



**DATE:** March 25, 1992  
**TO:** DISTRIBUTORS  
**FORM:** GREG MINKE

Dear Distributors:

This letter is in response to some of your requests for background information on fluid engineering Services Inc. of Stillwater, OK.

FES is an Oklahoma corporation authorized to perform a broad range of professional services for organizations throughout the world. Their service activities center around the needs of power and motion control, tribology, electro/hydro/mechanical control, and CAD.

FES has no official or unofficial connection with any other company or organization and is thus able to offer objective technical support to industry and government.

The founder of FES is Dr. E.C. Fitch, one of the most highly recognized authorities on Fluid Power Research in the world.

FES is a world leader in fluid research and controls one of the largest collection of technical archives in North America. This wealth of technology has immediate application in our field of industry.

Power Up is proud to have had our products evaluated at such a high level of technical expertise.

Now you know!

Greg

GM/ld



*Technical Bulletin*

**EFFECT OF POWER UP>NNL-690  
OIL FORTIFIER ON LUBE-OIL  
ANTI-WEAR CHARACTERISTICS**

Prepared for

**POWER UP INC.  
6155-6th Street S.E.  
Calgary, Alberta**

By

**FES, Inc.  
5111 North Perkins Road  
Stillwater, OK 74075**

**September 1990**

# TESTING PROGRAM FLUID ENGINEERING SERVICES, INC. STILLWATER, OKLAHOMA

In September of 1990 Power Up commissioned Fluid Engineering Services, Inc. (FES) to conduct a series of tests using New Power Up and a common name brand oil. FES used the personnel and facilities of the Fluid Power Research Center (FPRC) at the Oklahoma State University in Stillwater, Oklahoma.

The objective of the program was to investigate the effect of Power Up on lubrication oil anti-wear characteristics under boundary and hydrodynamic lubrication. In addition, the fluid film affinity retention characteristics of lubrication oil with and without Power Up were studied.

FES, after conducting an initial series of 14 tests, concluded that "test results reveal that the Power Up substantially improves fluid anti-wear characteristics under the surface contact (boundary) lubrication, thick film (hydrodynamic) lubrication and film retention conditions".

The tests were conducted using the "Gamma System". Included in the bulletin is a schematic of the Gamma System, and also an exploded view of the bearing and journal which are used. The system operation is similar to the actual operation of bearings and the lubrication of bearings.

As was mentioned above, the testing was conducted in three specific areas. The following is a brief description of the test and results in each area.

## I. CONTACT GAMMA WEAR (boundary lubrication)

A series of six tests were conducted using oil with and without Power Up at 50, 100, and 150 lb loads. The oil selected was Pennzoil 10W-40.

In the 3 test pairs, after the addition of Power Up, the amount of wear was reduced between 39 and 87 percent.

### SUMMARY OF SURFACE CONTACT GAMMA TEST

Test No.	Load	Power Up	OGS	AGS
117	50 lb.	none	7.33	5.23
118		3%	2.13	1.55
WRR%			70.9%	70.4%
SLI			3.44	3.37
119	100 lb.	none	7.93	4.75
120		3%	3.20	2.90
WRR%			59.7%	38.9%
SLI			2.48	1.84
121	150 lb.	none	20.30	19.75
122		3%	4.57	2.58
WRR%			77.5%	86.9%
SLI			4.44	7.66

For instance, in Test 117, 220 teeth are advanced; therefore OGS is equal to 7.33 (i.e., 220 teeth / (30 min)). In other words, the wear rate of the journal/bearing assembly used under Test 1 is equal to 7.33 gear teeth advanced per minute. In practice, the number of gear teeth advanced is proportional to the amount of wear (dimension decrease) of the journal/bearing assembly of the Gamma Wear Test System. Theoretically, one unit of gear tooth advanced is equal to 0.39 micrometer change of the journal/bearing assembly.

$$WRR (\%) = \left[ \frac{1 - OGS \text{ of Fluid with P.U.}}{OGS \text{ of Fluid without P.U.}} \right] \times 100\% \quad (1)$$

For example, in Test 117, the pennzoil 10W-40 without Power Up NNL-690 has a OGS of 7.33 teeth/min; while, in Test 118, the Pennzoil 10W-40 with Power Up has a OGS of 2.13 teeth/min. Thus, the WRR is 71 percent. In other words, the use of the Power Up Oil Fortifier in Pennzoil 10W-40 reduced wear to 71 percent of the wear without Power Up.

SLI is the Service Life Improvement Index, which indicates the factor of tribological element service life that can be improved using Power Up. SLI is derived based on the assumption of the service life of tribological element, which is inversely proportional to the wear rate: namely, a wear rate of 1 tooth/min has two times the service life of a wear rate of 2 teeth/min. Obviously, SLI is the ratio of OGS of fluid without and with Power Up, or

$$SLI = \frac{GS \text{ (without Power Up)}}{GS \text{ (with Power Up)}} \quad (2)$$

In other words, a tribological element has a service life of 1000 hours with fluid without Power Up thus, a SLI of 2.5 means the tribological element has a service life of 2500 hours with fluid with Power Up.

In the tree test pairs, the SLI was between 1.64 and 7.66. We are including with this bulletin the graph showing the test results of one pair of these tests at 150 lbs, (figure 3).

## II. THICK FILM GAMMA WEAR (hydrodynamic lubrication)

This test is similar to the contact Gamma, however, the journal turns at a much higher speed (2400 rpm) and the load applied to the bearings is light (0.5 to 1.0lb). This combination of conditions creates a constant film of oil between the journal and bearings (hydrodynamic lubrication).

Since the metal surfaces are not touching in this test, only contaminant wear occurs, and one would expect that the addition of Power Up to an oil would have little or no effect.

Test results showed an average of 18.9% wear reduction after the addition of Power Up. The average SLI under hydrodynamic conditions, was calculated at 1.23.

## III. FILM AFFINITY RETENTION

The film affinity retention is used to investigate the degree of wear protection that the fluid film on the surface of tribological elements can provide when the lubrication system loses its lubricating oil.

In the affinity retention section, the FES report states that a significant difference is seen at 50 pounds with Power Up, failure does not occur within the first thirty minutes, whereas without Power up, failure occurs within 8 minutes, (figure 4).

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**FES, INC. - 5111 N. PERKINS ROAD, STILLWATER, OK 74075**  
**Fluid Engineering Services**  
**(405) 743-4337**

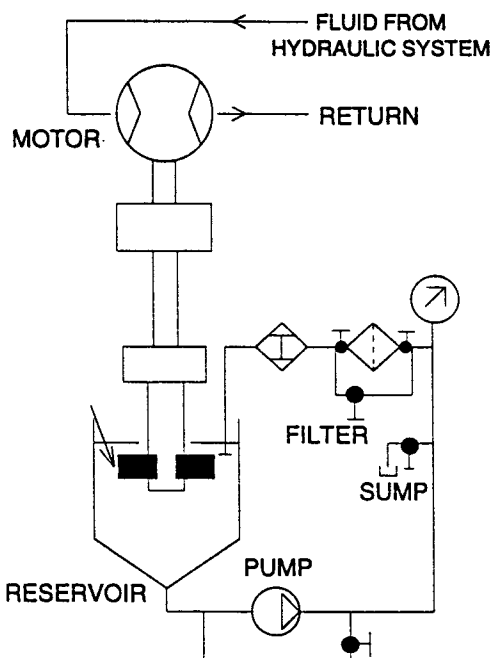


Fig 1: Schematic of Gamma System

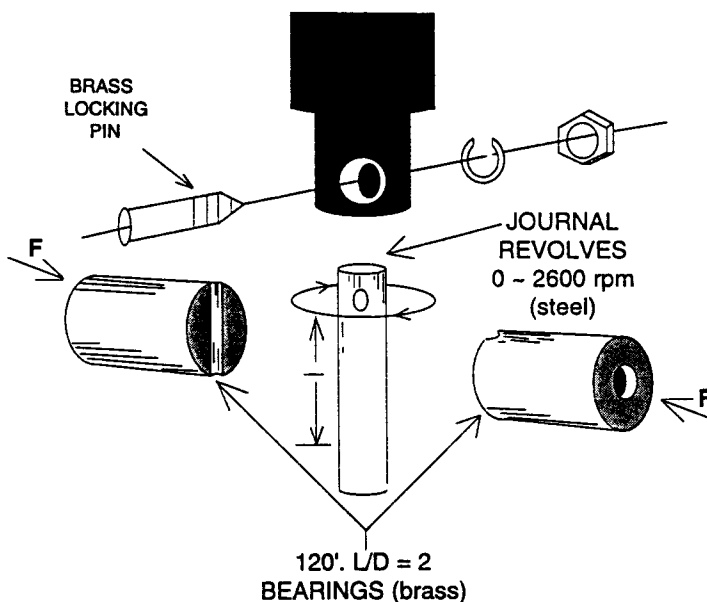


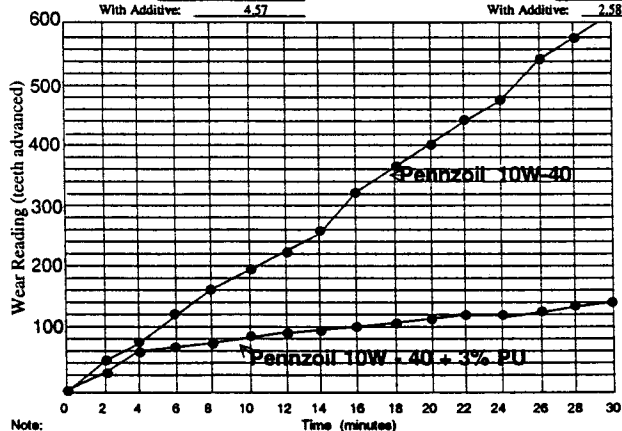
Fig 2: Exploded View of Bearing and Journal Arrangement for Gamma System

Fig 3

Fig 4

SURFACE CONTACT GAMMA TEST PROFILE

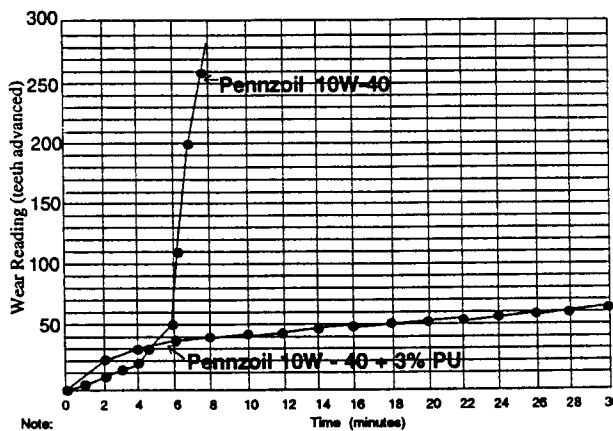
TEST NO: 121&122	DATE: September 10, 1990
TEST LOAD: 150 pounds	FLUID: 121 Pennzoil 10W 40/122 + 3% PU
ROTATIONAL SEEP: 290 rpm	TEMPERATURE: 150F
JOURNAL: Steel	BEARINGS: Brass
OVERALL GAMMA SLOPE: (teeth/min)	ADJUSTED GAMMA SLOPE: (teeth/min)
Without Additive: 20.3	Without Additive: 19.75
With Additive: 4.57	With Additive: 2.58



- Note:
- The overall gamma slope is the total number of teeth advanced divided by the total time.
  - The adjusted gamma slope is the slope during the later part of the test. The adjusted gamma slope permits test time for any interaction between the fluid and the gamma wear surfaces.

FLUID FILM AFFINITY RETENTION TEST PROFILE

TEST NO: 123 & 124	DATE: August 30, 1990
TEST LOAD: 50 pounds	FLUID: 123 - Pennzoil 10W-40
ROTATIONAL SPEED: 290 RPM	124 - Pennzoil 10W - 40 + 3% PU
JOURNAL: Steel	TEMPERATURE: 150F
BEARINGS: Brass	



- Note:
- The overall gamma slope is the total number of teeth advanced divided by the total time.
  - The adjusted gamma slope is the slope during the later part of the test. The adjusted gamma slope permits test time for any interaction between the fluid and the gamma wear surfaces.

From the test results obtained in this study, it is concluded that the Power Up NNL-690 substantially reduced the wear rate under these test conditions specified in this report with Pennzoil 10W-40.



**FES, INC.** — 5111 N. Perkins Road, Stillwater, OK 74075  
*Fluid Engineering Services*  
 (405) 743-3337

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## LAB ASSESSMENT REPORT

GS - 26  
July 27, 1992

REQUESTED BY: MR. JON CLEVELAND  
PACE MARKETING

FROM: GALILEO SALAZAR

SUBJECT: COPPER CORROSION TEST (Adapted form ASTM D130)

### REPORT:

A. COPPER CORROSION TEST (Adapted form ASTM D130)

#### 1 SCOPE

Copper strip test is designed to assess the relative degree of corrosivity of a petroleum product. Some petroleum using compounds that contribute to the corroding action on several alloys. It is suspected that long term use of such products will enhance the corrosion of these mechanical components (see Power Up Update, May 1991).

#### 2. METHODOLOGY

**MATERIALS:** A modified version of ASTM D130 can be easily performed using a few simple materials that can be made available to you upon your request:

2 - 3 in. long copper strip. A 1/4 in. diameter pipe available in hardware or plumbing stores is also appropriate.

2 - test vials.

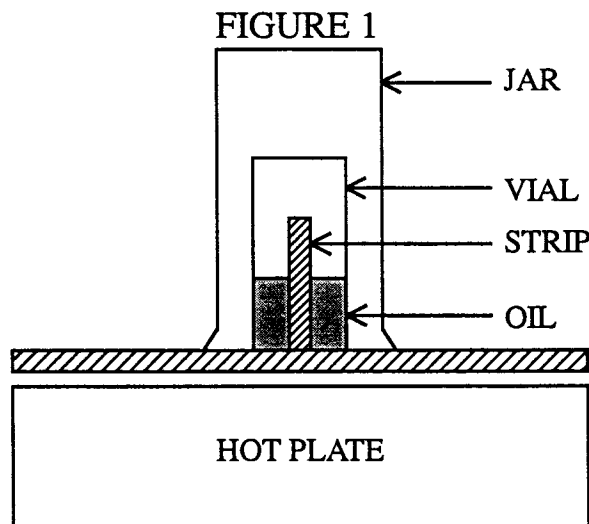
You will also require a hot plate, a thermometer that will measure temperatures above 210 °F, and a jar large enough to enclose the test vial.

#### **PROCEDURE:**

1. Polish copper strip to a lustre. Handle the copper strip by its edges. Avoid handling the strip with oily fingers.

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2. Fill the vial with sample oil, enough to cover half the copper strip.
3. Immerse copper strip in the oil bath.
4. Cap the vial with paper towels and place the vial on the hot plate. Heat the vial for two hours at a temperature of around 284 'F. The test vial can also be heated in an oven.
5. Examine copper tarnish on the ensuing surface and compare with ASTM Copper Tarnish Rating Chart (Power Up Update, May 1991).



B. AVAILABILITY OF SOCIETY OF TRIBOLOGIST LUBRICATION ENGINEERS (STLE) LUBRICATION HANDBOOK

This handbook is published by the Alberta Chapter of STLE and is available at Power Up Inc. for a nominal fee. Drop a fax to Lorraine D'Arcy regarding its availability.

Thank you for the inquiry. I am glad to be of some help. We will keep in touch.

Sincerely,

**POWER UP INC.**

Galileo Salazar  
Assistant Chemist  
Research & Development

GS/d

# WEAR PARTICLE MODIFICATION MECHANISM

## EUTECTIC FILM FORMATION

by J. Tan, Power Up Inc.

L. Leugner, Maintenance Technology International

In layman's terms, friction is a force that resists one surface from sliding over another surface. The two fundamental and unchanging laws of friction are:

- a) friction is independent of surface area;
- b) Friction varies directly with load.

Furthermore, a microscopic view of the surfaces of mechanical devices also remind us that each surface contains jagged asperities, (rough and uneven surfaces) no matter how closely the surfaces are machined. It is also well known that without some form of lubrication, these surface asperities will seize upon contact. At the very least some welding, adhesion and/or plowing of these asperities will occur.

Generally, there are three ways to reduce friction:

1. The use of bearing surfaces which are themselves sacrificial, such as low shear lead/copper bearings.
2. Replace sliding friction, such as with the use of rolling element bearings.
3. Improve overall lubrication, either by using differing or improved additives or through the use of different lubricants themselves; i.e. synthetics, solids, etc.

It is generally agreed among lubrication specialists and tribologists that friction may be at its highest level during the boundary lubrication regime (low speed, high load, startup, etc.). The boundary lubrication regime, simply

put, is the point where the asperities of two lubricated surfaces come into physical contact and the process of ploughing, welding and/or adhesion occurs.

The conventional method of reducing this phenomenon of boundary lubrication is with the use of a fully formulated lubricant that includes anti-wear or extreme pressure additives. These additives react with the asperity under extreme pressure and high temperature and instantly form an altered chemical film on the surface which acts sacrificially as the surfaces slide over each other. The film is worn away instead of the metal surface.

A second method of reducing boundary lubrication is to increase the lubricant's viscosity. While this is appropriate in some applications, secondary problems can cause an increase in the oil's internal friction. This shearing action will in turn increase operating temperatures that will create a potential for lubricant oxidation and may affect the film strength of the lubricant.

Even in heavily loaded machinery applications, such as gear drives and rolling element bearings, where elasto hydrodynamic lubrication occurs and the oil's viscosity increases dramatically to cause the lubricant to form a solid layer, the problem of boundary lubrication reappears as contact between surface asperities cause the sacrificial solid film to rupture.

Quite clearly, there are limits to which changes in oil viscosity, and/or the application of anti-wear and extreme pressure additives can be used to reduce the problems associated with boundary lubrication. Today, heavier loads, higher speeds and increased system pressures in all types of industrial and mobile machinery demand a new approach to the resolution of friction and wear in the boundary lubrication regime.

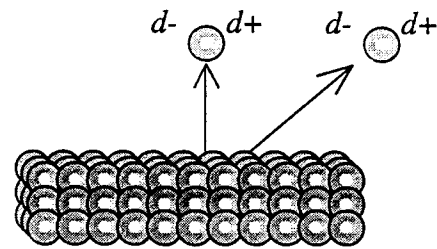
### The Two Categories of wear

Frictional surfaces between moving parts operate under two categories of wear normal and sever. The normal wear mode is characterized by the creation of particles in the range of 8 micrometers and smaller(3). These particles are those measured during conventional oil analysis, where Atomic Absorption Spectroscopy (AAS) or Inductive Coupled Plasma (ICP) techniques are used to monitor the rates of wear(2). The sever wear mode on the other hand, is characterized by the creation of wear particles in a size range of 10-250 micrometers(1). These particles can only be monitored by such oil analysis techniques as particle counts or ferrographic methods. This explains why some catastrophic equipment failures can occur with a dramatic increase in spectroscopic wear rates.

The wear modes described occur most frequently during the boundary lubrication regime and since frictional wear in some form is ongoing to some degree in every lubricated system, it was decided to take advantage of this phenomenon during the research and development of the new boundary lubricant, NNL-690, described in this paper.

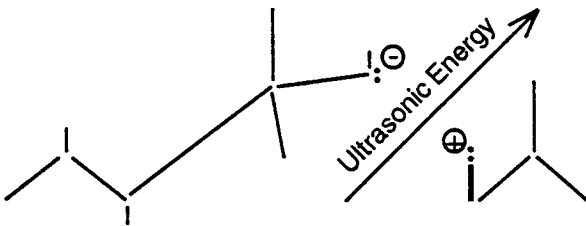
### The Influence of Ultrasonic Energy Toward the Wear Particle Modification Process

During the boundary lubrication regime, new wear particles are being created at the point of asperity contact.



wear particles are created at the metal interface by the shearing force of contacting metal surfaces. This action momentarily disturbs the iron-iron bond matrix. The freshly created wear particle has a momentary unbalanced distribution of electrons around the particle. This causes the particle to have a dipole moment, i.e. one end being more electro-positive and the other more electro-negative. The particle is said to be in an activated state.

At the same time ultrasonic vibrations are created by the shearing forces at the frictional interface between the wear surfaces (4). The ultrasonic vibration created by this friction is in the frequency range of 20,000 hertz to 300,000 hertz. The newly created wear particles are highly activated because of the momentary disturbance of the particle's \* crystal lattice brought about by the shearing force. Simultaneously, the boundary lubricant's (NNL-690) chemical structure undergoes molecular cleavage through \*sonochemical influence (ultrasonic energy) which results in the formation of certain organic radicals.

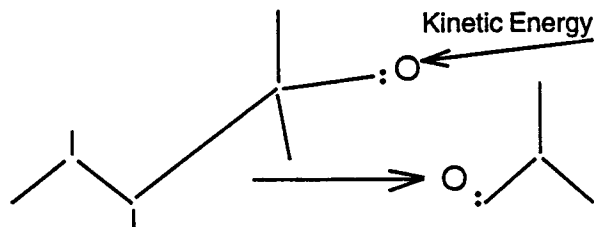


NNL Molecular Cleavage Forming Certain Desirable Organic Radicals.

These \*radicals combine instantaneously with the activated wear particles. This newly formed substance exists only at the point of contact and adheres to the metal surface by \*chemisorption.

#### Eutectic Film Formation by Wear Particle modification Mechanism

The ultrasonic energy emitted at the point of contact triggers their action between the NNL 690 lubricant's radical and the new wear particles. The result is the formation of a new substance that is described as organometallic.



NNL Radicals Combine with Activated Wear Particles Forming a Variety of Organometals. This Mixture of Organometals Constitutes the NNL Eutectic Film.

These organometals are composed of a variety of metals (depending on the type of wear particles generated) in combination with the organic radicals of the lubricant itself. These organometallic substances form a mixture which is eutectic (a mixture of materials with the lowest melting point) Under the influence of the reaction condition.

An ultra - thin eutectic film is created which acts like a solid lubricant which and withstand unit loads as high as 200,000 psi. The eutectic film is also fluidized by frictional heat in the course of mechanical movement(5). In its fluid state, tribological surfaces are made to hydroplane even under extremely high unit loading. This eutectic film becomes the new sacrificial film under boundary lubrication conditions and replenishes itself during operation. The degree of eutectic film formation and the speed at which it forms depends upon:

1. The shape and sliding direction of the asperities.
2. The loads and speeds encountered by the lubricated surfaces.
3. The viscosity of the carrier lubricant.
4. The degree of severity at which boundary lubrication conditions occur.

#### \*GLOSSARY OF TERMS:

Crystal Lattice - refers to the 3 dimensional arrangement of the atoms which make up a material such as iron or bronze.

Sonochemical - refers to the chemical reaction which takes place under the influence of ultrasonic vibration set up by friction which takes place during boundary lubrication conditions.

Radicals - refers to a fragment (of the NNL 690 chemical compound) which is created by ultrasonic vibration and which becomes electrically charged during the process.

Chemisorption - refers to the ability of a material to chemically bond (become attached) to a metal surface.

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