INTRODUCTION

What is TIOLOUB™ 1175? It's a solid, dry lubricant that is applied in a very thin film to lubricate and prevent galling on very high tolerance surfaces.

What is TIOLOUB™ 1175F? It's a solid dry film lubricant that incorporates a sealing agent which enables usage in areas that come in contact with moisture.

What makes them so different from other dry film lubricants? Unlike other products, Tiolube™ 1175 and 1175F are totally inorganic, and in addition they do not contain any ceramic, vitreous or sodium silicate materials.

A WORD ABOUT SOLID FILM LUBRICANTS

TIOLOUB™ 1175

is unaffected by hostile environments. To function effectively in the aerospace environment, a lubricant must handle extreme, rapid changes in temperature. It must work in vacuum as well as in atmospheric conditions. It has to withstand zero gravity and multiple gravities. The lubricant that does this is TIOLOUB™ 1175, an inorganic bonded dry-film lubricant which utilizes a specially formulated molybdenum disulfide (MoS₂) pigment working in combination with other lubricative pigments. TIOLOUB™ 1175 has been working in the challenging aerospace environment since 1966 and it met all the changing requirements. TIOLOUB™ 1175 prevents galling and increases the wear-life of metal-to-metal surfaces. Because of its low coefficient of friction and its unique binder, it offers a combination of performance not available with other solid film lubricants.

Most lubricants establish their own reputation in industry. No lubricant is a panacea, but TIOLOUB™ 1175 is a unique inorganic solid film lubricant and when used properly will offer a wide range of benefits.

Solid film lubricants are made up of three basic components:

1. Lubricative constituents or pigments to provide low shear strength; i.e., lubrication.
2. A binder system to adhere and to maintain a relatively large quantity of these constituents on the surface.
3. A propellant or carrier—usually consisting of solvent systems, plasticizers, and film formers for controlled application.

BINDER SYSTEMS, often called "binders," fall in the following categories; thermoplastic vinyl or alkyd resin types, thermosetting phenolic or epoxy resin types (most standard and common), silicone resin binders, sodium silicate binders, phosphoric acid binders, ceramic or vitreous binders, borate-type binders; and a couple of binder systems which require complicated processing, such as a MoS₂ "in situ" film binder and a binder system applied with a high-velocity impingement process. The TIOLOUB™ 1175 solid dry film lubricant is a complete divergence with respect to these conventional binder systems because it forms a direct chemical bond. It is a unique binder system—forming an unusual tenacious bond with all metals, such as stainless steel, aluminum and even titanium.
TIOLUBE® 1175

has met the test in outer space. Liquid lubricants often cannot be used in aircraft missiles and manned spacecraft. That's where dry-film lubricant TIOLUBE® 1175 is at its best. TIOLUBE® 1175 has repeatedly withstood temperatures from +1200°F plunging to minus 420°F. It has voyaged with TRW's Viking probe to the far reaches of the solar system, and flies in the nation's defense aboard such advanced aircraft as the Grumman F-14 and Fairchild-Republic's A-10. When the Rockwell Space Shuttle boosts into orbit, TIOLUBE® 1175 will be aboard, for the repeated demands of this multiple re-entry. TIOLUBE® 1175 is the solution to a wide variety of pistonbore applications in valves, regulators, temperature sensors, as well as engine bleed and airborne environmental control systems.

QUALITIES

The complex binder system of TIOLUBE® 1175 is established by a unique form of electrodeposition based upon a self-induced type of electrophoresis. This relatively slow chemical reaction is accelerated by external thermal stabilizing; 400°F with steel surfaces and only 325°F for aluminum.

COMPATIBILITIES

The lubricity of TIOLUBE® 1175 is provided by a specific combination of friction-and-wear-reducing constituents of controlled particle sizes, such as molybdenum disulfide, graphite and several others. This carefully selected blend of lubricative constituents is completely non-toxic with respect to dermal, as well as respiratory, toxicity. It can therefore be used in breathing oxygen systems, such as a thread lubricant in tubing or fittings; as a valve lubricant; or on other life support system attachments. TIOLUBE® 1175 inhibits fretting corrosion by separating highly loaded surfaces under extreme vibration conditions. In addition to its unique tenacity, load-impact resistance and thermal stability, the composition of TIOLUBE® 1175 is not seriously altered as a result of nuclear radiation. Its wear-life is unaffected after exposure to several levels of gamma or neutron irradiation.

PRODUCT DESCRIPTION

TIOLUBE® 1175 has been developed after three years of research and supported by more than 20 years of experience in dry lubrication and related fields.

SOME RECOMMENDED USES

TIOLUBE® 1175 has been successfully used on spherical bearings, ball bearings, sleeve bearings, ball screws, gears, cams, linkages, clamps, clevises, rivets, nuts, bolts, all types of special fasteners, couplings, shafts, journals, chains, and miscellaneous moving parts.
**EVALUATION OF TEST METHOD**

**FLUID RESISTANCE**
After immersion in:
- Xyline--Dioxane
- Trichloroethylene (MIL-P-27602)
- Carbon Tetrachloride
- Perchloroethylene
- Toluene--Naphthene
- Acetone-Hexane-Skyclol
- Kerosene--Gasoline
- Ethyl alcohol--Methyl alcohol
- Freon TF (trichlorotrifluorethane)
- Liquid nitrogen--Liquid helium
- Liquid oxygen (LOX)

After immersion in:
- MIL-S-3138, hydrocarbon fluid
- MIL-H-5606B, hydraulic fluid
- MIL-L-3822, engine oil grade 110
- MIL-0-3275, grease
- MIL-L-5624, jet fuel grade JP-4
- MIL-L-7807, oil
- MIL-O-5572, fuel grade 115-145
- MIL-H-8446A, hydraulic fluid
- MIL-F-5586, anti-icing fluid
- MIL-O-7116, greases
- Silicone fluids DC 200 and DC 550
- Mineral oil

**LOX IMPACT SENSITIVITY**
ABMA-LOX Test per NASA-MSC specification STD-106, requiring insensitivity to impact energy levels up to 72.5 ft.lbs.

**VACUUM OF SPACE COMPATABILITY**
A) After 21-days exposure to a vacuum of 10. 1 x 10⁻⁷ Torr or better @ 72°F.
Lubricant was applied on both sides of a .01 in. dia. wafer, 0.015 in. thick and made of PH15-7 steel. Coating film thickness was .0004 ± .0001".

B) After 16-day exposure to a vacuum of 10. 1 x 10⁻⁷ Torr or better @ 350°F.

**ALPHA LFW-1 TEST DEVICE**
Mild steel test specimens of R, 58-60 hardness. Thunke-type test ring coated with .0004 ± .0001" film thickness. Exposed to 630 lbs load = approx 90,000 psi average bearing load. Load was instantaneously applied. Speed 72 rpm or 26 ft/min. with unidirectional motion @ 72°F. No vacuum. Surface finish of unlubricated rider block was in the order of 0.18 in. microns rms. Neither specimen was phosphated prior to lubrication.

**TITANIUM FASTENER APPLICATION**
Locking torque test per MIL-N-25027B or .26 bolt made of 6Al-4V titanium of the NAS 674 type, versus uncoated A-286 nut of the MS21943 type.

---

**REQUIREMENTS OF LIMITS**

| No determination of film, swelling, blistering or loss of adhesion for 120 hrs. at room temp. under static conditions* |
| No determination of film, swelling, blistering or loss of adhesion for 24 hrs. at 72°F under static conditions* |
| No detonations, flashes, burning or charring of aluminum and stainless steel test cups after 20 consecutive impacts |
| No determination of film, swelling, blistering or loss of adhesion for 24 hrs. at 72°F under static conditions* |

**AVERAGE RESULTS & REMARKS**

| Unaffected by exposure to these various fluids. Passes. |
| Unaffected by exposure to these various fluids. Passes. |
| No effects whatsoever after a total of 60 impacts or three qualification test runs. Passes. |
| Weight losses observed were less than .001% of the total weight of the original materials. Passes. |
| Weight losses observed were smaller than .005% of the total weight of the original material. Passes. |
| 409,652 cycles, or 147,559 ft. The Uk = .008. 315,107 cycles, or 113,436 ft. The Uk = .025. This is the average of 9 tests. Passes. |
| Max. locking torque range 35-205 in-lb. Breakaway range 35-180 in-lbs. Passes. (All other inorganic products tested failed, including nickel and chrome plated bolts.) |

*As opposed to dynamic load conditions such as in sliding bearings.
FIGURE 1—Phenolic resin bonded solid dry film lubricant directly attached to a surface of 32 microinches rms.

FIGURE 2—Phenolic resin bonded solid dry film lubricant superimposed on a phosphate conversion coating which, in turn, was applied on a metal surface of 32 microinches rms.

FIGURE 3—1175 solid dry film lubricant with complete inorganic binding on a metal surface of 32 microinches rms.

<table>
<thead>
<tr>
<th>Corrosion Protection Guide for Most Steels When Coated with Ticolube 1175</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron-Nickel</td>
</tr>
<tr>
<td>High-Nickel</td>
</tr>
<tr>
<td>Super Alloys</td>
</tr>
<tr>
<td>High-Cobalt</td>
</tr>
<tr>
<td>Austenitic</td>
</tr>
<tr>
<td>Chromium-Nickel Steels</td>
</tr>
<tr>
<td>Precipitation Hardened</td>
</tr>
<tr>
<td>Hardened Steel</td>
</tr>
<tr>
<td>High-Manganese Stainless and Alloy Steels</td>
</tr>
<tr>
<td>Martensitic</td>
</tr>
<tr>
<td>Chromium Steels</td>
</tr>
<tr>
<td>High-Strength and Mar-Aging Steels</td>
</tr>
<tr>
<td>Tool and Die Steel</td>
</tr>
<tr>
<td>Tool Steels</td>
</tr>
<tr>
<td>High-Speed Tool Steels</td>
</tr>
<tr>
<td>Carbon and Low Alloy Steels</td>
</tr>
<tr>
<td>Tool Steels</td>
</tr>
</tbody>
</table>

COLOR CODE: 
- No plating required whatsoever.
- Plating preferred, especially in cases of direct exposure to severe corrosion-inducing environments.
- Plating definitely required.

4
COEFFICIENT OF FRICTION

It is impossible to make a single statement regarding the kinetic or static coefficients of friction of TIOLOBE™ 1175. However, as a general design rule, it is reasonable to incorporate in the stress calculation a $U_k = .10$ maximum under normal conditions and a $U_k = .05$ after including a bench cycling or burnishing operation prior to installation. The static coefficient of friction $U_s$ plays a role of lesser importance with solid dry film lubricants than the $U_k$. The $U_s$—usually 20-30% higher than the $U_k$—shall, therefore, no longer be considered. The $U_k$ is always given as a range, never as an absolute number. This is because the freshly applied 1175 lubricant initially undergoes a so-called period of "run-in" or "burnishing"—approximately the first 25-35 linear sliding feet—like most other products. The relationship between the initial high $U_k$ and its rapid decline to a steady-state value for most of its cyclic wear-life is illustrated in the following diagram:

The coefficient of friction of TIOLOBE™ 1175 comes quite close to that of conventional oils and greases, especially after it is burnished in.

1. The higher the bearing load, the lower the kinetic coefficient of friction. Load increase tends to promote the laminar re-orientation of the 1175 lubricative pigments into an ideal pattern. The re-orientation pattern eliminates interstices, which in turn reduce the internal shear stresses, thereby lowering friction coefficients.

2. Continuous exposure to light loads, especially under very low speeds, gives substantially higher kinetic co-efficient of friction and subsequent short wear-life. This can be prevented by initial bench cycling under higher loads or burnishing before the part is installed, since the relatively soft upper strata (layers) of the TIOLOBE™ 1175 are not sufficiently compacted and therefore are rapidly removed by the sloughing-off action of loose surface particles.

3. Increased substrate hardness gives lower coefficients of friction. Mating surfaces of maximum hardness result in less contact area and causes less surface deformation which in turn provides less surface sliding resistance for the TIOLOBE™ 1175's low built-in friction coefficient.

4. Coefficient of friction decreases slightly when surface speed increases; but only up to a limit: 40 linear sliding feet per minute. Beyond 40 ft./min., the $U_k$ or wear-life versus surface speed becomes inversely proportional. Solid dry film lubricants are limited in heat dissipation; they cannot carry away frictional heat under increased surface speed conditions.

5. The kinetic coefficient of friction of TIOLOBE™ 1175 with regard to temperature changes can be considered negligible; e.g. from $-452^\circ$F to $+650^\circ$F to $+1000^\circ$F the increase becomes catastrophic. As the temperature rises, the molecular lateral attraction of the 1175's lubricity constituents are weakened and finally overcome by thermal motions. The substrate surface asperities are able to penetrate more easily by the now completely disoriented film, thereby increasing the $U_k$.

---

TIODIZE® 1175F VALVE TIME-TEMP. CURVE-HIGH FORCE BELLows

**CYCLE DEFINITION:**
1. Vent the back of the piston opening valve
2. Build equal pressure across piston, bellows drives valve closed
3. 600 cycles 240 psig
4. 300 cycles 377 psig

**FLOW:**
Thru both inlets to outlet with orifice sized to pass 120 lbs/min at 377 psig at 1053°F

**Prior to this test this valve was subjected to 19,877 cycles at 50 psig for a total time of 56 hrs. above 620°F or 45 hrs. above 800°F. (the 45 & 58 are not additive)**

**TIME - HRS.** 0 1 2 3 4 5 6 7 8 9
Tiolube™ 1175F solved one problem for an F-14 assembly.

Dry Film Lubricant Test Evaluation of Tiolube™ 1175F

Trouble was encountered with the AV1120-9 isolation, bypass, and shutoff valve used in the environmental control system of the F-14 aircraft. One hundred thousand endurance cycles at temperatures of up to 1100°F and air pressures up to 535 psig were required to qualify this valve. As a result, several dry film lubricants were evaluated. The valve configuration is shown on this page. In addition to the lubricants evaluated, several bore platings and hard coats were evaluated such as Chrome, Triboloy, Stellite, Aluminum Oxide, Boride and Tungsten Carbide. These were not acceptable on a basis of cost, manufacturing techniques or functional testing.

Test Procedure:
Except for the data enclosed, the piston was cycled to 50 psig at 900°F. A cycle consisted of:

A. Pressurizing the valve
B. Venting the back of the piston opening the valve
C. Equalizing the pressure on both sides of the piston, which allowed the bellows spring to drive the piston to the closed position.

The graph on page 5 shows the valve being evaluated at higher pressures and temperatures with slow through the valve. The test on page 5 was performed at the start of each lubrication evaluation, however, only the "Tiolube™ 1175F valve performed satisfactorily after 20,000 cycles. The test described on the graph was also repeated after 50,000 cycles on the "Tiolube™ 1175F valve.

Summary:
Before performing the tests on the four dry film lubricants on the piston and bellows bores, several combinations of parts were dry film lubricated, such as piston rings, piston ring grooves, piston ring and not the bore. All moving parts, etc. These approaches were shelved for a variety of reasons too numerous to mention in this report.

Tiolube™ 1175F

The valve bore was coated with Tiolube™ 1175F. In addition to the cycles reported, 88,000 endurance cycles were performed with little deterioration of performance. The breakaway coefficient of friction (C) was 0.1 at the start of the tests and was 0.2 after 88,000 cycles. The test was stopped because development was considered completed.

Diagram:

ITT General Controls
(used on the F-14 ECS system)

Legend:

<table>
<thead>
<tr>
<th>Media</th>
<th>1100°F air</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>cycles - 88,000</td>
</tr>
<tr>
<td>B</td>
<td>breakaway friction - 0.1</td>
</tr>
<tr>
<td>S</td>
<td>stroke - 0.75 in.</td>
</tr>
<tr>
<td>P</td>
<td>peak velocity - 50 ft./sec.</td>
</tr>
<tr>
<td>Air In</td>
<td>100 psi air</td>
</tr>
<tr>
<td>P</td>
<td>pressure - 535 psig</td>
</tr>
<tr>
<td>B</td>
<td>bellows force - 55# retracted</td>
</tr>
</tbody>
</table>