HDPE Berm Pipe Radiation Integrity

Version 7.0 12/8/2011

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Introduction

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 radiation damage and its impact on the ability of the material to hold vacuum well enough to transport beam.

The radiation dose to the HDPE pipe is calculated for the expected normal running beam losses and tested for accidental direct hit beam pulses. 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. 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.

Normal Running

With the normal running conditions of 1E+13 protons per pulses delivered at one pulse a minute, which delivers 5.256E+18 protons per year, for a 1.27 inch thick and 760 feet long pipe at 1E-2 Torr pressure, it is calculated to receive an equivalent of 3.15E+13 interacting protons each year it is in service. A multiwire, with Beryllium Copper wires, will be placed just upstream of the HDPE pipe causing an equivalent of 8.00E+14 protons scattered to interact with the pipe.

Combined lost estimate is 8.34E+14 protons per year, this equates to 2.00E+5 Rads per year based on the pipe’s mass. Radiation damage to HDPE below 1E+7 Rads will not compromise its mechanical properties which are deemed as always satisfactory[[1]](#footnote-1), and is often satisfactory[[2]](#footnote-2) for 5E+7 Rads[[3]](#footnote-3). The calculation of the dose incurred by the HDPE pipe is presented below.

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| $$\left(\frac{8.32E+14(\frac{protons}{yr})×120(\frac{GeV}{proton})×1.60E-10(\frac{Joules}{GeV})}{7984.73 (kilograms)}\right)×100 \left(\frac{Rads}{Gy}\right)=2.00E+5 (Rads/year)$$$$\frac{1.00E+7 (Rads)}{2.00E+5 (Rads/year)} =50 years of Always Satisfactory$$$$\frac{5.00E+7 (Rads)}{2.00E+5 (Rads/year)} =250 years of Often Satisfactory$$ |

Figure 1 Calculation for yearly protons lost to Rads per year, and calculations for years for HDPE material to become *Always* and *Often* Satisfactory

Accident Pulse

Accidental loss is replicated using the same material blind flanges. Four flanges were procured, three were irradiated as one remained as the control. Each HDPE Blind flange is one inch thick and 21 inches in diameter. From the manufacturer they have a bolt-hole pattern for a back collar, and we specially machined the front face for a smooth finish and an o-ring groove to achieve a good vacuum seal before it was irradiated.

Individually each flange was placed in front of the Switchyard absorber line and was irradiated, with increasing amounts of pulses. Each flange had approximately a factor of 10 more than the previous flange. The spot size of the beam varied slightly from pulse to pulse as did the intensity but on average was consistent.

The flange with 1 pulse had a half hour cool-down period and the remaining flanges had an hour cool-down before we retrieved the flange. Each flange irradiated was frisked and surveyed to be Class 1, less than 1mR/hr[[4]](#footnote-4), only flange number four showed contact residual dose at 150 counts per minute, the others had no evidence of contact residual dose. Shown in Table 1 is the amount of integrated beam delivered to each flange, average spot size of the beam on the flange and the vacuum leak rate after irradiation.

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| Flange | Number of pulses | Average pulse intensity | Integrated Protons | Average 1 Sigma Horizontal (mm) | Average 1 Sigma Vertical (mm) | Vacuum Leak Rate$$\left(\frac{Torr ×l}{s}\right)$$ |
| 1 | 0 | 0 | 0 | N/A | N/A | 3.2E-10 |
| 2 | 1 | 6.94E+11 | 6.94E+11 | 2.521 | 2.915 | 3.2E-10 |
| 3 | 10 | 7.50E+11 | 7.50E+12 | 2.484 | 2.782 | 3.9E-10 |
| 4 | 124 | 5.81E+11 | 7.20E+13 | 3.161 | 2.627 | 3.3E-10 |

Table 1: Flange leak rate vs. integrated protons

 With the leak rates of the individual flanges not showing a very large difference a calculation of how many pulses it would take to change the mechanical properties of HDPE is considered. It takes 1.00E+7 Rads to degrade HDPE to Often Satisfactory from Always satisfactory. For each pulse at full intensity regulated by the E906 shielding assessment at 1.00E+13 protons per pulse, it would take 4,160 pulses.

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| $$\frac{4.16E+16 (protons)}{1.00E+13 (\frac{protons}{pulse})}=4160 pulses$$ |

Conclusion

 Under normal running conditions the calculated lifetime of the HDPE pipe exceeds the lifetime of the current experiment, (E-906 SeaQuest) and covers far into the future by a safety factor of greater than 12. With accidental proton beam losses on the pipe, it has the budget of at least 124 direct beam hits of 5.81E11 protons per pulse on the HDPE pipe (7.2E13 protons), without compromising the integrity of the HDPE beam pipe. It is also calculated to stand over 4000 full intensity accidental pulses.

1. Always Satisfactory is no changes to materials properties i.e. tensile strength, elongation, etc. [↑](#footnote-ref-1)
2. Often Satisfactory is the change is first detected in one or more properties [↑](#footnote-ref-2)
3. REIC Report 21 and Addendum August 31, 1964 [↑](#footnote-ref-3)
4. FRCM Chapter 4 Part 1 [↑](#footnote-ref-4)