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AN INVESTIGATION OF CORE OILS

BY

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AND

CARL E. SCHUBERT



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AN INVESTIGATION OF CORE OILS

I. INTRODUCTION

1. *Introductory.*—Most core oils consist of a drying oil, such as linseed, china wood, or perrilla oil, used as a base, compounded with some other oil or oils to lower the cost. The cheaper oils which may be used to dilute the basic oil are either semi-drying in nature, such as soya bean oil, or non-drying in nature, such as kerosene. Rosin is also used as a diluent, and a variety of combinations of oils is sometimes used to compound a core oil.

Apart from the question of cost, other ingredients may be added to core oils to give greater strength to baked cores and more resistance to moisture absorption.

The core oils tested were supplied by core oil producers from many parts of the country in order to make the investigation cover a diversified number of oils. In reporting the results each sample of core oil is designated by a letter of the alphabet.

2. *Objects of Investigation.*—This investigation was conducted (a) to determine whether or not there is a relation between the tensile strength of cores and the physical and chemical properties of core oils used as a binder; and (b) to determine the effect of moisture on the tensile strength of the baked cores.

3. *Acknowledgments.*—This investigation has been part of the work of the Engineering Experiment Station of the University of Illinois of which DEAN M. S. KETCHUM is the director and of the Department of Mechanical Engineering of which PROF. A. C. WILLARD is the head. Acknowledgment is made to PROF. A. P. KRATZ, Research Professor of Mechanical Engineering, for valuable aid and suggestions in analyzing the results of the investigation.

II. APPARATUS

4. *Apparatus Used in Investigation.*—The equipment used to determine the ash content of the core oils consisted of a porcelain crucible of 50 cc. capacity, a muffle furnace, and an analytical balance. A hydrometer, a thermometer, and a 500 cc. graduate were used in determining the specific gravities. The flash and fire points of the oils were determined by use of a Cleveland open cup, an iron standard

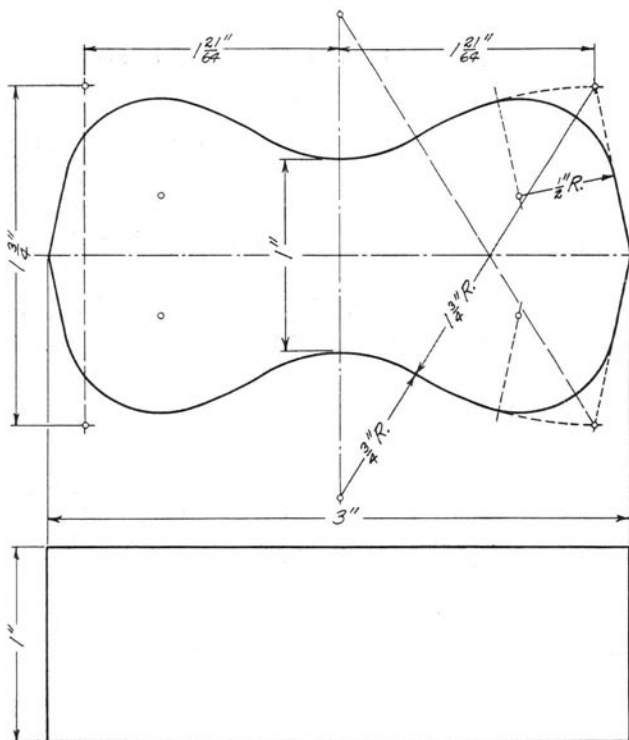


FIG. 1. TENSILE TEST CORE

for holding the cup, a thermometer, a gas burner, and a small gas flame for testing the oils.

A standard $\frac{N}{2}$ alcoholic caustic potash solution and a standard $\frac{N}{2}$ hydrochloric acid solution, a 200 cc. Erlenmeyer flask with return condenser, burettes, a water bath, a gas burner, and an iron stand were used in the determination of the saponification numbers of the oils.

In finding the iodine numbers of the oils a standard $\frac{N}{10}$ sodium-thiosulphate solution, a standard iodine monochloride solution (Wijs'), a standard $\frac{N}{10}$ potassium dichromate solution, a 10-per-cent solution of potassium iodide, chloroform, a glass-stoppered bottle, burettes, and a watch were used.

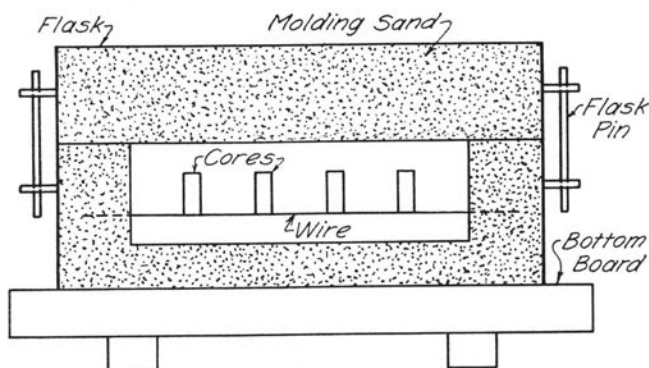


FIG. 2. CROSS-SECTIONAL VIEW OF GREEN SAND MOLD SHOWING TENSILE TEST CORES IN POSITION

The equipment recommended by the American Foundrymen's Association was used in the preparation and testing of the cores.* It consisted of a paddle-type sand mixer, a standard core box (see Fig. 1 for dimensions), a standard rammer, a number of core plates, a thermostatically controlled electric oven, accurate to plus or minus 5 deg. F., a balance, a set of weights, and a tensile strength testing machine.

Apparatus for the determination of the absorption of moisture is shown in Fig. 2. The briquettes were suspended on wires so that the cores did not come in direct contact with the molding sand. The mold was made from sand which contained 7 to 9 per cent moisture. Repeated checks of the moisture content of the sand were made to assure uniformity of procedure.

III. METHODS

5. *General Method of Procedure.*—The method of procedure adopted consisted in the determination of the specific gravity, the ash content, the flash and fire points, the saponification numbers, and the iodine values of the core oils.

A number of cores were prepared with each oil and baked by standard methods adopted by the American Foundrymen's Association.* A number of the cores from each oil were tested for tensile strength, and

*"Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sand," A.F.A., 1928, pp. 62-66.

the average tensile strengths of the cores prepared with each core oil were determined.

The average tensile strengths of the cores prepared with each core oil were correlated with the specific gravities, the ash percentages, the flash points, the fire points, the saponification numbers, and the iodine numbers of the core oils from which they were made. This was done to determine whether or not there was a definite relation between the tensile strengths of the cores and the physical and chemical properties of the core oils.

A like number of cores prepared with each core oil were subjected to a moisture absorption test as follows: Each of the cores was accurately weighed and placed in a specially prepared mold (see Fig. 2) for a period of 24 hours. At the end of 24 hours each core was weighed and the water absorbed determined. Next each core was tested for tensile strength and the percentage loss in tensile strength of the cores recorded. The amounts of water absorbed by the individual cores made from each core oil were averaged and the average was regarded as characteristic of the oil. The same procedure was followed for the tensile strength of the individual cores.

6. *Determination of Ash Content.*—A crucible was weighed on an analytical balance and a known weight of the oil to be tested was added to it. The crucible and oil were placed in a muffle furnace and the oil was ignited. The temperature of the muffle furnace was 1500 deg. F. After 30 minutes the crucible was transferred to a desiccator to cool. The crucible plus the ash was weighed. The original weight of the crucible subtracted from the weight of the crucible plus the ash gave the weight of the ash. The weight of the ash divided by the weight of the oil used multiplied by 100 represents the percentage of ash in the oil.

7. *Determination of Specific Gravity.*—About 400 cc. of core oil was placed in a 500-cc. graduate and a hydrometer and thermometer were introduced into the oil. The gravity was read directly from the hydrometer and the temperature of the oil was noted. The gravity of the oil was corrected to 60 deg. F.

8. *Determination of Flash Point and Fire Point.*—A sample of oil was placed in the cup and the thermometer introduced into the oil. Heat was applied by the gas burner and the point of flash was determined. The heating of the oil was continued until the fire point of the oil was attained.

9. *Determination of Saponification Number.*—Between 1 and 2 g. of the core oil was weighed out into a 200-cc. Erlenmeyer flask fitted with a cork to a return condenser. Twenty-five cc. of the standard $\frac{N}{2}$ alcoholic caustic potash solution was added from a burette and the flask heated on a water bath until the oil dissolved. When the oil was dissolved the flask was disconnected and cooled for a few minutes under a water tap. Then the contents of the flask were titrated with the standard $\frac{N}{2}$ hydrochloric acid solution in the presence of phenolphthalein as an indicator. Next a blank determination was performed on the alcoholic caustic potash solution which was digested on the water bath for the same length of time, cooled and titrated. The difference between the amounts of acid used in the two titrations gives the amount of acid necessary to neutralize the alkali used in the saponification. The saponification number of the oil was then calculated.

10. *Determination of Iodine Number.*—From 0.15 to 0.20 g. of oil was weighed out and transferred to a glass-stoppered bottle. Ten cc. of chloroform was added to dissolve the oil, and 25 cc. of the iodine monochloride was added with a burette. The iodine solution was allowed to act on the oil for 15 minutes and then 10 cc. of a 10 per cent solution of potassium iodide was added, and about 100 cc. of distilled water was used to wash down the sides of the bottle and stopper. A freshly prepared solution of starch was used as an indicator, and the excess of iodine titrated with the standard $\frac{N}{10}$ sodium thiosulphate solution. A blank determination was run on the iodine solution, chloroform, potassium iodide solution, distilled water, and starch solution. The number of cubic centimeters of thiosulphate used, subtracted from the amount required for the blank, represents the amount of iodine absorbed by the oil. The equivalent weight of iodine thus found was divided by the weight of the oil taken, and the result expressed in per cent as the iodine number of the core oil.

11. *Determination of Tensile Strength of Cores.*—Washed silica sand having a fineness analysis and fineness number as given in Table 1 was used to prepare all of the cores in this investigation. The chemical analysis of the sand was SiO_2 , 98.79 per cent, Fe_2O_3 , 0.05 per cent, traces of Al_2O_3 , MgO , CaO , and traces of the alkalis.

TABLE 1
FINENESS OF WASHED SILICA SAND USED IN INVESTIGATION

Sieve Number	Grams Remaining on Sieve	Sieve Number	Grams Remaining on Sieve	Remarks
40	0.00	200	2.30	A. F. A. classification places this sand in Class No. 4.*
70	2.25	270	0.40	
100	88.30	Pan	0.30	
140	6.30			

*"Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sand," A. F. A., 1928, pp. 62-66.

In order to simplify the testing it was decided that the only variable in the testing should be the core oils. Cores were baked in an electric oven and the temperature was controlled to within 5 deg. F., plus or minus, of 450 deg. F. The length of the baking period was 45 minutes, and the method of mixing the sand, oil, and water was the same for all of the core oils.*

The temperature of the oven and the baking period is in accordance with procedure recommended by H. L. Campbell,† as producing the greatest tensile strength under standard conditions. A ratio of 75 parts of sand to 1 part of oil, by weight, was used in preparing the core sand mixtures, and one per cent of water by weight was added to each mixture.

A total of 24 cores was prepared and baked from each mixture of sand. After cooling to room temperature twelve of the cores from each sand mixture were tested for tensile strength, and the results averaged in order to determine a characteristic value for each oil. The remaining twelve cores were used for the moisture absorption and loss in tensile strength tests.

12. *Determination of Moisture Absorbed by Cores and Percentage Loss in Tensile Strength.*—The twelve cores from each core mixture were carefully weighed to the fourth decimal place on an analytical balance, and placed in molds which were made from molding sand containing 7 to 9 per cent moisture. The cores were suspended on wires instead of allowing them to come in contact with the molding sand; otherwise the molding sand would adhere to the core, and it would have been difficult to determine accurately the weight of the core.

The cores were allowed to remain in the mold subjected to the moist atmosphere for a period of 24 hours. Upon removal from the

*"Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sand," A.F.A., 1928, pp. 62-66.

†H. L. Campbell, Preprint No. 29-1B, A.F.A., Apr. 8, 1929, pp. 289-294.

TABLE 2
PHYSICAL AND CHEMICAL PROPERTIES OF CORE OILS TESTED

Oil	Specific Gravity at 60 deg. F.	Percentage of Ash	Flash Point Deg. F.	Fire Point Deg. F.	Saponification Number	Iodine Number (WIJS 15 min.)
A	0.952	0.10	232	248	154	131
B	0.948	0.13	210	234	163	133
C	0.943	0.40	228	284	164	140
D	0.958	0.05	298	354	132	125
E	0.932	0.50	176	190	152	139
F	0.948	0.05	203	221	158	137
G	0.965	1.72	111	145	108	73
H	0.933	0.05	192	209	145	129
I	0.942	0.05	189	192	120	115
J	0.930	0.05	183	197	142	114

mold the inherent moisture was then determined by allowing the core to air dry in an atmosphere of approximately 35 per cent relative humidity until no further loss in weight occurred. The inherent or combined water was the difference between the initial weight of the core before placing it in the mold and the final weight after the evaporation of the surface moisture. The amounts of water absorbed by the cores from each core mixture were averaged.

Each core was tested for tensile strength after weighing, and the average tensile strength of the cores was determined for each core mixture. Then the average tensile strength of each core mixture was compared with the average original tensile strength of the cores from each core mixture, and the average percentage loss in tensile strength of the cores for each core mixture was computed.

IV. RESULTS OF PHYSICAL AND CHEMICAL TESTS OF CORE OILS

13. *Specific Gravity*.—Table 2 gives the specific gravities of all the core oils at 60 deg. F. When the specific gravities were plotted against the original tensile strengths of the cores it was apparent that there was no definite relation between the specific gravities of the oils and the original tensile strengths, and therefore the curve was omitted.

From the results of these tests it is apparent that specific gravity should be used as a general test, and in conjunction with the other tests, to predict the tensile strength of cores made from an oil, and not independently, because of the great number of possible methods used to process an oil.

14. *Percentage of Ash*.—Table 2 gives the percentages of ash of the core oils. Five core oils, I, D, J, H, and F all had approximately

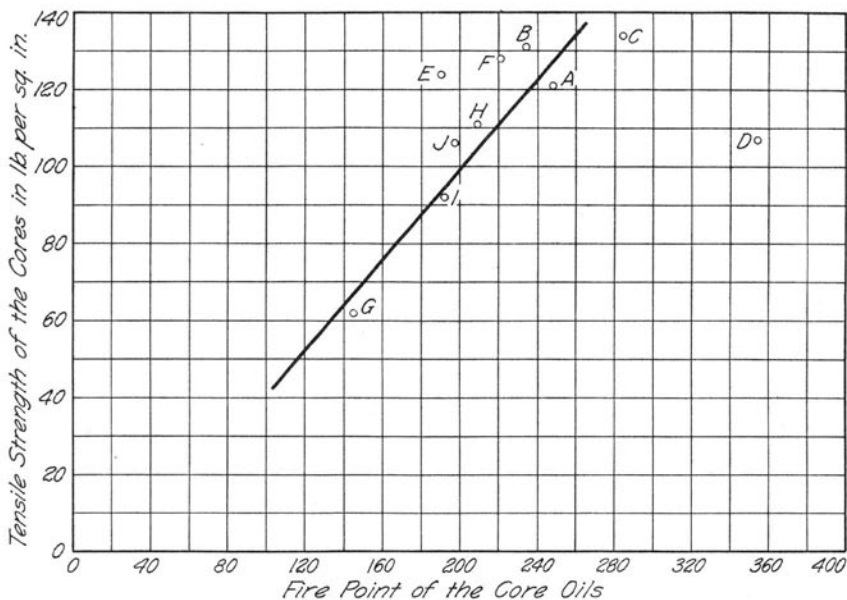


FIG. 3. RELATION OF FIRE POINTS OF CORE OILS TO AVERAGE TENSILE STRENGTHS OF CORES

0.05 per cent of ash, and the original tensile strengths of the cores made with these oils varied from 92 lb. per sq. in. to 128 lb. per sq. in., while core oil C had an ash content of 0.40 per cent, and the cores made therewith an original tensile strength of 134 lb. per sq. in. Oil G had an ash content of 1.72 per cent, and the cores an original tensile strength of 62 lb. per sq. in. As the ash content of a core oil may be high for a number of reasons, a relatively high percentage of ash is only in a general way indicative of low tensile strength, and should not be used by itself to predict whether or not a core oil will produce cores with low or high original tensile strength.

15. *Flash Points of Core Oils.*—Table 2 gives the flash points of all of the core oils in degrees Fahrenheit. The flash points of core oils E, F, B, and C were found to be 176.0, 203.0, 210, and 228.0 deg. F., respectively, and the corresponding average tensile strengths of the cores made with these oils were 124, 128, 131, and 134 lb. per sq. in., which indicated that the tensile strength of the cores made with these core oils varied directly with the flash point of the core oil. However, core oils J, I, H, A, and D did not give results consistent with those

TABLE 3
RESULTS OF TENSILE STRENGTH TESTS OF CORES

Oil	Average Tensile Strength of Freshly Baked Cores lb. per sq. in.	Average Tensile Strength of Cores after 24 Hrs. in Mold lb. per sq. in.	Average Percentage Loss in Tensile Strength	Average Gain in Weight of Water Absorbed by Cores g.
A	121	87	28.4	0.0092
B	131	107	18.2	0.0050
C	134	113	30.0	0.0100
D	107	67	37.6	0.0150
E	124	93	25.7	0.0089
F	128	72	43.4	0.0170
G	62	32	51.4	0.0238
H	111	65	41.1	0.0165
I	92	52	44.0	0.0180
J	106	73	32.8	0.0120

obtained with the other oils, and a well defined relation was not established.

The results of these tests may be explained by the fact that core oil manufacturers use a variety of oils to thin the basic drying oil and the flash point of the core oil may or may not depend on the temperature at which the thinner flashes.

16. *Fire Points of Core Oils.*—Table 2 gives the fire points of all of the core oils in degrees Fahrenheit. Figure 3 shows these results plotted against the average original tensile strengths of the cores from each core oil. In general, the results indicate that the average original tensile strength varied directly with the fire point. Core oils E and D, however, proved to be exceptions.

These exceptions may be explained by the fact that core oil producers use a variety of oils to thin the basic drying oil and the fire point of the core oil may or may not depend on the temperature at which the thinner burns. Hence, while a definite relation may be regarded as established for certain oils used, the relation cannot be regarded as sufficiently general to justify judging the worth of an oil on the basis of fire point alone.

V. RESULTS OF TENSILE STRENGTH TESTS

17. *Tensile Strength Tests on Freshly Baked Cores.*—Table 3 gives the average original tensile strengths in pounds per square inch of the cores made with each core oil.

A correlation of these strengths with the saponification and iodine numbers of each oil as given in Table 2 is shown graphically in Figs.

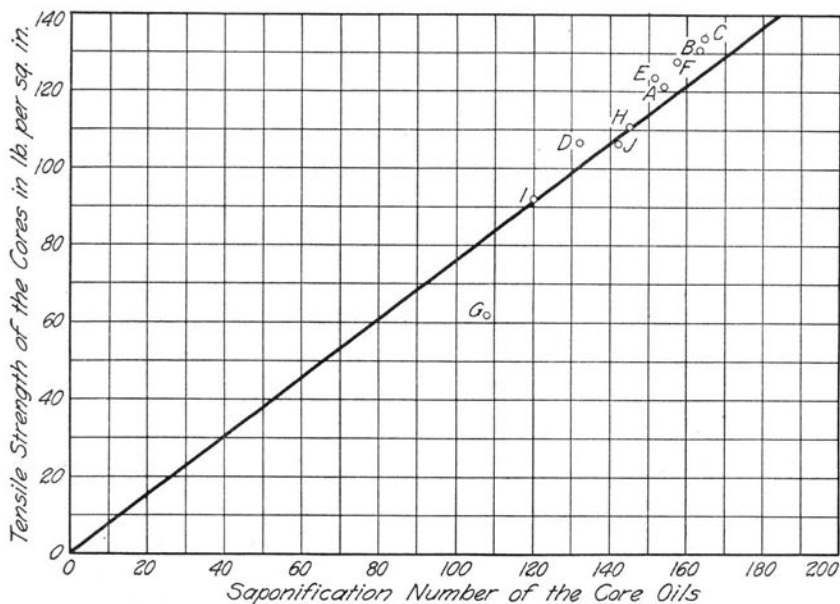


FIG. 4. RELATION OF TENSILE STRENGTHS OF CORES TO SAPONIFICATION NUMBERS OF CORE OILS

4 and 5, and indicates that the tensile strength of each core oil tested was directly proportional to both the saponification and the iodine number of the oil. It is evident that a linear equation may be used to calculate the approximate tensile strength of any core oil used in this investigation, if either the saponification or the iodine number of the oil is known.

Let the saponification number of the oil be represented by x and the average tensile strength of the core by y .

Then the straight line in Fig. 4 may be expressed by the equation

$$y = cx$$

$$\text{and } c = \frac{y}{x}$$

Hence, $\frac{\text{Saponification Number}}{\text{Tensile Strength}} = \text{a constant}$

Table 4 gives the values of this ratio $\frac{y}{c}$ for the saponification numbers of the oils tested. It will be noted that the average value of this ratio for these oils is 0.769.

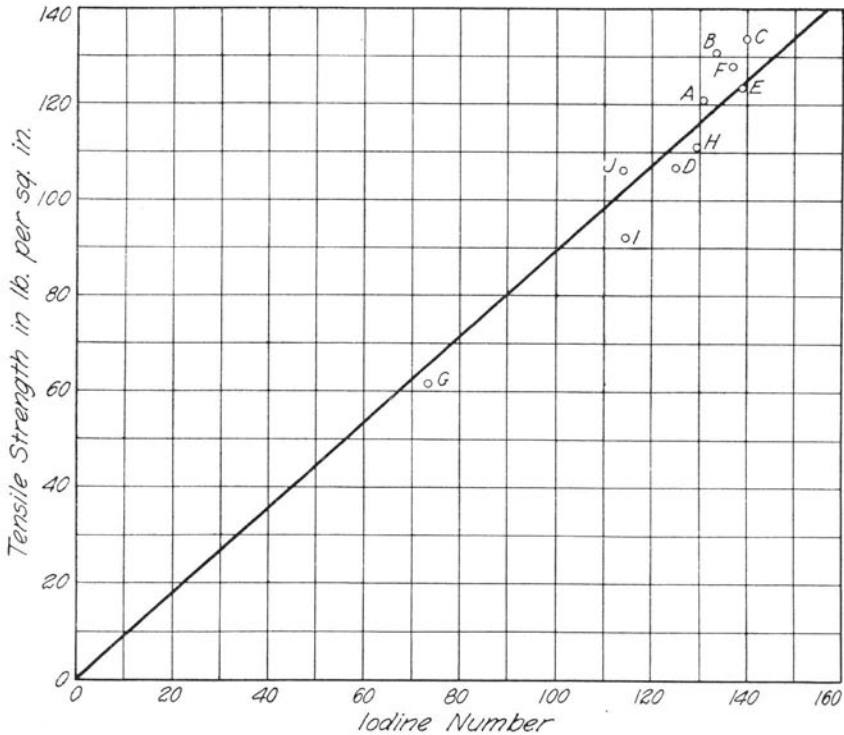


FIG. 5. RELATION OF TENSILE STRENGTHS OF CORES TO IODINE NUMBERS OF CORE OILS

Similarly, the ratio of iodine number to tensile strength for the oils tested can be represented by a straight-line equation, represented by the average line in Fig. 5. Table 5 gives the values of the ratio for these oils, and it may be noted that the average value is 0.8935, which also is in agreement with the value of the constant for the average line in Fig. 5.

Substituting the value of the average constant in the equation, and assuming an iodine number of, say, 140.0, the equation is

$$y = 140.0 \times 0.90$$

Solving for y , the tensile strength of the baked cores is found to be 126.0 lb. per sq. in.; this value compares favorably with the results obtained with core oil E. The actual average tensile strength was found to be 124.0 lb. per sq. in. The other core oils gave similar results.

TABLE 4
RATIO OF TENSILE STRENGTH OF CORE TO
SAPONIFICATION NUMBER OF OIL

Oil	Value of Ratio	Oil	Value of Ratio
A	0.786	F	0.811
B	0.804	G	0.574
C	0.816	H	0.765
D	0.810	I	0.766
E	0.815	J	0.746

Average value of ratio = 0.769.

TABLE 5
RATIO OF TENSILE STRENGTH OF CORE TO
IODINE NUMBER OF OIL

Oil	Value of Ratio	Oil	Value of Ratio
A	0.923	F	0.934
B	0.984	G	0.849
C	0.957	H	0.860
D	0.856	I	0.800
E	0.892	J	0.929

Average value of ratio = 0.8984.

The curves of both Fig. 4 and Fig. 5 are close approximations to a straight line, and the fact that the line does not pass through all the points indicates that certain discrepancies arose from the fact that it was impossible to control such variables as mixing, ramming and baking temperature more closely.

VI. PERCENTAGE LOSS IN TENSILE STRENGTH AND WATER ABSORBED BY CORES

18. *Percentage Loss in Tensile Strength.*—Table 3 gives the average percentage loss in tensile strength of the cores. Cores made with oil B lost the least amount in strength, namely 18.2 per cent; cores made with oil G lost the greatest amount in strength, namely, 51.4 per cent.

19. *Moisture Absorbed by Cores.*—The average moisture absorbed by the cores in grams is given in Table 3. Cores made with core oil B gained the smallest amount; the gain in weight was 0.0050 g. Cores

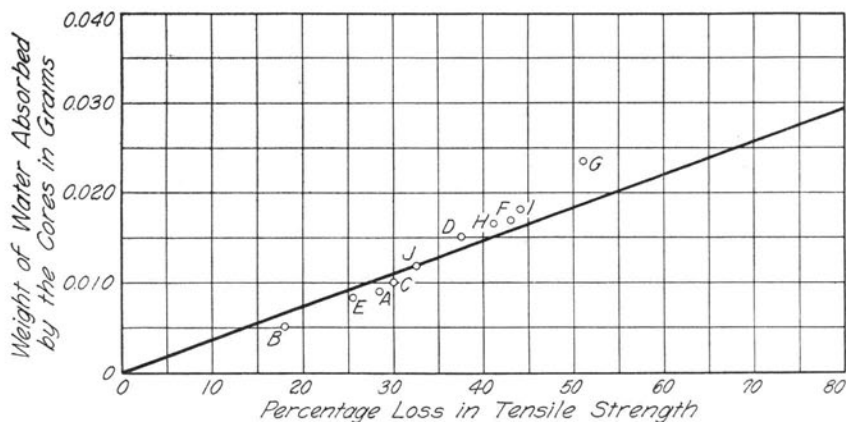


FIG. 6. RELATION OF WATER ABSORBED BY CORES TO PERCENTAGE LOSS IN TENSILE STRENGTH

made with oil G gained the greatest amount; the gain in weight was 0.0238 g.

Figure 6 shows graphically the percentage loss in tensile strength of the cores as correlated with the water absorbed by them.

All the cores tested showed that the percentage loss in tensile strength was proportional to the amount of moisture absorbed.

These results may also be represented by a straight line, the equation of which is

$$y = cx.$$

If y represents the average weight of moisture absorbed by the cores, and x represents the average percentage loss in tensile strength of the cores, then $c = \frac{y}{x}$. Hence,

$$\frac{\text{Average weight of moisture absorbed by the cores}}{\text{Average percentage loss in tensile strength of the cores}} = \text{a constant.}$$

Table 6 gives the value of this constant for each oil, from which it may be noted that the average value was 0.0037. Substituting this value of the constant in the equation and assuming the gain in weight of inherent moisture to be 0.0120 g., the equation becomes

$$\frac{0.0120}{x} = 0.0037.$$

Hence, $x = \frac{0.0120}{0.0037} = 32.40$ percentage loss in tensile strength of the cores. This value agrees closely with the results obtained with core

TABLE 6
 RATIO OF MOISTURE ABSORBED BY CORES TO PERCENTAGE LOSS IN TENSILE STRENGTH OF CORES

Oil	Value of Ratio	Oil	Value of Ratio
A	0.000323	F	0.000391
B	0.000274	G	0.000463
C	0.000333	H	0.000401
D	0.000398	I	0.000409
E	0.000346	J	0.000365

Average value of ratio = 0.0003703.

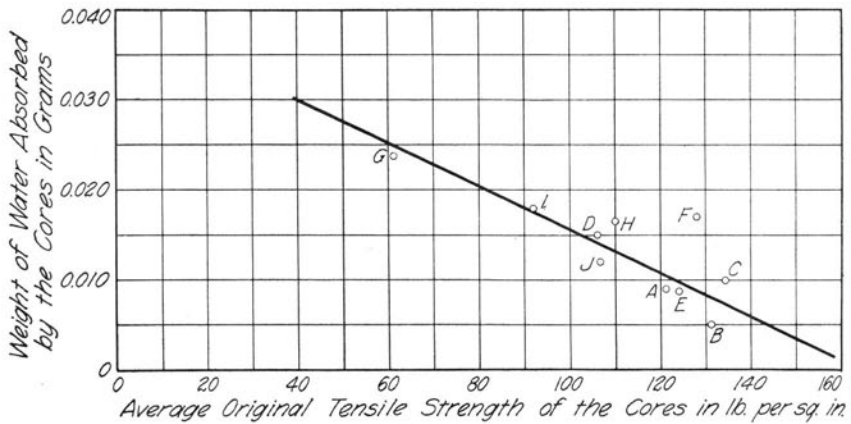


FIG. 7. RELATION OF WATER ABSORBED BY CORES TO AVERAGE TENSILE STRENGTHS OF CORES

oil J; in this case the actual average percentage loss was found to be 32.8 per cent. The other core oils gave similar results.

Figure 7 shows the average original tensile strength of the cores plotted against the weight of water absorbed by the cores. It is apparent from this curve that the water absorbed varies inversely with the original bonding strength of the oils, or the oils that produced cores of low tensile strength also produced the cores that absorbed the greater amount of water. Since Fig. 6 shows that the more water absorbed the greater the loss in tensile strength, it is evident that the use of oils of low initial bonding strength should be avoided because the loss of tensile strength is cumulative.

VII. CONCLUSIONS

20. *Conclusions.*—The investigation included a variety of core oils and the results found should be applicable to the core oils on the market at the present time. The following are the principal conclusions:

(1) Graphical correlation of the average original tensile strengths of the cores with the specific gravity, percentage of ash, flash point, and fire point of each respective core oil showed that no definite relations exist between these factors. Therefore, it would not be advisable to predict the strength-producing qualities of core oils on the results of a single test, but a complete analysis of all the physical and chemical properties of a core oil should be used to determine the quality or grade of the oil.

(2) The initial tensile strengths of the baked cores made from the ten oils by standard methods of mixing, ramming, baking time, and baking temperature, were found to be proportional to the saponification and iodine numbers of the core oils, and may be calculated from the following equations:

$$\frac{\text{Tensile Strength}}{\text{Saponification Number}} = 0.77$$

$$\frac{\text{Tensile Strength}}{\text{Iodine Number}} = 0.90$$

(3) The percentage loss in tensile strength of the baked cores made from the ten oils was found to be proportional to the amount of water absorbed by the cores, and may be calculated from the equation

$$\frac{\text{Water Absorbed by the Cores}}{\text{Percentage Loss in Tensile Strength}} = 0.00037$$

(4) The amount of water absorbed by the baked cores made from the ten oils varied inversely with the original tensile strength of the cores.

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