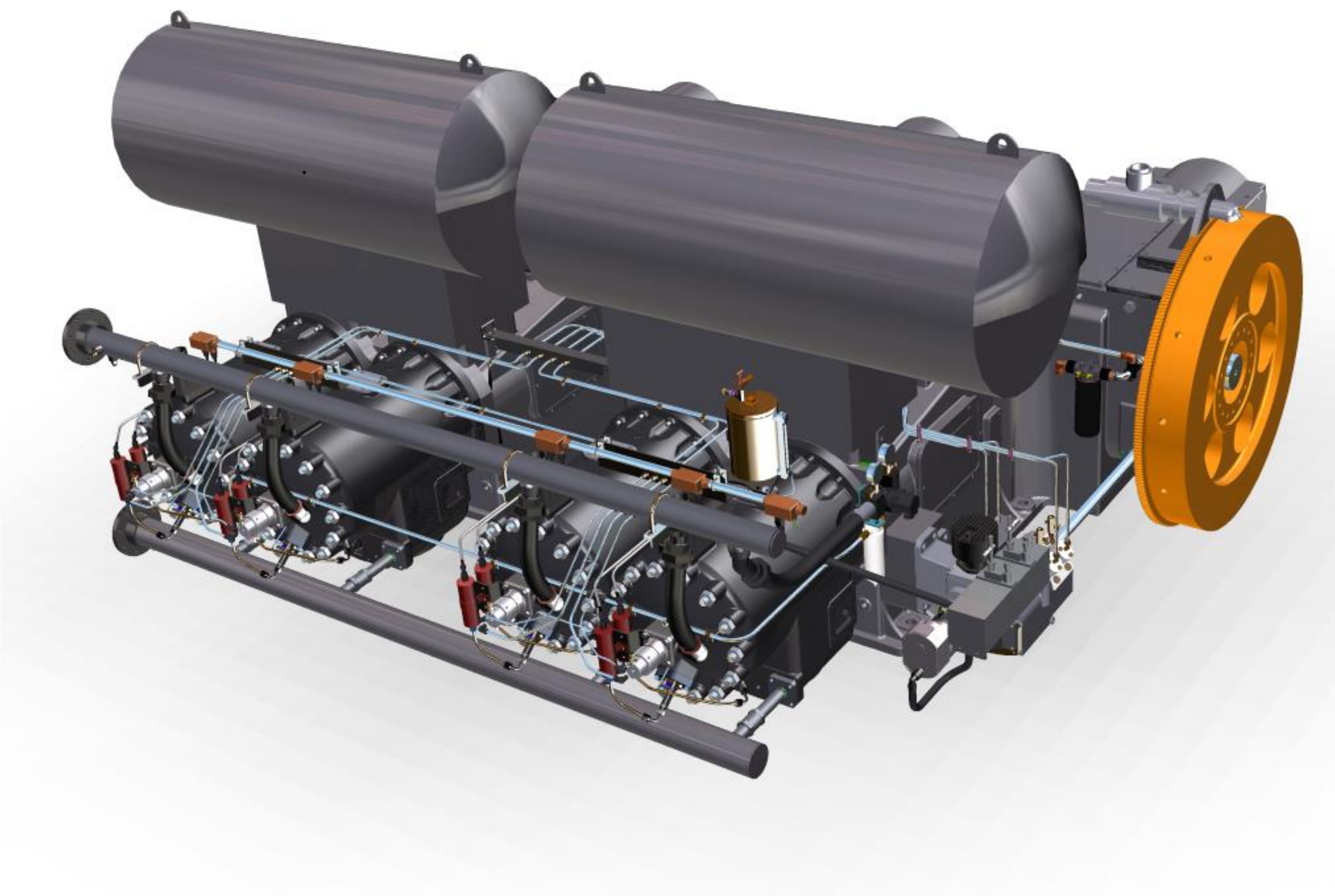
The Advantages of AJAX^{TM} Integral Engine-Compressors

A white paper for owners and operators of gas compression equipment



The Advantages of AJAX™ Integral Engine-Compressors

Bruce Chrisman
June 5, 2018

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ABSTRACT

Selection of optimum equipment for gas compression applications requires a thorough comparison of both engines and compressors. Important factors to consider include first cost, operating and maintenance costs, expected service life of the equipment, compression efficiency, and regulatory compliance issues.

In the following pages, the advantages of AJAX™ integral engine-compressor packages are presented. AJAX™ integrals[1] are robust, reliable, and have served the gas compression industry for many years with an impressive record of both low-maintenance requirements and online availability. AJAX™ integrals[1] feature a slow speed, conservative BMEP, two stroke engine design that results in fewer moving parts and lower maintenance than comparable high-speed compression packages. The AJAX™ engine-compressors operate with comparable high efficiencies and with minimal requirements for operator intervention during the life cycle of the equipment. This guide compares economic factors for AJAX™ integral engine-compressors and high-speed separable packages. It will summarize several years of field emissions data, and describes the results from recent R & D projects focused on additional performance enhancements that will further distinguish the AJAX™ integrals as a best in class compression package.

[1] A gas compression package having an AJAX™ integral engine-compressor.

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[2] Denotes a specific series of models for AJAX^{TM} integral engine-compressors.

1.0 INTRODUCTION

AJAX™ integral engine-compressors have an exceptional track record for reliability, ease of maintenance, lower operating and maintenance expenses, higher efficiencies, and overall greater online availability when compared to high-speed separable packages. In the following pages, results from field tests of AJAX™ engines will be shown, as well as an exhaust emissions comparison with another engine supplier, which verifies that emissions for AJAX™ engines meet or are lower than current emissions requirements. A comparison of BHP ratings and NOx levels for AJAX™ engines and a competitor's engines is presented in Section 3.3. Recent developments with the new AJAX™ 2800XLE² engines, which have resulted in large reductions of NOx emissions and increased BHP ratings, are discussed in Section 3.5.

With minimal maintenance required, AJAX™ integrals are especially well suited for operation in remote areas. These packages are typically monitored from a central office, and there is seldom a need to send a service technician to the remote site.

The selection of an AJAX™ integral package for a gas compression application provides many long-term benefits and unique advantages including the following:

- Economic
  - Minimal maintenance, parts and manual service hours compared to high-speed separable packages.
  - More gas compressed per engine BHP than high-speed separables.
  - Lower Total Cost of Ownership
- Performance
  - High tolerance to a wide range of fuels. The AJAX™ engine can operate with fuels having a large content of heavier hydrocarbons and an H_2S content up to 3 – 4 volume percent (Refer to Appendix A).
  - Single frame and one common crankshaft (compared to two of each for separable packages) resulting in a higher mechanical efficiency.
- Operational
  - Reduced parts stocking requirements.
  - No requirement for intake and exhaust valves, turbocharger, and aftercooler.
  - Single source responsibility as Baker Hughes, a GE Company, produces both the AJAX™ engine and the compressor.
  - Higher availability (98% is typical for an AJAX™ integral package).

2.0 BACKGROUND

2.1 Advantages of AJAX™ Engine-Compressors

AJAX™ integral engine-compressors have lower overall operating and maintenance expenses than high speed separable packages, a comparison of which can be found in Section 3.2

AJAX™ engines consistently have actual emissions levels lower than the quoted emissions levels. Emissions testing results are summarized and compared with quoted emissions levels in this paper. This data was collected during regulatory compliance testing at various customer sites.

Selection of an AJAX™ integral package for a gas compression application provides many long-term advantages, which are described in Sections 3.1 – 3.2.

2.2 Competitive Position of AJAX™ Integrals Compared to High Speed Separable Packages

Compared to high-speed separable packages, AJAX™ engine-compressors have similar performance and emissions control capabilities. However, AJAX™ integrals have distinct advantages with higher mechanical efficiencies and the ability to compress more gas per engine BHP.

3.0 ANALYSES AND DISCUSSION

3.1 Rationale for Using AJAX™ Integral Packages

3.1.1 Track Record for High Reliability

Engineers designed the AJAX™ integrals with a focus on strength and simplicity. These qualities resulted in substantially lower operating and maintenance costs and lower downtime than is characteristic of high-speed separable packages. In Section 3.2, you'll find a comparison of capital expenses and operating and maintenance expenses for AJAX™ engine-compressor packages and high-speed separable packages.

This data clearly shows that AJAX™ engine-compressors are the economical choice for a variety of applications, including:

- Gas gathering
- Processing
- Injection
- Transmission

Because of their rugged nature and low maintenance needs, AJAX™ integrals are especially well suited for operation in remote sites with harsh conditions, such as the DPC-2803LE installations shown in Figures 1 and 2 below.

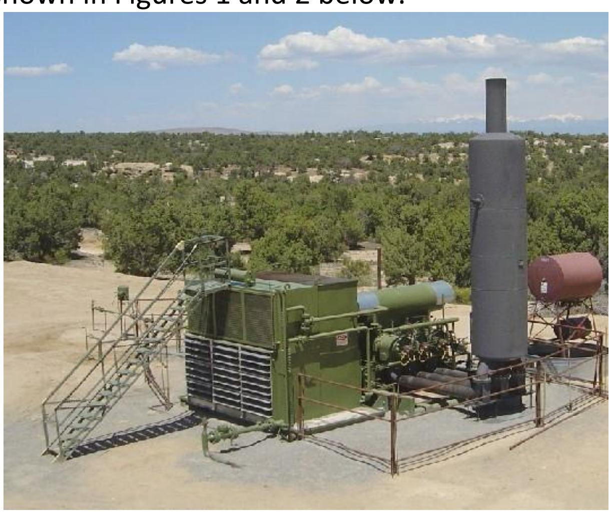


Figure 1: AJAX™ DPC-2803LE[3] Package in Southwestern U.S.

Figure 2: AJAX™ DPC-2803LE[3] Package in Southwestern U.S.

[3] Denotes a specific model of AJAX™ integral engine-compressor products.

3.1.2 High Compression Efficiency

Selection of a gas compression package is based on many factors, one of which is the BHP of the engine. However, the main factor to consider should really be the gas compression throughput of the package. AJAX^{TM} engine-compressor packages have a substantially lower BHP/MMSCFD than a high speed separable package, meaning that for the same rated engine power, more gas is compressed by the AJAX^{TM} package than a comparable high-speed package, resulting in higher revenue over time.

AJAX^{TM} packages feature an integral engine and compressor with an overall mechanical efficiency of 95%. However, separable packages consist of an engine and a compressor with two frames, two crankshafts, and their associated bearings. Considering a 95% mechanical efficiency for the engine and for the compressor, the HP available for compression for a separable package = 0.95 x 0.95 x engine BHP = 0.902 x engine BHP.

Additional gas compression efficiency advantages for AJAX^{TM} packages are presented in Section 3.2.1

3.1.3 Rugged Combustion System with No Valves or Turbocharger

The single frame and crankshaft design for AJAX^{TM} integral engine-compressors results in substantially fewer wearing parts than a high-speed separable package. The simplicity and ruggedness of the AJAX^{TM} two stroke engine design are illustrated in Figure 3. Unlike high-speed engines, the AJAX^{TM} engine does not have intake and exhaust valves and therefore does not need a valve train, which eliminates maintenance issues with the valves and valve train. Instead the intake air and exhaust are controlled with ports in the cylinder.

The two-stroke piston scavenged design eliminates the need for several parts, including:

- Turbocharger and aftercooler
- Intake and exhaust valves
- Rocker arms and pushrods
- Valve seats
- Camshaft and cam bearings for the intake and exhaust valves
- Timing chain/gears

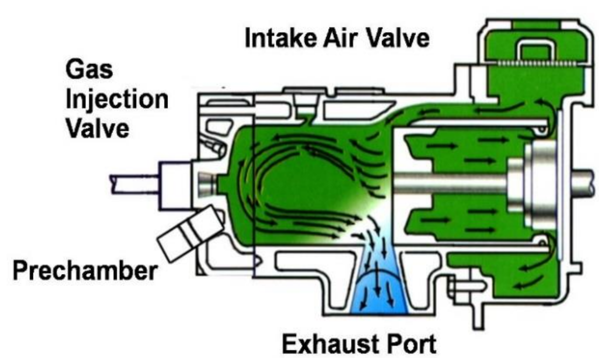


Figure 3: Power Cylinder of AJAX^{TM} Engine

The engine cycle begins with the intake air flowing through a check valve into the scavenging box of the AJAX^{TM} engine. As the piston moves toward the head end of the cylinder, the intake air is pulled into the volume at the crank end of the piston.

After the piston compresses the air and fuel mixture in the power cylinder, combustion occurs, which pushes the piston back toward the crank end of the cylinder. As the piston moves toward the crank end of the cylinder, it compresses the fresh air in the scavenging box. By the time that the piston timing edge uncovers the intake ports, the fresh air charge has been pressurized to about 10 psig. This pressurized air then flows through the ten intake ports into the power cylinder. This process provides a boost pressure to the power cylinder without the need for the turbocharger and aftercooler which are used with the high-speed engines.

3.1.4 Simple, Built-In Air Fuel Control System

The method for controlling the air fuel ratio throughout the operating range of an AJAX™ engine is described in Figure 4. The air flow is controlled by the swept volume of the piston in that the volume of air that is compressed on the back side of the piston is directly proportional to the engine speed. This results in a linear relationship between the air entering the power cylinder and the engine RPM, as shown in the top curve of Figure 4. The lower curve details the results produced by the AJAX™ electronic governor, showing that the fuel flow controlled by the governor is a linear relationship with the engine BHP. Combining the air flow and fuel flow curves results in control of the air fuel ratio throughout the operating range of the engine.

This system for controlling air fuel ratio is simpler and needs much less maintenance than the control systems used with high speed engines.

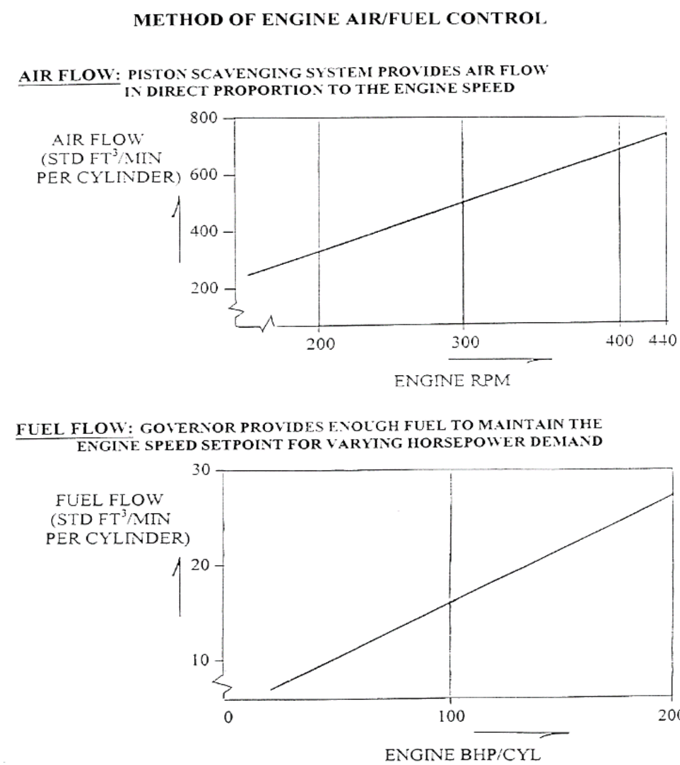


Figure 4: Air/Fuel Control Curves for AJAX™ Engines

3.1.5 Lower Operating and Maintenance Costs

The ruggedness and simplicity for an AJAX™ engine-compressor package result in much lower O & M costs than are typical for a high-speed separable package. These O & M costs are presented in Figures 5 and 6. AJAX™ packages feature low-speed, low BMEP operation with fewer moving parts than a comparable high-speed compression package, leading to reduced O & M costs over time. Additional O & M advantages for AJAX™ packages are presented in Section 3.2.1.

3.1.6 High Tolerance to Various Fuels

AJAX™ engines tolerate a wide range of fuel gases without requiring modifications to the engine. They perform well with fuels ranging from large inert gas content to large amounts of heavier hydrocarbons. They can operate continuously at the full rated BHP with fuels having a normal butane number up to 10, which corresponds with a mixture of 90% propane and 10% methane. With fuels richer than pure propane, a BHP derate curve is used to define the site rated BHP.

3.1.7 High Tolerance to Sour Gas

Because of the unique design of the AJAX™ engine, the power cylinder and scavenging box are isolated from the crankcase. Therefore, combustion blowby cannot enter the crankcase and cause an acidic attack to the bearings and other components. Further, the AJAX™ engine has no intake or exhaust valves to be damaged by acidic attack. The high tolerance to sour gas is described in Appendix A. Because of its design, the AJAX™ engine can operate continuously with fuels having an H_2S content of at least three percent by volume. An H_2S content greater than three percent needs to be approved by the Engineering department of Baker Hughes, a GE Company.

3.2 Comparison of First Cost and Operating Expenses for AJAX™ Integrals and High-Speed Separable Packages

3.2.1 Higher Mechanical Efficiencies, Higher Online Availability, and Lower Maintenance Costs

As described in Section 3.1.2, the mechanical efficiency for an AJAX™ integral engine-compressor is 95%, while the mechanical efficiency for a separable package is 90.2%, due to the two frames and two crankshafts used with high-speed separable packages.

In addition to having a higher mechanical efficiency, AJAX™ compressors feature generous valve flow areas, which equates to low pressure drops across the suction and discharge valves. Combining the higher mechanical efficiency with minimal pressure losses through the compressor valves means that AJAX™ packages exhibit much better compression efficiencies than high-speed separable packages.

Another consideration in selecting a package is the fuel consumption. Usually fuel consumption is expressed in BTU/BHP-hr for the engine. However, it's more meaningful to consider the fuel used by the engine compared to the gas compression capacity for the package, which gives AJAX™ packages a distinct advantage.

The typical online availability for an AJAX™ integral engine-compressor is 98% or higher, as compared to a typical 96% availability for a high speed separable package. This means that AJAX™ integrals are in service an average of 7.3 days more per year. The availability advantage for the AJAX™ integral package is based on low BMEP operation with substantially fewer moving parts at lower operating speeds than the high-speed separable packages.

The splash lubrication system for an AJAX™ engine-compressor means that there are no oil pump and no oil filter to maintain. The power cylinder of an AJAX™ engine is isolated from the crankcase so that combustion blowby products cannot enter the crankcase, meaning that oil changes are needed only once per year, as opposed to several each year for high-speed separable packages. The oil change interval for the AJAX™ integral can be extended beyond one year with an oil analysis program.

3.2.2 A Comparison of Costs for AJAX™ Integrals and High Speed Separable Packages

Selection of a gas compression package should be based on more than the initial capital cost of the package. It's critical to also consider factors such as gas compression efficiency, online availability, and operating and maintenance expenses over the long term.

As an example of the overall expenses for a compression package, Figure 5 compares an AJAX™ integral with a high speed separable package. The packages compared are rated at 400 BHP, and the expenses associated with these packages are based on operating continuously through the year at a production rate of 1.0 MMSCFD with a gas price of $3.00 per mcf.

In the BHP range of 400 to 600 BHP, the first costs for an AJAX™ integral engine-compressor and a high speed separable package are essentially the same. Outside this BHP range, the first costs for the high-speed separable packages are generally somewhat lower than those for the AJAX™ integrals. However, when the total costs for purchasing and operating these packages are considered, then the AJAX™ integrals have a substantial advantage. As shown in Figure 5, the total costs which need to be considered include the first cost, the O & M costs, and the online availability for the units. The O & M costs consist of fuel usage plus maintenance, including parts and service hours. The lost production costs are based on the typical online availabilities, which amount to 7.3 days of downtime per year for the AJAX™ integral and 14.6 days of downtime per year for the high-speed unit.

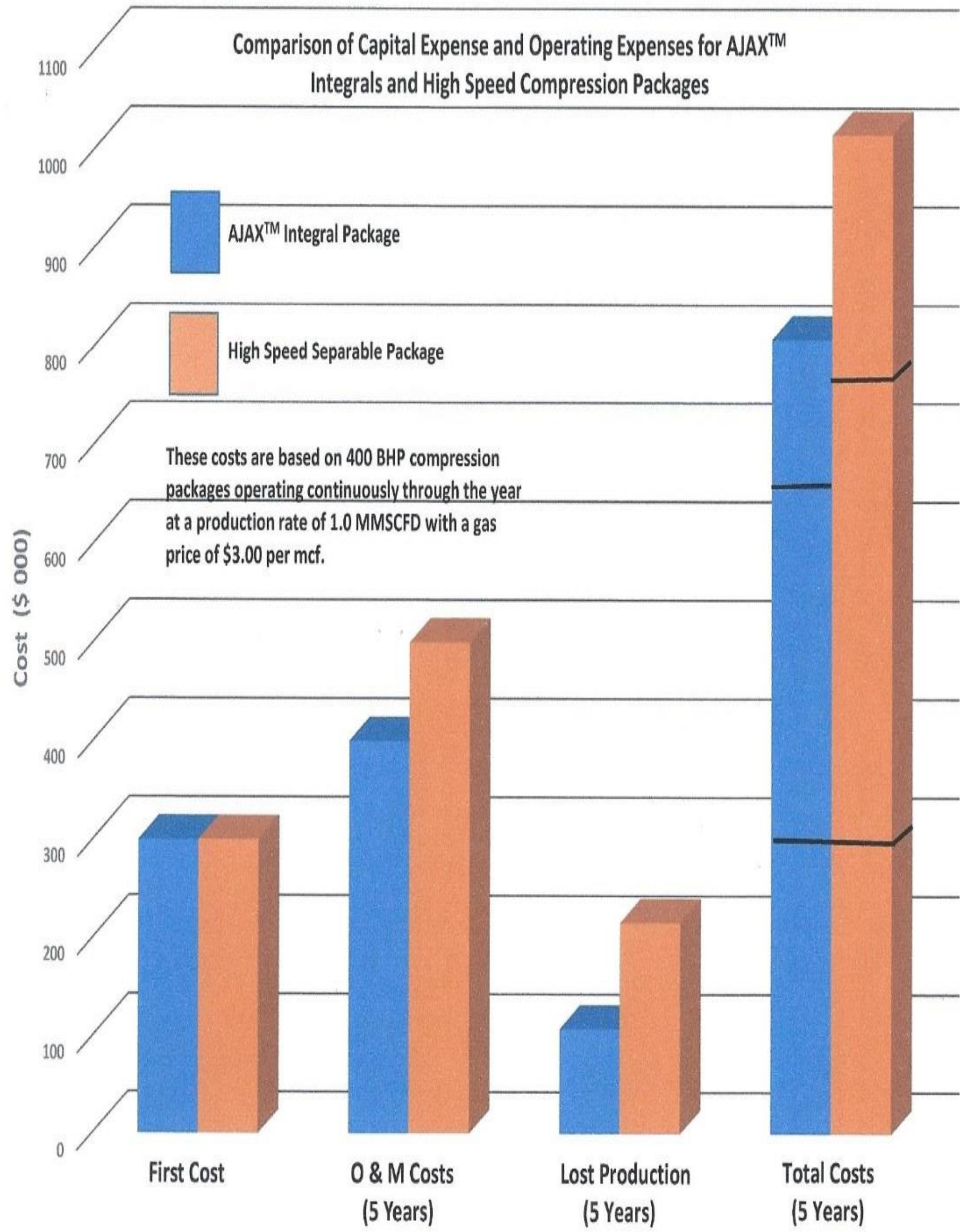


Figure 5: Comparison of First Cost and O & M Expenses

The resulting total costs for five years show a $210,000 savings for the AJAX™ integral.

This chart is based on a five-year service period for the packages, but the typical service life for an AJAX™ engine-compressor package is in the range of about 40 years, so the large advantage shown for the AJAX™ integral becomes even more critical over the expected life of the package.

The curves in Figure 6 compare the same 400 BHP packages which are summarized in Figure 5. These curves are also based on packages operating through the year with a production rate of 1.0 MMSCFD with a gas price of $3.00 per mcf. These curves originate with the first costs of the packages and plot the O & M costs over a period of five years. After five years, the AJAX™ integral has a cost advantage of $110,000. This advantage does not include the higher online availability for the AJAX™ integral.

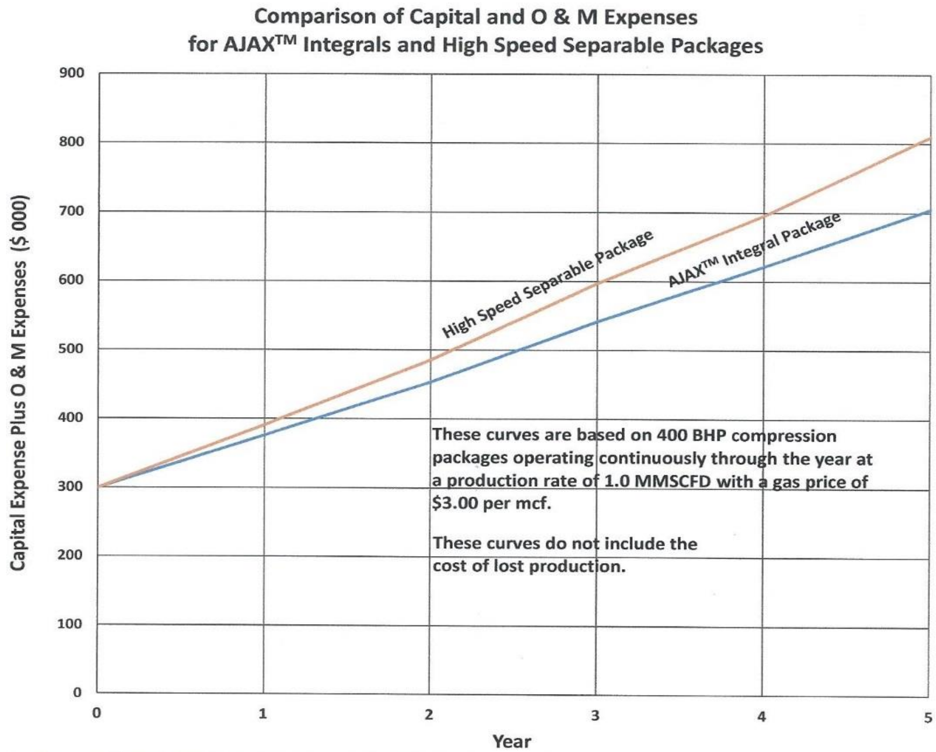


Figure 6: Comparison of Capital and O & M Expenses

3.3 Comparison of BHP Ratings and Exhaust Emissions for AJAX™ Engines and Alternative Engines

3.3.1 Exhaust Emissions Reduction Technology with AJAX™ Engines

AJAX™ engines operate with lean air fuel ratios, resulting in low CO and VOC emissions. The emission that is most difficult to reduce is NOx. Typically, the engine improvements aimed at increased BHP ratings and lower fuel consumption will increase the NOx levels. Therefore, Baker Hughes has focused much attention on reducing NOx while maintaining competitive BHP ratings and fuel economy.

During the last 30 years, there have been many developments for AJAX™ engines which were focused on reducing exhaust emissions. Introduced in 1991, the AJAX™ LE engine features a pre-chamber which allows the engine to operate at very lean air fuel ratios while exhibiting excellent combustion stability. With this pre-chambered design, the NOx at the rated BHP is less than 2.0 gm/BHP-hr at the rated BHP for all 2200LE and 2800LE series engines. Because of the lean and stable combustion, the published CO level is 1.2 gm/BHP-hr and the VOC level is 0.5 gm/BHP-hr at the rated BHP's for the 2800LE engines. These emissions levels are referenced to a standard average ambient temperature of 65 ^{O}F. The VOC level (Volatile Organic Compounds) is based on operating with pipeline quality natural gas (PLQNG). VOC is defined as NMNEHC (non-methane, non-ethane hydrocarbons)

In 2003 – 2004, patented designs were introduced for the AJAX™ exhaust expansion chamber and the AJAX™ oxidizing converter. The expansion chamber reduces the NOx level at the rated BHP by as much as 60%. This reduction occurs because the expansion chamber traps more air in the power cylinder by controlling the pressure pulses at the exhaust ports. The oxidizing converter reduces the CO level by > 80% and the VOC level by up to 70%.

Recent Baker Hughes development work focused on the 2800XLE design configuration. This design includes poppet intake valves with increased flow area, a new multi-orifice pre-chamber design, and a new gas injection valve design. With the XLE configuration, NOx levels have been reduced to < 1.0 gm/BHP-hr at the rated BHP with the emissions referenced to an ambient temperature of 100 ^{O}F. An analysis of the XLE engine performance is presented in Section 3.5.

3.3.2 Exhaust Emissions Curves for AJAX™ Engines and Alternative Engines

NOx emissions curves for AJAX™ engines and an engine supplied by another manufacturer are compared in Figure 7. These curves are plots of NOx levels vs. ambient temperature for the AJAX™ 2802LE engine, the AJAX™ 2802XLE engine, and another low emissions engine.

The alternative low emissions engine maintains a NOx level of 2.0 gm/BHP-hr at 425 BHP throughout the ambient temperature range. This curve is level because this engine is turbocharged and aftercooled. An intake manifold temperature of 130 ^{O}F is held regardless of the ambient temperature.

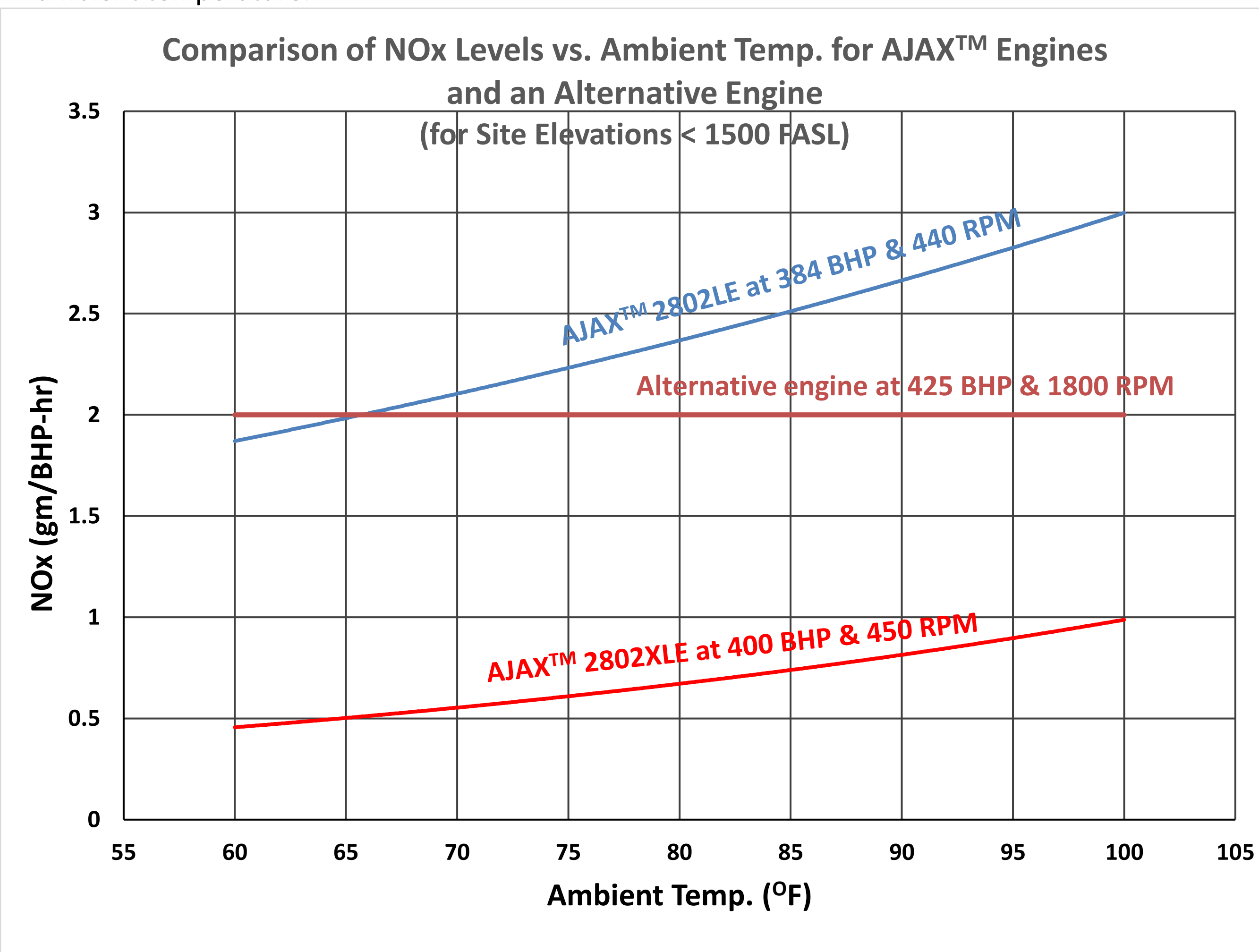


Figure 7: NOx vs. T_{AMB} for AJAX™ Engines and an Alternative Engine

The current production AJAX™ 2802LE engine is quoted at a NOx level of 2.0 gm/BHP-hr at its rating of 384 BHP at 65 ^{O}F. As the ambient temperature increases above 65 ^{O}F, the NOx level will increase as shown in the curve.

The design changes already incorporated into the 2802XLE engine result in large NOx reductions throughout the ambient temperature range. With the 2802XLE, a NOx of 1.0 gm/BHP-hr can be quoted at a rating of 400 BHP at 100 ^{O}F.

Figure 8 demonstrates the BHP available from AJAX™ engines and an alternative engine for constant NOx levels of 1.0 gm/BHP-hr for the AJAX™ engines and 2.0 gm/BHP-hr for the alternative engine. These curves plot the available BHP vs. the ambient temperature.

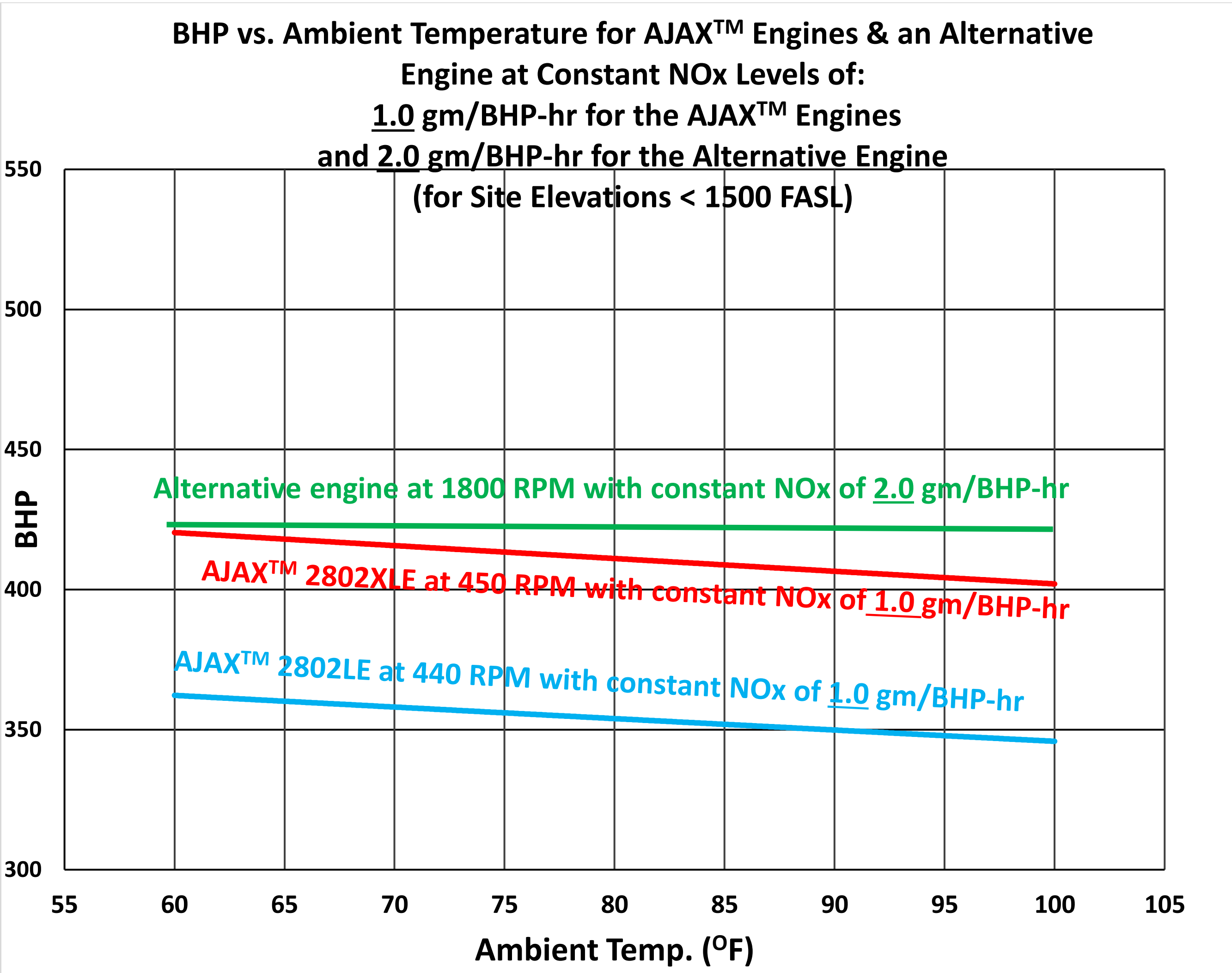


Figure 8: BHP vs. T_{AMB} for AJAX™ Engines and an Alternative Engine at NOx Levels of 1.0 gm/BHP-hr for the AJAX™ Engines and 2.0 gm/BHP-hr for the Alternative Engine

The curve for the alternative engine is flat because this engine is turbocharged and aftercooled. The curves for the AJAX™ 2802LE and 2802XLE engines express the BHP derate that is needed to maintain a NOx level of 1.0 gm/BHP-hr as the ambient temperature increases. The curves for the AJAX™ engines emphasize the large increase in BHP available with the XLE configuration.

Figure 9 expresses the BHP available for larger AJAX^{TM} engines and an alternative engine for a constant NOx level of 1.0 gm/BHP-hr. As before, these curves plot the available BHP vs. ambient temperature for the AJAX^{TM} 2803XLE engine, AJAX^{TM} 2804XLE engine, and the alternative engine through the ambient temperature range.

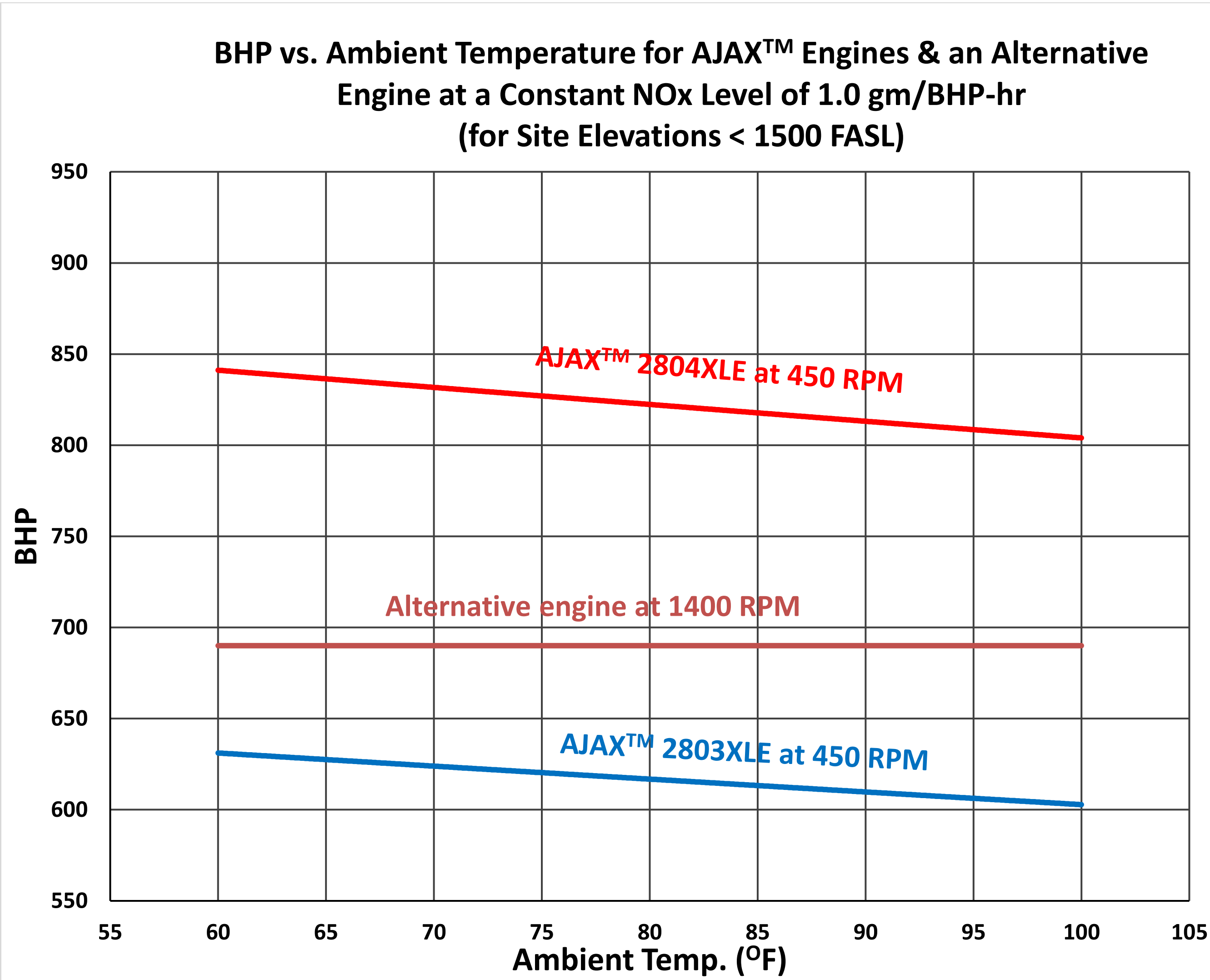


Figure 9: BHP vs. T_{AMB} for AJAX^{TM} Engines and an Alternative Engine at NOx = 1.0 gm/BHP-hr

The 2803XLE is rated at 600 BHP with a NOx of 1.0 gm/BHP-hr at an ambient temperature of 100 ^{O}F, and the 2804XLE is rated at 800 BHP with a NOx of 1.0 at 100 ^{O}F.

3.4 Analyses of Field Emissions Tests for AJAX™ Engines

3.4.1 Factors Affecting Exhaust Emissions Recorded at Field Sites

There are many factors at field sites which will cause the measured emissions to be different from the standard published emissions for AJAX™ engines. These factors include:

- Engine Load – Most field emissions tests are conducted with less than the site rated BHP. BMEP's below the rated load will decrease NOx and will increase CO and VOC's.
- Ambient Temperature – High temperatures can increase NOx, while low temperatures can increase CO and VOC levels.
- Cylinder Pressure Balance – It's important to have each cylinder carrying its fair share of the engine load, meaning that average peak cylinder pressures should be balanced to within ± 15 psi. If the average peak firing pressure is high for one or more cylinders, then the engine NOx level will increase substantially.
- Fuel Composition – exhaust emissions for AJAX™ engines are quoted based on the fuel composition at the site. Fuel composition has a strong effect on VOC levels in the exhaust. The ratio of NMNE hydrocarbons to total hydrocarbons (THC) in the exhaust is directly proportional to the ratio of NMNE hydrocarbons to THC in the fuel.
- Mechanical Condition of the Engine – Initial emissions quotations are based on a well-maintained engine. Factors such as leaking gas injection valves, worn rod packings, dirty air filters, worn piston rings, bad spark plugs, bad coils, and bad secondary wiring will all affect the emissions levels.

3.4.2 Results from Emissions Field Tests of AJAX™ Engines

During the last ten years, field emissions test results for AJAX™ engines have been collected into a database. For the purpose of this paper, results from many of these field tests were analyzed and put into the same format, and are recorded in the spreadsheet shown in Appendix B.

These field test results verify that AJAX™ engines consistently have emissions levels which are lower than the quoted emissions levels, thereby eliminating non-compliance issues.

All the emissions are expressed as gm/BHP-hr in this spreadsheet.

For eight of these field tests, the actual engine BHP was not recorded. However, sufficient data, such as compressed gas suction and discharge temperatures, allowed for the estimation of the BHP.

Figure 10: Oxidizing Converter with a DPC-2804LE

Oxidizing converters were in use for 17 of the tests in the spreadsheet. Exhaust expansion chambers were in use for five of these tests. Figure 10 is a photo of an oxidizing converter installed with a 2804LE application.

Figure 11 shows exhaust expansion chambers installed on a 2804LE package. VOC emissions were measured for six of these tests, and the formaldehyde levels were measured for two of the tests.

Four columns near the center of the spreadsheet record the measured NOx and CO levels and compare them to the NOx and CO levels which we would predict at the test conditions. For these tests, the actual NOx is less than the predicted NOx for the site conditions. For 20 of these tests, the actual CO is the same as or below the predicted CO level for the site conditions. In the three instances in which the actual CO was higher than predicted, the actual and predicted levels were very close to each other.

Figure 11: Expansion Pipes with a DPC-2804LE

3.5 Performance Results for AJAX™ 2800XLE Engines

Large NOx reductions for AJAX™ engines were recently achieved by improving the air flow to the power cylinder and modifying the gas injection valve and pre-chamber. The resulting engine configuration has been designated as the DPC-2800XLE series.

A comparison of the performance of the 2800XLE engines with alternative engines is provided in Figure 12.

CO and VOC levels for AJAX™ engines are low because of the lean operation of these engines. For sites requiring even lower levels of CO and VOC's, Baker Hughes provides oxidizing converters which remove 90% of the CO and up to 70% of the VOC's.

Engine	Rated BHP *	Rated Speed (RPM)	NOx @ Rating (gm/BHP-hr) *
AJAX™ 2802XLE	400	450	1.0
Alternative	425	1800	2.0
AJAX™ 2803XLE	600	450	1.0
Alternative	637	1800	2.0
Alternative	690	1400	1.0
AJAX™ 2804XLE	800	450	1.0
Alternative	1035	1400	1.0

*** For site elevations ≤ 1500 FASL & ambient temps. ≤ 100 ^{O}F.**

Figure 12: BHP Ratings and NOx Levels for AJAX™ Engines and Alternative Engines

3.6 Optimizing the AJAX™ Engine-Compressor Packages

Research into improving the design for AJAX™ engine-compressors is ongoing, and customer feedback is critical to this process, including initiatives to reduce the package footprint and to improve transportability. The package design team created narrow skid 2802LE packages which are 8.5 ft. x 38 ft. with the entire package, including the cooler, now able to ship on one truck. Additionally, the team looked at site preparation and determined that the skids could be pre-filled with concrete at the Baker Hughes plant and would therefore be ready for service without having a concrete pad at the compression site.

Figure 13: Narrow DPC-2802LE Package for Shipment on One Truck

4.0 SUMMARY

AJAX™ engine/compressor packages have an excellent track record for long term service reliability. Specific advantages of AJAX™ integral engine-compressors compared to high-speed separable packages include:

- Lower operating and maintenance expenses and higher online availability than comparable high-speed separable packages with a typical online availability of 98%, as compared to 96% availability.
- High tolerance to sour gas is described in Appendix A. Because of its design, the AJAX™ engine can operate continuously with fuels having an H_2S content of at least three percent by volume.
- AJAX™ integrals consume less fuel per MMSCFD of compressed gas than the comparable high-speed separable packages.
- AJAX™ integrals combine the engine and compressor with an overall mechanical efficiency of 95% compared to 90.2% for separable packages which comprise an engine and a compressor with two frames and two crankshafts.
- Performance and emissions control capabilities for AJAX™ engines are similar to those quoted for the high-speed engines used in separable packages.
- AJAX™ engines operate with lean air fuel ratios, which results in low CO and VOC emissions.
- Increased HP and large reductions in NOx levels with ambient temperatures up to 100 ^{O}F for the AJAX™ 2800XLE engines.

5.0 REFERENCES

1. AJAX™ Integral Engine-Compressor brochure, November, 2017
2. AJAX™ Oxidizing Catalytic Converter brochure, September, 2008
3. AJAX™ Exhaust Expansion Chamber brochure, 2017

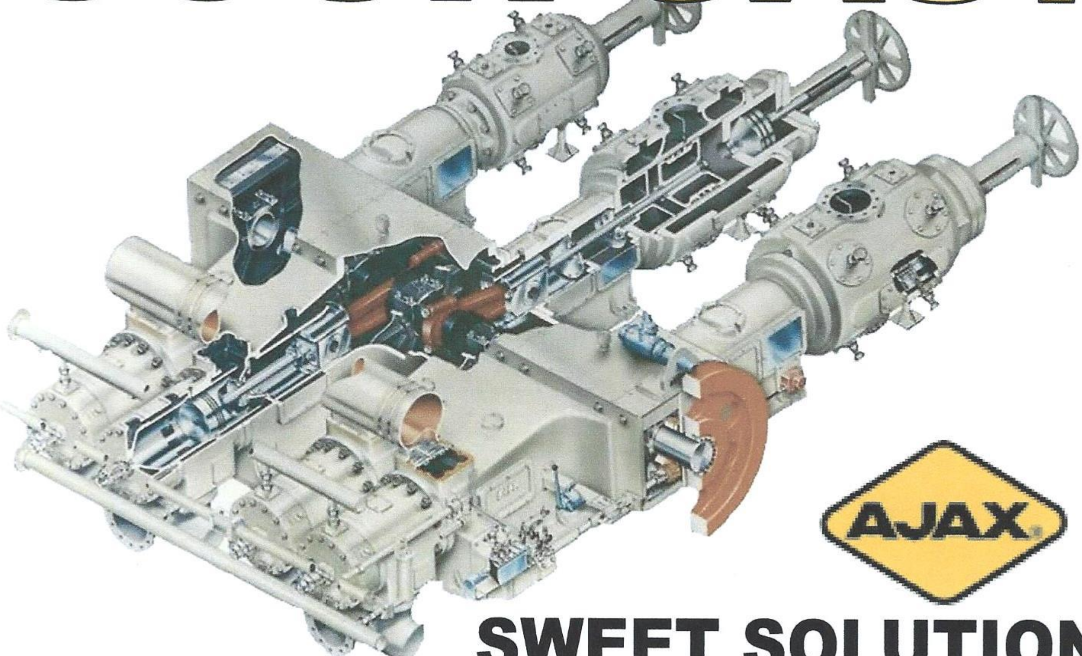
6.0 APPENDICES

A. Sour gas brochure[4] for AJAX™ engines
B. Spreadsheet of results from field emissions testing of AJAX™ engines

[4] This sour gas brochure was issued by Cooper Compression, which was a previous brand owner for AJAX™ integral engine-compressors.

Appendix A: Sour Gas Brochure for AJAX™ Engines

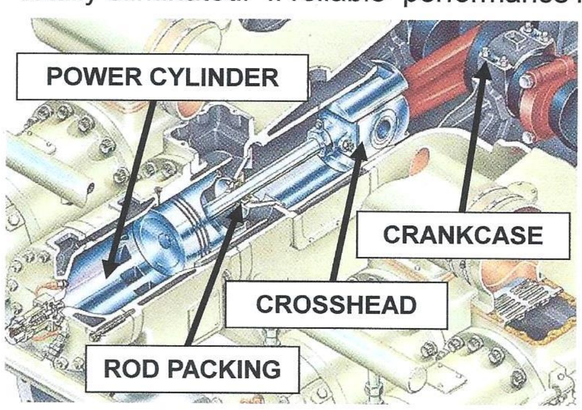
SOUR GAS?



AJAX

SWEET SOLUTION

The unique 2-stroke design of the Ajax integral engine-compressor eliminates the problems typically caused by H_2S presence in fuel gas. Because the power cylinder is isolated from the crankcase, blow-by can not enter the crankcase resulting in acid attack of the bearings. Unlike conventional 4-stroke engines, the Ajax does not have intake or exhaust valves so valve and seat wear are totally eliminated. If reliable performance is critical to your operation, Ajax is the sweet solution to your sour gas problems. Call your local Cooper Compression sales representative today.



The Ajax Integral Engine-Compressor can handle fuel gas H_2S content up to 3.0 mol%

COOPER COMPRESSION

2101 S.E. 18th Street, Oklahoma City, OK 73129
Tele 713 354-1925 Fax 713 354-1934
www.cooperenergy.com

<u>Appendix B</u>: Spreadsheet of Results from Field Emissions Testing of AJAX^{TM} Engines

Attached is an Excel File: “AJAX^{TM} Engine Emissions – Field Test Results”

Ajax Emissions - Field Test Results.xls