PROPOSED CENTRALIZED TRAFFIC CONTROL INSTALLATION
AND SECOND MAIN TRACK RETIREMENT
ON THE BOSTON AND MAINE RAILROAD

By

THOMAS J. LAMPHIER

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1949

Signature redacted

Signature of the Author...

Department of Civil and Sanitary Engineering

May 20, 1949

Signature of the Professor in Signature redacted
Charge of Research.......................................

38

Boston, Massachusetts
May 20, 1949

Professor Joseph S. Newell
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Sir:

In partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering, I submit herewith this thesis, entitled "Proposed Centralized Traffic Control Installation and Second Main Track Retirement on the Boston and Maine Railroad."

Respectfully yours,

Signature redacted

Thomas J. Lamphier

307717

ACKNOWLEDGMENT

The author is indebted to the Boston and Maine Railroad and to its employees, who were most helpful in making this thesis possible, and especially to Mr. E. N. Fox, Engineer of Signals and Telegraph, for his counsel and encouragement. The author also wishes to thank the General Railway Signal Company and the Union Switch and Signal Company for material concerning CTC installations.

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SUMMARY

Introduction

In their pursuit for greater operating efficiency and lower operating expenses, the railroads of this country have found in Centralized Traffic Control a most efficient form of train control. Centralized Traffic Control (CTC) may be defined as the operation of trains over a section of road without the general use of train orders and time-table authority. This method of train operation promotes generally higher operating efficiency and lower operating costs by increasing track capacity, decreasing delays, increasing average train speeds, increasing safety in operation, and by allowing retirement of trackage. It is with the last of these items, the retirement of trackage, which this work is concerned.

The retirement of trackage in connection with a CTC installation, while not very often done, results in the reduction of operating and maintenance expenses. The reduction in maintenance of way expenses is by far the most important advantage gained.

The particular road under consideration is that part of the New Hampshire Division of the Boston and Maine Railroad between Nashua and Concord, New Hampshire. This line is double-track and runs in the valley of the Merrimack River, and the maximum grade is .34% ascending northward. Fifty-three per cent of the line is on tangent track and the maximum degree of curvature is 6° 14 . The daily-except-Sunday traffic consists of nine passenger and four freight trains each way. There are no local freight trains, all set-outs and pick-ups being made by the regular freights.

Object

The purpose of this work is to design that section of line for single-track operation with Centralized Traffic Control and to study the savings to be obtained by the retirement of the second track now in use.

Methods and Conclusions

From a study of the freight and passenger time tables and train sheets of the New Hampshire Division, meeting points were determined. Combining the location of these meets with existing signal locations and local operating and physical conditions, the number and location of passing sidings was determined. The length of these sidings was established knowing the maximum length of trains, train speeds and various other factors, which will be presented later in the paper.

Power interlocking plants are located in Nashua, Manchester and Concord, and the line is at present signaled with Automatic Block Signals. The design and layout were made so as to require practically no alterations in these interlocking plants and line signals have been located to use existing signals insofar as was possible.

Following the final design, an economic analysis of the proposed installation was made. However, no accurate cost estimate of the installation or the annual saving to be obtained could be made, due to the inability to obtain cost data. A reasonable statement was obtained by using average values of installation and maintenance costs from Chapter III of the American Railway Signaling Principles and Practices. From these rather rough calculations, it would seem that rather substantial savings are assured and that the proposed installation is definitely feasible.

PREVIOUS INSTALLATIONS

The only recent installation of note, involving Centralized Traffic Control and the retirement of second main track is that one on the Chicago, Milwaukee, St. Paul and Pacific Railroad between Glencoe, Minnesota and Milbank, South Dakota, completed in 1946.

The installation was made on 137 miles of road and 34.94 miles of second main track were eliminated. There was a net annual saving of $84,288 for a return of 14.1 per cent on the total cost.

PROCEDURE

Number and Location of the Passing Sidings

Using the Boston and Maine Time Table No. 47, the Freight Train Symbol Book No. 48, and times taken directly from the New Hampshire Division train sheet, the graphic train sheet in the appendix was drawn up. The curves of the train movements were assumed to be straight lines between stations. This assumption was valid, as high precision was not required.

Passenger trains offer no particular problem when determining meets from train graphs, but freight trains do not necessarily follow time tables closely, thus giving rise to the problem of determining where they will meet other trains. Fortunately, on the New Hampshire Division, the eight freight trains daily are all scheduled trains and do follow the time table closely enough to permit a reasonable determination of their meeting points with other trains.

From the graphic train sheets, a table of the train meets was made up. This tabulation included both the time and place of the meet. The meets seemed to group themselves into five places; meets at Nashua, Manchester, and Concord, and meets approximately midway between these three cities.

The interlocking plants at Nashua, Manchester, and Concord are all of recent construction; and it was decided to leave these plants without alterations. Thus, the road was left double-tracked through these interlocking plants and was continued far enough out from them so as not to interfere with local switching movements and to have good sight distances at those places where the line was to converge to single-track.

Only two other sidings, or sections of double-track, were required, and from the train sheet it was possible to locate them, generally, at Reeds Ferry and Hooksett.

Length of the Passing Sidings

In CTC installations on single-track, it has been possible to obtain non-stop meets for about 40 per cent or less of the trains. It has been impossible to obtain a higher percentage of non-stop meets due to the shortness and inaccurate placement of passing sidings, trains failing to run on schedule, and to extra trains.

In this design, one of the precepts is to maintain present operating schedules, at least, and to provide for improving them if possible. Thus, nearly all meets must be non-stop. This was accomplished by providing long passing sidings and signaling these sidings.

To determine a basic length for passing sidings, the General Railway Signal Company's non-stop meet formulas were used. The calculations of the siding length may be found in the appendix. It is sufficient here to say that for a meet of two freight trains, a siding length of nearly 19,000 feet is indicated, and for the meet of a passenger train with a freight train a length of about 15,000 feet is required. These values are on the high side since very few of the freight trains are ever one hundred cars long and there are only three meets of freight trains. However, these long sidings provide a margin of safety of non-stop meets because of variance in the exact meeting point of trains.

These base figures were then changed to fit the local physical conditions; that is, establishing the turnouts on tangent tracks with long sight distances in both directions.

Final Location of the Sidings

The location of the sidings, considering only the present train meets, would have placed the Reeds Ferry siding much closer to Manchester than to Nashua, and the Hooksett siding much closer to Concord than to Manchester. This unbalance would lead to inflexibility in the operation of trains. Therefore, the proposed siding at Reeds Ferry was moved slightly southward towards Merrimack so that the distances from the siding to Nashua and Manchester were nearly equal and to have the industrial sidings at Merrimack on the double-tracked section to facilitate switching movements without interfering with other train movements. The Hooksett siding was also moved southward to balance the distances between Manchester and Concord and to include the spur track at Hooksett.

No attempt has been made to locate the position of the turnouts to the precision that would be required in a final design, but the Reeds Ferry siding extends approximately from station 368+00 to station 545+00. The Hooksett siding extends from station 1250+00 to station 1432+00.

From the line plan it will be seen that the southbound main line was retained in the proposed track retirement. The reason for this selection is that southward trains are superior to northward trains. However, in the final design, the track that had the best rail and road bed would be chosen.

As has been previously stated, the location of the end of the double-track at the interlocking plants was chosen so as not to interfere with local switching operations. At Nashua the turnout was carried out to station 150+00 as train meets are indicated north of the station.

At the south end of the Manchester interlocking, the turnout was placed as near as possible to the home signal of the interlocking plant. Rather sharp curves north of Manchester necessitated carrying the turnout out to station 927+00.

The turnout to double-track at Concord was located at station 1743+00 so as not to interfere with switching operations and train meets south of the Concord station.

Signals

The end of the double-track and the sidings would be laid with No. 20 turnouts, thus permitting medium speeds through them. The allowable speed through a No. 20 turnout is approximately 40 miles per hour. It is imperative, therefore, that the sidings and turnouts be signaled for rather high speeds.

In the proposed layout, the signals governing moves through diverging or converging routes would be signaled in the same manner as an interlocking plant; that is, all signals at these points are home signals and, as such, require approach signals. All proposed signaling is in keeping with the specifications of the Boston and Maine Railroad.

The signal governing moves from sidings or double-track are three-unit, searchlight-type signals. The top light is a fixed signal, and its only aspect is red. The middle unit has three aspects - red, green and yellow; and the bottom unit has four aspects - red, green, yellow, and flashing yellow. The indication for the flashing yellow is, "Proceed prepared to stop at the next signal; slow speed within interlocking limits." This differs from the regular bottom yellow in that the steady yellow indication is, "Proceed at restricted speed." The best aspect this signal may give is red over green over red - "Proceed at medium speed within interlocking limits." Medium speed is defined from the Boston and Maine Rule Book as a speed not exceeding 30 miles per hour.

The signal governing movements at the entrance to diverging routes is a three-unit signal, the top two of which may display three aspects - red, green or yellow. The bottom unit provides only for the red and yellow aspects. The bottom yellow is displayed under two reds for a diverging move against the normal flow of traffic or onto passing sidings.

The signal governing mainline movements at the ends of double-track or passing sidings is also a three-unit signal, the top two of which may display red, green or yellow. The bottom unit is a fixed red signal. The fixed signal is used only so that uniformity may be maintained in the signals of the railroad.

The approach signals are all two-unit signals, and each unit may display three aspects - red, green or yellow. The bottom unit is placed below and to the right of the high signal, when the approach signal is braking distance away from the home signal. When the approach signal is not braking distance from the home signal, the lights are placed one above the other.

The mainline track spacing is only thirteen feet and, therefore, no high signals could be placed between tracks on the sidings, and dwarf signals would not be acceptable, because of Interstate Commerce Commission restrictions. It is necessary, therefore, to use cantilever masts, for the siding signals. These are used in preference to signal bridges, due to the high cost of the latter.

The intermediate signals would be single unit, three aspect, search light type signals, and would be wired for an Absolute Permissive Block System.

The signals in the interlocking plants at Manchester and Concord would not be changed except the home signal at the south end of the Manchester interlocking, which would be moved a few hundred feet southward to the proposed point of the turnout, and the home and approach signals at the north end of the Manchester interlocking, which would both be moved northward about 1700 feet to the proposed turnout point.

Switches and Control Equipment

The turnouts to single track at Nashua and Concord would be equipped with spring switches and all other turnouts would have power switch machines. The switch machine at the south end of the Reeds Ferry siding would be a dual-control machine to facilitate switching movements at Merrimack.

All industrial sidings with hand-thrown switches would be provided with electric switch locks as indicated on the line plan.

In the proposed plan, the control equipment and panels would be located in the existing interlocking tower at Manchester. This tower is new, having been erected in 1944. There is sufficient room in this tower to house the control equipment, and switch panels could be attached to the existing board.

Economic Analysis

The estimate of cost and economic statement on the following two pages are not precise but, on the other hand, give reasonable enough values to make them useful in determining the advisability of installing a CTC system.

The line is laid completely with 112-pound rail, and the $47.00 is the value placed on that rail at the present time by the Boston and Maine Railroad.

The ties were assumed to have a small value, as many of the newer ones could be used in sidings and yard track. The standard for ties on the Boston and Maine is twenty ties to a thirty-three-foot rail.

No salvage value was stated for tie plates, joint bars, bolts, etc., and any value they might have would be balanced by the cost of tearing up the track.

The estimated cost of CTC per mile of track is an average of twenty-two installations. It is somewhat lower than the $9910 per mile for three installations on the Boston and Maine.

The maintenance unit costs were taken from Chapter III of the "American Railway Signaling Principles and Practices" and are average values for several railroads.

It is possible under the proposed plan to eliminate the day operator at Merrimack, but no indication was made of this since a second operator would be required for the day trick at the control tower in Manchester. The density of traffic on the line and the amount of switching done at Manchester does not seem to require more than one operator in the control tower except on the day trick.

The interest and depreciation charges are the standard charges used by the Boston and Maine Railroad.

Estimate of the Savings to be Derived
from the Installation of CTC and
Retirement of Second Main Track

A.	Abandonment of 21.65 miles of second Main Track		
	Value of 112 lb. rail at $47.00 per short ton		$200,600
	Value of 1/2 the ties at $.70		24,250
	Salvage value		224,850
B.	Estimated cost of the CTC installation		
	47.1 miles of track at $7,345		345,950
	Less salvage value		224,850
	Net cost of the installation		121,100
C.	Annual Saving		
	Reductions:		
	1. Maintenance of 21.65 miles of track at $1150		24,900
	2. Maintenance of Automatic Block Signals on 68.72 miles of track at $113		7,750
	3. Maintenance of 5 crossovers at $200		1,000
			33,650
	Deduct:		
	1. Maintenance of CTC signals on 47.1 miles of track at $205	9650	
	2. Maintenance of 8 turnouts at $100	800	10,450
	Net Annual Saving in Operating Expenses		$ 23,200

Economic Statement

1.	Net Cost of CTC Installation		$121,100
2.	Gross Saving per Annum		33,650
3.	Increased Annual Operating Expenses		10,450
4.	Net Reduction in Annual Operating Expenses		23,200
5.	Deduct Interest Charge at 4%	4840	
	Deduct Depreciation Charge at 3%	3630	
			8,470
6.	Net Saving per Annum		14,730
7.	Annual Return on the Net Cost	12.16%	

CONCLUSIONS

Before the Boston and Maine Railroad would carry through a design of this type, a 15% return on the investment would have to be assured. The 12.16% return indicated by this design approaches that expected by the railroad, and with certain refinements in the design, savings of 15% and more might be effected.

If each of the two sidings, at Reeds Ferry and at Hooksett, were shortened by 2000 feet, the net cost of the installation would be reduced to $107,450 and the Net Saving Per Annum would be increased to $16,740, thus bringing a return of 15.6%. The reduction in siding length would make the Reeds Ferry siding approximately 15,700 feet long and the Hooksett siding 16,200 feet long. Such siding lengths would not hamper the normal operation of traffic over this line and would still leave a large margin of safety for non-stop meets.

Another saving, which is not immediately apparent and cannot be definitely counted on, is the sale of portions of the abandoned right-of-way, which sale would decrease the net cost of the installation and increase the net annual savings by reducing taxes.

It is the opinion of the author that a design such as the one discussed in this thesis is definitely worthwhile, and would decrease the operating expenses and enhance the general operating efficiency of the Boston and Maine Railroad.

APPENDIX

Time Table of First Class Trains Between Nashua and Concord, N.H.

Outward Trains (Northward)

STATIONS	Miles from Bos.	3001	1	303	305	5	3601	307	313	3009	3051	325	329
		Sun.	ExSun	ExSun	ExSun	Daily	ExSun	Daily	ExSun	Sun.	Sun.	Daily	Daily
		AM	AM	AM	AM	AM	AM	PM	PM	PM	PM	PM	AM
Nashua	38.96	A 3.11	4.04	7.31	8.55	9.50		1.21	5.20	6.54	9.31	9.37	12.20
		L 3.33	4.15	7.44	9.02	9.52		1.24	5.23	6.57	9.33	9.40	12.22
Thorntons F.	44.73												
Merrimack	46.09	3.43	4.24	7.53	9.12	10.01		1.33	5.32	7.06	9.42	9.49	12.30
Reeds Ferry	47.78												
Goffs Falls	52.03	3.50	4.30	7.59	9.19	10.07		1.39	5.38	7.12	9.48	9.55	12.36
Manchester	55.68	3.55	4.35	8.04	9.24	10.12	10.19	1.44	5.43	7.17	9.53	10.00	12.41
		4.20	4.45	8.14	9.30	10.15	10.20	1.47	5.45	7.20	9.55	10.05	12.45
Martin	60.51												
Hooksett	64.37	4.32	4.57	8.25	9.42	10.27	10.33	1.58	5.57	7.32	10.07	10.17	12.57
Bow	71.00	4.40	5.05	8.35	9.50	10.35	10.42	2.05	6.05	7.40	10.15	10.25	1.05
Concord	73.32	4.45	5.10	8.40	9.55	10.40	10.50	2.10	6.10	7.45	10.20	10.30	1.10
		AM	AM	AM	AM	AM	AM	PM	PM	PM	PM	PM	AM

Time Table of First Class Trains Between Nashua and Concord, N.H.

Inward Trains (Southward)

STATIONS	Miles from Conc.	302	308	310	3006	316	3366	320	3604	332	20	24	26
		Daily	ExSun	ExSun	Sun.	ExSun	Sun.	ExSun	ExSun	Daily	Daily	ExSun	Sun
		AM	AM	AM	AM	AM	PM	PM	PM	PM	PM	PM	PM
Concord		6.10	7.50	9.30	9.45	11.45	1.40	2.20	3.55	5.00	5.50	8.20	8.35
Bow	2.32	6.14	7.54	9.34	9.49	11.49	1.44	2.24	3.58	5.04	5.54	8.24	8.39
Hooksett	8.95	6.23	8.01	9.41	9.56	11.56	1.51	2.31	4.08	5.11	6.01	8.31	8.46
Martin	12.81												
Manchester	17.64	6.34 6.41	8.13	9.52 9.56	10.08	12.07 12.10	2.03	2.42 2.47	4.23	5.22 5.27	6.12 6.16	8.42 8.53	8.58 9.01
Goffs Falls	21.29												
Reeds Ferry	25.54												
Merrimack	27.23	6.52	8.24	10.07	10.19	12.21	2.14	2.58		5.38	6.27	9.04	9.13
Thorntons F.	28.59												
Nashua	34.36	7.02 7.05	8.34	10.16 10.19	10.29	12.30 12.33	2.25	3.06 3.10		5.47 5.53	6.35 6.38	9.13 9.18	9.22 9.25
		AM	AM	AM	AM	PM	PM	PM	PM	PM	PM	PM	PM

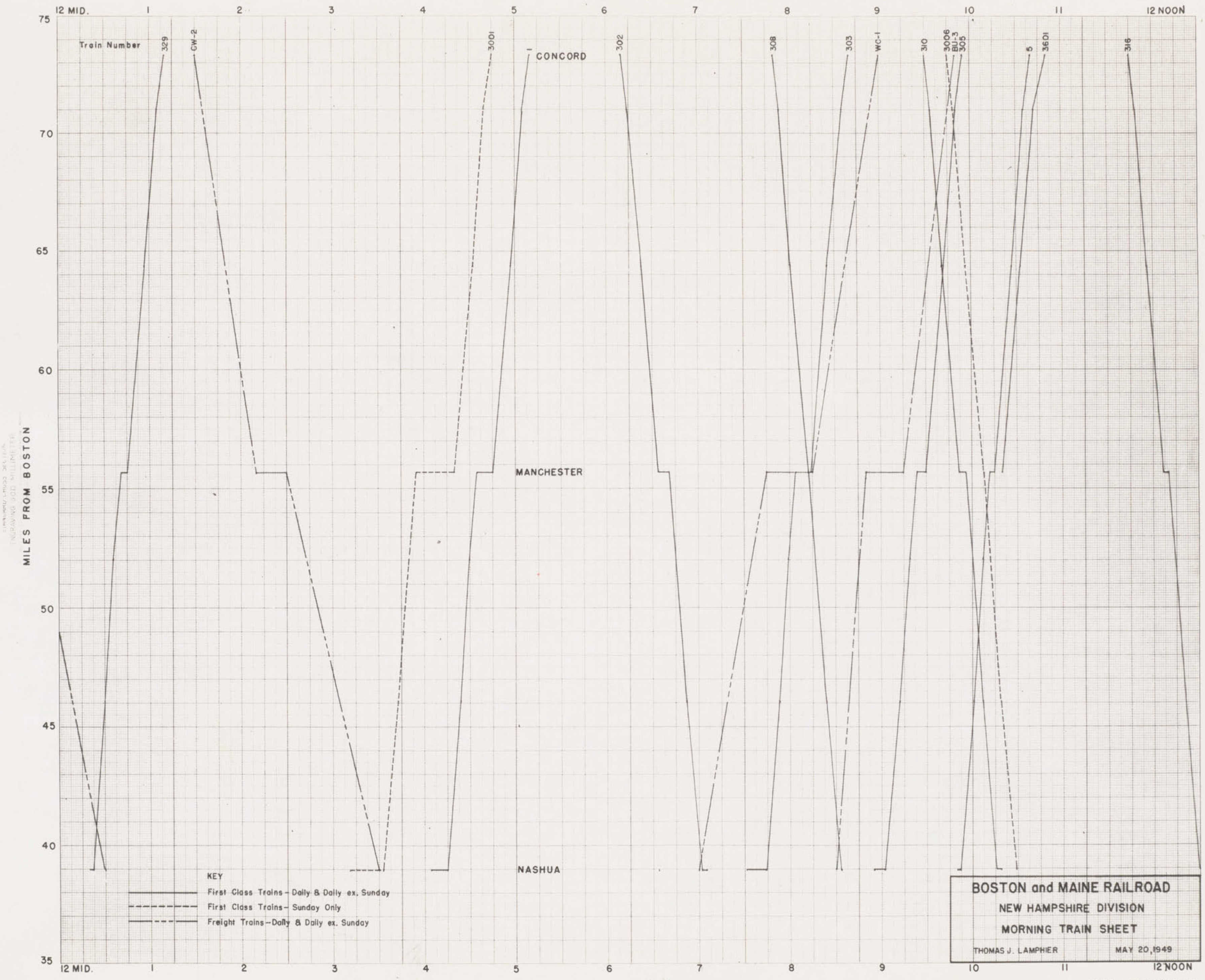
Boston and Maine Railroad

Freight Train Time Table Between Nashua and Concord, N. H.

(From Freight Train Symbol Book No. 48
and New Hampshire Division Train Sheet)

Northbound		WC-1	BU-3	BU-1	351X
		A.M.	A.M.	P.M.	P.M.
Nashua	Lv.	7:00	8:30	8:30	10:30
Manchester	Ar.	7:45	8:50	8:45	11:00
	Lv.	8:15	9:15	9:15	11:15
Concord	Ar.	9:00	9:50	10:10	11:50
		A.M.	A.M.	P.M.	P.M.

Southbound		CW-2	UB-2	352-X	JB-490
		A.M.	P.M.	P.M.	P.M.
Concord	Lv.	1:30	7:30	11:00	11:10
Manchester	Ar.	2:10	8:00		
	Lv.	2:30	8:30	11:25	11:40
Nashua	Ar.	3:30	9:00	11:50	12:30
		A.M.	P.M.	P.M.	A.M.


12 MID.
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2
3
4
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12 NOON
Train Number
329
GW-2
3001
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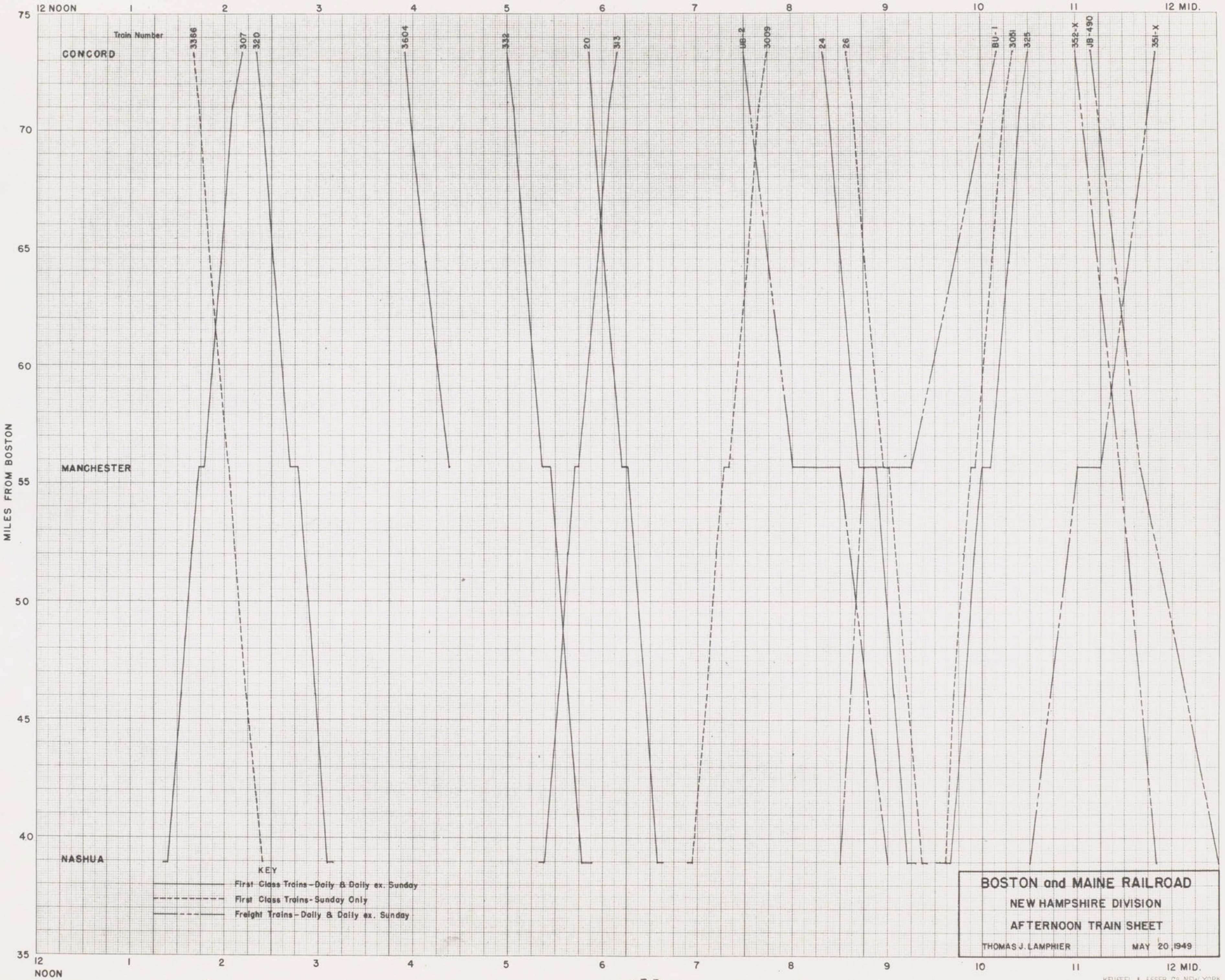
308
303
WC-1
310
3006
BU-3
305
5
3601
316
CONCORD
MANCHESTER
NASHUA
MILES FROM BOSTON
75
70
65
60
55
50
45
40
35
KEY
First Class Trains - Daily & Daily ex. Sunday
First Class Trains - Sunday Only
Freight Trains - Daily & Daily ex. Sunday
BOSTON and MAINE RAILROAD
NEW HAMPSHIRE DIVISION
MORNING TRAIN SHEET
THOMAS J. LAMPHIER
MAY 20, 1949
KEUFFEL & ESSER CO. NEW YORK



12 NOON
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Train Number
3386
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320
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UB-2
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BU-1
3051
325
352-X
JB-490
351-X
CONCORD
MANCHESTER
NASHUA
MILES FROM BOSTON
75
70
65
60
55
50
45
40
35
KEY
First Class Trains - Daily & Daily ex. Sunday
First Class Trains - Sunday Only
Freight Trains - Daily & Daily ex. Sunday
BOSTON and MAINE RAILROAD
NEW HAMPSHIRE DIVISION
AFTERNOON TRAIN SHEET
THOMAS J. LAMPHIER
MAY 20, 1949
12 NOON
KEUFFEL & ESSER CO. NEW YORK

Train Meets (Daily Except Sunday)

Train Numbers		Meeting Point (Miles from Boston)	Time
JB-490	329	40.8	12:24 A.M.
302	WC-1	39.5	7:01 A.M.
308	WC-1	55.7	8:13 A.M.
308	303	55.7	8:13 A.M.
308	BU-3	40.2	8:31 A.M.
310	BU-3	67.2	9:38 A.M.
310	305	64.0	9:41 A.M.
310	5	48.8	10:03 A.M.
332	313	48.8	5:35 P.M.
20	313	66.2	5:59 P.M.
UB-2	BU-1	50.0	8:40 P.M.
24	BU-1	55.7	8:45 P.M.
352-X	351-X	59.0	11:21 P.M.
JB-490	351-X	62.2	11:28 P.M.

Train Meets (Sunday Only)

Train Numbers		Meeting Point (Miles from Boston)	Time
JB-490	329	40.8	12:24 A.M.
302	WC-1	39.5	7:01 A.M.
3006	BU-3	72.0	9:47 A.M.
3006	5	54.1	10:10 A.M.
3366	307	61.7	1:55 P.M.
UB-2	3009	69.0	7:37 P.M.
UB-2	BU-1	50.0	8:40 P.M.
26	BU-1	55.7	9:00 P.M.

Determination of the Length of Passing Sidings[x]

$$L_{ps} = L_i + BD_i + 2L_t + 2.94tV_i + (L_s + SD_s + L_t)\frac{V_i}{V_s}$$

where:

L_{ps} = Length of passing siding (feet)

L_i = Length of inferior train (feet)

BD_i = Braking distance of the inferior train (feet)

L_t = Length of turnout (feet)

t = Time of operation of the switch machine (seconds)

V_i = Speed of inferior train (miles per hour)

L_s = Length of the superior train (feet)

SD_s = Sighting distance for the superior train (feet)

V_s = Speed of the superior train

Meet of Two Freight Trains

L_i = 4440 ft.

100 cars at 43 ft.
1-2 unit Deisel at 50 ft.
1- Caboose at 40 ft.

BD_i = 7500 ft.

L_t = 400 ft. (No. 20 turnout)

t = 15 seconds (estimated)

V_i = 35 miles per hour

L_s = 4440 ft.

SD_s = 1000 ft.

V_s = 45 miles per hour

[x] GRS Formulas

then:

$$L_{ps} = 4440 + 7500 + (2 \times 400) + (2.94 \times 15 \times 35) + (4440 + 1000 + 400)\frac{35}{45}$$

$$= 4440 + 7500 + 800 + 1550 + 4550$$

$\underline{L_{ps} = 18,840 \text{ ft.}}$

Meet of freight and passenger

$L_s = 700$ ft.

$V_s = 55$ m.p.h.

$$L_{ps} = 4440 + 7500 + 800 + 1550 + (700 + 1000 + 400)\frac{35}{55}$$

$\underline{L_{ps} = 15,640 \text{ ft.}}$

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NASHUA
THORNTONS FERRY
MERRIMACK
REEDS FERRY
GOFFS FALLS
MANCHESTER
Tower
MARTIN
HOOKSETT
BOW
CONCORD
YARD
1"=500'
1"=2000'
SYMBOLS
Color Light
Aspects
Type
R Y G Automatic
R Y G Semi. Auto.
R Y Non Auto.
R Fixed
Indicates Flashing Yellow
Track Symbols
Power Operated Switch
Spring Switch
Switch Lock
NOTE:
Only main line signals are shown through interlocking plants.
PLAN OF THE PROPOSED CTC INSTALLATION
and
SECOND MAIN TRACK RETIREMENT
on the
BOSTON and MAINE RAILROAD
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