Test Report # 30009800 Rev 0

AP1500 and AP1400T Gas Permeation Tests

Scope: This test report contains data on the outlet pressure rise caused by helium and nitrogen permeation through Vespel and PCTFE seats in model AP1500 and AP1400T regulators.

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Introduction

Description

Pressure regulators are used to reduce a high cylinder pressure (up to 3000 psig) to a low delivery pressure (typically 30-50 psig) and to reduce a low delivery pressure to a precise point-of-use pressure (typically 15-30 psig). When the system is not creating any flow demand the outlet pressure of the regulator can rise due to permeation of the process gas through the regulator seat material. In most gases, the permeation rate is so small that it would take years to observe a measurable pressure rise. In some light molecular weight gases such as hydrogen and helium, the permeation can result in a measurable pressure rise within days.

The purpose of this test is to determine the approximate pressure rise that can be expected due to helium and nitrogen permeation of the regulator seat. The model AP1500 and AP1400T pressure regulators were chosen for this test because they are used as both cylinder cabinet regulators and line regulators. Both regulators are representative of the different size seats used in many other AP Tech regulators. Both PCTFE and Vespel® seat materials were chosen for evaluation because PCTFE is the standard seat and Vespel material properties indicate it may have lower helium permeation.

All regulators were tested in the closed position. Testing in the closed position helps to eliminate all variables except for a seat leak from influencing the data.

Test Units

Two *AP1510S 2PW MV4 MV4*, two *AP1510S 2PW MV4 MV4 VS*, two *AP1410TS 2PW FV4 FV4* and two *AP1410TS 2PW FV4 FV4 VS* pressure regulators valves were evaluated.

Note: The data presented in this test report were collected under laboratory conditions. The only way to determine how a component will perform in a specific application is to test under those conditions and is the sole responsibility of the user.

High Pressure Nitrogen Permeation Test

Test Setup and Protocol

The pressure regulators were left in the closed position during the entire test. The pressure regulators were connected to a manifold that was pressurized to 2500 psig with nitrogen. A 30 inHg-0-30 psig range pressure gauge was connected directly to the outlet of the pressure regulator. The gauge was monitored periodically and the pressure rise recorded. The pressure regulators were kept in a temperature-controlled environment of 70±3 ºF to reduce pressure fluctuations due to temperature.

Results

The regulators are identified as AP1510 PCTFE #1, AP1510 PCTFE #2, AP1510 Vespel #3, AP1510 Vespel #4, AP1410T PCTFE #5, AP1410T PCTFE #6, AP1410T Vespel #7, and AP1410T Vespel #8.

The inlet pressure remained unchanged at 2500 psig throughout the test. No measurable rise in outlet pressure was observed after 14 days. The resolution of the outlet pressure gauge would allow an increase greater than 0.25 psi to be easily observed. A summary of the test results is shown in Table 1.

Test Regulator	Nitrogen Pressure Rise, psi
AP1510 PCTFE #1	0
AP1510 PCTFE #2	0
AP1510 Vespel #3	0
AP1510 Vespel #4	0
AP1410T PCTFE #5	0
AP1410T PCTFE #6	0
AP1410T Vespel #7	0
AP1410T Vespel #8	0

Table 1. Nitrogen Permeation Outlet Pressure Rise after 14 Days

High Pressure Helium Permeation Test

Test Setup and Protocol

The pressure regulators were left in the closed position during the entire test. The pressure regulators were connected to a manifold that was pressurized with a full helium cylinder to the maximum available pressure. A 30 inHg-0-30 psig range pressure gauge was connected directly to the outlet of the pressure regulator. The gauge was monitored periodically and the pressure rise recorded. The pressure regulators were kept in a temperature-controlled environment of 70±3 ºF to reduce pressure fluctuations due to temperature.

The internal volume in the low pressure side of the regulator to the pressure gauge was determined by calculation. This volume was then used to calculate the helium permeation rate.

Results

The inlet pressure for the AP1510 regulators was 2250 psig. The inlet pressure for the AP1410T regulators was 2150 psig. There was no measurable drop in inlet pressure for the duration of the test.

The regulators are identified as AP1510 PCTFE #1, AP1510 PCTFE #2, AP1510 Vespel #3, AP1510 Vespel #4, AP1410T PCTFE #5, AP1410T PCTFE #6, AP1410T Vespel #7, and AP1410T Vespel #8. The permeation test results for the AP1510 regulators are shown in Figure 1. The permeation test results for the AP1410T regulators are shown in Figure 2. The average permeation rate was calculated and is given in Table 2.

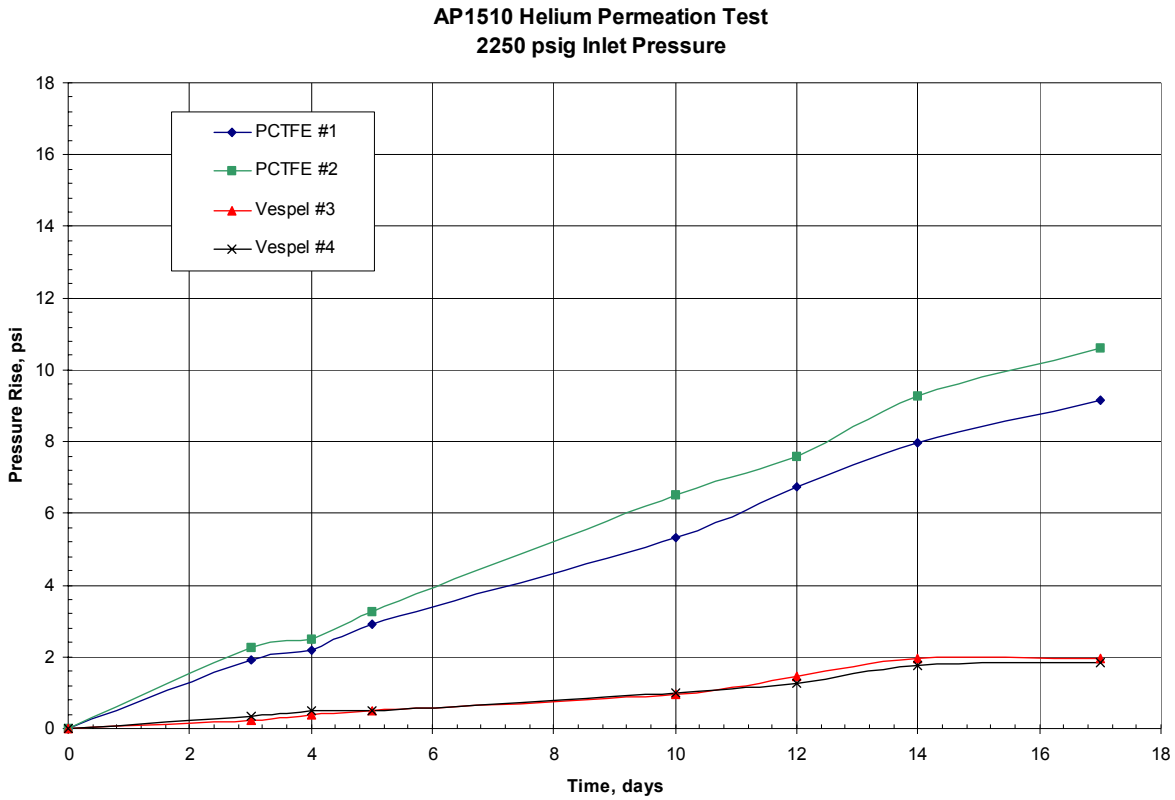

Figure 1. AP1510 High Pressure Helium Permeation Results

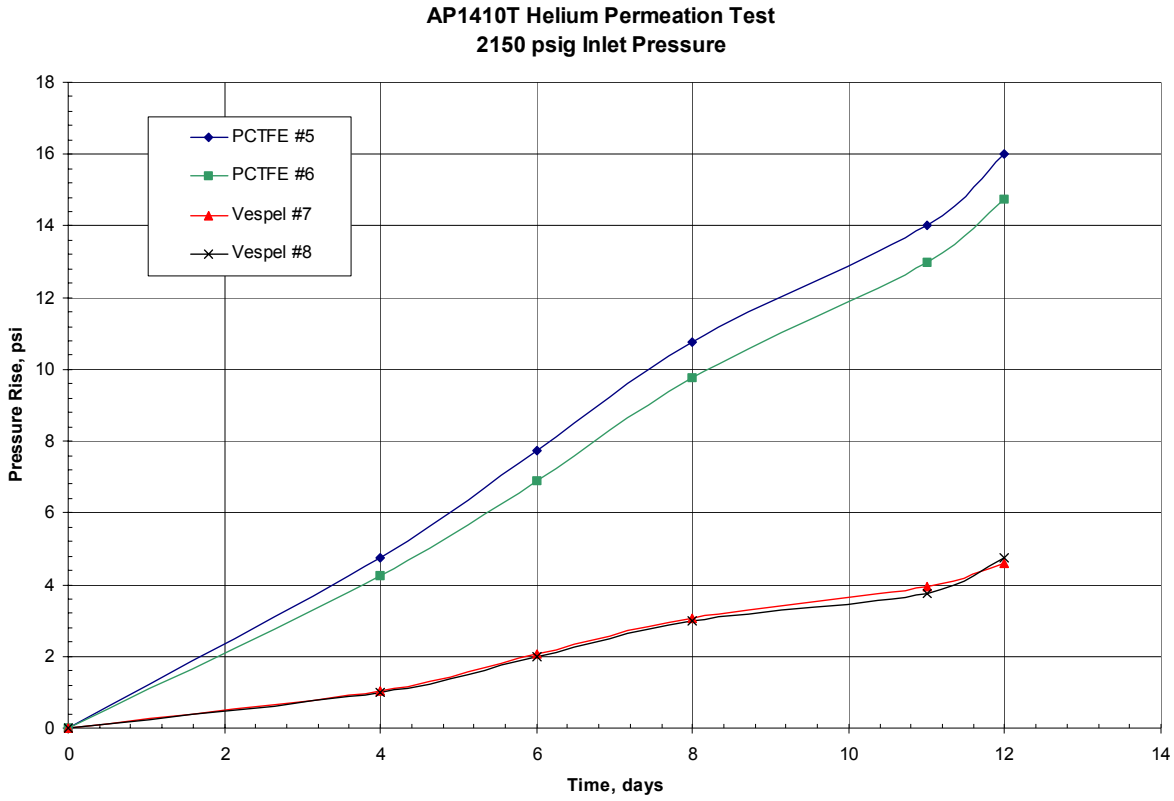

Figure 2. AP1410T High Pressure Helium Permeation Results

Test Regulator	Helium Permeation Rate, cc/min/psid
AP1510 PCTFE #1	2.2×10^{-5}
AP1510 PCTFE #2	2.5×10^{-5}
AP1510 Vespel #3	4.7×10^{-6}
AP1510 Vespel #4	4.4×10^{-6}
AP1410T PCTFE #5	1.1×10^{-4}
AP1410T PCTFE #6	1.0×10^{-4}
AP1410T Vespel #7	3.2×10^{-5}
AP1410T Vespel #8	3.4×10^{-5}

Table 2. Calculated Helium Permeation Rate from High Pressure Test

Low Pressure Helium Permeation Test

Test Setup and Protocol

The pressure regulators were left in the closed position during the entire test. The pressure regulators were connected to a manifold that was pressurized with helium to 160 psig. A 30 inHg-0-30 psig range pressure gauge was connected directly to the outlet of the pressure regulator. The gauge was monitored periodically and the pressure rise recorded. The pressure regulators were kept in a temperature-controlled environment of 70±3 ºF to reduce pressure fluctuations due to temperature.

The internal volume in the low pressure side of the regulator to the pressure gauge was determined by calculation. This volume was then used to calculate the helium permeation rate.

Results

The inlet pressure was 164 psig when the test started. After 30 days the inlet pressure had dropped to 160 psig.

The regulators are identified as AP1510 PCTFE #1, AP1510 PCTFE #2, AP1510 Vespel #3, AP1510 Vespel #4, AP1410T PCTFE #5, AP1410T PCTFE #6, AP1410T Vespel #7, and AP1410T Vespel #8. The permeation test results for the AP1510 regulators are shown in Figure 3. The permeation test results for the AP1410T regulators are shown in Figure 4. The average permeation rate was calculated and is given in Table 3.

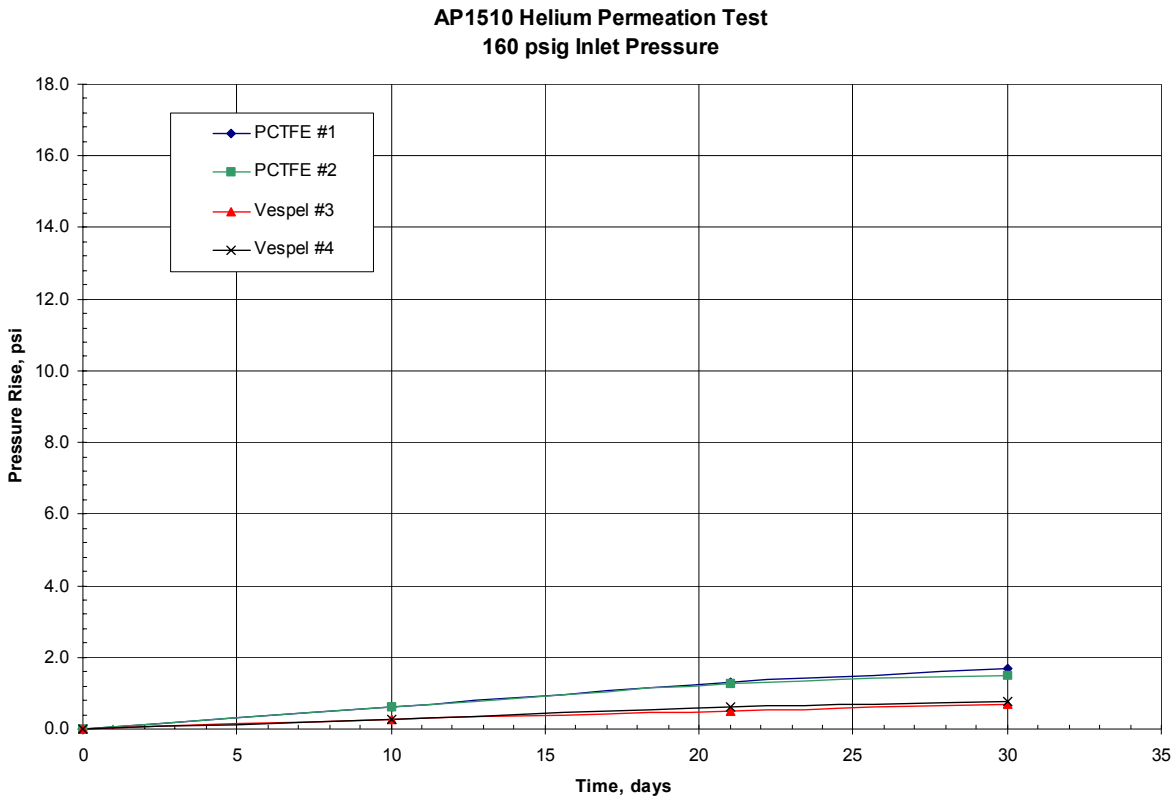

Figure 3. AP1510 Low Pressure Helium Permeation Results

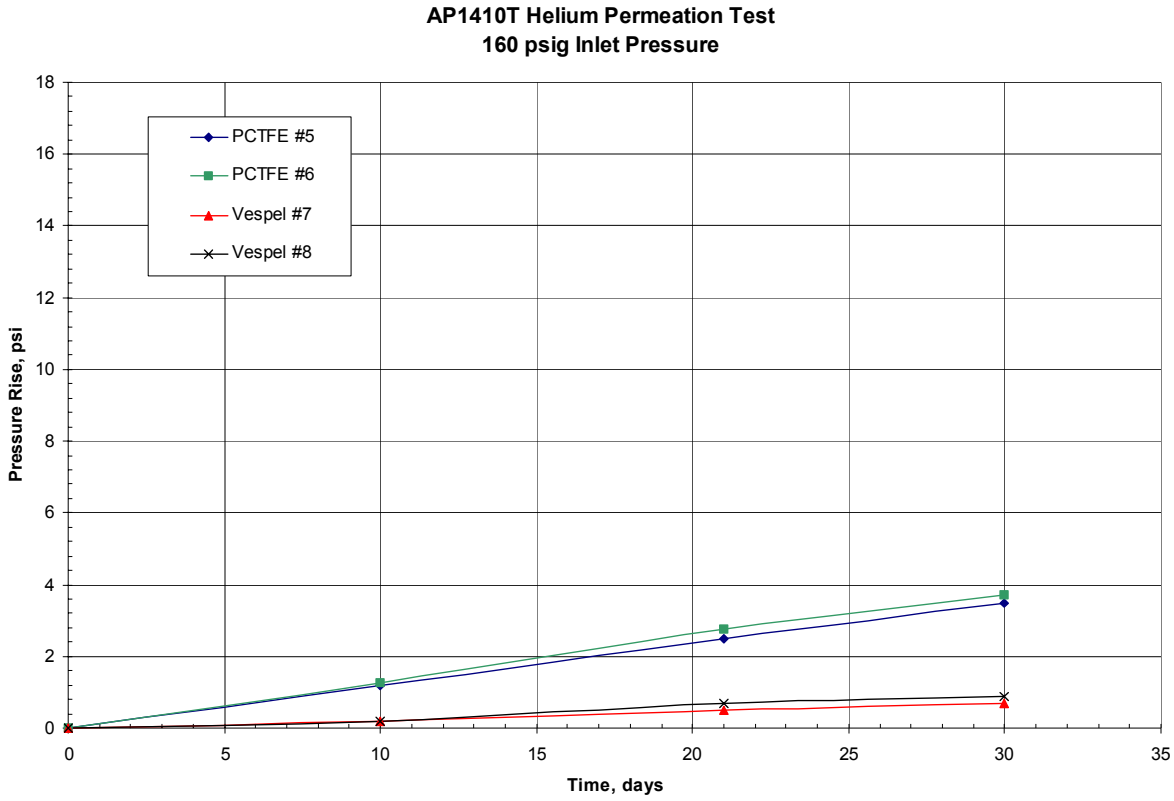

Figure 4. AP1410T Low Pressure Helium Permeation Results

Test Regulator	Helium Permeation Rate, cc/min/psid
AP1510 PCTFE #1	3.0×10^{-5}
AP1510 PCTFE #2	2.5×10^{-5}
AP1510 Vespel #3	1.2×10^{-5}
AP1510 Vespel #4	1.3×10^{-5}
AP1410T PCTFE #5	1.2×10^{-4}
AP1410T PCTFE #6	1.3×10^{-4}
AP1410T Vespel #7	2.5×10^{-5}
AP1410T Vespel #8	3.1×10^{-5}

Table 3. Calculated Helium Permeation Rate from Low Pressure Test

Summary

High pressure nitrogen permeation testing of AP1510 and AP1410T regulators did not observe an outlet pressure rise after 14 days. High pressure helium permeation testing of AP1510 and AP1410T regulators found that there was a significant outlet pressure rise in regulators with PCTFE seats. Low pressure helium permeation testing of AP1510 and AP1410T regulators found that there was a minor outlet presure rise in regulators with PCTFE seats.

The data showed that Vespel has a much lower helium permeation rate than PCTFE when tested under the same conditions. In the AP1510 regulators, the helium permeation rate was 5.2 times greater for PCTFE than Vespel in the high pressure test and 2.2 times greater in the low pressure test. In the AP1410T regulators, the helium permeation rate was 3.3 times greater for PCTFE than Vespel in the high pressure test and 4.5 times greater in the low pressure test. The reason for the difference in permeation rates at high and low pressure is attributed to (1) reduced inlet pressure load on the regulator poppet which may increase the seat leak rate and (2) very small leaks in the test setup connections which influence data taken over long periods of time.

According to the 3M *Engineering Manual* for Kel-F™ 81 PCTFE, the permeation rate for helium is 434 times greater than the permeation rate for nitrogen. Based on the helium permeation data for PCTFE, it would take approximately 740 days in the AP1510 regulator and approximately 320 days in the AP1410T regulator to obtain a 1 psi rise if tested under similar conditions with nitrogen. Therefore, it is logical that no pressure rise was detected in the 14 day duration of the nitrogen permeation test.

The data show that there is no measureable outlet pressure rise due to nitrogen permeation of either PCTFE or Vespel under typical conditions. Although permeability is not directly related to molecular weight, it is likely that gases with a higher molecular weight than nitrogen would also not have significant permeation through PCTFE or Vespel.

For regulators which are left pressurized for longer than two weeks with high pressure on the inlet side of the regulator and the low pressure side isolated, the data show that Vespel may be better choice of seat materials to prevent a significant increase in the regulator outlet pressure for light molecular weight gases such as helium and hydrogen. Gas source equipment that use a standby manifold ready to switchover and provide an uninterrupted supply of process gas is one possible application where Vespel may be a better choice for the regulator seat material than PCTFE.

For line regulators which are left pressurized for longer than two months with the low pressure side isolated, the data show that Vespel may be better choice of seat materials to reduce the rise in regulator outlet pressure for light molecular weight gases such as helium and hydrogen. It is suggested that for many applications it would be better practice to shut off the process gas source and vent the system pressure if the line is to be unused for this length of time.

Test report prepared by:

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