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# INTRODUCING SANTOTRAC*

a new synthetic lubricant
from MONSANTO

**TECHNICAL BULLETIN IC/FF-28**

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# Monsanto

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**A Unit of Monsanto Company**
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## INTRODUCING SANTOTRAC

SANTOTRAC is a new family of synthetic hydrocarbon lubricating oils and greases developed by Monsanto. SANTOTRAC offers the same excellent properties as petroleum base products and in addition offers:

higher temperature operation

greater lubricant film thickness

increased fatigue life of rolling contact bearings

increased power transmission in lubricated rolling "friction" (traction) drives.

## HOW SANTOTRAC WAS DEVELOPED

Modern technology calls for high speed, heavy duty, low noise, precision equipment with long service life and high reliability.

Great strides have been made in recent years in equipment to achieve this performance in varied automotive, aircraft and industrial applications. Vacuum metallurgy, use of computers in design and precision machining have all aided these advances.

Rolling contact traction drives appear to have many of the features desired for modern power transfer.

To improve their performance and to make them economically feasible for higher horsepower and more broad use, it was necessary that lubricants be developed which improve the performance of these drives over use of petroleum lubricating oils.

This was the challenge to lubricant manufacturers and Monsanto met that challenge with the development of SANTOTRAC - a family of synthetic hydrocarbon lubricating oils and greases having high coefficients traction, good lubricating properties and excellent stability over a wide range of operating conditions.

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## THEORY OF TRACTION IN A LUBRICANT

Traction in a lubricant is a relatively new concept for engineers although a very important one.

Friction is a familiar term when considering one surface sliding over another. This friction is undesirable and can be reduced by use of lubricants, often containing "oiliness" agents. This is a practice that has been known and used for many years.

Traction is different phenomenon. It is important in the lubrication of rolling contact elements that are transmitting power. It actually refers to the resistance to shear and slip of the lubricant film separating the rolling members, rather than the friction of sliding metal surfaces themselves. High traction is a desirable property of lubricants for traction drives.

In traction drives the tangential force or torque transferred between rolling contact surfaces is proportional to the coefficient of traction and the normal load (force) between the surfaces. Therefore, it is desirable for this coefficient to be as high as possible.

High coefficient of traction is an inherent property of a lubricant base oil related to the shape and behavior of the molecules themselves. SANTOTRAC synthetic hydrocarbon lubricants have the molecular properties that produce high traction coefficients.

The traction phenomenon occurs in the elastohydrodynamic regime of lubrication - regime in which loads are too high for a thick hydrodynamic film to exist, yet with proper surface finish not necessarily high enough for metal to metal boundary contact.

Original theories assumed that metal to metal contact was the mechanism for force transmission in rolling contact with the lubricant acting primarily as a coolant. However, experimental measurements of lubricant film thickness reveal that a lubrication regime exists between hydrodynamic and boundary lubrication. It is called elastohydrodynamic lubrication. In this regime, where traction drives operate, the metals are in elastic deflection about 1000 micro inches and film thickness of the lubricant is reduced to only 20 to 30 micro inches.

Several theories have been proposed to explain the property of high traction in a lubricant. The leading theory suggests that under high contact stress and high shear rates in rolling



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contact the viscosity of the film of lubricant in the contact area increases to a glassy solid state -- beyond that which pressure viscosity would account for. This pad of glossy solid film transmits tangential force or torque by resisting shear far more than liquid films can do. Further, the pad protects parts by preventing metal to metal contact and also inhibits fatigue crack propagation. Leaving the rolling contact area, the film returns to the liquid state and its normal physical properties. Coefficient of traction has been shown to be independent of nominal viscosity, pressure viscosity, viscosity index, specific gravity or other common physical properties. The more solid in character the lubricant film becomes the higher its coefficient of traction and the more torque can be transmitted for a given normal contact load.

Normal load in a traction drive determines the contact stress and is limited by the yield and fatigue strength of the metal parts. The power transmitted between the drive elements is limited by the amount of torque that can be transferred. The torque can be increased at any given normal load up to the point at which the elements would slip severely and allow boundary contact and seizure of the rolling elements. The maximum torque before gross slip is determined primarily by the lubricant, the normal load -- and to some extent the system temperature, rolling speeds and the rolling element design (shape, materials and surface finish).

The output of a traction drive of a given design then is limited primarily by the coefficient of traction of the lubricant. SANTOTRAC, having the highest coefficients of any known lubricants offer the maximum output capability for a traction drive.

Typical variations in normal load, rolling speed and lubricant temperature in traction drives all have some effect on coefficient of traction, but this is relatively slight with SANTOTRAC. Higher rolling velocity and higher temperature will decrease the traction coefficient. Depending on the drive design, increase in normal load between the traction elements can cause modest increase or decrease in the traction coefficient.

Traction coefficients can be reduced by spinning or twisting motions in the lubricant film. These are a function of the design of the drive and its elements and are found primarily in variable ratio drives.

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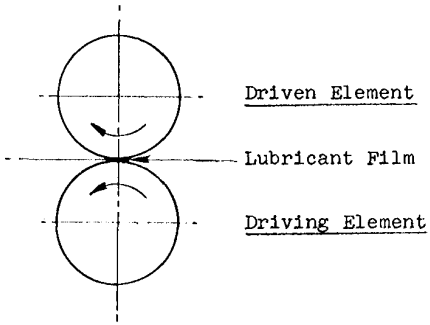
In normal operation there will be a small slip (0.1% - 3%) from one rolling element to the other. This necessary, small creep or slip is of no consequence in most applications provided the slip does not change significantly with torque demand and, therefore, cause large variations in output speed. SANTOTRAC lubricants cause less speed change of drives than other lubricants.




TRANSFER OF TORQUE THROUGH LUBRICANT FILM



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## TRACTION DRIVES

One of the major uses of SANTOTRAC lubricants is in traction drives. Traction drives are used for mechanical power transmission at fixed or variable speeds much like gear trains, belt drives, hydrostatics and variable speed motors. The benefits of traction drives are:

- excellent performance at very high speeds
- extremely low noise levels
- high efficiency
- variable speed control while operating under full load
- stepless, infinitely variable speed change within design range
- precision of speed settings
- high speed response
- adaptability to servo control
- low maintenance requirements

Now with the availability of SANTOTRAC lubricants three features are still further improved - they are:

- higher power transmission and less speed change with load
- high reliability and long service life
- smaller, lighter weight, lower cost drives than before

The cost/performance of traction drives is so upgraded by the use of SANTOTRAC compared to use of petroleum lubricants that these drives are now being designed for applications which were not practical before.

### How They Work

Mechanical traction drives work on the principle of transfer of rotary motion, torque and power through rolling contact of smooth elements loaded against each other. The transfer of torque takes place through a film of lubricant.



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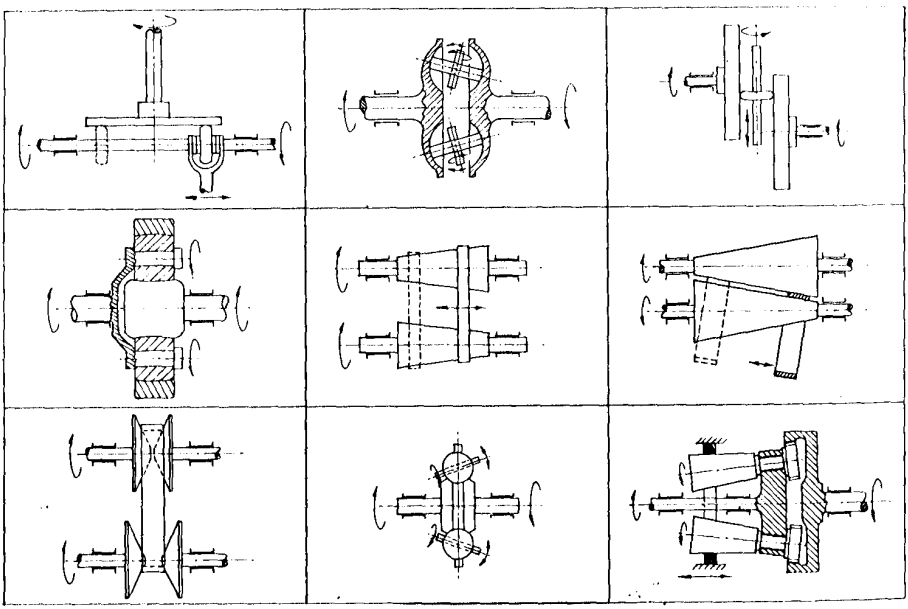
Traction drive elements vary in geometry from cone on ring, to ball on disk, disk on roller, torroidal disk on roller and other designs. In each case there are driving and driven rolling elements. By moving the rolling contact position relative to the rotation axis of the elements speed variations can be achieved.

The torque transferred from one element to the other is dependent on the normal contact loading and the coefficient of traction of the lubricant film. SANTOTRAC, under adequately high normal loading forms a lubricant film so resistant to shear that 50% to 100% more torque can be transferred before gross slip than when petroleum lubricants are used. This means that traction drives lubricated with SANTOTRAC can transfer more power, undergo less speed change with varying load demand, be made smaller and offer longer equipment life and higher reliability by reducing normal loading on the drive elements. Many existing traction drives if lubricated with SANTOTRAC, can be uprated to transfer 50% more power. Others, particularly fixed ratio drives, may allow transfer of up to 100% more power. Certain drives can be uprated simply by changing to SANTOTRAC lubricants, while others may require minor modification.



SOME BASIC TYPES OF VARIABLE SPEED DRIVES

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## THE PROPERTIES OF SANTOTRAC

### Performance

SANTOTRAC lubricants offer a wide range of viscosities from which you can select the lubricant best suited to your particular application. Whichever one you choose, you will be assured of high performance in traction, lubrication, and stability to high temperature and air as well as consistent properties from year to year and in supplies around the world.

### High Traction Means More Performance

Traction properties in a lubricant offers a new dimension to lubrication and mechanical design engineers. High traction often can permit the transfer of more power, the design of smaller, lower cost, higher reliability rolling contact systems or prevent skidding of rolling contact bearings.

### Top Grade Lubricants

SANTOTRAC lubricating oils and greases give the same excellent lubricating performance as petroleum oils used in automotive, aircraft and industrial applications. Some are formulated for heavily loaded sliding and boundary lubrication, others are formulated for different special needs.

SANTOTRAC has been tested or used as a lubricant and fluid for many purposes including:

Traction drives

Rolling contact bearing lubricants

Journal and sliding bearing lubricants

Gear lubricants

Hydraulic oils

Automatic transmission fluids

### Stability at High Temperatures Means Long Service Life

SANTOTRAC lubricants - both oils and greases - are stable to high temperatures, even in the presence of air. They resist sludging, varnish, or coking and resist acid formation at operating temperatures of 300°F and above for long periods of time.



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Simple Engineering Materials Can Be Used

SANTOTRAC lubricants are synthetic hydrocarbon based and as such are generally compatible with the same materials of construction as petroleum lubricating oils. Most paints, plastic and elastomer components used with petroleum oils can be used with SANTOTRAC. For example, Buna-N, polyacrylates, silicone and Viton elastomers can usually be used.

## THE SANTOTRAC LUBRICANTS

Because of the wide variety of applications and operating conditions, four SANTOTRAC lubricating oils and two SANTOTRAC greases have been developed, each with some outstanding feature.

All SANTOTRAC lubricants have high traction coefficients, excellent stability and are compatible with common materials of construction.

SANTOTRAC 30 - has the lowest operating temperature capability of the SANTOTRAC family, yet has excellent high temperature stability. It has a slightly lower traction coefficient than other SANTOTRAC lubricants, but coefficients are still much higher than those of petroleum lubricants.

SANTOTRAC 40 - has the fewest additives to take maximum advantage of the stability of the synthetic hydrocarbon base and to give extremely low-foaming characteristics.

SANTOTRAC 50 - has the best balance of properties for most uses... medium viscosity, good antiwear lubrication in sliding contact, stability, rust and foam protection and a high traction coefficient.

SANTOTRAC 70 - has the highest viscosity and best overall wear protection of the SANTOTRAC family.

SANTOTRAC 250-0 and SANTOTRAC 300-S - are high traction, high temperature greases with excellent thermal and mechanical stability. These greases are intended for applications which require high temperature grease lubrication and where traction is desired. The SANTOTRAC greases have the highest traction coefficients of any lubricants known to date.

Typical properties of the SANTOTRAC lubricating oils and greases are shown in the following tables.



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## PROPERTIES OF SANTOTRAC LUBRICATING OILS

| PROPERTY | TYPICAL VALUES | | | |
|---|---|---|---|---|
| | 30 | 40 | 50 | 70 |
| Kinematic Viscosity (cs) | | | | |
| at -40°F | 23,400 | -- | -- | -- |
| -20°F | -- | 31,600 | 41,500 | -- |
| 0°F | -- | -- | 5,120 | 93,904 |
| 100°F | 14.7 | 22.7 | 33.6 | 121 |
| 210°F | 3.10 | 3.68 | 5.61 | 11.4 |
| Pour Point (°F) | -65 | -45 | -35 | -10 |
| Density (g/cc) | | | | |
| at 100°F | 0.891 | 0.886 | 0.889 | 0.957 |
| 200°F | 0.853 | 0.850 | 0.855 | 0.919 |
| 300°F | 0.817 | 0.814 | 0.820 | 0.883 |
| Coefficient of Expansion (1/°F) | $4.58 \times 10^{-4}$ | $4.42 \times 10^{-4}$ | $4.42 \times 10^{-4}$ | $4.19 \times 10^{-4}$ |
| Vapor Pressure (mm Hg abs) at 350°F | 12 | 12 | 12 | 10 |
| Specific Heat (BTU/lbm°F) | | | | |
| at 100°F | 0.453 | 0.460 | 0.446 | 0.426 |
| 200°F | 0.509 | 0.514 | 0.506 | 0.478 |
| 300°F | 0.565 | 0.569 | 0.569 | 0.529 |
| Thermal Conductivity (BTU/hr.ft.°F) | | | | |
| at 100°F | 0.063 | 0.060 | 0.060 | 0.062 |
| 200°F | 0.061 | 0.059 | 0.059 | 0.061 |
| 300°F | 0.058 | 0.056 | 0.056 | 0.058 |
| Surface Tension (dyne/cm) Air Interface | | | | |
| at 100°F | 24.4 | 31.6 | 23.0 | 25.4 |
| 200°F | 21.4 | 27.0 | 20.7 | 22.1 |
| 300°F | 18.4 | 22.4 | 18.4 | 18.8 |
| Flash Pt., (°F) | 325 | 300 | 325 | 335 |
| Fire Pt., (°F) | 340 | 325 | 345 | 350 |
| AIT, (°F) | 605 | 600 | 620 | 675 |



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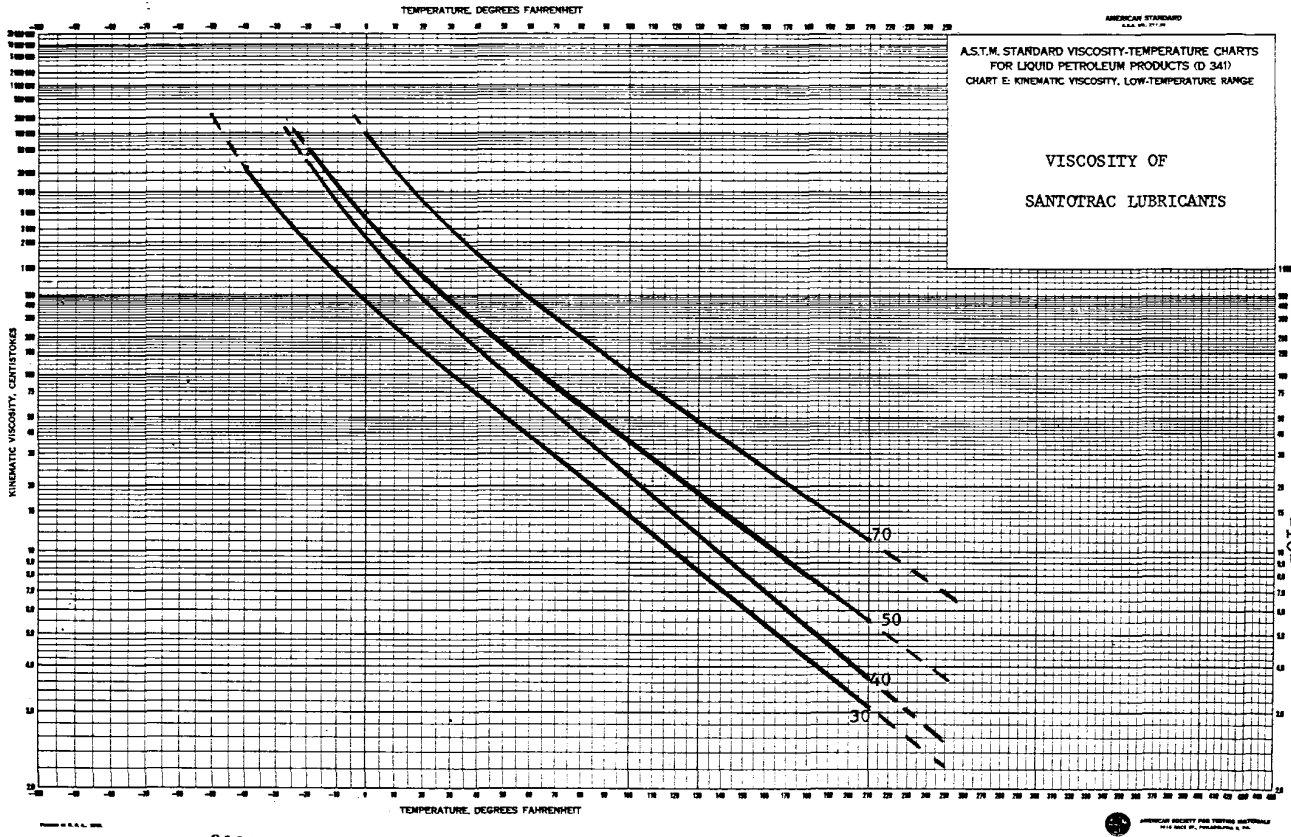




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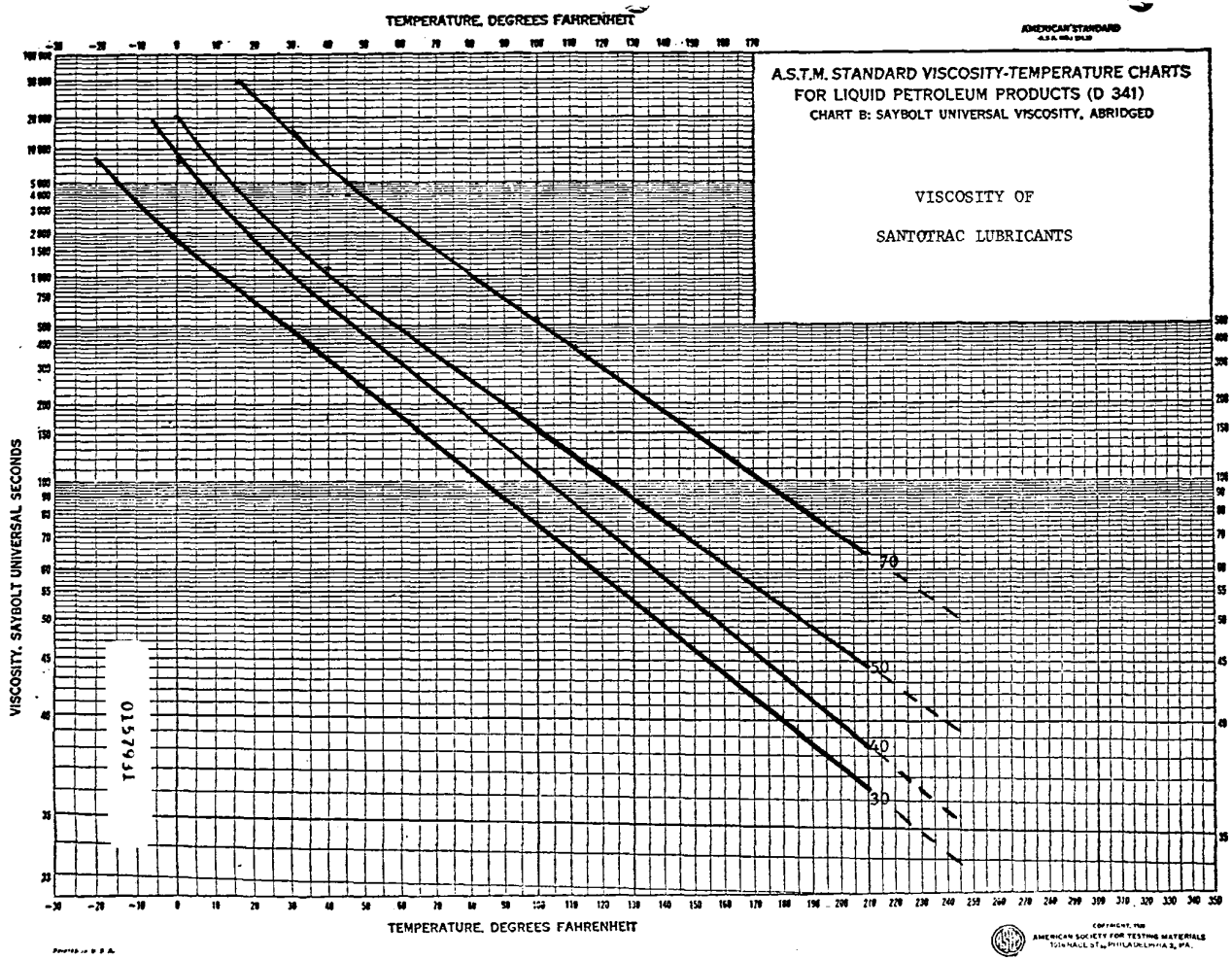


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## PROPERTIES OF SANTOTRAC LUBRICATING GREASES

| | Santotrac EP-2 | Santotrac HT-2 |
|---|---|---|
| Penetrations, ASTM D 217 | | |
| Unworked | 292 | 270 |
| 60 strokes | 290 | 283 |
| 10,000 strokes | 287 | 288 |
| 100,000 strokes | 289 | 260 |
| Roll Stability, ASTM D1831 | | |
| Initial Penetration | 74 | 64 |
| Final Penetration | 80 | 65 |
| Penetration Change | 6 | 1 |
| Dropping Point, ASTM D 566, °F. | 350 | 480 |
| Extreme Pressure Property, ASTM D 2509 | | |
| Timken OK Load, lb. | 45 | 20 |
| Scar Width, mm. | 1 | 0.7 |
| 4 Ball Wear, ASTM D 2266 | | |
| 200°F./1260 rpm/40 Kg/120 min. | | |
| Scar Dia., mm. | 0.71 | 0.48 |
| Rust Test, ASTM D1743 | | |
| 3 Bearings | #1 rating | #1 rating |
| Oxidation Stability, ASTM D942 | | |
| 100 hrs. Pressure Loss (psi) | | |
| @ 210°F. | 7 | 6 |
| @ 350°F. | -- | 5 |
| Specific Gravity, 25/25° | 0.93 | 0.94 |

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## THE TRACTION QUALITIES OF SANTOTRAC

Traction is the useful friction which causes transmission of power from one body to another in rolling contact - with small differences in surface speed. As used in describing SANTOTRAC, traction is specifically the desirable and useful friction offered by a lubricant film when one rolling element is used to drive another. It is measured as the coefficient of traction - which is obtained by dividing the tangential tractive force achieved at the contact area by the normal load applied.

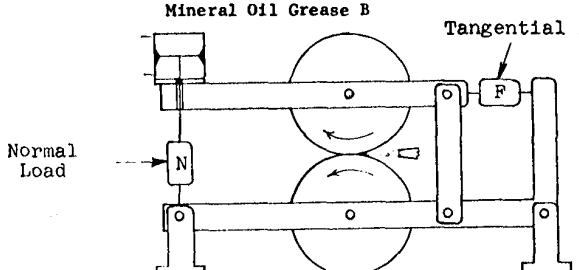
Many factors influence the traction coefficient besides the normal load, including temperature, speed, amount of slip, any spinning motion and to some extent the metallurgy and surface finish of the rolling elements.

The coefficient of traction of SANTOTRAC lubricants measured on a laboratory twin disk apparatus at conditions of 1% slip, 400,000 psi maximum Hertz stress, 200°F, and 3000 rpm are compared to commonly known lubricants in the table below. The disks are six inch diameter spherial section hardened steel.

| | Coefficient of traction |
|---|---|
| SANTOTRAC 40, 50, 70 | 0.095 |
| SANTOTRAC 30 | 0.084 |
| Naphthenic Petroleum Oil | 0.066 |
| Mil H-5606 hydraulic oil | 0.060 |
| Mil L-7808 jet engine lube | 0.039 |

**The coefficient of traction of SANTOTRAC greases HT-2 and EP-2 were measured in the same apparatus at 200,000 psi maximum Hertz stress and room temperature and compared to a mineral oil grease as follows.**

| | **Coefficient of traction** |
|---|---|
| **SANTOTRAC HT-2** | 0.125 |
| **SANTOTRAC EP-2** | 0.117 |
| **Mineral Oil Grease A** | 0.070 |
| **Mineral Oil Grease B** | 0.062 |




TWIN DISK APPARATUS

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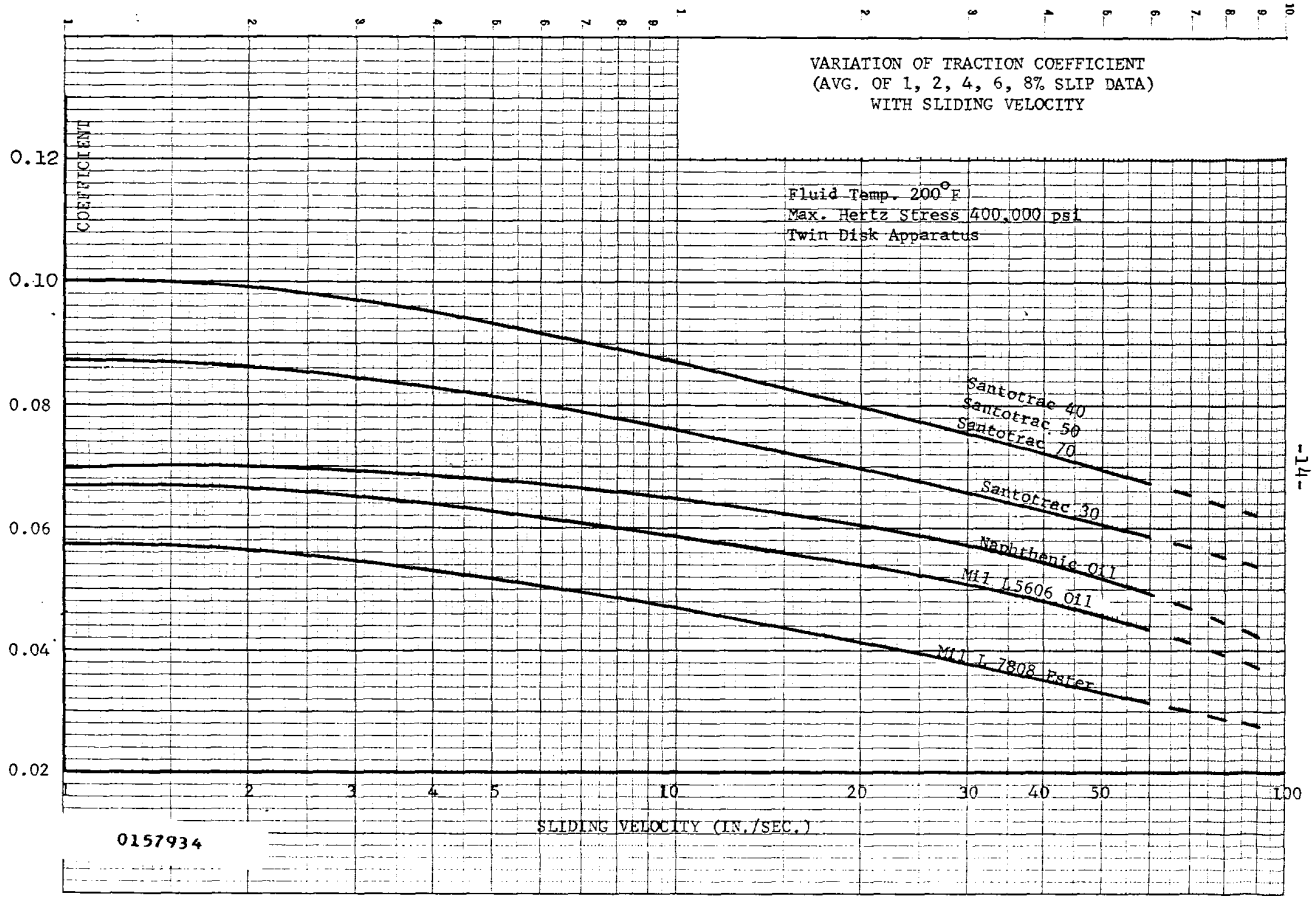
K-E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS



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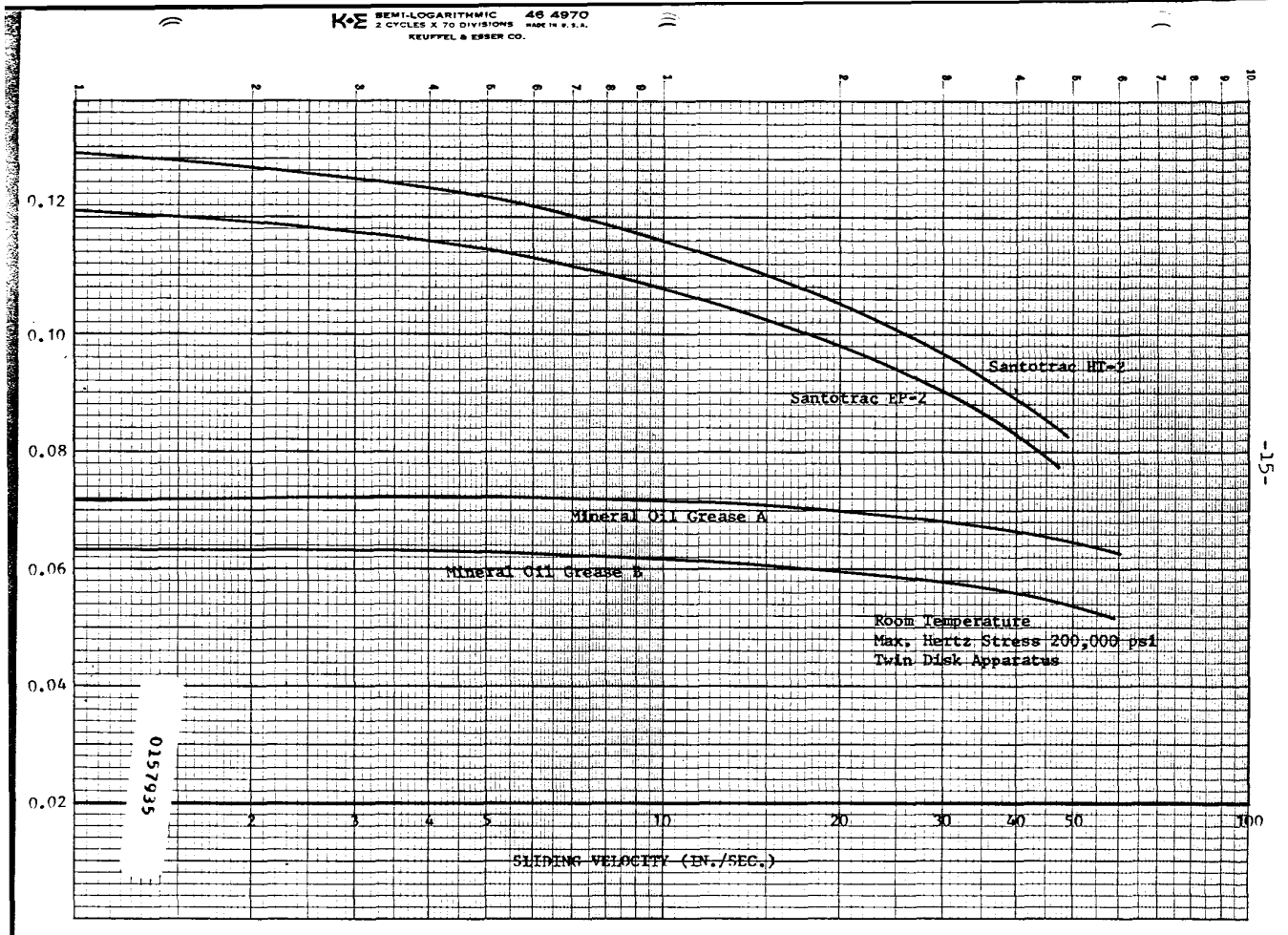




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## SANTOTRAC STABILITY AND SERVICE LIFE

The inherent thermal and oxidative stability of SANTOTRAC lubricants allows them to be used at higher temperatures and for much longer periods of time than petroleum lubricating oils.

SANTOTRAC can be used for long periods at 300°F in the presence of air (higher temperatures in the absence of air). This offers great advantage in the design, operation and maintenance of many types of equipment.

Fill-for-life or extended drain periods are possible with SANTOTRAC because of this stability against high temperature and air.

The following data compares the stability of SANTOTRAC to common petroleum lubricating oils.

| | SANTOTRAC | | | | PETROLEUM OILS | |
|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 70 | Naphthenic Oil | ATF |
| Oxidation Stability & Corrosion Modified Federal Test Method, Std. 791, Method 5308, 350°F/ 72 hrs/5 air/hr | | | | | | |
| Metal Wt. Change ($mg/cm^2$) | | | | | | |
| Mg | +0.01 | -0.01 | NC | +0.01 | +0.08 | -0.02 |
| Al | +0.01 | NC | -0.04 | NC | 0.00 | +0.04 |
| Fe | -0.03 | +0.01 | -0.03 | +0.01 | +0.02 | 0.06 |
| Cu | -0.34 | NC | -0.90 | -0.41 | -0.09 | -3.2 |
| Final Acidity, NN (mgKOH/gm fluid) | 1.2 | 0.31 | 0.54 | 1.86 | 5.0 | 6.0 |
| Viscosity Change @100°F(%) | 6.8 | 3.8 | 6.5 | 15.5 | 82 | 52 |

## SANTOTRAC LUBRICATING QUALITIES

When used in hydrodynamic or boundary lubrication, SANTOTRAC products are excellent lubricants and perform like premium petroleum lubricating oils. While actual field performance in the application intended is the only true test of a lubricant the following standard laboratory ratings are good for initial comparisons.



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| | SANTOTRAC | | | | PETROLEUM OILS | |
|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 70 | Naphthenic Oil | ATF |
| Four-ball Wear (mm scar dia) (200°F, 2 hrs 1260 rpm 40 Kg load-steel on steel) | 0.67 | 0.75 | 0.51 | 0.54 | 1.10 | 0.45 |
| LFW (mg wt loss of block) conforming bronze block sliding on hardened steel ring (280°F, 24 hrs, 72 ft per minute, 530 psi) | 3.8 | 8.5 | 1.4 | 0.9 | 21.8 | 0.7 |

## SANTOTRAC SHEAR STABILITY AND ANTI-FOAM PRPERTIES

The SANTOTRAC lubricants show shear stability and good anti-foam properties equivalent to petroleum oils. SANTOTRAC 40 is outstanding in its non-foaming property.

| | SANTOTRAC | | | | Petroleum |
|---|---|---|---|---|---|
| | 30 | 40 | 50 | 70 | ATF |
| Shear Stability (visc change at 100°F (%) ASTM Vol 1, Oct. 1961 p. 1160, 100°F/120 min sonic shearing | -5 | 0 | -11 | -24 | -15 |
| Foam ASTM D892 (ml foam after 5 min bubbling/ ml foam 10 min after bubbling) | | | | | |
| Sequence 1 75°F | 5/0 | 0/0 | 0/0 | 0/0 | 5/0 |
| Sequence 2 200°F | 35/0 | 0/0 | 22/0 | 20/0 | 13/0 |
| Sequence 3 75°F | 5/0 | 0/0 | 0/0 | 2/0 | 5/0 |

## RUST PROTECTION

SANTOTRAC lubricants are not corrosive. Like petroleum oils they do not prevent rusting from the presence of moisture unless formulated with a rust inhibiting additive. SANTOTRAC 30, SANTOTRAC 50 and SANTOTRAC 70 have been formulated for rust protection as shown in the data below.

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| | SANTOTRAC | | | |
|---|---|---|---|---|
| | 30 | 40 | 50 | 70 |
| Corrosion & Rust ASTM D665A-Distilled Water | No rust or corrosion | Severe rust and corrosion | No rust or corrosion | No rust or corrosion |

## SANTOTRAC MATERIALS COMPATIBILITY

SANTOTRAC lubricants being based on synthetic hydrocarbons are compatible with common metals, seals, paints and plastics - quite similar to the compatibility experienced with petroleum oils. However, specific critical component materials should be tested under conditions of the intended use. The following offers data on compatibility with some common elastomers(Page 19).

## SAFETY IN HANDLING

Acute toxicity screening tests were performed with SANTOTRAC 30, 40, 50 and 70 with the following interpretation on each product:

- Acute oral dosage: skin absorption and vapor inhalation at room temperature - classed as practically non-toxic.
- Skin irritation - classed as non-irritating
- Eye irritation - classed as slight irritant (The irritation experienced should be less than that from a 10% solution of toilet soap)

Interpretation:

These products do not appear to require any special handling. In case of excessive skin contact, wash off with soap and water as a hygienic procedure. In case of eye contact, flush out with water. The irritation experienced should be less than that from a 10% solution of toilet soap.

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| | SANTOTRAC | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 | | 40 | | 50 | | 70 | |
| | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| Elastomer Compatibility, ASTM D471 (7 hrs, 300°F, immersion) | | | | | | | | |
| Buna N | | | | | | | | |
| Durometer Hardness (Shore "A" Points) | 64 | 49 | 64 | 58 | 63 | 54 | 64 | 48 |
| Volumetric Swell (%) | -- | 10 | -- | 6 | -- | 6 | -- | 39 |
| Ultimate Tensile Strength (psi) | 1815 | 374 | 1815 | 521 | 1815 | 428 | 1815 | 297 |
| Ultimate Elongation (%) | 380 | 62 | 380 | 81 | 380 | 73 | 380 | 131 |
| Polyacrylate | | | | | | | | |
| Durometer Hardness (Shore"A" Points) | 66 | 47 | 65 | 55 | 66 | 57 | 66 | 50 |
| Volumetric Swell (%) | -- | 22 | -- | 15 | -- | 16 | -- | 47 |
| Ultimate Tensile Strength (psi) | 1668 | 1261 | 1668 | 1508 | 1668 | 1467 | 1668 | 1045 |
| Ultimate Elongation (%) | 179 | 181 | 179 | 185 | 179 | 197 | 179 | 183 |
| Viton A | | | | | | | | |
| Durometer Hardness (Shore "A" Points) | 58 | 54 | 59 | 57 | 58 | 57 | 59 | 54 |
| Volumetric Swell (%) | -- | 7 | -- | 5 | -- | 5 | -- | 13 |
| Ultimate Tensile Strength (psi) | 2118 | 1535 | 2118 | 1625 | 2118 | 1695 | 2118 | 1647 |
| Ultimate Elongation (%) | 475 | 458 | 475 | 445 | 475 | 477 | 475 | 472 |



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## PERFORMANCE BENEFITS OF SANTOTRAC IN A TRACTION DRIVE

### Power Rating Increase

The rating of a traction drive is directly proportional to the coefficient of traction of the lubricant used. This means that a 50% increase in the coefficient offers a drive that can handle half again as much torque at the same normal loading.

$$\frac{\text{Torque with SANTOTRAC}}{\text{Torque with oil}} = \frac{\text{Coefficient of SANTOTRAC}}{\text{Coefficient of oil}} = 1.5$$

### Increased Life of the Drive

The power rating of a drive can be held constant by reducing the normal load 50% and converting from petroleum oil to SANTOTRAC. The fatigue life of the drive elements is then increased because of the lighter normal loads.

The life of rolling contact elements is approximately inversely proportional to the cube of the normal load applied and therefore directly proportional to the cube of the coefficient of traction of the lubricant. This means that a 50% increase in the coefficient of the lubricant offers a drive that will last over 3 times as long at the same torque rating.

$$\frac{\text{Life with SANTOTRAC}}{\text{Life with oil}} = \left[\frac{\text{Normal load with oil}}{\text{Normal load with SANTOTRAC}}\right]^3 =$$

$$\left[\frac{\text{Coefficient of SANTOTRAC}}{\text{Coefficient of oil}}\right]^3 = [1.5]^3 = 3.4$$

### Power Rating and Life Increase

Part of both benefits can be achieved. Reducing the normal load slightly will achieve some of the increase in torque available with SANTOTRAC and also some increase in life of the drive.

### Size and Weight Reduction

The size and weight of a traction drive can be reduced when SANTOTRAC is used as the lubricant instead of petroleum oil. The size of the drive is related to the normal load on the elements which in turn is related to the coefficient of traction of the lubricant. For two drives of the same life and power rating the size is inversely proportional to the 0.45



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power of the coefficient of traction of the lubricant. This means that a 50% increase in coefficient offers a size and weight reduction of 16% in the drive.

$$\frac{\text{Size for SANTOTRAC}}{\text{Size for oil}} = \left[\frac{\text{Coefficient of oil}}{\text{Coefficient of SANTOTRAC}}\right]^{0.45} = \left[\frac{1}{1.5}\right]^{0.45} = 0.84$$

Size for SANTOTRAC = 84% of Size for oil ... a 16% reduction



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## GAIN IN FATIGUE LIFE OF ROLLING CONTACT ELEMENTS

The fatigue life of rolling elements is actually greater than calculated when SANTOTRAC is used because of this lubricant's inherent property of preventing fatigue failure. SANTOTRAC, unlike most synthetic lubricants offers a gain in fatigue life of lubricated rolling elements compared to when petroleum oils are used under the same load and speed conditions.

It is theorized that SANTOTRAC fills the normal surface cracks at the grain boundaries, the lubricant film becomes solid under high contact pressure, prevents crack growth into the surface and therefore helps prevent fatigue failure.

Laboratory data from rolling contact fatigue tests show the superior fatigue life properties offered by SANTOTRAC.

| | Stress Cycles x $10^6$ | |
|---|---|---|
| | $B_{10}$ Life | $B_{50}$ Life |
| Rolling Contact Fatigue<br>Pin: 3/8 in. dia., Rc 60 hardness<br>52100 Steel, 12,500 rpm, 300°F.<br>700,000 max. Hertz Stress | | |
| SANTOTRAC 30 | 3.2 | 6.4 |
| SANTOTRAC 40 | 4.2 | 7.0 |
| SANTOTRAC 50 | 4.9 | 8.9 |
| SANTOTRAC 70 | 6.1 | 12.7 |
| Petroleum ATF | 2.7 | 4.5 |
| Naphthenic Oil | 2.2 | 2.7 |
| Ester base MIL L 7808 | 1.3 | 2.7 |

SANTOTRAC lubricants give approximately twice the fatigue life of that offered by petroleum lubricating oils at the same load and speed conditions. In traction drives this property added to the life increase obtained by reducing normal loading means SANTOTRAC can increase fatigue life of rolling elements some six times over use of petroleum oils.

## SANTOTRAC FILM THICKNESS AND PRESSURE VISCOSITY PROPERTIES

SANTOTRAC helps prevent metal to metal boundary contact and permits slightly rougher surface finishes in high normal load rolling contact because it forms thicker lubricating film than petroleum oils.



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SANTOTRAC viscosity increases with pressure about twice as much as petroleum oils. SANTOTRAC has a pressure viscosity coefficient of 2 to 4 x $10^{-4}$ $psi^{-1}$ compared to 1 to 2 x $10^{-4}$ $psi^{-1}$ for petroleum oil. Film thickness in the rolling contact under elastohydrodynamic lubrication is proportional to the 0.6 power of the pressure viscosity coefficient. Therefore, SANTOTRAC with twice the pressure viscosity coefficient of petroleum oil forms a protective lubricating film 50% thicker than petroleum oil.

$$\frac{\text{Film Thickness of SANTOTRAC}}{\text{Film Thickness of oil}} = \left[\frac{\text{Pressure-visc. coef. of SANTOTRAC}}{\text{Pressure-visc. coef. of oil}}\right]^{0.6} =$$

$$\left[2\right]^{0.6} = 1.5$$

This can mean that an easy to handle, medium viscosity SANTOTRAC lubricant can be used to form the same film thickness under high load as a very high viscosity petroleum lubricant.



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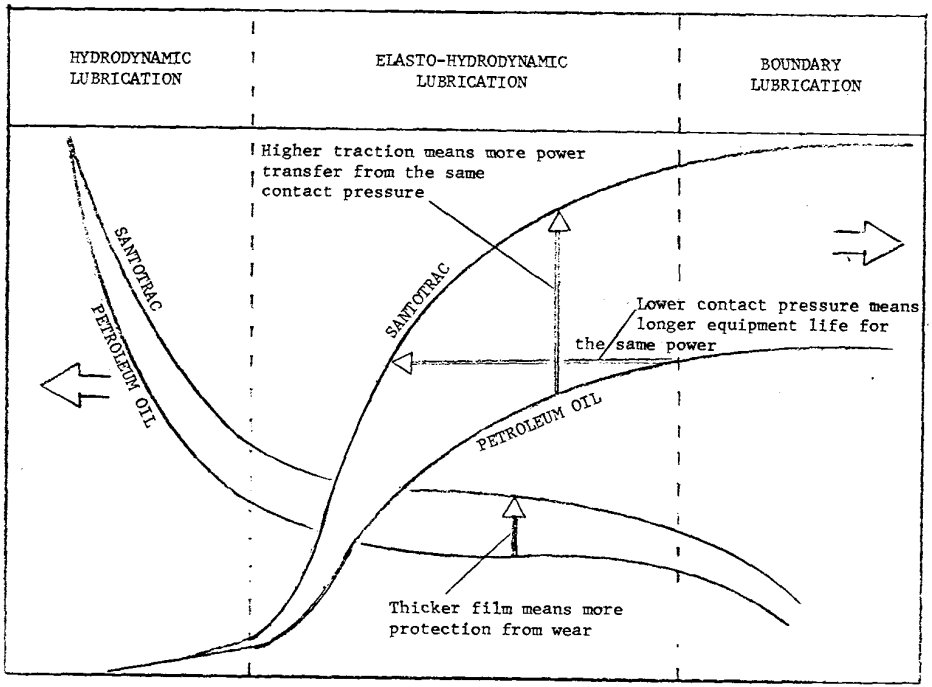


DIFFERENT REGIONS OF ROLLING ELEMENT LUBRICATION

AT A CONSTANT SPEED



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## SANTOTRAC PERFORMANCE IN A TRACTION DRIVE

In the development of high traction lubricants Monsanto and others evaluated the performance of SANTOTRAC in commercial traction drives. Results are very favorable.

In one test for example a modified commercial ball and disk drive was operated on a light naphthenic petroleum oil, then SANTOTRAC with the following results:

| | Naphthenic Petroleum Oil | SANTOTRAC |
|---|---|---|
| Output torque (lb-ft) | 35 | 70 |
| Slip % | 3.9 | 3.8 |
| Total losses, HP | 2.4 | 3.4 |

Test conditions were: Thrust load 2970 lbs
Speed ratio 1:1
Input speed 1500 rpm

In this test the power output of the drive is doubled and the overall efficiency is increased 5% by using the SANTOTRAC lubricant. Note, in the curve that follows that slip or change of speed of the drive with changes in output torque at various thrust loads is negligible with SANTOTRAC compared to when the recommended petroleum oil is used.

This drive is rated at 10 H.P. at 1440 rpm with petroleum oil lubrication. It could be rated at 20 H.P. with SANTOTRAC lubrication at the same normal loading.

This drive consists of two opposed conical disks with power transmitted between them through balls located on a fixed radius contact circle on each disk. The rotational axis of the balls can be tilted, to make a larger and a smaller contact circle on the two disks, thus increasing or decreasing the output speed of the drive.



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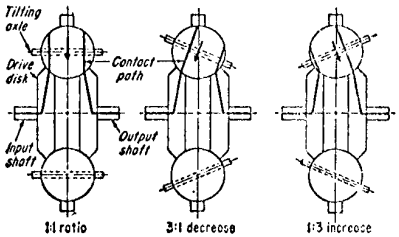
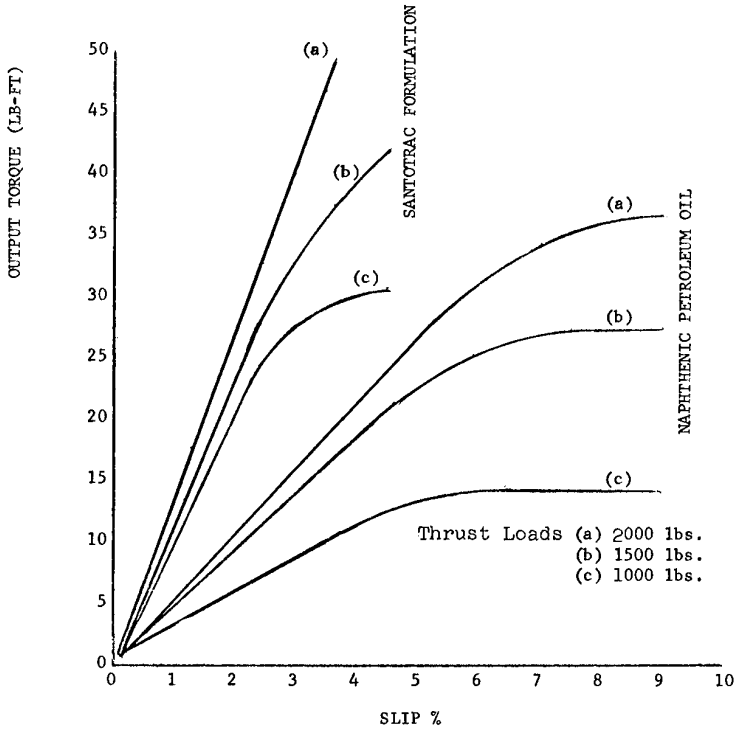



OUTPUT SPEED CHANGE FOR A
BALL AND DISK TRACTION DRIVE




VARIATION OF SLIP IN SPEED WITH TORQUE DEMAND

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