

## Technical Note PP 844-TN Slurry Abrasion Resistance in Polyethylene Pipe

Polyethylene (PE) pipe is a frequent choice for transporting slurry solutions. It has proven to have superior wear resistance to many different materials. For example, when carrying fine grain slurries, polyethylene has been shown in laboratory tests to be three to five times more wear resistant than steel pipes<sup>1</sup>. As the testing reveals, Performance Pipe offers an even superior slurry flow product than the typical PE4710 pipe with DriscoPlex<sup>®</sup> 4800 pipe. This technical note demonstrates how slurry flow affects polyethylene pipe, how slurry flow abrasion is tested for and measured, and analyzes the results of slurry abrasion tests on DriscoPlex<sup>®</sup> 4800 PE pipe and two different samples of conventional PE4710 pipe.

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### Key Points

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- Slurry flow causes abrasion in piping systems.
  - Turbulent flow is ideal for reducing the wear on polyethylene piping during operation.
  - DriscoPlex<sup>®</sup> 4800 pipe has better resistance to slurry flow abrasion than conventional PE4710 pipes.
  - Higher temperatures may improve the resistance of polyethylene to slurry flow abrasion, but more testing would need to be done to confirm these possibilities.
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### Slurry Flow in Polyethylene Pipes

Liquid slurry flow occurs when solid particles are carried in a liquid flow. For polyethylene piping systems, the liquid carrier is usually water and the solid particles are commonly granular materials such as sand, fly-ash, and coal.

Slurry particles wear down pipes through impingement. When particles bounce off of or slide along the inner surface of PE pipe, the particles start mechanically eroding the pipe. In order to reduce the amount of contact between the slurry particles and the pipe, it is important to keep the slurry in a turbulent flow. Turbulent flow suspends the particles in the liquid and greatly reduces the amount of contact between, and thus, wear done on the pipe as opposed to laminar slurry flow, when the slurry particles settle to the bottom of the pipe and slide along the bottom of the pipe surface. Durand's Equation (Eq. 1) gives the critical velocity needed to keep the slurry flow turbulent. Good practice is generally recognized as keeping the flow velocity at 30% above the critical velocity calculated with Durand's Equation.

$$V_C = F_L \sqrt{2gd'(S_s - 1)} \quad (\text{Eq. 1})$$

Where  $V_C$  = critical settlement velocity in feet/sec,  $F_L$  = velocity coefficient (given in Tables 2-7 and 2-8 in *Handbook of Polyethylene Pipe*<sup>2</sup>),  $d'$  = pipe inside diameter in feet, and  $S_s$  = specific gravity of the solids in the slurry mixture.

There are some general correlations between slurry properties and increased or decreased mechanical erosion to keep in mind. First, the rate of wear increases as hardness of the particles in the slurry increases. Second, the larger the particle sizes in the slurry, the more wear seen, and vice versa. This has shown to be true up until a particle size of about 100 microns. After that, the effect of a larger particle size on increased abrasion tends to level off. Third, rounded material has a ball bearing effect creating less wear, while sharp angular solids can gouge the material specimen and create more wear. Lastly, increasing the concentration of the solids increases the rate of material loss. However, this increase of material loss only occurs until

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<sup>1</sup> Pankow, Virginia R., *Dredging Applications of High Density Polyethylene Pipe*, 1987.

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<sup>2</sup> Plastic Pipe Institute. *Handbook of Polyethylene Pipe: Second Edition*, 2008. [www.PlasticPipe.org](http://www.PlasticPipe.org)

the wear surface interface is saturated, which typically occurs around 20 weight percent of the solid in the slurry. Once the interface is saturated, increasing the solids concentration in the slurry has a negligible effect on the rate of wear.

The slurry, depending on the components, can corrode non-PE pipe. There is potential for the erosion and corrosion to synergize in these non-PE pipes and result in higher material loss than is obtained by mechanical erosion or corrosion individually. Since PE pipes do not corrode, this further supports the benefit of PE pipes in abrasion applications.

### Measuring Slurry Abrasivity and Slurry Abrasivity Resistance

Slurry abrasivity can occur through mechanical erosion, chemical effects of slurry, and through additional synergistic effects between the two. There are three ways of quantifying or measuring slurry abrasivity and slurry abrasion resistance and how these components contribute to the overall slurry abrasion of a material. These are the Miller Number, the Gold Number, and the Slurry Abrasion Response (SAR) Number.

#### Miller Number and Gold Number

The Miller Number and Gold Number both measure the relative abrasivity of a particular type of slurry to a common material. Miller Number of a slurry type is determined by measuring the mass loss rate of a 27% Chrome Iron Wear Block for two hours, three times, and then using a curve fit program to determine the average mass loss rate. Typically, any Miller Number above 50 is considered abrasive enough to cause considerable pipe wear over time and must be accounted for.<sup>3</sup>

Gold Number is determined the same way, but instead uses a 24-Karat Gold Wear Block. While the 27% Chrome Iron Wear Block loses mass from erosion and corrosion, the 24-Karat Gold Wear Block is corrosion

resistant. Therefore, the Gold Number test is used to measure the mass loss rate of just the erosion process, while the Miller Number test shows the combined effects of both corrosion and erosion. The Gold Number test is used to more accurately measure less-abrasive slurries with Miller Numbers between 0 and 20.

#### Slurry Abrasion Response (SAR) Number

While Miller Number and Gold Number measure the abrasivity of different types of slurries, SAR Number measures the resistance of different materials to any type of slurry. SAR Number is measured using the volume loss of a solid wearing specimen in a given slurry. Therefore, the SAR Number is how we will compare our three different PE testing materials to determine which type of PE has the best resistance to slurry flow. The ratio of the specific gravity of the test material to that of the 27% Chrome Iron Wear Block is applied to the mass loss rate measured in the tests to calculate a relative rate of volume loss at two hours. In SAR tests, three runs of two hour tests are performed to determine the total mass loss.

#### SAR Number Tests for PE

The testing performed aimed to measure the resistance to wear due to slurry abrasion of three different types of polyethylene at both ambient temperature (73°F) and an elevated temperature (140°F). The three types of polyethylene used were our DriscoPlex® 4800 PE2708 pipe and two different PE4710 resin pipes that are referred to as PE4710-1 and PE4710-2. The testing was done per ASTM G-75 *Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)*.<sup>4</sup> Per ASTM G-75, the slurry used was AFS 50-70 Test Sand slurry, containing 150 g of AFS 50-70 Sand and 150 g of deionized water. This AFS 50-70 Sand slurry and the Standard 27% Chrome Iron Wear Blocks have the standard Miller Number and SAR Number of 120, respectively.

<sup>3</sup> ASTM G75-15, *Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)*, 2015. [www.ASTM.org](http://www.ASTM.org)

<sup>4</sup> ASTM G75-15, *Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)*, 2015. [www.ASTM.org](http://www.ASTM.org)

Pipe samples are provided for the test. These are then machined down to ½" x 1" x 3/8" test samples. The tests are done using a Miller Number machine, shown in Figure 1. The three samples are attached to the wear specimen mounting jig, where they are then lowered into columns with the ½" x 1" wear surface exposed to 300 mg of the AFS 50-70 Sand slurry. The test samples are moved back and forth in a reciprocating motion through the slurry by a piston, going through 5760 8" strokes in a two hour span. The samples are then taken off and weighed to determine the amount of mass loss. This is repeated two more times, such that three two-hour tests are performed to measure the overall amount of mass loss for each test specimen. These tests were run at each temperature for each material type twice. The SAR Numbers are determined by creating a best-fit curve with the results of the two tests (6 data points), and then taking the slope of the curve at the 2-hour mark. Then, the slope is multiplied by the ratio of the specific gravity of the test material to that of the 27% Chrome Iron Wear

Block and by a constant of 18.18 that makes the number relative to a Miller Number of 1. The result is the materials SAR Number.

The results were compared using the percentage of increased thickness loss for all of the materials compared to the best material overall and for each material at a particular temperature. The increased thickness loss was calculated using the following equation:

$$\% \text{ Increase in Thickness Loss} = \frac{T - T_{\text{Best}}}{T_{\text{Best}}} * 100 \quad (\text{Eq. 2})$$

Where T = thickness loss of the material and T<sub>Best</sub> = thickness loss of the best performing material for that subgroup. The results are shown in Table 1 and Graphs 1 and 2.

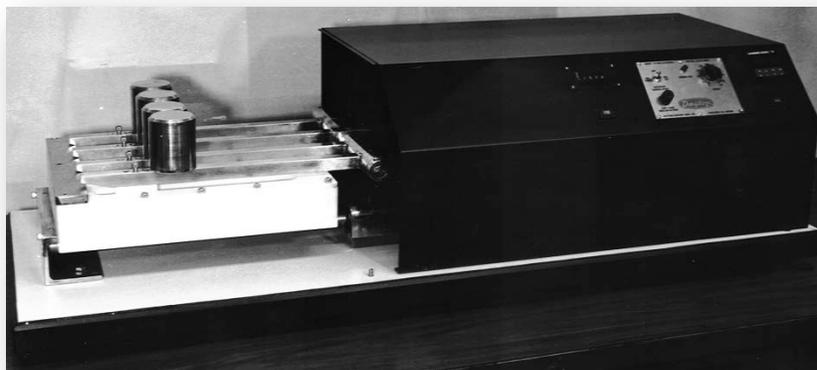
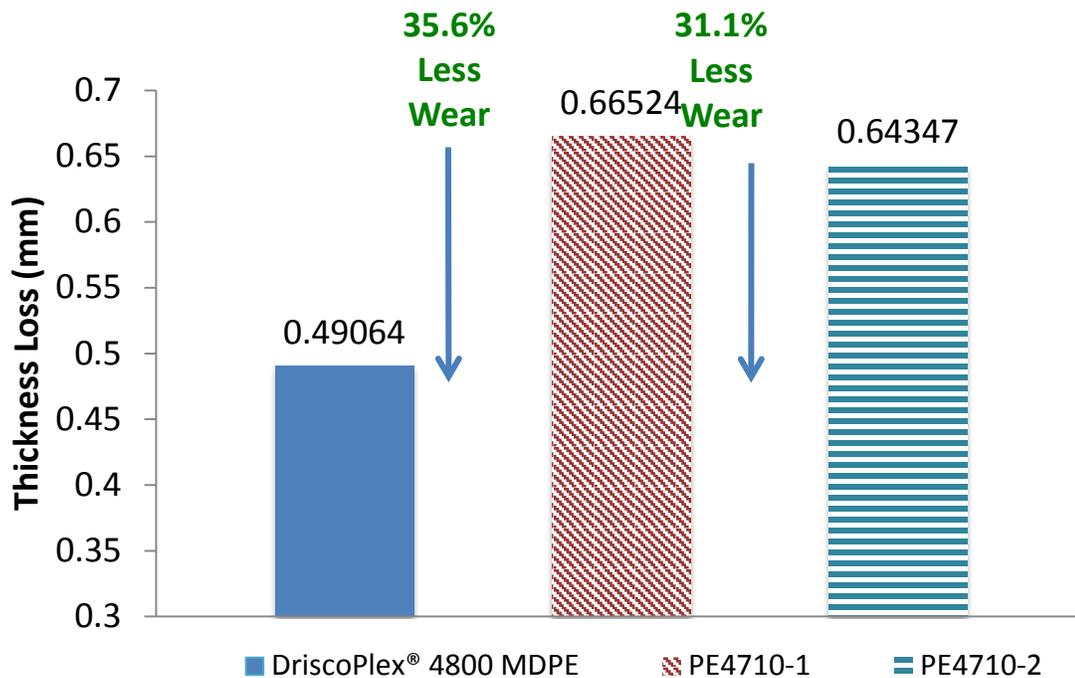


Figure 1: Miller Number Machine

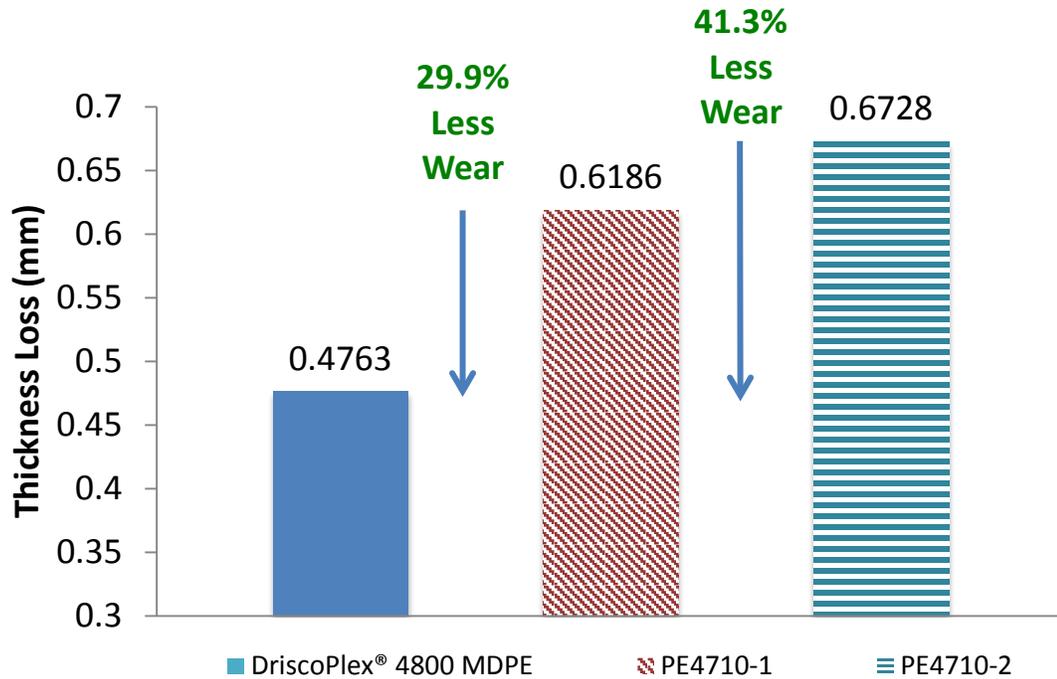
Table 1: SAR Numbers and Thickness Losses

Wear Block Description	Temperature	Specific Gravity	Block 1 Loss (mg)	Block 2 Loss (mg)	Average Loss (mg)	SAR Number	Thickness Loss (mm)	Increased Thickness Loss (Overall)
DriscoPlex® 4800	73°F	0.941	144.2	153.6	148.9	3532	0.49064	3.0%
PE 4710-1	73°F	0.960	211.3	200.8	206.1	4922	0.66524	39.7%
PE 4710-2	73°F	0.961	197.1	201.9	199.5	4785	0.64347	35.1%
DriscoPlex® 4800	140°F	0.941	139.6	149.6	144.6	3504	0.4763	0.0%
PE 4710-1	140°F	0.960	211.6	171.5	191.6	4606	0.6186	29.9%
PE 4710-2	140°F	0.961	206.8	210.4	208.6	4978	0.6728	41.3%

Graph 1: Thickness Loss (mm) for Polyethylene Pipe at 73°F



Graph 2: Thickness Loss (mm) for Polyethylene Pipe at 140°F



## Results

As can be seen from the tables, our DriscoPlex® 4800 consistently resulted in the lowest amount of thickness loss at both ambient temperatures and elevated temperatures, and thus had the best slurry abrasion resistance of the three material types. At 73°F, DriscoPlex® 4800 had the best slurry abrasion resistance with an SAR of 3532 and a thickness loss of 0.49064 mm. This thickness loss for DriscoPlex® 4800 at 73°F was 35.6% less than PE4710-1's thickness loss and 31.1% less than PE4710-2's thickness loss. DriscoPlex® 4800 outperformed PE4710 at elevated temperatures too, having an SAR of 3504 and a thickness loss of 0.4763 mm, which was 29.9% less than PE4710-1's thickness loss and 41.3% less than PE4710-2's thickness loss. In general, the DriscoPlex® 4800 performed at least about 30% better in terms of thickness loss at each temperature than both PE4710 materials.

Two characteristics of plastics that have been shown to improve abrasion resistance are increased side branching, when short polymer chains randomly bond

to the main polymer chain, and decreased hardness. DriscoPlex® 4800 pipe has more side branching and is softer than PE4710 pipe, so these characteristics could be explanations as to why DriscoPlex® 4800 displayed superior wear resistance. A study done in 2002 titled *Macromolecules*<sup>5</sup> found that the abrasive wear for plastics is primarily dependent on "the effective number of physical cross-links per macromolecular chain." In addition, a paper presented at Plastic Pipes VII titled *The Abrasion Resistance of Polymers Used in Slurry Transport Systems*<sup>6</sup> found that as hardness increased, abrasion resistance decreased for plastics, which is opposite the trend seen for metals. Abrasion resistance increased with a decreasing elastic modulus, which occurs when hardness decreases. Both of these characteristics, side branching and decreased hardness, are related to density. Increased density is directly proportional to increased hardness, and more

<sup>5</sup> T.A. Tervoort, J. Visjager and P. Smith, *Macromolecules*, 2002.

<sup>6</sup> D. Lowe and G. P. Marshall, *The Abrasion Resistance of Polymers Used in Slurry Transport Systems*, 1988.

side branching makes the polymer chains of polyethylene unable to pack together as tightly, so decreased side branching is characteristic of higher density materials. DriscoPlex® 4800 pipe is made up of medium-density polyethylene, while the PE4710 pipe is made up of high-density polyethylene, so the results of the slurry wear resistance would make sense when evaluating the materials with these two characteristics in mind.

In addition, it appears that the elevated temperature could help the polyethylene's resistance to slurry wear,

but this is contradicted by the increased thickness loss of the PE4710-2 sample. Increased temperature helping slurry abrasion resistance would make sense considering the correlation between wear resistance and hardness explained earlier, as increasing temperature softens the polyethylene. However, further testing at multiple intermediary temperatures would be necessary to determine if a true correlation exists between increased temperature and increased slurry wear resistance.

## REFERENCES

1. Pankow, Virginia R., *Dredging Applications of High Density Polyethylene Pipe*, Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180-0631, 1987.
2. Plastic Pipe Institute, *Handbook of Polyethylene Pipe: Second Edition*, 2008. [www.PlasticPipe.org](http://www.PlasticPipe.org)
3. ASTM G75-15, *Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)*, 2015. [www.ASTM.org](http://www.ASTM.org)
4. Tervoort, T.A., Visjager, J., and Smith, P., *Macromolecules*, 2002.
5. D. Lowe and G. P. Marshall, *The Abrasion Resistance of Polymers Used in Slurry Transport Systems*, Plastics Pipe VII, 1988.

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