ELECTRIFICATION OF THE
CHICAGO, TERMINAL OF C. B. & Q. RAILROAD

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ARMOUR INSTITUTE OF TECHNOLOGY
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Proposed Electrification of the Chicago Terminal Chicago, Burlington and Quincy Railroad.

A THESIS

PRESENTED BY

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The suburban service of the Chicago, Burlington and Quincy Railroad has assumed large proportions due to the building up of such suburbs as Riverside, La Grange, Hinsdale and Downers Grove. This service extends as far as Aurora, Ill., a distance of thirty-seven and a half miles from Chicago. In the following pages it is our purpose to discuss at some length and in detail the problem of applying electricity to this railroad as a means of propulsion.

The problem of electrification of the railroads in the city has been taken by the City Engineers. Some few years ago a half dozen prominent engineers took up this problem, using as a concrete example the Illinois Central Railroad. They took into account everything connected with such an undertaking, and came to the conclusion that, although a decided saving in operating expenses would follow, the initial cost would more than offset any gain, and would not warrant the change.
 Needless to say, we cannot go as far into this problem as we should like, for time does not permit, nor does our experience warrant any such step. As far as monetary considerations are concerned in this problem, we are totally at sea, first because the C. B. & Q. R. I. would not give us any information and second, we had no means of intelligently estimating costs of installing some of this apparatus herein considered. Therefore we have taken no account of costs, have neglected the freight service, and have only taken the suburban service as the subject of our discussion.

Before proceeding any further into the subject, it might be well to give a somewhat brief account of the territory served and the population of the suburbs en route. This can best be done by means of a table.
<table>
<thead>
<tr>
<th>Name of town.</th>
<th>Distance from Chicago</th>
<th>Population 1900</th>
<th>Population 1910</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago</td>
<td>0</td>
<td>1,698,575</td>
<td>2,185,283</td>
</tr>
<tr>
<td>Canal &amp; 16th St.</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Ave</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hawthorne</td>
<td>6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morton Park</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clyde</td>
<td>8.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Vergne</td>
<td>9.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berwyn</td>
<td>9.6</td>
<td></td>
<td>5,841</td>
</tr>
<tr>
<td>Harlem Ave</td>
<td>10.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverside</td>
<td>11.1</td>
<td>1,551</td>
<td>1,702</td>
</tr>
<tr>
<td>Hollywood</td>
<td>11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brookfield</td>
<td>12.5</td>
<td>865</td>
<td>1,445</td>
</tr>
<tr>
<td>Congress Park</td>
<td>13.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Grange</td>
<td>13.8</td>
<td>3,969</td>
<td>5,282</td>
</tr>
<tr>
<td>5th Ave. sta.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Grange</td>
<td>14.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stone Ave. Sta.</td>
<td>15.4</td>
<td>662</td>
<td>905</td>
</tr>
<tr>
<td>Western Springs</td>
<td>15.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highlands</td>
<td>16.4</td>
<td>1,970</td>
<td>2,675</td>
</tr>
<tr>
<td>Hinsdale</td>
<td>17.0</td>
<td>2,578</td>
<td>2451</td>
</tr>
<tr>
<td>W. Hinsdale</td>
<td>17.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarendon Hills</td>
<td>18.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greggs</td>
<td>19.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Grove</td>
<td>20.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downer Grove</td>
<td>21.2</td>
<td>2,103</td>
<td>2601</td>
</tr>
<tr>
<td>Belmont</td>
<td>22.6</td>
<td>820</td>
<td>624</td>
</tr>
<tr>
<td>Lisle</td>
<td>24.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naperville</td>
<td>22.5</td>
<td>2,629</td>
<td>3449</td>
</tr>
<tr>
<td>Joliet</td>
<td>33.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aurora, Ill.</td>
<td>37.4</td>
<td>24,147</td>
<td>29,807</td>
</tr>
</tbody>
</table>
It is usual when taking up such an enterprise as this to have a reason for so doing. To give one reason would be almost impossible, and yet, briefly, it is to give better service. Better service may cover any number of points some of which will be noted:

1st. increase of schedule speed.

2nd. decreased headway, i.e., increasing the number of trains.

3rd. the absence of smoke and cinders.

and last. the past and present legislation in regard to smoke abatement seems to indicate that future restrictions will be even more severe, and may be such as to make electrification almost a necessity.

It might be well at this point to introduce some factors in the present operating features of the road. Three tracks as far as Riverside are devoted exclusively to passenger service in the morning and evening rush periods. In the evening rush period, track #1 is used by westbound locals to Riverside; track #2 is used by westbound express and through trains to Downers Grove, Aurora and beyond; track #3 is used by eastbound trains either through, local or express.
From Riverside to Downers Grove two tracks are devoted to passenger service, and beyond this point two tracks can take care of all the traffic. Hence between Chicago and Riverside a minimum of three tracks is allowable, four are provided; between Riverside and Downers Grove a minimum of two tracks is allowable, three are provided; beyond Downers Grove a minimum of two tracks is allowable and two are provided.

From what has just been said it can easily be seen that the road is divided into three divisions as regards suburban traffic, viz.; the Riverside division, the Downers Grove division and the Aurora division. It is almost needless to state that the Riverside division of 11.1 miles consists of local service only. The Downers Grove division and Aurora division maintain express service. At times other than the rush periods some of the Downers Grove trains run as locals, while the Aurora trains still hold to the express schedule making, perhaps, a few more stops than in the rush periods. Due to a lack of time, it is our purpose to consider only the rush periods, since it is with these periods that we are most vitally concerned.

In the rush hours the Riverside locals carry six
cars, the Downers Grove trains, seven or eight and the Aurora trains nine cars each. The seating capacity of each car is approximately sixty persons. No baggage is carried during rush hours except on the Aurora division.

The present schedule speed of the local trains to Riverside is about twenty and eight tenths miles per hour; the express schedule to Downers Grove is twenty six miles per hour and the express schedule to Aurora is thirty miles per hour.

Upon making application to the C B & Q R R for information the writers were furnished with the road profile between Chicago and Aurora. All other information regarding traffic and present equipment they deemed it advisable to withhold. Under these circumstances it became necessary, in order to obtain traffic figures, to do so by actual observation. This was done by riding on the trains of the different divisions at various times during the rush period. It is believed that our figures concerning the traffic, as before given, represent what may be considered a little higher than average as the data was collected during the weeks preceding Christmas 1911, when traffic is unusually
heavy. We believe we are justified in using these figures for, while the traffic was undoubtedly heavier, the number of cars was not increased, as we ascertained later. The surplus was carried by making use of the standing room in the cars.

Up to this point we have been content to give some topics of general information, but we shall now concern ourselves with the actual problem of electrification. In order to make an intelligent choice of either a D.C. or an A.C. system, or a combination of both, it became necessary to consider them all. The systems considered are briefly as follows:

#1. A.C. Generation, transmission and propulsion.
#2. D.C. " " "
#3 A.C. " " " D.C. propulsion.

Each system in turn was taken up, discussed, the relative advantages and disadvantages noted. With this date at hand a choice even then was difficult unless we brought in some other factor. This factor which made system #3 our choice was that most of the railways in this country of about the same length are equipped with D.C. motors. Conditions which will be pointed out later made it imperative to transmit a large amount of power a consider-
able distance, making it advantageous to use A.C. as a mode of transmission.

Having decided to use direct current motors it next became necessary to make a choice of voltage to be impressed upon the motor. Here again we were guided to a large extent by standard practice in this country. We have railways operating on 600 volts, 1200 volts, 1500 volts and just now locomotives are being built for a terminal voltage of 2400. There is one 2400 volt railway, one 1500 volt, a few using 1200 but the most are using 600 volt equipment. Hence it is unnecessary to point out that all apparatus for 600 volts is more nearly standardized and has long since passed the experimental stage. Information and data absolutely necessary to us was far more abundant for this voltage, and after due consideration, we decided to use a pressure of 600 volts. Making allowance for losses all our calculations were based upon a terminal voltage of 550 at the train.

The use of A.C. for transmission and D.C. for propulsion necessitates of course the use of substations. The question of using motor generator sets or synchronous
converters was easily decided. The use of the synchronous converter in all branches of railway work is almost universal. Since the transmission voltage was relatively high transformers were necessary in either case, so the motor generator set was at a decided disadvantage.

Before being able to choose a motor we must go back for a moment to ascertain some necessary information in this respect. The present equipment calls for a car whose seating capacity is sixty. This is a fair size car for such service, and by using a car of the same seating capacity, we could materially simplify our calculations. Thus for a certain service to Riverside, if the rush period demanded thirty cars and we wished to decrease the headway to Riverside, we need only use fewer cars per train. A train of six such cars seated to a capacity of sixty each would weigh very close to 180 tons. This is the figure upon which all our motor calculations were based since a train of six such cars was considered sufficiently long.

The average length of run on the local service was about seven tenths of a mile. The shortest run was one half mile while many were six tenths miles. Thus we decided, that if a motor would work satisfactorily on .5,
.6, and 1.0 mile on a level tangent track, it would probably do the required work on the actual profile. On runs of .8 mile and over a maximum speed of 40 miles P. per hour was decided upon, and on runs less than .8 mile a maximum of 57.5 m.p.h. was sufficient. This was decided upon to have a uniformity in speed times curves and let the schedule speed take care of itself. The number of motors per car and the number of motor cars per train caused some trouble, and after a lengthy discussion, we recommend the use of four motors per car and two motor cars per train of six cars. This places a maximum load of 22.5 tons on each motor.

The approximate capacity of the motor was calculated to be 185 H.P. This was done by a method due to Storer and checked by Hutchinson's method. The formula of each is herewith shown:–

Storer's Method.

\[
\text{Rated H.P. of Motor } = 0.0031 \times (m \cdot a + f) \frac{X}{\sqrt{T + t}}
\]

Where
- \(a\) acceleration in ft per sec\(^2\)
- \(m\) mass in lbs of car weight.
- \(f\) train resistance, i.e., friction and windage.
- \(T\) length of run in sec.
\[ t \] time of stop in sec
\[ x \] time of acceleration in sec.

\textbf{Hutchinson's Method.}

Rated \( Kw \) of motor \( 0.254 \times B \)

where \( x \) a constant
\( B \) a "

each determined from Hutchinson's curves as given by Mr. Nichols.

\( X \) is the percentage of full load tractive effort required expressed as a whole number, i.e., for full load \( X \) equals 100; for half load \( X \) equals 50 etc.

Having found that an approximate capacity of 185 H.P. was necessary, the bulletins of the G. E. Co., and the West. Elect. & Mfg. were consulted. From these bulletins it was ascertained that the Westinghouse \#134, G. E. \#69B or the Westinghouse \#113 might do the work. West. \#134 motor is rated at 160 H.P., the G. E. \#69B at 200 H.P. and the West. \#113 at 200 H.P.

The choice of a motor depends on three things, the gear ratio, the ability to do the required work without undue heating and a low energy consumption for the required output. The ability to attain the required speed of course depends upon the gear ratio.
The heating of the motor depends upon the effective current or that continuous current which would produce the same heating. Energy consumption is invariably given in watt hours per ton mile and depends on the current consumption the voltage, the weight of the car and the length of the run.

As stated above the three motors selected must be tried on runs of 0.5, 0.6 and 1.0 mile respectively. Three gear ratios that would be likely to allow us to attain a maximum speed of 37.5 or 40 m.p.h. were considered, viz., 2.32, 2.56 and 2.85.

In order to facilitate the plotting of so many speed time curves, a curve of speed tractive effort was plotted for each gear ratio. This curve for gear ratio 2.56 is shown on Curve Sheet #1.

The writers assume that the reader has had enough experience with speed time curves to know they are drawn up. A starting acceleration of 1.5 per sec$^2$ a breaking acceleration of - 2.0 ft sec$^2$ and a train resistance of 10 lbs. per ton was assumed in plotting these preliminary curves. It was deemed advisable to place the three speed time curves and energy consumption curves for runs of 0.5, 0.6 and 1.0 mile respectively at the same gear ratio.
on one sheet. For purposes of comparison this is best. On Curve Sheet #2, will be found the curves as outlined above, for the West. #113 motor gear ratio 2.32. On Curve Sheet #3 and #4, will be found the curves for the same motor at gear ratio 2.56 and 2.95 respectively.

In order to plot energy consumption curves, a curve of current - speed was plotted for each gear ratio. This curve for gear ratio 2.56 is shown on Curve Sheet #5. Values of the watt hours per ton mile and of $I_e$ for each run and gear ratio are given on the respective curve sheets.

With the different values of $I_e$ and of the W.H./T.M. before us we decided on the gear ratio of 2.56 as the most likely to suit our conditions of service. How well this choice was made must be seen by the subsequent work. With this gear ratio decided upon, we now proceeded to apply it to the 7.13. #09B motor. These results can be seen on Curve Sheet #6. The value of $I_e$ and W.H./T.M. is noted on this curve sheet.

As can be seen from the curve, this motor failed to attain a speed of 37.5 m.p.h. on a half mile run, and could not be used for our purpose without causing a loss
of time on this account.

We next took up the West #134 in the same manner as before. The results are shown on Curve Sheet #7. The continuous current capacity of this motor as given by the manufacturer is 110 amp. at 400 volts. The values obtained as shown on Curve Sheet #7 are in excess of this. This motor if used would heat excessively.

We have considered now, three motors and three gear ratios. We have pointed out a few reasons why the West. #134 and the G. E. 69 B might not be suited to our work. In the case of each motor, however, there are other considerations which might make it advisable to use the motor in spite of what has been brought out. Our decision was made, taking into account all factors that might influence the motor when applied to the actual road conditions. Hence we recommend the Westinghouse #113 Railway Motor, 550 V. G.R. 2.50 with a continuous capacity of 150 amp. The characteristic curves of this motor are shown on Curve Sheet #8.

Upon considering the actual profile of the road we must take into account the grades. The effect of grades upon acceleration and torque and upon the time necessary
to attain 40 m.p.h. is shown on Curve Sheet #9. When drawn to a large scale other grade curves could be drawn by interpolation. How the speed time curves worked out on the actual profile are shown on Speed Time Curve Sheets #1 and 2. On Speed Time Curve Sheet #1 are shown the east and west bound curves for the express runs and on Speed Time Curve Sheet #2 are shown the curves for the local runs. The values for $I_e$ and of $W.H./T.M.$ are shown for each respective run. To show that the motor is well adapted to our service we have calculated the average $I_e$ and $W.H./T.M.$ for the total run eastbound and westbound both local and express. These results are shown in table II page 16.

Having completed the speed time curves we drew up a provisional schedule for the rush period A.M. and P.M. In order to obtain load curves it was necessary to make up both east and westbound schedules for each rush period. These schedules comprise both local and express service and we are each labeled at the top of the sheet.
<table>
<thead>
<tr>
<th></th>
<th>W.H./T.m.</th>
<th>$I_g$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Express Run</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Bound</td>
<td>32.4</td>
<td>85.9</td>
</tr>
<tr>
<td>East Bound</td>
<td>32.0</td>
<td>71.9</td>
</tr>
<tr>
<td><strong>Local Run</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Bound</td>
<td>84.0</td>
<td>120.0</td>
</tr>
<tr>
<td>East Bound</td>
<td>80.5</td>
<td>120.5</td>
</tr>
</tbody>
</table>
In comparing this schedule with the present schedule of the railroad some important changes will be noted. We have still maintained the three divisions as at present. The number of trains has been increased and the headway, consequently, decreased in like proportion but the total number of cars on each division has remained very nearly the same. The length of stop varies from 20 sec to one minute. These values may seem high but are considered fair, since they were obtained by actual observation. One minute stops are made on the express run at La Grange, Hinsdale and Downers Grove. On the Riverside Division we have increased the schedule speed to 24 m.p.h., on the Downers Grove Division to 28.5 m.p.h., while the schedule speed on the Aurora Division remains nearly the same. We have standardized the express and local runs, i.e., express trains now all make the same stops and local trains all make the same stops.

The central station for supplying the necessary energy will be located at Riverside on the Desplaines River. This was decided upon by the proximity of water, which is necessary in large quantities for the condensing equipment of the plant. The substations have been so spaced as to be of about the same capacity. Substation
Substation #1 will be near Western Ave., Chicago, and will furnish energy for the line between the Union Station and Morton Park. Substation #2 will be at Riverside in conjunction with the central station, and will take care of the road from Morton Park to La Grange, Stone Ave. Substation #3 will be at West Hinsdale supplying the line from La Grange, Stone Ave., to Downers Grove. Substation #4 will be at Naperville and furnish energy for the line between Downers Grove and Aurora.

For the rush period the load curves are given for one minute intervals. This was done by taking each substation and the line supplied by it, separately, and from the speed time and current curves, obtaining the total current taken from the line for every minute. This required that we know the exact location of every train at every minute. An allowance of 20% of the current required for propulsion was made for heating and lighting. Load curves for the morning and evening rush hours were determined for each substation and are known as follows:

<table>
<thead>
<tr>
<th>Curve Sheet</th>
<th>Substation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>#1</td>
<td>A.M.</td>
</tr>
<tr>
<td>&quot;</td>
<td>#11</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>#12</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
Curves Sheet #13

Substation #2 P.M.

Curves Sheet #14

Substation #3 A.M.

Curves Sheet #15

Substation #3 P.M.

Curves Sheet #16

Substation #4 A.M.

Curves Sheet #17

Substation #4 A.M.

The central station load curves are made up from the substation load curve. An efficiency of transmission of 80% was assumed (the 20% loss being total loss from A.C. generators to car motors) in working out all the load curves. The rush hour load curves for the central station are shown as follows:

Curves Sheet #18 Central Station A.M.

Curves Sheet #19 Central Station P.M.

In summing up the discussion on central and sub-stations, then, from an examination of the separate load curves of each, the rush period capacity of each might be tabulated as follows:

Substation #1 2700 K.W. Capacity.

Substation #2 2800 " "

Substation #3 2700 " "

Substation #4 2100 " "

Central Station A.M. 7200 " 

Central Station P.M. 7700 " "


These values do not represent the capacity as represented by the maximum peak loads as the latter in each case are instantaneous only. Allowing for an overload continuous capacity of 25%, the K.W. rating of the installed generators and converters would be about as follows:

<table>
<thead>
<tr>
<th>Substation</th>
<th>K.W.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>2150</td>
</tr>
<tr>
<td>#2</td>
<td>2250</td>
</tr>
<tr>
<td>#3</td>
<td>2150</td>
</tr>
<tr>
<td>#4</td>
<td>1700</td>
</tr>
<tr>
<td>Central Station A.M.</td>
<td>5800</td>
</tr>
<tr>
<td>&quot;</td>
<td>F.M.</td>
</tr>
</tbody>
</table>

While operating on the peak loads, the instantaneous overload capacity of the machines would never exceed 40%, which can be readily seen from an inspection of the load curves.

Coming next to the transmission line, to substation #1 we have stated before that the current transmitted will be A.C.:

- Maximum load transmitted: 3200 K.W.
- Length line: 7.5 mile
- Frequency of 25 cycles per second, 3 phase.
- Two distinct circuits will be provided both alike, and either alone capable of transmitting maximum power.
Size of wire - #2 B. & S. Gauge, copper, 1/4" diameter and area 66,310 circular mils.
Distance between wires on insulators 2 ft.
Inductance 1.77 m.h. per mile per wire.
Capacity .017 m.f. per mile per wire.
Charging Current 0.255 amp.
Natural frequency of line 6200 cycles/sec.
Apparent power at no load 3.25 k.v.a.
Inductive reaction per wire 2.1 ohms.
Capacity reaction per wire 50 ohms.
Regulation at unity power factor .79%
Regulation at 85% factor 1.97%

Substation #3

Maximum load 5000 K.W.
Length of wire 6.7 miles
Frequency of 25 cycles 3 phase
Two circuits provided as before.
Size of wire #1 B & S Gauge copper 0.29 inch
in diam. area 83,690 cir. mils.
Distance between wires 2 ft.
Inductance 1.76 m.h per mile per wire
Capacity .0175 m.f per mile per wire.
Charging current 0.228 amp.
Natural frequency 7200 cycles per sec.
Apparent power no load 2.9 K.V.A.
Inductive reaction per wire 1.86 ohms.
Capacity reaction per wire 54.0 ohms.
Reg. at 100% p.f. 1.02%
Reg. at 85% p.f. 2.6%

For substation #4 the size of wire required was calculated to be #3, B & S gauge. It will be of the same design as the other two, but the values were not worked out, as it was deemed sufficient to have two completely worked out.

In the previous pages it has been our desire to be as brief as possible. No details have been given except where absolutely necessary. No new methods have been brought out, and the schemes or equations for the methods of procedure herein contained, have been given in the classroom or can be found in any text book on electric railways. As a general reference covering the entire ground on which we have worked, we refer the reader to Electric Traction and Transmission Engineering" Sheldon and Hausmen.
Preliminary Curves

West: 113 - 400 M.P.H. G.M.: 683

Distance: 0.5 (Dotted) 0.6 - 1.0 Mile
PRELIMINARY CURVE
G.E. 69 B = 200 MP = G.R. 2.56
DISTANCE: 0.5 (DOTTED), 0.6, 0.10 MILE

0.5 MILE = W.N/T.M = 110.0
0.6 MILE = W.N/T.M = 150.0
1.0 MILE = W.N/T.M = 210.0

0.5 MILE = T° = 120.0
0.6 MILE = T° = 160.0
1.0 MILE = T° = 150.0

PROFILE PLATE A 4X20
J. ESSER & Co. NEW YORK
PRELIMINARY CURVES
WEST. X 134 - 160 M  G.R. - 2.36
DISTANCE - 0.5 (DOTTED), 0.6 - 1.0 MILE

0.5 MILE - W.H./T.M. = 121.0
0.6 MILE - W.H./T.M. = 101.0
1.0 MILE - W.H./T.M. = 70.5

0.5 MILE - I_o = 141
0.6 MILE - I_o = 132
1.0 MILE - I_o = 115
WEST & N13 RAILWAY MOTOR 550 V.
G.R. 2.56 36" WHEELS
CONTINUOUS CAPACITY 150 AMP.

AA TRACTIVE EFFORT
BB BRAKE HP
CC ELECT. HP.
DD SPEED
EE TIME TO RISE 75°C FROM 25°C
FF TIME TO RISE 20°C FROM 75°C
GG EFF. WITHOUT GEARS
HH APPROXIMATE EFF. WITH GEARS.
CURVES SHOWING EFFECT OF GRADES ON TIME REQUIRED TO ATTAIN A SPEED OF 40 M.P.H.

A 1% DOWN GRADE.
B 0.5% DOWN GRADE.
C LEVEL
D 0.5% UP GRADE.
E 1.0% UP GRADE.

TIME - SEC.
<table>
<thead>
<tr>
<th>Time</th>
<th>UNION STA.</th>
<th>CUNA</th>
<th>CANAL 9/16</th>
<th>WESTERN AV.</th>
<th>HAWTHORNE</th>
<th>MORTON PK</th>
<th>CLYDE</th>
<th>LA VERNE</th>
<th>BRYMN</th>
<th>HARLEM AV.</th>
<th>RIVERSIDE</th>
<th>HOLLYWOOD</th>
<th>BROOKFIELD</th>
<th>CONGRESS PK</th>
<th>LA GRANGE 5th</th>
<th>LA GRANGE ST</th>
<th>HIGHLANDS</th>
<th>HINSDALE</th>
<th>W. HINSDALE</th>
<th>CLARENDON HILLS</th>
<th>GREGGS</th>
<th>EAST GROVE</th>
<th>DOWNERS GR</th>
<th>BELMONT</th>
<th>LISLE</th>
<th>NAPERVILLE</th>
<th>ELCA</th>
<th>AURORA, ILL.</th>
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<tbody>
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<td>7:08</td>
<td>7:17</td>
<td>7:20</td>
<td>7:28</td>
<td>7:31</td>
<td>7:33</td>
<td>7:35</td>
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<td>7:43</td>
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<td>7:50</td>
<td>7:52</td>
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<td>8:02</td>
<td>8:05</td>
<td>8:08</td>
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<th>THRU</th>
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</thead>
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| 5:00 | 3 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 6:00 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7:00 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

**PROVISIONAL WEST BOUND SCHEDULE 5:00-7:00 P.M. EX SUNDAY**
<table>
<thead>
<tr>
<th></th>
<th>PROVISIONAL FIRST ROUND SCHEDULE</th>
<th>6:30 - 6:30 A.M</th>
<th>EX SUN</th>
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<td>1.</td>
<td>AURORA, ILL.</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>NO. OF CARS</td>
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</tr>
<tr>
<td>200</td>
<td>210</td>
<td>220</td>
<td>230</td>
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<tr>
<td>06:15</td>
<td>06:16</td>
<td>06:17</td>
<td>06:18</td>
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*Provost & Schools - Westinwood*
<table>
<thead>
<tr>
<th>Distance</th>
<th>Location</th>
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<th>To</th>
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<tr>
<td>0.4</td>
<td>LA GRANGE S Ave</td>
<td>5:53</td>
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<td>BROOKFIELD</td>
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<tr>
<td>0.5</td>
<td>HOLLYWOOD</td>
<td>5:59</td>
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<tr>
<td>0.7</td>
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<td>6:01</td>
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<tr>
<td>1.0</td>
<td>HARLEM AV.</td>
<td>6:03</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>BERWYN</td>
<td>6:05</td>
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<tr>
<td>0.5</td>
<td>LA VERGNE</td>
<td>6:07</td>
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</tr>
<tr>
<td>0.6</td>
<td>CLYDE</td>
<td>6:09</td>
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<tr>
<td>1.0</td>
<td>MORTON PK.</td>
<td>6:11</td>
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</tr>
<tr>
<td>Time</td>
<td>Route</td>
<td>Location</td>
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<tr>
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<td>0:00</td>
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<td>Union Sta.</td>
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<tr>
<td>1:4</td>
<td>1:4</td>
<td>Canal 4-16</td>
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<td>2:4</td>
<td>2:8</td>
<td>Western Av</td>
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<tr>
<td>1:0</td>
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<td>East Grove</td>
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<tr>
<td>0:8</td>
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<td>Downers Gr.</td>
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<tr>
<td>1:4</td>
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<td>Belmont</td>
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<tr>
<td>1:9</td>
<td>2:15</td>
<td>1151 E</td>
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</tr>
</tbody>
</table>
3° CURVE.

1° CURVE.

EL. 150

EL. 150

EL. 100

EL. 100

EL. 50

LAKE MICHIGAN DATUM (LOW WATER).

-0.22

-0.42

-0.37

-0.15

TRACK PROFILE - C.B. & Q. R.R.
CHICAGO TO AURORA.
LA GRANGE - STONE AVE. TO WESTERN SPRINGS.
12 MILES
W submerged = 870
t = 1,000

WESTERN SPRINGS TO HIGHLANDS.
10 MILE
W submerged = 655
t = 1,125

LA GRANGE - STONE AVE. TO WESTERN SPRINGS.
10 MILE
W submerged = 670
t = 1,000
TYPICAL WINTER LOAD CURVE.
RUSH PERIOD - A.M.
SUBSTATION - CHICAGO TO MORTON PK.
TYPICAL WINTER LOAD CURVE.
RUSH PERIOD A.M.
#1 SUBSTATION—CHICAGO TO MORTON PK.
TYPICAL WINTER LOAD CURVE
RUSH PERIOD - P.M.

SUBSTATION - MORTON PK TO LGRANGE STONE.
TYPICAL WINTER LOAD CURVE
RUSH PERIOD A.M.
"3 SUBSTATION - LERANGE TO D CROVE.

CAR LIGHTING AND HEATING.
TYPICAL WINTER LOAD CURVE.
RUSH PERIOD - P.M.
FORMATION - L. GRANGE STONE TO O. GROVE.
SPEED-TIME CURVE SHEET #1
EAST-WEST BOUND - EXPRESS RUN
PER PROVISIONAL SCHEDULE
WESTINGHOUSE TYPE #113 MOTOR

UNION DEPOT TO CANAL 16TH ST
1 1/2 MILES
W/1/m = .981
I'''c'h = 810

10 MPH
20 MPH
30 MPH
40 MPH
50 MPH

650 AMP
1650 AMP
1875 AMP
TYPICAL WINTER LOAD CURVE.
PUSH PERIOD - A.M.
& A SUBSTATION - D.ROVE TO AURORA.

CAR LIGHTING AND HEATING

AMP
3000
2700
2400
2100
1800
1500
1200
900
600
300
0
K.W.
1600
1200
800
400
0
Typical Load Curve - Winter
Rush Period - P.M.
4 Substation - O. Grove to Aurora.
TYPICAL LOAD CURVE - WINTER
RUSH PERIOD - P.M.
#4 SUBSTATION - GROVE TO AURORA.
TYPICAL WINTER LOAD CURVE
RUSH PERIOD 6-10 A.M.
CENTRAL STATION - RIVERSIDE

TRAIN LIGHTING AND HEATING
Typical Winter Load Curve
Rush Period - A.M.
Central Station - River Rose
TYPICAL MINUTE LOAD CURVE
RUSH PERIOD A.M.
CENTRAL STATION - RIVER RISE
TYPICAL WINTER LOAD CURVE
HIGH PERIOD - 7-11
CENTRAL STATION - RIVERSIDE.