

NEW SOLUTION – VIRTUAL ORIFICE, OLD PROBLEM – PRESSURE DROP USED FOR CONTROLLING THE CYLINDER NOZZLE RESONANCE

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For the past fifty-plus years, the standard orifice plate has been used to control high amplitude cylinder nozzle resonant gas pressure pulsations. Unfortunately, the orifice typically imposes considerable pressure losses (and equivalent horsepower losses) on the system when used to damp the acoustic resonance. A new means of controlling the cylinder nozzle resonance exists in the Virtual Orifice (VO) device, developed by the collaboration of the Gas Machinery Research Council (GMRC) and Southwest Research Institute (SwRI). The VO reduces the high amplitude cylinder nozzle pulsations without incurring additional pressure losses associated with an orifice. The Gas Machinery Research Council (GMRC) funded the Southwest Research Institute (SwRI) pulsation control research program that resulted in the conception and development of the virtual orifice (VO) technology.

High amplitude gas pressure pulsations at the compressor cylinder valves can cause high vibrations, efficiency losses, and significant reductions in valve life if these pulsations are not adequately addressed. The cylinder nozzle resonance, which is associated with the gas passage length from the cylinder valves to each compressor filter bottle, is typically excited by the pulsations inherently generated by reciprocating compressors. As compressor speeds, horsepower levels, and speed ranges have increased over the years, the cylinder nozzle resonance has become an increasing source of efficiency losses and mechanical vibrations for modern high speed machines. Using the conventional solution previously applied to low speed compressors, system designers and operating companies have damped the nozzle resonance with an orifice plate. The

virtual orifice offers an advancement in technology that can replace a standard orifice. Instead of damping the cylinder nozzle resonance, the virtual orifice is designed to absorb this resonance, which inherently provides more pulsation reduction and allows for the recovery of horsepower that is presently lost through the use of an orifice.

Side branch absorbers or Helmholtz resonators are well established pulsation control devices that have been used to reduce pulsations in compressor piping systems. The VO is essentially a Helmholtz resonator applied much closer to the cylinder. A 3-dimensional solid model with a transparent volume is depicted in Figure 1. When properly designed, the VO alters the acoustics of the cylinder internal gas passage such that the pulsations associated with the cylinder nozzle resonance are significantly reduced.

One unoccupied compressor cylinder valve cap per suction or discharge side of the cylinder is needed to install the VO. The VO can be installed on either the suction or discharge side of the cylinder (or both), depending on the need to control suction or discharge cylinder nozzle resonances. Therefore, if a 6-cylinder compressor has orifices installed at each suction and discharge flange of each cylinder, twelve pressure loss sources exist that could potentially be removed by installing twelve virtual orifices. The VO requires only one of the suction or discharge valve caps per cylinder. A virtual orifice installed on the suction side of a compressor cylinder is depicted in Figure 2.

To validate the SwRI natural gas laboratory data and a smaller, more compact VO prototype design, two virtual

orifices were installed on a natural gas pipeline compressor to absorb the suction cylinder nozzle resonance associated with each cylinder. Pulsation, vibration and performance data were measured at the field site for three configurations: 1.) A baseline case of the bare cylinder nozzle (no orifice); 2.) Cylinder nozzle with a standard orifice plate installed at the compressor cylinder flange; and 3.) Installation of the virtual orifice at the suction valve cap (as shown in Figure 2) and removal of the orifice plate.

As can be seen in Figure 3, peak pulsation amplitudes over the 0-200 Hz frequency range with the virtual orifice installed were approximately 50% lower than the pulsation levels with a standard orifice plate installed. In comparison to the baseline case, peak pulsation amplitudes were reduced by 70% with the VO installed compared to without any cylinder nozzle resonance control device.

Cylinder vibrations in the vertical direction caused by the cylinder nozzle resonance occurred at four times (4x) compressor running speed. With the installation of either a standard orifice plate or the virtual orifice, these vibrations were reduced by 20% to 0.6 ips (see Figure 4). Compressor efficiencies for the field test site utilizing an orifice plate or the alternative VO technology are summarized in Figure 5. With the installation of the virtual orifice on only the suction side of each compressor cylinder, compressor performance improved by 2.5 to 4.0%. Additional efficiency gains are expected when a VO is used to also reduce the discharge cylinder nozzle resonance. Installing the virtual orifice improved the pulsation, vibration, and efficiency characteristics of the compressor, compared to the baseline case without cylinder nozzle resonance control and the case of the standard orifice plate in the cylinder nozzle.

Implementing the virtual orifice on compressors is relatively simple and very beneficial. It can be installed on low or high speed compressors to control cylinder nozzle resonance for suction and discharge nozzles. As demonstrated by laboratory and field site data, the VO will improve pulsation, vibration, and performance characteristics. The GMRC and SwRI developed virtual orifice is a patent pending device that can be used to replace standard cylinder nozzle orifices at existing and future installations.

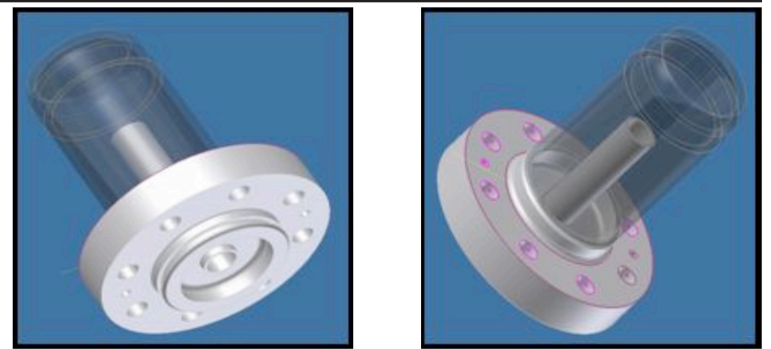


Figure 1. 3-D Solid Model of the VO

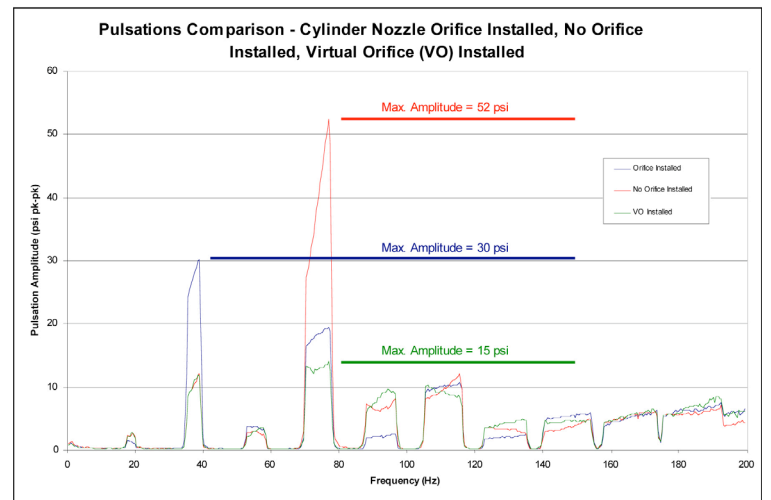


Figure 3. Pulsation Data Depicting the Effectiveness of the Virtual Orifice

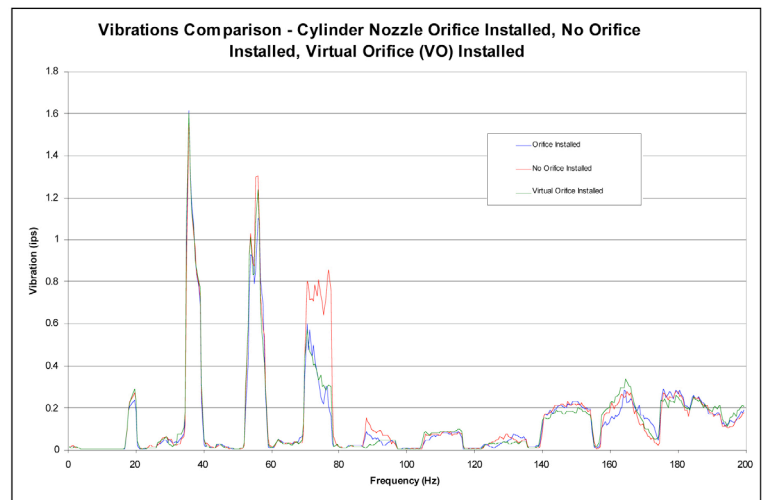


Figure 4. Cylinder Vertical Vibration Data Depicting the Effectiveness of the Virtual Orifice

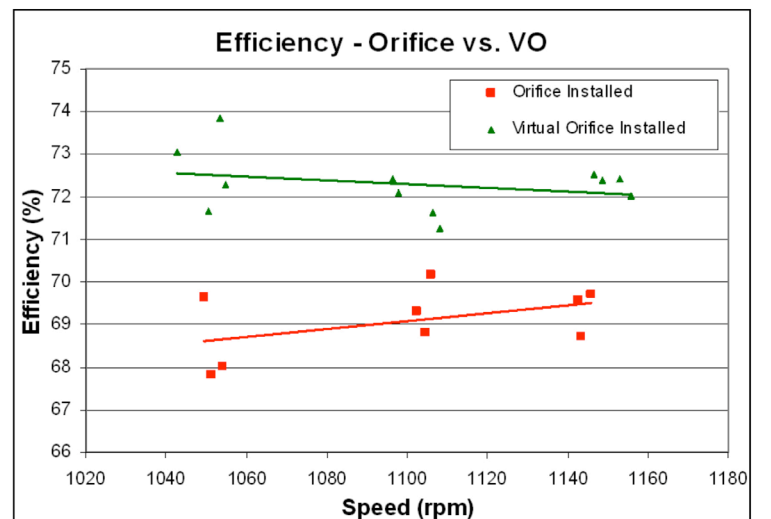


Figure 5. Overall Compressor Thermodynamic Efficiency Data Depicting the Effectiveness of the Virtual Orifice

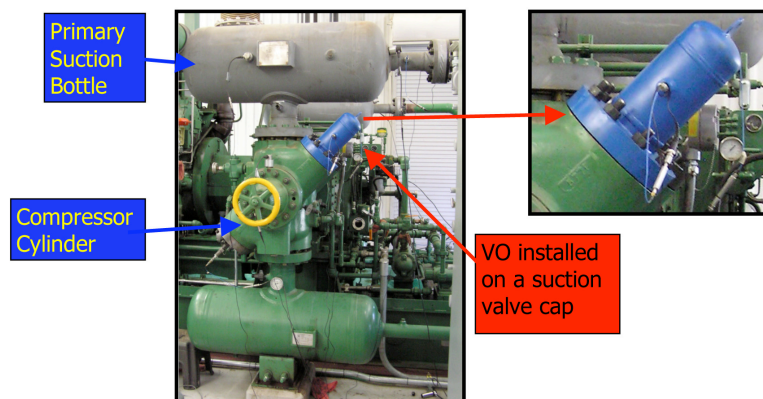


Figure 2. Virtual Orifice Installed on a Natural Gas Pipeline Compressor