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TO

The Wisconsin Engineer.

VOLUME I. JUNE, 1896—JULY, 1897.

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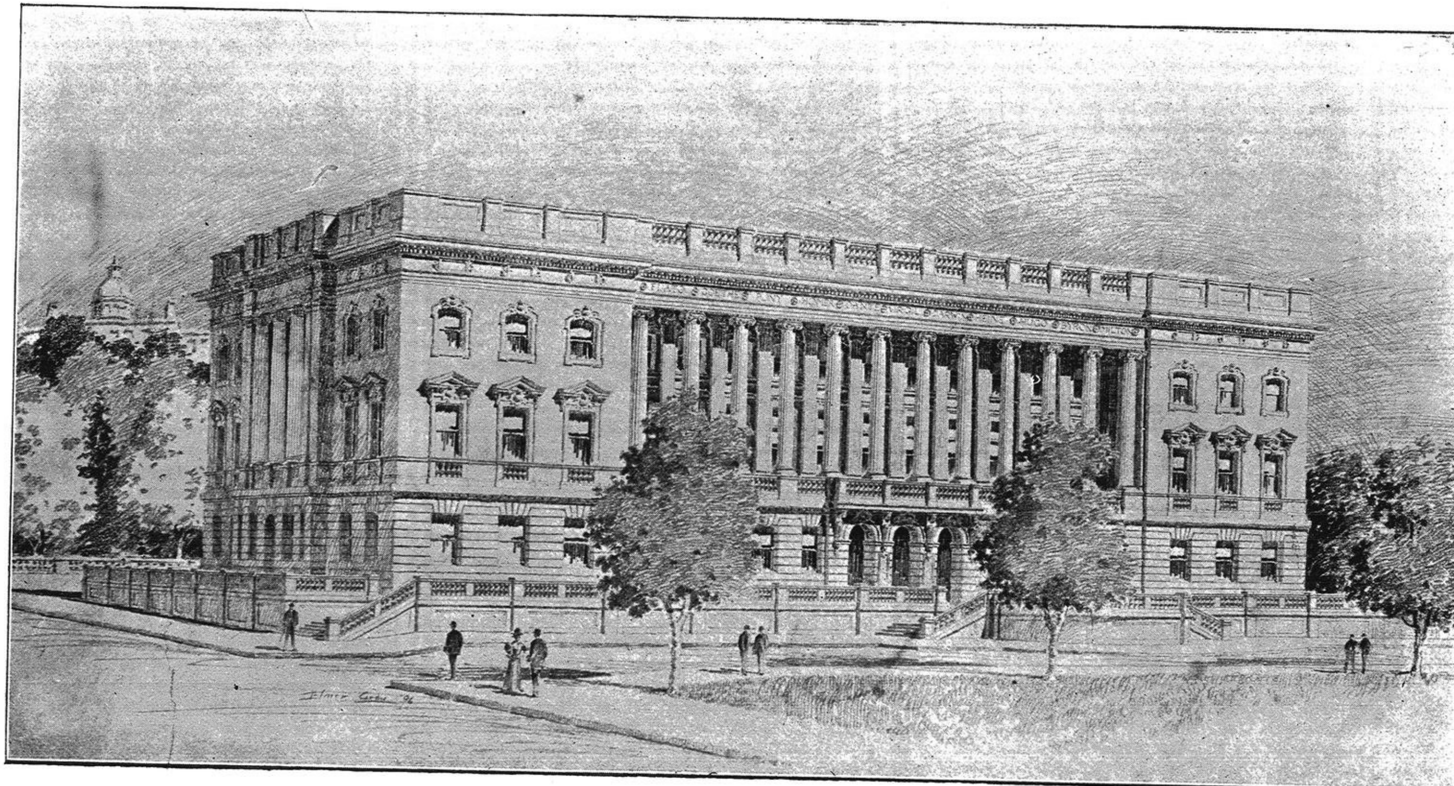

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The Wisconsin Engineer.

PUBLISHED QUARTERLY BY THE STUDENTS OF

THE COLLEGE OF ENGINEERING, UNIVERSITY OF WISCONSIN.

Vol. 1. Madison, Wis., June, 1896. No. 1.

GREETING.

With this number the Wisconsin Engineer comes out for its trial trip in the field of technical journalism. While, as with any new mechanism, alterations and readjustments will no doubt be found desirable, the assistance and words of encouragement received on every hand during the preparation of this number, have led us to hope for a genial reception and an interested and friendly inspection.

It has for some time been the desire of many students and alumni of the College of Mechanics and Engineering that they might have a representative among the periodicals issued by technical schools of the country; and that, if possible, they might take, as an institution, some more active part in the dissemination of engineering knowledge and experience. It is the aim of this journal to fill that want in so far as it may be able. It is desired more especially to make known the results of original investigations by students and others connected with the University and to publish communications of general interest from graduates who are engaged in the practice of their profession. From time to time will appear short notices of matters of unusual interest connected with the University, and space will also be allotted to alumni notes. Let it not be understood from this that our pages will be restricted entirely to the use of those connected with the University. Articles of merit will be gladly received from any who may see fit to contribute. A general index to periodical engineering literature is designed to be a special feature of the magazine. Our reasons for undertaking this work will be given more in detail in the introduction to that department.

The loyalty of our alumni and students to "Old Wisconsin" is proverbial and it is hoped that this publication may still further strengthen the feeling of brotherhood among them and prove a source of mutual benefit, while at the same time contributing something of interest to the profession at large.

APPROXIMATE METHODS FOR THE RAPID DETERMINATION OF AZIMUTH, LATITUDE AND TIME.

BY GEORGE C. COMSTOCK,

Professor of Astronomy and Director of Washburn Observatory.

The text books contain in sufficient abundance methods for the determination of latitude, time and the direction of the meridian with more than sufficient precision for the purposes of the engineer, but these methods are, as a rule, too laborious and too slow for use when economy of time is a consideration of prime importance. Methods for the practice of field astronomy which require no other apparatus than that ordinarily carried by the engineer and which involve no tedious logarithmic computations are among the desiderata of the profession and the tables which constitute the essential part of this paper are offered as a partial satisfaction of these requirements. For the determination of latitude and the direction of the meridian they presuppose no other apparatus than a properly adjusted transit and a watch regulated to local (mean solar) time. For the determination of time a Nautical Almanac is required, but the determination of time is usually made for purposes that otherwise require the use of the Almanac.

The argument of the tables, t, is the hour-angle of the pole-star and the tabulated quantities a and b are respectively the difference of azimuth and altitude between the pole of the heavens and the pole-star as seen from a place in 40° north latitude. An auxiliary table furnishes the means of adapting these quantities to any other latitude within the limits of the United States through the formulæ

$$A = 180° + Fa \qquad h = \varphi - b$$

where A denotes the azimuth of the star reckoned from south through west, h is its apparent altitude (including the effect of the refraction) and φ is the latitude of the place of observation.

The quantities a and b must be interpolated from the table for the time at which the observation was made, and to obtain the value of t corresponding to this time we note that an ordinary watch regulated to local time shows upon its dial at every moment the hour-angle of the mean sun. The hour-angle of the star is therefore equal to the time shown by the watch, plus the difference of right ascension of the star and sun, and as this difference increases with approximate uniformity at the rate of a little less than four minutes per day, we may put

$$t = W + 4^m (D - E)\ (1 - 0.015)$$

where W is the time by the watch, D is the date of observation and E is the epoch at which sun and star have the same right ascension. In consequence of the periodic recurrence of leap year in our calendar and of a number of minor causes which need not be specified, this epoch varies slightly from year to year, but it may be found with sufficient precision from the formula

$$E = \text{April } 11.8 + 0^d.35\ (T - 1900) - B$$

where T denotes the year for which E is required and B is the number of Feb. 29ths which have fallen in the interval from 1900 to the date of observation. A table of epochs computed from this formula to the nearest tenth of a day, is given below.

Owing to the motion of the pole of the heavens the quantities a and b change slowly with the lapse of time and their tabular values are strictly correct only for the year 1900. They may, however, be reduced to any other date within twenty years of 1900 by increasing the tabular quantity by one-half of one per cent. of itself for each year prior to 1900 or diminishing it by a like amount for each year subsequent to 1900. We shall represent these reduced values by a' and b' and shall then have the following formulæ and tables in which a and b are expressed in minutes of arc:

$$t = W + 4^m \left\{ Date - Epoch \right\} \left(1 - 0.015 \right)$$

t		a				b			t
h		′				′			
0	−	0	+		−	75	−		24
				25				3	
1	−	25	+		−	72	−		23
				24				7	
2	−	49	+		−	65	−		22
				20				12	
3	−	69	+		−	53	−		21
				15				16	
4	−	84	+		−	37	−		20
				9				18	
5	−	93	+		−	19	−		19
				3				19	
6	−	96	+		−	0	+		18
				4				19	
7	−	92	+		+	19	+		17
				10				17	
8	−	82	+		+	36	+		16
				15				15	
9	−		+		+	51	+		15
				20				12	
10	−	47	+		+	63	+		14
				23				7	
11	−	4	+		+	70	+		13
				24				3	
12	−	0	+		+	73	+		12

Setting $= 180° + Fa'$ *Latitude* $= h + b'$

φ	F	
°		
25	0.85	
		4
30	0.89	
		5
35	0.94	
		6
40	1.00	
		8
45	1.08	
		1
50	1.19	

Epoch			Epoch		
1896	Apr.	10.4	1901	Apr.	12.1
1897	"	10.8	1902	"	12.5
1898	"	11.2	1903	"	12.9
1899	"	11.5	1904	"	12.2
1900	"	11.8	1905	"	

An observation for azimuth or latitude is conveniently made as follows: Let the transit be levelled and let the observer compute in advance for some particular hour and minute by the watch the values of b' and Fa'. Set the horizontal circle to read $180° + Fa'$ and at the chosen hour and minute bring the star behind the intersection of the cross wires, using the lower motion of the instrument in azimuth so that the circle reading shall not be changed. The latitude is now given by the reading of the vertical circle, $\varphi = h + b'$, and the azimuth of any point toward which the line of sight may be directed will be given immediately by the reading of the horizontal circle.

If the latitude is approximately known it will often facilitate finding the star in the twilight to set the vertical circle to read the star's altitude, $h = \varphi - b'$, and looking into the telescope to turn the instrument *slowly* in azimuth until the star appears in the field.

An instrument whose horizontal circle has been adjusted to read true azimuths is said to be oriented. After the instrument has been oriented, if its verniers be made to read zero, the line of sight will lie in the meridian and time may be determined by noting the instant by the watch, T, at which any star of known right ascension, α, passes behind the vertical wire. The correction of the watch, referred to sidereal time, is given by the formula

$$\Delta T = \alpha - T$$

in which α will usually be obtained from the Nautical Almanac. For the determination of time by this method a star should be chosen which culminates south of the zenith and at as great an altitude as can conveniently be observed with the transit. To find the star set the telescope to an altitude equal to the declination of the star plus the complement of the latitude of the place and await its appearance in the telescope at the time

$$\alpha - \left[\alpha_0 + 4^m (D-E) (1-0.015)\right]$$

where α is the right ascension of the star and α_0 is the right ascension of Polaris.

Precision of the Result. If the error of the watch does not exceed two minutes the observation for azimuth or latitude may be made at any time when the pole-star is visible and the error of the result, due to the approximate character of the tables, will not much exceed one minute of arc in the most unfavorable case. If the watch can not be depended upon to within two minutes the same degree of precision, 1′, may be obtained by so timing the observations that the argument, t, shall fall at a part of the table where the tabular differences are small. The accuracy with which the time is determined depends mainly upon the accuracy of orienting the transit, but in general the value of ΔT may be relied upon to within five seconds or less, and this is sufficiently precise for the reduction of any azimuth observations made with an engineer's transit upon a circum-polar star within one hour of elongation

Note.—The date which appears in the formula for t is expressed according to the astronomical usage and changes from one day to the next at noon instead of midnight. For an observation made in the morning hours therefore the date must be that of the preceding day, civil reckoning, and the time by the watch must be increased 12 hours. Values of t greater than 12 hours are given at the right side of the table, and it may be seen that the sign of a is + for these values and – for those less than 12 hours.

Example.—The following observations intended to illustrate the use of the tables, were taken with a well adjusted transit and a watch assumed to be approximately correct. In interpolating the value of F from the auxiliary table the latitude was assumed to be 43°.

1896, May 17. Evening.

Date	May	17.3		F	1.05
Epoch	Apr.	10.4		$F a'$	−0°47′
Interval		36.9 *days*		b'	+1 5
x 4*m*		147.6*m*		*Setting*	179 13
Less 0.015		2*h* 25.4*m*		h	42 0
W		7 42.6		φ	43 5
t		10 8.0		*To mark*	187 54

Instrument set to read 0° 0′ and transit of β Leonis observed

T	7*h*	59*m*	13*s*	
α	11	43	48	(American Ephemeris)
ΔT	+3	45	35	(Sidereal)

The setting 179°13′ was computed in the five minutes which precede $7^h\ 42^m$ and the instrument set to this reading and directed toward Polaris at $7^h\ 42.6^m$. The reading of the vertical circle, h, gives the latitude and a subsequent reading to a terrestrial mark gives for its azimuth 187° 54′. The true latitude of the instrument was 43° 4′ 37″, and the true azimuth of the mark was 187° 54′ 10″. A comparison of the watch with the standard clock of the Washburn Observatory, made immediately after the observations, gave as its true correction to sidereal time $+ 3^h 45^m 35.5^s$.

It may be noted that the whole determination of azimuth, latitude and time above given occupied about thirty minutes, a considerable part of which was spent in waiting for a suitable time star after the instrument had been oriented. The determination of the azimuth of the mark was completed within ten minutes from the time the instrument was levelled.

STORAGE BATTERY AUXILIARIES FOR RAILWAY POWER STATIONS.*

W. H. WILLIAMS, '96.

The question of storage batteries as central station auxiliaries has been largely discussed in America during the past year. The discussions have been practical because they have given the results of experience instead of theory. European central stations have been successfully using them for several years, in fact there is scarcely a direct current central station of any importance in Europe without its accumulator plant. On the contrary, American engineers have been so prejudiced against them that it is only recently that any of them could be induced to even consider them. A large part of this prejudice is due to the abuse of the batteries. In the early attempts to use them they were frequently overtaxed and injured, and then discarded because they would not stand up under strains for which they were never intended. The manufacturers were in part responsible for this; for until recently their sole object has been to obtain the largest possible output per pound of plate, resulting in weak plates. Experience has taught them, however, that except for special service, mechanical stability rather than lightness is to be desired. As a result, strong, heavy plates are now more generally used, and batteries for the most severe service have become a possibility. For heavy work we are accustomed to build extra strong machinery, and the same rule should apply to storage batteries. The heavy

*A dissertation prepared for the class in Electrical Railways; read April 14, 1896.

machine costs more than the light one, but in the end is more economical.

Another singular thing in the storage battery development is that after years of effort to make a pasted plate superior to the Planté, the opinion is becoming general that in spite of its higher cost the Planté is by far the best, especially for the positive plate. The defects of pasted plates are loss of active material, short-circuiting, buckling and sulphating. A plate formed of a grid filled with active material must necessarily produce unequal action, either of the active material or the supporting frame. Due to this inevitable lack of homogeneity, some parts of the plate will contribute more to the discharge than others, with the result that at the end of a useful discharge no two parts of the same plate nor any two plates, will be in the same electrical or chemical condition. Again, due to the unequal expansion and contraction during charge and discharge, due to the different density and expansibility of the materials, something must give way—either the grid or the active material. Now where the active material is in such large units, perfect circulation and action of the electrolyte is also impossible and more or less sulphating results. Mr. Carl Hering recently stated that the ideal method would seem to be a vertical lead plate to act as a good conductor, with an extremely large surface, and a thin layer of peroxide on it, thoroughly exposed to a large quantity of acid which is capable of circulating freely. Now in the formed plate the active material blends gradually with the original substance of the lead itself, insuring the most perfect contact. This active material not only covers the surface but enters into the plate by minute roots, making a thin layer of the peroxide, thoroughly attached, and bathed on all sides by the electrolyte, thus ensuring uniform action upon every particle of the active material and thereby preventing sulphating. As these formed plates are nearly always grooved they present a large surface, and as the active material does not fill the grooves, buckling is prevented. The ideal plate then seems to be the Planté as it is now made by several responsible firms. Moreover, the ideal cell seems to have come from a union of these two types, and several of the most successful recent installations have consisted of Planté positives and Chloride negatives.

The recent discussion has seemed to show beyond a doubt that accumulators introduce marked economies and regulation in central station operation. The large and successful experience of the Boston Edison Co., the recent large installation of the New York Edison Co., and the installation of several smaller auxiliary plants, seems to show that the worth of the storage battery is beginning to be recognized in America.

The question naturally arises, if the storage battery adjunct is a good thing for a lighting station, why would it not be even more useful in a railway power station? A storage battery acts as a buffer between the external load and the dynamo, taking the shock of the variations without throwing it on the engines, thereby reducing the average variation in load to a small amount and making the machines more efficient. It is thus a most excellent regulator and maintains a nearly constant voltage at the switchboard. It also serves as a reservoir of energy, receiving energy when the load is below the normal and giving it out again when the load is above. In no class of electrical work is a regulator more necessary than in the operation of street railways. The variations in load, as every one knows, are enormous, frequently going, in the smaller stations, from friction load to full load in two or three seconds. Here then is a most excellent field for accumulators. The question is, can they satisfactorily meet the conditions?

There may be said to be three requisites for a railway power station,—reliability and certainty of operation, constancy of speed, and economy. The first is by far the most important; and so the street railway engineer will ask at once, "Can storage batteries stand the heavy discharges they will be subjected to in such work?" Perhaps the best answer to this question is to cite what they are now doing. The first set of accumulators in the Boston Edison Station was guaranteed to deliver 1,600 amperes on each side of the three wire system for 1 1-2 hours; and Mr. Edgar, their chief engineer, says they can readily deliver 4,800 amperes for 15 or 20 minutes if necessary. This battery was installed in 1893 and gave such satisfactory results that another battery of double the size was installed a year ago. A battery of 2,000 ampere hours' capacity was installed for the Germantown, Pa., Electric Light Co. in 1893, and has frequently been discharged at four times its normal rate, and has in case of accident carried the entire station load during the heaviest part of the evening, without injurious results. A battery of 240 cells was installed in Janaury, 1895, for the Merrill Light & Railway Co. The normal discharge rate is 50 amperes, but it has been used alone to operate the railway for a day at a time, during which the discharge frequently rose to 120 amperes, and the company reports no injury therefrom. The St. Denis Tramway Co. of Paris has been operating about 30 accumulator cars for the last four years. The cars are heavy, double-deckers, and the grades and curves of the two lines are unusually severe; yet the success and economy has been such that there is a probability that all the horse cars of Paris will soon be replaced by this system.

For station batteries, where space is not so valuable and weight no detriment, the plates can be made so large and strong that enormous overdrafts are possible, and buckling and short-circuiting well nigh impossible. The storage battery companies now stand ready to build and guarantee batteries for almost any conditions of service, provided the purchaser is ready to pay the requisite cost. We may conclude then that storage batteries as now made are fully as reliable as any of the generating apparatus of a power station.

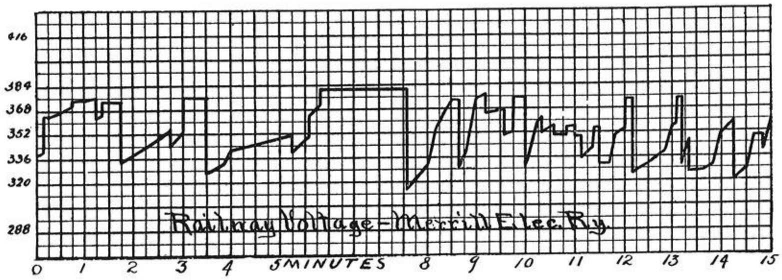

FIG. 1.—Generator alone.

As speed regulators, storage batteries are the only means of securing anything like constant voltage in a railway power station. They thus render possible the satisfactory use of turbines for operating small electric railways. The accompanying pressure curves taken from the Merrill station, show the regulation of a turbine driven railway generator operating only two cars. However, in a railway station variations of voltage, within reasonable limits, is not so vital a matter as it is in a lighting station. The principal value of the storage battery as a regulator is in furnishing a steadier, more economical load and thus raising the plant efficiency.

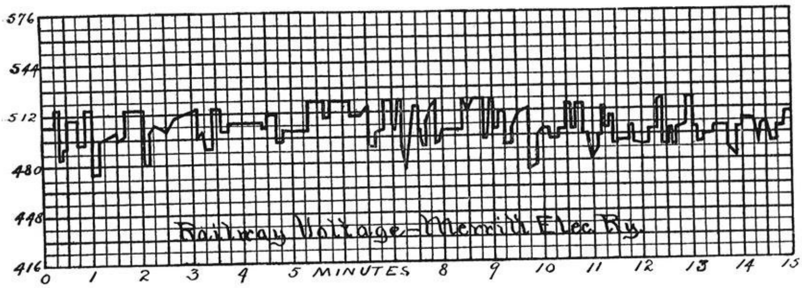

FIG. 2.— Generator and battery in parallel.

The question of economy of operation will therefore decide if accumulators are of value in a railway station. In the smaller of such stations the engines are, as a rule, worked at about half their rated capacity. This comes from the necessity of installing and operating engines twice as large as necessary for the average load in order to meet the enormous demands that may come at any moment, often amounting to more than double the average load. The test of the Madison plant last year showed seven cards of over 200 I. H. P. and one of 248, the rated capacity of the engine being 190 H. P. and the average load 117.5. The engines are therefore operated far below their economical load. Further it is a recognized fact that the economy of an engine, under the great fluctuations of load incident to a small power station is less than it would be under the same average steady load. There is little exact data upon this subject, but Prof. Unwin, as the result of some experiments, concludes that an engine working on a load varying rapidly between 25 per cent. and 100 per cent. falls in economy from 8.5 per cent. to 40 per cent. To be a little more exact for this particular class of work I have collected the following data:

TABLE I.—*Economy Tests of Seven Electric Railway Plants.**

No.	Date.	Place.	No. and Kind of Engine.	Total I. H. P. of Engines.	Average I. H P. Developed.	Average E. H. P.	Lbs. Steam per I. H. P. hr.	Lbs. Coal per I. H. P. hr.
1	1895	Madison, Wis..	1 Tand. Comp. Cond., Russell........	190	117.5	92.76	28.69	5.35
2	1891	Utica, N. Y....	2 Tand. Comp. Cond., A. & S..... ...	400	190.5	154.33	21.72	4.5
3	1894	Detroit.........	1 Tand. Comp. Cond., Phoenix........	150	70.1	45.	24.55	....
4	1895	Cortland, N. Y.	1 Tand. Comp. Cond., Watertown....	175	60.4	48.	27.4	5.2
5	1893	Hamilton, Ont.	3 Tand. Comp. Cond., G. McC. & Co..	820	482.6	362.1	22.68	3.13
6	1894	Auburn, N. Y..	1 Tand. Comp. Cond., McI. & S......	215	80.	63.04	27.34	3.19
7	1894	Ithaca, N. Y....	1 Tand. Comp. Cond., McEwen.......	350	161.2	......	22.67	....
			Totals............................	2300	1162.3	......	......	....
			Averages.........................	....	......	......	23.43	

*1. Thesis of Burgess, Crane, Frankenfield and Mead, 1895.
2. Electrical World, 1891.
3. Transactions A. S. M. E. Vol. 15.
4. Cassier's Magazine, February, 1896.
5. Sibley Journal of Engineering. Vol. 8.
6. Sibley Journal of Engineering. Vol. 9.
7. Sibley Journal of Engineering. Vol. 9.

TABLE 2.—*Economy Test of Five Engines on Steady Loads.**

No.	Date.	Place.	No. and Kind of Engine.	Rated H. P. of Engines.	Average I. H. P. Developed.	Lbs. Steam per I. H. P. hr.	Lbs. Coal per I. H. P. hr.
1	1893	Ridgeway, Pa....	1 Tand. Comp. Cond., McEwen.........	100	95.1	19.1	....
2	......	Pittsburg.........	1 Tand. Comp. Cond., Westinghouse...	130	140.	17.1	....
3	1890	Albion, Mich.....	1 Tand. Comp. Cond., Lansing..........	100	95.47	18.77	3.05
4	1890	Lansing, Mich...	2 Tand. Comp. Cond., Lansing..........	250	228.12	16.57	....
			Totals	580	558.69	......	....
			Averages.........................	.. .	......	17.59	....

*1. Transactions A. S. M. E. Vol. 14.
2. Westinghouse circular.
3-4. Transactions A. S. M. E. Vol. 11.

It should be noted that these engines were all of the same class, and that the last five were considerably smaller than the railway engines. The railway engines working, on an average, at half load used 23.43 lbs. of dry steam per I. H. P. hour, while the average of those on steady, nearly full load, is 17.59 lbs. From a large number of tests, of which these last four were a part, Prof. Carpenter gives the following as the water consumption on various steady loads for this same class of engines, in lbs. of dry steam per I. H. P. hour: 1-4 load, 26.7 lbs.; 1-2 load, 21.3 lbs.; 3-4 load, 18.9 lbs.; full load, 17.5 lbs.; 5-4 load, 18.6 lbs. The last five engines practically verify the full load rate; but the railway engines instead of using 21.3 lbs. per I. H. P. hour, used 23.43 lbs. or 2.13 lbs. per horse power hour more than they would have used on the same average steady load.

It is therefore evident that a station with 1-3 or 1-2 its power equipment in accumulators, thus allowing the engines to be worked at their most economical load, would save nearly 6 lbs. of steam per horse power hour of output, which for a station operating 30 cars would mean a saving of about three tons of al daily. It may be said that this is not a net saving since the efficiency of the batteries is less than that of the generators. The watt efficiency of the batteries would be from 80 to 84 per cent., and considering the facts that the generators worked at full load would have 3 to 5 per cent. higher efficiency, while the accumulators would not be in active service more than one-third of the time, it seems fair to assume that the losses in the accumulators would be compensated by the increased efficiency of the generators. Therefore whatever savings are made in the operation of the steam plant are clear gains, provided the first cost of the batteries is no greater than that of the steam plant which they take the place of. In fair sized plants a horse power of accumulators can be installed for the same cost as a horse power of steam, while for large equipments of triple expansion engines such as are used by the Boston, New York, and Chicago Edison companies, it has been found that the batteries cost 23 to 30 per cent. less than a steam plant of the same capacity.

Formerly the rapid depreciation of accumulators was one of the greatest objections to their use; but with present methods of manufacture their rate of depreciation is no higher than that of the average generating plant. As evidence of this, makers of storage batteries are now offering to enter into contracts with purchasers to keep the batteries in repair for from 4 per cent. to 6 per cent. annually on their cost.

As an example of the economy of a combined steam and storage battery station for electric railway purposes, the following data is taken from The Electrotechnische Zeitschrift of June 28, 1894, regarding the plant at Zurich, Switzerland. The dynamos are shunt wound, and in parallel with them is a battery of 300 cells having a normal discharge rate of 81 amperes and a possible discharge of 243. Part of the cells are charged from a small auxiliary dynamo, and are cut in or out as the occasion demands. The road is 2.8 miles long and has only 233 yds. of level track. The maximum grade is 6.48 per cent. The maximum number of cars used is 9, and their weight, loaded, 12,210 lbs. Cars are operated on 6 min. headway for 12 hrs. 54 min. and on 12 min. headway for 1 hr. 54 min. The total daily output is about 907 brake horse power hours, and as 2,960 lbs. of coal is consumed it is 3.3 lbs. per B. H. P. hour. Where no accumulators are used it is 5.5 lbs., so the daily saving is 2,000 lbs. of coal, equal to $2,580 yearly. The battery and switch apparatus cost complete, $7,400, so that 1-3 of this is saved yearly in coal. Allowing 5 per cent. for sinking fund and 5 per cent. for repairs, the battery pays for itself in coal savings in four years. This is an exceptionally favorable case, since at Zurich coal is high and batteries cheap. The cost of batteries in America is 40 per cent. to 50 per cent. higher than in Europe, partly because crude lead is higher and partly because of the desire of American manufacturers for too large profits. But still their cost is low enough so that they can be introduced with economy into many of the smaller street railway stations in case of the enlargement or construction of a new plant.

In order to ascertain the customary equipment of power stations in the smaller American cities the following data has been obtained largely through direct correspondence:

TABLE 3.—*Equipment of Railway Power Stations.*

Data from thirteen American cities of less than 35,000 population.

Place.	H. P. of Boilers.	I. H. P. of Engines.	Kind of Engines.	No. of Cars. Max.	No. of Cars. Usual.	H. P. Engines per Car. (Max.)	K. W. of Generators.	K. W. of Generators per car.	Miles track.
Aurora, Ill........	1000	875	3 Simple H. S..... 2 Comp. Cond. H. S	32	15	27	400	13	18
Superior, Wis.....	450	700	Simple, Corliss......	29	15	24	620	21.3	26
Bay City	660	700	Simple, Corliss......	30	20	23.3	510	17	25
Sioux City	400	400	Simple, Corliss......	20	20	20	320	16	20
Youngstown, O....	500	750	Simple, Corliss......	26	22	29	600	23	23
Jamestown, N. Y..	650	950	Comp. Cond. H. S....	42	18	22.6	840	20	20
Wheeling, W. Va..	525	750	Comp. Non-Cond. H. S	25	20	30	560	22.4	16
Terre Haute.......	450	600	Comp. Non-Cond.....	28	22	21.4	450	16.1	22
Anderson, Ind.....	320	250	Simple, Corliss......	10	8	25	200	20	11
Galesburg, Ill.....	200	250	Comp. Non-Cond. H. S	10	6	25	160	16	8
Cortland, N. Y....	200	350	Comp. Cond. H. S....	10	6	35	200	20	10
Auburn, N. Y......	150	215	Comp. Cond. H. S....	10	6	21.5	187.5	18.75	56
Madison, Wis.....	120	190	Comp. Cond. H. S....	9	8	21.1	180	20	......
Averages..........						25	....	19	

The average equipment is seen to be 25 I. H. P. of engines to each car (taking the maximum number of cars), and about 19 K. W. of generators.

The actual average power necessary to operate an ordinary single truck car cannot be fixed with much certainty, since the grades and the kind of track make such material differences. On roads with grooved rails the power used is considerably more than if the rail is a T, or side-bearing girder. On roads with average grades and curves, and either T or side-bearing girder rails, and good track construction, the following data of actual tests gives a fair idea of the necessary power required at the station:

TABLE 4.—*Power Required in Station to Operate a Single Truck Car.*

Data from Station Tests.

No.	Place.	No. Cars in Operation.	Max. I. H. P.	Aver. I. H. P.	Max. E. H. P.	Aver. E. H. P.	Max. Amp.	Aver. Amp.	Aver. I. H. P. per car.	Aver. E. H. P. per car.
1	Madison, Wis.	8	248	117.5	130	92.76	194	140	14.69	11.59
2	Utica, N. Y.	20	......	190.53	......	154.33	....	....	9.52	7.72
3	Wyandott & Detroit Riv.	3	141	70	90.27	45	200	67	24.25	15.54
4	Syracuse, N. Y.	7	......	51.4	......	33.5	....	50	7.34	7.8
5	Cortland, N. Y.	6	......	60.4	......	48	....	....	10.66	8
6	Auburn, N. Y.	6	......	80	......	63.04	....	....	13.33	10.5
	Averages								13.3	10.19

The average I. H. P. per car, to be developed in the station, appears from the above to be 13.3. The actual power required to propel a single car is more than this, varying from 11.38 E. H. P. to 24 in the tests recently made by Mr. Hering on the Baltimore roads, but being in the majority of cases about 15 E. H. P. The fact that not all the cars are in operation at the same time reduces the power required at the station. In suburban work where stops are few the station power required is more nearly the sum of the power taken by the several cars, as is seen in (3) Table 4. The same would be true of a city road,—the greater the number of cars, the more nearly the average station power would be to the maximum, and the fluctuations would be less. It seems safe to assume then that the average station operating 12 to 30 cars would not develop more than an average of 15 I. H. P. per car.

In order to exhibit clearly the economy, if any, of a combined steam and storage power station, I have prepared estimates of the first cost and operating expenses, by both methods, of two stations of different sizes, within the limits of which fully one-third of all American stations are found. The size of the equipment is based on Table 3. Depreciation can be fairly assumed, as already shown, to be at the same rate for the combined as for the all steam plant. It is evident that the labor expense of either would be the same, and also real estate. Somewhat more floor space would probably be required for the combined plant, and hence a larger building or an additional one. The only variables are, therefore, building, interest, taxes, depreciation, and the cost of fuel. The working load is assumed as 15 I. H. P. per car, for the usual number of cars. The maximum number of cars are usually operated but a few hours at a time, at intervals of several days, and there is none of the generating apparatus that could not easily stand an overload of 25 per cent. for the hours during which the maximum number of cars were operated. The data for the cost of steam plant is largely taken from a recent article by Prof. Carpenter in Cassier's Magazine for February, 1896; the cost of generators, switchboards, and batteries has been taken, in most cases, from those of recent installations and is believed to be reliable. The efficiency of the engines at full load is taken at 17.5 lbs. steam per I. H. P. hour., according to Prof. Carpenter; the efficiency at half load, rapidly varying, at 23.43 lbs. from Table I. Taking an average evaporation of 7 lbs. of water per lb. of coal, we have the coal used in the first case 2.5 lbs. per I. H. P. hour, and in the second 3.347 lbs. Eighteen hours is taken as the daily run.

ESTIMATE "A."

PLANT FOR A MAXIMUM OF 30 CARS—USUAL NUMBER, 25.

Direct Connected Units—Without Storage.

STEAM PLANT.—750 I. H-P. Tandem-Compound, Condensing, H. S. Engines and 450 H-P. Tubular Boilers, with condensers, feed pumps, heaters, and piping, set and connected	$25,200 00
570 K-W. Direct Connected Generators, with Switchboard and instruments, set and connected	21,700 00
Total cost, Generating Plant	$46,900 00

*OPERATING EXPENSES.

Interest, insurance and taxes, 10 per cent.; depreciation, 5 per cent., total 15 per cent	$7,035 00
18 hrs. x 15 x 25 x 365=2,465,000 H-P. hrs. yearly output. 2,465,000 x 3.347 lbs.=8,250,355 lbs. coal=4,125.17 tons, at $2.00	8,250 35
Yearly operating expenses, coal $2.00	$15,285 35
For coal at $3.00 add	4,125 17
Yearly operating expenses, coal $3.00	$19.410 52

*Other operating expenses the same for each.

SAME PLANT — WITH STORAGE.

STEAM PLANT.—375 I. H-P. Tandem-Compound, Condensing, H. S. Engines, and 225 H-P. Tubular Boilers, with condensers, feed pumps, heaters, and piping, set and connected	$13,335 00
300 K-W. Direct Connected Generators, with Switchboard and instruments, set and connected	11,700 00
250 Cells, 1,350 amp. hrs. cap. at 320 amp. (possible discharge rate, 640 amp.) including acid and necessary switching apparatus, complete.	23,000 00
Extra room and cost of setting up batteries	2,500 00
Total cost, Generating Plant	$50,535 00

*OPERATING EXPENSES.

Interest, insurance, taxes, and depreciation, 15 per cent	$7,580 25
2,465,000 x 2.5 lbs.=6,162,500 lbs. coal=3,081.25 tons, at $2.00	6,162 50
Yearly operating expenses, coal $2.00	$13,742 75
For coal at $3.00 add	3,081 25
Yearly operating expenses, coal $3.00	$16,823 00
YEARLY SAVING with combined plant, coal at $2.00	$1,542 60
YEARLY SAVING with combined plant, coal at $3.00	2,587 52

In order to insure reliability of service, no plant should have less than two generating units, and three is better. For this reason the combined plant in the following estimate is made up of 2-3 steam and 1-3 storage. This allows two generating units of 100 H. P. each, which, however, will only work ordinarily at 3-4 load. Their efficiency will therefore be 18.9 lbs. steam per horse power hour, and their coal consumption 2.7 lbs. per horse power hour.

ESTIMATE "B."

PLANT FOR A MAXIMUM OF 12 CARS—USUAL NUMBER, 10.

Belted Generators—Without Storage.

STEAM PLANT.—300 I. H-P. Tandem-Compound, Condensing, H. S. Engines, and 180 H-P. Tubular Boilers, with condensers, feed pumps, heaters, and piping, set and connected	$11,070 00
225 K-W. Belted Generators, with Belting, Switchboard and instruments, set and connected	6,200 00
Total cost, Generating Plant	$17,270 00

*Other operating expenses the same for each.

* OPERATING EXPENSES.

Interest, insurance and taxes, 10 per cent.; depreciation 5 per cent., total 15 per cent	$2,590 50
18 hrs. x 15 x 10 x 365=985,500 H-P. hrs. yearly output. 985,500 x 3.347 lbs.=3,298,468 lbs. coal=1,649.23 tons, at $2.00	3,298 46
Yearly operating expenses, coal $2.00	$5,888 96
For coal at $3.00 add	1,649 23
Yearly operating expenses, coal $3.00	$7,538 19

SAME PLANT—WITH STORAGE.

STEAM PLANT.—200 I. H-P. Tandem-Compound, Condensing, H. S. Engines, and 120 H-P. Tubular Boilers, with condensers, feed pumps, and piping, set and connected	$7,600 00
150 K-W. Belted Generators, with Belting, Switchboard and instruments, set and connected	4,400 00
250 Cells, 500 amp. hrs. capacity at 120 amp. (possible discharge rate, 240 amp.) including acid and necessary switching apparatus complete	9,300 00
Extra room and cost of setting up batteries	1,400 00
Total cost, Generating Plant	$22,700 00

* OPERATING EXPENSES.

Interest, insurance, taxes, and depreciation, 15 per cent	$3,405 00
985,500 x 2.7 lbs.=2,660,850 lbs. coal=1,330.04 tons at $2.00	2,660 85
Yearly operating expenses, coal $2.00	$6,065 85
For coal at $3.00 add	1,330 40
Yearly operating expenses, coal $3.00	7,396 25
YEARLY LOSS with combined plant, coal at $2.00	$176 85
YEARLY SAVING with combined plant, coal at $3.00	142 00

The estimates for the larger plant show a very decided economy in favor of the combined plant. But for the small plant just given, the comparatively large cost of the accumulators and the fact that the engines cannot work at their most economical load neutralize any gains that might otherwise be made, and the combined plant shows practically no economy over the steam. For a little larger plant,—large enough to use half steam and half storage without making the generating units too small,—say one running ordinarily 13 cars, with a maximum of 16,—for such a

*Other operating expenses the same for each.

station a combined plant would show a yearly saving of $300 to $1,000, depending on the price of coal.

Either of these combined plants would give just as reliable service as the all steam plant, and practically perfect speed regulation. For the safety of the station they would be preferable, as the batteries would relieve the engines of any sudden shocks and practically make fly-wheel accidents impossible.

Storage battery sub-stations would also be economical auxiliaries in some cases. It frequently happens that the power station, for various reasons, must be placed a long distance from the electrical center of the system, thus making necessary a large outlay in copper for feeding districts where traffic is exceptionally heavy. There are undoubtedly cases of this kind where a storage battery sub-station could be put in for the cost of the copper it would save, and greatly improve the operation of the line. This case might also arise on a long suburban line where the traffic is heavy.

The conclusions to be drawn are:

First.—In constructing medium sized new plants or remodeling and enlarging old ones, whenever more than 15 cars are to be provided for it would probably be economy to put in about half the power in accumulators. There would probably be no economy in placing storage batteries in large stations where the load is practically constant, and the engines are enabled to work at an economical point.

Second.—A storage battery plant in a station operating 30 cars would pay for itself in coal savings in 10 years where coal is $3, and in 16 years where coal is $2.

Third.—Many small plants could be satisfactorily driven from available water powers, by installing storage batteries to serve as regulators. In many cases they could store up and make available power which would otherwise be wasted while the cars were idle.

Fourth.—In feeding long lines, or distant traffic centers where it is difficult to maintain the pressure, storage battery sub-stations would in many cases prove economical.

Fifth.—The present cost of accumulators is one of the greatest hindrances to their more extended use.

THE THEORY OF ENERGY IN HYDRAULICS.

By L. M. HOSKINS, '83; M. S. '85; C. E. '87.

Professor of Theoretical and Applied Mechanics, Leland Stanford, Jr., University.

In text books on theoretical mechanics the theory of energy usually receives inadequate treatment. As a rule, little attempt is made to develop the theory logically from fundamental principles and definitions, while inconsistencies in the use of terms are often found which cannot fail to be confusing to the student. A like confusion is found in many works on applied mechanics, in the application of the theory of energy to practical problems. A reform in this matter is highly desirable in the interest of students, and is well worthy the attention of writers of text books. The following discussion is directed, not to the general subject here suggested, but to the application of the theory of energy in the single department of hydraulics.

The usual analysis of the transformations of energy in the flow of water is often perplexing to the student, since it seems to require an important departure from the conception of energy as applied in the mechanics of solid bodies. Writers commonly recognize in addition to potential and kinetic energy, a third form called pressure energy. Thus, in case of a stream of water in a condition of steady flow, any particle of water is said to possess energy by virtue of its mass and velocity (kinetic), by virtue of its weight and height above a horizontal reference plane (potential), and by virtue of the pressure to which it is subjected (pressure energy). As the particle moves with the stream, its velocity or its elevation may change, involving a loss or gain of its kinetic or potential energy; if the pressure also changes there is a gain or loss of the third kind of energy.

Consider the simple case of water flowing from a reservoir through a pipe, whose cross-section and elevation may be variable, and discharging into the air. To simplify the discussion, let it be assumed at first that there is no loss of energy by dissipation into heat, due to friction, impact among particles, or other cause, and that the velocity is the same at all points of any given cross-section. On this assumption it is well known that the following equation is satisfied:

$$z + \frac{p}{w} + \frac{v^2}{2g} = H = \text{constant}, \ldots\ldots\ldots\ldots (1).$$

in which *v*, *p*, and *z* denote the velocity, pressure per unit area, and height above an assumed horizontal datum plane, of the particles in any cross-section; and *w* is the weight of unit volume of the water.

Let the equation be multiplied through by W, which is taken to represent the weight of any particle of the water, giving

$$Wz + W\left(\frac{p}{w}\right) + \frac{Wv^2}{2g} = WH = \text{Const.}$$

Of the three terms in the first member of this equation, two represent energy; Wz is the potential energy of the particle due to its weight and elevation above the assumed datum, and $\frac{Wv^2}{2g}$ is its kinetic energy. The remaining term $\frac{Wp}{w}$ is commonly said to represent the energy possessed by the particle in the form of pressure; and the equation is interpreted as equivalent to the proposition that the total energy of any particle of water remains constant during the flow. Thus if B and C are any two successive cross-sections, and if the area of cross-section is greater at C than at B, while the elevation of the pipe decreases from B to C, the kinetic energy and the potential energy of the particle both decrease as it passes from B to C; but since the pressure must increase correspondingly in accordance with the above equation, it is said that the particle gains as much pressure-energy as it loses of the other two forces.

A careful analysis shows that this is an erroneous use of the term energy, if the word is to retain its ordinary meaning. A body possesses energy when its conditon is such that it can do work against external forces. This is the accepted meaning of the term, and to this use it should be confined. Now it seems clear that a body of incompressible fluid cannot do work simply by virtue of being under pressure. If water were perfectly incompressible, a volume of it confined in a cylinder by means of a piston could be subjected to a pressure of any intensity whatever without the performance of any work upon it. And conversely, it could do no work on the piston when the pressure was released.*

The term $\frac{W}{w}p$ cannot therefore properly be considered as representing the energy of the particle of water in question, and it is not true that the total energy of a particle remains constant during the flow. The total energy of a particle is in fact given by the sum of the two terms Wz and $\frac{W\,v^2}{2g}$; and what the general equation states is that as a particle loses energy its pressure increases correspondingly. If the whole body of water is considered, its total energy remains constant unless it is imparted to some external body or system; but there is a continual interchange of energy among the individual particles.

A stream of water confined in a pipe acts as a transmitter of energy, just as a belt transmits energy from one pulley to another; and the pressure at any point in the stream shows the rate at which energy is transmitted by the particles at that point, just as the energy transmitted by a belt is proportional to the tension it sustains. To make the statement definite, it may be said that the term $\frac{p}{w}$ in the general equation means the energy transmitted (by pressure) across the given section per unit weight of water discharge.

Thus, let a denote the cross-sectional area of the pipe at a point where the pressure is p and the velocity v, and let the two portions of the fluid separated by the section be designated as X and Y. The total force exerted by X upon Y, and the equal and opposite force exerted by Y upon X, are each equal to $p\ a$; and the work done per second by one of these forces and against the other is $p\ a\ v$, which therefore denotes the amount of energy transmitted from X to Y per second. The weight of water discharge per second is $w\ a\ v$. Hence, since $\frac{p}{w} = \frac{p\,a\,v}{w\,a\,v}$, it is readily seen that $\frac{p}{w}$ has the meaning stated.

To summarize, every particle of water is concerned in the transmission of energy in two ways:

(a) It possesses a definite quantity of energy (potential and kinetic) which it carries with it as it crosses any given section.

*This statement is practically true even considering the actual compressibility of water. The work performed on a cubic foot of water in applying a pressure of 10 atmospheres would be less than 5 foot-pounds.

This energy (per unit weight of the water) is represented by the terms $z + \frac{v^2}{2g}$.

(b) It receives energy from some adjacent particles and transmits it to others, by virtue of the pressure to which it is subjected. The energy thus transmitted across any section (per unit weight of water discharged) is represented by the term $\frac{p}{w}$

The sum $\frac{v^2}{2g} + \frac{p}{w}$ may now be interpreted as a whole. From the above analysis it is evident that it means the total energy carried across the given section per unit weight of water discharged. And the general equation (1) may therefore be interpreted as meaning that:

During any time, equal quantities of energy are carried across all cross-sections of the stream.

If losses of energy by dissipation, due to friction and similar causes, be considered, the general equation of flow is

$$\left(z_1 + \frac{p_1}{w} + \frac{v_1^2}{2g}\right) - \left(z_2 + \frac{p_2}{w} + \frac{v_2^2}{2g}\right) = H^1 \ldots\ldots\ldots (2)$$

in which the subscripts (1) and (2) refer to any two sections, and H' (called lost head) means the energy dissipated between the two sections per unit weight of water discharged. Interpreting as above the quantity $\left(z_1 + \frac{p_1}{w} + \frac{v_1^2}{2g}\right)$ denotes the energy carried across the section (1) per unit weight of water discharged, while $\left(z_2 + \frac{p_2}{w} + \frac{v_2^2}{2g}\right)$ denotes the like quantity for the section (2). In this case, therefore, the quantities of energy carried across different sections are unequal; the quantities carried across any two sections differing by the amount of the energy dissipated between.

The same principles are applicable in any case of steady flow of an incompressible fluid. No further analysis is needed for the purposes of the present discussion, whose object has been, first, to point out the error involved in the ordinary use of the term pressure-energy, and second, to indicate the correct method of applying the theory of energy in the ordinary problems of hydraulics.

ROADS OF WISCONSIN.

G. H. BURGESS, '95, AND J. J. MONAHAN, '95.*

Within the past four years, the question of good roads and how to obtain them has been brought into great prominence in Wisconsin as well as elsewhere. But while there has been a great deal of talking and thinking no important steps in the way of legislation have been taken, and as a consequence no work of importance has been accomplished other than that of bringing the people to a realization of the miserable condition of most of our country roads.

The road laws of 1893 in Wisconsin provide that the roads in any town shall be under the full supervision of the town board, and said town board may make and repair such roads by contract and appoint a competent superintendent of roads. The town board may procure machinery and materials; hire laborers and teams; and purchase gravel pits and stone quarries. All road taxes are to be paid in money except in townships which specifically vote to retain the labor system. The provisions in the above laws are steps in the right direction, but the road tax should be *required* to be paid in money and not made optional to the vote of the people. Again, the law should make some provision for the construction of more durable roads than are in use at present in the state. Some of the provisions of the New York law might be very advisable here. This law provides for county roads to be designated by the boards of supervisors and allows each county to issue twenty year bonds to pay the cost of construction and maintenance of such roads. In New Jersey they have what is known as the "State Aid Law," and under this law have been built roads which are not surpassed by those of any state in the union. Their law provides that, upon petition of two-thirds of the owners of property abutting on a given road, if the road be not less than one mile in length, the county board shall see that such road be improved by constructing a suitable stone

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road; provided, the said property owners express their willingness to pay an assessment of one-tenth of the cost of such improvement in proportion to the benefits derived. The whole amount of such improvements in any county in one year is not to exceed one-half of one per cent. of the ratables for the preceding year. The state agrees to pay one-third of the cost of roads constructed under this act out of the state treasury. The portion of the cost remaining after the property owners and the state have paid their shares is to be paid by the county in which such road is built. Such a law in Wisconsin would require a constitutional amendment as the constitution provides that the state shall contract no debts for internal improvements. This law would be very acceptable in the more thickly settled portions of the state.

That good macadam can be built for from three to four thousand dollars a mile has been ably demonstrated in New Jersey. Putting it at the higher figure, assume that a man owns land having a frontage on the road of half a mile; then if he is to pay his share of 10 per cent. he would pay one-fourth of 10 per cent. of $4,000, or one hundred dollars, for the construction of a macadamized road which would greatly increase the value of his property, lessen the cost of transporting his produce to market, and thus return his $100 several times over. In the New York highway manual for 1893, it is estimated that the difference between good roads and bad ones is $1.25 per acre annually on all farm lands in that state. Using this as a basis and assuming that the property is a quarter section or 160 acres, then in a single year the amount saved to the farmer would be $200 or double the amount paid for the improvement.

The property directly benefited by the improvement might be assessed a greater amount than 10 per cent. of the cost of the road and five or ten years be given in which to make the payments in equal annual installments, paying a suitable rate of interest on the amount unpaid each year. This would work no hardship on any property owner and would make it possible for many persons to stand an assessment who would be otherwise unable to do so. A highway commission should be appointed in this state similar to the one in Massachusetts, whose duties should be to bring the subject of improved roads before the people by holding meetings in the different parts of the state, and to oversee the construction of new roads.

Repairing roads by working out the road tax has resulted in more harm to the highways in the state than would have been done by years of traffic, and the sooner this system is abolished the better will it be for the highways. The farmers look forward to the spring road repairing as they would to a picnic, and the laziest hired man and the poorest team and wagon are sent to work out the tax. The wages for team and driver are $3.50 per day, while the same work could be done by contract for $2.00. The road is picked a little here, scraped there, and left in as bad condition when the work is finished as it was before the work was begun. The road taxes should be paid in money and the money should be placed in the hands of a road committee whose duties should be to see that such moneys are expended in the most advantageous manner possible. The men constituting such a committee should not be selected according to their political proclivities, but should be chosen with reference to their ability, and should receive a salary sufficient to induce competent men to undertake the work.

Each town should provide itself with a road-making outfit, and where such an outfit is properly used the very best dirt roads may be maintained at a very much less cost than at present under the old system. An outfit consisting of a grader, a four-ton roller, some scrapers and a plow can be purchased for about $600. A grader will grade from three-quarters of a mile to a mile of road per day, with three teams and two men, at a cost of about $15 per day, including the interest on the price of the machine. In the old way, to finish the same amount of work, would require two teams and forty men, at a cost of $55 per day; showing a saving by the use of the grader of $40 per day, with better roads as a result. If a roller is also used the cost will be increased $25 or $30, but still there is a great saving.

If, now, after purchasing a road outfit, the ordinary repairs be made each year at this greatly reduced cost, and with the money remaining after the work is finished as much substantial broken stone road as is possible be constructed, in a few years the roads will be in the best possible shape and at the same time the old roads will be kept in a much better condition at no increased outlay.

In constructing highways in this state, great care has been exercised to make the roads conform to the section lines as nearly as possible, and to attain this end high hills have been mounted in many cases where a detour of a few rods would have made a difference of from fifty to one hundred feet of rise and fall. One authority states that the distance may be increased fifteen times the vertical height avoided and be economical. On macadamized roads the limiting grade should be one in thirty, as on such a grade a horse must put forth a pull just double that which he would have to exert on a level grade.

The state of Wisconsin is quite plentifully supplied with good materials for the construction of hard roads. In the undeveloped northern part of the state are found granites which would make an excellent material for constructing macadamized roads. A few granite quarries have been developed in the east central portions, as at Berlin, Montello, and a few other places, and this granite could be crushed and shipped at no great cost to all parts of the state. In the southern and eastern part of the state occur great deposits of limestone, and most of this is suitable for macadamizing roads. Limestone will bind well, and form an impervious road if properly constructed. Quartzite also occurs in the southern and central part to a considerable extent. This makes a good durable top dressing, although it does not bind as readily as limestone and is not suitable for steep grades. Gravel is widely distributed throughout the state, especially in that geological area known as the drift area. It is generally mixed with a clay and is the best kind for road building purposes.

Over ninety per cent. of the roads in this state are common dirt roads. When these are properly constructed and well drained they answer the purpose very well during the greater part of the year, and for cross roads having a light traffic they are the only roads that it would be profitable to build.

The following table shows the amount of road tax paid during the past five years in a few counties of the state, the amounts having been furnished by the county clerks of the various counties:

County.	1890.	1891.	1892.	1893.	1894.
Brown	$13,600	$13,600	$13,600	$13,600	$13,600
Douglas	12,000	12,000	12,000	12,000	12,000
Juneau	9,800	10,900	9,400	8,500	8,200
Marinette	8,000	2,000	2,500	6,600	6,600
Milwaukee	56,000	56,000	56,000	56,000	56,000
Portage	12,400	10,500	11,100	11,600	12,700
Rock	49,300	39,200	38,000	38,300	43,700
Shawano	....	12,000	12,000	1,000	3,375
Walworth	38,100	35,400	37,900	33,100	34,400

The amounts which are the same through five years are an average for each year and are not the exact amounts. The total for the nine counties is $953,600 for the five years, or $190,700 per year. According to the census of 1890 these nine counties represent a population of 439,000 or 5-19 of the total population of the state. Figuring on the basis of population, the total road tax per year would be $724,600. This would build 360 miles of good macadam roads or even four hundred. But allowing two-thirds of this amount to be expended in road repairs, even then 120 miles of hard roads could be constructed each year. At this rate it would not be many years ere the roads of Wisconsin would be second to those of no other state in the union.

SUBWAYS FOR ELECTRIC WIRES.

W. C. BURTON, B. S., '93.

From the title it might be thought that we should here be in the province of the electrical engineer, but this is the case only to a very remote degree. One who understands the building of sewers is in a much better position to design conduits, than one who has only more purely electrical knowledge. The principal point which has, for the present at least, been firmly established by the experience of the last fifteen years with underground wires, is that the object of a subway system is to keep open and accessible a hole, into and out of which wires may be drawn, but these wires must carry their own insulation, with which the subway proper has nothing to do. This will of necessity always be true of telephone and telegraph wires, but time may prove that an insulating conduit may be made to carry railway and lighting wires—there are in fact one or two such now on the market, but of these, and of the various "built in" underground systems, like the Edison tube, there is no space here to speak.

A subway system, in the sense here meant, consists of a conduit of one or more ducts and manholes at suitable points for getting at it for the drawing in of cables, taking off services, and other purposes.

The essential qualities of a good conduit are (1) smooth and uniform interior surface, (2) durability, (3) strength—that is a conduit which cannot be easily broken into by a laborer's pick, or cracked by uneven settling of the ground—(4) flexibility in laying and bending to avoid obstructions in the street, (5) compactness—that is, it should occupy small space externally, for its capacity. The four types of conduit which are now in use, viz., iron pipe, cement lined sheet iron pipe, terra cotta tube, and wood conduit, in all their various forms, have been so frequently described that it is unnecessary here to more than mention them, and to see how each fulfills those essential requirements.

The greatest merit of iron pipe, for this purpose, is its flexibility—it can be bent in any desired curve to avoid an obstruction without in any way effecting the smoothness of the interior. Then, too, it is strong and not easily broken into when the streets are opened for any purpose, nor does it sag or crack if left exposed by excavations for considerable distances. On the other hand, it is expensive and of doubtful durability compared with some of the other types; consequently it should not be used on long, straight lines, particularly those consisting of large numbers of ducts, but it may frequently be used in connection with one of the cheaper classes for those sections of the line where obstructions are most numerous, or where it is necessary to approach very near the surface, thus requiring great strength.

Cement lined pipe is recommended by its smoothness of bore, even joints, and the ease with which it may be laid. It is the best of all kinds for drawing in and out cable, and is fairly durable, but must always be protected from mechanical injury by being imbedded in concrete. As regards flexibility it ranks very low and can only be bent in a curve of very long radius. Its cost is about one-half that of standard wrought iron pipe.

Terra cotta, in one form or another, is much used for conduits on account of its cheapness and great durability. To protect it from mechanical injury and hold it in position it must usually be surrounded by concrete, but when so laid it is absolutely indestructible by any natural process. In its best forms the external dimensions of the conduit are less for a given capacity than with any other type and it is fairly flexible, being made up in sections of such short lengths that it may be laid easily around a curve of twenty foot radius. The weakest point with this type of conduit is the fact that the interior of the tube is apt to be rough, and also, as it is necessarily in short sections (18″ to 30″ long) and in the ordinary forms laid with a simple butt joint, cemented over, the joints are numerous and the tube is apt to get out of line, thus making the drawing of cables difficult. Great care should be taken in laying conduit of this type to have the alignment of the sections good, and to allow it to remain undisturbed until the cement mortar has thoroughly set, before covering it over.

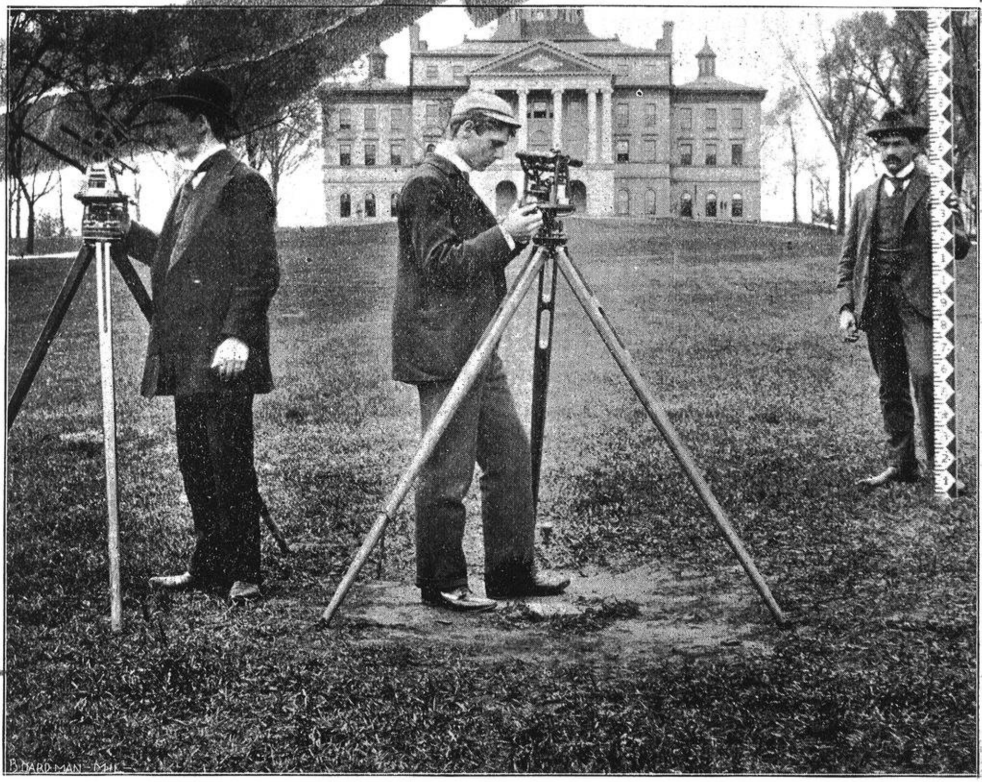
Wood conduits, variously treated to prevent decay in the ground, are cheap, quite strong, and smooth enough to make cable drawing easy. Sometimes, however, chemicals used in the wood-preserving compound have an injurious effect on the lead of the cable cover. Generally this type should only be used where a temporary subway is required, although it has given good satisfaction for a number of years in some places, notably Philadelphia.

The principal requisites of a manhole are a good foundation and sufficient size. The writer has seen a manhole (?) five feet deep, made only 20″x24″ in size, from a mistaken idea of economy, with the result of making it necessary for a man who has to do work on cables at the bottom, to be held by the feet, with his head down in the hole—neither a comfortable position nor one likely to enable him to do rapid or effective work. The manhole walls (of brick) should always rest on a bed of concrete at least six inches thick, to prevent irregular settling and consequent cracking, as well as to keep the hole dry. Whether a casting having a single or double cover should be used for the top, depends on local conditions. In places where large quantities of mud and water are likely to get into the hole, an inner water-tight cover will save enough time of men who have to work in the hole to more than pay for itself, and it will always give cleaner manholes and a generally better appearing system, with a comparatively slight increase of cost. The double cover also makes possible the locking up of holes, thus preventing any tampering with the cables—frequently a great advantage.

Since we are, with any ordinary subway system, wholly dependent upon the cables for insulation, the presence of water in ducts or manholes does no harm so far as ordinary operation is concerned. No conduit except one of iron pipe will entirely prevent the entrance of water, and even in that type there will always be water from condensation, so provision should always be made for draining the manholes where there are sewers low enough to permit of connection being made. Manholes full of water are very objectionable things on account of the time which must be spent in pumping them out whenever it is necessary to get at the cables. There is a theory that the conduit should be so laid as to drain toward the manholes at each end of a section, but it is frequently a very difficult and expensive matter to maintain a grade thus in a street full of pipes, sewers, and other obstructions, and there is no real reason for doing so—a "trap" filled with water between manholes is not at all a bad thing as a preventative of the free diffusion of gas. In the streets of all our large cities there are leaking gas mains, and it is absolutely impossible to build any underground structure into which the gas cannot enter in places. There are two ways of avoiding the evils resulting from this. First, the effective, but expensive, method used in New York, of pumping air into the subway and keeping the pressure there above that in the surrounding soil, thus preventing the entrance of gas, and second, by making connection to pipes which are run up the sides of buildings or up poles, and act as ventilating chimneys.

In laying conduit of course as nearly a straight line as possible should be followed where there is nothing in the way. Where, however, there are obstructions, bends in the line do little harm and if not too numerous or of too short radius do not even make the drawing in of cable appreciably more difficult. A small cable has been easily drawn through 200 feet of 2″ pipe and around two bends of 90 degrees with 18″ radius, but of course that sort of thing would not do with a 100 pair telephone cable. The depth of the conduit below the surface usually depends upon the location of other pipes in the street, and can rarely be determined upon in advance. A foot at least, however, should be allowed between bottom of pavement and top of conduit. An extra inch of thickness of concrete around the ducts or the use of a little better grade of cement are of much greater value in making a good system than air-line alignment, grades allowing perfect drainage, or great depth.

If, in designing and building a subway, the real objects and essential requirements were kept in view, and no attempt were made to give it qualities which are of no practical value, much of the cost of underground electric wires would be done away with.



NEW DATA ON INCREASED ACCURACY OF STADIA MEASUREMENTS.

LEONARD S. SMITH, C. E., '90.

Assistant Professor of Topographical Engineering.

In a bulletin of the University of Wisconsin,[1] dated May, 1895, the writer gave the data and conclusions of an experimental study of field methods, which insures to stadia measurements greatly increased accuracy. This study made clear for the first time the true cause of the large accumulative or systematic errors of stadia measurements, which have so seriously impaired the usefulness of the stadia method. The main conclusion of this study

[1] Engineering Series, Vol. 1, No. 5.

was that the errors in stadia measurements due to the "vibration or boiling of the air" were necessarily compensatory, and hence of only secondary importance; while the errors due to differential refraction, if not recognized and properly eliminated in the interval determination, would inevitably cause systematic errors.

The object of the present paper will be to give some new data taken from the field records of actual surveys.

Briefly stated, systematic errors in stadia measurements are due to the fact that the two lines of sight constituting a stadia reading, traverse strata of different density and are consequently refracted unequal amounts and sometimes even in opposite directions. This differential refraction is exceedingly irregular, differing in amounts and direction at different hours of the same day, and even at the same hour of different days.[1]

As this important fact has never been recognized, it has been the universal custom in determining the wire interval of the transit, to take rod readings on a base line at some particular hour of the day, thus making it almost certain that the wire interval so obtained would not be the average or true interval, to be used for every hour of every day.

Again, while many topographers recognize that the hour of their interval determination has some relation to the resulting accuracy of the work, no two seem to agree as to what hour is the proper one. Obviously the best time for determining the wire interval is that during which the refraction will most nearly equal its average value during the field hours, but on account of the irregularity of refraction, it is extremely doubtful if a single hour of the day can be selected, with any degree of certainty, that it shall represent average conditions of field work.

Instead, all uncertainty would be removed if a number of interval determinations were made at different hours and on different days, the average of which would assuredly represent a close approximation to the average conditions.

By following this method the writer has found no difficulty in securing a uniform accuracy of 1-2000 on short lines (one and one-half miles), and by the elimination of systematic error, a gradually decreasing error with increasing length of line, until

[1] A full discussion of the causes and conditions governing this peculiar phenomenon may be found in the bulletin.

at the end of eighteen miles of measurements, the accumulated error was but 1 in 10,000 (see page 138 of bulletin, Vol. I., No. 5).

A very interesting illustration of differential refraction on a large scale (which in fact is the only illustration the writer has ever seen on the subject outside of his own experiments) has recently been brought to his attention. This is found in appendix 3, Vol. II., of Colonel Walker's final report of the Great Trigonometrical Survey of India. Because of the inaccessibility of this report, the main facts on this point are here given.

The engineers were operating in a very level country, where the rays of light from the stations under observation grazed the surface of the ground. The differential refraction was first noticed between two stations, called Nár and Jeto, the former being on a slightly elevated table land between two river valleys, the latter being thirteen miles distant in the valley bottom. It was feared that the ordinary heliotrope would not be visible, so a second heliotrope was mounted on a tripod about sixteen feet vertically above the ordinary heliotrope.

Colonel Walker says, "The line between the instrument at Nár and the ordinary heliotrope at Jeto was not an air line at all, but passed through the ground for a distance of more than three miles, while the line between the instrument and the upper heliotrope could not have been more than 5.3 feet above the ground at the point of nearest approach. At Jeto both the auxiliary and the ordinary heliotropes were generally visible for about an hour after sunrise and before sunset, but in the middle of the day the lower one was always invisible, being below the apparent horizon. Here I noticed with surprise, one evening, that the two heliotropes were apparently very much closer together than it was possible they could be in reality; measuring the angle subtended I found it to be only 16.5 seconds, whereas the true subtense was 49.5 seconds. Three days afterwards in the morning, about an hour after sunrise, I found the apparent subtense to be as much as 97.7 seconds; thus its magnitude had varied from one-third to twice that of the true subtense, attaining a maximum value six times greater than its minimum value. This clearly showed that the amounts by which the rays of light proceeding from the two heliotropes were respectively affected by refraction must have varied materially at different hours of the day; the observations were only differential and did not give the absolute values of refraction, but it seems highly probable that the lower ray was very much more refracted than the upper in the evening and very much less in the morning."

This remarkable phenomenon led to a systematic study of both absolute and differential refraction, the details of which are given in the volume mentioned.

It will be sufficient to state that numerous instances of negative as well as positive refraction were found, ranging between the extreme values of — 0.09 and + 1.21 of the contained arc. Negative refraction was met with only between the hours of 1 to 3:30 p. m., and positive refraction between 3:30 p. m. and 10 a. m. After 10 a. m. signals were generally below the horizon so no observations were possible.

In the case of observations on differential refraction, it was found "that the refraction was sometimes greater in the upper ray and sometimes in the lower, but that the range from lowest to highest value at each station was always *greater for the lower than for the higher ray*.

"Between the hours of 1 and 3:30 p. m., whenever the sun was shining brightly, the apparent subtense was greater than the true and the refraction was lower in the lower ray than in the upper; but at the same time in cloudy weather the converse occasionally happened. On the other hand, between 3:30 p. m. and sunset the apparent subtense was always less than the true, and the refraction was higher in the lower ray than in the upper. These variations in subtense were evidently due to the co-existence of a lowering refractive power in the strata of the atmosphere nearest the ground with a raising refractive power in the strata immediately above, during the hours when the radiation of the heat of the sun from the ground was considerable, and to the converse condition of a greater raising power in the lower than in the upper strata when there was little or no radiation and consequently greater density in the lower than in the upper strata of the atmosphere."

The application of the above record to the subject of stadia measurements is easy to see, and it will be noted that the explanation given is essentially the same as that advanced by the writer, based upon observed stadia readings at different hours of the day. The only difference in the data is the relatively long distance of the sight from Nár to Jeto, it being thirteen miles instead of the few hundred feet which necessarily limit the length of a stadia reading. But even on so short a stadia sight as 1,000 feet, the writer has seen the rod intercept change by 0.19 of a foot (equals 40 seconds of arc) during different hours of the same day. Such large differences in rod readings can be understood when it is noted that if in the first case (see Fig. 1) the upper line

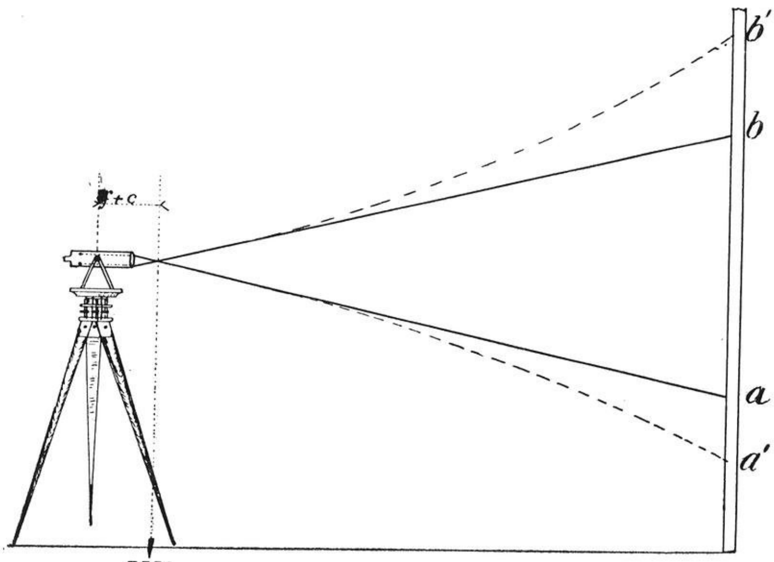


FIG. 1.—Differential refraction causing too large rod readings.

of sight be refracted negatively more than the lower, or if the upper line of sight be refracted negatively and the lower line of sight positively, then the observed intercept *a′ b′* will be larger than the true intercept *a b*. Again, if, as in Fig. 2, the upper line of sight be refracted upward (positively) and the lower line of sight downward (negatively), the observed intercept *c′ d′* will be smaller than the true intercept *c d*. It will be seen that the difference in the observed rod readings, namely, *a′ b′—c′ d′*, is about four times as large as any single refraction. Hence a small absolute refraction may be the cause of a large differential refraction.

A good illustration of this fact was recently sent the writer by one of the topographers of the Chicago Drainage Canal. The topographer was taking a stadia reading over a rise of ground, when he noticed that, in reading from the top of the rod downward the distance read was 725 feet, while in reading from a point near the ground upward the distance was shortened to 715 feet. For the reasons given above the former reading was more likely correct, though the manner in which the stadia interval was determined has a governing influence on this point.

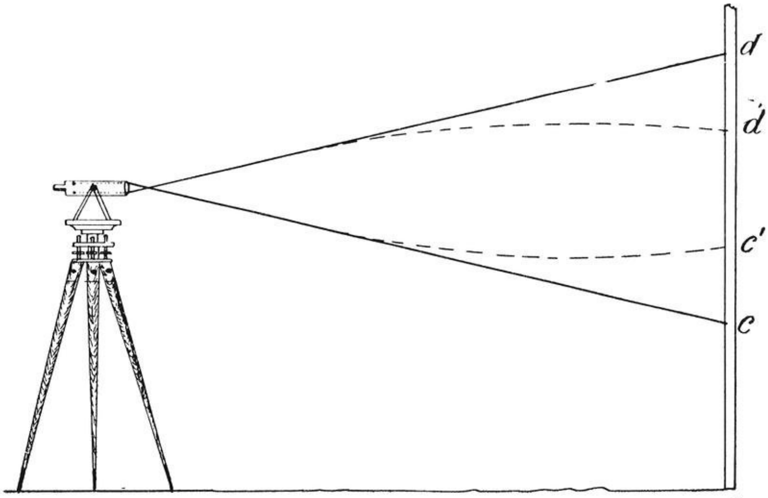


FIG. 2.—Differential refraction causing too small rod readings.

If in determining the stadia interval, the transit be centered a distance f + c back of the zero of base line (see Fig. 1), the angle formed by the upper and lower line of sight, constituting the stadia reading, will have its apex directly above the zero of the base line. Now, if it were not for the influence of differential refraction, the intercept on the stadia rod held at any point on the base line, ought to be proportional to the distance from the rod to the zero of base line. In other words, if we substitute in the usual stadia formula, $D=KS$, the several rod readings S_1, S_2, S_3, etc., and also the corresponding exactly determined base line distances to the rod D_1, D_2, D_3, etc., we will have an equal number of observation equations containing only one unknown quantity, namely, K, the stadia interval, and solving for K we should expect a series of values affected only by accidental errors. So much for theory. When put in practice this method almost invariably gives a series of values of K, differing systematically from each other, the best possible proof of the existence of differential refraction. Obviously this disturbing agency is the factor which determines the accuracy of stadia measurements.

The graphical method is well adapted for bringing out more clearly this point. If a curve be constructed, whose abscissae are the lengths of sight [varying from 80 meters to 400 meters], as determined by the base line measurements, and whose ordinates are the corresponding values of K, as determined above, such a curve should be theoretically a straight line parallel to the axis of X.[1] Instead, with rare exception, it is found to be a line cutting the axis of X.

Through the courtesy of the U. S. Commissioners of the International Boundary Survey, the writer has recently come into possession of the entire field records of twenty-four interval determinations made on that survey. These intervals, made with unusual care, cover about two years, and were made under conditions involving nearly every variety of climate, time of day, and season, soil, vegetation, etc. A few of the typical curves of these intervals will now be given.

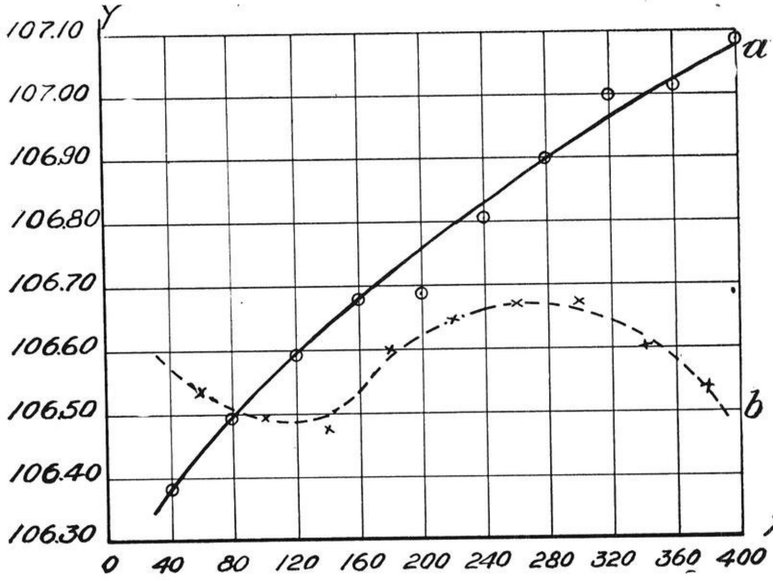
Fig. 3 represents two stadia interval determinations made at Nache Vera Valley, California, during consecutive days and on the same base line with same instruments, rod and observers. One interval was taken during the hours 6—7:30 a. m., the other from 4—5:30 p. m. Unfortunately the notes do not record which was morning and which afternoon, but the full line curve closely resembles the normal afternoon curve.

The first thing to note is that neither line is parallel to axis of X. Note also that the average ordinate [106.76] in curve (a), namely, the average value of K, differs from that of curve (b) [106.55] by 1-500. The interval used until this time was 106.98, which differs from (a) by 1-486 and from (b) by 1-250. The writer believes this to be a very unusual disagreement, and one explained by the position of base line, which lay along a small valley with trees so distributed that the line of sight traversed alternate strips of sun and shade, the former largely predominating. An abnormal refraction resulted, causing both determinations to differ widely from the average of several previous ones.

The extremes in temperature at this place in early morning and afternoon were very pronounced. Ice would nearly form

[1]The records of twenty-four such interval determinations show but one case in which the curve was even approximately parallel to axis of X.

FIG. 3.—Showing the interval determinations of Brandis Transit 1586 July 8 and 9, 1893 Nache Vera Valley, Cal.



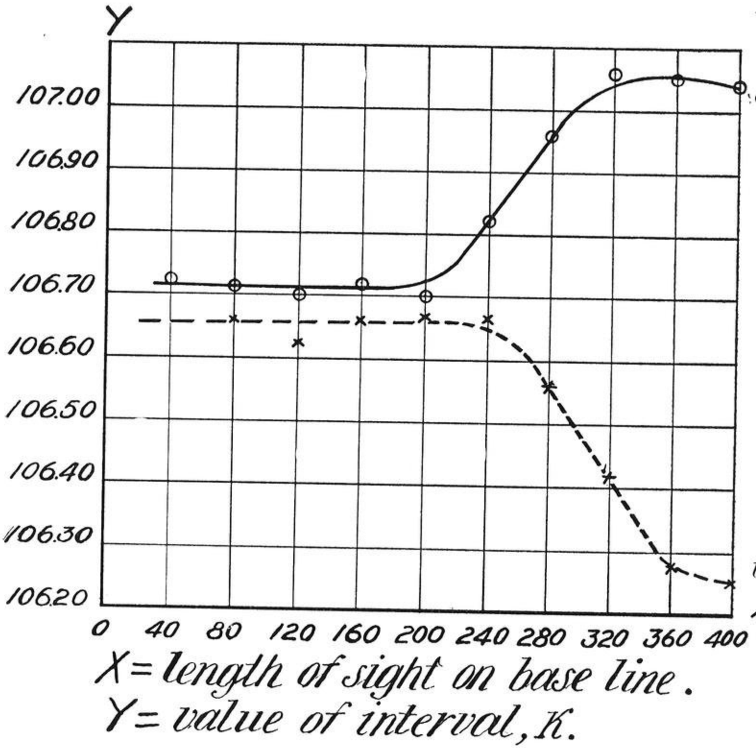
Law, X = *length of sights in meters.*
Y = *the corresponding interval.*

in morning, while during the afternoon the temperature would rise to 98 degrees Fah. The result of such a marked difference in conditions explains the large difference in the resulting intervals. The fact that the choice of an improperly located base line could cause so large an accumulative error as 1-486, would seem to justify more care in such selection than topographers have been accustomed to think necessary.

The point that should not be lost sight of in selecting the base line is, that its condition of soil, vegetation, etc., shall not differ widely from the corresponding conditions expected in the field.

In a former paper the writer called attention to the necessity of testing for a change of interval with a decided change in season. This point is emphasized by figure 4. Curves (a) and (b) represent respectively the interval determinations of March 20 and July 10, 1893, of Brandis' transit No. 1573, made at same morning hour. It will be seen that both curves are parallel to axis of X for a considerable distance, but on sights greater than 200 meters the platted ordinates [values of *K*] differ widely and systematically as is seen by the rapidly diverging curves. The average value of the ordinates in curve (a) is 106.85 while that of curve (b) is 106.53. That is if the former value represented the average conditions of winter, and the latter, of summer, a systematic error of 1-333 would be made in all stadia measurements executed during the summer by continuing the use of the winter value of K instead of its actual or true value at such time.

FIG. 4.—Showing the effect of season upon value of intervals.



In view of this proof of the inevitable change in the value of the interval, the common practice of painting a rod to correspond with the stadia interval of a certain hour and day, and then continuing the use of such rod unchecked and unchanged during the widely different seasons of this country,—oftentimes in fact for many years at a time, is seen to be inviting the large systematic error which almost without exception characterizes such work. If this evidence be taken to prove the fact that even so-called fixed stadia wires actually change their relative position, or what amounts to the same thing, appear to change on account of the influence of differential refraction at different seasons, then the present method of painting the rod to correspond with the determined interval is objectionable because of the cost of regraduating and repainting the rod to correspond to such change in interval. A method entirely free from this objection of cost, and one which the writer has found to stand every test during several years of field use, is that which uses rods divided into true units of feet, yards, or meters, and employs an interval factor in the computation of distances. With this system a change in the interval simply means the loss of an hour's time in the preparation of a new table for reduced or true distances corresponding to any rod reading.

In addition to the disadvantage of the present system of painting the rods pointed out above, the following are also worthy of consideration:

2. Rods cannot be interchanged among transits.
3. Old rods cannot be used with new transits.
4. Rods cannot be used in levelling without computing the necessary correction.
5. Levelling rods cannot be used in stadia work.
6. Observers with different personal equations cannot use the same rod without causing an accumulative error.

Few experienced topographers will deny the fact that many observers have a decided personal equation in reading a stadia rod. The more experienced the observer the more pronounced the personal equation. It seems to be due to a bias of judgment in making the bisections and in estimating the position of center of stadia wire. The following fact will illustrate this point: On the International Boundary Survey each transitman was instructed to observe the interval of his transit in conjunction with one other engineer.* An examination of the field notes discovers that some engineers had the same personal equation, while others differed quite radically, as is seen in following table of the first four interval determinations of Brandis transit No. 1584.

* In computing the average or working interval on this survey double weight was given to the observer who used the transit. Doubling the number of observers doubled the time necessary for the determination without any compensatory gain in accuracy. For this reason a single observer is preferable.

Brandis Transit, 1584.

Date.	Interval determined by		Number of Transit.
	Smith.	Van Ornum.	
April 11	104.61	104.57	B. No. 1584.
April 28	104.82	104.61	B. No. 1584.
April 29	104.83	104.63	B. No. 1584.
May 7	104.51	104.41	B. No. 1584.
Average	104.69	104.55	Difference = 1-750.

This transit measured the boundary line from El Paso to the Colorado river. Opposite each date will be found the separate interval determined by each of the two observers. It will be seen that all of Mr. Van Ornum's determinations of K are, without exception, smaller than the writer's, and that the average discrepancy would cause an accumulative error in measuring 1,040 ft. of 1.4 ft. or of 1 in 750. The size of this error, though serious enough, is not so objectionable as the fact that from its nature it must be systematic. The custom[1] of having the chief of party determine the working value of the interval, while his assistants do the observing, is thus seen to be wrong in both theory and practice. The better way would be to let the user of the transit determine the stadia interval himself, or if several engineers were using the same instrument let each determine his own interval.

An example of the case of two observers with very much smaller difference in personal equations is seen in the following table[2] taken from records same survey:

[1] In the recent survey of St. Louis the interval was determined by the assistant Engineer in charge, which his several assistants shared with him the field measurements.

The engineer in charge of the St. Louis survey states that, "There was a higher degree of accuracy noticed in the stadia work of the engineer who determined the wire interval;" also, that, "A uniform difference in the accuracy of work done by the several observers, was shown by the computation of the co-ordinates of stadia stations, thus indicating a different personal equation for each observer."

[2] The writer has not sifted out just the cases to prove this point, but in each case has given *all* the data available.

Date.	Locality.	Interval Determined.		Number of Transit.
		By Smith.	By Cunningham	
July 26, '92..............	Lang's ranch N. M.....	104.62	104.57	B. No. 1586.
January 18, '93..........	Yuma, Arizona.........	97.59	97.50	B. No. 1097.
January 19, '93..........	Yuma, Arizona.........	104.53	104.47	B. No. 1584.
January 20, '93..........	Yuma, Arizona.........	106.88	106.77	B. No. 1573.
Average...........	....	103.40	103.34	Dif. = 1-1722

In this case as in the one given above, the difference between the observed intervals is seen to have a constant sign, namely, each of Mr. Cunningham's values are less than the writer's, though the difference is small, being 1 in 1722.

The writer is aware that some experienced topographers will refuse to follow his suggestions, for the reason that in their opinion stadia measurements are sufficiently accurate already. For many purposes this is doubtless true, but these engineers certainly do fail to see the widening field of usefulness that would properly belong to the stadia method, when once its accumulative errors had been brought within proper limits. A large amount of expensive control now rendered indispensable by present careless methods could be advantageously omitted as unnecessary. It is no longer a question of a doubtful theory. Actual surveys have repeatedly demonstrated that not only in broken country is the stadia method a more accurate and a more expeditious way of making measurements than the chain, but in a level country as well.

POWER TESTS OF CENTRIFUGAL CREAM SEPARATORS.

A. W. RICHTER, M. E., '89.

Assistant Professor of Experimental Engineering, University of Wisconsin.

During the past two years a series of tests have been made to determine the power required for running the different kinds of centrifugal cream separators. In these trials, machines have been managed and tests of skim milks made by representatives of the University, instructions of the manufacturers regarding the running of the different machines being strictly adhered to.

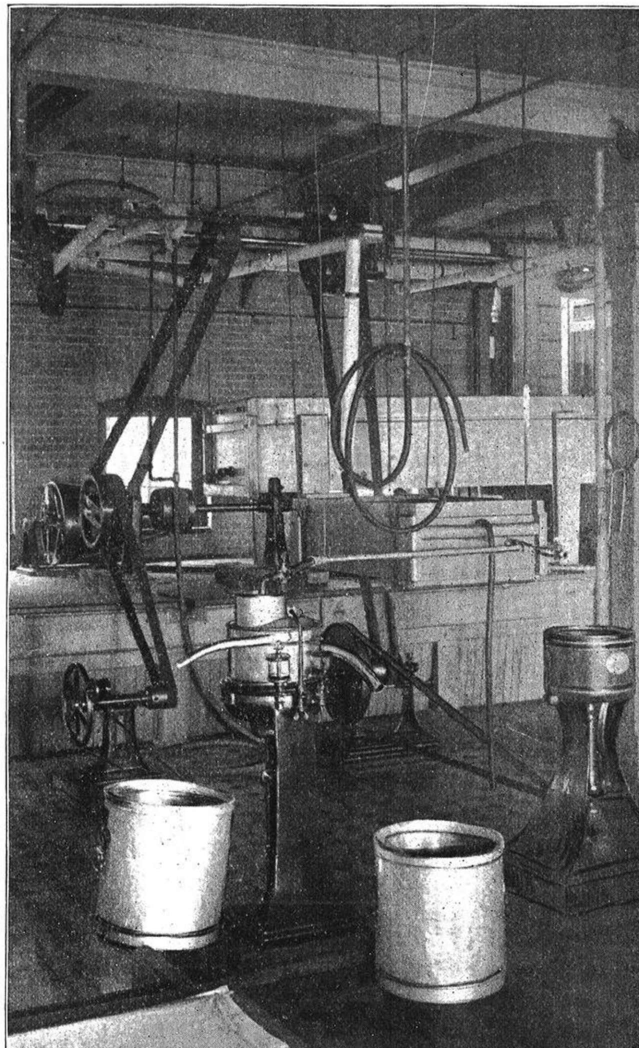


Fig. 1.—Testing a Separator of 2,000 pounds capacy.

Whenever agents representing different companies were present during the test they have been allowed to make necessary changes in their machines and invited to run them themselves, which privilege has in some cases been accepted; the observations, however, have in all cases been made by persons directly connected with the University.

The skim milk tests given have been made by the Babcock test. All of the machines were carefully lined up before the tests were made, and all instruments used were calibrated in the mechanical laboratory of the University both before and after the tests were made.

The machines tested are given in the following tables:

Vermont Farm Machine Co., Bellows Falls, Vermont.

1	United States, No. 1 B	2,000 lbs. rated capacity..........	Belt machine.
2	United States, No. 3..	650 lbs. rated capacity....	Belt and hand machine.
3	United States. No. 5..	300 lbs. rated capacity...........	Belt and hand machine.

De Laval Separator Co., Poughkeepsie, N. Y.

4	Alpha, No. 1...........	2,000 lbs. rated capacity.........	Belt Machine.
5	Alpha, No. 1...........	2,000 lbs. rated capacity	Turbine.
6	Alpha, No. 1...........	Run at a capacity of 2,500 lbs....	Turbine.
7	Alpha, No. 1...........	Run at a capacity of 1,700 lbs....	Turbine.
8	Alpha Acme...........	1,300 lbs. capacity................	Belt machine.
9	Standard..............	1,000 lbs. capacity................	Belt machine.
10	Baby No. 2............	300 lbs. capacity..................	Belt and hand machine.

Swedish Cream & Butter Separator Co., Bainbridge, N. Y.

11	Butter accumulator..	600 lbs. rated capacity, run as a separator.......................	Belt machine.
12	Butter accumulator..	400 lbs. rated capacity, run as a butter extractor...............	Belt machine.

P. M. Sharples Co., Elgin, Ill.

13	Standard Russian....	1,000 to 1,200 rated capacity......	Turbine.
14	Standard Russian....	1,000 to 1,200 rated capacity, run at a capacity of 1,400 to 1,500 lbs..............................	Turbine.
15	Imperial Russian......	2,000 lbs. rated capacity..........	Turbine.

A. H. Reid & Co., Philadelphia.

16	Reid Improved Separator	2,000 to 3,000 lbs. rated capacity.	Belt machine.

METHOD OF TESTING.

Belt Machine.—The power required to run the different belt machines was obtained by means of Morin dynamometers, as it was necessary to secure a continuous record in order to obtain accurate results. Power was furnished by a twenty-five horse power Reynolds-Corliss engine. The engine being at times greatly underloaded, the variations in the speed of the engine,

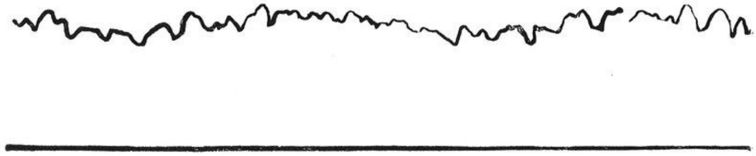


Fig. 2.—Card, Reid Improved Danish Separator.

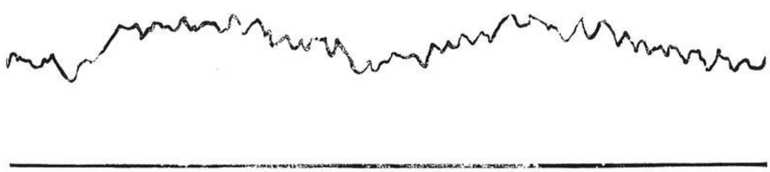


Fig. 3.—Card, Reid Improved Danish Separator.

Fig. 4.—Standard De Laval; engine loaded to about one-half of its greatest capacity
Horse power per card, 1.619.

Fig. 5.—Standard De Laval; engine loaded to one-eighth of its greatest capacity.
Horse power per card, 1.614.

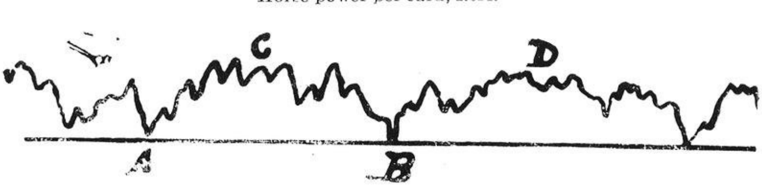


Fig. 6.—Card, Alpha Acme; engine decidedly underloaded.

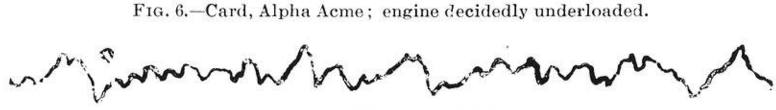


Fig. 7.—Card, Alpha, Acme; engine loaded to one-half its rated power.

although slight, caused considerable variation in the power transmitted to the separator, as is shown in Figs. 5 and 6. The shape of the curve shows that the average power required is not the mean of the A and C readings, but rather above such an average; for example, the average of the A and C readings, Fig. 6, is 8 per cent. less than that corresponding to the power actually required as obtained from a continuous record.

The power required to start the different machines was determined, as was also the effect produced when starting the flow of milk. In each of the above cases a continuous record was obtained. The De Laval Separator Co., the Sharples Separator Co., and the Reid Improved Danish Separator Co. direct that their machines be filled with water or milk before starting. In making the tests, we have, before starting, put a quantity of water or milk into the bowl of the machine equal to the amount remaining when shutting down after skimming, this being the maximum amount desired, thus placing the machine in a condition to give the maximum amount of power required. Four persons were required to take the necessary data for the tests: one to take the separator revolutions, another to note the time, a third to shift the belt from the loose to the tight pulley of the intermediate, and a fourth to take the dynamometer card and dynamometer revolutions. The separator was considered as having acquired full speed the instant the power required to run the machine responded to the variation of the engine speed, the time being checked by actual count at the separator. Before the starting tests were made, the machines were run for a short time to determine whether the oil passages, etc., were in good condition.

Before making the regular skimming tests the machine was operated a few minutes after the milk was started in order that it might first reach its normal condition. Dynamometer cards and all other observations were taken at five minute intervals. Average ordinates were obtained by the use of a planimeter.

Fig. 1 shows the general arrangement of the apparatus when testing the larger power machines. In this case it was necessary to add a countershaft in order to sufficiently reduce the speed of the dynamometer. When testing a small machine as a power machine no countershaft was required.

Steam Separators.—The steam separators were tested under similar conditions as those existing while testing the belt machines. Great care was taken so as not to change the conditions in any respect whatever. In all tests of this kind the exhaust steam was condensed in a surface condenser of the Wheeler type. All readings were taken at five minute intervals. Steam gauges and other instruments were compared with proper standards in the mechanical laboratory of the University.

Fig. 8 shows the arrangement of the apparatus used in testing the De Laval Alpha Turbine. A is a surface condensor used to condense the exhaust steam. To the bottom of the exhaust pipe B (in figure, back of the covered steam pipe) was attached a drain, which being very near the floor, was carried to the door step to the left. The end of this pipe, left open, was submerged in about one inch of water. The drip was collected and weighed. A U tube partly filled with mercury was connected with the exhaust pipe at D. The condensed steam was pumped out of the condensor into the tank E. It therefore became necessary to so regulate the speed of the pump as to create neither a vacuum nor a back pressure; this was accomplished in the following manner: Pipe F was disconnected at L and the exhaust pipe closed at that point. The speed was then regulated to give readings of the U tube as near zero as possible; these readings varied from one-eighth inch of mercury back pressure, to one-sixteenth inch of vacuum. The plug at L was then removed and the length of pipe F connected to the exhaust and allowed to remain open at the end H. This pipe was of sufficient length to condense any exhaust which might pass into it while testing the machine, and also maintained the back pressure in the exhaust pipe at an absolute zero. The machine was tested at capacities of 1,700, 2,000 and 2,500 pounds of milk per hour.

Fig. 9 shows the arrangement of the apparatus used in testing the Sharples machines. A larger condensor was used in this case, not on account of any larger amount of steam consumed, but because of the large amount of air mixing with the steam while in the separator and passing out of the exhaust pipe. This air amounted to about 30 cubic feet per minute in the smaller machine and about 80 cubic feet per minute while running the separator of 2,000 pounds capacity. The condensed steam collected at A. Fig. 9, had a temperature of about 60 degrees, but still a portion of the moisture was carried off mechanically by the air in the form of vapor. This vapor was collected in a tank into which were placed, horizontally, alternate layers of

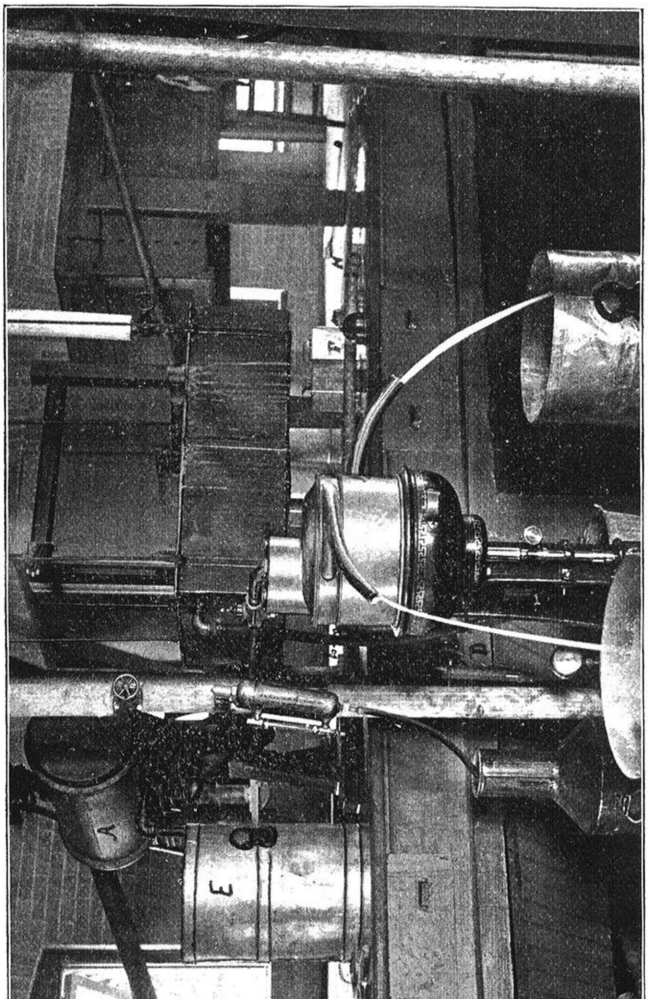


Fig. 8.—Testing the De Laval steam separator, Alpha No. 1.

paper and excelsior in such a manner as to compel the air to pass back and forth through the excelsior before escaping.

This proved a very good method of breaking up and collecting this vapor. The moisture in the air when leaving the excelsior tank, above what it contained when entering the separator was neglected when testing the smaller machine as it amounted to less than one-half pound during any one of the tests of one-half hour duration. While testing the larger machine, this factor was determined by means of temperature and hygrometric readings and taken as a part of the steam consumption.

SUMMARY OF RESULTS, AND CONCLUSIONS.

The intermediate required by a large belt power separator must be considered as a part of the machine. A portion of the work consumed in running the line shafting is also to be charged to the work required of the engine in each case. In the larger machines it is assumed that the power is transmitted by five feet of line shafting supported by two bearings; the power absorbed by this shafting is equal to that absorbed by the countershaft during the time the tests were made. The D. H. P. as tabulated includes this amount. If more machines are added to the plant it will necessarily require a corresponding increase in the length of shafting.

Every creamery, using belt machines, requires an engine of some kind as a source of power. The work consumed in engine friction and the pounds of steam per indicated horse power per hour (when using a steam engine) must necessarily be considered when we wish to determine the actual cost of operating one of these separators. When we wish to compare belt and turbine separators, it is also essential that we determine how much steam is consumed in the engine cylinder and the amount to be charged to each separator; this amount, however, is subject to the existing conditions, depending upon the size and style of engine, number of machines operated, care of attendant, and many other conditions of minor importance. In view of these facts we will assume the following conditions which we believe exist in the average small and medium sized creamery:

1. The separators are operated for three hours each morning.

2. Eighteen per cent. of the indicated horse power required to run the separator is consumed in engine friction.

3. The portion of the work required to overcome the friction of the shafting, which is to be charged to each separator, is equal to the amount required to run the countershaft during the time the tests were made. For the small sizes, not requiring a coun-

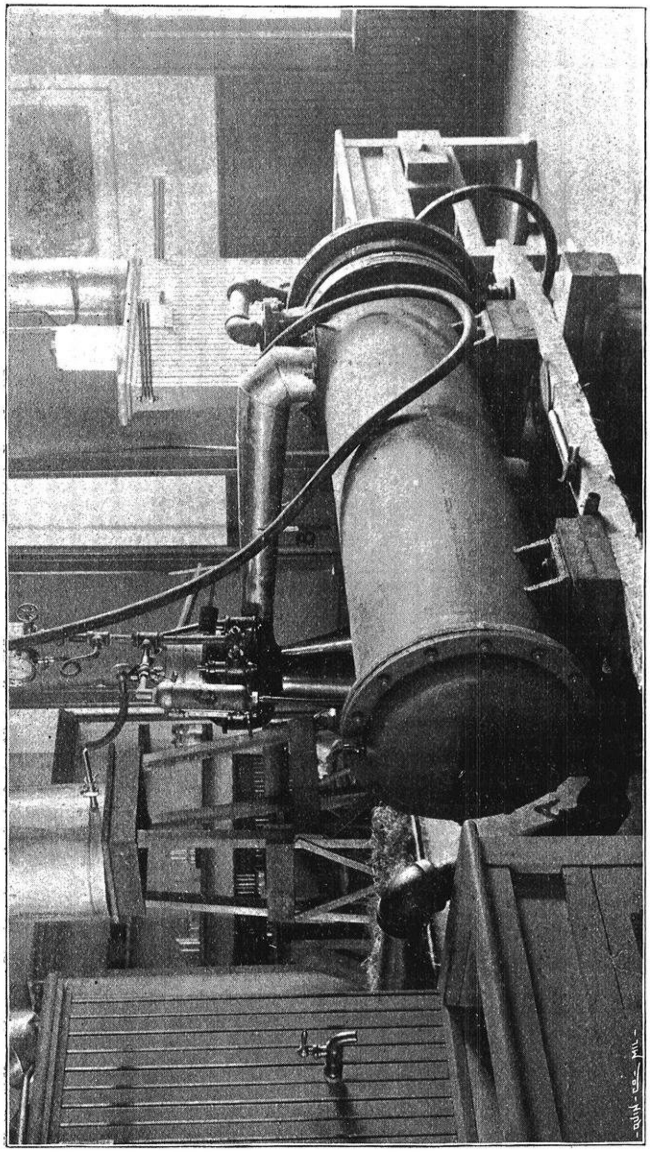


FIG. 9.—Testing a Russian steam separator.

tershaft, the friction of the shafting is assumed to be equal to 25 per cent. of the total indicated horse power.

4. The steam consumption is equal to sixty pounds per indicated horse power per hour.

According to the figures tabulated on page 57, we find a very marked difference in the power required to run the different machines and also in the pounds of steam per 1,000 lbs. of milk as found in the last column. This difference though it may appear surprisingly great, is easily accounted for upon a close inspection of the different machines. The greater portion of the work required to operate one of these separators is consumed in rotating the separator bowl; the quantity of milk passing through the machine has little effect upon the total power required, and consequently has a great effect upon the amount of steam required to skim one thousand pounds of milk. We have, therefore, every reason to conclude that the power required to run the machine varies chiefly with the mechanical construction and speed of the bowl, while the capacity of the machine farther effects the amount of steam required per one thousand pounds of milk separated. This is clearly shown by the tests of the Standard Russian Separator. This machine, when operated at a capacity of 1,148 pounds per hour, requires 140.1 pounds of steam per hour or 126.8 pounds of steam per one thousand pounds of milk separated. Increasing the capacity 23.7 per cent., the consumption of steam per hour is increased only 2.7 per cent. while in the pounds of steam per one thousand pounds of milk we find a decrease of 17 per cent. The same is shown, though less marked, in the tests of the Alpha Turbine. In view of the above we present the table given on page 58.

Comparing the Reid Improved and the U. S. No. 1, we find the speed of the material farthest from the center of rotation to be the same, and the distribution of the material also similar in both cases. The Reid bowl weighs 125 lbs. and has a greatest diameter of 16 inches, while the bowl of the U. S. No. 1 weighs but 84 lbs. and has a maximum diameter of 13.5 inches, which differences readily account for the increase of 70 per cent. in the power required to run the Reid Improved separator as compared with the United States No. 1. The increased capacity in the one case reduces this difference to 33 per cent. when comparing the final efficiencies or the pounds of steam per 1,000 lbs. of milk.

Results of Tests of Belt Power and Steam Separator.

MANUFACTURER.	Style.	No. of tests made	Rated capacity.	Aver-age capac-ity as oper-ated.	Average per cent. of butter fat in skimmed milk.	POWER REQUIRED TO START SEPARATOR. Time of starting average.	Aver-age D. H. P.	Aver-age I. H. P.	I. H. P. hours	POWER REQUIRED TO RUN SEPARATOR. Horse power above that required to run belt on loose pulley of inter-mediate.	Aver-age D. H. P.	Aver-age I. H. P.	Total I. H. P. hours for 3 hour run includ-ing I. H. P. hours required to start.	Total I. H. P. hours per 1,000 lbs. milk.	Pounds of steam per 1000 lbs. milk at the rate of 60 lbs. per I. H. P. hour, including amount required to start machine
Reid Separator Co.	Reid Improved.	1 & 3†	2,000-3,000	2,775	0.1 & 0.21	12 min.	3.23	3.92	0.785	2.956	3.24	3.95	12.63	1.517	91.
Vermont Machine Co.	U. S. No. 1	3	1,800-2,300	2,141.5	0.17	5 min.	2.56	3.12	0.26	1.63	1.91	2.32	7.22	1.124	67.4
De Laval Separator Co.	Alpha No. 1	2	2,000	1,991.7	0.1	5.33 min.	1.48	1.8	0.16	1.0	1.28	1.56	4.84	0.81	48.6
De Laval Separator Co.	Alpha Acme	3	1,300	1,229.6	0.11	2.0 min.	1.542	1.87	0.062	0.705	0.975	1.19	3.63	0.948	59.0
De Laval Separator Co.	Standard	3	1,000	971.5	0.19	2.82 min.	2.395	2.91	.137	1.37	1.65	2.01	6.17	2.116	126.9
Vt. Mach. Co.	U. S. No. 3	2	650	679.2	0.1	....	......	......	......	*0.27	0.36	0.44	1.32	0.645	38.7
Swedish Cream & But. Co.	But. ac. as a s p	2	600	430.9	0.21	1.83 min.	1.44	1.75	0.053	0.587	0.857	1.04	3.17	....	....
Swedish Cream & But. Co.	Butter Accum.	......	400	....	....	1.83 min.	1.41	1.75	0.053	0.661	0.93	1.13	3.44	....	....
Vt. Mach. Co.	U. S. No. 5	3	300	331.5	0.1	55 sec.	0.424	0.517	0.007	*0.015	0.20	0.246	0.74	0.742	44.5
De Laval Separator Co.	Baby No. 2	2	300	283.8	0.1	54 sec.	0.19	0.232	0.003	*0.08	0.11	0.134	0.40	0.472	28.3
							Aver-age qual-ity of steam per cent.	Lbs. of steam required to start machine.		STEAM, NOT INCLUDING AMOUNT REQUIRED TO START. Per 1,000 lbs. of milk.	Per hour.		Total steam used 3 hour run including amount to start.		
De Laval Separator Co.	Alpha No. 1, Tur	2	2,000	2,540.7	0.1	7.33 min.	95.4		23.9	85.4	217.		674.9		88.5
De Laval Separator Co.	Alpha No. 1, Tur	2	2,000	2,028.9	0.1	7.33 min.	96.4		23.9	94.0	190.7		596.		97.9
De Laval Separator Co.	Alpha No. 1, Tur	4	2,000	1,698.9	0.1	7.33 min.	94.7		23.9	102.9	174.9		548.6		107.6
P. M. Sharples Co.	Imp. Russian †.	3	2,000	2,041.6	0.32	....	95.2	20 to	24	81.3	166.1		520.2		84.9
P. M. Sharples Co.	Stand. Russian†	3	12-1,500	1,148	0.14	7.7 min.	96.7		16.5	122.4	140.1		436.8		126.8
P. M. Sharples Co.	Stand. Russian†	1	12-1,500	1,420.8	0.1	7.7 min.	96.9		16.5	101.3	144.		448.5		105.2

† Separator operated by a representative of the company.

* Power transmitted by belt leading to machine.

Belt Power Machines.

Style and Manufacture.	Separator Bowl.				Mode of transmitting power from intermediate to bowl.	I. H. P.	Capacity as operated.	Steam per 1,000 lbs. of milk.
	Weight, lbs.	Greatest diameter, inches.	Distribution of material.	Speed of material farthest from the axis of rotation, miles per minute.				
Reid Improved	125	16	Outer shell and axis	4.6	Belt transmission	3.95	2775	91.
U. S. No. 1	84	13.5	Outer shell and axis	4.6	Belt transmission	2.32	2141.5	67.4
De Laval Standard	43.5	12	Outer shell and axis	4.4	Rope transmission	2.01	971.5	126 9
Alpha No. 1	92	11.4	Throughout the bowl	3.3	Rope transmission	1.56	1991.7	48.6
Butter Accumulator	23.4	15.3	Outer shell and axis	5.5	Rope transmission	1.04	....	....
U. S. No. 3	19.4	7.5	Outer shell and axis	2.9	No intermediate; geared machines	0.44	679.2	38.7
U. S. No. 5	12.7	5.5	Outer shell and axis	1.9	do	0.246	331.5	44.5
Baby No. 2	10	5	Throughout the bowl	1.5	do	0.134	283.8	28.3

Again, comparing the Alpha No. 1 with the U. S. No. 1, we find that the Alpha bowl weighs 12 lbs. more than the U. S. bowl, but in this case the weight is more evenly distributed throughout the entire bowl and not simply in the outer shell and axis as is the case in the U. S. At the same time the speed of the material is considerably reduced, the material farthest from the axis of rotation having a speed of only 3.3 miles per minute as against 4.6 miles for the United States, and we find as before that there is considerable difference, in favor of the Alpha bowl, in the power required to run these machines. As the capacity is practically the same we find a corresponding difference in the pounds of steam required per one thousand pounds of milk separated.

Comparing the Alpha No. 1 with the Baby No. 2 (bowls of similar construction and manufactured by the same company), we find that the Alpha bowl weighs 9.2 times as much as the bowl of the Baby No. 2, the greatest diameter of the Alpha is 2.3 times that of the Baby No. 2, while the speed of the material of which the Alpha bowl is composed is 2.2 times that of the material of the Baby No. 2. In view of the above it is not surprising that the power required by the Alpha No. 1 is 11.6 times the power required to run the smaller machine. The large capacity in the one case accounts for the greatly reduced difference in the final efficiency.

Comparing the steam separators in a similar manner we find that the bowl of the Alpha is of better construction, mechanically speaking, while the Russian has the advantage of a more efficient turbine, resulting in practically the same total mechanical efficiencies.

Considered from a standpoint of economy in the steam consumption we find the Baby No. 2 most efficient. It might therefore occur to some of the readers of this paper that a number of these separators should be used in preference to one of the larger ones. There are, however, other conditions which must be taken into consideration. For example: Eight machines of the Baby No. 2 will skim as much milk per hour as one machine of the Reid Improved style and will require a little less than one-third the steam. The floor space may be the same in both cases. The first cost of eight machines of the Baby No. 2 would be much more than when using one of the Reid separators, while the extra work required to operate eight machines and clean eight bowls as compared to that required to operate and clean one machine makes the use of the smaller sizes entirely impractical and really places the larger machine ahead of the smaller one, in such cases, as regards the total final cost.

The table, page 57, shows that, generally speaking the belt separator is more economical than the steam separator, although some of the turbines, especially the Imperial Russian and Alpha No. 1, running at a capacity of 2,500 lbs., compare very favorably with the belt machines, even surpassing a number of them.

One of the most important results to be attained in the operation of a separator is close skimming. The Babcock skim milk test has done more to accomplish this end than any other one thing, as it provides a ready and rapid means of making tests of skim milks. The manufacturer must today be able to guarantee a machine that will leave no more than one or two-tenths of one per cent. of butter fat in the skim milk. No creamery company can afford to purchase a machine that will waste more than this amount. The average milk contains three and one-half per cent. of butter fat, every one-tenth of one per cent. of butter fat remaining in the skim milk represents a loss of two and eight-tenths per cent. in the yield; for a machine skimming two thousand pounds of milk per hour and running three hours per day, this means a loss of six pounds of butter per day; at fifteen cents per pound we have a loss of $270 per year or about fifty per cent. of the first cost of the machine.

The Reid Improved, United States and De Laval separators show most excellent results in this respect. Omitting the "Standard," which machine is still being used but which is not now being sold by the De Laval Company, being one of their old machines, we find that all of the De Laval separators average one-tenth of one per cent. The Reid and United States machines show results practically as good.

The Russian machines, especially the Imperial, did not skim as closely. Not only do the results of the regular steam tests show an average of 0.32 per cent. of butter fat remaining in the skim milk, but previous to these tests a number of preliminary runs were made by a representative of the company, with different bowls, to determine the skimming qualities of the machine. These trials show a percentage of butter fat remaining in the skim milk ranging from three-tenths to five-tenths of one per cent.

Omitting the Standard De Laval, which as before stated, is not now in the market, and the Butter Accumulator, which was still in the experimental stage during the time the tests were made, we find that the Imperial Russian is the only machine which at no time during the tests, shows a result as low as one-tenth of one per cent. of butter fat remaining in the skim milk.

SPECIFICATIONS FOR STRUCTURAL IRON AND STEEL.

BY B. L. WORDEN, B. S., '93.

With Wisconsin Bridge & Iron Company.

The preparation of specifications for structural iron and steel presents peculiar difficulties to an average man engaged in the general engineering practice, and the almost universal employment of these materials in work of all descriptions makes it an important part of the duties of every engineer. This together with the fact that comparatively few outside of those connected with manufacturers of structural steel and iron approach the subject with a thorough comprehension of what is required, is what has prompted this paper. It is hoped that the brief treatment here given may lead to a more complete study and consequently a better understanding of the nature of the subject by the readers of the "Wisconsin Engineer." It is intended more especially for those whose "experience" is yet to be acquired.

Specifications in general are intended to convey to the contractor a perfect understanding of the nature of the materials to be furnished and the work to be performed. Plans consisting of either general or detail drawings may be a necessary accompaniment, but it is the specification which ranks first in importance. Part of the specification may and often does consist of figures showing sizes, etc., and notes of explanation on the drawings, but dependence on these alone will leave room for various interpretations and consequent conflicts of opinion between the engineer and the contractor. It is manifestly unfair to either, that any doubt as to the scope or character of the work should exist. If the specification is loosely worded, the contractor in making his estimate interprets the various sections in such a manner as to cheapen the cost, enabling him to make a low bid and secure the work; while the engineer in charge may expect the best of everything and the endeavor to obtain it under a contract, made upon such a basis, will cause constant friction and endless worry. It is well to remember that good work can only be secured at a fair price and from responsible parties. A wide variation in the amounts for which various contractors propose to do a certain piece of work, indicates either an incompetency on the part of the bidders or an incomplete specification, usually the latter. Experience teaches contractors that a loose or imperfect specification means inexperience and ignorance on the part of those in charge of the work, and they realize that this causes unreasonableness with reference to unimportant though often expensive features, and knowing that the really important parts of the work will have to be taken care of in a proper manner whether required or not, reliable men bid high. This either rules them out of the competition or increases the expense of the work. Specifications should be as brief as possible, legal verbiage is entirely out of place. The same point should not be covered twice, nor should two separate clauses occurring at different places apply to the same thing. It should proceed from a general to a detail description, and above all should stop when the subject is covered. Some specifications show on their face that this is not the case, the author having gone on adding clause after clause, only stopping when the date for awarding the contract arrives after which the practice is continued in verbal instructions.

The young engineer upon commencing the practice of his profession will find a number of standard specifications for steel and iron. These standard specifications treat of the chemical and physical characteristics of the material as well as the methods of working the same into such shape as to be available in the finished structure. Many of these are the result of a life of experience and research and their authors men of high standing. Owing to the recent extension of the use of these metals and the comparative lack of reliable tests both in the laboratory and the crucial test of actual use, these specifications may differ more or less on minor points. A careful comparison will, however, show that the essential features are in agreement. The exact chemical composition, elastic limit, ultimate strength and elongation required for the various classes of work, show but small variations in the different authorities. As these quantities are more or less dependent upon each other, it is simply a question of what chemical composition and method of treatment will produce the required physical properties, and experience alone can demonstrate their exact relations. The various manufacturers in this country have agreed upon a specification covering these points for the different kinds of material. Their plants are equipped for manufacturing in accordance with these rules and they can produce material under them of reliable and uniform character. The foremost engineers in the country have been concerned in the determination of these formulae and as experience and practice demonstrate that an improvement can be made, they will be modified. It is manifestly to the manufacturer's interest to produce a thoroughly good article and it would seem advisable for young engineers at least, to place considerable reliance upon them, to take the material as it is manufactured and to use it to the best advantage. This insures a reasonable cost as well as a better delivery. It is sometimes the case that an engineer having charge of the construction of work where steel is employed, will specify a chemical composition almost, if not quite, impossible of production. The result is in the first place an increased cost, and next a delay in furnishing the structure which often proves a very serious matter. Instances are not unknown, especially when the mills have plenty to do, when orders have absolutely been refused, when to fulfill the specification would be difficult if not more or less problematic. Such a specification encourages the manufacturer in dishonest methods. He knows that the material called for is no better than his standard article and will sometimes endeavor to substitute the latter. The engineer has the privilege of straining material as much or as little as he may deem proper, and it seems to the writer that the better course to pursue is to take a good article as it comes to us and use it as advantageously as we may, rather than to call for something not to be had and to make ourselves miserable in trying to obtain it.

The workmanship also should be in accordance with recognized good practice which may be obtained from the standard specifications previously mentioned. Bridge and structural iron shops are in general equipped with tools capable of producing work according to the general practice, and the engineer will find that the fewer unusual requirements he puts upon the contractor for this part of the work the more satisfactory will be the result. It is not the intention in this or what has been previously written to advocate any laxity in the specifications. Workmanship consistent with the character and importance of the structure should be insisted upon. There is usually, however, more than one method of accomplishing one and the same result, and it is not necessary to insist that a special method shall be pursued when the customary practice will answer as well. Bad workmanship will probably show itself sooner than any other quality of the finished work, and it will not be long before the engineer using any amount of steel or iron will know what points to guard against. Until that time it is safe to rely upon the general practice in making up a specification. Details should generally be left to the iron contractor. If it is necessary to obtain a standard of excellence which the work must equal, it should be understood only as a guide and such modifications should be permitted as do not impair the strength or appearance of the work and which may better fit the tools used by the shop undertaking the contract.

In writing specifications for iron and steel, no engineer need fear to plagiarize. It is not a crime. Plagiarize freely from the proper sources and deem it rather a mark of ability to properly select your authorities. Originality is not to be aimed at for the purpose of being original. Generally such attempts on the part of the inexperienced men are proofs of ignorance. Neither is it necessary to make a slight change from the usual practice, such a course being almost a sure indication of the fact that the author is either not familiar with the usual practice or is trying to hide incompetence. Another error common in specifications written by such men is the confusion of the various classes of work, good and bad requirements are mixed together. Clauses found only in specifications calling for the highest character of work are found side by side with requirements indicating a poorer grade. Such specifications seem to result from the author's having collected all the available information within his reach and combined it into one production. It is a practice which cannot be too greatly condemned. In general the young engineer should follow in the footsteps of his predecessors except where a deviation is dictated by good and sufficient reasons.

A HOT TRAIL.

By J. L. VAN ORNUM, B. C. E. '88; C. E. '91;
Instructor of Civil Engineering, Washington University, St. Louis, Mo.

Waiting for the council of V—— to settle their differences, concerning the contemplated municipal improvements, proved too exasperating and I concluded to accept the position offered some time before by the Chief Engineer of the L. K. R. and V. R. R. I so informed him and reported for duty on the following Monday.

After talking of my previous work for him, he said, "Before you organize your party for the location survey, I have an investigation I would like you to undertake, concerning the intentions of a rival road in the mining region." He proceeded to state that the general manager had learned of an apparent intention of the X—— R. R. to extend their line into the newly developing fields and so destroy the supremacy of our road in that region. It was reported that a party of X—— surveyors was recently at work in the field and it was the desire of the general manager to learn of their intentions as fully as possible, without disclosing the fact of the investigation to them.

When our plans were about perfected, I asked the Chief if he could loan me a shot gun. "What do you want of that?" said he. "You are going out on serious business, not for pleasure." I explained that my idea was to pass as a hunter if I found my investigation about to be discovered by the rival engineers, and so cover the real purpose of my presence near their lines. The gun was obtained and other arrangements quickly made, and the next morning found me in the office of the division engineer at H—— inquiring concerning any new developments in the case. Nothing had occurred for a fortnight nor was anything definite known further than the presence at A——, three weeks before, of a fully equipped survey party. Taking the next train to A——, an examination of the hotel registers revealed several names from L——, where were located the general offices of the X——Railroad. Inquiry concerning these men developed the fact that they were engineers who had been at work in that vicinity, but they had not been seen for about two weeks. As A—— was the terminus of the X—— road, I concluded that the party had probably made the survey as an extension of the existing line.

Proceeding to the end of the tracks to verify the idea I found the theory less easily proved than formed. A thorough search was made over a constantly widening zone eastward from the end of the line, but it was not till late in the afternoon that the search was rewarded by the discovery, well outside the town, of the distinctive narrow line cut through the brush, the stakes being most obscure in size and height. This line was followed, as far as daylight permitted, to make sure of its identity. It gradually emerged from its obscurity, taking on all the well-known marks of the railroad location survey as it advanced into the woods.

The next morning, armed with the fowling-piece and a lunch, A—— was abandoned as the base of operations and the real work of following the line was begun. This proved comparatively easy all the first day and at evening the trail had been traced, many miles, to the south shore of a small lake about half a mile north of Y——, a station on our own line. However, here the curves were not run in, the character of the survey changing from a location to a preliminary survey.

The one hotel of Y—— furnished a good dinner and promise of a restful night, preparatory to a resumption of the search the next day. Of course the universal custom of small towns must be observed, leading me to the depot to watch the evening train come in. Imagine my surprise when I saw emerging from the smoker a full corps of engineers with their instruments, and alighting with an assurance that seemed to betoken a cinch on the town and all the surrounding country. Surprise changed to consternation when I beheld in the last to alight the well-known contours of my old University friend Q——! Fortunately his concern for the safety of his level had not permitted him to remove his anxious eyes from that precious charge, and the next instant my back was toward him as I walked toward the rear of the train. It would never do to remain over night in the same town with this party, and, necessarily, at the same hotel, especially as one of its members was an acquaintance; so I boarded the now moving train undiscovered, and spent the night again at H——.

The next morning's train eastward reached Y—— in good time. A little quiet observation upon the hotel resulted in the assurance that the rival engineers had already left for their field of operations. An examination of the register showed their bill unpaid, and concluding that it would therefore be an undesirable headquarters for me I paid my bill, called for my gun, and started out to reconnoiter, with the knowledge that any moment might bring me into undesired notice. On approaching the lake the party was seen at work where the trail had been dropped the previous night. A few minutes observation indicated their task to be running in of the curves of their preliminary line, showing that the latter was considered satisfactory for the location survey and carrying the probability that their presence would not be unpleasantly near if only the trail could be resumed far enough in advance to be beyond their observation. This proved more difficult than anticipated, owing largely to the unwonted activity and omnipresence of their chief of party, but it was finally accomplished without discovery.

Elation over once more having a clear field for rapid advance soon began to disappear. The ranges of hills obliged their line to soon approach our own railroad, and here the marks of the survey, generally so easily followed, became exceedingly obscure; and the increasing roughness of the region necessitated many angles and short tangents, all combining to impede progress. A start in one direction was no sooner made than the trail was lost, whether from most obscure markings or a change in direction minute search only would reveal. The meridian sun and stifling air of the valleys did not aid in expediting progress.

While delving in the midst of one of these hotbeds of obscurity the rythmic tread of a trained pedestrian on our nearby tracks was heard. Peering out I discovered the chief of party rapidly approaching. Presently he turned into the woods and was soon so near that I concluded to discreetly give him the right of way on his own line, and crouched down among the bushes at one side. Strangely enough the locality seemed to engage his close attention. He stopped for a moment opposite my hiding place and then started directly toward me. Discovery was only the matter of a moment and so I discharged the gun in the air, and, springing up, gazed into a tree with rapt attention. Some muttered exclamation appeared to be followed by a close scrutiny of the unexpected hunter, who continued to appear oblivious of his presence. After a minute or two he remarked on the fruitless shot, which was reluctantly admitted. Then, to shift attention from myself, I asked him the purpose of a slope-board he carried in his hand. "It's for use in measuring land," he said, "you could not understand it if I should explain all day." "Maybe not, but can't I help you, and get to learn?" Quickly came the reply, "No, I have all the help I want." "Be you a land surveyor?" "Yes, but don't bother me," he replied. "You can do better hunting than helping." Although this was very doubtful praise, I was as glad to go as he appeared to be to have me and I sauntered off, still scrutinizing the trees for game until beyond his view.

To re-discover the line beyond was a harder task than following its intricacies, and after it was found it still continued obscure. Besides there was an enemy in the rear who must be most carefully avoided now. The sun had set when the trail was finally followed to the edge of a marsh where progress might be easier. The evening train to H—— was still far from due, and the line might perhaps be followed as far as the station a mile eastward. However the first attempt to prolong it failed, and the second, and many succeeding ones suffered the same fate, until the deepening twilight merged into night,—and to weariness, hunger, and only a few miles progress, was added the discouragement of completely losing the trail.

With the morning new hope was added to determination. The search was renewed by beating back and forth in a widening path over the zone that the line must have taken across the marsh. More than an hour's work proved again unavailing and then I determined to follow the plan of the night before and try to trace the trail from the line at the bank, but with no better success. What could be done? I knew that the line must be planned for several miles further, and yet the most careful examination could not discover its prolongation.

Going backward and scrutinizing every inch for a clue, about a hundred yards from the edge of the marsh I found what had escaped attention in the twilight the night before,—a piece of paper folded and held in the bark of one of the stakes. This proved to be instructions written by the chief of party to his levelman, stating that at that point their line joined the old O—— survey, at an angle of 26 degrees left, following it for 2,800 feet, and then resuming their own line. Strangely enough the methodical Q—— had read the note when he reached that point and had faithfully returned it to its place, although its mission had been accomplished—at least as far as he was concerned! My previous discomfiture was thus explained, for I had followed their first line cut through to the marsh, which had been later abandoned back to this station; and it was not strange that I had been unable to discover the marks of the old survey, made half a dozen years before. Aided by the note so kindly left I resumed the trail and found the figures given reached the opposite edge of the marsh, where, with little difficulty, I found their line again and followed it readily to the end.

The finishing of the search had occupied till after noon, and the desire for a good meal suggested the only available hotel at Y——. The plan was unhesitatingly adopted as by this time the rival engineers would be at their work, even if they had gone in for lunch.

After the combined appetite of the sportsman and engineer was appeased I stood in the office preparing to leave, when members of the survey party began pouring into the room. They must have finished their work in that vicinity—a contingency I had not calculated upon. It would only arouse questioning if I should retreat through the dining room, so I pulled down my hat, turned up my coat collar and kept quiet for the moment, hoping that the confusion of entering a crowded room would divert from me the attention of Q—— and his chief. The latter had apparently been delayed to investigate some detail, and I appreciated his devotion to duty. As for Q——, he entered last, with his eyes fixed on his beloved instrument, which ever seemed to claim his whole interest. The next moment I had slipped unobserved out the door, with no danger now of discovery.

The rival line had been quietly and carefully surveyed. Their plan, as disclosed by their work, was to parallel our line to its end and a little beyond, and then construct a switchback around the end, thus enclosing it in a *cul de sac*. This procedure would have destroyed the supremacy of our line owing to the topography in the vicinity and to a previous agreement between the roads that they would have no grade crossings. To thwart this purpose it would only be necessary for our road to watch the other and keep its tracks always in advance of those of its rival. The L. K. R. and V. is still supreme at the mines.

I must beg all my engineer friends who have leveled on a railroad survey never to question me concerning this incident, else I may be obliged to seek refuge in the fiction, which writers so often use, that his tale is all imaginary.

THE TWO-WATTMETER METHOD AS APPLIED TO TRI-PHASE CIRCUITS.

BY B. D. FRANKENFIELD, B. S. '95.

In the two-wattmeter method of measuring power in a balanced tri-phase circuit, the following conditions obtain:

(*a*) One meter will read zero if the angle of lag between the pressure and the current is equal to sixty degrees, and the power in the circuit is represented by the reading of the other instrument.

(*b*) When the lag is less than sixty degrees, the power is obtained by adding the two readings.

(*c*) When the lag is greater than sixty degrees, the difference of the readings represents the power.

This is true whether the lag be positive or negative.

To prove this theorem, we will assume a specific case of a star connected induction motor. It holds equally well for mesh connection, but it is thought better to take a specific case than give a general proof.

The connections are shown in figure I and figure II is the corresponding vector diagram OA, OB, and OC represent the maximum pressures on coils A, B, and C respectively. The instaneous pressures will then be,

$$e_a = \sqrt{2}\, E \sin \theta,$$

$$e_b = \sqrt{2}\, E \sin \left(\theta - 120^\circ\right),$$

$$e_c = \sqrt{2}\, E \sin \left(\theta - 240^\circ\right),$$

where E is the effective pressure on one coil.

First, consider the meter D. The instantaneous pressure impressed on its pressure coil will be 30° in advance of OC, and its value will be,

$$e_{ac} = \sqrt{3}\,\sqrt{2}\,E \sin\left(\theta - 240^\circ + 30^\circ\right)$$
$$= \sqrt{3}\,\sqrt{2}\,E \sin\left(\theta - 210^\circ\right).$$

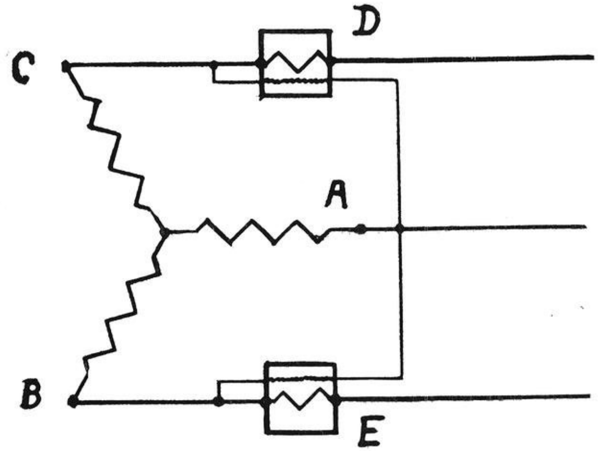


FIG. I.

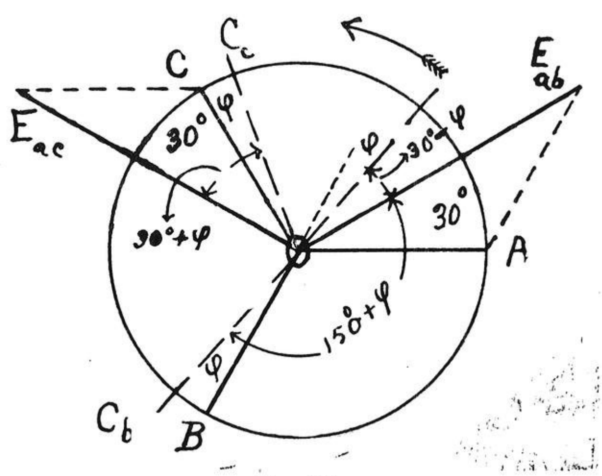


FIG. II.

The current in the current coil will be

$$C_c = \sqrt{2}\,C \sin\left(\theta - 240^\circ - \varphi\right),$$

where C is the effective current in one of the mains and ϕ is the angle of lag.

The phase difference of current and pressure is then,

$$(\theta-210^\circ)-(\theta-240^\circ-\varphi)=30^\circ+\varphi$$

Hence the component of *effective* pressure in phase with the current is,

$$\sqrt{3}\,E\cos\left(30^\circ+\varphi\right)$$

and the power as indicated by wattmeter D will be

$$P_d=\sqrt{3}\,C\,E\cos\left(30^\circ+\varphi\right)\ldots\ldots\ldots\ldots\ldots\ (a)$$

When $\varphi=60^\circ$ $P_d=0$;
" $\varphi<60^\circ$ $P_d=a+$ quantity;
" $\varphi>60^\circ$ $P_d=a-$ quantity.

This means that, as the angle of lag passes through the value 60^0, the terminals of the pressure coil of our instrument must be reversed, or the needle will disappear on the zero end of its scale.

Now, considering the meter E, we have the pressure from A to B leading OA by an angle of 30^0 and

$$e_{ab}=\sqrt{3}\,\sqrt{2}\,E\sin\left(\theta+30^\circ\right).$$

The instantaneous current is, in this case,

$$c_b=\sqrt{2}\,C\sin\left(\theta-120^\circ-\varphi\right);$$

and the phase difference between pressure and current is,

$$(\theta+30^\circ)-(\theta-120^\circ-\varphi)=150^\circ+\varphi.$$

The component of effective pressure in phase with the current is

$$\sqrt{3}\,E\cos\left(150^\circ+\varphi\right)$$

$$=\sqrt{3}\,E\cos\left(30^\circ-\varphi\right)^*$$

and the power as indicated by the instrument E is

$$P_e=\sqrt{3}\,CE\cos\left(30^\circ-\varphi\right)\ldots\ldots\ldots\ldots\ldots\ldots\ (b)$$

When $\varphi=60^\circ$, $P_e=a+$ quantity;
" $\varphi<60^\circ$, $P_e=a+$ " ;
" $\varphi>60^\circ$, $P_e=a+$ " .

* The supplement of $(150^\circ+\varphi)$ is taken because in practice $(150^\circ+\varphi)$ would be an obtuse angle and this would give a negative sign which has no practical significance, as the meter would be connected to read positive under any circumstances. All that we need to prove is that the reading does not change sign within the limits of $\varphi=0^\circ$ and $\varphi=90^\circ$. $(30-\varphi)$ is the acute angle between the vectors of current C_b and pressure E_{ab}.

This shows that the instrument will read positive for all values of ϕ met in practice, ninety degrees being the value of ϕ which gives a zero power factor.

An inspection of equations (*a*) and (*b*) shows that our theorem

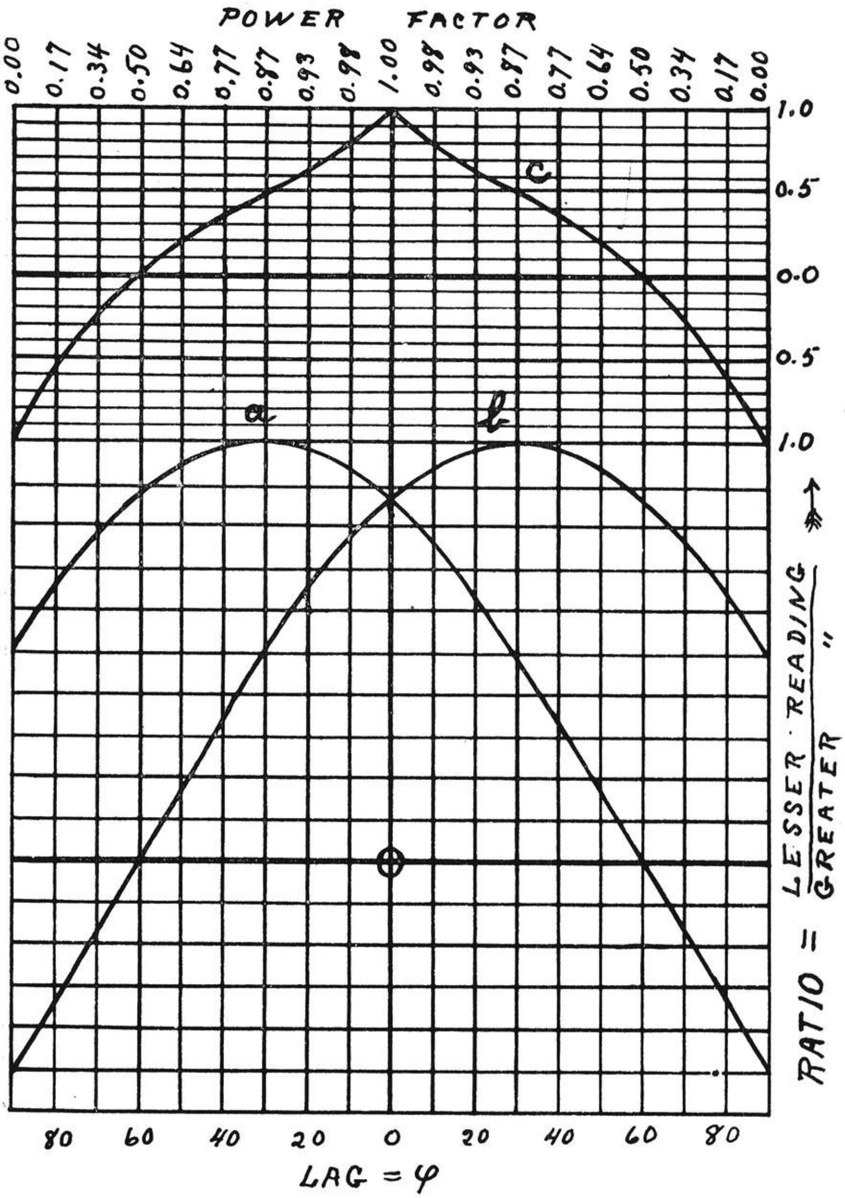


FIG. III.

holds for negative values of ϕ and that the terminals of meter E must be reversed at $\phi = -60^0$ while those of D need not be changed throughout the entire range. This is the case of a capacity load.

Equations (a) and (b) may be plotted as in figure III where ϕ is measured along the axis of X and the corresponding *relative* values of P_d and P_e along the axis of Y. Curves (a) and (b) correspond to equations (a) and (b) and are two sinusoids 60^0 apart. Two simultaneous ordinates for any value of ϕ will have lengths proportional to the readings of the wattmeters. The third curve (c) represents the ratio of the lesser reading to the greater. The power factor, plotted on the upper scale, is equal to cos ϕ.

We will now work a practical example using these curves.

Suppose we desire to know the relation between power factor and load of a certain tri-phase motor. Running light, the meters read 1340 and 895 watts respectively. The ratio of the lesser reading to the greater is 0.67. First of all we know that the lag is positive and we find from curve (c) that there are two positive values of ϕ which will give ordinates in this ratio. One gives a high power factor and the other a lower one. Our judgment tells us that as the motor is running light, the power factor is low and we find that the lag is 82^0 and the power factor 13 per cent. We also see from curves (a) and (b) that the number of watts expended in the circuit is equal to the difference of the readings, or 445.

When the machine is given another increment of load the power factor is obtained in the same manner, and the difference of the readings for each increment of load will represent the input until a power factor of 50 per cent. (corresponding to a lag of 60^0) is reached, when one instrument will read zero. Its pressure terminals must then be reversed and the sum of the readings will represent the input to the end of the test.

If a person has no idea of the power factor on the circuit tested, as might often be the case, he can vary the load until one meter reads almost zero. *If the reading of the other decreases at the same time, the power factor is greater than 50 per cent. and the readings should be added; if it increases, the power factor is less than 50 per cent. and the difference of the readings represents the power.* This is readily seen by an inspection of the curves.

Another instructive point which this diagram brings out is that if both instruments indicate the same amount of power, the lag is either 0° or 90° and the circuit is either in resonance or is entirely wattless.

The writer hit upon this graphic solution while trying to solve an actual problem in the two-wattmeter method. He claims for it this advantage: both the angle of lag and the power factor can be found without taking volt-ampere readings.

THE PROBLEM OF ECONOMICAL HEAT, LIGHT AND POWER SUPPLY FOR BUSINESS BLOCKS, SCHOOL HOUSES, DWELLINGS, ETC.*

BY G. ADOLPH GERDTZEN, B. S., '93.
Reviewed by Prof. Storm Bull.

This paper which has just been published as No. 8 in the Engineering Series of the Bulletins of the University of Wisconsin is a very valuable addition to the literature on the subject announced in the title. The author considers the possible solutions of the problem: the electrical, the gas, and the steam solution; he compares them under all possible circumstances as they may occur in practical life, and then draws his conclusions in favor of the use of gas, formed by a mixture of that produced by the retort and water-gas processes. This conclusion seems to the writer perfectly justified, as it is based upon the most reliable data and experiments to be found in technical literature, the author having thoroughly studied his subject both in technical journals and the best books in this line.

The electrical solution is first disposed of, it being easily shown that for the combined problem of heat, light and power supply, electricity can not yet compete with either steam or gas, the efficiency of the process of heating by electricity being so very low.

It would seem at first glance that steam should be the most economical, and in certain individual cases this is no doubt true, for instance for large steel frame buildings where there can be no flues in the walls and where a private installation would be advantageous. The principal reason why the economy of the steam method is lower than that of the gas, is that the load factor is very low and the stand-by loss great, because of the impossibility of

*Thesis presented for the degree M. E.

storing the steam, and because the demand will be very variable. A gas plant on the other hand, especially one in which the retort and water gas processses are combined, will have a low standby loss, and because of the easy storing of the gas it may be run at its full capacity or not at all, as the demand on gas requires it, and still very nearly retain the maximum running efficiency. This difference in economy is very clearly shown in the paper; but it should be noted that it only applies to comparatively small plants, where, for instance, the size of the engine furnishing power is less than 50 H. P. It should also be borne in mind that it is only in the combined problem of furnishing heat, light and power that the gas solution is the most economical one. It must, however, also be admitted that the use of gas simplifies the distribution of heat and light to the various rooms of a building as compared with steam, but this side of the question cannot be taken into account in a paper where the economy of the plant is to be the deciding question. One cannot help coming to the conclusion after reading this paper, that the heating of dwellings by means of gas ought to be very much more popular than it is at present. If a gas stove can utilize 80 per cent. of the heat produced by the complete combustion of the gas, it certainly will be a comparatively cheap method of heating dwellings in large cities where the cost of gas is low.

The author states in concluding his paper that a conservative engineer will ever be loath to leave an old system for a new one which has not been tried, but that the necessity of progress because of competition will force him to try a new system for furnishing heat, light and power to buildings, and it will then be found that the system proposed by the author is supported by sound and reliable conclusions from engineering facts of today. The writer of this review expresses the hope that the system may soon be tried, and he has no doubt that Mr. Gerdtzen's conclusions will be verified.

INSPECTION OF GOVERNMENT LAND SURVEYS IN WESTERN WASHINGTON.

L. T. GREGERSON, B. S., '95.

In order to make the work of an Inspector more clear, it will be necessary to give a brief outline of the original work. Whenever any sub-dividing of government lands is to be done, the Surveyor General receives bids for the work and awards contracts to "Deputies." The rate paid per mile depends upon the character of the country in which the work is to be done, that for mountainous country being higher than for level country. For work in ordinary timber the rate is about twenty dollars per mile, and for meandering about twenty-three dollars. Meandering is the most profitable, as it is generally much easier to work along the banks of a river than in timber.

The Deputy receives instructions from the Surveyor General as to how much of a township is to be surveyed, but he must use his own judgment in doing the work. That is, no work must be done where the country is so mountainous that it would be impracticable to survey it.

It is the duty of the Deputy to run and measure all lines as accurately as circumstances will permit. Section corners, quarter section corners, meander stakes, witness corners, etc., must be set and carefully marked. Bearing trees must be established and plainly marked also. This is a very important part of the work, and much stress is laid upon the kind of tree to be selected, and the manner in which it shall be marked. In connection with the work, a fairly accurate topographical map of the country must be made, which renders it necessary to take plusses of elevations and depressions and of streams. All streams over two chains in width should be meandered. If anything of interest is found on or near the line, such as indication of ore, or a rancher's cabin, it should be noted. The lines must be well blazed in order that the settlers may follow them readily in staking out their claims.

All of the work must be within the limits of 50 links per mile in alignment and the same amount in measurement. The limits were previously 80 links per mile, which seems to be a fair allowance, considering the difficulties which the Deputies have to contend with in a mountainous or heavily timbered country. A Deputy receives no remuneration for his work until it has been examined and accepted. This renders it necessary for the Commissioner of the General Land Office to send out men whose duty it is to inspect the work done by the Deputies.

An Inspector's party generally consists of four persons besides himself,—two chainmen, a flagman, and a cook. In a mountainous country where trails are few and far between, it is necessary to have two extra men for packing, who are generally referred to as the "mules."

It is the duty of an Inspector to examine at least fifteen per cent. of the Deputy's work, but the time spent on a particular contract depends largely upon the accuracy of the work. Where it is evident that the lines have been carefully run, part of them are simply measured; but at every post the bearing trees with their markings are noted.

Before starting out on a contract, the Inspector obtains as much information as possible regarding the survey, and in making up his party tries to get some one who was with the Deputy. The work is usually in a country so mountainous and so covered with underbrush and logs, that horse trails are very scarce and foot trails only can be relied upon. As in most localities it is necessary to take along all supplies for the party, we are here confronted by the worst feature of the work—packing. Each man has a very scanty supply of clothing and a blanket or two in which he is expected to carry from forty to fifty pounds of provisions when occasion demands, which is too often the case. When weary from a six or eight hour tramp under these conditions, one marvels at the endurance of the ranchers, who are sometimes seen with such articles as stoves and large trunks on their backs.

Having reached the point from which he wishes to start, the first thing for an Inspector to do is to establish a meridian. This work is of great importance and must be carefully attended to. The instrument used is generally a light mountain transit with solar attachment. The meridian is established by observations on Polaris, and the result checked by observations on the sun. It should be located not very far from camp, so that the instrument may be tested every morning before going to work. In running lines, an observation on the sun is generally taken every half hour on clear days. It is very important to get the variation often, for the needle may change a degree or two in a very short distance.

An Inspector generally uses the same starting point as was used by the Deputy, but this is not absolutely necessary. The lines are run only approximately. In thick timber the sights are necessarily very short and trees are very often on line. When this is the case, the instrument is set up behind the tree and the line continued by use of the needle. At every section corner and quarter post, the errors (if any) in the Deputy's line; the bearings and markings of bearing trees; and the character of the soil and quality of the timber is noted. The line is then continued from the post. In ordinary timber one mile per day is the average progress, while one and a half miles is considered good, and two miles unusual.

During the summer months the climate in Washington is nearly perfect. The days are very seldom too warm, and the evenings are never too warm for comfort. But in the fall, the rainy season commences, and if the siege be a long one, surveying must be discontinued for a time at least. When rainy or cloudy weather is anticipated, the Inspector establishes a meridian and runs his lines by back and forward sights. This, however, is necessarily a very slow process in thick timber, and requires two extra axemen and a back flagman.

When several contracts have been inspected, a report is sent to the Commissioner of the General Land Office giving an accurate description of the condition of the work. In this report, the diary of the party must be given, also the character of the country covered by the survey.

In spite of hardships the work with an inspecting party is very pleasant, and during the summer months is more of a vacation for the young graduate than anything else. When the winter rains set in, however, it is time for surveyors to leave western Washington.

A NEW METHOD OF MEASURING THE VARIATION OF THE CURRENT IN TELEPHONE TRANSMITTERS.

By ARTHUR H. FORD, B. S. '95,
Fellow in Electrical Engineering.

During the progress of some tests on telephone transmitters, it became desirable to measure the variation in the current flowing, due to the operation of the transmitter.

The methods first tried to get this variation were measurement of the vibration of the diaphragm of a telephone receiver placed in series with the transmitter directly, and also by a beam of light reflected from a mirror attached to the diaphragm a little distance from its center. Neither of these methods gave any results, so a very delicate electro-dynamometer of the Siemen's type was made and placed in circuit with the secondary of an induction coil having the transmitter and a battery in its primary. This method failed also.

It then occurred to the writer that the measurement of the secondary pressure of an induction coil would be as good, or a better measure of the change in the primary current, than the measurement of the secondary current.

Following out this idea, a large induction coil, which was designed to be used for Geissler tube effects, was connected with its primary in series with the transmitter to be tested and with a battry, while its secondary was connected to a quadrant electrometer. The calibration was accomplished by means of an intermittent current, having the same frequency as the source of sound, being passed through the primary and the electrometer deflections read with telescope and scale, the maximum value of the current being measured with a mil-ammeter. This method was entirely successful, but required a large volume of sound, which was furnished by an electric buzzer.

By this method the actual variation in the current can be obtained; and by measuring the total current flowing, the percentage variation can be found, and this is the true measure of the power of any transmitter.

The transmitters tested included practically all the types now in use, Hunnings, granular carbon, carbon ball and Blake. No one class could be said to have the largest variation in current as they differed so among themselves, the variation in the Hunnings type being from .008 to .25 the current flowing, and of all those tested, being from .00015 to .64. This variation depends quite largely on the current flowing, increasing in most cases as the current increases.

Some tests for clearness showed results which could be classified with some degree of certainty. They showed the clearness to be in this order: Standard, National, Blake, Hunnings from A. D. Sill, Hunnings from England. The other transmitters did not give very clear sounds, especially those of the carbon ball type. The reason that the first three give so clear a sound is that the part which produces the variation in resistance is either fastened to the diaphragm alone, or held against it by springs in such a way that the vibration is impeded as little as possible. The two Hunning's transmitters have very thin diaphragms of carbon and the carbon grains are very loosely placed in the space between the diaphragm and the carbon block, which accounts for the clearness with which they transmit speech.

A COMPARATIVE TEST OF A COMPOUND AND A SINGLE EXPANSION LOCOMOTIVE.

By W. S. HANSON, '95; F. I. HARTWELL, '95, and E. W. MEYER, '95.*

This test was made on two engines belonging to the C. & N. W. Ry. Co. on through freight service between Milwaukee and Sheboygan. Six round trips of 104 miles each were made with each engine. The engines were ten-wheelers of Schenectady make, one a single expansion 19″x24″, the other a two-cylinder compound 20″ and 30″x24″. All other dimensions were the same on both.

The object of the test was to compare the efficiencies of the two engines doing as nearly as possible the same work under the same conditions. A special effort was made to make a comparison of the engines only and care was taken to eliminate, both in the test and in the computations, all differences due to the boilers, such as variations in quality and pressure of the steam.

The average percentage of coal saved by the compound engine was 7.74 per cent.; water per I. H. P. hour, actual, 17.72 per cent.; water per I. H. P. per hour for dry steam at 160 lbs. gauge, 20.32 per cent.; water per ton mile, actual, 9.15 per cent.; water per ton mile for dry steam at 160 lbs. gauge, 11.94 per cent.; and water per mile per ton of train resistance for dry steam at 160 lbs. gauge 14.27 per cent. The last is considered to be the most nearly correct basis for comparison.

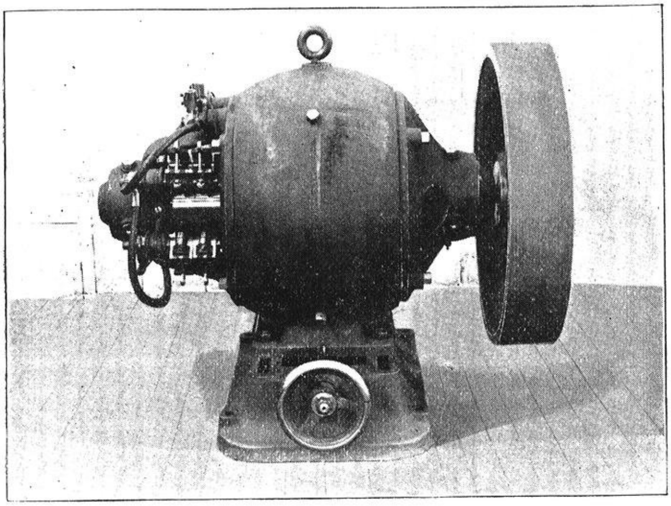
The road was characterized by sudden and frequent changes

*Abstract of thesis submitted for the degree of B. S. in Mechanical Engineering. See transactions Western Railway Club, Vol. 8, No. 1.

of grade. In this distance—52.2 miles—there are 16 grades of one per cent. and over. This, with other unavoidable circumstances, was unfavorable to the compound engine; and we are therefore justified in the conclusion that the compound made the saving indicated above under conditions which, in so far as they were not the same, were more favorable to the single expansion engine.

ELECTRIC MOTORS IN FACTORIES.

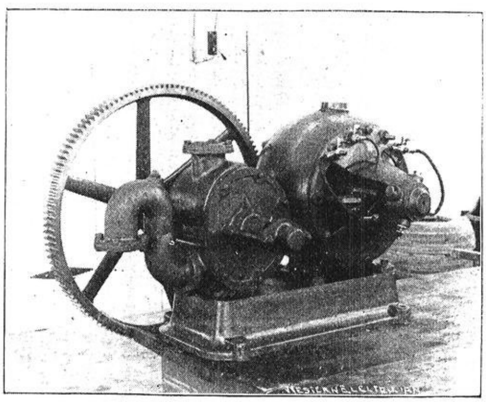
The problem of the application of electric motors to machine tools and other machinery, such as pumps and hoists, in factories is one of the most difficult of solution, yet the most fascinating to the designer. The advantages of such a system are self-evident and have been enumerated in nearly all the papers written on this subject; we will therefore pass at once to the methods of application.



Motor for direct shaft connection.

The most popular method at present is the group system, as applied to shops. Here a motor of standard design is belted to a short length of shafting which drives a group of machines. If possible, the machines are so grouped that all are idle at the same time and the shaft may then be shut down when the machines are not in use. This system saves the expense of maintenance and operation of long lines of heavy shafting and eliminates some of the overhead obstructions.

A large number of further economies could be practiced by direct-connection of the machines to motors, such as the entire obliteration of belts and shafting; and a great saving of time in the operation of machines requiring frequent variations of speed. The slow speeds at which such machines run seems to force upon us the use of gearing; as the cost of a motor which could be placed directly on a spindle in place of a cone pulley, and yet have



Direct connected motor and pump.

a respectable efficiency, is prohibitive, and a single gear of large ratio need be neither wasteful nor ungainly. So far, so good; but we are now confronted with a problem that has calmly withstood the most vicious onslaughts of the designer, viz., to build a motor having a wide range of speed, with easy gradations, which will be inherently self-regulating at any position of its controller switch, and be cheap, durable and simple in construction. We believe that this can and will be done some time in the future.

Our cuts represent two motors of special interest in this line. They were installed in the tannery of Pfister & Vogel, Milwaukee, by the Northern Electric Co. of Madison. The first is a motor designed for direct connection to a shaft which runs a fleshing machine. A test of this machine was first made by belting a motor to the counter shaft. A recording ammeter was placed in the circuit and frequent pressure readings taken. The load was of fluctuating nature with a maximum of 37 horse power, a minimum of 7, and an average of 14.8. A standard 25 horse power motor, wound to suit the speed of the shaft and capable of developing about 17 horse power at this speed, was direct-connected to the shaft by the fly-wheel clutch shown in the figure. The fly-wheel is large enough to take care of the peak of the load which lasts but an instant. A test of this motor, after installation, showed an average electrical horse power of 9.3 with only a small fluctuation.

Our second cut shows a tannery pump and motor fastened to the same base and connected by a spur gear. This was thought advisable because of the difficulty of belting where the pump is placed.

There are many points about the mechanical design of these motors that are strikingly original, Mr. C. M. Conradson, '83, being the designer. Two points clearly shown in the cuts are first, the boxes, which admit of the motor being operated equally well whether fastened to the floor, ceiling or wall; and second, the brush holders, which have a parallel motion that ensures noiseless running.

EDITORIAL NOTES.

A few words as to the inception of this publication may be of interest to alumni. During the early winter unusual interest in the project of issuing a journal was awakened among the students, largely through the agency of the engineers' societies, and encouraged by members of the faculty, the matter was taken hold of in real earnest. After communication with other colleges which issue technical periodicals, an organization was formulated, and soon afterward adopted by a mass meeting of engineering students. The organization, known as the Engineering Journal Association, includes as members the faculty and all students and alumni of the department, and has for its object the publication of a quarterly periodical. The board of editors, consisting of one post-graduate, three seniors, three juniors, two sophomores, and one freshman—no two of the same class to be also in the same course—are elected by their respective classes, with the exception of the member from the entering class who, with the managers, is chosen by the board of editors.

It is pleasing to note that all classes exhibited the same enthusiasm in this movement, many of the lower classmen taking a very active part. This is the kind of backing which will make the venture an assured success. It puts out of the question all misgivings as to the near future of the journal, before it shall have become well established.

Through the medium of the Wisconsin Engineer, the technical world will be given a better idea of the high standard of work done in our engineering department than it has had heretofore. In the past a few of the best investigations made in our laboratories have been published as University Bulletins. Many of the graduation theses of special merit have appeared as papers in the transactions of the various engineering societies, but here the opportunities are limited. We hope, hereafter, to give all the important work in this line, at least in abstract; so our readers may expect to see not only such articles as may appear, from time to time, in the transactions of our American engineering societies, but all the cream of the University's engineering achievements.

Many of our graduates have become noted engineers and their contributions to this magazine will always be of a practical nature. Their hearty response to requests for articles for this, our first number, indicates a bright future for our alumni department. We wish to express our gratitude to these men for the spirit with which they have taken hold of the work.

The illustration on another page of a busy morning hour in the reading room of the library brings out nicely a side of college work for which the engineering student can usually find little time, but which it seems to us for that very reason should be the more highly prized. He will hardly again have such an opportunity to obtain a general knowledge of other branches of his profession, and to familiarize himself with the great achievements in his own —both of which will be of great assistance to him in later years. During the early part of his course reading of the technical periodicals and works of reference serves to keep up his interest while he is threading the dry mazes of theoretical class work. Later he gathers points on the practical problems he is likely to meet and before the completion of his course he begins to feel in touch with the general engineering fraternity.

Nor should he cease adding to his fund of general information. Let him not be a "cold, calculating villain" who thinks of nothing but strength of materials and capitalized estimates; who is interested only in alignment and grades, valve gears, or armature winding. True, the hey-day of the "Jack of all trades" is past and he must direct all his best energies along his chosen path if he is to attain success. Nevertheless, though an enthusiastic specialist, he need not and cannot afford to be classed as "narrow." Men of the world—business men—with whom he will probably have more to do than he anticipates, will judge him by the standards with which they themselves are familiar. Of his technical knowledge they are not well able to judge, but if he exhibits lack of general information and grasp of problems of the day, they will set him down at once as a man who is not wide awake and possessed of the broad intelligence which would make him master of his profession. With all the opportunities presented in our university and the incentive given by co-workers, a little more time spent in thus filling in the perspective will not go amiss.

The Engineer starts off with an issue of 2,500 copies for the first number. This is just double the number at first intended, and is made possible by the support of advertisers and the generosity of the Board of Regents. It is the intention to issue at least 2,000 copies of each number during the coming year. It has also been decided to make the journal a quarterly instead of a semi-annual, as was first proposed. This will make the index more valuable, as well as our advertising space. The chances all seem to be more favorable for the success of a quarterly than for a semi-annual.

The trigonometrical survey of the senior and junior civil engineers will this year be widened out to connect with the stations established in the region by the United States Coast and Geodetic Survey. Several new instruments for use in geodetic work have been obtained, including a fine German alt-azimuth instrument and a complete precise level outfit from Kern & Co., Switzerland.

Professors Snow and Austin of the Physics Department have been doing much successful work with the "X rays." Since the early experiments in the general line now so familiar to all, in which many fine negatives of special value were obtained, they have been investigating along the line of the reflection of the rays. Besides the reflection through tubes and from pieces of metal placed behind photographic plates, experiments have been tried with the Crookes' tube placed in the focus of a parabolic reflector from a locomotive head-light. The fluorescent screen glowed faintly but certainly, when placed in front of the reflector when the direct radiation of the tube was entirely cut off. With a plain metal mirror behind the tube instead of the parabolic, no evidence of reflection great enough to excite the screen was found. This may perhaps be taken as an indication that the reflection is at least in part regular. Unsuccessful attempts have been made to repeat the experiments described by Becquerel (Comptes rendus, March 2, 1896) on some invisible radiations given out by fluorescent substances, which are capable of traversing bodies opaque to ordinary light. Though these experiments have been amply verified elsewhere, the results here have been negative. The salt used was uranium-nitrate. A photographic plate was exposed to its influence for twelve hours, the salt being a part of the time in the direct sun light. A new Edison screen of calcium-tungstate has been obtained with which better results in reflection are expected. They are now engaged on the diffraction of the rays.

A recent event worthy of note was the Second Annual Joint Debate between the U. W. Engineers' Club and the Engineers' Association. The debate was on the question of state and national ownership and operation of irrigation systems as opposed to private ownership, the affirmative being taken by H. C. Schneider, G. H. Jones and C. W. Hart of the Association, and the negative by F. J. Newman, R. D. Jenne and H. Murley of the Club. Both sides were supported in a most creditable manner, both in the array of data and arguments and in their skillful presentation. The contest, which was well balanced throughout, was decided in favor of government ownership, thus giving the Association its second victory.

Undaunted by the seeming failure of previous attempts of engineering students to organize a literary society, leaders in two factions in the fall of '94 successfully pushed to organization these two societies. The existence of the two has proven a benefit to each by creating a friendly rivalry and thus giving impetus to the best methods and work. The primary object of the societies is to supply a needed training in parliamentary practice, speaking, writing and debate, which is not had in the regular course. As somewhat secondary, though by no means a small matter, the societies aim to keep in touch with the engineering world by choosing for debates and papers live engineering topics and having in addition a weekly review of engineering periodicals. The weekly program of each society consists of papers, debates and reviews, sometimes varied by a special lecture from a member of the faculty or corps of instructors. One of the special features is the joint debate, nearly six months of study being put on the question by the respective teams. That the members of these societies have obtained a wider knowledge of current engineering practice and have improved in their ability to express themselves clearly and to the point is manifest.

ALUMNI NOTES.

—'94. Ed. Pratt has a position in the South Chicago Steel works.

—'95. Harry Fowle is in the electrical business at South Milwaukee.

—'94. R. M. Arms is working for the Ft. Wayne Electric Co. at Indianapolis, Ind.

C. H. Hile, Fellow '92--'93, is superintendent of the Boston Electric Ry. Co.

—S. R. Sheldon, '94, and P. A. Bertrand, '95, are with the Diamond Electric Co. at Peoria, Ill.

—'93. Fred H. Ford, secretary of the Peoples' Electric Co. of Madison, was married June 3rd to Miss Harriet Armour of Milwaukee.

—Herbert Gregg is in the mechanical engineering department of the C. & N. W. Ry. at Chicago.

—'95. R. C. Falconer is in the New York office of C. T. Purdy, '85, the well known engineer in tall building construction in Chicago.

—'95. E. W. Crane is with the Westinghouse Electric Co. at Pittsburgh, Pa.

—'94. R. J. Ochsner is operating the electric plant at a coal mine at Hymera, Ind.

—'93. J. G. Wray is assistant chief engineer of the Chicago Telephone Co.

—'95. Theodore P. Schumann died March 24, at Pittsburgh, Pa., where he was holding a position in the Westinghouse Electric Co. He was sick but a short time with typhoid fever.

—'95. Geo. H. Burgess has left the Edge Moor Bridge works and is now on the Pennsylvania Railroad at Pittsburgh.

—'94. W. A. Baehr is with the Wisconsin Bridge and Iron Co. at Milwaukee.

—'90. D. L. Fairchild, who has recently been promoted in the Geological Survey, is now located in Indian Territory.

—'95. Carl H. Kummel is located in Montana as an assayer and mining engineer.

WISCONSIN ENGINEER INDEX.

We believe that there is an absolute need for a well arranged index to engineering periodicals, which has not been supplied since the discontinuance of the index issued by the Association of Engineering Societies. The Technical Index of the Engineering Magazine is probably the most complete index which has hitherto been published; but on account of its arrangement, it is not practically available for ready reference. The Digests of The Electrical World and of Electric Power are both excellent, but their scope is confined to the field of Electrical Engineering, and as reference lists, they are open to the same objection as the Technical Index.

Believing that we can improve this condition of affairs, the editors of the Engineer decided to publish an index compiled from the index and digests above mentioned, with references to these when the description or digest is sufficient to warrant it. No attempt at description has been made further than to indicate reprints or abstracts of papers read before engineering societies.

IMPORTANT TO STEAM USERS.

FROM "THE SCIENTIFIC AMERICAN."

Having received many inquiries concerning the best method to protect the interior of steam boilers against the evil effects of pitting and other forms of corrosion, and also as to the best remedy for the removal and prevention of boiler incrustation, we consider it proper to quote reports of our acknowledged authorities on the use of steam, by whom thorough investigations have been made.

Among the many different remedies advertised, we find but one manufacturer whose products are recommended in our different scientific works of acknowledged authority,—Mr. Geo. W. Lord, Manufacturing Chemist, Phila., Pa.

Author Le Van, of The Franklin Institute of Phila., in a work entitled "The Steam Engine and Indicator," says, "The Boiler Compounds manufactured by Geo. W. Lord, of Phila., have a high reputation, not only as a preventive of boiler incrustation, but also for neutralizing acids and corrosive matter."

Author Edwards says, in "The American Steam Engineer," "Lord's Boiler Compound is the most widely known and extensively used. I have used Lord's Compound on land and at sea, during many years service, with the most satisfactory results."

Author John S. Fornum says, in a work entitled "Practical Points," that Mr. Lord's extensive trade is no doubt due to his scientific knowledge and skill, in furnishing a preparation suited to the requirements of each individual steam user.

In "The Engineers' Handy Book" by Roper, we find under the head of Scale in Steam Boilers, the following: "Lord's Boiler Compound appears to be the only chemical preparation in use, that will prevent the formation of scale, and remove it after it has been formed in any steam boiler."

Booth, Garrett & Co., Chemists of Philadelphia, who stand at the head of their profession, make the statement over their signature that "Lord's Compounds are free from any substance that could prove injurious to the Steam Boiler."

We could make quotations similar to the above from many other scientific works, if time and space would permit. Probably the best proofs of merit of the chemical preparations manufactured by George W. Lord, is in the fact that many other parties, who have recently entered into this line of trade, have offered to steam users, their different articles as "Lord's Boiler Compound," or in using the word "Lord" in some way to mislead the manufacturer.

The genuine chemical preparations, known under the head of "Lord's Boiler Compound" are manufactured only by the inventor, Mr. George W. Lord, analytical and manufacturing chemist, whose office is at 316 Union Street, Philadelphia, Pa."

Wisconsin Engineer Index

To Current Engineering Periodicals.

December, 1895, to April, 1896, Inclusive.

Explanation: W, words. M. Jan., W. Jan. 4, or P. Jan. at the end of the reference, indicates that a description or digest of the article may be found in the index of the Engineering Magazine of January, in The Electrical World digest of January 4, or in the Electric Power digest for January.

List of periodicals from which articles are indexed:

American Architect, The. *w.* $6. Boston.
Am. Engineer and Railroad Jour. *m.* $2. New York.
Am. Chemical Journal. *b-m.* $4. Baltimore.
Am. Gas Light Journal. *m.* $3. New York.
Am. Journal of Science. *m.* $6. New Haven.
American Machinist. *w.* $3 New York.
Am. Manufacturer and Iron World. *w.* $4. Pittsburgh.
American Miller. *m.* $2. Chicago.
American Shipbuilder. *w.* $2. New York.
Am. Soc. of Irrigation Engineers. *qr.* $4. Denver.
Annual Report of Illinois Society of Engineers and Surveyors. New York.
Architectural Record. *qr.* $1. New York.
Architect. The. . 26s. London.
Architecture and Building. *w.* $6. New York.
Architectural Review. *-qr.* $5. Boston.
Australian Mining Standard. *w.* 30s. Sidney.
Boston Journal of Commerce. *w.* $3. Boston.
Brick. *m.* $1. Chicago.
Brick Builder, The. *m.* $2.50. Boston.
British Architect, The. *w.* 23s. 8d. London.
Builder, The. *w.* 26s. London.
Bulletin Am. Iron and Steel Assn. *w.* $4. Phila.
Bulletin of Univ. of Wisconsin. Madison
California Architect. *m.* $3. San Francisco.
Canadian Architect. *m.* $2. Toronto.
Canadian Engineer. *m.* $1. Montreal.
Canadian Mining Review. *m.* $1.50. Ottawa.
Cassier's Magazine. *m.* $3. New York.
Clay Records. *m.* $1. Chicago.
Colliery Engineer. *m.* $2. Scranton.
Colliery Guardian. *w.* 27s. 6d. London.
Domestic Engineering. *m.* $2. Chicago.
Electric Power. *m.* $2. New York.
Electric Railway Gazette. *w.* $3. New York.
Electrical Age. *w.* $3. New York.
Electrical Engineer. *w.* 19s. 6d. London.
Electrical Engineer. *w.* $3. New York.
Electrical Engineering *m.* $1. Chicago.
Electrical Industries. *m.* $1. Chicago.
Electrical Journal. *m.* Chicago.
Electrical Plant. *m.* 6s. London.
Electrical Review. *w.* 21s. 8d. London.
Electrical Review. *w.* $3. New York.
Electrical World. *w.* $3. New York.
Electrician (Electn.) *w.* 21s. London.
Electricity. (Elec. Lond.) *w.* 7s. 6d. London.
Electricity (Elec.) *w.* $2.50. New York.
Electrochemische Zeitschrift. *m.* Ger.
Electrotechnische Zeitschrift. *w.* Ger.
Engineer, The (Eng.) *s-m.* $2.50. New York.
Engineer, The (Eng. Lond.) *w.* 36s. London.
Engineer and Contractor. *w.* $1. San Francisco.
Engineer's Gazette. *m.* 8s. London.
Engineering (Engng.) *w.* 36s. London.
Engineering and Mining Jour. *w.* $5. N. Y.
Engineering Magazine. *m.* $3. New York.
Engineering-Mechanics. *m.* $2. Phila.
Engineering News. *w.* $5. New York.
Engineering Record. *w.* $5. New York.
Engineering Review. *m.* 7s. London.
Eng. Soc. of the School of Prac. Sci. Toronto.
Eng. Soc. of Western Pennsylvania. *m.* $7. Pittsburgh.
Foundry. The. *m.* $1. Detroit.
Gas Engineers' Magazine. *m.* 6s. 6d. Birmingham.
Heating and Ventilation. *m.* $1. New York.
Ill. Carpenter and Builder. *w.* 8s. 8d. London
India Rubber World. *m.* $3. New York.
Gas World, The. *w.* 13s. London.
Indian and Eastern Engineer. *w.* 20. Rs. Calcutta.
Indian Engineering. *w.* 18 Rs. Calcutta.
Industries and Iron. *w.* £1. London.
Inland Architect. *m.* $5. Chicago.
Inventive Age. *s-m.* $1. Washington.
Iron Age. *w.* $4.50. New York.
Iron and Coal Trade Review. *w.* 30s. 4d. London.
Iron and Steel Trades Jour. *w.* 25s. London.
Iron Industries Gazette. *m.* $1.50. Buffalo.
Iron Trade Review. *w.* $3. Cleveland.
Jour. Am. Soc. Naval Engineers. *qr.* $5. Washington.
Jour. Assn. Eng. Societies. *m.* $3. St. Louis.
Journal of Electricity, The. *m.* $1. San Francisco.
Jour. Franklin Institute. *m.* $5. Phila.
Journal of Gas Lighting. *w.* London.
Journ. of Inst. of Elec. Engineers. London.
Jour. New England Waterw. Assn. *qr.* $2. New London.
Jour. of Royal Inst. of British Arch. *s-qr.* 6s. London.
Journal of Society of Arts. *w.* London.
L'Eclairage Electrique. *w.* France.
L'Electricien. *w.* France.
L'Energie Electrique. France.
L'Industrie Electrique. *b-m.*
Locomotive Engineering. *m.* $2. New York.
Machinery. *m.* $1. New York.
Machinery (Mach. Lond.) *m.* 9s. London.
Manufacturer and Builder. *m.* $1.50. New York.
Manufacturer's Record. *w.* $4. Baltimore.
Marine Engineer. *m.* 7s. 6d. London.
Master Steam Fitter. *m.* $1. Chicago.
Mechanical World. *w.* 8s. 8d. London.
Metal Worker. *w.* $2. New York.
Mining and Sci. Press. *w.* $3. San Francisco.
Mining Industry and Review. *w.* $2. Denver.
Mining Journal, The. *w.* £1. 8s. London.
Mining World, The. *w.* 21s. London.
National Builder. *m.* $3. Chicago.
Nature. *w.* $7. London.
New Science Review, The. *qr.* $2. New York.
Paving and Municipal Engng. *m.* $2. Indianapolis.
Physical Review. *b-m.*
Plumber and Decorator. *m.* 6s 6d. London.
Popular Science Monthly. *m.* $5. New York.
Power. *m.* $1. New York.
Practical Engineer. *w.* 10s. London.
Proceedings Engineer's Club. *qr.* $2. Philadelphia.
Progressive age. *s-m.* $3. New York.
Railroad Car Journal, The. *m.* $1. New York.
Railroad Gazette. *w.* $4.20. New York.
Railway Age. *w.* $4. Chicago.
Railway Master Mechanic. *m.* $1. Chicago.
Railway Press, The. *m.* 7s. London.
Railway Review. *w.* $4. Chicago.

Railway World. *m.* 5s. London.
Safety Valve. *m.* $1. New York.
Sanitarian. *m.* $4. Brooklyn.
Sanitary Plumber. *s-m.* $2. New York.
Sanitary Record. *m.* 10s. London.
School of Mines Quarterly. $2. New York.
Science. *w.* $5. Lancaster, Pa.
Scientific American. *w.* $3. New York.
Scientific Am. Supplement. *w.* $5. New York.
Scientific Machinist. *s-m.* $1.50. Cleveland.
Sibley Jour. of Engineering. *m.* $2. Ithaca, N. Y.
Southern Architect. *m.* $2. Atlanta.
Stationary Engineer. *m.* $1. Chicago.
Stevens' Indicator. *qr.* $1.50. Hoboken.
Stone. *m.* $2. Chicago.
Street Railway Journal. *m.* $4. New York.
Street Railway Review. *m.* $2. Chicago.
Tradesman. *s-m.* $2. Chattanooga, Tenn.
Trans. Am. Inst. Elect. Engineers. *m.* $5. New York.
Trans. Am. Inst. Mining Engineers. New York.
Trans. Am. Soc. Civil Engineers. *m.* $10. New York.
Trans. Am. Soc. Mechanical Engineers. New York.
Transport. *w.* £1. 5s. London.
Technology Quarterly. $3. Boston.
Western Electrician. *w.* $3. Chicago.
Western Mining World. *m.* $4. Butte, Mon.
Wiedemann's Annalen.
Zeitschrift für Beleuchtungswesen. Ger.
Zeitschrift für Electrochemie. *s-m.* Ger.

ACCUMULATOR—Elec. Rev. Lond. Jan. 24. W. Feb. 15.
—Blot—Elec. Rev. Lond. Feb. 14. 1500 w. W. Mch. 7. M. Apr.
—Cadmium—L'Elec. Feb. 22. W. Mch. 14.
—Cars—Elec. Eng. Lond. Jan. 24. P. Mar.
—Economics—Abbott and Dommerque. Elec. Jan. 8. P. Feb.
—Plates—Starkey. Elec. Rev. Lond. Apr. 3. W. Apr. 25.
—Present Day Types of—Elec. Lond. Feb. 14. Serial. Part 1. 2200 w. M. Apr.
—Station, Lawrence—Elec. Wld. Jan. 4. P. Feb.
—Testing, Notes on—Carl Hering. Elec. Wld. Jan. 4. Serial Part 1. 1800 w. M. Feb. P. Feb.
—Theory of—Loeb. Zeit. f. Electrochem. Mch. 5. W. Apr. 4.
—Theory of the Lead. Liebenow Elec.
—Traction—Elek. Zeit. Jan. 23. W. Feb 15.
—Traction—Jevous. Elec. Rev. Lond. March 20. W. Apr. 11.
—Traction—Fitzgerald, Elec. Rev. Lond. March 20. W. Apr. 11.
—Charging at a Constant Power—Simon. Electn. Mar. 21. W. Apr. 11.
—Present Day Types of—Electy. Lond. Feb. 14.
—The End Plates in—J. Langelaan, Elek. Zeit. Feb. P. Apr.
ACCURACY—Edit. Eng. Lond. Jan. 24. 2200 w. M. Mch.
ACETONE—See Asphaltum
ACETYLENE—New Sci. Rev. Jan. 1300 w.
—(Objections to it.) Eng. Rec. Feb. 8. 500 w.
ACETYLENE GAS—Elec. Wld. Feb. 1. 2000 w.
—W. R. Addicks. Am. Gas Lgt. Jour. March 9. 9000 w. M. Apr.
—for Power Purposes—Electn. Jan. 17. W. Feb. 8.
—Mystery—Eng. and Min. J. Jan. 18. 2500 w.
—Gas, Some Facts About—J. C. McMynn. Paper. Northw'n Elec. Assn. Elec. Rev. Jan. 25. 1800 w.
—Gas, The Truth About—A. Stetson. Elec. Feb. 12. 2800 w. M. Apr.
AIR BRAKE Devision, An Important—Ry. Rev. Nov. 23. 8000 w.
—Hose, The Bursting of—A. M. Waitt. Ind. Rub. Wld. Mch. 10. 2700 w.
—Instruction—Trav. Eng.'s Assn. Sept. 10000 w. M. Feb.
—Instruction Car—Ry. Rev. Feb. 22. 600 w.
AIR Braking, The Art of—Trav. Engs. Assn. Sept. 7700 w. M. Feb.
—The Uses and Advantages of a Public Supply of—F. Richards, Am. Mach. Feb. 13. 1000 w. M. Apr.
ALABAMA, The Phosphates and Marls of —E. A. Smith. Tr. A. I. Min. Eng. Feb. 4300 w.
ALKALI—See Electrolytic.
ALLOYS, Conductivities of—H. Le Chatelier. Elec. Rev. Lond. Jan. 17. P. Mar.
ALTERNATE Arc, Study of the—Elec. Rev. Nov. 9. P. Jan.
—Current Arcs, Researches on—H. Gorges, Electn. Elec. Wld. Jan. 11. P. Feb.
—Current Plant at Dover, Trials of—Electn. Jan. 17. 2000 w. M. Mar. P. Mch.
—Current—See Electrodynamic.
ALTERNATING Current Arc—Fleming and Petaval, Elec. Jan. 8. W. Jan. 25.
—Current Circuits—F. E. Millis, Phys. Rev. Mch. Apr. 2000 w. M. Apr.
—Current Curves, The Form Factor—J. A. Fleming, Electn. Jan. 10. F. Feb. Lond. Nov. 15. W. Dec. 7.
—Current Measuring Instruments—G. Benischke. Zeit. f. Elek. Jan. 1. P. Mar. W. Jan. 25.
—Current Plant, Tests of an—Kennedy and Thompson, Electn. Jan. 17. Elec. Eng. Jan. 17. Elec. Rev. Jan. 17. W. Feb. 8.

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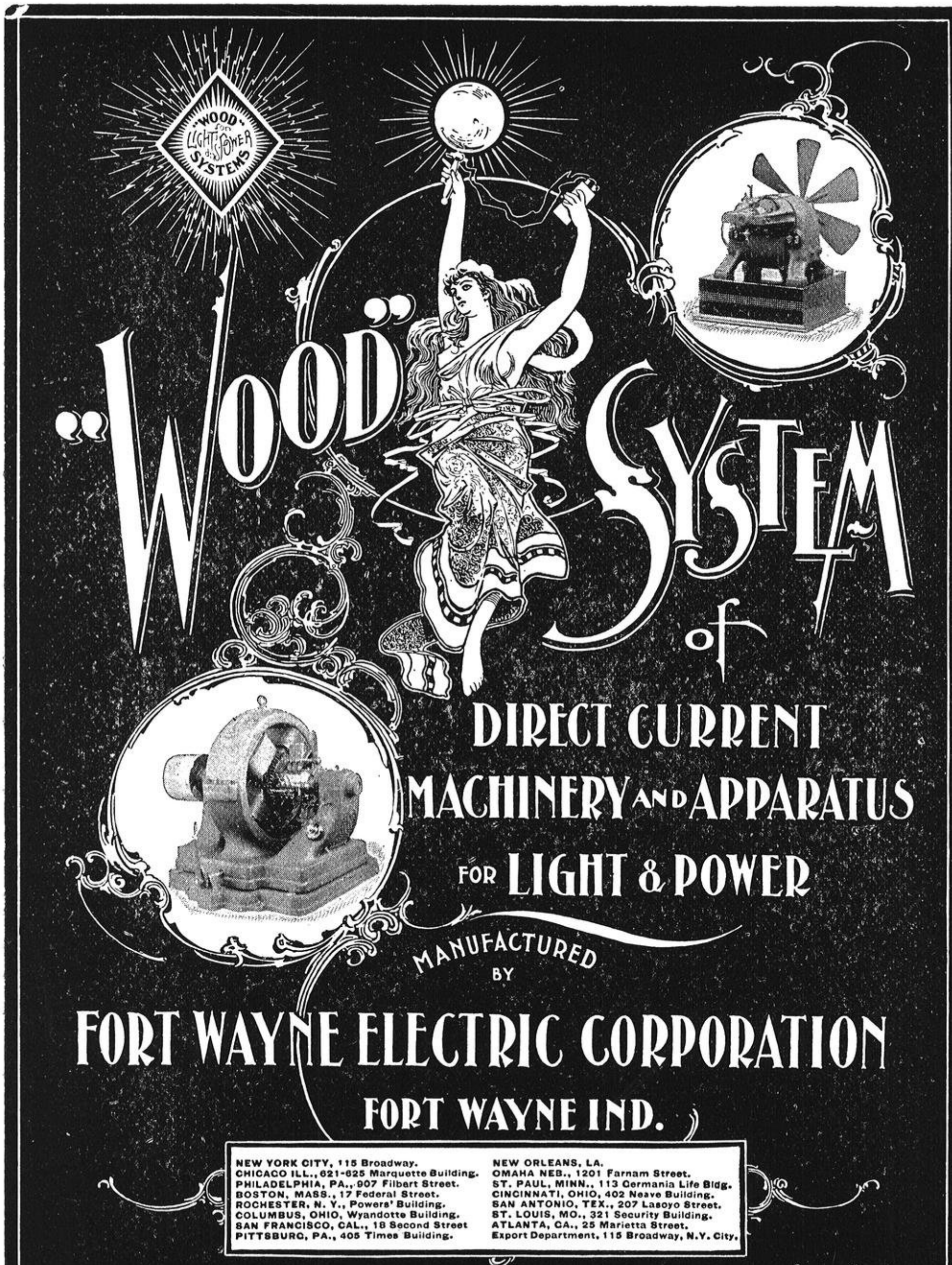
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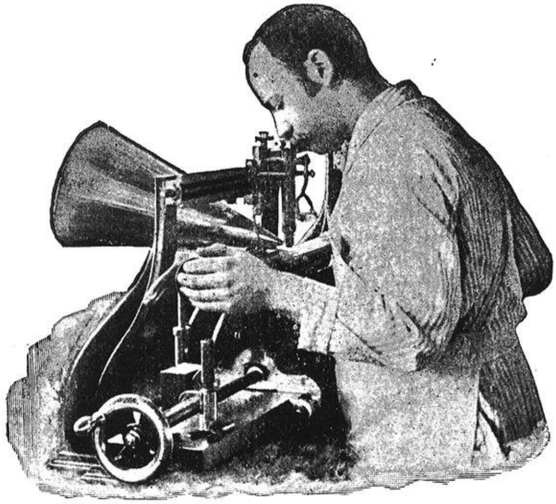

QUALITY OF WORK.

We have exceptional appliances for the attainment of accuracy.

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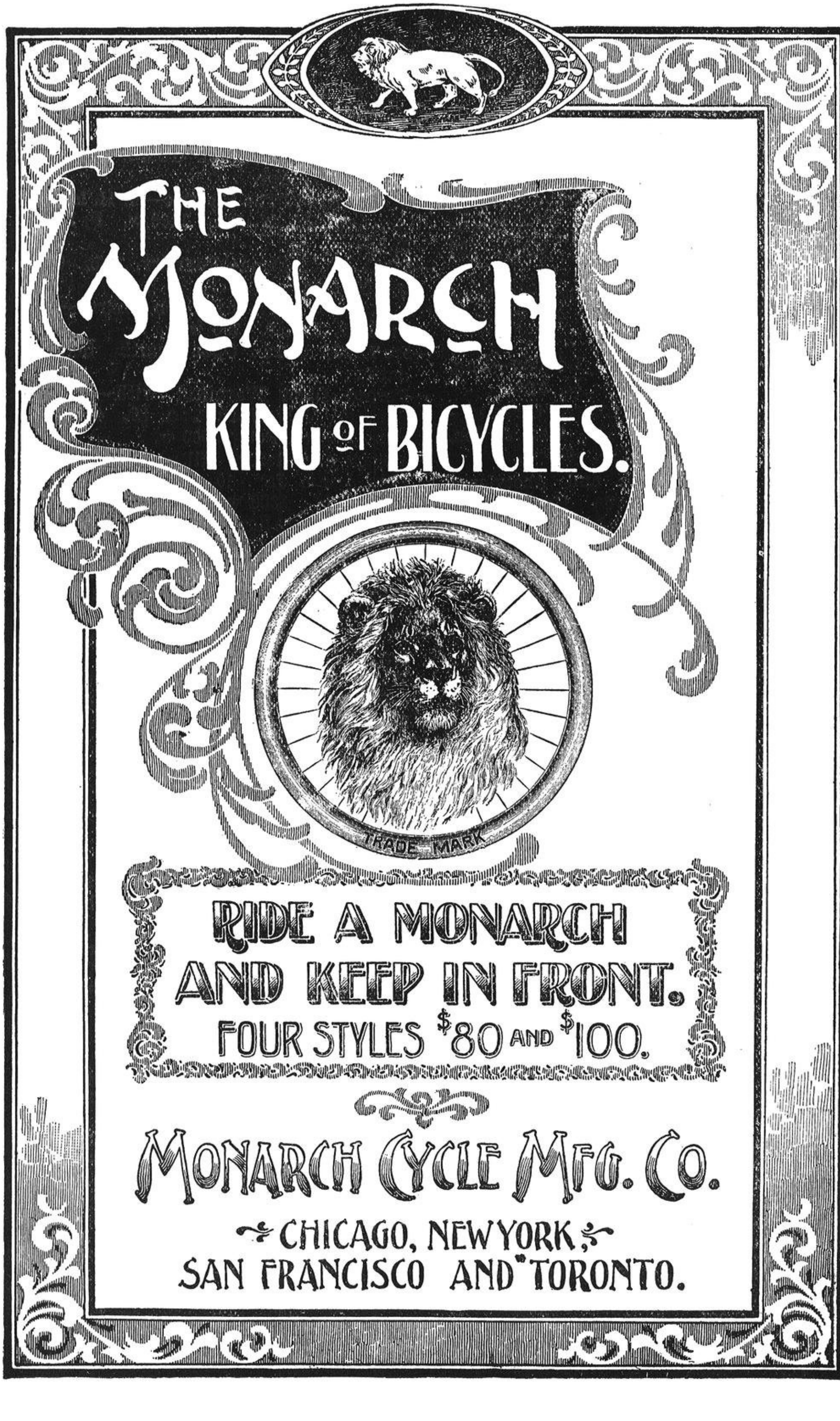
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Some Views in the College of Engineering,

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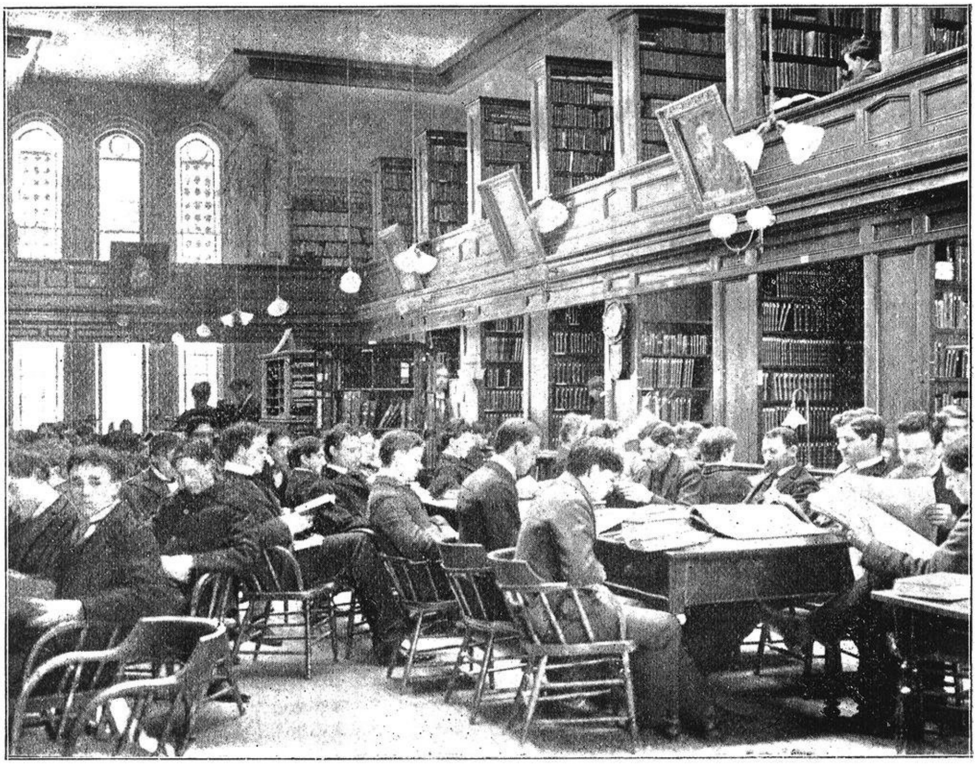
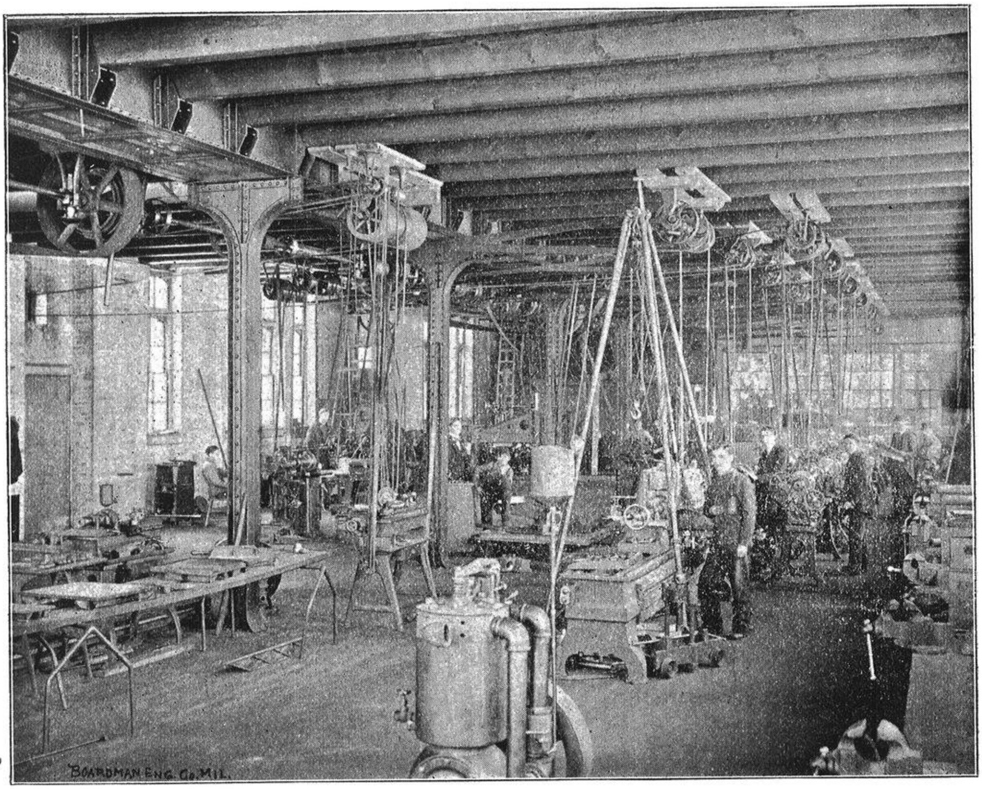


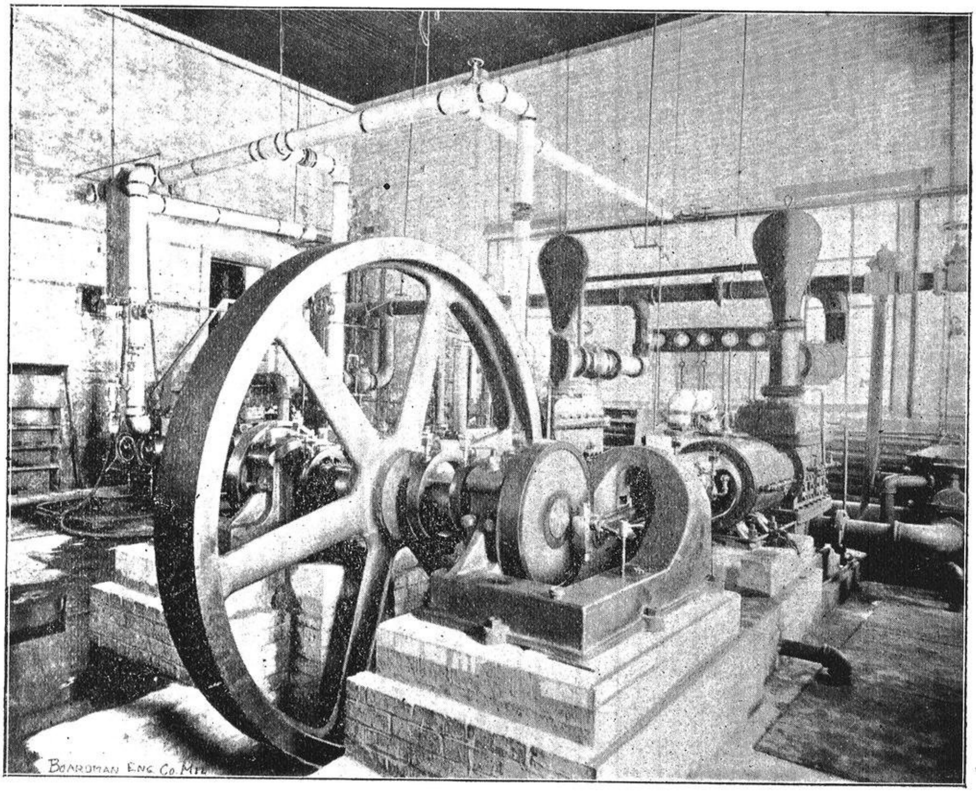
Reading Room in University Library.

This library contains over 32,000 books and 8,000 pamphlets, of which a large number—about 3,000 volumes—pertain to the engineering profession. About 200 of the best American and foreign periodicals are taken. The College of Mechanics and Engineering subscribes for seventy-five of a purely technical character. These latter are kept in the engineering reading room in Science Hall in order to facilitate the frequent use of them by the engineering students. The bound files, which are unusually complete are kept in the library. Aside from this collection, students have access to the large library of the State Historical Society (150,000 volumes) which is soon to be located on the lower campus in our new Library Building, and the city free library (13,000 volumes) in which may be found many works of a technical nature.



Iron-Working Shop.

THE MACHINE ROOM is located on the first floor of the Machine Shop Building. The equipment is very complete and affords good facilities for mechanical practice. The room is large (130 ft. by 42 ft.) and is well lighted, there being windows on three sides. The room can also be lighted by arc lights, a dynamo being provided for this purpose. The power is supplied by a fifty horse-power Cummer engine placed at one end of the room, but by throwing on a friction clutch the line shafting may be driven by the Weston engine in the Electrical Laboratory. The equipment of machine tools includes a large number of lathes, several drill presses, planers, milling machines, shapers, emery wheels and also a grinding lathe. There is bench room for 22 students, for the work in chipping, filing and scraping. The elementary work consists of exercises of which no practical use is made but later tool making is taken up, keeping the Tool Room supplied with taps, dies, reamers, arbors, etc. Generally some piece of machinery is in process of construction, the machine work being done by the students. Nearly all the engines in the Steam Laboratory, the large pump at the Pumping Station, the steam hammer in the Blacksmith Shop and other machinery were built here.



The University Pumping Station.

From the University Pumping Station, water from Lake Mendota is supplied to all of the eighteen University buildings for steam and lavatory purposes, and also to the State Capitol. The station is equipped with three pumps, two of these being direct acting, and one being compound.

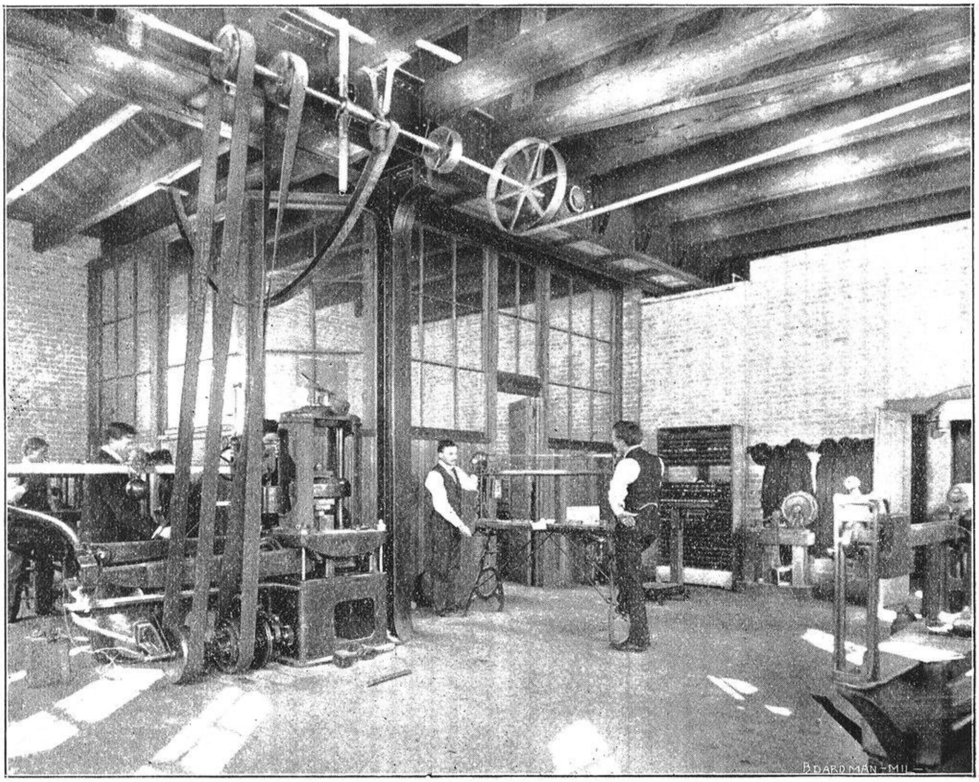
The pump in the foreground of the picture is of the usual Cross Compound type of engine, with the water cylinders placed tandem to the steam cylinders. The engine was designed by six Mechanical Engineering students of the class of 1893. All patterns were made and all machine work done by the students at the University shops, excepting that for the condenser and the fly wheel.

The stroke of the engine is 16 in., and the bore of the high pressure and low pressure cylinders is 10 in. and 13 1-2 in. respectively, and of the water cylinders is 6 in. The pump was designed to run at 65 revolutions per minute and will at this speed deliver nearly three quarters of a million gallons per 24 hours. In the surface condenser used, the tubes were expanded in the heads by the roller process, being the same as in tubular boilers. The condenser stands on end and is connected into the suction pipe so all water flowing to the pump must pass through it. In this way no water is used for condensation alone and the volume is such that the temperature of the water delivered is raised only 10 degrees. An automatic cut off controls the steam supply, and the governor is driven from the main shaft by a pair of spiral gears. The apparatus runs without an attendant except at starting and stopping, and with it the water supply is obtained at fully fifty per cent. less cost than before.

It may also be stated that the pump adds materially to the list of testing apparatus now available to the engineering students.

TESTING LABORATORY.

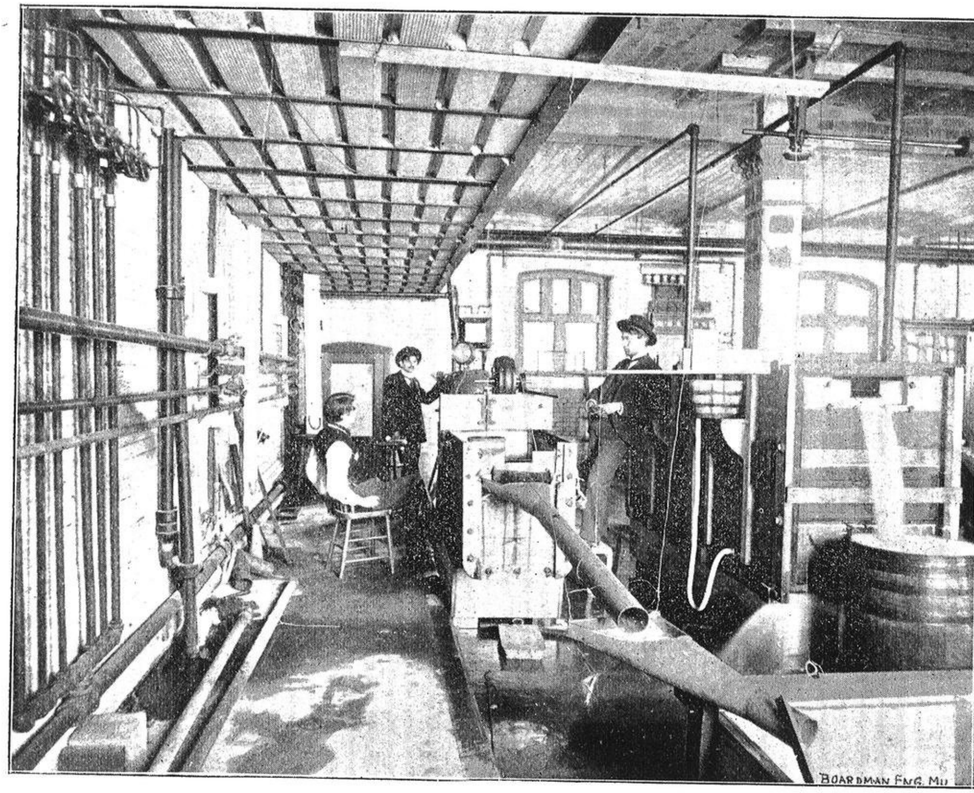
The testing laboratory now occupies commodious quarters in the west wing of the shop. In the foreground is seen a one-hundred thousand pound Riehle automatic and autographic testing machine. There are also several Olsen machines for tests in compression, tension and bending, a Thurston torsion machine, a Riehle cement testing machine and a large grinding wheel for preparing brick and stone specimens which are tested in connection with work in the Cement Laboratory adjoining.



Mechanical Testing Laboratory.

HYDRAULIC LABORATORY.

While hydraulics is perhaps the oldest of all branches of engineering, there is still great need of a better experimental determination of its laws, as was recently very forcibly brought out in a new water supply system in New Jersey where a pipe designed by an authority according to the most reliable formulae failed utterly to give the required flow. Our Hydraulic Laboratory contains high and low level tanks fitted for experimenting upon the flow of water over wiers and through orifices, nozzles and pipes. There are also several turbine wheels, motors, water meters and current meters and a convenient supply of gauges and other apparatus required in accurate hydraulic experiments. A head of seventy feet of water is furnished by an elevated tank.



Hydraulic Laboratory.

DYNAMO ROOM.

A letter from the National Electric Co., dated June 11, 1891, gives notice of shipment of our first machine. This dynamo was set up in the machine shop proper being the sole source of experiment for the students that year. The following year an Edison Arc, 10 light machine was presented to the University and through the efforts of Prof. Jackson two street car motors that had seen some use were also procured. This was thought quite an addition and all of the machines proved very good for experimental work, especially the street car motors. Since that time Prof. Jackson has continually made additions to our laboratory both in machines and apparatus until we now have the following:

LOW TENSION DIRECT CURRENT MACHINES.—An Edison shunt dynamo 7½ H. P., this machine being one of the historic machines exhibited at the World's Fair and used by Edison in his first exhibit of incandescent lighting. A National 4½ H. P. compound. A shunt dynamo 3 H. P. built by the Allgemeine Elektricitats Gesellschaft of Berlin and exhibited at the World's Fair. A Preal 4½ H. P. dynamo. An Eddy shunt, 6½ H. P. A motor-dynamo 2½ H. P. 110—19 to 6—300 A. C. and C. 1 H. P. motor.

HIGH TENSION DIRECT CURRENT MACHINES.—Edison Arc, 10 light. Fort Wayne Arc, 10 light. Two T. H. street car motors, 15 H. P., one of which has been connected up as a rotary transformer for 3-phase currents at a frequency of 30. A Crocker-Wheeler 12 H. P. motor. A Northern 4 H. P. motor.

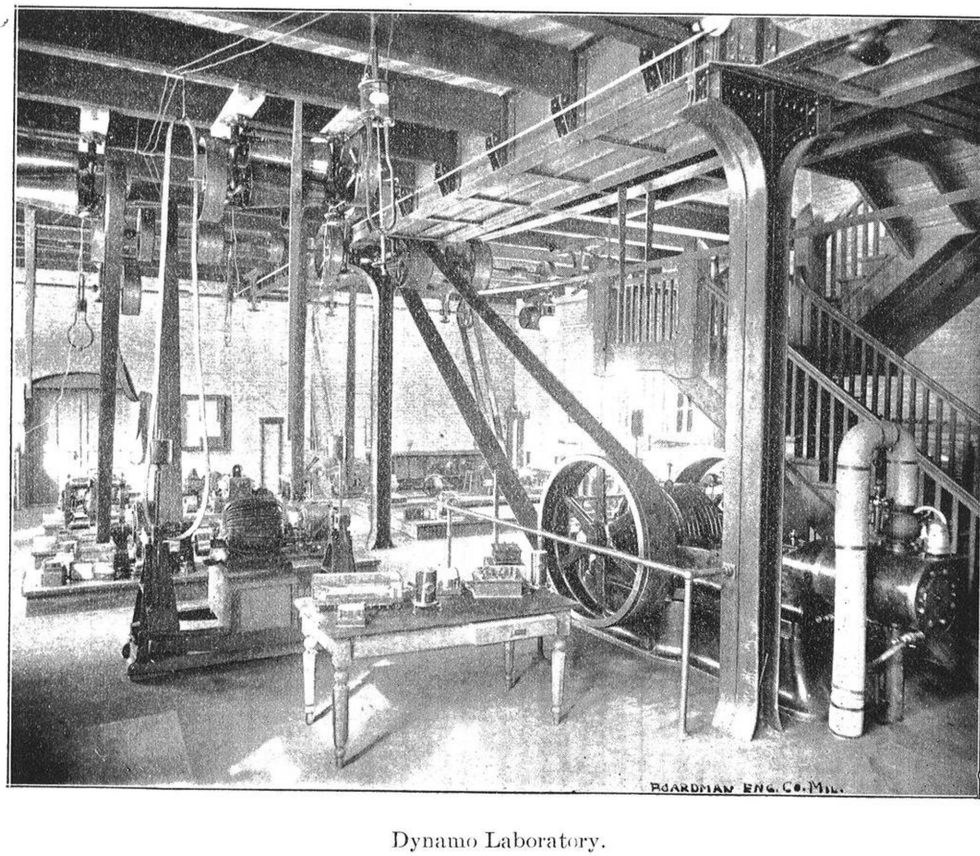
ALTERNATING CURRENT MACHINES.—

A La Roche 7½ H. P. A rotary transformer converted from a G. E. street car motor, 20 H. P., frequency 50. Two three-phase motors 2 and 5 H. P. built by the Allgemeine Elektricitäts Gesellschaft of Berlin and exhibited at the World's Fair. A Thomson indirect electric welder.

All machines with two or three exceptions are mounted on heavy oak platforms, both field and armature circuits are run under the floor from the base of each machine to terminals of the switchboard. Nine Weston station instruments of the round pattern are mounted on the wall in convenient places for testing and are also connected to the switchboard by independent circuits. The switch-board connects with the city lighting circuits and the 500 volt street car circuit, also with an auxiliary switchboard in the electrolytic laboratory and with another in the Physics laboratory of Science Hall. Situated at convenient places around the room and connected by separate circuits to the switchboard are eight tanks with adjustable terminals for water resistance.

Our bank of transformers consists of 16. no two alike, the greater part being of about 1500 watts capacity. Two primary and two secondary transformer circuits lead to the switchboard and by the use of connectors at the bank any combination can be made. The number, sizes and different makes, renders it possible to have a good chance for experimental work.

The switchboard is one of last year's improvements and nothing more convenient could be imagined. It has terminals for 100 complete circuits and by the use of flexible plug-in connectors almost any combination can be easily and quickly made between machines, instruments, etc., with no net work of wire lying around on the floor and with no unnecessary work as was formerly the case



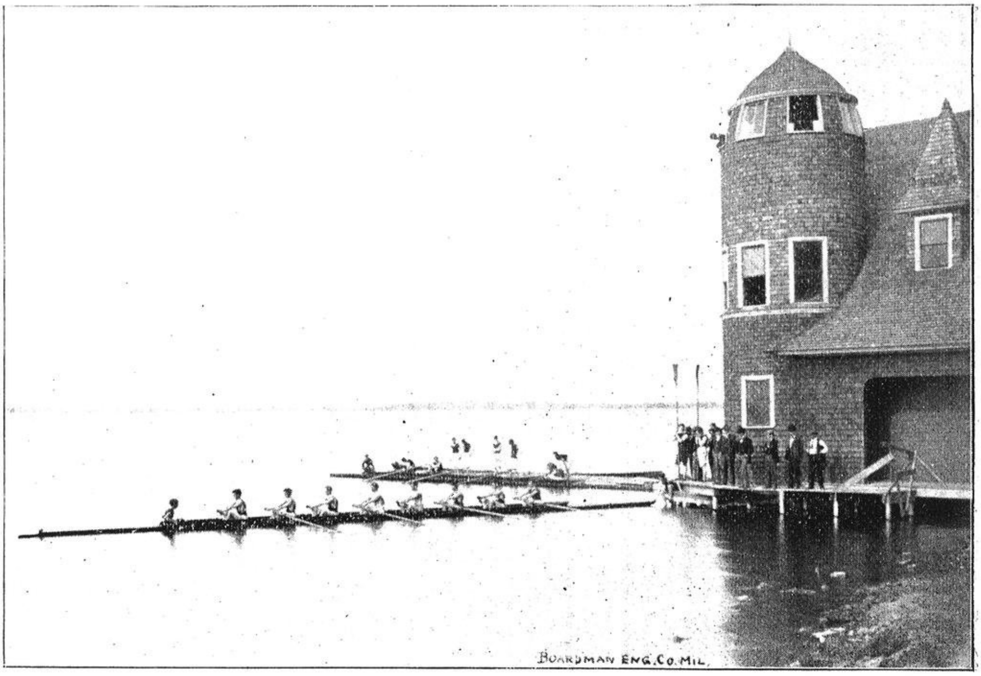
Dynamo Laboratory.

The instrument cases have gradually filled until we have a very good collection and almost any range can be reached in a. c. and d. c. voltmeters, ammeters, wattmeters, bridges, etc.

For power the dynamo room has its own engine, a 60 H. P. Weston, running at 250

rev. To prevent large pulleys the main shaft runs at 500 rev. and all machines are betted direct from the main shaft and one counter shaft, operated by a clutch pulley.

The main shaft of the dynamo room is also connected by a clutch pulley with the main shaft of the machine shop so that in case it is not desirable to run the Weston engine power may be obtained from the machine shop. Although the laboratory begins to shape itself into a very convenient and efficient arrangement many improvements and additions are to be made in the near future.



The 'Varsity Crew and Boat-house.

Wisconsin is a firm believer in the old saw, "All work and no play makes Jack a dull boy." The people of the state have shown their confidence in physical education by the erection of our magnificent Gymnasium, and among the students all branches of athletics are organized and have their enthusiastic devotees. Situated as the University is, on the shores of Lake Mendota, a beautiful sheet of water, admirably suited for rowing and similar sports, aquatics have come forward during the past few years with marvelous strides, and much enthusiasm and honest pride is manifested in the support of the only college crew between the Alleghanies and the Pacific Coast. The engineering students take particular interest in this department. On last year's 'Varsity crew were five engineers and in this year's boat they are represented by six men. On the second 'Varsity and class crews also they usually have a large representation in proportion to their number.

We may say that aquatics were inaugurated here in 1891 when the University was first represented by a gig crew and the first regatta was held. In the following year the Boat House shown in the view was built. The department is now equipped with three eight-oared shells, two eight-oared gigs, a rowing machine, two pair-oared gigs, and other apparatus. Heretofore all our races have been with such organizations as the Delaware Crew of the Chicago Navy and the Minnesota Boat Club. This year, however, we had our first college race, and easily defeated the Yale Freshmen at New Haven by ten lengths. This victory emphasizes Wisconsin's lead in boating, since the Yale 'Varsity crew which was sent to Henley, only defeated the Freshmen by four lengths. Coach O'Dea has brought our crew into national prominence.

Index of Advertisers.