Instrumenting Older Reciprocating Compressors

Indicator ported valve pressure sensor installation

Ray Jensen
Bently Nevada Systems Engineer
ray.jensen@ge.com

CONDITION MONITORING OF RECIPROCATING COMPRESSORS REQUIRES HAVING THE APPROPRIATE MEASUREMENTS AVAILABLE.

Introduction

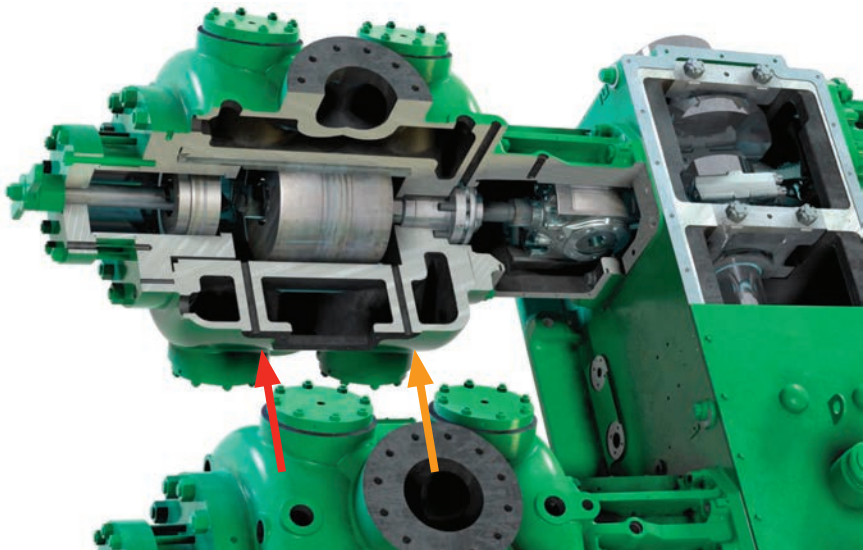
Many types of compressors are used in industrial processes. Among these, reciprocating compressors typically operate with the highest efficiency and excel in applications requiring high pressures and low to medium flows. Unfortunately, they also have the highest maintenance costs among compression equipment. In spite of this, there are applications in refining and chemical processes where the benefits of these compressors make them the best choice. There have been many articles highlighting the need for, and benefits of, condition monitoring on these machines. This article will focus on how to install pressure monitoring systems on machines that do not already have the necessary access points.

Benefits of Chamber Pressure Measurement

The majority of machines in industrial facilities function in a purely rotational manner. These include motors and centrifugal pumps and turbomachines such as axial or centrifugal compressors, gas turbines, and steam turbines. In these systems the largest forces acting on the rotor come from rotational effects such as unbalance, misalignment and rubs.

In reciprocating compressors, however, the largest forces come primarily from cylinder gas pressure and the cyclic acceleration of massive reciprocating components. Direct measurement of the pressure in the chamber and the resulting pressure and rod load waveforms provide the basis of calculating thermodynamic performance for each chamber, and for performing diagnostics for the most common malfunctions – including valve leaks, piston ring leaks, and crosshead pin failures. Without the pressure measurement the levels of forces on various components can only be estimated.

FIGURE 1: GE example. Reciprocating compressor cylinder cut away to show pressure ports in both the head-end (red arrow) and crank-end (orange arrow) chambers.



Measurements and data available with chamber pressure monitoring	
• Pressure waveform	• Gas force waveform
• Suction pressure	• Rod load waveform
• Discharge pressure	• Combined rod load
• Compression ratio	• Maximum rod tension
• Maximum pressure	• Maximum rod compression
• Minimum pressure	• Degrees of rod load reversal
Thermodynamic performance analysis	
• Discharge volumetric efficiency	• Indicated horsepower
• Suction volumetric efficiency	• Adiabatic flow balance
• Suction capacity	• Flow balance
• Discharge capacity	• Suction power loss
• Median capacity	• Discharge power loss
• Adiabatic Mean capacity	• Power to median capacity
Malfunctions	
• Suction valve leak	• Discharge valve leak
• Excessive rod load	• Piston ring leak
• Impact correlation	• Packing leak

TABLE 1: Directly measured and calculated values available when utilizing the Bently Nevada* 165855 pressure sensor, 3500 monitoring system, and System 1 software.

Most modern large reciprocating compressors sold today have pressure ports called indicator taps that are provided by the OEM. These ports are drilled through the cylinder walls into the chambers to allow the installation of pressure sensors (Figure 1).

A combination of the widespread availability of robust harsh environment pressure sensors and industry standards such as API 618 has led to the presence of indicator ports on many modern reciprocating machines. However, there are many compressors in use that do not have these ports due to the age of the machine or because they are not in a service that requires them.

These machines would benefit from the information provided by chamber pressure sensing combined with System 1* process calculations (Table 1), but without an indicator port it is not possible to make this measurement.

Retrofitting in-service compressors by drilling indicator ports through the cylinder walls as shown in Figure 1 is not recommended without compressor OEM review and involvement as any such operation can weaken the compressor cylinder structure with catastrophic results.

The best practice in such a case is to utilize a modified compressor valve to install the pressure sensors.

Indicator Ported Valves

These modified valves, called Indicator Ported Valves, or IPVs, directly replace an existing valve on the compressor and do not modify the pressure containment structure. Only one valve per chamber needs to be replaced with an IPV to make the pressure measurement available. Whenever possible a suction valve should be chosen as the point to install the IPV as these locations are cooler for the sensor and electronics, and at lower pressure making the installation safer and easier. In certain cases where a suction valve is not accessible to install the IPV a discharge valve can be utilized but special care should be given to the operating temperature of the location of the sensor and associated electronics to ensure a long sensor life and accurate reading.

IPVs consist of a standard valve assembly with the center bolt drilled or replaced with a hollow element that allows the connection of a port that

extends out through a modified valve cover that seals around the newly added port (Figure 2).

Due to the many configurations of reciprocating compressors and variations in the processes to which they are applied, IPVs are typically provided separately from the condition monitoring system. Many replacement valve vendors as well as machine OEMs offer IPVs and can be contracted to evaluate the machine dimensions as well as the process details to provide a suitable solution. Once the IPV is installed and the port is available, the installation of the sensor follows the same best practices for integral indicator taps including an appropriate isolation valve, sensor, and bracing to provide mechanical protection and avoid fatigue failure of the valve and sensor arrangement as shown in Figure 2.

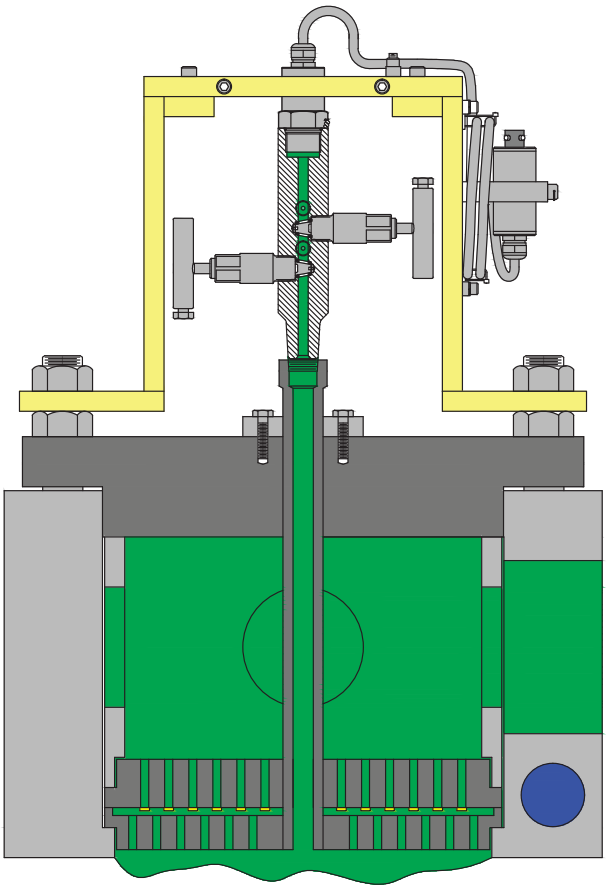


FIGURE 2: Cross section of IPV, valve housing, isolation valve, bracing (yellow shading) and pressure sensor. In this cutaway drawing of a suction valve, a double-isolation valve is shown installed in the IPV port. Green shading indicates the process gas coming into the suction valve (valve disc and seat components are at the bottom of the drawing).

Condition monitoring of reciprocating compressors requires having the appropriate measurements available. Real time monitoring of the chamber pressures on the machine is critical to understanding not just mechanical machine health such as loading and valve condition but it is the basis for making performance measurements, including actual flow rates, compression ratios, horsepower, and efficiencies.

Indicator ported valves provide an industry accepted and safe method of installing pressure sensors on virtually any reciprocating compressor. In future Orbit issues, we will describe how to install sensors in confined areas and accurately measure crank angle during compressor operation, in order to accommodate Pressure vs. Crank Angle (P-Θand Pressure vs. Volume (P-V) analysis.

References

- Howard, Brian. "Mechanical Protection for Cylinder Pressure Transducers." Orbit, Vol. 26, No. 1 2007.
- Davis, Greg. "Using PV Curves to Diagnose A Recip Valve Problem." Orbit, pp48-54, First Quarter, 2004.
- General Electric. "Protecting and Managing API-618 Reciprocating Compressors." Document Number 178896, Revision A.
- Howard, Brian. "Rod Load Calculations and Definitions for Reciprocating Compressor Monitoring." GER-4490. General Electric, June 2009.

1631 Bently Parkway South, Minden, Nevada USA 89423
Phone: 1.775.782.3611 Bently.com