HDPE Berm Pipe Vacuum

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Abstract

In the spring of 2011, the berm pipe from enclosure G2 to NM1 developed a significant leak. Vacuum pumps were destroyed when ground water infiltrated the quarter inch thick steel wall pipe. After months of troubleshooting and surveying, the idea to sleeve this pipe using High Density Polyethylene, or HDPE, pipe is considered. One aspect in deciding to use HDPE is to consider the ability of the material to hold vacuum well enough to transport beam.

Introduction

Based on vacuum readings of adjacent berm pipes, we consider looking at the vacuum at 1E-2 Torr as our base line for always satisfactory vacuum readings. Beam pipes upstream and downstream of the berm have better readings than 1E-2 Torr. Also before the water infiltrated the berm pipe, vacuum readings were in the tens of micro Torr range. However for the sake of this berm pipe, having vacuum pressures in the ten’s of micro Torr range is acceptable, any better would extend the life of the pipe.[[1]](#footnote-1)

The HDPE in consideration is DR11 14” HDPE. With an outside diameter at 14”, it has an average standard wall thickness of 1.27 inches and weighs 22.2 lbs/ft. Its density ranges from .93 to .97 grams/cc.

Small Pipe

 A small piece was procured of HDPE pipe and machined end cap combination, creating just one opened end. It was assembled by the contractor MAU. This piece is 1212 cubic inches in volume. It was cleaned out and a ported plate with an O ring seal was used. The initial pump down took some time with high initial pressures, more than likely due to residual water from cleaning. Then it was pumped down using a 150 CFM turbo cart / oil rougher and a pirani / cold cathode gauge set. Table 1 shows the pump down readings.

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| Pump Down test of small pipe |
| 2 hours | 9.0E-5 Torr |
| 48 hours | 7.0E-6 Torr |
| 120 hours | 2.0E-6 Torr |
| 336 hours | 2.0E-6 Torr |

Table 1 Pump down test of small pipe piece

 After the piece was under vacuum a Rate of Rise test was conducted. Once the valve from the vacuum pump to the piece of HDPE closed, the pressure instantly jumped. Once it settled a smoother trend of vacuum pressure was seen. Table 2 shows the readings of the rate of rise test.

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| Rate of Rise test of small pipe |
| Time | Pressure |
| 0 hours | 8.0E-5 Torr |
| 7 hours | 5.0E-4 Torr |
| 15 hours | 1.0E-1 Torr |
| 336 hours | 1.0E-1 Torr |

Table 2 Rate of Rise test on small pipe piece

Large Pipe

 With evidence from the small pipe pump down and rate of rise tests, we can conclude that the material of HDPE can hold vacuum to a certain level given a small volume. However our pipe will be closer to 760 feet long with multiple HDPE welds joining sections of HDPE pipe together.

 In order to replicate this pipe, we asked to have a twenty foot section of HDPE be cut up into multiple smaller sections and conduct the same tests as the small pipe. The pipe was sliced into XXX sections and on each end a T flange adapter was attached. This flange is a standard flange from the manufacturer. It has a bolt-hole pattern so that it can be connected to either HDPE flanges or metallic flanges via a back collar.

 The pipe was also placed on pipe stands to replicate some sagging in the transitions, along with a clear working space on each flange at both ends. Blind flanges were also delivered so that port holes could be installed to attach vacuum pumps at both ends. The ends were sealed with ported O ring plates. Each end was setup with a 150 CFM turbo cart / oil rougher, a pirani gauge, and an ion gauge. Residual water again played a part in initial high pressure during the pump down.

 Once pumped out respectable pressures were obtained. Several helium leak checks were then performed but the most significant was after a seam was removed with a hammer and chisel. No leaks were found at 1.8E-8 Torr liters per second. Table 3 displays the rest of the data of the pump down test on the large pipe.

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| Pump Down test of large pipe |
| Time | Pressure |
| 1/2 hour | 6.0E-3 Torr |
| 24 hours | 2.1E-3 Torr |
| 48 hours | 3.1E-4 Torr |

Table 3 Pump Down test of large pipe

 After the pipe was under vacuum a Rate of Rise test was conducted. Once the valve from the vacuum pump to the piece of HDPE closed, the pressure instantly jumped. Again after it settled a smoother trend of vacuum pressure was seen. Table 4 shows the readings of the rate of rise test.

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| Rate of Rise test of large pipe |
| Time | Pressure |
| 0 hours | 3.5E-4 Torr |
| 17 hours | 2.0E-1 Torr |
| 24 hours | 2.5E-1 Torr |
| 42 hours | 4.4E-1 Torr |

Table 4 Rate of Rise test on large pipe

 However the pipe was never cleaned out before the vacuum pumps were attached. It was noted that it could be possible to get even better vacuum readings if the pipe was cleaned out before pumping. A steam cleaner was brought through the center of the pipe and swept the entire length. Once the cleaning process was complete, another pump down test was administered. Initially there were some leaks detected by the porthole location to the vacuum pumps. Once those were fixed the large cleaned pipe pumped down. Table 5 shows the results for the first 30 minutes. Figure 1 shows the plot of the pump down test for the first 4 hours.

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| Pump Down test of cleaned large pipe |
|  | Pirani 1 | Pirani 2 |
| Time | Pressure |
| 1013 | 7.20E+02 | 7.20E+02 |
| 1018 | 4.10E+0 | 4.00E+01 |
| 1023 | 1.01E-01 | 1.04E-01 |
| 1028 | 4.20E-03 | 4.00E-03 |
| 1033 | 1.00E-03 | 8.00E-04 |
| 1038 | 8.20E-04 | 5.00E-04 |
| 1043 | 6.20E-04 | 4.30E-04 |

Table 5 Pump Down test of cleaned large pipe

Figure 1 First 4 hours of Pump Down test of cleaned large pipe

 Once the cleaned large pipe was pumped down, a rate of rise test was also then conducted. Table 6 shows the first thirty minutes of the test and Figure 2 is a plot of the first 38 hours of the test.

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| Rate of Rise test of cleaned large pipe |
|  | Pirani 1 | Pirani 2 |
| Time | Pressure |
| 1337 | Off Scale | Off Scale |
| 1342 | 4.00E-04 | 3.00E-04 |
| 1347 | 9.00E-04 | 9.00E-04 |
| 1352 | 1.50E-03 | 1.40E-03 |
| 1357 | 2.10E-03 | 2.10E-03 |
| 1402 | 2.80E-03 | 2.70E-03 |
| 1407 | 3.4 0E-03 | 3.30E-03 |

Table 6 Rate of Rise test of cleaned large pipe

Figure 2 First 38 hours of Rate of Rise test of cleaned large pipe

 For comparison from dirty pipe to clean pipe, Figure 3 shows the difference. Both tests conducted used the same pumps, and is scaled on the same time. The large dirty pipe minimum pressure reached 2.50E-04 Torr (0.368 Volts), and the large cleaned pipe reached 4.10E-05 Torr (-0.423 Volts).

Figure 3 Plot of Pump Down of Dirty and Cleaned pipe

Water Absorption

 When HDPE pipe is to replace the steel pipe that is current between G2 and NM1, there is likelihood that water will still infiltrate the steel pipe. To test the capabilities of the HDPE pipe we will test how well it stands constant contact with a water source on the skin of the pipe.

 For this test we begin to the smaller pipe. We placed the smaller pipe in an empty container and raised it off the bottom. Then we filled the container with water to halfway up the HDPE pipe’s rim. Once the water was settled we marked the inside meniscus and began to pump down on the small piece. Using the data from before we have an idea of the baseline vacuum pressure we expect at each interval.

Conclusion

 Here at Fermilab beampipes have always been made from a metallic substance, preferably stainless steel or aluminum. Berm pipes have been made of carbon steel with various size diameters. Not once has High Density Polyethylene been consider accomplishing the same task as steel.

 Looking primarily at the vacuum characteristics of HDPE there is substantial evidence that HDPE will perform just as well as carbon steel. Prior to pumping down, steam cleaning the inside of the pipe may slow down initial pumping, but once all the water vapor is removed vacuum pressures can achieve readings decade better.

1. Beams Doc 4000 V6 Irradiation [↑](#footnote-ref-1)