FILM STUDY GROUP

REPORT

T.O.M. REEL NO. 69

Prepared by

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## Abstracts on Reel 69

## U.S. Technical Oil Mission Microfilm

Abstracts
Reel 69 of T.O.M. film
Bag 4056

p. 25-29 Metal Cutting

A) Emulsifiable Oils

Cutting oils used so far produce skin infections. Emulsifiable oils containing tricresylphosphate are not fully satisfactory; addition of graphite dispersible in water, and colloidal sulfur are contemplated for improvement of lubricating properties as well as water-soluble cellulose for improvement of rheological properties.

Tests of lubricating properties made by periodically measuring by optical means the roughness of work produced.

B) Cutting Oils

In rifling gun barrels only non-emulsifiable cutting oils can be used. Test results in testing oils in this operation are unreliable, and vary with sharpness and quality of the cutting tool rather than with quality of oil. Fresh oil, and oil removed from turnings by centrifuging and also by extraction were analyzed.

Another operation in the production of rifles is used for testing quality of oils. Results of such tests show that fat-containing oils (90% rape oil, 10% turpentine oil) are far superior to non-fatty oils containing chlorine, sulfur, or phosphorus (e.g., fat-free chlorinated spindle oil).

p. 30-34 Forming of metals without Producing Shavings

Lubricating materials used in the "Neumeyer" process (a type of cold drawing of soft steel) are exposed to pressures of 15-20,000 kg./cm$^2$ and temperatures of 200-300°C. A substitute for the best lubricant, tallow, had to be sought, and in the comparison of various types of oils the "pressure-viscosity" - the slope of log Engler°/50 vs. pressure - was established as a useful criterion. The viscosity of fatty oils is tripled at 1000 kg./cm$^2$., while the viscosity of paraffinic oils increases 6-8 fold, of naphthenic oils 8-10 fold and of asphaltic oils 10-20 fold.

For hot-drawing of mild steel, Noris Zündlicht A G reports successful use of fat-free cutting oil in place of rape oil necessary heretofore.

Laboratory work is pursuing research on non-fatty lubricants, without, however, using extreme pressure additives in place of the fats. On the contrary, the trend is to replace the well known chlorine, sulfur, and phosphorus compounds in water-insoluble cutting oils Among emulsifiable oils, the "drilling medium HÖ" (neutralized sulfo-chloride of synthetic gasoline) of the I G Farben assumes a key position.

p. 35-40 Evaluation of Lubricants Used in Deep-Drawing of Cartridges

The following lubricants were tested with respect to their performance during actual manufacture:

A. 1% aqueous solution of soap shavings and lubricant soap.
B. An emulsifiable oil (proprietary)
C. An emulsifiable proprietary drawing grease
D. Experimental oil 1
E. Experimental oil 3
F. Drilling medium HÖ
G. Mixture of E, colloidal graphite and water

Details of composition of lubricants are given.

Results of tests are reported in detail.

Conclusions:

1) The use of all aforementioned lubricants is made possible only by "atramentizing" (i.e., cold phosphatizing) of the cartridge blanks.

2) Bibliography given to support statement that phosphatizing assumes an essential part in lubrication in deep-drawing.

4) In this manufacturing process, the soap solution is certainly superior to the other lubricants. An explanation for the startling result is offered.

5) A new lubricant, neutralized oil resin sulfonate, is to be tested and looks very promising in laboratory tests.

6) Drilling oil emulsions in conjunction with colloidal sulfur yield excellent results in cutting of metals when shavings are produced. In drawing of metals, where no shavings are produced, these lubricants fail completely, perhaps due to incompatibility of the sulfur with the phosphate layer.

8) Hardness of drawing matrices is of more importance in determining their rate of deterioration than the type of lubricant.

9) The failure of the graphite-emuls-oil mixture compared to soap solution is noteworthy. However, due to fluctuations in the quality of the soap, results are not entirely conclusive. Graphite has been very successful in the production of cartridges using unbonderized steel.

p. 41-45 <u>Method for Testing Oil Emulsions</u>

An attempt was made to develop a method for testing cutting oils by optically evaluating the roughness of cartridges periodically sampled during their manufacture. The method was not found useful.

p. 46-49 <u>Substituting Emulsions for Cutting Oils in Deep-Hole Drilling of Rifle Parts with Hard Metals</u>

In testing four experimental emulsions and cutting oils (composition given) it was found that: a) activated emulsions can be substituted for water insoluble cutting oils, b) more viscous oils are to be preferred to the thin spindle oils as a base for emulsion oils, c) colloidal sulfur in aqueous suspension has definitely advantageous properties in this process.

p. 50 <u>Testing of Lubricating Properties of Emulsions during Boring of Motor Cylinders</u>

Two emulsions were compared:

a) containing HÖ I. G. Farben (see preceding reports)
b) containing Trupon emulsifier.

The latter gave slightly better results. The composition of the Trupon emulsifier is not given. 0.2% sodium nitrite and trisodium phosphate are added to water to retard corrosion.

p. 51-58 <u>Discussion of the Lubricating Properties of Oils in Certain Metal Cutting Processes</u>

Experiments illustrating the dependence of work produced in metal cutting upon the fat content of the lubricant shows that cutting oils require a fat content of 40% to approach the quality of pure fat oils. Carbon, phosphorus, and sulfur-containing ("extreme pressure") additives are not satisfactory substitutes. Substitutes for fat substances for blending with non-fatty oils such as products of paraffin oxidation, synthetic fatty acids and their synthetic glycerides were considered. However, the oils of bituminous coal tar hydrogenation, considerably oxidized by passage of air (Brabag oils) were actually found to have very good lubricating properties in blends with cutting oils.

p. 59-63 Cooling Lubrication during Horizontal Drilling (High-Speed Deep-Hole Drilling) by Means of Emulsions

The lubricants used in peace time, rape oil-soft soap emulsions, can be replaced by N-emulsion (2% soft soap, 2% drilling oil or "HO" additive, 96% water). The ratio soap:oil can be somewhat reduced while maintaining good lubricating properties. Good results were also obtained with an emulsion containing 15% of a commercial drilling oil consisting of 30% emulsifier and 70% spindle oil distillate.

p. 64-70 On the Scattering of Performance Values in the Process of Deep-Drawing

The process of flow-pressing (Fliess-pressen) or cold-spraying (Kaltspritzen) of steel can be used to evaluate the behavior of lubricants at high pressures; the process of deep-drawing of cartridges cannot so be used because differences in the quality of the tools and in the hardness of the work cause too wide scattering of the test results.

p. 71-73 Large Scale Tests with V/Ka-L

Gives an account of testing of experimental lubricant Kadmer-Luers (described in previous report, not in collection at hand).

p. 74-78 On the Lubricating Properties of Compounded and of Chemically Activated Mineral Oils

In the manufacture of taps and dies, compounded oils are best lubricants. Naturally-aged synthetic oils are satisfactory but chemically active additives are unsuitable, especially those containing chlorine. The failure of the latter is possibly due to thermal decomposition to corrosive chlorine compounds.

p. 80-111 Investigation of Friction, Wear and Lubricating Power Using the Almen-Wieland* Oil Testing Machine by K. Kadmer, Inst. for Chemical Technology, Technical College, Munich

Forward

The report covers 32 pages. The material will be arranged in 16 groups of experiments of which the first 13 groups were treated under Chapter K 1/04/5.

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* Translator's Note: The Almen Machine is described in various places in the literature, including U.S Pat. 2,001,861 and The Mechanical Testing of Extreme Pressure Lubricants, J. Inst. Pet. 32, (1946) 206 by H. West.

Construction, installation and method of operation of the SAE Oil Testing machine of Almen-Wieland design have been described in the following publications: Kadmer, "Lubricants and Machine Lubrication", Chapt 2 (1941) 317-320 and W. Paul, Oel u. Kohle 1940, 475-477.

In the following tables P indicates the load expressed as the number of plates, each 1 kg. in magnitude. The load is transmitted to the interchangeable testing units by hydraulic means. In the case of the 1936 Model the transmission ratio amounts to 1:62.5, that is 1 kg. of applied weights corresponds to a load of 62.5 kg. on the test bushings. In the case of the 1941 Model the transmission ratio is 1:60. In both instances the test bearings are characterized by the following dimensions: diameter of journal or pin = 6.3 mm., length of bearing pin = 12.8 mm., internal diameter of bushing = 6.5 mm. and a bearing play of 0.2 mm.

These specific experiments were accomplished with the 1936 Model. Comparable data with the 1941 Model were obtained from Mr. Luers of Bremen.

Group 1 Various Mineral Oil Raffinates

| Oil No. | Designation | Color | d/20 | n 20/D | E/20 | E/50 | $W_p$ | M |
|---|---|---|---|---|---|---|---|---|
| 1 | Nitro benzene raff. | 3.5 | .862 | 1.477 | 13 | 3.3 | 1.85 | 3.73 |
| 2 | " " " | 5.5 | .896 | | 60 | 9.0 | 2.38 | 3.78 |
| 3 | " " " | 5.0 | .879 | 1.483 | 45 | 8.1 | 1.97 | 3.56 |
| 4 | $H_2SO_4$ raff. | 7.5 | .904 | 1.501 | 57 | 8.6 | 2.50 | 3.83 |
| 5 | Nitrobenzene raff. 99 AP | | .867 | 1.481 | 0.5 | 3.0 | 1.61 | 3.61 |
| 6 | Duo-Sol raff.117° AP | | .875 | 1.485 | 49 | 9.6 | 1.83 | 3.44 |
| 7 | " " " 109° " | | .896 | 1.484 | 118 | 16.4 | 2.07 | 3.50 |
| 8 | " " " | 6.6 | .876 | 1.486 | 49 | 9.2 | 1.83 | 3.42 |
| 9 | " " " | 6.6 | .876 | 1.486 | 49 | 9.2 | 1.83 | 3.42 |
| 10 | Sulfur raff.regenerated | | .905 | | 84 | 12.8 | 2.05 | 3.52 |
| 11 | Flugmot.Oil Green Ring | | .878 | 1.487 | 178 | 23.4 | 2.04 | 3.41 |
| 12 | " " Red " | | .878 | 1.489 | 124 | 17.6 | 2.04 | 3.45 |
| 13 | Brightstock, sap. #6.3 | | .908 | 1.507 | 425 | 42.4 | 2.25 | 3.45 |
| 14 | Flugmot. Oil, 100 hr. | | .885 | 1.488 | | 17.2 | 1.86 | 3.35 |
| 15 | " " 120 hr. 123 AP | | .886 | | 180 | 25.0 | 1.85 | 3.25 |
| 16 | " " 140 hr. | | .888 | | 225 | 30.6 | 1.88 | 3.24 |
| 17 | $H_2SO_4$ raff. (d) | | .916 | | 15 | 3.5 | 2.30 | 3.89 |
| 18 | " " (a) | | .895 | | 13 | 3.6 | 1.44 | 3.40 |
| 19 | " " (p) | | .920 | | 26 | 4.5 | 2.89 | 4.10 |

## Values of the Frictional Force R (kg.)

| Oil No. | Load Expressed as Number of Weights 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model 1936 | | | | | | | | | | | | | | |
| 1 | 6 | 16 | 29 | - | | | | | | | | | | |
| 2 | 6 | 18 | 36 | 55 | - | | | | | | | | | |
| 3 | 5 | 16 | 31 | 44 | 57 | 74 | - | | | | | | | |
| 4 | 8 | 12 | 26 | 37 | 47 | 65 | - | | | | | | | |
| 5 | 7 | 13 | 20 | 30 | 42 | 60 | - | | | | | | | |
| 6 | 5 | 19 | 28 | 41 | 65 | - | | | | | | | | |
| 7 | 10 | 21 | 36 | 54 | 73 | - | | | | | | | | |
| 8 | 5 | 12 | 20 | 28 | 38 | 50 | - | | | | | | | |
| 9 | 8 | 11 | 15 | 26 | 41 | - | | | | | | | | |
| 10 | 6 | 12 | 18 | 26 | 35 | 46 | - | | | | | | | |
| 11 | 5 | 12 | 22 | 28 | - | | | | | | | | | |
| 12 | 6 | 23 | 32 | - | | | | | | | | | | |
| 13 | 4 | 13 | 28 | 48 | 63 | - | | | | | | | | |
| 14 | 2 | 9 | 16 | 25 | - | | | | | | | | | |
| 15 | 4 | 11 | 19 | 27 | 32 | 41 | - | | | | | | | |
| 16 | 2 | 18 | 29 | 35 | - | | | | | | | | | |
| Model 1941 | | | | | | | | | | | | | | |
| 17 | 9 | 20 | 35 | 48 | 60 | 72 | 82 | 100 | - | | | | | |
| 18 | 9 | 19 | 31 | 43 | 53 | 64 | 73 | 107 | - | | | | | |
| 19 | 9 | 23 | 40 | 56 | 87 | - | | | | | | | | |

Note: The increase in the load is in stepwise 30 second intervals.

## Conclusions

The film strength (adhesiveness) of mineral oil raffinate is limited. Differences in the course of the raffination ($H_2SO_4$ and solvent treatment) cannot be correlated with respect to the intensity of the R value or with the slope of the curve or $\mu = R/P$. It appears that the variations of the R values are independent of the mineral oil. There exists no desirable agreement between the 1936 and 1941 Models for the mineral oil raffinates. The range of variation of the results is given as follows:

| | Load P, Number of Weights 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Model 1936 | | | | | | | | |
| R, average | 5.56 | 14.75 | 25.3 | 36.6 | 51.8 | 56.0 | - | |
| R, minimum | 2 | 9 | 15 | 26 | 32 | 41 | - | |
| R, maximum | 10 | 21 | 36 | 55 | 80 | 74 | - | |
| % Deviation | 144 | 81 | 83 | 80 | 93 | 59 | - | |
| Model 1941 | | | | | | | | |
| R, average | 9.60 | 20.70 | 55.6 | 49.6 | 66.6 | 67.9 | 77.5 | 103 |
| R, minimum | 9 | 19 | 32 | 53 | 64 | 64 | 73 | 100 |
| R, maximum | 9 | 23 | 40 | 56 | 87 | 72 | 82 | 107 |
| % Deviation | 0 | 19 | 22 | 26 | 30 | 12 | 12 | 7 |

The present finely worked condition of the small bushings achieved by means of turning and grinding is still not satisfactory for evaluation of mineral oil raffinates.

Group 2 Fatty Oils and Mineral Oil-Fatty Oil Blends

The mineral oil-fatty oil blends are free from other additives. Oil 20 is neat's foot oil, oil 21 is sperm oil, oils 22 and 23 are crude rapeseed oil, oil 18a is a blend of 97 per cent oil 18 with 3 per cent rapeseed oil, oil 18b is another blend with 3 per cent rapeseed oil fatty acid. These oils were studied in the 1941 Model. Oils 24-27, which were investigated in the 1936 Model have the following characteristics:

| Oil No. | Designation | Color | d/20 | n 20/D | E/20 | E/50 | $W_p$ | M |
|---|---|---|---|---|---|---|---|---|
| 24 | Gear Oil, 3% sperm oil | 10 | .925 | 1.517 | 200 | 20.8 | 2.69 | 3.78 |
| 25 | " " " " " | 10 | .930 | 1.519 | 210 | 42.5 | 2.70 | 3.69 |
| 26 | " " 4% " " | 10 | .927 | 1.518 | 145 | 40.6 | 2.49 | 3.59 |
| 27 | Aero Shell S, 1936 | | .914 | | 148 | 17.5 | 2.50 | 3.72 |
| 13a | Brightstock #13, 15% sperm oil | 8 | .904 | 1.500 | 124 | 19.2 | 1.76 | 3.73 |

Values of the Frictional Force R (kgs.)

| Oil No. | Load Expressed as Number of Weights | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 |
| 1941 | | | | | | | | | | | | | | | |
| 20 | 6 | 14 | 23 | 33 | 41 | 59 | 57 | 65 | 73 | 81 | 95 | 109 | 122 | 135 | 142 |
| 21 | 5 | 15 | 24 | 33 | 42 | 50 | 57 | 66 | 75 | 83 | 99 | 114 | 128 | 145 | 155 |
| 22 | 10 | 17 | 25 | 34 | 42 | 50 | 57 | 64 | 72 | 78 | 92 | 102 | 112 | 122 | 133 |
| 18a | 6 | 16 | 25 | 34 | 43 | 52 | 61 | 71 | 81 | 93 | 125 | 165 | - | | |
| 18b | 6 | 14 | 24 | 33 | 40 | 47 | 55 | 65 | 74 | 83 | 99 | - | | | |
| 23 | 8 | 15 | 21 | 28 | 33 | 38 | 43 | 47 | 51 | 56 | 66 | 75 | 84 | 93 | 101 |
| 1936 | | | | | | | | | | | | | | | |
| 24 | 2 | 10 | 28 | 45 | 59 | 70 | - | | | | | | | | |
| 25 | 2 | 9 | 20 | 37 | 50 | 66 | 69 | 76 | 82 | 92 | - | | | | |
| 26 | 3 | 8 | 27 | 53 | 78 | - | | | | | | | | | |
| 27 | 7 | 15 | 24 | 32 | 42 | 48 | 58 | 66 | 74 | 83 | 117 | - | | | |
| 13a | 3 | 12 | 22 | 32 | 42 | 50 | 59 | 63 | 75 | - | | | | | |

Note: The loads were increased each 30 second interval in this and other experiments throughout this work.

## Conclusions

The film strength of fatty oils is high; also the R value increases with increasing load much less than with mineral oils. In the case of mineral oils containing 3-4 per cent fatty oil there exists a good correlation between the 1936 and 1941 Models. While the great similarity of the fatty oils (20 to 22) is notable, oil 23 (crude rapeseed oil) shows an unusually low increase of friction with load. (At this point, the observation is made by the abstracter that a similar property is observed in fatty oils when the four-ball apparatus is used. In this case the low friction values are due to a longer time of contact with the lubricant before the test is run.)

## Group 3 Sulfurized Mineral Oils

In this group of experiments the sulfurized mineral oils are considered, i.e., a) mineral oils with a natural sulfur content and at the most little surface activity; b) with artificial sulfur additions without blending with fatty oils; and c) with additions of artificial sulfur with simultaneous additions of fatty oils by means of sulfurized fatty oils, "faktis". Only the 1936 Model was used in this group of experiments. See Table, Values of the Frictional Force R (kgs.).

### Group 3 Characteristics of Samples

| Oil No. | Designation | Color | d/20 | n 20/D | E/20 | E/50 | $W_p$ | M |
|---|---|---|---|---|---|---|---|---|
| 28 | 1.9% S, natural AP 80 | 4 | .928 | 1.519 | 56 | 8.5 | 2.40 | 3.79 |
| 29 | 2.1% S, natural AP 68 | 3.5 | .932 | 1.521 | 24 | 4.4 | 2.96 | 4.12 |
| 30 | 2.5% S, Sap.# 6.35 | 8 | .904 | 1.503 | 70 | 10.9 | 2.11 | 3.59 |
| 31 | 3.7% S, natural AP 57 | 7.5 | .930 | 1.516 | 11.5 | 2.8 | 2.73 | 4.16 |
| 13b | 6.5% Milk of S in Oil #13 | 8.5 | .911 | 1.507 | 440 | 42.4 | 2.28 | 3.47 |
| 30a | Oil #30 with 5% Rapeseed | 7 | .897 | 1.497 | 58 | 10.1 | 1.87 | 3.45 |
| 30b | Oil #30 with 5% Rapeseed "faktis" | | .901 | 1.490 | 77 | 12.1 | 2.06 | 3.54 |
| 32 | Cylinder oil with 5% Rapeseed "faktis" | 10 | .932 | 1.520 | 650 | 55.6 | 2.42 | 3.52 |
| 33a | 1.5% S, natural + 3% castor oil | | .900 | - | 9.2 | 2.6 | 1.95 | 3.87 |
| 33b | 1.5% S, natural + 5% fish oil | | .894 | - | 9.5 | 2.7 | 1.98 | 3.88 |
| 33c | 1.5% S, nat. + 1% olein + 5% fish oil | | .895 | - | 9.5 | 2.7 | 1.98 | 3.88 |
| 33d | 1.5% S, nat. + 10% fish oil | | .896 | - | 9.5 | 2.7 | 1.98 | 3.88 |
| 34 | 2.1% S, nat. 12% rapeseed oil (Hamig) | | .892 | - | 11.3 | | | |
| 35 | Cylinder Oil + 16% rapeseed oil +faktis" | 10 | .931 | 1.513 | 270 | 33.2 | 1.95 | 3.28 |
| 13e | Oil #13 with 15% sulfurized sperm oil | | .918 | 1.505 | 351 | 42.8 | 1.88 | 3.19 |

Values of the Frictional Force, R (kg.)

| Oil No. | Load Expressed as Number of Weights | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 |
| 28 | 8 | 16 | 30 | 46 | - | | | | | | | | | | |
| 29 | 8 | 15 | 32 | 55 | - | | | | | | | | | | |
| 30 | 4 | 17 | 34 | 50 | - | | | | | | | | | | |
| 31 | 6 | 17 | 34 | 54 | - | | | | | | | | | | |
| 13b | 2 | 9 | 20 | 38 | 50 | 68 | 91 | 121 | 170 | | | | | | |
| 30a | 5 | 11 | 21 | 33 | 42 | 52 | 61 | - | | | | | | | |
| 30b | 3 | 10 | 32 | 46 | 52 | 66 | 76 | - | | | | | | | |
| 32 | 2 | 13 | 31 | 45 | 58 | 69 | 82 | 99 | 115 | 132 | - | | | | |
| 33a | 4 | 10 | 19 | 29 | 36 | 46 | 63 | 78 | 91 | 100 | - | | | | |
| 33b | 5 | 12 | 21 | 30 | 38 | 45 | 60 | 79 | 99 | 130 | - | | | | |
| 33c | 5 | 19 | 33 | 53 | 74 | 95 | 108 | 119 | 135 | 157 | - | | | | |
| 33d | 5 | 19 | 31 | 45 | 58 | 69 | 83 | 97 | 112 | 132 | - | | | | |
| 34 | 4 | 18 | 28 | 40 | 48 | 59 | 69 | 80 | 89 | 96 | 113 | 172 | - | | |
| 35 | 5 | 12 | 29 | 42 | 68 | 73 | 88 | 99 | 107 | 117 | 132 | 147 | 167 | 190 | - |
| 13c | 2 | 8 | 14 | 32 | 32 | 48 | 57 | 69 | 80 | 93 | 126 | 150 | 160 | - | - |

Conclusions

With the mineral oils containing natural sulfur there exists singular surface activity and thus one would expect good lubricating properties. If one takes a cross section of the HC oils of Group 1 and compares them with the results of oils 28 to 31, the following picture is presented:

Average Frictional Force R (kgs.)

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Mineral Oils of Group 1 | 5.56 | 14.75 | 25.3 | 36.6 | 51.8 | 56.0 |
| Mineral Oils with natural sulfur content | 6.50 | 15.50 | 32.5 | 51.6 | - | - |

The film strengths of mineral oils with natural sulfur content is clearly less than those of the mineral oils of group 1, at 4 weights load. Conversely with the sulfur-rich mineral oils the friction readings increase more rapidly and this can be explained by the nature of the oils. The sulfur-rich oils are characterized, on the one hand, by high values for d and $n_D$ and on the other hand, by unfavorable values for m (slope of viscosity). It is certain that in these oils the sulfur is not in the surface active form. The mineral oils with a small fatty oil-natural sulfur content, as in Nos. 30a and 30b and 33a-c work out to be very favorable, not only in the lubricant film strength but also in a lowering of the friction values. The results therefrom are not inferior to those where mineral oil is blended with sulfurized rapeseed oil. A notable result is also shown by experiment 13b where mineral oil 13 is combined with 6.5 per cent milk of sulfur.

## Group 4 Effect of Small Amounts of Organic Phosphorous Compounds on Mineral Oils

In this experimental group the affect of small amounts of organic phosphorous compounds on mineral oils is described. The characteristics of the oils studied are:

| Oil No. | Designation | Color | d/20 | n 20/D | E/20 | E/50 | $W_p$ | M |
|---|---|---|---|---|---|---|---|---|
| 36 | Nitrobenzene raff. with 1% tricresyl phosphate | - | .887 | 1.491 | 115 | 18.2 | 2.07 | 3.51 |
| 37 | " " " | - | .881 | 1.488 | 60 | 10.4 | 1.93 | 3.48 |
| 38o | Coal gas oil | - | .855 | - | 65 | 10.7 | 1.93 | 3.48 |
| 38p | " + 1% tricresyl phosphate | - | .855 | - | 65 | 10.7 | 1.93 | 3.48 |
| 39 | $H_2SO_4$ raff. + 1% tricresyl phosphate | - | .877 | 1.487 | 29 | 5.9 | 1.94 | 3.62 |
| 40 | Nitrobenzene raff. + 1% TCP | - | .886 | 1.492 | 65 | 11.6 | 1.79 | 3.36 |
| 1a | Oil #1 + 12% lecithin | | | | | | | |
| 4a | Oil #3 + 3% TCP | - | .904 | 1.501 | 57 | 8.6 | 2.50 | 3.83 |
| 4b | " " + 3% triphenyl phosphate | - | .904 | 1.501 | 57 | 8.6 | 2.50 | 3.83 |
| 18c | Oil #18 + 3% TCP | - | - | - | - | - | - | - |
| 18d | " " + 5% Paraflow + 1% TCP | - | - | - | - | - | - | - |

Values of the Frictional Force, R (kg.)

| Oil No. | Load, Number of Weights 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model 1936 | | | | | | | | | | | | | | | |
| 36 | 2 | 8 | 16 | 26 | 34 | 43 | 53 | 61 | 73 | 84 | 122 | 144 | 162 | 192 | 220 |
| 37 | 6 | 15 | 23 | 33 | 42 | 48 | 57 | 66 | 74 | 82 | 94 | 118 | 140 | 192 | 218 |
| 38o | 3 | 12 | 28 | - | - | - | - | | | | | | | | |
| 38p | 2 | 12 | 27 | 41 | 38 | 72 | 85 | 95 | 105 | 115 | 137 | 158 | - | - | |
| 39 | 3 | 8 | 17 | 29 | 39 | 49 | 59 | 67 | 74 | 80 | 97 | 120 | 135 | 150 | 178 |
| 40 | 3 | 11 | 23 | 34 | 43 | 53 | 65 | 77 | 88 | 100 | 119 | 148 | - | - | |
| 40 | 3 | 10 | 22 | 36 | 45 | 54 | 65 | 73 | 84 | 95 | 115 | 126 | 140 | - | |
| 1a | 6 | 10 | 17 | 25 | 33 | 40 | 45 | 53 | 59 | 72 | 82 | 88 | 106 | 103 | 114 |
| 4a | 9 | 17 | 28 | 38 | 48 | 56 | 66 | 74 | 97 | 126 | 154 | - | - | | |
| 4b | 6 | 8 | 16 | 28 | 45 | 60 | 72 | 88 | 105 | 124 | 156 | 190 | - | | |
| Model 1941 | | | | | | | | | | | | | | | |
| 18c | 8 | 19 | 29 | 39 | 46 | 55 | 64 | 72 | 81 | 89 | 104 | 120 | 135 | 151 | 175 |
| 18d | 10 | 19 | 26 | 35 | 46 | 57 | 71 | 84 | 97 | 110 | 134 | 165 | 200 | - | - |

Conclusions

The addition of small amounts of tricresyl phosphate to mineral oil raises its film strength in the Almen-Wieland oil testing apparatus remarka ly. The friction readings are definitely under those of the oils containing fatty oil and sulfur and take their places with the highest of the mineral oils of group 2 with low fatty oil contents. The lowering of the R value in experiment 1a by means of 12 per cent technical soy bean lecithin (which usually contains 80-70 per cent soy bean oil besides 20-30 per cent lecithin) is remarkable. It seems to be advantageous to combine with mineral oil an active additive like sulfur or phosphorus in small supplements of fatty additives (the fatty oils are for blending).

Group 5 The Effects of Chlorinated Products on Mineral Oils

Conclusions

Organic chlorine compounds possess in many ways unmistakable surface action, which concerns the raising of the film strength of mineral oils. The friction readings of the individual models of the Almen-Wieland oil testing machine show important deviations. Of course it appears that the friction readings should be standardized on the zero point by running the testing machine without load.

The average friction values for pure mineral oils (group 1), fatty oils and fatty-mineral oils (group 2), phosphorus-containing mineral oils (group 4) and chlorine-containing mineral oils (group 5) are compared below for the 1941 Model of the Almen-Wieland machine.

Average Frictional Force R (kgs.)

| Lubricant | Load, Number of Weights | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 |
| Mineral Oil | 9 | 21 | 36 | 49 | 67 | 68 | 78 | 103 | - | 74 | 88 | 100 | 112+ | - |
| Fatty Oil | 7 | 15 | 23 | 32 | 40 | 49 | 53 | 61 | 68 | | | | | |
| Fatty-Mineral Oil | 6 | 15 | 25 | 34 | 42 | 50 | 58 | 68 | 78 | 88 | 110 | 165 | - | |
| Phosphorus-Containing | 9 | 19 | 27 | 37 | 46 | 56 | 68 | 78 | 89 | 100 | 119 | 144 | 167 | - |
| Chlorine-Containing | 8 | 19 | 32 | 45 | 57 | 67 | 78 | 88 | 99 | 110 | 136 | 171 | 215 | - |

By means of this summary one realized that the highly active chemical additives, that is phosphorus and chlorine compounds, raise the film strength of mineral oil very markedly in the Almen-Wieland oil testing apparatus. However, the lubricating capacity of fatty oils and fatty oils in combination with mineral oils is not attained owing to the somewhat higher friction readings, insofar as one considers the lubricating capacity as the reciprocal of the frictional force readings.

## Group 5 Characteristics

| Oil No. | Designation | Color | d/20 | n 20/D | E/20 | E/50 | $W_p$ | M |
|---|---|---|---|---|---|---|---|---|
| 42 | 4.5 E/50 + 2.5% Ceresin + 2.5% Chloronaphthalene + 3% $C_4Cl_6$ | | .904 | - | 26.6 | 4.5 | 2.25 | 3.80 |
| 43 | Synth.oil + 2% dichloroethylene + 3% $C_4Cl_6$ | 1 | .885 | - | 5.3 | 2.1 | 1.70 | 3.70 |
| 4c | Oil #4 + 3% ethyl dichlorooöleate | | .904 | 1.501 | 57 | 8.6 | 2.50 | 3.83 |
| 41 | Chlorinated spindle oil BG/H | 10 | | 1.509 | 18.9 | 3.7 | 2.93 | 4.15 |
| 41a | Acetone raff.of oil 41 | 10 | | 1.502 | 13.8 | 3.2 | 2.29 | 3.96 |
| 41b | Acetone extract of oil 41 | 10 | | 1.524 | 29.2 | 4.6 | 3.71 | 4.30 |
| 17a | Oil #17 + 10% α-chloronaphthalene | - | - | - | - | - | | |
| 17b | Oil #17 + 10% chlorothymol | - | | | | | | |
| 17c | Oil #17 + 10% trichlorophenol | | | | | | | |
| 18e | Oil #18 + 3% $C_4Cl_6$ | | | | | | | |
| 18f | Oil #18 + 3% chlorodiphenyl | | | | | | | |
| 18g | Oil # 18 + 3% $C_4Cl_6$ | | | | | | | |
| 18h | " " + 6% " | | | | | | | |
| 18i | " " + 12% " | | | | | | | |

## Values of the Frictional Force R (kg.)

| Oil No. | Load Expressed as Number of Weights | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 |
| Model 1936 | | | | | | | | | | | | | | | |
| 4c | 5 | 8 | 14 | 26 | 38 | 52 | 64 | 75 | 85 | 100 | 118 | 147 | 168 | - | - |
| 41 | 0 | 4 | 16 | 19 | 27 | 39 | 40 | 50 | 63 | 55 | 66 | 85 | 92 | + | + |
| 41a | 0 | 2 | 3 | 8 | 20 | 23 | 38 | 50 | 57 | 65 | 92 | 108 | 121 | 149 | 160 |
| 41b | 0 | 1 | 5 | 9 | 22 | 28 | 36 | 50 | 53 | 67 | 84 | 105 | 122 | 165 | 182 |
| Model 1937 | | | | | | | | | | | | | | | |
| 41 | 11 | 22 | 32 | 44 | 60 | 67 | 85 | 82 | 102 | 108 | 118 | 147 | 170 | 170 | 172 |
| Model 1941 | | | | | | | | | | | | | | | |
| 17a | 10 | 18 | 29 | 40 | 50 | 61 | 72 | 83 | 92 | 103 | 130 | 180 | - | - | |
| 17b | 11 | 21 | 32 | 43 | 53 | 63 | 74 | 85 | 96 | 109 | 147 | 195 | 220 | + | + |
| 17c | 7 | 12 | 19 | 36 | 40 | 50 | 61 | 72 | 85 | 96 | 117 | 138 | 161 | 183 | 206 |
| 18e | 9 | 20 | 30 | 40 | 50 | 59 | 68 | 76 | 83 | 90 | 108 | 130 | 156 | 195 | 250 |
| 18f | 6 | 16 | 26 | 35 | 44 | 53 | 63 | 72 | 81 | 90 | 115 | 149 | 220 | 250 | + |
| 18g | 5 | 18 | 35 | 49 | 63 | 76 | 88 | 99 | 110 | 122 | 153 | 200 | - | | |
| 18h | 7 | 20 | 36 | 52 | 69 | 82 | 94 | 105 | 117 | 129 | 157 | 210 | 250 | - | |
| 18i | 7 | 20 | 35 | 52 | 68 | 81 | 92 | 103 | 115 | 126 | 147 | 170 | 196 | 219 | 250 |
| 42 | 13 | 29 | 45 | 59 | 70 | 73 | 83 | 93 | 103 | 116 | 152 | - | | | |
| 43 | 3 | 16 | 31 | 45 | 58 | 71 | 83 | 94 | 104 | 115 | 137 | 163 | 205 | - | |

**Group 6 Oils Containing Two or More of the Already Known High Pressure Lubrication Additives**

In the cases of oils 45 and 46 the 1936 and 1937 models of the Almen-Wieland machine are in agreement with regard to film strength but not with respect to the friction values. Acetone treatment does not act selectively on the activated oils for the so-called high pressure additives divide themselves nearly equally in the raffinate and extract. The model 1941 Almen-Wieland oil testing machine yields relatively good reproducibility. If one compares the results of these experiments with the 1941 model (predominantly chlorinated but also containing phosphorus but in any case fatty oil free cutting oils) with the average of the chlorine-containing oils (refer to page 9), the two series are seen to be very similar.

**Average Frictional Force R (kgs.)**

| Oil Additives | Load Expressed as Number of Weights | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 |
| Chlorine and Phosphorus | 6 | 17 | 30 | 48 | 56 | 68 | 79 | 90 | 100 | 110 | 125 | 152 | 173 | 194 | 208 |
| Chlorine | 8 | 19 | 32 | 48 | 57 | 67 | 78 | 88 | 99 | 110 | 136 | 171 | 225 | - | |

**Characteristics**

| Oil No. | Designation | Color | d/20 | n 20/D | E/20 | E/50 | $W_p$ | M |
|---|---|---|---|---|---|---|---|---|
| 44 | Cutting Oil(HM) with S & Cl | | .898 | - | 10 | 2.8 | 1.82 | 3.77 |
| 45 | Cutting Oil(CFO) with S & X Sap. # <1 | 10 | - | 1.511 | 11.6 | 2.86 | 2.43 | 4.05 |
| 45a | Acetone Raff. of #45 | 10 | - | 1.502 | 10.9 | 2.76 | 2.34 | 4.02 |
| 45b | Acetone Extr. Oil #45 | 10 | - | 1.540 | 11.6 | 2.56 | 3.57 | 4.38 |
| 46 | Cutting Oil (CFO) S & $C_4Cl_6$ | 10 | - | 1.513 | 8.7 | 2.47 | 2.20 | 4.01 |
| 46a | Acetone Raff. of oil #46 | 10 | - | 1.504 | 8.2 | 2.44 | 1.98 | 3.90 |
| 46b | Acetone Extr. of oil #46 | 10 | - | 1.541 | 9.7 | 2.51 | 2.71 | 4.18 |
| 17d | Oil #17 + 10% trichlorophenol + 1% tricresyl phosphate | | | | | | | |
| 17e | Oil #17 + 0.8% Faktis, chloronaphthalene, Paraflow and TCP (each) | | | | | | | |
| 17f | Oil #17 + 1% each of additions in 17e | | | | | | | |
| 18h | Oil #18 + .8% each of additions in 17e | | | | | | | |
| 18l | Oil #18 + 2% chloroceresin + 1% tricresyl phosphate | | | | | | | |
| 18m | Oil #18 + 2% chloro. E. wax + 1% tricresyl phosphate | | | | | | | |
| 18n | Oil #18 + 3% chloro. E. wax + 1% tricresyl phosphate | | | | | | | |
| 18o | Oil #18 + 10% chloro. E. wax + 1% tricresyl phosphate | | | | | | | |
| 18p | Oil #18 + 3% Faktis + 3% $C_4Cl_6$ + 2% $C_2H_2Cl_2$ + 0.25% tricresyl phosphate | | | | | | | |
| 18q | Oil #18 + 3% Faktis + 3% $C_4Cl_6$ + 2% $C_2H_2Cl_2$ + .25% tricresyl phosphate | | | | | | | |
| 18v | Oil #18 + additives like 18q but with 0.5% tricresyl phosphate | | | | | | | |
| 18s | Oil #18 + 1.5% Faktis, + 1.5% $C_4Cl_6$ + 1% $C_2H_2Cl_2$ + 0.25% tricresyl phosphate | | | | | | | |
| 18t | Oil #18 + 3% chlor. E. wax + 6% $C_4Cl_6$ + 2% $C_2H_2Cl_2$ + 0.5% tricresyl phosphate | | | | | | | |
| 18u | Oil #18 + half of the addition of 18t | | | | | | | |
| 42a | 4.5 E/20 + 1% each Faktis, Paraflow, Chloronaphthalene and tricresyl phosphate | | | | | | | |

---forward----

Group 6 characteristics--forward

| Oil No. | Designation |
|---|---|
| 47a | Solar Red + 1% each Faktis, Paraflow, chloronaphthalene and tricresyl phosphate |
| 47b | Solar Red + 0.5% each the addition agent of 42a and 47a |
| 48a | 5.3 E/20 + 3% Faktis + 3% $C_4Cl_6$ + 2% $C_2H_2Cl_2$ |
| 48b | 5.3 E/20 + 3% Faktis + 3% $C_4Cl_6$ + 2% $C_2H_2Cl_2$ + 1% tricresyl phosphate |

| Oil No. | Load, Number of Weights | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | |
| Model 1936 | | | | | | | | | | | | | | | | |
| 44 | 5 | 13 | 22 | 33 | 42 | 48 | 68 | 93 | 125 | 136 | 170 | - | | | | |
| 45 | 0 | 1 | 3 | 12 | 21 | 24 | 41 | 48 | 63 | 84 | 100 | - | | | | |
| 45a | 0 | 1 | 9 | 16 | 28 | 33 | 45 | 54 | 61 | 80 | 103 | 220 | | | | |
| 45b | 3 | 12 | 15 | 18 | 28 | 34 | 50 | 57 | 73 | 88 | 107 | - | | | | |
| 46 | 0 | 2 | 4 | 5 | 26 | 27 | 42 | 45 | 70 | 77 | 98 | 125 | 166 | + | + | |
| 46a | 0 | 2 | 5 | 9 | 23 | 36 | 55 | 61 | 76 | 91 | 126 | 144 | 168 | 190 | 231 | |
| 46b | 0 | 2 | 5 | 8 | 20 | 31 | 43 | 52 | 69 | 68 | 84 | 102 | 125 | 142 | 172 | + |
| Model 1941 | | | | | | | | | | | | | | | | |
| 17d | 7 | 13 | 24 | 35 | 48 | 60 | 72 | 84 | 96 | 107 | 130 | 150 | 171 | 190 | 211 | + |
| 17e | 13 | 28 | 42 | 55 | 70 | 83 | 94 | 105 | 116 | 122 | 143 | 164 | 181 | 201 | 240 | + |
| 17f | 12 | 25 | 37 | 50 | 63 | 75 | 81 | 82 | 90 | 98 | 119 | 137 | 153 | 168 | 182 | + |
| 18k | 10 | 25 | 39 | 54 | 68 | 81 | 92 | 102 | 109 | 118 | 138 | 158 | 172 | 186 | 196 | + |
| 18l | 7 | 19 | 33 | 45 | 56 | 70 | 81 | 91 | 102 | 115 | 141 | 168 | 207 | 238 | - | |
| 18m | 7 | 17 | 30 | 44 | 56 | 69 | 81 | 91 | 102 | 111 | 135 | 158 | 185 | 206 | 212 | + |
| 18n | 5 | 15 | 29 | 40 | 53 | 66 | 79 | 90 | 101 | 111 | 132 | 151 | 172 | 200 | 250 | - |
| 18o | 4 | 15 | 30 | 42 | 53 | 64 | 75 | 85 | 92 | 100 | 116 | 130 | 144 | 157 | 165 | + |
| 18p | 6 | 20 | 35 | 48 | 61 | 74 | 86 | 98 | 110 | 123 | 155 | 193 | 217 | 220 | 220 | + |
| 18q | 6 | 15 | 28 | 42 | 54 | 67 | 82 | 95 | 106 | 118 | 140 | 159 | 183 | 218 | 233 | + |
| 18r | 3 | 15 | 32 | 46 | 60 | 73 | 86 | 98 | 110 | 121 | 145 | 170 | 202 | 215 | 240 | + |
| 18s | 6 | 19 | 33 | 46 | 59 | 71 | 83 | 94 | 105 | 116 | 139 | 162 | 197 | 226 | 237 | + |
| 18t | 5 | 15 | 29 | 41 | 52 | 63 | 73 | 83 | 93 | 101 | 119 | 133 | 150 | 166 | 178 | + |
| 18u | 2 | 14 | 26 | 39 | 50 | 63 | 75 | 85 | 93 | 101 | 118 | 132 | 149 | 173 | 225 | + |
| 42a | 9 | 25 | 38 | 51 | 63 | 73 | 86 | 96 | 103 | 113 | 129 | 140 | 154 | 174 | 200 | + |
| 47a | 5 | 7 | 12 | 33 | 41 | 51 | 61 | 72 | 82 | 92 | 112 | 130 | 144 | 163 | 183 | + |
| 47b | 4 | 6 | 14 | 23 | 35 | 44 | 52 | 62 | 73 | 83 | 93 | 113 | 135 | 161 | 177 | + |
| 48a | 6 | 18 | 31 | 43 | 56 | 68 | 80 | 91 | 101 | 111 | 131 | 146 | 161 | 174 | 189 | + |
| 48b | 6 | 19 | 34 | 48 | 62 | 75 | 88 | 101 | 113 | 126 | 151 | 177 | 216 | 239 | - | |
| Model 1937 | | | | | | | | | | | | | | | | |
| 45 | 13 | 24 | 36 | 47 | 59 | 64 | 82 | 89 | 105 | 125 | - | | | | | |
| 46 | 11 | 22 | 33 | 48 | 61 | 67 | 85 | 90 | 98 | 120 | 134 | 161 | 183 | 198 | - | |

Group 7 Compound Oils of Various Manufacture Which Are Not Described as High Pressure Lubrication Agents

Group 8 Commercial High Pressure Lubrication Oils, Gear Oils, Cutting Oils and the Like

Group 9 Naturally and Artificially Aged Oils

In the cases of oils 83 to 86 there is involved a product of the Fischer-Tropsch synthesis which was heated in a 100 cc. sample with the passage of 25 l. of air per hour. The oils designated by the index "0" are the starting materials. Oils 87 and 90 involve the acetone extracts of old oils resulting from natural use in power vehicles which were purified from foreign materials after standing two years. These old oils still appeared dark even after a light Fuller's earth treatment before extraction with acetone. The fresh oil of the tests was Metanol S with d/20 = .915, n 20/D = 1.510, E/50 12.6, $W_p$ = 2.40 and M = 3.72. Oil 87 is an old oil from a power machine driven with methane as fuel. Oil 88 is an old oil from a power machine driven with lignite Diesel fuel. R and E designate acetone raffinates and extracts, respectively. Oil 91E is the acetone extract of a tricresyl phosphate activated nitrobenzene raffinate (Fresh Oil: Color 7, d/20 .881, n 20/D 1.489, 33 E/20, 6.6 E/50, $W_p$ 1.83 and M 3.52) which had scarcely changed after a short test period in a Faun-Otto Motor. Oil 92 is a brightstock and oil 93 is an Edeleanu extract.

Conclusions

The film strengths of synthetic oils, and we could not expect otherwise, are logically inferior to corresponding HC lubricating oils. With artificial ageing they become acid in the usual way, whence they are simultaneously activated. The acetone extracts of the naturally aged oils out of power machine machines include, as expected, surface active materials, which confirms the result of 87E. In the cases of 88E to 90E, Fuller's earth treatment has apparently removed the active substances from the filtered old oils. In the extract of oil 91 the tricresyl phosphate is naturally still active. The acetone extract of 92 contains a weakly active substance. The Edeleanu spindle oil extract 93 is noticeably more surface active than mineral oil raffinates of equal viscosity.

Group 10 Lubricating Greases

Sample 94 is a calcium soap grease (from fish oil fatty acids). Sample 95 is a calcium soap grease (from tallow acids). Sample 96 is a fibrous sodium soap grease (G & S 1938). Sample 97 is a transparent metal soap grease (Shell 6255). Sample 98 is a graphited calcium soap grease (S & M 1938). Sample 99 is "Keenoil KG 20", of English manufacture and consisting of a dispersion of 20 per cent zinc oxide in mineral oil.

Conclusions

It is at first surprising that the greases show so clearly lubrication capacities so much more than it was suspected on account of their consistency. Between the individual fatty lubricants there are no remarkable differences. Zinc oxide serves in various cup greases (calcium soap grease) as a loading agent; however, its lubricating value appears doubtful. Also in England, Keenoil was spoken of many years ago and lubrication with zinc oxide-oil dispersions was known to be a false notion. The favorable effect of colloidal graphite is outstanding, as shown by run 99.

## Group 11 Effects of Hardness of the Bushings and Journals

In the case of the experiments described in the first ten groups, it is evident that the scatter in the results obtained is not wholly the expression of differences in lubrication ability of the oils and their additives, but also that real variations are involved in the mechanical quality and manufacture of the small bushings. Indeed, care is necessary to make the influence of these faces as nearly equal as possible. Yet even then scatter is unavoidable. Wieland recommends that the hardness of the small pin or journal be 80 Rockwell B on the average and the softer bushings 60-70 Rockwell B. Journals and bushings are finely turned and normally ground.

Values of the Frictional Force R (kg.)

| Exper. No. | Additive % Tricresyl Phosphate | Rookwell Hardness B | | | Lead, No. of Weights | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Journal | Bushings | Difference | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 |
| | | | | | Oil H | | | | | | | | | |
| 100 | 0 | 68 | 58 | 10 | 17 | 38 | | | | | | | | |
| 101 | 0.5 | 78-→ | 58 | 20 | 17 | 28 | 39 | 50 | 59 | 69 | 28 | 97 | - | - |
| 101 | 0.5 | 79 | 65 | 14 | 12 | 23 | 34 | 44 | 54 | 64 | 73 | 95 | 115 | 142+ |
| 102 | 1.0 | 81 | 61 | 20 | 13 | 24 | 36 | 47 | 58 | 69 | 80 | 98 | 106 | - |
| 103 | 1.5 | 78 | 68 | 10 | 15 | 27 | 40 | 52 | 61 | 68 | 77 | 96 | 109 | - |
| 103 | 1.5 | 80 | 59 | 21 | 17 | 27 | 36 | 44 | 52 | 57 | 66 | 84 | 102 | 120 |
| 104 | 2.0 | 76-67 | | 9 | 15 | 27 | 37 | 41 | 56 | 64 | 72 | 86 | 100 | 115+ |
| 104 | 2.0 | 75 | 62 | 13 | 18 | 27 | 37 | 47 | 55 | 63 | 67 | 83 | 97 | 116+ |
| 105 | 2.5 | 76 | 67 | 9 | 13 | 24 | 35 | 45 | 56 | 64 | 72 | 86 | 98 | 112+ |
| 106 | 3.0 | 73 | 60 | 7 | 14 | 25 | 36 | 47 | 56 | 69 | 72 | 88 | 100 | - |
| 107 | 4.6 | 77 | 62 | 15 | 13 | 24 | 34 | 46 | 54 | 62 | 68 | 83 | 96 | 110+ |
| 108 | 4.5 | 80 | 61 | 19 | 13 | 25 | 35 | 45 | 53 | 63 | 71 | 84 | 97 | 107 |
| 109 | 5.0 | 74 | 64 | 10 | 15 | 25 | 35 | 45 | 53 | 59 | 65 | 78 | 96 | 113+ |
| 109 | 5.0 | 85 | 61 | 24 | 14 | 25 | 36 | 47 | 56 | 66 | 75 | 90 | 104 | 113+ |
| 110 | 5.5 | 75 | 58 | 15 | 13 | 24 | 36 | 46 | 55 | 64 | 72 | 86 | 99 | 113- |
| 111 | 6.0 | 69 | 61 | 8 | 13 | 24 | 35 | 45 | 53 | 61 | 69 | 84 | 87 | 108- |
| | | | | | Oil S | | | | | | | | | |
| 112 | 0 | 78 | 56 | 22 | 15 | 29 | 41 | - | | | | | | |
| 113 | 0.5 | 79 | 59 | 20 | 12 | 25 | 39 | 48 | 53 | 61 | 70 | 93 | 106 | 119+ |
| 114 | 1.5 | 77 | 62 | 15 | 17 | 27 | 38 | 50 | 54 | 60 | 67 | 84 | 100 | 116+ |
| 115 | 2.0 | 79 | 64 | 15 | 18 | 30 | 40 | 49 | 58 | 65 | 72 | 92 | 104 | 115- |
| 116 | 5.0 | 76 | 60 | 16 | 14 | 25 | 36 | 45 | 52 | 59 | 69 | 80 | 92 | 104- |

In the 11th group of experiments the hardness of journals and bushings are measured for each test. A mineral oil raffinate, M, and a synthetic lub. oil, S, serve as the basis for increasing additions of tricresyl phosphate. The characteristics of the oils are the following:

| Oil | Color | Fluorescence | d/20 | E/50 | E/100 | $W_p$ |
|---|---|---|---|---|---|---|
| M | Red | Deep green | .883 | 8.9 | 2.13 | 1.62 |
| S | Yellow | Greenish | .853 | 8.2 | 2.00 | 1.78 |

Conclusions:

Differences in hardness (Rockwell B) between the journal and bushings fluctuate within wide confines, nevertheless a specific influence on the R values is not discernible. In general, the value of the frictional force is independent of the amount of tricresyl phosphate. Thus the average frictional force amounts to the following:

Average Value of the Frictional Force R (kg.)

| | Load expressed as No. of Weights | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 |
| Oil M | 15 | 26 | 36 | 47 | 55 | 64 | 72 | 88 | 102 | 115 |
| Oil S | 15 | 27 | 39 | 49 | 54 | 61 | 68 | 87 | 100 | 112 |
| R (max.) | 18 | 38 | 41 | 52 | 61 | 69 | 80 | 98 | 122 | 142 |
| R (min.) | 12 | 25 | 34 | 44 | 52 | 52 | 65 | 78 | 87 | 107 |
| Difference R | 6 | 13 | 7 | 8 | 9 | 12 | 15 | 20 | 39 | 35 |

Group 12 Comparison of Various Almen-Wieland Machines

For comparison there are presented results obtained with an Almen-Wieland machine, Model 1937 by F. Hildebrand. The abbreviations for the machines are: H-1937 = Hildebrand, K-1936 Kadmer and L-1941 = Luers.

Group 13 Influence of Bearing Composition on the Coefficient of Friction for Various Classes of Lubricants

In this group of experiments the oils were held constant and the test bodies were changed with reference to working or material in order to make clear the effect on friction and wear.

## Conclusions

The calculations of the bearing surface (as in the usual manner the diameter of the journal times the length of the journal) afforded in this case no useful picture. Also the data on specific surface pressures should be discarded. Finally the pressure follows on a straight line over a space of contact of 12.8 mm. and is unusually high even at a load of about 60 kg. It follows that by running under continuously increasing loads, grinding and the formation of running tracks usually of 2-3 mm. width result. A mathematical treatment of these reactions may be obtained only with considerable difficulty. Still, it is permissable to develop from the friction values R in kg. and the load P in kg. the quotient R/P as a dimensionless constant. If one inserts for P the applied load, then one gets the coefficient of friction $\mu = R/P$. However, if one should let P represent the number of applied weights as proposed by W. Paul, Oet u. Kohle, 1940, 475, then one obtains a constant of the slope in the R vs. P diagram.

$$f = R/P$$

Paul observed that f is a straight line function of R and P and that these straight lines in the R/P diagrams only break when, under circumstances long before conclusive welding of the surfaces sets in, strong wear occurs and the lubricant is displaced progressively from the affected areas. The detailed data offered by the foregoing work shows that this theoretical opinion of Paul's is in practice not completely correct. With no oil group the relation R/P is a straight line. It always takes the form of a readily bending curve, for which there is discernible the conclusive welding of the sliding surfaces through a distinct breaking of the curve. In order that this important correction can be placed in plain view the results obtained in the previous thirteen experiments are summarized in the following table:

Values of the Frictional Force R (kg.)

| Exp. No. | Oil and Additive (Steel Bearings) | Load P Expressed as Number of Weights | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 14 |
| 1 | Min.Oils, nat. | 6 | 15 | 25 | 36 | 52 | | | | | | | |
| 9 | Syn. Oils F & T | 4 | 19 | 23 | 43 | - | | | | | | | |
| 3a | MO S, nat. | 6 | 16 | 33 | 51 | - | | | | | | | |
| 3b | MO S, art. | 2 | 9 | 20 | 38 | 50 | 68 | 91 | 121 | | | | |
| 4 | MO P | 9 | 19 | 27 | 37 | 46 | 56 | 68 | 78 | 100 | 119 | 144 | 16[illegible] |
| 11 | MO P | - | 15 | 27 | 37 | 47 | 56 | 64 | 72 | 86 | 100 | 115 | |
| 5 | MO Cl | 8 | 19 | 32 | 45 | 57 | 67 | 78 | 88 | 110 | 136 | 171 | 21[illegible] |
| 6 | MO Cl | 6 | 17 | 30 | 48 | 56 | 68 | 76 | 90 | 110 | 125 | 152 | 17[illegible] |

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| Exp. No. | Oil and Additive (Steel Bearings) | Load P Expressed as Number of Weights 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Greases | 6 | 13 | 25 | 38 | 48 | 65 | 70 | 90 | 115 | 126 | 146 | - |
| 11 | Fatty Grease Graph | 2 | 6 | 10 | 15 | 24 | 29 | 38 | 41 | 48 | 58 | 80 | - |
| 12 | Fatty Oils | 7 | 13 | 23 | 32 | 40 | 49 | 53 | 61 | 74 | 88 | 100 | 112 |
| 2 | MO Fatty Oils | 6 | 15 | 25 | 34 | 42 | 50 | 58 | 68 | 88 | 120 | 165 | - |
| 3c | MO Faktis | 3 | 13 | 31 | 44 | 59 | 69 | 82 | 99 | 125 | 134 | 147 | 167 |
| 13f | MO P, RG | 10 | 26 | 35 | 48 | 60 | 80 | 98 | 125 | 138 | 168 | 180 | |
| 13f | MO RG | 8 | 16 | 25 | 35 | 45 | 58 | 20 | 95 | 140 | 155 | 170 | |
| 13f | GBz, MO | 15 | 28 | 40 | 50 | 60 | 80 | 105 | 130 | 185 | | | |
| 13f | MO P, GBz | 10 | 25 | 40 | 50 | 65 | 80 | 100 | 125 | 180 | 160 | | |
| 13f | MO, PbB | 10 | 24 | 60 | 70 | 85 | 100 | 120 | 140 | 200 | | | |
| 13f | MO P, PbB | 10 | 20 | 28 | 40 | 50 | 60 | 70 | 80 | 105 | 130 | | |
| 13f | MO PB | 10 | 25 | 28 | 45 | 65 | 90 | 122 | 152 | 180 | | | |
| 13f | MO P PB | 10 | 31 | 50 | 70 | 110 | 122 | 150 | 170 | | | | |
| 13c | Cast Iron MO | | | 26 | 44 | 50 | 43 | 44 | | | | | |
| 13h | Al MO | 3 | 6 | 10 | 18 | 23 | 27 | 30 | 36 | 43 | 55 | 69 | 80 |

Other tables are given for f and μ instead of R.

In 13f, the material of the journal was steel of Rockwell Hardness 95 on the B scale, the bushing material was variable: Bronze 8 (RG8), cast bronze 14 (GBz 14), lead bronze Z33 (PbB), and phosphcrous bronze, PB.

The graph on page 101 (reel page) shows R/P plainly to be a very crooked curve for all oils. The sulfur-containing oils (groups 3a, 3b and 3c) are the ones characterized by the steepest rise in friction with load. The chlorinated oils also show a steep rise in friction readings with load. The oils containing phosphorus (groups 4 and 11) show an average position. The fat-containing oils, particularly the fatty oils, show very favorable friction properties (groups 2a, 2b). In particular the effect of colloidal graphite on sodium soap grease (refer to series 10) is interesting.

For all oils one of three conditions applies in these tests: 1) The running under load with a sharp increase of the coefficient of friction increasing to a characteristic value for the particular oil or oil mixtures. 2) The running under load for all activated oils over a wide range of loads with nearly constant coefficients of friction. 3) Running under load with, by this time, unquestionably considerable grindings and finally welding of the bearing surfaces. Here the oils which have had their film strengths overcome through the prevailing experimental conditions show very high coefficients of friction. With high pressure oils, however, activated with phosphorus or chlorine and phosphorus and particularly fatty oil, the friction readings remain in this work still constant, i.e., with fatty oils about .120, with phosphorus-containing oils .150 on the average. With sulfurized fatty oils .170, for chlorine- and phosphorus-containing oils .175 while with chlorine only, the coefficient of friction rises to values greater than .200 and therefore continuous wear results.

The value of the quality of the steel used in the bushings is of decided influence on the results for R.

An experiment with cast iron as the bushing material has considerable interest.

Without a doubt, the attaching ability of the lubricant and therefore the lubricating capacity is less when the sliding surfaces are sand blasted than when the surfaces are suitably manufactured and finished.

The influence of non-ferrous metals as bushing materials in contrast to steel as a bearing material is self evident. The influence of the bearing materials is of more consequence insofar as the friction is concerned than the differences between active and non-active lubricants. With the bronzes there results no true welding but a progressive grinding which suspends countless glittering small particles in the oils. In a few cases the non-activated oil shows the same film strength as the activated oil and besides smaller frictional forces (refer to bushing materials RG8 and PB). In other cases (bushing material PbB), the activated oils show a constant lower friction reading. Aluminum-bearing metal is seen to be a very favorable material, in this case Lg-40, to which M v. Schwarz has already referred to in his work. The friction readings are unusually low with this metal. It becomes necessary for evaluation of lubrication to consider the characteristics of the metallic materials in this respect. This naturally complicates the picture on lubrication and lubrication problems.

## Group 14 Effects of Phosphating the Bearing Surfaces

In this experimental group a few oils were tested on bushings which were previously degreased and then phosphated. The treatment of the bushings was accomplished in this particular case with "Atramentol K", of IGF, supposedly a nitrate containing zinc phosphate solution. In 14a and b there is employed a hydrogenated brown coal tar oil of Brabag (ZR 30 with d/20 .877, n 20/D 1.4856, 10.4 E/20, 2.76 E/50, and 1.3 E/100. $W_p$ 2.11 and m 3.93, color 3. This oil was first studied in the untreated system and then with phosphated bearings. In experiments 14c and d a drilling oil consisting of 27% emulsifier "Trupon" HL 25N, 71% spindle oil distillate and 2% water. In experiments 14e and f a boring or soluble oil was used having the composition 32%

"Trupon HL 25N", 66% mineral oil Brabag ZR30 and 2% water. In the following table of data, P is the load (number of weights), R the frictional force in kg., dt the temperature rise in the oil bath and t/min. the temperature increase per unit time. The sign x indicates that the bearings were destroyed either through welding or the coupling lug of the test journal was broken. The minus sign means that the bearings were not seized but, however, more or less intense wear tracks could be seen. The plus sign means satisfactory bearing tracks.

Conclusions.

It is apparent that phosphating the sliding surfaces is advantageous to the lubrication in all three cases. While at lower loads, a somewhat higher friction appears. The treated layer facilitates better adhesion of the lubricant to the metallic surfaces. It seems to be necessary to test the advisability of the treated layers with experiments of longer duration.

Group 15 Soluble Oil Emulsions, Concentrated

In this group of experiments various water emulsions were tested with and without phosphating of the bearings. 15a and b: viscous emulsions made from 70 parts drilling oil (34% Trupon N, 64% Brabag ZR 30 and 2% water) with 30 parts water. Experiment 15c and d: thickish emulsion of 50 parts of the drilling oil with 50 parts water. 15e: a thickish emulsion of 50 parts drilling oil (27% Trupon N, 71% Brabag ZR 30 and 2% water) with 50 parts water. 15f: a blue grey emulsion consisting of 25 parts boring oil of the preceding composition with .5% water dispersed colloidal graphite (Hydrokollag) and 74.5% water. 15g: milky emulsion of 10 parts drilling oil (35% Trupon, 64% Brabag oil and 2% water) and 15h: a milky white emulsion consisting of 10 parts of activated drilling oil "V/Ka 1" (made of 30% Trupon, 60% spindle oil and 8% tricresyl phosphate and 2% water) and 90 parts water.

Conclusions

The lubricating ability of emulsions improves as the concentration of the soluble oil component decreases. Explains this surprising phenomenon in terms of the stability of the emulsions. The emulsion achieves the maximum lubricating power when the stability reaches the zenith, namely, at 5-10%. Phosphating of the testing bodies has a favorable effect throughout, for thereby adhesion of the emulsions to the metallic surfaces is promoted. The effect of water dispersed colloidal graphite is astonishing. Based on this result it is propitious to make the prediction for the use of graphited emulsions for deep drawing phosphated sheets or plates. By comparison of 15g and 15h, it appears that the activation of the mineral oil component by means of tricresyl phosphate is clearly accomplished. This is only possible if, in the process of lubrication, tiny particles of oil (at the most not greater than 1-3μ) are discharged into the active surfaces between which wear is ensuing and so come into effect on the sliding surfaces. It may come from this consideration that the use of activated mineral oil emulsions can be authorized for more difficult cutting operations--perhaps in the place of water insoluble cutting oils.

Group 16 Soluble Oil Emulsions in Dilute Concentrations

In this group of experiments are presented the drilling agent HO of IGF (coal gas sulfonate prepared through the sulfochloride) alone and in various water mixtures as well as other metal working emulsions and suspended dispersions in higher dilution and with addition of various thickening agents. Thus, 16a employs HO alone on untreated bearings; 16b an emulsion of 10% HO in untreated bearings; 16c the same on treated bearings; 16d 5% HO emulsion, untreated bushings; 16e a 2% dispersion of colloidal sulfur, untreated bearings; 16f a 2% dispersion of colloidal graphite with untreated bearings; 16g a combination of 8% HO, 2% colloidal sulfur, treated bearings; 16h a combination of 8% HO, 2% colloidal graphite, treated bearings; 16i a 1% sol of cellulose, Colloresin of IGF on untreated bearings; 16k the combination of the above 1% solution with 10% drilling oil, untreated bearings; 16l a 2.5% emulsion of tricresyl phosphate activated soluble oil "V/Ka 1", untreated bearings; 16m a 2.5% HO solution, bearings untreated; 16n a 3% lubrication soap solution, bearings untreated; 16o a 1% "V/Ka 1", untreated; 16p a 1% HO, untreated; 16q a 1% soap solution, bearings untreated; 16r a similar solution, treated; 16s a 1% drilling oil emulsion, untreated; 16t a 1% drilling oil emulsion, bearings treated; 16u a dispersion of .5% colloidal graphite, untreated; 16v the same dispersion on treated bearings; 16w a combination of 1% HO, .15% colloresin, bearings untreated; 16y 1% "V/Ka 1", .4% colloresin, untreated; 16z provided for untreated test bearings to be driven in a phosphating bath made as prescribed: 4.8 vol. per cent "Atramentol K", 4 vol. per cent accelerator 91, 2 per cent water; 16x employed the combination 1% HO, .4% colloresin, bearings untreated.

Conclusions

The drilling agent HO has a high film strength in the pure state and shows friction values which are even lower than the fatty oils. The bearing surfaces of the bushings are, at higher stresses, bare and groove free. A 10% HO solution shows similar favorable properties. If one uses phosphated bearings in testing the 10% solution, the friction readings at lower loads are definitely higher. This can be completely explained, however. It is surprising that the 5% HO solution is still better than the pure product and the 10% solution. The 2% dispersion of colloidal sulfur (Cosan) was in no way as effective as the 2% dispersion of colloidal graphite (hydrokollag). However, the colloidal sulfur in combination with water-emulsified fatty materials is not disadvantageous. In the combination 8% HO, 2% Cosan (16g) better results are obtained than with 10% HO (16c) at higher loads. The frictional forces are definitely lower in the blend and the bearings are definitely unchanneled--which is not the case with the 10% solution. The blend 8% HO, 2% Hydrokollag is better by far, however. The friction readings are unusually low and the bearing surfaces of the test specimens remain in perceivably better condition. Phosphating is advantageous. The sol of cellulose was, as expected, definitely no lubricating agent. Even the effectiveness of a 10% boring oil emulsion, for which an increase in viscosity would appear to be desirable in certain cases, could not be improved by this and similar thickening materials.

The 2.5% emulsions of active soluble oil V/Ka 1 was as satisfactory as an equal concentration of HO solution. At higher loads the active oil exhibits somewhat lower friction readings. A very favorabl lubrication is obtained with a 3% solution of a lubrication soap. It is here that the knowledge of the old practices of wire and sheet drawing find their confirmation. Accordingly, the soap solutions cannot be replaced in drawing processes without consideration. In all cases soap solutions are markedly superior to ordinary drilling oil, a fact which the forming and metal working processes will be affected by.

In the two illustrations of page 108 (reel page) it is apparent that with drilling oil emulsions and HO emulsions, the friction values become smaller with dilution. One per cent dispersions have markedly lower R and $\mu$ values than 10% emulsions. Could it be that the cooling action of the water is more essential than the lubricating action of the oils? This opinion however may at once be disposed of for in a 1% cellulose sol, the cooling action is present as in the foregoing examples. Yet it is characterized by neither low friction values nor film strength of the dissolved material. The only explanation remaining for the favorable lubricating properties of the highly diluted drilling oil emulsions, particularly in view of the fact that they can be activated, is that the formation of small droplets of oil still provides for sufficient lubrication, even at these dilutions. To be sure the film strength of simple drilling oil emulsions (16s) is limited.

If one compares the graphs of page 108 with those of pages 100 and 101, which represent water insoluble oils one finds that the R and $\mu$ values of the emulsions are markedly lower than those for pure oils. In the practices of metal working one finds, for this reason, still no equal.

An especially interesting picture is afforded by the series of experiments $16_o$ to $16_t$ in which various 1% emulsions may be compared. The film strength of the simple drilling oil-emulsion (16s) is limited. An active drilling oil emulsion (16o) was very much better. In the latter case there is a strong increase in friction at higher loads so that the 1% HO emulsions stand out relatively better. The final condition of the bearing surfaces of the latter is not satisfactory, however, for scarring of the journal and bushings is unmistakable. The 1% soap solution (16q) had the best effect. The frictional force moments at 1% concentrations were unusually low and the sliding surfaces had a high polish. As soon as one disturbs this condition of polish by phosphating, the friction values rise decidedly (16r in contrast to 16q). However with lubricating oils or cutting fluids, with insufficient film strength or adhesiveness, phosphating or similarly treating the sliding surfaces is advantageous (16t in in contrast to 16s). Also phosphating has a definitely favorable effect when one uses only aqueous colloidal graphite dispersions (16u and 16v).

From experiments 16w to 16y it may be observed that the thickening agents for oil in water emulsions, such as "colloresin" "Latekoll", and Collaeroal and the various Tylose" brands, do not destroy the lubricating effect of highly diluted emulsions.

When a solution of phosphating salt was prepared according to directions and then used as the lubricating medium (previously there had been reports of such solutions being used as cutting fluids in metal cutting) the results were unsatisfactory. The test bearings, when only half covered by liquid, ran with loud squeaking with evolution of steam. They did not weld conclusively but large tracks were dug in the bearing surfaces.

Final Conclusions

By the close of this study it was concluded that it is necessary to subject the journals and bushings before and after the experiments to an exacting and, where possible, mechanical-technical control. To the degree that steel journals and bushings do not seize one another and the lubricants (mineral oils to a limited condition of loading and fatty oils to higher loading) are free from chemically active surface acting additives, there may be seen in the bushing small bright tracks of the motion, 2-3 mm. across. It is clear also that when welding under overloads of the steel bearings occurs, material is probably pulled out of the bushings to a depth of 1 mm. and is welded fast to the journals in beaded form and also enormous local temperatures arise due to friction.

Model 1936 Table 16 Soluble Oil Emulsions

Frictional Force R (kgs.) for Various Lubricants

| P | 16a | 16b | 16c | 16d | 16e | 16f | 16g | 16h | 16i | 16k | 16l | 16m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 2 | 3 | 3 | 48 | 3 | 1 | 2 | 15-18 | 2 | 2 | 2 |
| 4 | 3 | 9 | 16 | 11 | 55-60 | 22 | 10 | 9 | 50-55 | 10 | 15 | 19 |
| 5 | 14 | 19 | 23 | 20 | 80-100 | 42 | 22 | 15 | 78-85 | 22-25 | 27 | 32 |
| 6 | 26 | 28 | 36 | 30 | 140-230 | 47 | 25 | 20 | 115-250 | 39 | 41 | 39 |
| 7 | 28 | 33 | 52 | 36 | 250 | 62 | 42 | 26 | X | 61-64 | 52 | 47 |
| 8 | 45 | 43 | 58 | 47 | - | 68 | 40 | 28 | | 68 | 64 | 55 |
| 9 | 48 | 52 | 74 | 55 | | 95-115 | 55 | 39 | | 100-250 | 76 | 65-61 |
| 10 | 62 | 54 | 72 | 59 | | 130-146 | 60 | 41 | | X | 86 | 70-67 |
| 11 | 66 | 71 | 93 | 67 | | 160-165 | 73 | 45 | | | 97 | 78-73 |
| 12 | 71 | 72 | 94 | 79 | | 172-168 | 78 | 50 | | | 105 | 85 |
| 13 | 100 | 76 | 99 | 84 | | 195-185 | 100-95 | 63 | | | 110-106 | 93-89 |
| 14 | 104 | 106 | 119 | 97 | | 198-182 | 105-140 | 75 | | | 109-105 | 100-92 |
| 15 | 109 | 131-167 | 121 | 102 | | 200-192 | 115-145 | 80 | | | 112-109 | 103 |
| 16 | 123 | 179-176 | 126 | 105 | | 206 | 130-150 | 82 | | | 118 | 114 |
| 17 | 128 | 178-159 | 153 | 114 | | 219 | 140-130 | 85 | | | 105 | 126 |
| 18 | + | - | + | 129 | | 223 | 173 | 92 | | | 130 | 140-150 |
| 19 | | | | 174-184 | | 223-210 | + | + | | | 136 | 168-162 |
| 20 | | | | - | | 230-250 | | | | | 142 | 179-181 |
| | | | | | | | | | | | + | + |
| dt (°C) | 22-53 | 29-58 | 20-46 | 24-46 | 31-44 | 24-63 | 33-56 | 33-45 | 18-24 | 23-28 | 21-54 | 18-46 |
| t/min. | 3.7 | 3.4 | 3.0 | 2.6 | 3.8 | 3.9 | 2.4 | 1.3 | | | 3.1 | 2.8 |
| pH | | 7.0 | 7.0 | | 6.3 | 8.3 | 6.3 | | | | 6.9 | 6.9 |

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Model 1936 Table 16(Continued) Soluble Oil Emulsions

Frictional Force R (kgs.) for Various Lubricants

| P | 16n | 16o | 16p | 16q | 16r | 16s | 16t | 16u | 16v | 16w | 16x | 16y | 16z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 2 | 2 | 2 | 21 | 1 | 1 | 4 | 0 | 6 | 1 | 4 | 0 |
| 4 | 10 | 6 | 4 | 7 | 28-25 | 5 | 7 | 30-37 | 20 | 10 | 6 | 16 | 25-30 |
| 5 | 19 | 14 | 8 | 9 | 31-32 | 8 | 12 | 53-59 | 33 | 13 | 8 | 23 | 65-95 |
| 6 | 21 | 18 | 10 | 11 | 35-32 | 9 | 18 | 75-80 | 50 | 18 | 11 | 30 | 150-230 |
| 7 | 27-33 | 24 | 9 | 15 | 41 | 15 | 24-28 | 96 | 64 | 20 | 15-20 | 42-50 | 80-230 |
| 8 | 28 | 33 | 11 | 17 | 53-65 | 22 | 34 | 120-125 | 79 | 22 | 24 | 69 | - |
| 9 | 31-28 | 35-30 | 15 | 20 | 80 | 25 | 40 | 185-195 | 83 | 27 | 31 | 85-100 | |
| 10 | 36-32 | 38 | 20 | 22 | 85-80 | 40-90 | 49 | 220-210 | 96 | 33 | 41 | 245 | |
| 11 | 37 | 34-40 | 20 | 25 | 81 | 140-295 | 56-65 | 245 | 110-115 | 37 | 48-43 | X | |
| 12 | 45-40 | 43 | 21 | 29 | 90 | X | 100-115 | + | 140-150 | 41 | 47 | | |
| 13 | 47-44 | 55 | 24 | 32 | 99 | | 140-245 | | 170-175 | 42 | 51 | | |
| 14 | 51 | 65-70 | 28 | 33 | 106-109 | | X | | 190-180 | 45 | 60-80 | | |
| 15 | 57 | 85-89 | 30 | 38 | 120-130 | | | | 182-185 | 46 | 245 | | |
| 16 | 60 | 103-78 | 35-40 | 40 | 140-155 | | | | 194-175 | 52-55 | X | | |
| 17 | 67 | 125 | 49 | 45 | 180-245 | | | | 189-193 | 57 | | | |
| 18 | 74 | 135-250 | 49 | 48-43 | X | | | | 215-220 | 61 | | | |
| 19 | 85-79 | - | 55-58 | 52 | | | | | 245 | 66-62 | | | |
| 20 | 105-91 | | 58-60 | 55-60 | | | | | X | + | | | |
| | + | | - | + | | | | | | | | | |
| dt (°C) | 23-39 | 23-38 | 21-32 | 11-27 | 20-43 | 20-24 | 22-28 | 22-50 | 21-55 | 19-29 | 16-28 | 19-26 | |
| t/min. | 1.6 | 1.7 | 1.0 | 1.6 | 2.6 | | | | | | | | |
| pH | 9.3 | | | 8.3 | 8.3 | 6.8 | 6.8 | 5.1 | 3.6 | 1.0 | 1.0 | 1.3 | |

Of the chemically active additives, organic phosphorus compounds produce a bluish polished sliding surface, the bearings do not seize with these materials. The question as the nature of the tarnishing colors can be treated offhand as iridescent layers of organic iron phosphorus compounds. K. O. Muller[1] has noticed in his studies on roller bearings that the course of the polishing is free from rust and he has also noticed a considerable increase of the ash content of the oils with high pressure lubricants, without a doubt on account of sulfur and phosphorus content. It appears that phosphorus additives in lubricants only prevent the wearing of sliding surfaces under loading, not, however, the corrosion of the same, particularly if it is assumed, for example, that tricresyl phosphate is split into phosphoric acid and cresol through local overheating and that both of these products are continually corroding.

Chlorinated hydrocarbons or the manifold variety of other chlorinated organic compounds used as lubricant additives show with used test bearings unquestionable signs of rust within a several weeks. Accordingly, such additives may be authorized for each case of metal working (drawing or cutting) limited by undergoing an after treatment, so that the question of corrosion of the work pieces is of secondary importance. One must abandon chlorine additives in high pressure lubrication for gears and highly loaded bushings.

Application of high pressure on sulfur base lubricants continuously produces in the Almen-Wieland machine a blackening of the bearing surfaces of the small bushings as long as the sulfur is active. This blackening was not noticed with mineral oils with natural sulfur content, which as we know contains the sulfur in the inactive non-corrosive form. In the mercaptan linkage of sulfurized fatty oils, however, the elemental sulfur (according to Blok) is liquefied by means of the local temperature flashes in the sliding surfaces and is thereby activated. In this case the sulfide films develop on the sliding surfaces. It is supposed that the sulfide film is responsible for progressive wear and progressive breakdown. Even with colloidal sulfur in aqueous dispersions, the film is discernible on the bearing grooves. The sulfiding of the sliding surfaces becomes noticeable at once if the elemental sulfur is combined with organic substances, also with water insoluble oils, or even with emulsifiable oils or soluble oil (HO and some others). Indeed, sulfide films appear on steel before atmospheric rusting when only water dispersed sulfur or sulfur-bearing aqueous emulsions are used. Likewise graphited aqueous dispersions deposit a noticeable blackening on the test bearing surfaces.

The phosphating of the bearings produces the known grey black color and dullness on steel and iron.

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1) Oel u. Kohle, 437 (1938).

The so-called "thermocolor-colors" should be used for determination of the temperature zones in the bearings. At the place of progressive local wear a temperature measurement is naturally impossible by this means. Even so the measurement of the oil-bath or emulsion temperature is not sensible as long as it is not possible to determine for sure the corresponding heat evolved by the test. For this reason, temperature observations are not included in the discussion.

p. 113-125 <u>Development of a New High Pressure Viscometer</u>

Describes three modifications of a viscometer for measuring viscosities at pressures to 5000 kg./cm.$^{-2}$ Claims a precision of about ±1.5 per cent for one of them. All three designs require fine and complicated machining and must be calibrated with oils of known viscosity. No data on viscosity at high pressures given.

p. 127-135 <u>Experiments on Oil Aging with the HWA Apparatus According to Noack</u>

A series of experiments on several oils for gears and fluid drives are described. Tests were made in the HWA apparatus, not described, at temperatures of 200, 250, 275 and 300°C for 1,2,3 and 5 hours. Reference is made to a previous report. Emphasis apparently placed on viscosity changes with some reference to vacuum distillation.

p. 137-157 <u>The High Vacuum Distillation of Synthetic Lubricating Oils and Mineral Oil Raffinates</u>

The oils discussed in this report came from four sources and are classified under the headings below:

A. Rhine-Prussia coal mine; Hamburg (Aiederrhein) MO-56-61 Comprising transformer oil, turbine oil, light and heavy motor oil, and low and high flash steam cylinder stock.

B. Ruhrchemie AG., Oberhausen-Holten. Synthetic oils Nos. 1200 and 3500 by Fischer-Tropsch synthesis.

C. Braunkohle-Benzin A.G. Zeitz isa. Machine oil raffinate, ZR-30

D. Oderfurter Mineralölwerke A.G., Mahrisch-Ostrau Naphthenic base oil from aqueous cresol extraction, unpurified paraffinic base oil from aqueous cresol extraction, purified, and bright stock from aqueous cresol extraction.

The oils in group A were prepared from a combination of paraffinic hydrocarbons and aromatic coal tar residues by von Kölbel's method. A rather complete analysis of these oils is given in the first table.

Vacuum distillations were performed at 0.005 mm.-0.010 mm. mercury on oils from the four groups, taking about three distillate fractions.

The distillation samples were further separated by alcohol or acetone extraction, in some cases giving a more viscous raffinate than extract, indicating size rather than type separation. Tables of properties of raffinate and extract oils include density, refractive index, viscosity at two temperatures, viscosity pole height, slope number and aniline point.

Other oils were separated into fractions by chromatographic adsorption through a column of alumina and the properties compared with those from acetone extraction and/or vacuum distillation of the same oil.

From these data relationships between refractive index and density were worked out whereby most mineral oils fell within a narrow band while fatty oils, decalin, styrene, cyclopentadiene, benzol and homologs, and castor oil fell outside this band. The Rhine-prussia oils also fell to the right of this band. On another chart the authors have shown the relationship between density-refractive index-viscosity (E/50) and aniline point on one graph bymeans of two series of sloping lines.

In another chart two density scales are used, one for hydrocarbons and one for the Rhine-prussia oils.

A comparison between the additive method (additivity of RI's) and the phase analysis (percentage difference) on the refractive index of the original oils and their component parts favor the former over the latter.

A graphical method of solvent analysis is illustrated using refractive index as ordinate and per cent solvent raffinate or extract as abscissa. The various oils described in this report are plotted and their analysis illustrated.

The variation between measured aniline point and that calculated from the first chart amounted to about 10-15 per cent with the Fischer-Tropsch (Group B) oils with the calculated values higher than measured data.

With the machine oil raffinate (Group C) the calculated aniline point runs 1-10 per cent below the actual value.

Solvent extraction analysis (with acetone) was made on the original fractions and oxidized fractions from a laboratory oxidation test.

The various fractions from naphthenic base stock, paraffin base stock and bright stock (Group D) were analyzed in a similar manner and the calculated aniline point varied from 10 per cent below to 13 per cent above the measured aniline point.

The change in viscosity with per cent distilled are plotted for a number of the oils from the four groups in Figure 4.

Two Ubbelohode blending charts, one for the range 1.00 to 2.0° Engler and the other for the range 2.0 to 20,000° Engler, are included as Figures 5a-5b.

Through the use of these blending charts the amount of bright stock of 30°E/50 was calculated for several oils of the various sources.

p. 169-180 Preparation of Water Soluble Lubricants from Lube Oil Acid Sludge

A number of low viscosity mineral oils (spindle oils) were sulfonated with fuming sulfuric acid. The resulting raffinates were extracted with alcohol to recover the oil-soluble sulfonates, while the acid sludges were washed with brine followed by the conversion of the water soluble sulfonates to the ammonium salts. A 50 per cent water solution of the ammonium sulfonates was tested as a lubricant in the Almen-Wieland Oil Test machine. The material was not outstanding in reducing friction and, after a week, caused rust formation in the apparatus. The sulfonate salts tended to decompose into free acids and ammonia upon standing.

No bag no.
p. 237-242 Foamed Coal

Any type of coal is suitable for the production of foamed coal with the exception of porous coals or coke. The range is therefore from the new brown coals to old bituminous. A coal having a high caloric value will give a good yield of foamed coal.

Coals having particle sizes ranging from 0.5 to 2.5 mm. are suitable without any further selection. Hence screenings, washings, and other waste coal sizes may be economically utilized.

Coal of that size range is put in mixers such as a concrete mixer and chemicals are now admixed. The additive here depends on the nature and use of the foamed coal.

1. For the preparation of producer gas for auto engines 1% calcium salts such as $CaCO_3$ and 1% $Fe_2O_3$ are added.

2. For rapid combustion 1-1/2% $KNO_3$ and 1-3% sulfur. If this latter type is to be used in internal combustion engines the sulfur addition must be kept low. Other oxygen carriers such as $MnO_2$, $Mn_3O_4$, or $KClO_4$ were not available in Germany during this time.

3. If foamed coal were to be used for the production of organic synthetics such as methanol, formaldehyde, or petrol suitable catalysts are also added here.

The next step entails the addition of a water soluble resin of the class derived from phenol or cresol. The resin should harden at 200°C, and water soluble ones are more suitable than alcohol solubles. Enough of the resin is added to give the coal mass a sticky feeling and a shiny appearance.

The mix is molded to briquettes or other suitable shape and baked to set the resin. After setting and drying the block or briquette is removed from the mold. It will now stand the shock of transport.

Technique of Process: As the baking temperature rises, water is removed both from the coal and the resin forming a very porous cake. At high temperatures such as combustion the resin carbonizes giving a coherent, high temperature structure. Slagging is thus avoided.

Foamed coal preparation is unsuccessful if the following happens:

1. Too much resin
2. Poorly selected resin
3. If resins harden prior to loss of water
4. If admixed chemicals decompose hardened material
5. If too great molding pressure used.
6. Too little chemical additive used.

If coal sizes smaller than those mentioned above are utilized the bulk density of the briquette is increased so that artificial air passages must be created by fine wires, tubes, etc., which are withdrawn after the hardening of the resin is completed.

The foamed coal makes excellent producer-gas but operational temperatures are higher being 1250°C instead of 950°C with conventional generator fuels.

Efficiency comparisons will be made between foamed coal and other fuels to determine if the former could be used to alleviate the present fuel shortage in German transport, as no new mining of coal is necessary and screening dumps could be reworked.

Foamed coal was used in experiments on thrust engines for aircraft.

Bag 3998 Item 2

p. 324-326 Duosol and Dewaxing Plant Flowsheets of German Vacuum Oil Company

These are schematic flow sheets of the Duo-Sol lube oil extraction plant at Bremen of the German Vacuum Oil Company of Hamburg. The dewaxing plant and solvent recovery systems are included. Interest is very limited but not totally nil. Refinery technologists or process engineers may be curious about comparing the German lay-out with those in the U.S A. Value of reproduction and translation of captions is questionable.

Bag 3518

p.422-480, 523 Item 1 On the Preparation and Reactions of Cyclooctatetraene

Describes the preparation, physical properties (p. 523 in Item 2) and reactions (catalytic hydrogenation, action of peracids, water gas and alkali metals, aromatization, halogenation, Diels-Alder, polymerization) of cyclooctatetraene.

Acetylene polymerizes with a nickel halide or cyanide catalyst, preferably in the presence of a solvent such as tetrahydrofuran, to cyclopolyolefins, in particular to cyclooctatetraene.

Cyclooctatetraene can react according to three basic ring types: (1), as an 8-membered ring; (2) as a bicyclic 6- and 4-membered ring compound, bicyclo-[2.4.0]-2,5,7-octatriene, and (3), as tricyclo $[1.5.0.0^{5,7}]$-4,8-octadiene (1,2,4,5-dimethylene-cyclohexadiene-2,5).

The following reactions take place when cyclooctatetraene reacts according to ring type (1): a) catalytic hydrogenation in the presence of nickel or a noble metal to cyclooctane; b) treatment with peracids to form a cyclic oxide, which can be hydrogenated to cyclooctanol, and which also reacts vigorously under the influence of heat and sulfuric acid to yield phenyl-acetaldehyde; c) with carbon monoxide plus hydrogen, cyclooctyl-carbinol is formed; d) with alkali metals, for example, lithium, cyclooctatetraene yields a dilithium derivative of 1,3,6-cyclo-octatriene, which on treatment with carbon dioxide and with an alcohol gives rise, respectively, to 2,5,7-cyclooctatriene-1,4-dicarboxylic acid and to the parent hydrocarbon, 1,3,6-cyclo-octatriene.

According to ring types (2) and (3) cyclooctatetraene reacts in the following ways: a) with oxidizing agents (permanganate or catalytically with air in the presence of vanadium pentoxide) aromatic type compounds (i.e., benzoic acid) are formed; b) quantitatively with mercuric sulfate to give phenylacetaldehyde; c) treatment with chromium trioxide leads to terephthalic acid, while with hypochlorous acid terephthalaldehyde is formed. Cyclooctane is transformed under the influence of selenium into p-xylene.

Cyclooctatetraene also reacts according to ring type (2) with retention of the 4-membered ring. Behavior of the cyclopolyolefin with halogens and in the Diels-Alder reaction has indicated the type (2) structure.

Cyclooctatetraene dimerizes on long standing, or, more rapidly, on heating; the structure of the dimer is not known. A dihalogen derivative also forms a dimer.

A long list of compounds obtainable from cyclooctatetraene is included. Some compounds of probable or unknown structure, as well as diene adducts, are also listed.

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Type reactions of acetylene are listed with a general discussion of their nature and the requisite conditions for effecting them. These reactions are:

1. Vinylation with acetylene of:
   a. Alcohols to give vinyl-type ethers
   b. Mercaptans
   c. Carboxylic acids
   d. Primary and secondary amines
   e. Nitrogen-substituted amides
   f. Trisubstituted ammonium hydroxides
2. Ethynylation with acetylene of:
   a. Alkanolamines
   b. Amines
   c. Aldehydes and ketones to give alkynols and alkynediols
3. Carbonylation with acetylene and carbon monoxide of:
   a. Alcohols to give acrylates
   b. Amines to give acrylamides
   c. Acids to give mixed acrylic acid anhydrides
4. Olefins and carbon monoxide with:
   a. Alcohols to give esters
   b. Amines
   c. Acids
   d. Hydrogen to give aldehydes
5. Carbon monoxide with alcohols and ethers:
   a. For example, with tetrahydrofuran to give $\gamma$-valerolactone and adipic acid
6. Acetylene, carbon monoxide and water in the presence of metal carbonyl hydride catalysts:
   a. For example, to give hydroquinone
7. The cyclic polymerization of acetylene.

There is a section describing the technical preparation and reactions of ethylene, the reactions of acetaldehyde and the preparation of butadiene.

A table of compounds derived from acetylene is included.