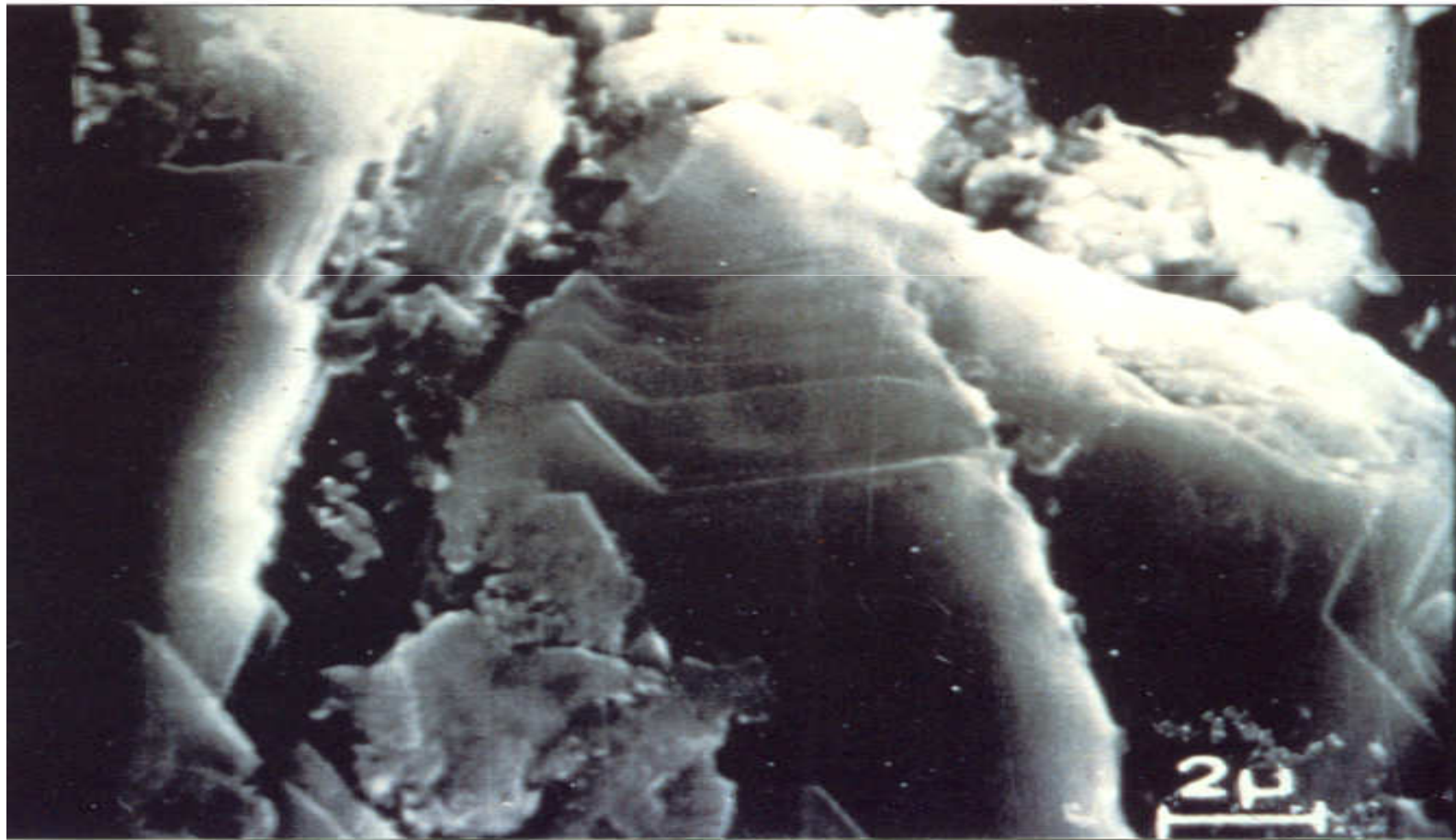


THE FACTS ABOUT MOLY AND ITS USE IN LUBRICANTS



WHAT IS MOLY

- **Moly is the common name used to describe various chemical compounds that contain the element Molybdenum (Mo).**
- **Molybdenum is a metallic element that has many unique characteristics as a metal.**
- **Molybdenum is most frequently used as an alloying addition in alloy and stainless steel.**
- **Molybdenum's addition to steel enhances the steels hardenability, weldability, toughness, heat and corrosion resistance.**

WHAT IS MOLY

- **Though Molybdenum is primarily used in steels it does find its way in lubricant formulations.**
- **In lubricants Moly is used in the following forms:**
 - **Molybdenum Disulfide (MoS_2)**
 - **Soluble Moly Compounds**
 - * **Molybdenum Dithiophosphates (M0DTP)**
 - * **Molybdenum Dithiocarbamates (MoDTC)**

MOLYBDENUM DISULFIDE (MoS₂)

- **The first recorded use of Molybdenum Disulfide as a lubricant was in the 1600's when early prospectors and settlers used it to lubricate wagon wheel axles.**
- **The first commercial use of Molybdenum Disulfide started in the 1920's.**
- **The need for improved lubrication and lubricants led to Molybdenum Disulfide's increased use in lubricants by the 1940's.**

MOLYBDENUM DISULFIDE (MoS_2)

- **Molybdenum Disulfide is widely used in lubricant formulations including greases, gear lubricants, open gear lubricants, conveyor chain lubricants, dispersions and bonded coatings.**
- **In Greases and Open Gear Compounds Molybdenum Disulfide is primarily used in a powder form.**
- **In gear lubricants, conveyor chain lubricants, etc. it is used in a colloidal suspension form**

MOLYBDENUM DISULFIDE (MoS_2)

- **In a colloidal suspension form the Molybdenum Disulfide particles are uniformly dispersed and suspended throughout the lubricating fluid it is being used in.**
- **Molybdenum Disulfide is available in three different particle sizes:**
 - **Technical Grade (5-7 micron particle size)**
 - **Technical Fine Grade (0.7 micron particle size)**
 - **Suspension Grade (0.3 micron particle size)**



Figure 1 Technical Grade Molysulfide®

**Technical Grade
7 Microns**



Figure 2 Technical Fine Grade Molysulfide®

**Technical Fine Grade
0.7 Microns**

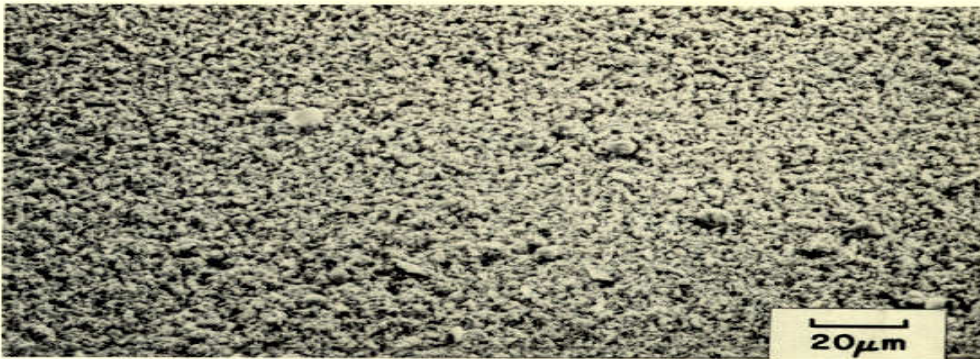


Figure 3 Suspension Grade Molysulfide®

**Suspension Grade
0.3 Microns**

MOLYBDENUM DISULFIDE (MoS₂)

- **The Technical Grade is used in lubricant formulations that are exposed to slow speed high loading and sliding conditions such as open gearing and open bearing applications.**
- **The Technical Fine Grade is used in lubricant formulations that are exposed to medium to high speed constant rotating conditions such as antifriction bearings.**
- **The Suspension Grade is used in colloidal dispersions.**

MOLYBDENUM DISULFIDE (MoS_2)

HOW IT IS PRODUCED

- **Molybdenum Disulfide occurs naturally as the mineral molybdenite.**
- **In ore bodies molybdenite is generally present in quantities ranging from 0.01 to 0.5%.**
- **Production of 2000 Pounds of Ore produces 4 to 6 pounds of Moly Disulfide.**
- **Molybdenum Reserves are mainly located in the Western Mountainous Regions of North America and South America (primarily in Chile)**

MOLYBDENUM DISULFIDE (MoS_2)

HOW IT IS PRODUCED

- **Molybdenum Disulfide is mined either through open pit or underground mining techniques.**
- **The ore is pulverized through a series of crushers and rotating ball and/or rod mills to very fine particles that may be only microns in diameter.**
- **The crushed ore is treated with a water slurry that contains various reagents and fuel oil or diesel fuel**
- **The fuel oil or diesel fuel coats the molybdenite particles making them water-repellant.**

MOLYBDENUM DISULFIDE (MoS_2)

HOW IT IS PRODUCED

- **The water slurry of molybdenite and oil mixture is placed into a flotation cell where it is agitated with air.**
- **The Molybdenite particles attach to the rising air bubbles and concentrate onto the surface of the slurry as a froth , where it is skimmed off into overflow tanks.**



MOLYBDENUM DISULFIDE (MoS_2)

HOW IT IS PRODUCED

- **The resulting concentrate which is 90% Molybdenum Disulfide is reground and treated with various acids to remove and dissolve any impurities such as copper and lead.**
- **The concentrate is then dried, deoiled and purified into the various lubricant grades of Molybdenum Disulfide.**
- **The end product is approximately 98 to 99% Molybdenum Disulfide.**

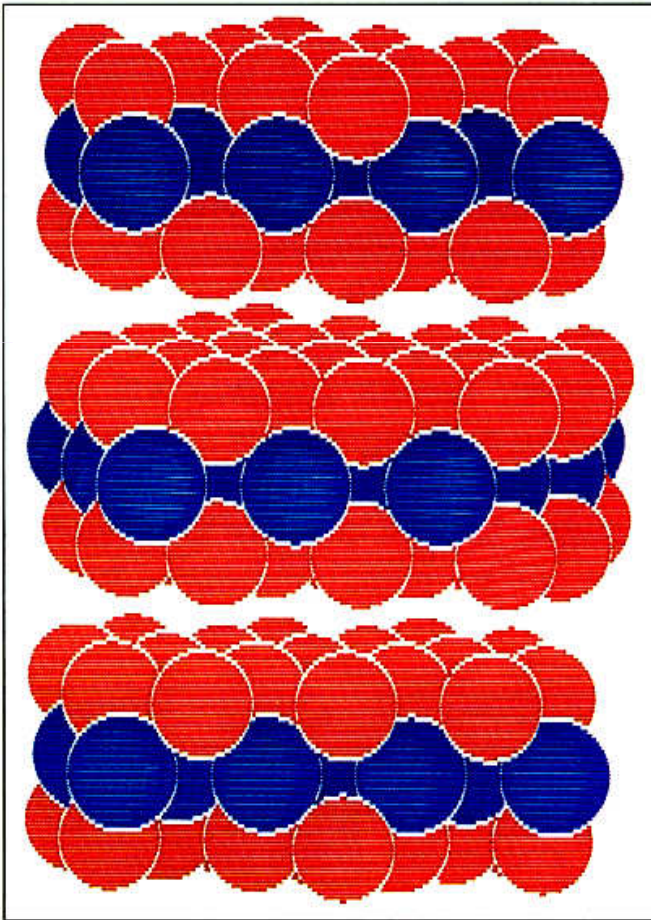
MOLYBDENUM DISULFIDE

HOW DOES IT WORK

- **Molybdenum Disulfide is one of the most important and widely applied solid lubricants.**
- **It is well suited for use in lubricants where adverse conditions such as high pressures, high shock loads, and high speeds cause the lubricant film to break down and prevent metal-to-metal contact.**
- **Temperature and pressure between the mating metal surfaces causes Moly to instantly form a thin solid lubricant film that is physically attracted to the metal's surface.**

MOLYBDENUM DISULFIDE

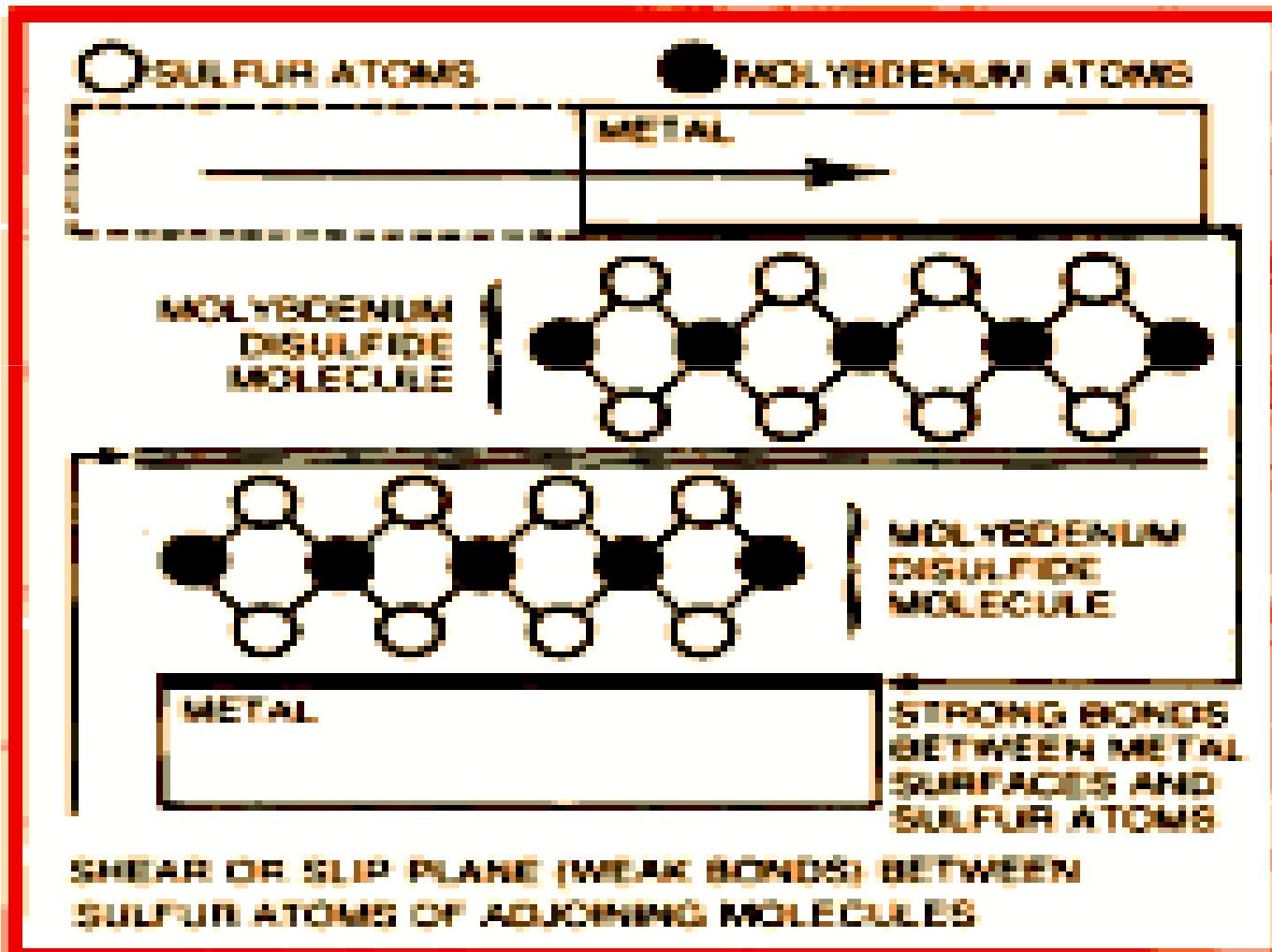
HOW DOES IT WORK



- This film consists of a plate-like structure containing layers of molybdenum atoms sandwiched between layers of sulfur atoms.
- Between each adjacent layer of sulfur atoms (in red color) are weak bonds that allow each plate to slide easily over one another resulting in a low coefficient of friction.
- Within each layer between the Sulfur-Molybdenum-Sulfur are strong bonds that help prevent the metal surfaces from contacting each other.

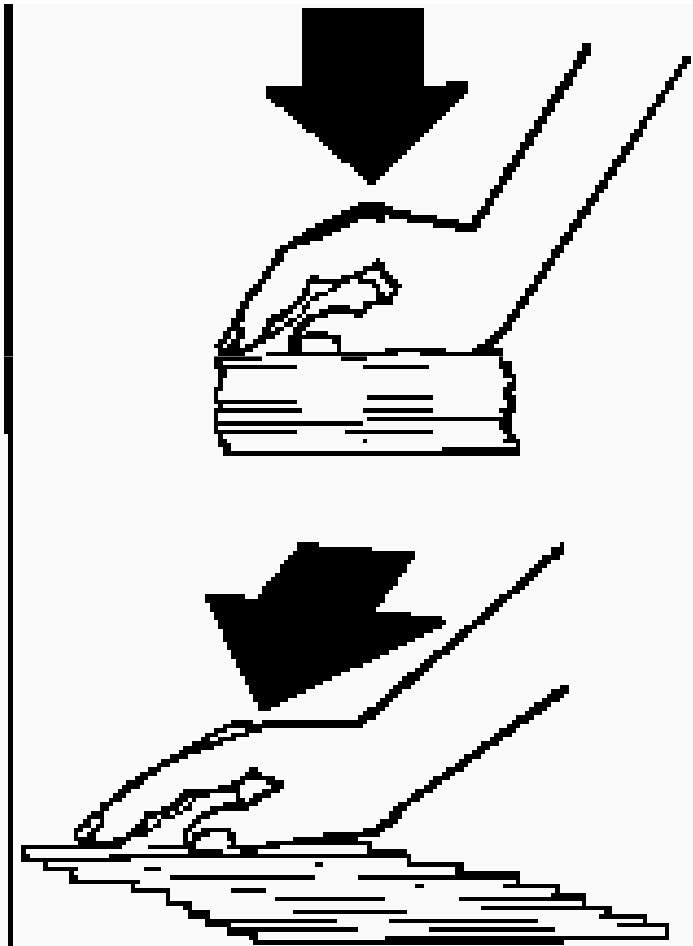
MOLYBDENUM DISULFIDE

HOW DOES IT WORK



MOLYBDENUM DISULFIDE

HOW DOES IT WORK



- A good comparison of how moly works is to relate the platelets to a deck of cards.
- The cards slide easily over one another when horizontal pressure and movement is applied, but take a considerable amount of pressure to move when a downward force is applied.

MOLYBDENUM DISULFIDE

HOW DOES IT WORK

- **The Moly film that is formed will withstand pressures up to 500,000 psi.**
- **As the Moly plates, it fills in and evens out the microscopic pits and valleys present in the metal surfaces.**
- **The thickness of the Moly film formed is a function of pressure and time and is limited to a maximum thickness of 1.2 microns (0.00004724 inches).**
- **This film is continuously renewed to the metal surface by the Moly that is suspended in the lubricant.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **Molybdenum Disulfide has several unique properties that distinguish it from other solid lubricants:**
 - 1. An inherently low coefficient of friction (0.03 to 0.06)**
 - 2. A film forming structure (Adhering and cohering properties).**
 - 3. A strong affinity to metals.**
 - 4. An extremely high yield strength (500,000psi)**
 - 5. Stability in the presence of most solvents.**
 - 6. Effective lubricating properties at a very wide temperature range (-375° to 752°F in air and up to 2000°F in a vacuum).**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **Molybdenum Disulfide will not react to most acids, except Aqua Regia and hot concentrated Hydrochloric, Sulfuric and Nitric Acids.**
- **Molybdenum Disulfide functions as a natural lubricant and its film forming characteristics are not dependent upon the presence of condensable water vapors.**
- **Molybdenum Disulfide is stable in air up to 700°F and does not undergo oxidation until that temperature is reached.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **The principal byproduct of the oxidation of Molybdenum Disulfide is Molybdenum Trioxide (MoO_3).**
- **Molybdenum Trioxide is a high temperature lubricant and it is not abrasive.**
- **Molybdenum Disulfide is not abrasive. This has been documented in various ASTM Abrasion Tests performed by various suppliers of Molybdenum Disulfide.**
- **Molybdenum Disulfide will not build up all over a bearing's or a metal's surface.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **Molybdenum Disulfide plates only to those surfaces where it is rubbed on to and only to a maximum film thickness of 1.2 microns.**
- **When used in antifriction bearing applications Molybdenum Disulfide will not come out of suspension and jam bearings .**
- **Lubricants containing Molybdenum Disulfide are used in a wide variety of bearing applications ranging high speed precision bearings to very large bearings found on earthmoving equipment.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **Lubricants that contain colloidal dispersion of Molybdenum Disulfide will not clog most types of filtration systems, will operate in automatic lubricators and other close fitting mechanisms.**
- **The particle size of the grade of Molybdenum Disulfide used in colloidal dispersions is 0.3 microns.**
- **If colloidal dispersions of Molybdenum Disulfide are not stabilized, the fine particles of Moly will clump together and form into larger particles which can quickly settle out.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **The type of colloidal dispersion of Molybdenum Disulfide uses in its gear lubricants and chain lubricants are stabilized to prevent settling out during use.**
- **The Moly particles are coated with a layer of stabilizer, which discourages clumping together**
- **The stabilizers used in the colloidal suspensions are compatible with a wide variety of additive systems and base oils.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **Molybdenum Disulfide is has been found in standard ASTM and U.S. Military Corrosion Tests to be non-corrosive.**
- **When used with other solid lubricants such as graphite, Molybdenum Disulfide has been found to work well with and enhance the other solid lubricant's load carrying abilities.**
- **Unlike other solid lubricants used in the formulation of lubricants Molybdenum Disulfide's are tightly and rigidly controlled by its various suppliers.**
- **Toxicology studies performed by various governmental and private agencies have found Molybdenum Disulfide to be relatively non-toxic.**

PROPERTIES OF MOLYBDENUM DISULFIDE

- **Though Molybdenum is a heavy metal it would take massive doses of Molybdenum Disulfide and other Moly Compounds to produce Acute Molybdenum Poisoning in Human Beings.**
- **In low concentrations Molybdenum is an essential trace element is a component in vitamin and mineral supplements and some Moly containing compounds have been found to have therapeutic uses.**
- **Molybdenum is also an essential micronutrient for plant and animal growth**

COMPARISON OF MoS_2

	MoS_2	Graphite	Teflon
Coefficient of Friction	0.03 to 0.06	0.05-0.15	0.03-0.1
Useful Temperature	-375° to 752°F Up to 2000°F in a vacuum	Up to 1,000°F depending upon the grade used	-328° to 572°F (above 617°F it forms hydrofluoric acid)
Yield Strength	500,000 psi	10,000 to 20,000 psi	5,000 psi
Adhesion to Metals	Very Good to Excellent	Very Good	Good Works Best on Soft Metals
Purity and Quality Levels	Rigidly Controlled	Subject to Wide Variabilities in Grades	Subject to Wide Variabilities in Grades
Anti-Wear Characteristics	Excellent	Good to Excellent	Good In some Cases can increase friction

SOLUBLE MOLY

- **Soluble Moly is the term used to describe certain liquid organomolybdenum compounds that are completely soluble in petroleum or synthetic base oils.**
- **Soluble Moly compounds like other lubricant additive systems such as detergents and dispersants or anti-wear additives are completely dissolved in the oil they are used in.**
- **Soluble Moly will not settle out, nor can it be filtered out since it becomes a complete part of the lubricant formulation and the fact that they are liquids.**

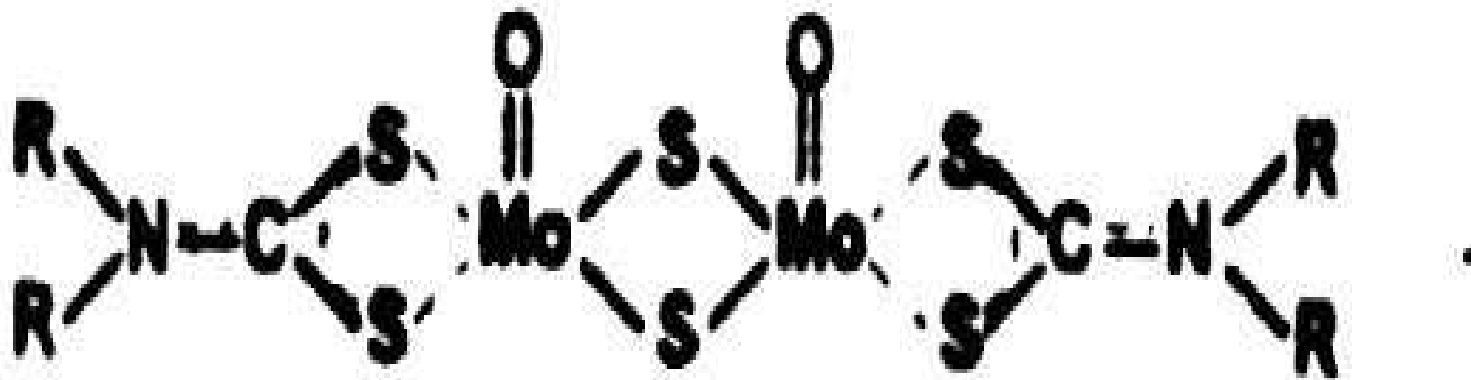
SOLUBLE MOLY

- **The only time Soluble Moly just like other additives can be filtered out of a lubricant is when sub-micron filtration (Less than 1 micron) is used.**
- **Soluble Moly is used in a variety of lubricant formulations ranging from engine oils to greases.**
- **Soluble Moly is widely used in Japan with the United States and the Europe being the next largest markets.**

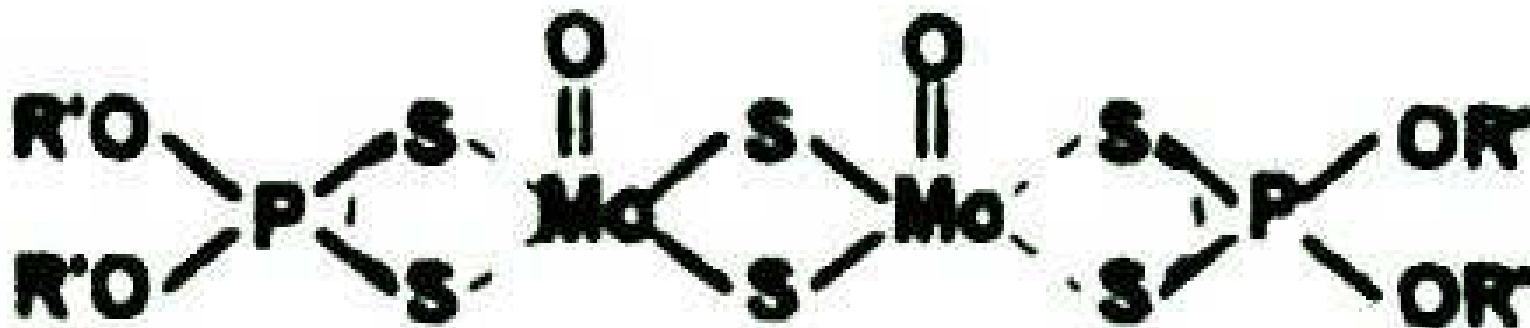
SOLUBLE MOLY

- **The predominate types of Soluble Moly Compounds used are:**
 - **Molybdenum Dialkyl Dithiocarbamate (MoDTC)**
 - **Molybdenum Dialkyl Dithiophosphate (MoDTP)**
- **These types of Soluble Moly Compounds are known as organomolybdenum compounds.**

SOLUBLE MOLY



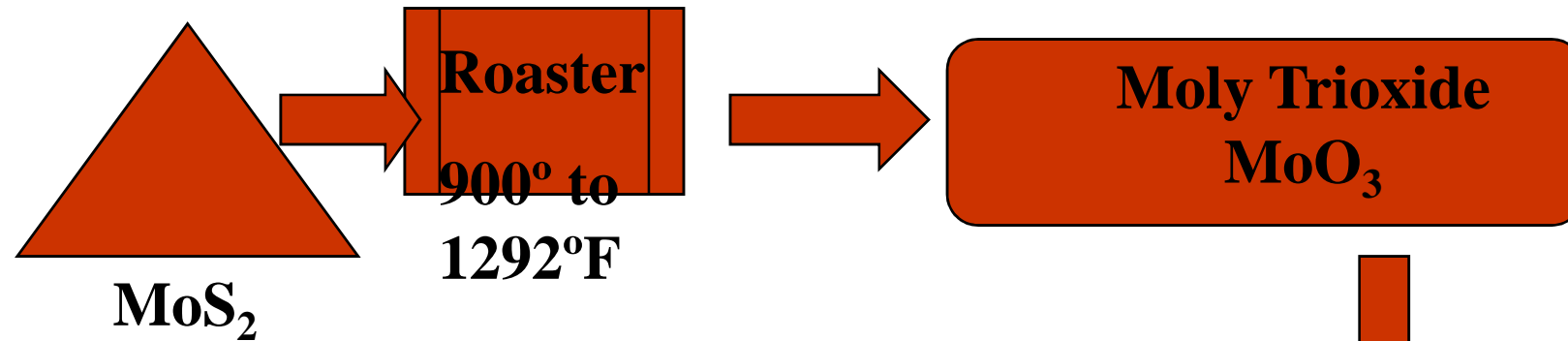
Molybdenum Dialkyl Dithiocarbamate



Molybdenum Dialkyl Dithiophosphate

SOLUBLE MOLY

HOW ARE THEY PRODUCED



charcoal



Natural Gas

+ **Vaporized sulfur**



+



Amine Salts and Esters, Phosphorus Esters or Salts

Soluble Moly Compounds

Dithiocarbamic

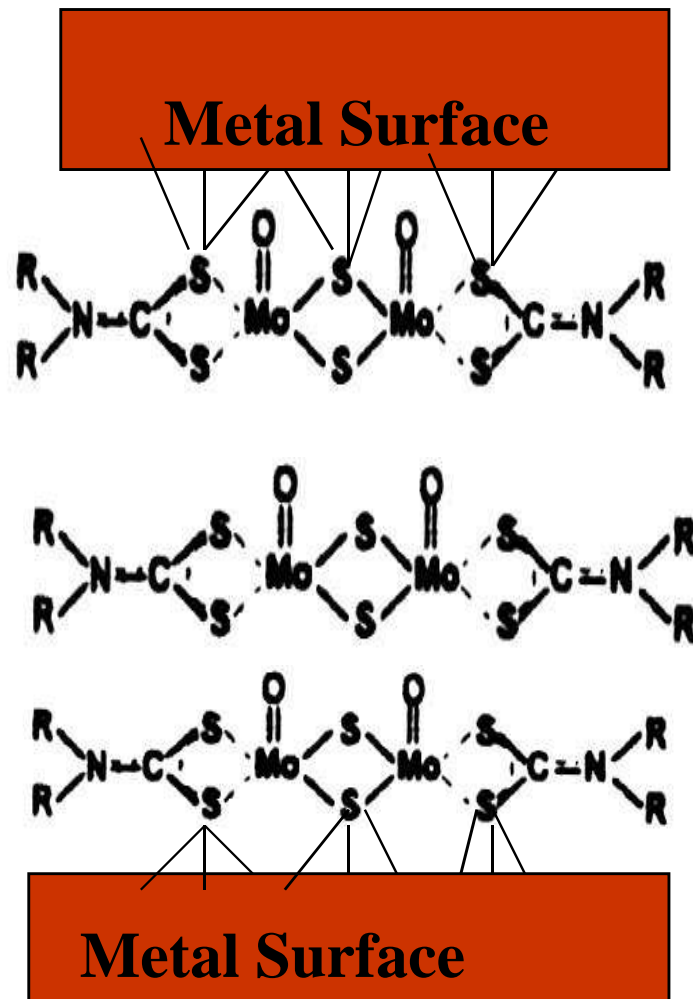
Dithiophosphate Acids, Esters and Salts

+ Copper Corrosion Stabilizers

SOLUBLE MOLY HOW THEY WORK

- **The use of Soluble Moly in various lubrication formulations particularly in engine oil is starting to grow due to its frictional modification properties.**
- **It is well suited for use in lubricants where adverse conditions such as high pressures, high shock loads, and high speeds cause the lubricant film to break down and prevent metal-to-metal contact.**
- **Temperature and pressure between the mating metal surfaces causes Moly to gradually form a over time a thin solid lubricant film that is physically attracted to the metal's surface.**

SOLUBLE MOLY HOW THEY WORK



- This film consists of a plate-like structure containing layers of molybdenum atoms sandwiched between layers of sulfur atoms.
- Between each adjacent layer of sulfur atoms are weak bonds that allow each plate to slide easily over one another resulting in a low coefficient of friction.
- Within each layer between the Sulfur-Molybdenum-Sulfur are strong bonds that help prevent the metal surfaces from contacting each other.

SOLUBLE MOLY HOW THEY WORK

- **Research done by General Motors, Ford and the Imperial College of London has found that Soluble Moly Compounds form very small crystals of Molybdenum Disulfide as they come into contact with the rubbing metal surfaces that are 0.00000001 to 0.000000025 microns in diameter and 0.000000001 to 0.000000002 microns thick.**
- **The Moly film that is formed will withstand pressures up to 500,000 psi.**
- **As the Moly plates and forms its film, it fills in and evens out the microscopic pits and valleys present in the metal surfaces.**

PROPERTIES OF SOLUBLE MOLY

- **Soluble Moly's coefficient of friction is 0.04 to 0.08**
- **Research done in the late 1980's and early to mid 1990's by Chevron-Texaco and in Japan have found that an engine's coefficient of friction can be reduced up to 80% by using Organo-Molybdenum Soluble Compounds.**
- **Organo-Molybdenum Soluble Compounds functions as a:**
 - **Frictional Modifiers**
 - **Anti-Wear Agents**
 - **Anti-Oxidants**

PROPERTIES OF SOLUBLE MOLY

- **In engine oils Soluble Moly Compounds particularly the Molybdenum Dialkyl Dithiocarbamate type enhances the anti-wear additive Zinc Dithiophosphate's anti-wear and friction reducing capabilities.**
- **Soluble Moly by functioning as an antioxidant it will enhance a lubricant's resistance to oxidation.**
- **Soluble Moly plates only to those surfaces where it is rubbed on.**

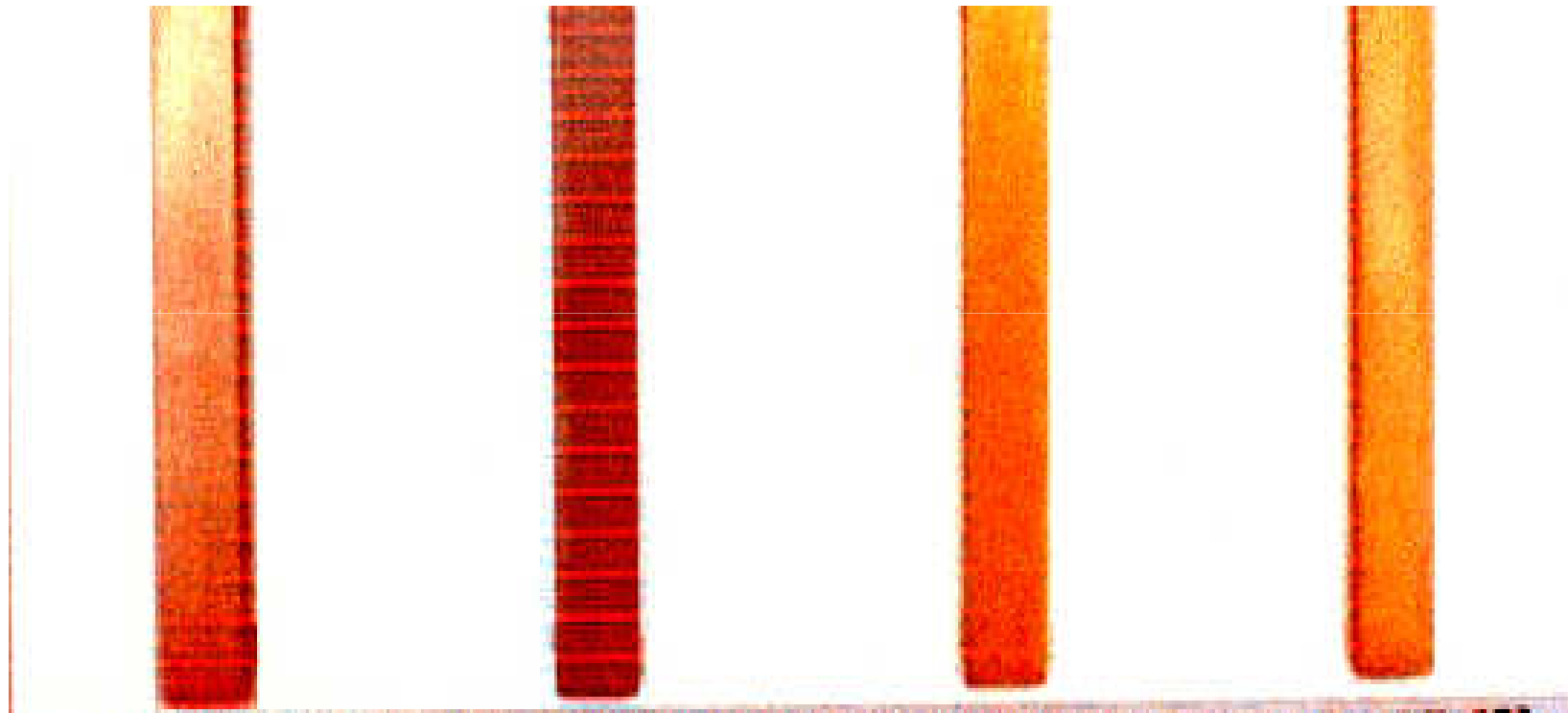
PROPERTIES OF SOLUBLE MOLY

- **Soluble Moly compounds are soluble and completely dissolve in petroleum base oils, synthetic base oils and in various solvents.**
- **Soluble Moly has a strong affinity to metals.**
- **Soluble Moly's film forming characteristics are not dependent upon the presence of condensable vapors.**
- **Soluble Moly will not build up all over a bearing's or a metal's surface.**

PROPERTIES OF SOLUBLE MOLY

- **Soluble Moly has an extremely high yield strength (500,000psi)**
- **Soluble Moly is stable in the presence of most solvents and acids.**
- **Soluble Moly when they are properly stabilized and used at the recommended treatment levels will not corrode copper and copper containing components.**

PROPERTIES OF SOLUBLE MOLY COPPER STRIP CORROSION TEST ASTM D-130



**Untested
Copper
Strip**

**Unstabilized
Soluble
Moly**

**Stabilized
MODTP**

**Stabilized
MODTP**

PROPERTIES OF SOLUBLE MOLY

- **The stabilizers also enhance the Soluble Moly's friction reducing and anti-wear characteristics.**
- **These stabilizers allow the molybdenum portion of the Soluble Moly to absorb into the metal's surface resulting in a surface that is more slippery than the original metal's surface, thus affording better anti-wear and friction reduction.**
- **The use of Soluble Moly Compounds in engine, gear hydraulic and industrial lubricant formulations have shown fuel economy benefits and energy reductions up to 5%.**

PROPERTIES OF SOLUBLE MOLY

- **Molybdenum Dithiocarbamate and Molybdenum Dithiophosphate can effectively lower the coefficient of friction and reduce wear up to 500°F and provides protection up to 600°F**
- **Molybdenum Dithiocarbamate is primarily used in and has been found to work best in engine oil and hydraulic fluid formulations.**
- **Molybdenum Dithiophosphate is primarily used in and has been found to work best in gear lubricant formulations.**