating Compression Brands

## Ajax™



Integral compressors up to 800 bhp

- Gas Gathering
- Gas Lift
- Fuel Gas Boosting

Reliability, availability, efficiency,  
low total cost of ownership

## Cooper-Bessemer™



Integral compressors up to 12,500 bhp

- Gas Storage
- Gas Transmission

Reliability, availability, efficiency,  
low total cost of ownership

## HSR



Separable compressors up to 9,000 hp

- Gas Lift/ Gathering
- Fuel Gas Boosting
- Gas Storage/ Transmission
- NGVs

Experience, flexibility support

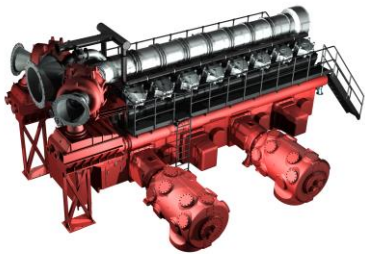
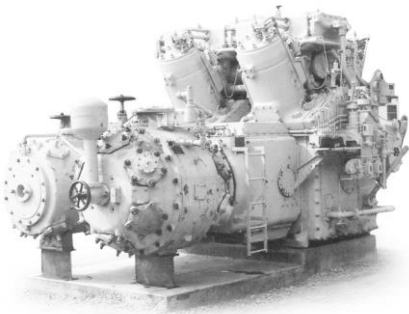
## Superior™



Separable engines up to 2,650 bhp

- Gas Lift
- Gas Gathering
- Gas Storage
- Gas Transmission
- Rugged, proven, fuel flexibly

# Long standing reputation for high quality engine products



First horizontal integral

Introduced GMV

Introduced W-330

Reintroduction of W-330C3

GE Oil & Gas becomes

a GE company

1833

1910

1929

1938

1947

1964

1994

2010

2015

2017

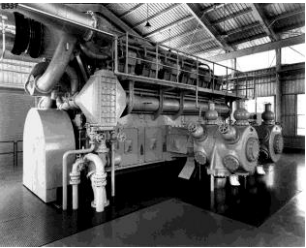
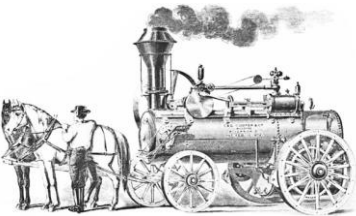
Cooper founded in Mt. Vernon, Ohio

Cooper merges with Bessemer Corp.

Introduced GMW

Last W-330C2

Acquired by GE Oil & Gas



# Agenda

## Why plan your Cooper-Bessemer overhaul up to one year in advance...

- RC service and repair center network
- RC technical capabilities
  - Field machining
- Best Practices:
  - Failure Modes & Effects Analysis (FMEA)
  - Proactive maintenance
  - Installed base tool
  - Red flag reviews (RFRs)
  - Comprehensive overhaul specification
- Conversions, Modifications & Upgrades (CM&Us)

# Reciprocating Compression integral engine services and repair center network

## Installation & Field Services

120+ Installation & Field specialists

Global support of planned & unplanned events

Planning & execution of scheduled overhauls

Personnel experienced in numerous GE & non-GE products

Specialty services including unit analysis and field machining

Network of GE Repair Centers

Services include:

- valve reconditioning
- camshaft re-lobing
- head & cylinder reconditioning
- water pump repair
- spray coating
- turbocharger repair
- Specialty services including unit exchange & unit overhauls

## BHGE North American Service Shops





# BHGE upgrade programs

## 4 Upgrade Programs

- Improvements in
  - Horsepower
  - Efficiency
  - Stability
  - Maintenance
  - Emissions
  - Safety

## 3 Genuine OEM parts

- Reduce lifecycle cost and improve reliability with genuine BHGE OEM parts solutions



## 1 Multiyear service agreements

- From BHGE's service shop network

## 2 Asset Performance Management

- Digital product connectivity
- Pivotal development point
- Reduce costs and improve availability with analytics

# Reciprocating Compression Technical capabilities

## Field Machining

Line bore main bearings on engine and compressor frames

- Wirelining to determine if bores are misaligned
- Metal-spraying bores to restore to OEM sizes, including clipping and spraying the caps

Machine/sleeve power cylinder bores on engines

- Boring diameters oversize to receive oversized liners if required
- Boring diameters oversize to receive inserts to bring bores back to OEM dimensions

Re-line compressor cylinders

- Machining the bore oversize to receive oversize piston and wearbands
- Boring the liner out if applicable and installing a new liner

Flange-facing and machining flat surfaces

- Crankshafts, flywheels
- Compressor cylinder end faces
- Engine top decks

Reclaim register fits on various components

- Crankshafts, flywheels
- Gear boxes
- Blower housings

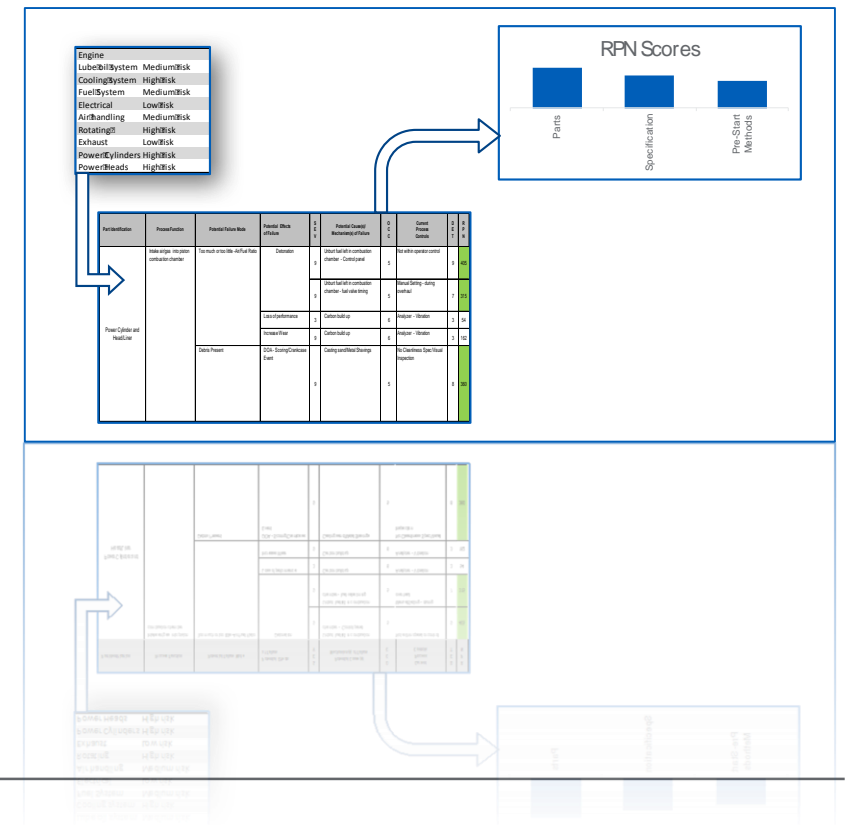
Ream holes

Remove broken bolts, studs



## Best Practice: Failure Modes & Effects Analysis (FMEA)

- Identified high risk engine systems based on historical engine issues
- Drilled down to key system component/functions
- FMEA on Rotating systems
- Review & revise specifications for increased clarity
- Review and bolster Supplier inspection capabilities
- Augment pre-Start Checklist with lessons learned
- Improve in house/Field inspection capabilities



# Best Practice: Benefits of proactive maintenance planning

- Planning for a Cooper-Bessemer overhaul can begin up to one year ahead of time. Benefits of this approach include:
  - ✓ Multiple reviews of overhaul BOMs ... eliminates omissions and errors
  - ✓ Identify and manufacture special order components
  - ✓ Pre-ordering of long lead items eliminating expediting charges
  - ✓ Reduce delays or interruptions ... overhaul executed as a single work stream utilizing the same crew from start to finish
  - ✓ Smoother overhaul execution ... smoother recommissioning

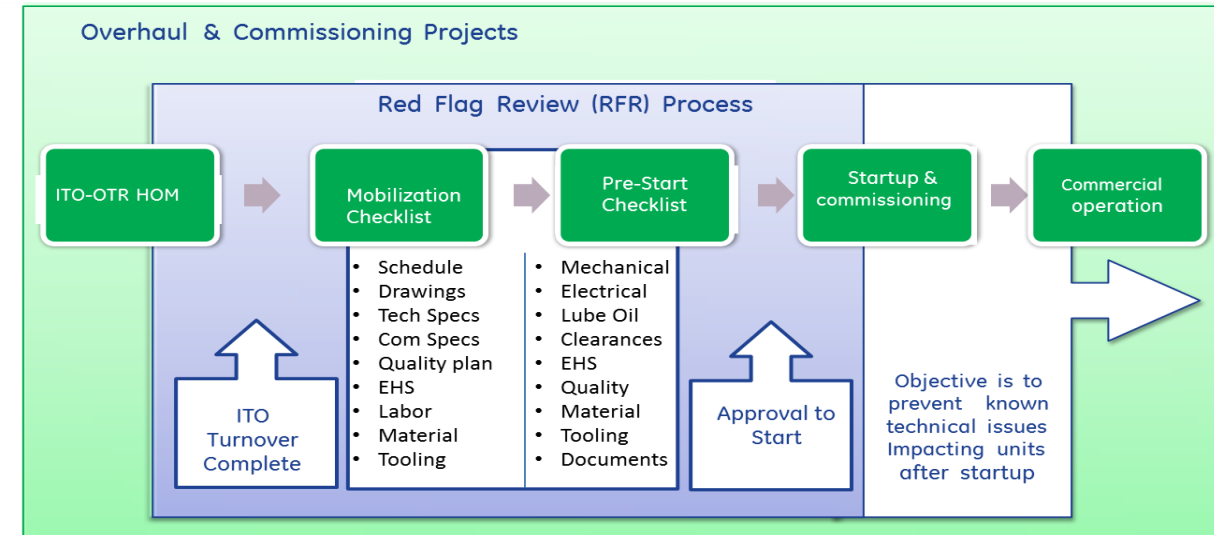


# Best Practice: Reciprocating Compression Installed Base tool

- Tracks customer equipment, configuration, operating hours, helps predict maintenance and overhauls
- IB
- Identify upgrades for your models

# Best Practice: Red Flag Reviews (RFRs)

- Assures mechanical & system integrity of a unit prior to startup
- Provides a high level check of unit and control systems
- Creates a communication channel between the field and Product Service
- Assures that all overhaul and commissioning audits and documents are followed
- Communication tool for all applicable Service Notices for implementation or disposition by field personnel





# Engine Upgrades

## GMV, GMV-TF, GMVA, GMVB, GMVC, GMVE, GMVG, GMVH

Δ Horsepower	GMV	GMV-TF	GMVA	GMVB	GMVC	GMVE	GMVG	GMVH
Increase engine speed			•		•			
Blower conversion	•	•						
Turbocharger	•	•	•			•		
Ambient uprate								•
Δ Efficiency	GMV	GMV-TF	GMVA	GMVB	GMVC	GMVE	GMVG	GMVH
Blower conversion	•	•						
Turbocharger	•	•	•			•		
Jet cell conversion	•	•	•	•	•	•	•	•
Dry exhaust manifold conversion	•	•	•					
Compressor poppet valves	•	•	•	•	•	•	•	•
Δ Stability	GMV	GMV-TF	GMVA	GMVB	GMVC	GMVE	GMVG	GMVH
Jet cell conversion	•	•	•	•	•	•	•	•
Δ Maintenance	GMV	GMV-TF	GMVA	GMVB	GMVC	GMVE	GMVG	GMVH
Exhaust By-Pass Valve Upgrade					•		•	•
Improved water inlet header	•	•	•	•	•	•	•	•
N12 power cylinders & liners					•		•	•
Ring Gear Starter	•							
Screw-on Oil Filter Kit				•	•		•	•
Spin-on Lube Oil Strainer Upgrade	•	•	•					
Turbocharger-to-Intercooler Seal				•	•		•	•
Δ Emissions	GMV	GMV-TF	GMVA	GMVB	GMVC	GMVE	GMVG	GMVH
Increase engine speed			•		•			
Blower conversion	•	•						
Turbocharger	•	•	•			•		
Ambient uprate								•
Jet cell conversion	•	•	•	•	•	•	•	•
Compressor valve caps o-ring seals	•	•	•	•	•	•	•	•
Δ Safety	GMV	GMV-TF	GMVA	GMVB	GMVC	GMVE	GMVG	GMVH
Crankcase Door & Explosion Relief Valve	•	•	•	•	•	•	•	•

# Engine Upgrades

## GMW, GMW-TF, GMWA, GMWC, GMWE, GMWH, V-250, V-275, W-330

Δ Horsepower	GMW	GMW-TF	GMWA	GMWC	GMWE	GMWH	V-250	V-275	W-330
Increase engine speed			•	•			•		
Blower conversion	•	•							
Turbocharger	•	•	•		•				
Ambient uprate						•	•	•	•
Δ Efficiency	GMW	GMW-TF	GMWA	GMWC	GMWE	GMWH	V-250	V-275	W-330
Turbocharger	•	•	•		•				
Jet cell conversion	•	•	•	•	•	•	•	•	•
Dry exhaust manifold conversion	•	•	•						
Compressor poppet valves	•	•	•	•	•	•	•	•	•
Δ Stability	GMW	GMW-TF	GMWA	GMWC	GMWE	GMWH	V-250	V-275	W-330
Jet cell conversion	•	•	•	•	•	•	•	•	•
Δ Maintenance	GMW	GMW-TF	GMWA	GMWC	GMWE	GMWH	V-250	V-275	W-330
Exhaust By-Pass Valve Upgrade				•		•	•	•	•
Hinged crankcase door	•	•	•	•	•	•	•	•	•
N12 power cylinders & liners				•		•	•	•	•
Ring Gear Starter	•								
Screw-on Oil Filter Kit				•		•	•	•	•
Turbocharger-to-Intercooler Seal				•		•	•	•	•
Δ Emissions	GMW	GMW-TF	GMWA	GMWC	GMWE	GMWH	V-250	V-275	W-330
Turbocharger	•	•	•		•				
Ambient uprate						•	•	•	•
Jet cell conversion	•	•	•	•	•	•	•	•	•
Compressor valve caps o-ring seals	•	•	•	•	•	•	•	•	•
Hinged crankcase door	•	•	•	•	•	•	•	•	•
Δ Safety	GMW	GMW-TF	GMWA	GMWC	GMWE	GMWH	V-250	V-275	W-330
Crankcase Door & Explosion Relief Valve	•	•	•	•	•	•	•	•	•

# Engine Upgrades

## GMP (Quad), Z-330

<b>Δ Efficiency</b>	<b>145L</b>	<b>145H</b>	<b>155L</b>	<b>155H</b>	<b>Z-330</b>
Jet cell conversion	●	●	●	●	●
Dry exhaust manifold conversion					
Compressor poppet valves	●	●	●	●	●
<b>Δ Stability</b>	<b>145L</b>	<b>145H</b>	<b>155L</b>	<b>155H</b>	<b>Z-330</b>
Jet cell conversion	●	●	●	●	●
<b>Δ Maintenance</b>	<b>145L</b>	<b>145H</b>	<b>155L</b>	<b>155H</b>	<b>Z-330</b>
Exhaust By-Pass Valve Upgrade	●	●	●	●	●
N12 power cylinders & liners	●	●	●	●	●
Screw-on Oil Filter Kit	●	●	●	●	●
Turbocharger-to-Intercooler Seal	●	●	●	●	●
<b>Δ Emissions</b>	<b>145L</b>	<b>145H</b>	<b>155L</b>	<b>155H</b>	<b>Z-330</b>
Jet cell conversion	●	●	●	●	●
Compressor valve caps o-ring seals	●	●	●	●	●
<b>Δ Safety</b>	<b>145L</b>	<b>145H</b>	<b>155L</b>	<b>155H</b>	<b>Z-330</b>
Crankcase Door & Explosion Relief Valve	●	●	●	●	●



We invent smarter ways  
to bring energy to the world.



**BAKER**  
**HUGHES**  
a GE company



# Backup

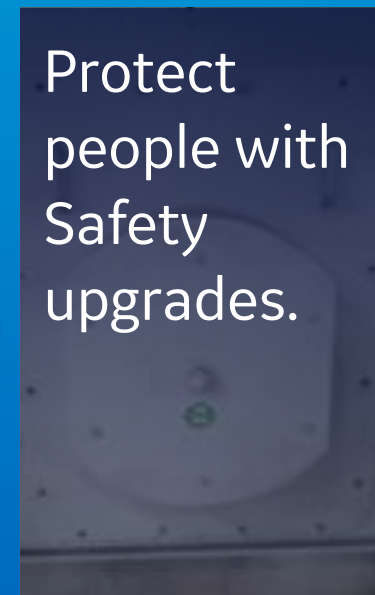
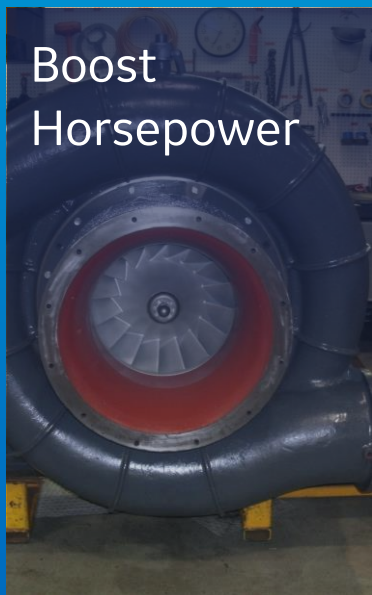




Cooper-Bessemer integral engine compressors

# Upgrades for all Cooper-Bessemers

Maximize productivity  
and safety with proven  
technologies and  
advanced solutions



# Increase engine speed

- Easiest way to gain more horsepower
- Engines currently rated at 250 and 300 rpm are excellent candidates
- Up to 10% increase in engine speed, resulting in a corresponding horsepower increase of 10%
- Tuned vibration damping system typically involves the addition of a shaft adapter, torsional damper and housing
- New compressor cylinders are not required because compressor piston displacement (cfm) is directly proportional to speed
- Four days to complete retrofit

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
✓				✓

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Blower conversion

- Increase the amount of inlet air to the engine by converting pump-scavenged units to blower-types
- Up to 25% improvement in horsepower, and a 12% decrease in fuel consumption
- Kit includes a new drive system (flywheel sheave and poly V-belt), blower assembly and engine air piping
- Installation typically takes about four days



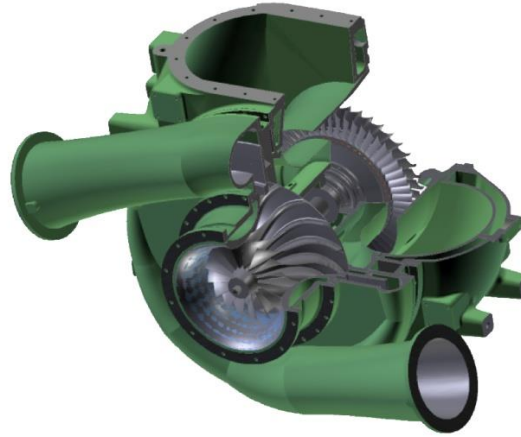
Cooper-Bessemer™ GMVA Blower

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
✓	✓			✓

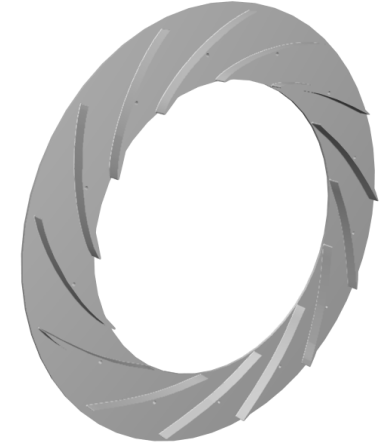
Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Turbocharger conversion

- Increase the amount of inlet air to the engine by converting blower-types to turbocharged units
- Up to 33% horsepower improvement and a 13% improvement in fuel consumption
- Turbocharger is exhaust-driven and feeds pressurized air to the blower inlet
- Installation requires about four days and includes replacing the exhaust manifold, piping, pistons and power cylinders



Cooper-Bessemer™ ET18



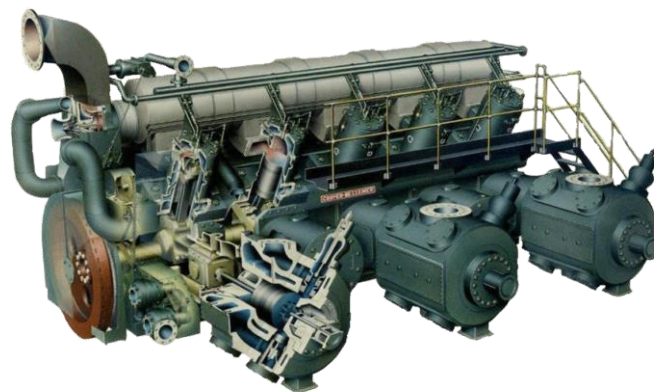
Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
✓	✓			✓

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓



# Ambient rating conversion

- Allows for greater engine output during periods of temperature lower than rated
- A combustion control system is required to maintain even thermal loading, and safe firing pressure limits.
- Allows an engine rated at 100°F to gain horsepower on a proportional basis as the temperature decreases up to a maximum of 125% at 40°F.
- An engine with an 80°F rating will be able to operate at 117% of the original horsepower at 40°F.



Cooper-Bessemer™ 10-GMVH Integral Engine-Compressor

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
✓	✓			✓

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Jet cell upgrade

- Pre-combustion chamber for poor combustion stability common in two cycle gas engines operating at less than rated torque
- Smooth consistent operation all the way throughout the engine operating range
- Fuel consumption reduction up to 23% at half load
- Easily adaptable to both pneumatic and PLC based engine control systems
- Power cylinder heads direct bolt-on replacement for existing ones



Jet Cell

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
	✓	✓		✓

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Dry exhaust manifold conversion

- Results in a large heat load reduction
- Up to 1,750,000 Btu/hr savings for one GMW-10. Allows better engine cooling, even in hot, dry climate
- Will not have the corrosion and cracking inherent with a water cooled unit
- Better overall coverage of hot components, radiant heat is lower
- The conversion is complete with bellows style expansion joints to absorb thermal and vibratory movement



W-330 Exhaust Manifold

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
	✓			

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Compressor poppet valves

- Reduces losses of up to 6-20% (as a percentage of total indicated horsepower), to only 4-12%. This translates to significant fuel or kilowatt savings
- Initial cost of up to 40% less than conventional ported plate valves
- Payback time is typically less than 18 months
- Unique, patented valve design
- Independent poppet operation
- Suitable for lubricated or non-lubricated service
- Interchangeable parts
- Engineered for your application



Texcentric EPV-750 Poppet Valves

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
	✓			

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓



# Improved water inlet header

- Flexible connection in new style header with new robust seal, virtually eliminates leaking during unit shutdowns
- Improved durability - solid, stainless steel construction promotes extended operating life
- Easier disassembly - removable sections allow for easy access to major components for repair
- Greater flexibility - flanged, stainless steel bellows-type connections ensure positive coolant sealing even under extended vibrations and many thermal cycles



New style flexible header

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# N12 power cylinders and liners

- Enhanced cylinder and liner surface lubricity
- Precision-bore geometry
- No chromates are rejected into the lubricating oil
- Improved surface integrity compared to chrome
- Anti-scuffing
- Sour gas application compatible
- Cylinders can easily be coated or plated for repairs
- Field tested and proven to perform as well as chrome
- Shorter lead times due to lack of plating requirement



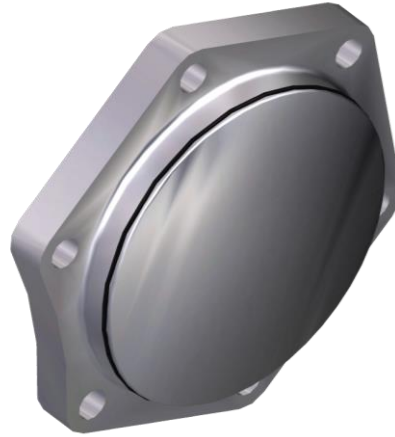
N12 liner

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Compressor valve caps o-ring seals

- Make a better seal resulting in fewer gas leaks
- Will not damage the cap fit in your cylinder
- Easier to remove your valve cap and valve for needed maintenance
- Existing damage can be machined and oversized o-rings used to seal the cap
- Eliminate having to pry existing copper and steel rings out of compressor valve pocket.
- Reduce using excessive torque to get copper and steel rings to seal.
- O-rings more readily available



Compressor valve cap o-ring seal

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
				✓

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Hinged crankcase door with upgraded sealing

- Facilitates crankcase inspection without removal of the crankcase door
- Reduces the chance of personnel injury caused by handling
- Hinges help with overhead crane access when the doors must be removed.
- Improved the door seal to address historical sealing issues
- Reduces the maintenance and environmental concerns with oil leaks in addition to reducing oil consumption and operating costs



Hinge Door Inner Seal

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	✓

Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Exhaust By-Pass Valve Upgrade

- Positive stop – assures the butterfly disk cannot be rotated beyond the closed position, thus assuring stick free operation
- Near zero backlash coupling – precise control due to no wasted movement
- Rotary actuator close coupled to valve shaft - no leaking hydraulic oil or sloppy linkages to maintain
- Positioner with high visibility dome indicator allows quick assessment of valve operation



Exhaust Bypass Valve

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓



# Crankcase Door and Explosion Relief Valve

- Technician analyses bolts prior to scheduled outage
- State of the art ultrasonic bolt testing instrument
- Reduces outage time



Explosion Relief Valve



Crankcase Door

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Spin-On Lube Oil Strainer

- Convert the existing CUNO lube oil filtration system to a “Spin On” filter element system rated from 7-23 microns, depending on the filter used.
- Reduced labor cost, downtime and oil spills due to easily changed filters
- Over the counter filter elements
- Extending bearing and bushing lifecycle due to better filtration of the lube oil
- Multiple ports on the filter body to monitor change in pressure across the filters



Spin-On Lube Oil Strainer

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Screw-On Oil Filter Kit

- Can be used on main engine oil systems of OEM turbochargers.
- Filtration can be changed by adding or removing blocks of 10µm non-relieving elements.
- Can be mounted in a convenient location with easy-to-read gauges, improving worker safety and reducing oil leaks.
- Minimizes oil leakage which can reduce slip & fall hazards
- Reduction of service hours and maintenance expense
- Downtime significantly reduced during replacement of filter elements



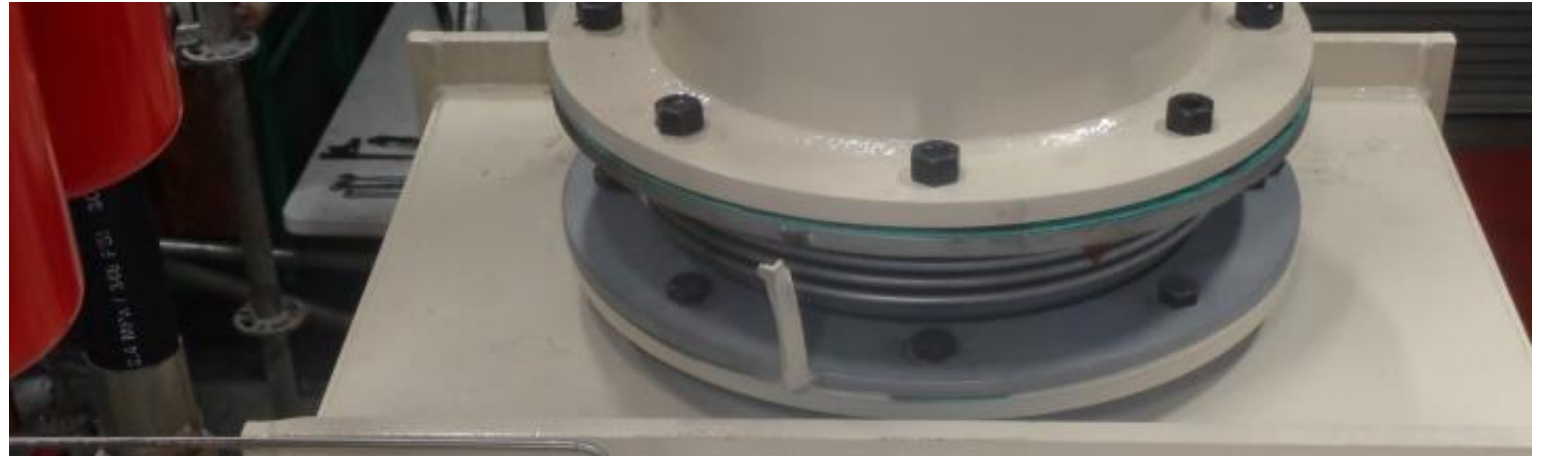
Screw-On Oil Filter

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓

# Turbocharger-to-Intercooler Seal

- Piston ring- style slip joint relies on near perfect alignment, condition of the seal and surface finish of the surface that the seal rides on
- Over time each of these items can degrade, resulting in combustion air leaks that can rob the engine of much needed combustion and scavenging air
- BHGE has recently engineered an upgrade of this joint to use a stainless steel bellows type expansion joint
- Used in exhaust manifolds for 30 years with proven reliability.



Seal upgrade on single ET24 W330 application

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓



# Ring Gear Starter

- A ring gear is installed on the engine flywheel and engaged by a pinion gear on the starting motor shaft to initiate engine roll over.
- Depending on torque requirements of the specific application up to four (4) pneumatic motors can be installed.
- Requires significantly lower supply air pressure to operate
- Lower volume requirements
- Readily available
- Low maintenance
- UX starters available
- Barring motor option



Ring Gear Starter

Customer Benefit				
Horsepower	Efficiency	Stability	Maintenance	Emissions
			✓	

Outage Applicability		
Major Overhaul	Top End Overhaul	Annual
✓	✓	✓



**BAKER**  
**HUGHES**  
a GE company

