DANVILLE - TERRE HAUTE INTERURBAN RAILWAY

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PROPOSED DANVILLE - TERRE HAUTE INTERURBAN RAILWAY.

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PREFACE.

The work contained herein is entirely of a preliminary nature. It is intended to determine only those engineering features, which have a direct bearing on the economic construction and operation of the proposed road. To fix upon the final details of the entire project, while seeking the answer to the question set forth in the statement of the problem, would entail an amount of time and labor wholly unnecessary and unjustifiable in view of the small additional accuracy that would be attained thereby.

The authors have attempted to clearly set forth their method of arriving at all conclusions, and in each case they have stated the reasons for their final selection.

The question of motor equipment was made the subject of a rigid and thorough investigation, because the selection of motor, gear ratio, and control equipment forms the basis of all calculations relating to the generation, transmission, and distribution of energy to the cars. Small changes

in gear ratio or control equipment not only affect the size and capacity of all apparatus in the system back of the motors but materially affect the cost of operation.

The authors take this opportunity to thank Mr. L. C. Hattley, Chief Engineer, Chicago and Eastern Illinois Railroad, through whose efforts they obtained valuable data regarding right-of-way, grades, profiles, and contours.

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A STATEMENT OF THE PROBLEM.

It is proposed to build and operate a highspeed electric interurban railroad from Danville, Illinois, to Terre Haute, Indiana. There are two possible routes: one via Paris, Illinois; the other via Clinton, Indiana. The route via Clinton runs parallel to the tracks of the Chicago and Eastern Illinois Railroad, which gives a very fine though infrequent service, making an express run in an average time of one hour and thirty minutes. Between Clinton and Terre Haute an interurban line is already giving local service, and a similar road operates between Danville and Paris. Along the route of the steam road there are many more villages and towns than along the route via Paris, where there would be less competition.

The country is comparatively level, requiring no heavy cutting and grading. The entire territory is a rich fertile farming land and the district around Danville is dotted with coal mines. Industries of various

A Statement of the Problem.

kinds are located in many of the smaller towns tributary to Danville, Terre Haute, and Clinton.

It is proposed to handle long-haul passenger traffic by fast limited trains and short-haul traffic by slower local cars; also, to handle carload and package freight and express, connecting directly with other electric and steam roads.

The problem is to determine the financial feasibility of constructing and operating an interurban electric railroad under the aforementioned conditions.

CHOICE OF ROUTE.

The choice of route, while practically limited to the selection of one of the two possibilities briefly discussed in the statement of the problem, presents a number of questions of w hich the immediate solutions are quite difficult and depend not only upon the future defelopment of the country, but to a very great extent upon the successful efforts of the traffic manager of the road in developing the riding habit of the rural and village population already living along a proposed route.

The maps of Illinois and Indiana indicate that there are many more villages and towns between Danville and Terra Haute along the route via Clinton, than along the one via Paris. This condition, no doubt, is a direct result of the country developing principally along the line of the Chicago and Eastern Illinois Railroad, which takes this route. If the proposed electric railroad is built through Paris, it is possible that the opening of the road will create a new development

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similar to that along the steam road. However, this will take time and meanwhile the electric road would be dependent upon heavy through traffic from Danville to Terre Haute for the greater portion of its revenue. This same revenue is available if the route parallel to the steam road is taken. Moreover, the district between Paris and Terre Haute is practically all farming country and the future development of towns and villages within a reasonable length of time is very questionable. On the other hand, competition with the railroad for traffic between intermediate towns and the terminals will demand a fast service equal to or exceeding that rendered by the steam road. This has been done on other lines without serious obstacles and the electric road will possess the additional advantages of greater frequency of service and more stops for a given schedule speed. The present tendency is to build electric lines parallel to steam roads where the country is already

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thickly settled. Experience has proved that it is wholly unsatisfactory to operate cars at a scheduled speed of approximately 40 miles per hour over anything but a private right-of-way; hence, no time need be wasted in considering pikes and country roads. It will be much easier and cheaper to secure a strip of land parallel to an existing steam road, than to open a new line through a thickly settled farming district, and will be less apt to antagonize the farmers, whose favor is very essential to success of the enterprise. The success of existing lines under similar conditions is thought to justify the selection of the Clinton route with the proposed electric parallel to the tracks of the Chicago and Eastern Illinois Railroad for the entire distance from Danville to Terre Haute.

Clinton is situated fifteen miles from Terre Haute; this is roughly one-fourth of the lenght of the proposed road. It is believed that the traction line already connecting Clinton with

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Terre Haute by a comparatively slow service will not prove a detriment, because the new road would give a fast and frequent service to towns beyond Clinton as far as Worthy.

Plate I. is a map of the recommended route, which connects the following towns and villages:

	Distance in miles from Danville City Limits.
Danville Terminal	-1.0
Danville Limits	0.0
Oaklawn	1.1
Brewer	2.5
Rileysburg	5.4
Jessie	7.8
Perrysville	11.2
Dickeson	13.7
Cayuga	18.0
Walnut Grove	20.6
Newport	23.7
Worthy	27.7
Mount Silica	28.4
Lanyons	28.9
West Montezuma	29.6
Hillsdale	30.8
Logan	31.7
Lewis Pit	33.3
Summit Grove	34.6
Wayne Pit	35.8
Norton Creek	36.8
Jackson	38.8
Clinton	39.2

Choice of Route.

	Distance in miles from Danville City Limits.
Lyford	40.0
Atherton	43.6
Keelers	44.3
Evanslane	46.3
Otter Creek Junction	48.0
Edwards	49.5
Dewey	51.1
Terre Haute Limits	53.3
Terre Haute Terminal	54.0

The route shown in Plate I.is fifty-five miles long. This consists of forty-eight miles over private right of way, four miles over city streets under franchise with the local governments, and three miles over the tracks of the terminal traction companies under contract with the latter.

Since the right-of-way is at one side of the right-of-way of theChicago and Eastern Illinois Railroad, a strip fifty feet wide is sufficient. No serious difficulties should be encountered in securing such a strip, for there should be little injury to adjacent property with the consequent high prices for real estate. We believe , there-

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fore, that $250 per acre is a fair estimate of the probable cost of right-of-way. A strip fifty feet wide and one mile long contains 6.06 acres. On this basis forty-nine miles of right-of-way will cost $73,000.

ESTIMATED ANNUAL INCOME.

Since the purpose of a traction company is to sell rides to the public, the first logical step in the consideration of any proposed enterprise is to determine, as accurately as possible, what the present and future demand for rides will be. Once this item has been determined, it is a comparatively easy matter to fix upon the type and capacity of rolling stock, to arrange a suitable schedule, and to solve in regular order those purely engineering problems which grow out of the proposed service.

THe annual gross passenger revenue represents the demand for rides. Obviously, it is a function of the city and rural population, of local industries, of the marketing places, and of the eenters of distribution and amusements. In fact, so many factors influence the operating revenue of an interurban electric line that nothing short of a careful study of each of the elements present in a given territory, followed by

Estimated Annual Income.

an equally careful analysis and comparison with existing roads operating in similar localities under much the same conditions, will lead to anything like a reliable estimate of the probable income. We shall proceed, therefore, first, to estimate the population served be the proposed road in 1916 and in 1920, and second, to arrive at a fair value for the gross operating revenue by comparison with roads already operating through like territory.

To further facilitate the work, the total inhabitants will be classified as rural population, intermediate town and village population, primary terminal population, and secondary terminal population, according to the following definitions:*

PRIMARY TERMINAL POPULATION. The population of the principal city into which the railway operates. In other words the population of that city

*L. E. Fisher, Economics of Interurban Railways.

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which is of the greatest commercial importance in the sense that it is a metropolis for the greater portion of the territory served.

SECONDARY TERMINAL POPULATION. The population of the other important terminals, distinct from the principal terminal, which are also of such commercial importance as to attract business from a considerable portion of the territory served, but not to the same extent as the principal terminal.

INTERMEDIATE TOWN AND VILLAGE POPULATION. The population of cities, towns, and villages, served by the line, beyond and between (where there are both primary and secondary terminals) but not including the primary and secondary terminals.

RURAL POPULATION. All the inhabitants served by the road and not included in the preceding definition.

In the following estimate all data was taken from the United States Census Reports compiled

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in 1910 and extrapolated for 1920. All villages having less than 75 inhabitants were included with the rural population. It was assumed that the proposed road would serve only that portion of the rural population, dwelling within two miles of the right-of-way. In order to arrive at a figure representing the rural population in each township, according to the foregoing definition, it was necessary to subtract from the figures quoted for the entire township the population of all villages, towns, and cities containing over 75 people, to assume that the remainder were uniformly distributed over the township, and to take a portion equal to the remainder multiplied by the ratio of the square miles served by the road in that township, to the total area of the township.

For example: the only town or village in Eugene Township with more than 75 inhabitants is Cayuga, which had 912 inhabitants in 1910. The total township population for 1910 was 2111.

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Subtracting 911 for Cayuga, leaves a total rural population of 1200. The area of the township is 33 square miles, making the rural inhabitants per square mile equal 36.4. Of this 33 square miles, the road would serve a strip four miles wide and 6.5 miles long, covering an area of 26 square miles. Hence, on the 1910 basis the road would serve 26 x 36.4 or 947 rural inhabitants in Eugene Township. By extrapolation from reports previous to 1910 the figure for 1916 is 1016 and 1920 is 1062.

TABLE I.

ESTIMATED POPULATION SERVED BY THE PROPOSED ROAD.

Name	Population in 1910	1916	1920
Primary Terminal Population.			
Terre Haute	58200	78480	92000
Secondary Terminal Population.			
Danville	27800	39300	47000

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(TABLE I. (Continued)

Intermediate Town and Village Population.

Name	Population in 1910	1916	1920
Rileysburg	75	75	75
Gessie	150	150	150
Perrysville	600	690	750
Cayuga	911	970	1020
Newpoet	732	732	732
Montezuma (across river from West Montezuma)	1537	1635	1700
Hillsdale	275	275	275
Summit Grove	80	80	80
Clinton	6230	8490	10000
Lyford	100	100	100
Total	10690	13197	14882

Rural Population Served.

Township	State	1910	1916	1920
Vermillion	Illinois	(Included with Danville)		
Highland	Indiana	530	542	550
Eugene	Indiana	947	1016	1062
Vermillion	Indiana	621	621	621
Helt	Indiana	625	635	650
Clinton	Indiana	1900	2158	2332
Florida	Indiana	644	675	700
Otter Creek	Indiana	2060	2732	3180
	Total	7327	8379	9095

Plate I. shows eighteen villages and towns directly on the route of the proposed road, which are not contained in Table I. These towns have

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less than 75 inhabitants and were, therefore, counted as rural population. There are ten towns having over 75 inhabitants and averaging 1320 people per town. This makes a total of 28 towns and villages along the route, all of which are tributary to the terminal cities. Clinton, which has 8490 inhabitants, serves as a local center for the thickly populated district as far north as Worthy. Hence Clinton will be much in the nature of a tertiary terminal . Express trains through this district will render roughly 25 minute service to Terre Haute and 55 minute service to Danville. In addition to serving the territory for which the population has been estimated the road may be expected to carry a heavy through traffic, because it serves as a connecting link between the interurban systems of Illinois and Indiana, which are already operating out of Danville and Terre Haute, as listed below:

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<u>Electric Lines Entering Danville.</u>

Illinois Traction System (connects to St. Louis)
Springfield, Illinois, via Decatur and Danville to Ridgefarm and Catlin
Danville to Grape Creek
Danville to Paris

<u>Electric Lines Entering Terre Haute.</u>

Terre Haute, Indiana and Eastern
Terre Haute via Indianapolis to Richmond
Clinton via Terre Haute to Sullivan

The traffic created by the population listed in Table I. will be consequent to the following general movements:

Source I.

(a) Intercommunication of the primary terminal population and the intermediate population.

(b) The intercommunication of the intermediate centers only.

Source II.

(c) The intercommunication of the secondary terminal population and the intermediate population.

(d) The intercommunication of the

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primary terminal population and the secondary terminal population.

The general characteristics of the territory, through which the proposed road will operate, conform to the characteristics of a territory hereafter referred to as "normal"; and defined by Mr. L. E. Fisher as a territory made up of cities, towns, and villages; which are supported by varied agricultural manufacturing or mining industries; which are free from the fluctuating influences of summer, health, or amusement resorts, or other similar traffic creating centers; and which are also free from serious business depressions due to local industrial conditions. Since the territory of the proposed road meets these requirements, it drawing comparisons attention may be wholly confined to normal roads operating in normal territories. By a normal road is meant a road having the following characteristics:

Private right-of-way outside of cities and villages.

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Roadbed constructed with reasonable curves and gradients.

Tracks laid with 70 lb. or 80 lb. rail and standard ties, 2-ft. centers.

Power house of ample size and constructed for economical operation.

Car equipment ample and of modern type.

Well constructed primary distributing system, and overhead or third rail secondary distributing system.

Substantially hourly service with local trains operating alternately with limited trains. Limited schedule practically equal to the schedule of the competing steam railway lines.

One or more broken package freight movements each way per day.

Rates of fare approximately two cents per mile with a reduction of from 10 to 25 percent when round trip tickets are purchased.

Table II. (following) shows the relation between distribution of population, as previously

TABLE II.

Relation of Population Distribution to Gross Revenue.

Case No.	Miles of Track	Primary Terminal Population	Secondary Terminal Population	Town and Village Population	Annual Gross Revenue
1	28.5	20,367	8,696	2,723	$ 84,522
2	32	25,776	7,353	2,150	18,000
3	130	2,185,283	55,783	35,400	1,210,170
4	93	233,650	20,081	26,879	428,456
5	40	19,359	17,010	2,700	152,535
6	320	233,650	62,650	112,097	1,899,706
7	65	63,933	3,765	7,642	257,868
8	39	12,687	10,480	5,439	135,748
9	41	223,928	6,305	4,625	123,863
10	32	8,981	13,650	7,369	306,962
11	82	31,297	11,080	1,695	91,219
12	199.5	423,715	31,770	14,711	858,135
13	67	74,419	9,491	12,433	207,150
14	364	50,217	24,076	4,892	222,110
15	26	18,266	5,501	6,552	118,292
16	222	560,663	49,651	74,146	1,106,219
17	150	560,663	228,194	36,023	1,009,638
18	122	704,478	51,670	39,006	664,687
19	95	31,140	38,189	13,163	420,690
20	40	66,950	25,768	2,477	235,665
21	40	51,678	31,140	4,853	247,668

TABLE III.

Division of Revenue between Sources I. and II.

Case No.	Miles of Track	Average Distance between Terminals	Revenue from Source I.	Revenue from Source II.	Revenue from Source II. per Capita of Population
1	28.5	28.5	$ 27,230	$ 57,292	$ 6.60
2	32	32	21,500	86,500	12.00
3	130	32	354,000	856,170	15.00
4	93	60	268,790	159,666	8.00
5	40	24	27,000	125,535	7.35
6	320	50	1,120,970	768,736	12.30
7	65	65	76,420	175,448	4.70
8	39	39	54,390	81,358	8.00
9	41	40	46,250	79,613	12.30
10	32	32	73,640	232,320	17.00
11	82	22	16,950	74,269	6.70
12	99.5	40	147,110	711,025	22.40
13	67	30	124,430	82,720	8.70
14	36.4	15	48,920	171,190	7.12
15	26	26	65,820	53,532	9.70
16	222	56	741,460	326,759	6.55
17	150	80	360,230	649,408	2.85
18	122	100	390,006	224,601	5.30
19	95	50	131,630	289,060	7.60
20	40	40	24,770	210,895	8.20
21	40	40	48,530	199,137	6.40

TABLE IV.

Revenue per Car Mile.

Case No.	Mile of Track	Gross Revenue	Car Miles Operated	Revenue per Car Mile
1	41	$ 123,863	639,290	$ 0.1954
2	17	66,750	313,498	.2122
3	20	108,086	572,977	.1886
4	25	141,085	474,564	.2975
5	32	107,278	341,542	.3111
6	51	33,240	558,428	.2385
7	38	149,304	648,728	.2301
8	46	230,142	1,052,089	.2166
9	23.7	70,618	191,674	.3684
10	40	145,689	638,987	.2284
11	320	1,889,706	5,852,994	.3081
12	101	546,980	2,229,714	.2383
13	62	405,890	1,370,924	.3103
14	122	620,568	2,146,413	.2889
15	40	234,516	818,425	.2865
16	32	101,993	341,542	.2986
17	222	1,068,219	3,818,028	.2965
18	30	67,416	367,460	.1985
19	170	999,274	3,276,608	.3083
2 0	45	355,469	923,705	.2826

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classified, and the gross operating revenue for 21 normal interurban electric lines operating in normal territories.

Table III. gives the division of revenue between Source I. and Source II. for the same 21 lines.

Table IV. gives the revenue per car mile.

The tables indicate:

(a) that the length of road has no bearing on the amount of operating revenue

(b) that the operating revenue is not governed by the primary terminal population

(c) that the relations existing between revenue from Source I. to the intermediate town and village population, do not exist between revenue from Source II. and the intermediate town and village population

(d) that the per capita average of intermediate town and village population

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equals $10

(e) the greater the average distance between two terminals the less the revenue from Source II. per capita of secondary terminal population

(f) where the secondary terminal is removed from the primary terminal a distance of forty miles or less, revenue from Source II. will vary between $6 and $20 per capita of secondary terminal population, depending upon the causes for intercommunication and upon the efficiency of the service

(g) where the distance mentioned in (f) is more than forty miles, the revenue from Source II. per capita of secondary population will diminish 10 % for each ten miles of increased distance

(h) the rural population cannot be used as a criterion for estimating probable incomes and hence it will not be further

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considered.

For 1916 the annual revenue of the proposed road from Source I. at $10 per capita of intermediate town and village population would be $131,970, and the corresponding revenue from Source II. would be $270,000, making the total gross annual income equal $401,970. The figures for Source II. are rather conservative, being estimated on a per capita basis of $8 per secondary terminal inhabitant less 14 %, because the distance between primary and secondary terminal exceeds 40 miles. The maximum value for this figure among the 21 roads listed in the tables is $22.40 per capita, and $8 is slightly more than the minimum for any of the roads.

On the same basis the annual revenue from Source I. for 1920 would be $148,820 and that from Source II. would be $323,500, making the total gross annual receipts equal $472,320.

ROLLING STOCK AND SCHEDULE.

The Chicago and Eastern Illinois trains make the run from Danville to Terre Haute in an average time of one hour and thirty minutes. To compete for long-haul traffic it is proposed to operate limited electric trains over the same distance in one hour and twenty minutes. Such an arrangement demands a schedule speed of 40 miles per hour, which can easily be obtained without excessive power consumption by the proper selection of motor, gear ratio, and control equipment.

The capacity of cars for through express service can be safely rated on the gross annual passenger revenue from Source I. The reports of the Interstate Commerce Commission show that for average normal electric lines the annual income other than passenger revenue is approximately 9 % of the total operating revenue. Hence the actual passenger revenue per day from Source I. would be

$$\frac{131,970 \times .91}{365} = \$329 \text{ in } 1916$$

Rolling Stock and Schedule.

and $\frac{148820 \times .91}{365} = \$370$ in 1920

For the long-haul service characteristic of interurban roads, it is necessary to provide seats for all passengers at all times except upon very special occasions; otherwise, the good will of the riding public will not be retained, much to the detriment of the operating company.

To render hourly limited service in both directions would require three cars in continuous operation with a ten minute layover at each terminal. Assuming that this service is continued from 8 a.m. to 6 p.m., that the maximum demand for seats is twice the average, and that the rate of fare is two cents per mile or one dollar per single trip, then the seating capacity per car must be

$$\frac{329 \times 1.5 \times 2}{3 \times 10 \times 1} = 33 \text{ seats in 1916}$$

and

$$\frac{370 \times 1.5 \times 2}{3 \times 10 \times 1} = 37 \text{ seats in 1920}$$

Rolling Stock and Schedule.

To render limited service in both directions every one and one-half hours would require but two cars. On this basis the seating capacity per car would be

$$\frac{329 \times 1.5 \times 2}{2 \times 10 \times 1} = 50 \text{ seats in 1916}$$

and $$\frac{370 \times 1.5 \times 2}{2 \times 10 \times 1} = 56 \text{ seats in 1920}$$

It is desirable to have but one type and size of car body for both local and express service; therefore, before finally fixing upon the seating capacity of express cars, it would be well to consider the requirements of the local service. The actual passenger revenue per day from Source II. would be

$$\frac{270,000 \times .91}{365} = \$672 \text{ in 1916}$$

and $$\frac{323,500 \times .91}{365} = \$806 \text{ in 1920}$$

Let C equal the seating capacity of the car and $\frac{C}{2}$ equal the average number of passengers per car. Then, with the rate of fare equal to two cents

Rolling Stock and Schedule.

per mile, the revenue per car trip would be

$$.02 \times 55 \times \frac{C}{2} = .55 \text{ C dollars.}$$

To provide an hourly local service at a schedule speed of 23.6 milesper hour requires five cars . Assuming that these cars are in service an average of 18 hours per day, the revenue per car day equals,

$$\frac{18}{2.5} \times .55 \text{ C dollars,}$$

and the total local passenger revenue per day would be

$$\frac{18}{2.5} \times 5 \times .55 \text{ C} = 19.8 \text{ C dollars,}$$

therefore, in 1916

$$C = \frac{672}{19.2} = 34 \text{ seats,}$$

and in 1920

$$C = \frac{806}{19.8} = 40 \text{ seats.}$$

On the other hand, to provide local service every one and one half hours at a schedule speed of 26 miles per hour, requires but three cars, in which case the local passenger revenue per day would be

$$\frac{18}{2.05} \times 3 \times .55 \text{ C} = 14.5 \text{ C dollars,}$$

Rolling Stock and Schedule.

therefore, in 1916

$$C = \frac{672}{14.5} = 46 \text{ seats,}$$

and in 1920

$$C = \frac{806}{14.5} = 56 \text{ seats.}$$

It is evident that the relation existing between the long-haul and the short-haul traffic is such, that the capacity of cars for the two kinds of service is equal, irrespective of the actual schedule adopted. Hourly limited and local service requires a total of eight cars in continuous operation, one car leaving each terminal every half hour. One-and-one-half hour service requires but five cars in continuous operation, one car leaving each terminal every forty-five minutes. This, however, does not represent a saving in the cost of three cars with a one-and-one-half hour schedule as against an hourly schedule, because the seating capacity of eight cars would be 40 seats each, while that of five cars would be 56 seats each. Assuming that the first cost per car seat is the same in

both cases, the saving in five large cars over eight smaller ones would be

$$\frac{40 \times 8 - 5 \times 56}{40 \times 8} \times 100 = 12.5\ \%$$

of the cost of the latter.

The principal objection to a five car schedule is the decreased frequency of service. However, this is not a serious matter, because in any case at least two additional cars would be needed during the morning and evening peak; during the remainder of the day it is believed a forty-five minute headway will suffice, particularly during the first five years of operation. The schedule can easily be changed to an hourly basis with one-half hour headway at some future time when the traffic has increased sufficiently to justify the purchase ~~ase~~ and operation of three additional cars of large capacity.

In this way the road would have large, roomy, comfortable cars at the outset. Handsome, smooth-running cars, well equipped and maintained with luxurious furnishings add materially to the

attractiveness of the road. They are an inducement and invitation to the public to ride. If such cars are coupled witha reasonable schedule speed and supplemented by polite and neatly uniformed car employees, the business obtained will be held. The inexpensive advertising of thousands of satisfied passengers is many times more valuable than tons of paper pamphlets containing printed invitations to ride, and should prove an important factor in the building up of a large regular business and in permanently increasing the general riding habit of the community at large.

When the public after having read glowing descriptions of the road, finally decides to take a ride, only to find small, dingy cars filled with uncomfortable rattan seats; the car bodies mounted on trucks which shake the passenger as if he were a bottle of medicine; and the car in charge of a grouchy "step lively" conductor; it usually waits for the steam train whenever it

contemplates a long journey and uses the electric for short distances only.

The car body designs should embody the strongest possible construction consistent with good appearance. Open cars are wholly out of the question, since one type of car must answer for both summer and winter service. The windows should, therefore, be of a pattern which gives a maximum opening and does not interfere with the view when open, and the frame should be so designed that double windows can be used during the winter months. The seats should be upholstered in plush, which is generally supposed to be less cleanly than rattan, but one has only to look at the rattan seats which have been in use for a year or more to disbelieve. No class of seat covering seems to succeed in evading dirt; hence, a covering should be adopted for comfort regardless of its supposed hygienic qualities. In this respect plush has the advantage, for rattan possesses the disagreeable characteristic of permitting the

Rolling Stock and Schedule.

passengers to slip from the seats during acceleration or retardation of the car. An objection often raised is that plush seats are more often subject to mutilation by hoodlums than rattan seats are. Actually, this has not been the case on roads using both types, and it may be added at this point that cars are never equipped so as to be beyond the possibility of mutilation by hoodlums anyhow.

Toilet rooms are a nuisance at the best, but a railway serves the public and the public demands them or uses the steam roads when theyaare absent.

We believe: that the appearance of the car and its fittings has a tangible value as no where else on the road; that a road should makes its best appearance at the cars and not indulge in fancy polished brassware and pressed bricked decorations at the power house and substations. We therefore recommend the car body shown in Fig. 1 and Fig. 2, to be mounted on the truck shown in Fig. 3, and operated essentially on a one-and-one-

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[illegible]

Rolling Stock and Schedule.

half hour limited and local schedule with a forty-five minute headway.

This car is manufactured by the American Car Company at St. Louis, Missouri. It is 40 ft. 0 in. long over corner posts and 52 ft. 3-1/2 in. over vestibules. The under frame is all steel construction; the weight of the body, less electric and air equipment is 32,380 lbs. It will seat 57 passengers, which is ample provision for the proposed schedule.

The truck shown in Fig. 3 is a J. G. Brill Company truck No. 23 M. C. B. 3 and weighs 11,760 lbs. The manufacturers recommend: that the weight of car body plus the equipment and passenger load should not exceed 88,000 lbs., that the speed should not exceed 65 miles per hour, and that the motors per truck should not exceed 200 h. p.

It will be seen from the following that we are well within the limitations as to weight.

Fig. 1a

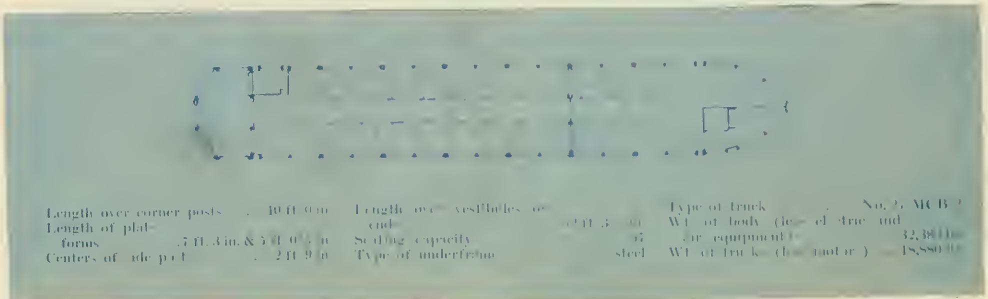

Length over corner posts
Length of plat-
forms
Type of truck
Type of underframe
steel
32,380 lbs.

Fig. 1b

Fig. 2

Fig. 3

Rolling Stock and Schedule.

	Weight in Pounds
One Car Body	32,380
Four Motors	8,000
Two Trucks	23,520
Air Equipment	3,000
Passenger Load	8,400
Control Equipment	4,000
Total	79,300

In all furthet caluclations we shall round off this figure and assume the total car weight equal to 40 tons.

Plate II. is a train sheet made up after a careful consideration of six preliminary schedules drawn in pencil only. This schedule requires: two express cars and three local cars in through service, one local car in service between Jackson and Terre Haute, two local cars for morning and evening service, two freight cars, and two milk cars. In addition there must be at least one spare express car, one spare local car, and one repair car equipped for emergency repair work.

The district from Terre Haute to Jackson is served by a local train in both directions

Rolling Stock and Schedule.

every forty-five minutes and an express train in both directions every hour and a half throughout the day with additional local service in the morning and evening. The district from Clinton as far north as Worthy is served by a local and an express train in both directions every hour and one half throughout the day, and with extra forty-five minute local service mornings and evenings. The remaining distance to Danville is less thickly populated. It receives one and one-half hour local and express service with one additional local train in the morning and in the evening.

Each night all the cars return to the car barns which are located at Worthy. For economical reasons it is desirable to have the car barns, repair shops, and power house all concentrated at a single point.

A south bound train consisting of one freight car and one milk car leaves Danville at 10 p.m. daily and a similar north bound train leaves

Rolling Stock and Schedule.

Terre Haute at 9:30 p.m. These trains pick up freight and distribute empty milk cans. They arrive at Worthy at midnight and remain in the barn until 5 a.m., at which time they continue their journeys south and north respectively, picking up and distributing package freight, and taking full milk cans destined for Terre Haute and for Danville, arriving at the freight terminals at 7:15 a.m., where they remain until the following night.

This schedule calls for an operation of 1,159,000 car-miles per year. On the basis of an annual income of $401,970 for 1916 this gives a car-mile revenue of 34.7 cents, which compares very favorably with Table IV. where the average revenue per car-mile is 32.5 cents.

Summing up the rolling stock for the purpose of estimating the cost, there results:

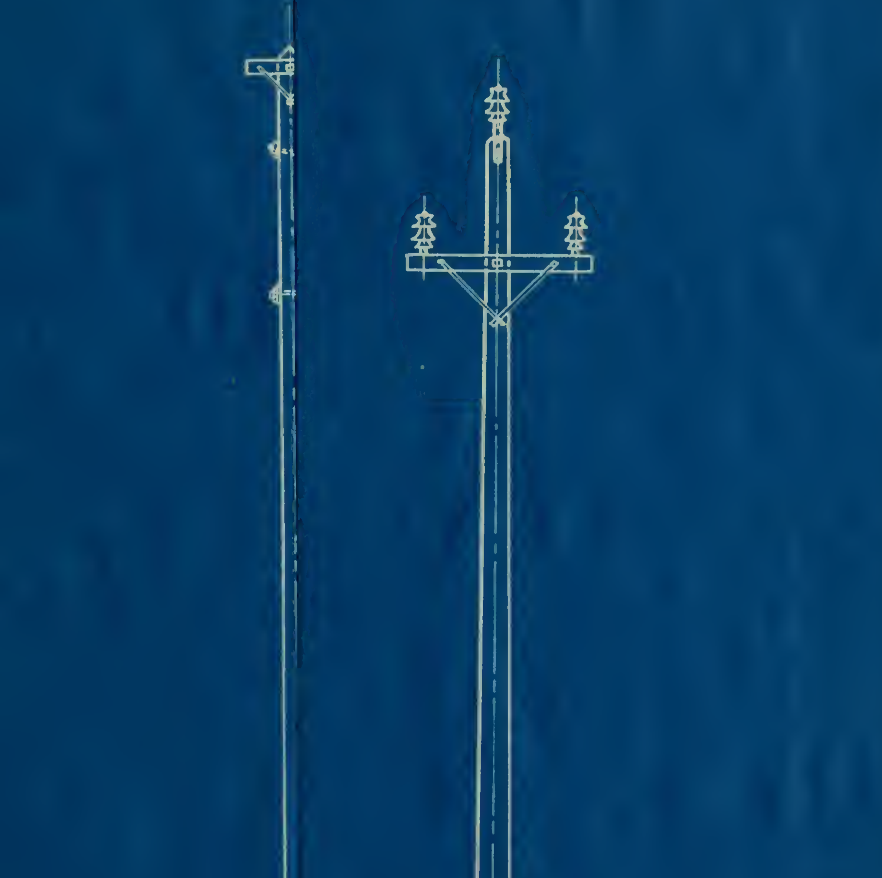
three express cars	$33,000
seven local cars	77,000
two freight cars	3,000
two milk cars	4,000
one repair car and trailer with equipment	2,200
Total	$139,200

ROADBED AND TRACK.

Probably the largest single cost item connected with the proposed road will be the outlay for steel rails. The size of the rail depends upon the weight of the rolling stock and upon the tie spacing. we believe, that with standard 2-ft. tie spacing and 40 ton cars attaining a maximum speed of 65 miles per hour, an 80 lb. rail will be required. The usee of 60 ft. rail lengths reduces the number of joints, thereby helping to eliminate noise and cheapening the cost of bonding. Hence we recommend the use of 80 lb. rail in 60 ft. lengths. This will cost $39 per ton.

The increasing scarcity of good ties accompanied by ascending prices makes the use of specially treated ties at a slightly greater first cost imperative in view of their longer life. High grade creosoted ties will cost 95¢ each in place and their use will prove a profitable investment in the long run.

Fig. 5 shows a typical section of the roadbed, basllasting, etc. The roadbed should be flat



lbed.

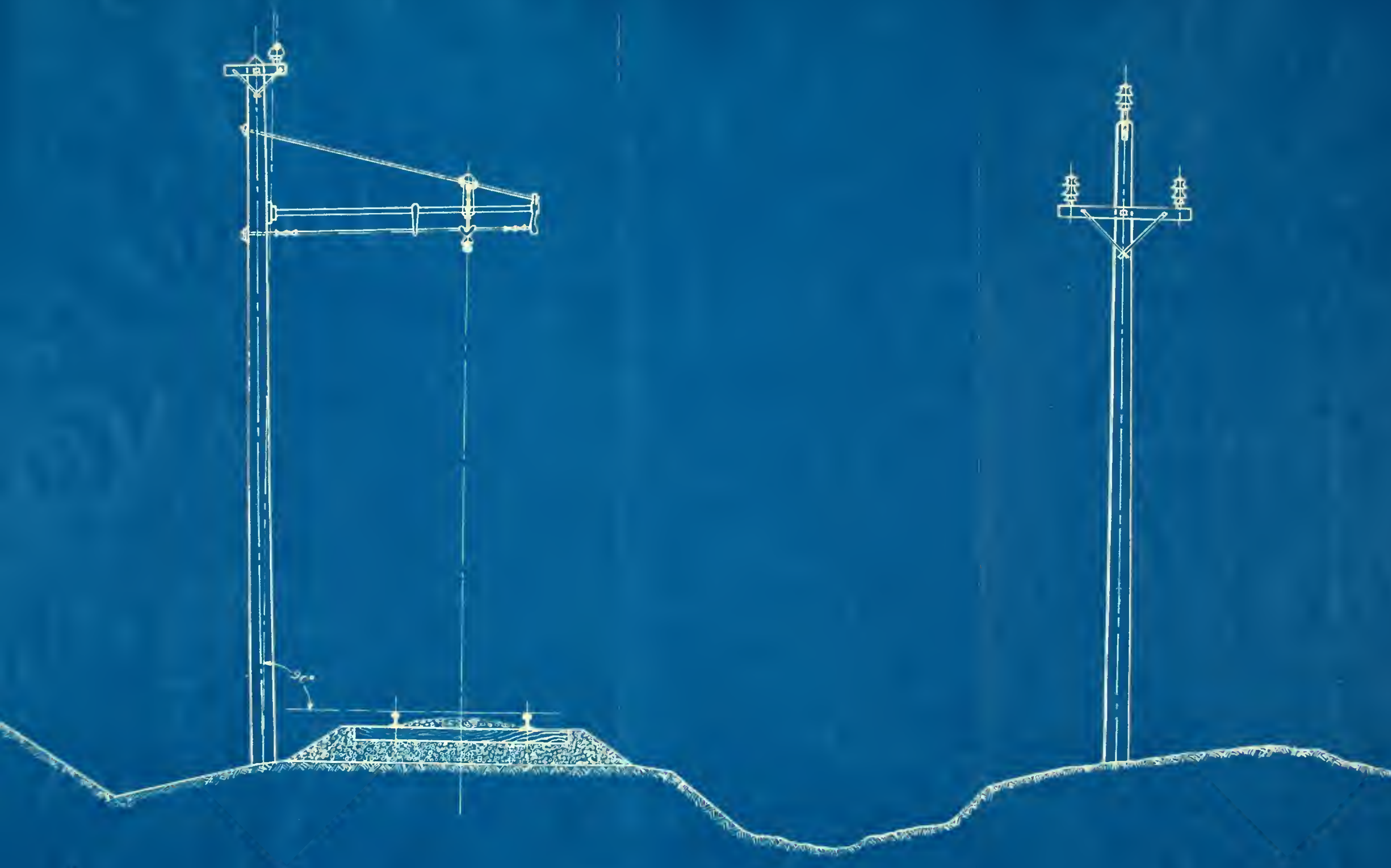


Fig. 4
Typical Section of Roadbed.

Roadbed and Track.

with a ditch at each side for drainage. It should be 16 ft. wide for single track, and 25 ft. wide for double track at sidings. While broken stone is very desirable for ballast because it is practically dustless, it is expensive in first cost and maintenance. Gravel is cheaper and is very satisfactory from a maintenance standpoint. Since a good grade of gravel can be obtained at several points along the route, its use is recommended for ballasting purposes. The depth of gravel under the ties should not be less than 10 inches.

The only place on the road where the company will be required to deal with paving is a one-half mile section of track at Clinton. The total cost of single track laid in paved streets where the railway company pays for paving 18 inches of the street outside the rails, excluding overhead construction, and using 9 inch girder rails, is about $5 per foot. This makes the cost of the one-half mile section equal to $13,200. At four

Roadbed and Track.

points the proposed line crosses steam railroads. The interest on an investment in overhead crossings is scarcely more than the cost of maintaining interlocking plants at these points and overhead crossings eliminate once and for all the danger of collisions occuring at these points.

The following is an estimate of the total cost of roadbed and track including bridges, crossings, etc.

Excavation and embankment	$ 94,000
Bridges, abutments, culverts	98,150
138,600 ties at 95¢ each	131,250
Ballasting at $1600 per mile	84,000
80 lb. rail at $39 per ton	288,290
Jpints, spikes, bolts, tieplates	29,500
Switches and special work	21,000
Labor on track at $300 per mile	15,750
9,240 bonds in place at $1.70	15,710
Cross bonds and special bonding at switches	2,000
Four above grade railway crossings	100,000
Farm and highway crossings	9,500
One-half mile through paved streets at Clinton	13,200
Total	$902,350

TROLLEY VOLTAGE AND OVERHEAD CONSTRUCTION.

Interurban railways, employing a potential of 1200 volts at the trolley, have now been in operation long enough to prove conclusively that there are no real objections to the use of this voltage on passenger cars. Possibly the first opposition to the use of a 1200-volt system will be found in existing ordinances at the terminal cities, which restrict or entirely prohibit such a potential on overhead trolley wires. Upon first thought this might be held as sufficient and valid grounds for dropping the entire matter of high voltage trolley wires from further consideration and at once adopting the old standard 600-volt system.

However, with scarcely any additional complications, cars intended for operation at 1200-volts in rural districts may be run at their normal efficiency and normal speed over city tracks equipped for 600 volts. Where the distance is short half speed may be sufficient and in many cases is all that city traffic conditions

[illegible]

[illegible]

will permit. Such being the case, the question naturally arises, what gains may be expected from the 1200-volt system over the 600-volt system.

The 1200-volt system offers a means of reducing first cost through a saving in the number of substations and in the copper of the secondary distribution system. This gain is a permanent asset to the road because it makes a definite decrease in the fixed charges for substations and distributing conductors, that cannot be accomplished in any other way than by raising the trolley potential.

The manager of a road may control the cost of operation to a certain extent, but he cannot materially alter the cost of getting energy to the cars, once the type and size of cars and the trolley voltage have been fixed upon. The use of a 1200-volt trolley system decreases the cost of delivering energy to the car in two ways: it reduces the number of substations, and it

improves the load factor and average efficiency of the substation apparatus. Increasing the track mileage fed by a substation, increases the load factor and therefore the efficiency of the substation apparatus. The total cost and maintenance is almost directly proportional to the number of substations.

That these advantages are not offset by any extraordinary car equipment or car maintenance costs is clearly demonstrated by the data in Table V.

TABLE V.

Car Data for 1200-volt and 600-volt Trolley Systems.

Car Data	600 Volts	1200 Volts
Cost each	$10,000	$11,000
Weight complete (in tons)	35	36
K. W. H. per car mile	2.80	2.88
Car Maintenance per day		
Mechanical	$ 1.00	$1.00
Electrical	.70	.77
Total	$ 1.70	$1.77

Trolley Voltage and Overhead Construction.

Data for this table was taken from a paper by Mr. Charles E. Eveleth (Proceedings A.I.E.E. vol. XXIX, 1910.) for what Mr. Eveleth terms a class "B" interurban electric line, under which class we believed the proposed road should be considered. Mr. Eveleth concludes his paper with the assertion, that a conservative estimate of the economy, obtained by a 1200-volt system as compared with the 600-volt system, in the elements of a railroad which are effected by the choice of system, that is, all the electrification material, would place the savings approximately as follows:

First Cost	10 to 20 %
Fixed Charges	10 to 18 %
Operation and Maintenance	10 to 15 %

Furthermore, experience has shown that the 1200-volt system is just as reliable as the 600-volt system.

Early 1200-volt lines employed direct suspension overhead trolley with some special form of porcelain insulators. The catenary form

[illegible]

[illegible]

[illegible]	[illegible]

[illegible]

[illegible]

Trolley Voltage and Overhead Construction.

of construction offers so many advantages for high voltage lines, particularly where high car speeds are attained, that it is now common practice to employ this type of construction for 1200-volt trolleys.

We recommend, therefore, that the proposed line be equipped with a 1200-volt trolley system using the simple catenary type of construction. Since the distances are short at each terminal where the cars will operate over the 600-volt lines of the terminal traction companies, no special provision need be made for full speed operation, because half speed will be all that safe operation on city streets will permit. However, it is desirable to have the air compressor operate at full speed at all times; hence, it is recommended that a combination dynamotor compressor be installed to operate at a constant speed on either voltage. The function of the dynamo will be to supply energy for car lighting and for control circuits. The necessary switching may

be entirely automatic, thereby rendering it foolproof.

Assuming an equivilent of 20 % curvature throughout the line, the cost of all overhead construction, except trolley and feeder copper, is approximately $1356 per mile of single track, making the total for 56 miles equal $75,950.

MOTOR EQUIPMENT.

The selection of railway motor equipment bears an important relation to the entire electrical system. It presents an intricate problem in numerous variables and is a subject well worth a rigid investigation even for preliminary work. For each particular set of operating conditions there is a single clearly defined solution leading to the selection of one particular equipment in preference to all others. However, the conditions of operation are subject to many irregularities which greatly increase the complexity of the problem and for which provision can be made only in a general manner. Therefore, the best that can be done in predetermination work, is to choose fair average conditions and proceed on this basis.

A railway motor for a given service can be selected in one of three general ways:

(a) by experimenting with various motors under the actual service requirements or on an equivalent duty cycle;

Motor Equipment.

(b) by determining graphically the motor characteristic required to produce an ideal speed-time curve, and then choosing a combination of motor, gear ratio, and control equipment, which will give the desired characteristic;

(c) by determining graphically what combination of motor, gear ratio, and control equipment meets the service conditions most economically.

Without question method (a) is the safest proceedure, but unfortunately it can scarcely be applied to preliminary work, when a road is merely a dissertation on paper. Methods (b) and (c) are both long and tedious proceedures and both eventually lead to the same conclusion. We prefer method (c) for a number of reasons, but principally because it evades the whole controversy of ideal speed-time curves and deals only with the performance of standard apparatus operating under the given conditions.

The first question which arises is one which

Motor Equipment.

demands more than a little consideration; viz., what are the average service conditions? Obviously, the local and express service must be differentiated and treated separately. The train sheet (PlateII.) requires a schedule speed of forty miles per hour for express cars and twenty-six miles per hour for local cars. The express cars have 14 regular stopping points, making the average length of run equal 4.5 miles. The local cars have 70 regular stopping points, making the average length of run equal 0.775 miles. For both classes of service, the total weight, including the passenger load, as previously estimated under "Rolling Stock", is 40 tons per car.

Plate III. is a profile of the road. It indicates a general upgrade from Terre Haute to Danville. The maximum grade, which is 1 %, is within the city limits of Danville. North of Dickason there is a 0.345 % grade four miles long. The maximum curvature is 4° and occurs

Motor Equipment.

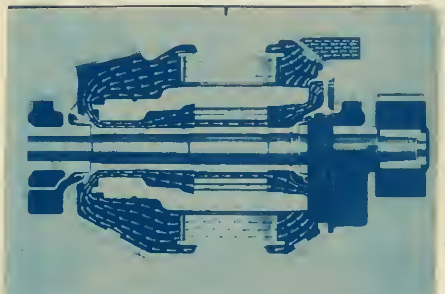
at Otter Creek Junction, while at other points the curvature varies from one to two degrees. Since the average express run is 4.5 miles long, there are several changes in grade and one or more curves in each run, while the shorter local runs are practically all on a single grade. Because of this difference we believe, that local car runs taken over succeeding sections of the road, vary so widely, that none of them represent typical operating conditions. The same cannot be said, however, of the express car runs. Hence, we chose a section of tangent level track 0.775 miles long to represent the average conditions for local runs, and the following section in the region of Perrysville to represent a typical express run.

Distance	Grade	Curvature
1.375 mile	0.345 % up	tangent
0.425	0.345 % up	2 deg. 10 min.
1.60	0.345 % up	tangent
0.20	0.10 % up	tangent
0.30	0.42 % down	tangent
0.10	0.15 % down	tangent
0.50	0 % level	tangent

Motor Equipment.

For the first approximations we find by reference to curves that, for a schedule speed of 40 miles per hour with 0.222 stops per mile, a 40 ton car requires four motors each having a nominal one hour rating of 100 h.p. In the same manner we find that a 40 ton car, operating at a schedule speed of 26 miles per hour with 1.29 stops per mile, requires four 90 h.p. motors. This corresponds reasonably well with the rating of motors on similar cars now in service on other lines.

The final choice of motor, gear ratio, and control equipment has such a vital bearing on the size of all the apparatus in the system back of the motors, that a careful investigation of several motors under the operating conditions already outlined is imperative. We shall study three motors of the type shown in Fig. 5, having a nominal one hour rating of 75, 100, and 140 h.p.; and we shall select that motor, gear ratio, and control which meets all of the service requirements at a



CIRCULATION OF AIR THROUGH MOTOR

Fig. 5

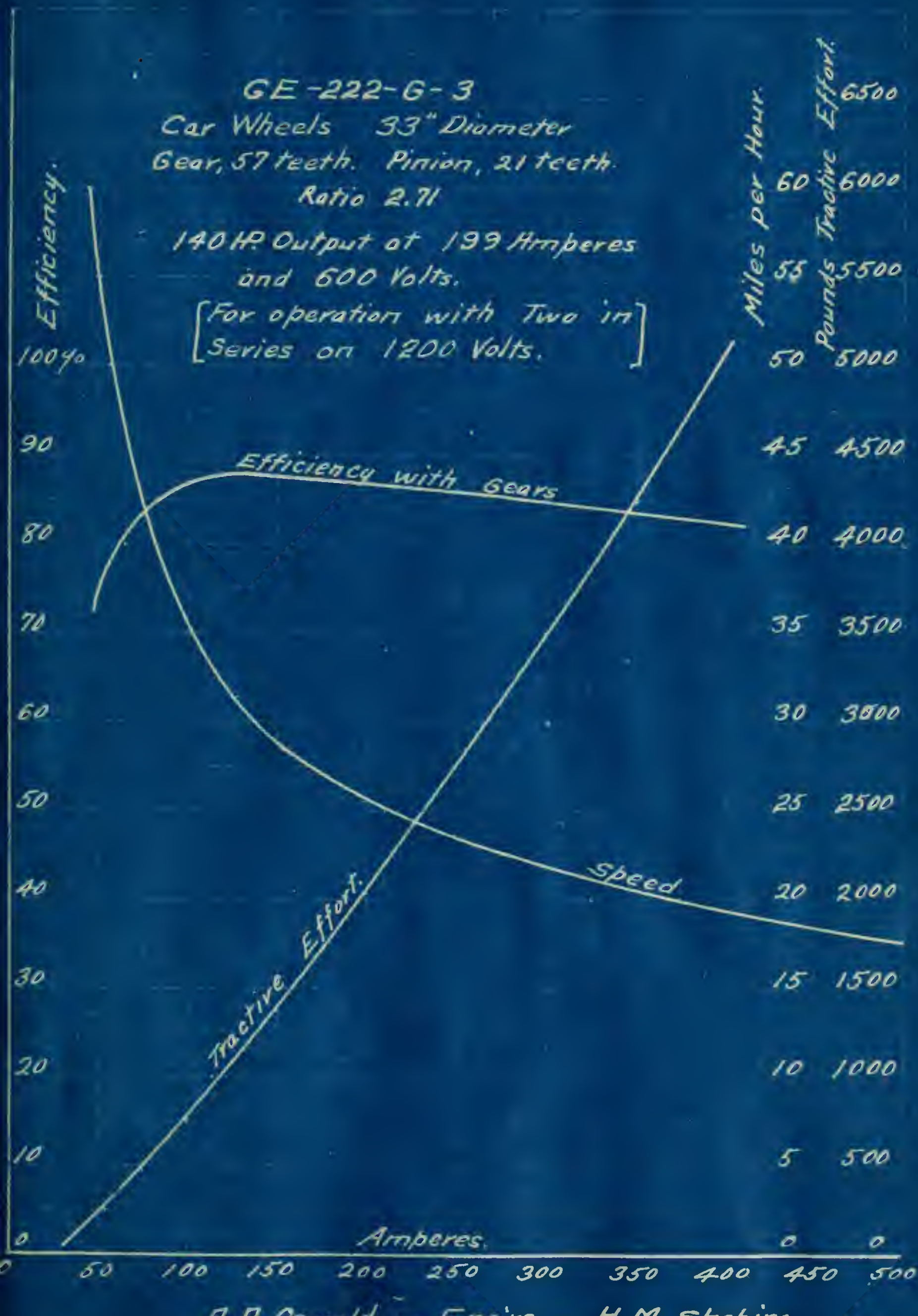
Motor Equipment.

minimum cost of operation. The characteristic curves for these motors are given in Fig. 7 to Fig. 24 inclusive.

To fulfill the service requirements, the motors must maintain the schedule speed, when making all stops under the full passenger load. They must do this without sparking at the commutator and without a temperature rise exceeding 75° C. They must have a sufficient reserve capacity to make up a reasonable amount of lost time due to unavoidable delays and must withstand severe overloads for short periods.

In order to study the performance of the aforementioned motors with various gear ratios, and rates of acceleration, the speed-time curves together with their subsidiary curves shown in Plate IV. to Plate XX., inclusive, were prepared. These curves were drawn according to the method of C. O. Mailloux. (Trans. A.I.EE., 1902, Vol. XIX; p. 901.) In general the method of proceedure consists in reducing all forces acting on a train

Fig. 7



A. R. Oswald. — Eng'rs. — H. M. Shapiro.

Fig. 8

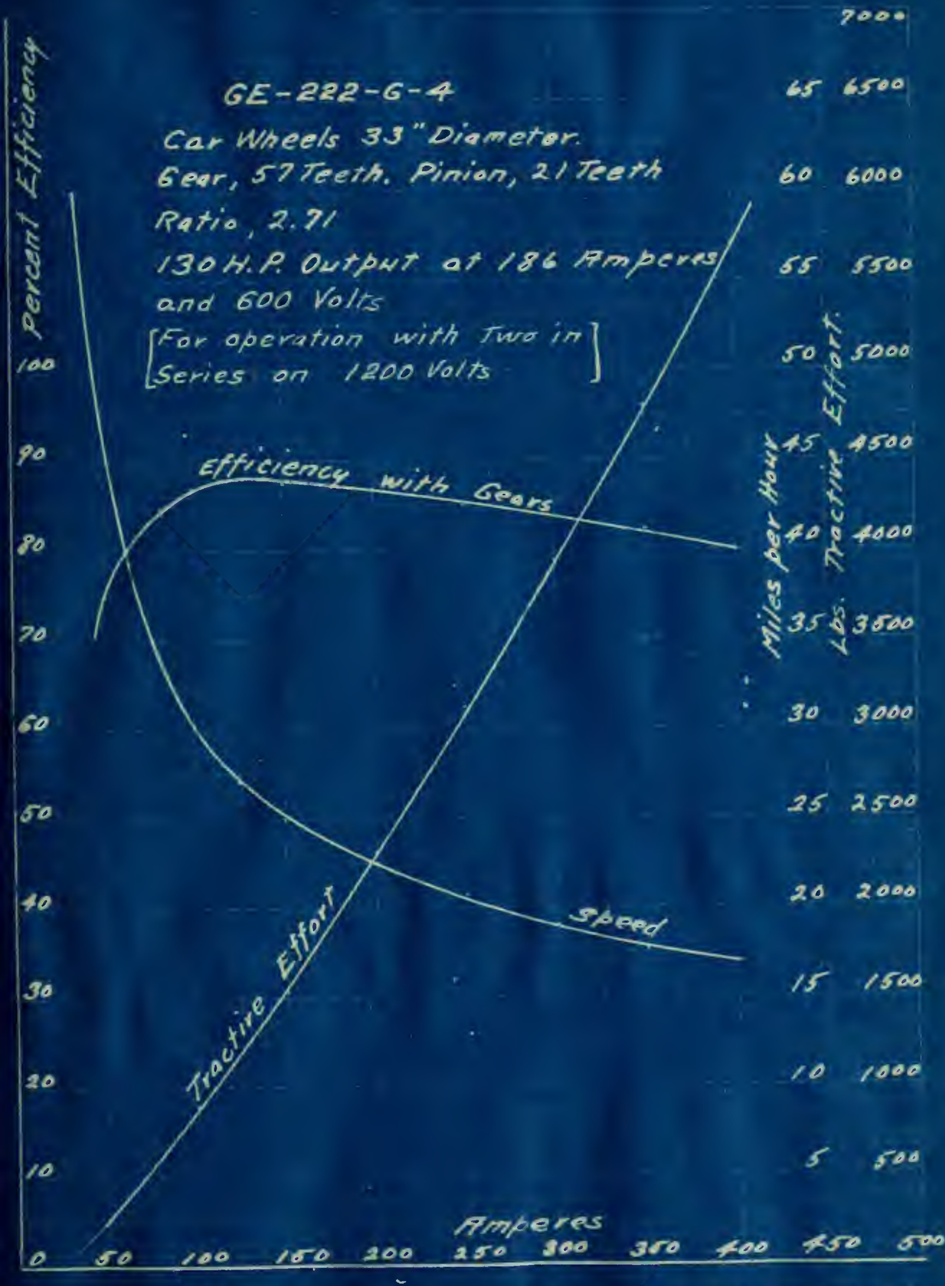


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Fig. 9

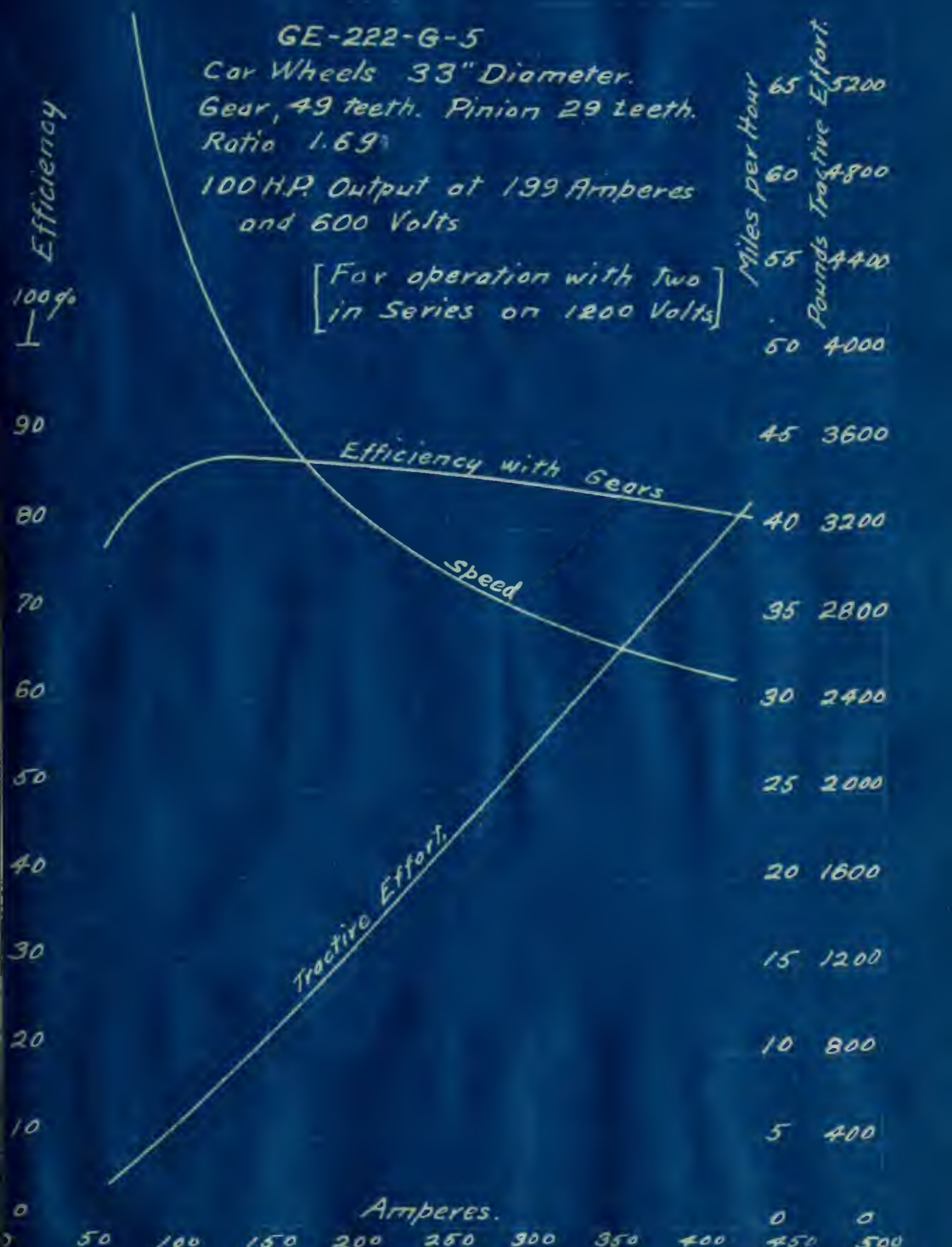

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Fig. 10

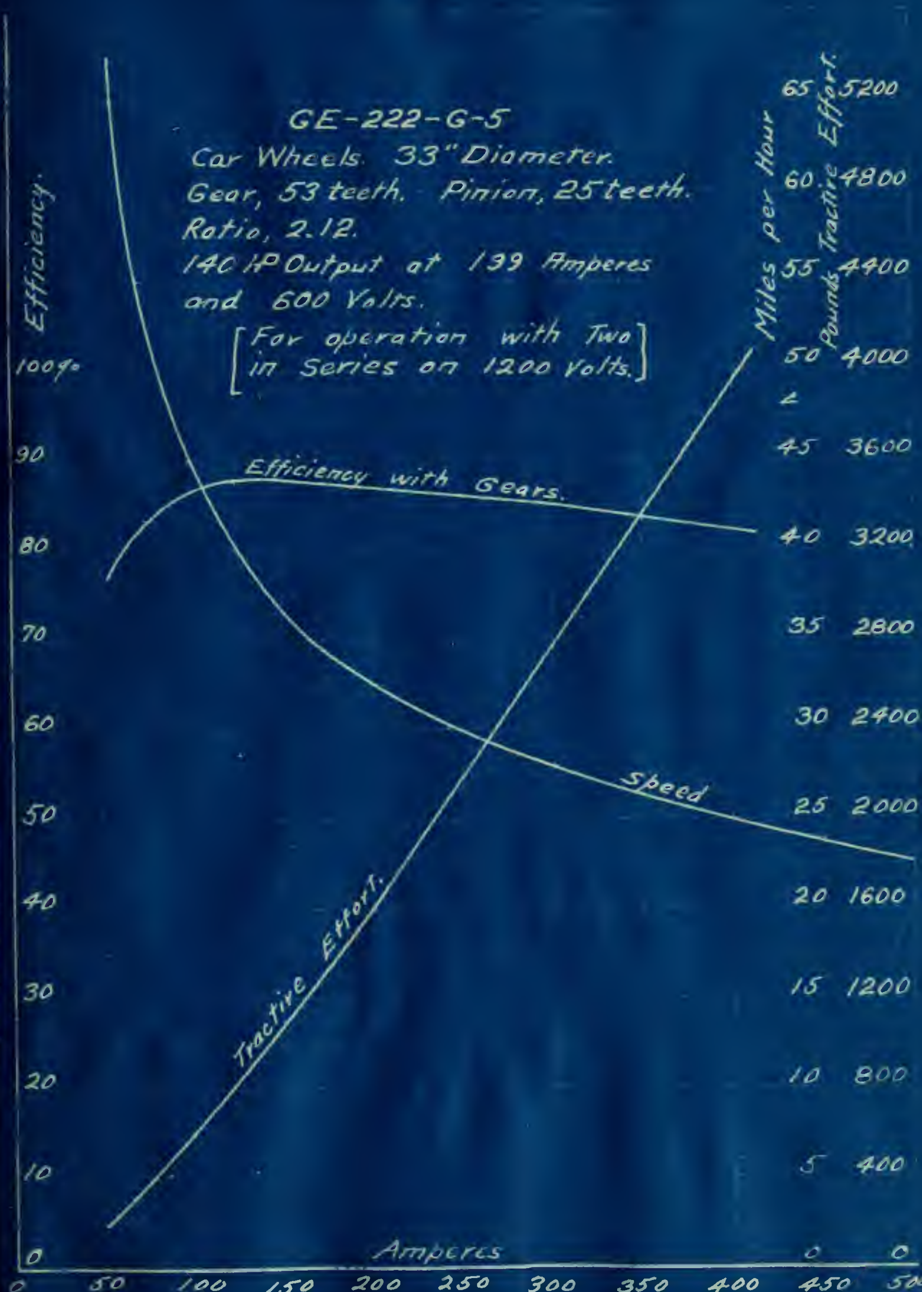

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Fig. 11

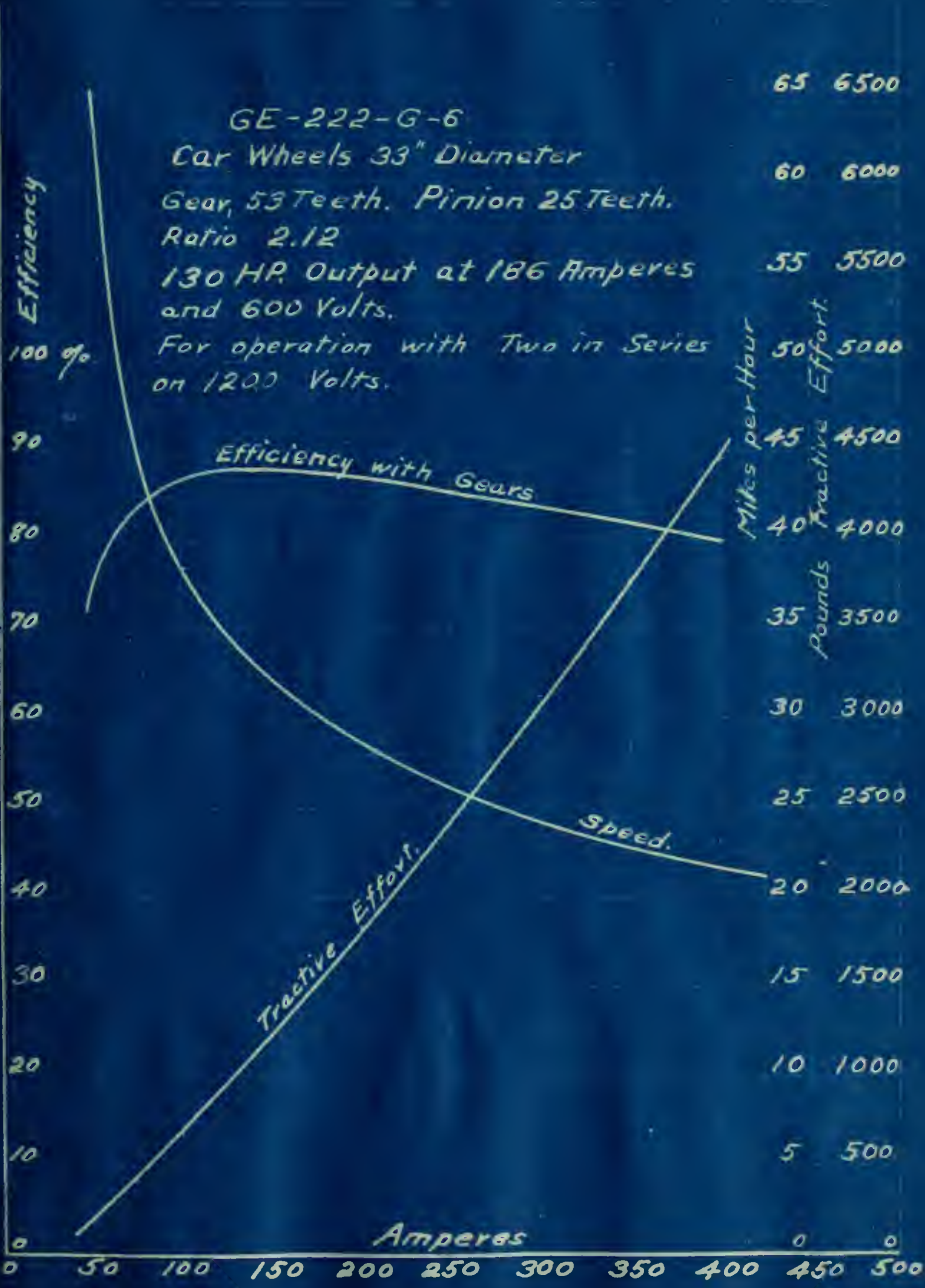

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Fig. 12

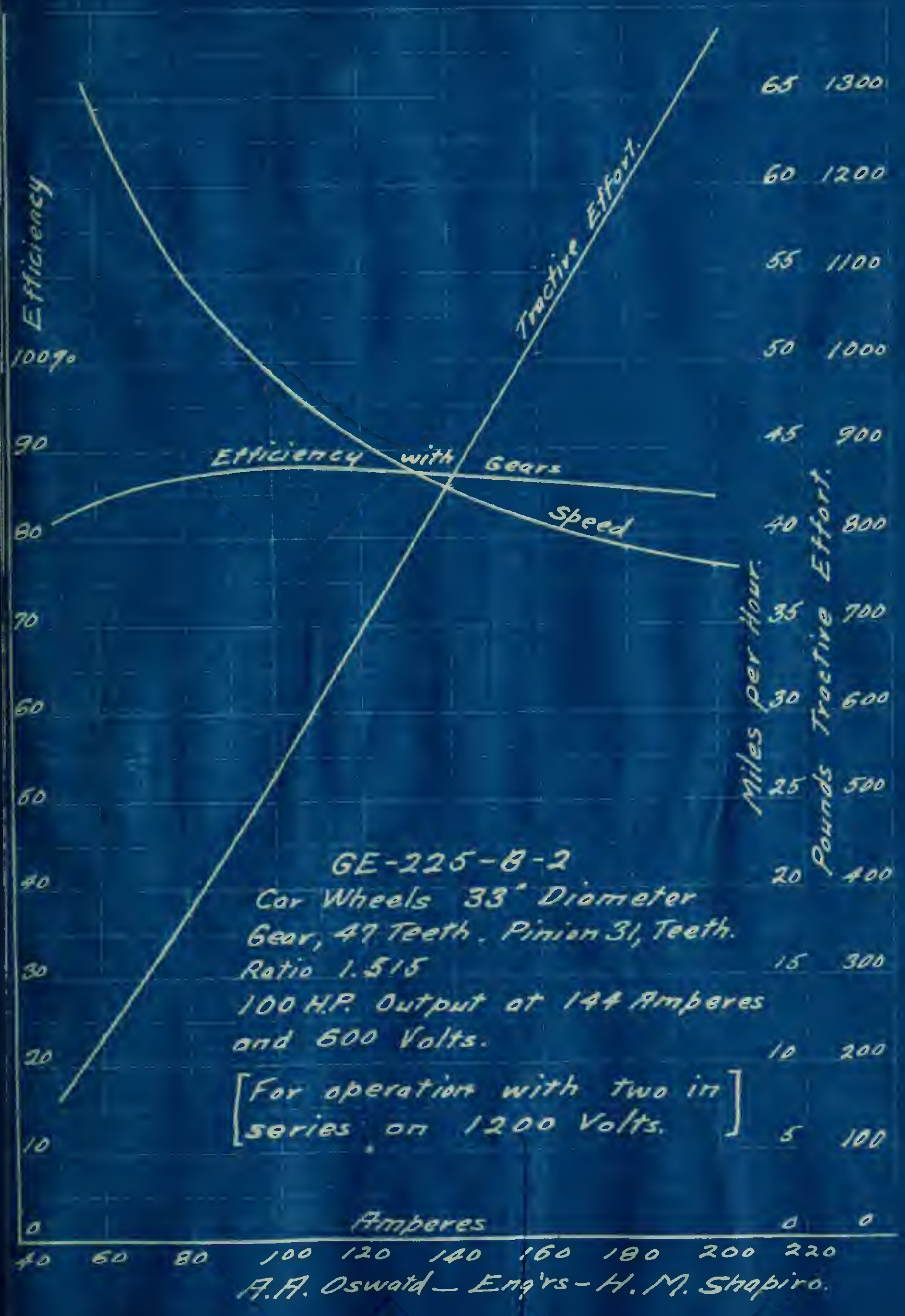
Efficiency
100%
90
80
70
60
50
40
30
20
10
0
40 60 80 100 120 140 160 180 200 220
Amperes
Tractive Effort.
Efficiency with Gears
Speed
65 1300
60 1200
55 1100
50 1000
45 900
40 800
35 700
30 600
25 500
20 400
15 300
10 200
5 100
0 0
Miles per Hour.
Pounds Tractive Effort.
GE-225-B-2
Car Wheels 33" Diameter
Gear, 47 Teeth. Pinion 31, Teeth.
Ratio 1.515
100 H.P. Output at 144 Amperes and 600 Volts.
[For operation with two in series on 1200 Volts.]
A.A. Oswald — Eng'rs — H. M. Shapiro.

Fig. 13

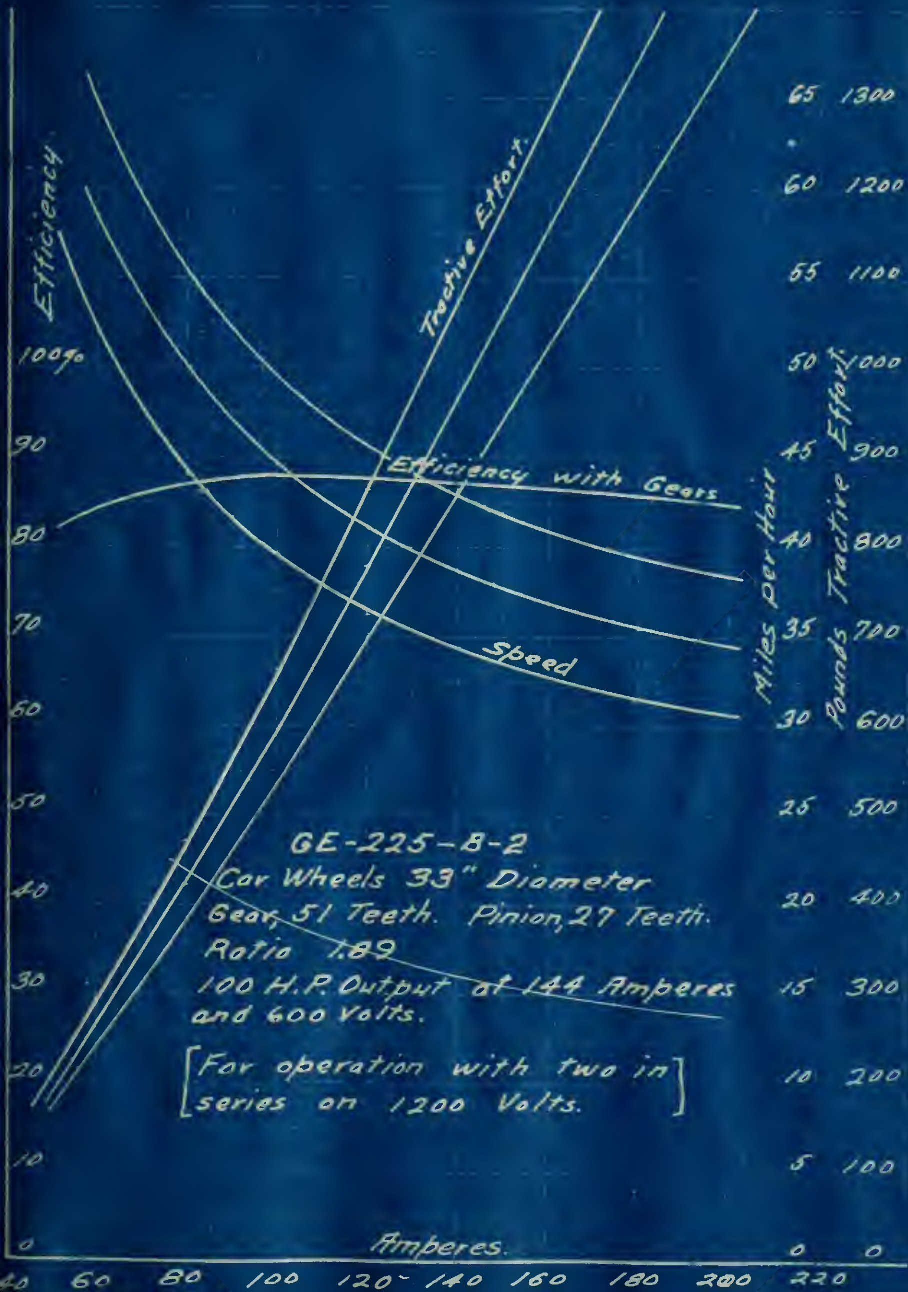

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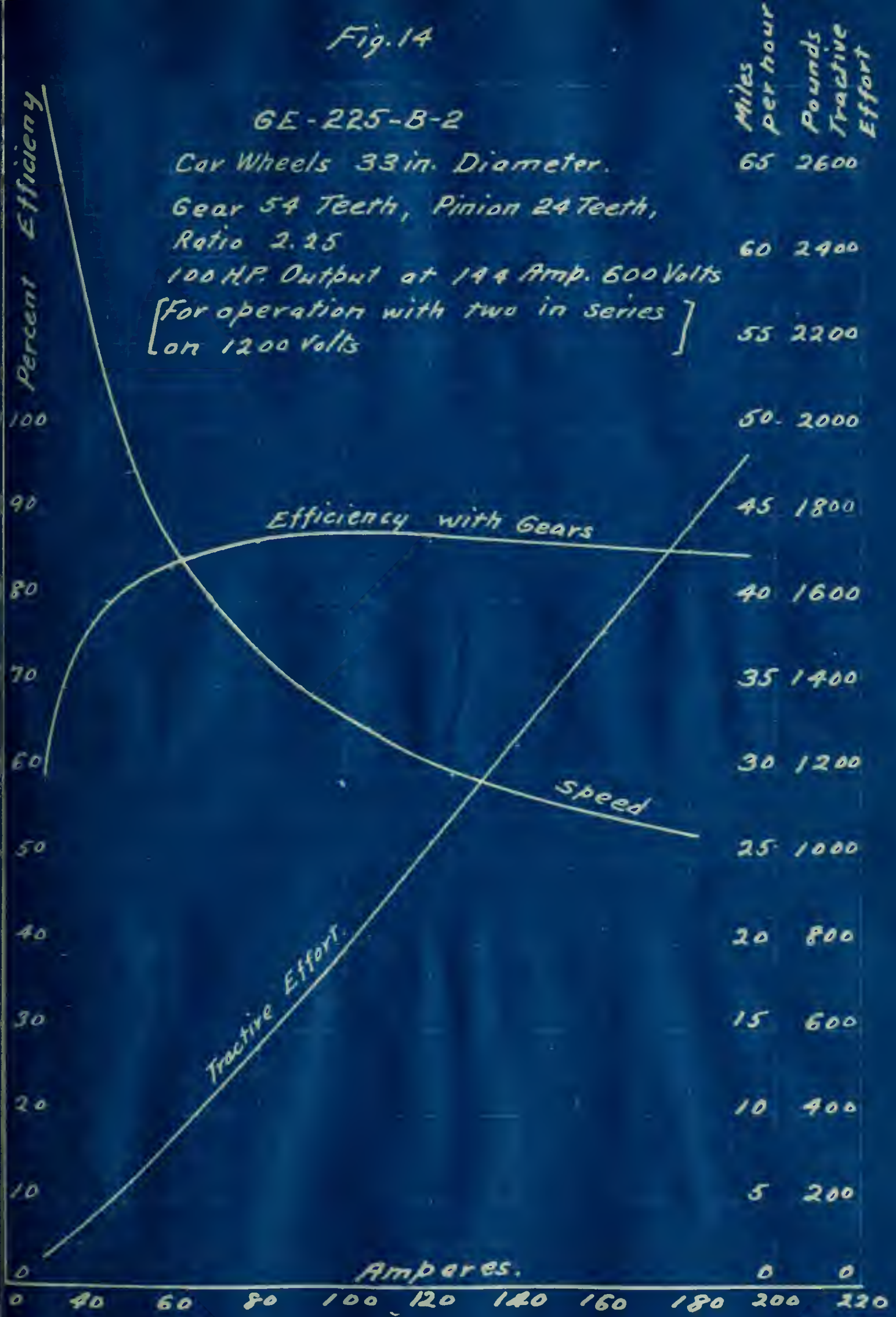
Fig. 14



A. A. Oswald - Engrs. - H. M. Shapiro.

Fig. 15

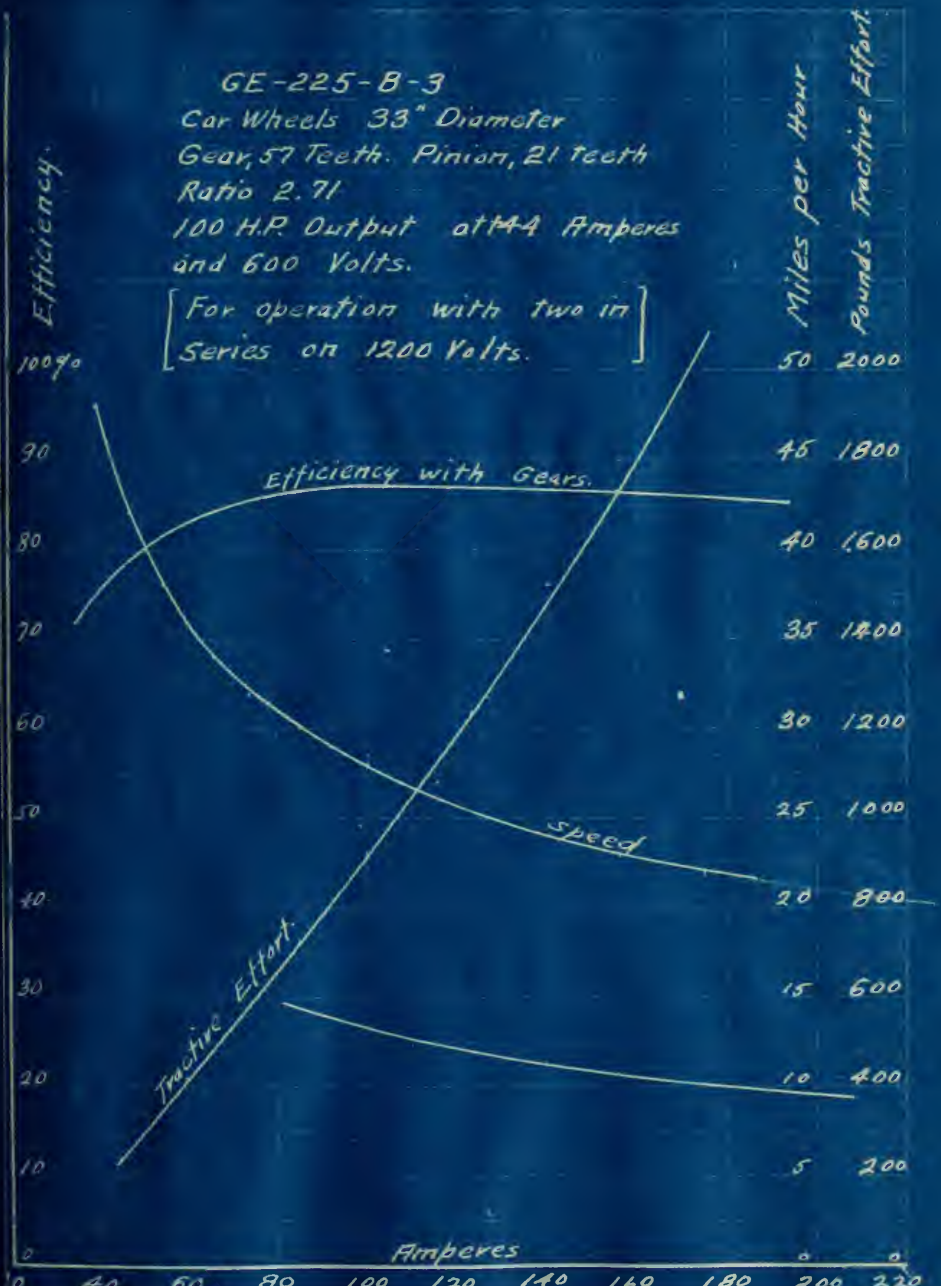


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Fig. 16

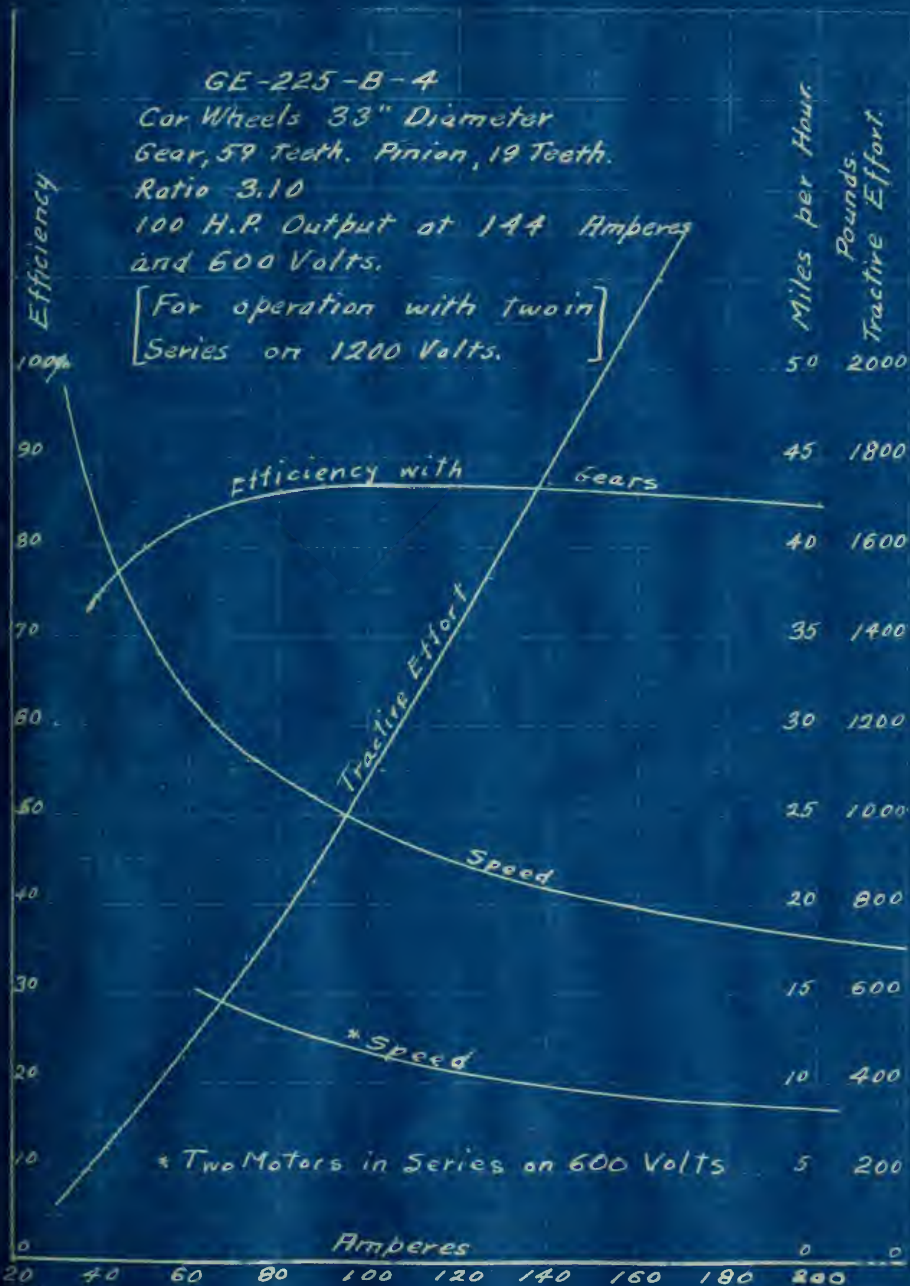

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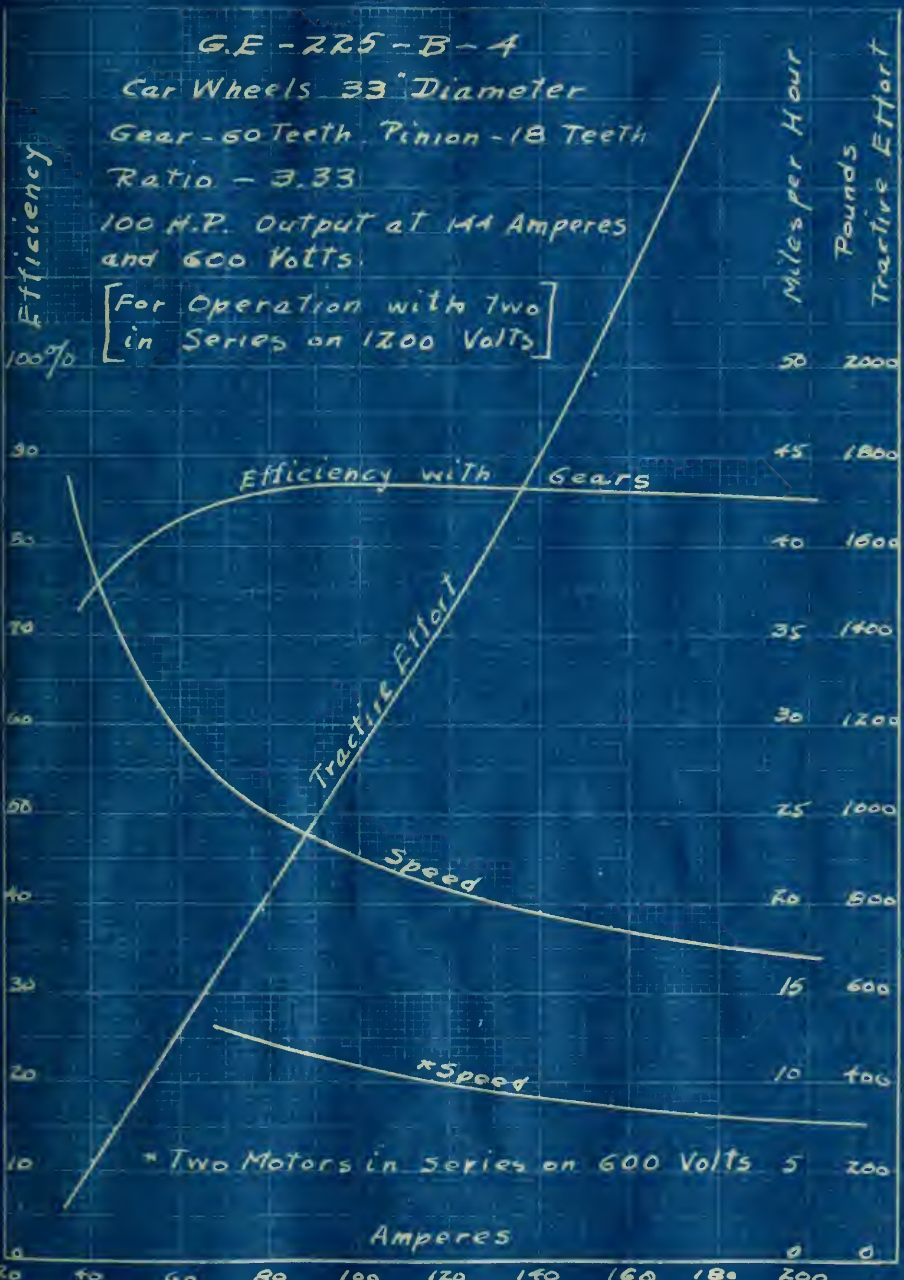
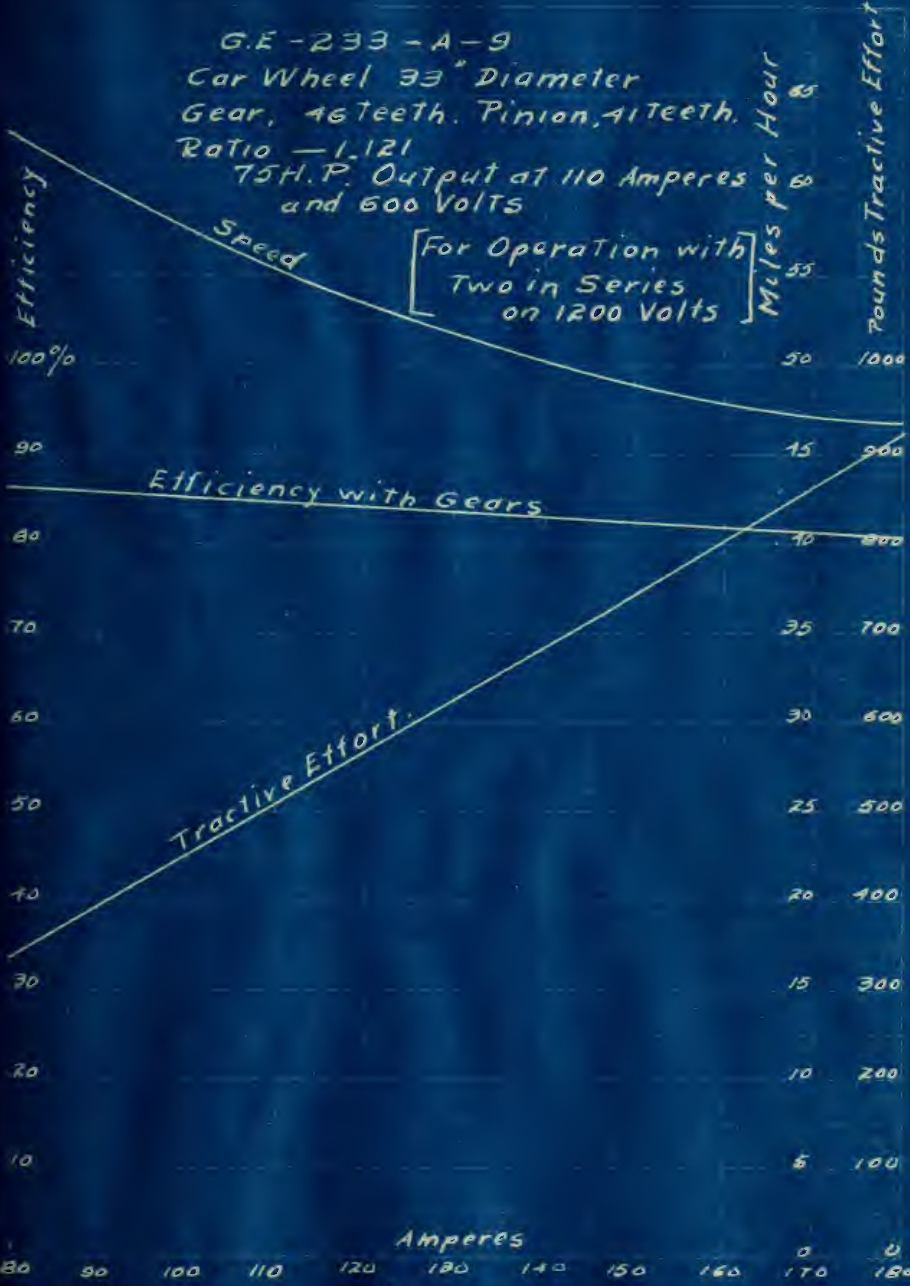
Fig. 17



A. A. Oswald - Engrs - H. M. Shapiro.

Fig. 18



A. A. Oswald. — Eng'rs. — H. M. Shapiro.

Fig. 19

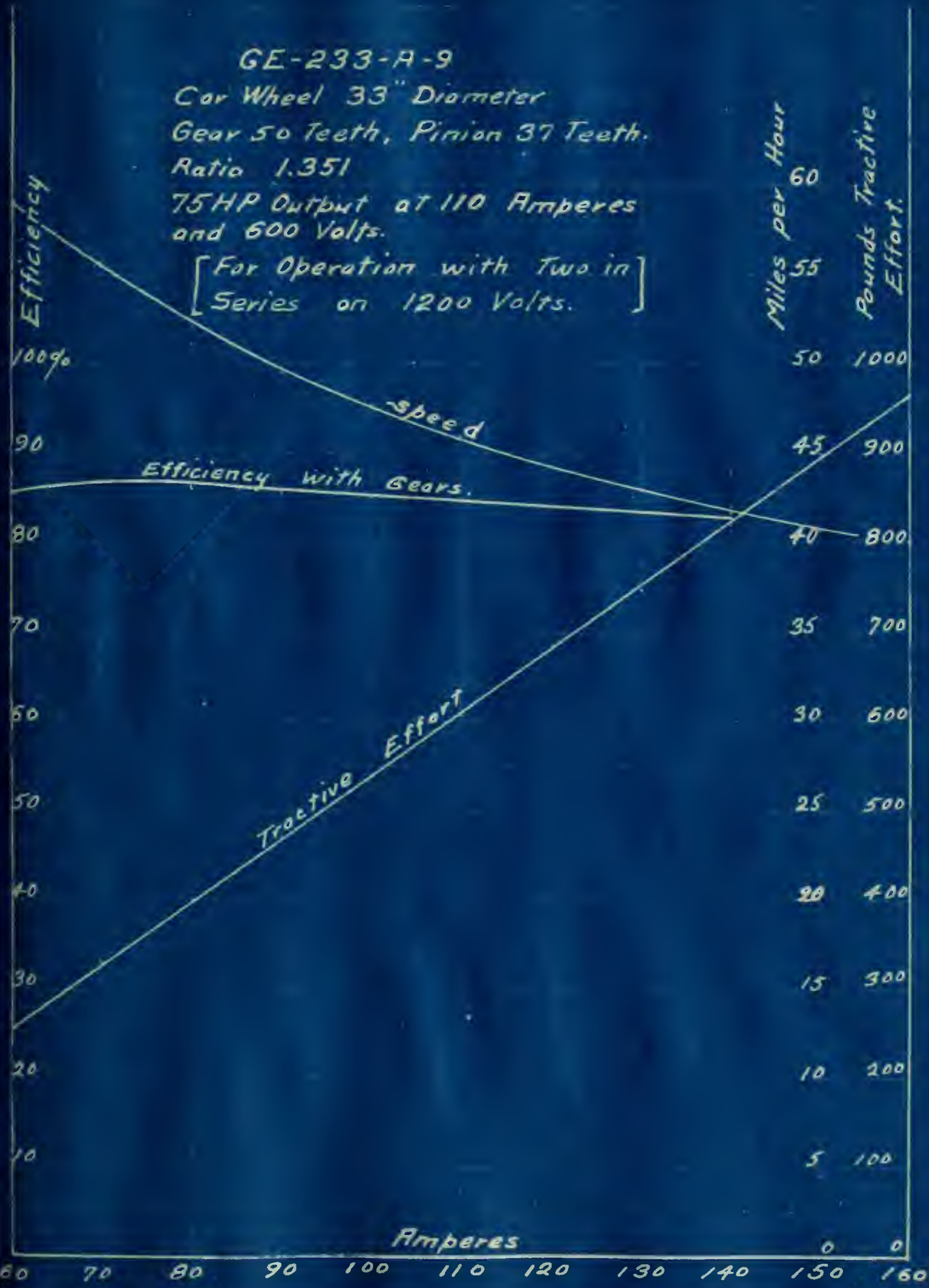


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Fig. 20

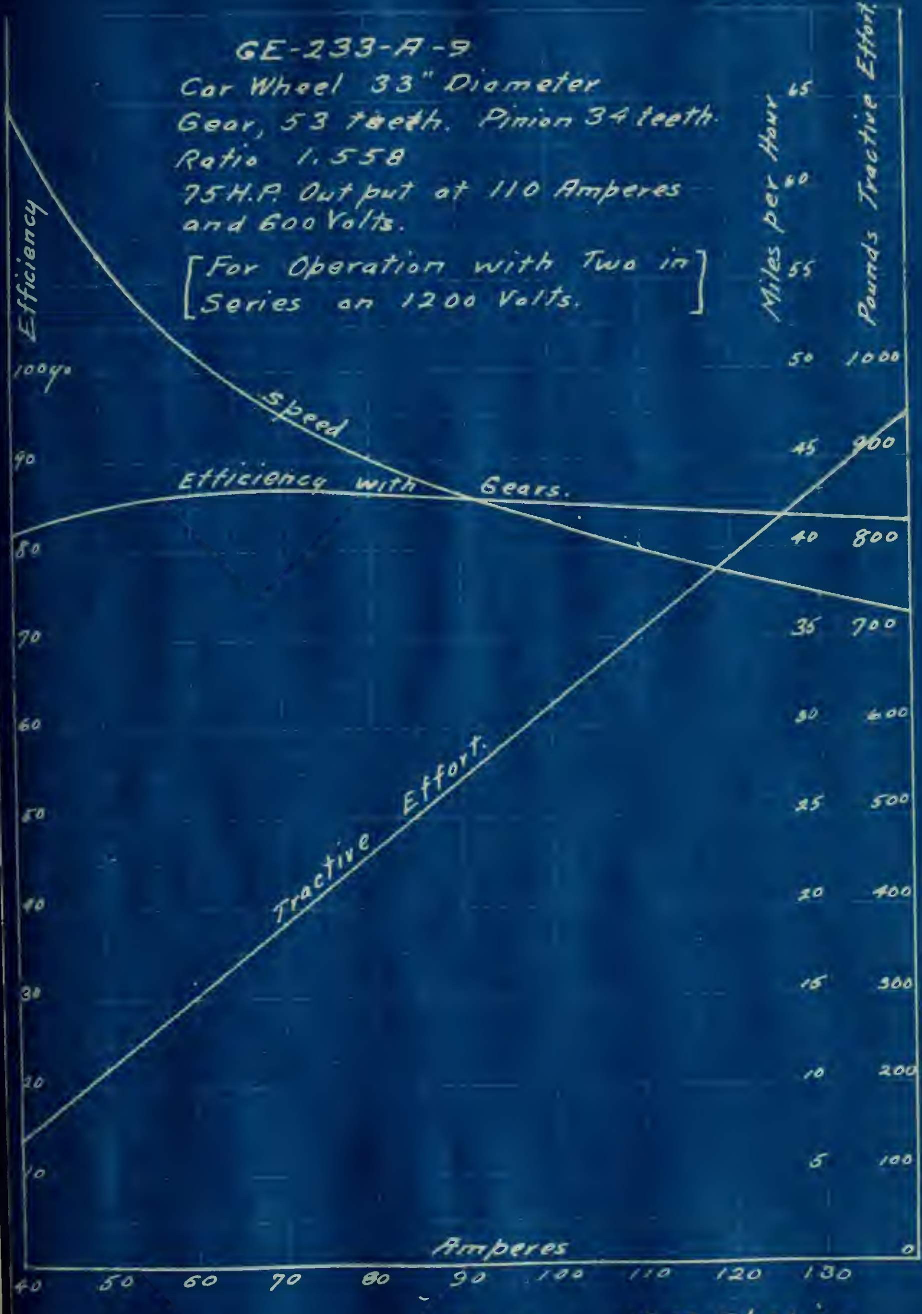

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Fig. 21

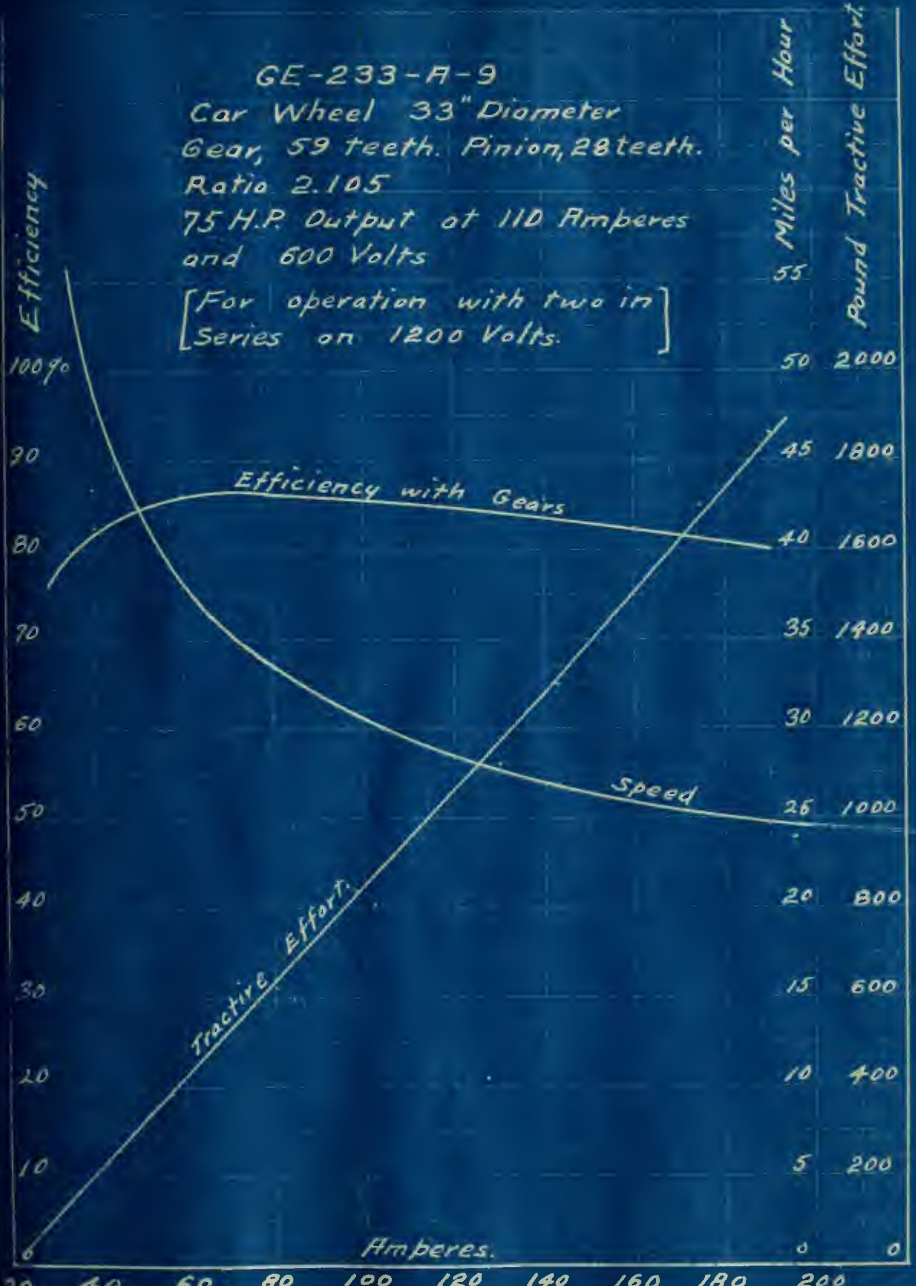

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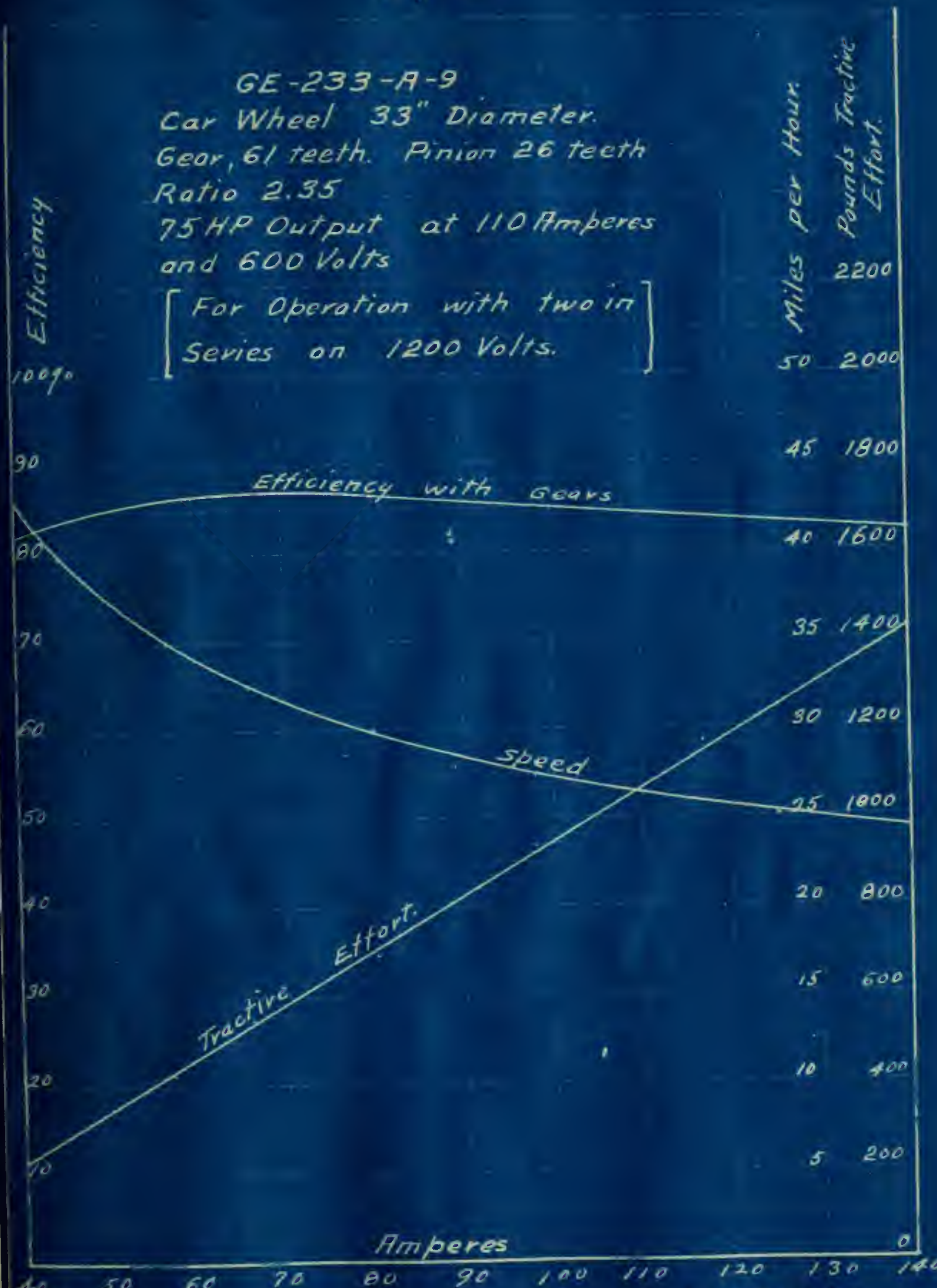
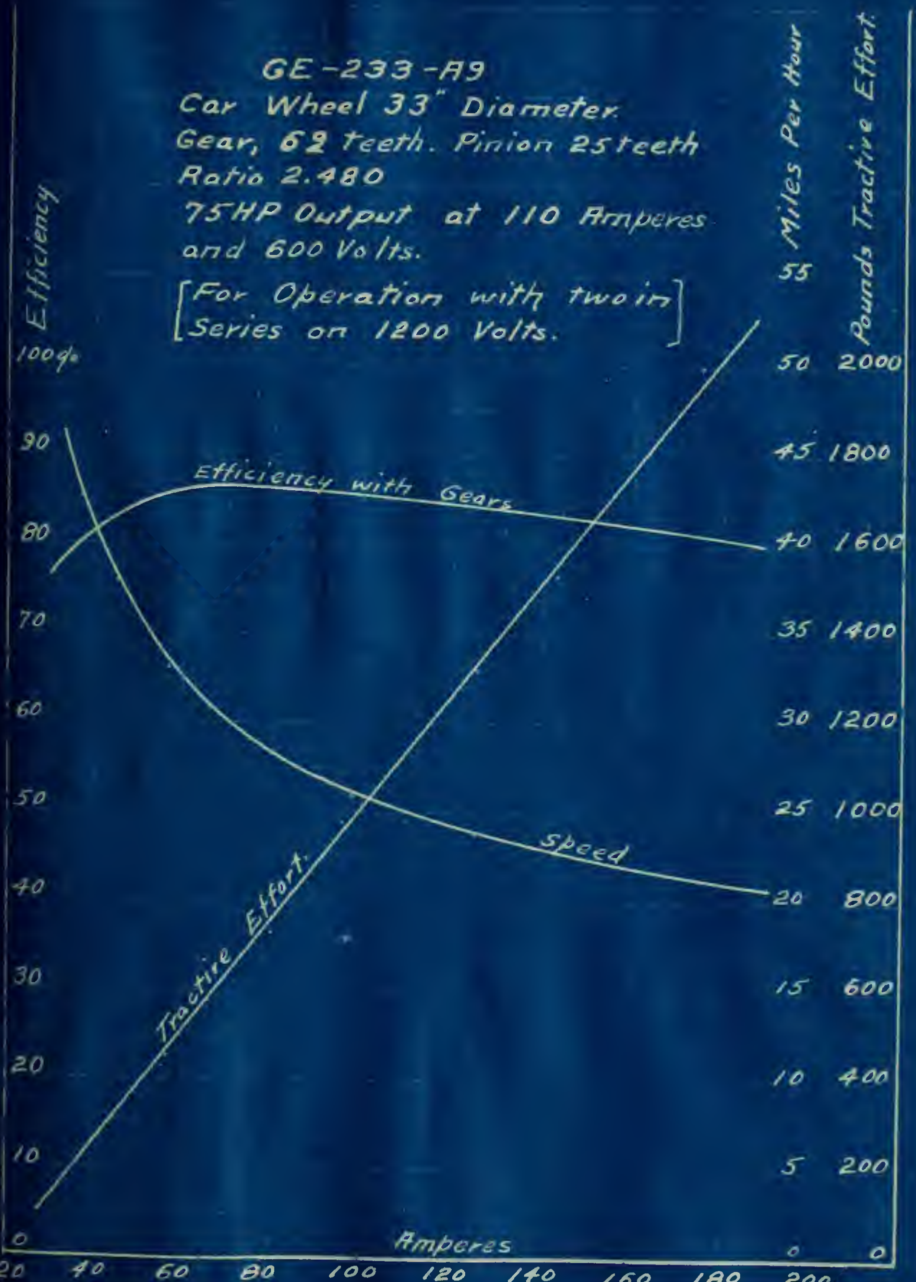
Fig. 22



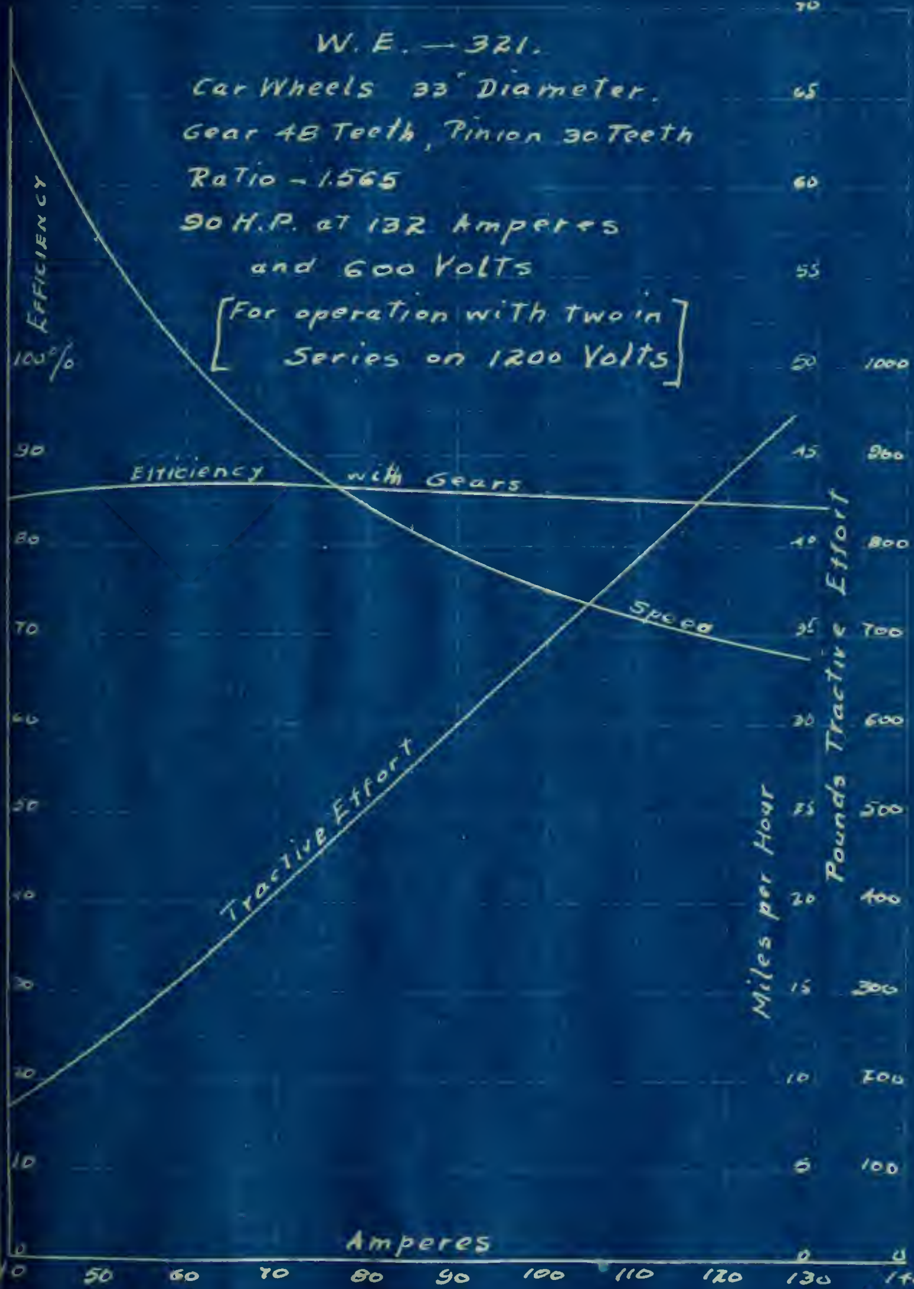
A. A. Oswald. — Eng'rs. — H. M. Shapiro.

Fig. 23



H. A. Oswald — H. M. Shapiro.
Engr's.

Fig. 24



A. A. Oswald - Eng'rs - H. M. Shapiro.

Motor Equipment.

to equivalent accelerations, constructing a chart of acceleration coefficients to represent these forces, combining the accelerations graphically, and with the aid of a chart of recipocals determining time increments corresponding to velocity increments. The summation of these last two items is the speed-time curve from which the subsidiary curves are subsequently derived by reference to the motor characteristics. Plate XXI. is a chart of reciprocals and Plate XXII. to Plate XXVII., inclusive, are charts of coefficients employed in constructing the speed-time curves.

Throughout the work the braking force was assumed to be constant and equal to 150 lbs. per ton. This is equivalent to a uniform negative acceleration of 1.65 miles per hour per second. While this assumption is not theoretically correct, is represents a fair average braking force and, because of the many uncertain elements involved, its use in predetermination caluclations has become an almost universal practice.

Motor Equipment.

Train resistance was calculated from the formula

$$f = \frac{50}{\sqrt{w}} + \frac{v}{25} + \frac{sv^2}{400}$$

where f = resisting force in pounds per ton

w = weight of train in tons

v = velocity in miles per hour

s = square feet projected area of car front

For the car shown in Fig.1 w equals 40 tons and s equals 110 sq. ft. Substituting these values

$$f = 7.91 + \frac{v}{25} + .00688\ v^2$$

To convert (f) to equivilent acceleration (a) we write

$$a = 0.01098\ f$$

or

$$a = 0.01098\ (7.91 + \frac{v}{25} + .00688\ v^2)$$

The curve representing this last equation is designated on the chart of coeficients as "equivalent acceleration of train resistance".

[illegible]

[illegible]

[illegible]

$$[illegible] =$$

where [illegible] = [illegible]

[illegible] = [illegible]

[illegible] = [illegible]

[illegible] = [illegible]

[illegible]

[illegible]

$$[illegible] =$$

[illegible]

[illegible]

$$[illegible] =$$

[illegible]

$$[illegible] =$$

[illegible]

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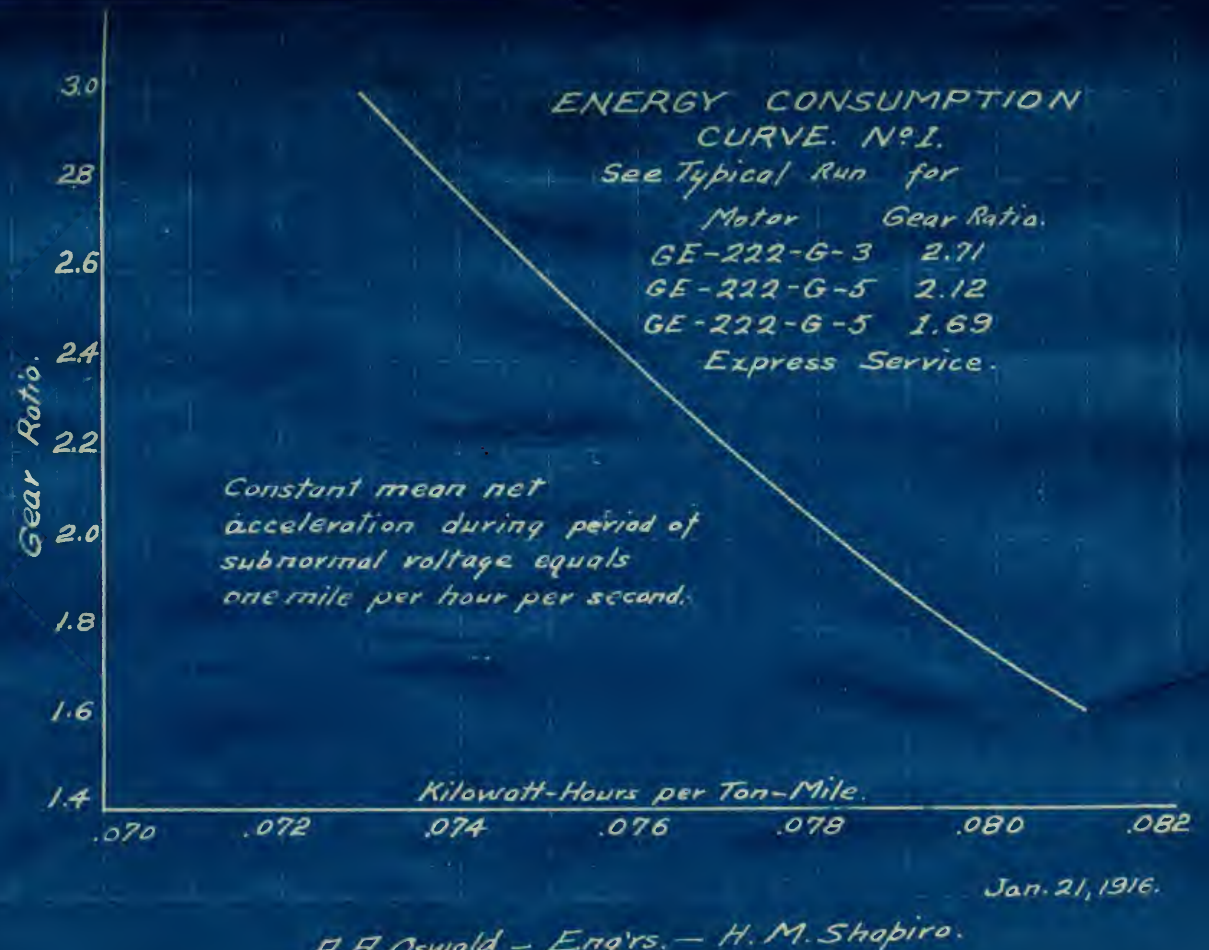
Motor Equipment.

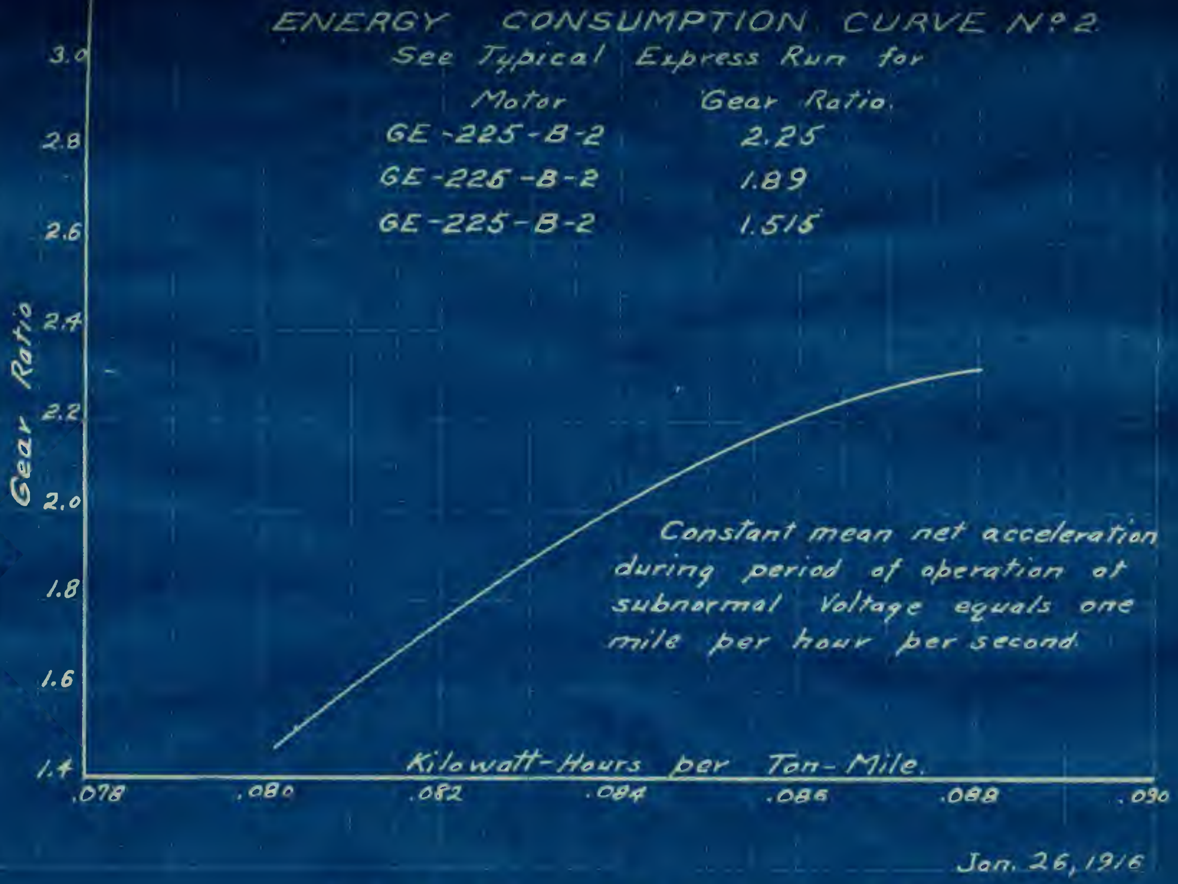
At first it was decided to fix the rate of acceleration during the period of operation on subnormal voltages at one mile per hour per second for all equipment, and to determine that gear ratio which would give a minimum energy consumption. Plate IV. and V. were constructed with this idea in mind. Plate IV. shows three complete speed-time curves and their subsidiary curves for motor GE-222-G; one for each of three gear ratios. Similarly Plate V. shows three curves for motor GE-225-B. The energy consumption curves and motor heating curves derived from Plates IV. and V. are given in Figures 26, 27, 31, and 32.

It soon became apparent, that fixing the rate of acceleration leads to an unfair comparison between motors of different rating and will not result in a selection giving maximum possible economy of operation. This method was abandoned, therefore, in favor of a longer proceedure as follows:



ENERGY CONSUMPTION
CURVE. №1.
See Typical Run for
Motor Gear Ratio.
GE-222-G-3 2.71
GE-222-G-5 2.12
GE-222-G-5 1.69
Express Service.
Constant mean net
acceleration during period of
subnormal voltage equals
one mile per hour per second.
Gear Ratio.
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
Kilowatt-Hours per Ton-Mile.
.070
.072
.074
.076
.078
.080
.082
Jan. 21, 1916.
A. A. Oswald – Eng'rs. – H. M. Shapiro.

Fig. 25



A. A. Oswald. — Eng'rs. — H. M. Shapiro.

Fig. 26

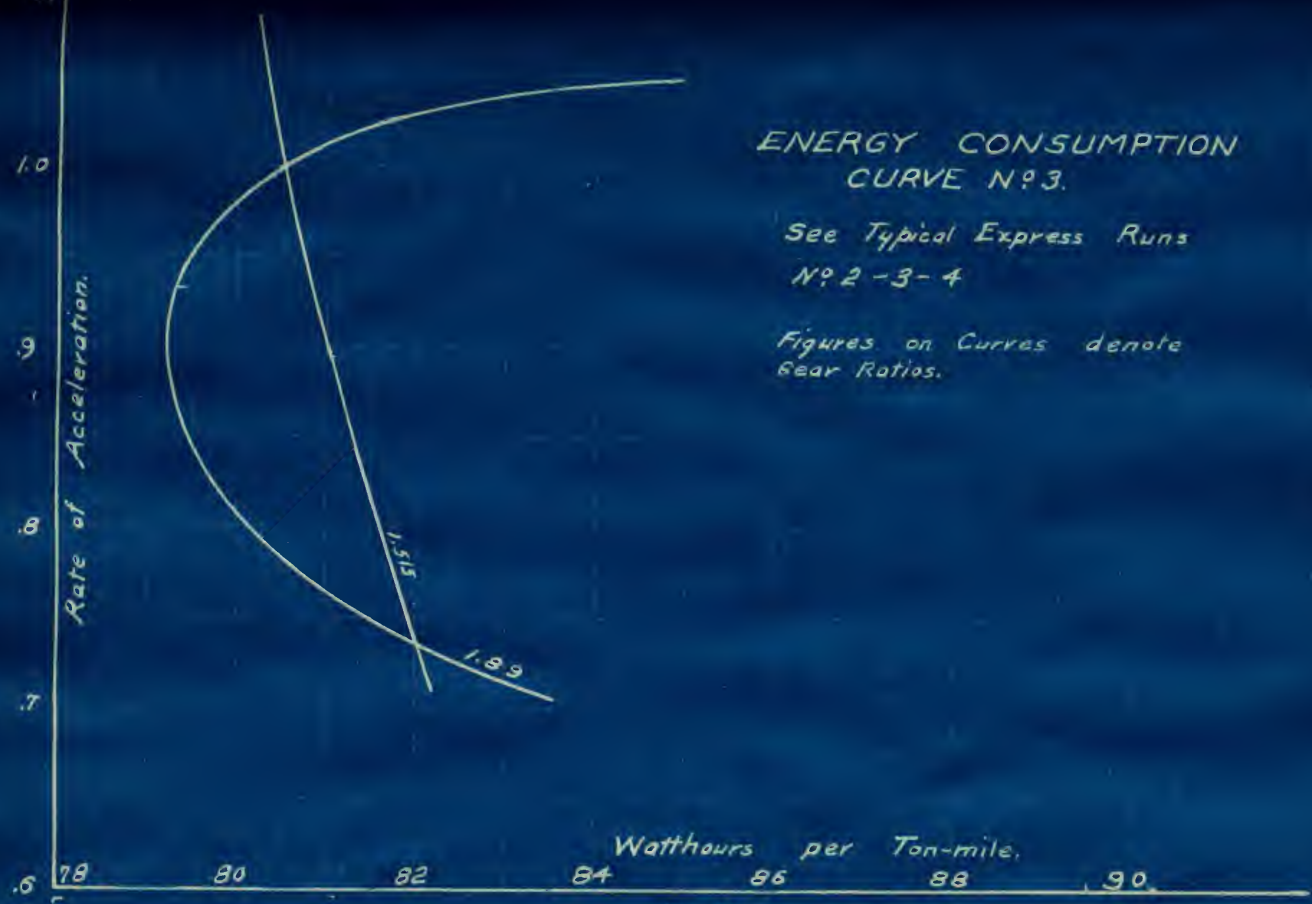


Fig. 27

A.A. Oswald. — Eng'rs. — H.M. Shapiro.

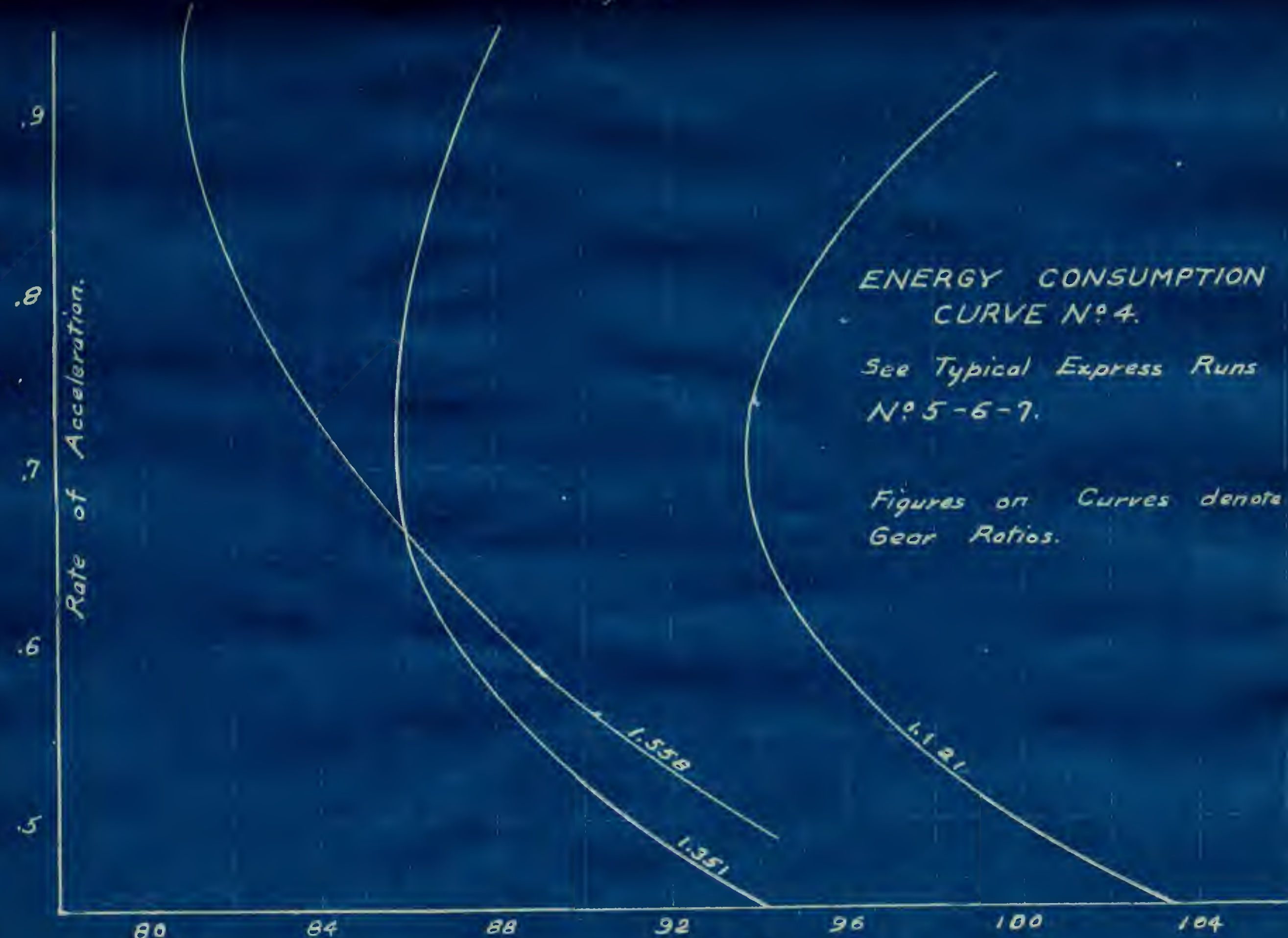


Fig. 28
A. A. Oswald. — Eng'rs. — H. M. Shapiro.

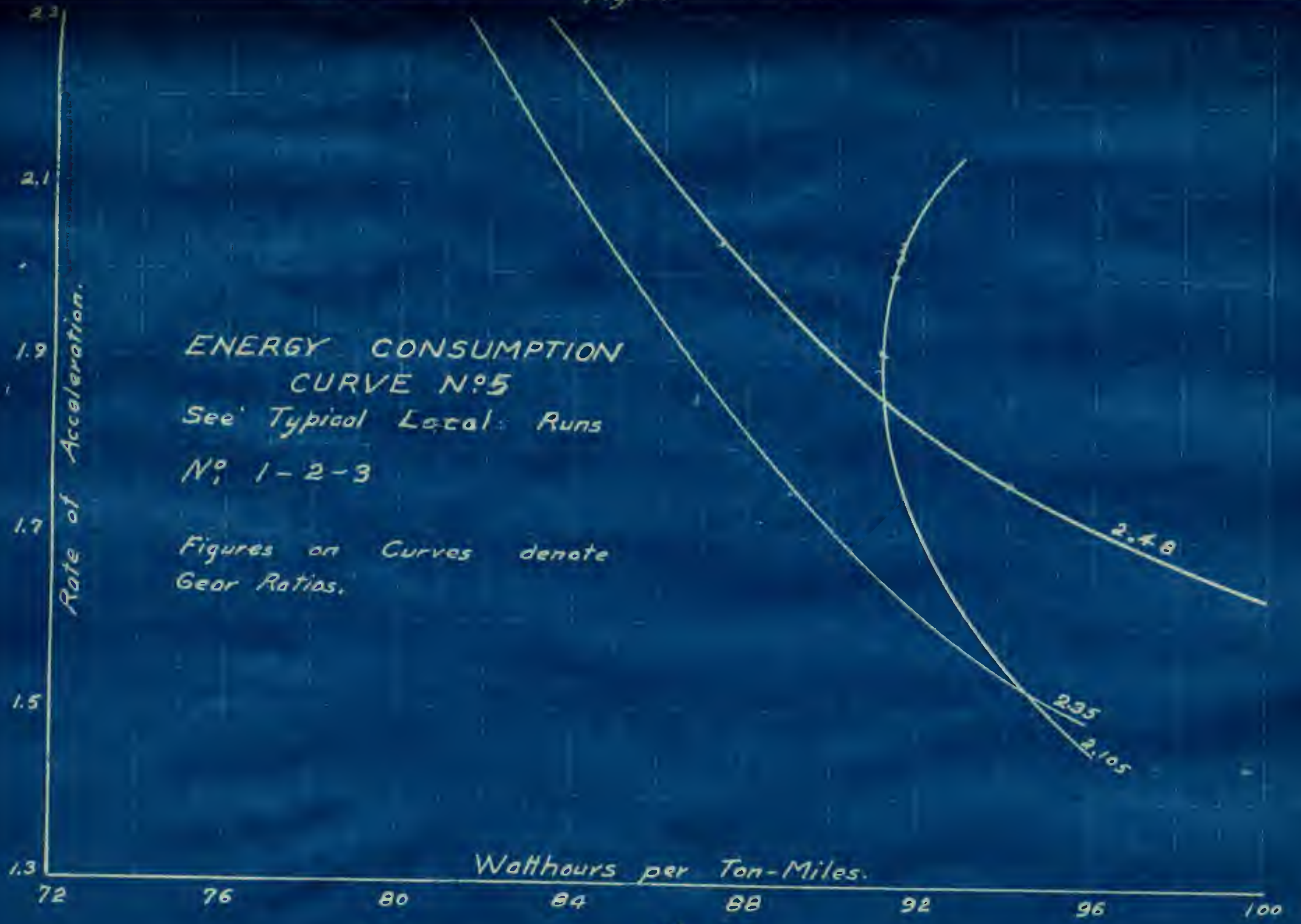


Fig. 29
A. A. Oswald. – Eng'rs. – H. M. Shapiro.

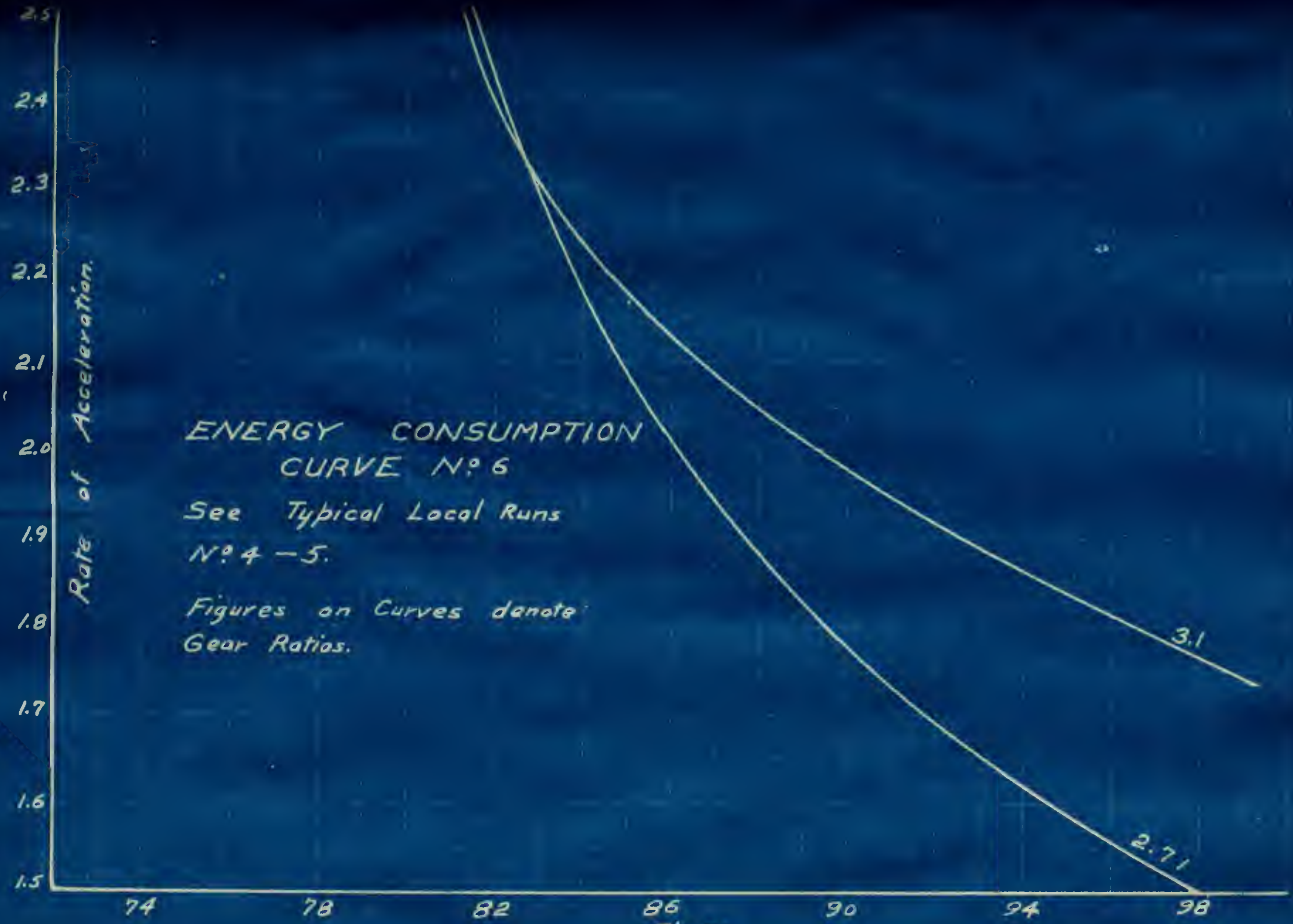


Fig. 30

A. A. Oswald. — Eng'rs. — H. M. Shapiro.

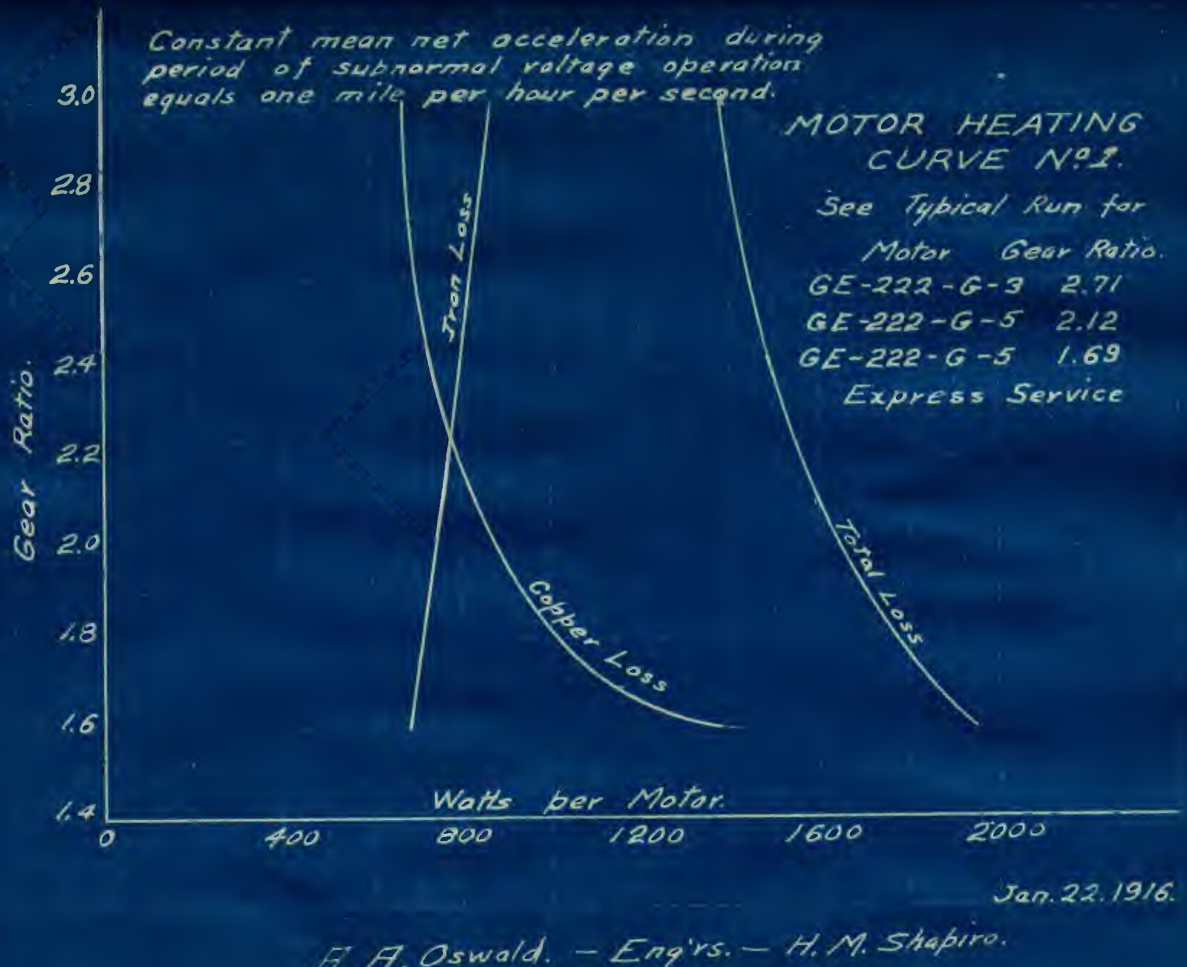
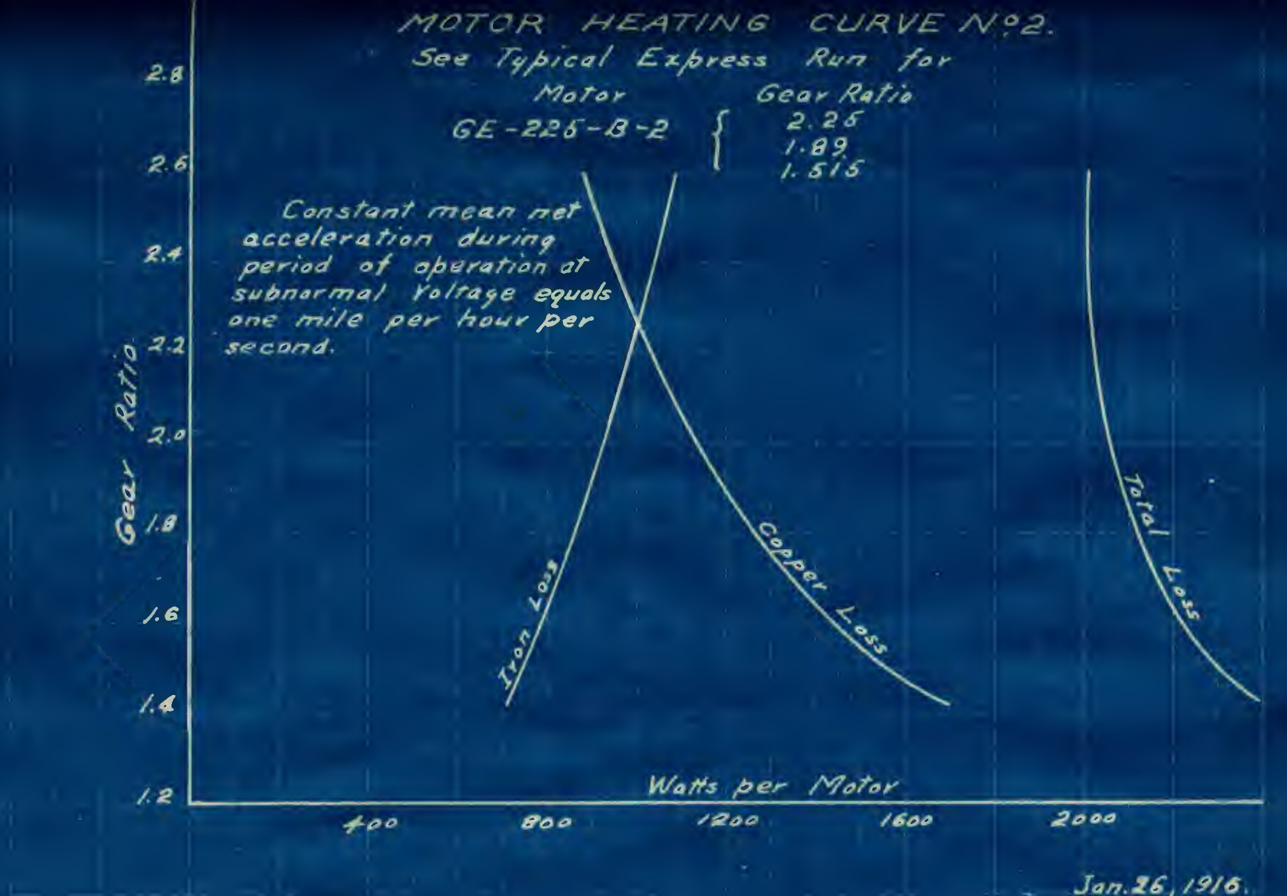

Constant mean net acceleration during
period of subnormal voltage operation
equals one mile per hour per second.
MOTOR HEATING
CURVE No. 1.
See Typical Run for
Motor Gear Ratio.
GE-222-G-3 2.71
GE-222-G-5 2.12
GE-222-G-5 1.69
Express Service
Gear Ratio.
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
Iron Loss
Copper Loss
Total Loss
Watts per Motor.
0
400
800
1200
1600
2000
Jan. 22. 1916.
A. A. Oswald. – Eng'rs. – H. M. Shapiro.

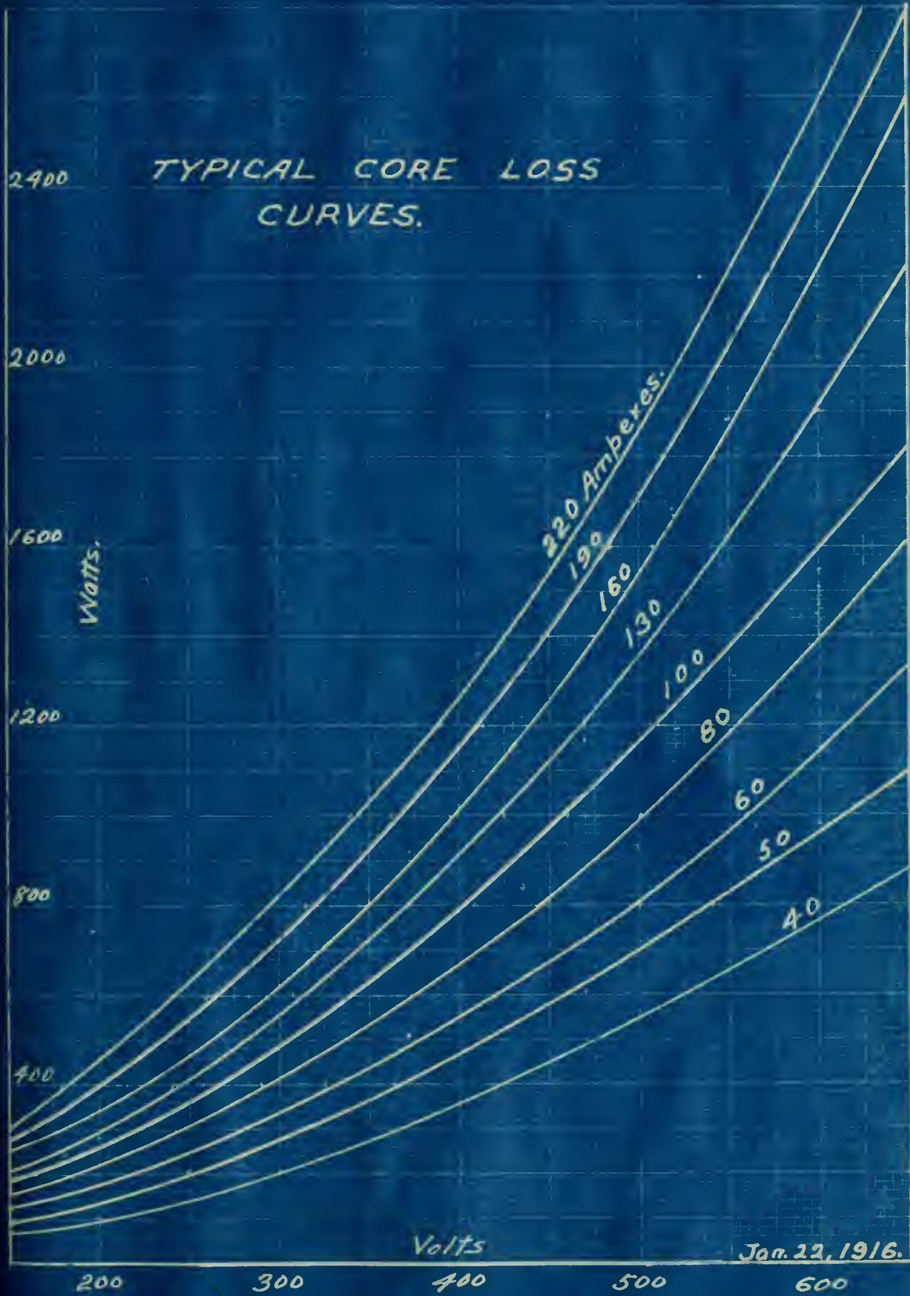
Fig. 31



A. A. Oswald. – Eng'rs. – H. M. Shapiro.

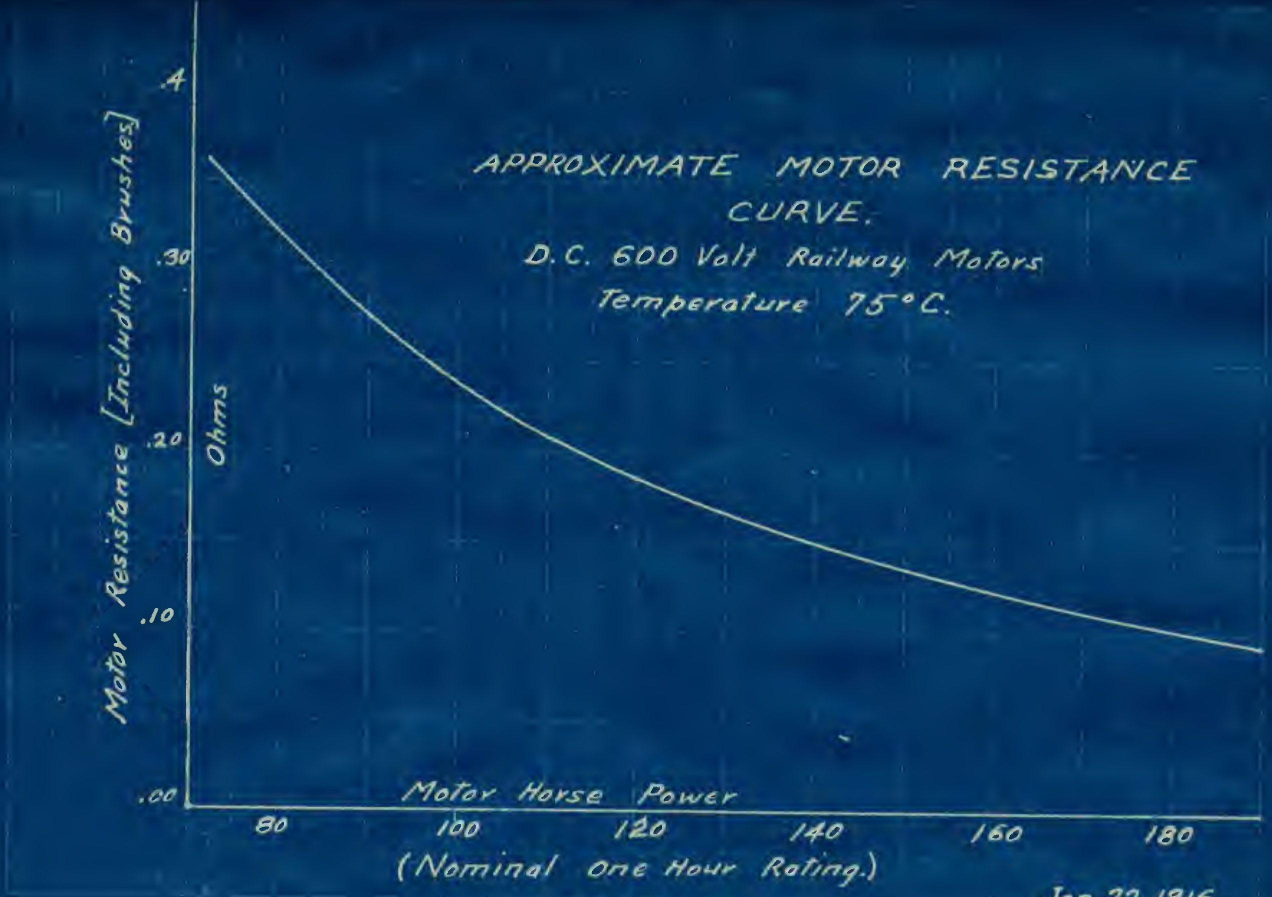
Fig. 32

Fig. 33



A. A. Oswald. — Engrs. — H. M. Shapiro.

Fig. 34



Jan. 22, 1916.

Fig. 34

A. A. Oswald. – Engrs. – H. M. Shapiro.

Motor Equipment.

For each combination of motor and gear ratio, three or more speed-time curves were drawn at different rates of acceleration;

The energy consumption corresponding to these curves was plotted as abscissa against acceleration as ordinates.

Proceeding on this basis, Plate VI. to Plate XV.,inclusive, were drawn. The data previously obtained from Plates IV. and V. was also used, and the energy consumption curves shown in Figures 27, 28, 29 and 30 were plotted.

An examination of these energy consumption curves, indicates that for each of the three motors, there is one gear ratio and one rate of acceleration which requires the least number of kilowatt-hours per ton-mile. For motor GE-225-B in express service, the minimum energy consumption is 0.0792 kilowatt-hours per ton-mile and occurs when the gear ratio is 1.89 and the acceleration is 0.9 miles per hour per second. In local service the same motor consumes 0.086 kilowatt-hours per

Motor Equipment.

ton-mile when the gear ratio is 2.71 and the rate of acceleration does not exceed two miles per hour per second. The use of higher accelerating rates is practical but only when special starting resistance is provided.

For motor GE-233-A in express service the energy consumption reaches a minimum of 0.0805 kilowatt-hours per ton-mile when the gear ratio is 1.558 and the acceleration is 0.95 miles per hour per second. The same motor in local service consumes 0.0852 kilowatt hours per ton-mile at two miles per hour per second when using a gear ratio of 2.35.

Both motors meet the heating requirements; but the commutating limitations of motor GE-233-A are such as to render its use undesirable for express service, because it would be commutating heavy currents at exceptionally high commutator speeds. Motor GE-222-G does not reach half its allowable temperature rise and therefore has excessive capacity. Since it is desirable to have

Motor Equipment.

but one size of motor for all cars (with two sets of gears) in order to reduce the number of spare motors carried in stock, we can confine all further attention to motor GE-225-B.

Having already determined the most efficient gear ratio and rate of acceleration, it is only necessary to consider economy of operation; i.e., minimum cost of energy per car-mile.

The cost of energy delivered at the car is dependent upon the cost of generation divided by the system efficiency, plus the fixed charges on all apparatus between the generators and the trolley wheel. If the maximum demand per car is several times the average demand, all the apparatus in the system must have a kilowatt rating sufficient to carry this maximum at a 100 % momentary over-load without injury , and the fixed charges on this excess capacity, which is required to meet the extreme momentary load, greatly increase the cost of energy at the car.

On large systems where there are hundreds of

Motor Equipment.

cars in operation, the starting current taken by a car does not materially effect the size of power house and substation units; but in an interurban system, such as the prosposed road, where there are but six cars in operation, the ratio of the maximum demand per car to the average demand per car bears a very close relation to the size of substationequipment, and hence it reflects upon the cost of delivering energy to the car. It is possible that what may prove to be the most efficient rate of acceleration is not the most economical one. While one equipment may give a minimum energy consumption, the current demand during acceleration may be such that the increased cost per kilowatt of delivered power more than offsets the actual saving in energy. In such a case a less efficient equipment with a lower maximum demand will be more economical.

In order to reach some conslusions in regard to the economy of operation of motor GE-225-B, Table VI. and the curve in Fig. 35 were prepared.

Motor Equipment.

The figures given in the table are based on a generating cost of 1.25 cents per kilowatt-hour at the power house switchboard, which does not include fixed charges and overhead expenses on the power plant equipment. Assuming an average system efficiency of 75 %, this makes the cost of energy at the trolley wheel, exclusive of fixed charges equal to 1.67 cents per kilowatt-hour.

TABLE VI.

Relation of Maximum Demand per Car to Cost per Kilowatt-Hour.

Ratio	1:1	2:1	3:1
	Cents per K.W.H.		
Energy Cost per K.W.H. at trolley	1.67	1.67	1.67
Fixed Charges on			
Power House	.203	.203	.279
Substation	.116	.116	.174
Transmission Line	.122	.183	.244
Feeder Copper for Equal Regulation	.291	.582	.873

With the aid of the curve shown in Fig. 35, we are now prepared to investigate the advantages that may be obtained by application of a double rate of acceleration and of field control to motor GE-225-B. The use of either double acceleration

Fig. 35

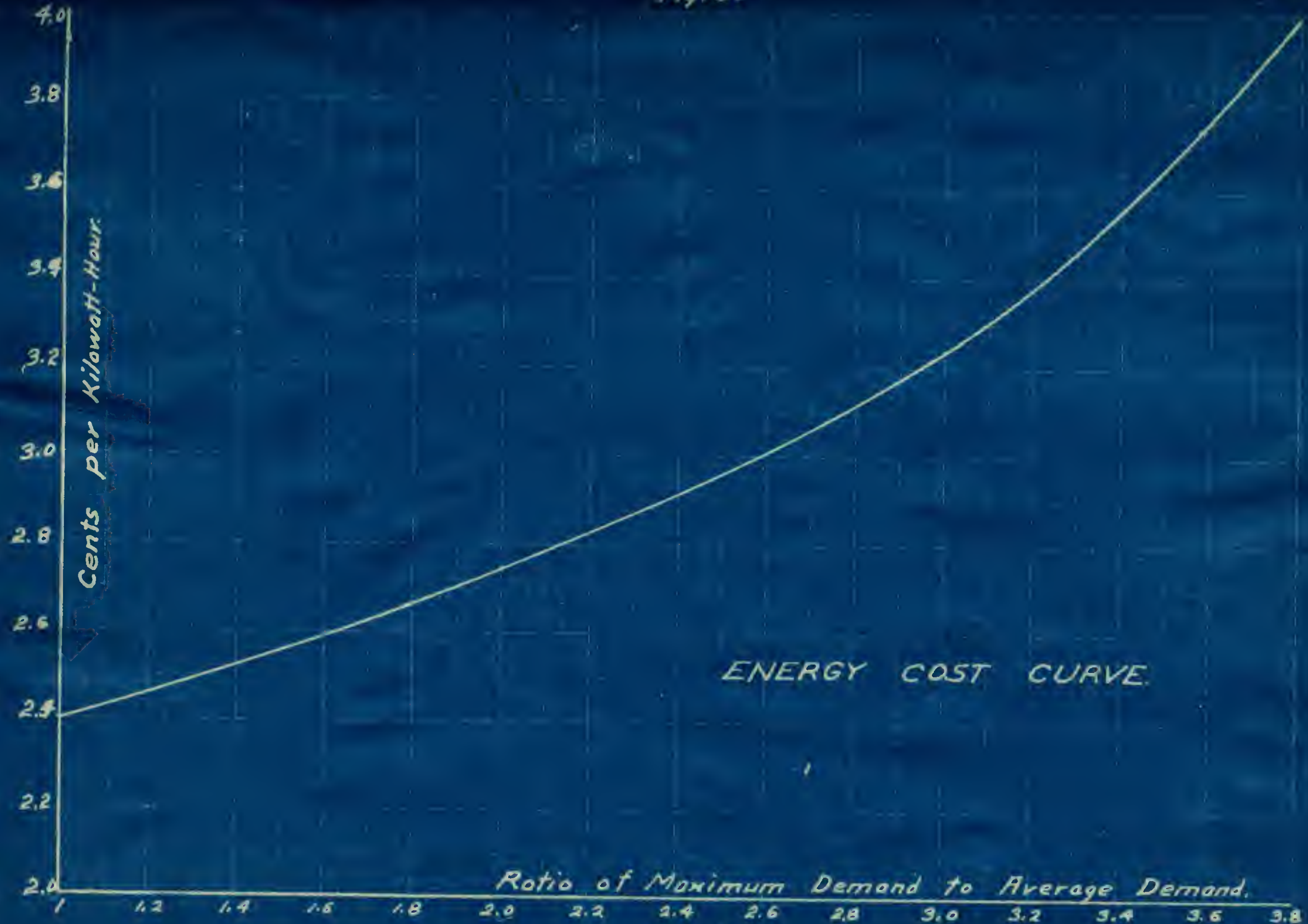


Fig. 35
A. A. Oswald.— Eng'rs. — H. M. Shapiro.

Motor Equipment.

or field control complicates the control system on the cars and can only be justified by showing an increased economy which more than offsets the additional first cost and maintenance.

In so far as speed characteristics is concerned, using field control is equivalent to changing the gear ratio. Hence, to use a 20 % field control in connection with that speed characteristic, which has already been shown to be the most efficient, it is necessary to choose a gear ratio 20 % larger than the one so found.

Plate XVI. to XX., inclusive, show the performance of motor GE-225-B for both local and express service when equipped for two rates of acceleration and for 10 % and 20 % field control. The series accelerating rate is increased slightly over the values used for single acceleration; at the end of the series period the current is allowed to decrease to one-half its original value before the motors are thrown

TABLE VII.

Comparative Costs per Ton-Mile
Motor GE-225-B Express Service.

Acceleration Mi. per hr. per Sec.				Kilowatt Demand per Car.					
Motor Units in Series	Motor Units in Parallel	Gear Ratio	Percent Field Control	Maximum	Average	Demand Ratio	Watt-Hours per Ton-Mile	Cost per K.W.H. in Cents	Cost per Ton-Mile in Cents
0.900	0.900	1.515	0	360	133	2.705	81	3.06	0.248
0.754	0.754	1.515	0	334	134.3	2.48	81.9	2.98	0.341
0.912	0.912	1.89	0	310	130	2.39	79.2	2.91	0.230
0.768	0.768	1.89	0	283	133	2.12	81	2.80	0.228
1.5	0.346	1.89	10	204	130	1.57	81.2	2.58	0.2095
1.5	0.456	1.89	10	228	128	1.78	79.9	2.66	0.2120
1.5	0.612	1.89	10	259	126.8	2.045	79.2	2.76	0.218
1.5	0.456	1.89	20	228	131	1.74	81.8	2.645	0.216
1.5	0.612	1.89	20	264	147.5	1.79	81.5	2.66	0.218
1.5	0.768	1.89	20	288	129	2.23	80.6	2.84	0.229

TABLE VIII.

Comparative Costs per Ton-Mile
Motor GE-225-B Local Service.

Acceleration Mi. per hr. per sec.				Kilowatt Demand per Car					
Motor Units in Series	Motor Units in Parallel	Gear Ratio	Percent Field Control	Maximum	Average	Demand Ratio	Watt-Hours per Ton-Mile	Cost per K.W.H. in Cents	Cost per Ton-Mile in Cents
1.50	1.50	2.71	0	336	109.5	3.07	98.1	3.29	0.323
1.75	1.75	2.71	0	370	101	3.67	90.6	3.84	0.348
2.0	2.0	2.71	0	406	96.1	4.21	86.1	4.26	0.367
2.2	2.2	2.71	0	425	93.3	4.56	83.6	4.55	0.381
2.5	1.0	2.71	0	264	104.6	2.525	94.1	2.97	0.279
2.5	1.5	2.71	0	336	99.0	3.40	88.6	3.56	0.315
1.75	1.75	3.1	0	336	110	3.05	98.7	3.27	0.323
2.0	2.0	3.1	0	350	99.6	3.51	89.3	3.67	0.327
2.2	2.2	3.1	0	391	94.3	4.15	84.5	4.21	0.356
2.5	1.25	3.1	11	266	95.9	2.78	86	3.10	0.298
2.5	1.00	3.1	11	237.5	102.7	2.315	92	2.875	0.2645
2.5	1.00	3.33	20	223	105	2.12	94.1	2.78	0.262
2.5	1.125	3.33	20	240	99.6	2.41	89.3	2.92	0.2605
2.5	1.25	3.33	20	257	96.6	2.66	86.7	3.04	0.263

[illegible]

Motor Equipment.

in parallel; and at the end of the parallel period, the field is weakened first 10 % and later 20 %. The net result of these operations is a practically flat current characteristic for the car, which is almost ideal from the standpoint of substation operation.

The resulting economy is clearly set forth in Tables VII. and VIII. In Table VIII. the best economy with a single rate of acceleration is 0.323 cents per ton-mile; with a double accelerating rate this is reduced to 0.279 cents; and with the application of field control it is further reduced to 0.2605 cents per ton-mile. This is a saving of 19.5 % in the cost of power for local cars. Similarly Table VII. shows a saving of [illegible]8 % in favor of field control for the express cars. Furthemore, the use of field control on express car motors permits operation on several effieient running points and improves the possibility of making up lost time when behind schedule.

The manufacturer's rating for motor GE-225-B

[illegible]

[illegible]

[illegible]

[illegible]

Motor Equipment.

for continuous service with ventilator covers on, is 85.3 amperes at 600 volts for a 65° C. temperature rise. This corresponds to a radiation loss of 3154 watts. Plate XVIII. shows that for local service, the motors will be called upon to radiate an average of 1505 watts. Plate XIX. shows that for express service the required average radiation per motor is 2010 watts. With such a margin there is little chance for this motor to overheat under the most severe conditions that may arise.

Figures 36, 37, and 38 are pictures of motor GE-225-B and its armature.

We recommend:

that motor GE-225-B be adopted for both local and express cars;

that the cars be equipped with four motors permanently connected two in series;

that they be controlled by a multiple unit system and have both 10 % and 20 % field taps;

ARMATURE

Fig. 38

GE-225-B RAI[illegible] OTOR

Fig. 36

Fig. 37

Motor Equipment.

that the gear ratio be 1.89 for express car motors and 3.33 for local car motors;

that the express cars have a series acceleration of 1.5 miles per hour per sec-ond and a parallel acceleration of 0.346 miles per hour per second;

that the local cars have a series acceleration of 2.5 miles per hour per sec-ond and a parallel acceleration of 1.125 miles per hour per second;

that express motors operate normally on 10 % field tap at full speed, 20 % to be used only when the car is behind schedule;

that the local cars operate normally on the 20 % field at full speed.

SUBSTATIONS AND SECONDARY DISTRIBUTING SYSTEM.

There are certain points along the roadway of a traction system, which may be considered as natural points for the location of substations. These are: the centroids of load, the power house when it is located on the line, and the middle or a point near the remote ends of the terminal sections. It is often desirable to have a substation located at a passenger station and in choosing location this has been kept in mind.

The recent success of automatically operated substations on interurban systems has proved conclusively the economic value of such installations The big item in substation operating costs is the wages of the attendants. The cost per station for a complete automatic equipment, installed in addition to the usual manually operated switchgear is $2700. Interest, depreciation, taxes, and insurance on this investment amounts to $405 per year, which is about one-fifth of the annual wages for substation attendance. In a five substation system two men inspect the automatic switchgear

Substations and Secondary Distributing System.

in each substation, twice daily. They take the place of eight regular operators, the substation at the power house being under the supervision of the power house attendant.

The adoption of automatic substations permits the use of smaller units spaced nearer together along the route, thereby giving better voltage regulation and a higher system efficiency. The drooping voltage characteristic of such a sub-station makes it possible for adjacent substations to aid in carrying the peak load that may occur on a station due to several cars starting or passing in its immediate vicinity.

In view of these facts we favor automatic substations and in all estimates shall work on the assumption that automatic equipment will be installed. The cost of operation, therefore, will be a minimum when the fixed charges are a minimum with all feeders of the most economic cross section.

If p = cost per 100 lbs. of conductor

Substations and Secondary Distributing System.

p' = cost of energy per horsepower-year

a = interest and depreciation

then the economical voltage drop per mile is

$$e = 8.1\sqrt{\frac{a \times p}{p'}}$$

With copper at $0.25 per pound p = $25. The cost of energy at the substation direct current bus is approximately two cents per kilowatt-hour or $109 per horsepower-year. Substituting these values in the above equation gives 11.4 volts drop per mile or

$$6750\sqrt{\frac{109}{25 \times 8.03}} = 5000 \text{ circular mills per ampere.}$$

It is at once evident that the use of the most economical feeder cross sections on a new road is prohibitive because of the tremendous outlay for copper.

The feeder system in each plan considered shall be designed for a maximum drop of 300 volts and later, when the road has become well established, additional copper may be added in order to reach the best operating economy. Hence, for the present case, the total operating cost will be a

minimum when the first cost is a minimum.

The number, capacity, and location of substations is so intimately related to the cost of the secondary distributing system, that satisfactory conclusions can only be reached by treating the whole system as a unit. We shall roughly estimate the cost of three systems having four, five, and six substations respectively, and shall determine therefrom, which system will be the most economical.

For the purpose of observing the effect of substation spacing upon the total cost of high tension transmission lines, $1420 will be taken as a first estimate of the cost per mile for 33,000-volt, three-phasetransmission lines. This is sufficiently accurate for making comparisons and will be reconsidered when the transmission line itself is taken up.

Four Substation Plan.

Consider first, the four substation plan with stations located as follows.

Substations and Secondary Distributing System.

Name of Substation	Distance from Danville Limits
Rileysburg	6.5 miles
Walnut Grove	20.6 "
Summit Grove	34.5 "
Evanslane	46.0 "

Plate XXVIII. is a chart showing the division of load between the substations for an express car or a local car at any point of the line. With the aid of this chart and the train sheet, Plate II., the substation average load curves, Plate XXIX., were plotted for the morning peak load. These curves include a 10 % allowance for air compressor, car lighting, headlight and control circuit power.

The ratio of average demand to maximum demand for express cars is 1.57 and for local cars is 2.12. On the assumption that at least one car in a section is taking normal running current or is coasting when the othersare starting, we shall use the ratio 1.57 in determining maximum momentary load. Should the momentary load exceed the value so estimated, the drooping voltage characteristic of the nearest substation will compel adjacent sub-

station to take a greater proportion of the load, thus saving the apparatus from destruction.

The average maximum peak load on Evanslane substation is 425 K.W. The maximum momentary load is, therefore,

$$1.57 \times 425 = 640 \text{ K.W.}$$

and the substation rating for a 100 % overload is $\frac{640}{2} = 320$ K.W.

Since this peak is of short duration and Summit Grove is running light during the same period, we believe a 300 K. W. rotary converter will suffice. The remaining 20 K. W. can be carried by Summit Grove.

The Summit Grove average maximum peak is 400 K. W. and the momentary maximum is

$$1.57 \times 400 = 628 \text{ K.W.}$$

making the converter rating equal 314 K. W. This is for extreme conditions in the morning, while the normal periodic peak calls for a converter rating of 270 K. W. Hence, a 300 K. W. converter will suffice.

Similarly Walnut Grove requires a converter

Substations and Secondary Distributing System.

rating of 225 K. W. We believe this should be increased to 300 K. W. in order to help out Rileysburg which has a very peculiar load curve.

The Rileysburg average maximum peak is 500 K. W. which requires a 375 K. W. converter rating. The normal periodic peak is but 300 K. W. and requires a converter rating of 225 K. W. Hence, if a 300 K. W. rotary converter be installed, the remaining 75 K. W. can be carried by Walnut Grove, which was overrrated by that amount. The use of converters all of one size has several advantages and, as already explained, the transfer of load during peaks to nearby substations is easily accomplished with automatically operated substations.

Approximate Cost of a 300 K. W.

Automatic Rotary Converter Substation.

300 K.W., 1300-volt rotary converter at $10 per K.W.	$ 3000
3 single-phase, 125 kva, 33,000-volt transformers at $7 per K.W.	2620
Switchgear	1900
Automatic Equipment	2700
Total Electrical Equipment	$10220

Substations and Secondary Distributing System.

Building and Fixtures	$ 2620
Erection	2410
Miscellaneous	150
Total..	$15,400

In orderthat the line drop will not exceed 300 volts under the worst conditions occuring in any section between substations, a 4/0 trolley is required in conjunction with the following feeders:

6 miles of 4/0 south of Evanslane
8 miles 250,000 cir. mils Walnut Grove to Summit Grove
8 miles 300,000 cir. mils Walnut Grove to Summit Grove.
6.5 miles 2/0 feeder north of Rileysburg

Summing up the cost of a four substation plan, we have:

Cost of Four Substation System

4 Substations 300 K.W.	$61,600
39.5 miles of transmission line	56,100
56 miles 4/0 grooved trolley wire	47,400
Rileysburg north feeder	3,830
Walnut Grove north feeder) Summit Grove north feeder)	17,580
Evanslane south feeder	5,075
Total	$191,585

Substation and Secondary Distributing System.

Five Substation Plan.

In the five substation plan the stations are located as follows:

Name of Substation	Distance from Danville Limits
Rileysburg	5.4 miles
Cayuga	17.5 "
Worthy	27.7 "
Jackson	38.8 "
Otter Creek	48.0 "

Proceeding in the same manner as before, the substatin load curves shown in Plate XXX. were plotted. Otter Creek substation has an average maximum peak load of 516 K.W., and a periodic average peak of 435 K. W. lasting six minutes. Its momentary rating should therefore be 340 K. W. However, Jackson and Worthy substations each have small loads during the Otter Creek peak and, therefore, a 300 K. W. rotary converter at Otter Creek will be sufficient.

Jackson substation has an average maximum peak load of 300 K. W. and a momentary load of 470 K. W. This calls for a rating of 230 K. W. and since the peak load occurs at the same time as the one at Worthy, and further since Jackson

is expected to carry a portion of the Otter Creek peak, we believe a 250 K. W. rotary converter should be installed.

Worthy substation has an average maximum peak of 425 K. W. lasting 20 minutes. The remainder of the day the period average peak is 300 K. W. Therefore, we believe that a 300 K. W. rotary converter will answer for all but the extreme morning peak, which can be carried partly by Jackson, where there is excess capacity, and partly by overrating Cayuga.

Cayuga requires but 200 K. W. but this has been increased to 250 K. W. in order that this station may crossfeed to both Worthy and Rileysburg during peaks at these stations.

Similarly Rileysburg needs but 250 K. W. with the schedule as it is now arranged but a change in schedule might give this station a load similar to that at Otter Creek, hence, we shall use a 300 K. W. rotary converter at this point in order that desirable shifts in schedule will

Substations and Secondary Distributing System.

not be hampered by limited substation capacity.

The following is an estimate of the cost of a 250 K. W. substation.

Approximate Cost of a 250 K. W.

Automatic Rotary Converter Substation.

250 K. W., 1300-volt rotary converter at $10.25 per K. W.	$ 2,700
3 - single-phase, 100 kva, 33,000-volt transformers at $8.25 per K. W.	2,500
Switchgear	1,600
Automatic Equipment	2,700
Total Electrical Equipment	$ 9,500
Building and Fixtures	2,400
Erection	2,130
Miscellaneous	140
Total	$14,170

In order that the line drop will not exceed 300 volts under the worst condition occuring in any section between substations, a 2/0 trolley wire is required in conjunction with the following feeders:

Size	Length	Location	Cost
2/0	5.4 miles	Rileysburg north	$ 2,280
#1	12.1 "	Rileysburg to Cayuga	4,050
2/0	11.1 "	Worthy to Jackson	5,900
2/0	4.0 "	Otter Creek south	2,130
		Total	$14,360

Substations and Secondary Distributing System.

Summing up the costs of a five substation plan, we have;

Cost of Five Substation System.

3 Substations 300 K.W.	$ 46,200
2 Substations 250 K.W.	28,340
56 miles 2/0 grooved trolley wires	29,800
Feeders	14,360
42.6 miles of transmission line	60,500
Total	$179,200

Six Substation Plan.

In the six substation plan the stations are located as follows:

Name of Substation	Distance from Danville Limits
Rileysburg	5.0 miles
Dickason	13.7 "
Newport	22.9 "
Hillsdale	30.8 "
Clinton	39.2 "
Otter Creek	48.0 "

Proceeding as before the substation load curves shown in Plate XXXI. were plotted.

Otter Creek substation has a maximum average peak of 325 K. W. and a periodic avergge peak of 285 K. W. The maximum peak rating is therefore

$$\frac{325 \times 1.57}{2} = 250 \text{ K. W.}$$

and the periodic peak rating is

Substations and Secondary Distributing System.

$$\frac{285 \times 1.57}{2} = 225 \text{ K. W.}$$

This being an end substation we believe a 250 K. W. rotary converter should be installed.

Clinton substation has a maximum average peak load of 225 K. W. and a periodic peak load of 200 K. W. This requires a rating of 175 K. W. and 160 K. W. respectively. In order to carry a portion of the Hillsdale peak we recommend a 200 K. W. rotary converter.

Hillsdale substation has an average maximum peak load of 342 K. W. and an average periodic peak load of 250 K. W. This requires a rotary converter rating of 270 K. W. and 200 K. W. respectively. Since Clinton has excess capacity the Hillsdale rotary converter need be but 250 K. W.

Newport substation has a 240 K. W. average maximum peak and a 140 K. W. average periodic peak. A 150 K. W. rotary converter will suffice because the morning peak comes when Dickason is running light.

Similarly Dickason substation will need but

Substations and Secondary Distributing System.

a 150 K. W. rated capacity because its morning peak comes when Newport has a light load.

Rilesburg substation requires a maximum peak rating of 235 K. W. It being an end station and, furthermore, because its load reaches peak values simultaneously with Dickason, no crossfeeding can be expected. Hence, we believe a 250 K. W. rotary converter should be installed.

The following are estimates of the cost of a 200 K. W. and a 150 K. W. substation.

Approximate Cost of a 200 K. W.

Automatic Rotary Converter Substation.

200 K. W., 1300-volt rotary converter at $11.00 per K. W.	$ 2,200
3 single-phase, 100 kva, 33,000-volt transformers at $8.25 per K. W.	2,500
Switchgear	1,250
Automatic Equipment	2,700
Total Electrical Equipment	$ 8,650
Building and Fixtures	2,200
Erection	1,940
Miscellaneous	130
Total	$ 12,920

Substations and Secondary Distributing System.

Approximate Cost of a 150 K. W.

Automatic Rotary Converter Substation.

150 K. W., 1300-volt rotary converter at $11.50 per K.W.	$ 1,700
3 single-phase, 75 kva, 33,000-volt transformers at $10 per K. W.	2,250
Switchgear	1,150
Automatic Equipment	2,700
Total Electrical Equipment	$ 7,800
Building and Fixtures	1,850
Erection	1,720
Miscellaneous	115
Total	$11,485

In order that the line drop will not exceed 300 volts under the worst conditions occuring in any section between substations a 2/0 trolley wire is required in conjunction with the following feeders:

Size	Length	Location	Cost
2/0	4.0 miles	Otter Creek south	$ 2,120
#0	7.8 "	Newport to Hillsdale	3,290
#0	8.7 "	Rileysburg to Dickason	3,660
#0	2.0 "	Rileysburg north	2,110
		Total	$11,180

Summing up the costs of a six substation plan, we have:

Substations and Secondary Distributing System.

Cost of Six Substation System.

3 Substations 250 K.W.	$ 42,510
1 Substation 200 K.W.	12,920
2 Substations 150 K. W.	22,970
56 miles 2/0 grooved trolley wire	29,800
Feeders	11,180
49 miles of transmission line	69,500
Total	$188,880

Comparing the three systems, we have:

five substationsplan	$179,200
four substation plan	$191,585
six substation plan	$188,880

Without any question the five substation system is the proper one to adopt. In order to make the system perfectly flexible for future changes in schedule and to further facilitate the process of cross feeding on overload, particularly in case an extra car or two are put in service, we recommend: that the two 250 K. W. substations be increased to 300 K. W., thereby making all the apparatus of the same size and interchangeable; and that a 3/0 trolley wire be used with the following list of feeders instead of the 2/0 trolley wire and feeders previously

Substations and Secondary Distributing System.

listed.

Size	Length	Location	Cost
#0	4.0 miles	Otter Creek south	$ 1,690
#0	11.1 "	Worthy to Jackson	4,700
#3	12.1 "	Rileysburg to Cayuga	2,540
#2	5.4 "	Rileysburg north	1,430
		Total	$10,360

With these changes the five substation system will still cost less than either the four or six substation system and excluding the transmission line, will be as follows:

Cost of Substations and Secondary

Distributing System.

5 Substations 300 K.W.	$ 77,000
56 miles 3/0 grooved trolley wire	37,600
Feeders	10,360
Total	$124,960

TRANSMISSION LINES.

Before proceeding with the transmission line, it is necessary to locate the power plant. The latter will necessarily be a steam turbine central station, since no hydroelectric developments are possible within an economical distance from the road; and its location will depend principally upon the center of distribution and the available water and coal supply.

A high grade black coal, remarkably free from sulphur and rich in carbon, can be obtained in large quantities from the coal fields of Vigo and Vermillion Counties in Indiana. This can be loaded on cars at the mines and moved to any point on the electric line without the services of any steam road.

The elctrical center of distribution is very close to Worthy and since river water is available here for cooling and condensing purposes, and since a substation already located at this point can be included in the power house building, and further, since the car barns and repair shops will be at

[illegible]

[illegible]

[illegible]

[illegible]

Transmission Lines.

Worthy, the power plant will also be located here.

To simplify calculation, the transmission line will be treated in four sections.

Section	Between	Length
I.	Rileysburg and Cayuga	12.1 miles
II.	Cayuga and Worth	10.2 "
III.	Worthy and Jackson	11.1 "
IV.	Jackson and Otter Creek	9.2 "

The cost of energy per kilowatt-year at the power house switchboard = $ 91.40

Annual fixed charges on power house apparatus per K.W. = $ 13.33

Total cost per kilowatt-year $104.73

This makes the cost per horse power-year equal $78.00.

With a 100 lbs. of copper conductor costing $25 and assuming a scrap value of 15 cents per pound, the annual interest, depreciation, and taxes, equals 8.03 % and the economical potential drop per mile is

$$e = 8.1\sqrt{\frac{8.03 \times 25}{78}} = 13 \text{ volts}$$

The transmission voltage for the first approx-

Transmission Lines.

imation may be taken as

$$E = 55\sqrt{L}$$

where L is the distance of transmission in miles plus the horsepower transmitted divided by 200.

Assuming a full load substation efficiency of 90 % the input is 330 K. W. per station. In order to apply the above mentioned formula, it will be necessary to assume a load of 660 K. W. concentrated at a point midway between Rileysburg and Cayuga, which is 15.975 miles from Worthy.

We then have

$$E = 55\sqrt{15.975 + \frac{660}{.746 \times 200}} = 24{,}500 \text{ volts.}$$

The three nearest standard voltages are 22,000, 33,000, and 44,000 volts, and we shall now determine which of these three will give the minimum operating costs. Sections I. and IV. will each have a concentrated load of 330 K. W. and Sections II. and III. will each have a load of 667 K. W.

The data given in Table IX. for each of the three voltages under investigation, is based on a balanced three-phase load at 0.8 power factor and

Transmission Lines.

an economic drop of 13 volts per mile.

TABLE IX.

Transmission Line Data

Sections I. and IV.

Line Voltage	Amperes Line Current	Economic Resistance per Mile	Size of Wire Selected	Actual Resistance per Mile
22,000	10.8	1.2	#4	1.347
33,000	7.2	1.81	#6	2.143
44,000	5.41	2.4	#8	3.406
		Sections II. and III.		
22,000	22.2	0.585	#0	0.528
33,000	14.8	0.878	#2	0.8474
44,000	11.1	1.17	#4	0.347

When the section of the line conductors is such as to satisfy Kelvin's law of economy, the yearly cost of the copper losses is equal to the amount representing annual depreciation, interest, taxes, and insurance on the first cost of conductors; and total annual charges on active line material, for a three-phase line, will therefore be

$$2 \times \frac{I^2 R \times p'}{746} \times 3 \times 1$$

where R is the resistance per mile of conductor and p' is the cost of energy per horsepower-year.

[illegible]

Transmission Lines.

Table X. was worked out with the aid of this formula.

TABLE X.

Total Annual Charges against

Line Conductors.

Voltage	22,000	33,000	44,000
Sec. I.	$1200	$ 850	$ 760
Sec. II.	1670	1190	1060
Sec. III.	1820	1300	1150
Sec. IV.	910	640	580
Total	$5600	$3980	$3550

In order totake into account the first cost, life, annual maintenance, and operating charges on each portion of the entire system which may be affected by a change in the transmission voltage, Table XI. was worked out on an annual basis.

TABLE XI.

Comparision of Annual Costs at

Different Transmission Voltages.

Items affected by change of voltage	Annual Charges 22,000	33,000	44,000
Line conductors	$ 5600	$ 3980	$ 3550
Transmission line excluding conductors	4230	5160	5910
Transformers	2230	2310	2390
Switchgear, including lightning arresters, entering bushings, etc.	960	1440	1920
Total	$13,020	$12890	$13770

Transmission Lines.

The 33,000-volt system is the most economical and we therefore recommend that this voltage be used with #6 line conductors in Sections I. and IV. and #2 line conductors in Sections II. and III.

The cost of the transmission line alone will be as follows:

42.6 miles of transmission line exclusive of conductors but otherwise complete, at $1100 per mile	$ 46,900
Line conductors	
3 - #2 conductors 21.3 miles)	
3 - #6 conductors 21.3 miles)	23,600
Total cost of line	$ 70,500

POWER PLANT.

For the reasons already stated under the caption of "Transmission Lines", the power plant will be located at Worthy on the west bank of the Wabash River. It will be directly on the route of the road and in addition to the generating apparatus, a 300 K. W. automatic substation will be installed in the same building. Plate XXXII. contains the complete substation average load curves. These curves were combined and 11 % added for losses in order to get the power house average load curve given in Plate XXXIII. The morning and evening peaks shown an average maximum demand of 1135 K. W. To obtain the momentary maximum demand, a diversity factor of 0.85 was taken on the assumption that all the cars but one would be taking the maximum demand at a given instant. Since the ratio of maximum demand per car to average demand for express cars is 1.57 and there are two express cars in service; while the ratio for local cars is 2.12 and there are six local cars in service, then the combined.

[illegible]

[illegible]

Power Plant.

ratio is

$$\frac{2 \times 1.57 + 6 \times 2.12}{8} = 1.98$$

and the momentary maximum peak load is

$$1135 \times 1.98 \times 0.85 = 1920 \text{ K. W.}$$

That would be a momentary overload of 28 %, if the installed generating capacity be 1500 kva.

We recommend that three generators be installed: two 750 Kva units and one 500 kva unit. The 500 kva unit will carry the load late at night and early in the morning. The two 750 kva units will carry the peak load at a 28 % overload and one 750 kva unit and the 500 kva unit will carry the normal all-day load. Should one 750 kva unit go out of commission for any reason, the remaining 750 kva unit and the 500 kva unit can carry the peak at a 50 % overload. The peak does not last over two hours and the machines can easily carry a 50 % overload for that length of time without over-heating. Plate XXXIV. to XXXVII., inclusive, show the general layout of the power plant and require no detailed explanation. The building

is 112 ft. wide, 120 ft. long, and 60 ft. high.

The turbine room contains: two 750 kva Curtis horizontal turbine units complete with condensers and auxiliary pumps, a similar 500 kva unit, one 35 K. W. turbine-driven exciter, one 35 K. W. motor-driven exciter, and a complete 300 K. W. automatic rotary converter substation.

The waterrate of the turbines is 24.1 lbs. per kilowatt-hour delivered by the generator with steam at 200 lbs. gauge pressure and 150° F. superheat. Assuming a feed water temperature of 200° F., one boiler horsepower will be required for each 1.25 K. W. delivered by the turbine unit.

It is now considered good practice to install a boiler capacity capable of carrying the normal load at the manufacturer's rating and to force the boilers during the peak load. The normal maximum running load is approximately 1200 K. W.; hence, the boiler capacity should be $\frac{1200}{1.25}$ = 960 boiler horsepower. The plans show six 250 h.p. Babcock and Wilcox boilers, two boilers being installed as

Power Plant.

a reserve unit. Provision has also been made for an additional 500 boiler horsepower and another generating unit. This will probably be required by 1920, if the development of the country continues at its present rate.

The auxiliary apparatus is all non-condensing and the exhaust steam is used for feed water heating.

Plate XXXVIII. is the Power Plant and Substation Wiring Diagrams. There is a 6600-volt transfer bus and a 33,000-volt main bus. Energy is taken from the generators at 6600-volts. Through a system of disconnects and a type K_2 oil switch, this energy may be delivered directly to a group of three single-phase transformers and thence to the main bus or it may be delivered to the transfer bus and thence to any group of transformers. When desired both connections may be made at once, thus tieing the transformers between the two bus systems and leaving their load independent of the load division of the generators.

Power Plant.

An incoming generator may be synchronized by the type K_2 switch connecting it to the transfer bus or by the type H_6 oil switch on the 33,000-volt side of the transformers.

The automatic substation is connected to the transfer bus, and a 440-volt local power circuit is also tapped from this bus through transformers.

The use of 33,000-volt oil switches necessitates the adoption of remote control devices and, therefore, the entire system was designed to operate from a control board directly in front of the high-tension switch gallery and overlooking the turbine room.

The following is an estimate of the complete cost of the power plant:

Estimated Cost of Power Plant.

Real Estate	$ 500
Excavations (16500 cu. yds.)	1,240
Turbine foundations	1,500
Iron and steel structure	16,350
Buildings (Roof and main floor)	17,420
Galleries, floors and platforms	3,700
Intake and discharge pipe lines	1,340
Ash storage pocket	1,400
Coal bins and crusher	2,890

Power Plant.

Estimated Cost of Power Plant (Con't.)

Crane	$ 1,100
Coal and ash conveyor	5,000
Coal and ash hoppers	2,200
Smoke stack	2,200
Boilers	19,500
Boiler setting	3,300
Stokers	3,150
Flues, dampers, and regulators	1,600
Pumps	1,600
Feed water heater	580
Piping	8,000
Pipe-covering	1,650
Valves	2,000
Surface condensors	13,500
Exciters	1,400
Steam turbine units (complete)	56,000
Transformers	12,300
Switchgear	9,800
Wiring for lights and motors	600
Oiling system	650
Compressed air system and small Auxiliaries	500
Painting, labor, etc.	3,200
Miscellaneous	3,000
Engineering and inspection	9,000
Total	$207,970

TOTAL COST.

In addition to the more important cost items already estimated, there are a number of accessories, such as telephones, block signals, stations and platforms, etc., which occupy a relatively small place compared to the whole, but whose success or failure may be very largely reflected in the financial returns of the road. These have all been included in the following summation of costs, which represents the approximate cost of the complete undertaking.

Right of way	$ 73,000
Roadbed and track	902,350
Wire fences	15,500
Overhead construction exclusive fof trolley and feeder copper	75,950
Five substations and trolley and feeder copper	124,960
Rolling stock	139,200
Transmission line	70,500
Telephone dispatch line	6,000
Block signal system	22,500
Station and platforms	15,000
Station and platform lighting circuit	4,100
General office	8,000
Car shops, machine tools, etc.	25,000
Accidents, contingencies, and miscellaneous	84,000

CONCLUSION.

The gross operating revenue was estimated as $401,970 for 1916 and $472,320 for 1920. The operating expenses may safely be assumed as 55 % of the gross receipts, which is a fair average result. There are roads operating as low as 45 % and many others close to 50 %. However, a niggardly operating policy will never build up a business; an intelligent increase in gross income is the only permanent means of improving dividends; hence, we believe 55 % is a sound estimate.

On this assumption the operating expenses would be $221,000 in 1916 and $260,000 in 1920, leaving a net revenue of $180,970 and $212,320 respectively, for interest, sinking fund, and dividends. If the road be bonded for $2,000,000 at 5 %, this will leave $80,970 per annum on the 1916 basis to apply on dividends, etc., and $112,320 per annum on the 1920 basis. Setting aside a special sinking fund of $15,000 per annum to meet any contingency that may arise, the road

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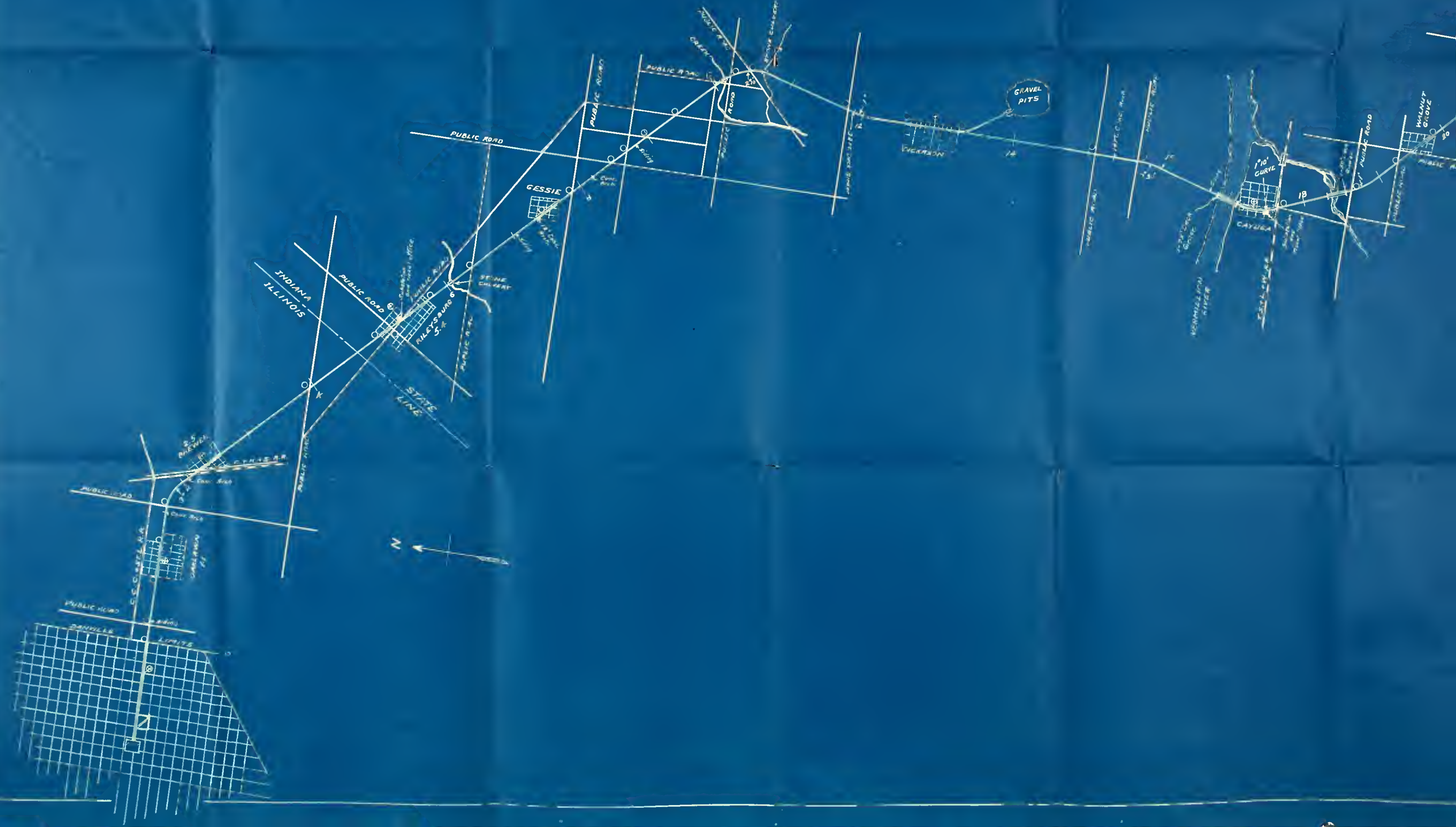
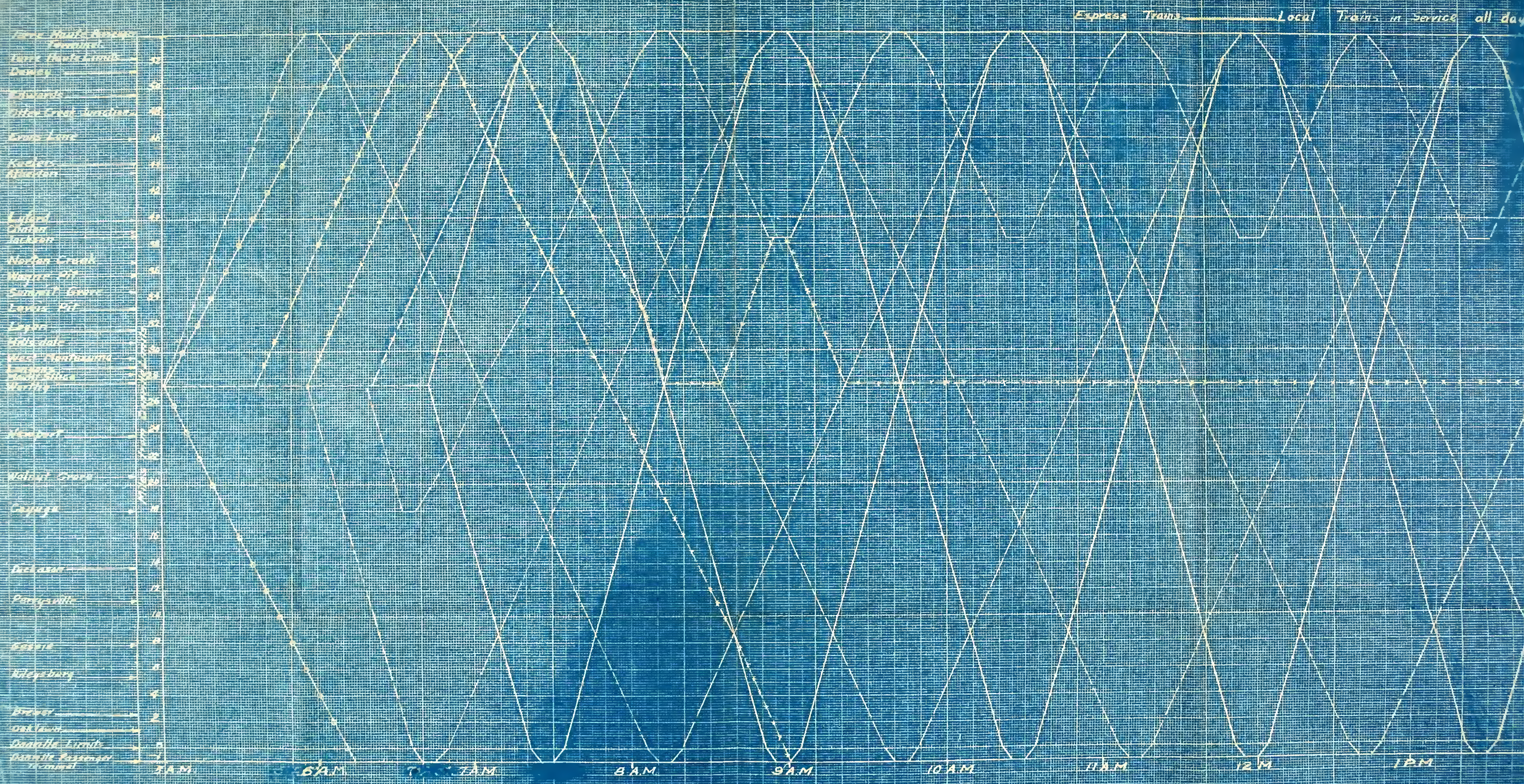


PUBLIC ROAD
GESSIE
INDIANA
ILLINOIS
STATE LINE
RILEYSBURG
STONE CULVERT
GRAVEL PITS
1°10' CURVE
CAYUGA
VERMILLION RIVER
WALNUT GROVE
18
N


WABASH RIVER
WORTHY
27.1
MT. SILICA
28.4
LANYONS
28.9
LITTLE RACCOON RIVER
LOGAN
31.7
SUMMIT GROVE
34.5
PUBLIC ROAD
N

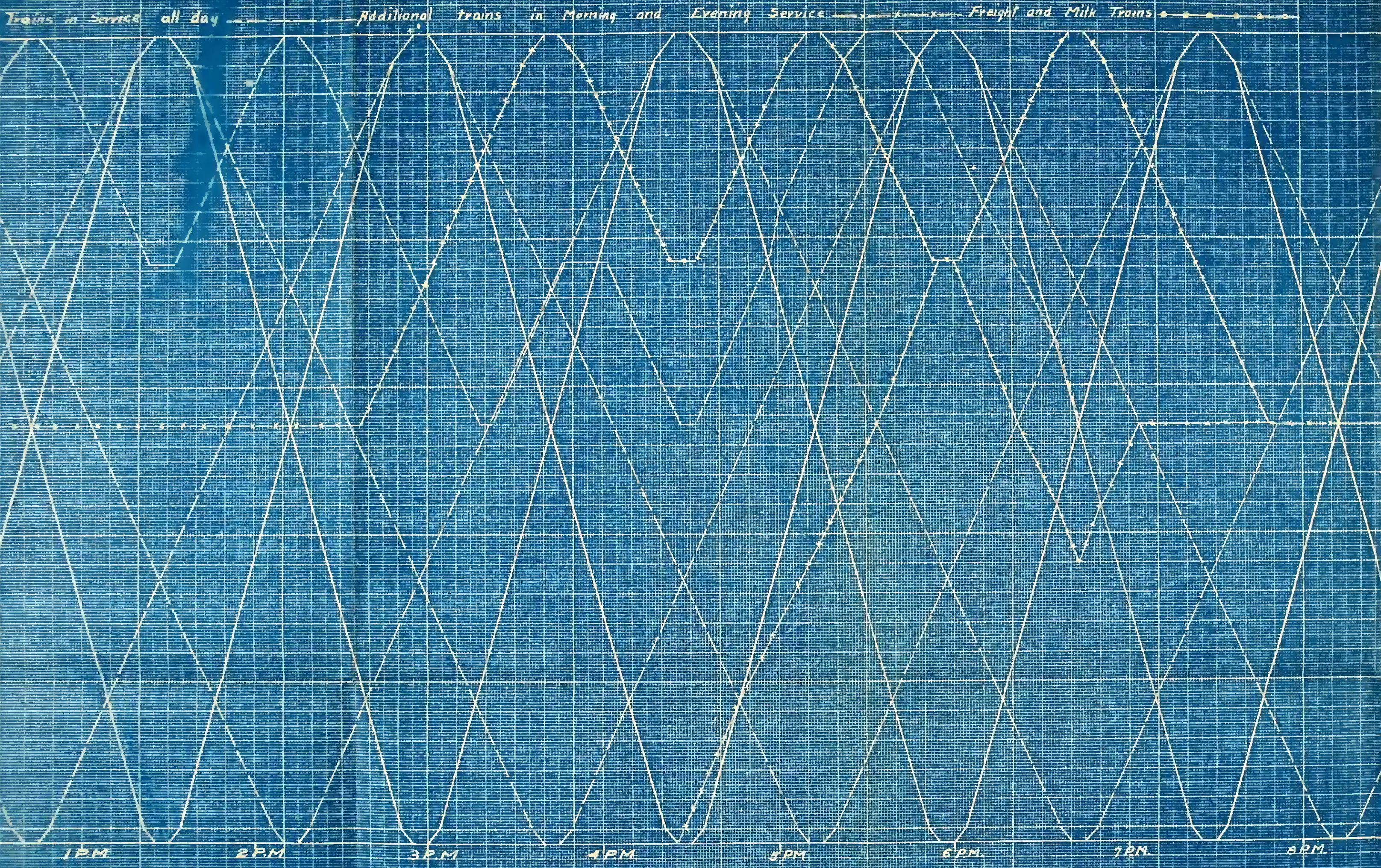
MAP OF ROUTE.
PROPOSED DANVILLE-TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
R. H. Oswald — Engrs. — H. M. Shapiro
Dec. 27, 1910.

PLATE I.



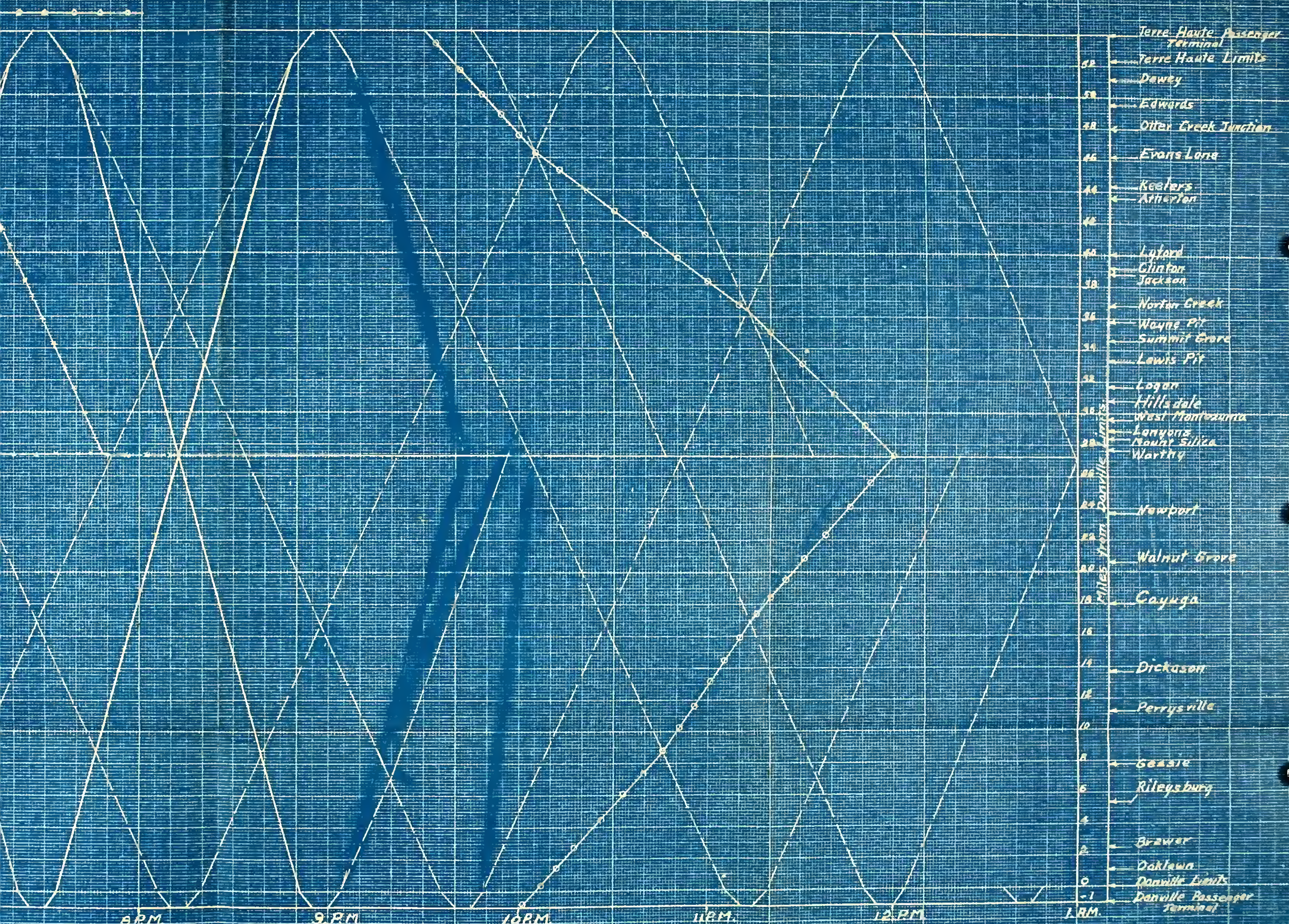
PROPOSED DANVILLE –

TRAIN SHEET.



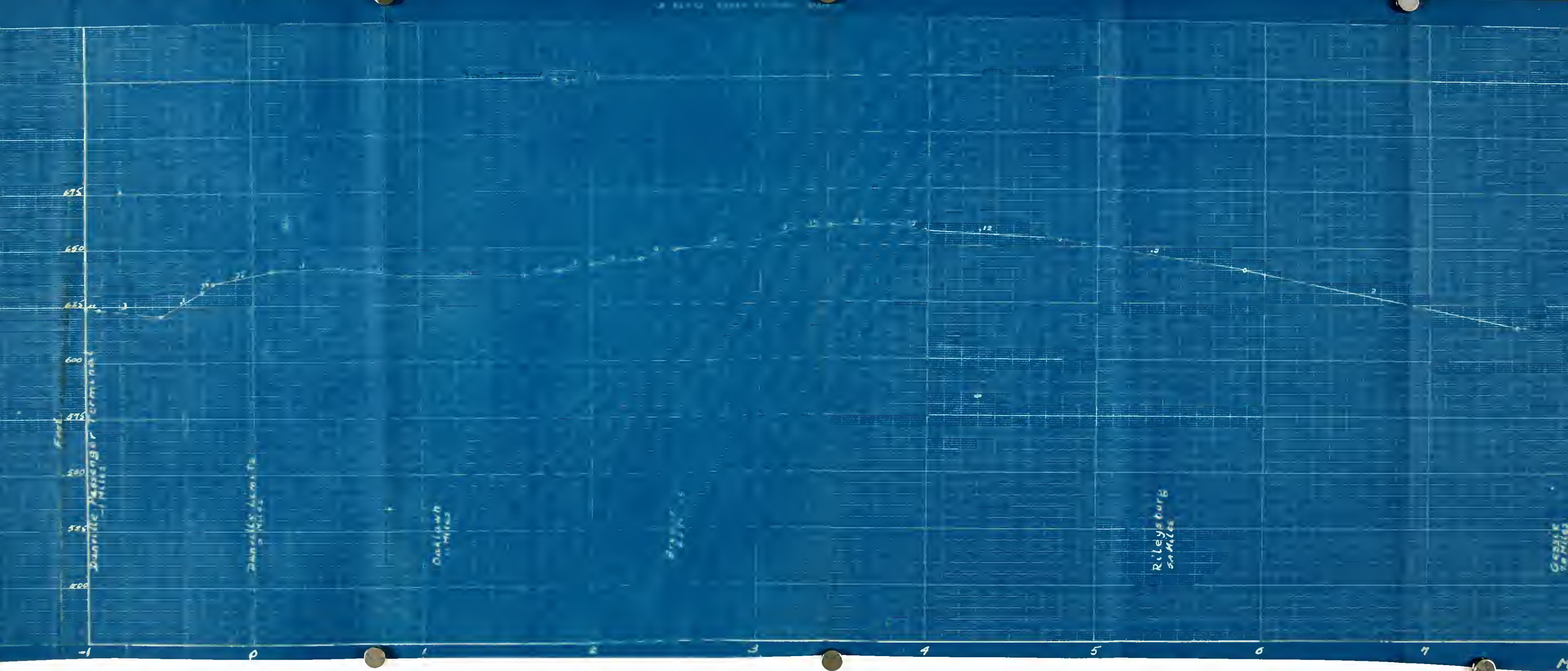
DANVILLE - TERRE HAUTE INTERURBAN RAILWAY.

A. A. Oswald — Engrs. — H. M. Shapiro.
March 26, 1916.

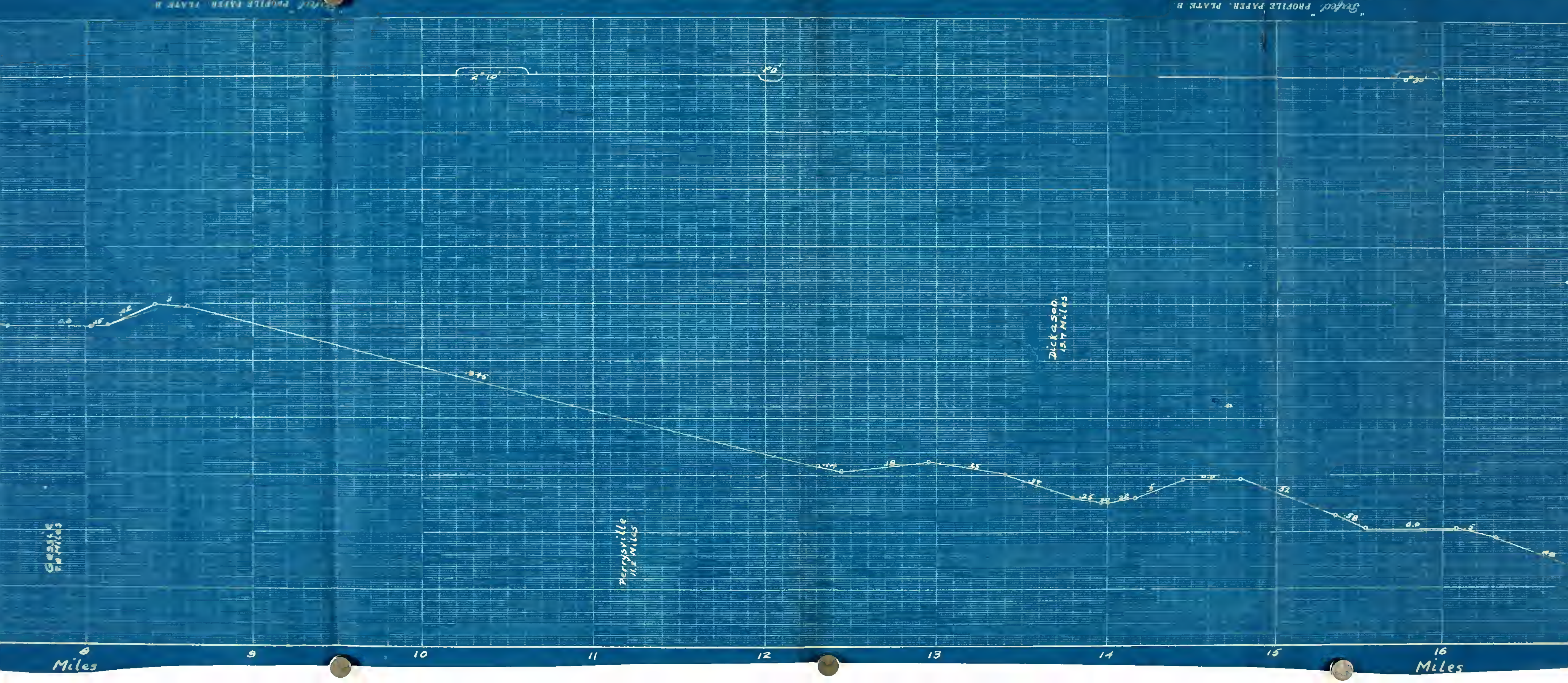


Terre Haute Passenger Terminal
Terre Haute Limits
Dewey
Edwards
Otter Creek Junction
Evans Lane
Keelers
Atherton
Lyford
Clinton
Jackson
Norton Creek
Wayne Pit
Summit Grove
Lewis Pit
Logan
Hillsdale
West Montezuma
Lanyons
Mount Silica
Worthy
Newport
Walnut Grove
Cayuga
Dickason
Perrysville
Gessie
Rileysburg
Brewer
Oaklawn
Danville Limits
Danville Passenger Terminal
Miles from Danville Limits
8 P.M.
9 P.M.
10 P.M.
11 P.M.
12 P.M.
1 A.M.

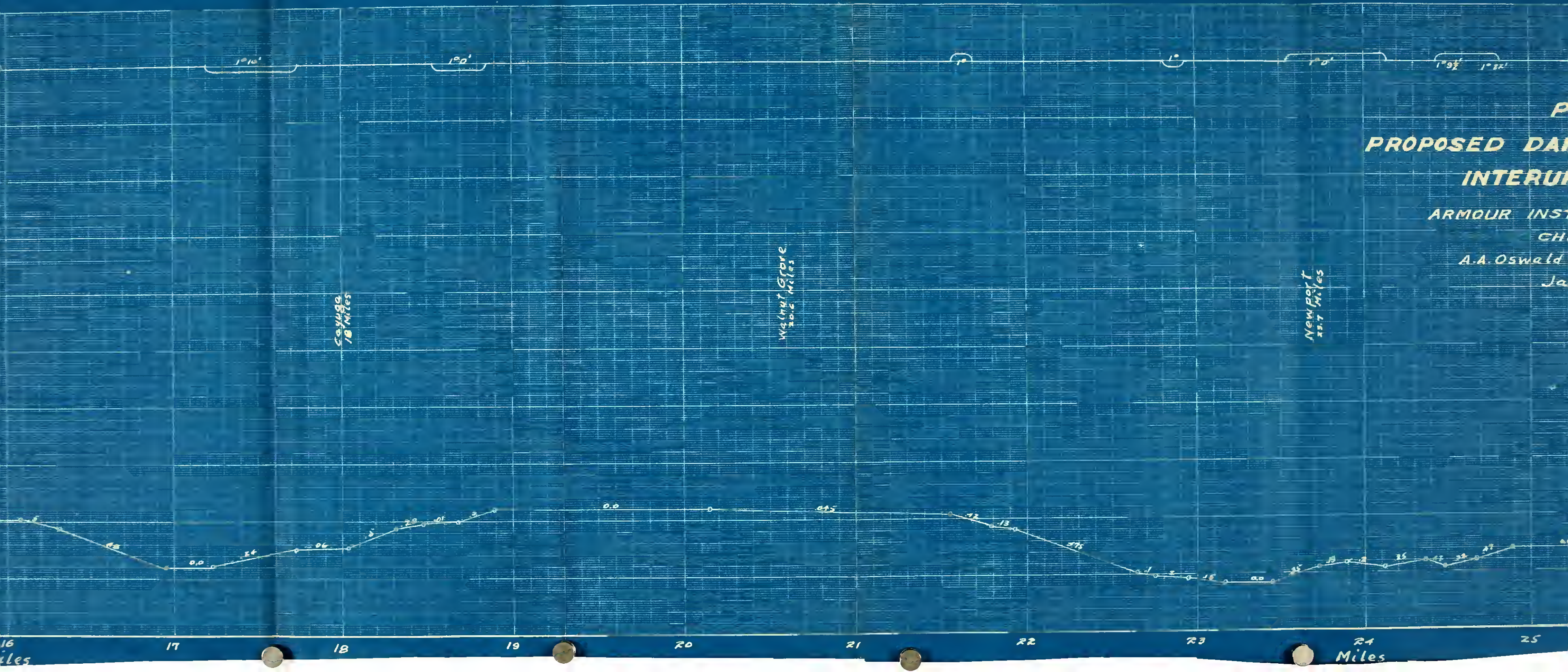
PLATE II.

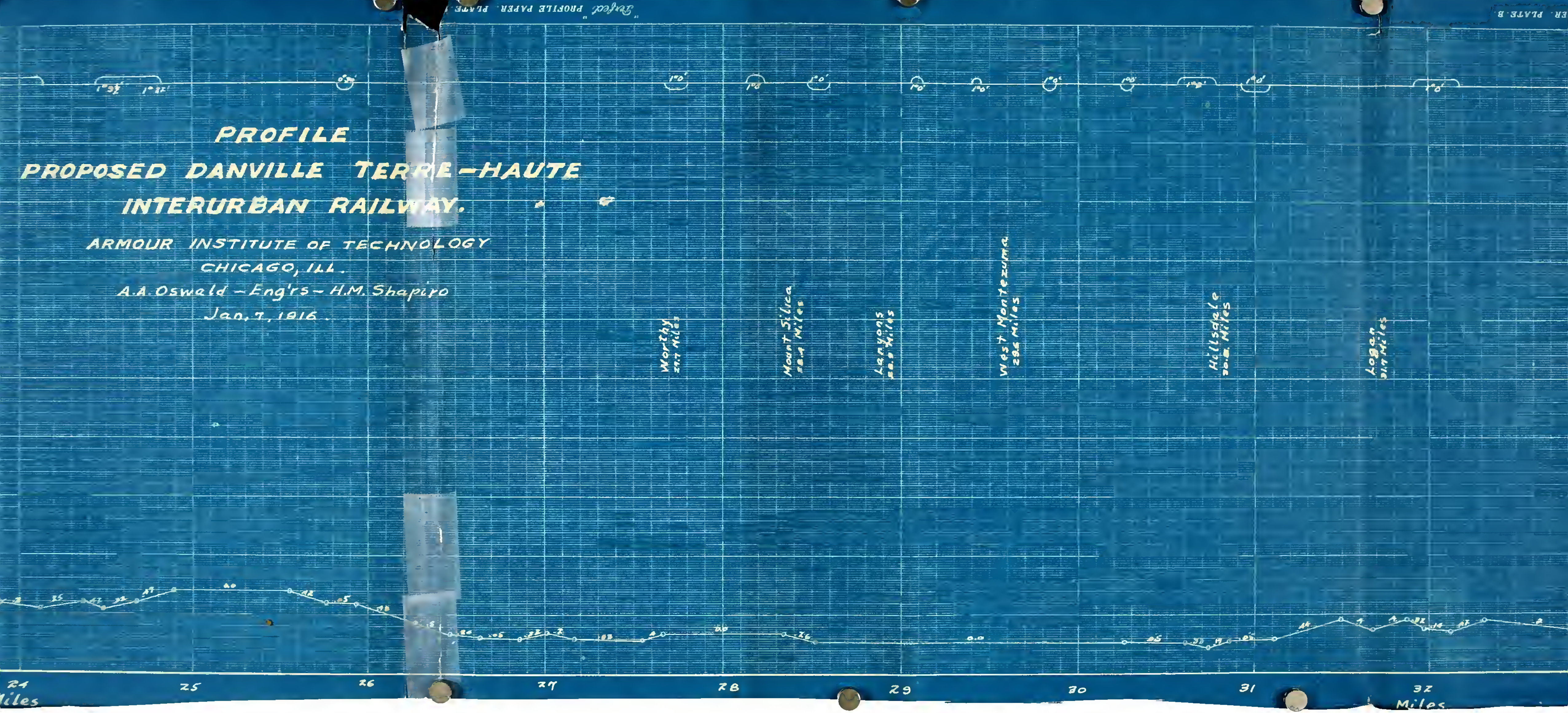


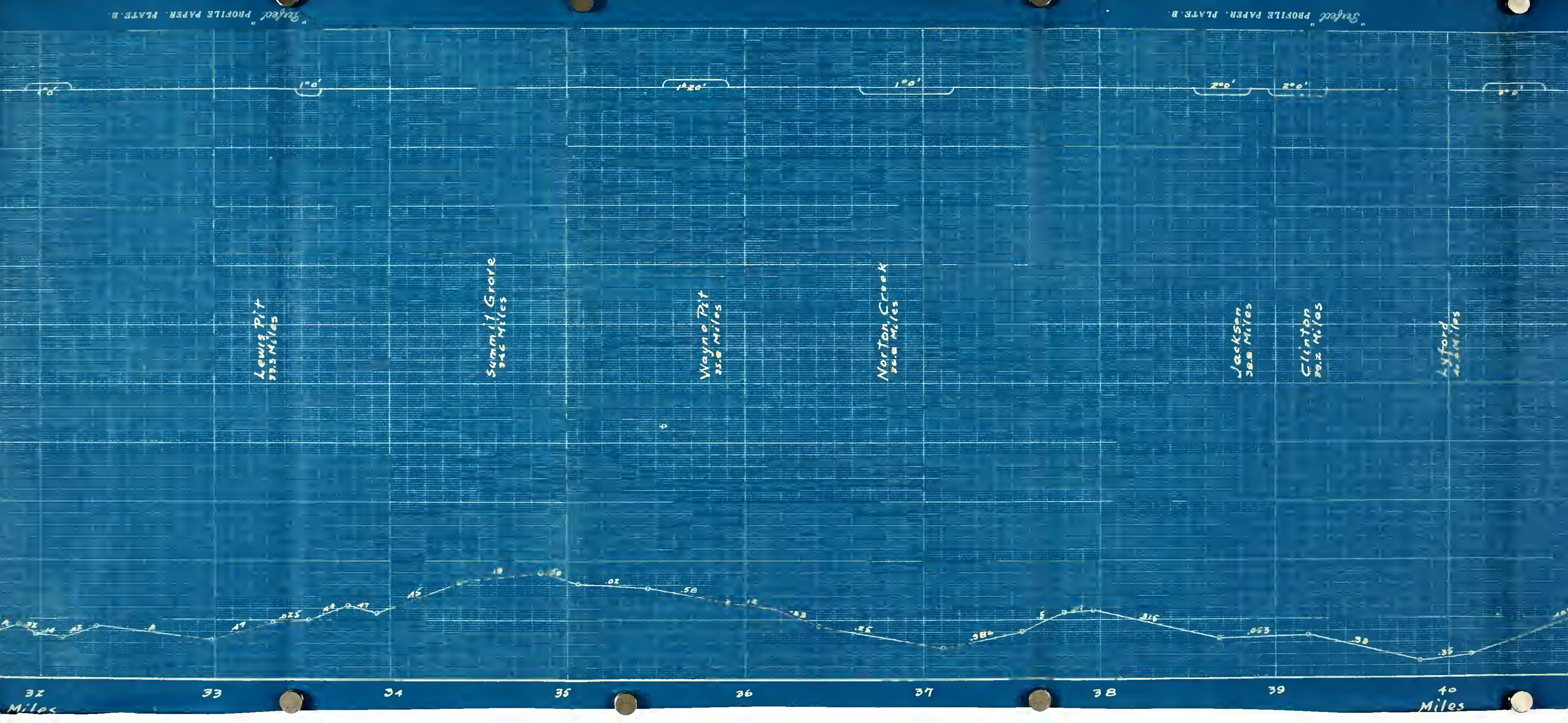
675
650
625
600
575
550
525
500
Feet
Danville Passenger Terminal
Danville Limits
Oaklawn
Rileysburg
-1
0
1
2
3
4
5
6
7



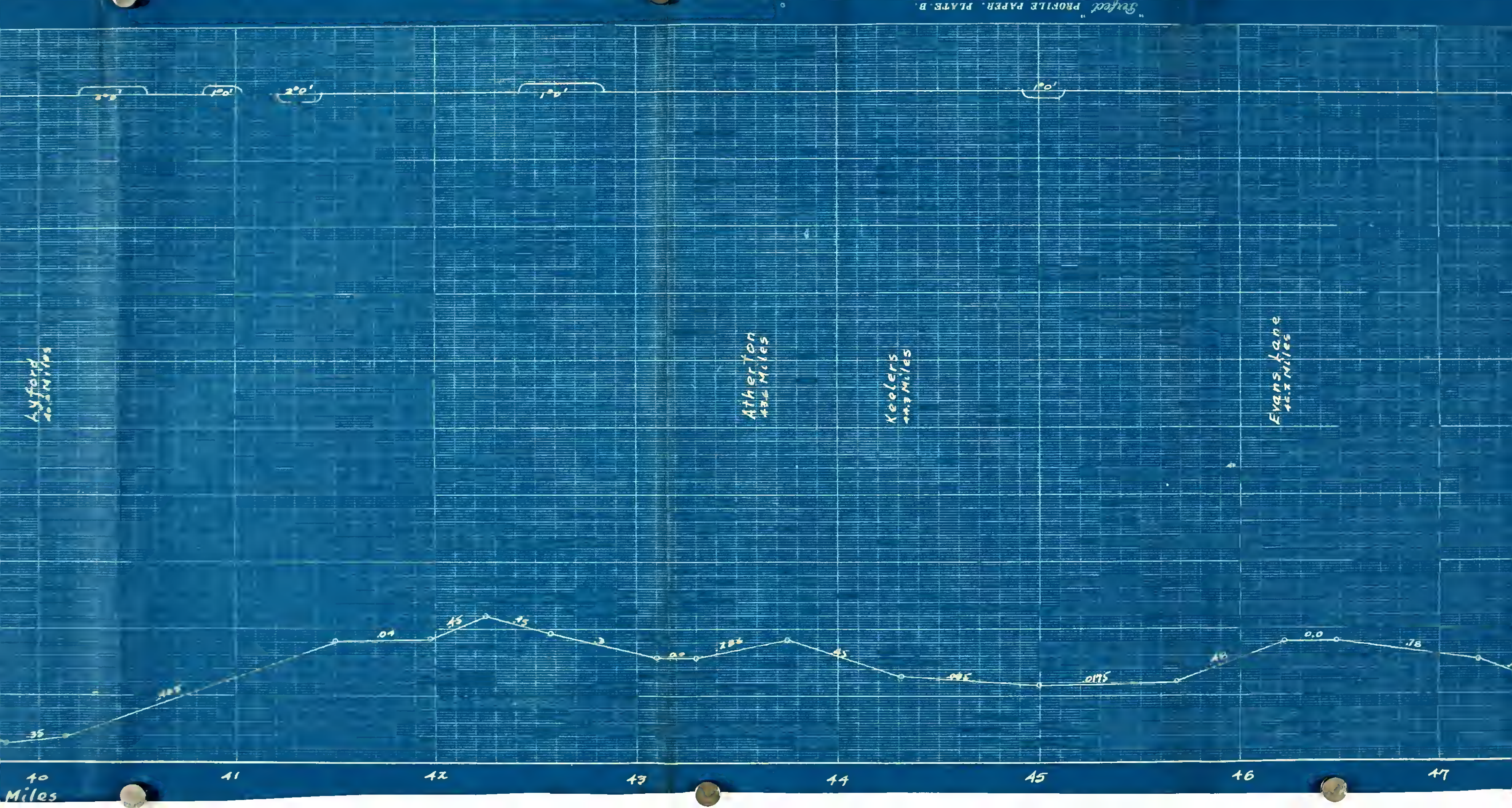
2°10'
1°0'
0°30'
Dickason
13.7 Miles
Perrysville
11.2 Miles
8
9
10
11
12
13
14
15
16
Miles
Miles


1°10'
1°0'
1°
1°
1°0'
Cayuga 18 Miles
Walnut Grove 20.6 Miles
Newport 23.7 Miles
PROPOSED DA
INTERU
ARMOUR INST
A.A. Oswald
16
17
18
19
20
21
22
23
24
25
Miles


PROFILE
PROPOSED DANVILLE TERRE-HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.
A.A. Oswald - Eng'rs - H.M. Shapiro
Jan. 7, 1916.
Worthy 27.7 Miles
Mount Silica 28.4 Miles
Lanyons
West Montezuma 29.6 Miles
Hillsdale 30.8 Miles
Logan 31.7 Miles
24 Miles
25
26
27
28
29
30
31
32 Miles



"Perfect" PROFILE PAPER. PLATE B.
1°20'
2°0'
Lewis Pit
Summit Grove
Wayne Pit
Norton Creek
Jackson
Clinton
Lyford
32
33
34
35
36
37
38
39
40
Miles


"Perfect" PROFILE PAPER. PLATE B.
1°0'
2°0'
1°0'
1°0'
Lyford
Atherton
Keelers
Evans Lane
.35
.04
.45
0.0
.78
40
41
42
43
44
45
46
47
Miles

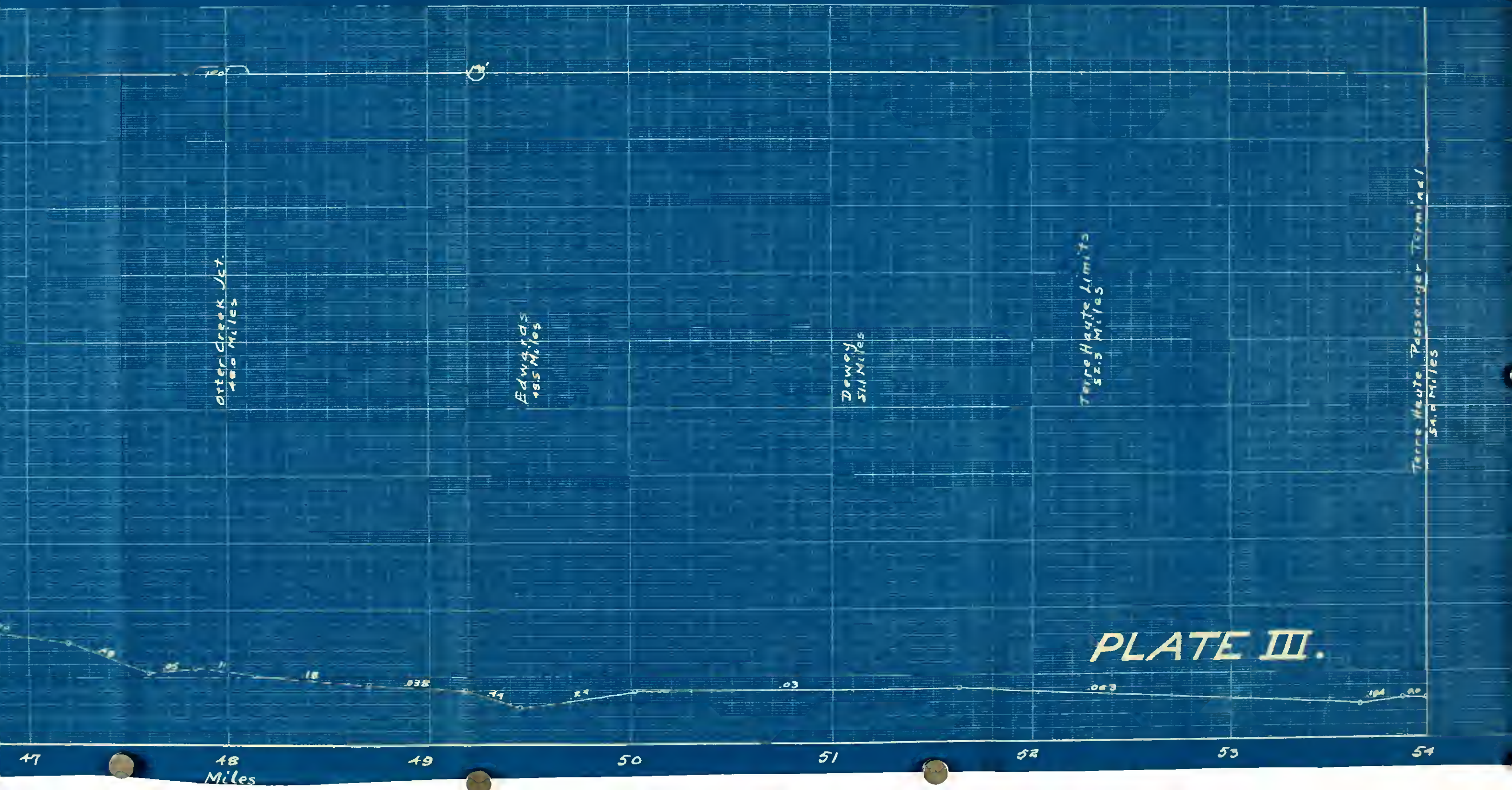
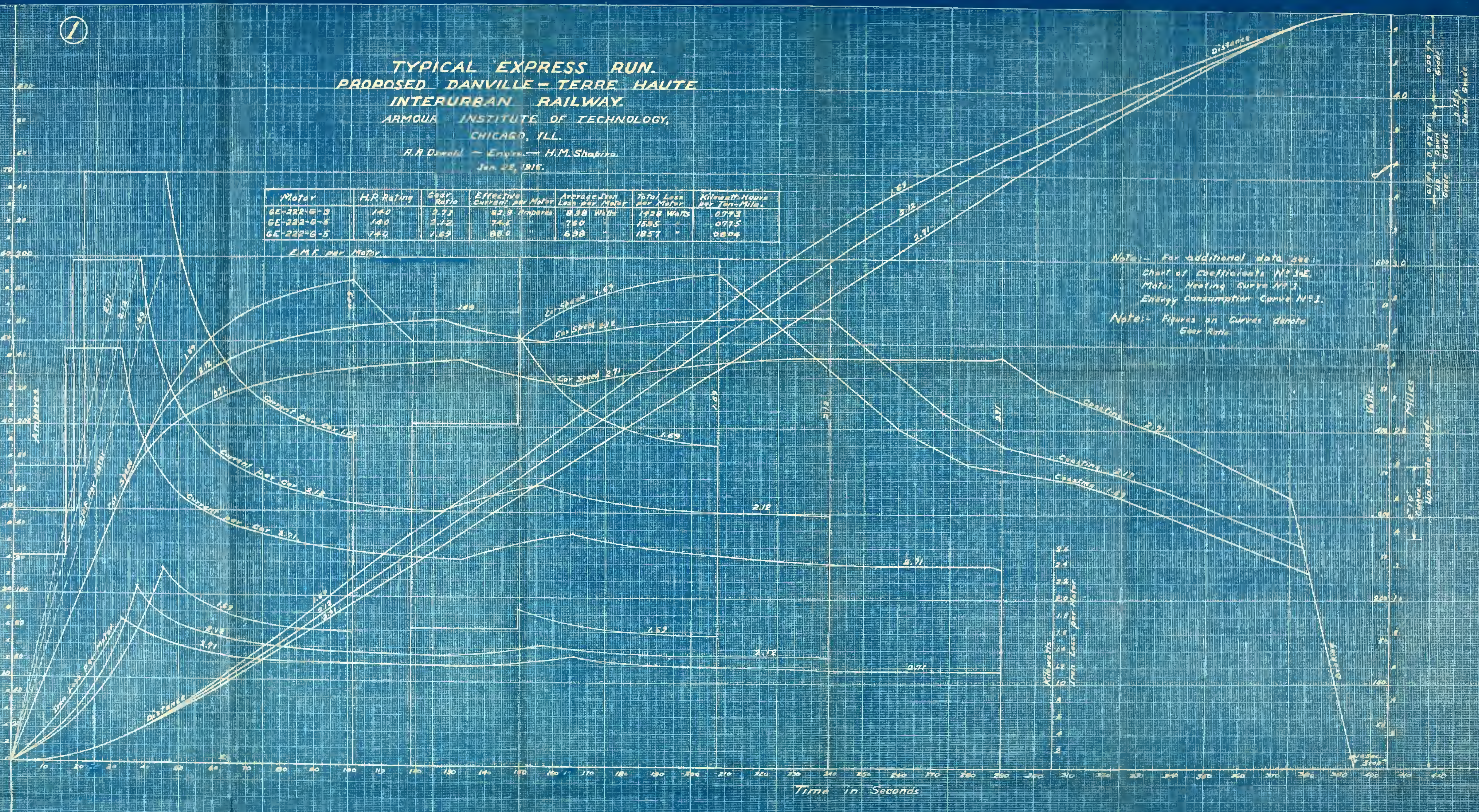

Otter Creek Jct.
48.0 Miles
Edwards
49.5 Miles
Dewey
51.1 Miles
Terre Haute Limits
52.3 Miles
Terre Haute Passenger Terminal
54.0 Miles
47
48
49
50
51
52
53
54
Miles

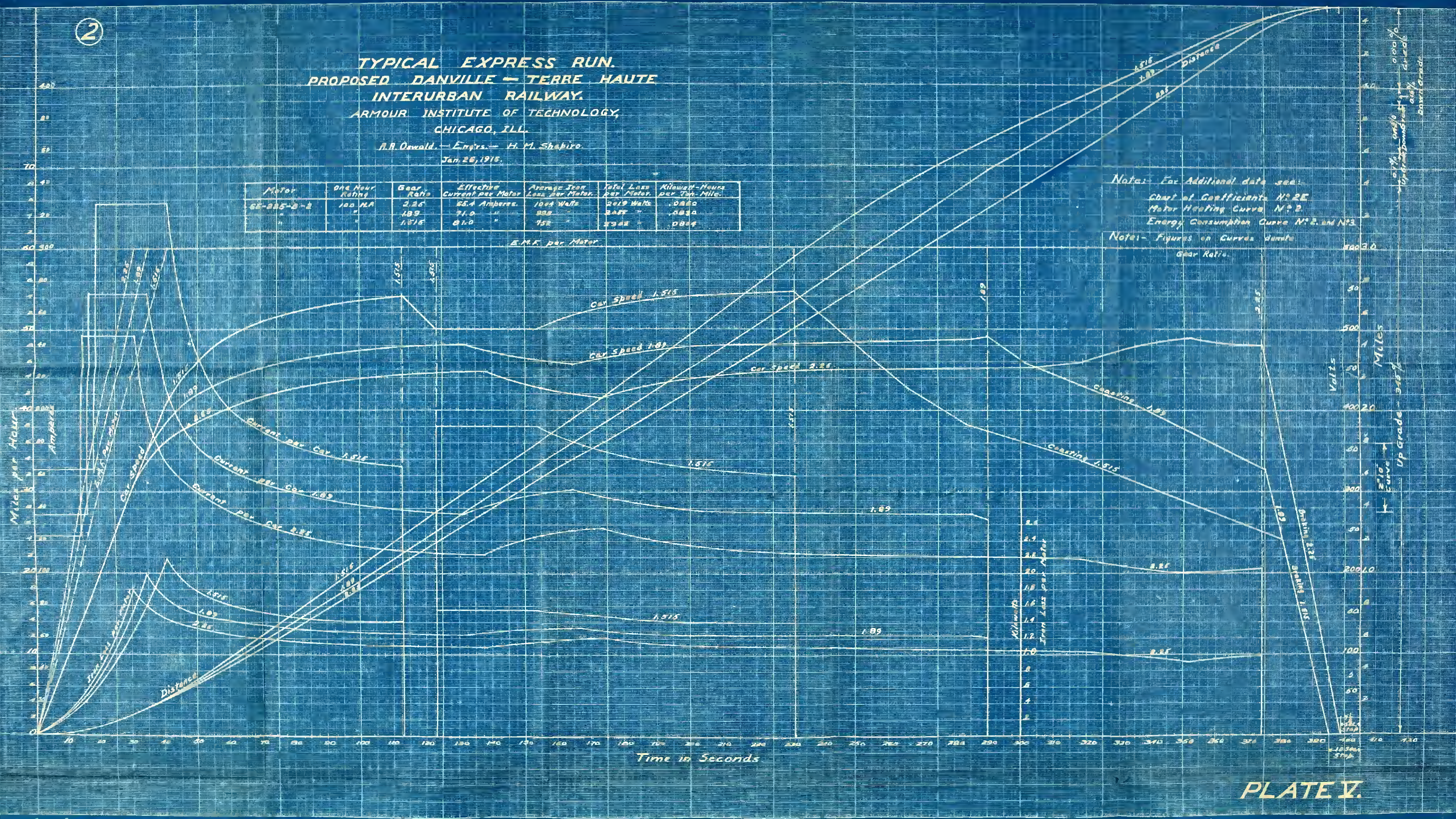
PLATE III.



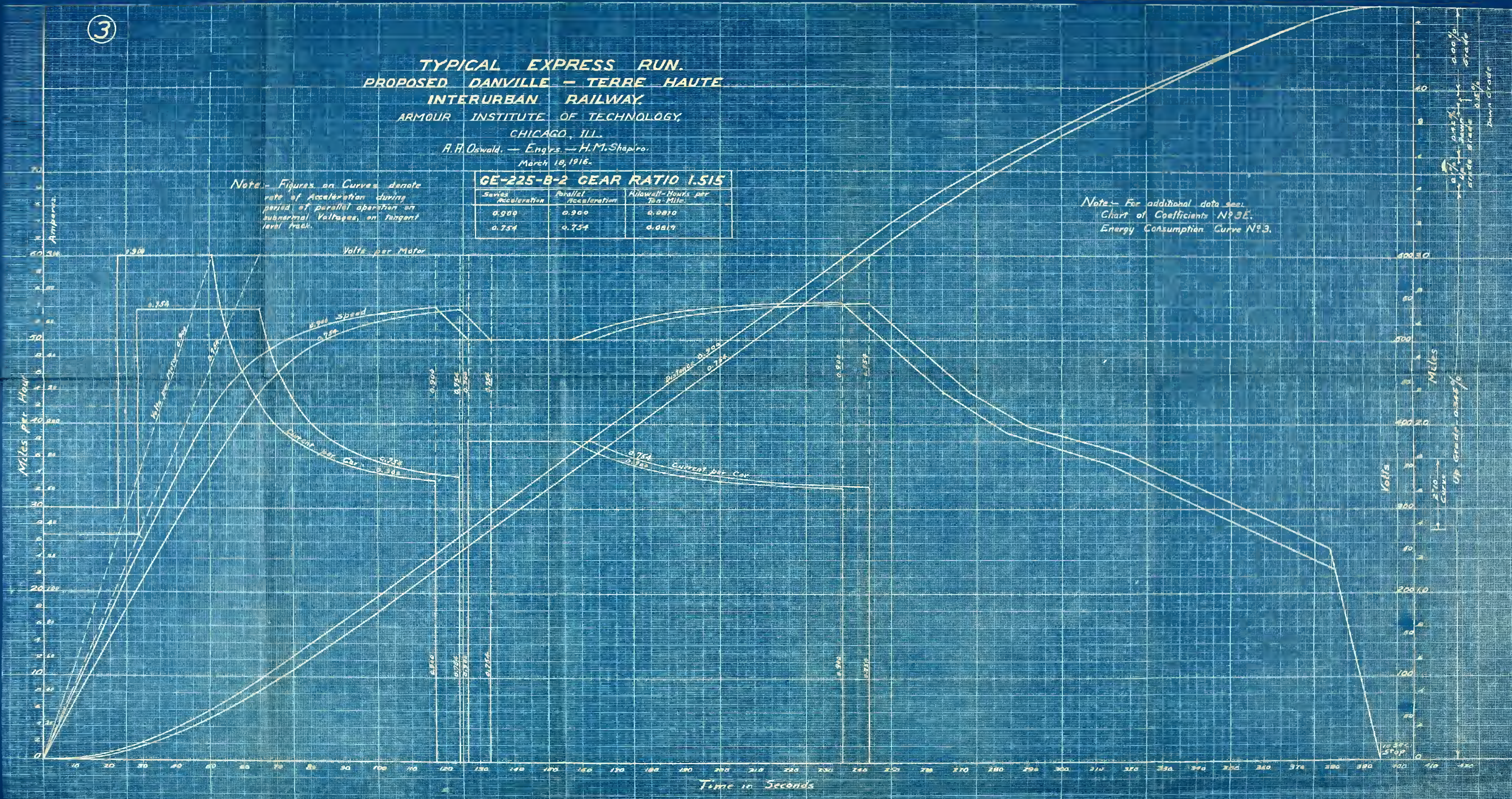
Motor	H.P. Rating	Gear Ratio	Effective Current per Motor	Average Iron Loss per Motor	Total Loss per Motor	Kilowatt-Hours per Ton-Mile.
GE-222-G-3	140	2.71	62.9 Amperes	8.38 Watts	1428 Watts	0.773
GE-222-G-6	140	2.12	74.6 "	760 "	1595 "	0.775
GE-222-G-5	140	1.69	88.0 "	698 "	1857 "	0.804

PLATE IV.

"Profile" PROFILE PAPER. Milwaukee EUGENE DIETZGEN Co.



Motor	One Hour Rating	Gear Ratio	Effective Current per Motor	Average Iron Loss per Motor.	Total Loss per Motor.	Kilowatt-Hours per Ton-Mile.
GE-225-B-2	100 H.P.	2.25	65.4 Amperes.	1004 Watts	2019 Watts	.0860
"	"	1.89	71.0 "	888 "	2657 "	.0830
"	"	1.515	81.0 "	752 "	2342 "	.0864



③
TYPICAL EXPRESS RUN.
PROPOSED DANVILLE — TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY.
CHICAGO, ILL.
A. A. Oswald. — Engrs. — H. M. Shapiro.
March 18, 1916.
Note:- Figures on Curves denote rate of Acceleration during period of parallel operation on subnormal Voltages, on tangent level track.
GE-225-B-2 GEAR RATIO 1.515
Series Acceleration | Parallel Acceleration | Kilowatt-Hours per Ton-Mile.
0.900 | 0.900 | 0.0810
0.754 | 0.754 | 0.0817
Note:- For additional data see:
Chart of Coefficients Nº 3E.
Energy Consumption Curve Nº 3.
Volts per Motor
Speed
Current per Car
Current per Car
Distance
Miles per Hour
Amperes
Volts
Miles
Time in Seconds

PLATE VI.

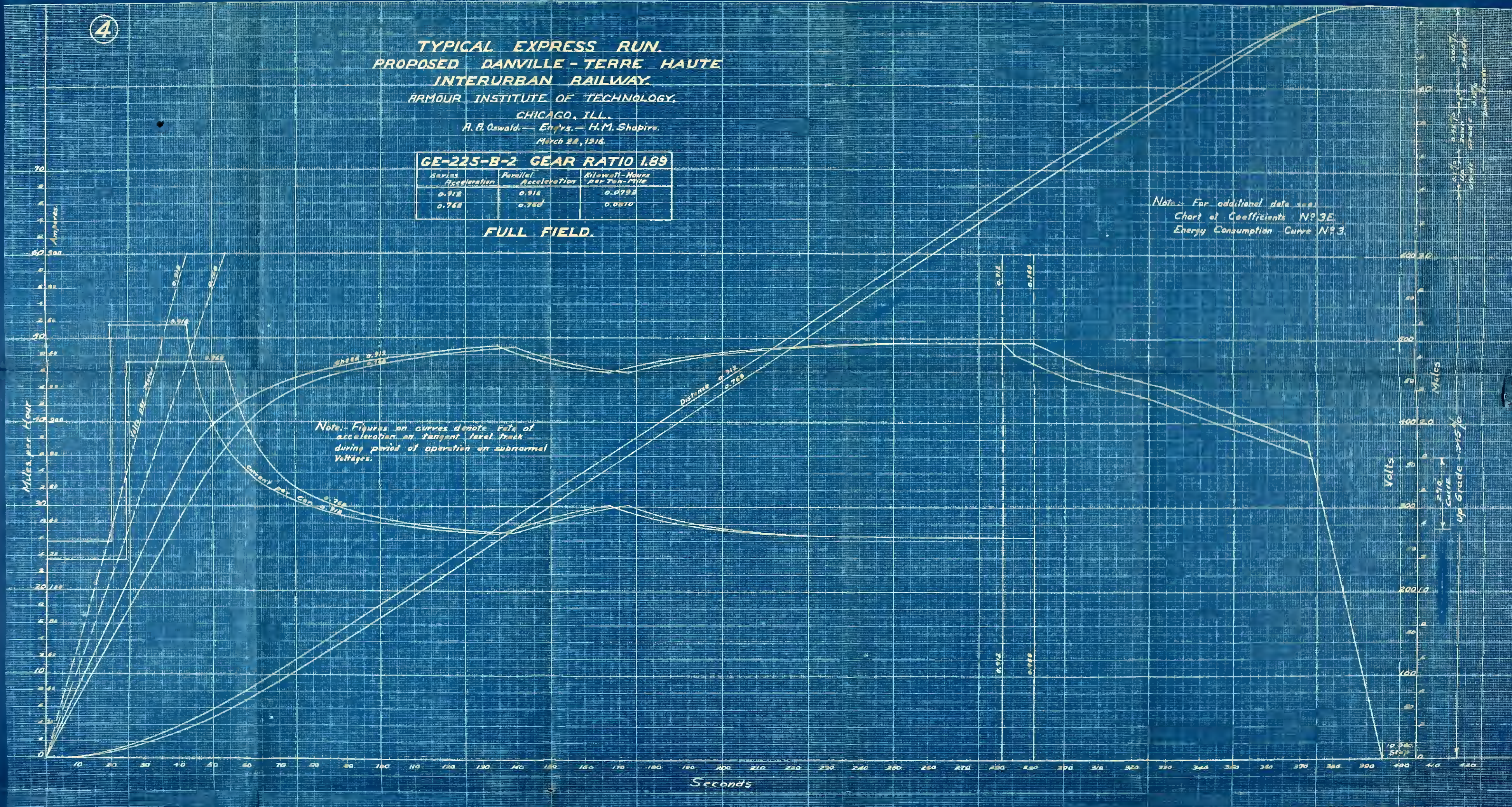


PLATE VII.

"Profect" PROFILE PAPER.
EUGENE DIETZGEN Co.

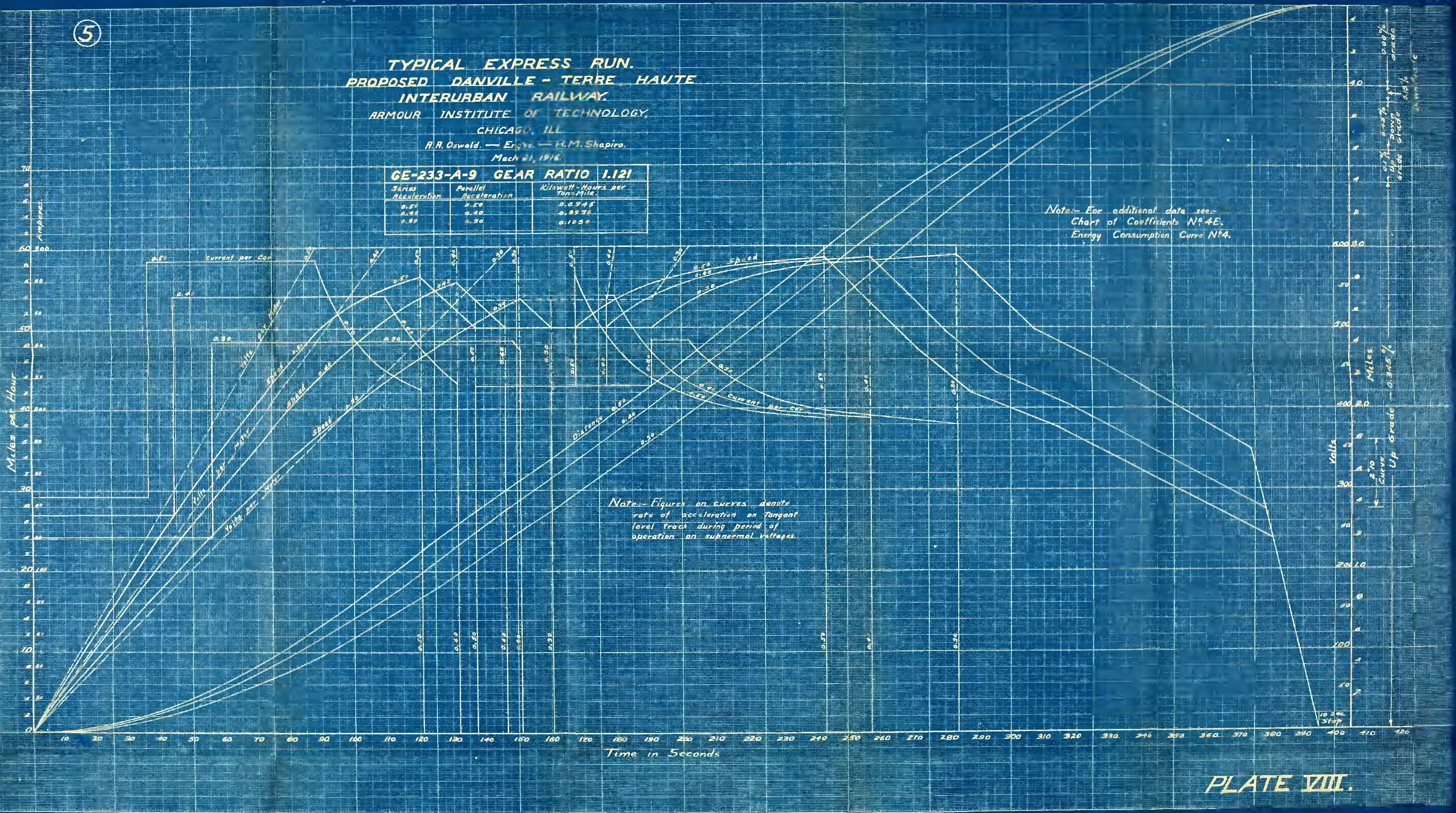
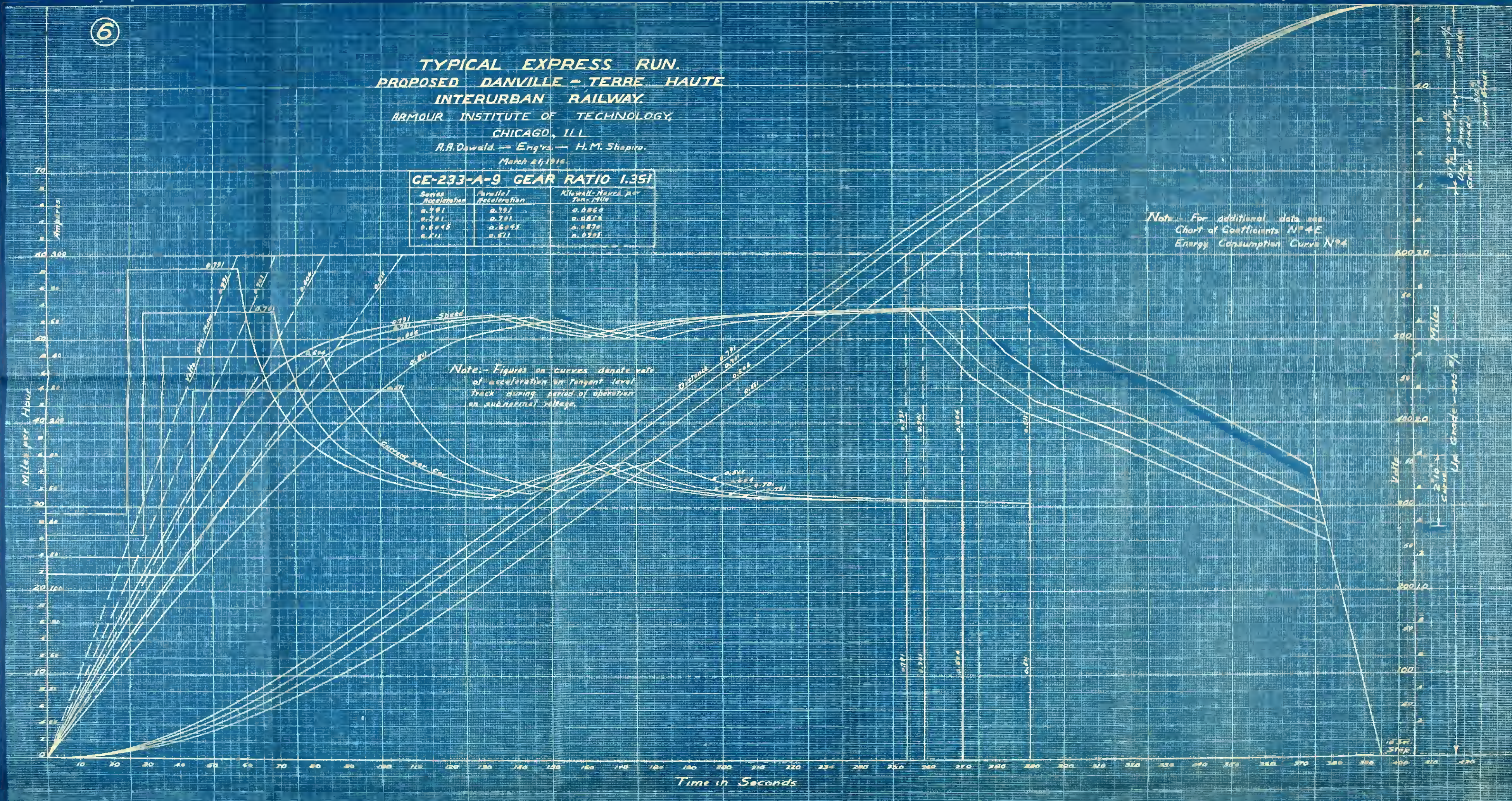

5
TYPICAL EXPRESS RUN.
PROPOSED DANVILLE - TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
A.A. Oswald. — Engrs. — H.M. Shapiro.
March 21, 1916.
GE-233-A-9 GEAR RATIO 1.121
Series Acceleration | Parallel Acceleration | Kilowatt-Hours per Ton-Mile
0.50 | 0.50 | 0.0945
0.40 | 0.40 | 0.0976
0.30 | 0.30 | 0.1050
Note:- For additional data see:
Chart of Coefficients No. 4E.
Energy Consumption Curve No. 4.
Note:- Figures on curves denote rate of acceleration on Tangent level Track during period of operation on subnormal voltages.
Current per Car
Speed
Distance
Volts per Motor
Miles per Hour
Amperes
Volts
Miles
Up Grade
Curve
10 sec. Stop
Time in Seconds

PLATE VIII.



6
TYPICAL EXPRESS RUN.
PROPOSED DANVILLE – TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
A.A. Oswald. — Eng'rs. — H.M. Shapiro.
March 21, 1916.
GE-233-A-9 GEAR RATIO 1.351
Series Acceleration
Parallel Acceleration
Kilowatt-Hours per Ton-Mile
Note.- Figures on curves denote rate of acceleration on tangent level track during period of operation on subnormal voltage.
Note.- For additional data see Chart of Coefficients Nº 4E
Energy Consumption Curve Nº 4
Miles per Hour
Amperes
Miles
Speed
Current per Car
Distance
Time in Seconds
10 Sec. Stop

PLATE IX.

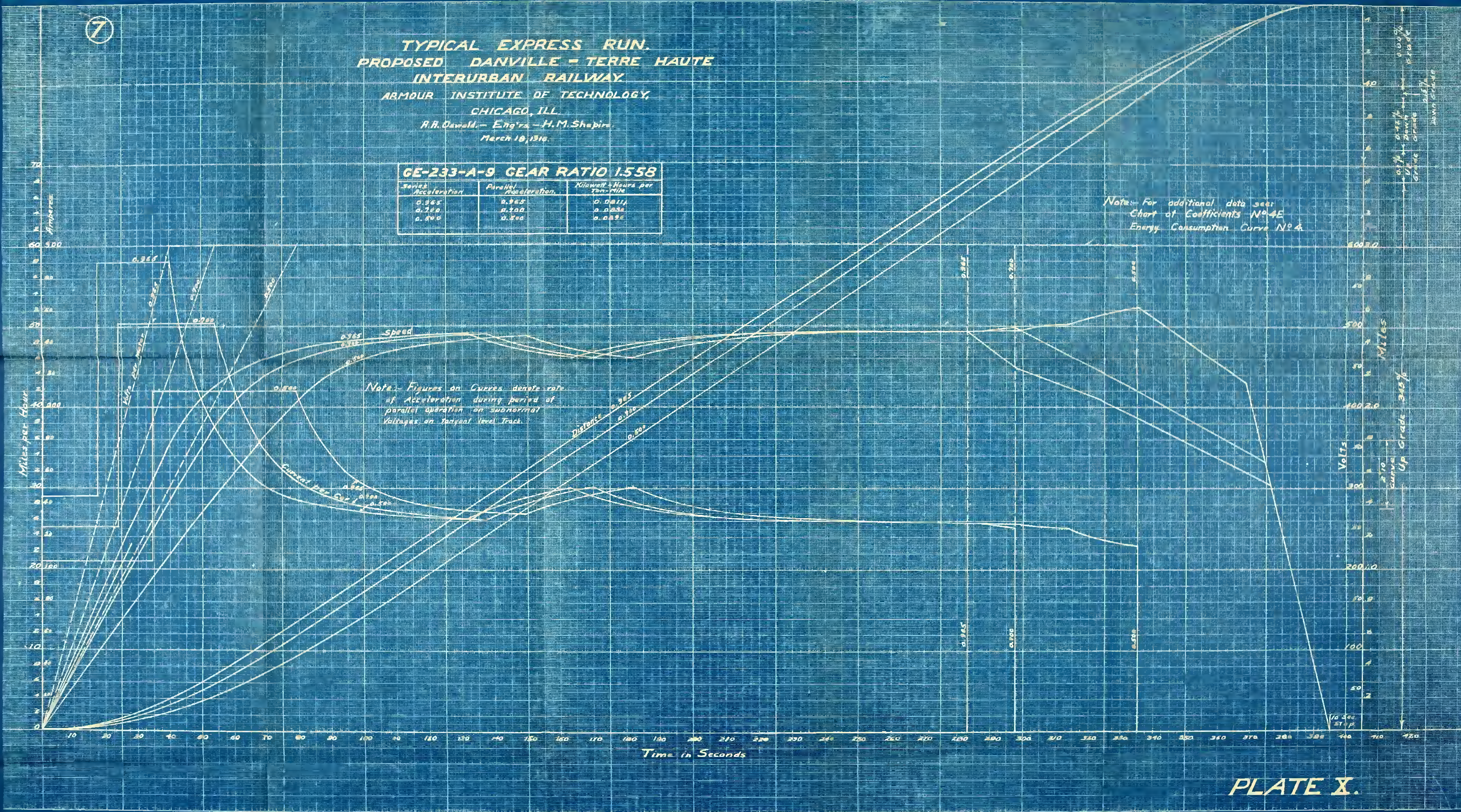

7
TYPICAL EXPRESS RUN.
PROPOSED DANVILLE - TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
A.A. Oswald. - Eng'rs. - H.M. Shapiro.
March 18, 1910.
GE-233-A-9 GEAR RATIO 1.558
Series Acceleration
Parallel Acceleration.
Kilowatt - Hours per Ton-Mile
0.965
0.700
0.500
0.965
0.700
0.500
0.0811
Note:- For additional data see: Chart of Coefficients Nº 4E
Energy Consumption Curve Nº 4
Note:- Figures on Curves denote rate of Acceleration during period of parallel operation on subnormal Voltages on Tangent level Track.
Speed
Distance
Current per Car
Volts per Motor
Miles per Hour
Amperes
Volts
Miles
Up Grade
Time in Seconds
10 Sec. Stop

PLATE X.

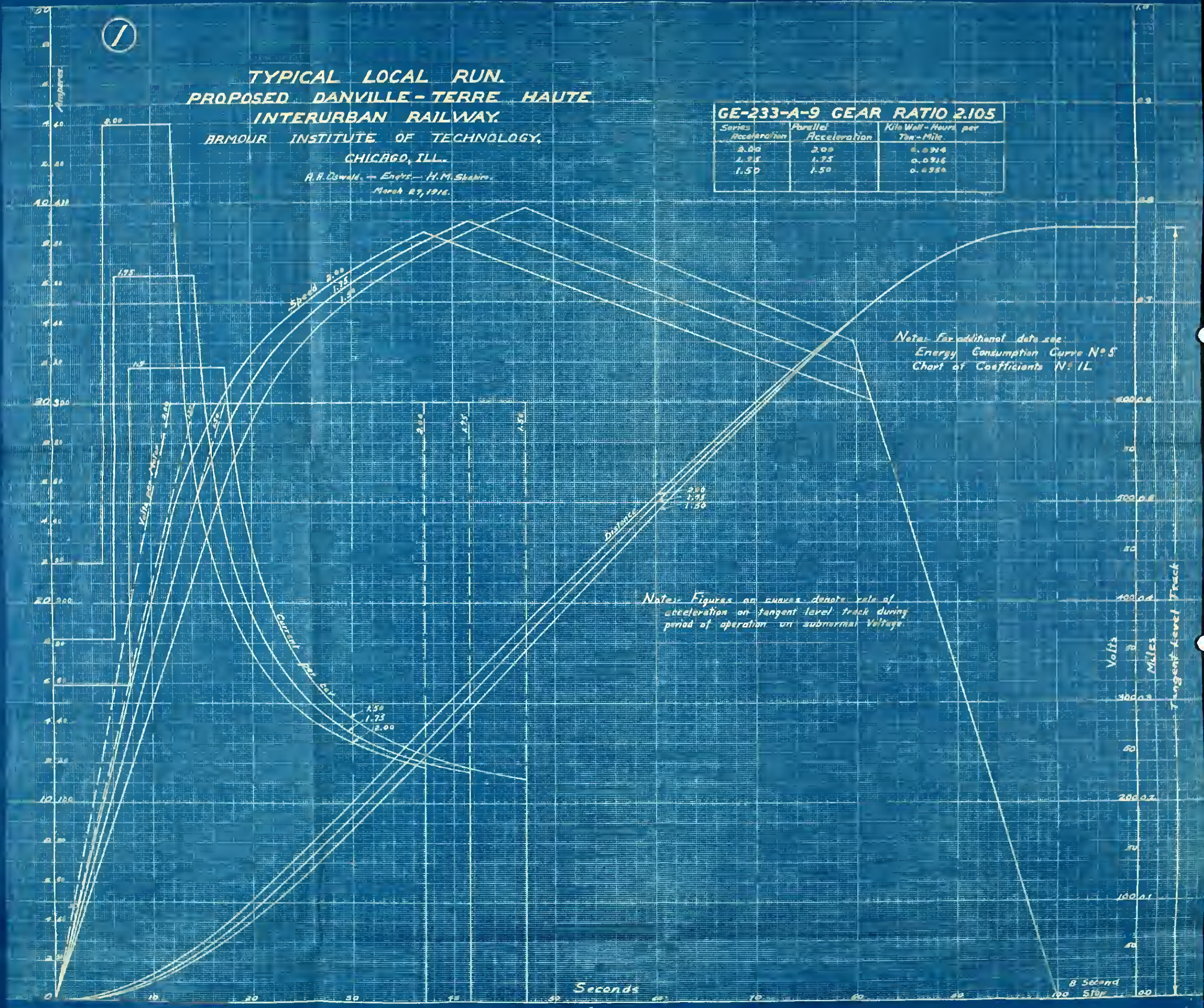
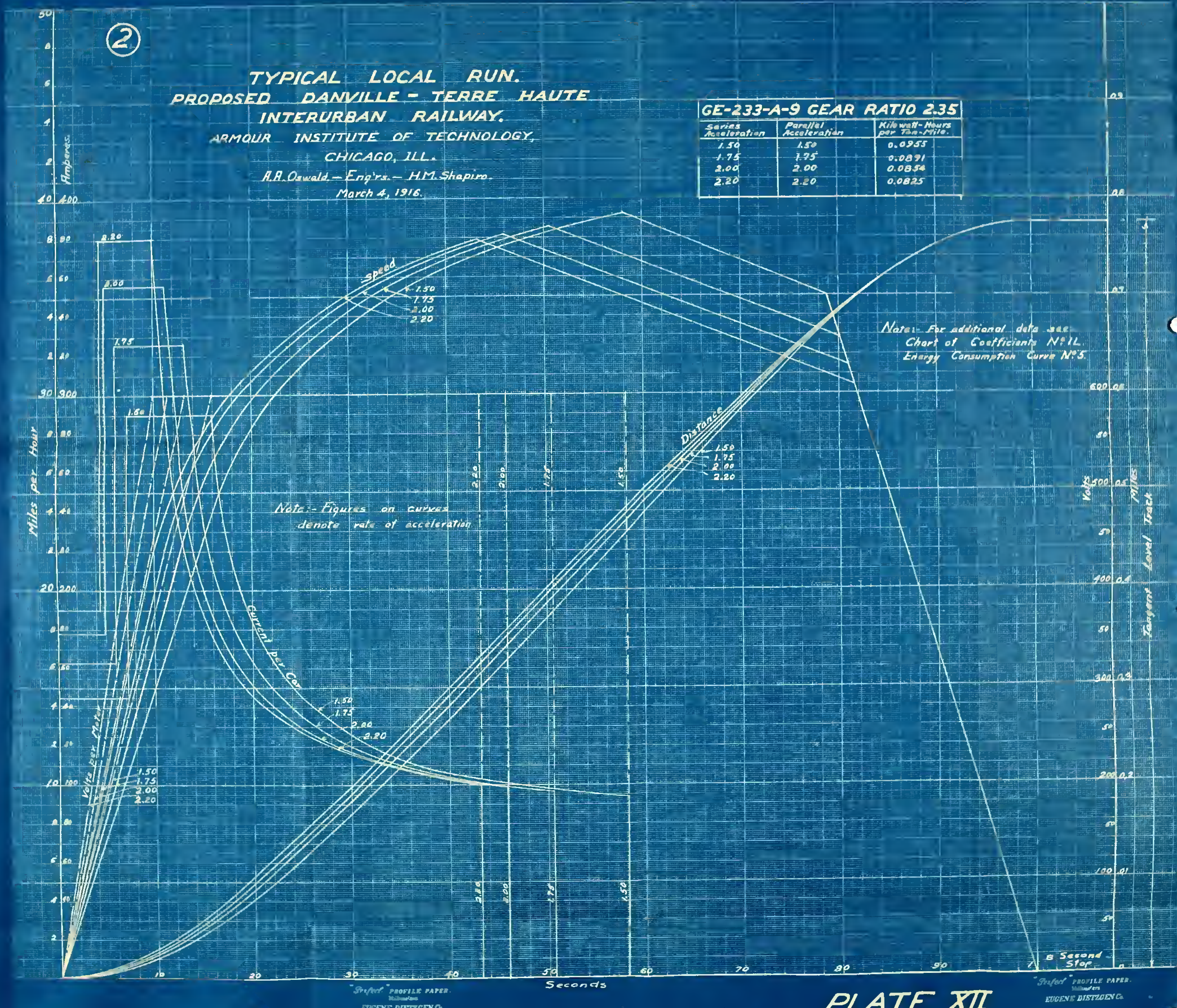
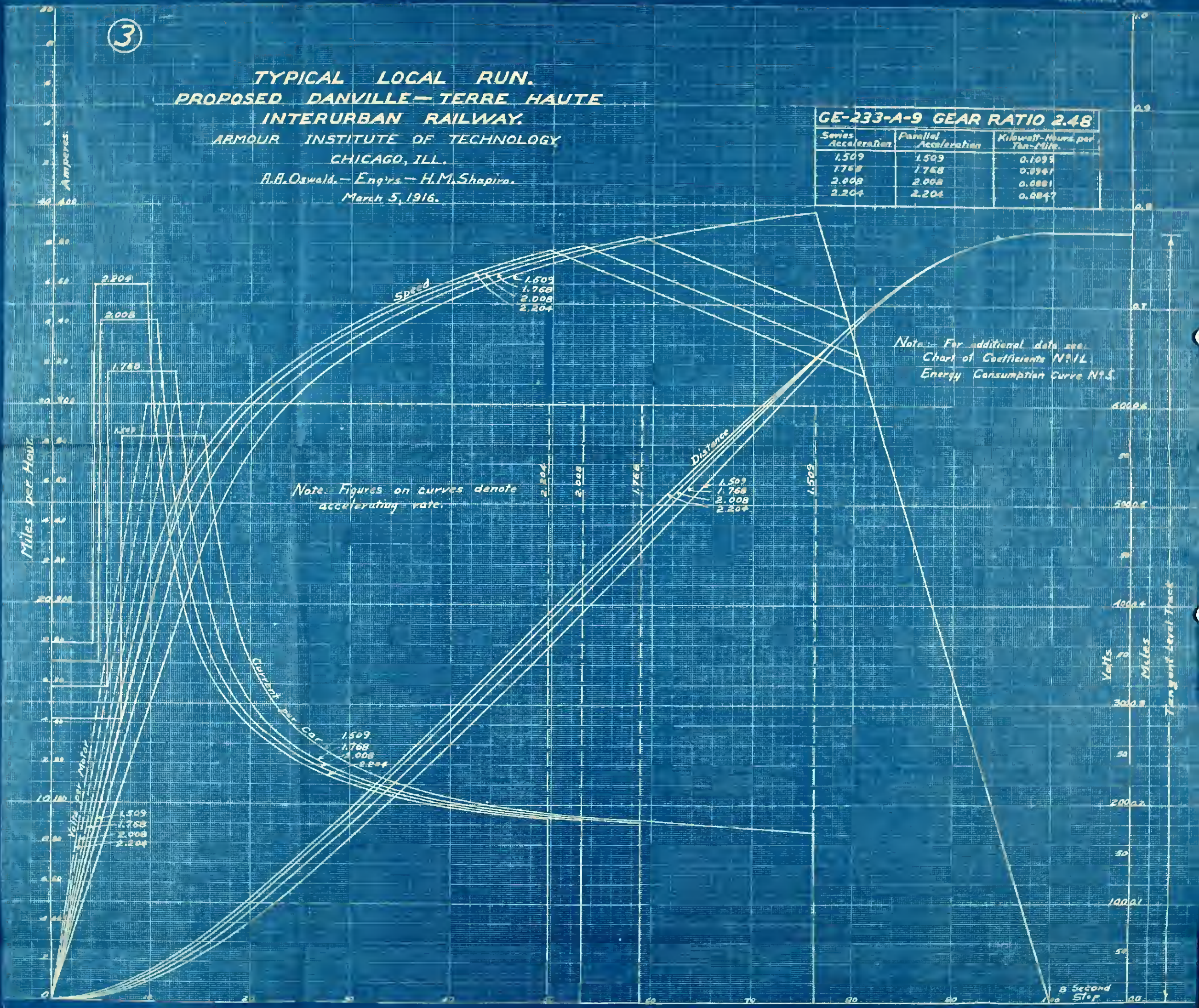

1
TYPICAL LOCAL RUN.
PROPOSED DANVILLE-TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
A. A. Oswald. — Engrs. — H. M. Shapiro.
March 27, 1916.
GE-233-A-9 GEAR RATIO 2.105
Series Acceleration
Parallel Acceleration
Kilo Watt-Hours per Ton-Mile
2.00
1.75
1.50
0.0916
Note: For additional data see
Energy Consumption Curve No. 5
Chart of Coefficients No. 1L
Notes: Figures on curves denote rate of
acceleration on tangent level track during
period of operation on subnormal Voltage.
Amperes
Speed
Volts per Motor
Current per Car
Distance
Seconds
Volts
Miles
Tangent Level Track
8 Second Stop

PLATE XI.



Series Acceleration	Parallel Acceleration	Kilowatt-Hours per Ton-Mile.
1.50	1.50	0.0955
1.75	1.75	0.0891
2.00	2.00	0.0854
2.20	2.20	0.0825

PLATE XII.



GE-233-A-9 GEAR RATIO 2.48

Series Acceleration	Parallel Acceleration	Kilowatt-Hours per Ton-Mile.
1.509	1.509	0.1095
1.768	1.768	0.0941
2.008	2.008	0.0881
2.204	2.204	0.0847

PLATE XIII.

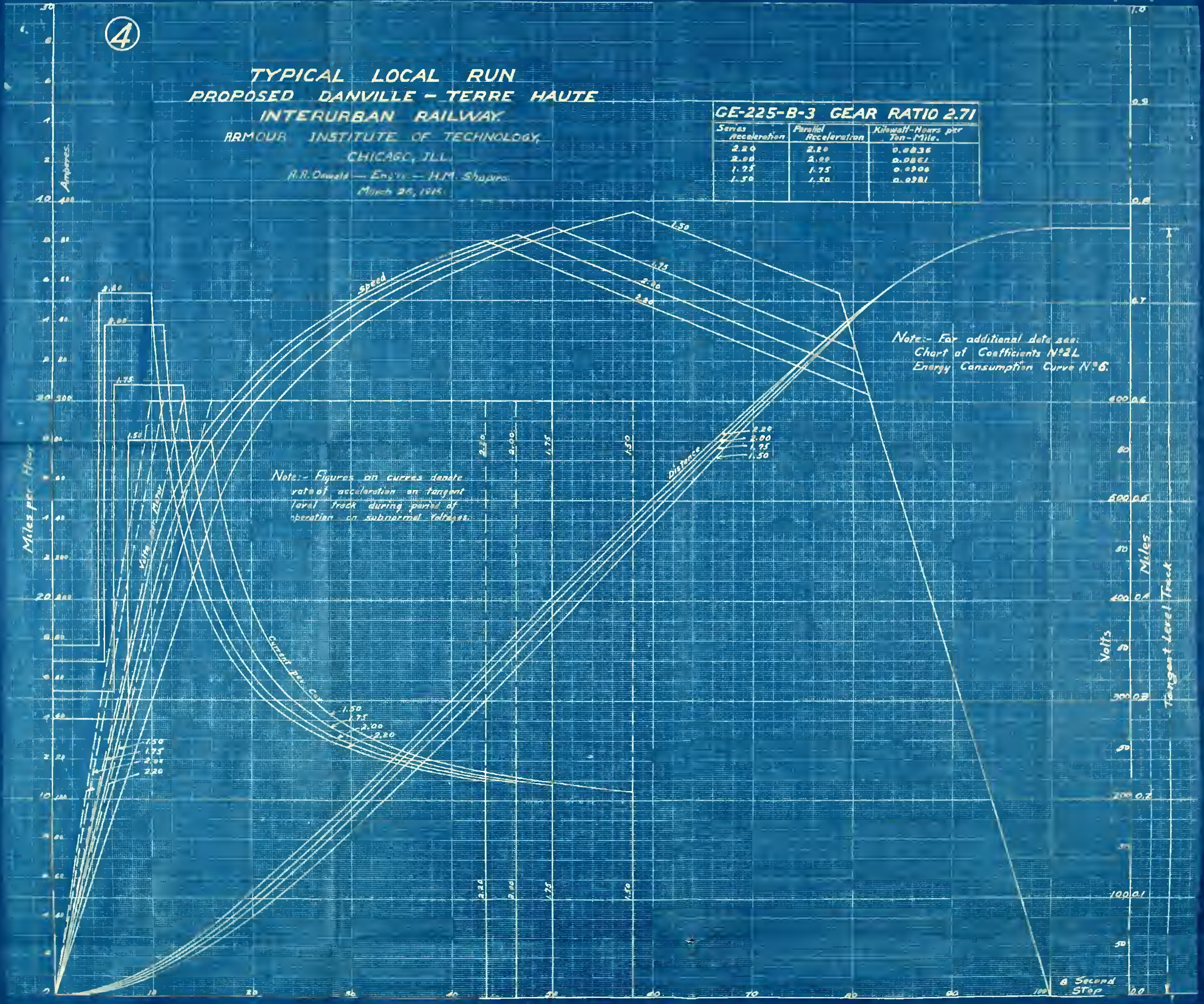
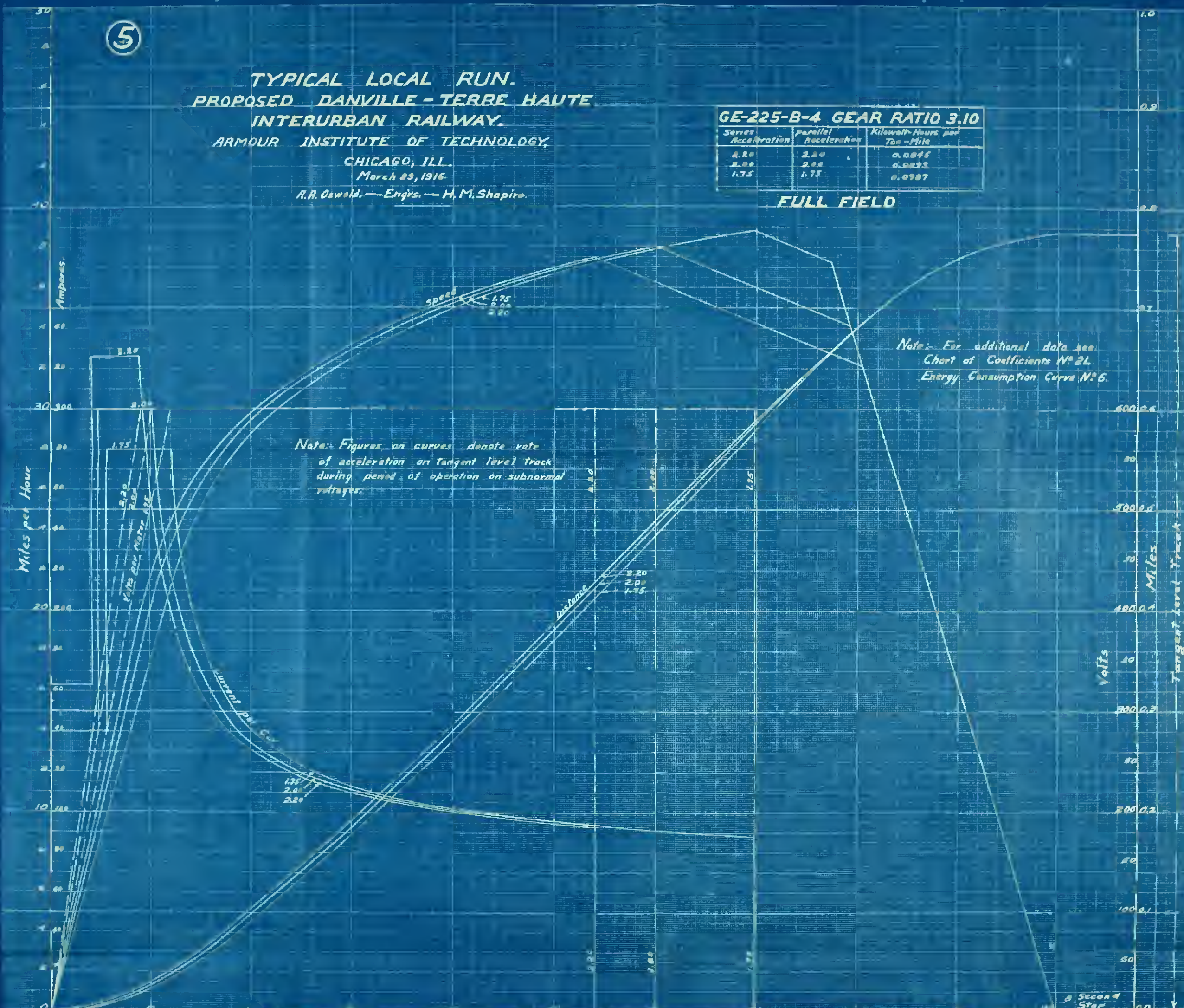
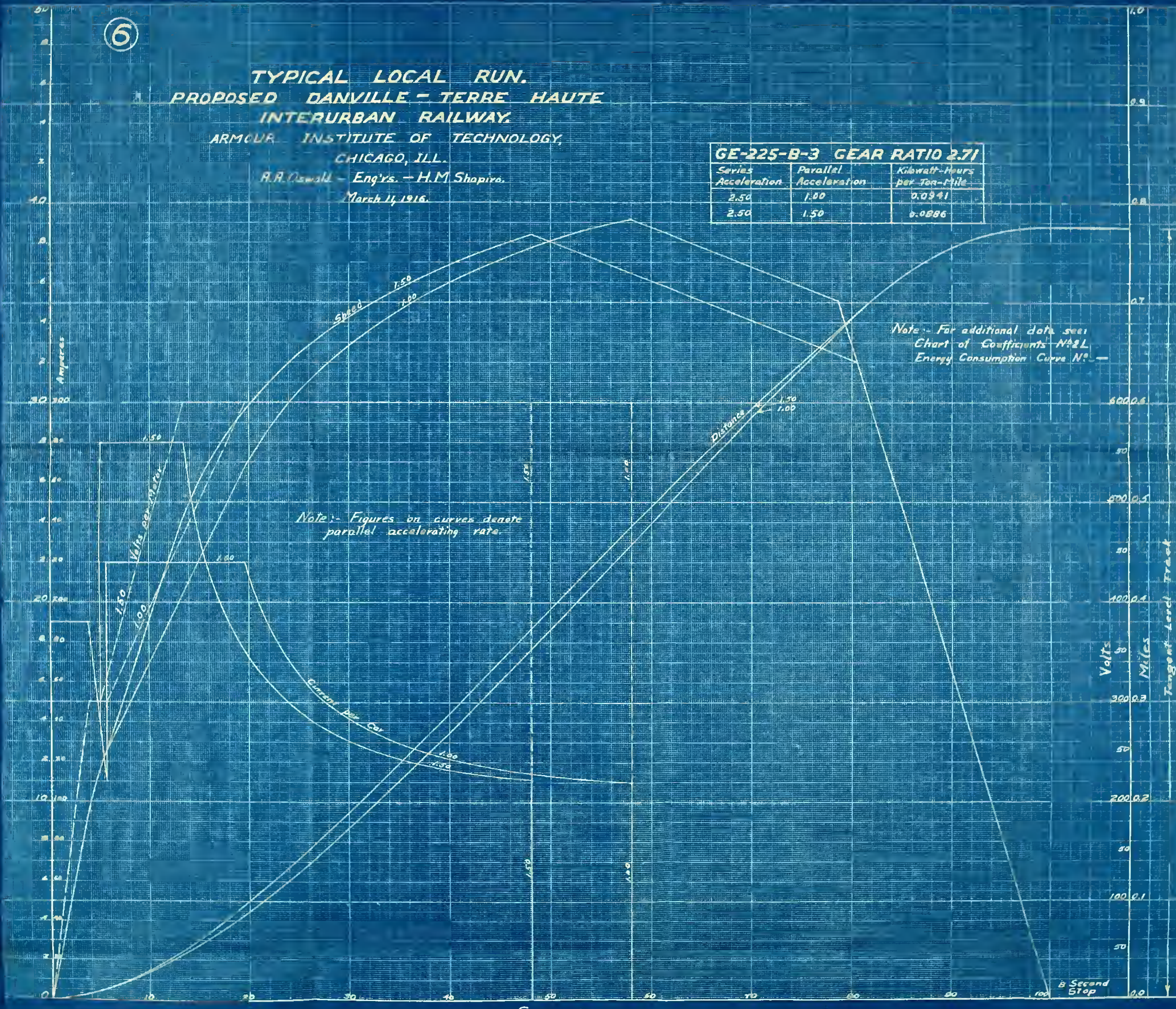

④
TYPICAL LOCAL RUN
PROPOSED DANVILLE – TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
A.R. Oswald — Engrs. — H.M. Shapiro.
March 26, 1915.
GE-225-B-3 GEAR RATIO 2.71
Series Acceleration | Parallel Acceleration | Kilowatt-Hours per Ton-Mile.
2.20 | 2.20 | 0.0836
2.00 | 2.00 | 0.0861
1.75 | 1.75 | 0.0906
1.50 | 1.50 | 0.0981
Note:- For additional data see: Chart of Coefficients Nº2L Energy Consumption Curve Nº6.
Note:- Figures on curves denote rate of acceleration on tangent level track during period of operation on subnormal voltages.
Speed
Distance
Current per Car
Volts per Car
Miles per Hour
Amperes
Volts
Miles
Tangent Level Track
Seconds
8 Second Stop
2.20
2.00
1.75
1.50

PLATE XIV.



5
TYPICAL LOCAL RUN.
PROPOSED DANVILLE - TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
March 23, 1916.
R.A. Oswald. — Engrs. — H. M. Shapiro.
GE-225-B-4 GEAR RATIO 3.10
Series Acceleration
Parallel Acceleration
Kilowatt-Hours per Ton-Mile
2.20 2.20 0.0846
2.00 2.00 0.0893
1.75 1.75 0.0987
FULL FIELD
Note:- For additional data see Chart of Coefficients No. 2L. Energy Consumption Curve No. 6.
Note:- Figures on curves denote rate of acceleration on tangent level track during period of operation on subnormal voltages.
Speed
Distance
Current per Car
Volts per Motor
Amperes
Miles per Hour
Volts
Miles
Tangent Level Track
Seconds
9 Second Stop

PLATE XV.



6
TYPICAL LOCAL RUN.
PROPOSED DANVILLE - TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
R.R. Oswald - Eng'rs. - H.M. Shapiro.
March 11, 1916.
GE-225-B-3 GEAR RATIO 2.71
Series Acceleration | Parallel Acceleration | Kilowatt-Hours per Ton-Mile
2.50 | 1.00 | 0.0941
2.50 | 1.50 | 0.0886
Speed
Distance
Current per Car
Volts per Motor
Note:- Figures on curves denote parallel accelerating rate.
Note:- For additional data see: Chart of Coefficients No. 8L Energy Consumption Curve No. —
Amperes
Volts
Miles
Tangent Level Track
Seconds
8 Second Stop

PLATE XVI.

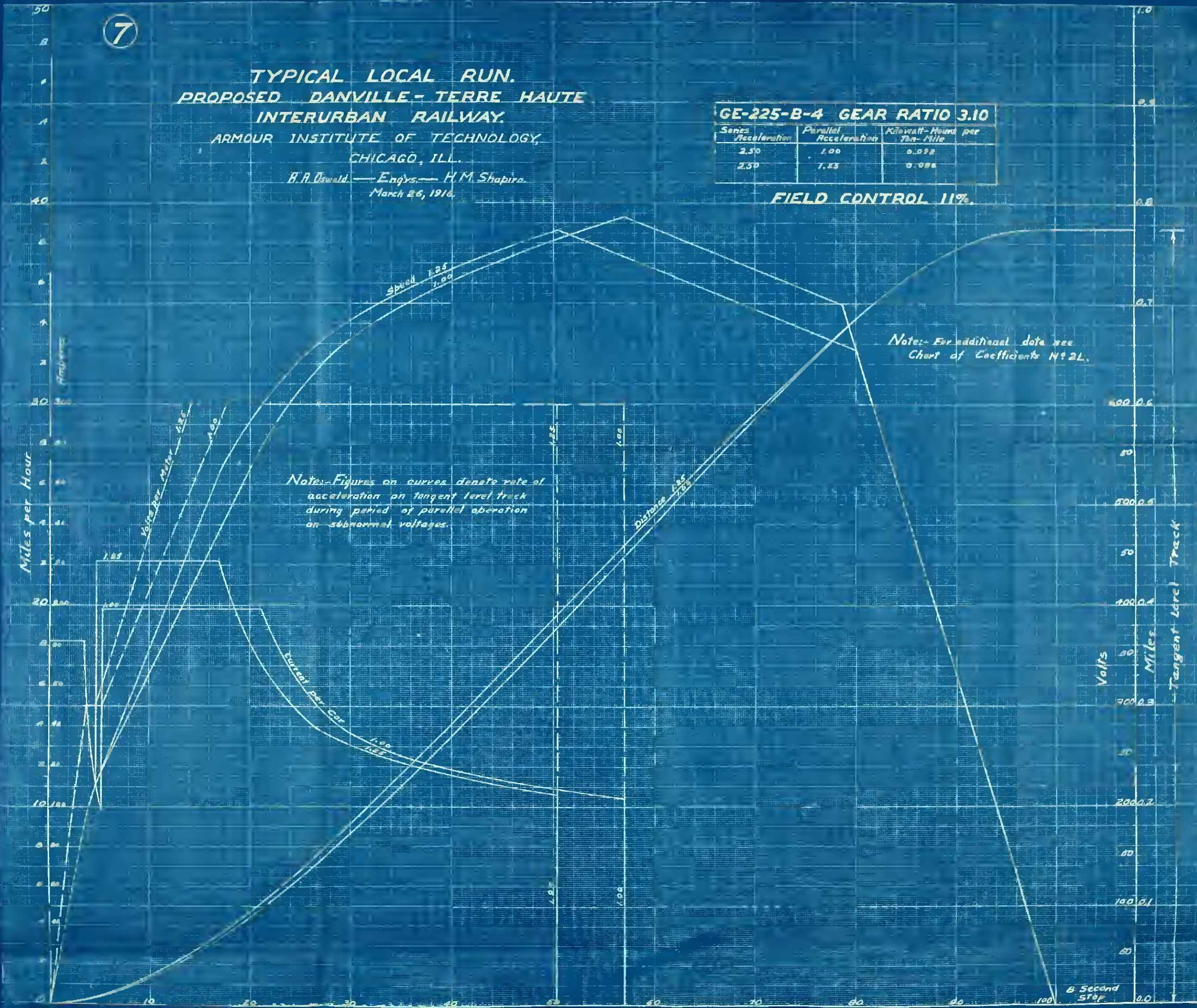
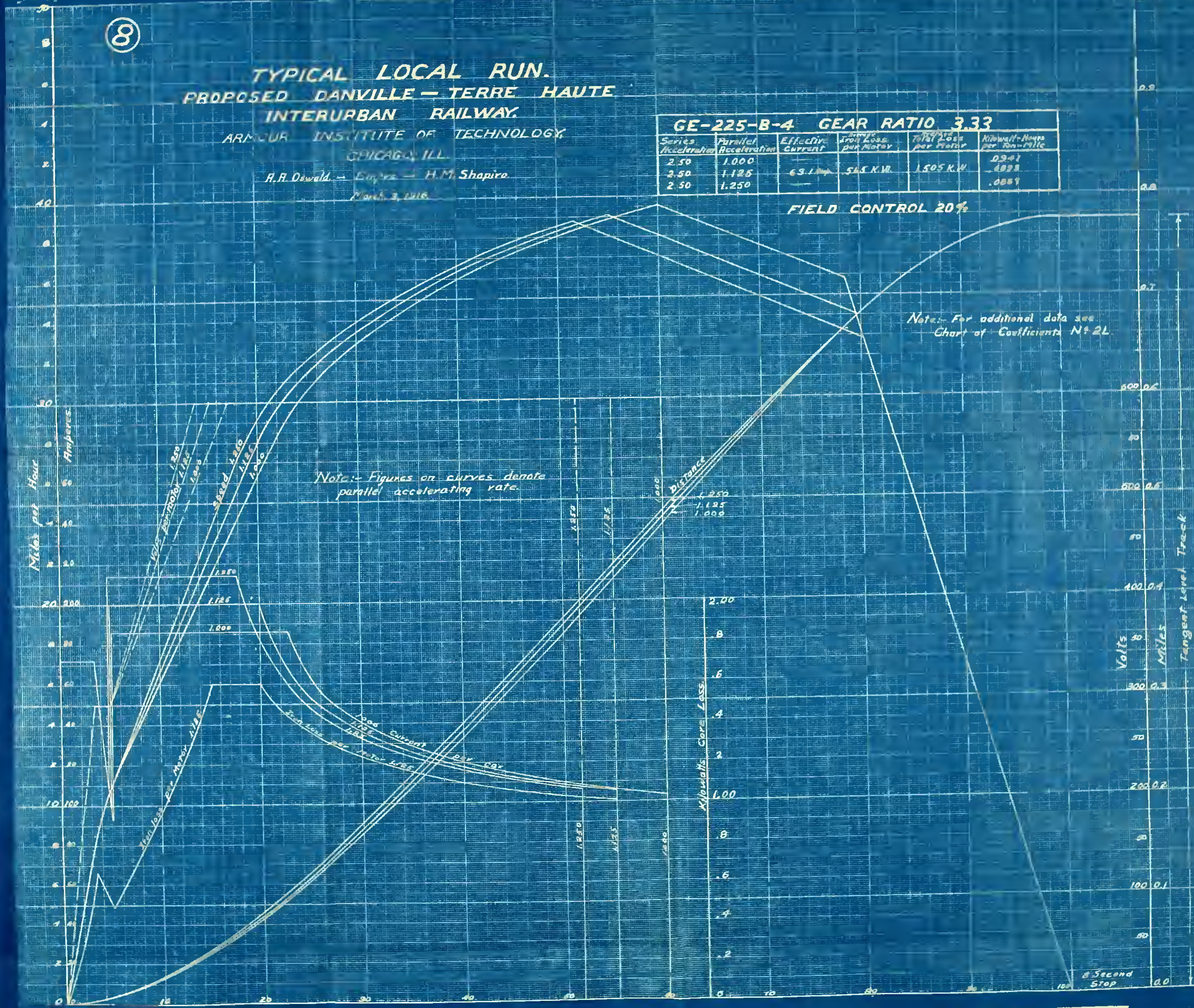
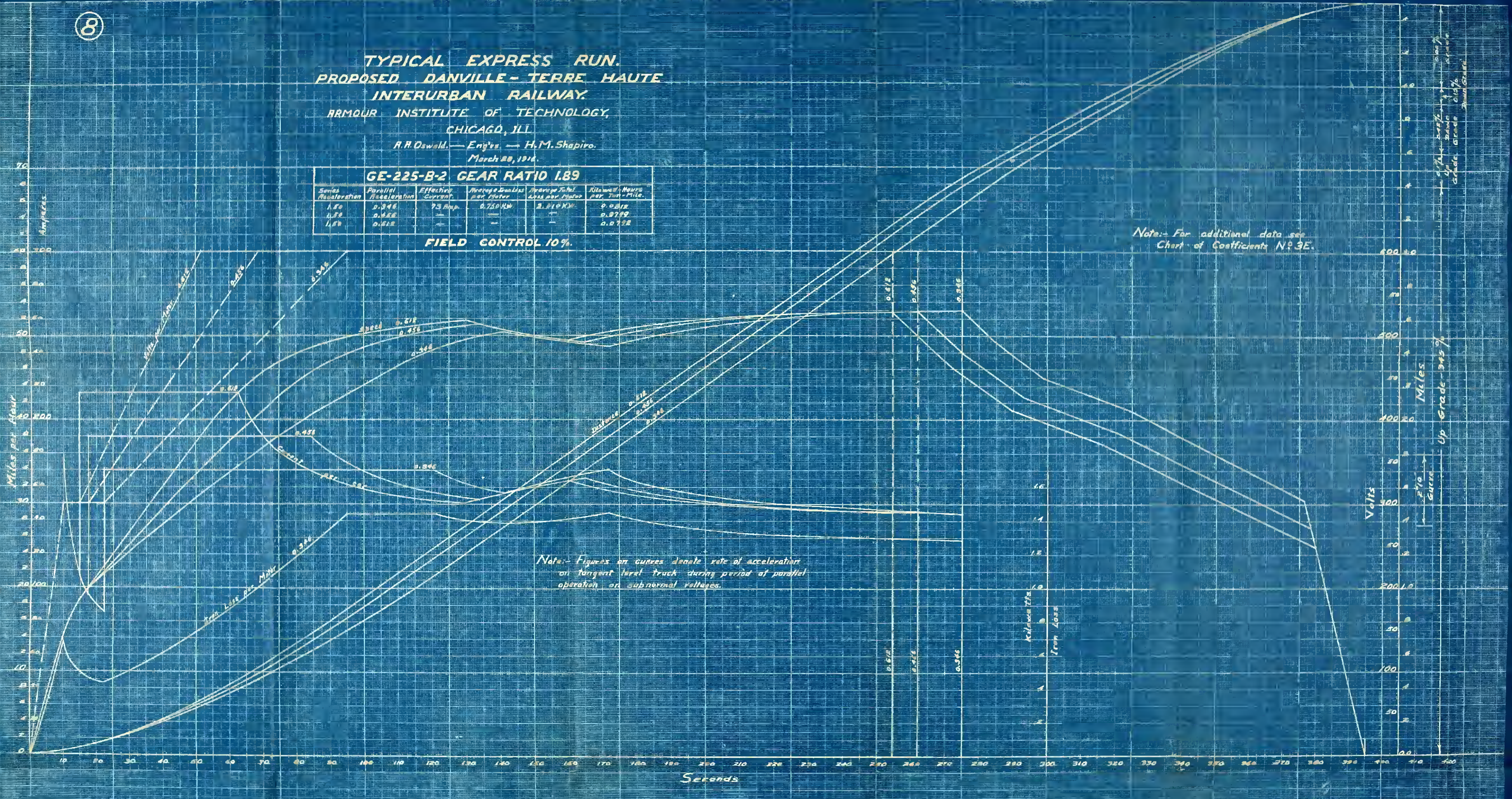

7
TYPICAL LOCAL RUN.
PROPOSED DANVILLE - TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY.
CHICAGO, ILL.
R. A. Oswald — Engrs. — H. M. Shapiro.
March 26, 1916.
GE-225-B-4 GEAR RATIO 3.10
Series Acceleration | Parallel Acceleration | Kilowatt-Hours per Ton-Mile
2.50 | 1.00 | 0.092
2.50 | 1.25 | 0.096
FIELD CONTROL 11%.
Note:- For additional data see Chart of Coefficients No 2L.
Note:- Figures on curves denote rate of acceleration on tangent level track during period of parallel operation on subnormal voltages.
Speed 1.25 1.00
Distance 1.25 1.00
Volts per Motor 1.25 1.00
Current per Car 1.00 1.25
Miles per Hour
Amperes
Volts
Miles
Tangent Level Track
8 Second Stop
Seconds
10
20
30
40
50
60
70
80
90
100

PLATE XVII.



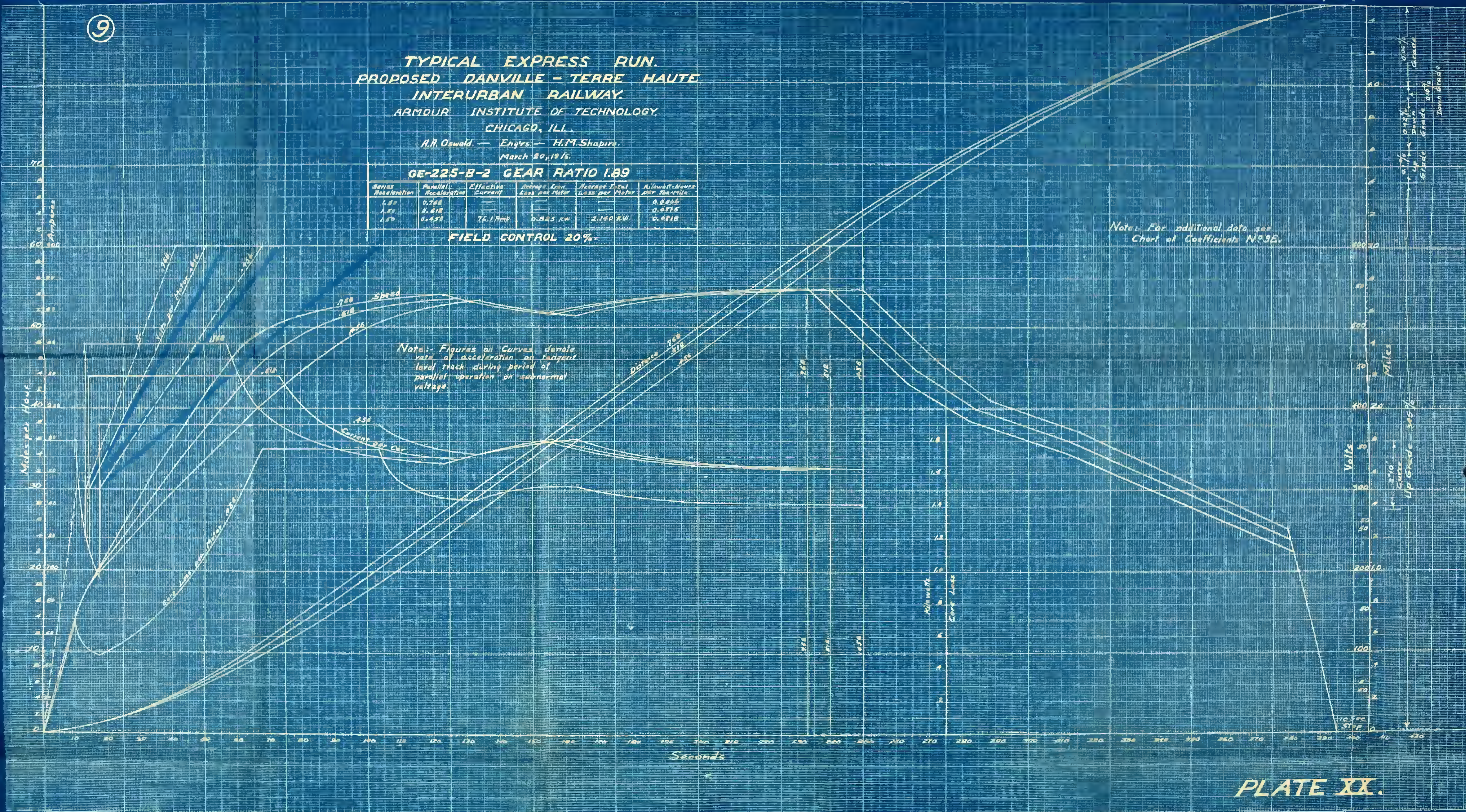
GE-225-B-4 GEAR RATIO 3.33					
Series Acceleration	Parallel Acceleration	Effective Current	Average Iron Loss per Motor	Average Total Loss per Motor	Kilowatt-Hours per Ton-Mile
2.50	1.000				.0941
2.50	1.125	63.1 Amp.	.565 K.W.	1.505 K.W.	.0933
2.50	1.250				.0859

PLATE XVIII.



Series Acceleration	Parallel Acceleration	Effective Current	Average Iron Loss per Motor	Average Total Loss per Motor	Kilowatt-Hours per Ton-Mile
1.50	0.346	73 Amp.	0.750 KW.	2.810 KW.	0.0812
1.50	0.456	—	—	—	0.0799
1.50	0.612	—	—	—	0.0792

PLATE XIX.



Series Acceleration	Parallel Acceleration	Effective Current	Average Core Loss per Motor	Average Total Loss per Motor	Kilowatt-Hours per Ton-Mile
1.50	0.768	—	—	—	0.0806
1.50	0.618	—	—	—	0.0875
1.50	0.458	76.1 Amp	0.825 K.W.	2.140 K.W.	0.0818

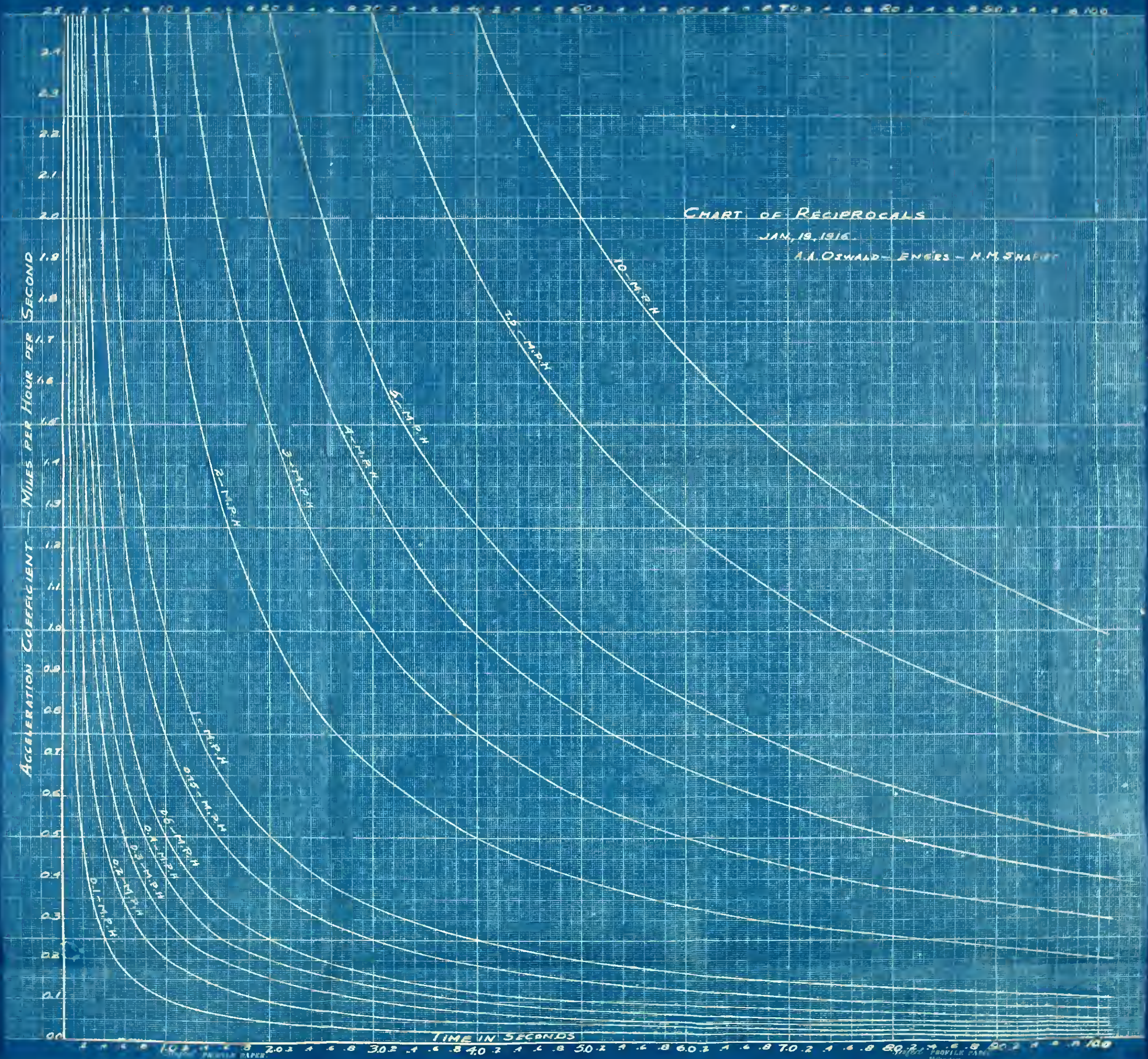


CHART OF RECIPROCALS
JAN. 19, 1916.
ACCELERATION COEFFICIENT — MILES PER HOUR PER SECOND
TIME IN SECONDS
10-M.P.H
7.5-M.P.H
5-M.P.H
4-M.P.H
3-M.P.H
2-M.P.H
1-M.P.H
0.75-M.P.H
0.5-M.P.H
0.4-M.P.H
0.3-M.P.H
0.2-M.P.H
0.1-M.P.H

PLATE XXI.

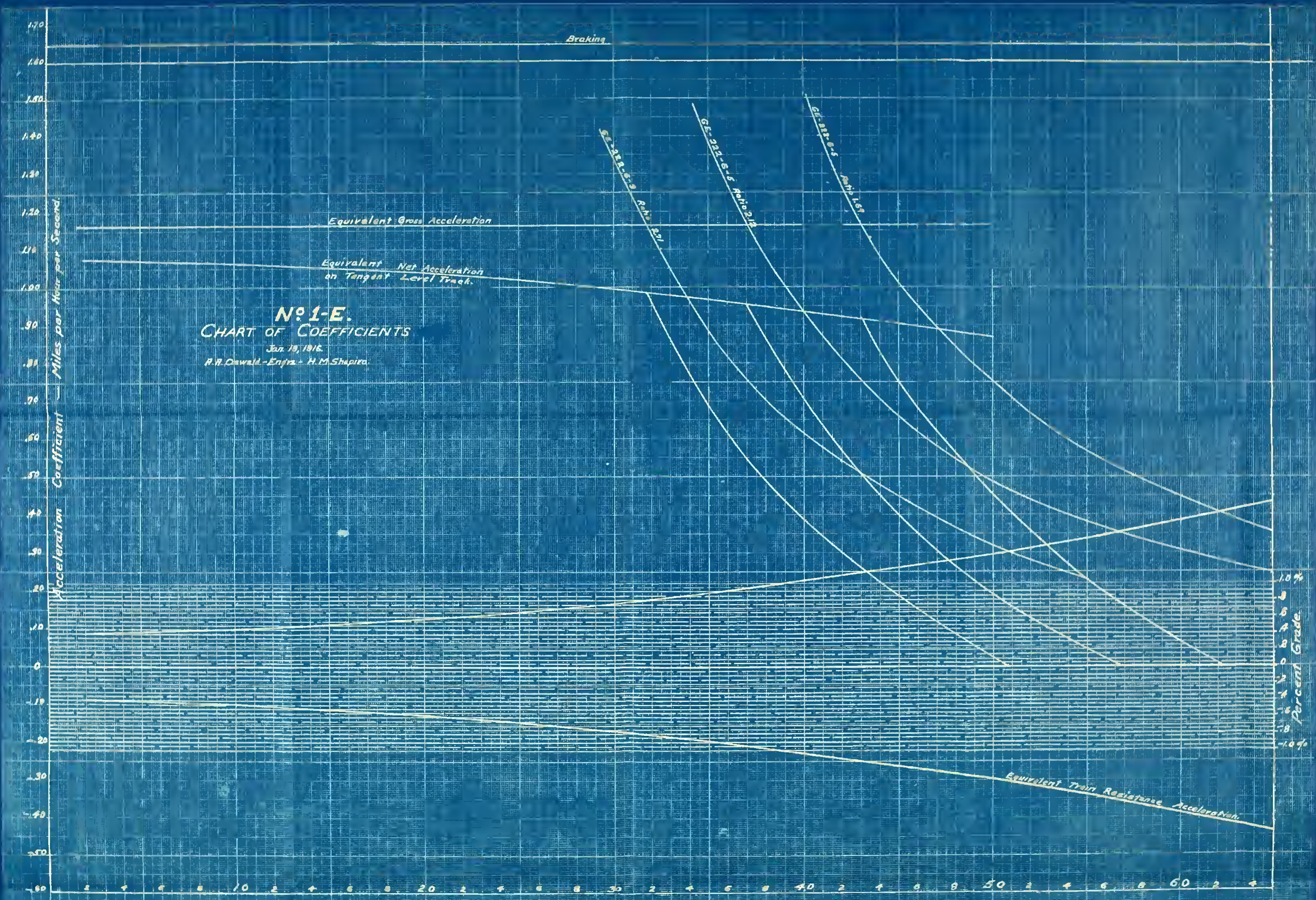
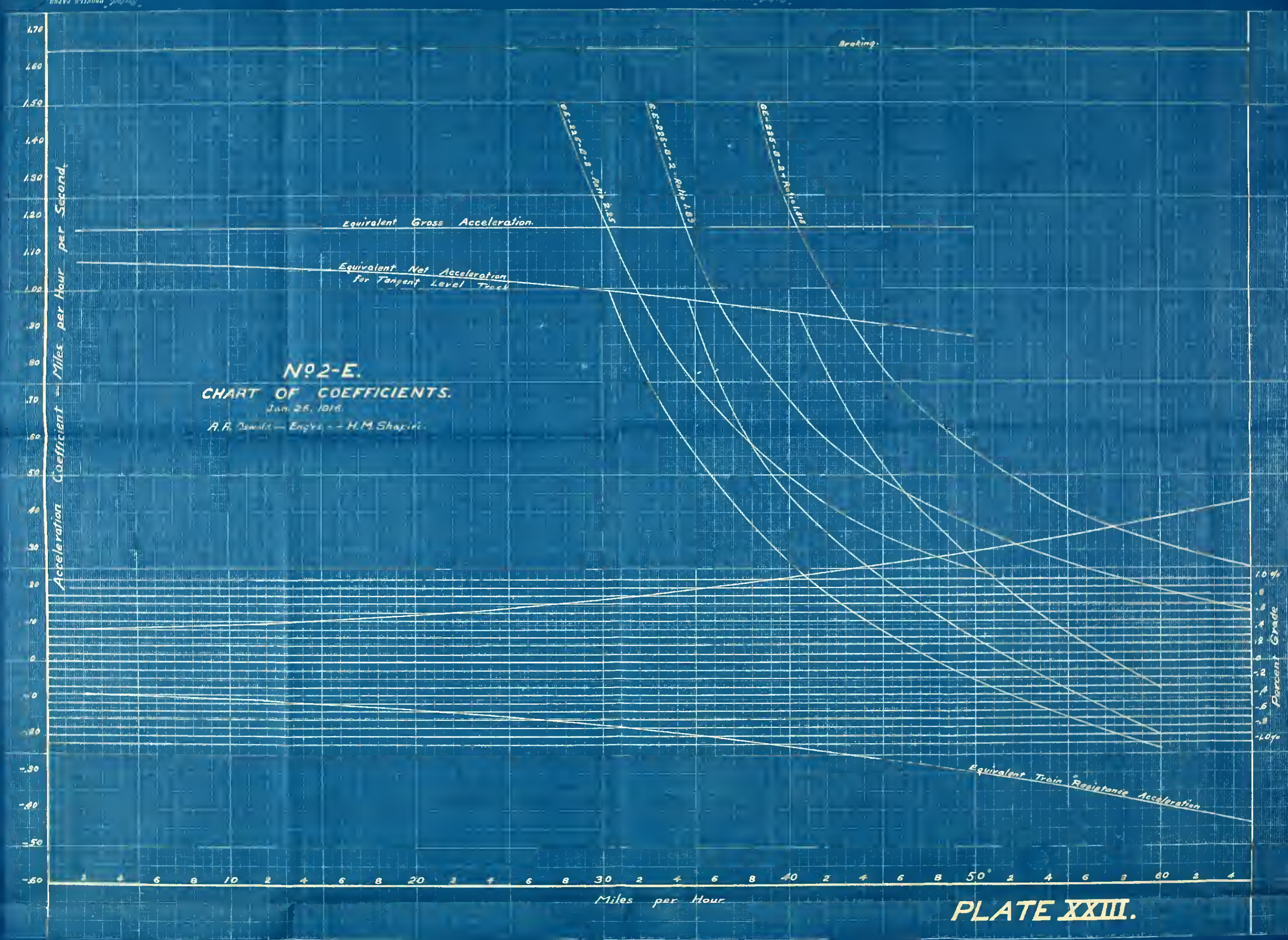
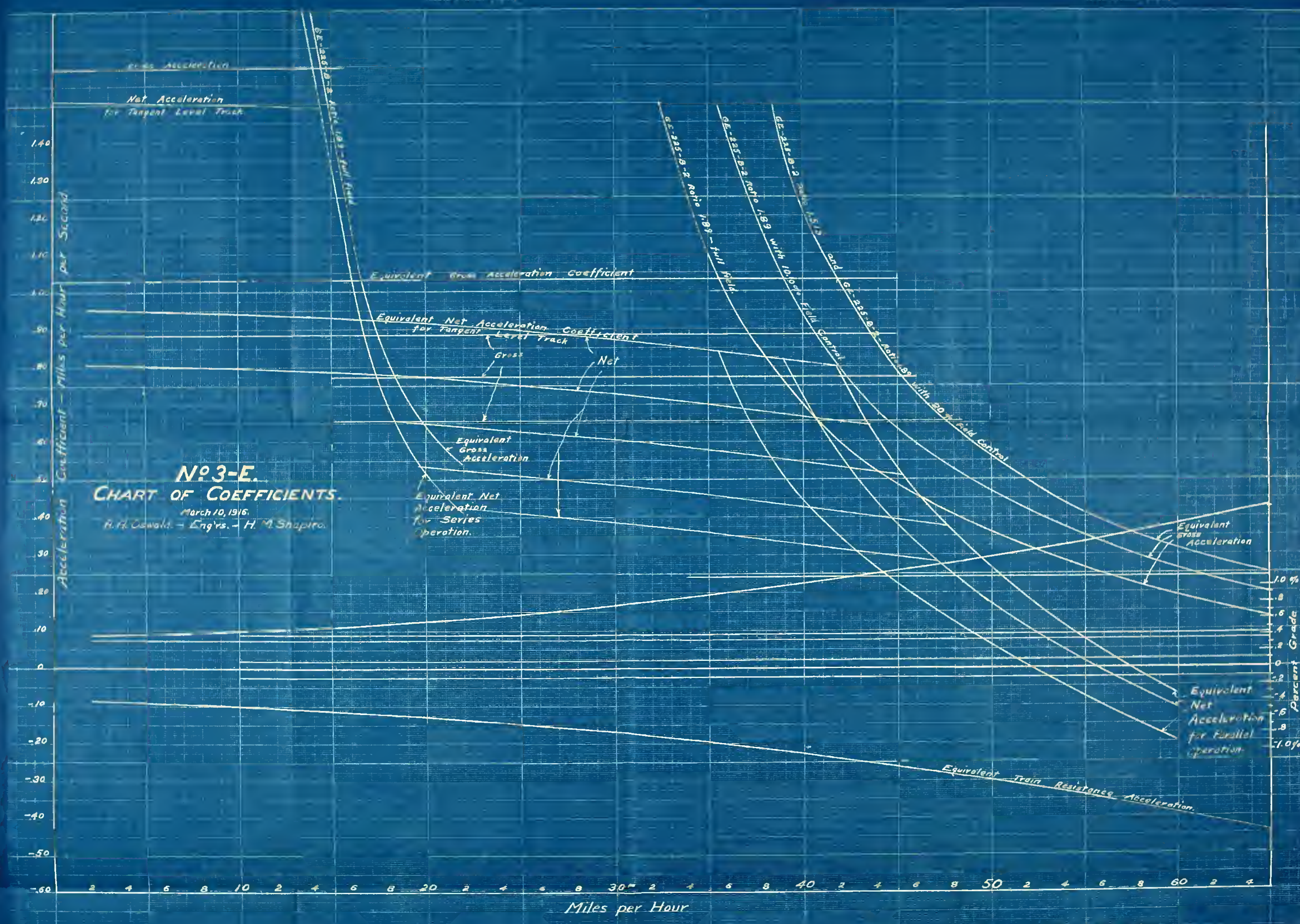

Braking
Equivalent Gross Acceleration
Equivalent Net Acceleration on Tangent Level Track.
No 1-E.
CHART OF COEFFICIENTS
Jan 19, 1916.
A.A. Oswald - Engrs. - H.M. Shapiro.
GE-222-6-6
Ratio 2.71
Acceleration Coefficient — Miles per Hour per Second.
Percent Grade.
Equivalent Train Resistance Acceleration.
MILES PER HOUR

PLATE XXII.



No. 2-E.
CHART OF COEFFICIENTS.
Jan. 26, 1916.
Engrs. H. M. Shapiro
Braking.
Equivalent Gross Acceleration.
Equivalent Net Acceleration for Tangent Level Track
Equivalent Train Resistance Acceleration
Acceleration Coefficient — Miles per Hour per Second.
Miles per Hour
Percent Grade
1.0%
-1.0%
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
-.30
-.40
-.50
-.60
10
20
30
40
50
60

PLATE XXIII.



Gross Acceleration
Net Acceleration
for Tangent Level Track
Equivalent Gross Acceleration Coefficient
Equivalent Net Acceleration Coefficient
for Tangent Level Track
Gross
Net
Equivalent
Gross
Acceleration
Equivalent Net
Acceleration
for Series
Operation.
No 3-E.
CHART OF COEFFICIENTS.
March 10, 1916.
R. H. Oswald. - Eng'rs. - H. M. Shapiro.
GE-225-B-2 Ratio 1.89 - full Field.
GE-225-B-2 Ratio 1.89 with 10.10% Field Control.
and GE-225-B-2 Ratio 1.89 with 20% Field Control
Equivalent
Gross
Acceleration
Equivalent
Net
Acceleration
for Parallel
Operation.
Equivalent Train Resistance Acceleration.
Acceleration Coefficient - Miles per Hour per Second
Percent Grade
Miles per Hour

PLATE XXIV.

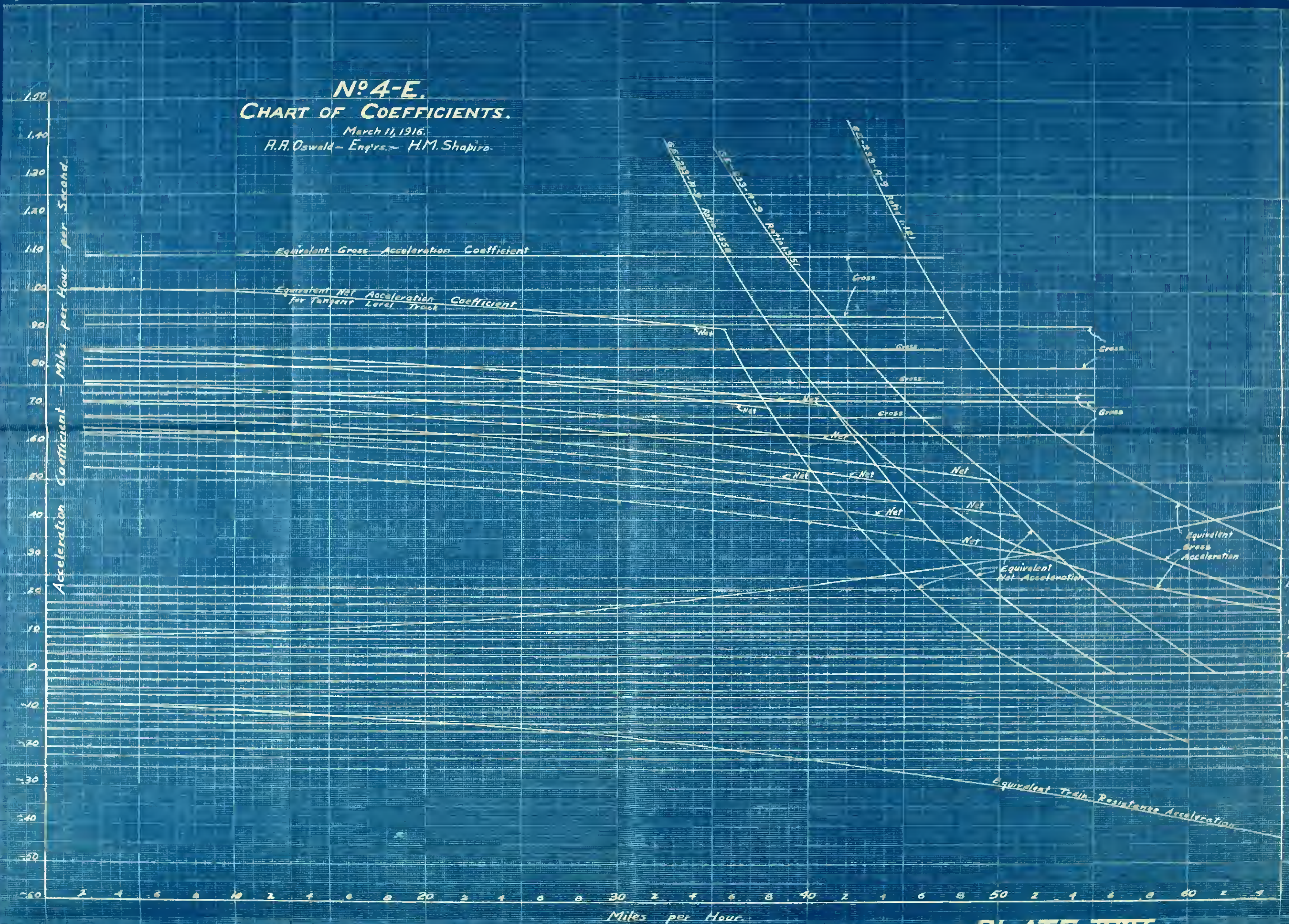

No 4-E.
CHART OF COEFFICIENTS.
March 11, 1916.
A.A. Oswald – Eng'rs. – H.M. Shapiro.
Acceleration Coefficient – Miles per Hour per Second.
Equivalent Gross Acceleration Coefficient
Equivalent Net Acceleration Coefficient for Tangent Level Track
Gross
Net
Equivalent Gross Acceleration
Equivalent Net Acceleration
Equivalent Train Resistance Acceleration
Percent Grade
Miles per Hour.

PLATE XXV.

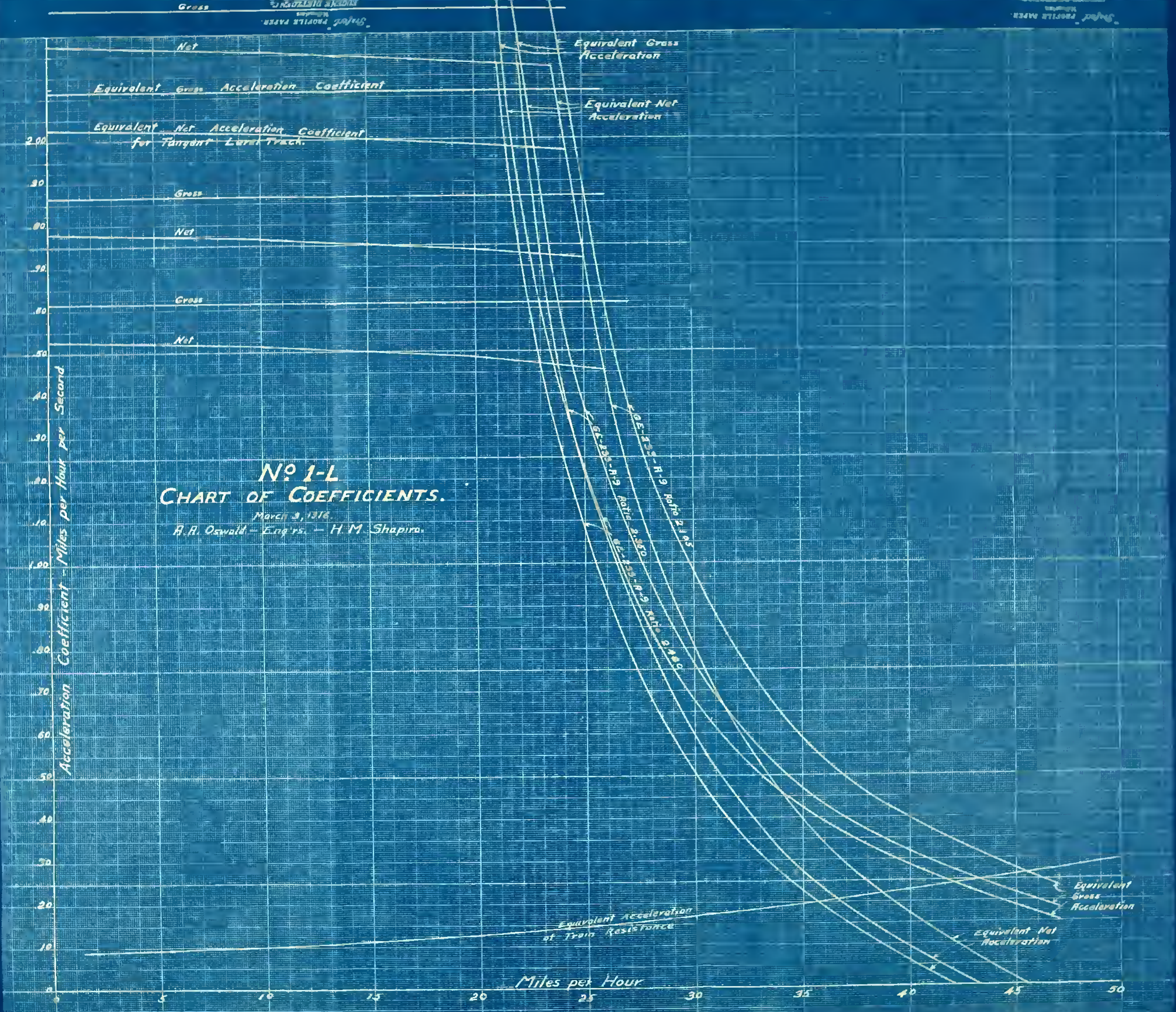

No 1-L
CHART OF COEFFICIENTS.
March 3, 1916.
B.R. Oswald - Eng'rs. - H.M. Shapiro.
Acceleration Coefficient - Miles per Hour per Second
Miles per Hour
Equivalent Gross Acceleration Coefficient
Equivalent Net Acceleration Coefficient for Tangent Level Track.
Gross
Net
Equivalent Gross Acceleration
Equivalent Net Acceleration
Equivalent Acceleration of Train Resistance
GE-235-A-9 Ratio 2.105
GE-235-A-9 Ratio 2.350
GE-235-A-9 Ratio 2.480
0
5
10
15
20
25
30
35
40
45
50
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
2.00

PLATE XXVI.

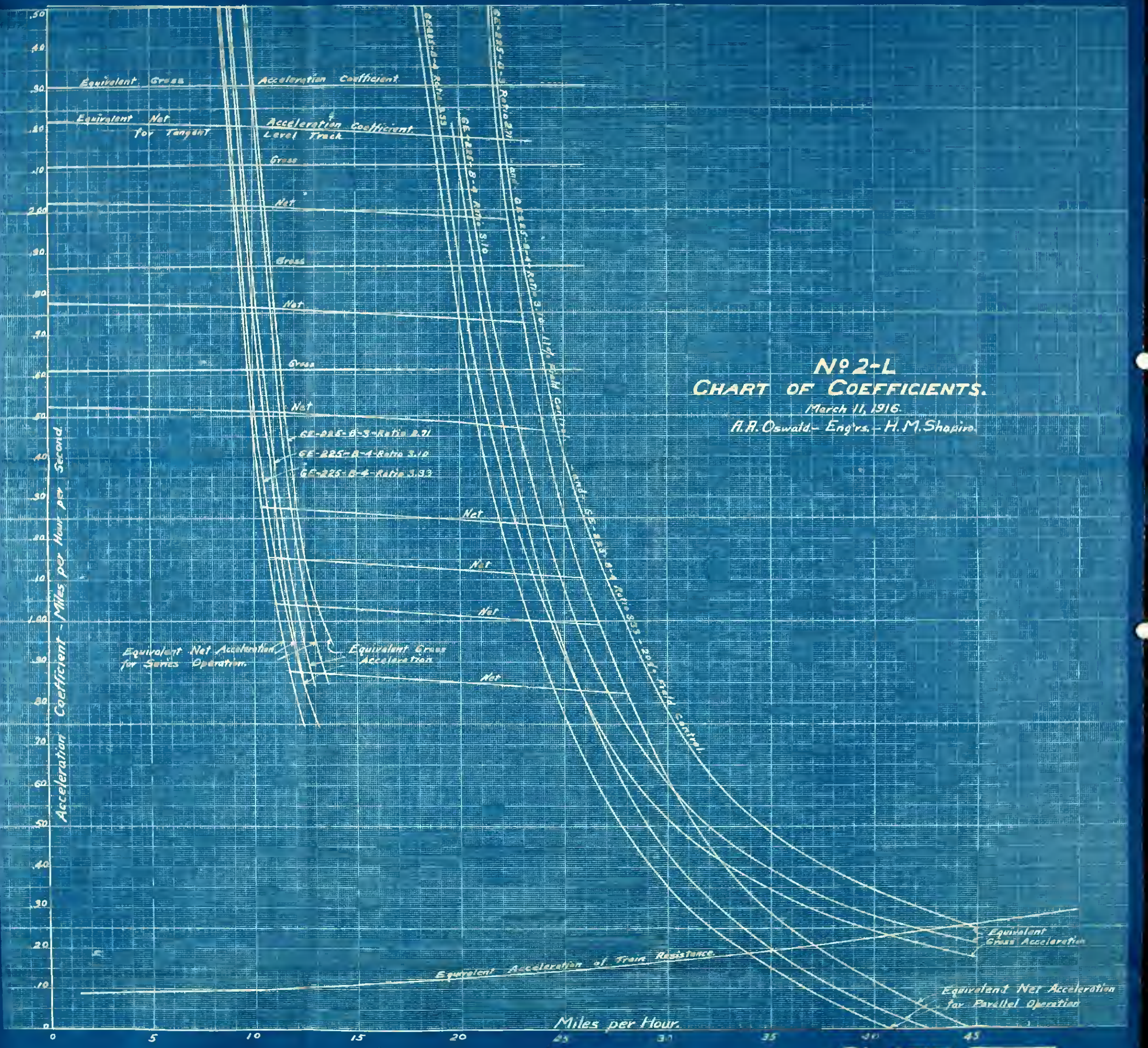
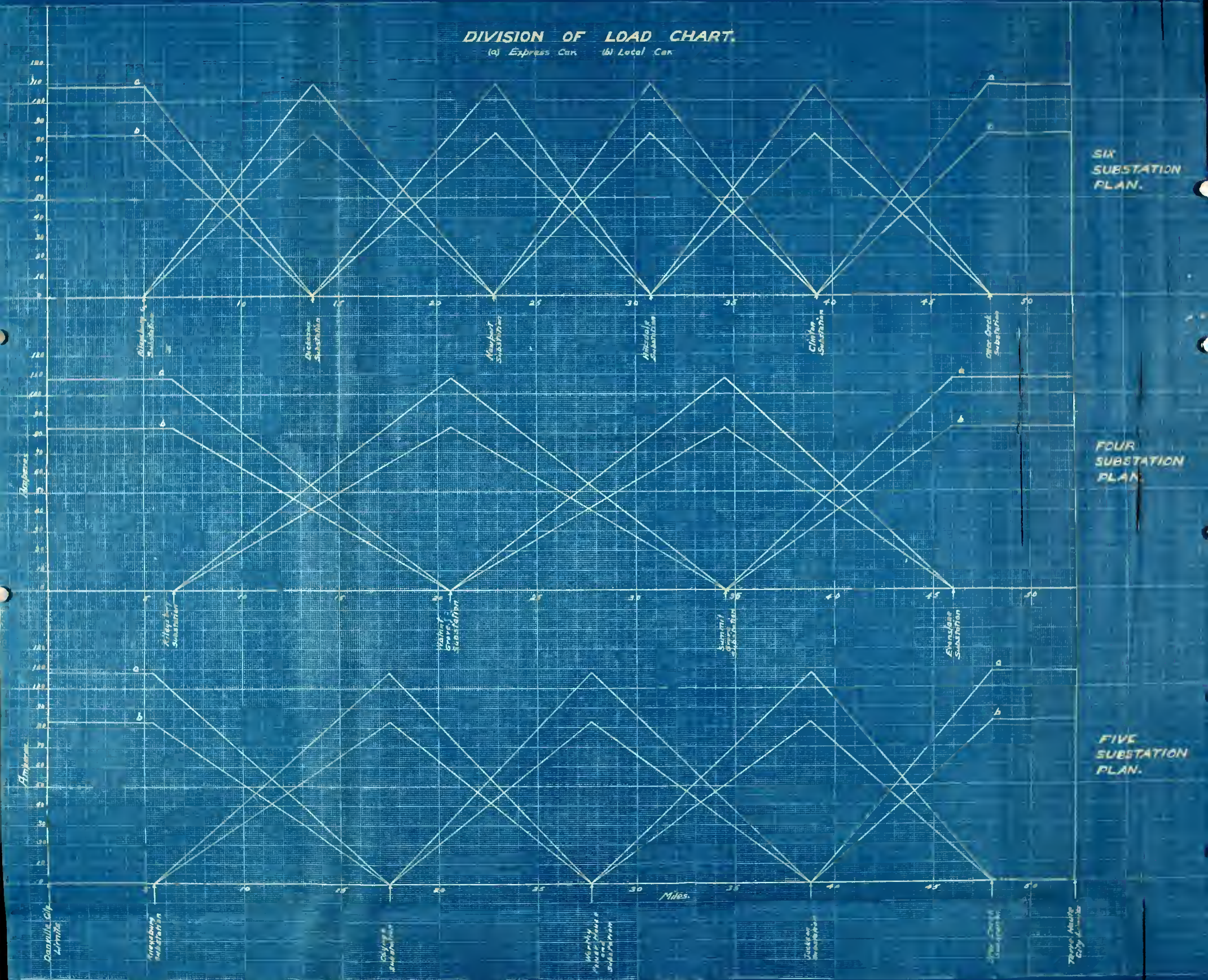

Nº 2-L
CHART OF COEFFICIENTS.
March 11, 1916.
A.A. Oswald.- Eng'rs.- H.M. Shapiro.
Equivalent Gross Acceleration Coefficient
Equivalent Net Acceleration Coefficient for Tangent Level Track
Gross
Net
GE-225-B-3-Ratio 2.91
GE-225-B-4-Ratio 3.10
GE-225-B-4-Ratio 3.33
Equivalent Net Acceleration for Series Operation.
Equivalent Gross Acceleration
Equivalent Acceleration of Train Resistance
Equivalent Gross Acceleration
Equivalent Net Acceleration for Parallel Operation
Acceleration Coefficient - Miles per Hour per Second
Miles per Hour.
0
5
10
15
20
25
30
35
40
45

PLATE XXVII.



A. A. Oswald. — Engrs. — H. M. Shapiro.
April 11, 1916.

PLATE XXVIII.

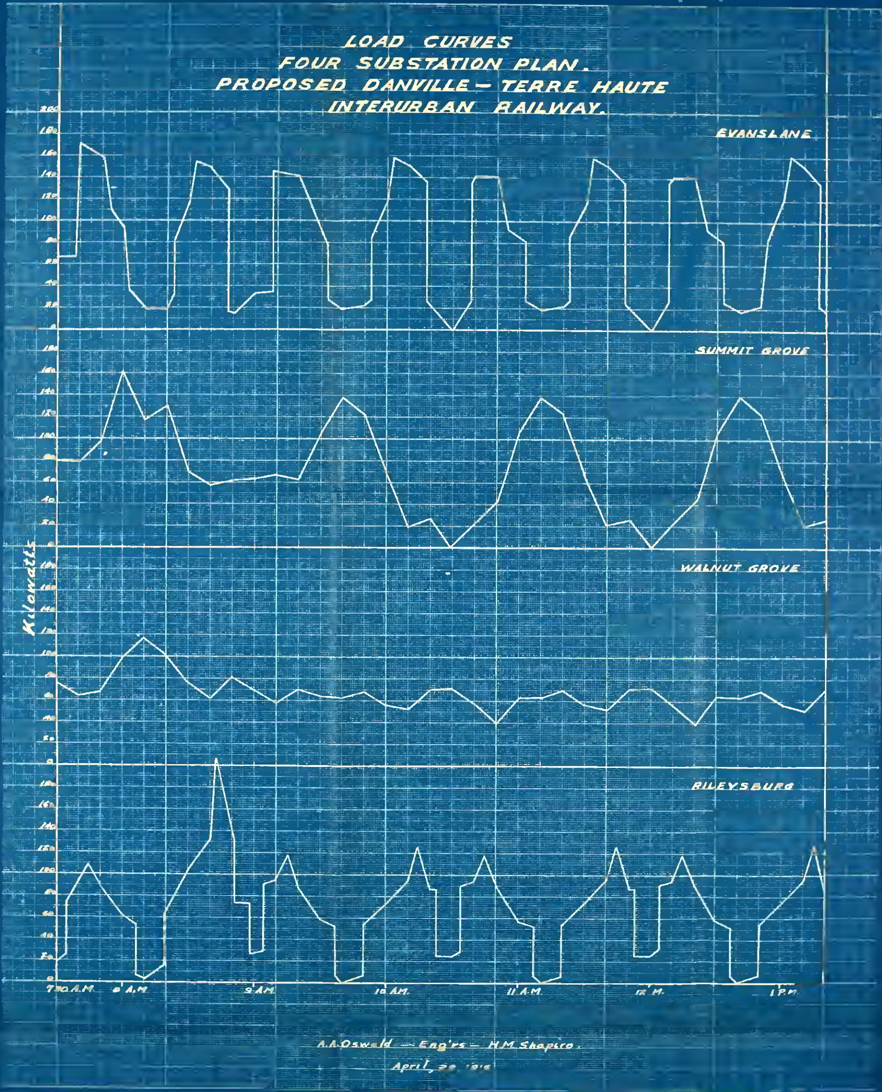
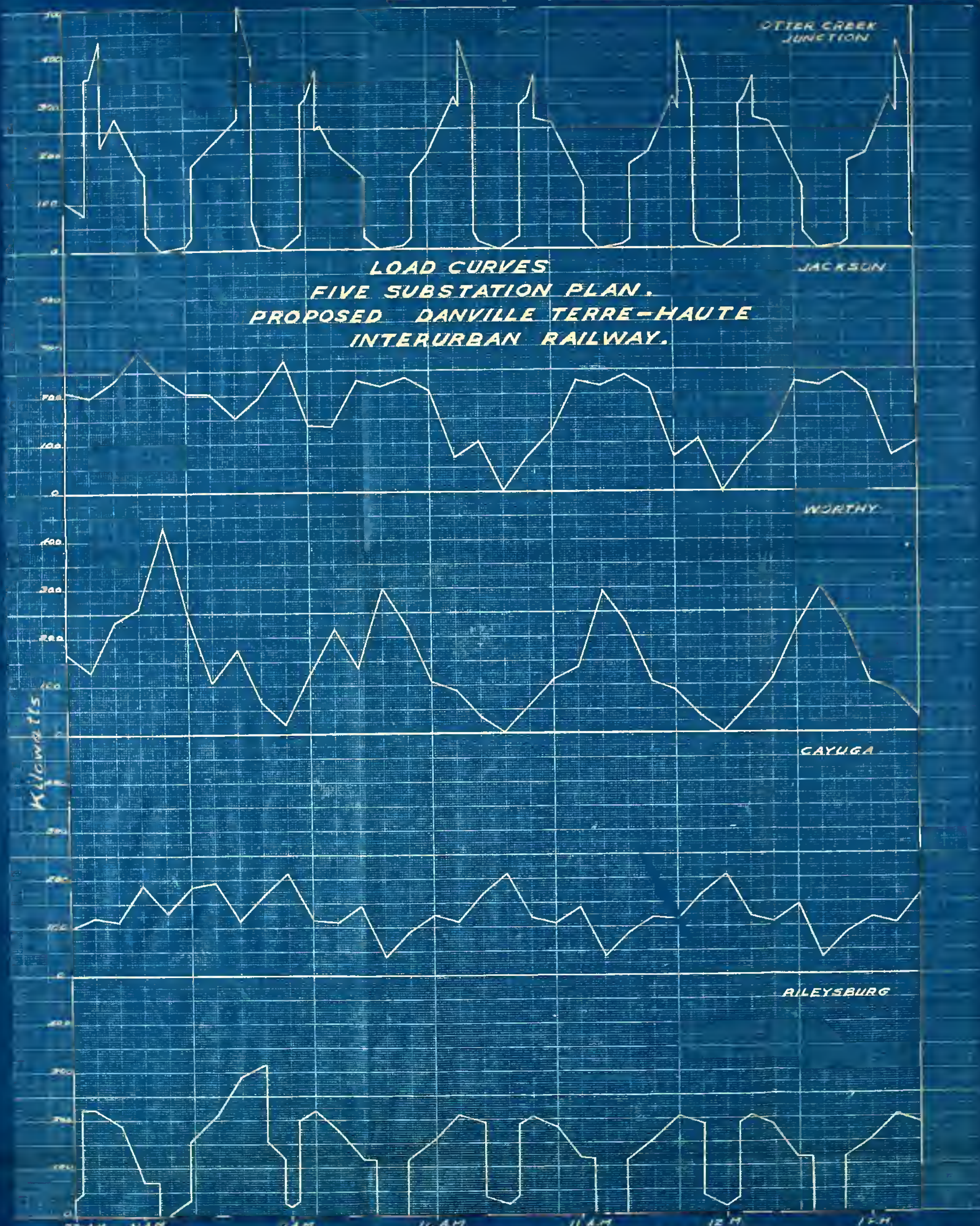
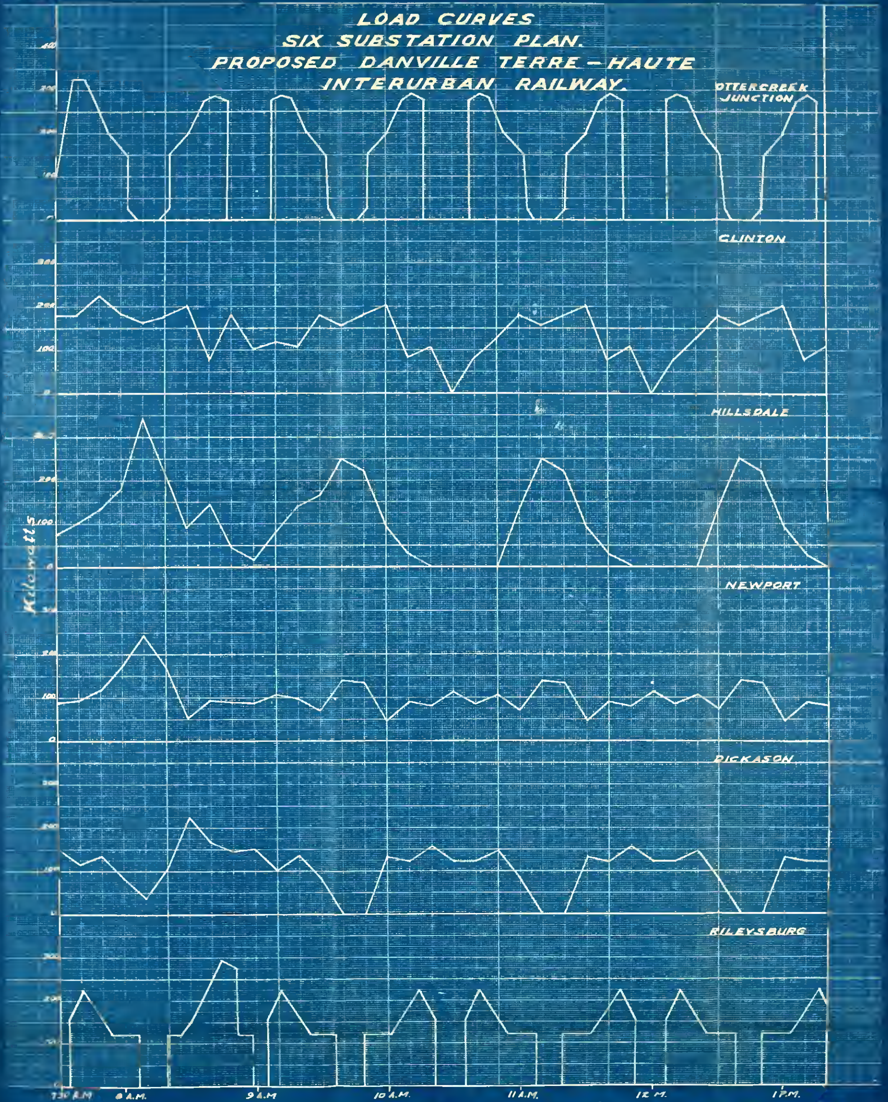

LOAD CURVES
FOUR SUBSTATION PLAN.
PROPOSED DANVILLE — TERRE HAUTE
INTERURBAN RAILWAY.
EVANSLANE
SUMMIT GROVE
WALNUT GROVE
RILEYSBURG
Kilowatts
7 A.M.
8 A.M.
9 A.M.
10 A.M.
11 A.M.
12 M.
1 P.M.
A. A. Oswald — Eng'rs — H. M. Shapiro.
April,

PLATE XXIX.



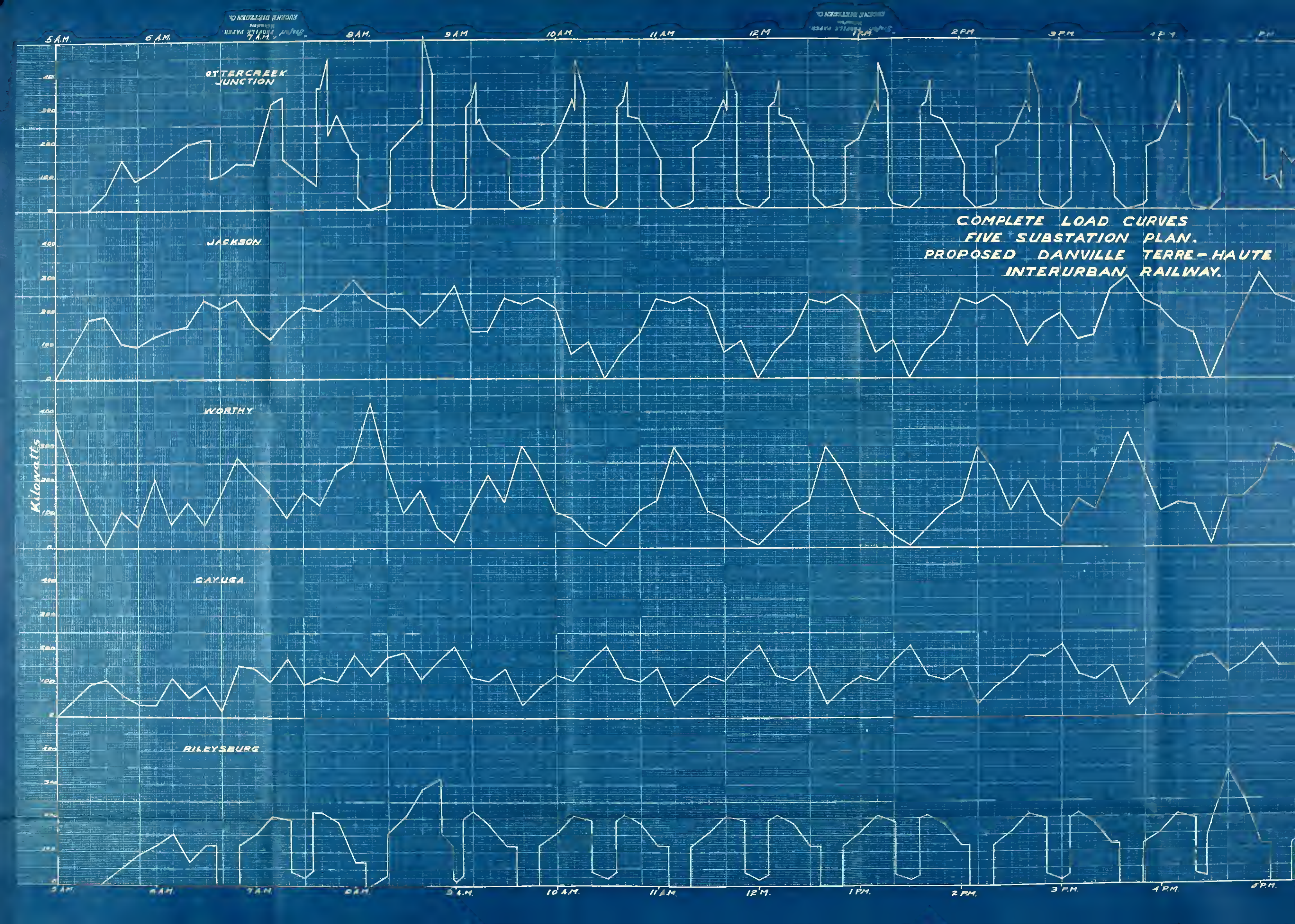
A.A. Oswald - Engrs - H.M. Shapir
April 20, 1916.

PLATE XXX.



A.A. Oswald — Eng'rs. — H.M. Shapiro.
April, 30, 1916.

PLATE XXXI.



COMPLETE LOAD CURVES
FIVE SUBSTATION PLAN.
PROPOSED DANVILLE TERRE-HAUTE
INTERURBAN RAILWAY.
OTTERCREEK JUNCTION
JACKSON
WORTHY
CAYUGA
RILEYSBURG
Kilowatts
5 A.M.
6 A.M.
7 A.M.
8 A.M.
9 A.M.
10 A.M.
11 A.M.
12 M.
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.

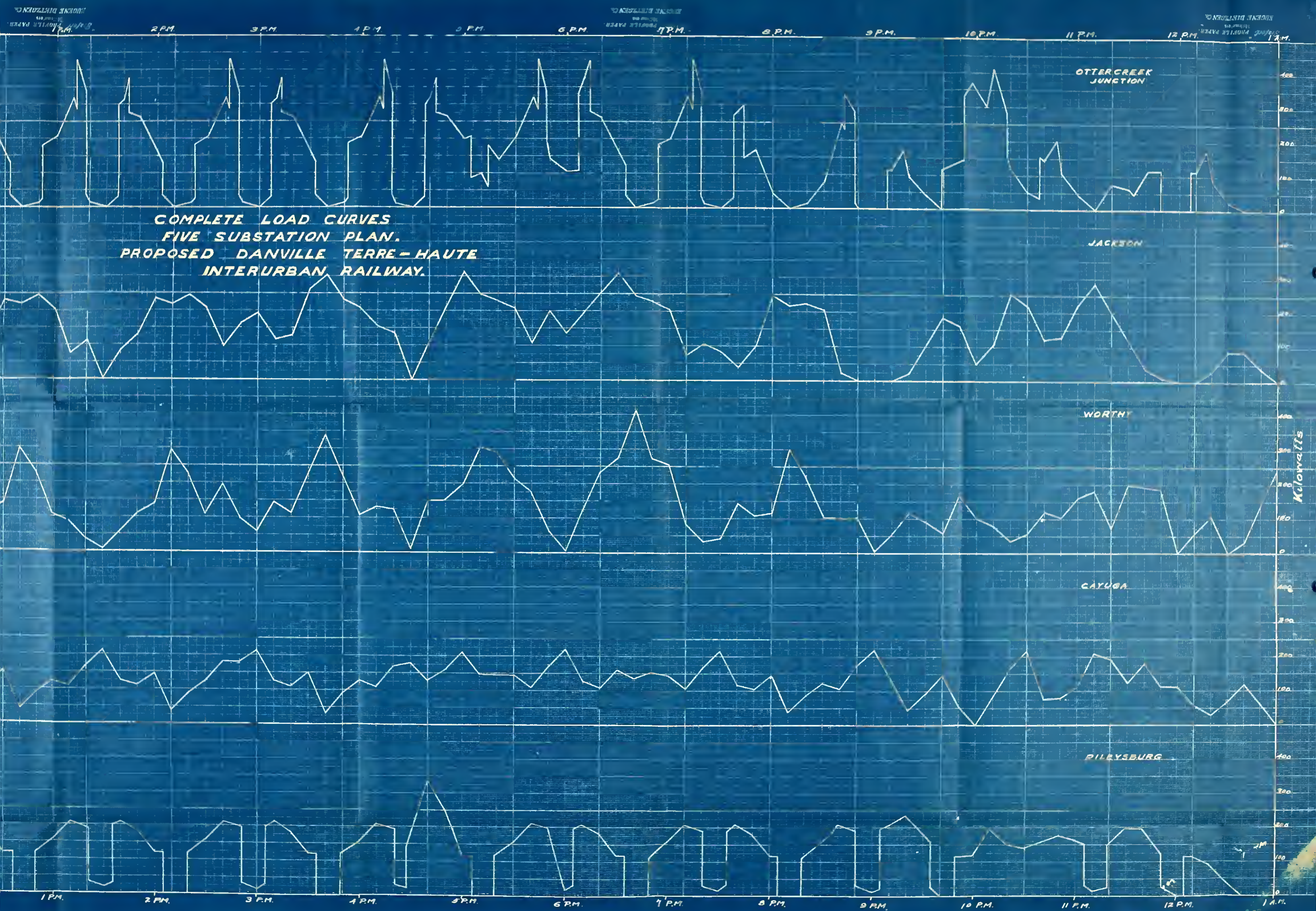
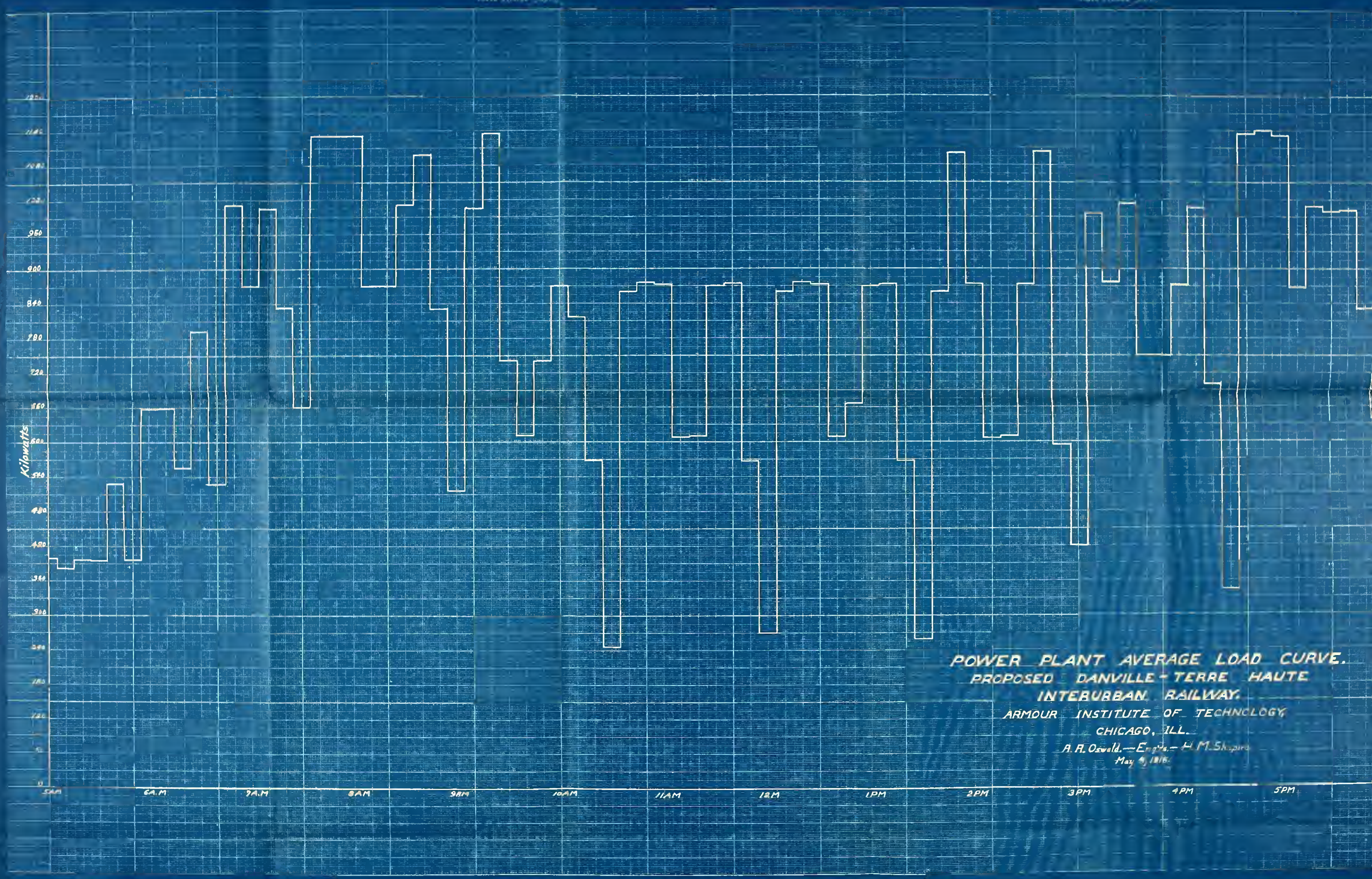

COMPLETE LOAD CURVES
FIVE SUBSTATION PLAN.
PROPOSED DANVILLE TERRE-HAUTE
INTERURBAN RAILWAY.
OTTER CREEK JUNCTION
JACKSON
WORTHY
CAYUGA
RILEYSBURG
Kilowatts
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
7 P.M.
8 P.M.
9 P.M.
10 P.M.
11 P.M.
12 P.M.
1 A.M.

PLATE XXXII.


Kilowatts
5AM
6A.M
7A.M
8AM
9AM
10AM
11AM
12M
1PM
2PM
3PM
4PM
5PM
POWER PLANT AVERAGE LOAD CURVE.
PROPOSED DANVILLE - TERRE HAUTE
INTERURBAN RAILWAY.
ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL.
A. R. Oswald. — Eng'rs. — H. M. Shapiro

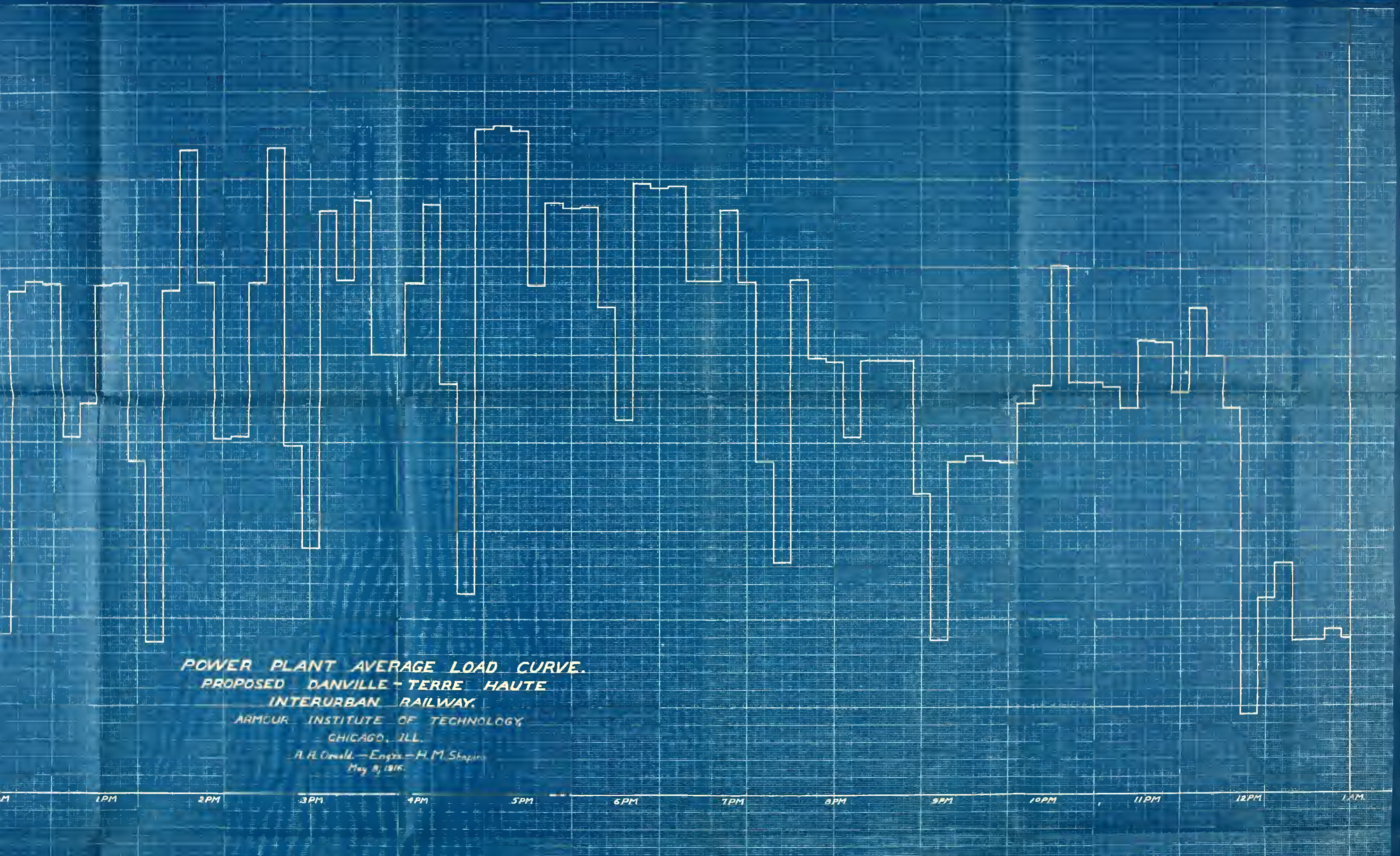
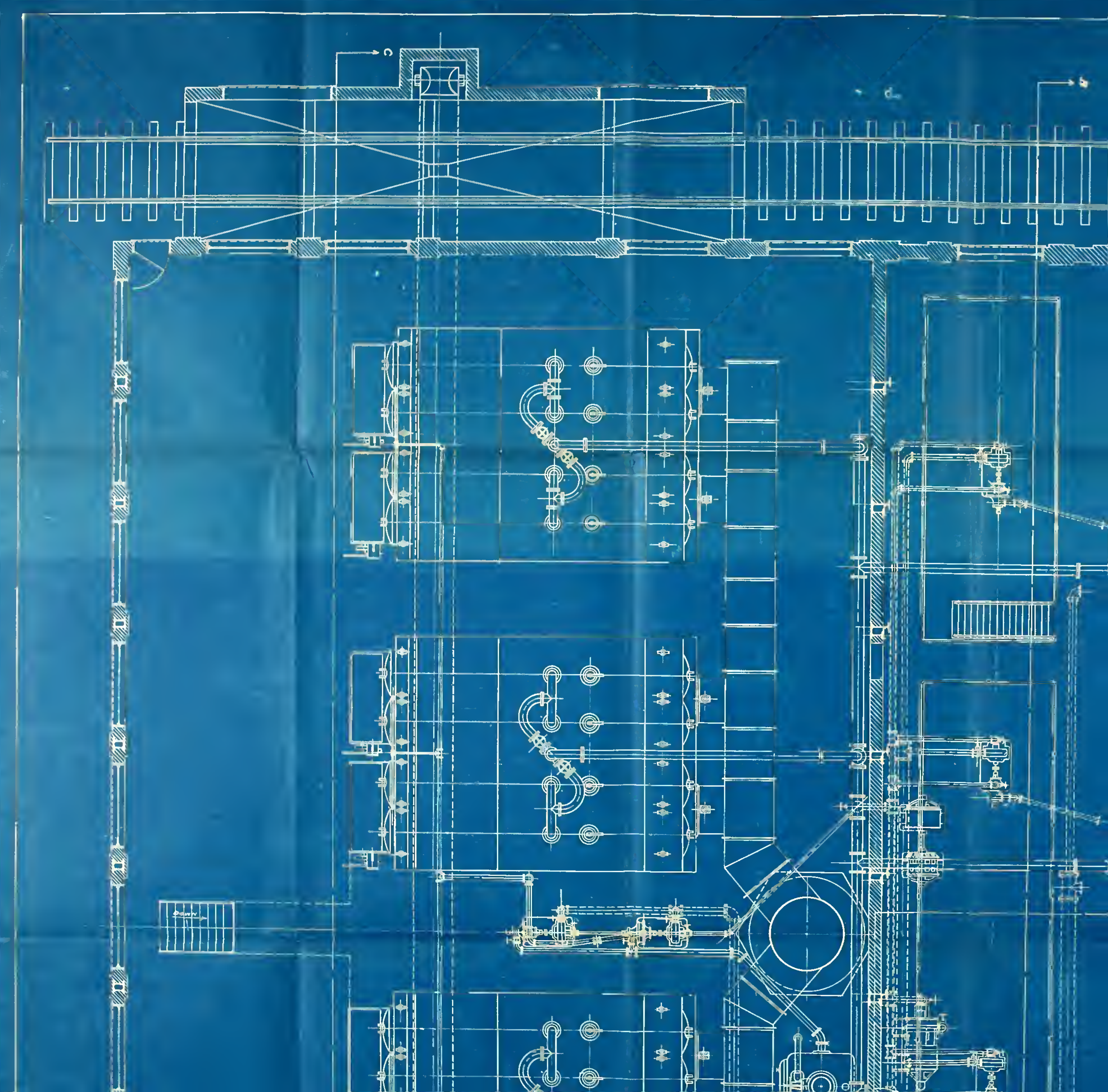
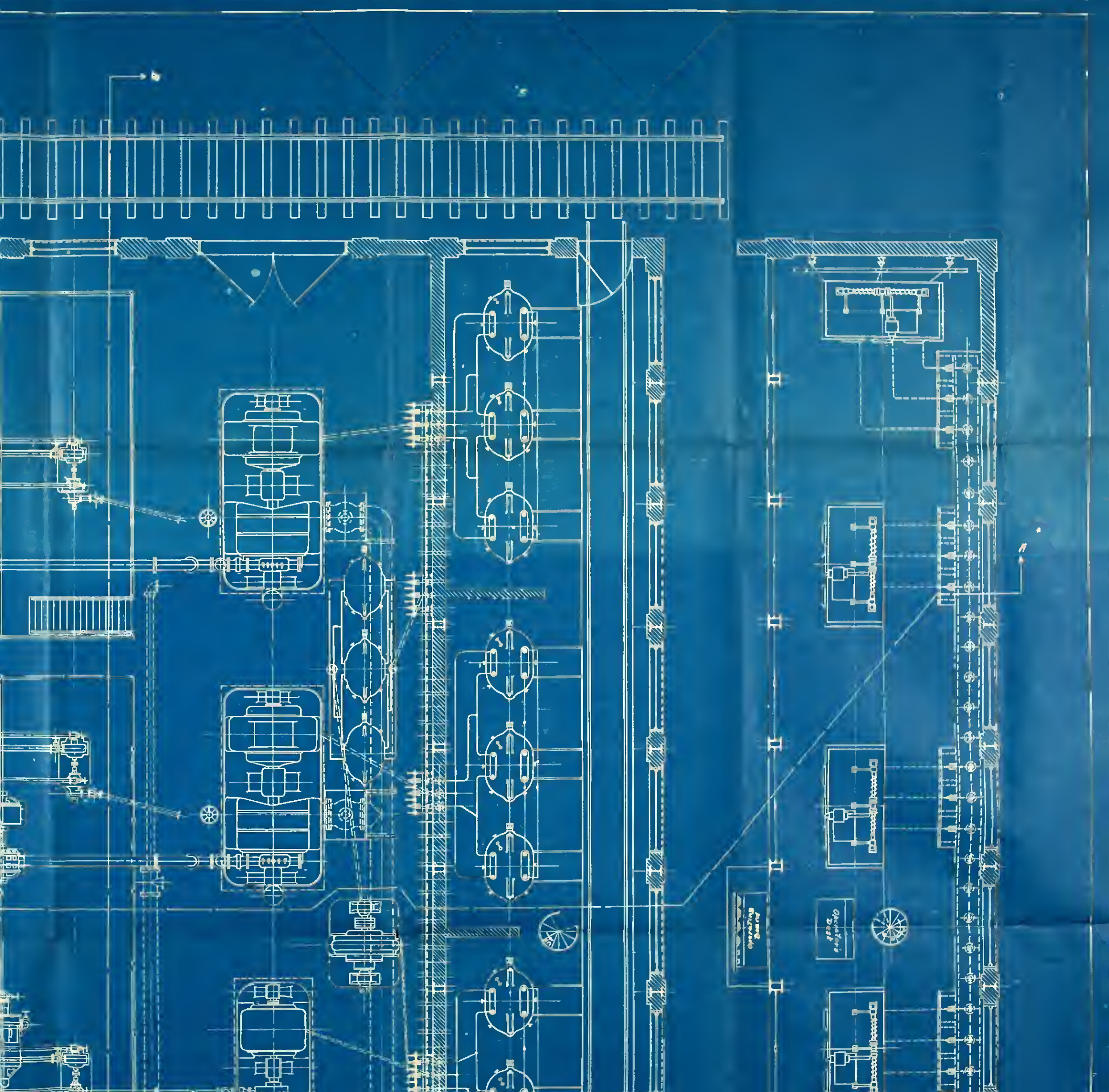
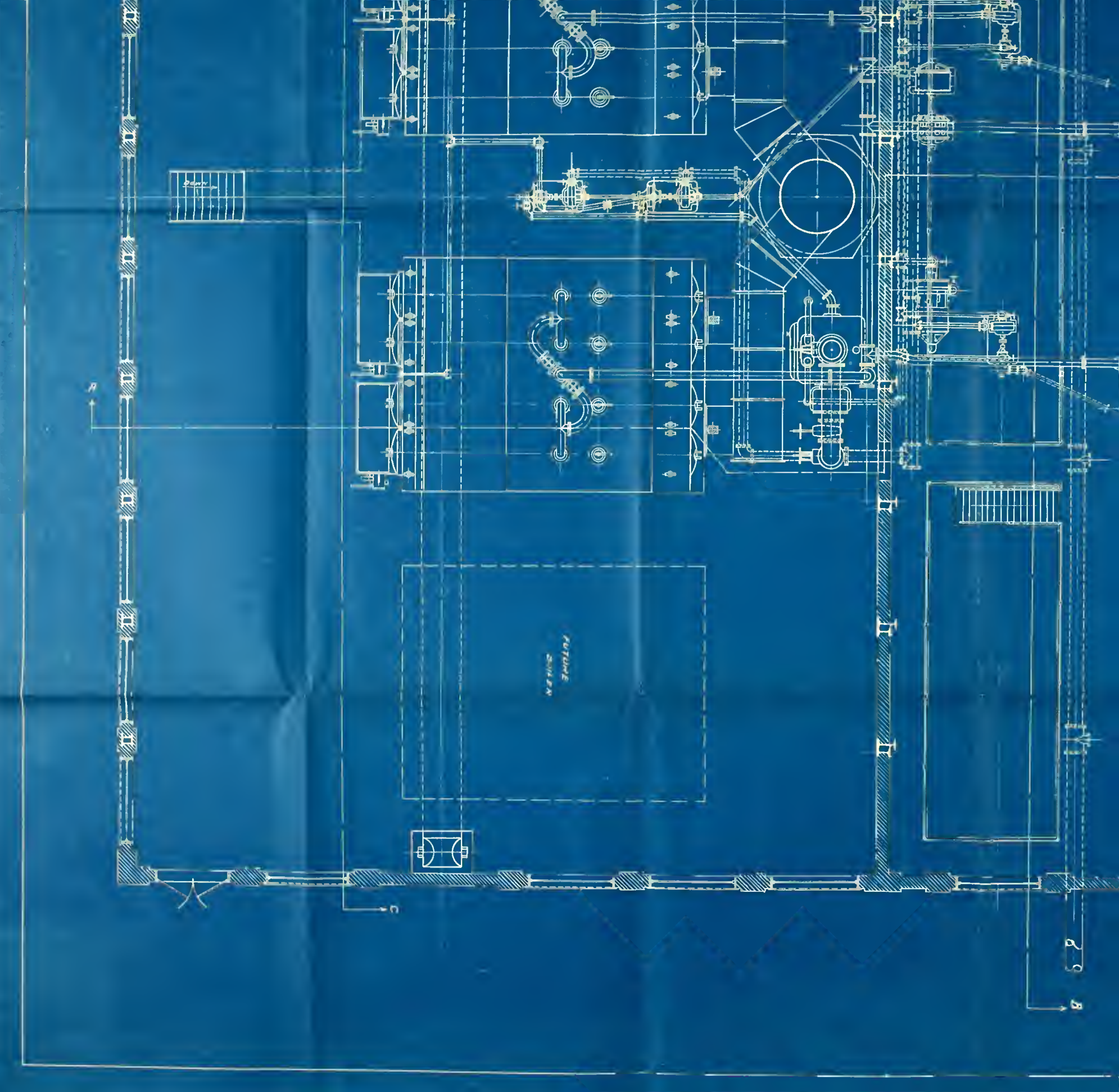
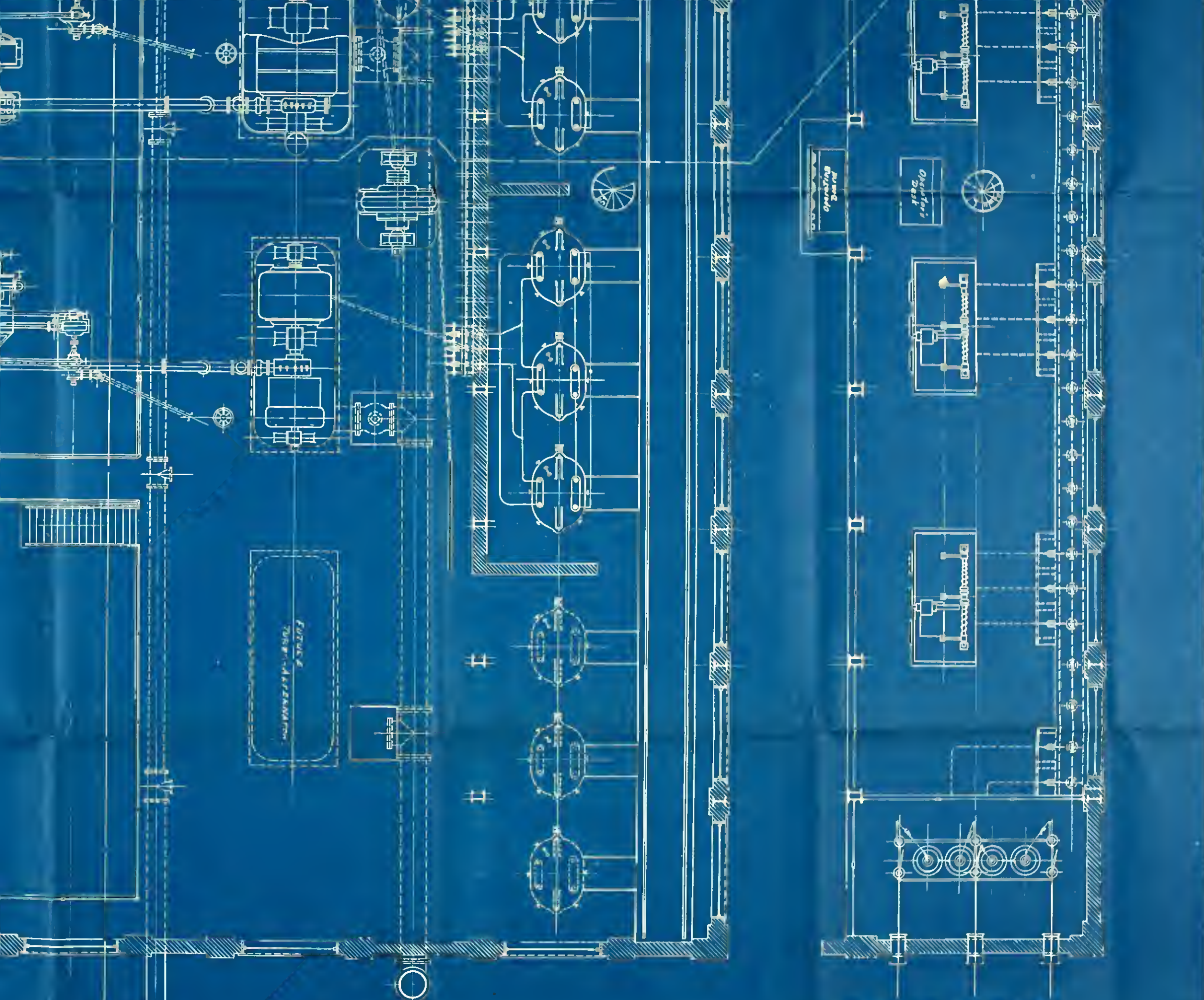


PLATE XXXIII.


DOWN


Operator's Desk


FUTURE
BOILER



-Plan-
Scale ¼" = 1 Ft.

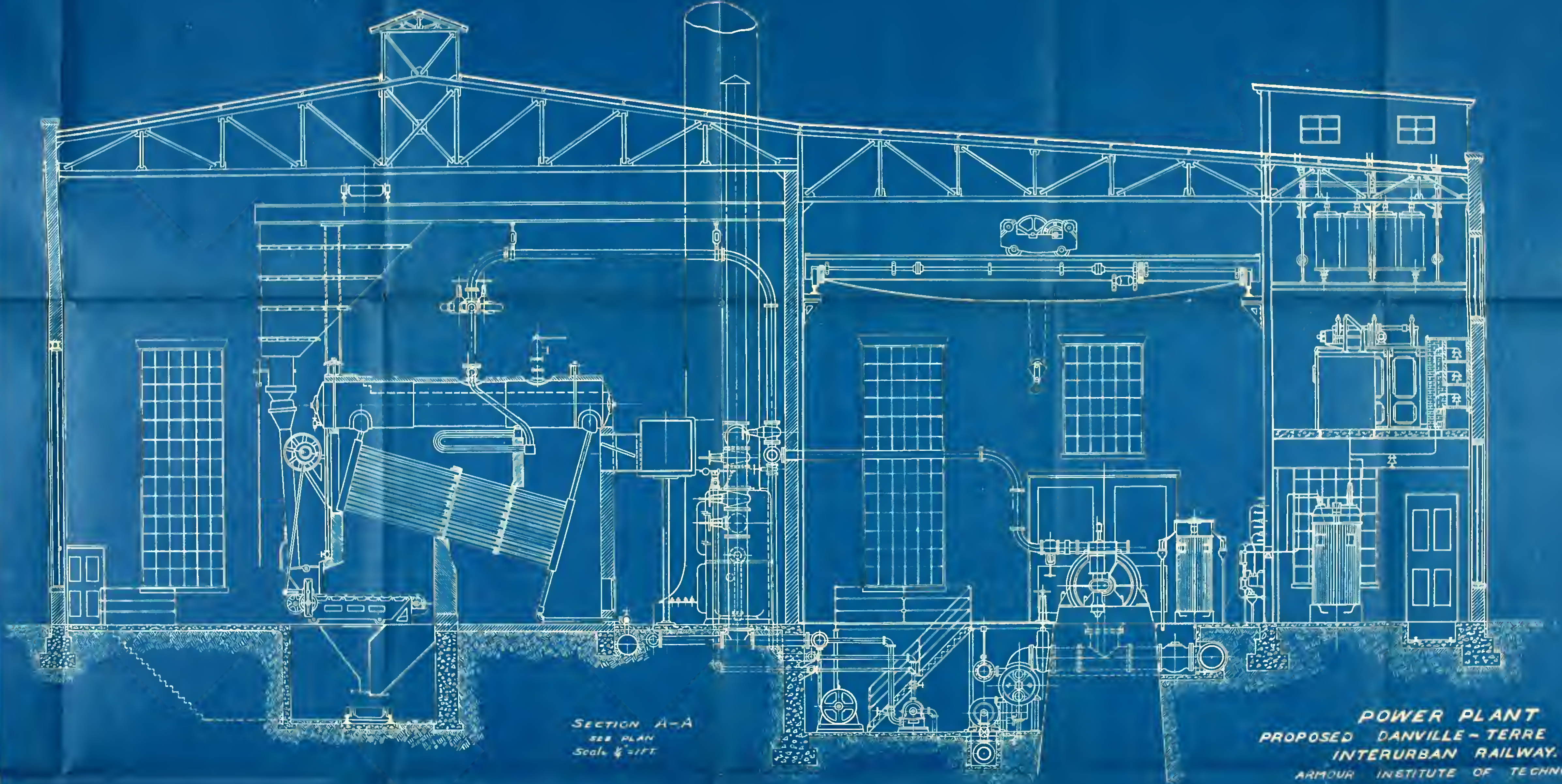
B

POWER PLANT
PROPOSED DANVILLE—TERRE HAUTE INTERURBAN RAILWAY.

ARMOUR INSTITUTE OF TECHNOLOGY.
CHICAGO, ILL.

R. A. Oswald—Engrs—H.M. Shapiro
May 15, 1916.

PLATE XXXIV.



SECTION A–A
SEE PLAN
Scale 1/8" = 1 FT.

POWER PLANT
PROPOSED DANVILLE – TERRE HAUTE
INTERURBAN RAILWAY.

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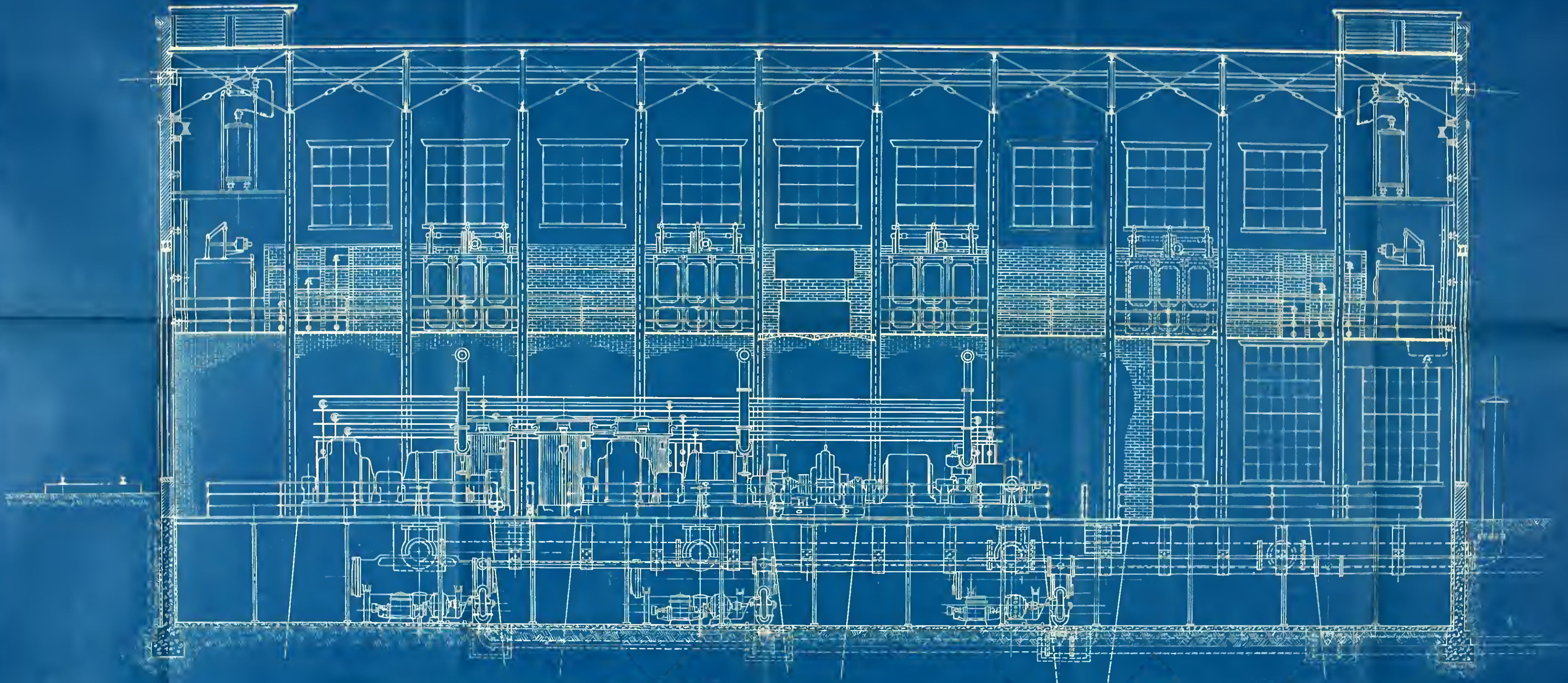
A. H. Oswald – Eng'rs – H. M. Shapiro
May 6, 1916

PLATE XXXV.



SECTION B-B
SEE PLAN
Scale ¼"=1'

POWER PLANT
PROPOSED DANVILLE - TERRE HAUTE INTERURBAN RAILWAY.

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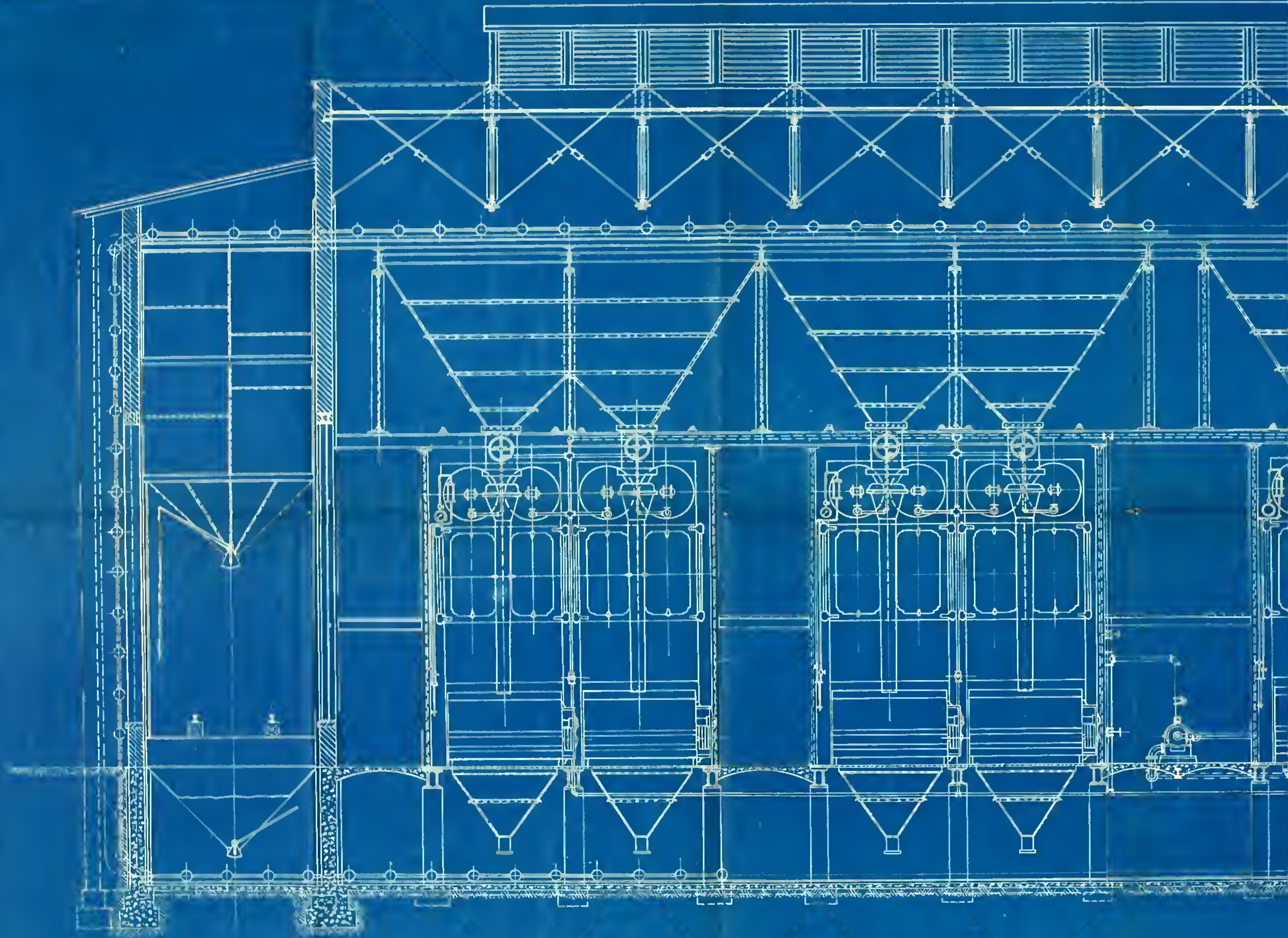
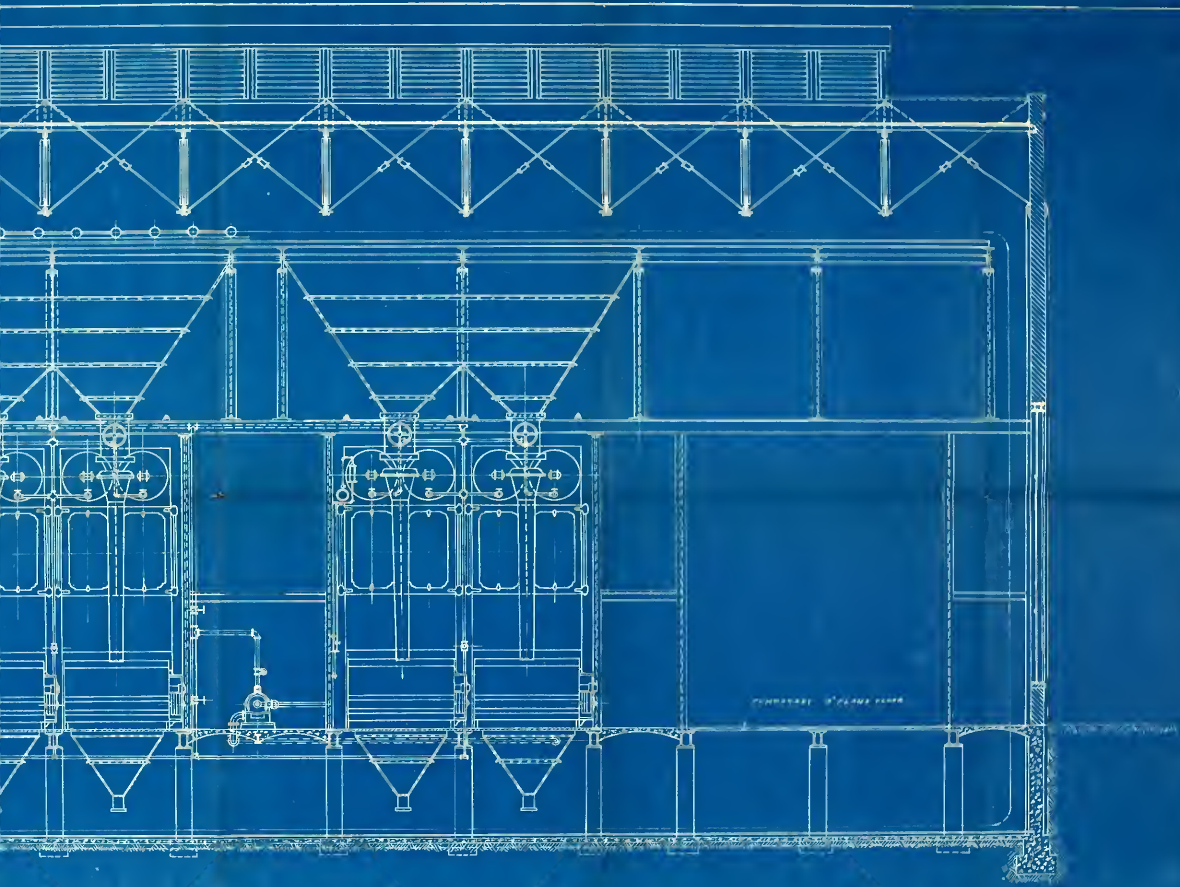
R. A. Oswald - Engrs. - H.M Shapiro
May 16, 1916.

PLATE XXXVI.



SECTION C-C
SEE PLAN
SCALE — 1/4" = 1 FT.



SECTION C–C
SEE PLAN
SCALE — $\frac{1}{4}$" = 1 FT.

POWER PLANT
PROPOSED DANVILLE – TERRE HAUTE
INTERURBAN RAILWAY.
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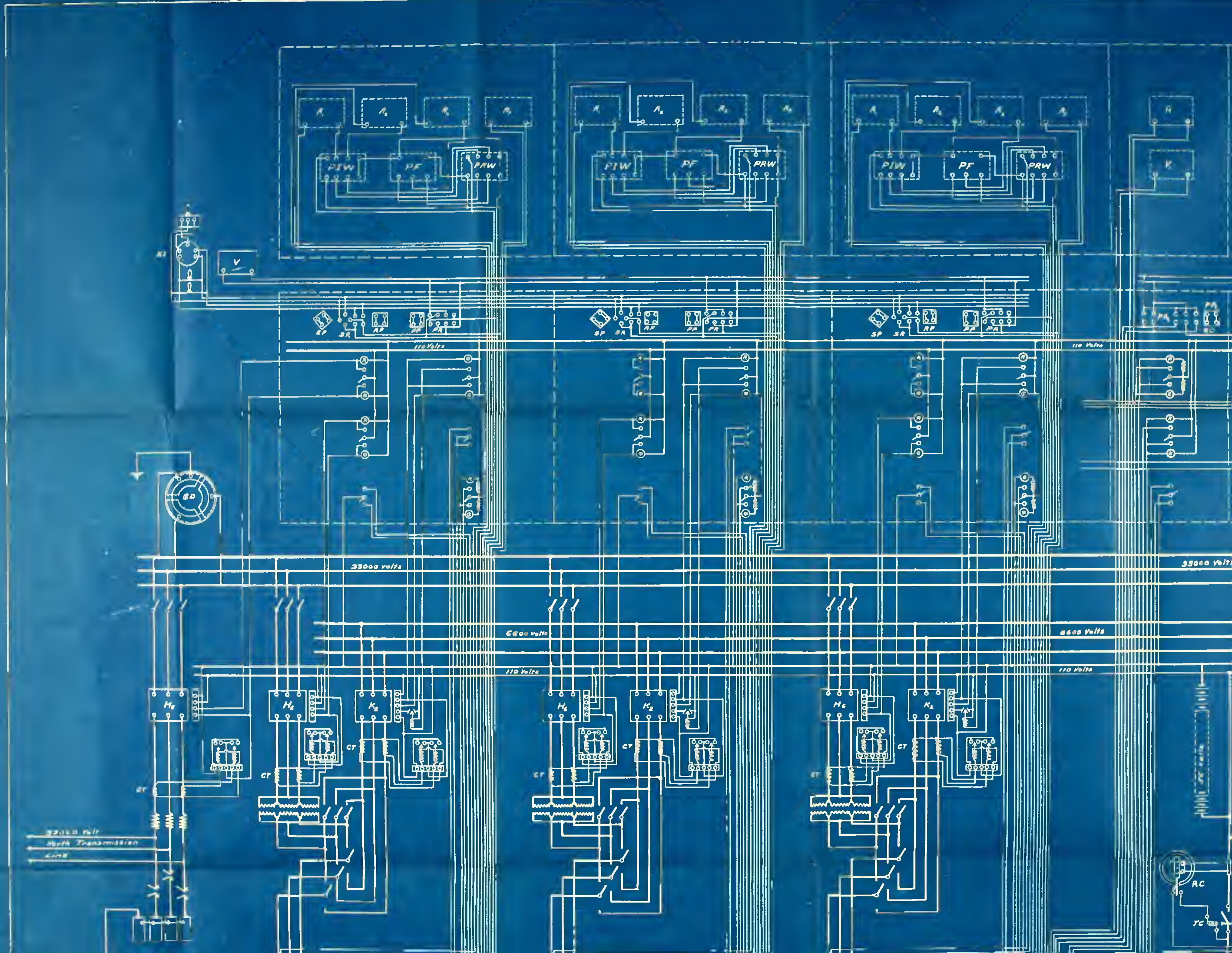
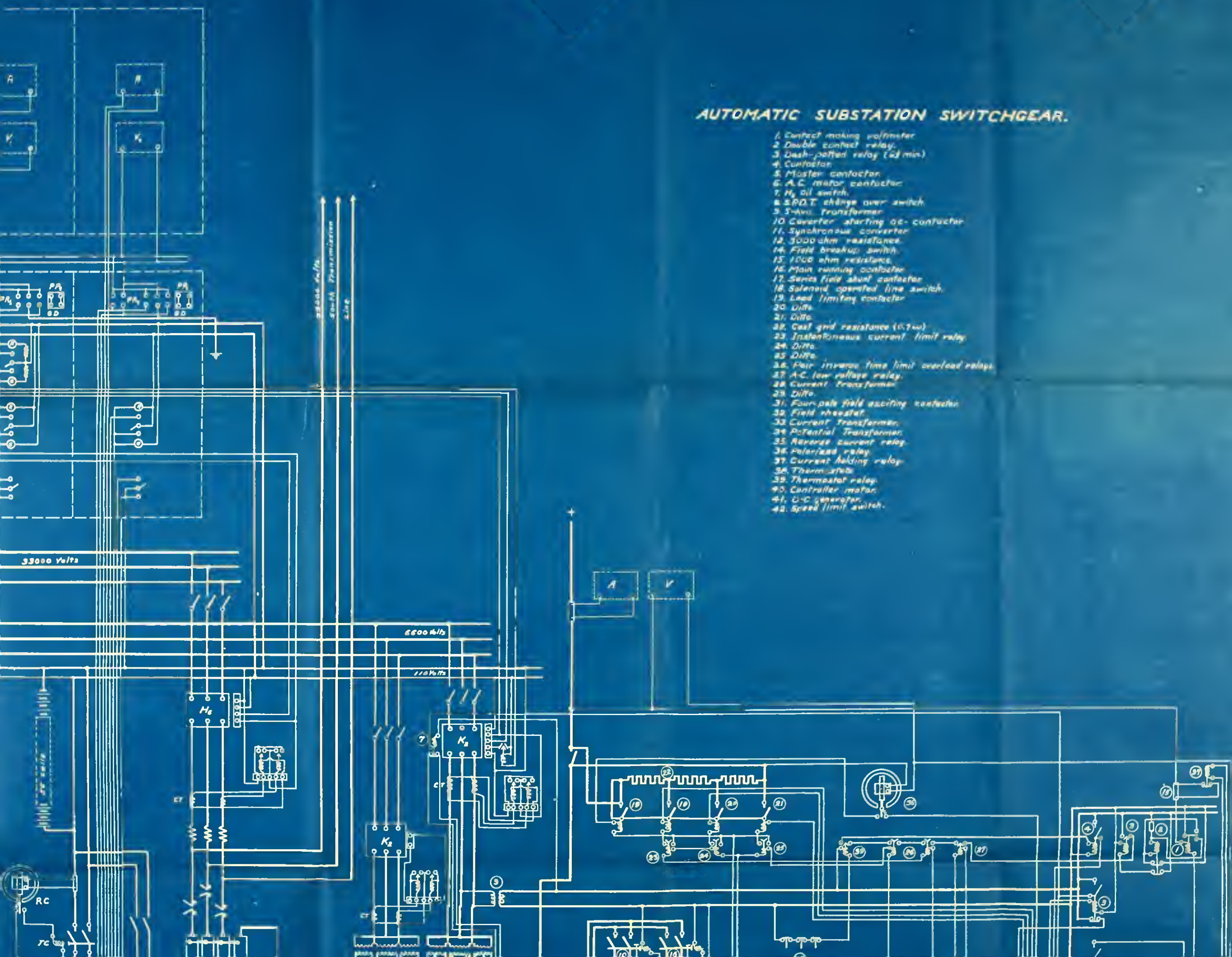
CHICAGO, ILL.
A. R. Oswald – Eng'rs. – H. M. Shapiro.
May 12, 1916.

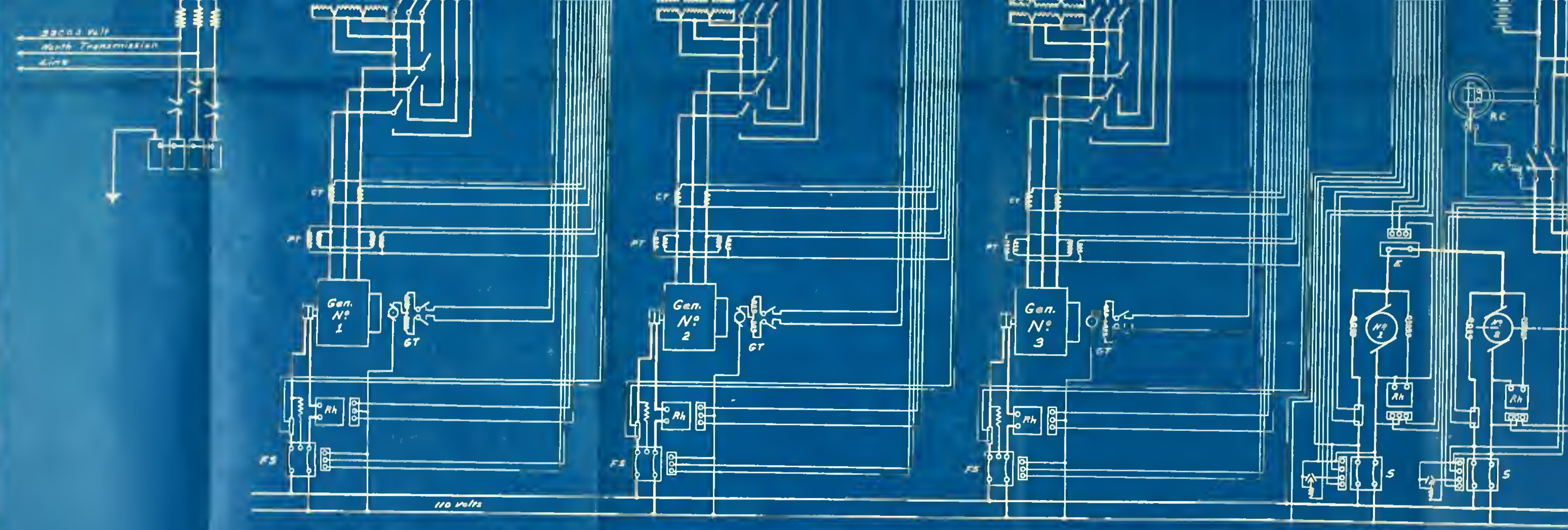
PLATE XXXVII.


PIW
PF
PRW
V
SP
SR
RP
PP
PR
110 Volts
GD
33000 volts
6600 Volts
110 Volts
CT
RC
TC



AUTOMATIC SUBSTATION SWITCHGEAR.

1. Contact making voltmeter.
2. Double contact relay.
3. Dash-potted relay (1/2 min.)
4. Contactor.
5. Master contactor.
6. A.C. motor contactor.
7. H_2 oil switch.
8. S.P.D.T. change over switch.
9. 5-kva. Transformer.
10. Coverter starting ac- contactor.
11. Synchronous converter.
12. 3000 ohm resistance.
14. Field breakup switch.
15. 1000 ohm resistance.
16. Main running contactor.
17. Series field shunt contactor.
18. Solenoid operated line switch.
19. Load limiting contactor.
20. Ditto.
21. Ditto.
22. Cast grid resistance (0.7 ω)
23. Instantaneous current limit relay.
24. Ditto.
25. Ditto.
26. Pair inverse time limit overload relays.
27. A-C. low voltage relay.
28. Current Transformer.
29. Ditto.
31. Four-pole field exciting contactor.
32. Field rheostat.
33. Current Transformer.
34. Potential Transformer.
35. Reverse current relay.
36. Polarized relay.
37. Current holding relay.
38. Thermostat.
39. Thermostat relay.
40. Controller motor.
41. D-C generator.
42. Speed limit switch.



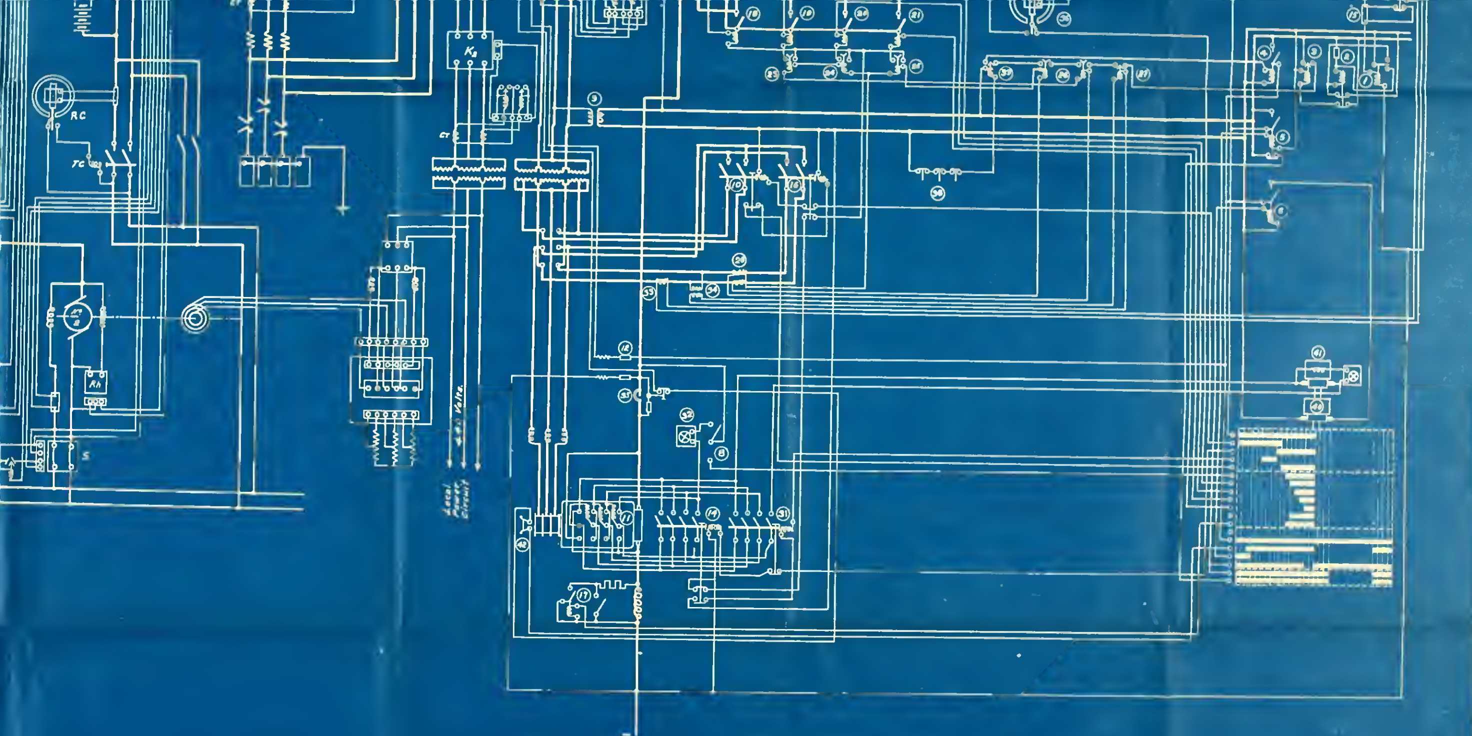
POWER PLANT SWITCHGEAR.

A Ammeter
V Voltmeter
CT Current Transformer.
PT Potential Transformer
F Fuse
FS Field switch.
H_E Oil switch.
K_1 Oil switch.
PP A-c potential plug.
PPe D-c potential plug.

PR A-C potential receptacle.
PRe D-C potential receptacle.
RP Synchronizing plug – running.
SP Synchronizing plug – starting.
Rh Rheostat.
S Exciter switch.
SI Synchroscope.
SR Synchronizing receptacle.
TC Trip coil.
GT Governor control

PIW Polyphase Indicating Wattmeter.
PRW Polyphase Indicating Wattmeter.
PF Power Factor Meter.
GD Ground detector.
E Equalizer switch
RC Reverse current relay.

Note:– Ground one leg on all instrument transformers.



WIRING DIAGRAM.
POWER PLANT AND SUBSTATION
PROPOSED DANVILLE – TERRE HAUTE
INTERURBAN RAILWAY.

ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.
A. R. Oswald. — Engrs. — H. M. Shapiro.
May 5, 1916.