

## Technical Note PP 820-TN Design Factor for DriscoPlex<sup>®</sup> PE4710 Pipe

### Safety factor versus Design Factor Is There a Difference?

#### What is a Safety factor?

The safety factor is the ratio of the failure load to the load actually carried in service. A single factor of safety would be too limiting in scope to design thermoplastic pipes, therefore a design factor is required.

#### What is a Design Factor?

According to ASTM D2837, "Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products", a design factor is a number less than 1.0 which takes into consideration all of the variables and degree of safety involved in a thermoplastic pressure piping installation in order to provide a continuous life with reliable confidence. It may sometimes be **applied by standard, specification or regulation**. Design factors are material specific. An adequate design factor for one material may not be sufficient for another, as different materials have different limitations.

#### What is the Safety factor for PE4710 Pipe?

The factor of safety definitely is not 1.6, or the inverse of the design factor, despite what you might have heard from competitive material manufacturers.

While the **Design Factor** for PE4710 is 0.63, this is a case where the design factor and safety factor are not the same. The design factor is specified by PPI TR-3<sup>1</sup> and is applied to a stress at an arbitrary standardized time period of 100,000 hrs or 11.4 years to obtain the Hydrostatic Design Stress. Of course, we all expect the pipes in our infrastructure to last much, much longer than that. The design factor provides us with a pressure rating at which there is a high degree of certainty the pipe will not fail due to internal pressure. Additionally, the 0.63 design factor results in a **Safety Factor** against short term over pressurization greater than **3 to 1** for as long as the pipeline is operated and a **Safety Factor** in excess of **2 to 1** against fatigue at a service life well in excess of 100 years.

Unlike PVC pipe resins, which only need to meet a generic formulation to be considered pipe grade materials, each PE pipe resin is individually tested over multiple ranges of temperatures and stresses to establish a stress life curve family that is unique to that specific resin. Based on performance it is categorized into grades. Historically the highest performing pipe resins were designated as PE3408, a designation first recognized in 1979. However, over the last 30 years there have been significant advances in the development of higher performing PE resins and pipes. Today the industry recognizes additional grades of PE pipes including the high performing PE4710 piping materials.

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<sup>1</sup> PPI TR-3, "Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe" is available at [www.plasticpipe.org](http://www.plasticpipe.org).

## How was the Design Factor of 0.63 selected for PE4710?

The Hydrostatic Stress Board has been the North American body that determines the appropriate design factor for each thermoplastic material since the inception of the methodology in 1958. The Hydrostatic Stress Board has member representatives from all aspects of the plastic piping industry - PVC, PE, PEX, CPVC, etc... - and they work through a consensus process to develop unbiased protocols for establishing the long-term hydrostatic design basis, design factors, and hydrostatic design stress for all thermoplastic materials used on pressure piping applications.

The pipe resins that are now identified as PE4710 were first introduced into the US in 1997. Test protocol prescribed by the Hydrostatic Stress Board, in compliment with existing test protocol established by the International Standards Organization, established additional test criteria for PE4710 pipes above and beyond the requirements of ASTM D2837. These include:

- 1) Validation of the linearity of the stress life curve to 50 years (rather than basing design on 11.4 years as with PVC)
- 2) Tighter correlation requirements for the stress life data points
- 3) Slow crack growth resistance of 500 hours under PENT testing per ASTM F1473. This is five times greater crack growth resistance than PE3608 pipes.
- 4) Based on PE4710 resin's ability to pass these more rigorous tests, the Hydrostatic Stress Board assigned and published in TR-4<sup>2</sup> a design factor of 0.63 for PE4710 pipe.

PE4710 PE pipe grades have been incorporated into AWWA C901, ASTM D3350, NSF, ASTM F714, ASTM D3035 and others. Ballots are underway and near completion throughout the industry which will complete the recognition of the new high performing material.

## What is the Difference between a Design Factor and a Safety Factor?

The introduction mentioned that the design factor depends on the resin. For instance the design factor for PE4710 is 0.63 whereas the design factor for PE3608 (formerly PE3408) and for PVC (technically PVC 1120) is 0.5. Even though the ratio of the 11.4 year strength to the allowable stress is 2 for a material with a design factor of 0.5, this does not mean that the material provides longer life or better performance than a material with a ratio of 1.6 and a design factor of 0.63, nor should it be interpreted to mean that the material has a safety factor of 2.

There is a subtle but significant error when the inverse of the design factor is referred to as the safety factor. The purpose of the design factor is to reduce the pipe's hoop stress to a value that is continuously sustainable in an application. The factor must account for things like the pipe's ability to withstand variations from continuous pressure such as short term over pressurization, surges, fatigue, thermal fluctuations, field handling, and variability in manufacturing, testing and materials. A single design factor value must encompass a variety of factors. To simply state that

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<sup>2</sup> PPI TR4, "PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe" is available at [www.plasticpipe.org](http://www.plasticpipe.org).

the pipe has a safety factor of 2, if its design factor is 0.5, or that it has a safety factor of 1.6 if its design factor is 0.63 is misleading. For instance, consider overpressurization. PE4710 with a design factor of 0.63 has a 3.2 to 1 or greater safety factor for short term overpressurization. Or, consider fatigue. It is well recognized that HDPE has a superior resistance to fatigue compared to PVC<sup>3</sup>. Fatigue is not predicted by D2837 curve but fatigue can definitely limit the life of a thermoplastic pipe. It would be incorrect to say that both HDPE and PVC pipes have the same safety factor against fatigue—even when they both have the same design factor, as in the case of PE3608. PP-402, “*HDPE and PVC: Working Pressure Rating and Fatigue Life*” shows that fatigue life is well over 100 years for PE3608 with a design factor of 0.5 and for PE4710 with a design factor of 0.63 for normal operating conditions whereas the fatigue life of PVC with a design factor of 0.5 is less than 100 years.

## Summary

The design factor for thermoplastic pipes is not the same as a safety factor. The design factor is all inclusive and provides the user confidence that the selected piping product operating at or below its TR-4 recommended design stress (with allowances for surge) will perform reliably and continuously.

For long term pressurization, the design factor is used to obtain the Hydrostatic Design Stress (HDS) which is defined in ASTM D2837 as the maximum hydrostatic stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. Table 1 gives the intercept of a PE4710 stress life curve with time at different HDS values. TR-4 lists an HDS for PE4710 of 1000 psi at 73°F.

**Table 1. Stress-Time Intercept for PE4710 Stress Life Curve (73°F)**

Hydrostatic Design Stress	Design Factor	DR 13.5 Pressure Rating	Safety factor Against Burst ASTM D1599	Projected Stress Life Intercept
1600 psi	1.0	256 psi	2.0	11.4 yrs
1440 psi	0.9*	230 psi	2.2	200 yrs
1280 psi	0.8*	205 psi	2.5	60,000 yrs
1000 psi	0.63	160 psi	3.2	10 <sup>10</sup> yrs

\*Hypothetical design factors used to illustrate the variation of the HDS with the projected intercept.

<sup>3</sup> Marshall, G.P., Brogden, S., and Shepherd, M.A. (1998) “Evaluation of the surge and fatigue resistance of PVC and PE pipeline materials for use in the U.K. Water Industry”, *Proceedings of Plastics Pipes X*, Gothenburg, Sweden.

## Conclusion

The Hydrostatic Stress Board assigns design factors to thermoplastic resins. They assigned a design factor of 0.63 for PE4710 pipe. As you can see, from the stress life projections, the design factor of 0.63 for PE4710 pipes represents no risk of premature failure. At those design conditions, PE4710 pipe has a high probability that the pipe will see no affect of the working pressure on the pipe's service life.

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