HDPE Background and Benefits

For the past 80 years, since its discovery, Polyethylene has established itself as one of the most reliable and versatile thermoplastics on the market. Recently, after the continued success and development of bi-modal HDPE resins throughout Europe, North America has followed suit in its implementation of PE4710 resins (preceded by PE3408 and PE3608 resins). The introduction of these bi-modal resins has demonstrated remarkable benefits, namely in the form of higher pressure ratings, less raw material needed, increased resistance to environmental stress cracks, and longer lifetimes.

Key Benefits of HDPE

- Smooth interior surface of HDPE allows for high flow characteristics
- Long service life – up to 100 years expected lifetime
- Versatile – HDPE is used in geothermal, gas, potable water, sewage and manufacturing
- When HDPE fittings are correctly fused to HDPE pipe it creates a leak-free joint that is just as strong, if not stronger, than the pipe itself
- Corrosion and chemical resistant
- Toughness and durability of HDPE prevents the propagation of an initial small failure into a large crack, particularly in areas with high seismic activity
- HDPE has the ability to operate in extreme weather conditions, ranging from 0°F to 140°F in typical pressure service installations. Many PE resins are stress rated to an elevated temperature of 140°F, along with a standard measurement at 73°F. According to the Plastic Pipe Institute, *"Typically, PE materials retain greater strength at elevated temperatures compared to other thermoplastic materials such as PVC. At 140° F, PE materials retain about 50% of their 73°F strength, compared to PVC which loses nearly 80% of its 73°F strength when placed in service at 140°F. As a result, PE pipe materials can be used for a variety of piping applications across a very broad temperature range."*

HDPE Classification System

The classification of HDPE materials is presented such that the first 2 letters (PE) specify the resin (Polyethylene); followed by a 4-digit number system, where the first digit denotes the resin's density; the second digit denotes its resistance to stress crack; and the last two digits signify its HDS at 73°F in units of 100.

- Thus, according to ASTM Standard D3350, resin identified as **PE3608**, with a cell class of 345674C, specifically calls out:
  - a density falling between 0.940 and 0.947 g/cm^3,

    - a PENT value of 100 hours
    - and an HDS of 800psi (with a design factor of 0.50).
- Whereas resin identified as **PE4710**, with a cell class of 445474C, specifically calls out:
    - a density falling between 0.947 and 0.955 g/cm^3,
    - a PENT value of 500 hours (for slow crack growth resistance)
    - and an HDS of 1000psi (with a design factor of 0.63).

Key Benefits of PE4710 Resin

Higher Density, which directly relates to an increase in tensile strength and chemical resistance. Higher density also allows PE4710 materials to use less raw material than PE3408/3608, while still accomplishing identical pressure ratings (more on this below). This allows for a decreased wall thickness (increased ID) in PE4710 pipe, which naturally increases water flow and improves thermal conductivity of the system. As it relates to pipes, substituting PE4710 pipe for pipes of a lower cell classification decreases system head loss, since the pipe's ID will increase.

Significant increase in SCG resistance: SCG is the most likely cause of failure in HDPE piping systems. This can be attributed to several reasons, such as poor backfill technique and rock impingements. According to the PPI, "The PENT (Pennsylvania Notch Test - ASTM F 1473) measures relative resistance to slow crack growth using a laboratory test method. A specimen is cut from a compression molded plaque. It is precisely notched and then exposed to a constant tensile stress at a temperature of 176°F (80°C). The time to failure is recorded and this failure time is related to actual service life in the field. The PENT test has proven to be a very good indicator of SCG in PE pipes. A published paper in Plastic Pipe VIII conference provided data, which correlated laboratory PENT values to field pipe performance. Based upon this data, a laboratory PENT value of 10 to 20 hours, should correlate to a field life of at least 100 years with very few failures. PPI determined that a requirement of at least 500 hours PENT slow crack growth resistance would provide assurance that high performance PE pipes will be highly unlikely to fail in the field in the slow crack growth mode."

The requirement for PE3408 PENT is maintained at 10 hours, PE3608 at 100 hours, and PE4710 at 500 hours.

Improved Hydrostatic Design Stress (HDS) levels: PE4710, at an HDS of 1,000psi, operates at higher hoop stresses than resins of lower pressure ratings (800psi for both PE3408/3608). Hoop stress is defined as the internal stress imposed on the inside of a cylindrically shaped part. At the same DR, PE4710 fittings are assigned a higher pressure rating than fittings manufactured from the older PE3408/3608 resins. In other words, for a PE4710 fitting with a comparable pressure rating to a PE3408/3608 fitting, the PE4710 fitting allows for increase in flow capacity.

The following is the standard calculation for HDPE piping pressure ratings:
PR = [2 (HDS) / (DR – 1)]

PR = pressure rating, psig
HDS = hydrostatic design stress, psi
DR = dimension ratio

Thus, it follows that DR11 PE3408 pipe exhibits pressure ratings of 160 psig:
PR = [2 (800) / (11-1)] = 160 psig.
And DR11 PE4710 pipe exhibits pressuring ratings of 200 psig:
PR = [2 (1000) / (11-1)] = 200 psig.

As you can see from the table below, pressure ratings increase significantly when switching from PE3408 to PE4710.

Pressure Rating (psig) Comparison Between PE 4710 and PE 3408

	DR9	DR11	DR13.5	DR17
PE4710	252	202	161	126
PE3408	200	160	128	100

Table 1 from ASTMD 2683-10 highlights the differences in cell classifications of different resins:

TABLE 1 Specification D3350 Classification of Polyethylene Fittings Materials

Physical Properties	Cell Classification and Properties for Polyethylene Pipe Materials							
	PE2606	PE2706	PE2708	PE3608	PE3708	PE3710	PE4708	PE4710
Density	2	2	2	3	3	3	4	4
Melt Index	3 or 4	3 or 4	3 or 4	4	4	4	4	4
Flexural modulus	≥4	≥4	≥4	≥4	≥4	≥4	≥4	≥5
Tensile Strength	≥3	≥3	≥3	≥4	≥4	≥4	≥4	≥4
Slow crack growth resistance (F1473)	6	7	7	6	7	7	7	7
Hydrostatic strength classification	3	3	3	4	4	4	4	4
Color and UV Stabilizer[A]	C or E	C or E	C or E	C or E	C or E	C or E	C or E	C or E
HDB at 140°F (60°C), PPI TR-4, psi (MPa)	[B]	[B]	[B]	[B]	[B]	[B]	[B]	[B]
HDB at 73°F (23°C), PPI TR-4, psi (MPa)	630 (4.34)	630 (4.34)	800 (5.52)	800 (5.52)	800 (5.52)	1000 (6.90)	800 (5.52)	1000 (6.90)

Conclusion

Given it's inherent benefits, it's impact on decreased installation costs, and it's fusion compatibility with resins of lesser cell classifications, PE4710 is quickly becoming more mainstream in the geothermal industry. As the industry continues to evolve, HDPE fittings and pipe will continue to be held to the highest standard to ensure installations of the highest quality and allowing peace of mind for contractors and end users alike.