

made it a habit of his life to go out two hours before he went to bed, no matter whether the evening was pleasant or stormy. This practice kept his brain active, because it secured refreshing sleep. William Cullen Bryant, the poet, the literary man, and the editor, for forty years before his death took systematic and vigorous exercise every day of his life. He took exercise the first thing on arising in the morning, and the last thing before going to bed. He walked from eight to ten miles daily, never using street cars, coaches, or elevators, so as to get the benefits and blessings of work. Too many persons do not have the resolution to do this.

METHOD OF ASCERTAINING BY MEANS OF A DYNAMOMETER CAR THE POWER REQUIRED TO OPERATE THE TRAINS OF THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD BETWEEN MOTT HAVEN JUNCTION AND GRAND CENTRAL STATION, AND THE RELATIVE COST OF OPERATION BY STEAM AND ELECTRICITY.*

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In August, 1901, the writer was commissioned by the New York Central Railroad Company to study the con-

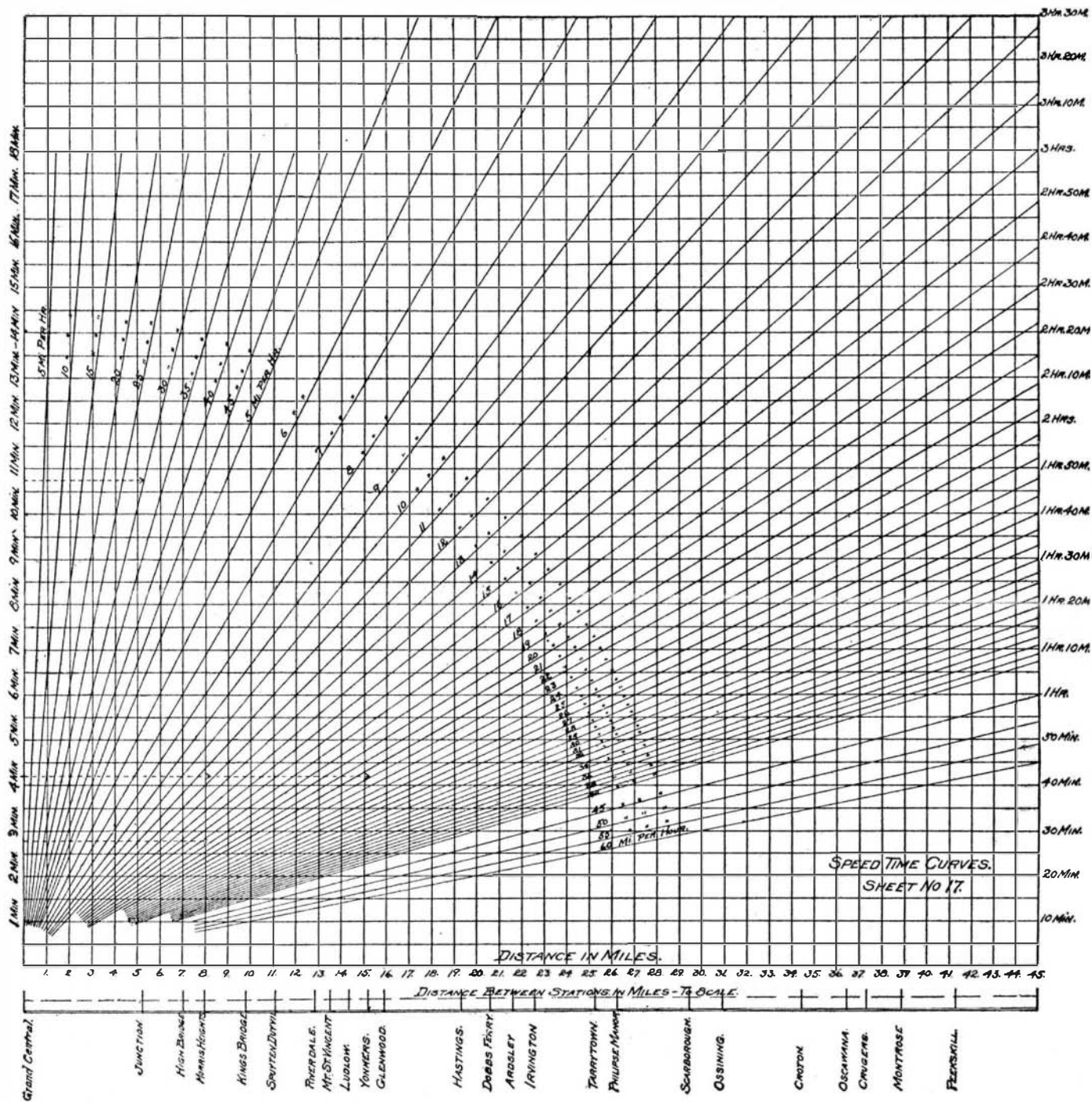
All money values relating to total cost of installation, real estate, etc., and many other elements upon which the final recommendations of the report were based, together with many of the general recommendations and conclusions themselves, are necessarily omitted from this paper, but it is believed that the data given is sufficiently complete to enable one to check the technical conclusions herein given.

Soon after taking up the work it became evident, on account of the number and weights of the trains to be handled and the numerous variable elements entering into the operating system, which would not adapt themselves conveniently to formulae, that the most practical and satisfactory way of ascertaining the power required to propel the trains was to measure, by means of a dynamometer car, the "draw-bar pull" of a sufficient number of trains of various weights, to determine the average power required per train and from this compute the general load diagram.

A dynamometer car known as "Test Car No. 17," owned jointly by the Illinois Central Railway Company and the University of Illinois, was secured, and men thoroughly skilled in its use were employed to operate it. This car was coupled between the engine and the train in each case, and operated on trains running over the different divisions of the road, so that not less than four runs, two or more in each direction, were made for each class of train. Since the

ings held together by stud bolts. The effective area of the largest cylinder is 60 square inches, of the intermediate cylinder 30 square inches, and of the smallest 5 square inches. It is intended that the working pressure of the oil in the cylinder shall be from 300 to 1,000 pounds, per square inch, and for this range of pressure the largest cylinder has sufficient capacity for the heaviest freight service, the intermediate cylinder would be used when working with a train of ordinary tonnage, and the smallest cylinder when working with a train of light tonnage. If it should become necessary all the cylinders could be coupled up in multiple, thus giving an effective piston area of 95 square inches.

The cylinders are reamed and the pistons and piston rods ground. The forward end of the gland is ground spherical and fits into spherically ground seat in the stuffing box casting. This spherical seat is used to permit the three sleeves to align themselves properly on the rod. The pressure of the oil keeps the gland on its seat and this oil pressure is supplemented by the pressure of several helical springs placed between the rear end of the sleeve and the plate at the inner end of the stuffing box. The pistons will gradually move forward on account of leakage, but so slowly that the cylinders can be refilled from the pump at stops, or if necessary, when the cylinders are under pressure. This design was resorted to in order to



ing eleven cars in length—no correction was made for head end air resistance.

The successive steps were as follows:

(1) In order to determine the average draw-bar pull for any given period, the entire area under the dynamometer pen record was found by a planimeter and divided by the length of base of the interval from start to stop, the result being the average draw-bar pull.

(2) From passenger records taken during dynamometer tests, a curve was plotted, showing the ratio of the weight of the live load to the light weight of the train.

(3) Dividing the average pull in pounds by the total weight of the train, the average pound per ton draw-bar pull over the run under consideration was obtained.

The average pounds per ton draw-bar pull (not tractive effort) for various lengths of run over the Mott Haven division were also plotted.

The number of variables entering into values obtained, such for example as the degree of skill of the engineer, the wind velocity, the condition of the track, agreement with schedule time, etc., make it impossible for any curve to pass through all its points and therefore, as above stated, these curves can only be taken as

the average speed at which this draw-bar pull was exerted, the horse power at the draw-bar becomes:

$$\begin{aligned} \text{H. P.} &= \text{foot pounds per minute} / 33,000 \\ &= \text{draw bar pull} \times \text{miles per hour} \times 5,280 / 33,000 \\ &\quad \times 60 \\ &= \text{draw bar pull} \times \text{miles per hour} / 375. \end{aligned}$$

This formula is represented graphically in Fig. 18, from which, knowing the draw-bar pull and speed, the horse power or kilowatts corresponding thereto is determined. Thus, for example, if the draw-bar pull is 4,300 pounds, at a speed of 36 miles per hour, to find the horse power or kilowatts corresponding thereto. At 4300 pounds, on the ordinate at the left of the figure, follow the dotted line to the right until it intersects the required speed curve, thence downward to the base line thus obtaining 410 horse power. If the efficiency of the motor is taken at 70 per cent, by following the ordinate at 410 horse power vertically to the 70 per cent curve and thence to the left, the kilowatt capacity required is found to be 440 kilowatts, which is the power required to propel the train, exclusive of the locomotive and head-end resistance.

METHOD OF OBTAINING DAILY LOAD DIAGRAM.

From a careful examination of the weights of all locomotives now in service on this division, it was

switching service, the ton-miles per year were found to be 250,285,710. Hence, the electrical energy required to haul a ton one mile over this division under the existing conditions would be

$$15,768,000,000 / 250,285,710 = 63 \text{ watt hours per ton mile.}$$

With this figure as a basis and the load factor as determined from the load diagram, the problem of determining the best method of producing, distributing and applying the power was considered.

CHOICE OF SYSTEM.

While it is the writer's opinion that the alternating current railway motor will yet prove to be the most efficient, all things considered, for long-distance railway work, it has not yet in his opinion demonstrated its ability to start under load as efficiently or to accelerate a train as rapidly as the direct current motor. The line under immediate consideration was short, the trains numerous and rapid acceleration desirable, all of which are conditions favorable to the direct current motor.

Furthermore, direct current motors with their necessary auxiliaries have become fairly well standardized and it is the only class of electric railway apparatus available from the manufacturers of the United States

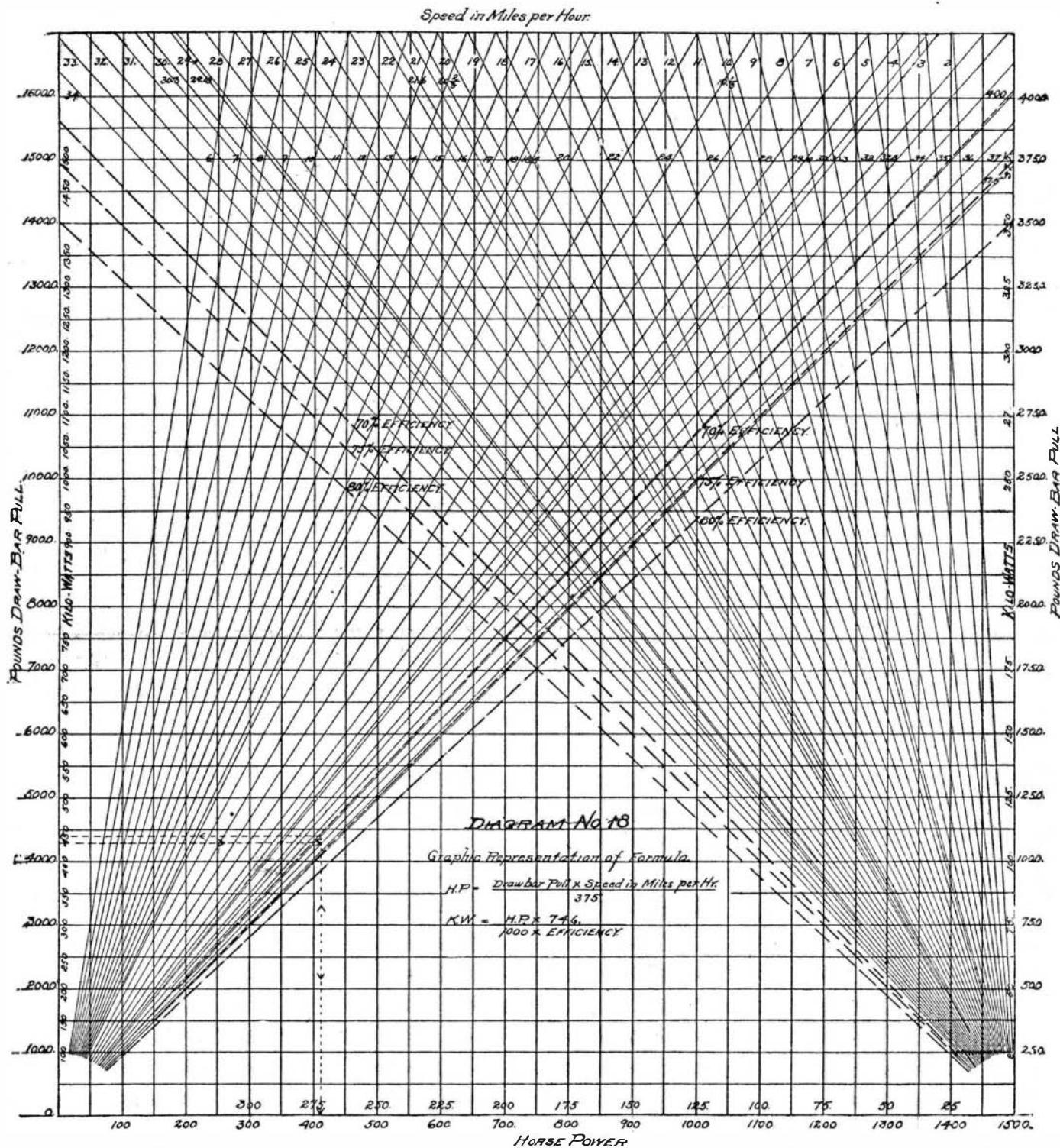


FIG. 18.—DESCRIPTIVE DIAGRAM OF DRAW-BAR PULL IN HORSE POWER AND KILOWATTS.

indicating the average value of a widely varying quantity.

(4) Fig. 17 shows a graphical method of obtaining the speed in miles per hour between any two stations when the time of run between these two stations is given. If the lower strip of this diagram be cut off along the dotted line and placed horizontally at the left with any station on the ordinate at the given time, the intersection of any other station with an oblique line gives the average speed between these stations.

For example, if the run from the Grand Central Station to Yonkers is made in 42 minutes, by placing "Grand Central Station" on the ordinate at the left at 42 minutes and running horizontally along the strip to "Yonkers," the oblique line here intersected shows the average speed to be 22 miles per hour; in the same manner, if the run from Grand Central Station to Mott Haven Junction is made in 10½ minutes, the average speed is thirty miles per hour. Again, by placing "Spuyten Duyvil" on the ordinate at the left at 28 minutes, and following horizontally to "Hastings," the average speed between these two stations is seen to be 18 miles per hour.

(5) The weight of every train arriving or leaving the Grand Central Station on a given day was obtained, and its average speed between stops determined from the above curves. Knowing, therefore, the average draw-bar pull in pounds required to haul a train, and

found that properly powered electric locomotives having a total weight of 65 tons each, all of which would be available for tractive effort, could satisfactorily perform the service of existing steam locomotives.

This horse power was obtained in the same manner as that required to haul the train, and was plotted separately on the train sheets; evidently, the friction of an electric locomotive in pounds per ton is greater than an equivalent weight of train, but this difference was considered in selecting the proper locomotive efficiency.

The average horse power when converted into kilowatts by means of the following formula (which is exhibited graphically in Fig. 18):

$$\text{k.w.} = \text{h.p.} \times 746 / 1,000 \text{ per cent} \times 1,000$$

where 1,000 watts = 1 k.w.

$$746 \text{ watts} = 1 \text{ electrical h.p.}$$

and 70 per cent = efficiency of locomotives gives the average kilowatt input required at contact shoes of electric locomotives for the period covered by each sheet.

In another instance it is shown that the daily average input required would be at the rate of 1,800 kilowatts and, therefore, the total annual input required at the contact shoes of the locomotives, for propulsion alone, would be $1,800 \times 24 \times 365 = 15,768,000$ kilowatt hours. From the total number of tons hauled yearly over this division, including passenger, shop trains and

without involving experimental work and large development expense.

In view of these facts and the probable necessity for rapid construction, the writer refrained from advising anything of an experimental nature and, therefore, recommended the direct current system in combination with the third rail for the main line, and the overhead construction for the yards, all of which have demonstrated fully their ability to meet the conditions imposed by railway operation so far as motive power is concerned, although there has not yet been an electric installation on any existing terminal that is as complex, or into which anywhere near the number of heavy trains enter as on this section of road.

Had the length of road under consideration been considerably greater, and had it been thought possible to secure sufficient time to conduct experiments or invite demonstrations by manufacturers of alternating current motor equipment, this class of apparatus would have been more seriously considered.

DISCUSSIONS AND ANALYSIS OF PLANS AND ESTIMATES.

In the preparation of estimates, twelve distinct plans of generation and distribution were considered and the results tabulated as shown in Table 4. All the estimates were computed upon the same basis so far as cost of fuel, labor and losses in transmission were concerned. The different headings in the table

TABLE IV.—Table of Estimates on Plans for Proposed Electrical Equipment of the N. Y. C. & H. R. R. R. Between Grand Central Station and Mott Haven Junction.

Plan	CHARACTER OF STATIONS ETC.	Operating Expenses					
		$H = \frac{E}{T}$ Total k.w. hours at power house	$M = \frac{F}{T}$ Total k.w. hours at contact shoe	$N = \frac{G}{T}$ Total k.w. hrs. at motor terminals	$J = \frac{B}{T}$	$K = \frac{C}{T}$	$L = (J+K)$
1.	Direct current power station at center of line and contiguous to tracks. 600 volt working conductor, no batteries	.447c	.60c	1.06c	14.02c	6.58c	20.60c
2.	Same as No. 1, with batteries in power house	.472	.66	1.137	14.65	6.71	21.36
3.	Same as No. 1, with battery substation near Grand Central Station and Mott Haven Junction	.475	.668	1.20	14.7	7.25	21.95
4.	Alternating current power station on river front near center of line, with rotary converter substations near each end of line. 11,000 volt A. C. and 600 volt D. C.	.572	.715	1.287	15.2	7.58	22.78
5.	Combined D. C. and A. C. Power station at Harlem River near one end of line and one rotary converter substation near the other end of line. 11,000 volt A. C., 600 volt D. C., no batteries	.570	.666	1.19	14.7	7.18	21.88
6.	Direct current feeders from Manhattan Railway substation located near center of line. Transmission from substation to working conductor, 600 volts D. C. energy to be purchased	2.5	.650	2.748	34.64	2.89	37.53
7.	Rotary converter substation at center of line. A. C. energy to be purchased from Manhattan Substation and transmitted at 11,000 volts. Energy to cost 1 cent less per k.w. hour than D. C. energy delivered	2.5	2.336	2.508	31.50	4.23	35.73
8.	Two rotary converter substations, one near each end of line. A. C. current to be purchased from Manhattan substation near center of line.	2.1	2.336	2.504	31.50	3.93	35.43
9.	Combined A. C. and D. C. power station near Harlem River at end of line. One substation near other end, and batteries carried on locomotives charged from working conductor	.519	.629	1.122	16.58	7.76	24.34
10.	One rotary converter substation near center of line, A. C. current purchased from Manhattan substation No. 7, batteries on locomotives charged from working conductor	2.12	2.4	2.502	34.40	4.08	38.48
11.	Direct current feeders from Manhattan substation No. 7, near center of line. Batteries on locomotives charged from working conductors	2.5	2.738	2.742	37.81	2.51	40.32
12.	Combined A. C. and D. C. power station at Harlem River near outer end of line. One substation near other end. Batteries in power station and substation. A. C. transmission 11,000 volts, D. C. conductors 600 volts	.55	.775	1.335	15.80	7.83	23.63

A. C. refers to alternating current.

D. C. refers to direct current.

here shown are deduced from another table not here published, the columns of which were as follows:

Column A.—Total Cost of Entire Installation.—Erected complete, consisting of power house, transmission circuits, feeders, sub-stations, track construction chargeable to electrical equipment, overhead construction and electric locomotives.

Column B.—Total Operating Expenses per Annum.—Including wages in power house and sub-stations and on rolling stock, together with all coal, oil, water, waste, repairs, etc.

Column C.—Fixed Charges per Annum.—Including interest at 4 per cent on total investment, and taxes at 2 per cent on buildings, sites, machinery and electric locomotives.

Column D.—Total Expense per Annum.—Made up of Column B plus Column C.

Column E.—Operating Expenses per Annum at Power House.—Including coal, water, oil, waste, etc., and repairs and wages.

Column F.—Operating Expenses per Annum at Contact Shoe.—Including coal, water, oil, waste, etc., and repairs and wages in power house; oil, waste, repairs and wages in sub-stations; and repairs (labor and material) on transmission lines.

Column G.—Total Expense per Annum Exclusive of Rolling Stock.—Including operating expenses per annum at contact shoe (as in preceding Column F) plus fixed charges as follows: interest at 4 per cent on total investment (less cost of electric locomotives) and taxes at 2 per cent on buildings, sites and machinery.

Column I.—Total Locomotive Miles per Annum.—Determined from information furnished through the Operating Department.

The explanation of the columns in Table 4 is as follows:

Column H is:

Column E (of table not published)

and represents the operating expenses per kilowatt hour at power house switchboard.

Column M is:

Column F (of table not published)

Total k.w. hours delivered to contact shoe, annually, and represents the operating expenses per kilowatt hour at contact shoe.

Column N is:

Column G (of table not published)

Total k.w. hours delivered to motor terminals annually, and represents the total cost per kilowatt hour delivered to motor terminals, exclusive of fixed and operating charges on electric locomotives.

The cost per kilowatt hour at motor terminals differs from the cost per kilowatt hour at the contact shoe only when batteries are carried on the locomotives, in which event the cost per kilowatt hour at the motor terminals is increased over the cost per kilowatt hour at the contact shoe by the cost of energy lost in the batteries.

Column J is:

Column B (of table not published)

and represents the operating expenses per electric locomotive mile. The values in this column are directly comparable with values now obtained in the present steam locomotive service, except that the operating expenses for steam locomotives as shown by the performance sheets of the Motive Power Department do not include any charge for water. From the best information available, the cost for water for the present service on this division is about .987 cent per locomotive mile, which amount added to the present cost as shown on the locomotive performance sheets, gives an amount which should be compared with the values of Column J.

Column K is:

Column C (of table not published)

and represents the fixed charges per electric loco-

motive mile, and is here tabulated merely as a step in obtaining

Column L (which is Column J plus Column K) and represents the total cost per electric locomotive mile.

While the results in Column L of Table 4 indicate that Plan No. 1 was the most advisable one to adopt, it was not seriously considered for the reason that it necessitated locating the power station in a part of the city where its erection would probably have been prohibited by the city authorities, but it was here introduced for comparison as indicative of the economy to be gained by placing the power station at the theoretical center of distribution. The same objections apply to Plans 2 and 3.

Plans 4 and 5 bring out quite clearly the difference in the cost of operation between two sub-stations and one, both plans permitting the location of the power station on the river front.

The difference in favor of Plan 5 is entirely due to the saving in labor of one sub-station.

Plans 6, 7 and 8 were studied with the object of ascertaining whether the purchase, instead of the generation of power, would offer a satisfactory solution of the problem.

The purchase of both D. C. and A. C. energy was considered on the lowest basis that it was thought possible for any existing company to furnish it, and it was found that the D. C. energy would cost the railroad company one-half cent more per kilowatt hour than the A. C. energy, in consequence of the interest, depreciation, maintenance, etc., of the transmission lines, rotary converters and other sub-station apparatus which would have to be furnished by the energy-producing company.

The prohibitive annual cost of these purchasing plans is at once observed by reference to Columns L and M, the plans only meriting consideration as representing a temporary arrangement that might be effected in order to allow rapid installation.

Owing to the more or less complex system of overhead or third rail yard construction made necessary by the nature of the case, and the advantages to be obtained by their elimination in the substitution of locomotives which could, for switching service, be self contained, though normally supplied with energy from the working conductors, a study was made of electric locomotives carrying batteries.

The results of these studies made under several different assumptions are shown under Plans 9, 10 and 11. From Columns L and N it is evident that whatever may be gained by the elimination of the overhead construction is largely offset by the additional cost of operation, although it will be observed that the cost per locomotive mile of Plan 9 compares favorably with the cost of Plan 12.

Plan 12 differed only from Plan 5 in a slight reduction in the capacity of the converting apparatus in the power house and sub-stations and the substitution thereof of two storage batteries (one located in or near the power house and one in the sub-station) each of such capacity that it, together with only a portion of the main station and sub-station machinery, would be capable of taking over the entire load of the line for a short period of time in cases of emergency.

The additional first cost and the slight increase in annual expense (as compared with Plan 5) represented by a reserve station capacity of this nature, was thought to be of secondary importance only, in view of the increased reliability of operation thereby obtained. The increased cost of operation in this plan over that of Plan 5 is due to the fact that the battery maintenance was figured at 10 per cent per annum, which is considerably higher than is ordinarily assumed, and will probably be considered excessive by some.

A battery of this kind would not only serve as a reserve but would prove of considerable value as a regulator of potential along the line, and in addition it would, notwithstanding its inherent losses, tend to reduce the power house operating costs by taking up the excessive load fluctuations of the system and permitting the load upon the engines to be maintained at or near their most efficient working capacity.

It was considered of the utmost importance in an

installation of this magnitude that the number of interruptions of power supply be reduced to a minimum, that no device which could increase the safety and reliability of the plant should be omitted, and that the probability of future extensions of the electrical system should be considered. As best fulfilling the above conditions, therefore, Plan 12 was the one specifically recommended for adoption.

OPERATING EXPENSES.

A careful compilation of all the expenses entering into the operation of the present steam service was made and the following comparative table (Table 5) of relative costs is believed to be correct, assuming that the present locomotives running between Mott Haven Junction and Grand Central Station should be abandoned and the service now performed by them duplicated by electric locomotives operated in accordance with Plan 12. It is assumed that the electric locomotives will be operated by the same class of men as those who now operate the steam locomotives and that they would receive the same rate of pay that they now receive.

This condition is not favorable to electric traction as it is not ordinarily necessary to have two men to operate an electric motor, but in the writer's judgment, it is not advisable to operate a service of this class under such exacting conditions without two men on each locomotive.

If the motor car system should be adopted, as it probably would be were the electrical equipment extended beyond Mott Haven Junction, or if the forward guard or brakeman were allowed to take the place of the second man while passing through the tunnel and yards, a saving equivalent to his wages could thereby be effected.

With two men of the same skill as at present employed on the locomotives, the figures are as follows:

TABLE V.

Steam. Electricity.

Operating expenses per locomotive mile exclusive of fixed charges but including water, labor, cost of cleaning and repairing tunnel, and all other expenses of locomotive operation	23.05	15.80
Fixed charges per locomotive mile assuming that it now requires 40 locomotives to perform the present service and that 33 electric locomotives could perform the same service	1.13	7.83
Total in cents	24.18	23.63

From these figures it appears that while there would be a slight annual saving in operating expenses in favor of electricity, it is not sufficient to warrant its adoption on the grounds of economy in operation alone, although its adoption can be justified on other grounds.

These figures could be made more favorable to electricity were an optimistic view of many of its advantages taken, and the probability is that practical operation will show a somewhat greater gain than here indicated, but it has been deemed best by the writer to maintain a conservative view throughout the entire investigation.

It is, however, safe to conclude that the saving in operation expenses by the electric system would be sufficient to offset the increased fixed charges due to the additional investment made necessary by its adoption.

The dynamometer car was operated by Edward C. Schmidt, Professor of Railway Mechanical Engineering of the University of Illinois. He was assisted by Messrs. J. J. Snodgrass and R. W. Lohmann.

Messrs. B. S. Harrison, Hugh Hazleton, R. W. Lohmann, J. J. Snodgrass, H. A. Strauss, and A. S. Court-right, assisted in the calculations and preparation of the report.

In connection with the investigation, a series of Comparative Acceleration Tests of Steam Locomotives and Electrical Equipment were made at Schenectady, the results of which are set forth in another paper prepared by Mr. W. B. Potter and the writer, which is to be read at this meeting.

ACETYLENE SOLVENTS.

M. Ed. Fouché, of the Compagnie Française de l'Acetylene dissous, has related to the French Physical Society the results of his experiments carried out during the past four years with acetylene, and its various solvents. The result of his researches shows that the best solvent for acetylene is acetone. This substance has a boiling point not less than 133 deg. Fahr., and is an excellent absorbent of the gas, one volume at 59 deg. Fahr. absorbing 24 volumes of acetylene at atmospheric pressure. The specific gravity of the solution is 0.71 at 48 deg. Fahr., that of liquid acetylene being 0.42. The solution has a coefficient of expansion only about one-fifth of that of the liquid acetylene. He found also that the presence of water in the acetone seriously retarded its absorbing power. Therefore, in order to obtain the most satisfactory results it is essential that as pure a solvent as is commercially obtainable should be utilized, and the acetylene should itself be thoroughly dried before passing it into solution. The latter cannot be exploded so long as the pressure of the dissolved gas is less than 140 pounds per square inch, but at double this pressure the whole mass can be detonated. By absorbing the acetylene in a porous medium no apprehension need be entertained of the solution exploding. Neither will it escape except by evaporation, even if the containing vessel be broken. The company with which M. Fouché is connected have adopted as an absorbent a special porous brick having a specific gravity of 0.5 and having 80 per cent of voids, experience with which has proved so satisfactory that the French authorities have, under certain conditions, legalized the manufacture and transport of the solution thus absorbed, in steel cylinders, or bottles, similar to those used for the carriage of compressed gases. The standard sizes have a water capacity equal to .071 cubic feet, .423 cubic feet and 3.53