Technology Optimizes Fleet Performance

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HOUSTON–There are still some in the industry who remember when natural gas sold for 16 cents an Mcf. At that price, gas was little more than a nice add-on to oil production, and no one gave much thought to optimizing its production. Today, eight of every 10 new wells drilled in the United States are gas wells, and operators are taking very serious notice of their bottom-line gas sales. Not surprisingly, optimizing production has become the name of the game in many gas fields.

For proactive North American independent natural gas producers, Internet-based compressor optimization and fleet management technology is giving company engineers and field operators powerful new capabilities for optimizing compressor operations and maximizing production. Independent producers from the Appalachian Basin to Western Canada are successfully applying the technology to their competitive advantage, achieving significant production and financial benefits.

The ever-growing demand for natural gas and accelerating overall decline rates in North American gas basins have forced independent producers to seek ways to work smarter. There are numerous examples of how gas producers are making more intelligent and innovative business decisions. From horizontal wells and new stimulation techniques to casing drilling strings and 4-D seismic, operators are finding creative ways to solve operational challenges. Technology and service providers are responding by offering smarter products.

Advanced technology is being implemented across the entire exploration, drilling and production spectrum. With the computer becoming nearly ubiquitous in the "daily grind" in the oil and gas business, new computing technologies are helping independent producers efficiently manage information, streamline operations, and make better financial decisions. Many technology providers have taken the next step by making software solutions available over the Internet, thereby creating the ultimate "24/7" round-the-clock scenario for product availability. Internet-based optimization technology is now being widely used in an area that not long ago was virtually neglected: compression.

In the past, compressor operations were viewed as little more than a necessary evil. Compressor optimization often meant driving near the compressor station, rolling down the truck window, and listening to make sure the unit was still running. Some companies have their operators faithfully record pressures, temperatures and run speeds, but never properly analyze what all of that data means in terms of compression efficiency and production. The tools simply did not exist to easily measure how compressors were performing, or accurately determine whether mechanical or setup inefficiencies were sacrificing production. The technology that did exist was often expensive, cumbersome and invasive, required highly skilled technicians to be able to use it, and did not provide a comprehensive solution.

Primary Goal

The operations and management of a producer's compressor fleet are often turned over to a leasing company or third-party service provider. But even the best third-party business partner may not share the producer's primary corporate goal: maximizing production. Achieving set run-time targets is a good start, but just because a compressor is running does not mean it is running efficiently. Underperforming or damaged components and inefficient setup can cost a producer far more in lost production volumes than the brief downtime it may take to address the issue. And who suffers when a compressor is not fully optimized?

Clearly, it is the company that owns the gas moving through the compressor. Inefficient compressor operation affects the producer's bottom line first. In the past, production and operations managers have not had an effective tool to oversee and manage leased compressor fleets to ensure they achieve maximum efficiency and production. Because they lacked the tools, most simply adopted a "delegate and abdicate" policy toward managing leased compressors. Not only is that is no longer necessary, but with wellhead prices of $5.00-$6.00, it also is no longer tolerable.

Over the past two decades, the technologies most often used to measure compressor performance fell into two categories: alarming systems and theoretical sizing programs. Alarming systems provide high-level compressor monitoring by notifying users when a pressure or temperature exceeds a predefined operational limit. Although alarming systems can protect a compressor from operating out of bounds, they do not help improve or optimize the compressor's performance.

Using theoretical sizing programs in an attempt to interpret actual field operating data has been a common practice in the industry for years. Many compressor manufacturers offer sizing programs on their Web sites that can be downloaded and used on any personal computer. This technology works very well for determining the necessary horsepower and cylinder sizes required for a new compressor application. In fact, that is precisely what the programs were created to do. However, using these same sizing programs to interpret actual field operating data has serious inherent limitations.

Sizing programs utilize theoretical operating data to predict theoretical operating results. A trained compression analyst must then compare these theoretical predictions to actual operating data and attempt to determine what inefficiencies or opportunities exist, if any. This process can take hours or even days to complete. Furthermore, the quality of the output is tied directly to the competence of the analyst and to whether the theoretical assumptions being made are actually true. Dozens of compressor sizing performance runs may have to be executed on an individual compressor before a reasonable match between the theoretical run and the actual operating conditions is found. Performance programs do not measure real operating performance, nor do they provide recommendations for improving operation and increasing production.

This leads to another practical limitation: the "human element" bottleneck. Producers with large numbers of compressors cannot effectively make rapid operational and maintenance decisions if they must wait hours or days for feedback on each unit. In addition, there simply are not enough talented compressor engineers available to turn the crank that many times. Also, this approach does not permit frequent analyses as conditions change, which they always do. The process simply bogs down in a sea of iterations.

Optimizing Performance

Producers need to have real-time detailed information on the performance of their compressors, both on the individual and fleetwide levels. This instant access to critical efficiency and fleet performance information allows decision makers to move their companies ahead of the competition.

The compressor optimization and fleet management technology available today represents a quantum leap forward when compared to traditional approaches. There are many, many pieces in the total puzzle of compressor optimization. Unfortunately, any technology that offers a solution to even a small portion of the process tends to be called "compressor optimization," as if it were dealing with the entire spectrum.

And what about compressor fleet management? Optimizing individual compressors can be extremely beneficial, but how does this translate into fleetwide performance evaluation and decision making when a producing company has a limited maintenance budget and personnel are struggling to prioritize resource deployment? The issues are further complicated when the individual tasked with making that decision is struggling to decide whether to buy or lease a new compressor, or utilize one already in the company's fleet, and has responsibility for a large number of compressors and does not have the time or desire to get bogged down in the minute performance details of each one.

A compressor fleet is truly an ever-changing puzzle that is comprised of many dynamic pieces of varied size, shape and orientation. Fortunately, the technology now exists to put all of these pieces together so that individual compressors can be optimized as well as entire compressor fleets.

Independent producers across North America are using this powerful Internet-based technology to fully optimize and effectively manage their compressor fleets. It accepts and accurately interprets real compressor operating data instantly, offering precise recommendations on how to optimize an individual compressor, and providing the necessary tools engineering and production managers need to effectively oversee their entire compressor fleets. The delivery platform is entirely on the Internet.

Operator Case Study

Equitable Production Co. is one North American independent producer actively using this Internet-based compressor management and optimization technology. As the largest gas producer in the Eastern United States, Equitable Production operates a fleet of approximately 200 reciprocating and screw compressors in Kentucky, Virginia, West Virginia and Pennsylvania. Like many producers, the company's compressor fleet consists of a wide array of different makes and models, including Ajax, Ariel, Chicago-Pneumatic, Clark, Cooper-Bessemer, Dresser-Rand, Frick, Gardner-Denver, Gemini, Joy, Leroi and Superior. The compressors range in size and function from 75 horsepower field gathering units to 2,250 horsepower plant units.

Equitable Production's primary motivation for adopting Internet-based compressor management/optimization technology is to maximize production. The company places a very high priority on achieving both maximum runtime and maximum efficiency from its compressor fleet. It is not enough to simply keep a machine running; it also must be kept running efficiently to ensure that no potential production volumes are being left on the table.

The company began implementing the technology across its fleet in mid-2004. Operators and mechanics gather weekly field data readings on each compressor, generating comprehensive compressor diagnostic reports via the Internet, which are then reviewed by company operators, mechanics and compressor specialists who use the information to identify performance problems in the machines and target opportunities to increase production. Equitable Production's compression and operations management group utilizes roll-up fleet management tools to evaluate fleet utilization, prioritize resource deployment, and ensure that the highest dollar-value opportunities or threats within the compressor fleet are being addressed.

Using this Internet-based compressor management and optimization tool, the company has identified, and subsequently resolved, numerous compressor performance issues, including:

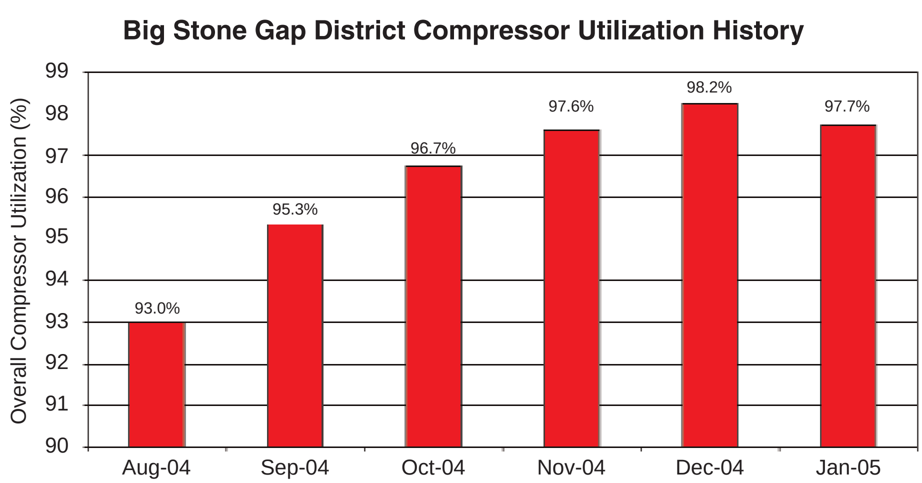
- Damaged valves;
- Damaged piston rings;
- Valve "stiction" caused by overlubrication;
- Bad gauges;
- Leaking bypass valves and scrubber dump valves;
- High rod load; and
- Inefficient pocket settings.

One example is the Nancy compressor, a 400-horsepower, two-stage Ajax unit moving approximately 2,000 Mcf of gas a day. Even though measured temperatures and pressures were within normal operating ranges, the diagnostic reports indicated that a significant amount of blow-by (recirculating gas due to valve or ring damage) was occurring in the first-stage cylinder, impacting production volumes by several hundred Mcf/d. Upon subsequent physical inspection, technicians found that part of the poppet valve assembly had been

FIGURE 1

Valve Damage on Nancy Compressor

FIGURE 2



sucked into the cylinder, as shown in Figure 1. Correcting this valve damage helped boost production by 400 Mcf/d, or $73,000 a month at a $6.00/Mcf gas price.

Another objective for Equitable Production in deciding to use Internet-based compressor management/optimization technology was to improve overall asset utilization (considering both horsepower and cylinder capacity utilization). The company's largest district, Big Stone Gap, was one of the first operating areas to be fully up and running with the technology. As shown in Figure 2, a significant increase in asset utilization has been realized.

Key Areas

State-of-the-art compressor optimization and fleet management technology includes four key areas:

- Data acquisition;
- Data analysis and interpretation;
- Performance feedback and optimization recommendations; and
- Comprehensive compressor fleet management tools.

Field data can be input for analysis by telephone, fax, Internet or supervisory, control and data acquisition. The speed at which compressor operating data can be acquired has been drastically improved through SCADA and other data gathering technologies, some of which use the Internet for information transfer. Data acquisition, however, does not equal compressor optimization; it is simply the first necessary step. Even though tremendous amounts of data can be acquired in real time, without real-time analysis, the activity only results in stockpiles of underexamined information. In addition, many gas producers do not currently utilize SCADA or electronic data gathering systems on their compressors. Compressor optimization technology must be able to accommodate them as well.

The real measure of any compressor optimization technology is how accurately it interprets and rationalizes true operating data. Unlike theoretical sizing programs, state-of-the-art compressor optimization technology takes actual operating data and precisely diagnoses actual compressor health and performance without resorting to theoretical assumptions.

After compressor operating data have been interpreted, performance feedback and optimization recommendations are necessary. The only feedback that alarming systems provide is some form of notification that the compressor is approaching predefined operational limits. Theoretical sizing programs offer feedback in the form of a list of predicted operating results that reflect the theoretical data that was entered.

With today's Internet-based compressor management/optimization technology, feedback is provided instantly (in less than one second) on all aspects of the compressor, including analyzing crucial valve or ring damage in each individual cylinder. Figure 3 depicts a sample diagnostic report for a common two-stage Caterpillar/Ariel compressor package. Company operators, mechanics and engineers can use the information contained in these reports to focus in on performance problems and identify opportunities to increase production.

As an example of how this Internet-based compressor optimization and management tool can improve fleet performance, Anadarko Petroleum Corp. has been effectively using the technology in its Canadian division for the past four years to maximize production, proactively control maintenance spending, manage its compressor fleet, and make smarter compressor-related decisions. Since implementing the technology, Anadarko Canada has realized significant fleetwide performance gains, including increasing overall

FIGURE 3

Sample Report (Two-Stage Caterpillar/Ariel Package)

Control Number	**5002**	**Cash Flow at Risk ($000)** $4.00/MSCF WI:100%	**145**
Report Date	Mar 7,2005	**CFR1 - 1 month lost production - blowby ($000)**	39
Compressor Name	Booster Station #2	**CFR2 - Lost production due to setup ($000)**	0
Location	New Mexico	**CFR3 - Unscheduled downtime lost production ($000)**	0
Operator Name	B. Hamilton	**CFR4 - 1 week down - damage ($000)**	75
Flow Total	2.678 MMSCFD	**CFR5 - 1 week down - high overhaul hours ($000)**	0
Incremental Production	0.254 MMSCFD	**CFR6 - Lost production due to field limitation ($000)**	31
Station Inlet Pressure	15.0 psig	**Availability (%)**	100.0
		Reliability (%)	100.0

Recommended Action: Production limited due to field. Hi Blowby. Blowby has increased since last report. Repair Valves/Rings. Losing Production due to first stage Blowby. Production has increased since last report.

Frame Made by Ariel	**Driver** Made by Caterpillar	**Cooler & Auxiliary**
Model JGA/4	Model G3408TA	Made by R&R Engineering
Throws 4 Stages 2 Stroke 3.00 inches	Max Derated HP 382 @ 1800 RPM	Model U1-103-16T2
Rod Load 11000C (lbs) / 10000 T (lbs)	Hoursepower Used 328	Fan & Aux. HP Draw 17
Compressor Run Speed 1629RPM	Running Speed 1629 RPM	

Stage Number		**1**	**1**	**2**	**2**
Throw Number		**1**	**3**	**2**	**4**
Cylinder Model		13-1/2JG	13-1/2JG	11JG	11JG
Cylinder MAWP	psig	115	115	150	150
Lube Status		Lube	Lube	Lube	Lube
Cylinder Action		DA	DA	DA	DA
Cylinder Diameter	inches	13.500	13.500	11.000	11.000
Rod Diameter	inches	1.125	1.125	1.125	1.125
Suction Temperature	°F	35.0	35.0	84.0	84.0
Discharge Temperature	°F	146.5	159.0	248.0	254.0
Temperature Rise	°F	111.5	124.0	164.0	170.0
Suction Pressure	psig	6.0	6.0	22.0	22.0
Discharge Pressure	psig	22.0	22.0	75.0	75.0
Compression Ratio		1.805	1.805	2.478	2.478
Pocket Adjustment	inches	0.000	0.000	0.000	0.000
Head End Spacers Added	Qty	0	0	0	0
Crank End Spacers Added	Qty	0	0	0	0
Running Clearance Head End	%	17.700	17.700	18.100	18.100
Running Clearance Crank End	%	15.800	15.800	16.000	16.000
Volume Efficiency Head End	%	85.479	85.485	76.292	76.297
Volume Efficiency Crank End	%	86.562	86.568	78.428	78.433
Mechanical Efficiency	%	83.809	83.809	87.617	87.618
Compression Efficiency	%	73.879	74.043	82.813	82.862
Blowby	%	**8.371**	**16.090**	6.715	**9.298**
Rod Load	**Internal**				
Rod Load Compression	lbs	3038	3029	5994	5989
Rod Load Tension	lbs	2982	2973	5867	5862
Total Internal Rod Load	lbs	6020	6002	11861	11851
Net Rod Load					
Rod Load Compression	lbs	7228	7228	6733	6776
Rod Load Tension	lbs	8719	8726	6991	7054
Minimum Degrees Reversal	Degrees	162	162	171	171
Minimum Rod Load Net Ratio	%	83	83	96	96
Hoursepower/Cylinder		61.6	61.5	89.9	89.8
Cylinder Flow	MMSCFD	1.421	1.421	1.393	1.393
Performance Flags					
High Rod Load	> 95%				
Low Min Degrees Reversal	< 70%				
Low Min Net Ratio	< 35%				
High Blowby	>7%	Yes	Yes		Yes
Low Volumetric Efficiency	< 20%				
High Temperature	> Max Design				
Gauge Maintenance (1 - Low 3 - High)	> 0				
Single Acting Cylinder	SACE / SAHE				
Maintenance					
Hours Since Last Top End Overhaul	125.0	Hours Since Last Oil Change			125.0
Hours Since Last Bottom End Overhaul	125.0	Total Run Hours on Unit			2670.0
Hours Since Last Compressor Overhaul	125.0	ByPass Open %			0.0
Scheduled Downtime Hours	0.0	Unscheduled Downtime Hours			0.0

Key Indicators: Horsepower Utilized..... **86.03%** Cylinder Capacity Utilized..... **90.50%** Boost..... **0.00 PSIG**

FIGURE 4

Sample Cash Flow-At-Risk Report (Powder River Basin, March 2005)

Unit #	Compressor Name	CFR1 Blowby (x $1,000)	CFR2 Setup (x $1,000)	CFR3 Downtime (x $1,000)	CFR4 Damage (x $1,000)	CFR5 Overhaul (x $1,000)	Subtotal CFR (15) (x $1,000)	CFR6 Field Limitation (x $1,000)	Total CFR (1-6) (x $1,000)
9002	Sand Creek #1	70	129	11	0	0	210	0	210
9008	Beryl	0	89	0	108	0	197	0	197
9001	Widow Woman #2	0	0	0	171	0	171	0	171
9006	Enterprise #1	0	0	0	0	0	0	118	118
9007	Enterprise #2	31	28	0	35	0	94	0	94
9004	Trout Creek	0	21	0	0	0	21	0	21
9005	Black Rock #1	0	5	0	0	0	5	0	5
9003	Gandy #1	0	0	0	0	0	0	0	0

Total Number of Units: 8
Total CFR1 Blowby: $101,000
Total CFR2 Setup: $272,000
Total CFR3 Downtime: $11,000
Total CFR4 Damage: $314,000
Total CFR5 Overhaul: $0
Total Subtotal CFR (1-5): $698,000
Total CFR6 Field Limitations: $118,000
Total CFR (1-6): $816,000

compressor utilization from 81 to 93 percent between late 2001 and early 2005, according to Allan Frankiw, manager of Anadarko's Canadian midstream group.

The only way a compressor can be optimized is by understanding the conditions under which the unit is operating, and then configuring it to obtain maximum production under those conditions. Finding what configuration is optimum requires not only a complete understanding of the myriad of variables that go into the compressor's operation, but also the weight of each of those variables and how changing the variables affects overall operation. A truly comprehensive diagnostic report (such as the one shown in Figure 3) takes all of these into account, accurately interprets them, and then tells the operator exactly how to configure the compressor to achieve optimum operation. All that is left for the operator to do is to physically make the changes.

Fleet-Level Optimization

The optimization of individual compressors does not provide the total solution to overall compressor fleet management. While many natural gas companies operate small fleets of compressors in small geographic regions, some are spread across North America or even other continents. Larger companies are often faced with the need to coordinate a number of smaller fleets, many of which operate autonomously and without concern for the company's overall production effort.

Advanced Internet-based management/optimization technology not only enhances individual compressor performance, but also takes compressor optimization to the fleet level, providing a completely new approach to total fleet management. It contains many distinct characteristics that can be fully utilized with only a computer and Internet access. Producers are using the technology to instantly generate district or fleetwide reports, such as:

- Exploitation reports that instantly identify underutilized "field limited" compressors and quantify the available incremental throughput capacity, allowing exploration/exploitation engineers to evaluate system expansion capabilities;

- Cash flow-at-risk summary reports (Figure 4), which prioritize the performance risks and opportunities throughout a compressor fleet from a monthly cash flow perspective; and
- Top 10 performance summary reports, which show the 10 highest-risk compressors in a fleet from several different perspectives, including overall asset utilization, potential damage and downtime risk, fuel and electrical optimization, high blowby, etc.

In today's business environment, it makes sound economic sense for gas producers to optimize compressor operations and maximize production. Many reservoirs are competitive. The no-flow boundary will eventually shift away from the well producing at maximum rate and toward the well that is not. In such cases, optimized compression can actually increase the reserves of the well.

There are many other compelling economic benefits for applying Internet-based compressor management/optimization technology, but the potential drawbacks associated with not doing so can be equally strong motivators. Consider the cost of compression-related lost production. Every Mcf of gas not produced today is effectively deferred until the end of the well's life. The time value of the deferral of that income can economically be very significant. What is worth $5.00-$6.00 an Mcf today may only be worth a present value of $1.00 or less at the end of the well's life. Lost or delayed production caused by compressor inefficiencies can cost a company big in the long run. ❒

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