

Ask Tom! Column

Polyethylene Chemical Storage Vessels: What's New and What's Right

Guest article by Marshall Lampson

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Many models and types of storage vessels are available to the chemical industry. These include stainless steel tanks, fiberglass tanks, as well as several varieties of polyethylene tanks. Each of these tank materials offer advantages over the wide range of tank properties which include chemical compatibility, impact resistance, weatherability, cost, high temperature performance, pressurized applications, stress crack resistance, etc. In light of this wide diversity of performance, a discussion of the benefits and features of each of the materials, as well as a short discussion regarding the cost differences between the polyethylenes, is appropriate. The goal of this discussion is to facilitate making the most appropriate choice in chemical storage tank material for any specific application.

The overwhelming consideration in specification and final judgment of any storage tank is performance in actual use. While other considerations such as initial cost, warranty, installation cost, appearance, etc. are also important, these dim in importance if the tank will not perform as required. Ultimately that performance can only be judged by monitoring the tank in actual service, under real conditions.

All three types of tanks have particular markets for which they are best suited. Metal tanks are used where corrosion is not a problem. Fiberglass tanks are used where physical damage is not a problem. Polyethylene tanks are growing rapidly in market share because they can be used where metal and fiberglass tanks cannot. They also compete well in most of the applications that have traditionally been filled by metal or fiberglass tanks. However, some confusion exists about the nature of the polyethylene used in storage tanks. The importance of polyethylene tanks in the market suggests that a basis understanding of polyethylene will help in the understanding of why these tanks are emerging as the first choice of many companies in the chemical storage industry.



There are two polyethylene materials used today in the manufacturing of chemical storage tanks -- linear polyethylene and crosslinked polyethylene. These materials are very different in molecular configuration, mechanical properties, performance and cost. While some sales documents written in the past have referred to these materials as being, "almost the same" or "having only basic differences," this is not true for storage tank applications. One difference is molecular weight.

Polyethylene is a polymer - a material composed of many long molecules that are highly entangled about each other. The molecules of polyethylene are made of a backbone or chain (polymer chain) of carbon atoms with hydrogen atoms attached to each carbon on the backbone.

The physical and mechanical properties of polyethylene are overwhelmingly dominated by the interactions or intermingling between the polymer chains. Generally, the greater the interactions, the better the mechanical properties. This is understood by realizing that when a force is applied to the polymer material, the force acts to force the chains apart or cause them to slide against each other. If there is a significant interaction or binding of the chains, the force is strongly resisted and the polymer molecules are separated less easily, thus making it more difficult for cracks to form between them. Also, the force needed to pull them apart is increased, thus increasing strength and stiffness; and their ability to dissipate impact energies is improved, thus increasing toughness. Other properties are increased as well. Therefore, to improve performance, polymer resin manufacturers and polyethylene tank manufacturers have consistently worked to increase the amount of interactions between the polymer chains.

One method to increase chain interactions is to increase the length of the polymer chain or, in other words, the molecular weight, which leads to increases in the amount of entanglement between polymers. Early polymer performance was adversely affected by the inability of polymer manufacturers to achieve high molecular weights. Gradually that problem was solved, but then it became apparent that if the molecular weight was increased too high, the polymer could not be processed well. As a result, a compromise was made between property performance and processing capability by choosing an intermediate length for the polymer chains. This compromise was made for all grades of linear polyethylene.



For many products, that compromise was acceptable. However, for chemical storage applications where long term performance is critical, the compromise invited a serious problem. Long term exposure to the environment often resulted in massive cracking and total product failure. The problem was simply that the polymer chains did not have the amount of interaction required to give long term performance. The problem (dilemma) was to increase polymer interactions while maintaining processing capabilities.

A breakthrough in polymer processing provided the solution to the dilemma. This breakthrough was to crosslink the polymer after the chemical storage tank had been formed. Crosslinking of polymers had been known for many years, as a technique to improve properties in thermoset polymers, but was always done during forming, never afterwards. The concept of forming a part and then crosslinking it was brilliant and highly successful.

Crosslinking is simply the formation of bonds between the polymer chains. These bonds, equal in strength and stability to the principal bonds along the polymer backbone, tie the polymers together, thus dramatically increasing molecular weight. In fact,

the length of the polymer chains and, therefore, the physical properties, such as stress crack resistance and impact resistance are much higher than can ever be achieved without crosslinking.

Now that we have an idea of the differences between these two polyethylene materials, let's look at some of the benefits and features of each one. The table below compares the two materials in a wide range of categories.

Table 1.

Property	Linear Polyethylene	Crosslinked Polyethylene
Range of chemical compatibility	Excellent	Excellent
Performance between 130° - 150° F.	Fair	Excellent
Impact Resistance	Good	Excellent
Weatherability	Excellent	Excellent
Stress Crack Resistance	Fair	Excellent
Initial Material Cost	Excellent	Good
Recyclability	Poor	Poor
Abrasion Resistance	Good	Excellent

As can be seen in Table 1, each material has strengths and areas for improvement. Let's discuss each of the properties listed in Table 1 so we can gain a better understanding of how it applies to chemical storage applications.

Range of Chemical Compatibility

Table 1 clearly shows that both linear polyethylene and crosslinked polyethylene offer excellent chemical resistivity. The chemical resistance information on the two polyethylene materials is generally assembled from a wide variety of sources in the industry. The information is based on practical field experience as well as laboratory testing conducted by the manufacturers of the polyethylene resin, third party laboratories, and chemical storage tank manufacturers.

Performance Between 130° - 150° F

Table 1 shows that crosslinked polyethylene performs much better in high temperature applications than does linear. Crosslinked polyethylene resin suppliers have developed over 50,000 hours (over 5 years) of hoop strength data on crosslinked resins at both 73 and 1400F and have found significant improvements in high temperature applications with crosslinked resins. Due to the crosslinking, which takes place at the end of the rotational molding cycle, larger and/or thicker-walled tanks can be fabricated out of crosslink compared to linear.

Impact Resistance

Most raw material and chemical storage tank manufacturers will agree that impact resistance is a key variable in assuring tank strength and structural integrity. The greater the impact strength, the more resistant the tank is to stress cracking and ultimately to tank failures. When comparing the two polyethylene materials, we need to look at two different impact tests that are performed. The first one of these is simply a drop dart test (ASTM D-1998-97) which measures a defined amount of impact resistivity in a homogeneous tank wall sample. This test shows that crosslinked polyethylene is approximately 25% more resistant than linear. The second test is called a Notched Izod (ASTM D-265) impact test. This test measures to failure the amount of impact resistivity

of a tank wall sample, which has been pre-notched. (A score or notch has been placed in the impact area to determine notch susceptibility of the given sample during impact.) This test shows that the toughness or impact resistance of a crosslinked polyethylene tank is more than 5 times better than a linear polyethylene tank. (17.0 ft-lb. versus 3.3 ft-lb.)

Weatherability

Table 1 shows that both materials have excellent weatherability properties. This is due to the excellent UV (ultra violet) inhibitors and IR (infrared) inhibitors compounded into the material by the resin manufacturers. Both materials will perform well under very harsh environmental conditions. Note that black chemical storage tanks are used much more often than natural-colored tanks because the black tanks offer better UV and IR protection. This is due to the use of carbon black in the resin which is the most efficient of the UV and IR protectant additives. Carbon black works as an absorber and therefore extends the life of the UV and IR inhibitor in the resin. This gives the chemical storage tank greater propensity for long and useful life.

Environmental Stress Crack Resistance

Table 1 shows a dramatic performance difference between the two resins when tested for Environmental Stress Crack Resistance (ESCR). The bent strip ASTM D-1693 procedure is the established method for assessing plastic failure resistance under the combined mechanisms of stress, notching, and chemical environment. The usual testing condition for polyethylene ESCR is Condition B, 50°C, 100% Igepal CO-630. This is an appropriate test for judging container performance in relatively low risk applications such as household chemical storage. Using these parameters, crosslinked polyethylene and most high performance linear resins show excellent results. However, for stringent chemical storage conditions, it is recognized that a more severe test is necessary. Under activated 10% Igepal exposure, one can estimate exposure resistance to more hostile environments. In activated Igepal conditions, crosslinked polyethylene resin coupons show no failures up to the test endpoint at 1000 hours. High performance linear resins show 50% failure in 50 to 200 hours. This means that in harsh chemical storage applications, crosslinked polyethylene offers dramatic performance improvement compared to high performance linear resins.

Initial Material Cost

Table 1 shows that linear polyethylene is less expensive than crosslinked polyethylene. This is true. Linear polyethylene resin for chemical storage tanks is approximately 35% less expensive than crosslinked polyethylene resin. This is due to the special additives present in crosslinked resin which are compounded into crosslinked during resin manufacturing.

Recyclability

Table 1 shows that neither material can be recycled very well for chemical storage applications. There are many claims in the industry today which state that linear polyethylene can be recycled. All though it sounds good, it is not very realistic. There are a couple of problems with recycling polyethylene. The first problem is that both crosslinked polyethylene as well as linear polyethylene lose much of their additive package, (i.e. anti-oxidants, UV inhibitors, release agents) during the manufacturing process. Therefore, a manufacturer of a quality chemical storage tank will not re-introduce already processed resin into their manufacturing process.

The second problem is with chemical permeability. Because the tanks are being used in chemical storage, over time there will be a small amount of permeation of the stored chemical into the inner wall of the tank. This permeation does not affect the performance of the tank because of the thickness of the wall, but it does affect the reusability of the polyethylene resin. There are really very few processes which can recycle used chemical storage tanks.

Abrasion Resistance

Table 1 shows that crosslinked polyethylene resins offer superior scratch resistance over linear polyethylene resins. This is simply due to the hardness and strength of the crosslinked material over linear. The material is simply less likely to scratch. Crosslinked polyethylene is used in the manufacturing of dump truck beds as well as duck sleds, pallets, and other products where abrasion is a consideration.

Summary

In summary, there are benefits and features of each material depending on the use and application. Most linear polyethylene materials are used in less critical applications such as toys, water tanks, and small agricultural tanks. The bulk of crosslinked polyethylene materials are used in high performance, highly critical applications such as chemical storage tanks, hydraulic reservoirs, and large bulk handling products (i.e. dump truck beds). As a consumer, it is up to you to make the decision regarding the type of polyethylene you will specify in your chemical storage vessel. High performance linear resins are the best choice for many rotational molding applications. Crosslinked polyethylene is a better choice for chemical storage vessels exposed to the environment, harsh chemicals, rugged handling, etc. Crosslinked polyethylene provides an additional cushion against the costs of tank failure, or environmental remediation.

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