Engineering Consulting & Training Services

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About Compressor Drivers in Gas Production and Transmission Applications[1]

By Fred K. Geitner, P. Eng.

Gas compressors that are used in natural gas production and transmission applications are fundamentally of two types: positive displacement, and centrifugal or turbo-compressors. Displacement compressors are reciprocating or rotary screw machines. Displacement compressors are designed to move relatively small quantities of gas at high pressure differentials. Smaller and medium sized reciprocating compressors, and for smaller gas flows lately, rotary screw compressors are applied in gas production and gathering where high pressure differentials are required. Turbo-compressors convey gas in large quantities with a relatively low pressure rise. Larger size turbo-compressors have been mostly utilized in long distance transmission services.

While there is a debate about whether to use large reciprocating compressors in gas pipeline compressor stations as opposed to turbo-compressors, one should keep in mind that the function of these two types of machines is based on completely different principles. Also, the efficiency of reciprocating compressors can be significantly lower than that of modern centrifugal pipeline compressors.[2]

The main parameters to be considered when matching a driver to a given compressor are size (BHP or kW) and speed (rpm). There are also secondary, albeit important, considerations (e.g., speed-torque behavior, the ability to couple the driver directly to the driven machine, speed variability, etc.).

Reciprocating compressors in gas production and gathering systems range in size from below ~ 100 BHP (75 kW) to around 6700 BHP (5000 kW) with a median size from about 1300 BHP (1000 kW) to approximately 2600 BHP (2000 kW). Rotary screw compressors used in oil and gas production applications exhibit approximately the same size ranges.[3] Reciprocating compressor speeds range between 200 and 1500 rpm, and rotary screw compressors have median speeds of about 1500 rpm.

Three types of compressor drivers are typically available: reciprocating gas engines, mechanical drive gas turbines, and electric motors. A fourth choice is a steam turbine driver, which is used extensively in hydrocarbon processing plants and other industries that have ample steam supplies.

Direct-coupled reciprocating gas engines have traditionally been the driver of choice for reciprocating and rotary screw compressors where remote access and the absence of electric utilities dictate the use of self-contained compression units. Table 1 illustrates the size distribution of natural gas fuelled reciprocating engines while at the same time demonstrating the lack of demand for small gas turbines – even though they are available.

Work Highlights

Process, Operations & Safety

Providing consultation on delayed coking fouling mechanisms and the origin of coke solids/fouling deposits, which has drastically reduced coker heater run length and unit onstream time to unacceptable levels.

Providing patent review and technical consultation regarding fuels hydroprocessing.

Providing long term process design and equipment layout support services at the client's office.

Materials/Mechanical

Provided mechanical and materials engineering support with respect to an aboveground atmospheric storage tank whose bottom had experienced severe underside corrosion and leaks multiple times after relatively short periods of operation and required major repairs. Developed a mechanical design specification for a replacement bottom that featured a double bottom design, cathodic protection, leak detection system, secondary containment, and mechanical design and installation features or proven reliable design.

Gas turbines have seldom been used as drivers for reciprocating and rotary screw compressors. The reasons are the high specific investment costs ($/kW) of smaller gas turbines, their low efficiencies, and their requirement for speed decreasing gearboxes since variable speed mechanical drive gas turbines normally operate at speeds in excess of 4000 rpm. Some reciprocating compressors could possibly be driven by microturbines. In the past, suppliers of microturbines had been targeting the reciprocating engine market. They soon realized that, for their costs, reciprocating engines were the lowest cost drive solution. Microturbines require 24/7 operation and a low maintenance load to be able to compete with reciprocating engines.[4] An electric motor drive, however, might well be considered in oil and gas producing locations and pipeline transmission stations where electric power is available. The following facts need to be weighed in order to justify the use of an electric motor driver:

1. Capital cost of constant vs. variable speed motors. Choosing the first over the latter will increase technical complexity where reciprocating engines have inherently some degree of speed variability.
2. Electrical power cost - $/kwh
3. Constant annual electrical demand cost as a function of installed kW, $/kW-yr.
4. Power Factor issues

Given a favorable constellation of the above criteria, an electric motor drive for reciprocating and rotary screw compressors could be more cost-effective than owning and operating a reciprocating engine driver.

Gas turbines come into their own as compressor power requirements increase. Approximately above 10,000 BHP (7500 kW) – sizes as shown in Table 1 – gas turbines become less expensive in terms of lower $/kW and increased thermal efficiency. It makes good sense to apply them to drive centrifugal pipeline compressors where speed requirements are much higher than those for reciprocating and rotary screw compressors. In most cases, a gearbox would not be required as gas turbine speed is matched to that of the centrifugal compressor. The following criteria must be considered when choosing a gas turbine driver:

1. Capital costs
2. Operations-and-maintenance requirements and costs
3. Thermodynamic efficiency
4. Turndown capability
5. Emissions performance

The following general points are common to all compressor drivers and should be assessed in deciding what driver type to use:

1. Suitability/Fit for purpose
2. Foot print consideration
3. Power-to-Weight ratio
4. Operation and maintenance considerations
5. Operational flexibility, i.e., speed range
6. Emissions
7. Life Cycle Costs (LCC)

Table 2 analyzes the cost of ownership of three median range compressor drivers: the reciprocating gas engine, the gas turbine, and the electric motor.

(*See next pages for Tables 1 and 2*)

References

1. Pipeline and Gas Technology Magazine, September 2009
2. Turbomachinery International, September/October 2008
3. Modern screw compressors have been produced in excess of 13,500 BHP (10,000 kW) for other industries. They have a MAWP limit of around 1500 psig (100 bar) with a pressure ratio of about 15 – reciprocating compressors have considerably higher MAWPs.
4. 2008 TMI Handbook

About the Author

Fred K. Geitner has over 40 years experience in design, maintenance, operation, and troubleshooting of machinery used in process plant and transmission pipeline applications. Registered Professional Engineer in the Province of Ontario, Canada. Expert witness for rotating and reciprocating process machinery and advises and teaches in the field of process machinery reliability improvement and maintenance. Worked as an engineering consultant for a major natural gas transmission company in Germany where he was involved in machinery technology liaison work (gas turbines and compressors) between pipeline companies in the newly independent states of the former Soviet Union and the German firm.

Please contact Vince Carucci (vcarucci@carmagen.com) if you'd like more information on Carmagen's expertise in this area.

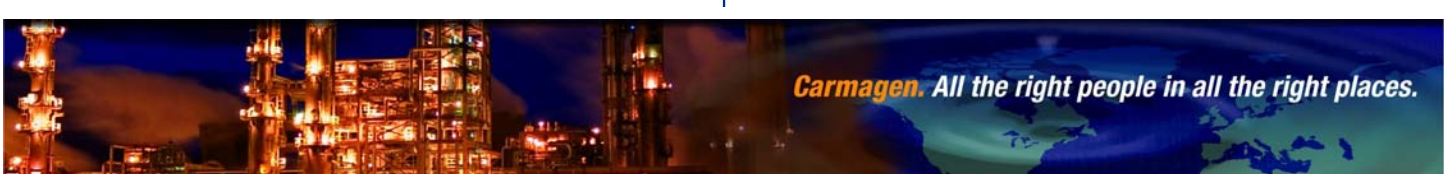

Table 1
Natural Gas Fuelled Mechanical Drive Orders
June 2007 to May 2008 & June 2006 to May 2007

Output Range, MW	Reciprocating Engines		Gas Turbines	
	2007/8	2006/7	2007/8	2006/7
	Units Ordered #	Units Ordered #	Units Ordered #	Units Ordered #
0.50 – 1.00	360	523		
1.01 – 2.00	1359	1328	0	0
2.01 – 3.50	71	77	0	0
3.51 – 5.00	5	0	2	3
5.01 – 7.50	0	0	12	19
7.51 – 10.00	0	0	15	6
10.01 – 15.00			30	21
15.01 – 20.00			26	54
20.01 – 30.00			132	58
30.01 – 60.00			23	47
60.01 – 120.00			0	4
120.01 – 180.00			0	0
>180.01			0	0

Source: CompressorTech – December 2008 p. 62-66

Table 2
Cost Analysis — Compressor Driver Alternatives

1.0 Common Variables

A	Gas Pricing	(Input)	$/ MMBTU*	3.47	$/GJ	3.29
B	El. Power	(Input)	$/MWh**	48.60		
C	Monthly El. Demand Charge	(Input)	$/kW	20		
D	Annual Operating Hours	(Input)	hr.	7000		
E	Operating, Surveillance & Monitoring (OS&M)	(Input)	$/hr.	75		

2.0 Operating Characteristics

				Engine	**GT**	**E-Motor*** **
F	Capacity	(Input)	BHP	2000	2000	2000
G	Capacity	(F X 0.7457)	kW	1491	1491	1491
H	Efficiency	(Input)	%	37.0	25.5	95.0
I	Inspection, Mtc., Repair & Overhaul (IMR&O)	(Input)	$/hp/yr.	40	60	5
J	Nox Emissions	(Input)	mg/m^3			

3.0 LCC Evaluation

				Engine	GT	E-Motor***
K	Specific Purchase Price (fob)	(Input)	$/kW	553	750	134
L	Investment	(K X G X 10-3)	k$	825	1,119	200
M	Installation & Commission-ing	(0.5 X L)	k$	412	559	100
N	Fuel Gas/Power Costs	(****)	k$/yr.	334	485	534
O	Demand Charge - El.Motor	(C X G X 12 X 10-3)	k$/yr.			358
P	Total Energy Costs	(N+O)	k$/yr.	334	485	892
Q	IMR&O Costs	(F X I X D/8760 X 10-3)	k$/yr.	64	96	8
R	OS&M Intensity	(Input)	%	50	75	25
S	OS&M	(D X E X R X 10-5)	k$/yr.	263	394	131

4.0 Summation

				Engine	GT	E-Motor***
AA	Total Investment	(L+M)	k$	1,237	1,678	300
BB	Operating & Mtc. Costs	(P+Q+S)	k$/yr.	661	1,070	1,039
CC	Interest Rate	(Input)	%	6		
DD	Operating Years (Project Life)	(Input)	yr.	15		
EE	Capital Recovery Factor	PMT(CC,DD,1)	-	0.103	0.103	0.103
FF	Capital Cost	(AA X EE))	k$/yr.	127	173	31
GG	Cost of Ownership	(BB+FF)	k$/yr.	788	1,243	1,070

Notes:

* Henry Hub Spot 7/28/09
** Mid-Columbia Spot 7/28/09
*** WPII Induction, 900 rpm
**** For engines & gas turbines: (A X D X G X 0.3412/H X 10-3)
For e-motors: (B X D X G/H X 10-4)