PENBERTHY®
A Tyco Flow Control Company

320 Locust Street
Prophetstown, IL 61277-1147
Voice: 815-537-2311 ext 160
Fax: 815-537-5764
E-mail: gsanders@penberthy-online.com
Date: Tue – 15 Feb 00

PenTech FAQ # 7 by Gary G. Sanders, Director of Engineering

Linings / Coatings

Background Information

Lining or coating a Penberthy product should be considered when the basic materials of construction of the product could be corroded, eroded or abraded by the process or environment.

A few definitions of terminology in the context of this FAQ:
Lining = material added to the inner (process wetted) surface.
Coating = material added to the exterior (non-process wetted) surface.
Corrosion = destruction of exposed material by chemical / galvanic attack.
Erosion = destruction of exposed material by physical fluid flow.
Abrasion = destruction of exposed material by moving particulate process material.

Most of Penberthy's standard products are of metallic construction. Standard products with few exceptions cannot be constructed using only lining / coating materials since such materials do not have sufficient strength to retain typical operating pressures. They could inflate like a balloon and burst. Therefore, a metallic shell geometrically close to the standard product is used for its pressure retaining strength. The shell is then lined or coated to protect the metal against corrosion or erosion / abrasion.

Corrosion Control with Polymer Linings /Coatings

A particular group of polymers (plastics) and elastomers (rubbers), the fluorocarbons, is dominant in the chemical / petrochemical industry because of its resistance to chemical attack. The polymer group is based on replacing the hydrogen in the ethylene monomer base with fluorine. Due to the energy levels of the carbon-fluorine bonds, the fluorocarbons tend to be very stable.

PTFE (**p**oly**t**etra**f**luoro**e**thylene) is the standard bearer of the group. It has the broadest range of resistance to chemical attack of the fluorocarbons as well as a relatively high useable temperature (range –325 to 500°F [-200 to 260°C]). PTFE is an ethylene monomer with fluorine replacement of all four hydrogen atoms in the base monomer. This is an extremely stable compound. With the exception of a few chemicals (mostly halogenics) it tends to be inert. Unfortunately, it is not a melt processable polymer, has essentially no adhesion to other materials (without very specialized techniques) and tends to cold flow when stressed. Two other fluorocarbons which share the duPont trade name Teflon™ that are not linearly fluorine saturated, are melt processsable and although not as thermally or chemically stable as PTFE are useful because they may be adhered to metallic surfaces:

- **FEP** (**f**luorinated **e**thylene **p**ropylene)
- **PFA** (**p**er**f**luoro**a**lkoxy[alkane, usually ethane])

When "Teflon™" is generically specified as a lining / coating for Penberthy products, either FEP or PFA is supplied with three exceptions: 1) PTFE may be used as a blow molded non-adherent insert lining for SFI's. Since it is a loose liner, it cannot be used in vacuum service. 2) PTFE is also used as the standard dielectric sheath coating material for LevelMark™ New Wave capacitance probes but with less vacuum restriction since it is more or less conformal. 3) Bolting (bolts and nuts) may be ordered encapsulated with 1 to 1.5 mils [0.03-0.04 mm] PTFE (Fluor-O-Kote#1™). **Caution**: When using bolting that is PTFE encapsulated, the coefficient of friction is reduced such that only ≈ 45% of the recommended torque values as stated in the Installation, Operation and Maintenance manual [IOM] should be used for equal closure force.

PCTFE (**p**oly**c**hloro**t**ri**f**luoro**e**thylene - Kel-F™, Daikin™) has its hydrogen atoms replaced with three fluorine and one chlorine. Very high viscosity makes this a difficult polymer to work with but it has very good chemical resistance. Due to its crystallinity, it tends to be transparent to translucent. PCTFE has the lowest permeability to water vapor and other gases of the fluorocarbon polymers. Useful temperature range is –240 to 400°F [-150 to 200°C]. PCTFE is primarily used by Penberthy as anti-corrosion shields for the flat glass used in liquid level gages and SFI's. For many applications, this is a better choice than the classic mica shields. Neither PCTFE or mica shields should be used in vacuum service. An aside: specialty glass shields are also available, e.g., UV reduction.

PVDF (**p**oly**v**inylidene **d**i**f**luoride - Kynar™) retains two hydrogen atoms with the other two replaced by fluorine. This polymer is melt processable and retains decent chemical resistance. It has greater strength plus better wear and creep resistance than the other fluorocarbon polymers. Useful temperature range is –140 to 300°F [-95 to 150°C].

By copolymerizing PTFE with ethylene as a bimeric unit, a melt processable, substrate adherent polymer is formed:

PETFE (sometimes called ETFE) **p**oly**e**thylene**t**etra**f**luoro**e**thylene (Tefzel™).

Copolymerizing PCTFE with ethylene yields:

PECTFE (sometimes called ECTFE) **p**oly**e**thylene**c**hloro**t**ri**f**luor**e**thylene (Halar™).

Both of these lose some chemical resistance and about 150°F [65°C] in maximum temperature usage from their monomeric parents but are very practical linings / coatings for metals. For example, PETFE applied in an 1/8" [3 mm] thick lining to a SFI body can only be trimmed with metal working tools. Obviously, anything that adheres to its substrate that well can be used in vacuum service.

The aforementioned adherent fluorocarbon linings / coatings standard nominal thicknesses for Penberthy products are 5, 10, 15, and 25 mils [0.13, 0.25, 0.38 and 0.64 mm], user preference. 1/8" [3 mm] PETFE is also available as an SFI lining to simultaneously control corrosion, erosion and abrasion.

Erosion / Abrasion Control

There are two schools of thought on this subject:

1. Make the lining soft and very elastic so that eroding / abrading materials will just bounce off the surface (same concept as a rubber padded cell?). Polymer linings (as described above) are sometimes used, although often a better choice is a fluorinated elastomer (e.g., Viton™). This is one option, e.g., for Penberthy's jet pump nozzles.

2. Make the surface extremely hard so it is difficult to erode / abrade. Stellite[tm], a cobalt alloy is a good example. Alternately, (although not a lining) critical parts may be made from hard materials; e.g., ceramics, high chromium irons, etc. Either of these methods also finds application in jet pump nozzles.

The choice depends upon the process materials and flow velocity. If particulate material with sharp projections is involved, a hard surface is preferable. If velocity erosion is the problem then a polymeric / elastomeric lining is usually the choice.

Miscellaneous Linings / Coatings

Usually used to combat corrosion although occasionally to harden the surface, metallic surface conversion / overlay techniques may be used. Some common examples are: phosphate conversion (for better coating adhesion / limited anti-corrosion); chromate conversion (anti-corrosion); oxide conversion (anti-abrasion); zinc galvanizing (sacrificial anti-corrosion); gold (anti-corrosion); nickel (anti-abrasion / anti-corrosion); hard chrome plating (anti-abrasion); tungsten / titanium carbide (anti-abrasion), etc.

While not always considered as such, paint is the most economical and basic coating. It is almost never used as a lining. Standard Penberthy “silver” paint is essentially aluminum flakes plus an alkyd binder with adequate solvent to allow spraying. It is fundamentally an economical anti-rust coating for carbon steel.

A dramatic step up is the three layer Penberthy 2600 paint system (marketed as ‘offshore’ since it is particularly effective against salty [chloride] environments). The 2600 system consists of: 1) a sacrificial base of inorganic zinc silicate primer; 2) an epoxide tie coat that is the ‘hard shell’ and 3) an overcoat of polyurethane that is somewhat elastic for toughness and very good weatherability (Refer to Penberthy Bulletin 2110 for more information).

Hints on Choosing

When attempting to control corrosion, the first step is to choose materials of construction that are either not or only minimally affected by the process. Consult corrosion resistance tables / charts. Manufacturers of the lining / coating are a reference source. A more comprehensive resource that I recommend is the three volume “Corrosion Resistance Tables”, P.A. Schweitzer, editor; ISBN 0-8247-9590-3; 0-8247-9591-1 and 0-8247-9641-1. Heed very carefully the temperature and concentration variables.

Sometimes control can only be achieved by planning for a limited amount, e.g., the ASME / ANSI “corrosion allowance” as shown in design formulae.

Specify welded and flanged assemblies since made up threaded connections will cut through most linings / coatings exposing the substrate.

Abrasion / erosion control – hard or elastic really depends upon the materials involved. If possible, use flow velocity reduction. It will ameliorate the problem since impact energy is dependent upon mass times velocity squared.

Finally, with the millions of chemical entities and flow regimes that exist, there seldom are perfect solutions – only feasible compromises.

[tm] – trademarks / acronyms cited in this FAQ are registered to: E.I. du Pont de Nemours & Company; 3M Company; Daikin Industries; Elf AtoChem NA, Inc.; Ausimont USA, Inc.; Cabot Corporation; Fluorocoat Corporation; Penberthy, Incorporated; American Society of Mechanical Engineers; American National Standards Institute as appropriate. Other manufacturers and brand names for some of these products exist. Inclusion in or exclusion from this paper should not be construed as any form of endorsement.

Acknowledgement to David Hamud – Dover, NJ for suggesting the subject addressed by this FAQ.