



# The Whitford Engineering Design Guide

**High-performance fluoropolymer coatings:  
What they are,  
how they function and  
how to use them  
to your best advantage**

**Whitford**

*Makers of the world's largest, most complete line of fluoropolymer coatings*

## **The purpose of this publication**

Every day, one way or another, we at Whitford learn a little bit more about the surprisingly complicated business of designing and making fluoropolymer coatings perform to their maximum ability.

Typically, much of what we have learned comes from our mistakes.

It occurred to us that the information we have accumulated (and indeed continue to accumulate as we learn) might prove as helpful to our customers as it has to us. It is for that reason that we have assembled some of our basic knowledge into this brochure.

We hope it will have been worth the effort.

The information included has many sources. Perhaps the most fruitful has been the practical experience that comes from Whitford's more than three decades of working with and learning about these remarkable materials.

Some of the statements presented are the result of long and painstaking laboratory tests and analyses, even if presented with the dogmatism of brevity.

Others are based on experimental work with specific products. Still others are the opinions of people who have broad and deep experience in the field of fluoropolymer coatings and are offered as the best recommendations under the circumstances.

We invite you to read this document with some care.

We ask you to test your imagination as to how a coating might minimize — or even eliminate — a design problem you're facing.

Think of problems caused by friction, poor release, corrosion, wear, noise. Think of other design and engineering problems for which a fluoropolymer coating may never have been tested.

You may join the growing list of designers and engineers who have opened their minds to the surprising versatility of high-performance coatings — and solved some difficult problems in the process.

If so, the purpose of this brochure will have been realized.

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# 1. The surprising success of high-performance coatings

## A. New options for designers

High-performance fluoropolymer coatings are remarkable low-friction, dry-lubricant materials that combine the capabilities of two types of “engineering plastics”. Fluoropolymers, with the lowest coefficient of friction of any known solid, are combined with high-temperature organic polymers to provide a unique and highly versatile combination of properties.

These tough lubricating coatings can operate successfully at temperature extremes which, at the low end, would render ordinary fluid lubricants too high in viscosity and, at the high end, would char them to ash.

Originally, low-friction solids were used for applications where sliding parts were heavily loaded, infrequently lubricated or operated at high temperatures. This has been true since the inception of dry lubricants, when ancient mechanics used graphite, talc, mica and other “slick” powders to reduce sliding friction.

But, with the development of modern lubricating coatings, other properties have been designed in — including outstanding corrosion resistance. Today, when mechanical parts operate under any of the above conditions, dry film lubricants are often the only sensible, safe and economical way to lubricate and protect them.

In the past, the only materials recognized as dry lubricants for such applications were graphite and molybdenum disulfide (MoS<sub>2</sub> or Moly) or blends of both. While useful, these materials solved only a limited range of problems. Moly coatings were typically used in high-pressure applications; graphite coatings were generally used in wet service or at elevated temperatures.

### Enter the matrix

Today’s fluoropolymer coatings are the result of design engineering done several decades ago.

The first fluoropolymer coatings were relatively soft films, the kind found on frying pans and a few nonstick applications in industry.

Then, in 1969, a team of polymer chemists and engineers devised the matrix concept for

coatings, “building” a coating to protect the soft fluoropolymer from wear while taking advantage of its low-friction property. On this concept, Whitford was founded and Xylan fluoropolymer coatings became a reality.

The first significant order for Xylan was for a brake adjustment mechanism for GM cars. This was followed by other applications: saw blades, viscous fan drives, journal bearings, switch detents, carburetor shafts, steam valve plugs, oil rig fasteners. The list grew quickly.

*Note: The full range of Xylan coatings has become so extensive that properties vary widely. The coatings referred to in this brochure are principally those designed for industrial applications, and the bulk of the data refers to them.*

Over the years, these self-lubricating materials have been used to solve a growing range of engineering and design problems.

Today, Xylan is the largest, most complete line of fluoropolymer coatings in the world. As the materials have been tried on an ever-widening spectrum of applications, we have learned a few things. For instance:

- A bonded, self-lubricating coating can last longer than hard chrome plating in certain high-wear applications.
- Xylan can cut the cost of some pistons, plungers and splines by eliminating polishing and lapping processes.
- Xylan can replace heavy metal platings on engine journal bearings.
- Xylan can replace plating on hydraulic pistons and extend their lives in corrosive environments.

## B. Components of Xylan

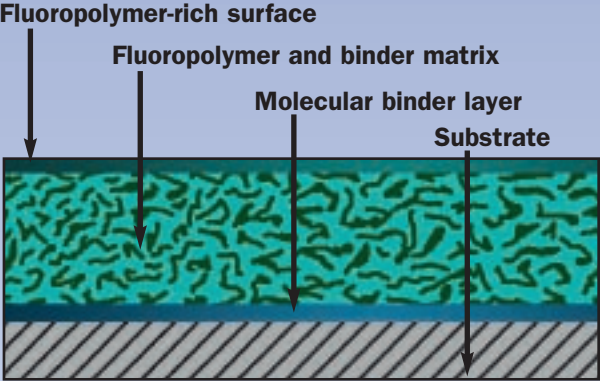
The Xylan coating matrix is composed of three basic ingredients:

- A polymer binder for film strength, adhesion and protection of the softer lubricating particles.
- A solid lubricant for low friction, release and resistance to wear.

- Pigments, fillers and reinforcements for color and additional properties such as hardness.

With the exception of Whitford's Dykor powders, all materials are suspended in solvent or water, providing a compatible carrier so that, together, they may be applied by conventional techniques such as spraying, dip/spinning, roller coating, tumble coating, coil coating, curtain coating, etc.

The result is thin, continuous, protective film barriers which resist chipping, spalling, abrasion, cold flow, temperature extremes, weathering and a wide range of corrosive environments.



**Fluoropolymer-rich surface**

**Fluoropolymer and binder matrix**

**Molecular binder layer**

**Substrate**

*A matrix coating is one in which some soft ingredients, such as the lubricant (PTFE), are enveloped in others (the matrix) such as harder, more wear-resistant binders.*

*If PTFE, for example, is used by itself (without the matrix), and is exposed to a wear surface, it quickly wears away. Combined with the matrix, however, the new structure solves the engineering problems as it protects itself.*

*Matrix coatings are adjustable. The specific properties of Xylan formulations depend on the materials used to form the total coating and their ratio to one another. By judicious selection of compounds, we can formulate a coating to have superior release, wear resistance, chemical resistance, high conductivity, etc.*

### The basic elements

**1. Binders:** Polymer binders hold the lubricating particles and hard fillers in place and enable them to adhere to a wide variety of substrates. The coatings derive most of their corrosion and thermal characteristics from these materials.

The first binder employed in Xylan was a thermosetting alloy, which offers exceptional toughness and is stable to 315°C/600°F. After

more than three decades, this binder is still widely used for industrial applications in which its superior properties and flexible cure schedule make it very adaptable. This class of binder is found in the 1000, 1600, 1700 and 8110 Series of Xylan coatings. (Ask for Whitford's "Introduction to the Xylan 1000 Series".)

Another rugged polymer employed as a binder in Xylan is a high-temperature-stable thermoplastic. It is extremely resistant to abrasion and chemicals, and is a good choice for components that operate in the presence of strong acids, bases or solvents. It is the binder used in the Xylan 1300 and 8300 Series coatings.

A third class of binder is a lower-temperature thermoset. Although not as tough as some polymers, it provides good corrosion protection, an exceptional array of colors, plus economy. It is a part of the Xylan 1400, 5200 and 5400 Series coatings (used on fasteners and other industrial hardware for corrosion protection).

**2. Lubricants:** Small particles of low-friction materials such as polytetrafluoroethylene (PTFE), molybdenum disulfide (Moly) and graphite, suspended in the wear-resistant binder, reduce friction at the surface. PTFE tends to be softer than the matrix, so when coated parts rub together, the lubricant smears along the surface of the coating and the mating surface, reducing friction.

PTFE is most commonly used in Xylan because it has the lowest coefficient of friction, is stable and effective at high and low temperatures, and is inert to chemical attack. Also, because of its low surface tension, it is an excellent release agent.

Other fluoropolymer lubricants include FEP and PFA, which are less porous because of better melt/flow characteristics, resulting in denser coatings that provide improved release. Both have excellent nonstick and good low-friction properties, and are stable in the presence of a wide range of solvents and corrosives.

Each fluoropolymer offers certain properties required in specific applications, such as FEP for its release and PFA for its glass-like finish, chemical resistance and ability to operate to 260°C/500°F.

Moly is preferred for high-load, low-speed applications. It increases the load-bearing capability and the wear resistance of coatings that

are filled with other lubricants (notably PTFE).

*Note: Encapsulating Moly in a matrix coating seems to eliminate its characteristic sensitivity to oxygen and moisture. That's why Whitford uses this lubricant in Xylan 1052 and 1425, which are designed for high-load applications.*

Graphite is used for applications with temperatures in excess of 260°C/500°F, and in wet service at lower temperatures. Its drawback: a higher coefficient of friction than PTFE or Moly.

**3. Pigments/Fillers:** Coatings are modified by pigments and fillers to provide properties not inherent in the primary ingredient, making them harder, more corrosion-resistant or adding color. For example, Xylan can be made electrically conductive by the addition of fillers such as carbon or metal particles.

**4. Carriers:** Solid components of coatings are dissolved in solvent or suspended/emulsified in water, which enables them to be applied as a paint. The solvents used as carriers for Xylan are chosen for ease of application, ease of cleanup, economy and environmental safety.

Different application systems (conventional air spray [siphon or gravity], electrostatic, HVLP, airless, coil coating, curtain coating, dip/spin) require different carrier combinations to achieve optimum coating performance. For instance, conventional spray systems require relatively slow (less volatile) carriers that enable coatings to level more uniformly on the substrate after spraying. Other application techniques, such as dip/spin, may require fast (more volatile) carriers to “set” the coating film rapidly while parts are being processed.

Because of the many formulation options possible with Xylan matrix coatings, they can be tailored to provide a wide and varied range of properties — to solve different problems. If you have unique requirements for lubricity, hardness, noise reduction, corrosion protection, environmental compliance — even electrical conductivity or resistivity — these coatings may be modified to meet your exact need.

### **Xylan “firsts”**

Whitford has frequently created special coatings to solve specific problems — leading to the extensive range of Xylan coatings today. In this process of solving problems, many “firsts” have

### **The 3 principal fluoropolymers used in Xylan coatings**

*PTFE (polytetrafluoroethylene): Has the lowest coefficient of friction of any known solid and is the fluoropolymer most widely used in coatings. It feels waxy to the touch. Also blends well with engineering polymer binders. Is inert to most chemicals and is approved for use in food applications.*

*FEP (fluorinated ethylene propylene): Has the best nonstick and non-wetting characteristics of the three. It feels oily to the touch and lacks the high-temperature stability of PTFE. It is somewhat more resistant to corrosives than PTFE. Approved for use in food contact applications. Has excellent stability in waterborne coatings.*

*PFA (perfluoroalkoxy): Has better release and non-wetting properties than PTFE, but not quite as good as FEP. Its wear characteristics are not as good as PTFE. It has nearly the temperature capability of PTFE.*

been achieved by Xylan:

- First polymer coating to survive the rigors of internal diesel engine application on piston skirts and journal bearings.
- First tough PTFE coating with a flexible cure schedule (see chart, page 22). You can apply it to temperature-sensitive materials such as forged aluminum or tempered steel without reannealing the parts, or to many polymeric parts without thermally degrading and/or warping them, even to paper.
- First coating to be used by engine manufacturers to achieve a boost in output power.
- First coating to be used to dampen “piston slap” and resultant wear in high-performance motorcycle engines.
- First coating to be used as a dynamic seal on air-conditioner rotor vanes.
- First coating to achieve a wear rate equal to bronze/steel bearings impregnated with PTFE-lead.
- First coating to replace cadmium and zinc as a corrosion barrier on small fasteners.
- First and only self-lubricating coating to be used by NASA on a storage vault for moon rocks.

## 2. High-performance coatings at work

From the development of the first Xylan product (1010), Whitford has modified the basic formulation to solve specific problems. This has led to new materials and combinations of materials so that, today, there are more than 3,000 different formulations of Xylan.

Few products are as beneficial in so many ways as the wide range of Xylan coatings. This very diversity, however, means that properties can vary widely.

Xylan dry-film lubricants can solve numerous problems, including friction/wear, corrosion, temperature extremes, sticking, vibration, galvanic activity, electrical insulation and conductivity. The selection of a coating depends on determining the problem of the application (wear, heat, corrosion, etc.) and matching it with the material that most effectively solves the problem.

### A. Friction

Friction causes heat, wear and loss of energy in dynamic applications. In severe circumstances, friction can cause overheating and seizure.

Friction also causes brinelling, galling, scoring, and underloading of fasteners.

Drive-line vibration and chatter result from friction. In these cases, stick/slip motion is usually the cause. This unstable sliding motion occurs at very slow speeds, when friction increases above the force causing the movement and motion stops, then drops below the moving force, at which point motion restarts.

Deformation or destruction of delicate mechanisms such as lock components can be caused by excessive friction.

Friction coefficients (measured by mating surfaces rubbing against a coating) typically vary from about 0.06 for PTFE materials to about 0.15 for Moly coatings, although values as low as 0.02 have been measured for some Xylan coatings.

Xylan coatings are particularly useful when temperatures exceed the operating limits of conventional mineral and synthetic oils. Because

Xylan coatings are based on resin systems with a wide range of temperature capabilities, they can be used from cryogenic levels to 260°C/500°F, with many being stable for brief periods at 315°C/600°F.

Where galling, abrasion, and high energy loss due to friction are anticipated, consider applying coatings of 25 microns/0.001 inch or more to minimize friction and wear. (See page 24 for this processing information.)

Potential applications include rotors for compressors, air-cylinder pistons, hinges, sliding bearings. The best coating choice is the one which provides the desired coefficient of friction and the maximum pressure/velocity (P/V) capability (see sidebar, page 7).

Using a Xylan coating in a bearing cavity in which a fluid lubricant is also used reduces friction losses in the bearing to the lowest possible level because Xylan is oleophobic (it sheds oil). During rotation, viscous shear forces within the bearing are reduced slightly. Thus, instrument bearings or other systems in which minimum bearing friction is critical can benefit from a thin coating (7.5 microns/0.0003 inch).

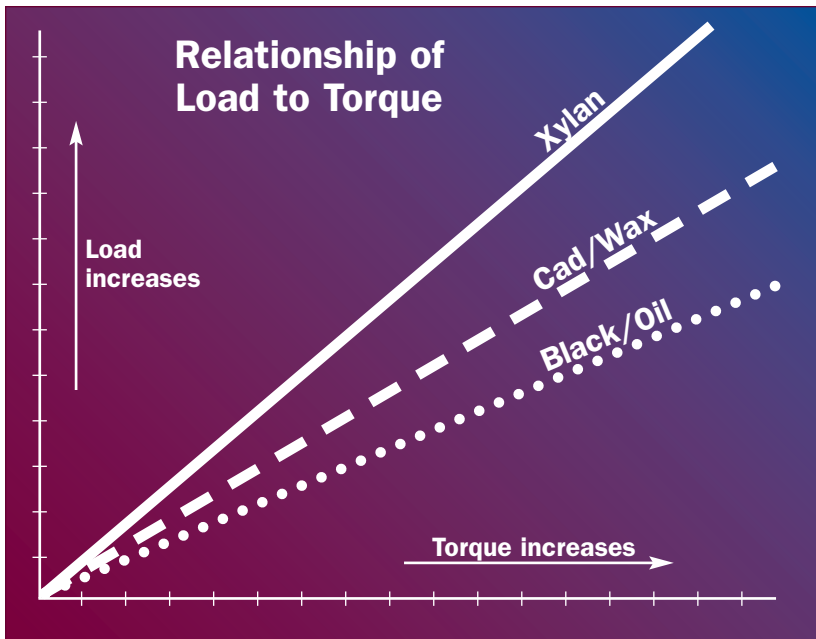
Excessive friction is also detrimental to bolted joints, in that much of the tightening torque is expended overcoming thread-to-thread and bearing-face friction. In these situations, if the bolt is not properly tensioned (preloaded), the joint can be unexpectedly weak in service.

In addition, improperly fastened parts are subject to backout when vibration occurs. Coating the threads reduces the makeup torque by as much as 65 percent.

Because of its toughness and corrosion resistance, a PTFE-matrix in a thermosetting binder is preferred for these applications.

### The oil embargo

The oil embargo of 1974 increased fuel costs as much as 80 percent, catching America with cars that averaged 3.5 km per liter/13.3 mpg. The situation for trucks was even worse.



Whitford recommends the use of direct-tension indicators (DTI) to determine proper make-up torque for each size or lot of fasteners used on a given application.

The automotive industry responded by attacking the causes of inefficiency: weight, drag, and friction. Weight and drag were reduced by successive generations of lighter and more streamlined vehicles. Friction, however, was another matter, particularly on the internal components of engines. Parts moving against each other create friction. Even parts that are well lubricated experience slight friction when surface asperities (peaks) rub together (especially when an engine is started, or when it is cold).

Previously, bonded dry-film lubricants had been used as insurance to back up fluid lubricants. However, the internal components of an engine operate in an environment that is hostile to most low-friction coatings. It is hot (>205°C/400°F), and many of the fluids encountered (fuel, combustion vapors, battery acid, brake fluid, glycol) attack many polymer coatings. Also, wear rates on pistons, bearings, gears, valve stems, and fan drives, are greater than most coatings can withstand.

Several formulations of Xylan coatings worked well in this environment. Xylan 1010, 1014 and 1052 were tried and selected for several applications because they were hard, wear-resistant, and stable at over 260°C/500°F. (Ask for Whitford's "Introduction to the Xylan 1000 Series".)

In one early experiment, a trucking firm test-

ed Xylan 1010 in the engine of a delivery unit, coating the pistons, bearings, connecting rods and crankshaft. Careful documentation proved that, during 200,000 miles/322,000 km, the engine used almost 15 percent less fuel.

Over the past fifteen years, engine manufacturers have determined that friction reduction has resulted in increases in engine output by as much as 16 percent.

In another example, a well known manufacturer of diesel engines used Xylan instead of PTFE "buttons" on piston skirts to reduce piston "slap". Other applications followed.

For viscous fan drives, a Xylan coating proved to be the ideal way to prevent the internal drive rotor from striking the drive housing. This eliminated the heat buildup that caused the drive fluid to gel.

Many of the parking-brake actuators found on vehicles are coated with Xylan — because it resists corrosion and the high thread loads (2,000 kg per cm<sup>2</sup>/28,000 psi).

Today, there are hundreds of different parts coated with Xylan in automobiles around the world, many of them in environments that would melt or degrade other coatings. From clutch actuators to air-conditioning compressors, these coatings improve the mechanical performance of the



Most low-friction coatings cannot survive the hostile environment of an engine's interior. Xylan can — with ease.

products by reducing friction, resisting corrosion and withstanding wear.

## B. Wear

Initial contact between mating metal parts results in momentary welding of asperities (peaks) on each surface. As each part continues to move, the welded asperities are ripped off, leaving behind minute pits.

Every bearing and wear surface, no matter how smooth the finish, has these asperities.

The problem is common to impellers and housings, air-cylinder pistons, machine slides, telescoping mechanisms, ball joints, plungers, gear-teeth, hinges, journal bearings, valves, power screws.

Xylan coatings provide a thin layer of lubrication to prevent the asperities on mating surfaces from making physical contact with each other. The selection of the best dry lubricant (PTFE, Moly, or graphite) for these applications depends primarily on the PV value (Pressure x Velocity), atmosphere, and temperature of the application (see sidebar).

In many cases, a dry film provides enough lubrication to eliminate objectionable wear. For example, a molded nylon detent for an automotive signal harness was failing prematurely due to heavy loads on the point of the detent. The sliding coefficient of friction between the detent and its mating cam was approximately 0.40, which resulted in severe abrasive wear.

When a 10 micron/0.0004 inch film of PTFE-loaded Xylan was applied to the detent, the coefficient of friction dropped to 0.12, and detent life was multiplied by over 200 percent.

Wear is often severe in bearing-type applications. Rods that slide through glands, rolling element bearings, slide assemblies, telescoping booms, ball reversers, rocker arms, ball joints, tracks, bushings, and thousands of other applications are configured so that one part rolls or slides over another part.

In most cases, friction and wear of the parts are reduced when one or both are coated with a dry-film lubricant. Also, the coatings serve as a thin cushion, spreading high point loads in bearings and reducing element fatigue.

The energy that is transmitted and dissipated

### What "PV" means and how to use it

*When two bearing surfaces rub against each other, wear is inevitable. The rate of wear is influenced by the pressure they exert against each other (P), the velocity at which they move over each other (V), the length of time they are in contact (T), and a wear factor constant (K) unique for each combination of surfaces. K is a function of the surface characteristics (roughness, coefficient of friction [COF], hardness, ability to resist deformation under load, etc.) and remains relatively unchanged at various PV.*

*The formula for calculating wear is:*

$$W = KPVT$$

**K:** wear factor unique to surfaces in contact, given in  $\text{in}^3 \cdot \text{min} / \text{ft} \cdot \text{lb} \cdot \text{hr}$  or  $\frac{\text{mm}^3 \cdot \text{min}}{\text{m} \cdot \text{N} \cdot \text{hr}}$ .

**Wear:** material (thickness) worn away in inches or millimeters.

**Pressure:** force between the surfaces in  $\text{lb}/\text{in}^2$  or  $\text{N}/\text{mm}^2$ .

**Velocity:** rate of motion in  $\text{ft}/\text{min}$  or  $\text{m}/\text{min}$ .

**Time:** duration of contact or operation in hr.

*If K and the thickness or wear tolerance of the bearing surfaces is known, then the service life of the bearing may be calculated for various combinations of Pressure and Velocity, or "PV factors".*

*Wear life will be directly proportional to PV factors below a certain limit. This "limiting PV factor" is the point at which increasing P or V converts normal wear into accelerated wear, often leading to catastrophic failure of the bearing.*

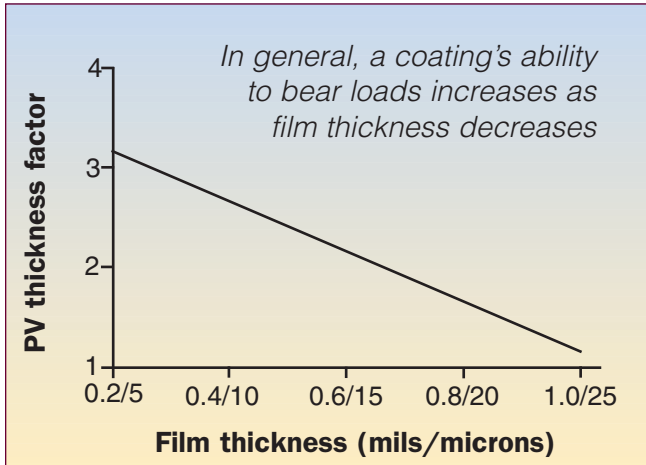
*Several factors influence the limiting PV factor, including temperature. Surfaces moving in contact generate heat which must be dissipated if the bearing is to survive. Low COF materials (lubricants, coatings) reduce the rate at which heat is generated and help preserve the bearing. All bearing materials, including fluoropolymer coatings, must be used below their limiting PV factor to avoid failure.*

in a bearing is a function of the PV of the application. As the PV increases, so do heat and wear on the bearing surfaces.

Dry lubricants have a "limiting PV value" that they can withstand for a reasonable wear life. Typically, the highest limiting PV which a 25 micron/0.001 inch coating of Xylan can with-

stand is approximately 50,000 (PV). This limiting value varies from coating to coating. Two factors to bear in mind:

First: the ability of a coating to bear loads increases as thickness decreases. For instance, while a 25 micron/0.001 inch film may be able to bear PV of only 50,000, a 5 micron/0.0002 inch film (the practical lower limit using current application techniques) may be able to bear PV of 150,000. For this reason, the PV tolerance of a coating may be modified by the film thickness.

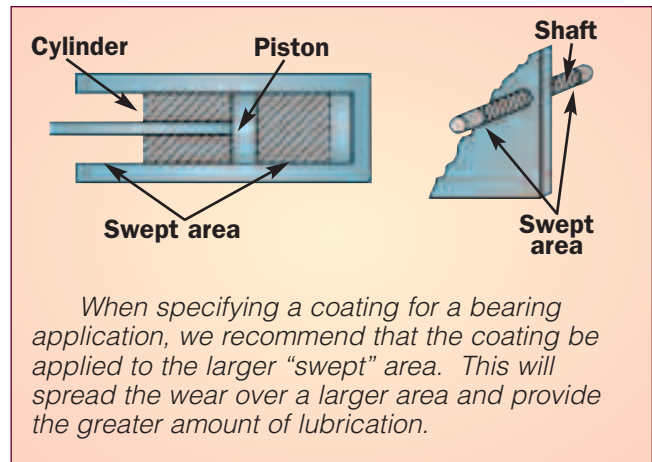
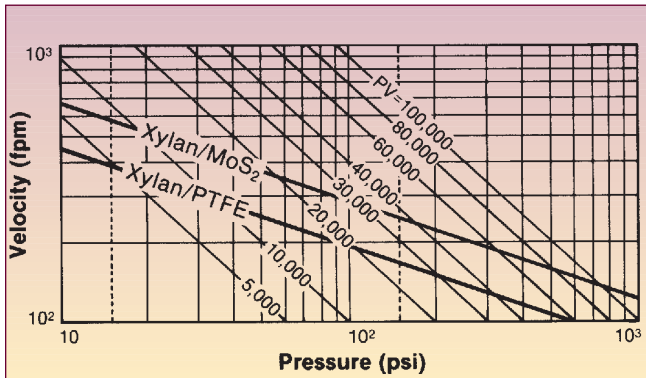


Second: the lubricants themselves. PV limits are not constant. They tend to increase with pressure and decrease with speed.

This is particularly true with Moly coatings, which work better under high pressure and low speed, where galling is the principal reason for failure.

The wear rates of many of the Xylan 1000, 1420 and 1600 Series coatings are equal to that of bronze/steel bearings impregnated with PTFE-lead when applied in thin films (17.5 microns/0.0007 inch).

For break-in, frequent starts, and marginal lubrication, remember: the period of greatest



wear to a moving mechanism is when it is new.

### Boundary lubrication failure

When equipment is started and stopped frequently, lubricants are subjected to stress, which can diminish their ability to lubricate. This can bring sliding metal surfaces into virtual contact (a condition known as “boundary lubrication”). If metal-to-metal contact does occur, the boundary lubrication can convert into actual failure as the metal surfaces meet and begin to wear, which can, in turn, lead to seizure.

A thin coating of Xylan reduces the chance of failure and lengthens the life of such products as sprockets, seal plates for compressors, pump pistons, cams, ball joints, conveyor trolleys, gears, journal bearings.

These coatings solved wear problems under start/stop conditions in reciprocating plungers in electrical solenoids. Typical plungers are chrome-plated (and extremely hard). But the starting and stopping at the end of each half-cycle put the plunger into a boundary lubrication condition, causing the plating to wear rapidly. When a matrix coating replaced chrome plating, the boundary lubrication condition was overcome and plunger life was extended by 90 percent.

A maker of chain saws uses Xylan 1010 as a fail-safe lubricant on the cage of the saw’s main bearing. Clearance between the cage and connecting rod is only 100 to 150 microns/0.004 to 0.006 inch. When the engine started, the bearing was in boundary lubrication and, without the coating, it tended to seize. As proof of the coating’s ruggedness, these engines run eight hours per day and have a life expectancy of three years.

PTFE-type Xylan coatings are recommended for applications where initial wear is anticipated to be light to moderate; Moly-type coatings are recommended for conditions of heavy wear, especially in high-load situations.

### Fail-safe

In any circumstance in which a mechanism *must* function when needed, even if only once, Xylan coatings provide a good margin of security, even under the most critical circumstances.

This includes aircraft parts such as bearings for turbine engines, solenoids, seat ejectors, actuators, door pins, and firing mechanisms for ordnance.

Another category is equipment that would be damaged were a component to fail. For example, removing a frozen bolt from chemical processing equipment could cause damage costing thousands of times more than the bolt. In refinery equipment, the use of a wrench is infinitely safer than the use of a cutting torch.

A good rule of thumb: apply coatings of approximately 25 microns/0.001 inch to the surfaces of these parts. This ensures that the component will function when required, and provides good lubrication and excellent corrosion protection.

### C. Nonstick (release) properties

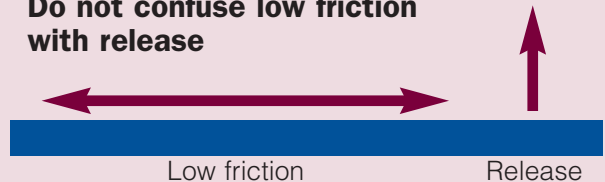
Nonstick should not be confused with low friction: the two are different.

Friction results from two surfaces sliding across each other and is measured by a dimensionless number that describes the reduction of drag (force) between the sliding parts.

Release is the property of a surface which results in the inability of substances to adhere to it. It is a function of surface energy that can be measured by the angle of contact between the surface and a drop of liquid (see diagram). The greater the contact angle, the lower the surface energy, and the greater release a coating has.

Release is generally associated with cookware, coated to release food materials. But release is equally vital to industrial processes such as thermoforming, rubber molding, automotive and adhesive assemblies, copy machines.

**Do not confuse low friction with release**



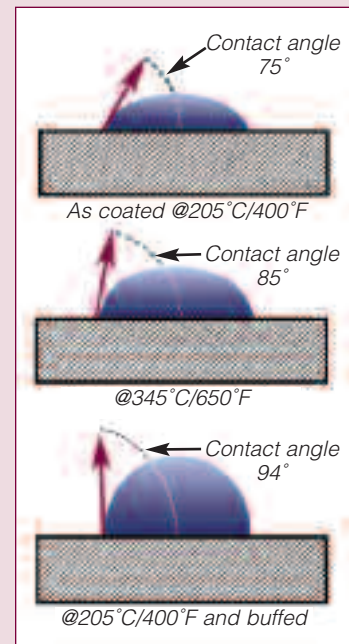
In many applications, buildup of foreign particles is a far greater problem than high bearing loads or corrosion. Examples: carburetor shafts, choke plungers, butterfly spindles, conveyor parts, instrument probes, fluid injectors, copy and printer rollers.

Buildup of dirt, ice, soot, scale, food and other foreign material can jam valve butterflies, throttle shafts, float elements, orifices, plungers, solenoids and other mechanisms.

If contamination of a surface is anticipated, it can be minimized with a thin coating of Xylan, which enables the part to shed the contami-

### Release and contact angle

*A drop of liquid on a coated surface forms a bubble whose shape is determined by the relationship between the surface tension of the liquid and the surface energy of the surface on which the liquid sits.*

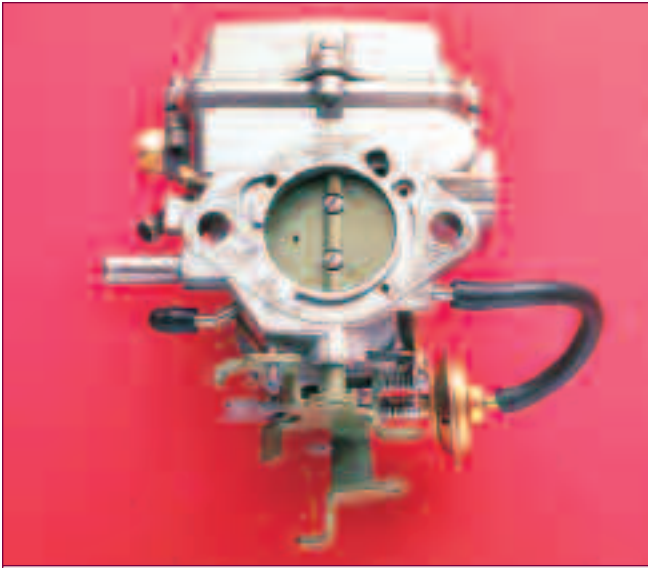


*The closer the tension and the energy, the greater the tendency of the liquid to flow out and wet the surface.*

*A high-temperature cure, or buffing the Xylan coating, increases release*

*by spreading the fluoropolymer into a film, which decreases the surface energy of the plane. The increased differential causes the surface tension of the bubble to draw itself up more into a sphere.*

*The contact angle is the tangent between the plane and the drop of liquid. Therefore, the greater the contact angle, the greater the release of the surface.*



### Eliminating ice buildup

*When air flows through a venturi, velocity increases and temperature decreases. Thus, when the ambient temperature is near freezing and moisture is in the air, the potential for ice to build up is high.*

*When carburetors were common, ice often formed at the throat in winter, causing the throttle butterfly to stick open or closed. A large “doughnut” of ice was sometimes visible on the outside of the carburetor.*

*The problem was eliminated by coating the throttle shaft and butterfly (shown here) with a thin (17.5 micron/0.0007 inch) film of a high-release coating such as Xylan 1010.*

*Ice continued to form, but was unable to adhere to the shaft or the butterfly and was swept into the engine and converted to water vapor. Thus, the dangers of losing power or having a throttle stick were eliminated.*

nants. If contamination is severe, buffing the coated surface will smear the fluoropolymer on the surface of the coating and increase its release property (see page 23, Part F).

A thin coating of Xylan (17.5 microns/0.0007 inch) is usually sufficient to eliminate the problem.

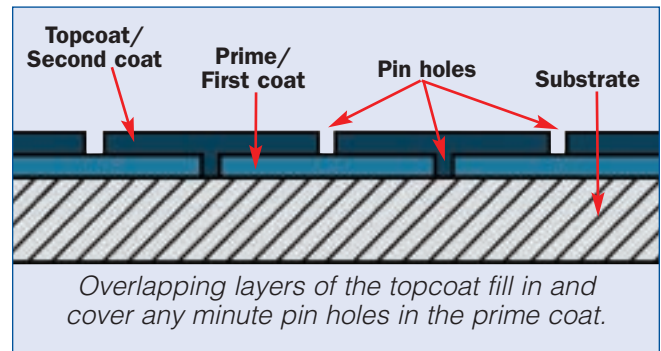
Most foreign matter is unable to cling to the waxy surface of the coating and falls off. What does not fall off is easily scraped off when the component brushes against a mating surface.

## D. Corrosion

The electrochemical process of corrosion is complex, and can result from single or multiple sources. Oxidizing fluids such as salt water, electrolytes, under-hood chemicals, wetting agents, by-products of combustion, acid fumes, food materials, process chemicals, fuels, car wash solutions, even high-performance synthetic lubricants, can attack metal.

Dissimilar metal unions (galvanic corrosion) and vibration between tightly joined components (fretting) can also cause corrosion. The effects range from catastrophic failure of studs/nuts on compressors to seizure of door-lock components.

Xylan coatings, particularly the formulations made with PTFE, offer a simple solution to the problem. Xylan is an excellent corrosion barrier, even if applied as a thin film. Most formulations form functional films at about 25 microns/0.001 inch. However, there may be microscopic pin holes in the coating.



For even better protection, the coatings can be applied in two thin layers so that pin holes in one layer are covered by the second layer.

Use of sacrificial primers increases the corrosion resistance (in some cases to over 7,000 hours in ASTM B-117 salt fog with less than 15% red rust). Certain Xylan coatings form excellent barriers to both acids and bases.

Even if corrosives eventually penetrate the coating and attack the substrate, little or no underburrowing occurs, so the parts may still be easily disassembled for refurbishing.

This is particularly important for process equipment in extremely corrosive atmospheres, such as chemical mixers, pumps and marine equipment. Even fasteners that normally suffer from heavy corrosion will remain functional if

they are coated prior to placing them in service.

When ferrous, aluminum, or even galvanized parts are to be exposed to oxidizing fluids or fumes, Xylan coatings can help protect them.

If corrosion is the dominant failure mode, choose a coating that offers the best protection from the specific environment. If the problem is a combination of corrosion and wear, a good choice would be a coating that performs well in the presence of corrosive elements and has a high nominal PV value.

For example, if corrosion is compounded by fretting (as found on compressor housings or other components subject to cyclic stresses), a hard, wear-resistant coating is the best choice.

### **Fastener-class coatings**

One of the greatest contributions made by fluoropolymer coatings is increased resistance to corrosion. Xylan coatings designed for fasteners and other small parts have improved corrosion resistance by a factor of five.

As the petrochemical industry developed, it began to demand better corrosion protection. Then came the automotive industry. But they wanted corrosion protection *and* low friction.

Specific formulations of Xylan were developed to combat the severe corrosion that affects the massive studs and nuts on oil drilling rigs and petrochemical processing equipment, as well as other items associated with the Chemical Processing Industry (CPI). These coatings also permit the use of less expensive (and stronger) metals in place of stainless steel and



*A coating on threaded fasteners retards corrosion, enables preloads to be set accurately and keeps fasteners functional even if they corrode.*

other more exotic and costly materials. They are applied by conventional spray and, when fully cured, resist both corrosion and mechanical damage. Note: if multicoats are to be used, oversize nuts may be required.

The problem with automotive fasteners was somewhat different. The typical automobile uses about 2,000 small nuts and bolts on trim, accessories, brake components and engine sub-assemblies. Pressured by more and more consumers complaining that their new cars were showing severe rust, automakers began a search for a better way to protect fasteners.

Previously, small fasteners were plated with cadmium. Corrosion resistance was about 96 hours as measured in a salt fog cabinet (ASTM B-117). Unfortunately, cadmium, a heavy metal, has serious environmental side effects and has been severely regulated or banned in many countries. (The EU, for example, has banned the disposal of cadmium and other heavy metals in landfills.)

The common replacement for cadmium is zinc plating. This, in combination with Xylan, provides the most cost-effective coating system on the market today.

The auto industry's search for better fastener protection led to a new set of standards of coating performance. One of the first was issued by General Motors. It called for a coating that provided at least 336 hours of salt-fog protection on self-drilling and self-tapping screws — after the screws have been driven through and removed from sheet-metal panels.

The Xylan 5000 Series was introduced to meet this standard. These coatings and their derivatives can be applied economically via the dip/spin method. More recently, Xylan 5230 was created, which offers the same performance without the use of chrome (a heavy metal and very unfriendly to the environment).

Testing this material, automakers and other users of threaded fasteners found that salt fog resistance increased to about 500 hours, more than 5 times the previous "best", with no danger of hydrogen embrittlement.

Another advantage of the 5000 Series is that the torque required to preload coated fasteners

is more uniform than that for other fastener finishes. "Torque scatter" is narrowed, meaning that preloads on fastened joints, made by robots, tend to be more uniform and the joints more secure (see chart, page 6).

Since the coatings permit the fastenings to be tighter, back-out, or loosening from vibration, is effectively eliminated.

Corrosion, as described above, does not include the severe chemical attack seen in chemical plants and refinery vessels. Ask Whitford for information on Dykor products for these uses.

### **E. Noise reduction**

Vibration generates noise. Vortices trailing high-speed impeller blades, impacting gear teeth, bearings spinning in races, slapping piston skirts, plungers sliding against the walls of actuators, reciprocating detents, and other sources of vibration are dampened when treated with Xylan. Under impact, noise generation is reduced.

In most cases, noise generation is effectively reduced by coatings of 25 to 40 microns/0.001 to 0.0015 inch. When corrosion is not a consideration, these films may be applied in one coat, although thicker coats may have greater energy-absorbing capacity.

If excessive noise is the primary problem, multiple coats of Xylan (up to 60 microns/0.0025 inch) may be applied to achieve optimum results. Caution should be taken to avoid excessive thickness, since the coating could be subject to delamination or tearing.

The choice of the best Xylan formulation for noise reduction depends on the problem. If corrosion is not a problem, apply a soft coating such as Xylan 1006; otherwise use P-92 primer and a topcoat of Xylan 1014.

A manufacturer of domestic dryers used a bearing coated with Xylan 1010 to replace an oil-impregnated bearing. The problem with the old bearing was that, after approximately one year of service, the oil migrated out of the bearing and the dryer developed an annoying squeak. The coating not only provided the required lubrication, but also eliminated the squeak.



### **Making cutting edges work better**

*Heat buildup from friction at the tips and flanks of saw blades leads to rapid loss of sharpness. A 25 micron/0.001 inch coating of Xylan reduces both friction and heat, extending the life of blades by a factor of three or more. It also reduces sap buildup. Similarly, a coating on hand pruners lowers friction to add power to the cutting force, making cutting easier.*

### **F. Temperature extremes**

Few fluid lubricants are recommended for use at cryogenic temperatures (most become solid) or above 205°C/400°F (they oxidize rapidly). The Xylan 1000 Series dry-lubricant coatings, however, operate comfortably at both extremes.

They retain their hardness at high temperatures because most binders for these coatings are thermosetting resins. Although pigments and binders in some Xylan coatings may discolor or above 260°C/500°F, the coatings continue to function. (For best results, coatings based on thermosetting resins should be cured at 30°C/50°F above the temperature at which they will be used.)

Xylan 1000 series coatings are also useful for preventing damaging "hot spots" between two rubbing parts, which enables some temperature-sensitive materials to operate at conditions under which they would otherwise fail.

### **G. Sealing**

Very thin coatings of Xylan show little tendency to cold flow (migrate under pressure), and thus are too hard to perform as conventional sealing surfaces. Applied in thicker films, however,

these coatings will deform sufficiently under pressure to form a tight thread-to-thread seal on pressure plugs, fittings, valve stems and other threaded fluid-power components. Tests of coated pressure plugs have shown that they resist leaking even when surge-tested repeatedly to 950 kg/cm<sup>2</sup>/13,500 psi.

The other characteristics of the coatings — low friction, corrosion resistance and high-temperature stability — are beneficial in these applications, too. The low coefficient of friction results in lower seating torques (as much as 60 percent). Because many Xylan coatings are stable up to 315°C/ 600°F, they will not migrate from threads when equipment is operated at high temperatures.

The coatings can be used as a dynamic seal, too. For example: when applied to the vanes of a powder metal rotor in an air-conditioning compressor, Xylan seals the rotor/housing interface, preventing leakage of the refrigerant past the rotor. To qualify for this application, Xylan 1010 was tested for 150 million cycles at 8,000 RPM, at a temperature of 185°C/360°F.

## H. Electrical characteristics

Most of the resins and several of the lubricating materials used in Xylan dry-film lubricants are excellent insulators, with dielectric strength in the order of 2,000 V/mil (25 microns).

The very low dielectric constant and dissipation factor, combined with the high dielectric strength and high-temperature capability of PTFE, FEP, PFA and the matrix resins, create formulations that are excellent insulators.

This insulating property renders a coated surface a good capacitor. When there is particle or air motion, or other static-charge-inducing systems, conventional Xylan coatings should be used with caution in the presence of static-sensitive products such as integrated circuits.

A fluoropolymer coating is called for on GM 6076-M as a masking coat for threads, protecting them from the heavy buildup of today's electrodeposited primers (a problem not only in automotive applications, but also in furniture, building equipment, etc.). The PTFE-based coating "masks" the threads and provides easy removal of the primer by the mating nut or bolt.



### **Rollers live a longer, more productive life**

*Xylan 1781 3-layer electrically conductive coating system gives end-users a smooth, coated surface that provides excellent toner release and a toughness that extends in-service life for all aluminum and steel copier and printer rollers.*

In addition, the coating reduces the torque between the coated parts and similar but non-primed fasteners in adjacent areas.

### **Conductive coatings, too**

When formulated with such materials as carbon black, graphite, or metallic compounds, coatings can be used as conductors. These formulations are preferred for static-sensitive systems such as computer printers and plastic web-handling equipment, or parts that operate in explosive atmospheres. Resistivity can range from 10 to 10<sup>12</sup> ohms/square, depending on the additives selected to make the coating conductive. Whitford also offers a line of electrically conductive coatings specially designed for copy and printer rollers.

An example: webs in paper and textile mills can be too dry to be conductive. This prevents utilization of the outstanding release properties of FEP heat-shrinkable tubing, because the static charge becomes a safety hazard. A conductive coating of Xylan solves the problem by providing the release while dissipating the static buildup.

When coatings are used to insulate or conduct, they should be applied in films of at least 25 microns/0.001 inch for maximum effectiveness. Coatings of less than 25 microns tend to be discontinuous, and therefore electrical properties are compromised.

## 3. Solving problems with Xylan coatings

The list of applications for these high-performance coatings is almost without end — and is growing. Here are a few examples of how various Xylan coatings have solved some interesting problems.

### Xylan stops tapers jamming

CCL Systems makes equipment to prestress the steel strands that reinforce concrete structures. One end of the strand is anchored; the other is grasped by a three-part tapered collet and collar held in the jaws of an extremely heavy-duty jack. Loads as high as 300kN (67,440 lbf) are applied until the concrete is set, forcing the tapered parts together.



Freeing the collet once the tension was removed — without permanently damaging the collet — was difficult. CCL Systems discovered that coating the wedges with Xylan 1052 eliminated the jamming completely and ensured reusability.

### Xylan unsticks sticky valves

No one pays attention to ball and plug valves — until they stick, which can cause process fluids to be lost, product damage, waste of energy, even danger to personnel.

Sticking valves are as common as the method generally used to “fix” them: a blow from a hammer, which usually damages the valve in the attempt to unstick it.

A better solution is to prevent the problem from occurring in the first place — with a thin coating of Xylan (25 microns/0.001 inch). Xylan



has been used on plug and ball valves for more than thirty-five years, to provide insurance that the valve will work when it must.

### Xylan improves blow-out preventers (BOPs)

Hydril, a manufacturer of BOPs (shown here), was unable to use an established plating material for corrosion protection and lubricity for its annular BOPs due to environmental controls. As a result, the company had to find a re-



placement surface-finishing technology for the internal surfaces which would facilitate quick sealing in the event of unexpected down-hole pressure spikes and have the ability to stand up to harsh, corrosive wellbore fluid conditions.

Xylan 1052, a low-speed, high-pressure, anti-galling, dry-film lubricant was tested. The BOP bowl, piston and head were first coated with a corrosion-resistant primer. Then Xylan 1052 was applied. The new coating system was tested through 50 actuation cycles. Not only did Xylan 1052 pass the test, it also improved lubricity and was placed in service. The BOPs are periodically pulled from the field for inspection and rework (remanufacture). Then they are recoated and returned to service to help protect operating personnel and the environment.

### Xylan lengthens life of sleeve bearing

A unique powder metal sleeve bearing (developed by Beemer Precision, Inc., of Fort Washington, PA) uses Xylan 1052 to extend its



service life in high-load, low-speed applications with rotating and oscillating motions.

The tough nonstick coating virtually eliminates the need for “break in” because of its low coefficient of friction, ideal for startup.

After startup, the coating continues to

function, helping lengthen the life of the bearing.

### **Xylan reduces wear on air-cylinder pistons**

In more and more applications, oil/air mixtures are either proving unsafe or are interfering with process cleanliness.

In environments in which lubricated air is not allowed by OSHA regulations or because of other safety considerations, air-cylinder pistons should be coated.

The easiest, most effective way to eliminate the oil/air problem and provide proper lubrication for moving parts is to coat air-cylinder pistons with 25 microns/0.001 inch of Xylan 1014 or 1424, which also extends the lives of the pistons.

### **Xylan saves bearing cages as secondary lubricant**

When compressors are shut down, the primary lubricant settles below the bearings. As a result, startup can frequently be damaging to the bearings.

A coating of Xylan is used as a secondary



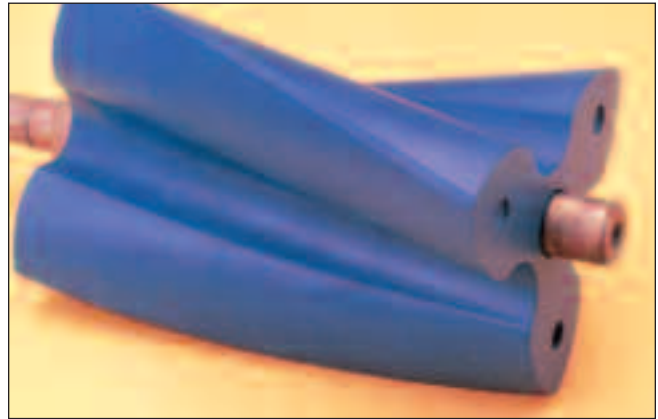
lubricant to provide low-friction movement until the primary lubricant begins circulating.

### **Xylan quiets blower**

How much noise can a coating dampen? That depends on the application, but the results obtained in diesel engines are indicative.

By coating only the rotors of a supercharger, a drop in noise emissions of 2.5 dbA was measured and the efficiency of the blower was significantly improved.

Another benefit: in the case of a bearing malfunction, the Xylan coating would act as an emergency lubricant to keep the blower from self-destructing before it could be shut down.



### **Xylan shows stability under fire**

Experiments conducted to reduce losses caused by friction in diesel and spark-ignition engines demonstrated that this environment was difficult for any lubricant to endure. Matrix coatings, however, had proved their worth in other hot-engine applications.

Xylan 1010 was applied to pistons which were operated for a quarter of a million miles. The coating showed some signs of scorching — indicating that the pistons ran in excess of 260°C/500°F — but it was still operational, and the pistons showed little wear.



The scorching can be seen in the photograph — as can the coating, still in place, ready to perform and protect the piston.

## **Xylan coating prevents leaks past threads**

Pressure vessels, valves, pipe unions, storage tanks, reactors, pipe lines, and other fluid-containment equipment are often fitted with threaded plugs for inspection, pressure relief, filling, or tapping.

Coatings on pipe plugs not only improve their performance and reliability but also make them easier to use. A thin film of Xylan eliminates the PTFE tape normally wrapped around the threads to seal them.



In addition, the corrosion protection and low-friction properties of the coating greatly reduce break-out torques, enabling users to remove the plugs at a later date without destroying them.

In most instances, the pipe plugs may be reused without difficulty.

Xylan coatings are also available in many colors, enabling users to color-code particular plug sizes and different alloys.

## **Xylan proves a winner on the track**

Reducing weight and minimizing wear are two major objectives of car designers around the world — especially in car racing. But there is a problem: the lighter the material, the greater the tendency to wear.

Cosworth Engineering, internationally renowned designers of high-performance engines, has solved many design problems with Xylan coatings on engine components:

- Aluminum cylinder liners save weight, but they suffer from scuffing. A collar of Xylan sprayed around the base of the cylinder liner eliminates the problem, even in the engine's

hostile environment of heat, oil and friction.

- Cosworth replaced steel throttle plates with aluminum, which is lighter, but running between aluminum guides soon caused scuffing. So they coated the throttle plate and the guides with Xylan, solving the scuffing problem and providing permanent dry lubrication, even in the presence of gasoline vapor.

- Magnesium castings are lighter, but contact with harder materials (such as the sintered iron rotor in Cosworth's oil scavenger pump) caused wear, rendering the castings unserviceable. A coating of Xylan 1010 completely solved the problem. Even after extensive racing trials, no appreciable wear was evident.

Having proved itself on the race track, Xylan is now enabling production car designers to cut weight and wear as they improve performance — all at a lower cost.



## 4. Whitford primers

Most Xylan coatings are formulated to function as single-coat materials. There are times, however, when a primer will provide significantly improved performance, and therefore more than justify any additional cost.

Note: There is a difference between “primers” and “basecoats”, and the two should not be confused. Whitford defines the terms as follows:

- Primer: a coating designed to stand alone and function by itself, but that can also be used to enhance the performance of a different topcoat.
- Basecoat: a coating designed to be part of a specific system, without which the system will not perform as specified. Basecoats generally will not function properly alone.

Primers can be organic or inorganic, metallic or non-metallic. The selection of which primer is most suitable for an application depends largely on the desired performance enhancement, the environment in which the coating system will operate, and to a lesser degree on the topcoat to be used.

The mechanisms of corrosion control are quite complex. However, as a general principle, Xylan primers improve corrosion resistance by one of three methods. The first is inhibition. The use of select pigments inhibits the corrosion reaction and promotes the formation of a stable, passive oxide layer on the metal surface.

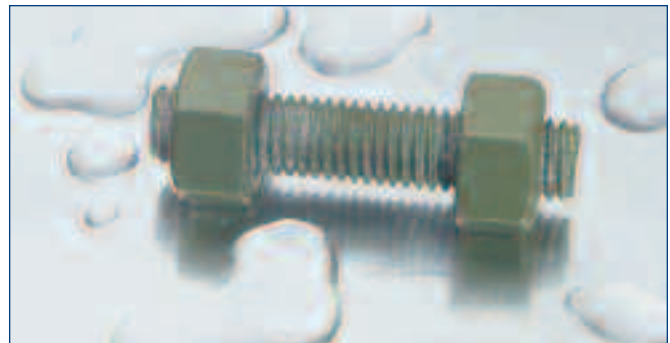
The second is sacrificial protection. Primers highly filled with anodic metallic pigments cor-



*Xylan, when combined with a zinc-rich sacrificial primer, can withstand 1,080 hours of exposure in the salt-fog cabinet. Rust is minimal, the coating is still functional and the fasteners are fully serviceable.*

rode more readily than the base metal. The by-products of this sacrificial corrosion then fill pores within the coating, further reducing the corrosion process. The third is the use of inert fillers, which can increase the length of the diffusion path of the necessary components of corrosion. By providing a barrier to oxygen and moisture, the corrosion reaction is greatly reduced.

Regardless of the primer selection or the environment to which the coating system is exposed, a primer will only offer enhanced performance if applied to a properly prepared surface. This is so important to developing the full potential of high-performance coatings that the next chapter is dedicated to proper surface preparation and application conditions.



*Left: Coated bolt but with no primer in ASTM B117 after 500 hours. Right: Same conditions but with a primer. What a difference the use of the right primer can make!*

## 5. Applying Xylan

Applying coatings is more complicated than it appears, and unfortunately space prevents us from covering all the finer points. For a complete evaluation of your application, consult a Whitford Quality Approved Applicator early in the design process (for a list of these, please call your Whitford representative).

### A. Substrates

Xylan can be applied to almost any clean, dry, oil-free surface. The only materials to which it will *not* adhere are those with inherent release characteristics such as polyolefins and similar fluoropolymers (although, with special surface preparation, Xylan will adhere to these as well).

#### Virtually all metals

Almost every structural metal can be coated with Xylan, including steel (carbon and stainless), aluminum (wrought and cast), copper (and alloys), and titanium. Note: high nickel- and chrome-bearing alloys, and some platings of nickel, can also be coated if abrasive blasting is used and the coatings are applied within an hour or two of blasting.

Special precautions must be taken with powdered-metal parts. These parts appear ideal for coating: their surface is porous and provides good “tooth” to which a coating can cling. However, since many of these parts have been treated with resinous impregnants, oils are trapped within the porosity. To coat them, bake the parts at a temperature *higher* than the cure temperature. Any contaminants which bleed to the surface during the bake must be thoroughly removed. Then, the parts can be coated.

Die-cast parts can be a problem. They are typically cast using aluminum, zinc and magnesium alloys that can be “gassy” and porous. When coated parts are cured, the gas trapped in internal cavities expands and erupts. When cured at over 235°C/450°F, these parts may have numerous eruptions on the coated surface. To evaluate whether the substrate can withstand the cure temperature, prebake a part to 10-15°C/20-25°F higher than the anticipated cure.

### Plastics

Many plastics can be coated with Xylan. Note: vinyl products containing a high content of plasticizer can cause adhesion problems. Nylon, PEEK, PEK, PPS, ABS, polycarbonate, epoxy, polyester, phenolic — all can be coated.

Parts made of these materials must be cured at temperatures well below the softening temperature of the substrate to avoid distortion and polymer degradation.

### Elastomers

Some Xylan coatings may be applied to elastomeric parts not expected to elongate more than about 30 percent in service. Greater elongation may cause these coatings to crack. If a discontinuous coating is not objectionable, elongation greater than 30 percent is permissible. (Note: Whitford has developed flexible finishes that can be elongated to 150 percent or greater with no cracking of the coating. Ask for Whitford’s “Flexible Finishes” brochure.)

Elastomeric parts successfully coated with Xylan include bushings, mounts, automotive door and window seals, vibration dampeners. Substrates include natural rubber, EPDM, SBR, butadiene and its derivatives, and silicones.

### Glass and ceramics

Fluoropolymer coatings will adhere to clean ceramic and glass surfaces, but curing the coating without cracking the substrate can be difficult. (If possible, use glass or ceramic intended for high temperatures.) In most cases, a low-temperature cure (below 150°C/300°F), followed by a slow cool-down period, will not crack the substrate. For glass parts, coating adhesion may be improved by a fluorine etch or the use of a primer.

### Fabrics and composites

Xylan coatings are increasingly being used (for low friction and release at elevated temperatures) on woven and nonwoven industrial textiles made from such modern materials as carbon fiber. One of the most successful applications of Xylan involves a fabric bearing which is woven

from a nylon/glass blend, then coated and cured.

These composite bearings are used under the compressor blades of large bypass fanjet engines. The natural porosity of fabrics forms sponge-like “wells” into which the coating penetrates. In service, this extra supply can continue to provide PTFE to a wear surface long after the coating is worn away from a smooth substrate.

Xylan adheres well to other composites, too, provided release agents have not been applied to the material.

### **Paper and wood**

Xylan adheres well to uncoated or unvarnished paper products as well as wood. As unlikely as it may seem, the coatings perform every bit as well as they do on metal and other substrates. Cure temperatures should not exceed 180°C/350°F.

## **B. Preparation**

Cleaning and pretreatment are important. Every surface to be coated must be clean, since few coatings adhere to dirty or oily substrates.

*Note: The second-best coating over the best surface preparation is likely to perform better than the best coating over the second-best surface preparation.*

There are many ways to clean a part, each with advantages and disadvantages. Some techniques go beyond cleaning and create surface “structures” that enable a coating to cling better. It is often desirable to use a combination of cleaning methods to achieve optimum adhesion. The more common methods are:

**Vapor degreasing** used to be the most widely used cleaning technique, but fell into disfavor because of regulatory restrictions on the use of cleaning solvents.

Where permitted, degreasing remains an excellent technique for removing foreign materials from fingerprints to machine oils. It is an economical technique for cleaning small batches. Avoid using it on parts that may be attacked by the solvent, such as plastics, composite parts, or metal parts with organic inserts.

**Alkaline washing** involves cleaning parts with moderate- or high-pH cleaners. This is preferred for high volumes of parts and is generally

as effective as vapor degreasing. Parts which should *not* be alkaline-washed are those which may be adversely affected by the chemistry involved (such as aluminum and magnesium).

**Grit blasting** with aluminum oxide or carborundum particles is a common cleaning technique, preferred for parts whose surface contaminants — rust, scale, corrosion, old coatings — must be attacked physically to be removed. It is not, however, the most effective technique for removing oily or fluid contaminants. When parts are particularly oily, alkaline cleaning or pre-baking them before blasting will improve the effectiveness of the blast and reduce contamination of the blast medium.

Grit blasting does more than clean; it roughens the surface and enhances mechanical adhesion by increasing the surface area to which the coating can cling. A grit medium from 36 to 220 mesh/250 to 70 microns is recommended for blasting most metal parts. (Note: the particle size quoted above runs from larger to smaller.) Steel grit is generally avoided because minute particles may be left behind and become starting points for oxidation.

**Shot blasting** is similar to grit blasting, but employs metal or other “shot” as the blast medium. For parts which will be used in fatigue/fretting applications, this process can be beneficial because it imparts residual compressive stresses on the surface of the parts, thus lengthening their lives under cyclic loads.

**Tumble blasting** is another variation in which parts — usually small parts — are placed into a rotating cylinder along with an abrasive medium which abrades the part surfaces. The effect varies with the medium employed, but is much the same as grit blasting. This technique is less effective than fluid cleaners for removing machine oils and other similar contaminants.

**Acid or alkaline etching** is an excellent technique both for cleaning and roughening the surface of aluminum parts. Because the size of the equipment is considerable, it is usually reserved for high-volume production parts.

**Pickling** is common for removing rust/scale from ferrous parts after cleaning. It should not be used on parts that will be highly loaded, since it can cause hydrogen embrittlement.

**Phosphating** is a secondary surface prepa-

ration for steel which is generally used after vapor degreasing, alkaline washing or grit blasting. Whitford normally recommends a modified zinc or manganese phosphate with a fine crystalline structure. Zinc phosphate is used for static applications, and manganese phosphate for dynamic and higher-temperature applications.

A thin layer (15-25 gms/m<sup>2</sup>) of zinc phosphate on the surface promotes better adhesion and dramatically increases corrosion resistance and chemical protection. A good alternative: Xylan 4070 Primers, which outperform conventional phosphating.

Iron phosphate may be less expensive, but zinc phosphate has superior corrosion resistance and better protection from corrosive creep. Whitford prefers zinc phosphate. Note: Manganese phosphate has better corrosion resistance and thermal stability than zinc, but can be more difficult to apply, especially to high-alloy steel.

**Anodizing:** An electrochemical treatment of primarily aluminum which can greatly increase hardness. It creates a porous, corrosion-resistant surface that is excellent for coating, provided it has not been sealed. (Other metals, such as manganese and titanium, although much less common, may be anodized.)

**Conversion coating:** Normally applied in a bath to create an "active" surface to promote adhesion of the coatings. Specially formulated phosphates are available for use on aluminum. Ask about Whitford's Activ8/Passiv8.

### Other factors

**Combinations of pretreatments:** These are required for the best overall coating adhesion and corrosion protection. For common substrates, industry practice has been to use the following pretreatments or combinations:

- Carbon steel: vapor degrease/gritblast/phosphate or plate.
- Aluminum: alkaline wash/etch or grit blast.
- Stainless steel: heat oxidize/grit blast.
- Chrome and nickel plate: vapor degrease/pre-bake/grit blast.

**Coating material preparation:** *It's important to mix or roll all ingredients according to the Product Data Sheet which accompanies the first*

*shipment of each Whitford product.*

**Preheating:** Preheating parts prior to coating is recommended when parts are in humid atmospheres because condensate on cool parts can cause defects. Preheating is also useful when parts of great mass are coated and oven dwell times to bring them up to temperature would be uneconomical, or when films that are thicker than normal are required.

We recommend that preheating *at the time of coating* be limited to no more than 65°C/130°F to avoid solvent or water "boiling" on the surface of the parts. Thin or light-gauge parts may require greater temperatures because of their tendency to lose heat rapidly during transfer from the heat source to the coating area. Note: Preheating is *not* recommended with Xylan 5000 Series coatings.

## C. Application techniques

The techniques used for applying Xylan depend on the shape of the part, the number of parts, the desired transfer efficiency, the application rate and the type of carrier used in the Xylan formulation. Here is a brief guide:

**Spraying:** By far the most versatile and widely used technique to apply Xylan is spraying. There are five basic types: conventional (also known as siphon or gravity), HVLP, airless, pressure pot, and electrostatic.

- Conventional: The choice for small numbers of parts, where considerable manual work is required. Almost any Xylan formulation can be applied by this technique.
- HVLP (high volume, low pressure): A variation that reduces air pressure and increases liquid volume. Its greater efficiency reduces the number of Volatile Organic Compounds released (see Chapter 9, page 30) and can increase transfer efficiency.
- Airless: Similar to the siphon system but uses hydraulic pressure to move and atomize the liquid instead of air.
- Pressure pot: Similar to conventional spraying, except the coating is under positive pressure. This technique moves more coating than a conventional system and is recommended for larger production runs. Almost any Xylan formulation can be applied by this system.
- Electrostatic: The recommended process

for very high production conditions or when an electrostatic “wrap” is needed to coat complex shapes efficiently. Rods, wires, outdoor furniture and other parts that require a 360-degree coating are examples. Not all formulations lend themselves to electrostatic spraying with conventional equipment. Some (such as water-based products) may require special electrostatic systems.

**Bulk techniques:** These are the most economical methods of applying coatings to small and intricate parts such as fasteners, clips and other irregularly shaped pieces. Transfer efficiency is exceptionally high: as much as 95 percent of the coating is applied to parts. Bulk coating techniques operate in two basic ways:

- **Dip/spin coating:** This is just what the name implies. A basket filled with parts is immersed in a reservoir half-filled with coating, raised out of the coating but still within the reservoir and spun to carry off excess fluid by centrifugal force. Following that, the parts are cured. Because parts are in contact with each other, which can prevent complete coverage of the coating, at least two passes through this process are required to ensure total coverage.

- **Barrel/tumble coating:** This technique involves tumbling parts and spraying them while hot air passes over them. This method is preferred for extremely lightweight or flat parts (such as washers or small O-rings) which tend to “nest” together.

Four other methods are:

- **Coil coating:** This uses high-speed rollers to apply precise film thicknesses to wide, continuous sheets of metal, which are subsequently drawn or stamped. This process is used very successfully for high-volume coating of cookware, bakeware and small appliances.

- **Curtain coating:** A high-volume application technique in which parts are passed through a falling curtain of the liquid coating. It's fast, economical and highly efficient (virtually no waste).

- **Roller coating:** Similar to coil coating in that it uses rollers to apply the coating to the surface. In the case of roller coating, however, the coating is applied to metal blanks rather than continuous rolls of metal. The process is used for high-volume applications like cookware and bakeware. One of its drawbacks is that it tends

to create striations in the coating which are visible in the finished and pressed piece. These striations are often referred to as “chicken tracks”.

- **Pad or screen printing:** Adding a patterned or decorative coating over standard coatings using a pad or a silk screen.

### **Coating fabrics**

The application techniques by which fluoropolymer finishes and coatings are applied to textiles may differ significantly from those utilized for applying coatings to metal, rubber or plastic substrates.

Application can be accomplished by padding, in which the greige (pronounced "grey" and meaning "untreated") fabric is immersed in a bath of the finish and the excess is removed by passing the wet fabric through padded rollers. Padding spreads the finish evenly over both sides of the fabric, minimizing application time and effort.

Textiles can also be coated or impregnated by "knife over roller". This method uses a viscous coating that is metered onto a rotating roller, which supports the entire web of the fabric. As the fabric passes over the roller, the forward motion produces a well of coating, also known as a rolling bank, behind a stationary knife. The gap between the knife and the roller is the primary determinant of the amount of coating deposited onto the fabric. Variants of the knife-over-roller method include knife-over-table, knife-over-air, and knife-over-gap. Knife coating is used for single-side application of the coating onto the fabric.

Similar in popularity to knife coating is roll coating of fabrics. All variants, such as direct roll, kiss coating, gravure, and reverse roll, utilize a rigid roller partially immersed in the coating solution. The coating is either directly applied to the fabric or is transferred to other rollers prior to deposition onto the fabric. Each variant affords different levels of efficiency, flexibility and precision of deposition weight.

Other possible application techniques for fabric coatings may include transfer coating, rotary screen printing, or simply spraying.

### **D. Flashing and curing**

Achieving a tough, continuous film requires a

flashing process, in which the carrier is vaporized by brief exposure to an elevated temperature (but lower than the cure temperature), and a curing process, in which the coating resins link into a continuous film.

Most Xylan coatings can be cured via convection ovens and infrared (IR) ovens. Some special formulations can be cured with exposure to ultraviolet (UV) light. Only a few formulations are suitable for cure at ambient temperature. The curing process is a time/temperature relationship. In all cases, the higher the temperature, the shorter the curing time (see chart). Note: altering the time/temperature relationship will affect performance (see F, next page).

**Convection systems:** These use heated air to cure the coatings. They are, by far, the most common type used to cure Xylan. Sophisticated production ovens, which employ conveyors to move parts, usually have at least three heat zones within them: a warm-up zone, a bake zone, and a heat-extraction zone.

**Infrared systems:** A line-of-sight process that allows fast heating of the surface of the coated substrate (as opposed to other, slower systems, which must heat the total part). Efficient, but must be controlled carefully to avoid overheating. Very effective for flat or shallow parts.

**UV systems:** These initiate a photochemical reaction that is far faster and uses far less energy than thermal systems. UV also reduces the footprint of the curing line significantly.

**Curing schedules:** These vary for different Xylan formulations. However, some Xylan coatings permit wide latitude in the selection of cure temperatures so that cure can be compatible with the part. For instance, you may want to limit the cure temperature of a die-cast part to 380°C/715°F, or for a formed aluminum part to less than 235°C/450°F.

*Note: Cure time is the period that begins when parts reach and remain at cure temperature, not oven dwell time (the entire period during which the parts are in the oven).*

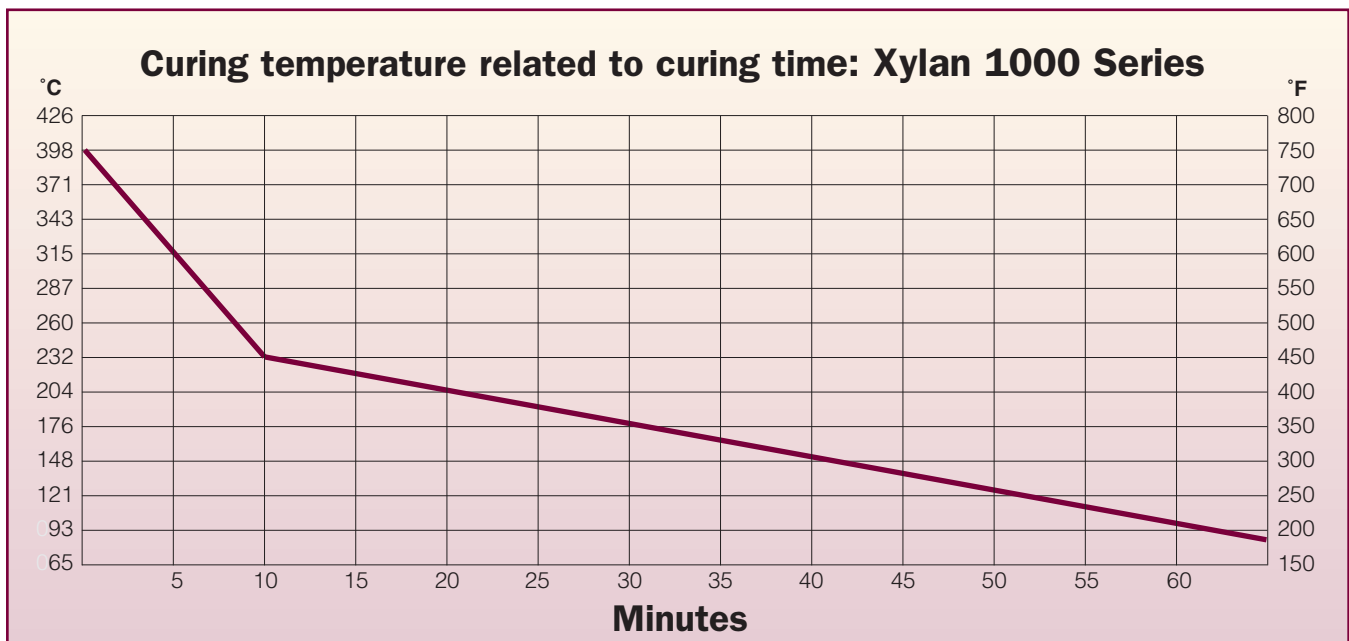
**CAUTION:** Entrapped air in such parts as rollers or insulated/jacketed vessels may become a “bomb” and explode when heated to cure temperatures. An air-relief hole or pressure-relief valve must be a part of the assembly.

### E. Surface considerations for maximum wear resistance

Should the coating be applied to both surfaces of the mating parts?

The answer is generally no, for reasons of cost. Only a small increase in lubricity is gained by coating both surfaces. However, part life may be doubled because of the greater thickness. Remember: in most cases, it is easier and more economical to coat the exterior of a part rather than the interior (a shaft instead of a bearing).

When there is a difference in mating materials, it is preferable to coat the softer of the two



surfaces (the one which, in boundary-lubrication conditions, could suffer the greater damage).

The mating surface affects the wear rate of a coating. For instance, the wear rate on a coated journal that supports an aluminum shaft is as much as 50 times that of an identical bearing that supports a carbon steel shaft. (See “What ‘PV’ means and how to use it”, page 7.)

The roughness of a mating surface also has an effect on coating wear. The optimum surface has 8-12 micro-inches/0.2-0.3 microns (RMS). Surprisingly, hyper-smooth surfaces (less than 4 micro-inches/0.1 microns (RMS) produce higher wear rates than those with a finish between 15-30 micro-inches/0.375-.75 microns (RMS).

A smoother surface permits less transfer of PTFE to the mating surface and friction increases — causing wear. Surfaces which are *rougher* than 30 micro-inches/.75 microns (RMS) also result in high rates of abrasive wear, increasing as the roughness increases.

Caution must be used with coatings in cathodically/anodically protected assemblies (contact your Whitford representative).

## F. Special cure and postcure

Some Xylan coatings can be processed to improve performance for specific applications. For instance, cure affects adhesion, release, hardness, corrosion resistance, friction properties, wear rate, and flexibility. Here are some suggestions for enhancing coating performance:

- **Curing for maximum hardness and chemical resistance:** For applications in which coatings will be subjected to extreme wear, we recommend that they be cured at the upper (hot) end of their cure schedule. This results in maximum crosslinking of the binder.

- **Curing for nonstick/release:** Release can be increased by post-curing at elevated temperatures or by buffing the surface after it has been thoroughly cured.

- **Curing for multiple coats:** If applying multiple coats to a part, in most cases the first and intermediate coats should be flashed but not fully cured prior to the application of subsequent coats. This increases the bond between each layer and results in a stronger, denser coating.

(See PDS for more specific instructions.)

## G. Additional considerations

- **Postforming:** Some Xylan formulations may be stamped, deep-drawn, bent, punched, drilled, machined, and otherwise manipulated without damaging the coating — provided that the part is properly pretreated before coating.

- **Controlled removal for precision sizing:** Many Xylan coatings may be applied in thick films and then machined, buffed, centerless ground, sanded, etc., to achieve a very high gloss and an extremely close tolerance.

- **Higher builds:** Thicker films may be achieved by preheating the substrate as previously mentioned or by using formulations with higher solids, which are available in most, but not all, Whitford products.

- **Coating removal:** Once applied and cured, fluoropolymer coatings can be removed from a part mechanically by sand/grit blasting, or thermally by degrading the coating (at 480°C/900°F). Use caution when degrading thermally.

**Important:** At temperatures >300°C/>575°F, fluoropolymer coatings give off fumes which can cause “polymer fume fever”, a condition not unlike a mild, 24-hour case of flu (there are no known long-term effects). If you take fluoropolymers to these high temperatures, be sure that the work area is well ventilated.

### Substrate removal:

#### when to make room for a coating

Coatings are generally applied to parts without any provision for the thickness that they add (coatings are not included in the original design). This is particularly true when coatings are used as corrosion barriers (within some limits, the thicker they are, the better). This is also true of parts that are stamped or deep-drawn.

In many bearing applications, however, tolerances are too tight to add another 17.5 microns/0.0007 inch of material without any provision for it. For these situations, use this guide: *where parts form an interference fit, remove an amount of substrate material that is equal to half the thickness added by the dry coating film.* In all cases, parts treated in this manner should be thoroughly performance tested.

## Guide to application and processing techniques

Application	Substrate	Pretreatment	Post treatment	
Friction/wear	Steel (ferrous)	Degrease, grit blast to 100 µin/2.5 µm.	Can be polished	
	Steel (stainless)	Degrease, grit blast to 100 µin/2.5 µm.	Can be polished	
	Aluminum (die-cast)	Degrease or alkaline wash, grit blast to 40 µin/1 µm.	Can be polished	
	Aluminum (wrought-bare metal)	Degrease or alkaline wash, grit blast to 80-120 µin/2-3 µm.	Can be polished	
	Aluminum (anodized)	Degrease or alkaline wash.	Can be polished	
	Babbitt metal	Degrease.	Can be polished	
	Bronze (sintered)	Bake to 260°C/ 500°F, degrease or alkaline wash.	Can be polished	
	Cast iron	Degrease, grit blast to 60 µin/1.5 µm.	Can be polished	
	Non-metallic	Clean nondestructively.	Can be polished	
Corrosion barrier	<ul style="list-style-type: none"> <li>• Fasteners</li> </ul>	Steel (ferrous)	Degrease, grit blast to 120 µin/3 µm, phosphate and/or plate, apply primer/topcoats.	None required
	<ul style="list-style-type: none"> <li>• Other</li> </ul>	Steel (ferrous)	Degrease, grit blast to 120 µin/3 µm, phosphate, apply primer & topcoats.	None required
		Iron (cast)	Degrease, grit blast to 120 µin/3 µm, apply primer & topcoats.	None required
		Aluminum (cast)	Alkaline wash, grit blast to 120 µin/3 µm, apply primer and topcoats.	None required
		Aluminum (wrought)	Degrease, grit blast to 120 µin/3 µm, anodize if practical, apply primer and topcoats.	None required
		Brass, bronze	Degrease, grit blast to 120 µin/3 µm, apply primer and topcoats immediately following blasting.	None required
Electrical applications	Steel	Degrease, grit blast to 60 µin/1.5 µm, apply two 0.0007 in/17.5µm coats with intermediate cure at 120°C/250°F.	Spark test (if insulating), ohms per square (if conductive)	
	Aluminum	Alkaline wash, grit blast to 60 µin/1.5 µm, apply two 0.0007 in/17.5µm coats with intermediate cure at 120°C/250°F.	Spark test (if insulating), ohms per square (if conductive)	
	Copper	Degrease, grit blast to 60 µin/1.5 µm, apply two 0.0007 in/17.5µm coats with intermediate cure at 120°C/250°F.	Spark test (if insulating), ohms per square (if conductive)	

## 6. Whitford flexible finishes and the automotive industry

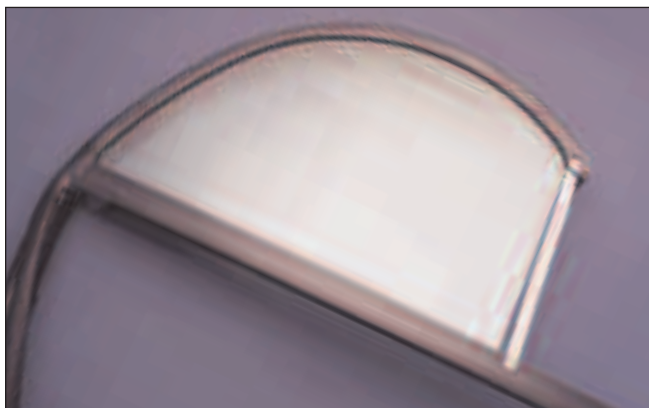
In 1986, Whitford identified a need for alternative products to traditional methods of post-treating elastomeric seals and moldings. These conventional treatments included polyamide and polyester flocking agents, silicone solutions, fine particle chinks, and specialty greases.

Whitford's R&D technicians set a high priority on these new products, and within months had the first product developed and tested. The products have evolved over the years, and today are better than ever.

Whitford's new products were designed to meet increasing performance demands of automotive manufacturers including:

1. Reduction of coefficient of friction.
2. Suppression of noise generated by seals due to micromovement between the car doors and the car body.
3. Elimination of sticking of seals to car doors.
4. Protection of rubber and thermoplastics against the effects of weathering.
5. Offering of novel colors, appearances, and textures.

In addition to these attributes, the new products (marketed under Whitford's "Xylan" trade name) are cost-effective, easy to apply through a variety of spray and brush techniques, and are available in waterborne, VOC-compliant forms engineered to meet the most vigorous environmental regulations in the world.



*Xylan flexible finishes are ideal for applications such as EPDM weatherstripping.*



*Whitford's flexible finishes are used by major automotive manufacturers all over the world.*

### Who's using Xylan?

Xylan coatings for flexible finishes have been tested and approved and are used by more than 30 automotive manufacturers around the world.

As more and better coatings for flexible finishes are developed by Whitford (a never-ending project), more manufacturers are taking advantage of their benefits.

### A variety of substrates

EPDM (ethylene-propylene-diene monomer) rubber is one of the most common substrates on which Xylan flexible finishes are used. Nevertheless these coatings are also being used on many other surfaces, including NBR, PVC, TPEs, TPOs, acrylics, ABS, and polyesters.

### Pretreatment

Depending on the quality of the substrate and the performance requirements of the coating, substrate pretreatment may be required. Adhesion of Xylan products can be optimized by solvent degreasing, priming, corona discharge, plasma treatment, flame treatment, or through mechanical abrasion.

### Curing

Xylan coatings are easily cured by conven-

tional methods, although the fastest, most efficient, least expensive of all is by ultraviolet light. Whitford was the first coating company to develop UV-curable coatings for flexible substrates.



*Xylan flexible finishes are designed to withstand the most demanding climatic conditions that vehicles can encounter, from blistering heat to sub-zero freezing, and still perform.*

The UV cure has these advantages:

- Uses a fraction of the energy of conventional ovens.
- Once powered up, the UV-cure equipment stabilizes in minutes, saving hours of time a conventional oven takes to reach full heat.
- Saves space by replacing the many feet of a curing oven with a cabinet not much larger than an office desk.
- Does not impart heat to the substrate, allowing temperature-sensitive materials to be used.

### **Typical applications**

Xylan flexible finishes have an exceptional track record in a diverse array of automotive applications. In glass-run channels, Xylan's remarkable abrasion resistance ensures long-lasting, smooth, silent window operation combined with consistently low levels of friction. When used on trunk (boot) seals, this versatile material provides excellent release even in the most adverse conditions.

Additionally, Xylan protects door seals, body seals, and drip rails by providing superior exterior durability. These products have surpassed the most rigorous automotive specifications for resistance to accelerated weathering and water immersion. Further, they have been engineered

to provide outstanding release characteristics, as well as to eliminate the "stick-slip" effect, which reduces noise attributed to the micro-movement of seals against glass and painted body panels.

### **Quality standards**

Whitford is one of a select group of companies which have achieved and maintained the highest quality standards in the industry.

This commitment to the most exacting standards is carried out by quality assurance teams at each of Whitford's worldwide facilities where these products are manufactured.

### **Choosing the right coating**

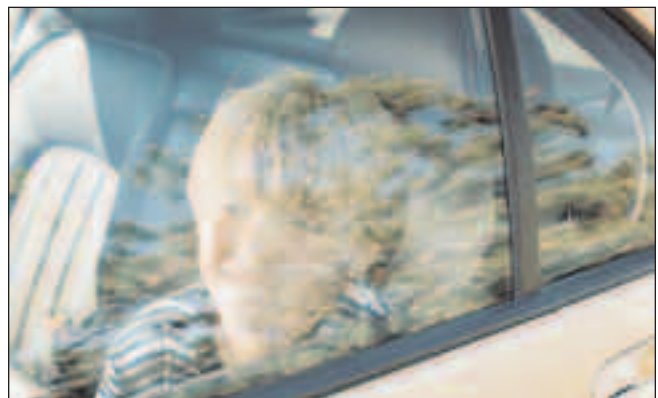
Whitford supplies coatings which have been formulated to solve specific problems on a variety of substrates. The coatings are classified into the following categories:

**1. Glass-Run Applications:** These products are designed to withstand the abrasive forces associated with the movement of glass windows along seals during operation.

**2. Weatherstrip Applications:** These include coatings for primary and secondary door seals, trunk (boot) seals, and hood (bonnet) seals. These coatings ensure freeze-release, weathering resistance, and noise suppression.

**3. Appearance Applications:** These coatings are generally recommended for decorative effects, and have excellent weathering resistance. They are used for a colored, textured (soft feel), or metallic effect.

*Note: Many Xylan coatings for flexible substrates have found use outside the auto industry.*



*Thanks to Xylan, the absence of itch and squeak lets the beauty of nature speak in its own quiet way.*

## 7. Whitford coatings and the textile industry

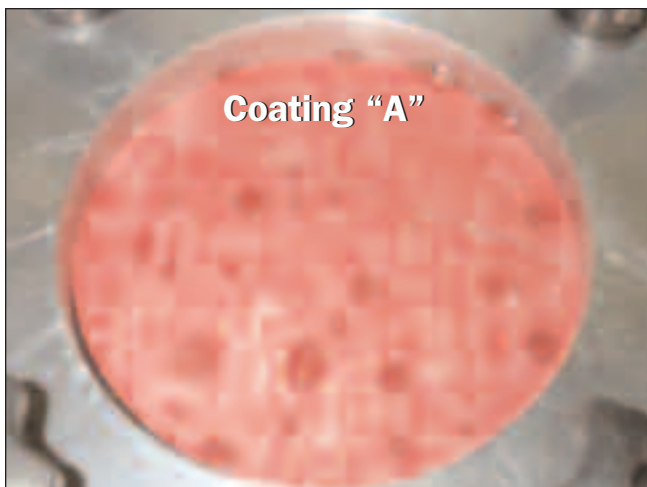
Perhaps the most revolutionary change in the world of textiles in several thousand years was the invention of synthetic fibers. The next most revolutionary change was the introduction of surface treatments to enhance the performance of textiles in many ways, such as water repellency, release, strength, resistance to chemicals, etc. Whitford has been a leader in the development of special coatings and finishes for the textile industry (such as EterniTex®).

EterniTex coatings are typically a blend of PTFE and other fluoropolymers reinforced by a matrix, designed to provide a wide range of benefits. Belts coated with EterniTex, for example, last up to ten times longer than the same belts coated with PTFE.

### Superior water repellency

There are many different treatments to help prevent the passage of water through fabric. Some repel moisture better than others. Some last longer. EterniTex offers a treatment that works better than most other treatments available. It offers additional benefits, too:

- Increased, longer-lasting water repellency.
- Increased fabric strength.
- Outstanding protection against ultra-violet damage.



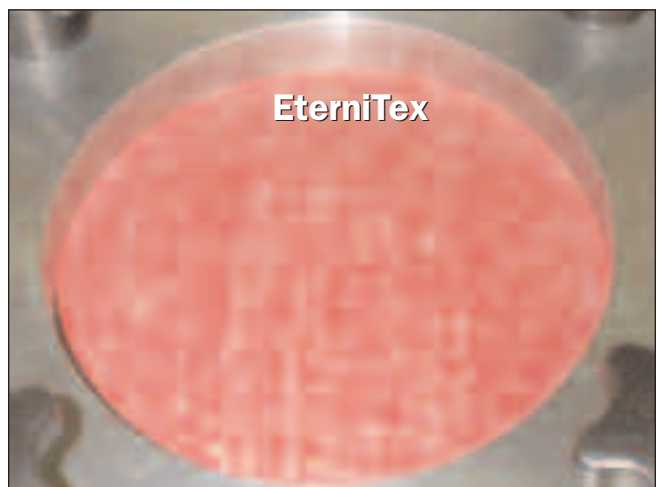
Coating "A" at 600 mm of hydrostatic head: the moisture penetrates from below and shows clearly on the top of the fabric.



Superb resistance to UV has been designed into EterniTex to prolong fabric life as well as protect fabric color.

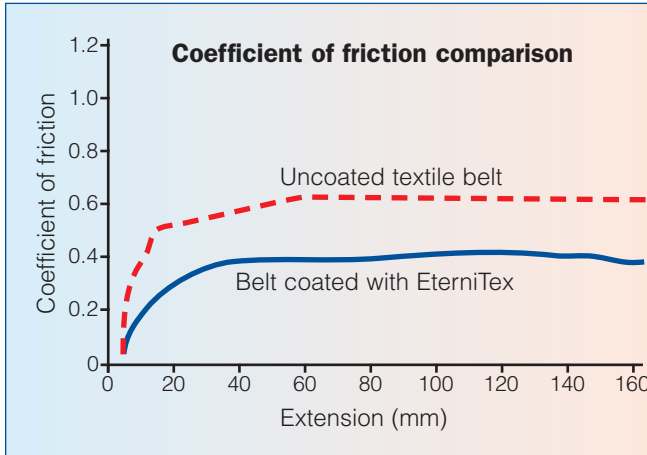
EterniTex also offers maximum release on high-temperature textiles. Typical application: high-temperature belting. EterniTex provides release up to 240°C/465°F and dramatically extends service life on a woven Kevlar® laminating belt compared to the same belt treated with silicone.

Other formulations, designed for low-temperature belt applications, provide outstanding resistance to abrasion and wear as belts bend around rollers and rub against the deck.



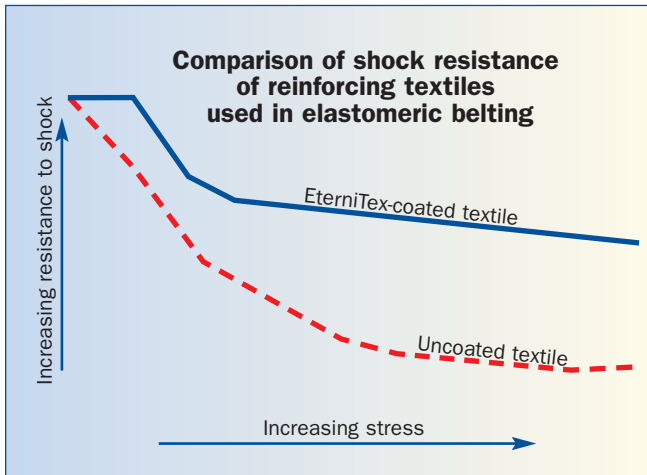
EterniTex, with its superior water repellency, shows no signs of water penetration, even at 2,000 mm of hydrostatic head (more than 3 times as much).

Service life is extended by at least several times. Another benefit: controlled friction, which contributes to longer life. And EterniTex can be made conductive to dissipate static discharge, always a threat to the workplace.



### Superior belting reinforcement

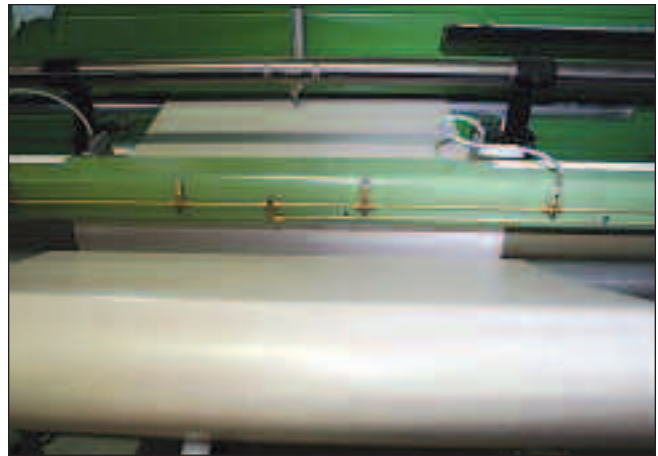
Textiles coated with EterniTex are also used as a reinforcing component to add strength to conveyor and power-transmission belts. The EterniTex coating creates an internal lubricating system within the weave of the fabric. This allows the fibers to move easily against each other as the belt is subjected to stress and strain, rather than to abrade each other. It also enables far greater capacity to absorb shock under tension — without damage to the textile.



Uncoated textile versus same textile coated with EterniTex. The uncoated version tolerates only limited deformation, while the coated version tolerates more, easily doubling the life of the belt.

### Superior thinking

The classic uses for textile coatings and fin-



A laminating belt coated with EterniTex for excellent release properties and longer belt life.

ishes are well understood, and it is generally a question of finding the material that provides the best solution for a particular application.

As new versions of EterniTex are developed, pioneering minds are taking these treated fabrics into entirely new areas, where they are having a significant impact. For example:

- Reprographic textiles
- Gasket materials
- Filtration textiles
- “Quiet” textiles
- Anti-wicking fabrics (lighter, more efficient sails for racing boats)
- Breathable waterproof fabrics (tents, tarpaulins).

These superior coatings of EterniTex are easily applied by all conventional methods used in the textile industry. And they are virtually all VOC-compliant.

*Note: Please see page 21 for application methods related to fabrics.*



EterniTex prevents wicking, reducing the weight of sails (and its UV resistance protects colors, too).

## 8. Calculating the real cost of a coating

That may sound like a simple task, but the answer is more complicated\*. If you judge price by the cost of a gallon, liter or kilo, you will not only be wrong but may wind up paying far more than you think. That's because a *lower* price for a given quantity or weight may mean a *higher* price per unit area of coverage.

The only valid way to compare the cost of a coating is to compare the cost of coverage of a given area at a specific film thickness (normally 25 microns/0.001 inch).

What gives a coating its coverage? The answer is the amount of solids by volume\*\* it contains (not solids by weight). And few coatings contain the same amount of solids. A typical (and real) example:

- Coating "T" costs \$80.00 per gallon. Coating "X" costs \$88.00 per gallon, or 10 percent more *per gallon*.

- Coating "T" has 13 percent volume solids. Coating "X" has 20 percent volume solids.

- 20 divided by 13 gives 1.54, so the gallon of Coating "X" has 54 percent more volume solids, which means that "X" covers 54 percent more square feet or meters than "T."

- Coating "T" gives 209 square feet of coverage. Since Coating "X" gives 54 percent more, it covers 321 square feet.

- \$80 (the cost of "T") divided by 209 gives a theoretical cost\*\*\* of 38.3 cents per square foot. \$88 (the cost of "X") divided by 321 gives a theoretical cost of 27.4 cents per square foot.

- You pay 10 percent "more" per gallon for Coating "X." Yet, in terms of coverage (actual cost), Coating "T" is really 40 percent more expensive than Coating "X."

There are a few other factors worth mentioning that are not directly related to cost/coverage:

1. Cost also depends on *transfer efficiency*, the percentage of coating that actually reaches and remains on the part. And transfer efficiency depends on several factors, including the formulation, the method of application used, the config-

uration of the part and the skill of the applicator.

2. The pretreatment you select can have a significant effect on cost. And it will affect performance of the part.

### Calculating coverage and cost

*The volume of one U.S. gallon represents 1604 square feet of liquid at a thickness of 25 microns/ 0.001 inch. The liter represents 1000 square meters at one micron (or 40 square meters at 25 microns). Obviously, these coverage figures change proportionally with coating thickness. With coatings that are less than 100 percent solids (all liquid coatings), these figures decrease proportionally. Use the following formulae to calculate coverage:*

Coverage/US gallon (in sq. ft.) =

$$\frac{(1604 \text{ ft}^2/\text{mil}) \times (\% \text{ solids by volume})}{\text{film thickness in mils}}$$

Coverage/liter (in sq. mtrs.) =

$$\frac{(1000 \text{ m}^2/\text{micron}) \times (\% \text{ solids by volume})}{\text{film thickness in microns}}$$

Finally, cost per unit of area =

$$\frac{\text{Cost/gallon or liter}}{\text{coverage/gallon or liter}}$$

*\*In some industrial applications, the coating may be only a small part of the total cost because of the cost of the labor needed to mask, rack, multicoat and package (as well as the cost of packaging materials).*

*\*\*Volume solids: all liquid coatings contain a variety of solid materials. When the coating is cured and the liquids driven off, only the solids remain. **Weight** solids are different, so don't be confused. Some solid ingredients weigh more than others, but don't cover as much area. Coverage depends on the thickness of the coating and the area covered, which is volume, not weight.*

*\*\*\*Theoretical cost assumes 100 percent transfer efficiency in application of the coating.*

Ask for a copy of Whitford's Cost Calculator, which comes as an Excel spreadsheet and automatically calculates everything you might want to know about a coating's coverage with the simple click of the mouse.

## 9. Protecting the environment

The so-called “Green Movement” is here to stay. And well it should be. Most of us have ignored the environment and contributed to the contamination of the world in which we live. One of the manifestations is the emphasis on VOCs — Volatile Organic Compounds\* — and the need to lower and control emission of these chemicals.

Whitford supports this and presents the following to help you understand the restrictions and measure the VOCs you may be emitting.

### What are VOCs?

VOCs are those ingredients in a paint or coating, defined as photochemically reactive by the USA’s Environmental Protection Agency, that escape into the atmosphere during the drying or curing process. With some exceptions, organic solvents are classified as VOCs.

In general, Whitford coatings come under the “Extreme Performance” industry guideline. (“Extreme Performance” includes coatings exposed to any of the following: the weather all of the time, temperature consistently above 95°C/205°F, detergents, abrasive and scouring agents, solvents, corrosive atmospheres or similar environmental conditions.) This guideline calls for the following limits on VOCs:

- Pigmented coatings: normal use . . . 3.0 lb/gal.
- Pigmented coatings:  
extreme performance. . . . . 3.5 lb/gal.
- Clear coatings: . . . . . 4.3 lb/gal.

Note: some countries measure VOC limits in *metrics* (grams per liter). To make the conversion, simply multiply the lb/gal by 120. For example: 3.5 lb/gal x 120 = 420 gms/ltr.

### A few more things to remember

In most of the United States, regulations permit the *averaging* of VOCs emitted during a 24-hour period. If you use a low-VOC material, you can also use the same amount of a high-VOC material (as high as the other was low) — provided the total amount of VOCs produced during

that period does not exceed the local limits.

There is little question that present VOC limits will be tightened as time goes by.

Southern California, with severe air quality problems, has led the way to more stringent regulations. Recently, the state raised the transfer efficiency requirement for wood-spray equipment from 40 percent to 65 percent. And legislation now limits VOCs for the “extreme performance” category for coating metal parts and products as follows:

Air-dried		Baked	
<u>lbs/gal</u>	<u>gms/ltr</u>	<u>lbs/gal</u>	<u>gms/ltr</u>
3.5	420	3.0	360

The calculations for these VOCs, of course, *exclude* the water and other exempt compounds.

### Not all the news is bad

Whitford has spent considerable time (and funds) engineering new coatings that conform to, and surpass, the most stringent regulations in the world. Many of our coatings are low-VOC and/or waterborne. We’re developing more products of this type, which will be announced as they come on stream.

If you’d like information on any of these products, or have questions regarding VOCs, please contact your Whitford representative.

### How to measure VOCs

There is a simple formula for calculating the amount of volatile organic compounds in any solvent-based coating:

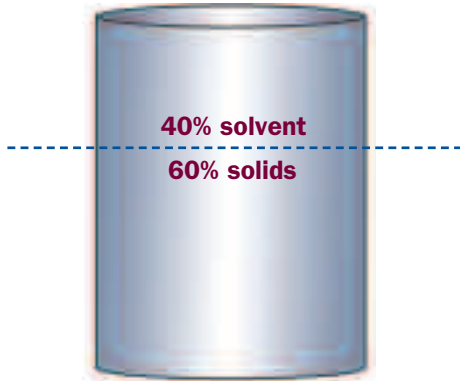
$$\text{VOCs} = \text{Density (lb/gal)} \times (1 - \% \text{ solids by weight})$$

The following examples show how the formula works in several types of coatings. (Note: these are white coatings with the ratio of TiO<sub>2</sub> to resin at 1 to 1; the assumed density of the organic solvent at 7.5 lb/gal; the density of the resin solids at 9.5 lb/gal.)

*\*Since “VOC” is an American term, the formulae are expressed in the units of measurement used by US regulatory authorities.*

## Solvent-borne coatings

By weight



### Specifications

% solids by weight . . . . 60  
 % solids by volume . . . . 43.1  
 Density . . . . . 10.67 lb/gal  
 Coverage . . . . . 691 sqft/gal @1.0 mil

To calculate the VOCs in this coating, substitute the correct numbers in this formula:

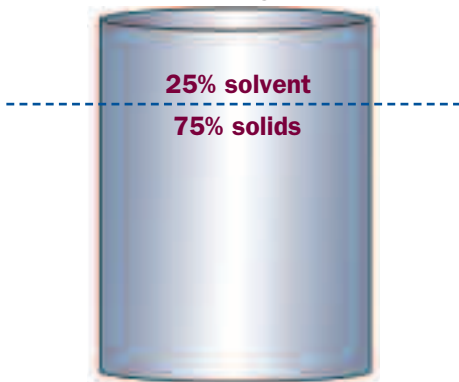
$$\text{VOCs} = 10.67 \text{ lb/gal} \times (1 - 0.60)$$

or

$$\text{VOCs} = 10.67 \text{ lb/gal} \times 0.4 = 4.28 \text{ lb/gal}$$

## High-solids coatings

By weight



### Specifications

% solids by weight . . . . 75  
 % solids by volume . . . . 60.3  
 Density . . . . . 11.93 lb/gal  
 Coverage . . . . . 691 sqft/gal @1.0 mil

The formula remains the same:

$$\text{VOCs} = 11.93 \text{ lb/gal} \times (1 - 0.75)$$

or

$$\text{VOCs} = 11.93 \text{ lb/gal} \times 0.25 = 2.98 \text{ lb/gal}$$

## Waterborne coatings

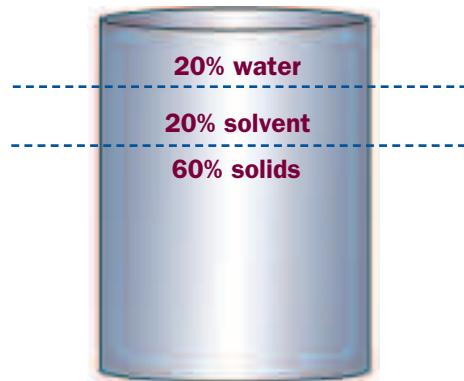
Volatile Organic Compounds are now calculated in terms of pounds per gallon of coating *less* water and *less* exempt compounds (of which there are few).

After removing any water and exempt compounds, the material remaining is expanded to the gallon equivalent — giving a VOC reading higher than the actual VOCs for that gallon.

In this example, the formula becomes slightly more complicated:

$$\text{VOCs} = \text{Density} \times \frac{(1 - \% \text{solids by weight} - \% \text{water by weight})}{(1 - \% \text{water by volume})}$$

By weight



### Specifications

% solids by weight . . . . 60  
 % solids by volume . . . . 44.4  
 Density . . . . . 10.98 lb/gal  
 Coverage . . . . . 712 sqft/gal @1.0 mil  
 Water weight @20% . . . 2.20 lb  
 % water volume  
 @8.33 lb/gal . . . . . 0.26 (2.20/8.33)

As before, substitute the values in the formula as we do here:

$$\text{VOCs} = \frac{10.98 \text{ lb/gal} \times (1 - 0.6 - 0.2)}{(1 - 0.26)}$$

or

$$\text{VOCs} = \frac{10.98 \text{ lb/gal} \times 0.2}{0.74} = 2.97 \text{ lb/gal}$$

If you'd like information on low-VOC products, or have questions regarding VOCs, please contact your Whitford representative.

## 10. Whitford's wide range of other products

Whitford manufactures the largest, most complete line of fluoropolymer coatings in the world — as well as a group of inorganic coatings.

Fluoropolymer coatings first became known as cookware coatings for their release and easy cleanup properties. They were not uniform and suffered from poor adhesion and durability.

Over time, and especially within the past few years, cookware coatings have evolved into increasingly sophisticated systems.

Here is a simplified list of Whitford products.



*Xylan: one-coat products.*



*Xylan Plus: two-coat products.*



*Xylan Eterna: three-coat products.*

Xylan is Whitford's brand name for a wide range of one-, two- and three-coat conventional and reinforced nonsticks. These coatings come in many different variations that offer a wide variety of performance levels at remarkably low prices.

Whitford uses the 7000 and 8000 designations for all Xylan coatings used for food contact or food-associated applications.

In the United States, the Food & Drug Administration (FDA) regulates coatings that come into contact with food. In other countries,



*Xylan on the inside, Xylac on the outside. Whitford coatings are used on cookware and bakeware in countries all around the world.*

similar regulatory authorities serve essentially the same purpose. While a complicated issue, it is worthwhile mentioning that any coating sold by Whitford for use in food applications meets the most stringent requirements of authorities throughout the world.

For answers to any questions in this complicated area, please contact Whitford's Regulatory Affairs Department.



Quantum2 is Whitford's nonstick "doubly reinforced to outlast all conventional nonsticks". Reinforced internally with hard ceramic particles, it has twice the durability of other reinforced nonsticks (that's why the "2" in "Quantum2"). It is ideal for cookware and bakeware.



QuanTanium is "reinforced with titanium to stand up to almost anything". That's because certain alloys of titanium, the lightest, toughest

metal known, are many times harder than the aluminum and steel used in the pots and pans themselves. While not as resistant to wear and abrasion as Eclipse, it consistently outperforms other internally reinforced cookware coatings.



Tests show that Eclipse outlasts other internally reinforced coatings by a significant factor. The reason: a unique primer reinforced with a high percentage of materials virtually as hard as diamonds. The midcoat also contains the reinforcing materials, leaving the topcoat dedicated entirely to “release”.

Eclipse is ideal for all types of aluminum cookware and bakeware, from smooth to grit-blasted to hard-anodized.



It was Excalibur that took nonstick coatings to the top end of the cookware market. That's because Excalibur is far more than a nonstick coating. It is a unique *system*. What makes it different from — and superior to — all other nonsticks is that it is *externally reinforced*.

The substrate is blasted with an abrasive. Then, white-hot particles of stainless steel are sprayed onto the surface. Welded to it, they form permanent “peaks and valleys” that provide a tough base for the nonstick coatings.



*The secret of Excalibur's durability: a patented stainless-steel alloy that forms a hard matrix into which three coats of tough nonstick are sprayed.*

A first coat of tough nonstick is applied, settling down into the valleys. Then, a second and third coat are applied, filling in all the valleys and covering the peaks. The coatings are now bonded to the surface for extra durability.

Excalibur combines the strength of stainless steel with the low friction and release characteristics of nonsticks.



The Suave line includes Whitford's “soft-touch” and “silk-touch” coatings. Suave offers new dimensions to the aesthetic and tactile possibilities of design. The soft-to-the-touch texture provides a firm, comfortable grip to help prevent slipping. Suave comes in an unlimited range of colors (color-matching is easy) and has good resistance to wear.

Suave is user-friendly, easily applied to phenolic, ABS, melamine, PVC, methacrylates, nylon, aluminum, iron, stainless steel, and cures at low temperatures.



*A Suave coating on many items provides a handsome, matte, rubber-like surface that improves grip and helps prevent things from slipping. And Suave comes in many eye-catching colors!*

## Ultralon

Acquired from ICI, Ultralon products come in one- and two-coat systems for industrial applications such as conductive multicoats for fuser and release rollers on photocopiers.

# Xylac

Xylac coatings are high-temperature decorative finishes for cookware and associated products, bridging the gap between acrylic paints and more expensive porcelain coatings while maintaining resistance to all household cleaning and dishwashing compounds.



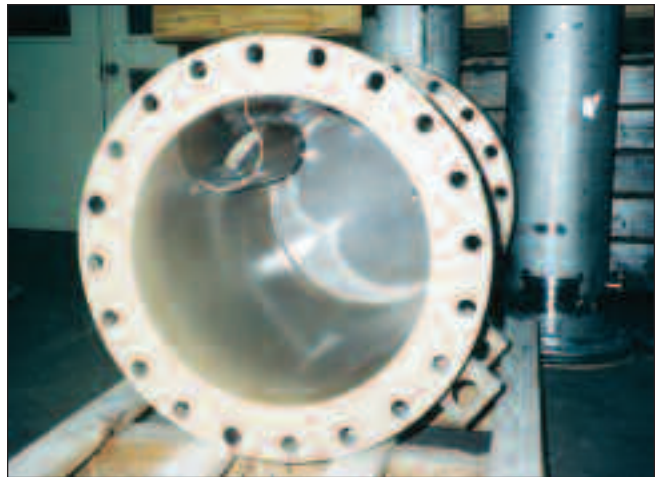
*Xylac decorative exterior coatings offer many options to add eye appeal to products, from high-gloss clear coats to colorful hammertone finishes.*

All are based on organic polymers with outstanding high-temperature properties, unlimited colors, one-coat coverage, excellent gloss retention at elevated temperatures, adhesion to all metallics, flexible cure schedule(s), minimal surface preparation, and high impact resistance.

# Dykor

Dykor 200s and 600s are combinations of resins from the polyvinylidene (PVDF) family and appropriate fillers, typically graphite and mica. When combined and applied at 0.6 mm/25 mils, the system provides outstanding chemical, corrosion and UV resistance.

Dykor 700s are attractive, functional powder coatings often used for wire goods and small electric appliances. A range of formulations is available offering various colors, levels of easy-clean, and operating temperatures. Dykor 800s are high-build fluoropolymer powder coatings for chemical resistance and high release.



*Dykor protects against many hostile environments. It comes in both liquid and powder forms.*

# Xylar

Xylar coatings are thin-film surface-protection finishes, ideal for extending the lives of parts where environments are extremely hot, corrosive and/or abrasive.

Based on an alloy of ceramic and metallic materials, Xylar forms a thin, hard, high-temperature-stable, sacrificial ceramic metallic barrier. In many cases, these coatings enable parts to be used in environments that would normally preclude their use. In others, they enable designers to replace expensive super alloys with less costly metals coated with Xylar. Topcoats may be added to modify or improve the properties of the basecoats (such as increasing corrosion resistance or decreasing coefficients of friction).



*Xylar 2 Silver protects against high-temperature oxidation, provides sacrificial corrosion protection and resists atmospheric and salt-water corrosion.*

## 11. Polymeric Systems, Inc.

Late in 2003, Whitford reached an agreement with the shareholders of Polymeric Systems, Inc. (PSI), to purchase the company. Polymeric Systems, Inc. develops and manufactures high-performance sealants, caulks, and epoxy adhesives. Its leading product line is a 2-part epoxy putty stick, offered in a range of formulations, each for specific applications.

The origins of PSI date from 1959, when Ted Flint, a chemical engineer, and a partner started a business to manufacture adhesives and sealants. That business was sold to Teledyne Corporation in 1967.

Ted Flint then formed Polymeric Systems in 1969. Its first product was a line of sealants for the insulating glass industry.

In 1972, Mr. Flint developed a 2-part epoxy putty product with an innovative core/shell (cylinder form) for easy user application. Strong patent protection was secured for the product

technology, with additional patents obtained for improvements incorporated into the expanding product line. The company experienced steady growth through its sale in 2003.

The company was merged into Whitford and is now housed in Whitford's headquarters in Pennsylvania, due west of Philadelphia. Polymeric Systems' operations occupy 80,000 square feet in Whitford's multi-story building on sixty-three acres of property (which allows substantial room for expansion).

While PSI does private-label and toll manufacturing, it also markets its own products.

PSI-labeled products include a range of construction sealants and epoxy putties, pastes and gels (all of which are available for private label). PSI's entire product line is either low in solvents or solvent-free. A new line of non-irritating epoxy adhesives has just been introduced and patents filed on this unique material.



One of PSI's leading product lines is a series of 9 patented Epoxy Putty Sticks, each custom-formulated to provide fast, easy and permanent repairs to a series of materials from concrete to wood to plastic to metal.



*QuikWood® epoxy patches wood easily and quickly. It can be sanded, stained and painted.*

PSI's epoxy putty sticks consist of pre-measured components (an activator and base) in cylinder form, allowing the required portion to be cut, then mixed and molded by hand prior to use. This line has evolved into a family of nine products specifically formulated to adhere to a variety of surfaces — including metals, wood, plastic, fiberglass and concrete — and for a range of temperature and moisture conditions. There is even a version that can be mixed and applied under water for plumbing or marine use.

In recent years, the Company has developed some PSI-branded sales of epoxy sticks through do-it-yourself (“DIY”) retail channels.

PSI has two other major product-line offerings: urethane- and silicone-based elastomeric sealants. These are reactive products of single, 2-part, and multi-part components, packaged in liquid or paste form in containers from tubes to drums. The primary markets for these elastomeric sealants are the construction, marine, automotive, and wood construction industries.



*Sili-Thane 801 offers all the benefits of silicone and polyurethane-type sealants with none of the disadvantages. There are no solvents or isocyanates. VOCs are less than 1%. 801 adheres well to a wide range of substrates, resists discoloration and is paintable.*

In 1995, PSI brought to market a new packaging system called SUM PAK.® This is a single-use pack of a two-component reactive adhesive or sealant. The package holds the two components in separate pouches until pressure is applied (such as with a pencil or pen pressing over them), at which point the components are released into a series of chambers connected with mixing holes. The top is cut with scissors, and the same pencil or pen moves up the package, forcing the two components through the mixing holes until they reach the top, thoroughly mixed (actually achieving molecular mixing). The glue is applied as needed. The remarkable pack is easy to use, with no mess, and offers an extended shelf life.



*PSI's SUM PAK®: The patented package uses upward pressure to burst the two pouches holding separate ingredients, which are then mixed — perfectly — by the channels through which they pass on the way to the top. “Molecular” mixing in a matter of a few seconds!*

PSI's production is geared to accommodate varying batch sizes to increase flexibility — a requirement for most private-label manufacturers. Many of these systems have been custom-designed for the PSI products, particularly the epoxy putty sticks. Its packaging systems capabilities include tube and cartridge filling systems, pail filling, labeling and capping, blister packs, as well as a custom-designed form, fill and seal machine for their SUM PAK products.

To no small extent, the products produced by PSI overlap those produced by Whitford (especially in terms of raw materials), so the coming together of the two companies made good sense from every perspective — and from the very beginning.

## 12. A word from our sponsor

**W**hitford Corporation was founded in West Chester, Pennsylvania, in 1969. Six months later, Whitford Plastics Limited was founded in Runcorn, England. From the start, Whitford has taken a global approach to its business.

Since then, Whitford has grown into a world-wide organization with manufacturing facilities in seven countries, direct employees in eight more, and agents in an additional 25. We operate in more than fifty countries.



*Whitford suggests that customers send samples of their finished products for laboratory testing to assure maximum coating performance.*

### What business are we in?

Some companies develop products in the abstract — and then bend problems to fit the products. At Whitford we take the opposite point of view.

We believe that we are in the business of solving problems more than the business of selling products. The coatings we engineer are simply the vehicles by which we solve problems for our customers.

We believe that the way to a better product is to start with a specific problem, then create a product specifically designed to solve it.

It is this approach to the business that has led Whitford to have the largest, most complete line of fluoropolymer coatings in the world — despite the fact that one of our competitors is larger than we are in terms of annual turnover.

Our worldwide mission statement summarizes what we do:

*“We provide attentive, innovative solutions to our customers’ problems via our products and related technology.”*

This philosophy, of course, demands a serious commitment to research and development.

One advantage that Whitford enjoys is that we are a private company, so we can allocate our funds as we see fit. As a result, we commit an annual average of at least six percent of our sales to R&D, something disinterested shareholders of a public company (who expect larger dividends every quarter) would be unlikely to permit.

### May we help?

You may have a design problem that a fluoropolymer coating could solve. If so, we’d like to hear from you. Please tell us about the problem in sufficient detail so we can determine if we have the precise product to solve it.

If we don’t, we’ll create one.

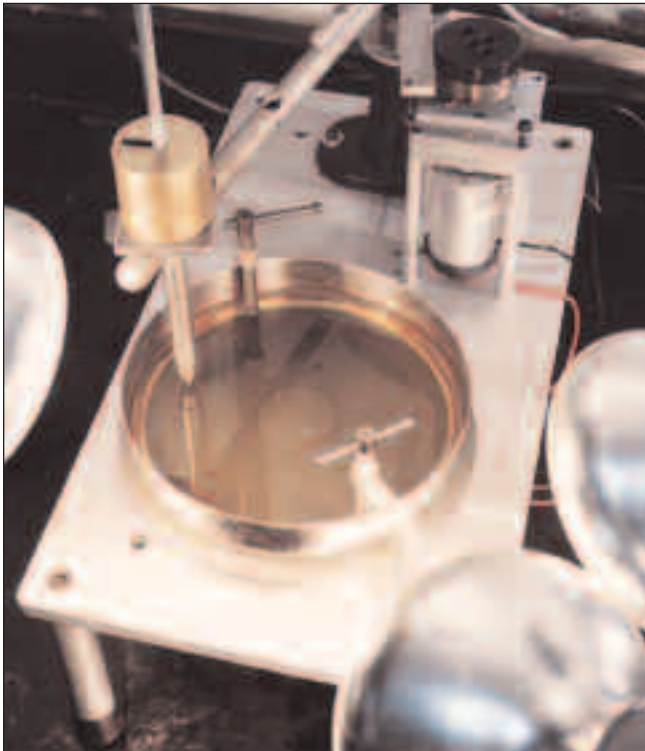


*Whitford’s Rheometer measures the flow and deformation of component materials in a coating formula, key to film formation, curing and aging.*

## Index and glossary

**T**hese definitions are given primarily in their relation to high-performance fluoropolymer coatings and their use in this publication.

**Abrasion:** A wearing, grinding, or rubbing away by friction. Pages 3, 5, 25, 26, 27, 33.



*Whitford's unique Gyrograph provides a sensitive measure of abrasion and coating adhesion, especially of intercoat adhesion (a common source of failure).*

**Additives:** Materials added to coatings to enhance certain properties. Page 13.

**Alkaline wash:** Cleaning process that employs a high pH solution (caustic). A good choice for parts with little buildup of contaminants. Pages 19, 20, 24.

**Aluminum oxide:** Hard particulate medium used in grit blasting to clean and roughen surfaces that are to be coated. Pages 19, 41.

**Anodizing:** Creating a hard oxide layer on aluminum parts via an electrolytic process. Unsealed hard anodized surfaces have a porosity that makes them excellent substrates for coatings. Page 20.

**Babbitt metal:** a soft alloy of tin, copper and antimony. Page 24.

**Binder:** Tough polymer that acts as an adhesive to join elements of matrix coatings. Pages 2, 3, 4, 5, 12, 23, 39, 40.

**Boundary lubrication:** Condition in which a lubricating film between sliding surfaces has lost its hydrodynamic property due to heat, pressure or low speed. As a result, the surfaces are virtually touching, separated only by a layer of lubricant too thin to be effective. Potential for metal-to-metal contact and damage to surfaces is great. Page 8.

**Break in:** Initial wear of mechanical components when large surface asperities (peaks) can cause high friction and wear rates. Page 15.

**Brinelling:** Surface fatigue of steel components that undergo cyclic stress, which causes minute flexing resulting in work-hardening of the surface. Eventually, brinelling may cause surface cracking or spalling. Page 5.

**Buffing/Burnishing:** Process of polishing a cured coating to enhance release and low friction properties. Pages 9, 10, 23.

**Carrier:** Liquid portion of a coating in which solids are dissolved or suspended. Pages 3, 4, 20, 22.

**Cold flow:** Tendency of plastic materials to migrate slowly under heavy loads and/or over time. Pages 3, 12.

**Conductor:** Material that can support flow of electrical current. Coatings are normally insulators, but can be modified with certain fillers and pigments to make them conductive. Page 13.

**Corrosion:** Process of metal decomposition (oxidation) in which metal ions are united with oxygen to form metal oxides. Fluoropolymer coatings provide excellent barriers against most corrosives. Pages 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 14, 16, 17, 19, 20, 23, 24, 34.

**Crosslinking:** Quality of thermosetting plastic resins in which polymer chains combine during curing process. In general, the greater the crosslinking, the tougher and more chemically resistant the coating. Page 23.

**Cryogenic:** Temperatures less than -130°C/-200°F. Bonded dry-film lubricants continue to perform at these temperatures. Pages 5, 12.

**Curing:** Process of bonding or fusing a coating to a substrate. Pages 1, 4, 18, 21, 22, 25, 26, 30, 37.

**Dielectric strength:** Ability of a coating to resist the passage of direct electric current. Page 13.

**Dip/spin:** Coating application technique in which small parts are placed in a basket that is lowered into a coating bath, then raised and spun to remove excess coating. An economical system for coating high volumes of small parts. Pages 3, 4, 11, 20, 21.



*Dip/spinning is ideal for small, complicated parts.*

**Dry (solid) lubricants:** Solid materials such as PTFE, Molybdenum Disulfide ( $\text{MoS}_2$ ) and graphite that have low coefficients of friction. Pages 2, 7.

**Elastomers:** Any of various elastic substances resembling rubber. Page 18.

**Electrostatic spray:** Spray application process in which the coating and part to be coated are oppositely charged; process provides excellent “wrap” of coating around the part, even on sides opposite the spray gun. Page 21.

**Engineering plastics:** Plastic resins that have high-performance properties such as high temperature stability, hot hardness, abrasion resistance, and corrosion resistance. Page 2.

**EPDM:** Ethylene-propylene-diene monomer, an elastomeric substitute for rubber used extensively in the automotive industry. Pages 18, 25.

**Epoxy:** A flexible resin, usually thermosetting, made by polymerization of an epoxide and used

chiefly in coatings and adhesives. Pages 18, 35.

**Fabrics:** Woven or nonwoven materials that can be impregnated with fluoropolymer coatings to impart low friction, improve chemical resistance, and increase strength. Pages 18, 19, 21, 28.

**FEP (fluorinated ethylene propylene):** A thermoplastic member of the fluoropolymer family of plastics. FEP has the best nonstick and nonwetting properties of these materials. Pages 3, 4, 13.

**Fillers:** Pigments and other solids used to alter properties of coatings. Pages 3, 4, 17, 34.

**Flashing:** A brief subcure (at lower temperatures than the final cure) to drive off solvents/carriers prior to full cure. This helps prevent bubbling. See “Partial cure.” Pages 1, 21, 22.

**Fluoropolymers:** Family of engineering plastics containing fluorine, characterized by high thermal stability, almost universal chemical resistance and low friction. Pages 2, 4, 18, 23, 27.

**Fretting:** Wear phenomenon caused by vibration among tightly clamped or fastened surfaces. Pages 10, 11, 19.

**Friction (dynamic):** Resistance to continued motion between two surfaces; also known as sliding friction. Pages 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 15, 16, 18, 23, 24, 25, 26, 28, 33, 34.

**Friction (static):** Resistance to initial motion between two surfaces. Pages 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 15, 16, 18, 23, 24, 25, 26, 28, 33, 34.

**Graphite:** Carbon-based dry lubricant that is preferred for high-temperature applications. Pages 2, 3, 4, 7, 13, 34.

**Hot hardness:** Ability of a coating to retain hardness and wear resistance at elevated temperatures. Usually a characteristic of coatings based on thermosetting resin binders. Page 38.

**HVLP (high volume, low pressure):** A type of spray gun utilizing high pressure in combination with low air velocity to increase transfer efficiency and reduce air pollution. Pages 4, 20.

**Hydrogen embrittlement:** Embrittlement of carbon steel caused by absorption of atomic hydrogen in plating, pickling or acid cleaning processes. Pages 11, 19.

**Kesternich:** German scientist who developed the Kesternich Cabinet and test method used for



*Whitford keeps Kesternich cabinets running virtually all the time at several of its research laboratories around the world.*

acid-rain simulation (DIN 50018). Page 39, 40.

**kN:** Kilo-Newton, a measure of force, also expressed as “pounds force” (lbf). Page 14.

**lbf:** Pounds force, a measure of force, also expressed as “kilo-Newtons” (kN). Page 14.

**μ:** One micron, a millionth of a meter. Also expressed as μM, or micro-meter. Page 24.

**μ inch:** One micro-inch, a millionth of an inch. Page 24.

**Matrix coating:** One in which some ingredients, such as the lubricant (PTFE), which is soft, are enveloped in others (the matrix, such as harder, more wear-resistant binders). Pages 3, 4, 8, 15.

**Moly, moly disulfide, molybdenum disulfide, MoS<sub>2</sub>:** Four names for the same naturally occurring substance that has good low-friction and high load-bearing properties. Pages 2, 3, 4.

**Noise dampening:** The absorption of sound vibrations. Xylan coatings form good noise-reducing surfaces. Page 12.

**Oleophobic:** Oil-shedding. Page 5.

**Partial cure:** A process sometimes utilized when multiple layers of fluoropolymer coatings are to be applied. The first coat is incompletely cured. The second coat is applied and both are fully cured together. See “Flashing”. Page 39.

**PFA (perfluoroalkoxy):** Thermoplastic member of fluoropolymer family of engineering plastics, characterized by excellent release and low friction. Pages 3, 4, 13.

**Phenolic:** A resin or plastic, usually thermosetting, made by condensation of a phenol with an aldehyde and used for molding, insulating, coatings and adhesives. Pages 18, 33.

**Phosphating:** Surface pretreatment used on ferrous parts that provides a very thin crystalline film that enhances both corrosion resistance and adhesion. Pages 19, 20.

**Polymer fume fever:** 24-hour flu-like symptoms (with no known long-term effects) caused by inhaling the gases released during fluoropolymer decomposition. Page 23.

**Post cure:** A second cure at high temperature to enhance specific properties such as release and nonwetting. Page 23.

**Postforming:** Process of shaping parts after a coating has been applied and cured, a technique commonly used with stamped, blanked, or spun parts. Page 23.

**Powder metal:** Material formed by compressing metal particles and heating (sintering) to solidify and strengthen them. Pages 13, 14.

**PPS (Polyphenylene sulfide):** A thermoplastic engineering polymer second only to PTFE in chemical resistance. In fact, PPS is unaffected by any solvent to 400°F/205°C. Page 18.

**Preheating:** Warming of parts prior to application of coating, recommended when adhesion is critical and when parts are being coated in humid atmospheres. In some cases, this technique can be used to achieve higher-than-normal film builds. Pages 20, 23.

**Preloads (for fasteners):** The “tightness” of a fastener equals the make-up energy applied minus the energy required to overcome friction at the fastener’s bearing surfaces and threads. Page 11.

**Pressure spraying:** Coating technique similar to siphon spraying, except that the coating is delivered from a pressurized pot to the spray nozzle under positive pressure. Generally used for high-volume production. Page 24.

**Pretreatment:** Processes for cleaning and conditioning a substrate to be coated. Next to the choice of coating, this may be the most important factor in the use of high-performance

coatings. Pages 19, 20, 25, 29.

**PTFE (polytetrafluoroethylene):** A thermoplastic member of the fluoropolymer family of plastics. PTFE has the lowest coefficient of friction of any known solid and the highest temperature resistance of the fluoropolymers. Pages 3, 4, 5, 6, 7, 8, 9, 10, 13, 16, 19, 23, 27, 28.

**PV, limiting PV (LPV) factor:** Mathematical limit of a coating's load-carrying ability and wear resistance under bearing conditions. Pages 7, 8, 11, 23, 25, 33, 34.

**PVDF (Polyvinylidene fluoride):** High-molecular-weight thermoplastic of vinylidene fluoride with greater strength, wear resistance and creep resistance than FEP, PFA or PTFE. Page 34.

**Resistance (electrical):** The opposition offered by a coating to the passage through it of an electric current. Pages 1, 2, 3, 5, 10, 11, 12, 17, 20, 22, 23, 26, 27, 28, 33, 34.



*Salt-fog cabinets perform an ongoing and important role at Whitford in the development of fastener-class coatings with better resistance to corrosion.*

**Salt fog:** ASTM B-117 test procedure that simulates the corrosive environment caused by road salt and marine spray. Pages 10, 11.

**Sand blasting (also grit blasting):** Surface cleaning and roughening process that provides a mechanical "tooth" to aid coating adhesion. Media include aluminum oxide, carborundum, even crushed walnut shells. The medium must be chosen to match the substrate and the for-

eign material on the substrate to be removed. Pages 19, 20, 23.

**Static electricity:** An imbalance of positive and negative charges usually associated with two nonconductors rubbing together. Page 5.

**Stick-slip (chatter):** Unstable sliding condition in which movement of one part over another starts and stops, caused by temporary overcoming of static coefficient of friction. Page 26.

**Substrate:** Any surface to be coated. This can include metals such as steel, cast iron, bronze, brass, aluminum, stainless steel, chromium, and (with special precautions) nickel. Paper, most plastics, wood, leather, fabrics, and glass can also be coated. Pages 1, 3, 4, 10, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 33, 36.

**Thermoplastic:** Plastic resin that softens when reheated. Pages 3, 25.

**Thermoset:** Plastic resin that crosslinks during cure so that it does not soften when reheated. Pages 3, 5, 12.

**Transfer efficiency:** The amount (percentage) of a coating that actually reaches and stays on the part being coated. Some coating methods give far higher transfer efficiency than others. Pages 20, 21, 29, 30.

**Volatile organic compounds (VOCs):** The ingredients in a paint or coating, defined as photochemically reactive by the USA's Environmental Protection Agency, that escape into the atmosphere during the drying or curing process. Pages 20, 30, 31.

**Wear:** Deterioration by friction (abrasion, spalling, cutting, fretting). Pages 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 15, 16, 19, 22, 23, 24, 27, 33.

### **For more information...**

*While this document may seem lengthy, it is only scratching the surface of the knowledge that we have acquired over the years.*

*Whitford offers many brochures, flyers and the like with far greater detail on specific subjects.*

*If you'd like more information on a given subject, please contact us.*



### **How to contact Whitford**

Whitford manufactures in 7 countries, has employees in 8 more and agents in an additional 25. To find the office nearest you, please visit our website: [www.whitfordww.com](http://www.whitfordww.com) or email us at [sales@whitfordww.com](mailto:sales@whitfordww.com).

# **Whitford**

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