PICK THE PERFECT THERMOPLASTIC FOR PULP AND PAPER PIPES AND VESSELS

GARY DENNIS

THE RANGE OF CHEMICALS PUMPED, POURED, PRECIPITATED, AND PRESSED THROUGH PIPES, TANKS, TOWERS AND NOZZLES PRESENTS PULP AND PAPER ENGINEERING AND MAINTENANCE PEOPLE WITH THE SAME PROBLEMS THEIR CHEMICAL PLANT COUNTERPARTS FACE.

IN A PAPER MILL, pH RANGES FROM LESS THAN ONE IN souring acid tanks and lines to more than 13 at caustic storage and addition points. Aggressive additives that control foam, neutralize metals, and make paper stiffer, softer, whiter, and brighter combine in fast moving, high temperature fluids to attack the strongest stainless steel and ruin otherwise rugged resins.

To protect pipes and provide the longest possible service life between changeouts, it is important to select the lining material that will endure exposure to aggressive chemicals for years to come. The most appropriate plastic for a particular pipe may or may not be the most expensive on a per-foot or an installed cost basis. A basic understanding of how different thermoplastics perform in pulp and paper applications will assist mill engineers in getting the most from their installation or retrofit budget.

Kynar Flex® lined vessel

MAKING THE MOST OF METAL

Carbon steel is a common material used for piping and also represents the base substrate when lining with a thermoplastic pipe or formed sheet for tanks. Carbon steel is low cost, offers high structural strength, and is available in standard lengths and sizes. However, corrosive attack by the aggressive chemicals commonly found in the pulp and paper mill limit its use. Therefore, the need arises for a thermoplastic lining.

Exotic metals offer improved corrosion resistance. Higher installed costs, chloride ion corrosion, oxidation, and wear of the inner film layer by abrasive liquids and slurries form its Achilles heel. Weld areas of stainless steel pipe can also cause specific corrosion concerns.

Due to the diverse nature of processes in a paper facility, many other alternative materials may find application. Fiberglass reinforced plastic (FRP) and rubber linings have been used with various success when encountering low pressure and temperature applications. It is the scope of the paper to report on areas where thermoplastic's are commonly used.

THE TOP THREE THERMOPLASTIC LININGS PLUS ONE

Table I compares installed costs of 400 ft of 2 in. lined pipe with various materials. Unlined carbon steel is used as the base line. Comparison costs for the line assumes 25 elbows and 15 tee connections. The pressure rating on the pipe can be considered "standard" or schedule 40 as it is known in chemical process industry installations.

Pipe material	Total costs	Cost ratio to carbon steel
Carbon steel	$12,480	1.00
Polypropylene-lined steel	$23,657	1.90
PVDF-lined steel	$30,771	2.47
PTFE-lined steel	$36,745	2.94
Hastelloy C-276	$71,280	5.71

I. Installed cost comparisons of materials of construction

Kynar® solid pipes and fittings

The most common thermoplastic lining materials encountered in areas of the mill are in the center of the Table: Carbon steel lined with PP (polypropylene), PVDF (polyvinylidene fluoride), or PTFE (polytetrafluoroethylene). All three resins have been used in mills for two decades or more.

The spectrum of thermoplastics used in paper mills comprises two main groups: fluorinated and nonfluorinated. PP is a very common nonfluorinated thermoplastic used in hundreds of different applications from packaging to cold weather clothing to pipe linings. It offers chemical resistance to many corrosive fluids, is relatively low cost, and excellent in caustic environments. Polypropylene is not recommended with most chlorinated "C" solutions found in pulp bleaching stages such as chlorine and chlorine dioxide; as well as oxidizing acids. Its continuous use temperature limit for linings is generally recognized in the 220°F range.

PTFE is widely known as Teflon® , a high temperature material that lines pipes and anything else that needs corrosion and slip resistance. This fluoropolymer offers the broadest range of chemical inertness and temperature limits up to 450°F. Its actual continuous use properties are limited by low tensile strength, and high vapor transmission rates, which can allow for vacuum collapse of the lines under temperature and pressure.

PVDF, known most commonly as Kynar® resin, falls between PP and PTFE, both chemically and in applied cost. PVDF is especially resistant to halogen and acid environments. The thermoplastic's high tensile, heat deflection, and abrasion resistance allows its use up to 275°F without experiencing significant loss of mechanical properties. While having overall exceptional chemical resistance, PVDF is not recommended in amine, ester, and ketone solutions.

A relatively recent addition to the top three is an impact modified grade of PVDF known as Kynar Flex® copolymer resin. It shares many characteristics with PVDF homopolymer, and the copolymer is ideally suited for lining applications by virtue of its increased flexibility and elongation properties. This new PVDF resin has proved to be an advantage in lined pipe and tanks subjected to wide variations in temperature. Temperature fluctuations can cause high stress areas at the flange or joints due to expansion and contraction differences with the thermoplastic and steel substrates. This allowance for increased stress crack resistance also extends to high pH solutions and improvements in the ability of component parts to withstand low temperature. This factor has been recognized by its use in cold weather climate mills in northern areas.

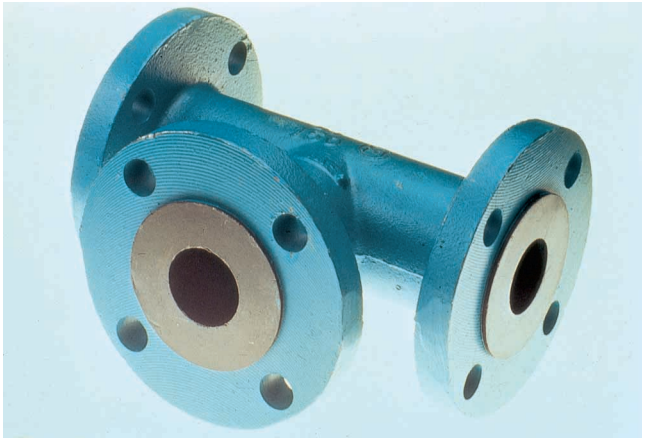
Table 2 lists some common plastics in mill pipe linings along with trademark names and percent of fluorination used in their manufacture. Percentage of fluorination determines many of the characteristics that can make thermoplastics useful as lining materials in the mill. More fluorination generally means less reactivity. The fluorinated plastics listed are chemically inert even to years of exposure to concentrated acids such as hydrochloric and sulfuric acid. These acids can be found in recovery systems, sampling lines, and papermaking for controlling the pH of fiber and water systems. Fluorination also reduces flammability to near zero. In most circumstances, fluoroplastics will not burn when exposed to open flame. They are also stable at high temperatures.

STRENGTH AND TOUGHNESS: BARRIER AND BENDING PROPERTIES

PVDF homopolymer is the strongest of the pipe lining thermoplastics; strong enough that it can be used as stand alone pipe, both in mills and many other industries. As shown in **Table 3**, its tensile strength tops the physical property chart and is much higher than both PP and PTFE. PVDF copolymer, has tensile strength between that of PVDF homopolymer and PP. All three (PP, PVDF copolymer, PVDF homopolymer) maintain tensile properties significantly higher than PTFE. Abrasion resistance values are also listed in Table 3. Abrasion and toughness characteristics become especially important when handling diverse compositions of corrosive wastes and slurries.

Abbreviation	Trademark	Name	% Fluorination (by weight)
PTFE	Teflon	Polytetrafluoroethylene	75%
PVDF (copolymer)	Kynar flex	Polyvinylidene fluoride	61%
PVDF (homopolymer)	Kynar	Polyvinylidene fluoride	59%
PP	———-	Polypropylene	0%

II. Names and percent fluorination of pipe lining thermoplastics



Kynar Flex® lined pipe

In addition to chemical resistance and extremes in temperature and pressure, other characteristics can determine the appropriate lining material for a specific area of the mill. Flexural modulus and percent elongation at break determine the amount of give a thermoplastic has before stress related cracking can occur. Table 3 shows that PP, PTFE, and PVDF flex allow for a high percentage of expansion and contractions within the steel substrate. This can be evidenced by their high elongation at break valves. A comparison of PVDF homopolymer and PVDF flex copolymer can be found in **Table 4**.

Permeability, the rate at which various liquids and gases penetrate plastics, can also determine the limits of lining materials. PTFE offers the broadest limits to chemical attack, but gases pass through it at many times the rate of PVDF or PP. **Table 5** compares PVDF and PTFE. (PP can be considered to exhibit low permeation in the areas it is used in the mill). Corrosives pass through PTFE at a rate that requires the drilling of weep holes to avoid back pressure collapse in many lined pipe applications. This factor tends to especially prevail in the halogenated environments commonly found in the bleach plant. Weep holes are not required in either PVDF or PP installations.

LOCATING LININGS IN THE MILL

All three thermoplastic lining materials mentioned have a place in mills based on their performance and character. Because of the extremes of pH typical in a pulp mill as well as high temperatures, one pipe lining can not be used throughout the bleach plant, and, in some places, only one material can be used effectively. Standard bleachants such as chlorine dioxide, sodium hypochlorite, and sodium chlorate require the use of a fluorinated thermoplastic. PVDF homopolymer has had wide application in elemental chlorine bleaching. A primary reason is low permeability. PVDF flex copolymer can be used equally as well. PTFE, due to its high vapor transmission rates, has had limited use with elemental chlorine.

An impermeable lining is also desirable with sodium hypochlorite. In this case, PVDF flex copolymer offers extended benefits where the PVDF homopolymer often failed due to stress related cracking. PP offers utility in caustic extraction stages and non-oxidizing type acids.

FOUR LININGS, FOUR RULES

There is no typical paper mill as there are various sequences and systems used at a given facility. The appropriate lining material depends on the particular bleaching agents, as well as temperature and pressure in the pipes and vessels. But basic recommendations can be made:

1. PP or mild steel lines are generally acceptable with caustic solutions and offer cost savings when compared to other materials of construction. PP acid resistance depends on temperature and concentration.
2. PTFE where temperature extremes exceed other lining materials and permeability does not pose a problem.
3. PVDF homopolymer when mechanical strength (stand alone pipe or solid valves and pumps) are the primary requirements.
4. PVDF flex copolymer in acidic or chlorinated service when lining pipes of vessels. It combines low permeation with high tensile and elongation characteristics and its applied cost falls between PP and PTFE.

Despite all the changes and innovation in the modern pulp and paper facility, the above rules will continue to apply. Bleachants will corrode everything they touch except fluorinated plastics.

Abbreviated name	Melting Point temperature (°F)	Deflection temperature at 66PSI °F	Abrasion resistant (mg/1000 cycles)	Elongation at break (%)	Tensile at yield
PTFE	620	250	500-1000	300	1600
PVDF homopolymer	335	284	5-10	100	7000
PVDF flex copolymer	315	255	7	300	5000
Polypropylene	330	225	15-20	350	3500

III. Properties of thermoplastic lining materials

While no single lining is right for any mill, careful selection and use of PP, PTFE, and PVDF will meet the majority of possible lining requirements in mills today. Many factors enter into the decision of which plastic to specify, but a basic knowledge of resin characteristics will help to make informed selections of these critical components. While these decisions aren't run of the mill, they will help make the mill run.

Gary Dennis is the marketing manager for the chemical process industry for Elf Atochem North America, Inc. at 2000 Market Street in Philadelphia, PA 19103. Elf Atochem North America, Inc. can be located on the web at www.elf-atochem.com

Mechanical Property	PVDF Homopolymer	PVDF Copolymers
Tensile strength at yield	5,000-8,000	4500-5500
Elongation at break	50-150%	300-400%
Tensile modulus (1% secant)	200-300x10^3	110-140x10^3
Flexural modulus	165-325x10^3	160-180x10^3

IV. Mechanical Properties of PVDF Resins

		PTFE	PVDF homopolymer
Water vapor	g/m^2.dbas	5	2
Air	cm^3 /n^2.dbas	2000	7
Oxygen	cm^3 /m^2.dbas	1500	20
Nitrogen	cm^3 /m^2.dbas	500	30
Helium	cm^3 /m^2.dbas	3500	600
Carbon dioxide	cm^3 /m^2.dbas	15000	100

V. Gas permeability