Test Report # 30016558 Rev 0

Adiabatic Compression

With Constant Bleed Valve

Scope: This test report contains test data on the effects of adiabatic compression in nitrogen service on AP3600 diaphragm valves, and the effect of including constant bleed valves ahead of the test valve to reduce temperature rise.

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Table of Contents

Introduction

Adiabatic Compression

Heat is generated when a gas is compressed from a low pressure to a high pressure. When the pressurization occurs at a sufficiently fast rate, heat transfer to the surrounding environment can be considered negligible (adiabatic process). In gas handling systems, adiabatic compression is used to refer to the heat of compression that occurs when a cylinder valve (or any high pressure isolation valve) is rapidly opened to pressurize a section of tubing such as a pigtail (flexible tube line from the cylinder to the gas source manifold) from atmospheric pressure to full cylinder pressure. The highest temperature in the tube line is found at the end furthest from the cylinder valve. Often times, a closed isolation valve is at the end of the tube line and is exposed to the heated gas. As the fixed volume of line is charged, energy required to "push" gas into the volume is converted to temperature change. The process can be analyzed using the 1st Law of Thermodynamics:

$$\sum m_{in}\left(h_{in}+\frac{v^2}{2}+gz\right)-\sum m_{out}\left(h_{out}+\frac{v^2}{2}+gz\right)+Q_{in}-W_{out}=\Delta U \quad \text{eq. 1}$$

For a charging volume system, $m_{out}=0$

Assuming heat transfer is negligible (Adiabatic), $Q_{in}=0$

There is no work done on or by the system, $W_{out}=0$

Assuming an initially vacated line where $m_1=0$, it follows that $m_{in}=m_2$

Simplifying eq. 1 yields:

$$\left(h_{in}+\frac{v^2}{2}\right)=u_2 \quad \text{eq.2}$$

Equation 2 tells us that the final energy in the system is dependent on two variables; the enthalpy of the gas entering the system and the velocity at which it enters. Testing has shown that the temperature build up from this adiabatic process is sufficient to damage seats. Reducing the enthalpy in, velocity in, and increasing time of reaction (thus making Q_{in}, non-zero; allowing heat to transfer away from the system) can reduce the final internal energy of the system, which in turn means reducing the final temperature of the system.

It was theorized that the addition of an orifice upstream of the test valve could reduce the temperature rise due to adiabatic compression. A constant bleed valve was used so that as the cylinder charges the system, the closed CB valve orifice would restrict the velocity of the inlet gas. The CB valve can then be pneumatically actuated during venting to allow gas to exit the system at a more rapid rate.

Test Units

Model AP3600SM 3PW MV4 MV4 MV4 manual, diaphragm valve were used for testing. **Figure 1.A** shows a sectional view of the AP3600 valve body. AP3000SM CB009 2PW FV FV4 and AP3000SM CB009 2PW FV FV4 were installed immediately before the Test Valve to test whether or not temperature in the Test Valve would be affected. Figure 1.B shows a sectional view of the

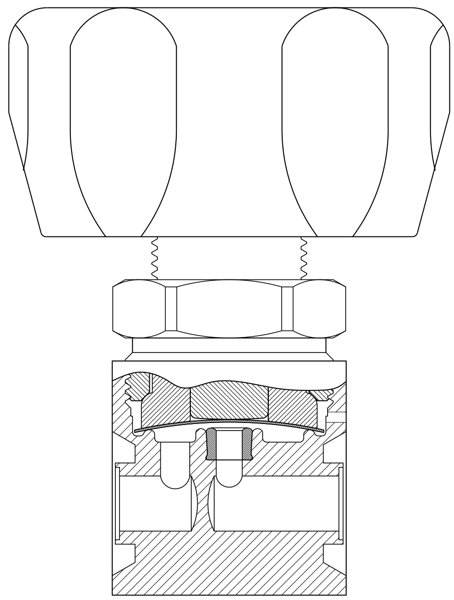

Figure 1.A AP3600 Valve Sectional View

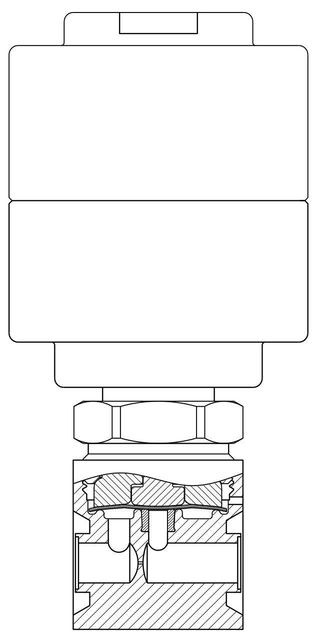

Figure 2.B AP3000 CB Valve Sectional View

Adiabatic Compression Test

Test Setup and Protocol

The test setup is shown in **Figure 3**. An AP3002 N.O. air actuated, diaphragm valve (V1) was connected to a high pressure line capable of delivering 3000 psig. This valve rapidly pressurizes the tube line at the inlet to an AP3600 manual, diaphragm Test Valve. An AP3000 air-actuated, diaphragm valve N.C. (V2) was used to vent the tube line. V1 and V2 were actuated using the same pneumatic actuation line so that while one was open, the other would be closed, and vice versa. They were connected to a PLC to be actuated 1 second on, 1 second off for 20 cycles. A 0-3000 psig (0-207 bar) range transducer was used to monitor the tube line pressure. The transducer output was recorded using a data acquisition system at 100 samples per second. The tube used was 1/4 inch steel tube with .180 inch (4.6 mm) inside diameter. The length of tubing before the test valve was 4 feet (1.2 m) long and installed at the inlet to the test valve. A T-type thermocouple was installed in the test valve such that the tip of the probe sat directly beneath the seat. The CB valves with orifice sizes of .005" and .009" were installed immediately ahead of the test valve. They were actuated with the same pneumatic line, such that during test pressurization, the CB valve was closed, and during venting, the CB valve was open.

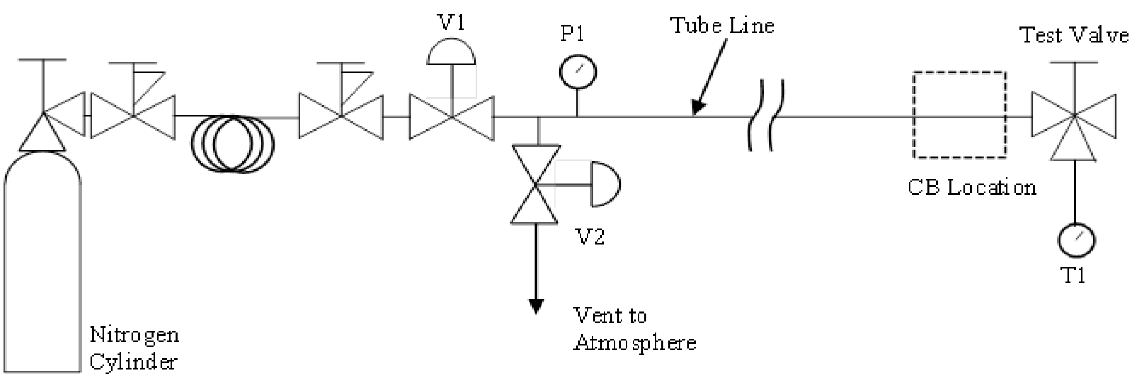

Figure 3. Adiabatic Compression Test Setup

The test procedure consisted of the below steps.

1. Set Source Regulator to deliver 2100 psi
2. Begin data acquisition
3. Begin PLC, which

   Closes V1 and opens V2 to vent system to atmospheric pressure for 1 sec

   Opens V1 and closes V2 to rapidly pressurize system for 1 sec
4. Repeat step 3 for 20 pressurization cycles.

Results

A summary of the test results is shown in **Figure 3,** which details the temperature and pressure vs time as the system is cycled. The control test with no CB valve installed reached a max temperature of 192 °F (88.9° C) after 20 cycles. The CB009 reached a max temperature of 158°F (70° C) after 20 cycles, an 18% reduction in temperature rise. The CB005 reached a max temperature of 149°F (65° C) after 20 cycles, a 23% reduction in temperature rise. Note that the fill time for the system upstream of the CB valve location is consistent for all three tests. The pressure rises from 0 to 1900 psig in .1 sec. However, the pressure at the test valve builds up slower with the CB valve installed before it. Measuring the pressure rise downstream of the closed CB005, the pressure rises from 0 to 1900 psig in approximately 1.25 seconds. **Figure 4** shows the temperature rise of the CB005 test set up where instead of cycling every second, the valves were cycled once the pressure at the test valve reached 2000 psig. The max temperature measured after a minute of testing was 100 °F (38°C).

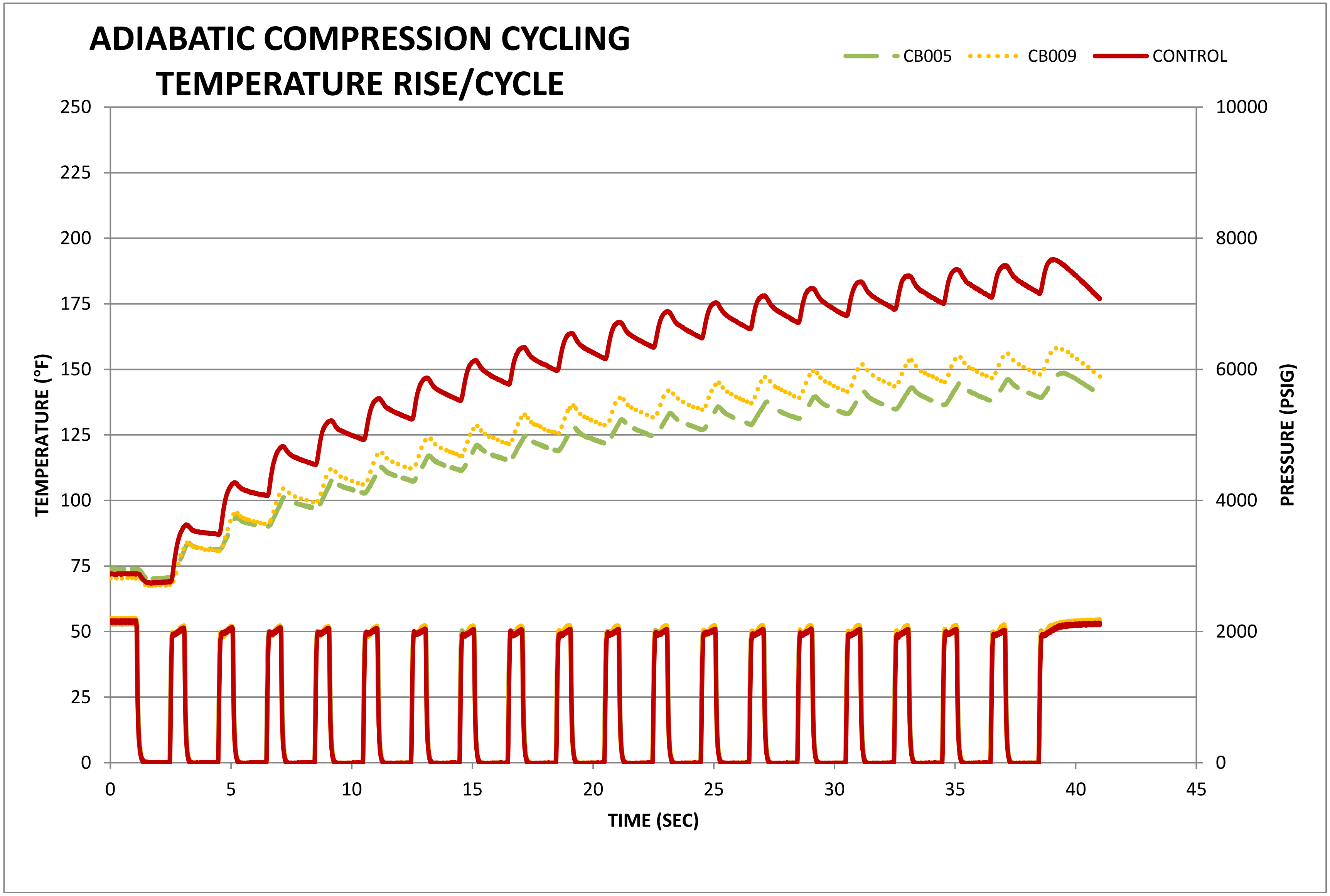

Figure 3. Adiabatic compression test. 2100 psig, 20 cycles. Control, CB005, CB009

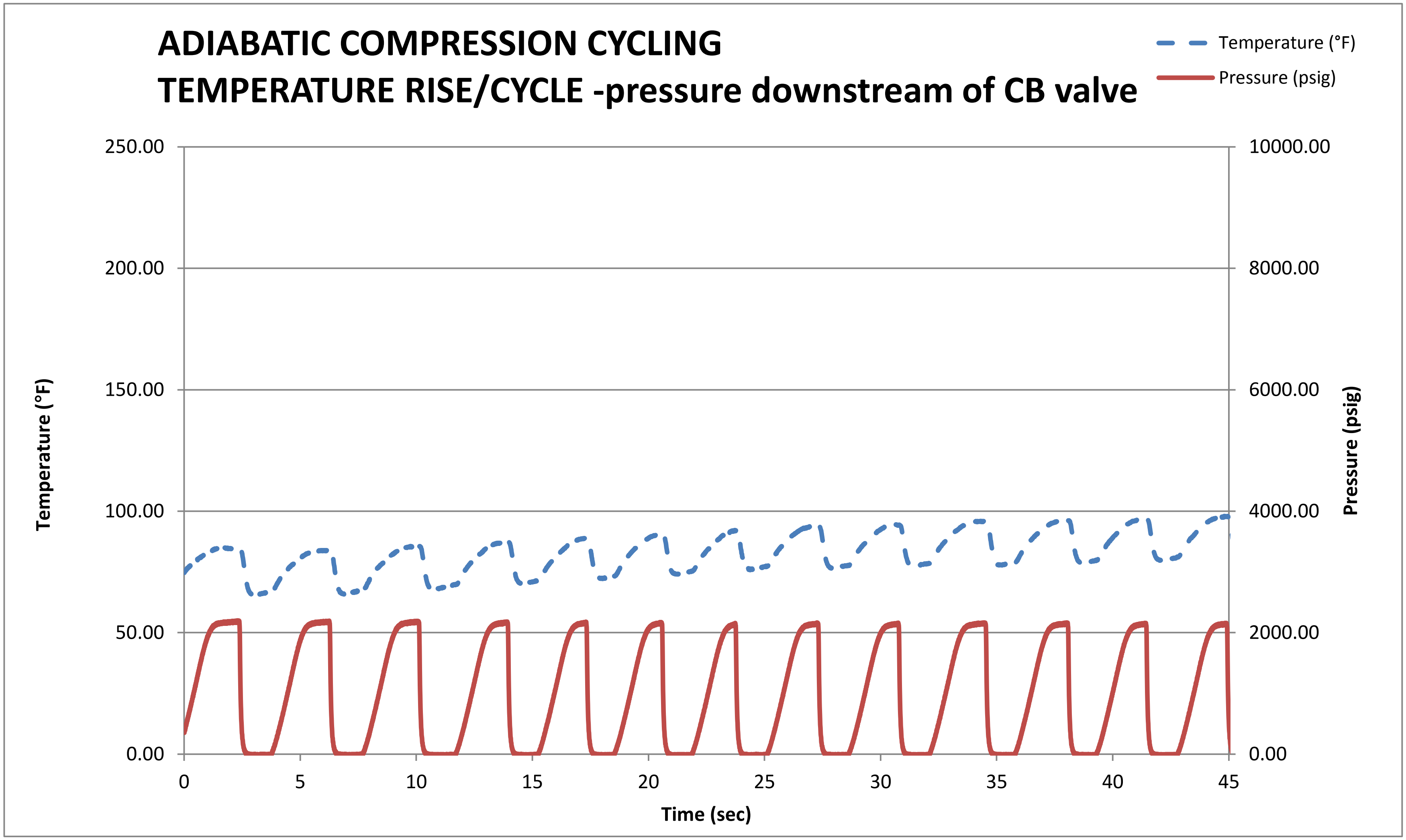

Figure 4. Adiabatic compression. Pressure downstream of CB005 valve. Cycled at max pressure.

Summary

Adiabatic compression testing was performed in nitrogen service to determine if adding a constant bleed valve before the test valve would reduce the temperature rise at the test valve's seat. The test data found that adding a flow restricting device before the test valve will slow the pressure build-up at the test valve and reduce the temperature build up due to Adiabatic Compression.

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