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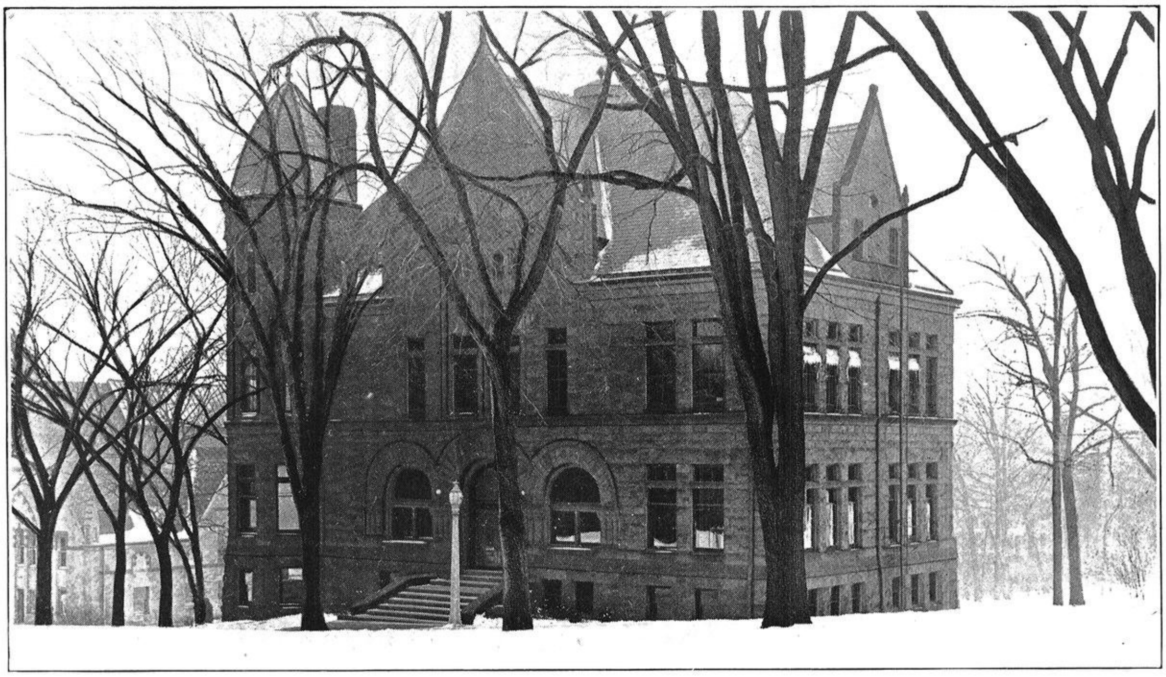

WELL! WELL! WELL!
IS THAT THE LAW SCHOOL?
or *Lean on your canes, you cripples!*

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The Wisconsin Engineer

UNIVERSITY OF WISCONSIN

VOL. XXVI, NO. 5 MADISON, WIS. FEBRUARY, 1922

THEORY ON THE MECHANISM OF PROTECTION OF WOOD BY PRESERVATIVES

PART II.

The Isolation of Barren Oil From Coal-Tar Creosote and a Mathematical Proof of the Existence of a Solubility Partition.*

By ERNEST BATEMAN,

Chemist in Forest Products, Forest Products Laboratory, Madison, Wis.

In the January issue there was presented "A Theory on the Mechanism of the Protection of Wood by Preservatives." This theory as applied to creosote presumed that creosote consisted of 2 groups of compounds, 1 of these being sufficiently soluble in water to render the water toxic, the other insoluble and hence non-toxic and that the non-toxic oil acts as a reservoir for the toxic oils and feeds them automatically to the moisture in the wood.

It is the purpose of this paper to present a progress report of the new results obtained since last year. The paper is divided into two distinct parts: First, experimental work of obtaining a non-toxic or "barren" oil from coal-tar creosote; and, second, a mathematical treatment to point out the existence of a solubility partition in data already existing and published for other purposes.

A fairly definite relationship[2] has been shown between the toxicity of coal-tar creosote and the amount of creosote which distills below 270° C., the oils containing the larger proportion of low-boiling oils being more toxic than those containing lesser amounts. It was natural, therefore, in looking for a non-toxic, or barren oil, that those oils having the largest proportion of high-boiling materials should be first attacked. The work at the U. S. Forest Products Laboratory at Madison, Wis., has been confined to high-boiling creosotes.

The first work was on fraction 4, which has been frequently mentioned in connection with various experiments of the laboratory. This fraction was first distilled through a Hempel flask and all the material boiling below 270° C. rejected. This distillate above 270° C., was cooled and freed from solid matter by freezing and pressing. The liquid thus obtained was washed first with caustic soda solution, and then with dilute sulphuric acid to remove as much as possible of the tar acids and tar bases which it contained. It was then boiled for 3 weeks with solutions of acids and alkalis, using fresh acid and alkali each day and alternating the treatments until finally the aqueous solutions remained clear and gave no tests for tar acids or tar bases. The oil was then dried and distilled. When this oil was tested for its toxicity against *Fomes annosus* by the standard toxicity test used at the Forest Products Laboratory, 20% of the oil failed to kill the fungus, although there was a slight retardation in its growth. The yield of this oil was rather small, probably due to the excessive amounts of solid hydrocarbons.

High-boiling liquid coal-tar wood-preserving oils were next investigated as a source of barren oil. An ordinary commercial oil was selected, which had the following distillation[3], using an ordinary flask:

	Per cent.
Up to 285° C.	24.7
From 285° C. to 340° C.	28.5
From 340° C. to 410° C.	35.4
Residue above 410° C.	11.4
Total	100.0

A total of 1300 c.c. of oil boiling between 285° C. and 410° C. were obtained. This oil was treated with dilute acids and alkalis, as previously described in fraction 4 and afterwards distilled and tested for its toxicity. A yield of 820 c.c. of bright, clear oil was obtained, amounting to 63% of the original oil, boiling between 285° C. and 410° C., or 40% of the total oil. This "barren" oil failed to kill *Fomes annosus* when used in amounts up to 20%.

Fig. 1 shows a culture of *Fomes annosus* growing on agaragar, containing 20% of barren oil 2 weeks after inoculation with the fungus. This experiment shows conclusively that there is in coal-tar creosote a non-toxic, or barren oil, and that this barren oil may be present in considerable quantities which supports the theory as given last year[4].

Shackell[5] has shown that in the case of limnoria the effective toxic material is at least dissolved in water. In fact, the methods used in testing the toxicity of materials against both the marine borer and fungi are such as to practically prove that water solubility is a necessary function of a wood preservative. If we accept this water

*Presented at the Seventeenth Annual Meeting of the American Wood-Preservers' Association.

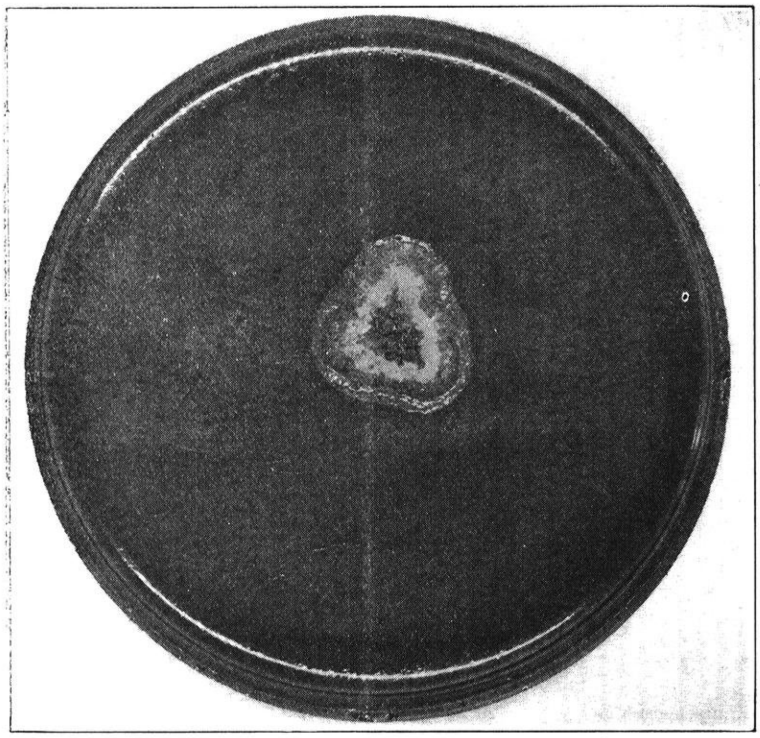
[1]Proceedings, American Wood-Preservers' Association, 1920, p. 251.

[2]Wood-Preserving, Vol. III, No. 4, 1916.

[3]The previous experiment showed that it was somewhat easier to obtain a non-toxic oil if the fraction were cut at 285° C. rather than 270° C.

[4]Proceedings, American Wood-Preservers' Association, 1920, p. 251.

[5]Office report at Forest Products Laboratory, digest published A. W.-P. A., 1916.



Courtesy, American Wood Preservers' Ass'n.

FIG. 1: CULTURE OF *Fomes Annosus* GROWING ON AGARAGAR

solubility as proven, then there remains only to show that the non-toxic oil acts as a reservoir for the toxic material to make the proof of the theory complete.

The second part of this paper deals with a mathemathical treatment of toxicity data collected by Humphrey and Shackell, and attempts to show that a solubility partition[6] exists in certain coal-tar fractions. If there is a solubility partition, then the creosote may under certain conditions act as a reservoir for the toxic materials.

Shackell presented a record of his experiments on limnoria to the American Wood-Preservers' Association in 1916, in which he showed the effect of known quantities of preservatives upon the wood destroyer. As a measure of the effect, he chose the length of time required to kill limnoria immersed in sea-water containing the preservative. Curve 1, Fig. 2, shows the time required to kill 1 or more limnoria when immersed in various concentrations of phenol in sea-water. The time required to kill 1 limnoria was chosen, because it was impossible to obtain from the data the time required for all of them, and also because this strength of preservative is the minimum which can be considered as effective, since naturally the weak animals would be killed first.

The equation for this curve is $YX^{3/2} = K$.

Where Y is the time required to kill, X the concentration of the preservative, and K the constant.

[6]When any material is mutually soluble in 2 other materials which are insoluble in each other, the mutually-soluble material divides itself between the 2 media in a very definite manner, if these 3 materials are mixed together. The manner in which the mutually-soluble material is divided is such that its concentration in 1 medium is in a definite and fixed ratio to its concentration in the other. This ratio is called solubility partition, and is always the same for any 3 materials.

The left side of the equation includes the killing time and concentration of preservative. It does not refer to the type of preservative used, but merely says that by varying the concentration, the killing time is varied. The same equation, but with a different value for K, should, therefore, fit all water-soluble preservatives when used against the same organism. Curve 2, Fig. 2, shows the curve for cresol derived from this equation by solving for K at the 1% point. The resulting curve passes through the other experimental points within the limits of experimental error, thereby proving the accuracy of the question.

Shackell also mixed 10 gms. of fraction 1 and 100 gms. of sea-water, and then tested the toxicity of the water. He then diluted the toxic water with an equal amount of sea-water, and subsequently diluted this to contain only one-fourth of the original toxic material dissolved from the 10 gms. of creosote.

Fig. 3, curve 1, shows the effect of diluting the water-soluble material obtained in 100 gms. of water from 10 gms. of fraction 1. The point plotted at 5% represents the concentration of water-soluble material obtained by diluting the above solution to one-half its volume. The point plotted at 2:5% represents a second dilution of the
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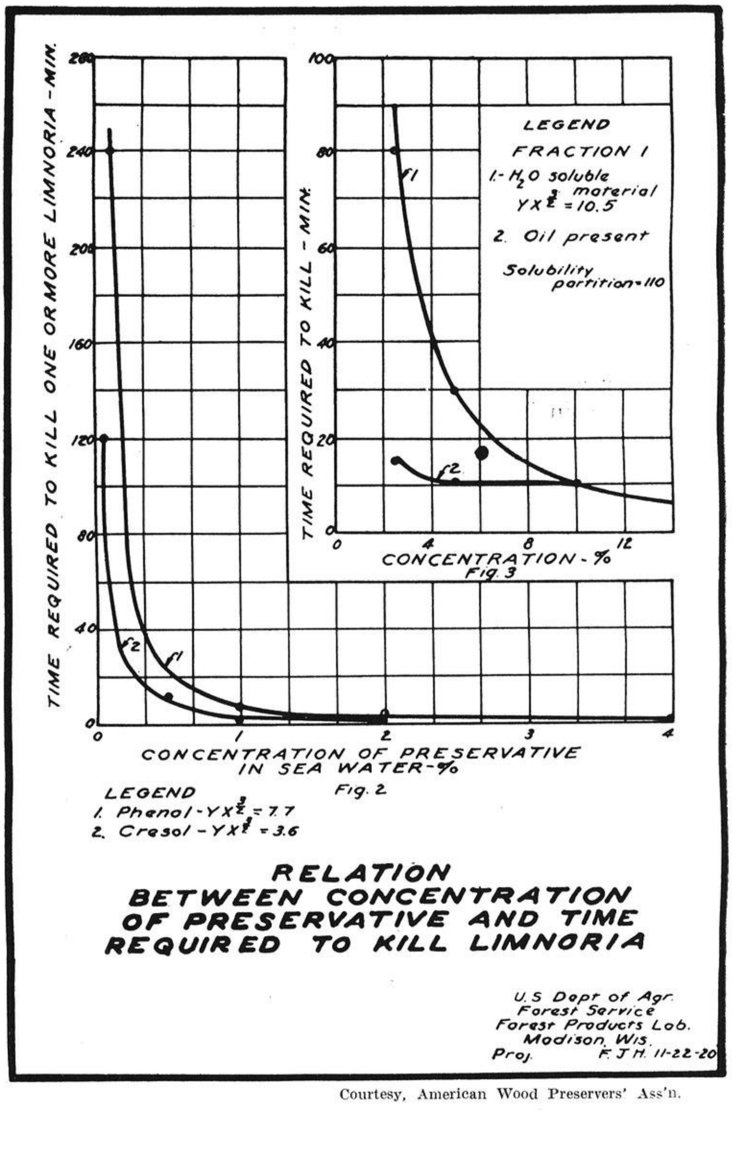

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The curve was obtained by solving for K in the equation $YX^3/_2 = K$, using the point plotted 5%. The curve passes through the other 2 experimental points. This shows that the water-soluble-toxic material in fraction 1, when separated from the oil, affects limnoria in the same manner as other water-soluble materials.

Shackell further tested fraction 1 by using 2½ gms., 5 gms., and 10 gms. of creosote suspended in 100 c.c. of sea-water. Curve 2 in Fig. 3, represents the toxicity of fraction 1 when different amounts of oil are used in contact with water.

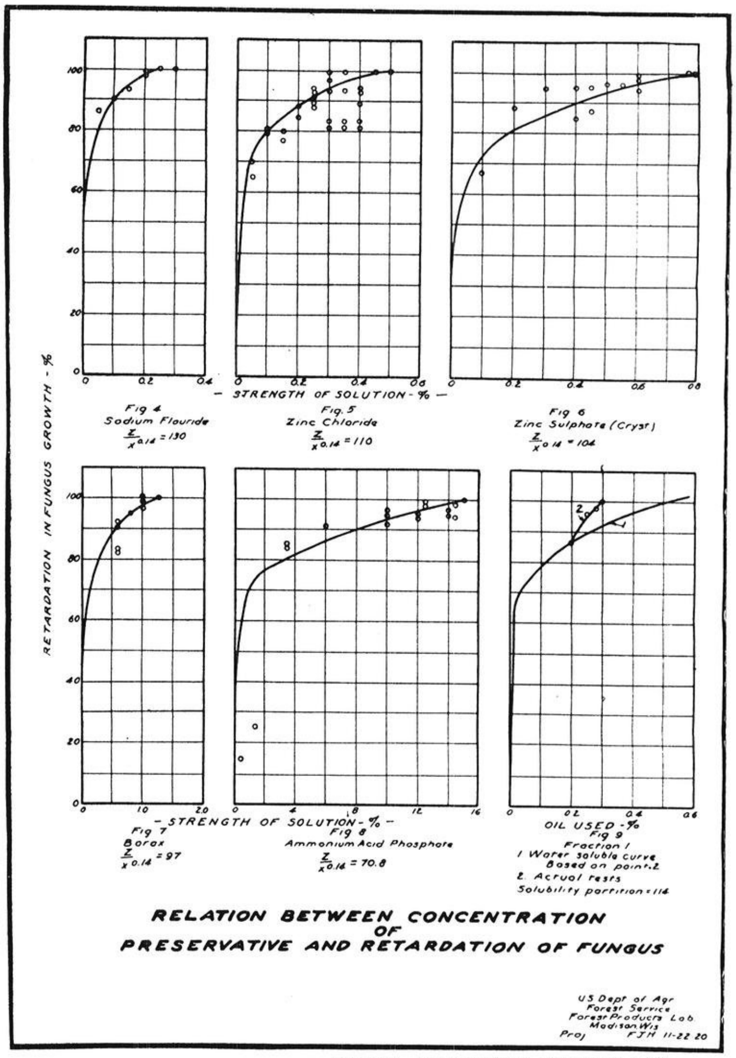
If the water dissolved all the material from the creosote, then he should have obtained the same result if he used 10 gms. of creosote and 100 gms of water, and subsequently diluted the water solution to one-half its strength, as he did by using 5 gms. of creosote and 100 gms. of water. If, however, the toxic material were much more soluble in oil than in water then he should get a stronger aqueous solution, using 5 gms. of creosote than with 10 gms of creosote, and subsequently diluting to one-half strength.

Let us suppose that the toxic material in some given oil is 100 times more soluble in the oil than it is in water and that we have 1 gm. of toxic material dissolved in 9 gms. of oil. If we put this oil solution in contact with water the toxic material will divide itself between the oil and the water in such a manner that the concentration of the toxic material in oil is 100 times its concentration in water. The amount of toxic material dissolved in the oil will be the concentration in the oil multiplied by the weight of oil. Similarly, the amount of toxic material in the water will be its concentration in water multiplied by the amount of water. If then we put 1 gm. of toxic material and 9 gms. of oil in contact with 100 gms. of water, the amount dissolved in the 2 media will be in proportion to their weight times their concentration. For oil this will be 9 x 100, and for water 100 x 1; that is. 0.9 gm. of toxic material will stay dissolved in the oil, and 0.1 of a gram will be in the water. The concentration of the toxic material in water will, therefore, be 0.1%.

If, however, only 4.5 gms. of oil were used and 0.5 gms. of toxic material with 100 gms. of water, then the ratio would be for oil 4.5 x 100, and for water 100 x 1. The toxic materials in this case would be divided as follows: 0.41 gm. dissolved in the oil, and 0.09 gm. dissolved in the water. The concentration in the water would, therefore, be 0.09%. In other words, by reducing the amount of oil and toxic material by 50% we have reduced the strength of the water solution by only 10%. If then we find the results obtained by using one-half as much oil different from the results obtained by diluting the water solution to one-half its concentration it proves that some of the toxic materials are held in the oil. Curve 2 in Fig. 3 represents the toxicity of fraction 1 when different amounts of oil are used in contact with water.

From these two sets of data the solubility partition of the toxic material in the toxic oil and water can be calculated if we assume that equal effects on the limnoria are caused by equal concentration of the toxic material in water. Neither the concentration of the toxic material in water nor the amount originally present in creosote need be known for this computation. Calculations based on these hypotheses show that the solubility partition of the toxic oil in the non-toxic oil and in water are as 100 is to 1, that is, the toxic oil is 110 times more soluble in creosote than it is in water.

The data collected by Humphrey on the toxicity against



Courtesy, American Wood Preservers' Ass'n.

FIG. 4-8.

Fomes annosus have also been analyzed mathematically. it seems likely that the equation $Z/X^{0.14} = K$ is correct for this fungus, where Z is the percentage retardation in the growth of the fungus caused by the concentration of the preservative. Z is obtained by subtracting the retarded growth as measured in the petri dish, from the normal growth of the fungus, and dividing by the normal growth.

Figs. 4 to 8 show the equations and experimental data of 5 materials which have been tested against this fungus. It is to be noted that the equations differ from each other only in the value of K. The data and the curves fit as well as could be expected, particularly in view of the fact that the data were not collected with the idea of subjecting same to mathematical treatment, but only to give some idea of the toxicity of the preservatives. If then we apply this equation to some point on the toxicity data of fraction 1, we ought to obtain a second pair of curves from which the solubility partition could be calculated.

Fig. 9 shows such a pair of curves. The lower curve is derived by solving for K in the equation $Z/X^{0.14} = K$, using the 0.2 point, which has been checked 6 times with an error of less than 1%. Here again, as in the case of limnoria we find that the curve, which should have held if it were a straight solubility condition, does not hold for oil solutions. The solubility partition calculated from this data is 114, which is not far different from the 110 obtained from Shackell's data. Further proof of this is, of course, necessary before it can be accepted as final, but it is at least a very strong indication of the correctness of the theory put forth last year.

Experiments are now under way to substantiate the calculated data discussed. Should these experiments show and it seems likely that they will, that this is the correct hypothesis it will point out the way in which experiments must be conducted: (1) to foretell the probable life of any wood-preserving oil, be it coal-tar creosote, coal-tar solutions, water-gas tar, or any other oily material; (2) to determine how far we might go in diluting creosote in order that ties may have the same preserved life as their mechanical life; and (3) to fortify creosote against the attacks of marine borers. Experiments of the nature are, however, time-consuming and expensive, and at our present rate it may require a long time for the work to be completed.

Part III.

Experimental Proof of the Theory by Means of the Toxicity and Solubility Partition of a Number of Tar Acide.*

In two previous papers on the same subject there has been presented a theory on the mechanism of the protection of wood by preservatives and proof of the existence of a large portion of the oil in the non-toxic or barren state. The existence of a solubility partition of the toxic material in non-toxic oil and water has been shown from mathematical considerations. This paper gives a number of determinations of the toxicity of pure organic chemicals and measurements of their solubility partition in barren oil and water. It proves that the theory on the mechanism of the protection of wood by preservatives is correct when applied to tar acids, present as such, in creosote oil. No claim is made that tar acids are entirely responsible for the protection afforded by creosote. In fact, it can be fairly well demonstrated that some of the tar acids are of little value for this purpose and that certain hydro-carbons have a very considerable toxicity. It seems very probable that the active principles of coal-tar creosote can be divided into three groups—hydro-carbons which are soluble in water, tar bases, and tar acids—with the possible addition of a fourth group, viz., those compounds containing sulphur. The tar acids were chosen for the first work because they were known to be toxic, because many of them could be easily prepared, and because an easy method of determining them in their pure state was available when suitably modified to meet our conditions. Work on the other classes of compounds is contemplated and is already under way.

*Presented at the Eighteenth Annual Meeting of the American Wood-Preservers' Association.

The investigation naturally divides itself into four distinct parts—preparation or purification of the active poisonous materials and preparation of the barren oil; determination of the toxicity of the poisonous compounds; determination of their solubility in water and their solubility partition between the "barren oil" and water; and tests to show that based on these determinations calculations can be made which will predict with accuracy the toxicity of solutions of the active poisons when dissolved in barren oil. Much of this work which is of a rather technical nature will be omitted from this paper but will be published in chemical journals under the title, "The Phosphomolybdic Acid Colorimetric Method of Determination of Phenols as Applied to Higher Phenols and a New Standard," by C. L. Henningsen, Assistant Chemist in Forest Products, and "The Solubility of Some Higher Phenols in Water and Their Solubility Partition in 'Barren Creosote Oil' " by Bateman and Henningsen.

Table 2—Toxicity of Various Phenols Against *Fomes Annosus* by Petri Dish Method.

Phenol	Toxicity amount required to kill Fomes Annosus	Remarks
	Per cent	
1. Carbolic Acid	0.1	
2. Ortho cresol	0.07-0.08	
2₂. Meta cresol	0.06	
3. Ethyl phenol	0.04	
4. Propyl phenol	0.03	
5. Butyl phenol	0.04-0.05	
6. Isoamyl phenol	0.05	
7. Xylenol	.04	
8. Mesitol	About 0.05	Probably evaporated from petri dish.
9. Penta methyl-phenol		Saturated solution not strong enough to kill.
10. Alpha naphthol		
11. Beta naphthol	0.02	
12. Phenanthrol		Solubility 0.005 per cent. Saturated solution not strong enough to kill.
13. Anthranol		Saturated solution not strong enough to kill.
14. Biphenol		Saturated solution not strong enough to kill.
15. Alpha binaphthol	0.03-0.04	Saturated solution not strong enough to kill.
16. Thymol	0.2-0.5	
17. Resorcinol	0.2-0.5	
18. Pyrogallol	0.02-0.03	
19. High boiling tar acids		

METHODS USED

The methods used for determining the concentration of the phenols in water solution was a modification of a colorimetric method used in biological chemistry and known as the phosphomolybdic acid method. This is an extremely accurate method capable of detecting phenols in concentrations as low as one part in 20,000,000 and yielding a fairly accurate determination in concentration as low as one part in 500,000.

The solubility partition of the toxic materials was determined by shaking together weighed amounts of toxic materials, "barren oil" and water, and then determining the concentration of the water solution. The concentration of the aqueous solution multiplied by the weight of water gives the amount dissolved in the water. This weight subtracted from the weight of toxic material originally taken gives the amount dissolved in the oil. The concentration of the toxic material in oil divided by its concentration in water is the solubility partition. The determinations of solubility partition were all carried out in a thermostat regulated to a constant temperature of 77° F. The temperature was maintained with an accuracy of at least one one-hundredth of a degree. The temperature 77° F. was chosen because this is the temperature at which the petri dishes are maintained in the incubator. The toxicity tests were carried out in accordance with the standard petri dish method used at the Forest Products Laboratory.

RESULTS OF TOXICITY TESTS

The results of the individual tests have been omitted because of the large number of tests made. Approximately 200 petri dish tests were run to determine the toxicity. The toxicity of the various phenols as determined by us in the petri dish are given in table 2.

Particular attention is directed to Nos. 13 and 14 in this table. Biphenol is made by attaching two molecules of carbolic acid together. It might reasonably be expected that this phenol should be at least as poisonous as carbolic acid. It does not seem to have the least effect upon the fungus. It is practically insoluble in water. β-naphthol is the most toxic phenol with which we worked. It might reasonably be expected that bi-naphthol, a combination of two molecules of naphthol would also be poisonous, but it also does not seem to have any effect. It is almost insoluble in water. The phenols of phenanthrene and anthracene (Nos. 12 and 13) have but little action They also have a very low solubility. A saturated solution of phenanthrol in water contains two parts in 100,000. This strength of solution scarcely retards the growth of fungus.

Solubility partition determinations were made only on those whose toxicity seemed to warrant further work. Table 3 gives the results of these determinations.

TABLE 3—SOLUBILITY PARTITION OF PHENOLS BETWEEN BARREN OIL AND WATER

No.	Phenol	Solubility partition at 77° F.
2₂	Meta cresol	5.3-5.0-5.3-5.5-5.1-5.0-5.1-5.1
4	Propl phenol	100-118
5	Butyl phenol	134-136
6	Isoamyl phenol	189.5-181.6
8	Xylenol	22.7-20.3
11	B-Naphthol	49.5-50

From the toxicity and the solubility partition we ought to be able to calculate the toxicity of oil solutions if the theory proposed is correct. In order to test out the correctness of the theory two of the phenols were chosen—both of which are present in coal-tar. They are M-cresol and β-naphthol.

Two solutions of M-cresol in barren oil were prepared one containing 11.37 per cent M-cresol, the other 5.12 per cent M-cresol. Calculations based on a toxicity between 0.05 and 0.06 per cent cresol and a solubility partition of 5.1 shows that in the petri dish between 0.208 and 0.219 gms. of the 5.12 per cent solution and between 0.08 and 0.096 gms. of the 11.37 per cent solution would be required to kill. Likewise, two solutions of β-naphthol in barren oil were prepared, and the first containing two per cent the other five per cent of β-naphthol. Calculations based on a toxicity of between 0.01 and 0.02 and a solubility partition show that it should require between 0.131 and 0.396 gms. of the two per cent solution and between 0.0416 and 0.099 gms. for the five per cent solution.

Petri dish tests were then made having at least one concentration of greater strength than required by the calculation, one somewhat less than the calculated and one between the two calculated limits. The results of these tests are given in table 4. In all four series of tests

TABLE 4—TOXICITY TESTS OF SOLUTIONS OF TOXIC MATERIALS IN BARREN OIL.

Weight of solution taken Per cent	Ave. radial growth at end of six months	Calculated result
	Toxic oil containing 5.39 per cent Cresol	
0.97	(1) 1.5 (2) 2.5	Below killing point range, therefore should grow.
1.18	(1) None (2) None	Within killing point range, may or may not grow.
1.39	(1) None (2) None	Above killing point range, should not grow.
	Toxic oil containing 11.37 per cent cresol	
0.39	(1) 6 (2) 121	Below calculated killing point, therefore should grow.
0.48	(1) None (2) None	Within calculated killing range, may or may not grow.
0.56	(1) None (2) None	Above calculated killing point, therefore should not grow.
	Toxic oil containing 2 per cent B-Naphthol	
0.29	(1) Over 40 (2) Over 40	Below calculated killing point range, therefore should have grown.
0.68	(1) None (2) None	Within calculated killing point range, may or may not grow.
2.09	(1) None (2) None	Above killing point range, therefore should not grow.
	Toxic oil containing 5 per cent B-Naphthol	
0.106	(1) Over 40 (2) Over 40	Below toxic range, therefore should have grown.
0.223	(1) 26 (2) None	Within calculated killing point range, therefore may or may not grow.
0.555	(1) None (2) None	Above killing point range therefore should not grow.

the oils, when the calculations showed they were below the toxic limit, the fungus grew; in all the oils when calculations showed that no growth should be obtained, none was obtained. In other words, if we know the toxicity of the poisonous compound and the solubility partition of the poisonous compound between oil and water we can calculate the toxicity of solutions within the limits of our measurements.

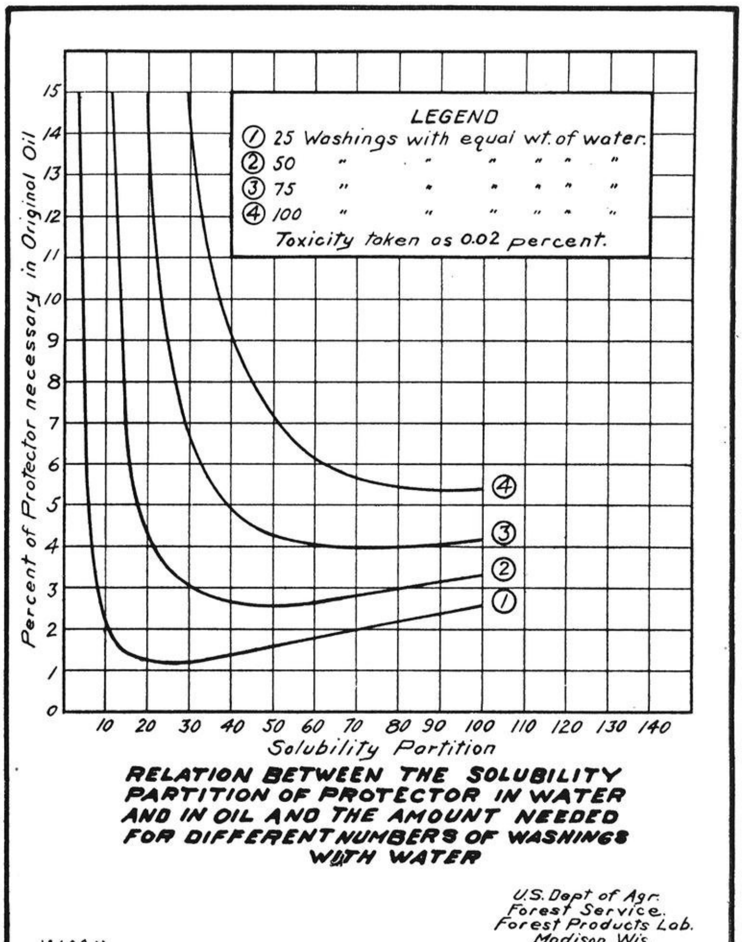
One of the most important factors which governs the value of a preservative is its life, that is, how long will the material act as a poison. The life will, of course, vary with varying conditions. Two of the most important means of loss of poisonous materials are loss by volatilization and loss by leaching. Loss by volatilization is dependent upon the vapor pressure of the poison in the oil and the area of surface of the oily layer exposed to the air. The loss by leaching is dependent upon the amount of water entering and leaving the treated wood and the solubility partition of the poison in oil, or upon the rate at which the toxic material diffuses through the treated wood and upon the solubility partition of the toxic material in water and non-toxic oil. We have at present no data upon the rate of leaching of the toxic materials from wood, but for our purpose we can take as a measure for this the number of times that we might wash an oil solution with an equal volume of water. If we had such a solution and knew the concentration of the toxic material in barren oil, the toxicity of the pure material and the solubility partition in the oil, we should be able to calculate the number of times we might wash

TABLE 5—EXPERIMENTAL AND CALCULATED EFFECT ON TOXICITY OF WASHING BARREN OIL SOLUTION OF PHENOLS

Phenol used	Weight of phenol taken	Weight of oil	Water used each washings	No. of washings	Calculation shows that	Found
	grams	grams	cc			
Cresol	.2000	4.034	20	3	Should not grow	No growth
Cresol	.2000	4.060	20	3	Should not grow	No growth
Cresol	.2000	4.033	20	4	Should grow	3-5mm.
Cresol	.2000	4.023	20	4	Should grow	2-6mm. growth
Cresol	.2000	4.008	20	5	Should grow	6-8mm. growth
Cresol	.2000	4.156	20	5	Should grow	7-9mm. growth
Beta-naphthol	.050	2.20	100	1	Should not grow	No growth
Beta-naphthol	.050	2.62	100	1	Should not grow	No growth
Beta-naphthol	.050	2.26	100	2	Probably slight growth	1-1mm. growth
Beta-naphthol	.050	2.32	100	2	Probably slight growth	3-4mm. growth
Beta-naphthol	.050	2.13	100	3	Should grow	6-10mm. growth
Beta-naphthol	.050	2.22	100	3	Should grow	3-7mm. growth

the oil with water and still have the aqueous solution poisonous. If, for instance, a five per cent solution of cresol in barren oil was washed or shaken with an equal weight of water the cresol would divide itself between the water and the oil in the proportion of its solubility partition. If this were repeated a number of times, the point would finally be reached when the water solution would not be poisonous enough to inhibit fungus growth. Calculations based on the toxicity of cresol and its solubility partition show that the effect should be produced at the sixteenth to nineteenth washing. Similar calculations on a five per cent solution of β-naphthol in oil show that the same effect should be reached between 85 and 125 washings. To carry out this number of washings experimentally would be very tedious and time consuming. In order, therefore, to reduce the number of washings larger quantities of water were used. With the five per cent cresol solution in barren oil water equal to five times the weight of oil was used at each washing. With the five per cent solution of β-naphthol in barren oil water equal to 45 times the weight of oil was used at each washing. Calculations show that after the fourth washing of the cresol solution the oil should still contain enough cresol to inhibit the fungus in a petri dish. At the end of the fifth washing the amount of cresol present is within the toxic range and might or might not grow, while at the end of the sixth washing the fungus should certainly grow.

Table 5 shows the results of petri dish tests on various washings made on five per cent solutions of M-cresol and β-naphthol in barren oil and the result of calculations based on the solubility partition theory. Since we are able to calculate the effect on the toxicity of dissolving a toxic material in a non-toxic oil and further calculate the effect of washing this solution with water, it is of interest to show what the effect of the solubility partition has upon the life of the preservative and upon the amount required to protect for a different number of washings. Figure 1 shows a series of curves obtained from calculations of the amount of protector dissolved in oil necessary to make the water poisonous for 25, 50, 75 and 100 washings. When the toxicity of the protector is taken as being the same in all cases and is placed at 0.02 per cent, the curves show that if wood is to be placed where



Courtesy, American Wood Preservers' Ass'n.

FIG. 1. AMOUNT OF PROJECTOR NECESSARY TO MAKE THE WATER POISONOUS FOR VARIOUS WASHINGS.

it would be subjected to moderate leaching action such as is equivalent to 25 washings with equal volumes of water, the most economical materials would be those having solubility partitions between 10 and 70, and that a solution containing two per cent or less of these materials would accomplish this end if their toxicity were 0.02 per cent or less. If the leaching is somewhat more severe, equivalent to 50 washings with equal volume of water, the materials should have solubility partitions between 30

(Concluded on Page 98).

THE ORDNANCE CAMP

By D. A. McArthur

Junior Mechanical.

On a burning hot Sunday morning last June thirty Mechanicals, Chemicals, and Miners boarded a special Pullman at Chicago for the trip to the R. O. T. C. Ordnance camp at Aberdeen, Maryland. After passing Gary the scenery was no more interesting than a typical hydraulics problem, so the fellows turned to the overworked pasteboards for amusement. The liveliest game discovered was seven card stud with deuces and jacks wild. Perhaps it was as a result of the games that the waiter received, after serving supper, an aggregate tip of five cents from four fellows.

Most of the fellows retired early, expecting to rise early and see the Alleghenies, but a few decided that they would wait until midnight, and take a look at Pittsburg. The latter were badly disappointed, however, as light from a few blast furnaces was all that could be seen. The next morning several of use rose at four o'clock and saw the mountains from the observation car platform. At about ten we arrived at Washington and made a fifteen-minute tour of the city. Having lost only two men during the tour we continued our trip, arriving in Aberdeen to be carried to the Proving Ground in a big bus. To say that we filled the bus would be stating the case very loosely. At the gate a guard wearing a business-like looking pistol stopped us, but at the words "R. O. T. C." he waved us inward. We soon found that these letters were enough to pass us almost anywhere. After passing an impressive row of big guns and tanks we arrived at our barracks, which were much too conveniently situated across from the guard house.

It might be well to explain just what the Aberdeen Proving Ground is. It is situated at the head of the Chesapeake bay only a few miles from Baltimore and is where all the ordnance of the U. S. Army is tested. Ordnance includes, besides guns and ammunition, tanks, tractors, trailers, gun mounts, gun carriages, armor, fire control apparatus, and many other minor supplies. An immense artillery range is used for actual firing at the big guns. The largest gun in the U. S. has been fired there at a range of almost thirty miles. Several aircraft are posted at the Proving Ground to test drop bombs. At the time we were there most of them were away at maneuvers, but two Handley-Paige bombers and several De Haviland 4's were in use. After finding our bunks we met about one hundred fellow engineers from Boston "Tech" and Cornell and Yale who had arrived several days before us. They soon went off to work while we drew our uniforms. Two army captains, who were to be our company commanders, fitted us and saw that every man was satisfied. We began to think that we were of some importance, but the next morning we lost all of that respect for ourselves, however. At 5:45 we were routed out of bed and at six o'clock formed for our first taste of "Monkey Drill." Monkey Drill is no more than simple calisthenics, but to us it will never be anything but Monkey Drill. We did all sorts of exercises while counting aloud, "One, two, one, two, one, two," and so on, ad infinitum. The captains told us what to do while the major kindly urged us to yell louder. For the first week it was hard work, but soon we didn't mind it at all. The captains then stopped working and let different R. O. T. C. men lead the companies. Some rare commands were heard, such as "Hopping exercise. Ready, *Hop!*" Some bright man wanted to give a fairy dance exercise but was afraid of the results of such a command so we were spared from being fairies.

Each day after breakfast we cleaned up barracks and then reported for an hour's infantry drill. That done, we attended ordnance classes for the rest of the day. We were there so short a time that we barely dipped into the work and naturally no course became uninteresting because of overwork. We all gained a good general idea of ordnance work, however, and also learned many practical things from an engineering standpoint.

One of the most extensive courses taken was Tanks, Tractors, and Trailers. We concentrated our work on the U. S. Army five-ton caterpillar tractor. We took three machines almost entirely apart and then did the best we could to put them together again. The lieutenant in charge assured us before we left that he expected to find most of the parts within a few weeks. This work gave us a very good idea of tractor construction, for the function and construction of every part was impressed upon our minds, causing, somehow, sore fingers and stiff backs. The most interesting part of this course were the driving lessons. We practiced for some time on the roads and then the officers picked out the worst holes they could find for us to negotiate. Stalled engines were so common that we didn't even cuss them. Before the lessons were over most of the men were fairly good drivers, however. The favorite sport in this class was to race down the concrete road on high. Fifteen miles per hour seemed like sixty in those rattling tractors.

One of the most intereting days was spent working on a sixteen-inch gun mounted on a disappearing carriage. It was the gun which caused so much comment in technical magazines when it was first fired about three months ago. At the time we were there it was not yet ready for firing, but was sufficiently mounted for us to see how it worked. The officer in charge gave us some figures on the weight of the gun but they were so big that we couldn't fully comprehend them. The gun proper and the counterweight weighed one million pounds, I believe. Just to give us a taste of supposedly hard work we were asked to traverse the gun by hand. We looked at the two little hand-wheels and declined with thanks. However, after trying them we found that the thousands of tons of weight moved very easily. In fact we moved the gun so swiftly that something jammed and they did not find the trouble until after we had left. The carriage used with this gun could only be utilized in permanent fortifications, for over a year was required to mount the one at Aberdeen. Another sixteen-inch gun has been mounted since then on another type of carriage, the operation taking only about two months.

We received a taste of firing big guns one day when we fired a twelve-inch gun mounted on a railway mount. The regular gun crew let us do all the work that day from loading the projectile to actually firing the gun. Just before the breech block was closed the captain showed us the little brass pressure gauges and explained their use, saying that they are placed in the breech of the gun just behind the powder, and that the pressure in the gun is measured by the difference in the dimensions of the little cylinders before and after firing. After the gun was fired we opened the breech block and immediately a bright young man from Yale cried, "Why, there's something in there!" He had an entirely original idea that the gauges traveled with the projectile, which landed about twenty miles away in Chesapeake bay, and for all we could see, sank a dozen ships.

On certain days all shipping is kept from parts of the bay to allow big-gun firing. It is ascertained by wireless that no boats are in danger before the shot is fired.

We had many other interesting experiences, in fact, so many that it would be impossible to try to tell of all of them here. One of the outstanding frights of our lives occurred when a sergeant began to pound T. N. T. with a sledge hammer. There was a near stampede until we were assured that there was absolutely no danger of its exploding. Another fright occurred when a tractor, going over a ridge, nearly tipped over backwards. If everybody had not held their breaths it probably would have done so.

One big point of interest was the museum, for in it was every type of modern war apparatus. There were two of the German forty-two centimeter howitzers which leveled Liege and Antwerp, a German tank shot full of holes, the fifteen-foot telescope through which the Kaiser occasionally watched the fighting, and other articles of interest too numerous to mention. It can be seen that we were not bored by seeing the same things more than once. To be truthful, there were lectures where differential equations as long as your arm were used, but these were few and just made us see how little we knew.

During our stay at camp, Major General C. C. Williams, Chief of Ordnance, visited us. Previous to his visit we had stood much in awe of the numerous captains and majors, but it amused us greatly to see that they felt exactly the same way in the presence of the general. The general gave us a short talk and among other things told us that we were the main hope of the ordnance department for the future. We went to bed that night to dream of two silver stars on our shoulders. The general's visit caused the formation of a queer hypothesis, namely, "The more they know the less they say." The general talked about ten minutes, the colonel usually spoke about half an hour, while the captains took an hour and the lieutenants always used the full two hours allowed them.

It must not be thought that all we did was work and listen to lectures. There was ample time for all kinds of sports and amusements. Baseball, tennis, and swimming were the favorite sports. For swimming, we used the officers' pier, which was only a couple of hundred yards from the barracks. A fine baseball diamond was located a few feet from the barracks, and a ball game was played every night, either among ourselves or against members of the balloon company. On the Fourth of July a team of R. O. T. C. motor transport men played us, but after a few innings everybody lost track of both scores. Nevertheless, we had a good time. A tennis tournament was held, using the officers' courts, but all the Wisconsin men were eliminated early. Passes to Aberdeen were to be had for the asking. A piano was provided in the recreation room. In short, every type of desire was gratified.

In speaking of sports one must not forget our lessons in bed-making and floor sweeping. One morning the captain of Company A remarked before the company that one man simply could not learn to make his bed properly. "Mr. Wupper is the one I mean," he added. Benny immediately began to do better. On inspection the captain soon discovered the trick of sweeping out under the extra shoes. "I did that when I was in school, too," he told us. He was almost overcome one morning, however, when he happened to look into the stove and found it almost bulging with all the shoe boxes of the barracks.

Before leaving we entertained the officers at a dinner one evening in the mess hall. Everybody made speeches and felt fine. The climax came when the results of questionnaires as to who was handsomest, ugliest, wittiest, and so forth were read. Many Wisconsin men won places but none so many as did "Shifty" Lewis. He was elected to everything from handsomest to second ugliest. While speaking of "Shifty" it is well to say that several Baltimore junk dealers bid on the souvenirs which he collected. Probably the most popular award was that which gave "Red" Warren, one of our frosh, the title of Worst Pest.

When the time came to leave camp everybody felt that they had spent an enjoyable and profitable five weeks. We will never forget those tractor races, those trips to the flying field, the sixteen-inch gun, the pistol practice, the great eats with real darky waiters to serve them, and most of all, the finest officers we ever knew. Although they drilled us half to death, made us make beds just so, and put us on cosmoline detail, they were nevertheless the real friends of every man.

RADIO CONTROL

By H. H. Germond and W. P. Flynn,
Junior Electricals.

Radio control of auto-motive devices is a fertile field of endeavor in which the surface has barely been scratched. Men of such caliber as Tesla, Branley, and Hammond have devoted many years to the study and experimental development of radiodynamics, as the art is called, and their results have been of great interest and value. Army and navy engineers, realizing the possibilities in this field, have carried the work along to the point where it is no longer merely an interesting scientific toy, but has become a reliable means of defense in the form of radio controlled torpedoes.

The first constructive experiments in radiodynamics were probably those of Nikola Tesla, beginning in 1892 and culminating in his boat, th "Telautomaton", in 1897. His further work has been more in the nature of wireless transmission of power rather than in radio control. There have been numerous other experimenters, among whom Dr. Branley stands out as a prolific contributor of new apparatus. Credit is also due to Lodge, Muirhead, and Marconi, whose refinements in appartus have made possible many of the modern developments.

John Hays Hammond, Jr., has carried on the most extensive research in recent years. His investigations soon showed the preference of vacuum tube circuits over the earlier, and none too sensitive, coherer.

The development of selective wave apparatus and the advance in radio itself has made this new means of control so certain that in recent bombing tests the battleship Iowa was completely controlled throughout its manoeuvres by wireless.

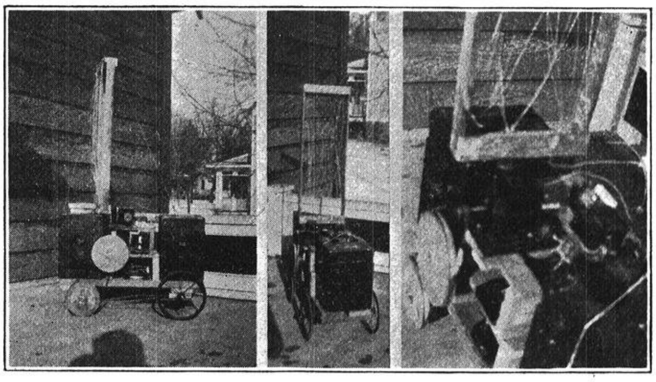
It is of interest to note that "Signal," the student club composed of those who attended Camp Vail the past summer, is following out some experiments along this line. At the least meeting prior to the Christmas recess the authors of this article gave a demonstration of radio control, using the cart shown in the accompanying illustrations. The apparatus was of simple, home-made construction and was designed to start and stop at the pleasure of the operator.

The cart proper was a wooden framework mounted on wheels. Two four-volt storage batteries furnished the current for the driving motor. A telegraph sounder was equipped with a contact device to close the circuit through the motor. A Pony relay controlled both the sounder and the decoherer, which was an ordinary electric doorbell. A filings coherer was used as the receptor of electrical oscillations.

The coherer consisted of a cardboard tube about two inches long and half an inch in diameter filled with iron filings. Best results were obtained with a mixture of filings and screenings varying from fine to rather coarse.

The work will not be left at this point, however, for the control will be extended to include many more features, such as to turn the cart to the right, to the left, to reverse, etc.

The Military department of the university is giving its heartiest cooperation in this work for most of the apparatus was standard Signal Corps material, and was loaned for this purpose.



The Radio Controlled Cart

AN APPLICATION OF MECHANICS TO STRUCTURAL GEOLOGY

Did you ever stop to figure out how many ancestors you should have had in the year 1 A. D.? Someone else has, and maybe you'll think they are trying to put something over on you when you see the results, but try it yourself and see. Your presence on this earth means that you have a father and mother, which in turn, means that you have or did have two grandfathers and two granmothers, four great-grandfathers and four great-grandmothers, etc. Your ancestors form a geometrical progression whose ratio is two. Considering three generations to a century, there have been 3 x 19 = 57 generations since the year 1 A. D. This means that somewhere around the year 1 A. D. you had $2^{57}-1$ ancestors or about 144,000 Billion. Someone has figured it out that if they were to occupy every part of the surface of the earth, deserts and oceans included, there would be but one square foot of surface for about every three people. Something's wrong somewhere. Can you figure it out?

Baseball

For the first time in some years, the baseball team is to take a spring training trip. The team will leave April 8 and play eight or nine games during their eleven day absence. Wisconsin baseball teams are under a handicap due to weather conditions, and it is hoped that this trip will be the thing to offset the handicap. The baseball team will play in all about twenty-five games this year.

Someone has suggested that "Hippo" Vaughan, who is working for the Fairbanks-Morse Co., at Beloit be secured to give the pitchers a few pointers, and it sounds pretty good. If Alexander had any influence on the Illini pitching staff last year, it surely was a good one.

PATENT LAW AND THE ENGINEER

By E. L. Goldsmith, e '15

"The senior engineering student who recognizes his call to labor in patent law work will do well to inquire of the Commissioner of Patents regarding vacancies in the Examining Corps and the entrance conditions therefor," says Mr. Goldsmith.

The field of patent law embraces all the arts and sciences, particularly including agricultural appliances, household articles, medical appliances and processes and other fields too numerous to mention, as well as all branches of engineering. The patent lawyer thus becomes acquainted with the latest advance in all of the arts and sciences, either through his own particular work or through the patents which are granted weekly. In addition to the foregoing, the patent lawyer is concerned with the legal rights and remedies of his clients that relate to patents and patent contracts.

There is thus open to the engineer or technically trained student a splendid field for future advancement, providing he has an excellent knowledge and use of the English language, is studiously inclined and is quick in his perceptions, as well as accurate therein. If a frequent change of subject matter or problems is necessary to sustain or stimulate your interest in work and you are endowed with the aforesaid talents, the field of patent law should be particularly inviting, as well as profitable to you.

To the engineering student, therefore, who decides that patent law is his particular field, several roads to success are open. One road leads directly to a patent law office, another to a law school and subsequently to a patent law office; while the third leads to the Patent Office. The United States Patent Office at the present time has a considerable number of vacancies in the Examining Corps, and to secure an appointment therein, certain technical training is required. These requirements can be readily ascertained by communicating with the Commissioner of Patents at Washington, D. C.

An appointment, either temporary or permanent, in the Examining Corps gives the appointee a first hand knowledge of the Patent Office practice, its personnel and its requirements, as well as its needs and failings. A foundation of patent law practice, procedure and training thus is secured at government expense. Several excellent law schools and universities are located in the National Capital and offer late afternoon and evening classes for government employees which lead to professional degrees. A three or four-year term in the Patent Office with a simultaneous attendance at one of the law schools should provide the potential lawyer with a complete foundation for future success.

The subsequent course open to the trained patent lawyer is the association with a recognized and reputable patent lawyer or firm of lawyers with whom the young lawyer will acquire rapidly the experience in office practice, handling clients and preparing legal papers. From this stage in his career the success obtained in later life is determined by the integrity, application to work and absolute honesty of the young lawyer.

The senior engineering student who recognizes his call to labor in the foregoing patent law work will do well to inquire of the Commissioner of Patents regarding vacancies in the Examining Corps and the entrance conditions therefor.

THE LAY OF A PHOEBE KAY

My Phoebe key has been with me since nineteen hundred and four,
And on the square, I won her fair, though some of the gang were sore.
I didn't mind being called a grind, and I wore here then with glee,
And you can bet I wear her yet, right out where folks can see.

In college days I won no bays in the giddy social rout;
I was *de trop* at any show where women were about.
I tried for glee; but they soon dropped me, and a freshman won my place;
I hit the booze with other stews, but I couldn't stand the pace.

At end I proved so punk I moved the football coach to tears;
I was a dub, and on the scrub I played for three long years.
I tried for third, but a faster bird took the regular job from me;
And at the mile I plugged a while; my best was a poor 5:03.

At every game it was the same; I never could reach the top;
And though it's true I won a U, it wasn't a good fair cop.
But the Phoebe key they handed me when I took my cap and gown,
Was proof enough, if he has the stuff— you can't keep a good man down.

Believe me, boss, it's been no loss, when hunting a job or such,
To swing a key and let 'em see your brains don't need a crutch.
I've got a hunch when you size the bunch that's setting the pace today
Along in the van you'll find a man who's wearing a P. B. K.

(Mick, The Conning Tower)
New York Trinbune.

IS COMMERCIAL TRAINING ADVISABLE FOR STUDENT ENGINEERS?*

By H. H. WHEATON,
Senior Civil.

The advisability of placing any course of study in the curriculum of an educational institution depends primarily upon the benefit which students who take the course will derive from it. Any study which will aid an engineering college in turning out graduates who will become better engineers is of value, both to the institution and the graduate. There are many branches of technical training valuable to a man entering an engineering career which must be left out of the work he does at school. The four-year term is too short a period in which to study these subjects, and it is already crowded with mark of importance to him in the line which he has chosen. It can seldom be said of any school that the courses it offers are all the most useful and most important ones for the undergraduate upon which to spend his time. Experience must show what it is best for him to acquire before he begins his practical work, and when the changes which are taking place in the business world, in the lines of endeavor open to young men, and in profession for which a man may be fitting himself, are considered, it is evident that the question of what the curriculum should contain will always remain at least partially unsolved.

The young engineer cannot spend enough time in school to learn the details of his profession, but must grasp those fundamental principles which will aid him in building a thorough knowledge of the job he undertakes, and in forming an engineering judgment that will stand by him in his work. In spite of the fact that the college course is already crowded, the changes taking place in the work of the engineer and in his relation to the industrial world make the question of commercial training for him of vital importance.

Until recent years the engineer has been looked upon as a servant to the man of business. He has done as the latter has wanted things done, and used money only as he has been directed to use it. When he has been consulted it has been with reference to the technical matters involved in an enterprise, and he has not been looked to for advic in any matters pertaining to business questions and considerations.

This situation is changing rapidly, and the change would come more quickly were the engineers themselves prepared to make it. The engineer of the future must be a man who can be called upon to examine a project not only as one who will actually do the work, but as one who must know whether or not the plan is advisable from all other standpoints as well as his own. He must be the adviser of the man of business not only in technical matters but in the affairs of business as well. Because he must hold such a position he must receive a training which will be of the most value to him in the discharge of these duties. He must be prepared to report upon the possibilities of financial success as well as success in construction and operation. He must bear the same responsibilities as formerly in the solution of technical problems but he must supplement his reports with advice on financial and commercial aspects of the problems. In this consulting field he will find his best opportunities, and he will be best rewarded if he is successful. It is this fact which has raised the question of giving the graduate commercial training before he commences his work.

This change in the engineer's line of work is both desirable and necessary—necessary for his own success and for that of the men by whom he is employed.

The professional men are, as a class, not as able to hold their own in times of financial depression as are the men of business, and if the engineer is to strengthen his position he can only do so by inter-weaving his interests with those of the business world in such a manner that he will be a necessity at all times, and not an asset only when conditions are good.

In 1907 the first thing the employers did when the panic burst upon the country was to drop most of their engineers from their payrolls. In a few weeks the engineers all over the United States were clamoring for jobs at any price, and men who had left good positions for new ones found the new positions had passed out of existence while they were on their way to fill them. Such a condition of affairs would be impossible were the engineers connected closely with the industrial and commercial side of the business, but as long as they remain in the position they held in 1907 they will be discarded as useless luxuries when periods of depression develop.

Another reason for the demand for business training is because the employers are unsatisfied with the ordinary engineering graduate. The technical schools have become so standardized that almost no school varies from a set course of study, and they have not changed to meet the demands of the world. The world wants men with commercial as well as technical training to carry on the work now opening up. The United States is about to embark upon an enterprise to distribute all sorts of American made goods, tools, implements, and processes, to the world. The natural agents for the introduction of such tools and machines are engineers, men whose training enables them to select the proper implement to fit the conditions, to determine the proper size of the implement, and install it if necessary. Buyers demand that they negotiate with men capable of explaining the things they sell and the engineer is best fitted for such work.

Business men, wishing to send out competent salesmen, look over their designers and engineers until they find some who show promise, and then train them to take the buiness jobs. This method is slow and expensive,

(Continued on page 95).

*A Tau Beta Pi Topic.

SCIENTIFIC RESEARCH AS A CAREER

By Dr. W. R. Whitney,

Director Research Laboratory of General Electric Co.

In 1200 American industrial plants and many college and government laboratories, more than 10,000 men and women trained to be insatiably curious about the 90 odd elements which compose everything today are discovering new materials, new methods and improvements over the old. They are the country's industrial research workers. They fill the ranks of a profession whose value to industry is becoming of increasing importance.

Research is not new. It has been going on in one form or another ever since early man began to experiment with this and that to learn how to make better clothes and more palatable foods and more effective tools and weapons. But modern science had to produce a vast number of highly valuable contributions to knowledge before its experimentation was accepted by industry as of real value.

However a few triumphs such as the making of wrought tungsten and the creation of a score of entire new industries around cellulose compounds which research men hit upon, were proof enough of the scientists' worth to business. Well equipped laboratories for them to work in, and the freedom with which they delve into the unknown now attract more and more young men and women eager for a creative career.

The man who will be successful in research work must however, be of more than average ability. He must possess interest and a broad imagination. Above all he must be honest with himself—be interested in truth and not merely in proving or disproving a hobby. It is not necessary for him to be a phychologist. He should have a wide perspective and the ability to distinguish between the essential and non-essential in his work in relation to the practical applications of it. He should possess an inquiring mind and the ability to get at the meat or kernel of whatever he may undertake. He must, in addition, know how far to push investigation. In other words, he must be practical. He should question everything, even common facts—taking nothing for granted. The questioning mind of Dr. Irving Langmuir who started an investigation to find out how oil spreads out on water, resulted finally in the ability to measure the size of molecules. Ingenuity is an important asset, as is also resourcefulness. The research worker must know facts about matter,—call it physics, mechanics, chemistry, electricity, or what not. The more he knows about his own science, other things being equal, the more he will accomplish, and the broader his knowledge of other sciences, the greater will be his ability. Above all, the man must be interested. If interest is absent, he must forego the excitement and pleasure of research for thy will seldom come to him.

Research work is not confining in the sense that a man is anchored to a desk on a routine job like bookkeeping, for instance, for there is a mental freedom about it. It differs from other fields in that current output is proportionate to the sum of previous effort and to be pre-eminently successful he should possess a general physique above the average. At the same time physical make-up is relatively unimportant since there is always a field for activity if one has the necessary mental qualifications. A well balanced research man usually does not follow the example of Mr. Edison, who works without sleep, and so prolongs a useful life. Edison should be considered an exception, as probably most would-be emulators would have died from the exposure he has withstood.

The college trained man is more likely to succeed. Although a college training is not absolutely essential, it gives an acquaintance with facts that emboldens one to try things. Research can best be described by the word "trying". An A.B. training might increase his pleasure in living but does not necessarily make him a better research worker.

Mental vision and wide interests are the most valuable requisites. Familiarity with economics and the humanities helps to give a man a sense of proportion as long as they do not district him from his work. Many men have lost their own or patron's money because they were hypnotized, or possessed by some single idea, plan or invention which ordinary schooling could have corrected.

Contradictions of the laws of thermodynamics and the production of something from nothing are still on the wing. During the war, of the hundreds of thousands of ideas submitted only one-tenth of one percent were worthy of even being investigated. Most of them were submitted by people who had received little or no schooling. Their will and wish was fine, but they had not had a chance at good education.

In short, a well rounded technical education is best and since physics and chemistry are fundamentals of Research work, these should be emphasized. Whether or not a man specializes in any particular field makes little difference as there are probably equal opportunities in all.

After he gets his educational training he should go after a job where there is a definite opportunity to do research work with a minimum of routine. Private work at present offers better opportunity than government work. Colleges often form good stepping stones in a young research man's career because he learns there to do much with little and to appreciate the value of published information or "literature.'

Mr. Iwao Kugimiya, a railway engineer in the employ of the Government of Japan, was a visitor in the department of Railway Engineering.

PRINCIPLES OF ANTI-FRICTION BEARING DESIGN AND CONSTRUCTION

TOBIAS DANTZIG, PH. D.
S K F Industries.

Classification of Anti-Friction Bearings

Reduced to its essential features, an anti-friction bearing consists of an inner race, an outer race, a set of balls or rollers, and a retainer separating the rolling elements. The races are provided with grooves closely conforming in their section to the rolling element. When unloaded, the rolling elements touch the races in points or lines and the first classification of anti-friction bearing is based on the nature of this contact. Thus, we have the two-point contact ball bearing, the three-point contact, etc. As the commercial ball bearing of today is mostly of the two-point variety we shall restrict ourselves to the study of this type.

The line joining the two points of contact gives occasion to a further classification. This line of contact may be perpendicular to the axis of rotation, like in most single row bearings, or it may be inclined to the axis like in most double row bearings, or finally it may be parallel to the shaft as in thrust bearings. We have thus the normal contact bearing, the angular contact and the thrust bearing.

The Ideal Baering

In order that we may more readily grasp the nature of our problem, let us here introduce the notion of the ideal anti-friction bearing. This mechanism of universal application would meet to the highest degree all the fundamental requirements that can be asked of a bearing. These requirements are:

(1) Efficiency.
(2) Load carrying capacity.
(3) Inherent ability to maintain alignment.
(4) Inherent ability to maintain the relative position of various parts.

Let us analyze step by step, how these requirements affect the design and construction of the bearing.

Efficiency

The anti-friction bearing attains its high efficiency by eliminating, as much as possible, all sliding motion and the resulting sliding friction. The operation of the ideal bearing would be based on rolling motion only. This would require thoroughly hardened surfaces, ground with great accuracy and highly polished. But, while necessary, these conditions are not sufficient. Pure rolling of the balls between the two races would further require that the contact between the surfacs should be in points only. Now the elements of a ball bearing are elastic and not rigid. Under pressure the balls as well as the races deform and the contact becomes a small area instead of a point. This is true of any bearing that is loaded. In the nature of things, therefore, some sliding friction is unavoidable in a loaded anti-friction bearing.

Furthermore, we must bear in mind that we have two distinct motions; that of the rolling element on the inner race, and that of the outer race on the rolling element. As long as the line of contact is normal to the surfaces of angular contact bearing as well as in a thrust bearing, the races, both rolling motions are compatible. But in an angular contact bearing as well as in a thrust bearing, pure rolling is theoretically impossible. Not only is the operation of such bearings accompanied by sliding but there is even distinct spinning of the ball about its line of contact.

Another source of sliding motion is the rubbing of the balls against the retainer or their action on each other in a retainerless bearing.

From the standpoint of efficiency, therefore, the ideal bearing must be of the normal correct type and the contact of the surfaces should be not intimate but as near a point as possible.

Capacity

The considerations leading to a maximum capacity are best illustrated on a concrete example. Take for example the Hess-Bright Bearing No. 6305 containing seven 3-8 inch balls. Let us imagine it mounted on a horizontal shaft and loaded with a vertical load of 700 lbs. downward. If the balls and races were rigid the load would be distributed uniformly among the balls each carrying 100 lbs. But this is not the case. The elements of the bearings are all elastic. The lower balls will be compressed, freeing the upper balls practically of all load. The bearing load is transmitted unequally and the bottom ball will take the greater part. From the laws of elasticity this maximum load can be readily computed. It is found that in a normally fitted bearing this maximum ball load is approximately five times the average, i. e. in our case about 500 lbs.

Now, the capacity of the bearing is the maximum load under which it can safely operate and this evidently is determined by the capacity of its weakest member, whether this be the rolling element itself, the race or the retainer. It is usually assumed that the retainer can be built as strong as the occasion requires. Consequently the problem reduces to this: Given two hardened polished surfaces in contact, what pressure can be applied without deforming the surfaces permanently or affecting unfavorably the material of which the surfaces are composed? It is found that this load depends on several factors which are taken up here in the order of their importance.

(1) This load varies as the cube of the allowable mean pressure to which the material can be subjected.

(2) It varies inversely as the square of the elastic modulus of the material.

(3) It is proportional to the square of the diameter of the section of the rolling element in the plane of rolling.

(4) It increases with the intimacy of contact.

This last condition can be best seen if we consider two extreme cases. Consider first a sharply pointed cone in contact at the apex with a ball. The common area is exceedingly small and a relatively small force will make a permanent blunt in the point of the cone as well as a permanent dent in the ball. If the same ball be put in contact with a spherical socket of the same diameter, the common area is very large. The capacity of such a combination is obviously very large.

But the ability of carrying radial load is only one-half of the story. The ideal bearing must be able to carry in combination radial and thrust loads. With this in view let us take up again our example of the Hess-Bright No. 6305 with its seven balls mounted on a shaft and let us apply a load of 700 lbs. in the direction of the axis of rotation. Under the action of this load there will be a relative displacement of the two races. Part of this is due to the internal clearance in the bearing, part to the compression of the balls. The bearing which is of the normal contact type when loaded radially will become under these circumstances of angular contact. The load will be distributed uniformly among the balls but then each ball will carry not 100 lbs. but 100 multiplied by the secant of the angle which the contact line makes with the axis. Taking, as before, the maximum allowable ball load as criterion, we can from it derive the thrust capacity of the bearing. Apart from the fact that we cannot exceed this maximum, there are other limitations. One of these is the depth of the groove as the balls must be prevented from riding on edge. Another is the friction which is much greater in angular contact. Finally there is the retainer which is more severely strained under combined loads.

To resume then; to achieve maximum capacity the ideal ball bearing must have the greatest number of balls of the largest size, balls and races of highly polished hardened steel of great elasticity, the grooves deep and uninterrupted, and the contact between balls and races very close. This latter condition is in direct contradiction with high efficiency.

Alignment

In many applications a complete alignment of bearings mounted on one shaft is difficult to achieve. This is due to inaccurate machining of the housings as well as deflection of the shaft under load. Whatever the source of mis-alignment the ideal bearing must have inherent means for taking care of it, or else the severe internal loads generated through mis-alignment in addition to the regular loads may result in serious overloading. In most commercial bearings a slight alignment is maintained by utilizing the internal clearance in the bearing. This, however, is not quite satisfactory where considerable bearing spans may exist. In order to assure alignment under all conditions it is necessary to provide either in the bearing itself or through a special washer a spherical surface which will enable the rotary part of the bearing to tilt within the stationary.

Self-Containedness

The necessity of maintaining the relative position of the different elements of the bearing is of the utmost importance. In this respect bearings can be divided into separable and self-contained. In the separable type the internal fit is maintained by means of adjusting the locking devices. Apart from the fact that this method leaves the fit to the discretion of the man who does the mounting, these adjusting devices are not positive enough, especially as we must remember that the internal fit is usually maintained within one-half of 1-1000 inch. In the self-contained bearing, the internal fit is inherently maintained subject only to wear of the different parts, which is negligible as long as abrasive material is kept out of the bearing.

Methods of Assembly

The ideal bearing would, therefore, by necessity, be self-contained and this brings the question of assembly to the fore-ground. In fact the greatest single obstacle in the way of achieving the ideal bearing is the method of assembly. Let us then pass in review, the different methods used in assembly of commercial bearings.

(1) The Filling Notch—Notches in the shape of circular arcs are made in both races and the balls are introduced by slight force through the gap thus formed. A full set of balls can be put into such a bearing. Little, if any, thrusts can be carried.

(2) The Shallow Edge—The outer race has a deep edge on one side and a shallow one on the other. Inner race, retainer and balls are assembled first. The outer race is expanded in hot oil and forced over the inner part. The accuracy of the bearing is probably affected by the fact that it is difficult to achieve uniformity in expansion and shrinking. Thrust can be carried only in one direction.

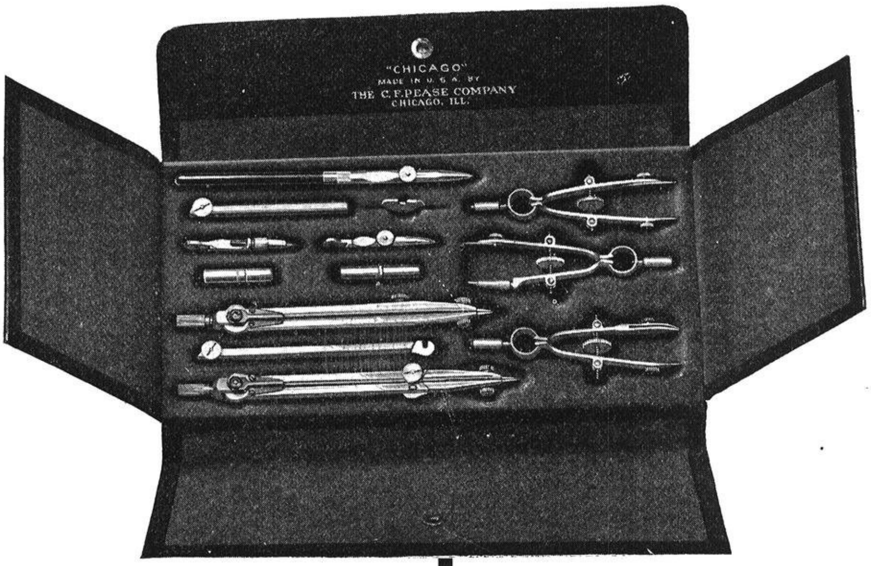
(3) The Split Race—One of the races is split, usually the outer. Bearings of this type are usually of the double row angular contact variety. The two halves are kept together by a shell. It is difficult to achieve great accuracy in this type. Under thrust only one row of balls is loaded.

(4) Eccentric Displacement—Both races are uninterrupted and the grooves extend equally deep on both sides. To assemble, the two races are placed eccentrically and the balls introduced in the crescent shaped space. By spacing the balls the two races are brought into concentric position. Bearings of this type can carry large thrusts in both directions. They are capable of great accuracy and close fits. The reproach usually advanced is that only about one-half of full set of balls can be put in this bearing.

(5) The Spherical Groove—The outer race groove is a zone of a sphere. The rotary part of the bearing can be freely tilted within the outer race. The inner race, retainer and all but two balls are assembled first. This is then introduced into the spherical race through the shortest diameter. The two remaining balls are then

(Concluded on page 10, ad section).

PEASE CHICAGO DRAWING INSTRUMENTS ARE UNSURPASSED



They are manufactured by us right here in our Chicago factory and are unsurpassed by any line of drawing instruments, either foreign or domestic, in accuracy, quality, workmanship and finish.

Pease Chicago Drawing Instruments are made by skilled workmen of the highest grade tool steel and nickeled silver obtainable. They are perfectly balanced and contain that degree of precision so necessary in high grade instruments.

PARTS INTERCHANGEABLE

Pease Chicago Drawing Instruments are so manufactured—their standards so maintained, that any part of any instrument is interchangeable with the like part of any similar instrument. Months or years may intervene between the time of manufacture, but each part will be an exact duplicate of every other part like it.

A REQUEST WILL BRING OUR CATALOG D-21

THE C. F. PEASE CO., 807 N. Franklin St., Chicago

Blue Printing Machinery—Drafting Room Supplies—Drafting Room Furniture

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209-211 West Water St. Milwaukee Wis.

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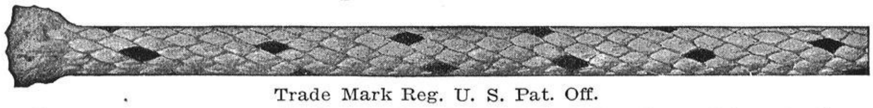


Trade Mark Reg. U. S. Pat. Off.

Made of extra quality cotton yarn, carefully inspected and guaranteed free from all imperfections of braid or finish. The colored spots are our trade-mark, used only with this quality.

We make braided cord of all sizes, kinds and colors, for all purposes, including sash cord, clothes lines, trolley cord, signal cord, arc lamp cord, and many special cords for special purposes.

CATALOGUE AND SAMPLES GLADLY SENT ON REQUEST

SAMSON CORDAGE WORKS **88 Broad Street, Boston 9, Mass.**

EDITORIALS

PEP UP! ST. PAT DAY IS COMING

Kissing the sacred, or shall we say famous, Blarney stone, which now reposes in its secret vault deep under our building, and listening to St. Pat, who always likes to tell how he chased the snakes out of Ireland, has been an established custom at our school. The celebrations two years ago were featured by an Engineer Cardinal; last year they centered around a monster parade. Why not have both this year?

Abig parade is practically assured. Polygon boasts that it will make all former exhibitions look like the funeral of a Mexican peon. If arrangements can be made with the Cardinal and eqully successful paper should also be published on the 17th. And to finish the day right wouldn't the annual Engineers' dance be just the thing?

Since making the lawyers crawfish after challenging us in football last fall we have participated as a unit in no activities, and surely one big day this spring will not be excessive. Other engineering colleges that recognize the value of such activities have no classes on the day of celebration. Of course we are here to study, but is unceasing application to one's books makes him so self-centered that society can rightfully call him selfish, then he had better attend a six months' commercial school of engineering and get the same results at less cost. Participation in outside activiteis develops that trait of prime importance, unselfishness, which can be developed by no amount of association with books or application of though in classroom. Putting hours of work into building a float for the parade which will cause other people amusement is mutually beneficial. Therefore—

Pep up—the day is only a month away!

Taken all in all, a course in the history of science, or scientific literature, is an excellent cultural course for engineering students. *P. B. McDonald.*

STUDENT CONTRIBUTIONS

The work of Mr. Germond and Mr. Flynn in constructing and voluntarily describing for publication their radio controlled cart is highly commendable. More of such original work, which requires individual planning from start to finish and gives training which no laboratory courses can give, should be encouraged. Although writing for the Engineer may not be fully comparable to writing for a commercial technical magazine, the process has some earmarks of the work which sometime every successful engineer must do. Contributions from students are always gladly received and it is hoped that such articles will increase in number.

ADVERTISING FOR SCHOLARSHIP

"The Lay of a Phoebe Kay", which appears elsewhere in this issue, might well have been chosen by any of several advertisers in this issue to convey to their future customers and employees, we students, their monthly message.

"Tackle your obstacles", "The electrical industry needs men who can see far and think straight", and much other similar advice written in an interesting manner forms a valuable part of this publication and should not be overlooked by the student reader.

The pet hypothesis of the ambitionless, namely that good scholarship is not an aid to professional success, should be effectively blasted by these same advertisements. Dispensing of mental trash during drawing and laboratory periods, an exceedingly popular manner of wasting time in our school, is inexcusable.

"Maybe it's against all campus tradition," says another ad, "but some men who stood in the upper third in their class and who entered this company years ago have since become its executives.

Practice without theory is blind, and theory without practice is empty. *Dr. Schurmann.*

GOETHALS AND THE LAKES WATERWAY

If the newspapers have reported Gen. Goethal's views on the Great Lakes-St. Lawrence Waterway project correctly, we wonder if his name belongs among the list of greatest living engineers, as it appeared last year.

Saying, "There is not enough water to carry ocean going boats to the head of the Great Lakes, * * * deepening the lakes would be prohibitive * * * the project is visionary * * * I wonder if the power development project really is not behind it * * * the idea that New York is opposed to the project for selfish reasons it bosh," and then finally admitting that he had not even seen a report on the project is surely not creditable to his reputation as an engineer.

Had Gen. Goethals seen the report of the international joint commission, he probably would not have stated so emphatically that the Lakes were too shallow for ocean going boats. Had he realized the immense economic saving it will cause, which no doubt will dwarf those of the Panama canal, he would not have called the project visionary. Finally, it certainly is not worthy of Mr. Goethals to "wonder if power interests are not really behind it".

"The west thinks highly of the General and it would like to keep its good opinion" says the Milwaukee Journal

(Continued on page 95).

ALUMNI NOTES

E. D. BADER

TECHNICAL CLUB ELECTS OFFICERS

At a meeting of the Technical Club of Madison, held on January 9, Professor C. I. Corp was elected vice-president for the coming year and Professor L. F. Van Hagan was elected director for two years. Professor D. W. Mead is the retiring president. Under his vigorous management, the club has attained a membership of about 200, and has taken an active part in civic matters. The club, through a committee headed by Professor Corp, was largely instrumental in bringing about a reorganization of the health department of the city. Another committee, headed by John N. Cadby, a 1903 graduate of this college, acted as steering committee for the licensing bill in the last legislature.

CIVILS

J. G. Bennett, c '18, suffered an attack of malaria fever while at Fort Myers, Florida, and found it necessary to resign his duties as city manager. He is now convalescing at Cedar Rapids, Iowa.

Clifford Allen Betts, CE '13, and **Charles James Moritz**, c '11, were admitted to membership in the American Society of Civil Engineers.

Erwin Dames, c '20, who has been representing Benham & Mullergren, Kansas City Consulting Engineers, at Duncan, Oklahoma, is now at 4027 Kenmore Ave., Chicago.

L. S. Davis, c '10, is a hardward dealer at Granton.

"Moose" Hanson, c '20, visited school during exam time, ostensibly to enjoy seeing us poor under-graduates write exams. "Moose" is with the Highway Division at Lancaster, and tells us that **G. I. Germond, T. W. Reilly**, c '12, **Francis Hiestand**, c '20, and "Dick" **Hiestand**, min '21, are at the same place.

C. B. Henrichsen, c '21, is with the Bergen Pen. Power Co., at Dale Station, Bergen, Norway.

Wm. G. Huber, c '20, who has been sick and unemployed during the greater part of 1921 is now getting back into the running. His present address is 338 Meyran Ave., Pittsburgh, Pa.

Paul Huntzicker, c '19, has changed his address from Holly, Colorado, to 717 Thatcher Bldg., Pueblo.

F. W. Krez, c '21, is with the Kohler Co., Kohler, near Sheboygan, Wis.

Herman Larsen, c '13, is an engineer and contractor at Princeton, Ind.

Henry Metz, c '20, may be addressed at 36 S. Franklin St., Chicago.

L. C. Rockett, c '15, has changed his address from 46 Arlington Place, Oshkosh, to 603 S. Quincy St., Green Bay, Wisconsin.

Lewis R. Sherburne, c '20, spent a part of his holiday vacation on the campus. He is still on the Miami Conservancy Project.

Sanford Smith, c '20, is employed with the Bell Telephone Company of Pennsylvania, care of C. H. Cogswell, Pittsburgh.

R. W. Stewart, c '99, has changed his mailing address from the City Engineer's Office to 1200 Arapahoe Street, Los Angeles.

M. C. Steuber, c '16, is plant engineer at the Rankin Works of the McClintic-Marshall Construction Company, Pittsburgh, Pa.

A. Rollin Striegl, c '21, is located in the U. S. Engineer Office, 406 Federal Bldg., Milwaukee.

Howard Thwaites, c '16, is now with the Edward Gillen Construction Company at Racine.

Wm. J. Titus, CE 13, is president of the Indiana Engineering Society. Mr. Titus presided at the first session of the Forty-third Annual Convention of the Society which was recently held at Lafayette, and responded to the welcome extended to the society by the President and the Dean of Purdue University.

K. E. Wagner, c '10, is located at 534 Bulkley Building, Cleveland, Ohio. Wagner is representing the Massillon Reinforcing Bar Company, a firm that is engaged in rolling and fabricating reinforcing steel.

Albert M. Wolf, c '09, is associated with Lawrence M. Harper, under the firm name of Wolf & Harper, Engineers. The firm is engaged in general engineering business. The offices are at room 1508, 7 West Madison Street, Chicago, Ill.

Harold Wood, c '13, is assistant engineer with the N. Y. Central R. R.

Karl L. Zander, ex-c '22, spent the greater share of his Christmas vacation in Madison. Karl expects to be back in school next semester.

MECHANICALS

H. K. Dean, m '21, is a test engineer with the T. M. E. R. & L. Co., Milwaukee.

William C. Epstein, m '15, has removed from Pittsburgh to 2312 Highland Ave., Cincinnati, Ohio.

Dean Foster, m '06, is a consulting engineer and a member of the Mid-Continent Oil & Gas Association, Tulsa, Okla.

A. L. Gilbert, m '15, is a mechanical engineer with the Wisconsin State Department of Engineers, Madison.

C. F. Hanson, m '20, is representing the Standard Oil Company in California. His address is 1051 West 47th St., Los Angeles.

E. R. Hill, m '17, has applied for membership in the A. S. M. E. He is now factory manager for the Canadian Ironing Machine Company, Woodstock, Ontario.

H. J. Hirsheimer, m '91, resides at La Crosse.

A newsy letter from **Burton E. James**, m '21, came to our attention recently. "Business, at Westinghouse, is improving," says James, "and I feel sure that this year's graduates will not make a mistake in coming here.

"At present I am in the Mechanical Design School with four other fellows. This will run from January 1, to July 1. We are given problems of all descriptions, some that have not been solved and others merely for practice in the standard methods of design. The five of us get together, scrap it out, and reach the best solution we can. I find it very interesting and instructive. Another mechanical and myself showed Mr. Lamme that the mechanicals were just as capable of absorbing electrical information as the electricals were; so tell your mechanicals to go to it, if they want to get in here, for they have just as much of a chance as an electrical.

"If any of the bunch want to get any information about coming here I would be glad to write them. Naturally I would like to see some of them next summer and fall.

Glenn C. Richardson, m '17, is running a lumber yard at 1911 South B Street, Elwood, Indiana. In a recent letter, he says "I served an apprentice course in the retail lumber business shortly after I returned from the Grand Mixup. Also found time to serve an apprentice course at the plant of the Bucyrus Steam Shovel Company in South Milwaukee, so that I am not altogether unacquainted with the mysteries of engineering as applied to manufacturing establishments. Might say that I consider the training they give about the finest one could expect to receive and certainly take pleasure in recommending it to anyone seeking experience of that nature."

P. A. Royer, m '21, is with the Corn Products Co., Pekin, Ill.

C. E. Saecker, m '18, recently applied for membership in the American Society of Mechanical Engineers. He is connected with the Appleton Machine Company, Appleton, Wis.

Edward Schrank, m '18, is chief engineer of a paper mill at Wisconsin Rapids.

Robert B. White, m '18, former editor of the Engineer, visited us recently. He says that he is married to Miss Jeannette Gilbert of Boston, Mass., who was an overseas Red Cross Nurse during the war. White is now in charge of the lubrication department of the Taxman Refining Company, 116 South Michigan Blvd., Chicago.

Clarence W. Zachow, m '16, has been appointed Mechanical Engineer of the Minneapolis, St. Paul & Sault Ste. Marie Ry., with headquarters at Minneapolis. The appointment was effective January 1.

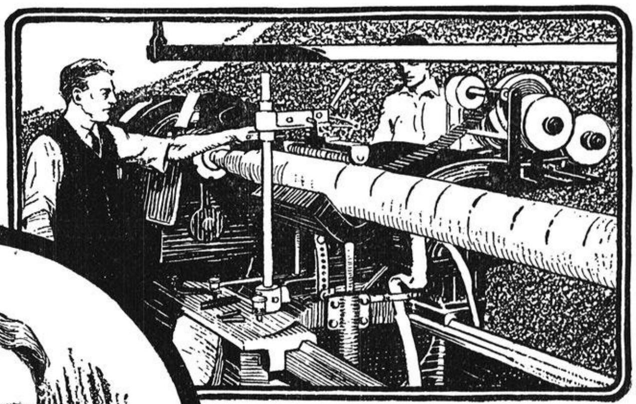
CHEMICALS

Ernest Butterman, ch '21, is assistant plant superintendent of the Monarch Textile Company of Chicago.

H. L. Christensen, ch '21, may be reached at 147 Moore St., Berlin.

H. A. Gollmar, ch '16, has changed his address to 542 Cass St., Milwaukee.

Winding high voltage insulation. ***1894—***
2,200 Volts



Winding high voltage insulation, ***1921—***
220,000 Volts

Charles E. Skinner

WHAT is insulation?—a necessary evil;—the insulation engineer?—likewise a necessary evil;—such, too often, was the oldtime formula. What wonder, with such a stigma, that the vast majority of budding engineers of bygone years side-stepped that branch of the electrical art which was in such ill-repute.

Fortunately, a few far-visioned young men of unusual caliber saw the great possibilities in this field of endeavor and concentrated many of their best years upon it. Foremost among these few who have developed the insulation problem to a leading position in the art, stands Charles E. Skinner, the head of the Research Department of the Westinghouse Electric & Manufacturing Co.

For over thirty years, Mr. Skinner has been delving into the whys and wherefores of the insulation problem, from extreme theoretical studies to the most practical applications. His work began at a time when there were no theories worth while to consider, and when there were no methods worth while to work with. It was not only necessary to develop the insulation art from the ground up, but all the tools of attack had to be developed, and this latter means far more than mere words can convey.

As an insulation engineer, Mr. Skinner has always faced the necessity of utilizing a great array of materials which are inferior in mechanical characteristics to those of the rest of the structure, such as papers, fibers, cottons, fabrics, mica, varnishes, asphaltums, oils, and various other unmechanical materials. Such materials are practically all affected, or destroyed, by undue heat. Many of them are easily penetrated by moisture, the arch enemy of insulation. Practically none of these materials individually is ideal for the purpose desired, nor are they perfect in combination. Consequently, the history of insulation is a story of struggle, of frequent disappointment, and ofttimes mysterious failure.

It is now fully realized that the insulation engineer is a vital and constructive factor in the development of the electrical art. With the great advances in recent years his high position in the art is becoming more and more recognized, as the difficulties of his problems are better realized. It may be said truly, that the high position of the Westinghouse Company is due, to a large extent, to the far reaching accomplishments of its insulation engineers, of whom Mr. Skinner is the leading exponent.

Westinghouse

W
WESTINGHOUSE
ELECTRIC

This advertisement appears in all the prominent college magazines in this country.

Chester M. Kurtz, ch '21, is teaching mathematics in the Riverside High School, Milwaukee.

John Mertes, ch '19, is superintendent of the city gas plant in Fond du Lac, Wis.

A. E. Montgomery, ch '21, has requested that future copies of the ENGINEER be sent to him in care of the Consolidated Water Power & Paper Company, Wisconsin Rapids. Montgomery says, "I look forward to each issue of the ENGINEER with the greatest interest as it serves to keep one in touch with one's classmates as well as with those still in school."

John J. Oberly, ch '20, is assistant to the foundry superintendent of the Tractor Works, International Harvester Co., 2600 West 31st Blvd., Chicago.

Arnold C. Vobach, ch '21, recently resigned his position with the Madison Gas & Electric Company, and is now located at Colby, Wisconsin.

O. B. Westmont, ch '21, is in the research department, Carborundum Co., Niagara Falls, N. Y.

R. J. Zaumeyer, ch '21, is with the Kimberly Clark Paper Co., Niagara Falls, N. Y.

ELECTRICALS

W. R. Buxton, e '13, may be addressed at P. S. C. Box 1024, Davenport, Iowa.

A. H. Gould, e '21, and **G. W. Schroeder**, e '21, are with the T. M. E. R. & L. Co., Milwaukee.

G. S. Jackson, e '18, resides at 544 Woodward Ave., Jackson, Mich.

E. A. Mueller, e '21, and **H. A. Peterson**, e '21, are with the A. T. & T. Co., Chicago, Ill.

F. G. Mueller, e '16, may be reached at 461 Malden St., Chicago.

Ross W. Rogers, e '21, has changed his address from 211 Burr Oak Ave., to 6454 Eggleston Ave., Chicago.

Allard Smith, e '98, suggests that members of the '98 class make arrangements to attend the 25th Reunion in 1923, and urges that plans and publicity helpful to drumming up the crowd be gotten under way at least a year in advance of the time when the reunion is to take place.

MINERS

M. N. Bramlette, min '21, lives at 704 Twentieth St., N. W., Washington, D. C.

Ralph Jordan, min '21, is doing research work in the mining school at Idaho University.

Warren W. Walters, min '21, is still with the Bell Telephone Company of Chicago.

ENGAGEMENTS

Miss Doris Cooper to **Rexford Vernon**, c '18. Mr. Vernon is with the Wisconsin Highway Commission as assistant division engineer, located at Lancaster.

BIRTHS

To Mr. and Mrs. **W. B. Schmidley**, e '05, Janesville, a son, Richard Nichols, Sept. 28.

To Mr. and Mrs. **Donald F. Schindler**, m '15, Compton, Calif., a daughter, Pauline Berman, Aug. 30.

To Mr. and Mrs. **H. N. Shaw**, e '18, 1328 27th St., Milwaukee, a daughter, Dorothy Lillian, Oct. 4.

(Continued from page 93)

in commenting on his attitude and advising his New York friends to first supply him with a copy of the report of the international joint commission before he talks against the project in the west. A news item in the same issue of the Journal states that Mr. Goethals is closely connected with the development of New York both as a great commercial center and as a port.

Gen. Goethals' attitude may be prompted by "good business", but certainly not by creditable engineering judgment and ethics.

"Sulphur Elimination in Blast Furnaces" was the subject of a talk given by Prof. McCaffery before the American Chemical society Wednesday evening, Feb. 8. Professor McCaffery has been spending considerable time in research on that subject the past months.

THESES—1921-22

CIVILS

A. J. Knollin, G. M. Hoe, R. B. Powell. Direction Prof. Corp
Loss of Head in Wood Stave Pipe

S. L. Rolland Direction Prof. Mead
Investigation of Water Power at Dunkirk, N. Y.

B. Bjornson, H. Gude Direction Prof. Mead
Hydro Electric Development on the Paint River

E. R. Moxon, C. B. Christianson Prof. Kinne
Design of a Reinforced Concrete Building

B. Zelonky Direction Prof. Corp
Study of an Ejector for Low Head Turbine Installation

W. C. Thiel, L. H. Shapiro, G. E. Schubring Direction Prof. Mead
Investigation of an Irrigation Project at Medford, Ore.

H. F. Brown Direction Prof. Kinne
Design of a Reinforced Concrete Office Building

W. R. Reuter, A. F. Youngberg Direction Prof. Withey
Comparison of the Effects of Different Methods of Floating Concrete on its Resistance to Wear

H. M. Radley, P. P. Livingston Direction Prof. Corp
The Discharge through Tainter Gates

W. B. Newing Direction Prof. Corp
A Coefficient Study of Triangular Weirs of Various Angles

F. F. Varney, M. A. Geilfuss Direction Prof. Mead
Investigation of the Huntington Creek Irrigation Project

E. S. Birkenwald Direction Prof. Kinne
Design of a Reinforced Concrete Arch Bridge Across the Yahara at Rutledge Street, Madison, Wis.

C. E. Wheeler, L. E. Chase, W. O. Zervas Direction Prof. Mead
Hydro Electric Development on the Peshtigo River at Caldron Falls

W. F. Moehlman, E. M. Barnes Direction Prof. Mead
A Gravity Water Supply for the City of Dunkirk, N. Y.

O. N. Rove, L. H. Kessler Direction Prof. Ward
Air Lift Pump Performance wtih Size of Eduction Pipe Increasing upward from Foot Piece.

J. R. Butler, M. S. Douglas Direction Prof. Kinne
Design of a Reinforced Concrete Building

A. Rohlfing, R. Spetz Direction Prof. Withey
The Effect of Delay in Placing on the Strength of Concrete

W. J. Connell, P. E. Hanson Direction Prof. Withey
Effect of the Use of Large Size Aggregate up to Three Inches on Strength Concrete

G. R. Schneider Direction Prof. Kinne
Design of a Reinforced Concrete Arch at Spooner St. Crossing of Illinois Central Track.

MINERS

T. D. Jones, J. C. Tsao, H. G. Hymer Direction Prof. McCaffery
Floatation of Zinc Ores

W. F. Uhlig Direction of Prof. McCaffery
Electrolytic Zinc

G. M. Lundberg, L. H. Hahn Direction Prof. McCaffery
The Partition Coefficients of Sulphur as FeS, MnS, CaS, between Anorthite and Cast Iron

L. R. Mann Direction Prof. McCaffery
The Location of an Electric Steel Foundry

M. O. Flom, H. J. Lueck Direction Prof. McCaffery
Partition Coefficient of Sulpuhr between Slag and Metal

G. F. O'Brien Direction Prof. McCaffery
Standard Tests for Foundry Molding Sands

J. B. Holmes Direction Prof. McCaffery
Tests of a Copper Smelting Furnace

G. W. Wegner Direction Prof. McCaffery

W. O. Knoll Direction Prof. McCaffery
Iron Ore Tonnage Estimates

L. M. Scofield Direction Prof. McCaffery

During examination week there were 68 men taking a short course in meter work at the Electrical Laboratories. The men are practical men who do meter and central station work. The course, consisting both of lectures and laboratory work, consists of testing and adjusting watt-hour meters.

CAMPUS NOTES

R. B. BOHMAN

Punch the flues in that old clay pipe and bring out that green shirt and tie, for St. Pat's day is only a month away.

Through the generosity of E. K. Loverud, a student in civil engineering, the Stoughton High School has been placed on our subscription list and will receive the WISCONSIN ENGINEER for a year. This custom, which was established this year, is one that should become permanent. Every high school in the state should be receiving the ENGINEER. Unfortunately, it cannot be sent gratis. How about your high school,—shall its students have an opportunity to know the University?

Thanks, Mr. Anonymous, for that front cover suggestion. Keep up the good work.

The Eleventh Annual Road School of the Wisconsin Highway Commission was held during the week ending Saturday 28, 1922. Reports show that the School was well attended, practically every State county being well represented. The purpose of the School is to bring together for an exchange of ideas, division engineers from all parts of the state, as well as the local state officials and contractors.

Prof. Anderson, to a Steam and Gas class: "Using a text book in an examination is like holding an ear of corn in front of old Dobbin. Dobbin can't quite reach the corn, but he is happy while it is there."

The nearest things we have to co-eds in the Engineering Building, besides a few of the co-eds themselves, are the Engineers who wear "galoshes".

But, as one was heard to remark, when chided for not wearing his in open and flapping style, "Nix, brother, I'm not out for Candy Shop honors this year."

KELSOMINING AGAIN

Prof. Kelso: "I hinted you wouldn't remember that a week, and you haven't."

Hanley: "Well, I didn't want to disappoint you!"

Mr. Woy, speaking of public utilities and their complexities: "You have too many women to deal with in such cases."

Wisconsin's stellar ski artists, Norberg, Kvaven and Strom, participated in the National Championship Ski Meet recently held at Cary, Illinois, on January 22. That they did not cop all the bacon was due, perhaps, to the ill effects caused by accepting a ride to the hill in a funeral hearse. The steep, 115 foot scaffold, situated on a hill still higher, gave the spectators the impression that similar conveyances would be needed afterward by all the jumpers.

Spending two weeks in the care of the New York police instead of the same time registering and starting the past semester caused Solberg, m '23, to give up scholastic hopes and return to Norway for the time being. Prof. Pat Hyland, his advisor, had a merry time trying to convince the officials that Solberg was not a confirmed criminal, even though he happened to be near the scene of a crime. Communications were exchanged several times with the Norwegian consul at New York before the all-wise guardians of the law were convinced that they hadn't made a remarkable haul.

At least the weather man was pleasant during the recently passed agony week.

Again we are losing some of our friends, the graduates between semesters.

Did you ever realize the various reasons for which graduates leave school? Some leave because their four years is "up"; some leave a soft snap, some leave because they think they have acquired a sort of polish, and some leave a finishing school, so called on account of what it does to father.

Some of the Civils have been heard to remark that they wish the courses in Railways had never been invented. All of which leads us to believe that the above individuals have no objections to "horseing" their way through school.

Sweet Co-ed, on the hill: "Why, George, you didn't visit with me on the train coming out to Madison."

Above-mentioned George: "Er—I'm sorry, Gertie, but I already had a suitcase and grip as it was".

Dean F. E. Turneaure has an article, "English Impact Measurements Analyzed", in the Engineering News-Record of January 19, 1922.

COMMERCIAL TRAINING FOR ENGINEERS

(Continued from page 89).

and is wasteful both to the employer and to the salesmen. If a man is sent out at once without training, he is at first inefficient, and he receives his business education at a great expense in the school of hard knocks. The employer and employee would both be greatly benefited could the latter receive some training along commercial lines before he undertakes a task which requires it.

The country needs more men like Captain Eads, Hugh Cooper, Thomas A. Edison, Alexander Graham Bell and John Hays Hammond, men who possess the higest engineering qualifications combined with business ability, who can design and build their projects, and also interest capital and deliver a fair profit to the investors. Nothing could be done which would add more to the dignity and influence, and remuneration of the engineering profession than to elevate the engineer from the strictly technical man to one whose opinion and authority would be supreme in all matters pertaining to industrial development.

The new question is, why shall not the engineer be his own employer, the head of some business of an engineering nature, instead of a mere hired expert? The war has shown that this is the age of the engineer, and he should endeavor to retain the prominence which circumstances connected with the war have given him. By combining some commercial training with engineering education the technical schools would be doing a great deal towards helping the engineer to play this important part in the industrial world of the future.

GRUMBLINGS OF THE COLLEGE GROUCH

Whatssa idea? The sweet thing who burdens the ambient with the subtle odor of Djer Kiss also burdens it with the less subtle pink wrapping of Wrigley's malleable product, thereby adding to the color scheme of our campus beautiful. The faithful subscriber to the Cardinal tosses the sheet to the fitful breezes when he has read the skyrockets, and another touch of grace and beauty is added to the landscape. The devotees of Lady Nicotine adorn the front steps with their handsome forms and numerous fag ends and matches. Who do these birds and lady birds think is going to clean up after them—that is, assuming that they do think? A handful of laborers can't keep the campus in shape for public inspection if they have to buck 7000 people who don't give a whoop for appearances. And dear old mother with her kind heart and weak discipline isn't on the job to pick up after her spoiled darling.

At that, we saw a professor who ought to set the example, go down the hall opening his mail and scattering the torn ends of envelopes in his path. Some bringing up that boy had.

THE MECHANICIAN DEPARTMENT

HELMER SORENSON,
Graduate Student.

Tucked away below the Engineering library, there exists a little known but very important department, the Mechanician Department. Engineering students are often unaware of this department until the latter part of their stay here at school. It is proposed to inform the world of the special interesting work done by the men in this department in a series of short articles dealing with the particular jobs that come through it.

The Mechanician Department makes and repairs all the special apparatus used in the Engineering laboratories. Professors doing research work, or students working for a master's degree or on a thesis subject come here to have the models built that are used to test out their ideas. This interesting work is in charge of Mr. Romare, chief mechanician.

Following is a brief description of the ac.c.—d.c. converter now under construction for the author:

Alternating current is applied to the stationary winding of a polyphase induction motor, producing the familiar revolving magnetic field. A stationary direct current armature from a synochronous converter will replace the induction motor rotor. The accompanying drawing shows the brush gear which is now under construction. A small ½ H. P., 3-phase motor will rotate this at synchronous speed about the direct current commutator. The brushes will be adjusted until a maximum potential difference exists between the positive and negative brushes. This corresponds to picking off the peak voltage of the alternating current wave form.

The advantage of this scheme lies in the elimination of the rotation of the large, heavy armature, and substituting the electrically revolved magnetic field. The usual air gap is unnecessary and will be eliminated in the commercial machine; the final apparatus being simply a manyphase, oil-cooled transformer with synchronously driven brush gear. Commutation of practically any d.c. voltage will be possible because of the absence of a reactance voltage. It is hoped that this apparatus will have a higher efficiency than any existing a.c.—d.c. converter.

Do we, as college students, realize the relative significance of the impressions we are making with our associates?

We are constantly being calibrated; every move we make as well as every word we utter makes an infinitesimal change in the impression we have already made upon others.

In after life, we will be continually coming in contact with our college associates. In many cases we will look to them for cooperation if not support in the business world. The extent of the cooperation, or support, we will receive will invariably be in accordance with the impression we made in college. D. O. A.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, STUDENT SECTION

A meeting of the Student Section was held on January 11, in the Auditorium of the Engineering Building. After a short business meeting, the members were favored by a few musical selections of saxophone and piano variety, by R. O. Strock and R. B. Bohman

ENGINEERING STUDENT- FACULTY COMMITTEE SUGGESTS CHANGES IN LAB WORK

That the routine features of laboratory work should be reduced to a minimum, and that the time thus conserved should be devoted to practical phases of the subject under study was strongly urged at a meeting of the Student-Faculty committee of the College of Engineering, on January 12, and presided over by Dean Turneaure. The allegation was made that in some courses a large portion of the student's time is spent in reading a meter, watching a gage, or weighing water,—things that must be done in performing an experiment, but which do not bring much real benefit to the man who does them. An effort will be made to show how work of that nature can be reduced in quantity without impairing the effectiveness of the instruction.

An apparent inclination on the part of some instructors to discriminate in favor of type-written reports and against hand-written ones was called to the attention of the committee, and, after some discussion, a resolution was passed protesting against such discrimination.

THEORY ON WOOD PRESERVATION

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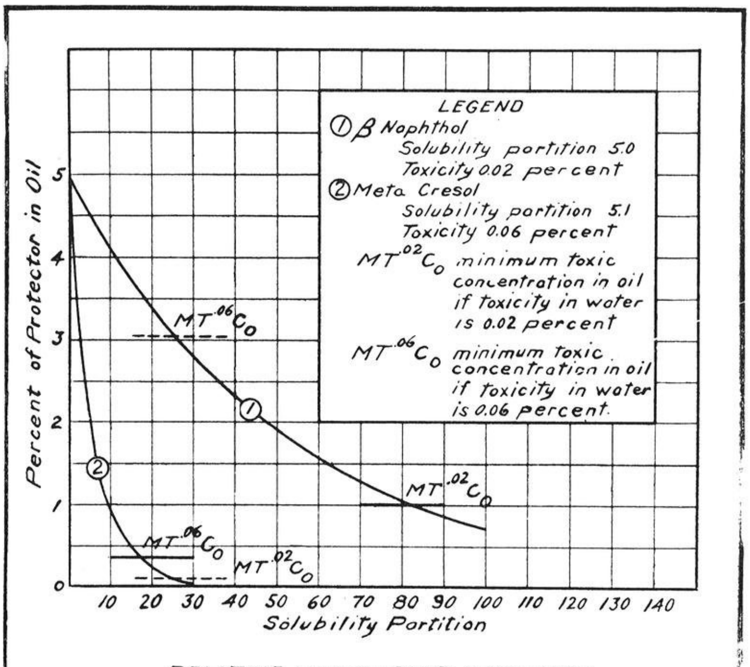
and 80. A three per cent solution of such materials would be required provided that its toxicity is 0.02 per cent or less. If, however, as is usually the case, the materials have different toxicities, a slightly different condition is raised. Figure 2 shows the rate at which five per cent solutions of M-cresol and β-naphthol in oil lose their toxic materials when washed with water. The solubility partitions of these materials are 5.1 and 50.0 while their toxicities are 0.06 per cent and 0.02 per cent, respectively. The minimum toxic concentration of the poison in oil (MTC_o) is, therefore, the toxicity of the compound multiplied by the solubility partition plus 1. For the two phenols in figure 2 the minimum killing concentration of the poison in oil (MTC_o) is 0.35 per cent and 1.02 per cent. These are represented in the curve by straight horizontal lines marked MTC_o. When this horizontal line cuts the curve, the point of intersection indicates the number of washings this solution may undergo and still have the last washing poisonous. For the five per cent solution of cresol this is 17, but for the five per cent solution of β-naphthol it is 82, that is the β-naphthol is approximately five times more lasting than M-cresol. If, however, the toxicities of M-cresol and β-naphthol had been reversed, then the minimum toxic concentrations in oil would have been represented by the horizontal dotted lines marked ($MT^{0.02}C_o$) for the cresol and ($MT^{0.06}C_o$) for the naphthol and the life of both solutions would have been the same for the initial concentration of five per cent. This indicates that long-lived pres-



RELATIVE LIFE OF FIVE PERCENT OF β. NAPHTHOL AND CRESOL IN BARREN OIL

Courtesy, American Wood Preservers' Ass'n.

ervatives ought to contain very poisonous materials having high solubility partitions.

CONCLUSIONS

It is very evident from the above data that in order to kill timber-destroying fungi by tar acids they must first of all be soluble in water. In an homologous series the toxicity of the tar acids increases with the size of the molecule up to the point where the solubility is equal to the minimum toxic concentration. If a saturated solution of a compound does not produce a toxic solution, a similar compound, but with higher molecular weight, will not do so.

The permanence of tar acids is governed by their solubility partitions and their volatility. The most permanent are those which are least volatile and have the highest solubility partition.

The most effective wood preserving material is one whose toxicity and solubility partition or volatility are such that it will accomplish its purpose with the smallest amount of material. The amount of material required is dependent not only on the characteristics of the preservative but also upon the kind of service which is required.

The theory on the mechanism of protection of wood by preservatives has been proved experimentally as far as tar acids are concerned.

INDUSTRIAL LIGHTING CODES.

In order to protect workers from accidents and eye sight damage, no less than five states, New York, New Jersey, Pennsylvania, Wisconsin and Oregon have now in force lighting codes for industrial establishments. Other states are now considering the adoption of an industrial lighting code, and it seems only a question of time when all the states will adopt such a code.

Proper lighting of work places is not only of great importance to the operators working therein, directly affecting their safety and eyesight, but it is a factor of equal importance to the employer, as quality and quantity of output are deciding factors of profit or loss in the operation of the plant.

The introduction to the Wisconsin code reads as follows: "Insufficient and improperly applied illumination is a prolific cause of industrial accidents. In the past few years numerous investigators, studying the cause of accidents, have found that the accident rate in plants with poor lighting is higher than similar plants which are well illuminated. Factories which have installed approved lighting have experienced reductions in their accidents which are very gratifying.

"Of even greater importance, poor lighting impairs vision. Because diminution of eyesight from this cause is gradual, it may take the individual years to become aware of it.

"This makes it all the more important to guard against the insidious effects of dim illumination, of glaring light sources shining in the eyes, of flickering light, of sharp shadows, of glare reflected from polished parts of work. To conserve the eyesight of the working class is a distinct economic gain to the state, but regardless of that, humanitarian considerations demand it.

"Finally, inadequate illumination decreases the production of the industries of the state, and to that extent, the wealth of its people. Factory managers who have installed improved illumination, are unanimous in the conviction that better lighting increases production and decreases spoilage."

The Wisconsin Commission has adopted a rule to the effect that, "diffusive or refractive window glass shall be used for the purpose of improving day light conditions or for the avoidance of eye strain, wherever the location of the work is such that the worker must face large window areas, through which excessively bright light may at times enter the building."

A glass is now available which meets the above requirements. It properly diffuses the light and prevents sun glare passing into the building and is known as Factrolite.

Engineers of to-day are making a thorough study of illumination, so that they may be able to plan and lay out industrial plants, to scientifically increase their efficiency to as near the maximum as possible. This accomplished the engineer is not only doing something worth while for his employer, but is doing quite as much for himself by coming into prominence with modern ideas.

If you are interested in the distribution of light through Factrolite, we will send you a copy of Laboratory Report—"Factrolited."

MISSISSIPPI WIRE GLASS CO.,
220 Fifth Avenue,
St. Louis. New York. Chicago

No. 8.

PRINCIPLES OF ANTI-FRICTION BEARING DESIGN AND CONSTRUCTION

(Continued from page 91).

snapped into position. Self-alignment to any degree is assured in this bearing.

Even this rapid description of typical modern bearings is sufficient to convince us that none of them meets all the requirements of the ideal bearing. To satisfy certain fundamental purposes one or the other of the characteristics described above is sacrificd. At best, therefore, the modern anti-friction bearing is a good compromise. Which of these compromises is nearest to the ideal, I leave to your own judgment. I have certain convictions in this matter, which, however, I do not wish to air here.

Two facts must be borne in mind when making a bearing selection for any bearing application. First of all, that the choice of the bearing must be made only after a thorough analysis of the different factors involved in the application. In the second place, a bearing recommendation does not end with a proper selection of type and size, but implies a well planned method of mounting, fitting, lubricating, etc.

An anti-friction bearing properly applied is a marvel *of efficiency and service,* wrongly applied it is a source of trouble. It is this that makes the quality of the engineering service given by a bearing company of as great importance as the quality of the product itself.