SINTEF REPORT

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Testing of ProLong Super Lubricants "Anti- Friction Metal Treatment"	87-03-12
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ABSTRACT

This report describes a friction and wear testing of ProLong Anti-Friction Metal Treatment for lubricants. A Block on Ring machine is used for the test. About 110 tests have been performed. The product was found to have a significant wear reducing effect - an interesting matter proposed for further testing.

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	Tribology	Tribologi
	Oil additive	Additiv for olje

SUMMARY

This report deals with a friction and wear study of the ProLong Anti-Friction Metal Treatment for lubricating oils. A Block-on-Ring machine was used for the test. Typical test protocols were selected to secure boundary lubrication.

Material combinations of Steel vs Steel and Bronze vs Steel were tested. Oils used for the test were mineral engine oil, two different synthetic engine oils, and gear oil.

Approximately 15% ProLong in the oil was found to give the best results, an average of about 50% wear reduction. Because of the positive results from these tests, further work is proposed to study expecially the effect on viscosity and the long term effect on real machines. More details from the tests are presented as an Appendix in a separate volume.

INTRODUCTION

SINTEF Division of Machine Design was approached by ProLong for an independent friction and wear test of their product, an anti-friction additive for lubricants.

The supplier claims that their product, when mixed in a specified proportion with any lubricating oil on the market, will reduce wear and increase the load carrying capacity of the lubricating film.

The purpose of this test was to verify if the product would meet the supplier's statement and to estimate the optimum quantity of product in the oil. For a primary evaluation of the product, we found a standard type wear testing machine well suited. Depending on the results from this test, and our client's needs and intentions, we can foresee the need to perform more detailed wear studies or even real wear tests on engines, gears, and hydraulic equipment.

For the present test we applied a contact pressure somewhat above the normally acceptable pressure for a journal bearing of similar material in order to obtain boundary lubrication and accelerate the wear. With the selected loading conditions, the pressure was about 2 times higher than recommended for bearings at the stage when the width of the wear track is 0.5mm.

One problem experienced during such tests is the increase in hydrodynamic effect caused by the increasing contact area as the wear is taking place. With this method, we start out from zero and this must be taken into consideration while comparing the results.

TEST PROCEDURE

Rig Description

The test was run on a Block-on-Ring machine. The mechanism of this machine is briefly shown in **Fig. 1** on page 3.

The ring (1) was a standard roller bearing outer race with a 40mm outside diameter x 20mm wide. The ring was fixed on a very well balanced shaft, rotating in journal bearings at a speed of up to 1700 rpm. For this test, 800 rpm was selected for the final testing, due to temperature build up at higher rpms. There was no cooling arrangement except for the lubricant.

The test specimen (2), in this case a block of metal, is mounted in a specimen holder (3) which can rotate around its shaft (4), maintaining line contact between ring and block. The specimen is pressed against the ring by a force P applied by a pneumatic cylinder (5) acting through a lever system. The force P can be increased stepwise or continuously from 0 to 110 N over an adjustable time period. Loading was selected depending on specimen material.

As the ring is rotating, the friction force F between the ring and the specimen will pull on the specimen holder that is held back by the arm (6) through a ball contact. The friction force will thus act directly on the arm and bend it. The moment in the arm is measured with strain gauges (7) and a strain gauge bridge, converted back to friction force, and printed out on a stripchart recorder. Unwanted noise in the signal is filtered out.

The specimen temperature was measured with a thermocouple located between the specimen and its holder.

The different mixtures of lubricating oil were fed by natural fall through a pipe from a tank to the contact area between the specimen and the ring. The flow was kept constant at agbout 50 ml/minute.

The material of the rotating ring is standard roller bearing steel AISI 52100. The materials of the mating test specimens were white metal, bronze, and 2510 AFNOR 90 MCW5 steel (C 0.9, Mn 1.2, Cr 0.5, W 0.5, V 0.1), case hardened to 58 HRC.

Loads P applied to the blok and ring were as follows:

Steel vs Steel	P = 1075 N
Bronze vs Steel	P = 358 N
White Metal vs Steel	P = 179 N

Test Routine

The shaft was first speeded up and rpm adjusted. Next, the flow of lubricant was connected and the block lowered. The load was then steadily increased to the maximum permitted value within 5 minutes. Each test was then run for half an hoaur.

From the printouts were found:

Maximum friction force

Minimum friction force whenever a minimum occurred

Friction force after the run-in period, stable curve at the end of the test

Maximum temperature

Width of the wear track was measured with a microscope, and the volume of the worn material was calculated. For some tests, the roughness of the wear track was measured, and for some others, Scanning Electron Microscopy was used.

THEORY

The ring and block form an elementary plain bearing with hydrodynamic lubrication. The oil wedge formed in such a bearing is a function of speed N (rpm), load P, and oil viscosity Z. Under fluid film conditions, an increase in oil viscosity or speed will increase the oil film thickness and the coefficient of friction, whereas an increase in load will decrease them.

The separate consideration of all these effects forms a rather complex picture. To simplify this picture, the viscosity Z, the Speed N, and unit load P are normally combined into a single dimensionless factor called the ZN/P factor. Although no simple equation exists that expresses the coefficient of friction or the friction force for any bearing in terms of ZN/P, the relationship can be shown by a curve as indicated in Fig. 2 below.

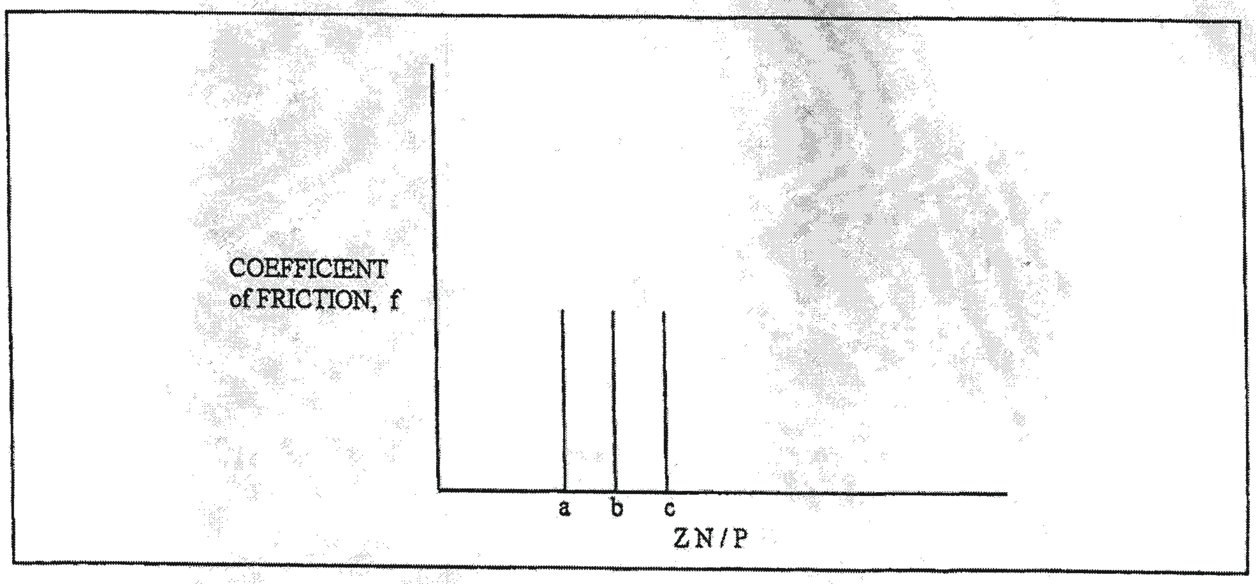

Fig. 2. Typical effect on bearing friction caused by viscosity Z, speed N, and load P.

In Fig. 2, boundary lubrication exists in the zone to the left of a, while full fluid film lubrication exists in the zone to the right of c. Boundary lubrication means that the condtions do not allow a full fluid film to be established. Some metallic contact will take place, causing friction and wear, and very high coefficients of friction may occur. In the following wear test we are operating in this boundary lubrication zone.

The zone between a and c is called the mixed lubrication zone. Minimum friction may be found in this area as indicated by b. For reduction of friction losses, it would be desirable to operate with a ZN/P value in the area a to c. However, in this area a minor disturbance of the conditions, such as a speed reduction or a shock load, may lead to film rupture. Bearings are therefore designed for an operating ZN/P value in the zone to the right of c. Normally the bearing is designed for a ZN/P value 5 times the minimum one at b. This factor is called the bearing safety factor.

A curve similar to the one in **Fig. 2** may be developed experimentally for any fluid film bearing, including this test bearing formed by the flock and ring. However, the geometry of the block will change rather rapidly during the running in period, even though N and P are kept constant and Z is changed, due to increased temperature. Because of the increasing contact area, the surface pressure will decrease. Possible wear-resistance in ProLong Anti-Friction Metal Treatment will try to slow this proceess. The surface pressure may be difficult to control.. Consequently, a typical ZN/P curve should be drawn only after the geometry has stabilized.

In this test, concentration was on friction force and temperature measurements, as well as studies of wear tracks.

TEST RESULTS

Optimum ProLong Blend

Different blends of ProLong in multigrade, commercial mineral engine oil were tested on Steel vs Steel. For each mixture, the test was repeated once. Rotational speed was kept at 700 rpm. Results are plotted in **Fig. 3**. Friction coefficients are given for the end of each test after run-in. 0% ProLong blend means pure engine oil without ProLong. 100% ProLong blend means pure ProLong.

Temperature was not measured during this test. The curve indicates 15% ProLong blend as an optimum effect for mineral engine oil.

Surface roughness of the wear tracks is indicated in **Fig. 4**. Original roughness R_a of the specimens as prepared before testing is 0.5 to 0.6 um. This original roughness is not completely worn away for any of the specimens. Thus, higher roughness value in the tracks indicates less wear, as more of the original surface roughness is still present.

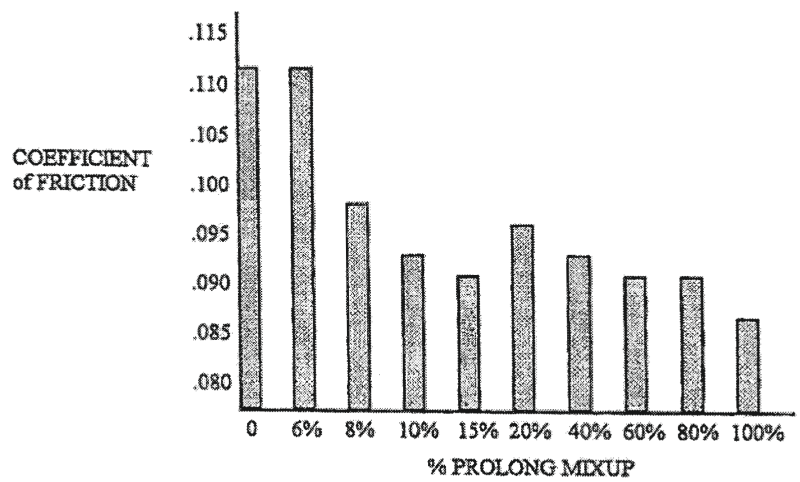

Fig. 3. Friction Coefficient Related to ProLong Blend in Mineral Engine Oil.

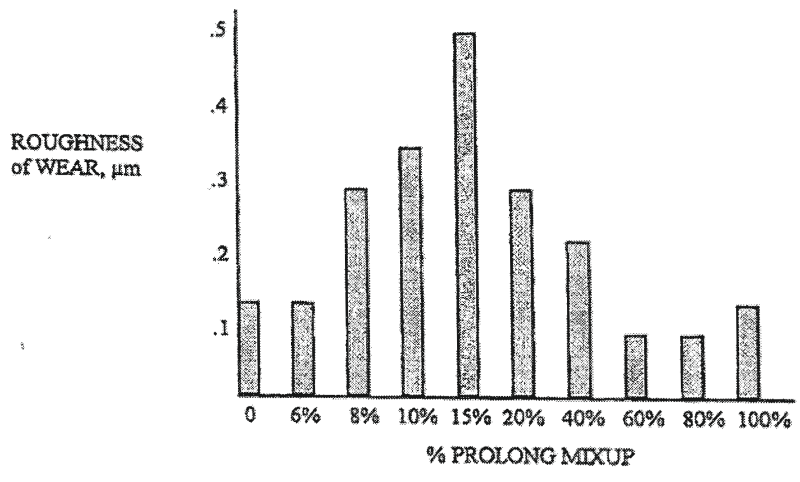

Fig 4. Surface Roughness of Wear Track With Different ProLong Blends in Mineral Engine Oil.
Material: Steel vs Steel

As can be seen from the figures, roughness, as well as friction coefficient, indicate an optimal effect at about 15% ProLong blend. For higher blends of ProLong, the roughness value indicates a wear rate or surface smoothening of the same level as for pure oil, while the friction coefficient at the end of the test is lower.

The optimal mixture may be different for other materials and/or other lubricating oils. For the further testing, 10% and 15% ProLong were selected in addition to pure oil.

Effect on Steel

Measurements During Testing

The ProLong effect on steel was measured for 4 different lubricating oils. Specimen temperature was recorded in addition to friction force. Shaft speed was increased to 800 rpm for all of the following tests.

Because the same scale was suitable for both the temperature (°C) and the friction force (Newton), the friction force was not converted into coefficient of friction. Had this been done, the curve would have remained the same, with only the scale changing.

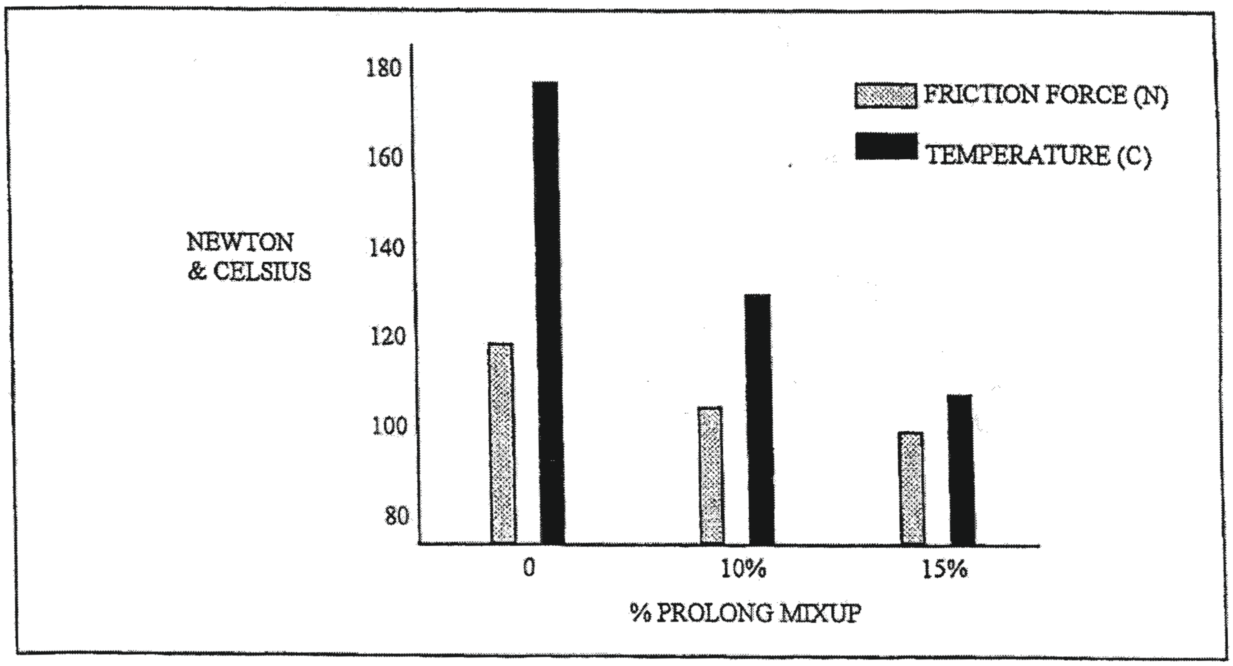

Fig. 5. Friction Force and Temperature (Same Scale) Related to ProLong Blend in Mineral Engine Oil

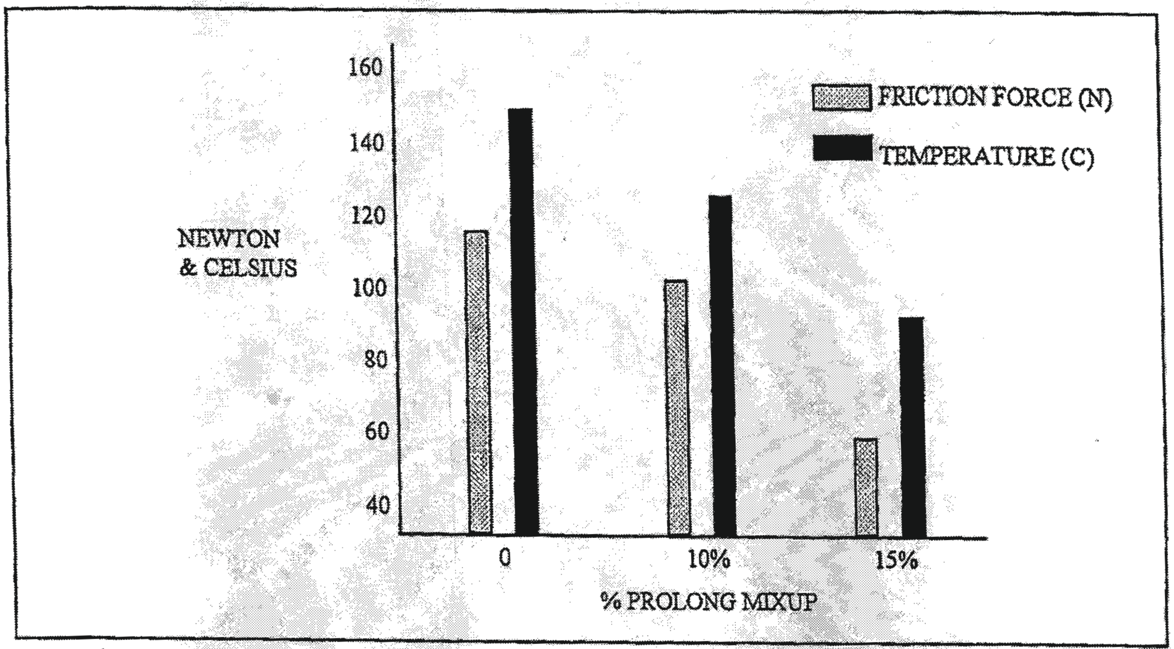

Fig. 6. Friction Force and Temperature (Same Scale)
Related to ProLong Blend in Commercial Synthetic Engine Oil No.1.

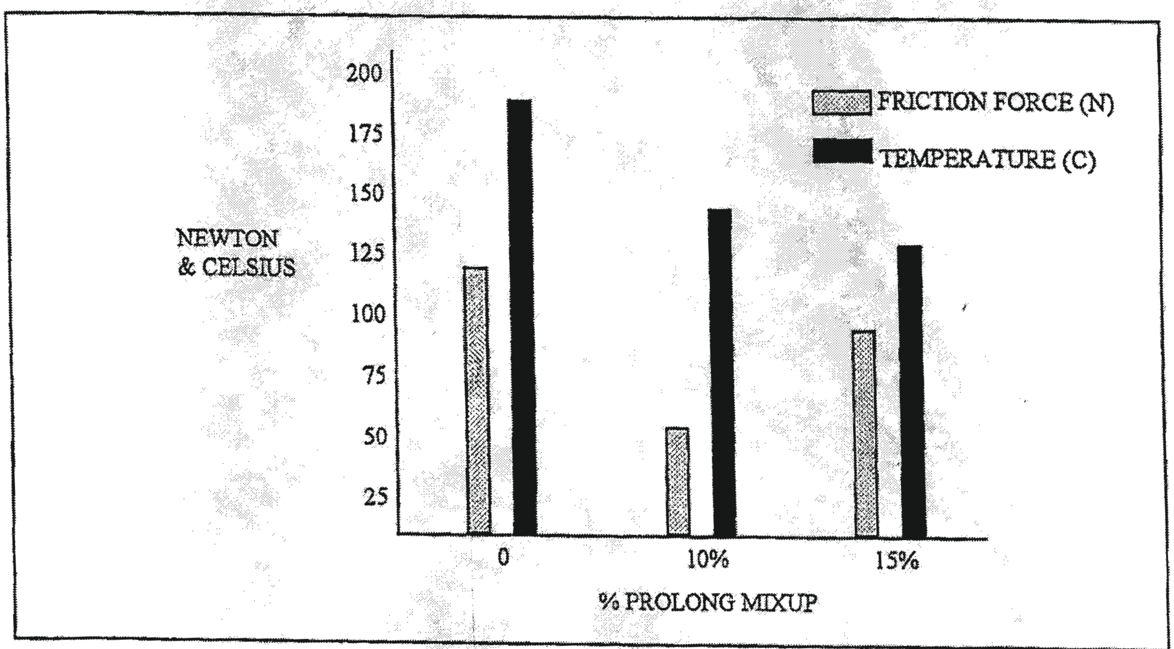

Fig. 7. Friction Force and Temperature (Same Scale)
Related to ProLong Blend in Commercial Synthetic Engine Oil No. 2.

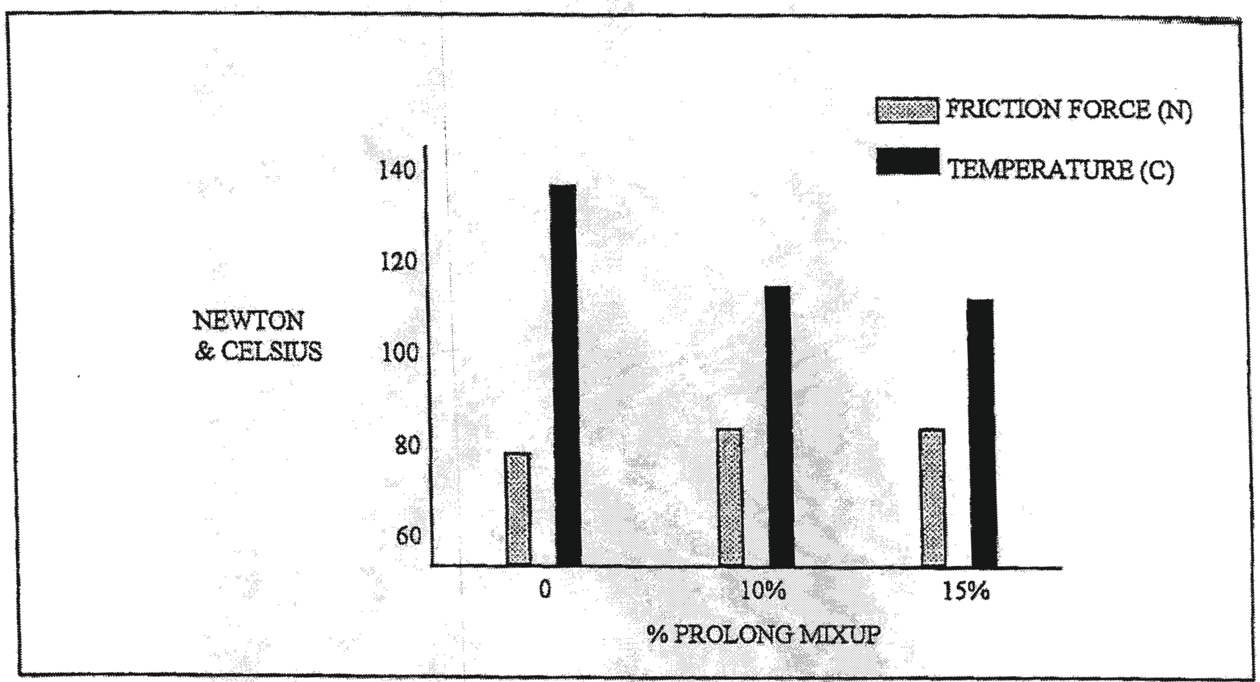

Fig. 8. Friction Force and Temperature (Same Scale) Related to ProLong Blend in Commercial EP Gear Oil.

For commercial mineral engine oil and synthetic engine oil No. 1, there is a considerable decrease in friction as well as temperature by use of ProLong, and a 15% blend gives the best result. The effect in synthetic oil is best.

For commercial synthetic engine oil No. 2, the lowest friction tends to occur at about 10% ProLong blend. However, the temperature is further reduced at the 15% blend.

For gear oil, the temperature is reduced by mixing in ProLong, but a similar effect on the friction force did not occur. On the contrary, the friction force was slightly increased by mixing in ProLong. Due to this, the temperature decrease is not as big as for the engine oils.

It can be seen that the temperature does not exactly match the friction force as one would expect. We would therefore assume that this product has a cooling effect either by convection, by evaporation of some volatile materials, or by local material melting because of eutectic functioning of the product.

Wear Measurements

The specimen wear represented by the width of the wear track was measured with a microscope. Depth of the track is more difficult to measure, but is given by the width and the diameter of the ring. Worn off material may then be calculated for a unit lenth of the track as $w^3/32$, where w is the width of the track. Worn off material from the steel vs steel test is shown in **Fig. 9** for all lubricating oils tested.

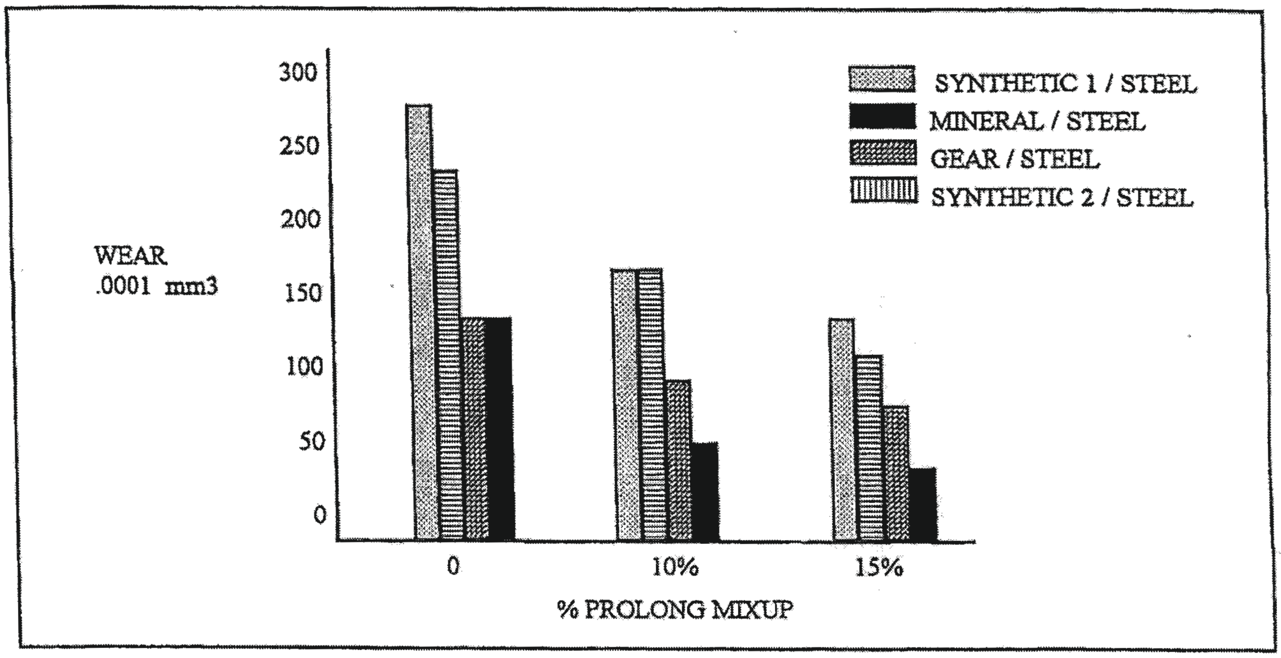

Fig. 9. Worn off material as a function of ProLong Blend.

The mineral engine oil and the mineral gear oil show the same amount of wear before ProLong is mixed in. The wear reductiion effect is as high as 45% for 15% ProLong mixed in gear oil, and for engine oils it is even more. Interesting to note is that synthetic oils show a very high degree of wear compared to mineral oils.

With 15% ProLong mixed in, the wear rates for the synthetic oils are brought down to the same level as for the mineral oils without ProLong. The reduced ProLong effect in the gear oil may have some connection with the additive package already existing in EP oils.

Survey of Test Results

Fig. 10 gives a general view of the results from Steel vs Steel tests. The table shows the percentage change in friction, temperature, and wear. The percent values were calculated from test data with 10% and 15% ProLong blend.

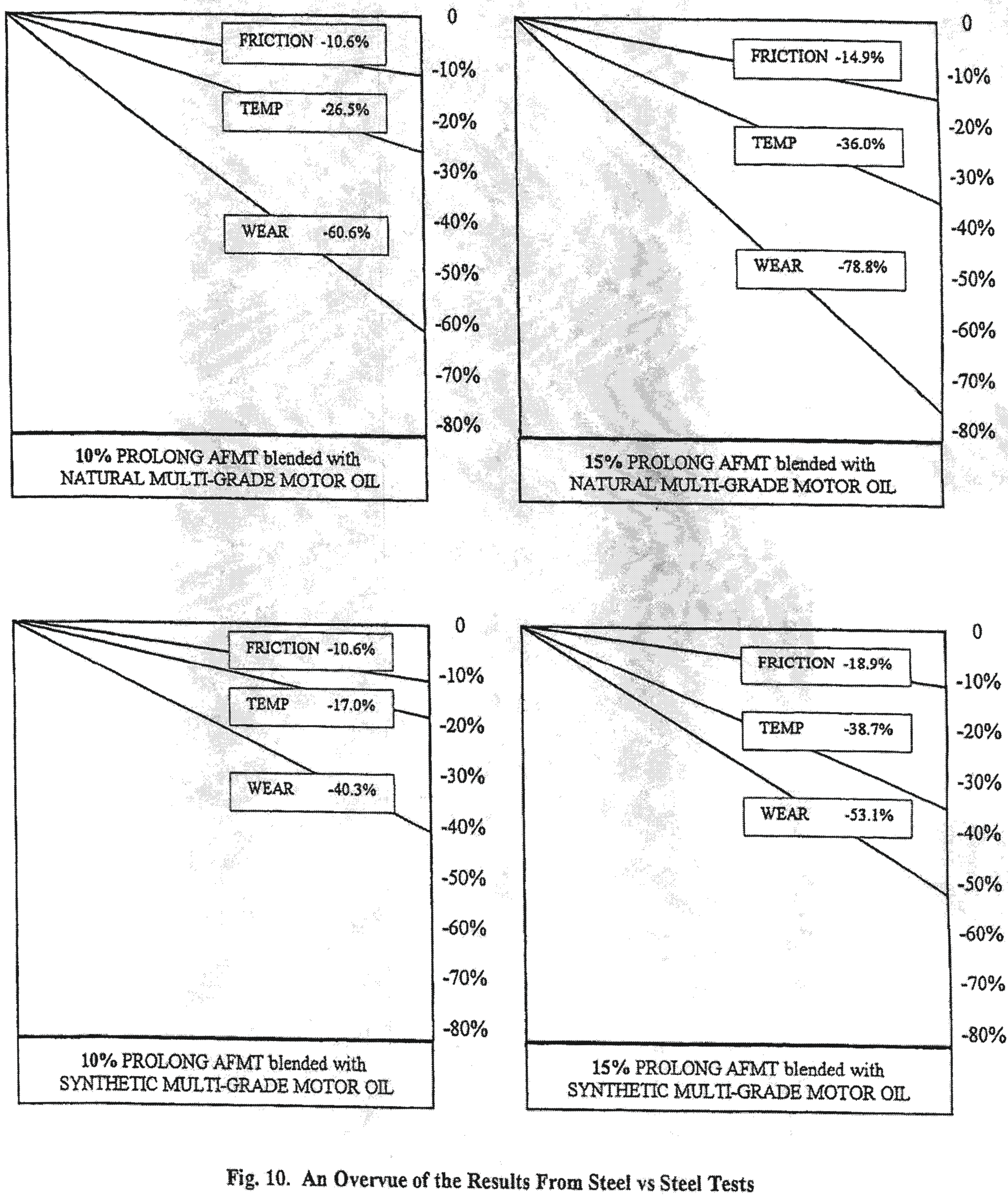

Fig. 10. An Overvue of the Results From Steel vs Steel Tests

Scanning Electron Microscope Studies

Studies were carried out with the Scanning Electron Microscope for:

Specimen material for reference purposes

Wear track from mineral oil test

Wear track from mineral oil with 6% ProLong

Deformed zone in wear track from 6% ProLong test

In the wear track from pure mineral oil, an enrichment of calciuim, copper, zinc, and sulfur was found, compared to the reference material analysis.

Effect on Bronze

Measurements During Testing

Bronze was tested as for steel, except for the load which was set to 358 N maximum. Three different lubricating oils were used. The following figures show the friction force and temperatures recorded at the end of the tests, each of them of 1/2 hr duration.

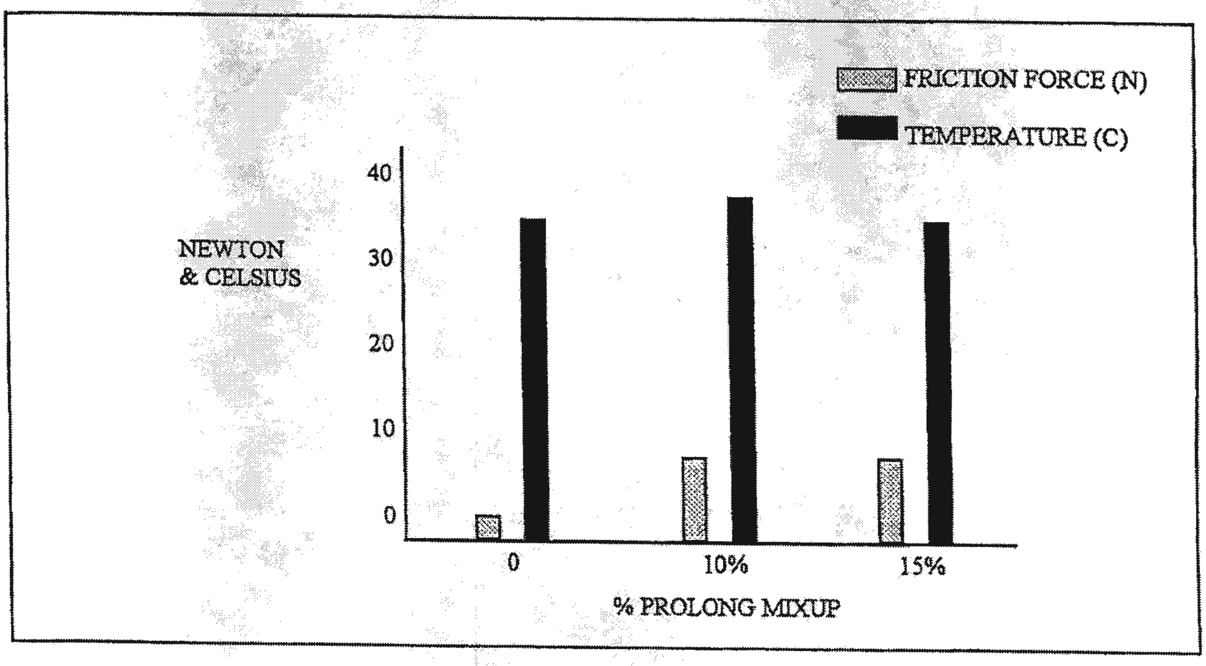

Fig. 11. Friction Force (N) and Temperature (°C) (Same Scale) Related to ProLong Blend in Commercial Mineral Engine Oil

The same oil with 6% ProLong blend left a wear track with an enrichment of nickel, while the contents of copper and zinc were reduced. Other elements were the same as for the test with pure mineral oil.

In the deformed zone from the 6% ProLong blend test, chromium, iron, and nickel contents were the same as for the wear track outside the zone, while silicon, manganese, and sulfur contents were reduced. In this zone, the total percentage of elements also decreased to 80% compared to 88% otherwise.

Deformation zones in the wear track occurred only for oils with ProLong mixed in. Such zones tended to occur more frequently for low and high ProLong contents, and less for 10-15% ProLong blends.

The deformations look like cold welding, which means that local melting had taken place. One reason may be nonuniform material containing zones of another structure having a lower melting point than the surrounding material. Provided ProLong has a eutectic function, it may reduce the melting point of the material enough to cause local melting of these zones at the load applied, which is unrealistically high for normal bearings. An explanation of why these deformations do not normally occur at ProLong blends of 10-15% may be a better cooling effect from these mixtures. Hardness measured in the wear track may indicate a slightly increased hardness due to ProLong. The Scanning Electron Microscope studies were made in addition to the tests agreed upon, just for an indication. For a final conclusion from this study, a larger number of SEM studies would be needed.

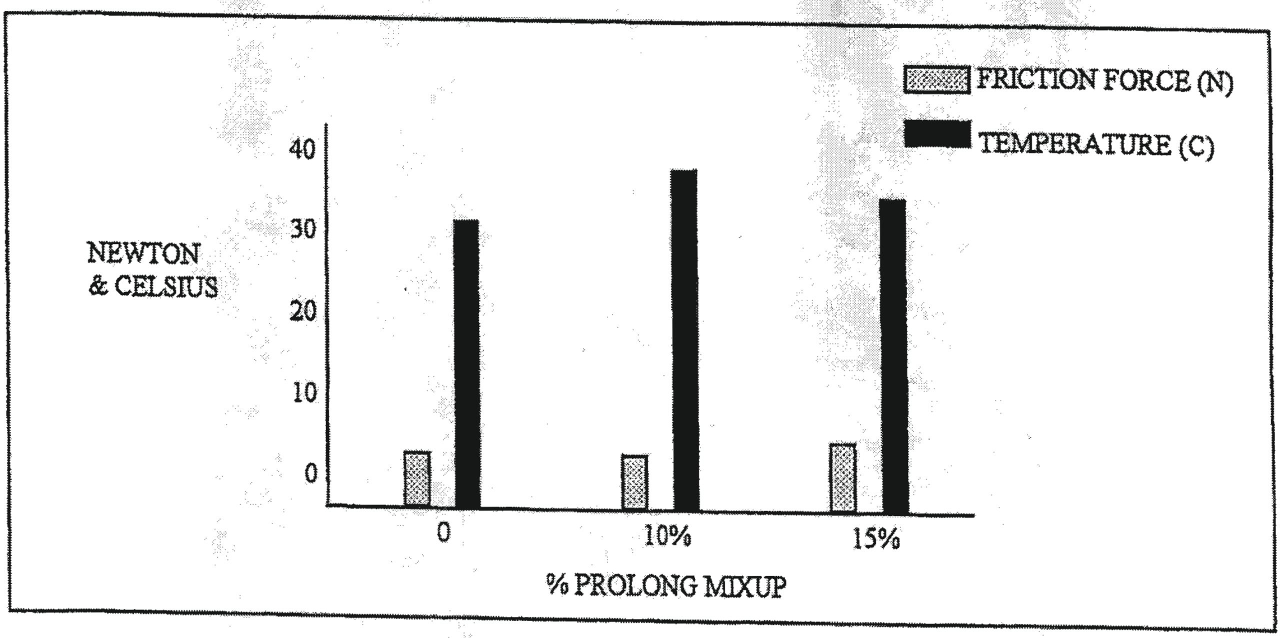

Fig. 12. Friction Force (N) and Temperature (°C) (Same Scale) Related to ProLong Blend in Commercial Synthetic Engine Oil No. 1.

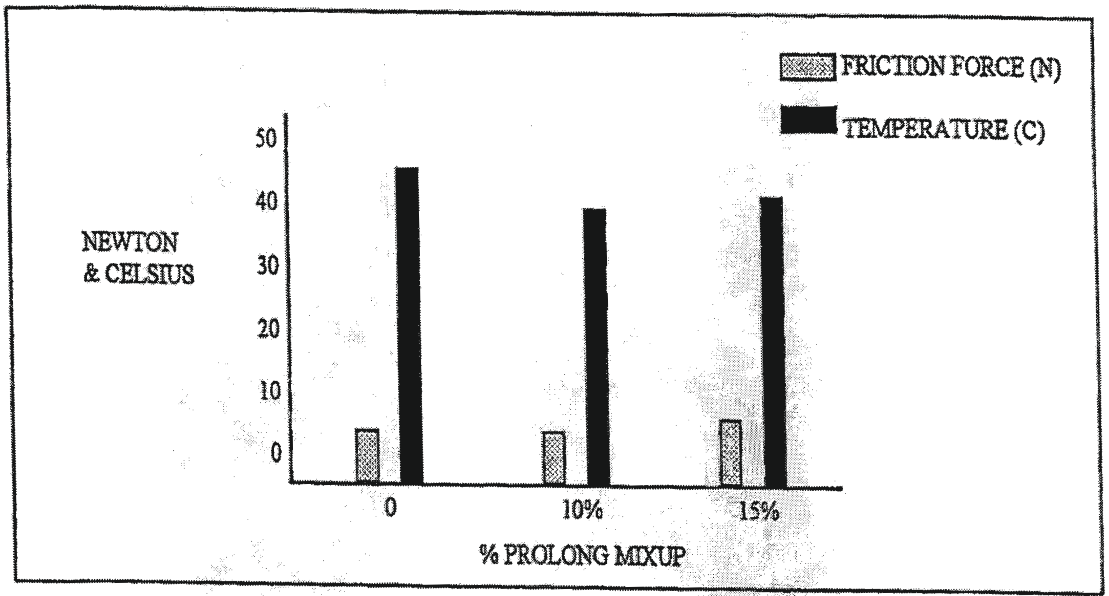

Fig. 13. Friction Force (N) and Temperature (°C) (Same Scale) Related to ProLong Blend in Commercial EP Gear Oil

It should be noticed that the friction and temperature values from the bronze tests are rather low compared to steel tests. Rigid conclusions cannot be drawn on smaller curve fluctuations because the accuracy for such measurements must be taken into account.

As may be seen in the figures, there is a slight increase in friction force for the bronze vs steel contact for all of the oils when ProLong is mixed in. One reason for these results may be the effect of ProLong on the viscosity. Although viscosity has not been directly measured in this project, it has been observed that ProLong tends to reduce the viscosity. Keeping the rotational speed N and load P constant, the viscosity Z is the only factor that can reduce the ZN/P value in **Fig. 2**, and increase the coefficient of friction in the boundary lubrication zone.

Wear Measurements

An increase in friction force, as was shown for the bronze test, would normally result in greater wear. However, in this case all the tests clearly indicate a considerable reduction of wear by using ProLong, as shown in **Fig. 14.** For synthetic oil, 10% ProLong showed the greatest wear reduction.

Some structural changes in the material may be found, as for steel, explaining this higher wear resistance. Being outside the agreement for this project, SEM was not done on these specimens.

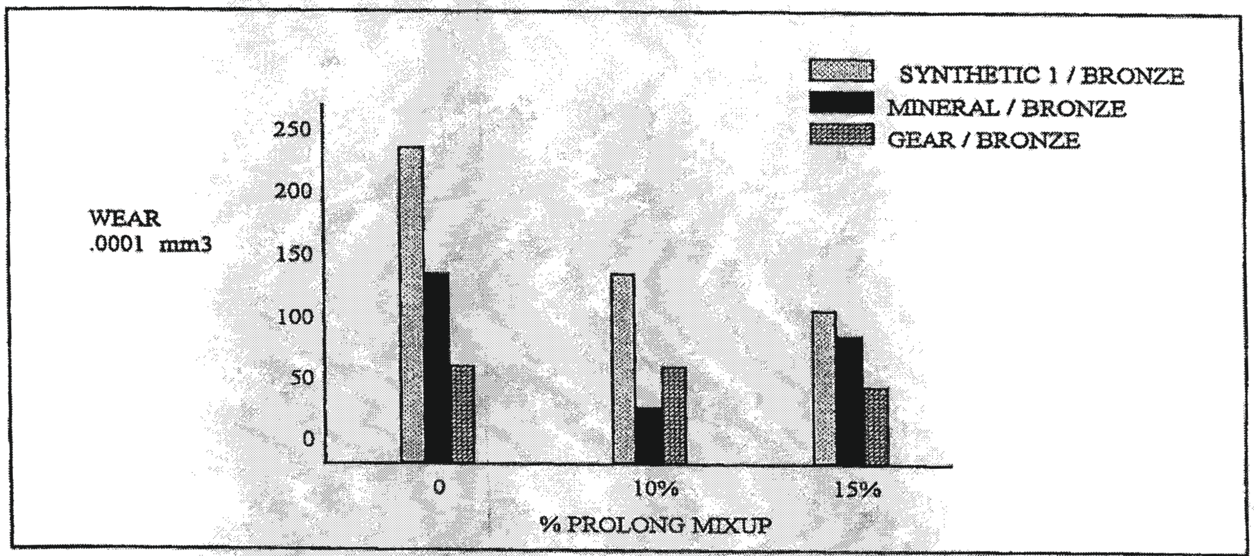

Fig. 14. Worn Off Bronze Material Related to ProLong Blend In Mineral and Synthetic Engine Oils and in EP Gear Oil.

Survey of Test Results

Fig. 15 gives a general overview of results from Bronze vs Steel tests. The table shows the percentage change in friction, temperature, and wear. The percentages are calculated from test data with 10% and 15% ProLong blends.

Effect on White Metal

As white metal is a comparatively soft material, the load had to be further decreased. At 180 N, which is about 2 times the acceptable load for such a brearing, there was a tendency of full hydrodynamic lubrication, reference **Fig. 3.** As soon as the load was increased to bring the ZN/P value into the boundary lubrication zone, some material was worn, resulting in a larger area and further hydrodynamic lubricatlion.

With this low load, the specimen tended to float on the turbulent oil flow, and no comparative measurements could be done.

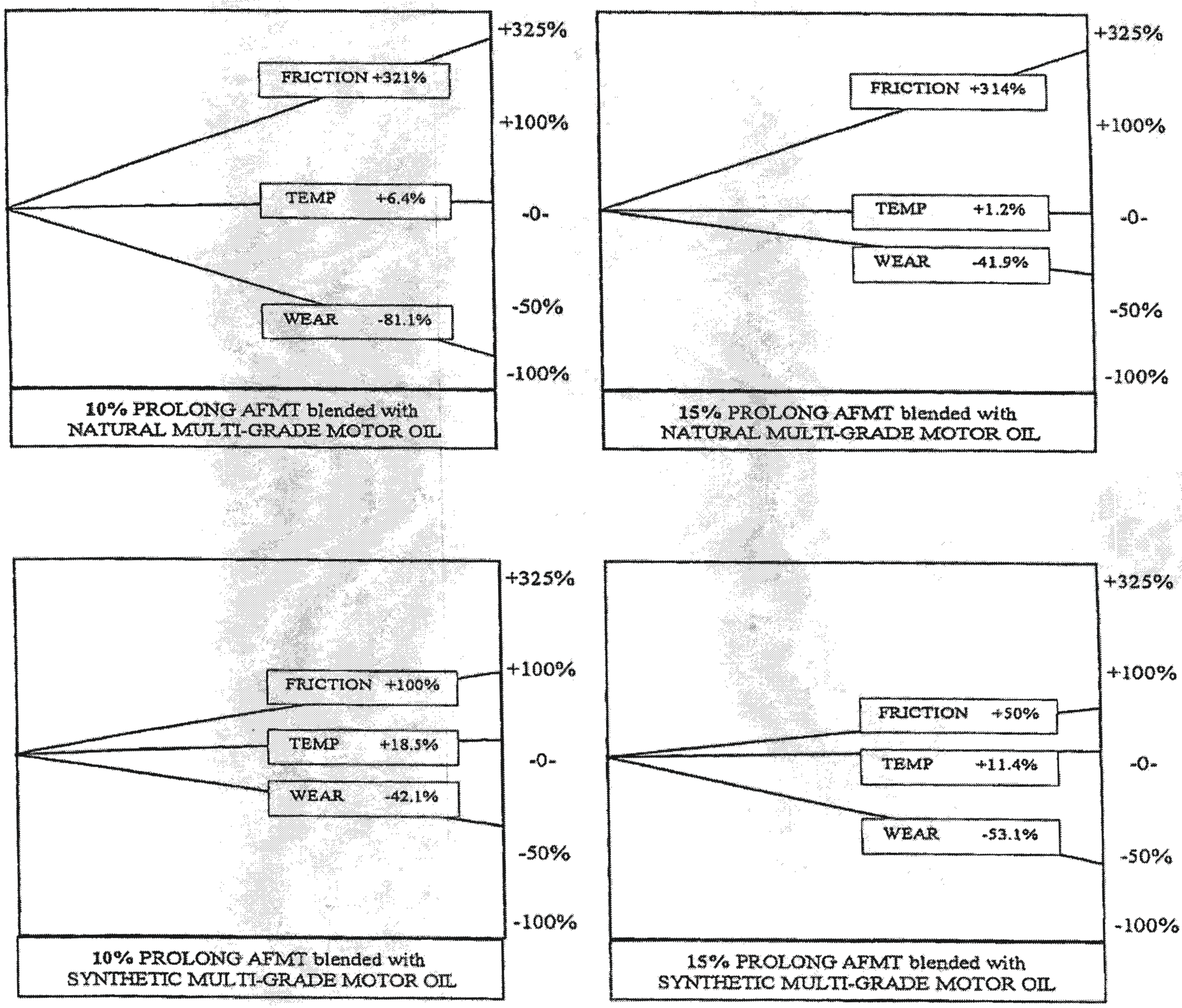

Fig. 15. An Overvue of the Results From Bronze vs Steel Tests

Other Measurements and Limitations

The specific gravity of ProLong Anti-Friction Metal Treatment was found to be 1.15, which corresponds to the manufacuter's specifications. This is quite heavy compared to ordinary oils, and mixability should be subject to further studies.

ProLong was analyzed for its sulfur content, because high sulfur content is not recommended for engines. Sulfur was found to be 0.1% by volume, which is also according to the manufacturer's specification. The sulfur mixed in from ProLong is therefore considered negligible.

Viscosity of ProLong was not measured during this series of tests. It is, however, specified by the manufacturer to be 10-15W. As could be seen during these tests, the viscosity of heavier oils is reduced if ProLong is added in large quantities. For these tests, the effect of viscosity is not critical because the test bearings operate in the boundary lubrication zone anyway. A lower viscosity will affect the ZN/P value, and hence one would expect even more reduction of the friction measured in the tests, provided the viscosity was maintained.

CONCLUSIONS

Results from these tests should be used as an indication only. Measurements are taken from specified laboratory tests without simulation of any actual machinery situation. Real machines may have variable temperature ranges and loading conditions which may result in other findings. Other material combinations than the tested ones will also exist.

These tests have revealed a significant wear reducing effect from the ProLong Anti-Friction Metal Treatment for lubricating oils.

In total, 110 tests were run. Averages for these tests show that for Steel vs Steel, friction, temperature, and wear were reduced by approximately 20%, 30%, and 55% respectively at a 15% ProLong blend in the oil (Fig. 16).

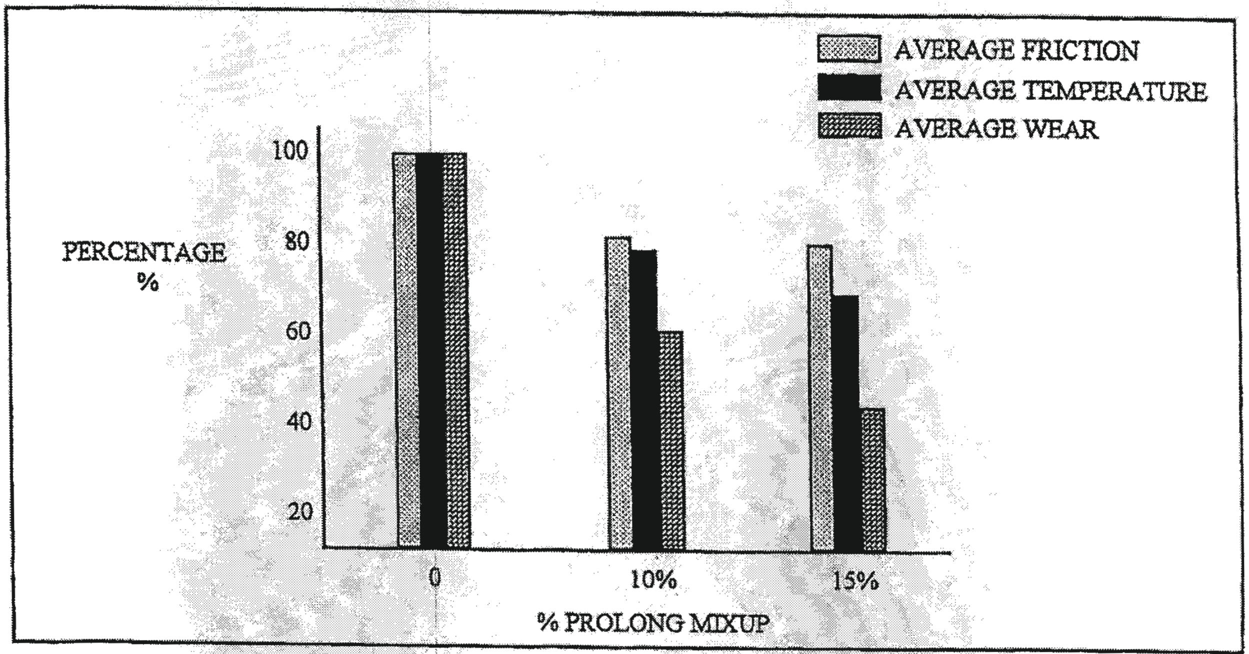

Fig. 16. Average Friction, Temperature, and Wear from All Steel vs Steel Tests.

For Bronze vs Steel, averages from the tests show that friction is increased by approximately 75%, temperature is almost unchanged, and wear is reduced by approximately 45% with 15% ProLong mixed in the oil (Fig. 17).

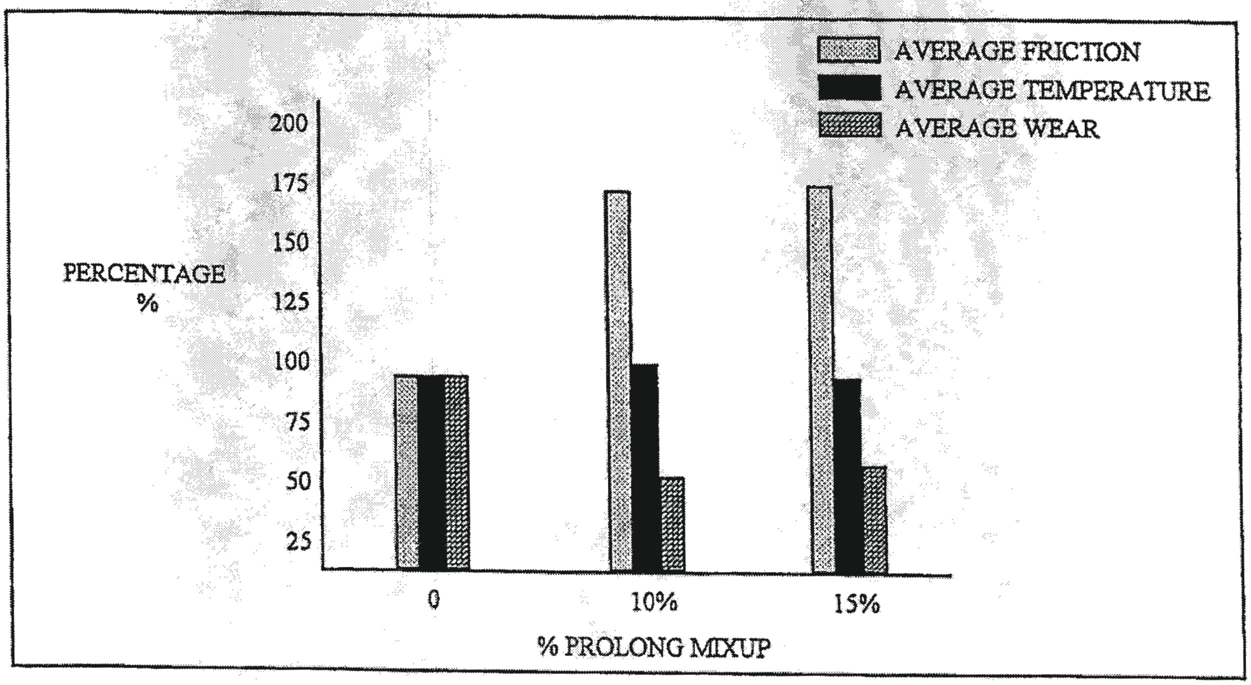

Fig. 17. Average Friction, Temperature, and Wear from All Bronze vs Steel Tests.

It should be noted that although the friction is increased approximately 75% for Bronze vs Steel by using ProLong, this friction is still low compared the the 25 times higher friction for Steel vs Steel, where ProLong showed a significant friction reducing effect.

Occasionally performed SEM analysis of the wear track on steel indicates a possible surface treatment and increase of hardness due to ProLong. This will need some further investigation.

Specific gravity and sulfur content were found to meet the manufacturer's specifications, 1.15 and 0.1%, respectively. No restrictlions for use should be required due to sulfur content.

Due to the significant results from these tests, the product is proposed for further long term testing on real machines. Possible surface treatment effects and eventual long term effects on temperature due to possible evaporation of the mineral spirits contained may be relevant for further study.

Analysis of the affinity of the ProLong Anti-Friction Metal Treatment to lubricating oils, especially regarding the effect on viscosity and particle size distribution, is also proposed.

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SINTEF Research Report

SINTEF - The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology. SINTEF works extensively with the major oil companies of the North Sea oil operations including - Shell Oil, Mobil, State Oil, Phillips etc.

Prolong Super Lubricants, Inc. contracted SINTEF to test our **"Anti-Friction Metal Treatment"** (AFMT) on Steel/Steel and Steel/Bronze metals. Friction, temperature and wear studies were to be completed. Four different oils were selected by SINTEF for comparisons; two synthetic oils, one mineral engine oil and a gear oil were used. (Mineral oils being the base for engine oils.)

The maximum results occurred when 10-15% **Prolong Super Lubricant** mixtures were used. Prolong **AFMT** was carried to the metal by all four oils chosen. Reduction in wear was the greatest single benefit. Tests were carried out at ratios from 5% to 15%.

Results from 110 tests on each material were as follows:

REDUCTION IN STEEL/STEEL AVERAGES:
20% Coefficient of Friction
55% Wear
30% Temperature

REDUCTION IN STEEL/BRONZE AVERAGES:
Less dramatic reduction in the coefficient of friction or temperature.
However, wear reduction of 45% occurred.

*Ratios of up to 15% are recommended for heavy industrial use. The ratios for general use is based on both economics and performance. Having analyzed these and other reports, **Prolong Super Lubricants, Inc.**, recommends a 6-10% mixture ratio for general usage. Refer to guide and spec. sheets.

Summary of SINTEF Report

The **SINTEF Group** is the largest technological research organization in Northern Europe. The Group is composed of four separate organizations: **SINTEF** - The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology. **IKU** - Continental Shelf and Petroleum Technology Research Institute A/S. **EFI** - The Norwegian Research Institute of Electricity Supply A/S. **MARINTEK** - Norwegian Marine Technology Research Institute A/S.

SINTEF Summary STF-18-F87013

This report deals with a friction and wear study of the **Prolong Super Lubricants, Inc. AFMT** for lubricating oils. A Block on Ring machine has been used for the test.

Typical test data are based on boundary lubrication.

Material Combinations like Steel/Steel and Bronze/Steel have been tested. Oils used for the test have been mineral engine oil, two different synthetic engine oils and gear oil.

Approximately 15% Prolong Super Lubricant AFMT mixture in the oil is found to give the best results - with an average wear reduction of 50%. Except for an increase in the Steel/Steel friction in gear oil and in the low friction in Bronze/Steel contact, a considerable reduction of friction and temperature occurred.

Because of the positive results from this test further testing is proposed. **Prolong Super Lubricants, Inc.** long term policy is to keep pace with new technology by continuing research.

The following chart outlines the type of lubricant, percentage of **AFMT** used, and the percentage of reduction of:

FRICTION	17.5% Average Reduction
TEMPERATURE	25.0% Average Reduction
WEAR	47.5% Average Reduction

Lube oil	Friction		Temperature		Wear		% Pro-Long
	Mineral	Synthetic Multigrade	Mineral	Synthetic Multigrade	Mineral	Synthetic Multigrade	
Multigrade synthetic engine oil no. 1	%	%	%	%	%	%	
	-10.6	-10.6	-26.5	-17	-60.6	-40.3	10
	-14.9	-48.9	-36	-38.7	-78.8	-50.7	15
Multigrade Synthetic engine oil no. 2		-51.6		-21.3		-29.8	10
		-16.7		-30.3		-53.1	15
EP gear oil	+6.3		-15.3		-34.8		10
	+6.3		-19.5		-48.5		15
Average value from 65 STEEL/ STEEL tests	-15		-20		-40		10
	-20		-30		-55		15

TEST RESULTS

SETA-SHELL FOUR BALL EXTREME PRESSURE TEST (A.S.T.M. D-2783-82)						
	PRODUCT	LOAD KGF	TIME SECONDS	TEMP. °F	Avg. Scar Size mm. LENGTH	WIDTH
A	Texaco Havoline 10W30	780	10.0	65	2.94	2.44
B	Texaco Havoline 10W30 **plus 10% AFMT Concentrate**	780	10.5	66	2.16	2.02
A	Esso Pro Tec 10W30	780	10.05	65	2.91	2.51
B	Esso Pro Tec 10W30 **plus 10% AFMT ConcentrateA**	780	10.01	65	2.21	2.16
A	Mohawk Hydraulic-AW46	500	10.1	72	2.50	2.32
B	Mohawk Hydraulic-AW46 **plus 15% AFMT Concentrate**	500	10.0	72	1.24	1.22
A	Mohawk Winter Chain Oil	780	10.0	67	6.00	4.50
B	Mohawk Winter Chain Oil **plus 10% AFMT Concentrate**	780	10.0	67	3.00	2.44
A	Mohawk All Season Hydraulic	500	10.0	72	6.00	6.00
B	Mohawk All Season Hydraulic **plus 10% AFMT Concentrate**	500	10.05	72	1.35	2.03