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Emissions Upgrades Boost Compression

Editor's Note: The following concludes a three-part series on optimizing gas compressor and gathering system performance. Part I appeared in the March issue, and focused on improving the efficiency and profitability of compression operations. Part II, published in the May issue, presented a comprehensive approach to evaluating the performance of gathering systems.

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Scott Greer
and Chris Olson

DENVER–In today's world, one thing everyone can agree on as sure as death and taxes is that government will require a reduction of the energy industry's environmental impact. Regardless of one's personal opinion of the validity of global warming, the industry can expect politicians to embrace an energy "policy" that implements some form of cap and trade on carbon emissions.

Rather than addressing other strategies a company may employ, this article focuses on upgrading a gas compression and treatment facility to reduce emissions and improve overall efficiency. Accomplishing this requires looking beyond typical methods of improving efficiency and reducing emissions, while focusing on upgrades that provide long-term return on investment and ways to recover "lost energy" to reduce operating costs.

New energy policy initiatives may actually make it profitable for companies to reduce emissions. This article evaluates upgrades made to a typical four-unit, three-stage, 1,340-horsepower compressor facility to not only keep pace with impending environmental policies, but also provide the economic justification to do even more (Table 1).

One of the first upgrades was to equip the compressor engines with advanced air-to-fuel ratio controller modules and remote air intakes to dramatically increase engine loading. However, the need for these upgrades primarily was driven by two other factors: emissions and overheating. Since these upgrades would not increase gas throughput at lower suction pressures (the cylinders were too small), a change to larger, same-class cylinders was justifiable.

This represented a quick and easy solution, and although it helped, more could be done. The next step was to take a look at the method of cylinder loading. The normal operating philosophy usually dictates the need to maximize run time rather than maximize throughput. This makes sense, since few facilities are fully manned. An operator is likely not going to be on site to catch a unit when it shuts down. Therefore, once a comfortable setup is achieved, units normally are left to run without operator control for long periods. The downside to this method is that the units utilize only part of their maximum throughput potential (in this case, typically 85-88 percent, and even less during the heat of summer).

Consequently, the next compressor cylinder upgrade was automated unloading devices. Utilizing pneumatically actuated front head unloaders on multiple cylinders allows a unit to vary its load to match continuously changing ambient and process conditions. In contrast, based on current operating philosophy with manual

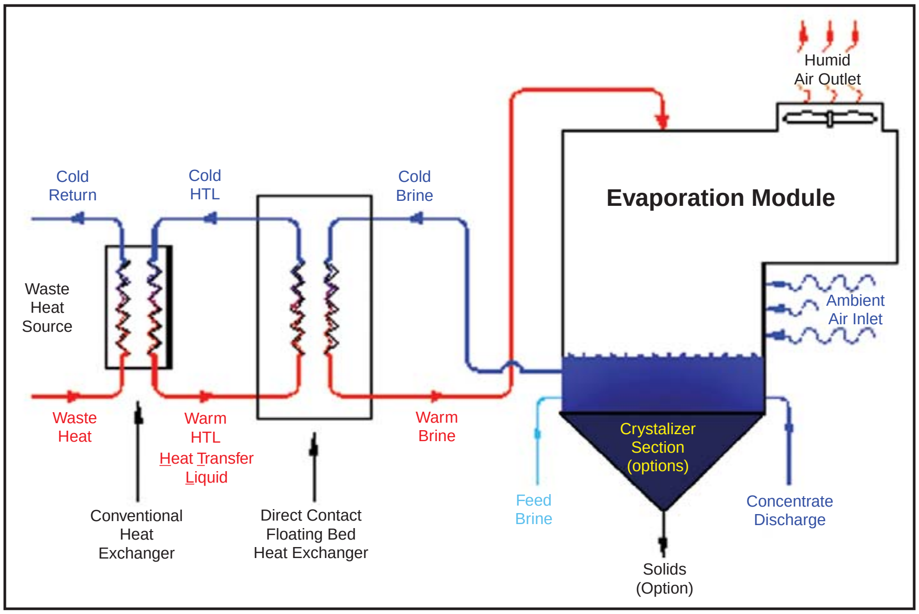
TABLE 1

Facility Economic Summary

UPGRADE	Four, 3-stage 1,340-Horsepower Compressors	Total Cost ($)
Larger Cylinder Bores		380,000
Unit PLC		720,000
Facility PLC		100,000
Larger Catalyst/Silencer and Insulation		157,000
Remote Monitoring		920,000
Evaporative system		3,800,000
Waste Heat Generator		512,000
Vapor Recovery Units		150,000
TOTAL COSTS		**6,739,000**
BENEFIT		**Total Savings ($)**
Additional Flow @ $6.00/Mcf	3.28 MMcf/d	7,183,200
Produced Water @ $4.00/bbl (net)	1,200.00 bbl/day	1,752,000
TOTAL SAVINGS		**8,935,200**
RETURN ON CAPITAL INVESTMENT	**0.75 YEARS (9.1 MONTHS)**	
10 YEAR ADDITIONAL REVENUE	**$72,375,120**	

FIGURE 1

Evaporative Reduction and Solidification System Schematic



unloading, this was not possible except for extremely short periods. Once a unit was set up, it would stay that way, at least until the next scheduled service.

When taking an annual average of the entire operating map, it can be concluded that the original cylinder performance was 4.58 million cubic feet a day. The upgrades pushed this average up to 4.98 MMcf/d, an 8 percent increase.

Smarter Controls

These devices do not run themselves, so the system needed smarter controls. Many companies approach the concept of programmable logic controllers (PLC) with resistance. Today, computer-based control systems are becoming smaller and cheaper by the minute. Although there is sometimes a learning curve, PLC are similar to personal computers in that they are far easier to use than ever before, while also becoming far incredibly more complex than ever before. The key is the user interface.

The interface is how the operator interprets and manipulates what the PLC is doing. A gauge panel has a very simple interface. However, there is not much ability to manipulate the data being observed; only the ability to change alarm set points. On the other hand, a PLC interface can look very complex. However, with only a minimum amount of effort, navigation through a PLC will become quite simple, just like a PC.

Where a PLC really distinguishes itself from gauge panels is in the ability to drive systems such as automatic unloading and remote monitoring. Although remote monitoring is possible with simple annunciator panels, its capability can be very limited.

Another benefit of a PLC is the ability to log operating and compliance data that can be retrieved and manipulated automatically, as well as remotely. To take this one step further, a facility PLC could be utilized for peak-shaving applications or unload the facility to a safe operating zone if, for example, certain equipment goes down.

The ability to check on any operating parameter of any piece of equipment without leaving the office can be a valuable asset. One improvement to this system is a Web-based satellite system that allows users to access data from anywhere in the world. This also reduces environmental impact by eliminating poles, receivers and transmitters. Novel technologies in equipment monitoring are emerging to meet the increasing demands of companies that want to know how efficiently their equipment is performing in real time. Simple run status is not enough anymore.

Functions such as monitoring real-time performance, calculating dynamic forces, logging environmental compliance data, generating operating maps, scheduling preventative maintenance, managing parts inventory, troubleshooting alarm conditions, testing lube oil samples, generating monthly unit performance reports, and automated dispatching of maintenance personnel are some of the prepackaged features available with today's remote monitoring systems.

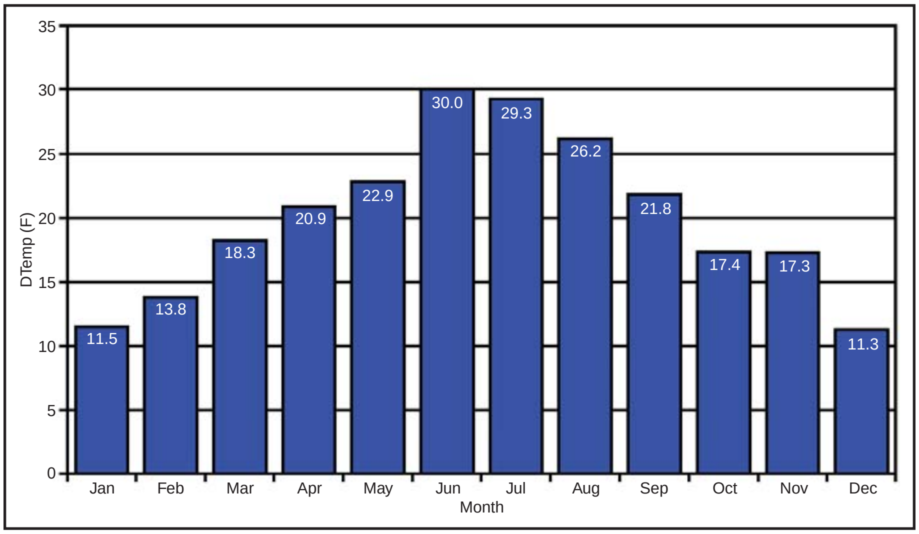
Taking a closer look at a few of these functions, the first point of emphasis is that a remotely monitored system can evaluate changing conditions (temperatures and pressures) as well as warn operators of a potential failure. The ability to know what condition caused a unit to shutdown before arriving on the scene can save costly hours of downtime by allowing the operator to know beforehand what to expect, what parts and tools to bring, and which people to dispatch.

Second, the data recorded on daily operating log sheets is quite useless. Often, the time of day is not noted and it is hard to determine what this data actually means later. Not having to send an operator to do nothing more than record a few data points frees time for other more important functions as well. The elimination of unnecessary trips to the field reduces vehicle emissions and operating costs.

Replacing the existing engine cooler drive sheave with a clutch-pulley system that disengages the cooler drive when the evaporative system is operating makes additional horsepower available for compression.

FIGURE 2

Temperature Differences (Brine Evaporative Cooling versus Radiator Air Cooling)



The third advantage is trend analysis. The ability to collect historical operating data ultimately leads to a proactive operating strategy instead of being constantly reactive to problems as they occur, and will keep operations more efficient.

Reducing Waste Brines

Another opportunity operators can embrace to expand the capability of their compressor facilities is to use waste heat from engines and compressor stages to reduce or eliminate waste brines associated with hydraulic fracturing flowback fluids and produced water. Waste brine generally is trucked from well sites to evaporative ponds or disposed through deep well injection. Handling and disposal of brines often burdens the producer with high operating expenses and substantial environmental liabilities.

The specific technology employed in the case study facility to utilize waste heat brine reduction/elimination is called an evaporative reduction and solidification system (EVRAS). The system is unique in its ability to use low-temperature waste heat to reduce brine to either a highly concentrated fluid or solid salts. The evaporative system uses a process similar to that of cooling towers, allowing for lower-temperature cooling than is possible with common air-cooled radiators. It benefits compression operations by providing lower cooling temperatures to the engines and compressors. The cooling tower principle enhances engine performance during high-temperature ambient conditions and improves total throughput and efficiency by lowering intercooler and after-cooler temperatures.

As illustrated in Figure 1, the system consists of three concurrent phases:

- A heat exchanger transfers waste heat into a heat transfer liquid (HTL) stream.
- The heated HTL stream is brought into direct contact with a cold brine stream, after which the cooled HTL is conveyed back to the first stage for reheating.
- The warmed brine from the second stage evaporates, concentrates and cools, allowing salt crystals to precipitate and fall into a receiving sump. The cooled, reduced brine is then reheated in the second stage and the salts are removed. The process is scale-free and self-cleaning. The third stage can be likened to a typical evaporative pond that is being kept constantly warm while experiencing a continuous wind blowing across it.

With the amount of waste heat available at the facility, the operator can employ units using the engine jacket and auxiliary water and the compressor interstages and after-cooler. An expected average yearly evaporation is 1,200 barrels of brine water a day. For producers without access to or paying high costs for disposal, this system provides an economical option. The 10-year annualized cost for a single system is under $1.15/barrel.

Lower-Temperature Cooling

A key benefit of the evaporative system is that the engine and compressor can now use lower-temperature wet bulb cooling rather than ambient dry bulb cooling. Figure 2 shows actual monthly temperature differences of brine evaporative cooling versus fin-type radiator air cooling.

Many compressor operators recognize the additional power available in the winter months because of the consistently lower engine, turbocharger and interstage/after-cooler temperatures. Closing the cooler louvers to minimize overcooling recovers 80 percent of the auxiliary power load. With this system in place, a facility can theoretically operate with the louvers closed year-round, which is similar to operating all year in ambient temperatures of 65 degrees Fahrenheit. This can substantially reduce the parasitic load and provide up to 50 more horsepower for compression.

To expand on this savings even more, the case study facility includes a clutch-pulley system to disengage the cooler drive when the evaporative system is operating, resulting in an additional 10 horsepower available for compression. After a little research, a clutch design was found with a torque rating of 750 foot-pounds and a continuous operating capability of 100 brake horsepower and capable of operating between 250-1,400 rpm. The clutch is designed to replace a standard engine pulley and can be engineered to any sheave specification. The normally open clutch is operated by a 90-watt signal and will only be engaged when the evaporative system is in use and the louvers are fully closed. The clutch replaces the existing engine cooler drive sheave.

The evaporative system also can be applied to the gas interstage and after-cooling circuits. Using the wet bulb cooling on a 100-degree day, the system can reduce the after-cooler discharge temperatures from 120 to 85 degrees Fahrenheit. This reduction has a tremendous impact on the throughput of the downstream dehydration unit. Applying an 85 degree temperature to the compressor interstages results in a more efficient cylinder, and therefore, increased compressor throughput.

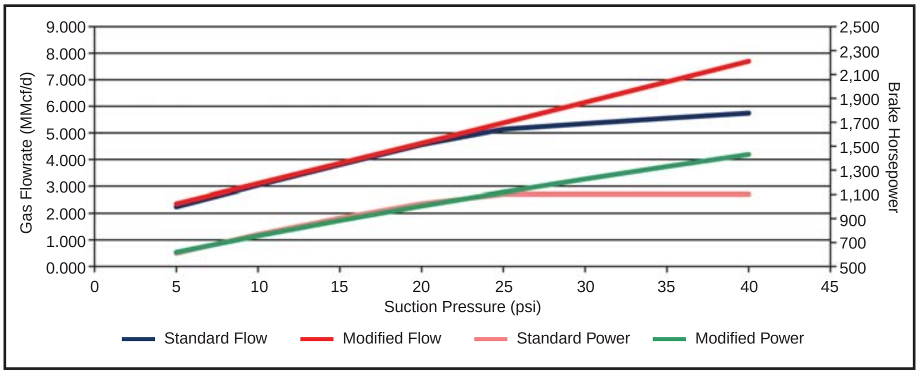
Figures 3 and 4 show total performance comparisons of each of the compressors without the evaporative system on a 100-degree day versus the improved throughput with all of the upgrades installed.

‘Green’ Upgrades

How can operators make compression facilities as “green” as possible in order to comply with anticipated energy policies, and not only with regard to air pollutants, but also noise pollution. The truth is, the environmental impact of any compression

FIGURE 3

Modified versus Standard Engine (100-Degree Day)



facility can be reduced simply by employing some common sense.

At the case study facility, the common sense solution has been to focus on the engine silencer/catalyst unit, but not in the way one might expect. The focus is on insulating the exhaust system to capture two benefits: improved catalyst efficiency and additional noise mitigation.

Catalysts do not work well at low temperatures. In order for a catalyst to perform as required, it should operate at no less than 700 degrees Fahrenheit for a rich-burn engine. A typical lean-burn engine exhaust temperature would be 900-950 degrees. However, it is realistic to expect an uninsulated exhaust temperature to lose as much as 200 degrees, thereby putting the catalyst in an operating range that would limit its ability to meet emission permit requirements.

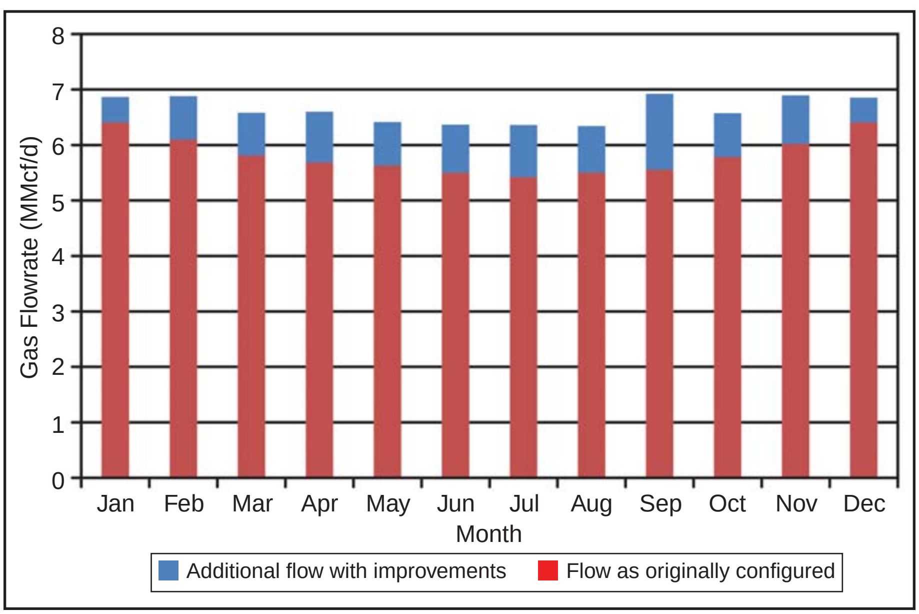
Although it is not a permitted constituent, one of the major issues facing companies today is noise. Many companies believe that specifying a hospital- or critical-grade silencer is above and beyond what will be required. However, these terms may be misleading. Having a silencer of this grade does not keep a neighboring property owner from picking up the phone and registering complaints. Since the engine is the single largest contributor to gas compression facility noise levels, it is an area worth a closer look.

Typical silencers reduce noise that can be detected by the human ear in the middle octave ranges. Outside of this range, the noise attenuation is undetectable. This is not necessarily a problem for higher frequencies, since the human ear cannot hear these frequencies anyway. Where the problem lies is in the lower frequencies. The noise at these frequencies travels long distances as a rumbling sound with associated vibrations, and is a source of irritation to the surrounding environment.

The way to eliminate this source of irritation is to increase the volume of the silencer. The larger unit will allow the lower-frequency sound waves to fully develop and be captured. This larger shell also has the benefit of still using standard catalyst elements. The shell is insulated internally with a proprietary material, helping reduce both the radiated noise and shell temperature (less than 100 degrees Fahrenheit on contact). This reduced shell temperature improves safety and shell corrosion concerns, and has the secondary benefit of removing a cooler hotspot. Eliminating hotspots, along with the vertical insulation, allows for potentially reducing the size of the cooler and the parasitic load.

FIGURE 4

Monthly Flow Improvement



Capturing Tank Vapors

The case study gas compressor station has low (10-30 psi) and high (850-900 psi) pressure liquid storage tanks on site. Liquid condensate volume between both low- and high-pressure systems can be in excess of 200 barrels/day. Vapors from the liquids are rich (2,200 Btu/foot^3) and can be up to 200 Mcf/d. Usually, these tank vapors are vented to the atmosphere. However, venting increases overall site emissions and eliminates a source of additional gas revenue.

Capturing the tank vapors with a conventional vapor recovery unit (VRU) often results in the introduction of oxygen to the system, as well as operational losses in excess of the value of the vapors being recovered. These units become high-maintenance items because of their constant cycling as a result of fluctuating volumes and pressures. A three-stage approach will reduce complications associated with typical VRUs.

First, low-pressure gathering system liquids are collected in a heated, three-phased separator, while the collected flash gases are routed directly to the suction of the compressor package.

Second, high-pressure system liquids are collected in a dedicated pressure vessel and controlled to maintain a pressure and level (the level control protects the three-phase separator from the pressure on this vessel).

Third, the liquids collected in the low pressure three-phase separator are routed to the storage tanks. To prevent oxygen entering the dedicated storage tanks, they are pressure controlled. The flash gases from the liquids are vacuum collected by an educator powered by a glycol circuit with its own dedicated pump (eliminating the need for an additional stage of compression and cooling required for conventional VRU recovery systems). The collected gases are compressed by the eductor and enter the suction gas stream to the compressors.

The value of the recovered vapors is $8.00/Mcf/d for the same 200 barrels of condensate produced per day.

Waste Heat Generation

Another way to create a greener facility is to make it electrically self-sufficient. For the case study facility, we have investigated the latest waste heat generator (WHG) technology to generate enough power to operate all of the PLC panels, the evaporative systems, the VRU and other small system requirements. The collective power draw for all of the system upgrades is roughly 150 kilowatts.

Using the surplus waste heat not being utilized for water evaporation, there is still enough waste heat to operate three WHG systems. In fact, each compressor package will generate a minimum of 75 kW, for a total of 300 kW. However, the facility only requires 150 kW. Therefore, only two operating units need to be used continuously, with a third as a backup. Each WHG system uses low-temperature (200 degrees) waste heat in a closed-loop system. The mobile units have a small footprint, zero toxic byproducts, zero emissions, zero fossil fuel requirements and are carbon neutral. The payback over utility supplied power is about four years at a per-unit electricity cost of $0.06/kWh.

The WHG operates similar to other "waste heat-to-power" technology, but with several innovations. The system uses a closed-loop refrigerant (R245FA) application. The liquid refrigerant is heated, converting it to a high-pressure gas. The heated gas then is directed into a patented twin screw rotary turbine (effectively a twin-screw rotary compressor operating in reverse) that drives a standard generator. The resulting low-pressure vapor then is cooled to a liquid by either the cooled evaporative system HTL fluid or cool incoming brine water. Using the twin-screw, positive-displacement system makes the unit substantially more efficient than traditional turbine waste heat-to-power designs.

As the upgrades on the case study facility illustrate, several innovative methods are available to producers to improve the efficiency of their gas compression facilities. These improvements applied with current technology have resulted in annual increased throughput and efficiency of 12 percent on the facility. Evaluating the costs compared to the return on investment illustrates a payoff time of nine months.

More important than the increased production and potential savings, however, is the increased percentage of gas produced to total emissions generated. Most of these upgraded systems are mobile in nature, and are capable of being transferred with existing units or moved independently to similar compression facilities. Looking beyond typical methods for improving efficiency and reducing emissions can provide both economic and environmental advantages by focusing on upgrades that provide long-term return on investment.❐

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