APTech Test Report #30008900
Revision 0

ADIABATIC COMPRESSION TRAP TESTING

May 15, 2003

Scope: This report summarizes testing that was performed to verify the effectiveness of using an adiabatic compression trap to reduce gas temperatures at critical locations in a high pressure gas system.

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Introduction

This document reviews some testing that was performed to determine the effectiveness of using an adiabatic compression trap to reduce the gas temperature at critical locations in a rapidly pressurized high pressure gas line.

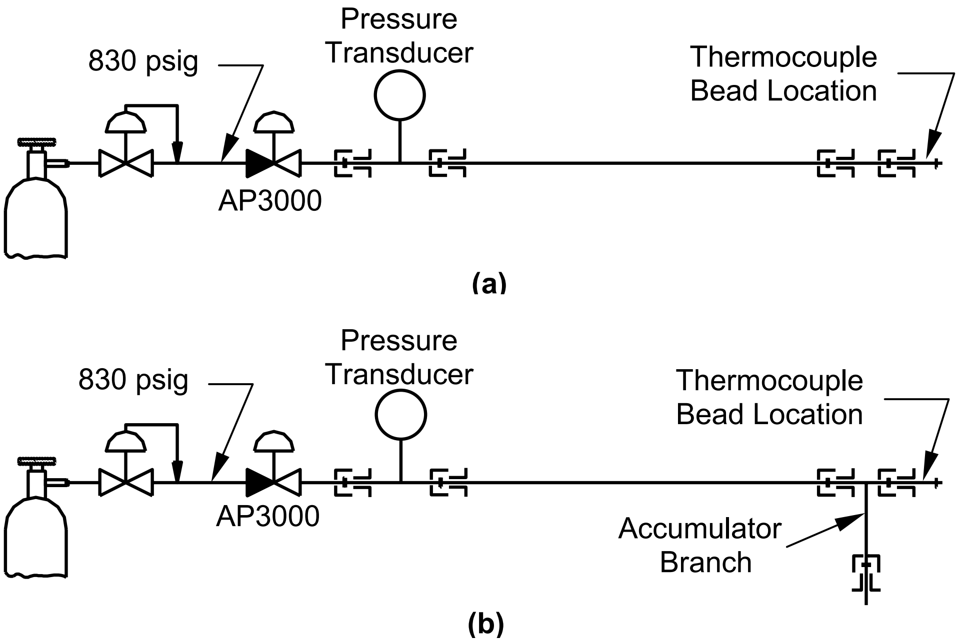
When a gas line containing low pressure gas is filled rapidly with high pressure gas, the original low pressure gas in the line is compressed into the far end of the line. The compression of this gas can significantly raise its temperature causing damage to components such as polymer valve and regulator seats exposed to the hot gas.

One method for reducing the exposure of components to the hot gas, is to place a gas accumulator at the far end of the line. The objective is to contain the hot gas within the accumulator away from the more heat sensitive components. This type of accumulator is sometimes referred to as an adiabatic compression trap.

In this testing, the temperature at the end of a gas line was monitored while the line was rapidly pressurized with nitrogen gas. A tee was then added near the end of the line to create a small accumulator and the test repeated. Additional lengths of tubing were incrementally added to the accumulator branch of the tee to increase the accumulator volume. The test was repeated after each additional length of tubing was added. The peak temperatures were then plotted against the relative volume of the accumulator.

1. Test Setup and Procedure

All testing was performed with nitrogen (N_2) gas. A high pressure gas line system was setup as shown in **Figure 1**. Several sections of ¼ inch outer diameter, .035 inch wall, stainless steel tubing with ¼ inch face seal end connections along with some shorter ¼ inch face seal test fittings were joined together to create the gas line. The upstream valve was an APTech AP3000, high pressure, pneumatically actuated, diaphragm valve. The actuation pressure was 80±2 pounds per square inch, gauge pressure (psig).



(a)

(b)

Figure 1. Test setup.

A thermocouple was installed at the end of the line with the bead located .2 inches from the end of the line. The thermocouple was a .010 inch wire diameter, type K, beaded weld thermocouple with an approximate time constant of 1.3 seconds. The time constant was defined as the time required to reach 63% of an instantaneous temperature change. A 0-1000 psig inline pressure transducer was installed near the inlet end of the line. The upstream regulator was adjusted to approximately 830 psig.

Prior to each test run, the line was vented down to 1 atmosphere of pressure and closed off. The system then sat for a minimum of 30 seconds to allow the system temperature to return to room temperature. Next, pressure and temperature readings were recorded every 10 milliseconds while the upstream AP3000 valve was opened to rapidly pressurize the line. The temperature versus time recording was used to obtain the peak temperature. The pressure versus time recording was used to obtain the fill time. The fill time was considered to be the amount of time required to reach 95% of the pressure change.

3 test runs were performed for each accumulator volume size. The peak temperature and fill time were averaged for each set of 3 test runs. The first 3 test runs were performed with no accumulator branch (accumulator volume of zero) as shown in **Figure 1(a)**. A tee was then added just upstream of the thermocouple as shown in **Figure 1(b)**, to create a branched accumulator for the next 3 runs. Additional lengths of tubing were added to the accumulator to increase the accumulator volume in subsequent test runs. The upstream volume between the valve and the tee was 1.49 cubic inches. The downstream volume between the tee and the end of the line containing the thermocouple was .0447 cubic inches. The accumulator volume ranged from .0261 to 1.03 cubic inches.

2. Results

The temperature and pressure readings versus time for run 4 are shown in **Figure 2**. The temperature and pressure readings versus time for the other runs appeared similar. The pressure drop after the initial peak is believed to be a result of a combination of pressure transducer overshoot and an actual pressure drop resulting from regulator overshoot and the cooling of the gas. The delay between the peak pressure and the peak temperature is due to the slower response time of the thermocouple compared to the transducer. This delay and the shape of the curve indicate that the measured peak temperature is somewhat less than the actual peak gas temperature due to the delayed response of the thermocouple. However, the data was considered sufficient to compare the effectiveness of accumulators of different volume.

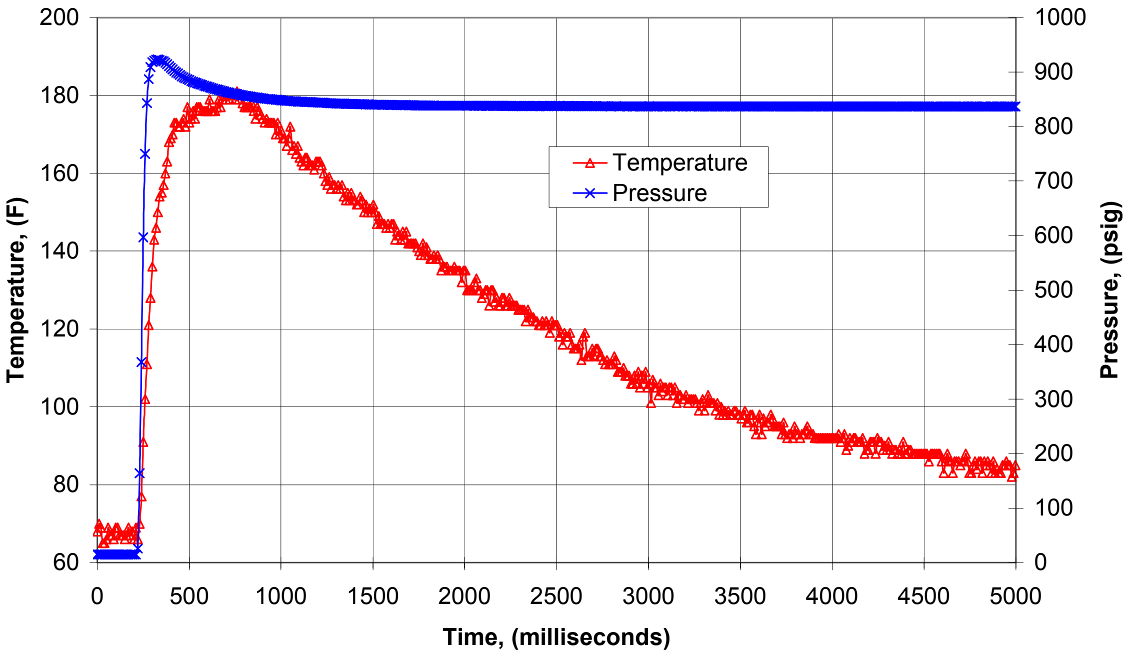


Figure 2. Temperature and pressure readings versus time for run 4.

Table 1 lists the accumulator volume and corresponding average system fill time for each set of 3 test runs.

Accumulator Volume (cubic inches)	**Average Fill Time** (milliseconds)
0	63
.0261	57
.0886	60
.156	70
.318	70
.662	94
1.03	103

Table 1. Average system fill times.

Predictably, the fill times increased as the accumulator volume, and thus the system volume, increased. This increased fill time in itself should help reduce the peak temperature by allowing more time for heat to transfer out of the hot compressed gas during compression. However, this effect is not believed to have had a significant effect on the peak temperatures reported below, since the response time of the thermocouple was an order of magnitude larger than the longest fill time.

Figure 3 is a plot of the peak temperature versus the volume of the accumulator relative to the volume upstream of the branch. The volume upstream of the branch was held constant throughout the testing. The plotted peak temperature was the average of the peak temperatures from the three test runs at each accumulator volume.

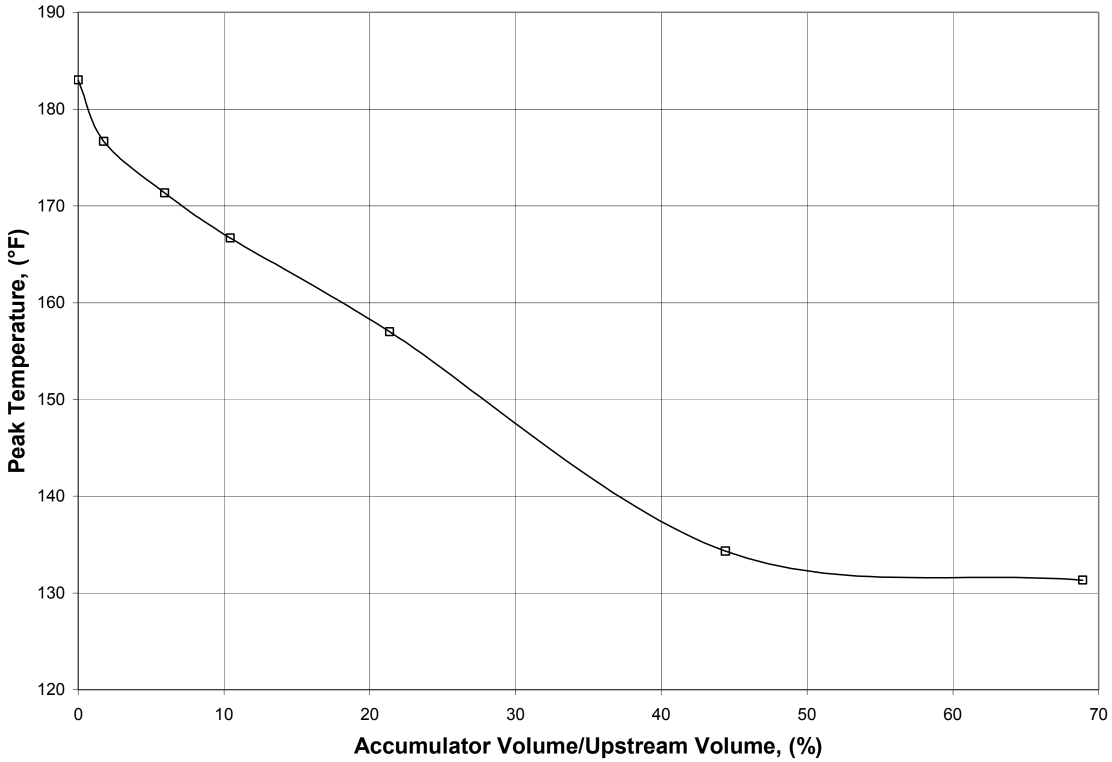


Figure 3. Peak temperature versus relative accumulator volume.

3. Conclusion

The plot of peak temperature versus relative accumulator volume in **Figure 3** shows that the peak temperature at the end of a rapidly pressurized gas line can be significantly reduced by adding an accumulator.

While this plot shows the general effectiveness of adding an accumulator it should not be used in system design for the purpose of calculating a required accumulator volume based upon a maximum allowable peak temperature. The actual peak temperatures that will occur in any other system will likely be much different from what was found here due to different inlet pressures, fill times, system geometry, materials, gases, etc.

4. Summary

When a gas cylinder valve is opened, the rapid pressurization of the downstream line to full cylinder pressure can lead to high gas temperatures at the far end of the line. These high gas temperatures can damage polymer seats and seals in components such as isolation valves and pressure regulators. The data shown in this report demonstrates that a properly located gas accumulator can be used reduce the peak temperatures seen in these components.

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