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VOL. XXVII, No. 7 MADISON, WIS. APRIL, 1923

RECENT DEVELOPMENTS IN ELECTRON TUBES

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When Edison in 1893 discovered that electricity may flow through a vacuum between a heated filament and a cold plate it aroused little interest among engineers since the currents thus obtainable were of the order of a few micro-amperes only. However, the possibility of utilizing the effect for the rectification of alternating currents was early recognized, for it was found that a current could be obtained only when the potential of the plate is higher than that of the filament. Although the general laws governing the emission of electrons from hot bodies were established by the work of Fleming,[1] Thomson,[2] and Richardson,[3] between the years 1896 and 1901, it was several years later that the mechanism of the process was explained. Richardson then showed that electrons may leave bodies solely because of the kinetic energy they possess in virtue of thermal equilibrium with the molecules of the body from which they escape, and that no chemical action at the surface is required as had been postulated in some of the earlier theories. He thus established the existence of pure electron emission.

The first application of thermionic currents to engineering problems was made by Fleming about 1898 when he utilized the unilateral conductivity of a two element tube for rectifying the high frequency antenna currents in the reception of radio signals. Although rectification is in itself an important property, the electron tube would never have played its present important role had not some way been found readily and efficiently to control the "space current" between the filament and the plate. Thus far three ways have been devised which are known respectively as the "static", "magnetic", and "secondary emission" methods. While the former is most commonly employed, nevertheless the others have important possibilities. It is the purpose of this article to set forth briefly the fundamental principles of each method and to lay special emphasis on the last two, for they have not perhaps received the consideration they deserve.

Static Method

This method of controlling the space current is the most direct and may be understood by reference to Figure 1 in which F, G and P represent the filament, grid and plate respectively. The filament is heated by the battery A to a temperature sufficient to cause it to emit electrons. These are drawn through the meshes of the grid to the positively charged plate which they enter, and, passing through the external circuit, constitute a current measured by the ammeter. For a given potential maintained at P, the number of electrons reaching the plate depends upon the potential of the grid. If the grid is sufficiently negative no electrons will pass through and the plate current is zero. For a considerable range of grid voltages the relation between space current and grid voltage is nearly linear.

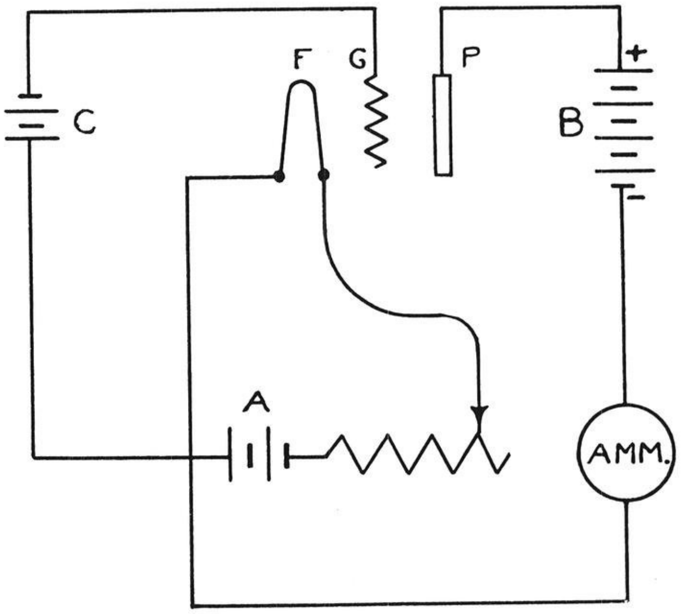

FIG. 1. FILAMENT, GRID, AND PLATE. *The filament is heated by the battery A to a temperature sufficient to cause it to emit electrons.*

This method possesses many advantages. For example, the power required to maintain a given potential on the grid is small; even when its potential is positive, relatively few electrons strike it because of its small area. Hence very little current is furnished by the battery C and none at all when the grid is negative. On the other hand, the battery B may be capable

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[1] J. A. Fleming, Phil. Mag., Vol. 42, Page 52, 1896.
[2] J. J. Thomson, Phil. Mag., Vol. 48, Page 547, 1899.
[3] O. W. Richardson, Proc. Camb. Phil. Soc., Vol. 11, Page 286, 1901.

of furnishing comparatively large currents with which considerable amounts of power may be associated. The device operates as an electrical throttle valve which may be closed or opened to any desired fraction of its total carrying capacity. Again the time required for an electron to traverse the distance from filament to plate is exceedingly small. A simple calculation shows that for a potential of 1000 volts on the plate and a distance between it and the filament of 1 cm., an electron requires only one thousandth of a millionth of one second for transit. The plate current accordingly responds to changes in grid voltage with remarkable quickness, and the device may function at frequencies of many million cycles per second. When operated in this way it may be used as a detector of high frequency radio waves, as an amplifier, or, when connected with suitable oscillatory circuits, as a generator of continuous alternating currents. Electron tubes operating on this principle are generally called "Pliotrons".

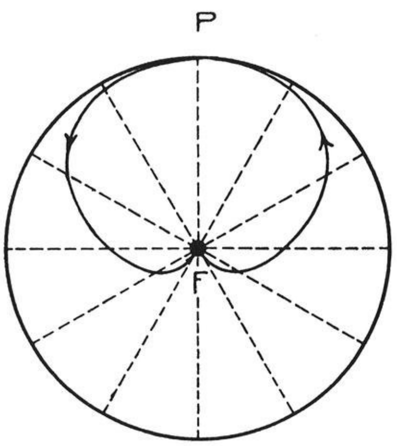

FIG. 2. CYLINDRICAL PLATE AND FILAMENT. *A longitudinal magnetic field will cause the electrons to follow a curved path.*

Magnetic Control

This method of control rests upon the fact that an electron moving at right angles to a magnetic field is acted upon by a force tending to deflect it at right angles both to its own motion and that of the field across which it is passing. Tubes of various forms have been suggested for utilizing this effect, but the simplest is that devised by Hull[1] of the General Electric Company. In Figure 2 let P be a cylindrical plate along whose axis is placed a heated filament F which serves as a source of electrons and let P be maintained by a battery at a potential higher than F. Electrons emerging from the filament travel radially to the plate as indicated by the dotted lines. If, however, a longitudinal magnetic field is introduced, for example by passing a current through a solenoid wound about the tube in which the elements are mounted, the electrons follow a curved path but all eventually reach the plate if the field does not exceed a certain critical value. At this field, an electron travels the heart shaped curve indicated in the figure and will just miss striking the plate and return to the filament by a symetrical path as indicated by the arrows. Under these circumstances, no electrons reach the plate and the valve accordingly is closed. For fields slightly less than this, all the electrons emerging from the filament reach the plate and the valve is open. This method of control differs from the static method described above in that it has a sharp "cut off"; that is, the valve is entirely open or completely closed. This abruptness may, however, be

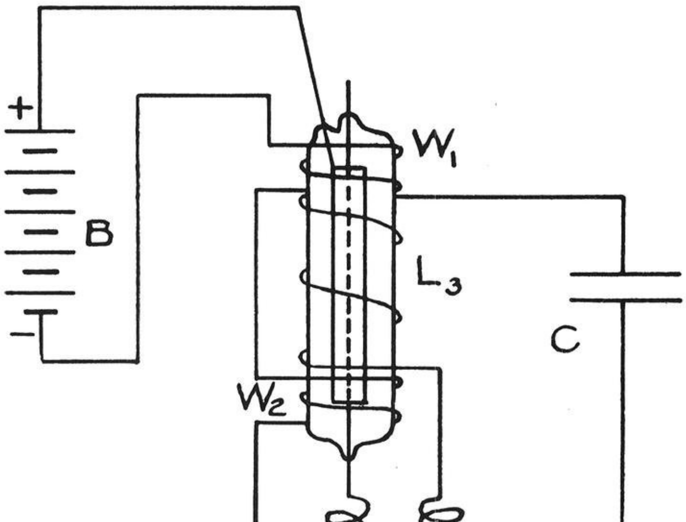

FIG. 3. DIAGRAM OF THE MAGNETRON. *This device has been found to be a very efficient source of sustained oscillations.*

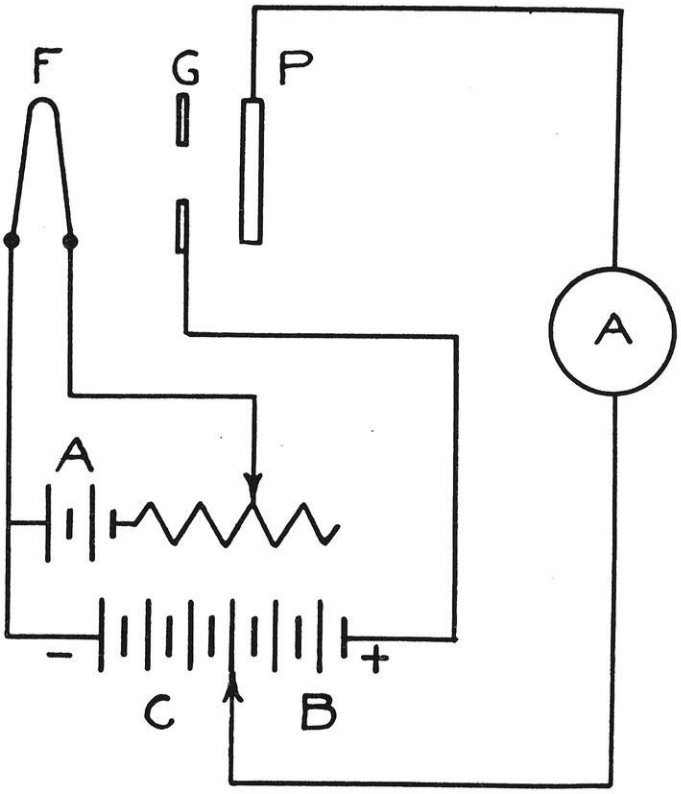

FIG. 4. DIAGRAM OF THE DYNATRON. *It consists of a three-element tube similar to the pliotron except that the finely meshed grid is replaced by a metallic plate with relatively large perforations.*

[1] A. W. Hull, Journ. Institute of Electrical Engineers, Sept., 1921.

somewhat modified, by placing the filament slightly off the axis of the plate or inclining it at an angle. An electron device operating on this principle is called a "Magnetron".

A valve of this sort may be made to trip itself if the space current is used to energize the solenoid which produces the deflecting field. To do this, it is only necessary to place the solenoid in series with the bat-

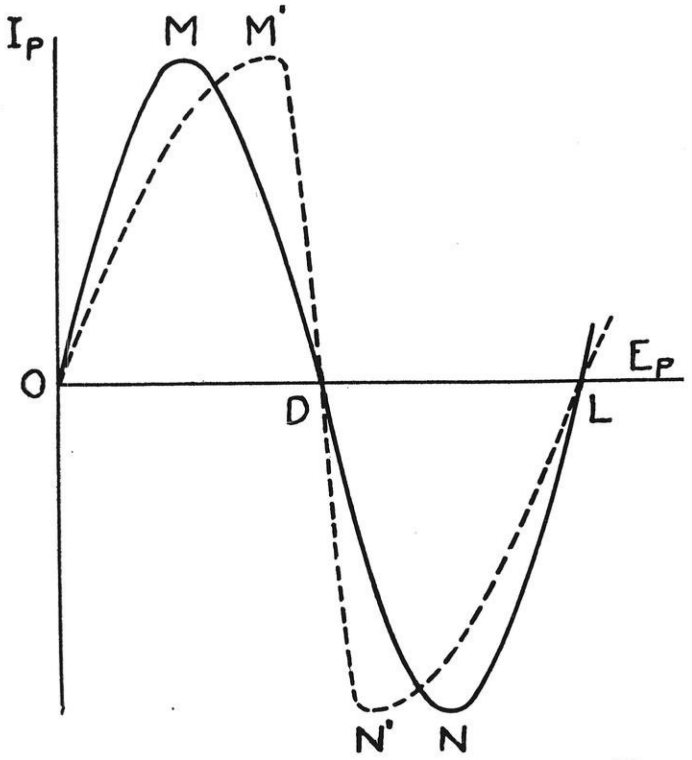

FIG. 5. RELATION BETWEEN PLATE CURRENT AND VOLTAGE APPLIED. *For small voltages the plate current increases with voltage, but as soon as the impinging electrons arrive with sufficient velocity, secondary emission from the plate occurs.*

teries furnishing the potential difference between filament and plate. When the key is closed, the current rises until the critical field is established when no electrons can reach the plate. The current then ceases and the magnetic field is withdrawn, which opens the valve, allowing a current again to flow and the process is repeated. The current is thus interrupted, the frequency of interruption depending upon the plate potential and the electrical constants of the circuit.

An arrangement by which a magnetron may be used to generate sustained oscillations is shown in Figure 3. A tube with its cylindrical plate and axial filament is indicated as surrounded by three coils, W_1, W_2, and L_3. Current from the battery B flows to the plate and thence through the space to the filament. That is, electrons move out from filament to plate. The current then flows out of the filament through the coil L_1, then through the deflecting coils W_2 and W_1 and back to the battery. The deflecting coils are so designed that when carrying the normal plate current their field is not quite sufficient to close the valve. A second circuit, consisting of the coils L_2 and L_3 and the condenser C, is arranged as indicated, mutual inductance existing between L_1 and L_2. When the battery circuit is closed, the rising current in L_1 induces in L_2 an E. M. F. which starts oscillations in this circuit. The magnetic field in L_3 due to this transient current, added to the fields of W_1 and W_2, is sufficient to close the valve which interrupts the current through L_1 when the process begins over again. The oscillatory current through L_3 opens and closes the valve and the energy to maintain the oscillations is supplied from L_1 through the mutual inductance M. The period of the oscillations is determined by the inductance and capicatance of the secondary circuit. This device has been found to be a very efficient source of sustained oscillations.

Secondary Emission

This method rests upon the fact that, when a metal is bombarded by electrons moving wtih sufficient velocity, others, called "secondary electrons" are liberated. The necessary speeds of the primary electrons and the copiousness of the secondary emission depend upon the metal under bombardment. In some cases, it has been found that, for each primary electron impinging upon

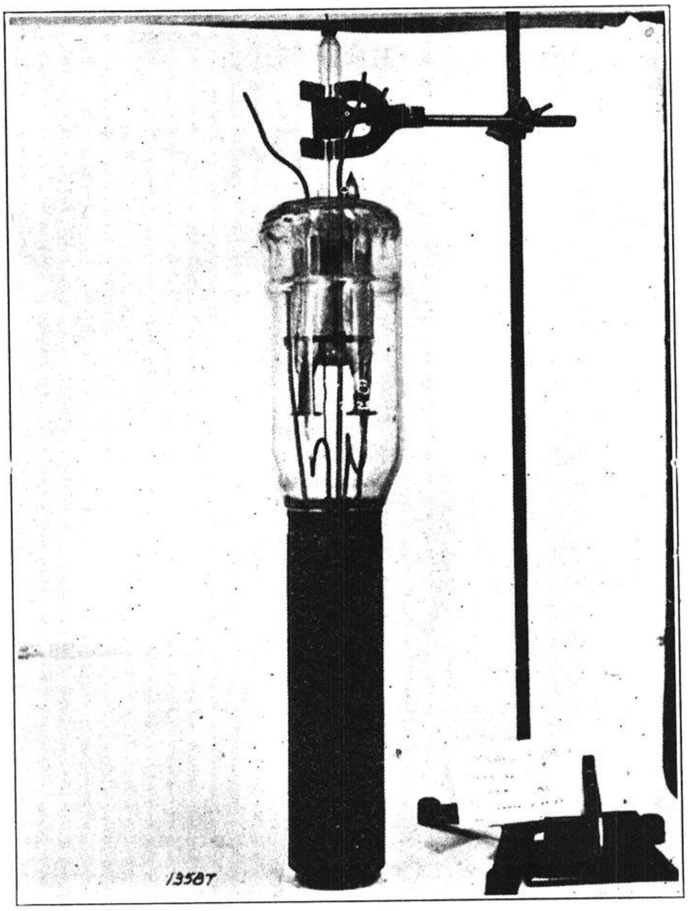

FIG. 6. A 100 K. W. WESTERN ELECTRIC POWER TUBE. *The filament requires a current of 91 amperes to heat it.*

a metal, as many as twenty secondary electrons may be expelled.

This effect has been utilized by Hull[1] to construct an

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[1] A. W. Hull, Phys. Review, Vol. 7, Page 1, 1916.

electron tube called the "Dynatron" with controllable space current. It consists of a three element tube similar to the pliotron except that the finely meshed grid is replaced by a metallic plate with relatively large perforations. The action may be understood by reference to Figure 4 in which the filament, grid and plate are represented by F, G and P respectively. Let us suppose that the connections to the external circuits are as indicated, and that the movable contact C is at the negative end of the battery B. The plate then is at the same potential as the filament and an electron emitted by the filament at a point opposite the orifice in G is accelerated toward the right and passes through the opening with a high velocity. Since P is at the same potential as the filament the electron is retarded between G and P and arrives at P with zero velocity. It is then accelerated back toward G, passes through the opening and is again brought to rest at F. If nothing were to interfere, it would oscillate back and forth at a frequency depending upon the distance between F and P and the potential of G. If, however, the contact C is moved to the right, the retarding potential beween P and G is less than the accelerating potential between F and G, and electrons strike P with a definite velocity and, entering it, produce a current which may be measured by the ammeter A.

The relation between the plate current and the voltage applied to it is shown by the solid curve of Figure 5. For small voltages, the plate current increases with voltage, but, as soon as the impinging electrons arrive with sufficient velocity, secondary emission from the plate occurs. These secondary electrons are drawn toward G, many of them entering it. The current to P is equal to the difference between the primary electrons arriving and the secondary electrons leaving it per unit time. With increasing voltage on P, the secondary emission increases and the plate current decreases until, at a voltage indicated by OD, the secondary emission just balances the primary electrons received, and the plate current is zero. For higher values of plate potential, the secondary emission is sufficient to cause a reversal in the plate current. This effect cannot continue indefinitely, however, for as C is moved further toward the right, the potential difference between G and P is decreased and fewer of the secondary electrons reach G. Beyond the point N, the current becomes less negative and at L we again have a condition in which the primary and secondary electrons balance, giving a zero current. For plate voltages greater than OL, the plate current increases in much the same manner as in the two element tube. Between M and N the filament-plate circuit possesses the remarkable property that an increased voltage produces a decreased current and vice versa. This is often spoken of as "negative resistance", since, in a positive resistance, the current is proportional to the voltage. The steepness of the curve between M and N may be increased by the introduction of a resistance in the external circuit between C and P. In this case the curve OM^1N^1L is obtained. This is evident, for, in the interval between O and M^1, the voltage on the plate increases less rapidly than the changes produced by shifting C because of the drop due to the increasing current through the resistance. But between M^1 and N^1 the plate voltage changes more rapidly than that in C since the plate current is decreasing in this interval.

If now a suitable resistance is introduced in the plate circuit, as explained above, and the voltage is adjusted so that the tube is operating at an appropriate point on the steep part of the characteristic curve, then a small additional voltage introduced in this circuit produces a relatively large change in current. The tube may then serve as an amplifier. Again, if an inductance, shunted by a condenser, is introduced in the plate circuit, continuous oscillations may be maintained. The action here is similar to that of the Poulsen arc which also possesses a characteristic with a negative slope. Its operation is, however, much more stable than that of the arc, since it does not depend upon gaseous ionization for its source of electrons. The condenser may consist of an antenna and ground, in which case the tube serves as a means of converting direct current energy into that of electromagnetic waves.

Hull has also introduced a fourth electrode in the form of an ordinary grid between the perforated electrode and filament and found that by changing its voltage, the amplitude of the oscillations may be controlled. If voice frequency variations of voltage are applied to this grid, the tube then performs the double function of oscillator and modulator in a radiophone transmitter. Whe nthus equipped with a fourth electrode the device is called a "Pliodynatron".

Probably the two most important developments in the radio art in the past year are the low filament current tubes for reception and the high power tubes for transmission. The one great difficulty in maintaining a receiving set has hitherto been the annoyance incidental to maintaining storage batteries for heating the filaments and many have been deterred from installing sets for this reason. Filaments have now been devised which may be heated by a current of one-quarter of an ampere and may thus be operated on dry cells. The life of a dry cell used intermittently for this purpose is about 1000 hours. Some of these tubes require less than 1½ volts and thus a single cell suffices.

Of far greater importance, however, is the high power transmission tube brought out simultaneously by the Western Electric and the General Electric Companies. The ordinary form of electron tube is very definitely limited in its power capacity because of the difficulty in dissipating the heat necessarily liberated by its operation. A simple calculation shows that, with potentials of only a few thonsand volts, electrons strike the plate with velocities of many thousand miles per second and, even though their mass is small, the heat developed in the plate by their bombardment is considerable. Since a high vacuum must be maintained within

(Continued on page 135)

TESTS ON THE EFFECT OF VARIATIONS IN CONSISTENCY ON THE STRENGTH AND WEAR OF CONCRETE FOR ROADS

By M. O. Withey

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Introduction. The proportion of water used in mixing a batch of concrete bears a very important relation to a number of properties. It affects (1) the time required to produce a uniformly mixed batch; (2) the flowability in chuting devices; (3) the spreading or working quality in the forms; (4) the uniformity of the set mass of concrete. The proportion of water caught in the concrete when it sets materially affects the density, porosity, permeability to water, strength, and resistance to abrasion. "Consistency" is a term rather loosely applied to cover one or more of the following meanings: The degree of rigidity or fluidity, the degree of flowability, or the degree of workability which is inherent in the fresh concrete.

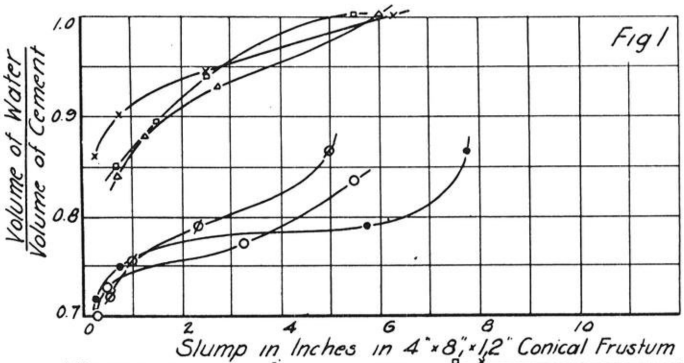
The rather startling results of researches by Abrams at Lewis Institute,* and others, on the effects of consistency on strength and wear have led to considerable agitation for the use of drier mixes in concrete construction. Mixes of maximum strength are of such stiff consistency that they require very much more labor to place and finish in a road than do the mixes of somewhat greater plasticity. Therefore a knowledge of the relative workability, strength, and wearing qualities of road mixes, varying in consistency from that which is stiff enough to produce maximum strength to a consistency which will flow into place, is of much value. In order to secure such information with regard to mixes used in road construction, the Wisconsin Highway Commission had a series of tests on 78 small slabs and a like number of compression cylinders made in the Materials Testing Laboratory of the University of Wisconsin during the summer of 1920.

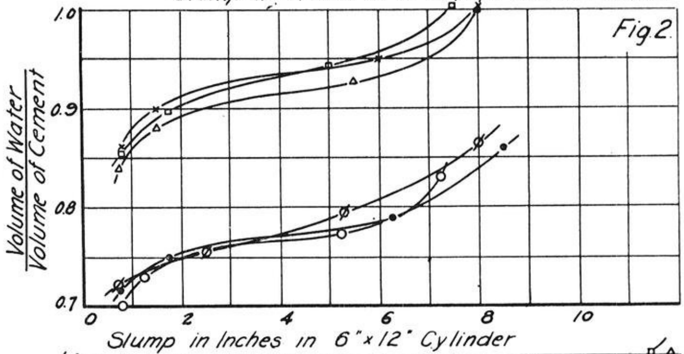
TABLE 1
Physical Properties
Sands and Coarse Aggregates

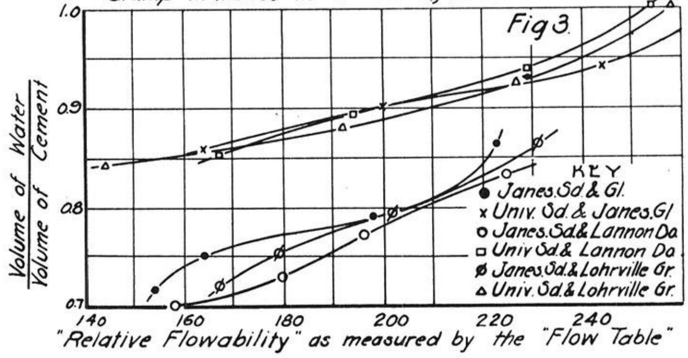
Coarse aggregate in each case consisted of 1:1:2 proportions (by wt.) of No. 1 (¼ in. to ½ in.), No. 2 (½ in. to ¾ in.), and No. 3 (¾ in. to 1¼ in.) material.

AGGREGATE	% coarser than Sieve No. 4	28	100	% Silt (by Vol.)	Weight per cu. ft. (lb.)	FINENESS MODULUS of aggregate	of 2:3½ mix. (by vol.) with J. Sd.	U. Sd.
Janesville Sand	8.0	55.2	98.4	3.5	113.5	3.1	----	----
University Sand	0	7.6	93.0	----	104.0	1.6	----	----
Janesville Gravel	100	100	100	0	105.1	7.4	5.75	5.29
Lannon Dolomite	100	100	100	0	95.1	7.4	5.66	5.18
Lohrville Granite	100	100	100	0	92.3	7.4	5.62	5.12

Materials. For these tests, it was considered advisable to use a well-graded sand of good quality in part of the specimens, and a fine-grained sand of poor grading in the remainder. The coarse aggregates selected were Janesville gravel, crushed Lannon dolomite, and crushed Lohrville granite. The gradings, the specific







weights, and the fineness moduli for the individual aggregates and the different mixtures of aggregate are given in Table 1.

It should be noted, in connection with these aggregates, that there is a wide range in the hardess of the coarse aggregate, the Janesville gravel and Lannon dolomite being of fair hardness and toughness, whereas the Lohrville granite was much harder than either of the former. It should also be noted that the grading of the coarse aggregate was kept constant in all tests, but the grading of the mixed aggregate varied somewhat in the different sets of specimens, as indicated by the values of the fineness modulus tabulated in the columns at the right of Table 1.

*See bulletins Nos. 1, 2, 5, and 8 of the Structural Materials Laboratory, Lewis Institute, Chicago.

Method for Making Specimens. It was decided to adopt a slump of ¾-inch for the basis of all consistency determinations, as determined in tests in a 6x12-in. cylinder. After having determined the probable amount of water to produce this consistency with a given set of materials, three wetter consistencies were arbitrarily determined by increasing the water required for the ¾-in. slump by 5%, 10%, and 20%. By this procedure, it was felt that the fluidity of the concrete and its working qualities would be varied through the range likely to be used in road construction.

Four methods were employed for measuring the consistency:

(1) By the slump of a freshly-molded 6x12-in. cylinder.

(2) By the slump of a freshly-molded conical frustrum 4 in. in diameter at the top, 8 in. in diameter at the bottom, and 12 in. high.

TABLE 2

Results of Tests to Ascertain the Effect of Variations in Consistency on the Abrasive Resistance and Strength of 1:2:3½ Concrete

Mix was 1:2:3½ (by vol). Coarse aggregate in each case consisted of a 1:1:2 mixture (by weight) of No.1 (¼ to ½ in), No. 2 (½ to ¾ in), and No. 3 (¾ to 1¼ in) material. Js = Janesville sand; JG = Janesville gravel; U = University sand; L = Lannon dolomite; LG = Lohrville granite.

Rattler was loaded with 6 slabs and dummy forming inner lining of barrel of rattler, and a charge of 150 lb. of small and 50 lb. of large cast iron shot standardized for paving brick tests. Charge was given 1800 revolutions in clockwise and 1800 revolutions in counter-clockwise rotation at 30 rpm. Slabs rattled at 28 days were re-tested at 90 days and then broken in cross-bending.

Spec No.	Aggregate: Fine	Aggregate: Coarse	Per cent Water	w/c (by vol)	Consistency Data*: Slump by 6"x12" cylinder (in.)	Consistency Data*: Slump by 4"x8"x12" frustum (in.)	Consistency Data*: Sine of angle of repose of chute	Consistency Data*: Relative Flowability (%)	Vol Cem / Vol Concr	Test at 28 Days: Ave. compressive strength (lb./sq in.)	Test at 28 Days: Ave. Loss of Weight in rattler (%)	Test at 90 Days: Ave. Loss of Weight in rattler (%)	Test at 90 Days: Ave. modulus of rupture (lb./sq in.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
C1 - C3	Js	JG	6.5	0.718	0.75	0.25	0.47	154	0.210	3415	6.77	4.16	783
C4 - C6			6.8	0.751	1.75	0.75	0.42	164	0.207	3340	6.75	4.52	874
C7 - C9			7.15	0.790	6.25	5.75	0.44	198	0.208	2876	7.11	4.77	909
C10 - C12			7.8	0.864	8.50	7.75	0.40	223	0.208	2964	9.31	4.85	848
									Ave.	3149	7.48	4.58	854
C13 - C15	U	JG	8.0	0.860	0.75	0.25	0.46	164	0.210	2225 **	11.80 **	6.57	646 ø
C16 - C18			8.4	0.903	1.50	0.75	0.44	200	0.212	2028 **	10.48 **	5.96	641
C19 - C21			8.8	0.945	6.00	2.50	0.44	244	0.212	2105 **	10.07 **	7.37	541 ø
C22 - C24			9.6	1.032	8.00	6.25	0.43	266	0.210	1646 **	10.40 **	7.11	592 øø
									Ave.	2001	10.69	675	605
C25 C27	Js	L	6.7	0.700	0.75	0.25	0.47	158	0.224	3082 **	6.10	4.31	950
C28 C30			7.0	0.731	1.25	0.50	0.43	179	0.224	2559 **	6.25	4.41	986
C31 C33			7.4	0.772	5.25	3.25	0.43	196	0.220	2595 **	6.71	4.97	913
C34 C36			8.0	0.835	7.25	5.50	0.44	225	0.222	2165 **	7.23	4.79	856
									Ave.	2600	6.57	4.62	926
C37 - C39	U	L	8.4	0.854	0.75	0.50	0.47	167	0.223	2251 **	8.23	6.50	698
C40 - C42			8.8	0.895	1.75	1.50	0.42	194	0.223	2258 **	8.81	6.36	677 øø
C43 - C45			9.25	0.940	5.00	2.50	0.43	229	0.223	1939 **	8.51	6.94	614
C46 - C48			10.1	1025	7.50	5.50	0.45	254	0.225	1970 **	10.16	7.15	597 øø
									Ave.	2104	8.93	6.74	647
C49 - C51	Js	LG	7.0	0.721	0.75	0.50	0.44	167	0.222	3107	5.77	2.21	789
C52 - C54			7.35	0.756	2.50	1.00	0.45	179	0.220	3232	5.96	2.71	758
C55 - C57			7.7	0.794	5.25	2.25	0.46	204	0.220	2577	6.91	2.60	783
C58 - C60			8.4	0.866	8.00	5.00	0.47	231	0.220	2142	7.59	3.17	707
									Ave.	2764	6.56	2.67	759
C61 - C63	U	LG	8.4	0.841	0.75	0.50	0.47	144	0.224	2316	8.12	3.73	589
C64 - C66			8.8	0.881	1.50	1.25	0.44	192	0.224	2277	9.00	3.81	577
C67 - C69			9.25	0.928	5.50	2.75	0.42	227	0.222	1967	8.99	4.13	508 øø
C70 - C72			10.1	1.012	8.00	6.00	0.44	258	0.222	1769	9.52	4.48	403 øø
									Ave.	2082	8.91	4.04	519

* Each value in columns 6, 7 & 8 represents 3 tests; those in column 9 one test.
ø One result only   øø Ave of 2 tests.   ** Tests duplicated - ave. of 6 results.

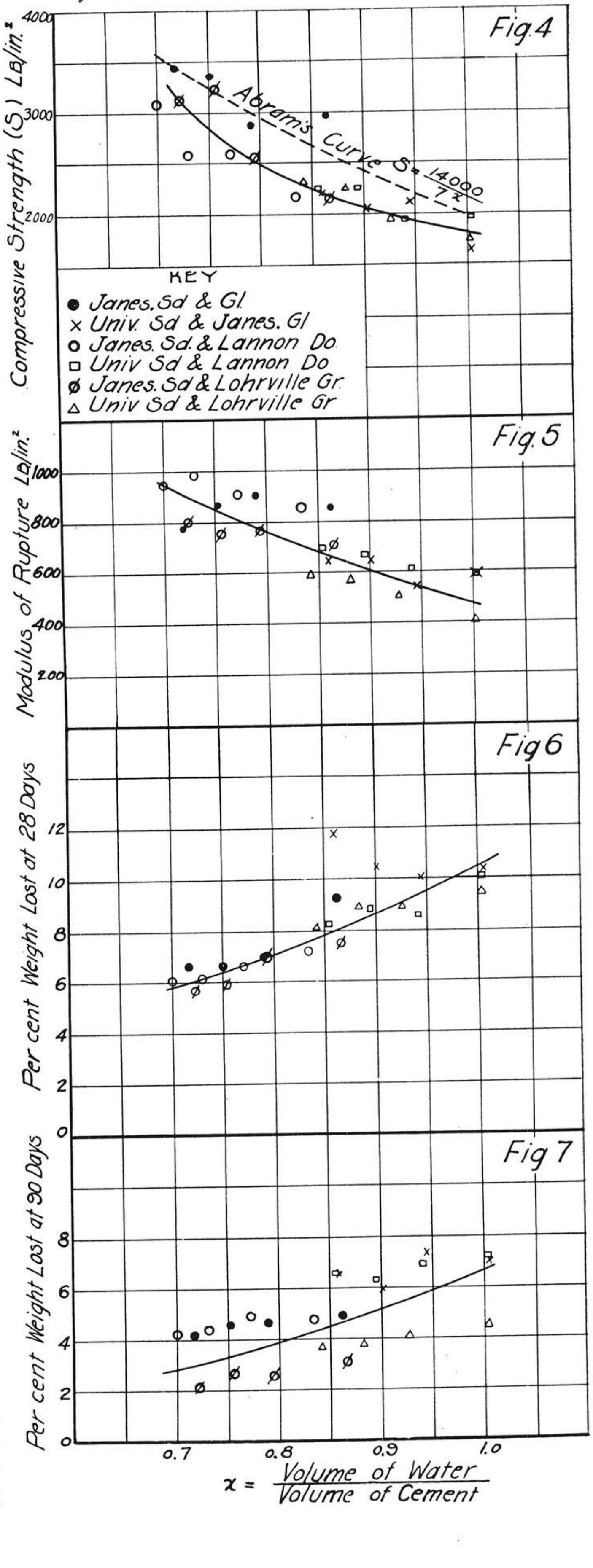
(3) By determining the sine of the angle with the horizontal of a galvanized iron plane 25 in. long and 16 in. wide when the plane carrying a freshly-molded 6x6-in. cylindrical mass of concrete was tilted until the concrete began to slide down the plane.

(4) By a flow table similar to that used by the United States Bureau of Standards. The flow table is provided with a metal top 30 in. in diameter, supported at the center by a vertical steel shaft which is connected to a cam in such a manner that the table may be gradually raised ½ in. and suddenly dropped from this height. In making a test with this appartus, a conical frustrum of fresh concrete 8 in. in diameter at the top, 12 in. in diameter at the bottom, and 6 in. high is molded in the center of the table. It is then given 15 drops, and measurements are made of the new diameter of the mass of concrete. The ratio of the average diameter, after test, to the initial diameter, 12 in., expressed in per cent is called the relative flowability.

Three abrasion slabs, 4½ in. deep, 8 in. wide, and 19½ in. long, and three 6x12-in. compression cylinders were made of each consistency and of each set of aggregates. These specimens were molded one at a time, on different days, so that the averages include variations due to personal equation of the operator and differences in conditions in the laboratory on these days. The materials required to make a slab and a cylinder were thoroughly mixed by hand in a small mixing tray; the cylinder mold was filled with three equal portions of concrete which were puddled as the individual layers were placed by 25 strokes from a ½-in. steel rod. The slab mold was completely filled, the sides surfaced with a mason's trowel and the top screened with a wooden straight edge. After standing approximately one-half hour, the tops of both cylinders and the slabs were smoothed with a few strokes of a steel trowel. By this procedure, it is evident that more or less of the excess water was removed from the tops of the specimens of the wetter consistencies. It should be noted, however, that such procedure produces effects similar to the rolling and belting operation used to finish the surface of a concrete road. After the cylinders had stood for four to five hours, they were capped with a thin coat of neat cement. The caps were leveled by means of small plates of glass.

Curing. After remaining one day in the molds, all specimens were placed in the moist closet. The slabs were removed when 24 days old, and stored 3 days in the hall before they were given the initial wear test. The cylinders were removed at the end of 28 days. They were then measured, weighed, and tested. After the 28-day wear tests, the slabs were placed out of doors in a cage where they cured under atmospheric conditions until 90 days old, when they were again rattled and then subjected to the cross bending test.

Results of Tests. The consistency data given in Table 2 and Fig. 1, 2, and 3 plotted from this data, show that the relative flowability gotten from the flow table measurements varies more uniformly with the ratio of water to cement (by volume) than the measurements gotten from any of the other methods. Doubtless the results would have been still more uniform if three trials by the flow table had been made on each mix, as



was the case in other methods of measurement. Considering the results obtained on all concretes, it appears that slump, when measured by the cylinder, varies in a more regular manner with the water-ratio than when measured by the conical frustrum. The changes in slump produced by constant increments in water-ratio are, however, much greater for ranges in slump between 2 in. and 6 in. than for ranges above or below these limits.

In the tests with the inclined plane, it was observed that concrete of the drier consistencies slid when the chute was inclined as noted in Column 8, Table 2,—whereas, for the wetter consistencies, it flowed down the chute. Measurements of the angle of repose with a smooth inclined plane appear to be of no value in determining variations in the consistency of concrete.

From the data in Column 10 of Table 2, it will be noted that the cement contents of the set concretes were not influenced by variations in consistency, but that the stone concretes contained approximately 5 per cent more cement than those made with gravel. The range in the ratio of cement to concrete, by volume, was 0.207 to 0.225, or 1.40 to 1.52 barrels of cement per cu. yd. of concrete.

Considering variations in the compressive strength of concrete (Column 11, Table 2), made from the same aggregates but varying in consistency, it will be observed that the strength decreases more or less regularly with the ratio of water to cement; but the magnitude of the effect of increases in the water-ratio is quite different with different sets of aggregates. It seems likely that the latter discrepancies are partly due to the greater ease with which the mixes containing university sand and those containing gravel were compacted. Under the same amount of puddling, more water was removed from the wetter mixes made from these aggregates than from the harsher working concretes, and consequently the variation in strength would be less in the former than in the latter. From Fig. 4, in which the average compressive strength of every mix is plotted against the values of the water ratio (x), it appears that the general law $S = \frac{A}{B^x}$, brought out by Abrams, holds true over the range of these tests. The values of the constants A and B for these tests, due to conditions in aggregates, cement, curing conditions, and methods of working, differ from the constants in the equation which he derived for gravel and sand mixes.

It will also be noted that the average strengths of all mixes of Janesville gravel is somewhat superior to the average strength of all stone mixes. This is due partly to the better grading (higher fineness modulus—see Table 1), and partly to the fact that less mixing water was required by these mixes to get the same consistency. With gravel containing very smooth particles, it is probable that the above mentioned advantages would be more than offset by the lack of surface adhesion between the particles and the mortar.

The transverse strength, which is measured by the modulus of rupture, follows a law quite similar to that for compressive strength, as may be seen by comparing the curves in Fig. 4 and 5. It should be noted, however, that the groups of specimens made from any one aggregate do not obey the general law so closely; that, in general, there is less difference between the average transverse strength of the driest and wettest batches made from any one set of aggregates than is indicated by the curve of averages for all specimens. In considering these data, it should be noted that the slabs were tested with the worn side uppermost, and that in this position the upper fibres were under compressive stress. The superiority of the specimens made with Lannon dolomite in transverse strength is noteworthy. This superiority is attributed to the combination of good bond between the stone particles and the mortar and to the high transverse strength of the stone particles.

The resistance of the various mixes to wear is indicated in columns 12 and 13 of the table and in Fig. 6 and 7. These data are also in agreement with those those of Abrams in regard to the general relation of water-ratio to wear. Again, it should be noted, however, that the effects of variations in the water-ratio on wear are not uniformly the same in the mixes made with different sets of aggregates. The effects are proportionately less pronounced in the mixes containing university sand than in those containing Janesville sand. This discrepancy is especially noticeable in the mixes of university sand and Janesville gravel. The results of duplicate sets of tests on these mixes failed to disclose agreement with the general law in either set of results or in the average of the two sets of results, which is given in the table. On the other hand, the wear was much greater in specimens of university sand than with specimens of like consistency and coarse aggregate made with Janesville sand. At the 28-day period, the excessive wear of the mortars made of university sand caused marked unevenness in the wear of specimens containing these mortars. This was especially noted in the mixes containing granite and university sand. Again, at 90 days, the wear of the slabs containing university sand was much less uniform than in those containing Janesville sand. The specimens containing granite, however, wore much more evenly at this age than at 28 days. Attention is directed to the low wear in the mixes containing granite when tested at the 28-day period. The wearing resistance at the 90-day period for the same mixes is very markedly superior to mixes of similar consistency and fine aggregate but differing in coarse aggregate.

Considering the effect of the substitution of a fine-grained sand like university sand for a well-graded sand like Janesville sand, it is apparent that the mixes made with the fine sand require much more water than those made with the well-graded Janesville sand, in order that the same consistency may obtain in both classes of mixes. The necessity of using higher water-ratio with concretes made of fine sands is the principal

(Continued on page 136)

FINANCING A COLLEGE EDUCATION

By Lewis H. Kessler

Instructor in Hydraulic Engineering, University of Wisconsin

The problem of financing the coveted college education worries many a high school senior of high ambitions but limited means. He learns that he must expect to spend about $3600 during the four years of college, besides foregoing the earnings he might have if he went to work at some job, and is quite likely to decide that the total cost of an education is nine or ten thousand dollars and that it is much too expensive for him. Mr. Kessler's analysis of the problem makes it evident that, so far as the accumulation of wealth is concerned, at the end of his four years' course, the man who goes to college is not so far behind the man who goes to work as is commonly believed.

Is a college course worth the financial sacrifice it entails? Can I afford to go to college? Have these questions been overheard by you, asked of you, or are you even now asking them of yourself, your friends, or Dad?

They were the questions asked by the writer in the fall of 1918, the answers to which were to determine one of the most important decisions of his life. No one seemed qualified to answer them. Those who might have ventured to reply had been to college in those days when expenses were about $250 a year. The library showed a dearth of information on this subject, and college catalogs left these questions to be answered from a small table headed "Probable Expenses", from which is was extremely difficult for a high school senior to draw sound conclusions. Much was learned through chats with friends as to the value of an education and the engineering press at that time gave splendid articles that would inspire any boy who had been planning for four years to make engineering his life work. It was this inspiration, along with the inherent desire to become an engineer some day, that pointed the way to college. After four years of college, the writer in turn was asked these questions by boys who were trying to decide whether to go to college and enter technical courses, or go to work. The deciding factor with the inquirers was the *cost* in dollars and cents; and, readers, it has been the observation of the writer that cost is the deciding factor in many a young fellow's decision to enter or not to enter the technical courses of our universities.

It was with considerable satisfaction that the writer could give his dad, and the home town boys who came to him, definite financial information drawn from his own experience, and to a considerable degree point the way to a college education; that he could show how four years of college could be accomplished and still leave a man almost as far ahead financially as though he had gone to work. The writer does not wish to be misunderstood on this point; he is not trying to prove that going to college is a financially desirable undertaking for everybody—each individual must determine that for himself; but he does wish to offer the record of his own college fiances as encouragement to those who desire a technical education and are willing to sacrifice some things to gain it. These records, when presented before several boys who were afraid to tackle the financial problems so closely related to a technical education made them resolve to try to go thru college, and right now one is making good at Wisconsin in his Frosh year.

Perhaps others will be encouraged to analyze their four years' work along similar lines for the benefit of men who will make good engineers and loyal sons of St. Pat.

What One Student Earned and Spent

In 1918, after being released from active service in the Navy with about $100 in his pocket and a suit slightly outgrown, the writer decided to complete the four years' college work eventually leading to a degree of Bachelor of Science in Civil Engineering. He figured that it would take all of his efforts to do just this one thing and anything he did in the summer might make or break the next year at college. He did not look upon college as four periods of nine months each with an intervening three months of rest and relaxation; it was to be a steady four-year pull. So his expense account has been carefully kept from September 8, 1918 to July 8, 1922, inclusive, to determine what his college course actually cost him in money. The figures herein presented refer to these forty-six months. You will note the words "carefully kept". To the best of the writer's knowledge and belief, his expense account is correct; at the utmost it could not be more than $2.00 in error. It was kept accurately in order to reveal to Dad and to friends that a college education can be considered a financially sound proposition and, incidentally, an excellent investment.

Here are the facts: The 46 months cost $3791.39. At the end of the Summer Survey Camp, July 8, 1922, the inventory of the writer's property amounted to about $1043. (The insurance company offered to insure it for $1000.) The property was in every way essential to living and nothing had been accumulated that would not be of value in the chosen profession. Let us see how the writer obtained the $3,791.39. He had $100 to begin with; he earned $2,061.29, or 54.5% of his total expenses, during the months he attended col-

(Continued on page 134)

EDITORIALS

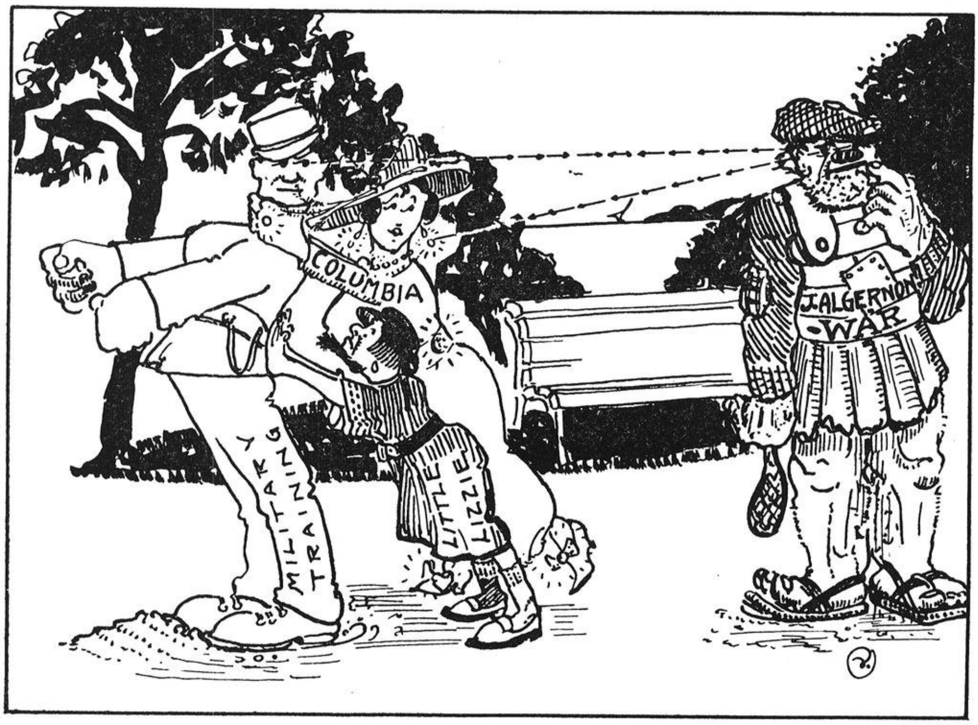
ARTICLES FOR THE ENGINEERING COLLEGE MAGAZINES

"Oh, yes," says the person who is not a student in an engineering college, "our university publishes an engineering college magazine, but it is too technical for the ordinary reader."

The ideal magazine that is published by technical students is not intended for outside readers. The material it presents is of a nature that appeals largely to the technical student, but it should not be of a nature that would make it impossible for the non-technical student to read. The reason for this is that the student doesn't care for the highly specialized technical reading matter. He wants something that will be fairly easy to read; the technical stuff he can find in a thousand and one other places.

The material must appeal to him. His greatest interest lies in science, certainly, and for that reason the articles published in his magazines should be about science. But they should be written in simple non-technical language and should not be hidden behind a barricade of integral signs and involved formulae. They should preferably be well illustrated and should always contain a strong touch of human interest.

A young engineer who can present his ideas in the language of the day has taken a long step toward success. One way in which he can learn this method of expression is by making use of his college magazine by submitting articles to the publication. The Wisconsin Engineer always stands ready to accept such articles; indeed, our cup of joy would be full if we could obtain them in any considerable amount. Since that is the only kind of an article the majority of readers care for, why not try your hand at one? You will find that your efforts will be amply repaid.



LITTLE LIZZIE—*"Leave us at once, or that rough man may be tempted to pick on ma."*

PROTECTING YOUR FRIENDS THROUGH INSURANCE

Sarah Bernhardt ended a brilliant career deeply in debt; people who served her and trusted her are facing the possibility of serious losses. She was a great artist and many idiosyncrasies that would condemn the common are forgiven in her because she was an artist. Nevertheless, our mind reverts to another artistic soul — Mark Twain — who spent the evening of his life working to pay off debts which, without any especial condemnation from the public, he could have evaded. The act of Mark Twain deepened the affection which Americans already felt for their great writer; it has been a trait of our people to respect a debt, and to honor the man who pays his debts.

The writer of the article on Financing a College Education, which appears in this issue, states that he was in debt several hundred dollars at the end of his college course. His experience is probably a common one in that respect. Friends, relatives, and parents invest much money in young men. What is their security? Of course, the word of the college man is good; he will pay his debts if he lives and has no bad luck. But suppose that he doesn't live or has bad luck; what becomes of the investment that has been made in him? If he has been a thoughtful fellow, the investment will still be safe, for it is not difficult to protect it. How? By insurance. No man who is under financial obligations to parents or friends should fail to guard his benefactor from loss. It should be a point of honor to carry enough insurance to protect one's friends.

No college man is as good as he tries to make his professor believe he is, nor as bad as he tells his girl he is. —Jester.

THE PAN-AMERICAN RAILWAY With over 6500 miles of the proposed 10,116-mile Pan-American Railway completed, and the securing of additional capital by South America for the building of railways, it seems not at all improbable that the project will be completed, and that part of the traffic between New York and Buenos Aires will be carried by rail.

Of what significance is this undertaking to the engineer, to industry, and to the public in general? What benefits will accrue to the country when this international trip may be made in fourteen days instead of the twenty now required for the average boat trip?

Consider the case of the American consulting engineer who is doing work both in the United States and in South America. To him the saving of twelve days on each trip may mean a thousand dollars earned. If he makes the trip three times a year, in that period he can save over a month of time.

The business man, whose presence is always necessary in swinging big foreign deals can save a six-day delay by boarding a train instead of a steamer. Delays due to storms will be largely avoided.

Fruits, which in the past have been sent so unripe as to be almost unfit for food may then be shipped six days later, and will be in better condition when they arrive.

The railroad will be the means of linking United States and South American interests more closely, a linking which from many standpoints is desirable. It will lead to understandings which are not possible when twenty days of water separate the countries.—E. D. L.

"While there is a well-defined limit to physical stature, there is no known pituitary body limiting mental development. Given proper conditions a man should continue to develop mentally during his whole life. The proper conditions for continued mental growth is the primary business of the college or university to supply."

—G. W. Munro.

BROADCASTING FOOTBALL GAMES Here's good news for the grad. Next fall, when the big football games are being played out on Randall field, you will not have to sit in suspense, gnawing your finger nails as you await news of the outcome of the battle. No indeed. Instead, you will tune in on WHA and get the game red hot,—cheering, band, and all the rest of the trimmings, for arrangements are being made to broadcast the whole proceedings direct from the field.

The successful broadcasting of the basketball games this winter shows that such broadcasting is feasible. The listener received almost as much of a thrill as though he were present at the contest. The playing of the band, the referee's whistle, the applause, the thrilling moments of silence and suspense, the enthusiast's wild "Atta boy, Rollie!" all came along with the reporter's running comment on the progress of events. More than five hundred letters commending the broadcast were received following the Michigan game.

THE STUDENT AND WORLD AFFAIRS

(*The following has been selected by the Wisconsin Engineer as the best editorial in the March numbers of the Engineering College Magazines. It appeared in Tech Engineering News.*)

For a century and a half the voice of the people has been increasingly the greatest influence in the determination of the policy of the world's governments. Today public opinion is easily the dominating factor in every one of the world's leading nations.

This tremendous power that the public holds in its hands is not always a power for good. And if the governing in the world is to be done wisely, public opinion must be wisely and thoughtfully formed.

* * *

The college students of today will generally be the leaders in all fields of endeavor tomorrow. Upon them, as such leaders, will fall the burden of controlling the formation of the future public opinion. That they do it well and wisely necessitates their having a knowledge of the facts in the case, it requires them to have some knowledge of the world's governments and of the trend and meaning of current political events. To be thus acquainted with world and national politics one must read the reliable publications of the day. Hence it becomes incumbent upon the present college student to develop in himself the habit of reading authoritative articles and of forming his opinions only after a consideration of all sides of the question. Today this habit may be of little direct value to him, though he no doubt will find it interesting as well as informative, but tomorrow it will enable him to live under a government more wisely conducted and more effective in results.

"It is my constant observation of four engineering works, employing about 20,000 men, that engineers reach the limit of their usefulness from defects of character, rather than from want of technical attainments. Our greatest difficulty is to find courage, candor, imagination, large vision, and high ambition."—Col. H. G. Prouty.

FELLOWS AND SCHOLARS FOR 1923-24

The following men were selected to fill the fellowships and scholarships in engineering for next year by the engineering faculty in the meeting of March 26: Kenneth M. Watson, senior in chemical engineering, fellowship in chemical engineering; Werner I. Senger, senior in mechanical engineering, fellowship in mechanical engineering; Hugo L. Rusch, senior in electrical engineering, and George F. Corcoran, senior in electrical engineering at South Dakota State College, scholarships in electrical engineering; Henry T. Heald, senior in civil engineering in the State College of Washington, scholarship in civil engineering. Senger and Rusch are members of the staff of the Wisconsin Engineer. The fellowships are worth $500 each a year, and the scholarships $250 each a year.

ALUMNI NOTES

CHEMICALS

R. W. Cretney, ch '21. who has been with the Southern Illinois Gas Company, at Murphysboro, Ill., is with the Thermatonic Carbon Company, of Monroe, La., Address: P. O. 1299, Monroe, La.

Paul Stimson, ch '16, is a test engineer with the Inland Steel Company, at Indiana Harbor, Ind.

CIVILS

Philip K. Schuyler, c '21, has recently been put in charge of bridge surveys for the North Carolina State Highway Commission, with the title of assistant engineer. Address: Raleigh, N. Car. He has sent in to the college information about openings with that commission.

Rexford Vernon, c '18, heating and ventilating engineer with the Johnson Service Company, recently successfully passed examination for appointment as second lieutenant, U. S. A. His appointment and assignment to the engineers corps of the army has been recommended by Secretary War Weeks, and the appointment by the President is expected to follow.

J. R. Vernon, c '18, has left his position as assistant division engineer for the Wisconsin Highway Commission at Lancaster, to enter the employ of the Johnson Service Company, at Milwaukee ,who are engaged in the manufacture of temperature control systems.

Robert Parker, c '16, is a designing engineer with the Dayton-Moran Company, at Pueblo, Col.

J. F. Kunesh, c '14, chief Hydrographic Engineer, Republic of Haiti, will receive mail addressed to him in care of Commander A. L. Parsons, Engineer-in-chief, Republic of Haiti, Port au Prince, Haiti, via Postmaster, N. Y. C.

Paul Paine, c '14, is a highway engineer with the Minnesota Highway Commission.

Leigh Jerrard, c '08, Ce '11, is a civil engineer with the N. W. R. R. Co., with Headquarters at Winnetka, Ill.

ELECTRICALS

Herbert G. Lindner, e '21, is in the Transmission Engineering Department of the Wisconsin Telephone Company, at Milwaukee, Wis. Address; 1118 Hayes Ave.

B. S. Spieth, EE' 21, instructor in Steam and Gas, is working on the problem of air filtration in cooperation with the American Society of Heating and Ventilating Engineers, at Pittsburg, Penn.

Chase Donaldson, e '20, formerly appraisal engineer with the American Gas and Electric Company, has resigned to take up the position of investigator of security issues with Hayden, Stone, and Company, 25 Broad St., N. Y. C.

G. L. Bostwick, e '17, is a sales engineer. Address; 1930 E. 94th St. Cleveland, Ohio.

John A. Hoeveler, e '11, E. E. '14, electrical engineer of the state industrial commission, has been named on a committee to revise the city electrical code of Madison, by Mayor Kittleson.

Harold Wile, e '12, died on February 14, 1923 ,as the result of injuries received while cranking his automobile, which was in gear. When in college, Wile was very popular and engaged in numerous activities. He won an athletic "W" in swimming, was captain of his swimming team, and made a very good scholastic record. Since his graduation he was active in alumni work, having been secretary and treasurer of the University of Wisconsin Alumni Club of Chicago for several years. Although only 32 years of age at the time of his death, he had attained commendable success in the insurance business, in which he was engaged as a member of the firm of Klee, Rogers, Wile and Loeb. He is survived by his wife, Mrs. Adell Frankel Wile, his mother, Mrs. Joseph Wile, his sister, Mrs. S. G. Levy, and his infant son Richard.

Edward Schildauer, e '97, EE '11, who is connected with the National Aeronautic Association of the U. S. A., predicts Chicago as the center of the future airship routes of the world. He recently contributed an article to the U. S. Air Service Magazine, on the development of airship transportation and its probabilities for world extension in the future.

Henry Lardner, e' 93, EE '95, vice president of the White Engineering Corporation, N. Y. C., is a trustee of the United Engineering Society, which holds in trust the Engineering Building on 39th St., which is a headquarters for the National Engineering Societies, and is chairman of the Library Board of Engineering Societies Library.

Walter Schneider, e '10, is a valuation engineer for the Ohio Bell Tlephone Company, at Cleveland.

L. E. Rice, e '05, has moved from Scranton, Penn, to New Jersey, where he is connected with the Atlantic City Electric Company.

MECHANICALS

T. B. Maxfield, m '22, has been promoted from the position of student engineer to special assistant, Production Department, General Electric Company, Schenectady, N. Y. Address: Box 12, R. D. 8.

Bert. H. Puerner, m '20, in sending his subscription to the WISCONSIN ENGINEER, writes as follows: "I have been out here since December in the interests of the Allis Chalmers Company. Am out here on the Mojave Desert, redesigning a plant for the Golden State Portland Cement Company. Expect to be out here for several month longer, so please start sending the Engineer right now."

Levi L. Henry, m '15 writes as follows: "I have been employed by the Detroit Institute of Technology, (Y. M. C. A. School) for the past four years. My principal job has been teaching engineering subjects, but for the past two years I have also been responsible for the courses of study and the instruction of a new five year co-operative engineering course leading to the B. S. Degrees in Mechanical, Electrical, and Chemical Engineering.

W. C. Epstein, m '15, superintendent and general manager of the Miami Foundry Company, Miamisburg, Dayton, Ohio, lives at Glenbeck Blvd., Route 16.

MINERS

Don V. Slaker, min '20, writes that he is opening a new branch of the Hayes Wheel Company, in Atlanta, Georgia, Alabama, Mississippi, Florida, and South Carolina as territory. He says that he and his wife have been making a preliminary rtip over the territory in a Chevrolet Coupe, mixing pleasure with business.

W. K. Fitch, ME '13, has offices at 749 Leader News Building, at Cleveland, Ohio.

Frederick Dorner, m '05, resides at 548 Milwaukee St. Milwaukee, Wis.

CAMPUS NOTES

EARL L. CALDWELL

HELLO, EVERYBODY!

Here we are again. How's the old folks at home? and every little thing? Good, we hope, for Campus wants everybody to make a grand clean-up of this year's orgy. Speed up, Clarence, or the moonlight nights will come and ruin you. Campus would like to see the boys have their work well in hand by "The Merry Month of May", as one can then sit in the moonlight more comfortably. Campus, in fact, plans to be done with everything except the finals by May the first.

"Oh, give me the monnlight,
And give me *the* girl;

but that's not really necessary. We are fully equipped provided it doesn't rain. N'est-ce pas?

HOW TO KNOW THEM

The civil engineer—squint eyes.
The chemical engineer—acid stains on pants.
The electrical engineer—magnetic personality.
The mechanical engineer—dirty hands.
The mining engineer—callouses.

—J. A. S.

BRIDGE CONTRACTOR—"So you think I ought to give that engineer beau of yours a job. Does he know any thing about a bridge?

DAUGHTER—"Oh yes, Daddy; he's a bridge expert. Last night he won four dollars and eleven cents."

—C. P.

It has been decided that the great snow-ball fight between the lawyers and the engineers shall take its name from the fact that the lawyers were defeated and were forced to leave the field in a hurry. Let it be known henceforth as the Battle of Bull Run.

—C. P.

K. J. King, M. E. 4, has taken Jimmie Woods' place in the Machine Design Department.

AND THE WORST SHALL BE LAST

PROFESSOR MEAD (Explaining abou tthe Dayton flood) —"Besides the 400 people that were killed and the 1600 horses that were drowned in the streets, 1200 Studebaker pianos were destroyed."

Imagine having a pretty girl for a surveying partner. Imagine sitting under a tree with her on these lovely spring afternoons, fudging notes, and putting one over on Professor Owen. Oh me, oh my! Paul Bishop, you're a lucky bow-wow.

—E. K.

DID HE ANSWER CORRECTLY?

INSTRUCTOR—"In considering this problem, we must know all of the initial conditions. Lyons, will you give us the unit weight of this 15-inch, 42-pound I-beam?"

Jimmie Woods, of football fame and more recently of the Machine Design Department, has taken a brand new job. It is an appealing one, too. Jimmie is an efficiency engineer with the L. S. Ayres & Co. department store of Indianapolis, Ind. Pat Hyland says Jimmie is bound to make good because he doesn't know anything about the business, and hence will be able to tell them a lot.

But we fear for Jimmie. Ayres & Co. have more beautiful Shebas than the Follies—so keep your fingers crossed, Sir James.

MR. STIVERS—"There is a rock outcrop near the site of a proposed aqueduct. How can you tell whether the stone is fit for use in the structure?"

IHLING—"I'd examine the outcrop for weathering and ask the nearby inhabitants how long the rock had outcropped. From this the rate of weathering could be found."

R. E. Purner of the Machine Design Department has been batting 1000% in the Hospital League. It seems that Purner's appendix resisted breaking off its old home ties, and set up such a commotion as to put Purner down for extra bed duty. Purner reports, though, that things are functioning "better and better", and we hope to see him about the time you read this.

SUMMER WORKING, SOME ARE NOT

FIRST COMMERCE STUDE—"What are you going to do this summer?"

SECOND COMMERCE STUDE—"I have a position in father's office. And you?"

FIRST C. S.—"Oh, I don't expect to do anything either."

—Z. J.

A new material of construction having peculiar properties has recently been developed. If a test specimen be placed in tension, the piece gets shorter instead of

longer. Several large buildings in Milwaukee are incorporating this material.

At this juncture you, the victim, should feverishly yell "What is it?" and I, in leaving, will say "a cigarette."

CALCULUS YELL

E to the X, dx, dx,
E to the X, dx, dx,
E to the X, E to the X,
Rho, Theta. —Colorado Engineer.

WE WOULD LIKE TO MEET HER!

The Daily Cardinal says the He-man's club complains that the Co-eds have control of all the campus publications. As far as we know, the fair co-edith who has joined the ranks of the plumbers has not vamped the members of our staff thus far. Please note, ye Cardinal reporters.

OUR ? CLINIC

The attitude adopted by the clinic is brilliantly reflected in the experience of a Junior E. E.

This E. E. *was sick,* and the doctor's first words were, "What's the matter with you?"

But the E. E. wasn't so dumb either, because he piped up: "I don't know; that's what I came over to find out!"

The clinic has brains and science galore—Hooray—but—they are as serviceable as a blind, deaf, and dumb life-saver. An appointment at the clinic is as valuable as a tip on the races. You speculate either way, for the clinic only *makes* appointments, and does not keep them. If you made a dozen appointments, you might see a doctor, providing you waited about ten or twelve hours. You must wait, and wait, and wait, and wait; for that is the unwritten law of the place. If you need attention quickly, don't go to the clinic; your life insurance will be paid before they know you are even on the premises. It is suggested that:

1. Since a man requires less of a doctor's time than does a woman, let there be several doctors designated to handle men exclusively.

2. The doctors drop the policy of the "student be damned"; *give* service and not *condescend* it; look at an appointment as if they were the patient, and keep it as they would if they were the patient.

3. The doctors stop "horsing" about the place, and do more work.

This may seem satirical and cynical, but these words are based on the truth as borne out by observation, comment, and comparison.

YOU HOLD ME AND I'LL HOLD YOU

A junior civil designed a form for a concrete retaining wall without providing for bracing it. Asked how he expected the form to stay in place he explained, "Well, I figure that as the concrete is poured in at the top the forms will be supported by the concrete."

BAR RATS SEEK THEIR HOLES

(By our War Correspondent who served at the Front)

When the ground-hog, on February 2, saw his shadow, he broke his neck and the U. S. Submarine corps' submergence record in an endeavor to get back into his hole; but the ground hog was as slow as a Madison street car at 6 p. m. when compared with the alacrity displayed by the bar rats in their mad endeavor to get into the law shop after trying to stop the onslaught of attacking plumbers, Wednesday morning, March 21.

After having formally issued a challenge in the Daily Cardinal to our shyster neighbors for a snowball fight, the prides of St. Patrick lined themselves twenty deep in the middle of the upper campus at the appointed hour, 9:50 a. m. With two or three feet of snow as ammunition, a barrage of snow balls was laid down on the law shop before the dumbbell inhabitants thereof fully realized that their fortress was in danger.

With some little hesitation the beseiged Gladstones sallied out, but were met with a blood-curdling yell that would have raised hair on a billiard ball. At the sight of their victims the plumbers gave vent to their fury and snow balls flew thicker than old shoes at a wedding. The lawyers were licked to a frazzle; they had no more chance than one of their snowballs would have in — the pyrometry lab.

For every law snowball that hit an engineer, enough snow was sent in the other direction to stop a freight train coming down a mountain side with the brakes off. The benighted laws, thinking that they had run afoul of an Alpine avalanche, crawled into the darkest corner of their shop there to await an awful end.

After clearing the whole south side of the upper campus of so-called life, the lords of the campus returned to their classes no more ruffled than if they had just come from a lecture in descriptive geometry. Today the cripples really need their traditional canes, but they don't spend any time sitting around on their front porch waiting for the engineers to give them the razz.

WHY BOTHER ABOUT OIL SHALE?

Professor Rood told his class in Central Stations about the great quantity of oil absorbed by woolen socks in walking across the oily floors of a central station. "The stockings become literally saturated with oil due to the capillary action of the soles and the great affinity of the socks for oil," he said. If you are economical and wring out the socks when you get home after walking through an 'oily' station you will not only obtain a supply of grease for the frying pan, but also a sufficient quantity of oil for the lubrication of lawn mower, sewing machine and flivver.

—P. J. B.

OH, WELL, DO IT YOUR OWN WAY, HORACE

The economics shark was busily computing percentages, long hand, for a table of statistics. "Say, buddy," said his engineer roommate, "why don't you use my sliderule for that? You could do twice as much work." The mild, blue eyes under the green shade were raised for a moment. "Quite so, quite so," came the soft answer, "But you see, old dear, I haven't twice as much work to do."

STIFF COURSES

Of all stiff courses under the sun,
Reinforced concrete is the stiffest one.

Of all stiff courses under the sun,
Petrology is the stiffest one.

Of all stiff courses under the sun,
The Medic course is the stiffest one.

DOC PRICE COMES HOME

In the early hours of dawn, Mrs. Doc Price was awakened by a series of noises: First, the opening of a door, which banged against the stop and shook the house; then the cat let out a terrible cry; a chair was overturned with a crash; and, finally, the light flashed on. "Doc', she cried, "Is that you? What are you doing?" Then a voice she knew floated meekly to her over the ruins: "Yes, dear, it's me. I'm sneaking in."

FATHER WAS RIGHT

In a tired voice, Professor "Pat" Hyland was lamenting: "Last night, at two o'clock in the morning, when I was walking up and down on the cold floor in my bare feet, with a crying child on each arm, I couldn't but remember that father wanted me to be a priest,—and I thought I knew better than he did."

IT DEPENDS UPON LOCAL CONDITIONS

Professor Spieth—"On this engine, does the eccentric follow or lead the crank?"

Senior Civil—"Oh, they always revolve together; but, of course, it depends upon which way they are turning."

WHAT YOU GOT ON HIM, DOC?

Scene—Class in structures.

Characters—Professor "Bill" Kinne, Sherm Green, and Doc Price.

Professor Kinne—"Well, Sherm, you're late."

Sherm—"So is Doc."

Professor Kinne—"That doesn't matter about Doc."

Sherm—"Why not?"

Professor Kinne—"Well, we married men have to stick together."

According to Professor Rood, the vibration in the international bridge at Niagara Falls is so great that in crossing it, "a horse is not allowed to run faster than a walk."

VOLK INDEXES NEWS RECORD

The Engineering News Record announces a Consolidated Index of all its articles from 1917-22. The index is the work of our own Librarian, Professor Fred E. Volk.

DEFINITIONS FROM AN ENGINEER'S NOTE BOOK

(The following has been selected by the Wisconsin Engineer as the best bit of original (presumably) humor appearing in the March number of the Engineering College Magazines. The Kansas Engineer gets the credit for it and thereby wins the hand-carved, spaghetti crochet hook.)

Blizzard—The inside of a hen.
Oxygen—An eight-sided figure.
Dispel—to spell incorrectly.
Buttress—A nanny goat.
Frontispiece—A headlight on a Ford.
Furlough—A fur bearing animal.
Monomaniac—A man with only one wife.
Observatory—A place where flowers are kept.
Tonsorial Parlor—Where you go to have your tonsils removed.
Dogmatic—Pertaining to the culture of dogs.

HYDRAULIC LABORATORY THESIS WORK

A number of interesting thesis investigations are being carried out in the hydraulic laboratory this spring by the senior and graduate students.

Mr. Paul Huntzicker, fellow in hydraulics, is investigating the nature of the flow and loss of head where a stream flowing in an open channel or ditch suddenly enlarges due to a deepening or widening of the channel.

Mr. C. E. Wheeler, scholar in hydraulics, has been making a series of tests on small air-lift pumps intended especially for farm conditions. He has had his equipment in a well about 3 miles west of Madison.

Mr. I. R. Haddorff and Mr. Arnold Zander have also been working with an air-lift pump. They have made a series of tests of the pumping equipment of the waterworks at Clinton, Wisconsin. One object has been to determine the most economical size of air compressor and motor to serve the air-lift pump.

Mr. Cecil Russell, graduate student, has been studying the discharge coefficients of overflow weirs which are placed on the side of a channel. This is a continuation of the undergraduate thesis work which he and Mr. Carl Zander did.

Mr. Hugh Kent and Mr. L. T. Sogard are determining the discharge coefficients for weirs with crests that are inclined at an angle to the horizontal. Such a weir will have varying depths of water over it, a situation that not infrequently happens in practice, but for which there is little experimental data.

Mr. W. H. Collins also has an unusual weir problem. He is studying the discharge over weirs that have their crests placed at an angle with the direction of flow in the approach channel.

Mr. J. E. Noran is investigating the loss of head in standard increaser pipe fittings. He is having to determine the loss in different sizes of pipe as an auxiliary part of the work.

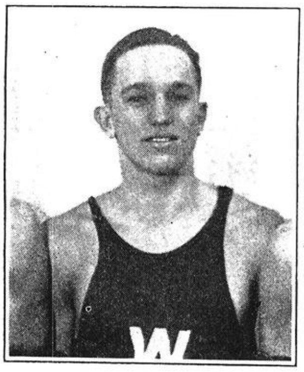
Mr. O. J. Bandelman is making tests from which he expects to determine the correct coefficients of discharge

(Continued on page 133)

ATHLETICS

OUR ENGINEER-FISH

Czerwonky, (pronounce it like the Cz in Czar, the C being silent like the "q" in billiards), set a new national intercollegiate record in the 200-yard breast stroke event at the intercollegiate swimming meet at Princeton, Saturday evening, March 24, when he navigated the distance in 2:47 flat.



H. E. CZERWONKY

Czerwonky, with the appendage, "Hugo E.", is a junior mechanical, and for the past two years has been one of the mainstays of Joe Steinhauer's natators. All last year he copped firsts and seconds in the breast-stroke and back-stroke events; this year, together with Captain Johnny Bennett, he has been chiefly responsible for what success the team has had. The team this year made a creditable showing, taking third in the conference meet, despite the ineligibility jinx which annually plays havoc with the swimming squad.

Czerwonky's only rival is Faircy of Minnesota, but with another year of competition he is expected to be the equal of the Gopher star. The new college champion was elected captain of next year's team recently. For his work in the Princeton meet, Czerwonky will probably be awarded a major-sport W.

SPRING FOOTBALL BEGINS

With the selection of Jack Ryan, former Darttmouth star, as head football coach, the job of filling the vacancy caused by Richards' departure has at last been completed, and the athletic council can sit back, mop its brow, and await results. Results seem to be immediately forthcoming, too, for the new mentor had 38 men out for the first time on March 21 to start spring training. Setting up exercises and instruction in wrestling for the improvement of stance are being given the recruits. Kibo Brumm, the terrible line wrecker of the 1921 team, is out after a complete recovery from injuries sustained in a fall last summer. Kibo is a junior civil.

STATE HIGH SCHOOL BASKETBALL TOURNAMENT

The Wisconsin State Basketball Tournament, which is held in the armory each spring, attracted much attention this year; the snappy games put up by the contenders showed that high school basketball is but a step behind the intercollegiate game. With a fast attack and an air tight defense, the Wisconsin (University) High School cinched the title by drubbing the much favored Oshkosh aggregation 26 to 13 in the final game of the series.

The Wisconsin Athletic Review has given a cup to the high school association to be known as the Al Knollin Trophy. This cup is awarded at the annual tournament to the team displaying the best sportsmanship. Appleton was awarded the trophy this year.

GYM TEAM WINS CONFERENCE CHAMPIONSHIP

On March 17, Wisconsin's gym team took first place in the conference gym meet held at Ohio State. The Badger team was composed mainly of veteran gym men; consistent team work on the part of a well balanced squad was the reason for the success, rather than the individual work of any particular man.

THE CONFERENCE BASKETBALL TIE

With the closing of the Conference basketball race a tie for the championship between Iowa and the Badgers, the students of both institutions were very much dissatisfied and a strong, though futile endeavor was made through the Daily Cardinal to arrange for a play-off. As usual, the powers-that-be did nothing, so while the Chicago "Trib" puts Iowa first on the list with 11 won and 1 lost, we disagree and put Wisconsin on top with the assurance, yea even the boast, that the Cardinal could swamp the Hawkeyes and here's why: Indiana beat Iowa 23 to 21 and we beat Indiana within the next ten days by a score of 35 to 17, which is 14 more points than Iowa scored on Indiana. Therefore, we could beat Iowa by ten points, allowing a factor of safety of 4, with no more effort than we beat Indiana: *quod est demonstrandum.*

HYDRAULIC LABORATORY THESIS WORK

(Continued from page 132)

to use for orifices placed on the end of a pipe for any given ratio or orifice area to pipe area.

Mr. Sherman Green and L. A. Schmidt are investigating the loss occasioned by a reverse bend in a pipe line. They find two standard elbows put together to form an "S" offer considerably less than twice the resistance to flow either one of them do when in the line separately

Mr. K. D. Farwell and T. M. Niles are determining the banking-up effect on the outside of bends in open channels and the loss due to the presence of a bend in a flowing stream.

Mr. John T. Desmond and Mr. O. W. Torgeson are preparing to study the resistance to flow through corrugated culvert pipe from 8 inches to 2 feet in diameter.

FINANCING A COLLEGE EDUCATION

(Continued from page 125)

lege, and $1130.10, or 29.8% of his total expenses, during the summer months; finally, an indebtedness of $500 was incurred. The property of the writer is an asset of $1043 and the borrowed money is a liability of $500 which would seem to show that the writer had made $543 by going to college. However, he believes that he would have accumulated at least as much property, perhaps in somewhat different form, if he had not gone to college, and that the debt of $500 represents what college cost him.

"But," my readers will say, "what about the money you might have earned and saved while not going to college?" Investment houses, banks, and employers of young men assert that the average young man before the age of 25 has been self-supporting but has saved practically nothing. Let us consider what the man at work might have earned and might have spent to see if this is reasonable. The writer feels that if he had been working instead of going to school he could not have made more than $100 a month during the first 18 months, or $1800; during the next 18 months he would probably have been raised to $125 a month, making a total of $2250 for this period; and during the remaining 10 months he might have made $140 a month, or $1400. Thus, $5450 would have been the grand total of his earnings. After many discussions with those familiar with young men living during the same 46 months that the writer was attending college, the following estimate of the average monthly expenditures has been passed upon as being reasonable and perhaps a little conservative: Room $20, board $35, clothes $20, laundry $5, travel $5, insurance $4, spreads $5, incidentals $8 and amusements $15, or a total of $117 a month or $5382 during the 46 months. Thus, $5450 would have been the grand total of his earnings against an expenditure of $5382, leaving a balance of $68 which would have been cash on hand. So these figures show, at least in a general way, why a young man before the age of 25 has been self-supporting but has saved very little. It has taken all of his earnings to live during this period. The writer feels that he would have been no exception to the rule, and that during this time he could have been self-supporting, but probably would have failed to save any money. So, on July 8, 1922, the writer believes that college cost him only $500 in money.

My reader will wonder why the man at work would spend $5382 while the college man would spend only $3791 during the same period. The writer *knows* that the earning power of a student in a technical course is more limited than that of the man at work because of the many hours of study and recitation necessary to complete successfully such a course, but he also *knows* that, due to this time taken up by study and recitation, the student does not find the opportunity in which to spend as much money. Furthermore, because of the decreased earning power, the thrifty student is compelled to form the habit of saving and making his earnings go as far as possible, while the man at work is not forced to form this valuable habit. This habit of saving is undoubtedly an asset in itself and should not be overlooked when considering the value of an education as a whole.

Engineers Earn as They Learn

What is the significance of these figures to Wisconsin Engineers? The writer does not believe that there is such a thing as an *average* student in the strict sense of the word, but, if we can assume, for the sake of discussion, a student approximating to some degree an *average* student, these figures will have more of a personal touch to them. Let us see how the average Wisconsin engineer obtains his funds while attending college and how much he spends during his course.

On November 27, 1921, questionnaires were circulated through the various classes in the college. The questionnaire contained two pertinent questions; namely, "What per cent of your necessary expenses do you earn?" and "Approximately what does a school year at Wisconsin cost you?" These questions were answered by 747 students, which was a large percentage (about 60%) of the enrollment in the college. Assistant Dean A. V. Millar and Miss M. O'Keefe have tabulated the data presented below, which was obtained from answers to the first question:

PERCENTAGE OF EXPENSES EARNED BY 446 ENGINEERING STUDENTS AT WISCONSIN DURING 1921—1922

Class	% of Necessary exp. earned during school year only by men doing outside work.			% of Necessary exp. earned during entire year, including vacation periods, by men doing outside work		
	Min.	Max.	Av.	Min.	Max.	Av.
Freshmen	5	100	46	5	100	52
Non-Promoted Freshmen	15	100	48	15	100	53
Sophomores	3	100	58	3	100	52
Juniors	10	100	57	10	100	54
Seniors	10	100	54	5	100	52

NOTE—Students living at home in Madison were not considered in the tabulation of these data.

Of course, not all of the 747 students were doing outside work for remuneration while attending college. In order to supplement this table and obtain more information of interest, the writer studied the original questionnaires and determined the following facts:

No. of students submitting questionnaires	747
No. of students unemployed	301 or 40.1%
No. of students wholly or partially self-supporting	446 or 59.9%
No. of students earning 100% of their expenses	85 or 11.5%
No. of students earning between 50% and 100% (average about 85%)	108 or 14.5%
No. of students earning between 8% and 50% (30% average)	253 or 34.0%

NOTE—Earnings during vacation were considered in compiling these data.

It will be of interest to know in reference to these questionnaires and these data, that in all of the classes with the exception of the freshman class, more than 50 per cent of the students were doing outside work; so the

freshman class, the largest of them all, is responsible to a considerable degree for the 40 per cent average of the men not doing outside work. To see if this were true this year, the writer examined the freshman records in Professor Millar's office and found that, from fairly accurate records, out of 264 freshmen, 94 or 36% of the class were doing outside work. Employment records of the other classes for this year are not available, in fact, little information regarding the outside employment of students is available in the entire university.

The above figures indicate that the majority of engineers are partially self-supporting and that a surprisingly large number are largely or entirely self-supporting. They also indicate that the inclusion or exclusion of the earnings during summer vacations has little effect upon the averages. In the light of these figures the writer feels that his own financial experience was nothing exceptional—that it may be accepted as something that the average man can duplicate.

In answer to the second question of the questionnaire, "Approximately what does a school year at Wisconsin cost you?" the following average cost was determined:

Number students in estimate	Total expended by this number	Average for year
747	$610,715.00	$817.55

During the 46 months, the writer's average expenditure was $987 for the entire year, and for the school year it was about $790 for each year of the 4 school years, which closely approximates the average expenditure of the 747 engineering students. Although the price level fluctuated somewhat during the writer's course, his expense account shows that the cost per year was practically the same each year and this is especially true during the last three years of his course. So as far as college expenses are concerned the writer approximates the *average* engineering student.

In further comparison of the writer with the average student, he finds that his scholarship has not been very far above the average and in several cases it has been lower. Also, the writer was not entirely immune from social activity, for during the first two years he enjoyed active membership in a social fraternity, which is not uncommon to the ordinary engineer. The writer has also engaged in athletics as much as the ordinary engineer finds time. Then again, it is not uncommon for students at Wisconsin to find a life partner, and the writer followed precedent in this matter. The figures given at the beginning of this article include all of the expenses incident to courtship and marriage. A further significant fact is, that the first two years of the writer's course were spent at the University of Chicago and the last two at the University of Wisconsin, both Big Ten institutions and not so far distant but that prices and activities approximate each other as the expense account of the writer shows. So, all in all, the writer feels that he can safely say that he belonged to the class with the "average student"—the student who tries to do justice to scholarship and the activities of student life in so far as his financial condition will permit him.

The Intangibles

You will note that the writer has made no attempt to capitalize the value that associations, business connections, and practical experience might have on the earning power of the man who did not go to college nor has he discussed the relative value to the state of the untrained man and the college graduate. However, you have been forming habits, making associations, and cultivating friendships which may easily equal those of the man who could not go to college.

The question of the financial value attached to business associations is, and probably always will be, a debatable one.

The engineer and his Dad will find it difficult to estimate the cash value of the business connections formed by the man who went to work and to compare this cash value to that of a college education and the associations formed by the college man. Each individual must evaluate these associations for himself.

It is hoped that you can analyze your four college years so that you can reveal to Dad something definite regarding your four years' investment and that both of you will be able to encourage the younger men who are asking, "Can I afford to go to college, Dad?" or "Can I afford to go to college, Bill?" You have been there; you ought to know. Show them a college course is worth while financially; that during this period there is usually no accumulation, but that a sound investment has been made and a valuable asset has been obtained.

DEVELOPMENTS IN ELECTRON TUBES

(Continued from page 120)

the tube, and as glass and quartz, the only materials suitable for containers, are poor conductors of heat, the plates quickly reach temperatures above which operation becomes unsafe. This fact has limited the tubes heretofore built to capacities of one or two kilowatts.

It had long been realized that the ideal arrangement would be to make the plate serve as the container for it could then be water cooled. Insulation capable of withstanding potentials of several thousand volts must, however, separate the plate and filament and the general arrangement of parts requires air tight metal-glass seals one or more inches in diameter.

Seals of this character have been developed by Housekeeper[1] of the Western Electric Company. They are capable of withstanding repeated heating and cooling from temperatures ranging from that of liquid air to 350°C. without cracking or impairment of their vacuum holding properties. This result was secured by obtaining an intimate connection between glass and metal either by chemical combination or by mere wetting, and in so proportioning the glass and metal parts that the forces of adhesion are greater than the tensile stresses developed by temperature changes. The metal used is copper which is readily wetted by melted glass, and the tensile stresses are reduced by making it very thin where it joins the glass. Three types have been made which are known as ribbon, disk and tubular seals re-

[1]Bell System Technical Journal, Vol. 1, Page 1, July, 1922.

spectively. In the ribbon seals, the cross section of the metal is lenticular with a very thin, sharp edge. In the disk seal, a thin copper disk is made to adhere to the end of a glass tube, the disk being slightly greater in diameter than the tube. A glass cap is placed at the back of the disk to increase the mechanical strength. Tubular seals are made by joining copper and glass tubes together end to end. For this purpose the metal coming in contact with the glass is sharpened to a very thin edge and the glass is made to adhere to it either on the inside or the outside. Metal and glass tubes up to four inches in diameter have been joined in this way.

Figure 6 shows a hundred kilowatt tube made by the Western Electric Company. The general arrangement of parts is similar to that of the smaller tubes. The anode is a piece of seamless copper tubing fourteen inches long and 3.5 inches in diameter closed by a copper disk welded into the end. The filament is of tungsten, 60 mils in diameter and sixty-three inches long, and requires a current of 91 amperes to heat it. The leads are copper rods one-eighth of an inch in diameter and enter through copper disk seals one inch in diameter. The grid is constructed of molybdenum wire and is wound around three molybdenum supports. In its manufacture, glass blowing difficulties were of no small magnitude. Because of its weight, the anode had to be supported in gimbals while it was being sealed in, and special appliances to hold the grid filament assembly had to be devised.

It is hardly possible to overestimate the advantages to the radio art to be derived from these tubes. A single one will replace the large radio frequency alternators now in use in some high power stations, machines which have cost thousands of dollars to build. For radio telephony, the possibilities are even greater than for telegraphy. The power of phone sets has never equalled that of telegraph sets because of the difficulty, of controlling large outputs by voice operated modulation devices. These powerful tubes solve not only the problem of producing high power radio frequency currents, but of modulating them as well. In fact it would seem that in the very near future we shall see the elimination of the arc and alternator transmitters, and the gradual replacement of the radio telegraph by the telephone, and shall have available, for every day commercial use, trans-oceanic as well as trans-continental radio telephony.

TESTS ON CONCRETE

(Continued from page 124)

reason for the inferior strength and wearing qualities of these mixes.

Conclusions. The following conclusions are tentatively advanced as a result of this series of tests:

(1) The flow table appears to be the most satisfactory method of those tried for measuring consistency, with the 6x12-in. cylinder next in value. The flow table in the present form is best suited to laboratory work, whereas the cylinder-slump test may be used to advantage in the field.

(2) The general laws which Abrams has advanced concerning the effect of the ratio $\frac{\text{Water (by volume)}}{\text{(Cement by volume)}}$ on the strength and abrasive resistance of concrete are corroborated for the range of these tests. Roughly, within the limits of water ratios herein considered, these laws are: That the strength and resistance to wear decrease as the water-cement ratio increases.

(3) In interpreting these laws, it must be remembered that the water-ratio for the concrete at the time it leaves the mixer is a most important factor in determining the tendency to segregate in transportation and in placement, the stiff consistencies segregating less than the more fluid, whereas the water-ratio of the concrete when it sets is a factor which greatly influences the strength, wearing resistance, shrinkage, and other physical properties.

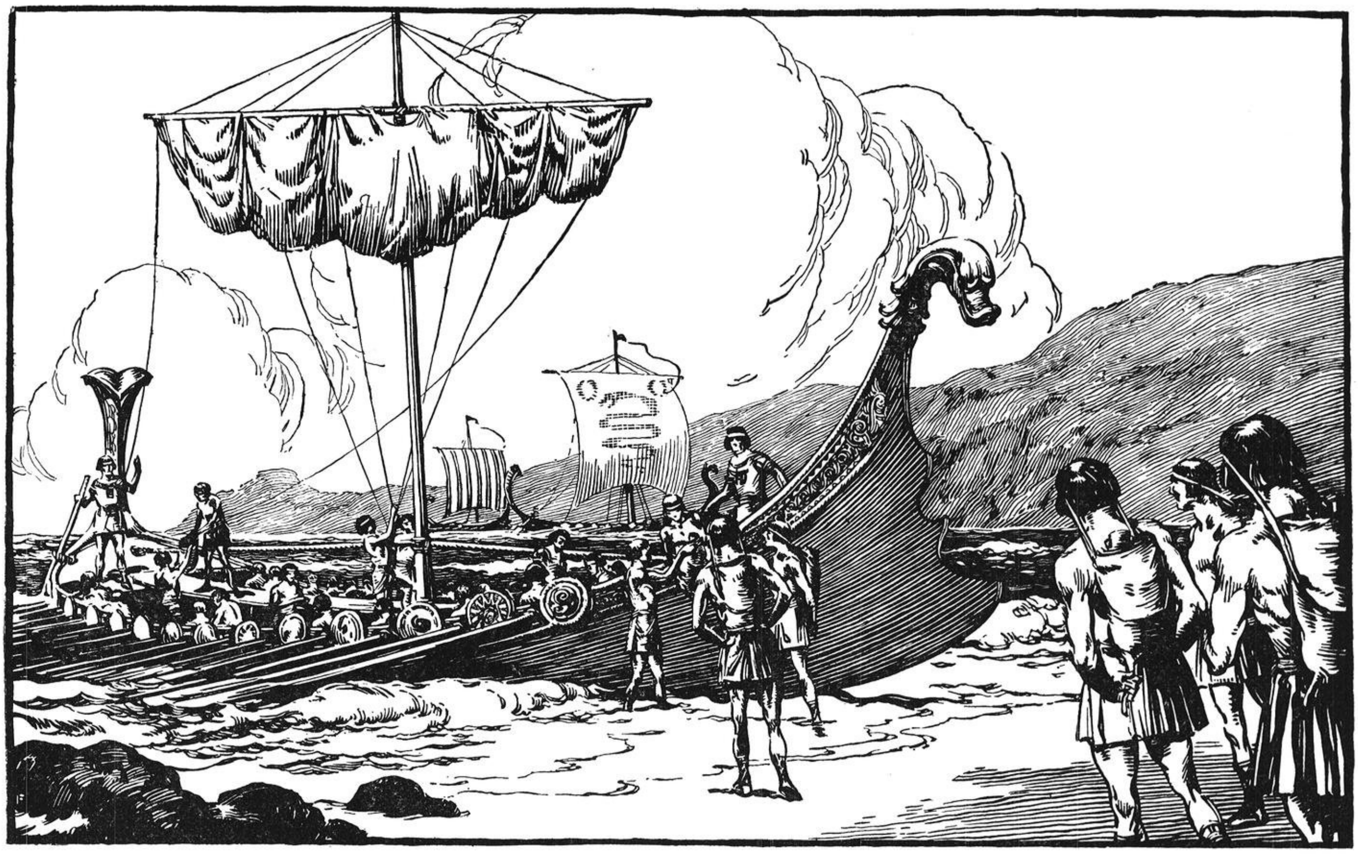
(4) From the data herein recorded, it does not appear that concrete which is being mixed at the roadside (no transportation) will segregate appreciably when the relative flowability as measured by the flow table is less than 200, or, considering well-graded aggregates, when the slump in the 6x12-in cylinder is less than 6 in. With very fine-grained sands of proper grading, the upper slump limit should be reduced to 4 in.

(5) For workable mixes having consistencies less than the segregation limits, see (4), the tests show that other factors than the water-cement ratio, such as workability or removal of water after placing in forms, have a decided tendency to equalize the strength and wear of concretes made of the same aggregates but differing in consistency. Considering only mixes for road construction, it seems evident that the water content of fresh concrete of the more fluid of these consistencies is quite likely to be reduced by a number of factors during field operations, until the water content of all mixes is nearly the same. The factors which appear to influence such changes are: The striking off, the rolling and the belting of the surface of the pavement, the evaporation of water from the surface, and the absorption of the sub-grade.

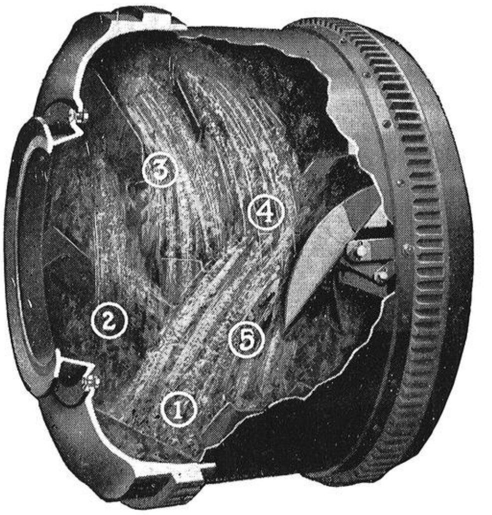
(6) From present knowledge, it would therefore seem that the desirable range in relative flowability for concrete road construction lies between 150 and 200, as measured by the flow table, or, with well-graded aggregates, between a 1-in. and 6-in. slump, as measured by the 6x12-in. cylinder. For any given set of materials the consistency should be as stiff as the methods of placing and finishing permit.

(7) The excessive wear of concretes of normal proportions containing very fine-grained sand and the uneven wear of such concretes containing hard coarse aggregate are important results from these tests.

Acknowledgment: The laboratory work and most of the computing done in making and reporting these tests was performed by Mr. D. H. Stiles, formerly Assistant Engineer for the Commission. He was aided in the laboratory by W. Laflash, Laboratory Attendant.



Why does Koehring Five Action Mixing Principle give Plastic Concrete?



(1) Blade cuts through materials with churning action. (2) Blade carries materials up, spilling down again against motion of drum. (3) Materials hurled across diameter of drum. (4) Materials elevated to drum top and cascaded down to reversed discharge chute which (5) with scattering, spraying action, showers materials back to charging side for repeated trips through mixing process.

TESTS made at Purdue University by Professor W. K. Hatt prove that plasticity of concrete depends on the proper mixing. To obtain this plasticity in the minimum time, the individual particles of cement, sand and stone must be so mixed that they will find their proper position in the concrete. Then the cement acts as a lubricant and the concrete will be plastic and easy to work, instead of harsh and difficult to place.

The Koehring Five-action Re-mixing Principle prevents separation of aggregate according to size—coats every particle of aggregate thoroughly with cement—and delivers plastic uniform concrete to the last shovelful of every batch.

KOEHRING HEAVY DUTY

KOEHRING COMPANY
MILWAUKEE WISCONSIN

KOEHRING