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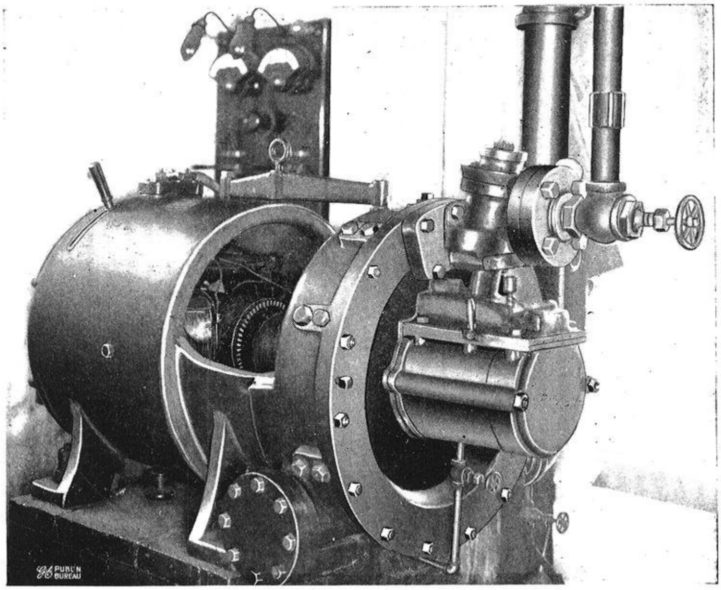
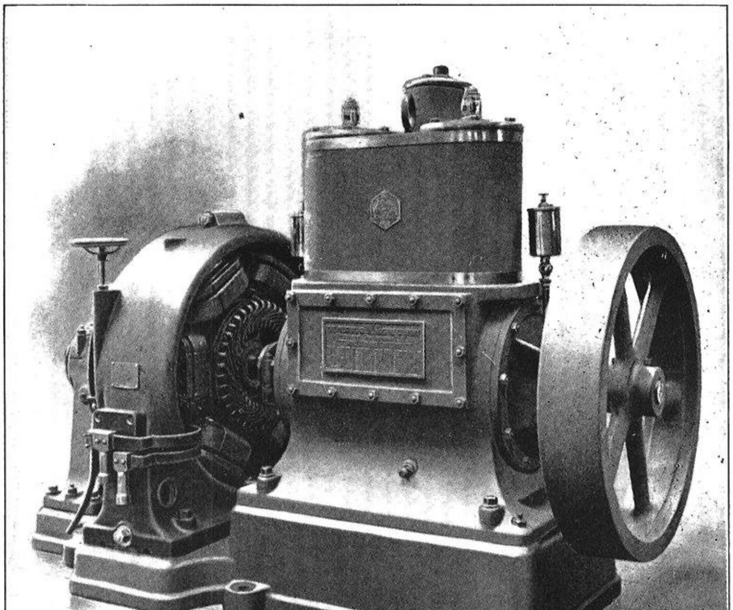


25-K. W. Curtis Turbine-Generator.



Westinghouse Engine and Generator Lighting Set.

THE WISCONSIN ENGINEER

VOL. XI APRIL, 1907 NO. 3

VIBRATIONS IN PASSENGER TRAINS FROM HIGH SPEED ELECTRIC LIGHTING ENGINES.*

F. W. HUELS, '03.

Presented before the Western Society of Engineers, December 19, 1906.

The vibrations in passenger trains caused by the reciprocating action of the high speed engine of the electric generating sets constitutes one of the principal objections to their use. These engines produce vibrations that are sometimes of considerable magnitude, owing to lack of perfect balance of the reciprocating parts. The vibrations are transmitted back into the train, since the whole train is elastic. Thus a source of annoyance to the passengers is created which railways would be glad to get rid of, and steam turbines are now replacing reciprocating engines in the train lighting field because they have the advantage of no vibration.

It is interesting and of some importance to know something about the magnitude and character of these vibrations. So far as is known to the writer, no attempt has been made, heretofore, to make measurements of them. In the following pages the results of tests of this kind are presented.

Method of Locating Generating Sets as Adopted by Various Roads.

In Plate 1 is shown the method of locating the generating set as adopted by the Chicago, Milwaukee and St. Paul Railway Company. Here the engine is placed crosswise in the

*Reprint from *Journal of Western Society of Engineers*, April, '07.

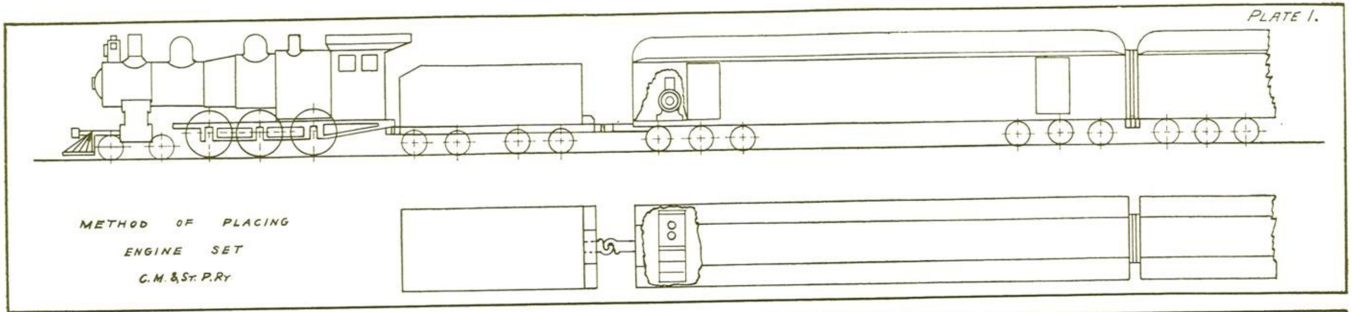


PLATE I.
METHOD OF PLACING
ENGINE SET
C.M.&ST.P.RY

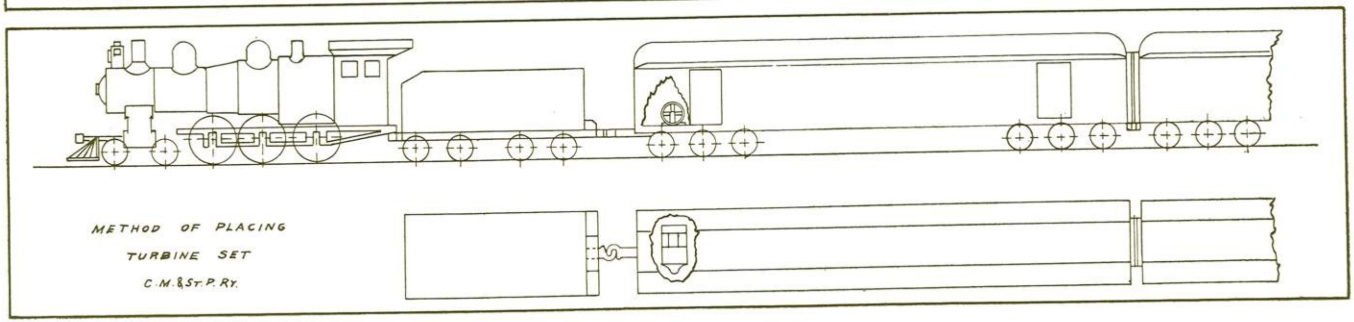
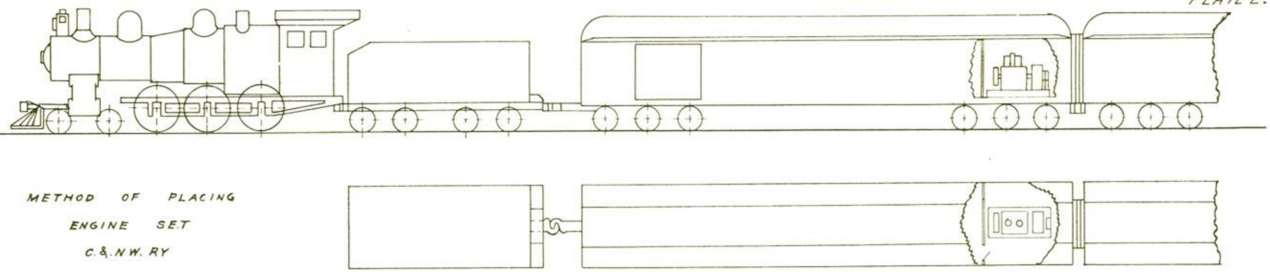
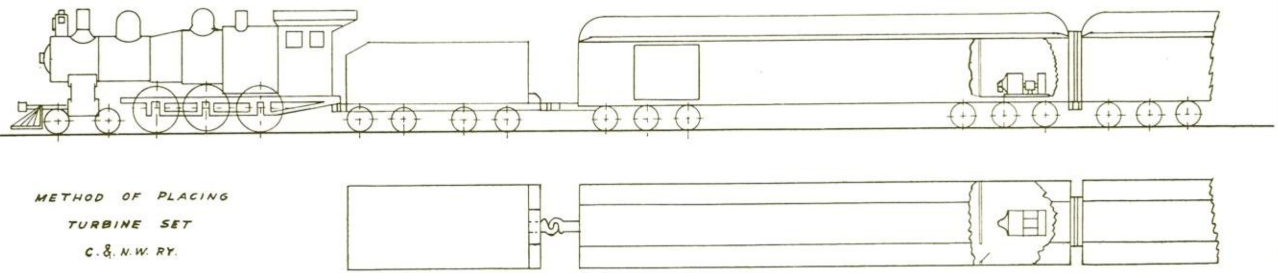

METHOD OF PLACING
TURBINE SET
C.M.&ST.P.RY.

PLATE 2.



METHOD OF PLACING
ENGINE SET
C. & N. W. RY.



METHOD OF PLACING
TURBINE SET
C. & N. W. RY.

baggage car and as close to the locomotive as possible. This location is at a point about three feet ahead of the forward king bolt. It is claimed that in this way the piping between the locomotive and the lighting engine is reduced to a minimum length, thereby reducing the condensation of steam in the pipe to a minimum.

The Chicago and Northwestern Railway and the Northern Pacific Railway adopt the arrangement shown in Plate 2. Here the generator is placed so that the shaft is parallel to the length of the car and at a point over the rear king bolt. The Chicago and Northwestern Railway uses this system because the front part of the car is the express compartment, and the door leading into it is kept locked. By placing the set in the rear of the car, the electrician can attend to it without disturbing the expressman. In this arrangement the distance between the locomotive and generator is as much as fifty feet, which produces a considerable amount of condensation in the steam pipe.

Further, it has been claimed that the vibrations could be felt farther back in the train when the latter arrangement is employed because the "vibration center" is farther back in the train. The experiments on vibrations described in this paper seem to bear out this point, as will be observed by making an examination of Plate 9.

Vibration Indicators and Seismographs.

For measuring vibrations of this kind, instruments known as "seismographs" or "seismometers" are used. This name was originally given to instruments constructed to measure the movement of the ground during earthquakes. Webster's dictionary gives these definitions:

> "Seismometer: An instrument for measuring the direction, duration, and forces of earthquakes and like concussions."
>
> "Seismograph: An apparatus for registering the shocks and undulatory motions of earthquakes."

One of the types of earth movements that are recognized and of which measurements are made, consists of:

Sudden displacements or "earth tremors," resembling earthquakes in the rapidity with which they take place, but differing from them in that they can be detected only by means of instruments on account of the smallness of the motion.

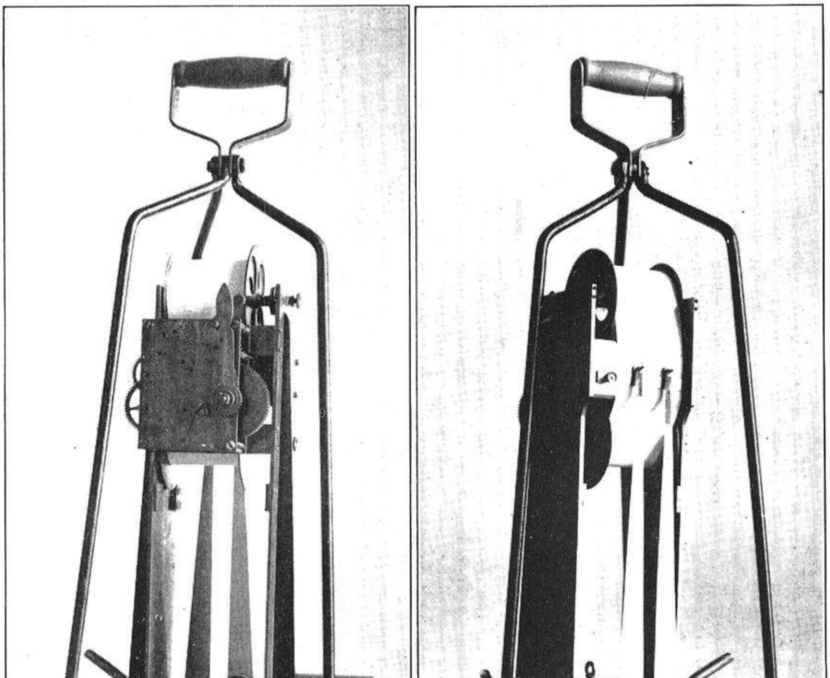
It can be seen that this class of movements or "earth tremors" resembles the vibratory movements caused by the reciprocating engines of train lighting sets. Hence, instruments used to measure this type of movement will be considered further.

The following notes taken from an article on the "Seismometer" in the Encyclopaedia Britannica show the principles upon which these instruments are based.

"In the first type of measurements what may be called the 'inertia method' is followed. A mass is suspended with freedom to move in the direction of that component of the earth's motion which is to be measured. When an impulse occurs the supports move, but the mass is prevented by its inertia from accompanying them. It supplies a steady point to be used as a standard of reference in determining the extent through which the ground has moved in the direction in question. . . . In all instruments, designed to furnish a steady point, the suspended mass must have some small stability, else it would be unmanageable; but its period of free oscillation must be greater than that of the earthquake motions which it is employed to measure. . . . The whole movement is resolved into rectilinear components, and these are separately recorded. . . . on a plate or drum which is kept in continuous movement, so that the record of each component takes the form of an undulating line, from which the number, succession, amplitude, velocity, and acceleration of the component movements can be deduced and the resultant motion determined."

The Vibration Indicator Used in These Tests.

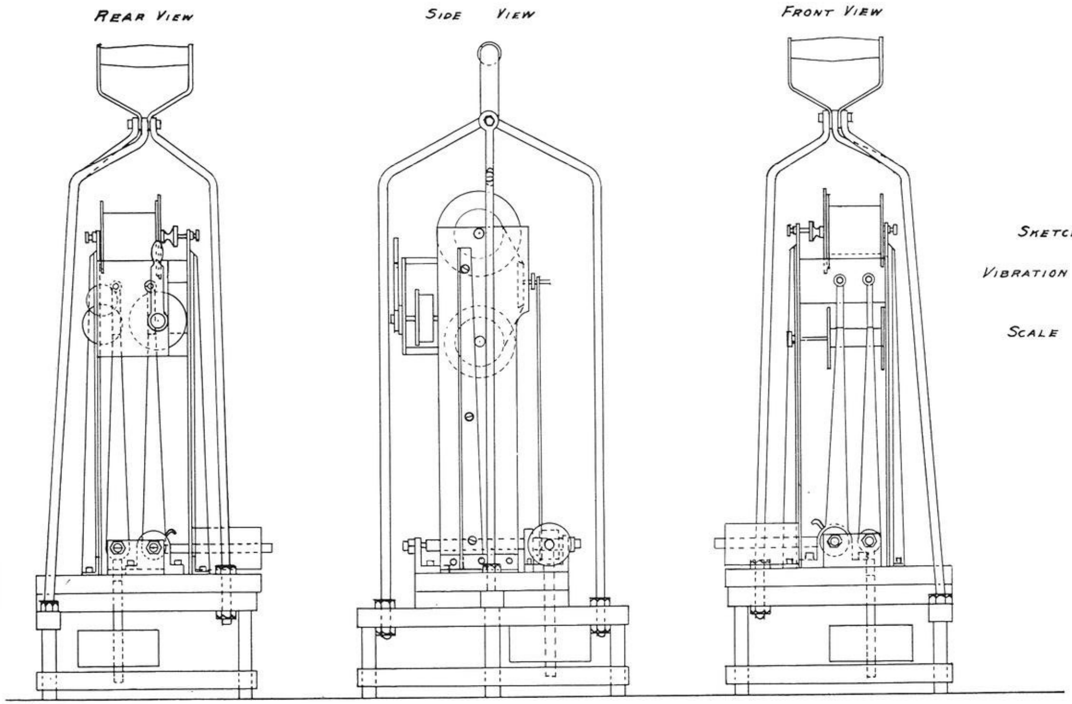
The ordinary types of instruments used to measure earthquakes are not suitable for work on railway trains, because they are over-sensitive, not portable, nor compact. Something less sensitive, but compact and portable, is required. Consequently, the instrument shown in the following pages was



Rear View. *Front View.*

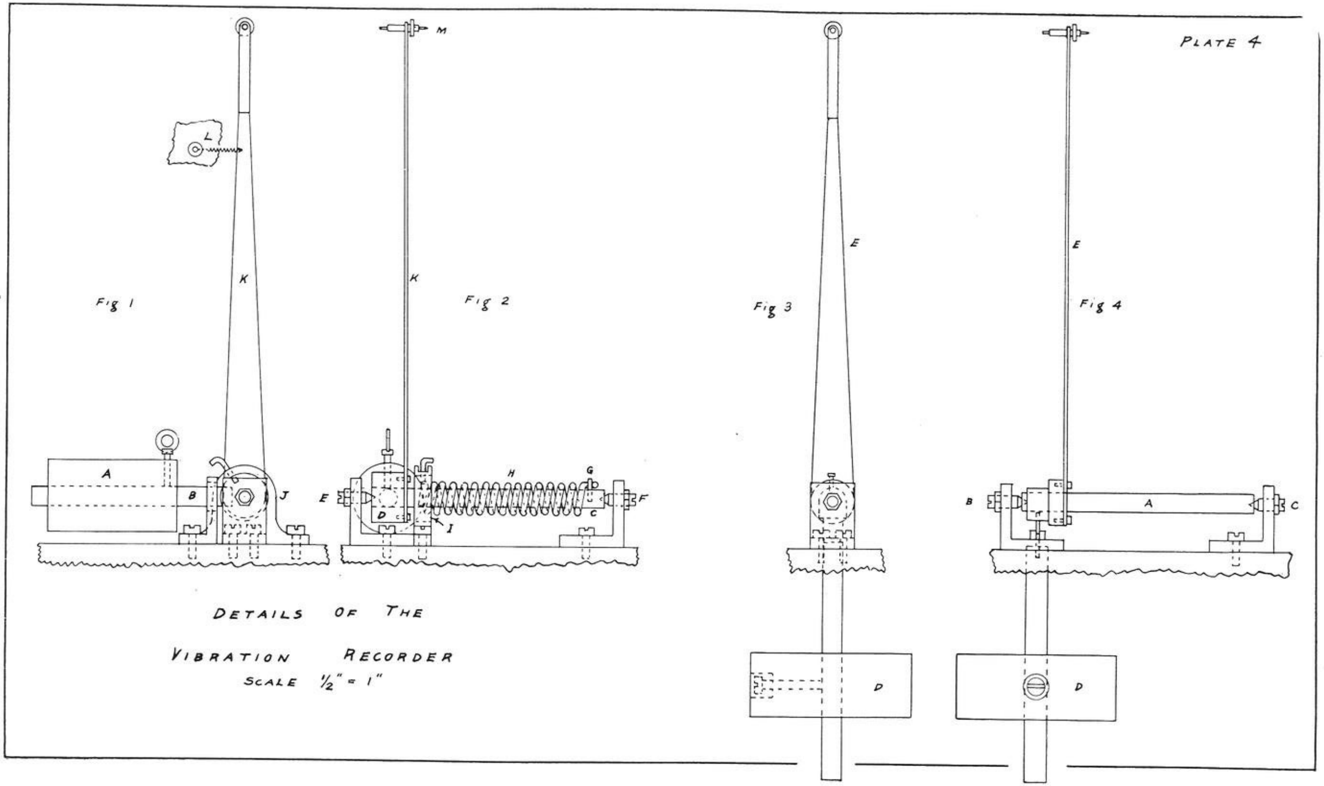
Vibration Recorder.

PLATE 3



SKETCH OF
VIBRATION RECORDER
SCALE 1/4" = 1"

PLATE 4



DETAILS OF THE

VIBRATION RECORDER

SCALE 1/2" = 1"

developed. It is a modification of the forms already described. The movement, whatever it may be, is resolved into two components, one vertical and the other horizontal.

The instrument consists of four principal mechanisms which may be described as follows:

1. A mechanism for indicating and magnifying the vertical component of the motion.
2. A mechanism for indicating and magnifying the horizontal component of the motion in one direction.
3. A mechanism for permanently recording both vertical and horizontal components on the same record sheet.
4. A base with suitable framework serving to support mechanisms 1, 2, and 3, and which serves to give stability to the apparatus.

The Vertical Motion—The vertical component of the motion is recorded by the device shown in Plate 4, Figures 1 and 2.

A cylindrical brass weight, A, weighing two pounds, is supported upon the lever, B. The spindle, C, is solidly fastened to B, and at right angles to it, by means of the collar, D. Spindle C is then mounted upon a base by means of the pivots, E and F. At one end of C is the pin, G. Mounted upon C is a coil spring, H, consisting of thirty turns of Number 12 iron wire. One end of this spring is fastened around the pin, G, and the other end is solidly soldered into a collar, I. Collar I fits into the support, J, and is so arranged that the torsion of the coil spring can be regulated. A light aluminum pointer, K, carrying a pencil at its upper end, is mounted upon the collar, D. It magnifies the displacement of the weight, A.

The operation of this device is as follows: When A is moved downward and then released, it returns to its normal position. This normal position is horizontal and it is kept there by placing the proper tension upon the spring, H. When A is moved upward there is a tendency to continue upward. A small spring, L, may be attached to the pointer, K, its tension being regulated to bring the weight back into its normal position.

Now, for up and down movements of the points, E and F, corresponding to movements of the base of the instrument, some point in A tends to remain stationary on account of the inertia of this weight. As already mentioned, the resulting relative movement is indicated and magnified by the pointer, K, and a record of it is made by the pencil point, M, at the end of the pointer.

It can be seen that a horizontal displacement of the points, E and F, will have no effect upon the weight, A, and will produce no displacement of the pointer, K. Hence, this device records the vertical component of the movements of the base.

The Horizontal Motion—The device by means of which the horizontal motion is recorded is shown in Plate 4, Figures 3 and 4. Such movements are detected by pendulums.

A spindle, A, is pivoted at the points, B and C. Hanging from the spindle, and rigidly fastened to it, is a circular piece of cast iron, D, weighing four and one-fourth pounds. An aluminum pointer, E, carrying a pencil point at its upper end, is also fastened to the spindle.

By examining Figure 3, it will be seen that when the points, B and C, are quickly moved to the right or left, some point in the weight, D, will remain at rest on account of the inertia of the weight. This will cause a multiplied record of the displacement to be made by the pointer, E.

A vertical displacement of the points, B and C, will cause no movement of the pencil point with respect to B and C. Consequently, this contrivance will be unaffected by the vertical component of the motion but will record the horizontal component.

The Recording Mechanism—For permanently recording the vibrations, a strip of metallic paper, two and one-half inches wide, is made to pass under the pencil point by means of clock-work. The paper is unwound from one roller and wound upon another.

Metallic paper and ordinary paper have been used. Brass points, black lead, and indelible copying lead have been used for pencil points. Experience has shown that brass points do not make a satisfactory mark. By using metallic paper and either black lead or indelible lead points a fine record is obtained on the smooth surface of the metallic paper. A further advantage of using indelible points is that the record may be strengthened and permanently fixed by dampening it. This makes a very satisfactory method.

The Base and Framework—These three mechanisms, that for the vertical motion, that for the horizontal motion, and the clock-work for driving the paper, are all supported by the necessary framework upon a heavy iron base. A handle is also provided by means of which the instrument can readily be carried about.

Method of Obtaining Data.

The instrument whose characteristics have just been described was set upon the floor of the car under test and allowed to operate. A record was obtained which showed the horizontal and vertical components of the motion of the car floor at that particular point. The instrument being portable, was next set up on various cars of the train and at various points on the cars.

For instance, when a record of the vibration of the baggage car, caused by the lighting engine, was desired, a test was made at the time the train had come to a standstill at some station. The instrument was placed, say, three feet from the generating set, and operated long enough to obtain a record. It was then carried to the center of the car, then to a point above the rear king bolt of the car or to the rear platform, a record being taken at each of these points.

Then, if there was time, it was set up in the second, third, and other cars of the train. As a rule, however, the stops are of short duration and it is impossible to obtain more than one record at each stop. It is only at junction points, at points where water is being taken by the locomotive tender, or while standing in the coach yards, that several records can be made. As a result of this the records are not all simultaneous.

Trains, Cars, and Systems Which Have Been Tested.

Through the courtesy of the Chicago, Milwaukee and St. Paul Railway Company, and the Chicago and Northwestern Railway Company, it was possible to make tests of the nature and magnitude of the vibrations produced by the generating sets in use on some of their finest trains. The Chicago, Milwaukee and St. Paul Railway Company allowed me to make tests on the "Pioneer Limited," an electric lighted train running between Chicago and Minneapolis. Similar tests were made on the "Northwestern Limited" of the Chicago and Northwestern Railway Company, running between the same points. It was thus possible to get comparative results.

Tests were made on Westinghouse "Standard" engine sets and Curtis steam turbine generator outfits on both roads. A summary of these may be given as follows:

1. Pioneer Limited, Chicago, Milwaukee and St. Paul Railway Company. 20 K. W., Westinghouse Standard Engine and Generator, from Milwaukee, Wisconsin, to Tomah, Wisconsin.
2. Pioneer Limited, Chicago, Milwaukee and St. Paul Railway Company. 25 K. W., Curtis Steam Turbine and General Electric Generator, from Tomah, Wisconsin, to Milwaukee, Wisconsin.
3. Northwestern Limited, Chicago and Northwestern Railway Company. 20 K. W., Westinghouse Standard Engine and Generator, from Madison, Wisconsin, to Minneapolis, Minnesota, and return.
4. Baggage Car, 216, Chicago and Northwestern Railway Company, 25 K. W., Curtis Steam Turbine and General Electric Generator, standing in coach yards of the Chicago, St. Paul, Minneapolis and Omaha Railway Company, at Minneapolis, Minnesota.

Results of Tests.

In the following pages are given tables and diagrams showing the results of tests made in the manner just described. These data are largely self-explanatory. The vibration was resolved into its horizontal and vertical components and in the diagrams these are shown by the upper and lower curves, respectively. The number of vibrations per minute, the extent of the vibrations, in inches, and remarks relating to the station, position, and time of the record, are given.

These records were taken on trains that were as nearly alike as possible in all respects. 20 K. W. Westinghouse engines, and 25 K. W. Curtis turbines were tested on both trains, the only difference being that the sets in the case of the Chicago, Milwaukee, and St. Paul trains were crosswise and in the front of the baggage car, while, in the Chicago and Northwestern trains they were lengthwise and in the rear of the baggage car.

Plate 9 gives comparative results at various points on the trains. The figures at the top of the records on this sheet indicate the number of the record in Plates 5, 6, 7, and 8.

TABLE I.

TESTS OF VIBRATIONS CAUSED BY A WESTINGHOUSE, 20 K. W. TRAIN LIGHTING SET.
"PIONEER LIMITED," C. M. & ST. P. RAILWAY.

Engine, Number 4245. 7½" x 7". 400 R. P. M. Generator, Number 58538.

	VERTICAL.		HORIZONTAL.		REMARKS.		
Record Number.	Number of Vibrations per Minute.	Extent of Vibrations in Inches.	Number of Vibrations per Minute.	Extent of Vibrations in Inches.	Station.	Position.	Time.
1	410	0.03	410	0.01	Milwaukee	Baggage car Three feet from engine	9:01 P. M.
2	344	0.03	344	0.01	Pewaukee	Baggage car Three feet from engine	9:43
3	377	0.02	377	0.01	Hartland	Baggage car Three feet from engine	9:53
4	322	0.03	322	0.01	Oconomowoc	Baggage car Center of car	10:11
5	396	0.02	396	0.02	Watertown	Baggage car Center of car.	10:30
6	None Perceptible		None Perceptible		Watertown Jct.	Buffet car Rear platform	— —
7	384	0.01	384	0.01	Portage	Buffet car Center of car	11.55
8	405	0.01	405	0.01	New Lisbon	Baggage car Rear of car	1:14 A. M.
9	374	0.05	374	0.01	New Lisbon	Baggage car Center of car	1:15
10	386	0.02	386	0.01	Camp Douglas	Baggage car Near generator	1:30

TABLE II.

TESTS OF VIBRATIONS CAUSED BY A GENERAL ELECTRIC, 25 K. W., CURTIS TRAIN LIGHTING SET.

"PIONEER LIMITED," C. M. AND ST. P. RAILWAY.

May 5 and 6, 1906.

Baggage Car, Number 410.
Turbine, Number 3229.
Generator, Number 111775.
Steam Pressure, rated, 80 pounds per square inch.
Amperes, 200; Volts, No load, 120; Full load, 125.

REMARKS.

Rec. No.	Station.	Position.	Time.
11	Camp Douglas	Baggage car Three feet from engine	2:37 A. M.
12	New Lisbon	Baggage car Three feet from engine	2:43
13	New Lisbon	Baggage car Center of car	2:51
14	Portage	Baggage car Center of car	4:00
15	Watertown Junction	Baggage car Center of car	5:25

TABLE III.

TEST OF VIBRATIONS CAUSED BY A WESTINGHOUSE, 20 K. W. TRAIN LIGHTING SET.

"NORTHWESTERN LIMITED, C. AND N. W. RAILWAY.

Baggage Car. No. 1107.

Engine, Number 4171. $7\frac{1}{2}'' \times 7''$. 400 R. P. M.

Generator, Number 52974.

	VERTICAL.		HORIZONTAL.		REMARKS.		
Rec. No.	Number of Vibrations Per Minute.	Extent of Vibrations in Inches.	Number of Vibrations Per Minute.	Extent of Vibrations in Inches.	Station.	Position.	Time.
16	382	0.03	None Perceptible		Lodi	Baggage car (1107) near engine	11:19 P. M.
17	388	0.02	388	0.03	Baraboo	" " " " "	11:55
18	403	0.03	403	0.06	Reedsburg	" " " " "	12:26 A. M
19	400	....	400	0.06	Elroy	" " " " "	1:05
20	400	0.10	400	0.02	"	" " " " "	1:10
21	400	0.01	400	0.01	"	" " (589) center of car	1:12
22	408	0.03	408	0.02	Camp Douglas	" " (1107) near engine	——
23	390	0.01	None Perceptible			" " (589) center of car	7:00 P. M.
24	None Perceptible		None Perceptible			Buffet car (589) rear platform	
25	390	0.01	None Perceptible			Baggage car (589) rear platform	
26	None Perceptible		None Perceptible			"Deerfield" middle of car	
27	390	0.08	390	0.02		Baggage car (1107) near engine	
28	390	0.04	390	0.02	Minneapolis	" " " center of car	
29	390	0.02	None Perceptible		Coach Yards	" " " front of car	
30	390	0.08	None Perceptible			" " " near engine	
31	390	0.02	None Perceptible			" " " center of car	
32	390	0.02	None Perceptible			" " " "	8:00 P. M.
33	390	0.02	None Perceptible			Buffet car (589) rear of platform	
34	None Perceptible		None Perceptible			"Deerfield" front platform	
35	388	0.06	388	0.02	St. Paul depot	Baggage car (1107) near engine	8:35 P. M.

TABLE IV.

TESTS OF VIBRATIONS CAUSED BY A GENERAL ELECTRIC, 25 K. W., CURTIS TRAIN LIGHTING SET.

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY.

July 21, 1906,

Baggage Car, Number 216.
Turbine, Number 2907.
Generator, Number 111715.

REMARKS.

Rec. No.	Station.	Position.	Time.
36	Minneapolis Coach Yards	Baggage car Next to generator	6:30 P. M.
37		Baggage car Next to generator	
38		Baggage car Next to generator	
39		Baggage car Center of car	
40		Baggage car Center of car	

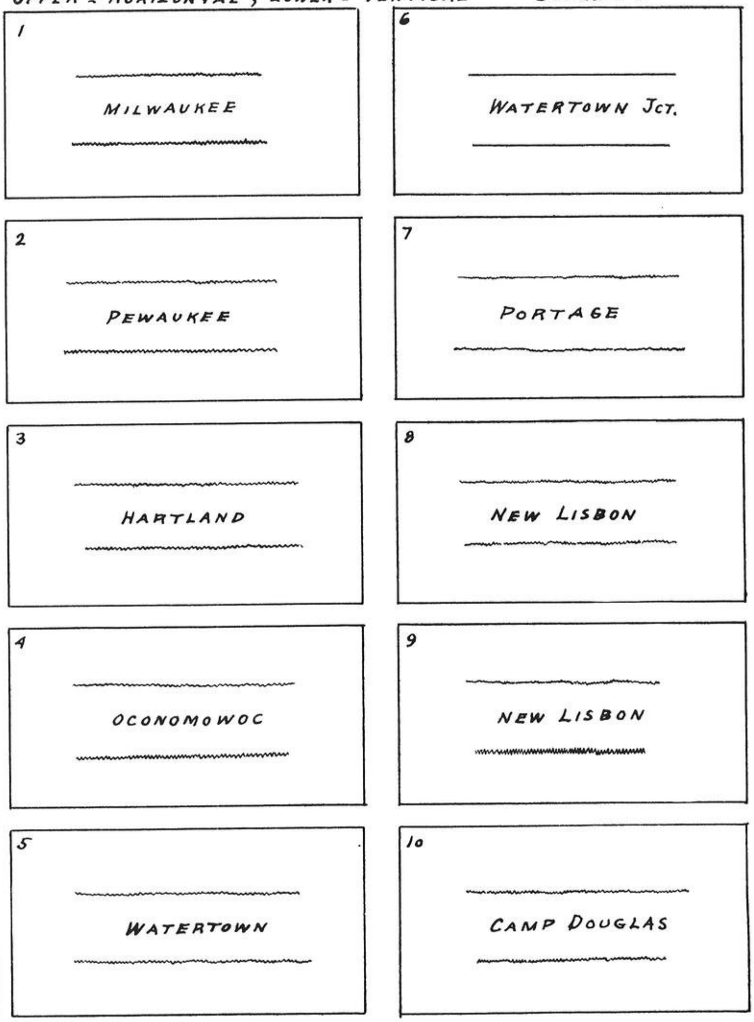
Resume.

From the experiments recorded in this paper and from general observations it appears that reciprocating engine train lighting sets, as installed at present, produce vibrations of considerable magnitude, due to unbalanced forces set up in them by the reciprocating motion of their parts. Many of you, no doubt, have experienced them while traveling upon electric lighted trains. The waves of vibration thus produced are transmitted back into the train for a distance which depends to some extent not only upon the method of placing the generating set in the car and its position in the train, but also upon the nature and condition of the coupling, buffing, and vestibuling devices. Other factors, some of which are pointed out in what follows, influence the extent of the vibratory waves and the distance of their transmission. The vibration becomes apparent when the train is at rest, but as soon as the train starts and when under way the pitching and tossing of the cars is great enough to destroy the effect of

"PIONEER LIMITED" C. M. & ST. P. RY CO, PLATE 5.

WESTINGHOUSE STANDARD ENGINE 20 K. W.

UPPER = HORIZONTAL, LOWER = VERTICAL SCALE = 2



"PIONEER LIMITED" C. M. & ST. P. RY. CO., PLATE 6.
GENERAL ELECTRIC CURTIS TURBINE
UPPER = HORIZONTAL, LOWER = VERTICAL. SCALE = 2

11

CAMP DOUGLAS

12

NEW LISBON

13

NEW LISBON

14

PORTAGE

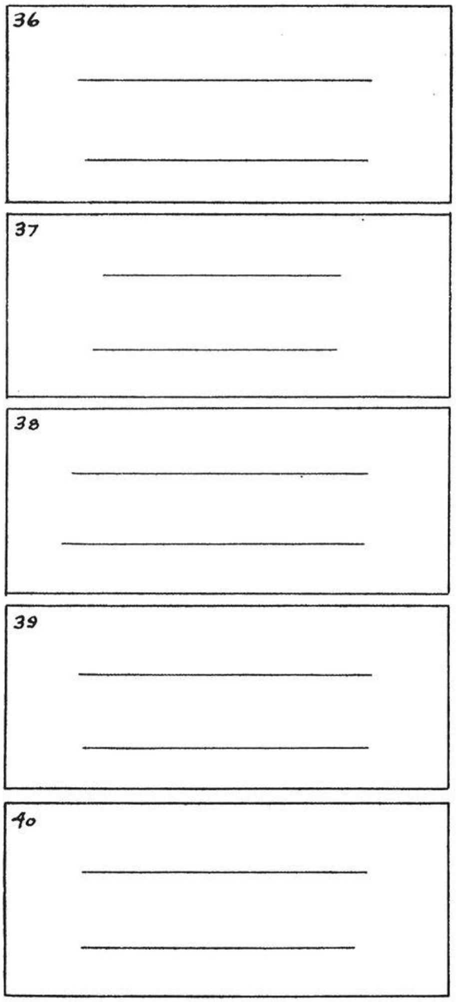
15

WATERTOWN JCT.

BAGGAGE CAR 216. C. & N.W. RY. CO. PLATE 8.

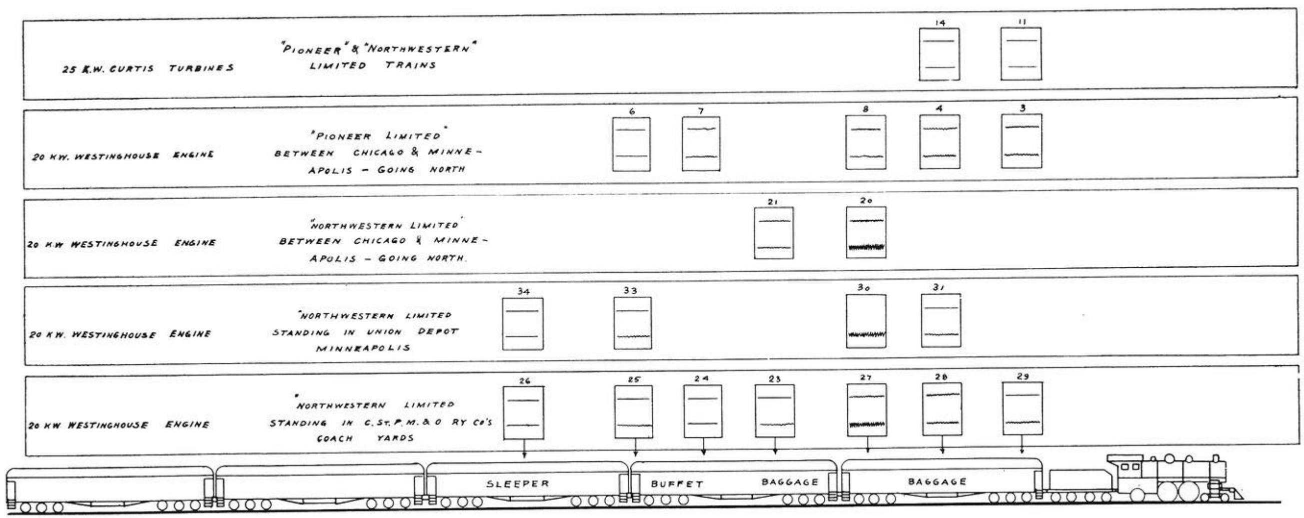
GENERAL ELECTRIC CURTIS TURBINE

UPPER = HORIZONTAL, LOWER = VERTICAL SCALE = 2



RECORDS TAKEN IN C. ST. P. M. & O. YARDS.

PLATE 9.



SKETCH SHOWING VIBRATION AT VARIOUS POINTS ON THE TRAIN AS MEASURED

UPPER CURVE = HORIZONTAL COMPONENT LOWER CURVE = VERTICAL COMPONENT the vibrations caused by the lighting set. It appears from the records that the vibrations produced are of a complex character, and that they can be resolved into components. In this work the vibration of the car floor was resolved into vertical and horizontal components, the horizontal component being determined longitudinally in the car. There is also a lateral horizontal component of the vibration, but it is not recorded in this paper, since it is of small extent and often absent. Thus the car vibrates in three dimensions. The component vibrations appear to have a "peaked" wave form and where both components exist there are as many horizontal as there are vertical vibrations.

The vibration frequency is in the neighborhood of 400 per minute and, since the lighting engines run at this speed, it may be said that there is one vibration per revolution of the electric light engine. Or, what is the same thing, there are as many vibrations as there are revolutions. Hence, the number of vibrations depends upon the speed of the lighting engine.

The extent of the vibration is greater in some parts of the car than in others. The minimum vibration seems to be found at the points of support of the car floor—the king bolts. The vertical vibration is nearly always greater than the horizontal vibration, but exceptions to this have been observed. Thus, the maximum vertical displacement shown on the vibration records is 0.05″ in the Chicago, Milwaukee and St. Paul tests and 0.10″ in the Chicago and Northwestern tests. The maximum horizontal displacement as shown on the records is 0.02″ in the Chicago, Milwaukee and St. Paul tests and 0.06″ in the Chicago and Northwestern tests. This displacement of 0.06″, however, is an exceptional case. Since the vibration recorder magnifies the vibration two-fold, the actual vibration is one-half of the amount indicated by the figures. It is quite probable that the real displacement is somewhat greater than this, since the friction of the instrument absorbs some of the energy of the vibrations.

The buffers and vestibule plates transmit the vibrations from one car to the other, but as the cars are not rigidly coupled together, the energy of the vibrations is largely lost in the flexible joints. The vibration is greatest in the vicinity of the lighting set and becomes less as the distance from the set increases. In other words, some parts of the train vibrate more than others, the most vibration being found at the front end of the train and the least at the rear of the train. The tremblings can be detected in the third and sometimes in the fourth and fifth car from the generating set, depending upon conditions.

The amount of vibration depends upon the manner in which the train comes to a stop. When the train comes to a stop with the buffers and vestibule plates tight together, much vibration is felt in the train, but when the buffers and plates are loose, less vibration can be detected. This is shown when the train comes to stop on a grade. If the grade is down, the cars press against each other and put the buffers and plates into intimate contact. The result of this condition is that the vibration is quite noticeable. If the grade is up, the cars tend to separate, the buffers and plates are not in close contact and a small amount of vibration is transmitted back into the train.

Similar conditions arise when water is being taken at a station. When the engine is "spotted for a water tank," it must be brought into position carefully. If the engineer gets the tender too far ahead of the water spout he backs up a trifle, thereby, "bunching" the train and putting the buffers and plates into intimate contact. This condition makes the vibrations strongly perceptible. On the other hand, if the tender stops too far back of the spout, he goes forward a trifle, thus loosening the contacts. A small amount of vibration is then transmitted.

Another point, in this connection, is that as soon as the train comes to a stop vibrations are felt. But, in starting up again, as soon as there is a pull on the drawbar and before the locomotive driver wheels have made a quarter turn, the vibration disappears. At the instant of starting the buffers are pulled apart so that the vibrations are not readily transmitted.

The weight of the train, the weight of the cars, and the weight of the load have an effect on the magnitude of the vibrations. This is apparent, since it takes more energy to shake a heavy load than it does to shake a light one. Having given an engine set, whose impulses produce vibrations of a certain magnitude on light cars, it is probably safe to assume that the same engine will produce vibrations of smaller size on heavier cars.

The size of the reciprocating unit enters into the question. The moving parts of a large unit, being larger, will produce greater disturbing forces, and, for a given weight of car, will produce larger vibrations than a smaller unit. For instance, the records in this paper show that the vibrations can be detected as far back as the third car from the locomotive for 20 Kilowatt Westinghouse sets. In February, 1906, while the train was standing in the Chicago, Milwaukee and St. Paul depot at Minneapolis, the vibration was barely perceptible without instrumental means in the fifth car from the locomotive, a 25 Kilowatt Westinghouse set being in use at this time.

The records plainly show that the trains equipped with turbine lighting sets are exempt from the annoying vibrations which are likely to traverse a train from a reciprocating engine set.

Aside from the vibrating effect of these lighting sets, noises are produced which are annoying at times. With the Westinghouse set, when the steam pressure is low, a knocking or pounding of the engine takes place when under load. This noise is transmitted back into the train for a considerable distance. The speed (400 r. p. m.) is low enough so that each separate knock can be heard. With the turbine set, a humming or buzzing sound is observed. The higher speed of the turbine (3,600 r. p. m.) makes a noise characteristic of high speeds.

METHODS AND RESULTS OF THE WISCONSIN WATER POWER SURVEY.

SEASONS 1905 AND '6.

L. S. SMITH, C. E., '90,
Assoc. Prof. Topographic and Geodetic Engr.

The importance of its water power resources to a state so remote from coal mines as is Wisconsin is not likely to be overestimated. Unquestionably, these powers are destined to exercise a wide influence on the development of the state. For, unlike the other great natural resources of the state, such as the forest and mineral wealth, the utilization of which means the final destruction of the source of supply, the water power resources are as certain and eternal as the sunshine itself.

Wisconsin water powers have not received, in the past, the attention to which their value and importance entitle them. This condition has resulted, in large part, from a lack of general information regarding their location and extent. It was for the purpose of supplying this information that the legislature of 1905 appropriated the sum of $2,500 for the survey of the most important rivers. This sum was duplicated by the United States Geological Survey, and a contract for a co-operative state and federal survey was signed in August, 1905. The organization and supervision of the survey was placed in the hands of the writer.

Mr. V. H. Reineking was put in charge of a transit party, which surveyed the Black River for a distance of 63 miles above Black River Falls, as well as the Flambeau River from its mouth to a point near its source, a distance of 120 miles. In the latter work he was relieved, at his request, by Mr. G. A. Diestler. Mr. D. H. Dugan, in charge of another party, successfully surveyed the Wisconsin river from Kilbourn to Tomahawk, a distance of 197 miles, as well as 25.8 miles of the Eau Claire and 81.7 miles of the Peshtigo River. Several other University of Wisconsin men were also employed as rodmen, and added to the progress by their intelligent and faithful services.

The chiefs of the party amply justified the confidence reposed in them, and, in spite of lack of experience in this kind of work, have done the work so well and with such speed as to easily set the record in this work, both as regards accuracy and cost.

METHODS.

Specifications: The specifications for doing the work were nominally made by the United States Geological Survey, but the writer was given a free hand to make such changes as seemed desirable. Several important changes were made which added to the value of the work and greatly reduced the cost.

Magnetic Control: The most important modifications introduced into the field methods of these river surveys was one which substituted the magnetic needle for the control of all the directions. This change has resulted in such a large saving to the state, without sacrificing any needed accuracies, that it may be briefly stated. On other similar joint State and Federal Surveys, it has been the custom to run an accurate transit or meander line along the bank of the rivers. The points occupied by the transit were accurately marked by stakes and the true direction or bearing of each line was noted, both looking forward and backward. This required all the stations to be occupied by the transit in order that the instrument might be properly oriented with respect to the meridian. Of course this secures great accuracy of location, but it is too expensive for preliminary surveys of this character. Especially is this true of a state like Wisconsin, in which the magnetic needle is fairly reliable, when properly checked by stellar determinations. Accordingly, all the surveys have been made with the "transit and stadia method," all directions being determined by the needle. This has increased the speed of the work by about 33 per cent. The recent hydrographic conference at Washington has endorsed this method, and in the future this method will be used wherever possible in all surveys of this nature.

Section Lines: Another new and valuable feature of our Wisconsin river survey was the requirement that frequent ties should be made on section lines where they crossed the river. This required but little loss of time, and it makes possible the location on our maps of the ownership of all falls and rapids. This accurate location of the water powers is next in importance to the determination of their size and extent. In similar surveys in Maine, Virginia and Georgia, no attempt was made to locate property lines, partly, perhaps, because the United States Land System does not obtain in the Eastern states.

Wye Level Control: The government specifications required that lines of accurate wye levels should be run in each river valley and permanent bench marks established for the control of the transit topography. Four hundred miles of such levels were run at an expense of $1,277.00, or $3.23 per mile. The cost of these levels varied from $2.16 per mile, in a settled country with good roads, to $4.85 per mile on the Peshtigo River, in a wild country, devoid of settlements and roads.

Primary levels (double rodded line) on river surveys in Maine cost $10.60 per mile, and $9.13 in Virginia during 1905–6. It is extremely doubtful whether much increase in accuracy is gained by a double rodded line. Accumulative errors can be best eliminated by running the line forward and backward.

As the main purpose of such general surveys is to point out the location of possible power developments, showing only the general physical conditions for such development, the private civil engineer must still be employed for the expensive detail survey, showing the certain practicability and cost of the development.

The writer has always believed, and our work under discussion abundantly proves, that the transit is capable of running levels with all needful accuracy for the work under discussion. He submits that, as an engineering proposition, all money spent for securing needless accuracy is practically thrown away. The $1,277.00 spent on Wye leveling in Wisconsin was not, however, quite thrown away. The checks thereby provided have shown so conclusively that the transit alone is sufficient that at a recent conference of the United States Geological Survey officials, the Wye level was officially abandoned for river surveys.

As little on the subject of the accuracy of transit leveling has appeared in engineering literature, it will be of interest to examine in detail the checks on our Wisconsin work. In judging this work, it should be kept in mind that the turning points were distant apart, on the average 1,600 to 2,000 feet, and that the men doing the work had had no typographic experience, except such as is afforded by the summer school of surveying. It is very noticeable that the accuracy improved as experienced was gained in the work.

In the stretch of 58 miles of levels run on the Black River (see Table 1), it will be seen that the largest error per mile

TABLE 1.

ACCURACY OF TRANSIT LEVELING ON BLACK RIVER.

No. of Check	Distance in Miles	Error in Stretch				Accumulative Error		Total
		Plus	Minus	Σ Error	Per Mile	Total	Per Mile	Miles
1.	2.3	.09	....	+ .09	.04	+ .09	.04	2.3
2.	2.3	.44	....	+ .44	.20	+ .53	.12	4.6
3.	2.4	.17	.69	− .52	.20	+ .01	.001	7.0
4.	3.6	.23	.54	− .31	.09	− .30	.029	10.6
5.	4.6	....	.14	− .14	.03	− .44	.030	15.2
6.	5.2	1.50	....	+1.50	.29	+1.06	.050	20.4
7.	3.8	....	.57	− .57	.15	+ .49	.020	24.2
8.	3.2	1.01	....	+1.01	.31	+1.50	.055	27.4
9.	3.6	.72	.90	— .18	.05	+1.32	.042	31.0
10.	3.6	.20	....	+1.20	.33	+2.52	.073	34.6
11.	6.3	.49	.59	− .10	.02	+2.42	.06	40.9
12.	4.8	.31	.75	− .44	.09	+1.98	.044	45.7
13.	5.2	.27	.17	+ .10	.02	+2.08	.041	50.9
14.	1.8	....	.78	− .78	.40	+1.30	.025	52.7
15.	5.3	....	.79	− .79	.14	+ .51	.009	58.0
					Ave. .15			

on any stretch was 0.33 of a foot and that the average error per mile was .15 of a foot. But paying attention to the sign of the error, it is found that these errors compensated to a remarkable degree. Thus at the end of 10 miles, 20 miles, 31 miles, 41 miles and 51 miles, the accumulative errors were .03, .05, .04, .06 and .04 per mile respectively, while the error of the entire 58 miles was less than .01 of a foot per mile, or .067 $\sqrt{\text{miles}}$. This accuracy is about as good as is usually secured by short sight and with an accurate Wye level.

The same engineer next surveyed the Flambeau river, with even better results, as shown in Table 2. His largest error

TABLE 2.

ACCURACY OF TRANSIT LEVELING ON FLAMBEAU RIVER.

No. of Check	Distance in Miles.	Error in Stretch				Accumulative Error		Total Miles
		Plus	Minus	Σ Error	Per Mile	Total.	Per Mile	
1.	3.4	.27	.05	+.22	.06	+.22	.06	3.4
2.	2.5	....	.58	−.58	.23	−.36	.06	5.9
3.	2.8	.17	....	+.17	.07	−.19	.02	8.7
4.	2.5	....	.28	−.28	.11	−.47	.042	11.2
5.	1.5	....	.08	−.08	.05	−.45	.045	12.7
6.	2.2	....	.10	−.10	.045	−.65	.043	14.9
7.	4.1	....	.69	−.69	.16	−.134	.070	19.0
8.	4.4	.62	....	+.62	.14	−.72	.031	23.4
9.	2.7	.40	....	+.40	.14	−.32	.012	26.1
10.	1.3	.20	....	+.20	.16	−.12	.004	27.4
11.	1.6	.22	....	+.22	.13	+.10	.003	29.0
12.	1.9	.38	....	+.38	.20	+.48	.015	30.9
13.	5.0	....	.28	−.28	.05	+.20	.006	35.9
14.	2.5	....	.68	−.68	.15	−.48	.013	38.4
15.	1.2	.34	....	+.34	.22	−.14	.004	39.6
16.	2.5	.22	....	+.22	.08	+.08	.002	42.1
17.	2.4	.02	....	+.02	.008	+.10	.001	44.5
18.	3.1	....	.27	−.27	.087	−.17	.004	47.6
19.	3.1	.09	....	+.09	.028	−.08	.002	50.7
20.	4.2	....	.02	−.02	.004	−.10	.002	54.9
21.	1.0	....	.06	−.06	.06	−.16	.006	55.9
22.	1.8	....	.27	−.27	.15	−.43	.008	57.7
23.	3.6	.51	....	+.51	.07	+.08	.001	61.3
24.	6.6	....	.03	−.03	.005	—.05	.001	67.9
25.	4.8	.46	....	+.46	.096	+.51	.007	72.7
26.	1.4	.11	....	+.11	.078	+.62	.008	74.1
27.	4.0	.05	....	+.05	.012	+.67	.008	78.1
28.	3.2	.22	....	+.22	.070	+.89	.011	81.3
29.	3.6	....	.56	−.56	.153	+.33	.004	84.9
30.	3.0	....	.04	−.04	.012	+.29	.003	87.9
31.	4.4	... .	.03	−.03	.007	+.26	.003	92.3

on any stretch was .22 of a foot per mile, with an average of .09 of a foot. Of the 31 checks, 14 showed minus and 17 plus errors. This compensation of errors is also seen by a comparison of the accumulative errors at 11, 23, 31, 42, 50, 61, 73, 81 and 92 miles from the beginning. The error was .47, .72, .48, .08, .08, .08, .51, .89 and .26 of a foot, respectively. The criterion for good Wye leveling ($.05 \sqrt{\text{miles}}$) would have meant an allowable eror of 0.48 of a foot in this length of 92.3 miles, as compared to .26 of a foot actually secured.

Taking up now the work of the other party on the Wisconsin and Peshtigo rivers, Tables 3 and 4, equally good results

TABLE 3.

ACCURACY OF TRANSIT LEVELING ON WISCONSIN RIVER.

No. of Check	Distance in Miles.	Error of Stretch				Accumulative Error		Total Miles
		Plus	Minus	Σ Error	Per Mile	Total	Per Mile.	
1.	18.1	1.14	1.77	−0.63	.039	− .63	.039	18.1
2.	14.6	....	2.73	−2.73	.187	−3.36	.103	32.7
3.	15.0	.45	....	+ .45	.03	−2.91	.061	47.7
4.	15.0	....	.28	− .28	.02	−3.19	.050	62.7
5.	27.0	.45	.55	− .10	.004	−3.29	.036	89.7
6.	8.0	.04	.01	+ .03	.003	−3.26	.033	97.7
7.	16.3	.16	.53	− .37	.023	−3.63	.032	114.0
8.	6.3	.10	.04	+ .06	.01	−3.57	.029	120.3
9.	25.0	.86	....	+ .86	.03	−2.71	.019	145.3
10.	23.0	.85	.17	+ .68	.02	−2.03	.012	168.3
11.	10.7	.49	.16	+ .33	.03	−1.70	.010	179.0
12.	6.0	.54	....	+ .54	.09	−1.16	.006	185.0
13.	6.0	.38	....	+ .38	.06	− .78	.004	191.0
14.	9.0	.34	.13	+ .21	.02	− .57	.003	200.0

are seen. On the Wisconsin, about one-third of the turning-points between Grand Rapids and Kilbourn, a distance of 90 miles, were taken with vertical angles. The largest errors are found in this, the first stretch to be surveyed. The largest error in any stretch of river is .19 of a foot per mile, the smallest .01 of a foot per mile, and the average error per mile only .04 of a foot. Testing the accumulation of error, it will be seen that the largest error was near the beginning of the line, and that it quite steadily decreased until at the end the total error of 200 miles of transit levels was only 0.57 of a foot. The total error which might be expected from a line of 200 miles of Wye levels is .75 of a foot. The record of work on this river in which only level readings were taken on turning-points (110 miles) is still better; the average error on the 9 checks was .032 of a foot per mile.

TABLE 4.

ACCURACY OF TRANSIT LEVELING ON PESHTIGO RIVER

No. of Check	Distance in Miles	Error of Stretch				Accumulative Error		Total Miles
		Plus	Minus	Σ Error	Per Mile	Total	Per Mile	
1.	2.1	.16	....	+.16	.08	+ .16	.08	2.1
2.	1.9	....	.17	+.01	.09	+ .01	.002	4.0
3.	3.6	0.72	....	+.72	.19	+ .71	.09	7.6
4.	1.5	.13	....	+.13	.09	+ .84	.09	9.1
5.	4.7	.32	....	+.32	.07	+1.16	.08	13.8
6.	2.5	.13	....	+.13	.05	+1.29	.078	16.3
7.	5.0	.02	....	+.02	.004	+1.31	.062	21.3
8.	5.0	.16	....	+.16	.032	+1.47	.056	26.3
9.	7.6	.17	....	+.17	.022	+1.64	.049	33.9
10.	4.0	.0	.94	−.94	.23	+ .70	.018	37.9
11.	5.1	....	.46	−.46	.09	+ .24	.005	43.0
12.	2.4	....	.04	−.04	.017	+ .20	.004	45.4
13.	3.5	.81	....	+.81	.23	+1.01	.02	48.9
14.	1.3	....	.03	−.03	.02	+ .98	.02	50.2

Eighty-two miles of transit levels were run on the Peshtigo River, the greater part being in a rough, rocky and sparsely settled country. 50.2 miles of these transit levels were checked by Wye levels. The largest error per mile in any stretch was .23 of a foot, the smallest, .02 of a foot and the average .09 of a foot. The largest accumulation of error at any point was 1.64 feet while that at closing was .98 feet. The accumulative error *per mile* gradually decreased from .09 feet near the beginning to .02 feet at the end.

Attention is directed not so much to the small size of the errors as to the fact that the errors *compensate to a remarkable degree.* It is perfectly manifest that the transit as a leveling instrument is capable of doing leveling with an accuracy well within the limits required on preliminary surveys

TABLE 5.

TOTAL AND UNIT COST OF WISCONSIN COOPERATIVE RIVER SURVEY, 1905–1906.

L. S. SMITH, *Hydrographer in Charge.*

River Surveyed	Spirit Leveling			Topography			Map and Profiles			Cost of Reconnoissance and Supervision Per Mile.	Total Cost Per Mile of River	Total Cost
	Total Miles	Total Cost	Cost per Mile	Total Miles	Total Cost	Cost per Mile	Tot. Miles Mapped	Total Cost	Cost Per Mile			
Wisconsin..	187.3	$403.	$2.16	197.0	$981.	$4.97	197.0	$171.	$0.89	$0.73	$8.61	$1698.00
Eau Claire..	0.0	0.	0.00	25.8	177.	6.87	25.8	11.	0.44	1.00	8.29	213.80
Peshtigo ...	40.0	194.	4.85	81.7	521.	6.36	81.7	40.	0.50	0.70	9.98	815.20
Black	69.3	213.	3.10	63.0	213.	3.38	63.0	57.	0.90	1.10	8.76	552.30
Flambeau ..	102.0	467.	4.58	119.5	796.	6.69	119.5	106.	0.90	1.25	12.71	1519.00
Total.....	398.6	$1277.	$3.24	487.0	$2688.	$5.52	487.0	$385	$0.79	$0.90	$9.85	$4798.30

Method—Transit and Stadia with Wye Level Control.
Scale—1 inch = 1000 feet.
Contour Interval = 10 feet on land and 1 foot on water.
Section Lines frequently located.

of this character. The omission of the Wye leveling on this work will save many thousands of dollars in future work of this character.

Cost, unit and total: The collection of the data shown in Table 5 has cost much labor and study. In this table, the cost of 487 miles of river surveys is separated into its four principal items, viz: Wye leveling, topography, office mapping and supervision. For 187.3 miles of the Wisconsin River, these items totaled $1,698.00, or $8.61 per mile, and 25.8 miles on the Eau Claire cost $8.29 per mile without leveling. 81.7 miles of Peshtigo River survey cost a total of $815.20, or $9.98 per mile. The unit cost on Black River was $8.76, while that on Flambeau was $12.71. The reason for this excessive cost is found in the fact that the work was greatly interrupted by storms. This necessitated three trips of the party from Madison to this river, causing large expense for transportation. Thirty-eight days in all were lost because of travel, stormy weather and holidays, including Sundays, the cost of which was $418.00. Could this delay have been avoided, the cost per mile would have been reduced to $9.21. The average cost of the 487 miles of the river surveyed and mapped was $9.85.

It may be of interest to compare this with the table of cost of similar work in Maine during 1905–6. The average of such cost of completed maps as far as is shown is $17.40, or nearly double that of our Wisconsin work. The forest, geological and other features controlling the cost are quite similar in the two states.

In Virginia, where the conditions for doing such work are much less favorable, 130 miles of river survey cost in 1905 $4,101, or $31 per mile. This included $9.13 per mile for primary levels.

The reduction of the cost of river survey to less than $10 per mile is due primarily to the changes introduced in party organization, together with the simplification of field methods. The cost of supervision also was very little, probably not one-half of similar work in the East.

Future field work of this nature will be made at still smaller cost, due to the omission of Wye level control, now found unnecessary.

Maps and profiles of these rivers, based on this survey, are now being printed by the U. S. Geological Survey and will soon be available for distribution upon application to the director of that survey, at Washington, D. C., at the nominal price of five cents per sheet.

A STUDY OF TRAIN RESISTANCE.

J. G. VAN ZANDT,
Instructor in Railway Engineering, U. W.

Train resistance is a subject upon which a great many men have been experimenting and for which a great many conclusions have been made. The present condition of train resistance formulae and data would give the casual observer the idea that little was known regarding the value of this important factor in railroad economics. (See Plate X.) It has been well said, however, that the "actual variation in the results of the experiments is not as great as the apparent difference and that extended careful study would reconcile many discrepancies."*

Analysis.

The factors which go to make up the resistance which has to be overcome by the power of the steam in the boiler of the locomotive to move the train are many and difficult of exact determination. In general we may classify them as follows:

(1) ACCELERATION.

There is necessary a force to change any body from a state of rest, or motion of one speed, to motion of another speed. This depends upon the weight of the body to be moved, and would therefore vary with the tonnage of the train.

(2) GRAVITY.

Whenever there is an inclination of the track from level there will be a component of the force of gravity acting in the plane of motion down that grade which must be overcome by the locomotive in moving the train in the opposite direc-

*Report of Committee on Economic. Location Amer. Ry. and Maintenance of Way Association, 1907.

tion. This depends upon the mass or weight of the train and the rate of the grade.

(3) FRICTION.

There are so many factors which come under this head that it is with considerable difficulty that a complete classifi-

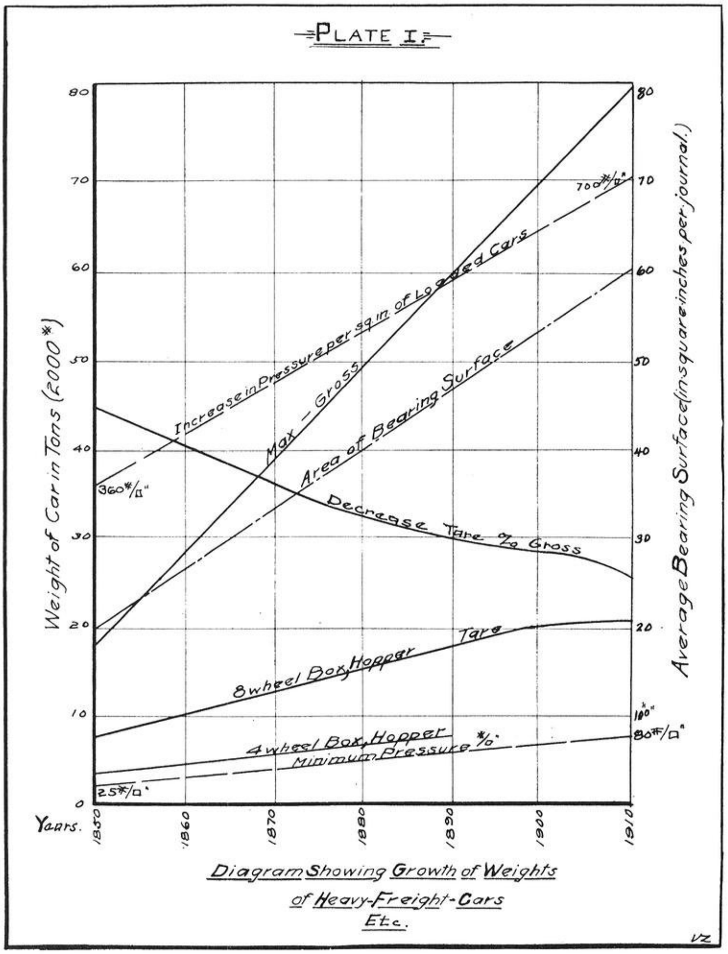


PLATE I.

Diagram Showing Growth of Weights of Heavy-Freight-Cars Etc.

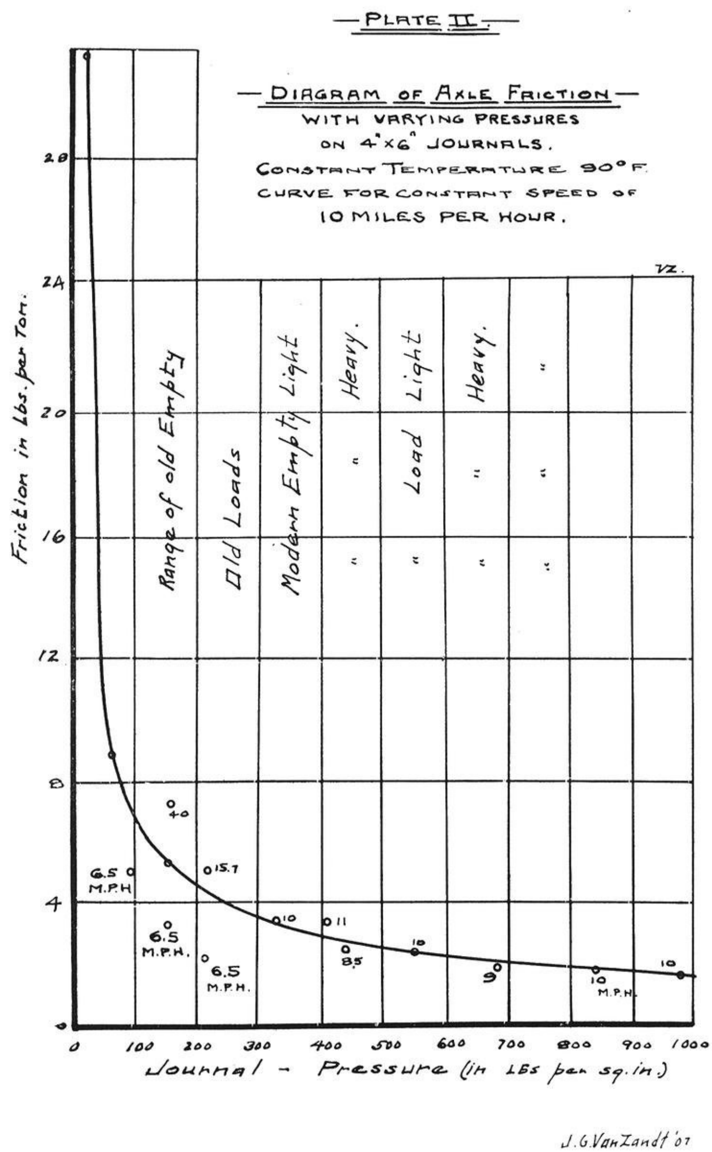
cation be given, which would not be unreasonably long. A general analysis would reveal the following notable factors:

(a) Journal friction. This would include the friction in the journals of all the car wheel axles and those of the locomotive (and in a sense includes the friction of the moving parts in the locomotive). This depends upon the design of the journals and the lubrication, and, as will be shown later, would vary with the number of journals and pressure upon them. The speed does not materially effect this factor after it reaches that value at which a continuous film of oil is kept running between the surfaces in contact.

(b) Rolling friction. By this is meant the friction caused by the wheels being in contact with the rail as if there were no flanges. It is generally acknowledged to be caused by a peculiar wave in the rail just in front of the wheel which depresses the track with its weight and therefore would vary as the weight upon the wheels and the condition of the roadbed. The weight of the rail (size and shape) and the size of the wheel would also affect this factor, together with other minor influences as line, surface, snow and dirt.

(c) Flange friction. All other resistances between the wheel and the rail than those included in the rolling-resistances, would come under this head. On level tangent this factor would be largely dependent upon the design of the rail and flanges. It would also be materially increased if a strong side wind were blowing against the train. On curves the flange resistance would depend upon the degree of the curvature, the design of the trucks and other turning parts, the size of the car wheels, the weight upon them and the gauge of the track. The speed of the train would also affect the friction, since centrifugal forces would tend to increase the friction on the flanges unless sufficient elevation of the outer rail were provided.

(d) Wind friction. Besides increasing the flange resistance the friction of the air against the ends and sides and the suction at the back of the cars would increase the total resistance somewhat.


—PLATE II.—
—DIAGRAM OF AXLE FRICTION—
WITH VARYING PRESSURES
ON 4"X6" JOURNALS.
CONSTANT TEMPERATURE 90° F.
CURVE FOR CONSTANT SPEED OF
10 MILES PER HOUR.
VZ.
Friction in Lbs. per Ton.
Journal - Pressure (in Lbs per sq. in.)
0
100
200
300
400
500
600
700
800
900
1000
4
8
12
16
20
24
28
Range of old Empty
Old Loads
Modern Empty Light
Heavy.
Load Light
Heavy.
6.5 M.P.H
6.5 M.P.H.
6.5 M.P.H.
40
15.7
10
11
8.5
10
9
10 M.P.H.
10
J. G. VanZandt '07

Discussion of Method.

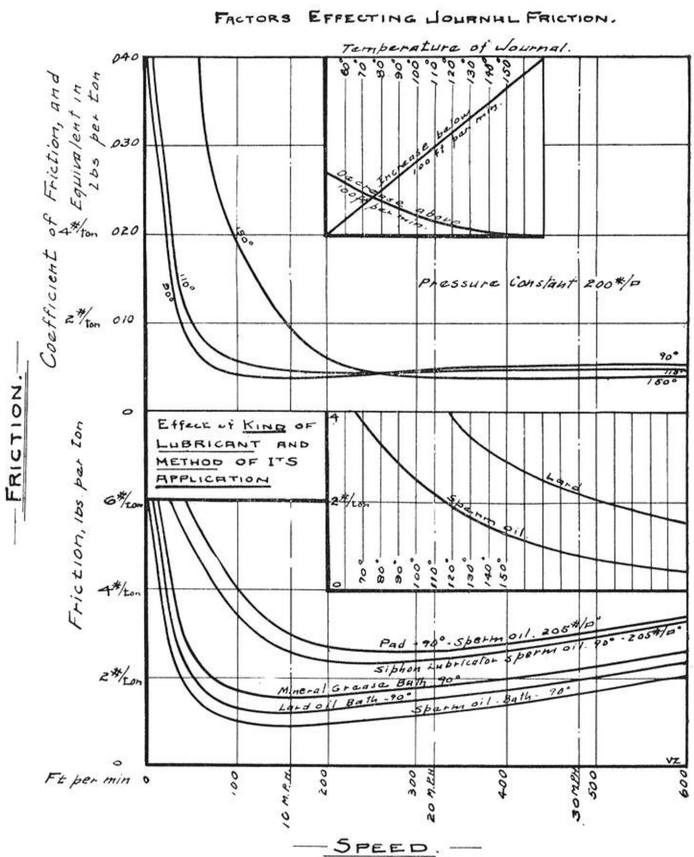
It is evident that the above classification omits numerous resistances little known and generally of insignificant amount, but nevertheless in existence. The term "oscillation and concussion" has been applied as a general name for these miscellaneous factors. It is hardly conceivable that friction can be possible except there be parts in contact, and since the rail must eventually receive all the resistance not caused by the air, all "miscellaneous resistances" must be included in the changing from one speed to another.

Many of these factors can be computed with reasonable accuracy by well known laws of physics. The acceleration resistance and grade resistance can be readily found in this way. The third factor of friction is only determinable by experiment. For this thousands of tests have been made, and we are by no means without valuable data, which has been made by careful observers under favorable conditions for the determination of this quantity. It would be reasonable to apprehend that with different kinds of cars and track different results would be found, especially as so many of the factors which go to make up the frictional resistance, as enumerated above, are dependent upon these very conditions for their value. Hence it will be well to consider the conditions of these many experiments and see if there is not some basis upon which the widely varying results can be reconciled.

Before establishing this basis it may be well to note that there is abundant opportunity for choice. When the plotted results of many experiments literally cover a diagram with lines (as in Plate X) almost any conclusion can be made, and to some extent proven to be justifiable. It will be the object of this determination to assume only the most reasonable of conclusions and to insist on complete knowledge of the conditions of experiment, taking the observed results without reference to the original conclusions made from them, except where nothing else remains to be used.

Of the hundred or more train resistance formulæ in existence there are four or more general types which may be arranged into general forms, as follows:

PLATE III



$$\text{I.}\quad R = a + bV$$

$$\text{II.}\quad R = a + bV + \frac{cAV^2}{D}$$

$$\text{III.}\quad R = a + bV^2$$

$$\text{IV.}\quad R = a + \frac{bVn}{Q} + \frac{cV^2n}{Q}$$

in which "a, b, c" are constants and "A" is area exposed to wind. "D" and "Q" are tonnage values and "n" is number of cars in the train.

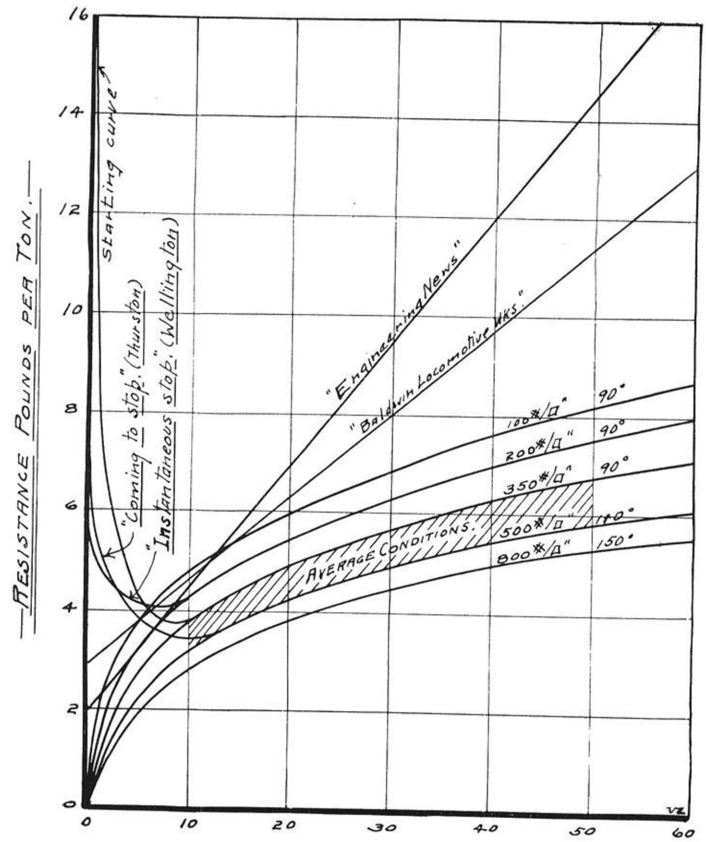
These deal only with the frictional resistances, the first factor being a constant for the journal friction, the second for the remaining resistance, sometimes exclusive of the wind friction which is given a separate factor varying as the square of the speed. There are very few—of which the fourth formula is an example—which take into consideration the size of the train. Even here there is no mention of the size of the car bodies and wheels or the number of wheels to the car.

It is obvious that all those factors which are derived from the contact of the rail with the wheels will vary with the number of wheels. Thus with a six-wheel truck we would reasonably expect to find the journal resistance larger than a four-wheel truck. The exact amount of this friction of course depends upon the design of the journal, the materials in contact and the weight upon it, together with the speed. Mr. A. M. Wellington gives for five miles per hour a co-efficient of .02 for loads of 300 pounds per square inch, and .03 for 150 pounds per square inch. This would indicate that at low speeds the friction would not vary greatly with the weight. At twenty miles per hour .018 is given. Mr. G. R. Henderson suggests; "If we assume .02 for truck journals, we will not be far from the actual values." It is evident that the coefficient remains very nearly constant after reaching that speed at which the lubricant is well applied. Hence we may state that *generally speaking the journal friction will vary directly as the number of wheels.*

In regard to the action of the wheels in a truck of six as compared with one of four wheels, it may be said that there is every evidence that the rolling resistance in pounds per ton is not increased by this addition of wheels. If a passenger truck be tested in straight level track, for several reasons it would offer less resistance in pounds per ton of load than a four-wheel truck under the same load. First, the rolling resistance which is caused by the elastic wave in front of the wheels would be materially less for two trucks of six than for three of four wheels each, since the wave once made by the first wheel does not affect the second but slightly, and hence but two waves instead of three should have to be made. Hence

PLATE IV.

TOTAL JOURNAL FRICTION.



the rolling resistance would reasonably vary inversely as the number of wheels in the truck. Under normal conditions on a straight level track the flange friction would no doubt be much less in the two six-wheel trucks, since the alignment and rigidity would be much in favor of reduced friction. The same might be said of oscillation and concussion and other miscellaneous friction factors. On curves also the resistance would be less, as the number of flanges cutting the rail is less. *Wellington states that "the wear (measure of resistance) on front wheels is more than double that on rear," which would prove that the fewer front wheels there are the less would be this friction. Hence for two six-wheel trucks the amount of friction would be less than for three four-wheeled ones, there being two sets of front wheels in one case and three in the other. *Therefore the flange friction* would appear to vary inversely as the number of wheels in the truck. Taking a general view of it, then, it may be reasonably stated that *rail resistances vary in pounds per ton, inversely as the number of wheels carrying the load.*

Applying these two principles in a preliminary way to two of the most famous and well established formulæ for train resistance, we will find a reconciliation which will show that both may be right. These formulae were both derived from experiments made on good track, under practically the same circumstances, and while the ranges of speed were not wide, they have been extended experimentally and substantially checked throughout. It has been stated that there were five thousand experiments made (unfortunately the records are not preserved) from which the present "Baldwin Locomotive" formula was derived. These were made, however, on high-speed passenger cars of twelve wheels. It usually is written as follows:

$$R = 3 + \frac{V}{6}$$

If now this were adjusted for freight cars of eight wheels we have the first factor reduced by the ratio of 12 to 8 and the second increased by the same ratio, hence it becomes

$$R = 2 + \frac{V}{4}$$

which is the celebrated "Engineering News" formula.

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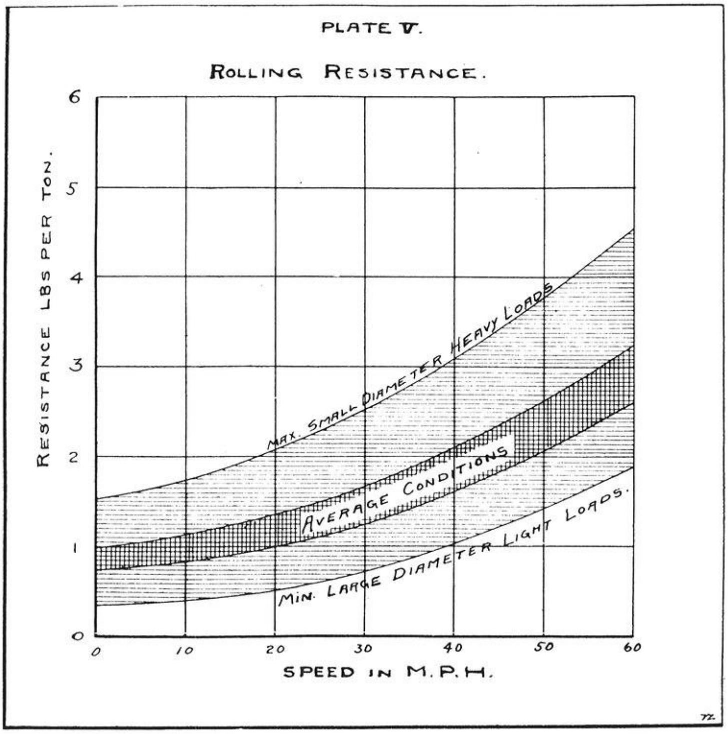
* The Economic Theory of Railway Location, page 284.

The remarkable part of this coincidence is, that from an aggregate of many experiments on heavy freight trains, the formula seems to check remarkably, but for passenger cars the "Baldwin" is best checked. An investigation into the derivation of the former, however, shows that it also was found by experiment upon passenger cars, but at speeds such that the "Baldwin" formula fits the points as well as the one selected for them, if not better.

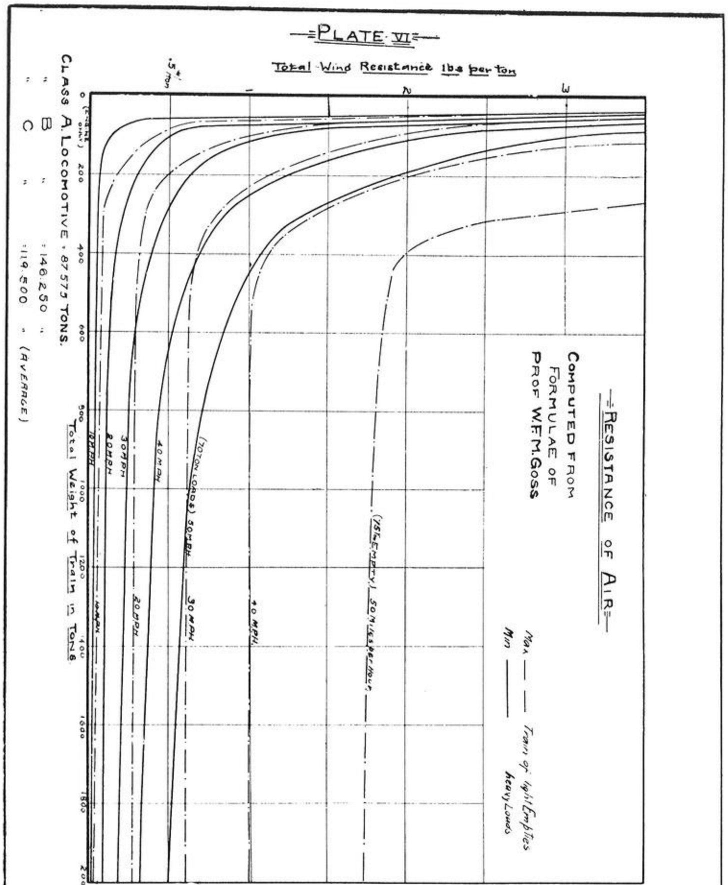


The numerous charges that these formulae are based upon figures derived from tests on track "some of which is the best in the world" and do not represent ordinary practice have not been greatly justified in the light of later experiments. In fact, the latest formulae give even lower values, and the evidence that these are too low grows less as improved rolling stock becomes prevalent and better road-bed conditions are more common. The truth is that the many apparent discrepancies can be accounted for by the very fact that improvements are being made in all parts causing resistance, and the history of formulae shows that the older the formulae (generally speaking) the higher are its values.

With this preliminary reconciliation the wheel unit of the type of freight car in use would present the most practical basis. It might be possible to reduce all present formulae, as in the above case, to the freight car unit, or even to the basis of the number of wheels and the weight upon them. It is safer, however, to use the data from which these formulae were derived with this basis for closer investigation and better conclusion than to take the mean adopted by the observer or computer.

To decide just what correction should be made for empties and loads involves a great many problems. We have to take into consideration the fact that the term "loaded" is only comparatively indicative of the weight of a car. Some of the older experiments were with loaded cars the weight of which was not more than some modern empties, whereas some loads of today are twice what they were at that time. It is evident that with the basis of wheel tonnage this will be reconciled, the weight on the wheels alone determining the rate of the correction. It is well known that empties under the same tonnage "pull harder than loads," which is most reasonable from this standpoint. This would justify the observation that old formulae give higher results for loaded cars than modern. It is evident that some old cars were empties—speaking from the standpoint of wheel tonnage only—though they were loaded to their capacity. No absolute rule can be made for this correction, though many attempts have been made which were very unique and useful. It has been contended that the grade over which the empties were pulled should enter as a factor in the allowance, also the speed and the location in the train. Under the present basis it is evident that the above mentioned factors are all taken care of and allowance of unknown quantity will not be necessary in such cases.

Extreme conditions, such as excessively long, heavy trains, or very light, short trains, will inevitably lead to different re-



sults, as the factors of oscillation and concussion and the averaging effect of long trains, as well as the effect of the locomotive momentum and resistance, is greatly increased or diminished as the size of the train changes. A large number of experiments have been made with the drop or coasting tests and are subject to criticism on the grounds that they do not represent the conditions of actual road service. Others were made with a dynamometer car between the tender and train, and this, though the best available method, is often conducted so as to take no account of the momentum and resistance of the locomotive. Many have sought to get the desired information from taking indicator cards from the locomotive while it was in operation, and have risked their lives sitting on the engine cylinder as more than a mile passed every minute beneath them, but afterwards took wild assumptions for the internal friction of the locomotive.

It is a lamentable fact that there is little reliable data regarding the resistance of trains in starting. Wellington's starting curve seems to have been well checked in some experiments, but shown to be considerably off in many others. The conditions of the experiments would probably give account for the widest differences.

There are so many things that affect the resistance of trains that is appears necessary to take them up individually and study them with the aim in view of reducing from extreme conditions to ordinary ones by a deduced allowance based on experimental data. Taking the several items in their order, let us first consider the axle or journal friction alone.

Journal Friction.

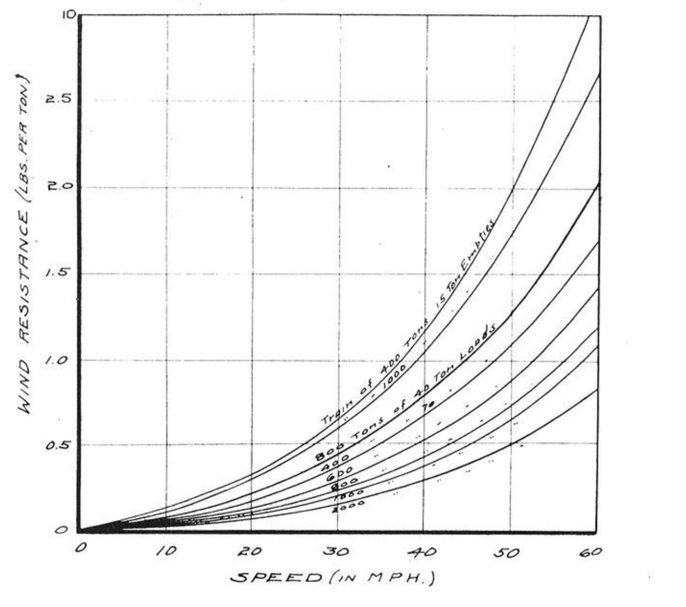
There have been some remarks about the "ends of the axles" rubbing against the bearings, but in modern cars this is overcome. Of course the side thrust of the car, or the deflection of a wheel on a curve to change the direction of the movement of the car body, will produce a sidewise force on the bearings, but that may be considered under the abnormal "miscellaneous friction" caused by oscillation. The axle in itself where it comes into contact with the bearing will create friction which will vary with

(1) the weight upon it;
(2) the size of the journal and general design;
(3) the speed and lubrication.

Friction is well known to be caused by the irregularities of the surfaces in contact and, generally speaking, it may be said that the brighter or smoother the surface the less the friction. Since it is an irregularity that we are dealing with, it is obvious that any attempt to give a formula of universal applicability will be useless. There are limits to which the friction may extend by the changing of conditions, and these

PLATE VII.

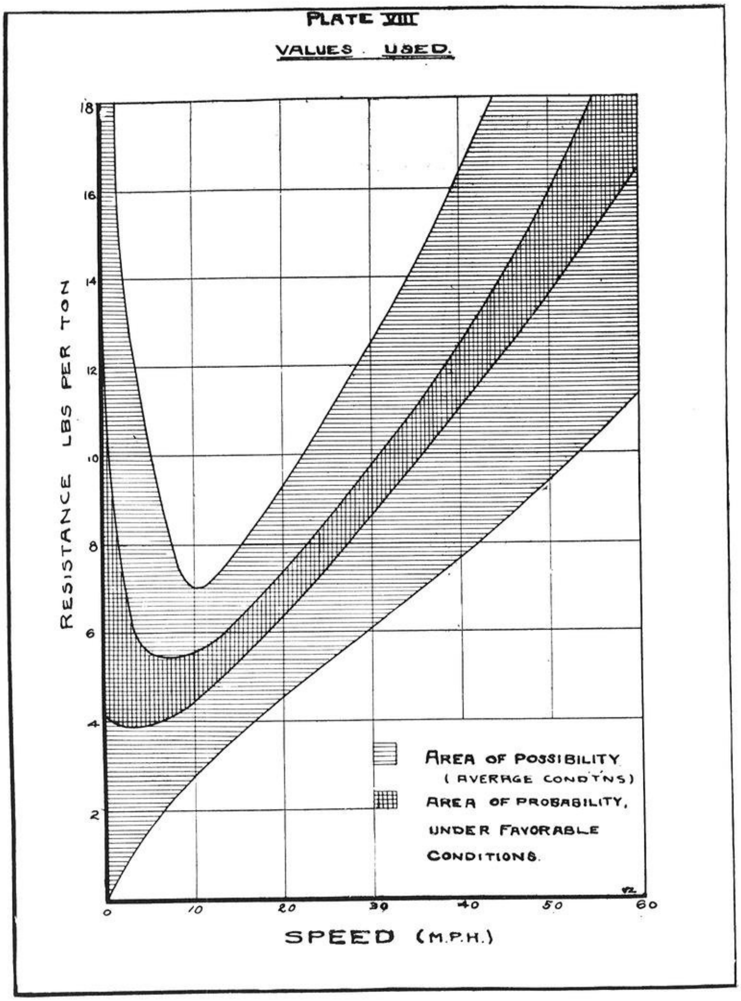
ALLOWANCE FOR WIND RESISTANCE.



may be determined with reasonable accuracy, so that we can find certain conditions which give average results at all times about the same. The purpose here, then, is the reduction of the results of experiments on journal friction from all conditions.

The frictional variation due to changes of weight have been well worked out by Mr. R. H. Thurston, who gives in his "Friction and Lost Work in Machinery and Mill-work" a table showing the values which he obtained by the use of a special instrument of his invention. These show that at a given temperature the coefficient of friction at freight train speeds and pressures varies inversely with the square root of the pressure. He also adds that "high pressures give lowest loss of power by friction." The starting or static friction is given as varying with the cube root of the pressure per square inch. He proves that the old theory that the friction was not changed by the pressure is false, and gives many results and diagrams to show the variation. Taking the longitudinal section of an axle as the measure of the area to withstand vertical pressures, and dividing it into the wheel load, we get an average pressure per square inch which is reasonably approximate. Taking a very light car of old type, which might weigh eight tons empty, and distributing that over the eight wheels of a maximum of forty square inches bearing, we have fifty pounds per square inch. At the other extreme we have a modern car of fifty tons capacity weighing seventeen tons, or total of nearly seventy tons, which may even reach eighty tons in some cases.

In Plate I are plotted approximate curves showing the growth of the factors relating to the weight on the bearings during the years which have produced the train resistance formulæ to be discussed. Among the things which may be noted from this figure are the decrease of the tare in per cent. of gross weight of cars, which would materially affect any allowances for empty cars, and the increase in pressure per square inch of bearing surface. Regarding this latter the experiments for the determination of the coefficient of friction as affected by the weight show that there is little appreciable difference under high pressures, but a great deal more under lower pressures. This is clearly shown in the figure on Plate II, which represents the variation at a constant speed and temperature for differences in pressure. From this and other figures of similar character it appears that over 95 per cent. of this variation is between 0 and 50 pounds per ton, and that the remainder, which would represent the pressures used in heavy car journals, lies between the narrow limits of from 2 to 7 pounds per ton of train resistance for all conditions of temperature and pressure. The size of the journal decides, of course, the pressure per square inch, and would give a



small difference, but, within the limits of modern axles, one of very negligible quantity. The kind of oiling device will also affect the amount of friction under other constant conditions. (See Plate III.) Assuming that most journals do not have the high standard of excellency which a sperm oil bath test would indicate, but that generally speaking the pad of oil and waste would lubricate rather sparsely the average freight car axle in ordinary practice, and further assuming that the conditions which govern car axle friction vary in the same general way as those which have been so well determined with better oiling devices, which govern axles in the testing laboratory, we can proceed to analyze the subject more safely.

For this determination we have available numerous tests of a remarkable variety and scope, from which definite laws have been well established. Among these are the conclusions of Mr. R. H. Thurston (above quoted), which briefly are as follows:

"Coefficient of Friction varies as the speed (over 10 M. P. H.)."

"Coefficient of Friction varies inversely as the square root of the pressure (over 50 pounds per square inch and over 10 M. P. H.)."

"Coefficient of Friction varies inversely as square root of the temperature (over 10 M. P. H.)."

"Coefficient of Friction at rest (static) varies as the cube root of the pressure."

"Coefficient of Friction coming to rest is constant (about 6 pounds per ton)."

"Coefficient of Friction increases with the temperature (below 10 M. P. H)."

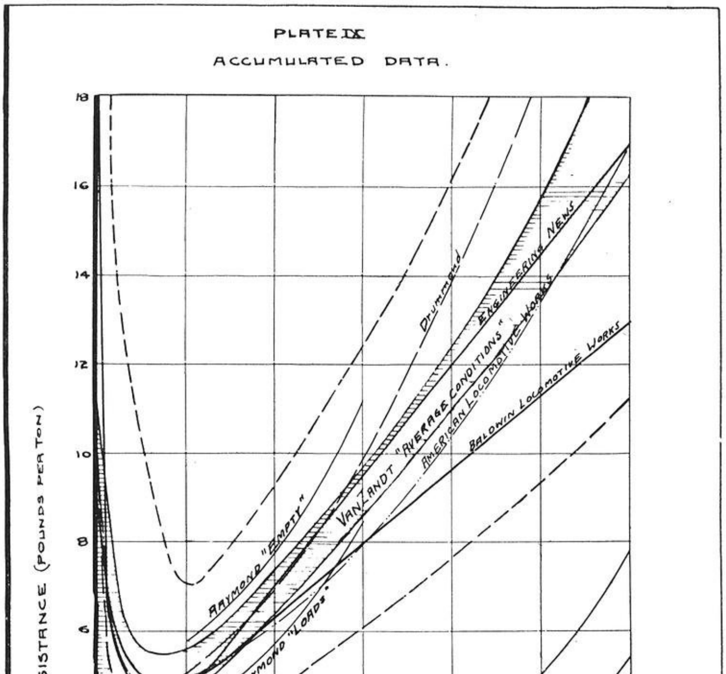
"Coefficient of Friction varies as fifth root of the velocity divided by square root of the pressure."

This last is merely a conclusion of the author from general observation, but does not include the variation of temperature. The same general conclusion is given from the tests of the Inst. of Mech. Engrs. of England, except that the last step is expressed as follows:

"The Coefficient of Friction varies as the square root of the velocity divided by the pressure."

It is evident that if any expression could be derived which would include all three of the variables that we would have the desired result.

If now we write P' for $1 \div P^{\frac{1}{2}}$ and T' for $1 \div T^{\frac{1}{2}}$, we have the three following variations;



F. varies as P' while V and T' are constant.
F. " " T' " P' " V " "
F. " " V " P' " T' " "

and it follows that

$$F = C(V \ x \ P' \ x \ T')$$

To determine the value of the constant "C" a substitution of values of actual tests will give an average which will be practically correct for all conditions. From the many tests which have been made on car journals an average comes very close to the figure ten, and hence that has been used.

Substituting these values we have finally;

$$F = \frac{10\sqrt[3]{V}}{\sqrt[5]{PT}}$$

The limits of these variables are the reasonable limits of practice. "V" varies between 10 M. P. H., and 60 M. P. H., "P" from 100 to 1,000 pounds per square inch and "T" from 90° to 150°. The results of these computations made by substituting in this formula are shown in Plate IV.

It is evident from the figure that instead of taking this first term, then, as a constant, it should be a variable as indicated. This gives reason for the numerous values of this constant quantity, which values are all included (under different conditions) in the above formula. An investigation made by the American Railway Engineering and Maintenance of Way Association, shows that out of 62 formulae, the constants varied from "zero" to "eight," the distribution being as follows:

Values	0 to 2	2 to 4	4 to 6	6 to 8	Total
Number of formulae	6	32	16	8	62
Per cent of Total	9.7%	51.6%	25.8%	12.9%	100%

It is evident that the above formula allows of all these values under certain conditions which in many cases were found to be nearly identical with those under which the values were derived. The majority at from 2 to 6 speaks well as an approximate check.

Rolling Resistance.

In regard to the second item, that of rolling resistance, the same general method is adopted. The particulars will not be here elaborated, but the principle is the same. Data on rail depressions and stresses is available and many interesting records of tests are prepared, which when properly adjusted and arranged, give satisfactory results. It may be of interest to state that light passenger locomotives with the heavy drivers separated by some distance, give higher rolling resistance than the heavier freight locomotives with wheels bunched together. Further it is ascertained that gravel ballast is better than stone for reduced rolling friction. Plate V shows the result of this investigation.

Air Resistance.

As to the determination of the air resistance, the formulæ of Prof. Goss are available and the data reliable, having been fairly checked by experiment. Taking his conclusions, the following results have been computed:

Prof. Goss' Formulae:

"(a) Locomotive resistance in train $= .11V^2$
(b) " " alone $= .13V^2$
(c) Car " " train $= .01V^2$
(d) Last car " (caboose) $= .026V^2$."

For mixed trains we will have then,

$$\text{total} = \frac{R_L \times L + R_C \times C}{W}$$

where R_L = Resistance of Locomotive.
L = Weight of Locomotive.
R_C = Resistance of cars.
C = Weight of cars.
W = Total weight in tons.

For $R_L \times L$ use formula "(a)" or "(b)."
$R_C \times C$ use formula "(c)" x number of cars + "(d)."

No. of cars $= \frac{W - (L + 10)}{15}$ for "empties" at maximum of 15 tons.

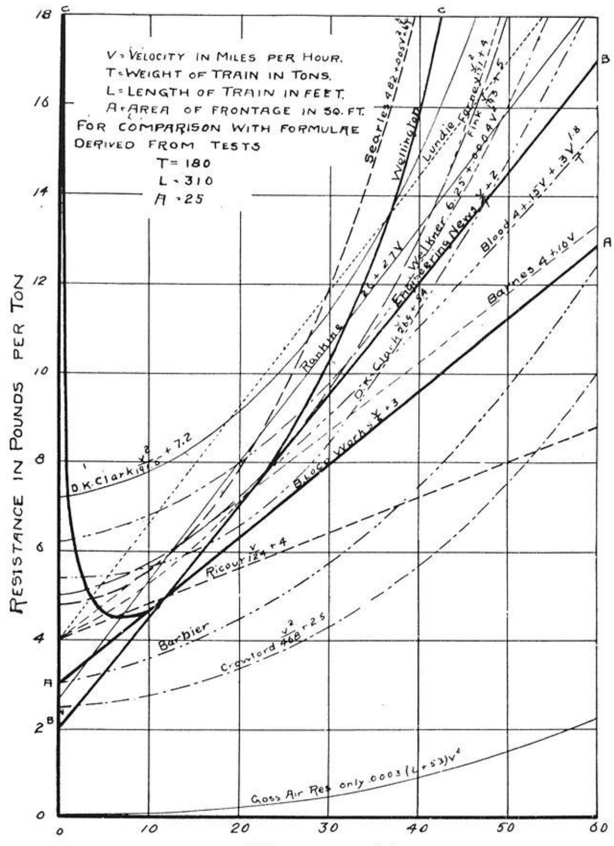
$= \frac{W - (L + 10)}{70}$ for "loads" at maximum of 70 tons.

Conclusions.

Having worked out all conditions of speed and trains, the results appear on Plate VI. This shows that the variation in air resistance is largely dependent upon the kind of train hauled, the resistance in pounds per ton being below one pound for all normal conditions, but varying between practically zero and ten or more pounds per ton. Plate VII indicates the allowance made in the final summation. Plate VIII shows the range of the values used, and Plate IX the accumulated data. The area of possibility is evident and that of probability is also indicated on both.

PLATE X.

OLDER FORMULAE.



COMPARATIVE-DIAGRAM OF TRAIN RESISTANCE CURVES REPRESENTING VARIOUS FORMULAS.

The results show rather decidedly that though there may be conditions under which all these values given in Plate X may be correct, yet by careful study the values most nearly accurate for special conditions can be found by a careful investigation.

THE PRESERVATION OF NOTES, CLIPPINGS, ETC.*

G. J. DAVIS, *Instructor in Hydraulic Engineering.*

As soon as the collection of data† is begun the collector is confronted with the problem of selecting a suitable system of filing them. No system has been devised which is entirely satisfactory to any one, and none ever will be devised which will be satisfactory to every one. Moreover, there seems to be no system which has anything like universal use in America. It is not the intention to give in this paper any new contribution to knowledge on the subject, but to give a brief review of some of the methods devised for classifying and filing, in order that one starting the accumulation of data may profit by the experience of others in this difficult field, and that he may be enabled to select a method which will best suit his purposes.

A good system is one in which manuscript notes, clippings, drawings‡, tracings, blue prints, specifications, photographs, pamphlets, trade catalogs, and all other forms of records of data may be filed so that they can be easily and quickly

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* Note: The following abbreviations are used in the references given in this paper: For the months of the year, Ja, F, Mr, Ap, My, Je, Jy, Ag, S, O, N, D, as used by librarians generally. The reference "Eng. News, 30∠415[23]," should read "Engineering News, Volume 30, page 415, column 2, about three-tenths down the column." This device is convenient in locating a bit of information having no title, but occurring perhaps in an article having a different general subject.

† Engineer's taking notes—its importance. Editorial Eng. News, 30∠415[23]. Use of photography in data collection. R. A. Fessenden, Electrical World. 28∠222.

‡ A method of preparing and preserving records of railway real estate. Arthur Haviland, Eng. News, 48∠353, 0 30, '02.

A method of filing drawings is described in R. R. Gazette, 27∠10-15. (The drawings are bound together in order of completion, without regard to subject, and the volumes are paged and indexed. A card catalog enables one to find any desired drawing.) Indexing and filing machine drawings, J. J. Harman, Eng. News, 57∠151.

found. Some methods, although very convenient for finding data, require such an expenditure of time and labor in filing that they defeat their own purpose of rendering the engineer's library an efficient instrument. If the system is to be used by many persons it must be so arranged that the material can not become mixed or lost, and that it may be readily understood by new men in the office. The system should permit of unlimited growth.

There are two general methods of filing records; first, simply to put away the material in convenient receptacles in order of receipt, indexing the material as it is filed; second, to classify the material by some system, keeping all material on a given subject together.

If the first method* is used, the index, preferably a card catalog, may be arranged as a dictionary catalog† or the cards may be grouped into classes. A dictionary catalog, such as used in libraries generally, is very convenient, but involves a stupendous amount of labor in making out the cards. In addition to the labor of filling out cards for every article filed this system has the great disavantage of having the material scattered. In order to look up a given subject it may be necessary to take down and remove a paper from each filing case and then replace them when through.

In the second method the material itself is grouped in classes which are arranged in a logical order of sequence, and data on a given subject may therefore be found by reference to the general classification scheme, with indexes or catalogs.

There are several systems of classification, most of them devised by librarians. There are general classifications embracing all branches of knowledge, such as the Dewey system and the Cutter system, and special classifications for

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* See Trans. Am. Soc. Mech. Engrs. 16∠610. (Uses 7 sizes of filing cases, sorting out the material according to the size and filling one case of each size at a time. Uses card index.)

† See Rules for a Dictionary Catalog, by C. A. Cutter, Special Report U. S. Bureau of Education.

special branches of knowledge such as those adopted in the libraries of the great engineering societies.*

The labor and cost of divising a consistent and logical classification is vastly beyond the dreams of one never having attempted it. It should have a properly titled place for every subject in which its possessor may be interested and each should be preceded and followed by the most nearly allied subjects, but this aim must sometimes be made to yield to practical usefulness. The uniform and urgent advice of the experienced is to adopt a poorer scheme already made rather than undertake so Herculean a labor as to attempt to devise a new one.

The first treatise on the subject of classification seems to have been Mr. Melvil Dewey's Decimal Classification and Relative Index.† It was developed chiefly in the interests of library economy.

By this system all knowledge is arbitrarily divided into nine groups which are arranged in as logical an order as possible. A tenth division is left for matter too general to go into any of the others. The main divisions with their numbers are

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* A classification and catalog system for an engineering library. F. R. Hutton, Trans. Am. Soc. Mech. Eng. 17/423. (Contains the classification used in the library of the Am. Soc. Mech. Engrs. Other systems are given in the discussion of this paper.)

See also the classification used in the Library of the Am. Soc. of Civil Engrs. as given in their Library Catalog.

† A copy of this book giving the complete system may be seen at the cataloging rooms of most libraries. A general engineering classification and index, W. L. Chase. Trans. Am. Soc. Mech. Engrs. 14/780. (Gives an extension of the Dewey System for the headings Steam Engineering, Hydraulic Engineering, Heat, Air, Gas, and Oil Engineeeing.) An extension of the Dewey Decimal Classification applied to Mechanical Engineering and Railway Engineering. Published by the Mechanical Engineering Department of the University of Illinois. A plan for the classification of military books on the Decimal System. Edward S. Holden, West Point, N. Y., U. S. M. A. Press 1905, 48 p. 8°. (Has been tested at West Point 12 months and adopted.) Decimal Classification of Institut International de Bibliographie. Fasc. No. 31: Division (62) Sciences d 18 ingenieur. Bruxelles, Institut Internat. de Bibliographie.

000	General	500	Natural Science
100	Philosophy	600	Useful Arts
200	Religion	700	Fine Arts
300	Sociology	800	Literature
400	Philology	900	History

Each of these groups is subdivided into nine others, for example, "Useful Arts" is composed of

600 Useful Arts—General Matter:

610	Medicine	660	Chemical Technology
620	Engineering	670	Manufactures
630	Agriculture	680	Mechanic Trades
640	Domestic Economy	690	Building.
650	Communication and Commerce		

Each of these groups can be again subdivided and so on indefinitely. For instance, if it is desired to file an article on the cost of transportation of freight, we would think over the nine main divisions and decide whether it belonged under Sociology or under Useful Arts, according to the method by which the subject was treated. Deciding on the latter and looking over the list of Useful Arts we would place the article under 650—Communication and commerce. Classifying further would lead to 656.0 Transportation, further 656.2 Transportation by railways, 656.23 Railway traffic and rates, and finally, 656.232 Cost of transportation. In hunting for an article the same analysis of its subject is gone through, leading finally to the place where all material on that subject may be found. In some instances it will be necessary to look in two places to get all information on a subject. To illustrate, suppose the design of a conduit is to be undertaken. The engineer would find information relating to the flow of water in conduits under

500 Science	(510....		
	(520....		
	(530 Physics	(531	
	(540. ..	(532 Hydraulics	(531.1
		(533	(531.2
			(531.3
			(531.4
			(531.5 Flow in Conduits

and information relating to the design and construction of conduits under

600 Useful Arts (610
(620 Engineering (
(628. Sanitary Eng.
(628.1 Water Supply

Nearly all engineering, which is applied science, is based directly upon a pure science and many books and data relating to engineering are really treatises in the other field as well. Fault is therefore sometimes found with the Dewey system on account of the difficulty of separating pure science from applied science, but there is no necessity for confusion. Where science, apparently pure, is directly applied to the design or construction of apparatus or structures, the material should be filed under applied science. One would naturally look under both headings for a subject which was on the line between.

The system allows each to use minute subdivisions where he wishes or needs them, without being forced into refinements in subjects where he has few records to preserve or little interest. No new place for a subject ever has to be learned. When a place in the collection gets too crowded, it costs only pure manual labor to move it along and provide for indefinite expansion at any point. When a new subject comes up, its classification mark is established beside related subjects, or as an extended decimal of the subject of which it is a natural off-shoot.

The numbers appear formidable, but it is not necessary to use them much under ordinary conditions. When a new subject comes up it is only necessary to number a cover of some sort and drop into it all articles that may be found on that subject, not necessarily numbering each article. Where most of the material falls under one head, e. g., Engineering, the first two figures might be left off. Under such a method 1.3 would mean 621.3 electrical engineering, or a letter may be used as E-3.

In some systems an attempt is made to keep together all material on the same subject, though treated from different standpoints. This is an advantage, but is not completely possible in a system embracing the whole range of knowledge.

In connection with his classification scheme Mr. Dewey publishes a "Relative Subject Index," arranged alphabetically and embracing some 20,000 subjects, so that one attempting to file an article on a subject with which he is not conversant may find it in the alphabetical list which will refer to its proper class number. But this feature, though very useful to library catalogers, is not essential to a specialist, for in his own line of work there will be no difficulty in his deciding the proper place for an article, and in other lines he is not likely to have a great deal of matter, and there is hence no necessity for minute subdivision there. In any line there is no necessity of having a minute classification until a large amount of material is accumulated. The subdivision can be made gradually. When a certain subject is referred to, and it is found that considerable material has been accumulated on that subject, it should not be returned to the general group from which it was taken, but a new subdivision may then be started. In general, except for special purposes, the collection need only be divided into groups of such size that any individual item may readily be found in its group. This limits the number of items which should be included in any one group, and the larger the collection the more minute must be the classification.

The Dewey system has many opponents. The arrangement of the divisions of engineering is unfortunate, and a logical arrangement is, in some cases, prevented by the fact that the number of possible subdivisions in any group is limited to ten. Increasing the number of subdivisions precludes the possibility of using the simple Arabic numerals. The Cutter system, used largely in libraries, adopts the alphabetical system, which allows twenty-six subdivisions. It has some advantages over the Dewey system, but is not generally considered entirely satisfactory in engineering branches.

The Dewey system has been described in detail because it is the one which has been used for some years by the writer, and with which he is therefore most familiar, and also because in some engineering lines it has been extended to minute subdivisions by specialists.

The mechanical details of filing systems are as varied as the classification schemes.

Where many persons are to use files, small clippings, etc., may be pasted to sheets of uniform size, which can be fastened into uniform covers by McGill's fasteners, adding sheets as they accumulate and assigning one cover to each subdivision of the classification scheme. Some engineers cut up all their engineering papers and society publications and bind each article with others of its class. This method is extremely convenient for reference, and there is little chance of losing articles when the volumes are taken away from the library, but considerable expense is involved in the clipping and pasting, and often where two desirable articles on different subjects occur on opposite sides of a sheet one page must be typewritten.

It would be a great convenience if the editors of magazines and society publications containing the longer articles would always commence articles on the right-hand page and have at the top or bottom of each page on which an article commences the name and number or date of the magazine. It would not occasion more than three or four blank pages at most in any magazine and these might be used for matter of only temporary interest.

By far the greater number of engineers file the records loosely in special boxes, envelopes, standard pamphlet cases, or letter files of either the horizontal or vertical system. A saving of space is effected by having different sizes of boxes and sorting the material according to size, but it amounts in effect to having as many different libraries, each one of which must be consulted for information. The cases should be convenient in size to fit all likely clippings without excessive folding, and should be dust-proof.

As a simple and inexpensive method to start with and one which will not involve any loss if it is afterward decided to adopt a pasting scheme, the writer would suggest the purchase of, say, one-half dozen pasteboard transfer cases of the vertical letter file size and style, with, say, 300 folders. Decide on some classification scheme and write on the upper left hand corner of the folders the numbers or symbols, and on the right corner the subjects of the subdivisions which are of interest, and on which it is expected material will be accumulated. The numbers or class symbols will be of use mainly in readily returning a folder to its place after having it out for use. There will be some blank folders left over which can be used for expanding the system later. Ordinarily an engineer's library is so meagre that all books can be remembered by the owner, and by simply keeping books of similar nature together on the shelves they can readily be found without a formal cataloging. Pamphlets thick enough to stand might have a number or class symbol written on the upper left corner and be arranged in systematic order on the shelves, either with the books or, since they are unsightly, in a separate library obscured from view. Thin pamphlets and everythlng else except large drawings can be dropped

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Additional references are:

Discussion of filing systems. Trans. Am. Soc. Mech. Engrs., 16/610. Illustrated.

Filing systems for engineers' offices. R. R. Gaz., 27/9.

An engineer's private note book. J. H. Gregory, Eng. Rec., 42/350.

Preservation of clippings. Eng. Rec., 39/159; 39/265.

The best form of scrap cabinet. T. S. Miller, Eng. News, 23/105.

Office organization and equipment. Eng. Rec., 27/4, D 3, '92.

International catalogue of scientific literature. Royal Soc. of London. Does not include applied science.

Manual of Library Classification. J. D. Brown.

Decimal catalog of books in the Carnegie Library of Pittsburg in the classes of Useful Arts and Natural Sciences. 50c. postpaid.

Special rules on cataloging, to supplement A. L. A. rules. Library of Congress. (Library of Congress is preparing a very complete classification, using both letters and numerals. The Engineering Classification is not yet published. The Outline Scheme of Classification and Class Q, "Science" are available.)

into their proper folders in the vertical cases, numbering each article or not, according to the conditions of use. Generally it is not necessary. If it does not seem desirable to cut up periodicals, the more important articles can be indexed and the index cards be dropped into the general file. Later, if it seems desirable, more expensive filing cases can be procured to match the other office furniture.

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EDITORIALS.

At the time of going to press the members of the Junior Class of the College of Engineering are away on the annual inspection trip. As will be remembered, the faculty decided a year ago to make this trip compulsory, and set the time for the week preceeding the Easter vacation. There are two trips which may be taken, one to Niagara Falls, Buffalo, Dunkirk, Pittsburg and the surrounding country, and the other to Milwaukee and Chicago.

Those going on the Eastern trip, about ninety in number, left Madison, Friday, March 22d, and arrived in Niagara Falls, Saturday morning. This part of the trip was enlivened by their train running into an open switch, throwing several cars off the track, but luckily no one was injured. Saturday and Sunday were spent at Niagara Falls, inspecting the water power installations on both sides of the falls and sight-seeing. Monday was spent at Buffalo and Tuesday at the Brooks Locomotive Works, at Dunkirk, N. Y. Wednesday, Thursday and Friday were spent at Pittsburg, visiting the Westinghouse plants, the Nernst Light Works, the Pittsburg Water Works, American Bridge Co., Union Switch and Signal Co.'s plant, etc. The party left Pittsburg, Friday night, arriving in Chicago, Saturday, A. M., when they disbanded. Profs. M. C. Beebe and H. J. Thorkelson were in charge of this trip, and were assisted by Messrs. J. W. Watson, J. H. Vosskuehler, E. A. Loew, W. S. Kinne, and F. M. McCullough.

Those on the western trip left Madison Monday A. M., March 25th, and spent that day and Tuesday in Milwaukee. At this city the C., M. & St. P. car shops were visited; also the Commerce St. station of T. M. E. R. & L. Co., Allis-Chalmers plant, Bucyrus Steam Shovel Works and others. Wednesday, Thursday and Friday were spent in Chicago, visiting the Western Electric Co.'s plants, the Illinois Steel Co., the Fiske St. station of the Commonwealth Electric Co.; also some substation, a pumping station and other engineering works.

Messrs. J. C. Potter, M. O. Withey and R. McA. Keown were in charge of this party.

On Friday, March 8th, the faculty and students of the College of Engineering had the pleasure of listening to a talk by Mr. Arthur D. Wheeler, President of the Chicago Telephone Co., on the subject, "The Relations of Common Utility Corporations to the Community." Mr. Wheeler said that his subject was so broad that he would endeavor to limit his discussion to one phase of it, namely, "The Opportunities and Duties of the Representatives of Common Service Corporations."

Mr. Wheeler first discussed common service corporations in general, and then took up the work of a large telephone company. He was of the opinion that a corporation is the only organization which could economically conduct such vast enterprises as the one with which he is connected. It was not because the organization was a corporation that various conditions seemed unjust and unfair to the outsiders. The corporation is merely one way to centralize business interests; it is not a thing apart, but is simply what the employes and stockholders are—is what they make it. Power is bestowed upon the corporation by the people, and may be withdrawn at any time.

In a great measure, it is for the employees to decide whether the corporation is to be classed among the good or the bad. If the employee uses every opportunity to do right, and is faithful to his duties, and if the stockholders do their part, there is no reason why the corporation should be classed as bad. If the employees have the qualities necessary for an all round man, those of concentration, promptness, honesty, tact and courtesy, there should be no occasion for criticism of the corporation.

Mr. Wheeler closed by saying that a great many of the troubles of the corporations are due to the false statements printed by the sensational newspapers; from the standpoint of ethics, the newspapers should be held responsible for many of the conditions for which they blame the corporations.

The Association of Civil Engineers at Cornell have just published the first number of *The Cornell Civil Engineer*, a monthly journal edited by a board selected from the student members of the association. For fourteen years the Transactions of the Cornell Association of Civil Engineers have been published yearly, and it is now the intention of the association to publish the transactions of their meetings in the *Civil Engineer.* This issue contains several good articles on various phases of Civil Engineering, besides considerable information about the Cornell University and the alumni of the College of Civil Engineering, which would be of more interest to the latter than any one else.

THE ENGINEER extends congratulations to the Association of Civil Engineers for the good impression made by their first issue, and best wishes for continued success.

On Friday, March 1st, Mr. Chas. C. Brown, consulting engineer, of Indianapolis, Ind., spoke to the faculty and students of the College of Engineering on the subject, "Some Relations of Stream Pollution and Water Purification." Mr. Brown has had much experience in the work of planning water works systems and has studied the question of stream pollution thoroughly, so he was well prepared to give a most interesting talk on this subject. The discourse could be divided into two main parts, a description of conditions causing stream pollution and the results of these conditions, and a discussion of laws relating to stream pollution already in force in the various states. Suggestions were made by which the laws already passed could be much improved. Mr. Brown's article will be published in full in a later number of THE ENGINEER, and is well worth the attention of any one who was so unfortunate as to miss the lecture when given.

At the semi-annual election of Tau Beta Pi the following men of the class of '08 were elected to membership: O. O. Kuentz, M. E., Milwaukee; A. H. Pitz, C. E., Manitowoc; L. H. Huntley, C. E., Neillsville; R. C. Disque, E. E., Burlington, Iowa; M. D. Cooper, E. E., Black River Falls; J. O. Reed, C. E., Madison; E. P. Abbott, C. E., Madison; G. W. Van Derzee, E. E., Milwaukee; J. H. Thickens, Ch. E., Appleton; H. J. Knelling, C. E., Shullsburg.

These men were initiated into the fraterity March 14th, and were given a house-warming at the fraternity parlors on the evening of March 20th.

ALUMNI NEWS.

Earl E. Hunner, '00, Assistant Engineer of the Oliver Iron Mining Co., visited Madison several weeks ago. Mr. Hunner has had an extensive mining training, and thinks mining is a great field for engineers. He thought a trip into the mining country of Minnesota would to some be as valuable as the Eastern trip is to others, and advised that students interested in mining take such a trip with the Geological students, who go up into that country every year.

There are at work at present on the Valuation Staff of the Milwaukee Street Railway Co., under the direction of Prof. W. D. Pence, twenty-three men, of which nine are either alumni or former students of the University of Wisconsin. Mr. Sarso, '04, is Assistant Engineer and Chief Roadway Inspector. W. F. Sloan, '04, is Field Electrical Inspector. A. C. Olson, '02; E. M. Straight, '06; E. S. Brown, ex-'06; F. L. Anders and C. L. Eustace are Assistant Field Inspectors.

Prof. H. J. Thorkelson, '98, and L. D. Williams, '01, are office assistants.

W. R. Mott, '03, stopped in Madison a few days, while en route from Niagara Falls to his home in Decorah, Iowa.

O. O. Wagle, '05, has given up his position in Valley City, N. D., and is now employed in Chicago. At present he is conducting some experiments for D. C. Jackson at the University.

F. H. Mann, '05, in the employ of G. N. R. R. in British Columbia, recently spent several days in Madison.

W. A. Rowe, '04, has accepted a position with a Mining Company in the Black Hills.

Sherman Moore, '02, on the Great Lakes Survey, is doing some valuable research work on "Twist in Triangulation Stations."

W. G. Kirchoffer, '97, Consultiug Engineer, Madison, Wis., is installing water works at Port Washington, Alma Center and West Bend, and is building a sewer system at Waupaca, Wis.

There are several corrections to be made to the alumni directory as published in our last issue. The corrected addresses are given below.

Biegler, P. S., B. S. E. E., '05, Iowa City, Iowa, Instructor in Electrical Engineering, Iowa State University.

Blood, F. H., B. S. E. E., '05, Schenectady, N. Y., General Electric Co.

Burkholder, C. J., B. S. E. E., '96, Charlotte, N. C., Southern Power Co.

Calvin, C. J., B. S. E. E., '06, Iron Mountain, Minn., Oliver Iron Mining Co.

Crumpton, W. J., B. S. E. E., '04, Madison, Wis., with D. C. & W. B. Jackson.

De Lay, F. A., B. S. E. E., '02, Ann Arbor, Mich., Instructor, University of Michigan.

Ehreke, G. W. R., B. S. E. E., '02, Chicago, Ill., Chicago Street Railway Co.

Frost, D. K., B. S. E. E., '04, Schenectady, N. Y., General Electric Co.

Gibson, W. J., B. S. M. E., '02, Madison, Wis., Northern Electric Co.

Hancock, E. H., B. S. C. E., '98, La Fayette, Ind., Asst. Professor of Applied Mechanics, Purdue University.

Inbusch, W. H., B. S. E. E., '05, Los Angeles, Cal., Pacific Telegraph & Telephone Co., Engineering Dept.

Krippner, A. T., B. S. E. E., '04, St. Louis, Mo., Kinlock Telephone Co.

Mann, F. H., B. S. C. E., '05, Princeton, B. C., Assistant Engineer of Construction, Great Northern Railway.

Moritz, E. A., B. S. C. E., '04; C. E., '05, Chicago, Ill., Bridge Dept., C., M. & St. P. Ry.

Mott, W. R., B. S. E. E., '03, Decorah, Iowa.

Reed, C. S., B. S. M. E., '05, Richmond, Va., American Locomotive Works.

Vinson, A. W., B. S. M. E., '05, Milwaukee, Wis., Cutler-Hammer Clutch Co.

Willison, C. D., B. S. E. E., '05, Chicago, Ill., Electrical Service Supplies Co.

On February 14th, at the Hotel Pfister, occurred the marriage of Miss Clara Stillman and Rudolph B. Hartman, '02, both of Milwaukee. Mr. and Mrs. Hartman are at present on a wedding trip, including the West Indies, Panama and California, and will be at home to their friends after April 1st at the groom's home, on West Clybourn St., Milwaukee.

Miss Mary Carr and Mr. J. P. Burns, '04, of Watertown, N. Y., were united in marriage February 12th. They will reside in Watertown, where Mr. Burns is employed as a draftsman with the Erie Canal Improvement Co.

The engagement of Miss Lucy M. Lewis, of Manitowoc, and Mr. Willis Whitby, '04, of Chilton, Wis., has been announced.

Edw. Wray, '05, has gone to Porto Rico, where J. G. White & Co. are engaged in installing a large dam and electric power plant, and in building thirty miles of electric railroad.

BOOK REVIEW.

The Steam Engine and Other Heat Motors, by W. H. P. Creighton. John Wiley & Sons, 1907. 8vo. Cloth, illustrated, $5.00.

This book was written primarily as a text-book, to be used by undergraduate students of college grade. It takes up the subject of the steam engine in a way different from many other text-books, and the author's idea seems to be to make the work attractive as well as instructive.

The first chapter reviews the elementary principles and gives a general view of the steam engine plant. The next two chapters treat of the indicator and the curves of work and expansion. Next follows a chapter on valve diagrams and plain slide-valve design. The design is treated both from the theoretical and practical standpoint. The following four chapters are devoted to the subject of heat and entropy; the processes of measuring the effects of heat are treated first in a general way, and later in the specific cases of water and steam, also the measurement of heat losses; the treatment of entropy is full and complete. Two chapters are devoted to the auxiliaries, and two to engine control, including both revolution control and speed variation control. The chapter on multiple expansion engines is very complete. A new method of drawing compound engine indicator cards direct from round numbers is introduced, which simplifies this process greatly. The chapter on the results of steam engine tests gives a good criterion by which to judge the performance of an engine. Superheated steam and steam turbines are then discussed, and a full discussion of the theory and practice of gas engine and gas-producer operation, and of refrigeration, are given. The appendix is given up to the various tables which would be useful in making any calculations pertaining to the design and operation of heat engines.

There are many illustrations which serve to make the subject matter clear.

In this book the author has given a valuable addition to the text-books on the steam engine; he introduces new methods of presenting the subject and gives to others the results of his years of practical experience, both as operator and teacher.

Modern Steam Engineering, by Gardner D. Hiscox, M. E. The Norman W. Henley Publishing Co. 1906. Cloth, Illustrated, $3.00.

This is a simple, instructive and up-to-date book on stationary engineering, written for engineers and firemen engaged in such work. It contains a practical discussion of the care and management of boilers, engines, pumps, refrigerating machinery, elevators, and air compressors. There are also four chapters by Newton Harrison which deal with the construction and operation of generators and motors.

In connection with each part is a set of questions, with answers, such as are likely to be asked by Examining Boards,

This book will prove to be of great value to those who have a practical knowledge of the machines above mentioned, but who would be unable to follow through the complex mathematical discussions of the text-books in use in our schools. The mathematics in this book does not go beyond the simplest arithmetical substitutions in the formulae given. Any man with an ordinary common school education and a fair understanding of logarithms could handle all the mathematics.

The steam tables and others are not carried out as many places as would be necessary for use in design, but are accurate enough for the purpose for which they are intended.

The discussions of the various types of engines and turbines, and of valves and valve-gears, are very simple, yet complete.

The electrical section gives a very simple discussion of electric generators and motors, switch-board work and storage batteries, and electric lighting.

This book contains nothing new; there is simply a rearrangement of material and a change in language to suit the class for which it was written. For this purpose it is a most excellent work.

A Tale of Two Types. This is the title of a booklet sent out by the Cutler-Hammer Manufacturing Co., describing in detail, and giving a comparison of, the ventilated and enclosed types of resistances for use as starting boxes. This company manufactures both kinds, and have studied the question thoroughly. The pamphlet gives the underwriters' rules relating to the installation and construction of rheostats at present in force, and also the final draft of proposed amendments to these rules. These amendments declare against the ventilated type of resistances, in spite of the fact that four manufacturers out of five recommend it as best suited for general purposes.

Those interested in this matter would do well to procure a copy of this booklet.