A STUDY OF FREIGHT TRAIN OPERATION ON THE BOSTON AND MAINE RAILROAD WITH SPECIAL REFERENCE TO TONNAGE RATING AND UTILIZATION OF MOTIVE POWER

by

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May 28, 1931.

Professor A. L. Merrill,
Secretary of the Faculty,
Massachusetts Institute of Technology

Dear Sir:

In accordance with the requirements for the degree of Master of Science in Railroad Operation, I herewith submit a thesis entitled "A Study of Freight Train Operation on the Boston and Maine Railroad with Special Reference to Tonnage Rating and Utilization of Motive Power".

Respectfully submitted,

Signature redacted

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I N T R O D U C T I O N

INTRODUCTION

This thesis is divided into two main portions. The first is devoted to the question of tonnage ratings, the second to utilization of motive power.

The matter of tonnage rating has been considered quite fully, both in its general aspects, and as applied to the Boston and Maine Railroad. The various methods in common use are discussed in some detail, and the adjusted tonnage method has been treated very fully, with descriptions of various mathematical methods of establishing such ratings where no test data is available. A number of incidental factors which enter into the establishment of ratings have also been considered.

Time did not permit a full study of the second question, but a general survey was made of the factors entering into motive power utilization, with a few specific cases to indicate a method applicable to a thorough study. The impossibility of making a full study was due in large part to the form in which the records of the Boston and Maine Railroad touching on freight train performance are kept. A form has been made up which, if used, will permit a full study to be made at any time, either of individual trains, or of the situation as a whole.

The author takes pleasure in acknowledging the assistance given by the officials and employees of the Operating Department, the Bureau of Statistics, and the Engineering Department of the Boston and Maine Railroad for their helpful attitude in giving free access to any desired records, and for their suggestions on various points.

Use was also made of the mimeographed notes on tonnage ratings used in the fourth year course in Railroad Transportation at the Massachusetts Institute of Technology.

Definitions:

Car Rating:- The method of establishing the haulage capacity of locomotives by assigning to each class a definite number of cars regardless of the weight of the cars, the assignment varying with the ruling grade of the run. Now obsolete in freight service, though sometimes used in passenger service.

Flat Tonnage Rating:- The method of establishing the haulage capacity of locomotives by means of assigning to each class a definite number of gross tons, regardless of the average weight of the cars in the train, the assignment varying with the ruling grade of the run.

Adjusted Tonnage Rating:- The method of establishing the haulage capacity of locomotives by means of a fictitious weight of cars consisting of the actual gross tonnage of the car, plus an additional number of tons, which is a constant for all weights of cars for a given ruling grade.

Canadian Pacific Formula:- The method of establishing the haulage capacity of locomotives based on the assumption that the car with the lowest gross resistance is one in which the weight of the lading is twice the tare weight of the car. The rating is the actual tonnage of such cars, and if lighter cars occur, the actual gross tonnage is increased by a percentage of the difference between the tare weight and half of the weight of the lading.

Mean Resistance Ratio:- The method of establishing the haulage capacity of locomotives that is based on the resistance of an average weight car, lighter cars having their weight increased and heavier cars their weight decreased by a percentage that increases as the weight departs from the normal or average value. 40 tons is commonly taken as the average. This method requires a special computing machine.

Passenger Rating:- A rating given locomotives in passenger service, allowing for the high speed of the service.

Car Factor:- The amount by which the actual gross tonnage of a car is increased to find the adjusted tonnage of the car. A constant depending only on the ruling grade over which the train will pass.

Ruling Grade:- The grade in a rating district which limits the tonnage which a locomotive can haul. It may not be the steepest grade, if a sharp curve occurs on a slightly flatter grade, or if the steepest grade is short enough to be operated as a momentum grade, or so short that it is equivalent to a flatter grade (See "Equivalent Grade").

Equivalent Grade:- The hypothetical grade resulting from reducing a steep grade, shorter than the normal train length, to compensate for the fact that only part of the train is on the steep portion.

T O N N A G E   R A T I N G

TONNAGE RATING

The tonnage rating tables of the Boston and Maine Railroad, as published at the present time (employees' timetable #8, effective April 26, 1931), contain many errors, both basic and incidental, and on the whole are in a very poor condition.

Locomotive Classification

Included in the "General Special Instructions" in the back of the timetable are two tables headed "Tonnage Rating Classification of Locomotives" and "Tonnage Rating Classification of Switchers". These tables divide all of the motive power into 14 classes for the purpose of assigning tonnage ratings. These classes are designated by numbers. For example, the number 85 presumably indicates that the engines in this class have 85% of the tractive effort of those in class 100. The latter class is made up of consolidation type (2-8-0) engines, known as type K-8d on the Boston and Maine, which have a rated tractive effort of 40,500 pounds.

However, in many cases, there is a wide variation between the actual percentages of tractive effort and the classes in which the locomotives are placed. Table I indicates the actual situation as it exists at present. In some cases the actual variation is worse than the table indicates. For example, the B-15 and B-15a types with 62.5% tractive effort are placed in class 70 along with the P-1 and P-2 types, which have 78.0% tractive effort. However, the smaller engines are not superheated, and so should have their rating reduced rather than increased. The result is that, in order to have a rating that the smallest engine in the class can handle, the 70 class is assigned only about 66% of the K-8d rating, though this is really too high for the B-15's, while the P-1 and P-2 engines are given 20% less than their capacity.

TABLE I

Comparison of B. & M. Tonnage Rating Classification with the Actual Percentage of Rated Tractive Effort, Type K-8d considered as 100%

B. & M. Class	Percent T.E.	Engine Types
40	42.5	A-40c
45	45.0	A-41abcdef
60	53.1	C-15h
	53.8	J-1, J-1abcdef
	57.0	C-10
65	57.0	C-19bc
	59.8	C-21de
70	62.5	B-15, B-15abc
	78.0	P-1ab, P2-bcd
80	77.4	G-11a
85	79.5	G-11b
	82.5	K-5a, K-6b, K-7, K-7abc
100	100.0	K-8d
105	122.4*	P-3a
115	119.0	K-8bc
125	124.1	H-1a
	126.0	H-2a
140	140.0	H-3a(without booster)
175	176.0	S-1ab(without booster)
200	201.0	T-1ab
	205.0	S-1ab (with booster)
210	205.0	H-3a (with 2 boosters)

*This percentage is allowing 12,000 pounds tractive effort for the Booster.

The 40 and 45 classes are not shown in Timetable #8, the data being taken from Timetable #7.

See Appendix A for further details of these locomotives.

Of course the "P" type locomotives are used only in passenger service, and the rating tables would not really apply to this service. But that being the case, why show them at all? They certainly cannot handle the assigned rating in a passenger train, while if they should be used in freight service, if given only their rating they would not be fully utilized. A better method would be to assign freight ratings to all motive power, determine the percentage of the freight rating that a locomotive can satisfactorily handle in passenger service, and apply that percentage to all such locomotives. A still better method would be to develop a full set of passenger ratings and publish them in addition to the freight ratings.

Table I shows that, unless some classes of engines have rather basic design features not indicated in the leaflet "Locomotives and Tenders - Classification and Description", as published by the Mechanical Department of the Boston and Maine, some of them are badly underrated, and others as badly overrated, in the general assignment into tonnage classifications.

Passenger Ratings

Due to the higher speed required in passenger service, it is impossible for a locomotive in that service to handle freight ratings. An example illustrating this is given below.

Assume a district with a ruling grade of 1.09%, corresponding to that from East Deerfield to East Gardner, Massachusetts. Basing all computations of train resistance on the tables produced by Professor Schmidt as a result of his experiments under the auspices of the University of Illinois Experiment Station, and using the data for a P-2 locomotive, the following results are obtained:

Slow Freight	-	50-ton cars - 14 m.p.h.	. .	953 tons or 19 cars
Fast Freight	-	50-ton cars - 30 m.p.h.	. .	632 tons or 12 cars
Passenger	-	65-ton cars - 45 m.p.h.	. .	394 tons or 6 cars

A speed of 45 miles per hour was picked for the passenger train as that is the speed required of the eastbound "Minute Man" to maintain its schedule over the grade involved. That the assumptions of train resistance are on the safe side is demonstrated by the fact that this train, with six cars, is being handled by an engine of this type regularly. Furthermore, two of the six cars are pullmans and one is a dining car, so that the gross weight of the train is nearer 425 tons than 390.

The current rating for this type of engine is 775 tons, while 78% of the 100-class rating for the district is 987 tons, or slightly more than the engine can handle according to the above; and 80%, in which class the engine should nominally fall, is 1012 tons, or 6.1% in excess of the above theoretical figures, while the passenger train that it is actually handling is 9.0% in excess of the theoretical value.

In the above example, the "Passenger Percentage" would be 42. In other words, the engine in Passenger service should handle 42% of the slow freight rating. A more detailed exposition of this passenger percentage is given in Appendix K.

Tonnage Ratings

Turning to the tonnage rating tables published in the timetable, we find them to be in fully as chaotic a condition as the locomotive classification. The locomotives are at present divided into 14 classes, ranging from 40% to 210%. Of these the Fitchburg Division tables show only 6; the New Hampshire Division, 8; and the Portland Division, 5. The individual ratings for the various districts were originally intended to be definite percentages of the 100-class rating; e.g., the 115-class should be 115% of the 100-class, etc. (This will not be strictly true where the effect of train length on the "Effective Ruling Grade" is considered. This will be discussed more in detail below). However, as indicated previously, these class numbers do not correspond exactly to the percentage tractive effort of the various types of locomotives. This fact has been recognized in some cases, and not in others. In Table II are given the summarized results of a complete check-up on the percentages actually in use. The 100-class rating has been taken as 100%, and the ratio of all other classes for which ratings are published have been computed for all districts. In the table, the first line indicates the class. The second indicates the percentage that should be used for that class in order that the smallest engine of the class will not be overloaded. Then are given the mean of all the figures of the division, by divisions; the high extreme figures, the mean of the ten highest; the mean of the ten lowest; and the extreme lows. The 100-class is omitted, as it is the basis for the calculation of the others, and so would be 100 in all cases.

TABLE II

Comparison of Percentages of Ratings in Use with the Correct Percentages

Class	175	115	105	85	80	70	65	45
Correct Percentage	176	119	109	80	77	62	57	42
Mean Figures								
Fitchburg Div.	179	116	108	84	--	66	--	--
New Hampshire Div.	--	116	106	84	79	67	64	44
Portland Div.	--	116	108	85	--	69	--	--
Extreme High								
Fitchburg Div.	218	157	142	104	--	77	--	--
New Hampshire Div.	--	133	121	90	85	79	69	48
Portland Div.	--	160	147	91	--	77	--	--
Mean High								
Fitchburg Div.	186	127	116	89	--	74	--	--
New Hampshire Div.	--	122	111	87	82	72	66	46
Portland Div.	--	134	123	86	--	72	--	--
Mean Low								
Fitchburg Div.	162	114	104	74	--	59	--	--
New Hampshire Div.	--	114	105	79	68	58	52	37
Portland Div.	--	112	104	83	--	67	--	--
Extreme Low								
Fitchburg Div.	143	110	101	67	--	53	--	--
New Hampshire Div.	--	108	104	72	63	53	42	29
Portland Div.	--	110	101	80	--	63	--	--

Full details of these tables will be found in Appendix C.

The figure of 104% for the 85-class rating on the Fitchburg division is obviously an error, as no one would give the 85-class a higher rating than the 100-class over the same rating district. One other obvious typographic error was found.

It appears that in many cases the 115 and 105-classes have been raised to a value that experience has indicated the locomotives are capable of handling, without changing the other classes to correspond. This situation is not as serious as it might seem at first, in view of the fact that the classes below the 85 are not used in road freight service to any great extent, and in the few cases where they are used, they are on local freights which would rarely be called upon to handle a full tonnage train. The same is true to a lesser extent of the 85-class, and is somewhat true of the 100-class. In the case of the 105-class, only one locomotive of this class remains in service (neglecting the P-3a type, which is in passenger service only).

This leaves the 115, 175, and 200-classes as the important ones. It appears from the above tabulation that no ratings are given for the 200 class, and that ratings for the 175-class are given for the Fitchburg Division only. This is not strictly the case, as on the Fitchburg Division, the statement is made that 175-class engines with booster may be given 11% higher ratings than those without. On the basis of the averages given above, this would put the 200-class at 197% of the 100-class on this division. Also, adjusted tonnage ratings are given for both 175 and 200-class between Ayer and Mechanicville in both directions. On the New Hampshire Division, flat ratings are given for both 175 and 200-class from Boston to Concord, N.H., and adjusted tonnage ratings between Concord and Westboro in both directions. On the Portland Division, ratings for 175-class both with and without boosters are given between Portland and Boston, and between Portland and Worcester, in both directions, and for 140 and 125-class between Boston and Salem, and between Boston and Wilmington Jct., in both directions. These Portland Division ratings are on a flat basis, but a bulletin has been issued (dated September 30, 1929) giving the following additional Class "A" adjusted tonnage ratings:

From Ayer to Portland for 200 and 175 classes
From Portland to Lowell for 200 and 175 classes
Also, on the Fitchburg Division and New Hampshire Division
Between Greenfield and Berlin for 115 and 105 classes

Accordingly, some sort of a tonnage rating, either adjusted or flat, has been issued for the 200 and 175-class engines for all portions of the system over which they can operate except:

From Winchendon to Gardner
Concord N.H. to Boston
and in both directions
Between Hoosick Jct. and North Bennington
Wilmington and Wilmington Jct.
Boston and Swampscott
Worcester and Nashua (via Portland Division)

Most of these districts are of little importance from the standpoint of the operation of heavy power. Through Portland to Boston freights run via Wilmington Jct. and Wilmington, but the flat rating for other classes between those points is 75% higher than the straight Portland to Boston rating, so there is no need of considering that district in loading a locomotive. The other districts that are not covered are not used to any extent for heavy power except that from Concord N.H. to Boston. Here the rating is much higher than from White River Junction to Concord, but with the present helper service over the hard spots of the run, there might at times be a question as to the possible tonnage for a Santa Fe or Lima engine from Concord to Boston.

Looking at the other side of the picture, ratings are published for 115-class engines on many of the branches which are restricted to 70-class engines and even smaller. Ratings are published for the entire system for 105-class engines of which only one remains in freight service. Similarly, the New Hampshire Division rating table shows ratings throughout the division for 45-class engines, while the table of "Tonnage Rating Classification of Locomotives" which indicates the class to which types of engines are assigned, does not show any such class. (This refers to Timetable #8. Timetable #7 indicates that a total of 46 engines should have this assignment. They are all old engines, having been built between 1895 and 1911, are of the 4-4-0 type, and are used only in passenger service). As a matter of fact, Timetable #8, in the classification table, makes no provision for a total of 62 engines which are still in service, while it mentions specifically, by number, several engines which have been retired. It shows a 50-class, containing only two engines (both in passenger service) but no ratings are given for the class at any point. These two engines are older than those formerly in class 45, which has been omitted, though ratings are shown for the class on the New Hampshire Division, as mentioned above.

The only other serious difficulty remaining in the current tonnage rating tables is the fact that in a few places on the Fitchburg division two ratings are shown for 175 and 200-class engines - both adjusted and flat. It is an accepted fact that the adjusted tonnage rating is preferable to the flat rating. Accordingly, in the few cases where the former have been established, all temptation to make use of flat ratings should be removed by omitting them from the tables, indicating by means of an asterisk,or other sign, that adjusted ratings will be found for the district in question. The same situation obtains between Greenfield, Mass., and Berlin, N.H., on the old Connecticut River Division, 105 and 115-class engines being involved. The adjusted ratings, for this latter set do not appear in the Timetable, having been issued in bulletin form in September, 1929. It is very doubtful if they are being used at all at the present time. Appendix D contains all of the adjusted tonnage ratings that are shown in Timetable #8.

Effective Grade

Appendix J contains a full discussion of the effect of train length on the "Effective Ruling Grade". For present purposes it will suffice to say that if a steep grade is short (less than a train length), with appreciably flatter grades at each end, then the longer the train passing over the grade, the less effect the grade has on it. This is due solely to the fact that only part of the train is on the steep portion, the rest being on relatively flat grades; and has no reference to so-called momentum grades.

Thus we see that as the engine class increases, the effective ruling grade becomes less steep. Accordingly, there would be some tendency in the case of engines of class higher than 100 to show percentage ratings higher than their tractive effort would indicate, and conversely in the case of the lower class engines. This is only true if the ruling grade is less than 5000 feet long (assuming a 125 car limit) as the limiting case, the maximum length decreasing as the steepness increases.

This may account for some of the variations in the percentages shown in Appendix C. If the high classes have high percentages, or the low classes low percentages - within certain limits - it may be for this reason.

Adjusted Tonnage Rating

As stated above, it is an accepted fact that adjusted tonnage ratings are vastly preferable to the more common flat ratings. Consideration of the matter of train resistance will show why this is the case. If the Schmidt's tables of car resistance be considered accurate, (and they are as good as any available), the rolling resistance on straight level track of a 20-ton car (an empty) at 25 miles per hour is 9.3 pounds per ton, while that of a 70-ton car (a heavy load) at the same speed is only 4.1 pounds per ton. As a result of this, a locomotive with 21,900 pounds tractive effort available at the drawbar at 25 miles per hour on straight level track, (corresponding to a Boston and Maine type K-8d, or 100-class) would be able to handle the following trains, if composed of cars of the average weights given, on a division with an equivalent ruling grade of 0.5%, compensated for curvature:

20-ton cars - resistance 19.3# per ton* - 1040 tons, (52 cars)
40-ton cars - resistance 16.0# per ton* - 1255 tons, (31 cars)
70-ton cars - resistance 14.1# per ton* - 1425 tons, (20 cars)
(See Appendix B-1 for computations)

*Resistances include 10 pounds per ton grade resistance.

In other words, an engine under these conditions of grade and speed, can handle 37% greater tonnage of heavily loaded cars than it can of empties. This difference becomes greater as the ruling grade becomes less steep, and vice versa. The limiting case would be a division with a descending "ruling" grade of 0.205%, on which the engine could handle an infinite tonnage of heavily loaded cars (i.e., the train would roll down the hill, once it was started), while it could handle only 4210 tons of empties. This is, of course, an absurd case which would never occur in practice, but it serves to illustrate the situation.

If flat ratings are to be used, the question arises as to which tonnage is to be used, that for 20-ton cars, or for 70-ton cars, or some in-between figures, as that given for 40-ton cars, assuming that 40-tons is the average car weight occurring in the given direction on this district. If the last expedient is used, and it is probably the most practical, then if a train happens to be made up with an average car weight below 40 tons, the locomotive will be overloaded, and cannot make its time, while if the train is composed of heavy cars, the locomotive will not be fully utilized.

On the other hand, if an adjusted rating of 1665 tons, with a car factor of 12 is assigned, the locomotive will have full tonnage under all conditions of car weight. (The adjusted tonnage of a train is the actual tonnage, increased by the number of cars multiplied by the car factor). Thus the above three trains will have the following adjusted tonnages:

20-ton cars - 1040 + (12 x 52) = 1665 "Adjusted Tons"
40-ton cars - 1255 + (12 x 31) = 1638 "Adjusted Tons"
70-ton cars - 1425 + (12 x 20) = 1665 "Adjusted Tons"

It will be noted that in the case of the 40-ton cars, the figure is not exact, though one more car would exceed the rating. This is due to a combination of facts:-

1. The rate of variation of car resistance with weight is not exactly a straight line, while the adjusted tonnage rating method assumed that it is.

2. The car weight does not divide evenly into the rating, and it is necessary to take the smaller number - disregarding all fractions.

3. The car factor is commonly used as the nearest whole number, which causes some variation from the theory.

The error is much smaller than the flat tonnage method of rating produces, and the only method that would fully avoid this small error is too laborious for practical use. (This refers to the "Drawbar Pull Method", in which the rating is the available drawbar pull, and the actual resistance of each individual car is computed and the sum made to equal the available drawbar pull).

Form of Tables

Another matter deserving consideration is the question of the form of publication of ratings. As has been implied in the foregoing, at the present time, the Boston and Maine is putting their tonnage ratings in the Employees' Timetable, under the heading of General and Special Instructions. This has a number of disadvantages:

1. It increases by four pages an already bulky book. This is important from a standpoint of cost as well as of convenience to employees.

2. It removes the feasibility of changing the ratings between dates of publication of the timetable (normally published every six months, more or less).

3. It places the tables in the hands of all employees, which is unnecessary, and in some cases actually undesirable. Yard clerks, and the conductors of local freights are the only men (other than officials and junior officials) who have any occasion to use the tables in general. While it is not really objectionable, it is undesirable to place ratings in engineers hands, as they will make use of them as an excuse for slow running time or other trouble.

4. It makes the use of the tables inconvenient as it is necessary to turn through several pages in the back of the timetable to find the desired set of ratings.

Accordingly, it is desirable that they should be published in a separate booklet. Some railroads publish them in the form of blueprints, furnishing each employee only those sheets which he will have occasion to use. This probably is the cheapest form, having only the disadvantage of poor legibility in bad light, such as is commonly found in yard office and cabooses at night.

The Canadian Pacific publishes its tables in a small booklet, about the size and shape of the various Air Brake Instruction and similar booklets. This has the advantage of convenience in handling, but necessitates small type, and considerable abbreviation. They use the general form of a timetable, listing the important stations along a route, and showing ratings between each pair of stations, rather than giving one limiting rating for each district with the statement that additional tonnage will be handled between certain stations, without specifying what this additional tonnage is. This method is very good, but requires more work in the original preparation of the tables.

Probably the most convenient form for use would be in a loose leaf book about 8" by 10", listing after the manner of the Canadian Pacific as cited above, giving only the large stations. For example, the Fitchburg Division Main Line would appear as follows:

TABLE III

Adjusted Tonnage Ratings for Single Locomotives

Between	Car Factor	Class of Engines 200	175	115	100
Main Line, Eastbound					
Rotterdam					
	12	7750	6750	4700	3950
Mechanicville					
	8	5450	4750	3200	2700
Johnsonville					
	7	4250	3780	2550	2150
North Adams					
	6	3850	3400	2300	1950
East Deerfield					
	5	2710	2410	1610	1350
East Gardner					
	12	7750	6750	4700	3950
Fitchburg					
	9	5100	5400	3600	3050
Ayer					
	7	4450	3900	2650	2200
Boston					

The above are the "A"ratings. Weather allowances would be shown as percentages of the "A" rating.

The above ratings must not be considered as the correct ones, they were picked as being approximately correct, for purposes of illustration only. It would be desirable, in case this method were followed, to show the limiting rating for an engine district in bold face type, so that it could be picked out quickly.

Provision for Unknown Factors

The only remaining matter for consideration is the question of the percentage of the theoretical rating that it is safe to assign to an engine. The whole question of train resistance is empirical, and subject to considerable error. If an engine be assigned the full rating that the theory indicates it should be able to handle, there would be no reserve to take care of the unknown factors, among the most important of which is the engine crew. Given a full tonnage train, one crew might be able to make the time easily, while another might not even be able to get the train over the road without help. Other factors include exceptionally hard pulling cars, an unexpected heavy head wind, an unforseen rain storm, a tender full of slack coal, and any of the dozen things that pull a locomotive's effectiveness slightly below 100%. While the car resistance figures are supposed to be high enough to allow for this, it may be found that a full theoretical rating is a little too high for good operation.

One simple and practical way of overcoming this is to compute the ratings for a speed of 15 miles per hour, assuming that it is intended that the ruling grade shall be passed at 10 miles per hour. This throws in a small factor of safety that will probably be ample for all normal conditions.

Resume of Appendices

Appendix A contains the data for computation of percentage tractive effort of the various types of locomotives in use on the Boston and Maine Railroad.

Appendix B contains the computations for the tonnage that a P-1 or P-2 engine can handle up a 1.09% grade at various speeds, and with freight and passenger cars.

Appendix B-1 contains the computations for the tonnage that a K-8d locomotive can handle up a 0.5% grade, with the train composed of cars of various weights, at a speed of 25 miles per hour.

Appendix C contains the present tonnage ratings in use on the Boston and Maine Railroad, expressed as percentages of the 100-class ratings, and illustrates the divergence from the correct percentage that exists in many instances.

Appendix D contains a statement of the adjusted tonnage ratings now effective on the Boston and Maine Railroad.

Appendix E contains a statement of a quick, though approximate, method of transferring the present flat ratings to adjusted tonnage ratings.

Appendix F contains a brief resume of the methods of tonnage rating now in use on six of the larger railroads in the Eastern part of the United States and Canada.

Appendix G contains a detailed discussion of adjusted tonnage rating.

Appendix H contains a mathematical comparison of the methods of tonnage rating outlined in Appendix F.

Appendix I contains an outline of two methods of establishing adjusted tonnage ratings graphically.

Appendix J contains a discussion of the effect of train length on the ruling grade.

Appendix K contains a discussion of passenger ratings.

Recommendations

In consideration of the foregoing, the following changes are recommended in the present tonnage rating tables:-

1. Reclassify all locomotives in accordance with the following table:-

TABLE IV

Recommended Locomotive Ratings

Based on Percentage of Rated Tractive Effort of K-8d Class.

Rating	Percent of K-8d T.E.	Present Rating	Class	No. of Eng.	Date Built
45	42.5	40	A-40c	6	1899
	45.0	45	A-41abcdef	47	1911
55	53.1	60	C-15h	1	1900
	53.8	60	J-1,J-1abcedf	34	1909
60	57.0	60	G-10	78	1910
	57.0	65	C-19bc	2	1898
	59.8	65	C-21de	24	1906
65	62.5	70	B-15,B-15abc	123	1910
80	78.0	70	P-1ab,P-2bcd	82	1916
	77.4	80	G-11a	30	1913
	79.5	85	G-11b	23	1916
85	82.5	85	K-5a,K-6b,K-7,K-7abc	63	1911
100	100.0	100	K-8d	40	1911
120	119.0	115	K-8bc	95	1916
	122.4	105	P-3a	10	1923
125	124.1	125	H-1a	2	1916
	126.0	125	H-2a	22	1922
140	140.0	140	H-3a(without boosters)	10	1928
175	176.0	175	S-1ab(without booster)	15	1920
200	201.0	200	T-1ab	25	1929
210	205.0	210	H-3a(with 2 boosters)	2	1928
	208.0	200	S-1ab(with booster)	15	1920

The above classification is based solely on rated tractive effort. The K-8bc rating is for the 200# boiler pressure, there being only one of this class left with 180#

pressure. The dates, above, are the year in which the newest engine of the class involved was constructed. The following are the changes in classification involved:

Reduced	5	C-15h, J-1, J-labcedf, C-19bc, C-21de, B-15, B-15abc, G-11b.
Increased	5	A-40c, K-8bc,
Increased	10	P-lab, P-2bcd, S-lab (with booster)
Increased	15	P-3a

It will be noted that the only locomotives reduced in rating are the older types, with the exception of the G-11b, all being over twenty years old. In practically all cases, these engines are used in light passenger and local freight service, in which service they are rarely loaded to their rating, and so the actual rating given is of little moment.

2. Establish adjusted tonnage ratings for the entire system as soon as practicable. These may be based on the present flat ratings until some better data regarding locomotive capacities can be assembled. A method for doing this without too much labor is given in Appendix E.

3. In case it is felt that recommendation No. 2 cannot be carried out at the present time, revise the present flat rating tables to make them consistent and complete. This can be done in a very few hours by assuming the present 115-class ratings to be correct (it should be known if there are any districts where they are seriously in error), considering them as 119% and computing the other classes on the basis of the following table:

TABLE V.

Class	Percent
45	42
55	53
60	57
65	62
80	77
85	82
100	100
105	109
120	119
125	124
140	140
175	176
200	201
210	205

The above is assuming that the reclassification embodies in recommendation 1 is adopted. If the present classification is maintained, the following would be the correct percentages to use.

TABLE Va

Class	Percent
40	42
45	45
60	53
65	57
70	65
80	77
85	80
100	100
105	109
115	119
125	124
140	140
175	176
200	201
210	205

Care should be taken that no ratings are published for districts from which the corresponding locomotives are excluded by reason of their weight. For example, a 115-class rating should not be published for a district in which the heaviest engine permitted is 70-class.

4. Publish the tonnage rating in a book separate from the timetable.

5. Develop and apply a definite system of passenger ratings. These should be published in the same book as the freight ratings. They may be either an entirely separate set of ratings, or may be based on the freight ratings.

U T I L I Z A T I O N O F M O T I V E P O W E R

UTILIZATION OF MOTIVE POWER

A study of freight train operation during the month of November, 1930, was made, with a view to developing some feasible method of keeping track of the performance of individual trains, from the standpoint of locomotive utilization.

To cover the question of locomotive utilization, it was necessary to include helper service, and tonnage and cars handled, as well as the general view of the movement of power. Inquiry developed the fact that no regular record was kept of performance which segregated the reports by trains. Accordingly, it was necessary to make use of the daily "Freight Train Performance Report", giving the tonnage and cars handled, and the arrival and departure times at terminals and a few intermediate points, as well as a detail of all delays. In addition, in order to determine the extent to which helpers were used, it was necessary to make use of the daily "Freight Roster", which lists the numbers of all engines used for each train, giving the points between which each engine was used (in addition to other information with regard to crews, etc., which was not used in this study).

A form was prepared, on which the information for each train could be entered as it was drawn off from the above mentioned daily reports. In the final tabulation of the information, it was deemed desirable to prepare sheets covering each section of the longer runs, breaking the run up into parts terminating at the important yards along the route, in order to secure greater ease in the analysis of the results. For example, train PM-1, running from Rigby, Maine, to Mechanicville, New York, via South Lawrence, Lowell, Ayer, and East Deerfield, was broken into three sections, extending respectively from Rigby to Ayer; from Ayer to East Deerfield; and from East Deerfield to Mechanicville. According to the Freight Symbol Book effective at the time, this train was supposed to reduce or fill out its tonnage at Ayer and East Deerfield, so that it could really be considered as three trains, from the viewpoint of locomotive utilization.

In view of the limited information given on the daily reports, it was necessary to assume that the cars and tonnage taken from Rigby were carried all the way to Ayer, that from Ayer was carried all the way to East Deerfield, and that the cars and tonnage taken into Mechanicville were handled all the way from East Deerfield to Mechanicville. This is probably not strictly accurate, and is even less accurate in parallel cases with other trains, but it is the best that could be done unless the Conductor's "Wheel Reports" were examined, and time would not permit of this being done.

Various Kinds of Percentage Utilization

In considering the matter of percentage utilization of motive power, there are several methods that may be used.

The first of these would be to compare the total gross ton miles which the locomotive produces with the gross ton miles which it would have produced had it had full tonnage throughout its run. This general method can be further subdivided into two methods, depending on whether the potention gross ton miles are computed considering each rating district of the run separately, or considering the limiting rating as applying to the entire run. The other general method is to compare the tonnage of the train with the rated tonnage. This second method is also susceptible to subdivision into the same two method as is the first. Considering the two sub-methods, it will be seen that from a practical standpoint, the second (considering the limiting rating as applying to the whole run) is the only feasible one. It is not practical to place a yard at the end of each rating district, so as to reduce or fill out the tonnage to fit the rating for the district.

If all cars are hauled the whole distance, the two general methods would produce the same result, as the gross ton miles produced would equal the gross tonnage at any point multiplied by the length of the run, but if cars are picked up or dropped during the run, then the first method will produce a lower ratio of actual to potential than will the second.

It is also preferable to use the second general method (considering tonnage rather than ton-miles). In many cases, a train is scheduled to pick up tonnage at one or more points along its run. This results in its being lightly loaded out of its initial terminal, to allow for the tonnage to be picked up. If the pick-up point is some distance away from the initial terminal, the resultant ton-milage will be very low for the run, while traffic conditions require the work to be handled in this way. Accordingly, it seems preferable to consider the actual gross tonnage handled when the train is most nearly loaded to tonnage, and to compare this with the rating.

The remaining point that has to be decided is the question of helper service. Very commonly a train will have a helper during a relatively small portion of its run. The rating for this portion of the run becomes the sum of the ratings of the two locomotives. If the tonnage is 75% of this combined rating, shall each engine be considered as handling 75% of its tonnage, or shall the principal engine be considered as handling full tonnage, and the helper as handling the excess over the single locomotive rating? If the division Utilization is being determined, or the figure for the train, it makes no difference which system is used. But if it happens that a check up of an individual locomotive is being made, it would make considerable difference. Such a check-up might be made in order to find out whether or not it is practicable to put a big engine into storage, replacing it with a smaller one. The second method appears to be the preferable one, particularly if the principal engine has nearly full tonnage through the remainder of the run.

As the records of train performance are kept at present, it would be a very difficult job to make any sort of a check of the performance of an individual train over a period of more than a few days. It is necessary to check over the Daily Performance reports, and Rosters, and draw off the data desired. The former reports are on large sheets, and are difficult to work with if a number of them have to be gone through at one time. While the Rosters are on small sheets, there are many of them for each day, and each train may appear in three or four different places on a given day.

If a form made up like the one shown in Appendix L is used, and the information entered on it every day, as the reports are issued, when it is desired to check up any individual train, the information for any period can be obtained in a few minutes. It would require the time of one man for about two to three hours a day to draw off all of the symbol trains, and keep the records up to date. When such information is desired by the management, it is usually desired promptly, and a delay of a day or two in assembling the data may result in considerable expense through failing to rearrange schedules to fit the traffic promptly.

Furthermore, the man handling this work could make a report daily or weekly, indicating that certain trains are not handling full tonnage regularly. If it is found in these reports that two or more trains over similar runs are running light for a period, it may be a fairly simple matter to make a few slight changes in schedules, combining the two trains for portions of their runs, with a resultant saving in operating expense that may run into quite large figures.

Appendix M gives the tabulation of the performance of train PM-1 for November as being typical of those studied. The following table gives a summary of the results of several trains for which the data was drawn off and fully worked up.

TABLE VI

Summary of Train Operation Data, Showing Tonnage Handled

November, 1930

Train	From	To	Tons Handled	Potential Tons	Percent Handled
MC-2	M	E	125,209	128,300	97.59
CM-1	A	E	66,967	76,553	87.48
	E	M	71,271	72,103	98.85
RL-2	R	M	*137,343	*152,892	89.83
	M	E	113,578	128,030	88.71
	E	A	100,530	119,551	84.09
	A	L	* 59,367	*124,700	47.61
BM-1	B	E	69,173	81,490	84.89
	E	M	67,813	86,261	78.61
MB-2	M	E	95,510	103,530	92.25
	E	B	84,066	106,338	79.06
PB-8	P	B	*105,962	*121,100	87.50
PM-1	P	A	116,998	142,130	82.32
	A	E	99,659	114,437	87.08
	E	M	81,272	109,323	74.34

* These tonnages are flat. All others are adjusted.

The following symbols are used for stations:

- A - Ayer
- B - Boston
- E - East Deerfield
- L - Lawrence
- M - Mechanicville
- P - Rigby
- R - Rotterdam Jct.

Examination of the above will show that in most cases, the percentage utilization is good (in two cases, extraordinarily high), but that in four cases it falls below 80%.

With reference to the 98.85% figure developed by CM-1 between East Deerfield and Mechanicville, and the 97.59% of MC-2 on the reverse run, it should be noted that a series of fuel tests were being run on these trains at the time, and a particular effort was made to maintain the tonnage at a constant, high figure. These figures demonstrate what can be done, but it is probably not practicable to achieve them in the course of regular operation.

It is true, that before any operation can be condemned on the above figures, it is necessary to extend the study to find out the basic cause of the low figure. In two cases it appears in a Westbound movement. On the Boston and Maine, the predominant traffic movement is Eastbound, and it is necessary to run Westbound trains comparatively light in order to get the engines to the West end of the line for movement East. A similar situation probably applies in the case of RL-2 from Ayer to Lawrence. The engine from RL-2 normally takes LR-1 from Lawrence the following day. This train appears to run very light, having averaged only 1440 actual tons during November, 1930. The heaviest day was 2350 tons (within the 115-class rating) while RL-2 had only five days when it could not have been handled by a 115-class engine. Accordingly, it might be advisable to investigate the possibility of changing from a heavy engine to a Consolidation for the portion of the run from Ayer to Lawrence. Both trains stop at Ayer for some time, and the change could be made.

With the performance records as they are maintained on the Boston and Maine at present, a complete study of the situation would require entirely too much time to admit of its being done for this thesis, and any conclusions drawn without a complete study would be valueless. However, if complete records were kept as indicated in Appendices L and M, for a month or two, it would be possible with very little work to pick out the trains that are turning in a poor tonnage record, and by considering the whole list of such trains, it is very possible that combinations will show up where, by minor adjustments of schedules, it will be possible to change an engine from one train to another, using a smaller engine for the remaining portions of the two runs.

Points that must be kept in mind in such a study are:

1. The direction of heavy traffic. On the Boston and Maine, it is in general towards Boston, and trains running away from Boston must frequently be run fairly light.

2. Helper service, and light engine milage. It is frequently possible to cut light engine miles by using an engine as a helper that would have had to run through light anyway. This saves both the return milage of the helper if it is used on a short portion of the run, and also the light miles of the engine used. It is still an open question as to whether it is more economical to operate an engine light, or to put it on as a helper where no helper is needed. The second method saves the wages of a flagman, but it is a question as to the relative fuel consumption of (a) two engines on a light train versus (b) one of the engines on the train and the other run through light.

3. Inaccuracy of Freight Schedules. Even though trains are scheduled very carefully, one can never be sure that they will maintain their schedules. Accordingly, if one is counting on taking the engine from one train to use on another, care should be taken that there is sufficient leeway to admit of the first train being an hour or two late, and still leave time to properly hostle the engine, without delaying the second train.

4. Necessity of a certain amount of dead time for locomotives. An engine cannot be in service twenty-four hours a day. A matter of six hours or so should be allowed each day at some point for running repairs. It may be found that this time can be cut safely.

5. Necessity of reserve power. At many points it is necessary to maintain a certain amount of power ready to leave on one or two hours notice, to handle extra trains, to go out as a relief engine in case of an engine failure, to replace power in for a wash-out, to act as helpers, etc. This makes it impractical to definitely schedule all power for definite trains.

A P P E N D I C E S

APPENDIX A

Present Tonnage Rating Classification

The following table lists all of the types of locomotives in use at present on the Boston and Maine Railroad, grouping them by rated tractive efforts, and indicates the percentage of tractive effort of each type, considering the K-8d as 100%. The last column gives the class in which the locomotives are now placed.

Type	Loco. Numbers (inclusive)	Whyte Class	Rated T.E.	Percent of K-8d	B.& M. Class
A-40c	932 - 943	4-4-0	17200	42.5	40°
A-41abcdef	954 - 1029	4-4-0	18200	45.0	45°
B-15, B-15abc	1360 - 1499	2-6-0	25300	62.5	70
C-15h	2050	4-6-0	21500	53.1	60
C-19bc	2074 - 2075	4-6-0	23100	57.0	65
C-21de	2100 - 2126	4-6-0	24200	59.8	65
F-6	65	0-4-0	12400	30.6	--
F-10	64	0-4-0	16650	41.1	--
G-10	200 - 309	0-6-0	23100	57.0	60
G-11a	400 - 429	0-6-0	31300	77.4	80
G-11b	430 - 452	0-6-0	32200	79.5	85
H-1a	600 - 601	0-8-0	50300	124.1	125
H-2a	610 - 631	0-8-0	51000	126.0	125
H-3a (1)	640 - 647	0-8-0	56800	140.0	140
H-3a (3)	648 - 649	0-8-0	83000	205.0	210
H-3b	650 - 654	0-8-0	56800	140.0	140
J-1, J-1abcdef	3205 - 3244	4-4-2	21800	53.8	60
K-5a	2329	2-8-0	33400	82.5	85
K-6b	2352 - 2359	2-8-0	33400	82.5	85
K-7, K-7abc	2360 - 2429	2-8-0	33400	82.5	85
K-8bc	2640 - 2734	2-8-0	48200	119.0	115
K-8d	2600 - 2639	2-8-0	40500	100.0	100.0
P-1ab	3600 - 3611	4-6-2	31600	78.0	70
P-2bcd	3611 - 3689	4-6-2	31600	78.0	70
P-3a	3700 - 3709	4-6-2	49600*	122.4	105
S-1ab (1)	3000 - 3029	2-10-2	71300	176.0	175
S-1ab (2)	3000 - 3029	2-8-4	84400	208.0	200
T-1ab	4000 - 4024	2-8-4	81400	201.0	200

° Rating not published in Timetable #8.
-- Rating not published in Timetable #7 or #8.

* Allowing 12000# T.E. for booster.
(1) Without booster
(2) With 1 booster (on tender truck).
(3) With 2 boosters (on tender trucks).

There are two classes, 35 and 50, containing a total of three engines, the 905, the 1144, and the 1165, types A-39b, A-47e, and A-45, respectively, which have not been considered in the above table. Class 35 is shown in Timetable #7, but not in #8. Class 50 is shown in both.

APPENDIX B

Tonnage Computations

1. **Capacity of P-1 and P-2 Locomotives, East Deerfield to East Gardner, at Various Speeds.**

Grade 1.09%.

Locomotive data:

Cylinders	22" x 28"
Drivers	73"
Boiler Pressure	200#
Rated Tractive Effort	31,600#
Weight on Drivers	155,400#
Total Weight of Engine	248,000#
Weight of Tender (Loaded)	148,100#

Speed for 250 ft./min. Piston Speed 14.8 m.p.h.

14 m.p.h.:

Mechanical resistance, locomotive, 27# per ton

27 x 155,400 ÷ 2000 = 2098#

Level track resistance, engine truck and tender
(freight figure for 70 ton) 3.4 x 240,700 ÷ 2000= 4409#

Grade resistance, total engine and tender
1.09 x 20 x 396,100
÷ 2000 =4317#

Total engine resistance 6824#

Net available for pull behind tender 31,600 - 6824 =24776#

Car resistance straight level track,50-ton cars	4.2
Grade resistance, 1.09 x 20	21.8
Total unit car resistance	26.0

Tons Engine can handle, 24,776 ÷ 26.0 = 953 tons = 19 cars

30 m.p.h.

Locomotive resistance, as above,
2098 + 4317 + 4.5 x 120.35 — 6956#
Piston speed = 3 x 168.8 = 506 ft./min.;
Factor = .767
Gross tractive effort = 31600 x 0.767 — 24200#

Net available for pull behind tender . . . . . 17244#

Car resistance, 5.5 + 21.8 = ... 27.3#

Tons engine can handle, 17244 ÷ 27.3 = <u>632 tons</u>

= <u>12 cars</u>

45 m.p.h.

Locomotive resistance, as above . . . . 7149#
Gross tractive effort, as above . . . . 17917#

Net available for pull behind tender . . . . . 10768#

Passenger car resistance . . . . 27.3#

Tons engine can handle, 10768 ÷ 27.3 = <u>394 tons</u>

= <u>6 cars</u>

2. <u>Capacity of K-8d Locomotive, with Trains Composed of Cars of Various Weights</u>.

Grade 0.5% Compensated.

Locomotive Data:

Cylinders	20" x 30"
Drivers	61"
Rated Tractive Effort	40,500#
Weight on Drivers	186,100#
Total Weight of Engine	210,000#
Weight of Tender, (loaded)	153,000#

Piston speed at 10 m.p.h. . . . . 275.5 ft./min.
25 m.p.h. . . . . 688.8 ft./min.
Speed factor (A.L.Co. Tables) 612

Tractive effort at 25 m.p.h. . . . . 24,800#

Mechanical resistance (27 x 186,100 ÷ 2000)	2510#
Lead truck and tender straight lever track resistance 177,500 x 4.1 ÷ 2000	360#
Grade resistance (20 x 0.5 x 363,600 ÷ 2000)	1820#
Total engine and tender resistance	4690#

Available at drawbar - (24,800 - 4700). Consider as 4700# 20100

20-ton cars - 20,100 ÷ (9.3 + 10)	- 1040 tons	52 cars
40-ton cars - 20,100 ÷ (6.0 + 10)	- 1255 tons	31 cars
70-ton cars - 20,100 ÷ (4.1 + 10)	- 1424 tons	20 cars

For Adjusted Tonnage Rating on above:

$$1040 + 52x = 1425 = 20x$$
$$32x = 385$$
$$x = 12$$

$$12 \times 52 + 1040 = 1665$$
$$12 \times 31 + 1225 = 1638$$
$$12 \times 20 + 1425 = 1665$$

Adjusted Tonnage Rating is 1665 tons, Car Factor, 12.

APPENDIX C

Present Tonnage Ratings as Percentages of the 100-Class Rating

In the following tables, all of the flat tonnage ratings, as published in Timetable #8, are reduced to percentages of the 100-class rating for the corresponding district. For example, in the first case, the Boston to Ayer Ratings are as follows:

175 class	2750 tons	2750 ÷ 1700 = 162%
115 class	2020 tons	2020 ÷ 1700 = 119%
105 class	1835 tons	1835 ÷ 1700 = 109%
100 class	1700 tons	100%
85 class	1400 tons	1400 ÷ 1700 = 82%
70 class	1050 tons	1050 ÷ 1700 = 62%

The 100 class is not shown in any of the tables, as it is the basis for computation, and so would be 100 in all cases.

At the end of each table is given the range in percentage for each class for the division. The lines marked "Normal High Figure" and "Normal Low Figure" are the mean of the ten highest and the ten lowest figures, respectively. The mean for the division is the arithmetical average of all the figures.

On the last page of the appendix is given the mean and extremes for the system.

Fitchburg Division Tonnage Ratings

Rating Class	175	115	105	85	70
Boston to Ayer	162	119	109	82	62
Ayer to Fitchburg	163	119	108	72	62
Fitchburg to East Deerfield . .	178	120	109	78	61
*East Deerfield to Athol	179	119	108	73	61
*Athol to Fitchburg	178	119	109	67	61
Fitchburg to Ayer	147	118	108	82	62
Ayer to Boston	175	141	128	83	68
Fitchburg to Bellows Falls . . .	-	112	101	72	56
Bellows Falls to Fitchburg . . .	-	112	101	72	56
South Acton to Hudson	-	115	104	81	66
Hudson to Marlboro	-	117	107	78	67
Marlboro to South Acton	-	113	103	82	66
Ayer to Milford	-	115	105	81	74
Milford to Ayer	-	117	106	81	76
Ayer to Greenville	-	117	106	81	66
Greenville to Ayer	-	117	106	81	66
Worcester to Winchendon	.218	157	142	85	68
Winchendon to Gardner	-	116	106	85	68
Gardner to Worcester	.143	113	103	85	68
*East Deerfield to North Adams .	177	119	108	71	62
*North Adams to Mechanicville .	177	118	108	82	61
McVille to Rotterdam	189	119	108	82	66
Rotterdam to McVille	176	121	110	82	64
*McVille to North Adams	157	122	111	86	69
North Adams to East Deerfield	170	127	115	85	53
Troy to Johnsonville	150	123	112	91	69
Johnsonville to Troy	-	118	108	83	67
Hoosick Jct. to White Creek .	-	119	108	86	72
White Creek to Hoosick Jct. .	-	118	107	89	71
McVille to Saratoga Springs .	-	115	104	82	66
Saratoga Springs to McVille .	-	118	108	82	60
Schuyler Jct. to Schuylerville	-	118	108	82	61
Schuylerville to Schuyler Jct.	-	118	108	82	61
Springfield to White River Jct.	188	116	106	79	76
White River Jct. to Greenfield	194	117	107	76	67
Greenfield to Springfield . .	185	110	110	90	58
East Northfield to Keene . .	-	-	108	104	69
Keene to East Northfield . .	-	-	106	81	75
Boston to Oakdale	-	115	105	85	75
Oakdale to Northampton . . .	-	116	106	85	73
Northampton to Oakdale . . .	-	115	105	85	73
Oakdale to Boston	-	117	105	85	77
Mean for Division	179	116	108	84	66
Upper Extreme	218	157	142	104	77
Normal High Figure	186	127	116	89	74
Normal Low Figure	162	114	104	74	59
Lower Extreme	143	110	101	67	53

* Provided for in 175 class and 200 class in Adjusted Tonnage Ratings

Present New Hampshire Division Ratings

On a basis of percentage of 100-class ratings.

	115	105	85	80	70	65	45
Boston to Nashua	133	121	85	80	68	65	45
Nashua to Concord	118	108	80	-	-	-	-
Concord to Franklin	114	105	85	80	68	65	45
Franklin to Canaan	117	107	85	80	68	65	45
Canaan to Westboro	115	105	85	80	69	65	45
Westboro to Canaan	118	109	76	71	62	58	40
Canaan to Concord	114	105	85	80	68	65	45
Concord to Boston	114	105	85	80	68	65	45
Concord to Lakeport	118	108	85	80	69	65	45
Lakeport to Plymouth	116	107	81	75	64	60	42
Plymouth to Woodsville	116	106	81	74	62	59	41
Woodsville to Plymouth	116	105	81	76	62	59	43
Plymouth to Lakeport	118	109	84	69	59	55	39
Lakeport to Concord	116	105	72	63	53	51	35
Plymouth to North Woodstock	115	104	81	-	62	45	45
Woodsville to Whitefield Jct.	118	109	84	64	55	52	35
Whitefield Jct. to Jefferson	115	105	74	69	56	54	39
Jefferson to Bowman	121	105	85	72	61	59	41
Bowman to Berlin Mills	115	105	85	81	69	65	45
Berlin Mills to Bowman	115	104	85	64	61	57	36
Bowman to Whitefield Jct. . .	116	105	85	79	69	66	45
Whitefield Jct. to Lancaster	115	105	85	80	69	65	45
Lancaster to Groveton	115	105	86	80	69	65	45
Groveton to Lancaster	116	105	85	80	69	65	45
Lancaster to Whitefield Jct.	116	105	85	80	69	65	45
Whitefield to Woodsville . . .	119	108	88	83	79	42	29
Wing Road to Fabyan	116	105	85	81	69	65	45
Woods. So. Yd. to White.Mt.	115	105	85	80	68	65	45
White River Jct. to Wells Riv.	116	105	88	64	56	52	36
Wells River to White Riv.Jct.	123	109	79	64	57	51	35
Bow Jct. to Hooksett	108	105	85	80	68	65	45
Hooksett to Bow Jct.	116	105	85	80	69	65	45
Lowell to Bedford	115	105	84	79	69	65	45
Bedford to Boston	116	106	85	80	68	65	45
Boston to Bedford	116	106	85	80	68	65	45
Bedford to Lowell	115	105	85	79	69	65	45
Bedford to Concord, Mass. . .	126	114	90	85	74	69	48
Concord,Mass. to Bedford . .	115	105	85	79	70	65	45
Winchester to Wilm.(Wob.Loop)	117	105	85	80	68	65	45
Wilmington to Win.(Wob.Loop)	115	105	85	80	68	65	45
Wilmington to Wilm.Jct. . . .	114	110	89	84	73	68	47
Wilmington Jct. to Wilmington	116	105	85	80	70	65	45
Montvale to Stoneham	117	105	85	79	68	65	46
Concord to Bradford	117	105	85	80	69	64	46
Bradford to Edgemont	116	105	85	80	70	64	45
Edgemont to Claremont Jct. .	115	105	85	80	68	65	45
Claremont Jct. to Newport	113	105	85	80	68	65	45

New Hampshire Division (Continued)

	115	105	85	80	70	65	45
Newport to Edgemont	115	105	84	80	68	66	44
Edgemont to Concord	115	105	85	80	68	65	45
Franklin Jct. to Tilton	115	105	84	80	67	64	46
Tilton to Franklin Jct.	115	105	85	80	68	65	45
Franklin to Bristol	115	105	84	80	70	65	45
Bristol to Franklin	115	105	85	80	70	64	45
Nashua to Wilton	116	105	85	80	68	65	45
Wilton to Elmwood	115	105	85	79	68	65	46
Elmwood to Keene	115	105	85	80	68	64	45
Keene to Elmwood	116	105	87	80	69	66	46
Elmwood to Greenfield	115	105	84	80	68	66	44
Greenfield to Nashua	115	105	85	80	69	64	45
Winchendon to Peterboro	120	107	85	80	68	65	46
Peterboro to Winchendon	119	108	84	80	68	66	44
Contoocook to Elmwood	116	105	85	80	70	65	45
Elmwood to Peterboro	116	105	85	80	69	64	45
Peterboro to Elmwood	116	105	85	80	69	64	45
Elmwood to Contoocook	116	105	85	81	69	65	45
Manchester to East Weare	115	105	85	80	69	65	45
East Weare to Henniker Jct. . .	116	105	85	80	68	65	45
Henniker Jct. to Manchester. . .	115	105	85	80	68	65	45
Parker to New Boston	115	104	84	80	68	65	45
Mean for Division	116	106	84	79	67	64	44
Upper Extreme	133	121	90	85	79	69	48
Normal High Figure	122	111	87	82	72	66	46
Normal Low Figure	114	105	79	68	58	52	37
Lower Extreme	108	104	72	63	53	42	29

Present Portland Division Ratings

On a basis of Percentage of 100-class ratings.

	115	105	85	70
Boston to Portland	120	110	80	63
Portland to Boston	120	110	80	63
Worcester to Ayer	132	121	85	70
Boston to Portland, (Est.)	127	115	85	70
Portland to Boston, (Est.)	127	115	85	70
Ayer to Nashua	121	111	85	70
Nashua to Ayer	121	111	91	66
Ayer to Clinton	122	112	85	69
Clinton to Worcester	128	118	78	67
Nashua to Alfred	113	104	84	70
Alfred to P.T.Limit	114	105	85	68
P.T.Limit to Alfred	114	105	84	69
Alfred to Rochester	115	105	85	69
Rochester to Nashua	115	105	85	72
Dover to Farmington	115	105	85	70
Farmington to Lakeport	115	105	85	70
Lakeport to Dover	115	105	85	70
Lawrence to Windham	114	104	85	77
Windham to Manchester	114	105	85	68
Manchester to Windham	114	105	85	68
Windham to Lawrence	114	105	85	69
Manchester to Candia	114	105	84	68
Candia to Portsmouth	115	105	85	68
Portsmouth to Raymond	112	103	84	67
Raymond to Candia	115	105	85	70
Candia to Manchester	115	105	85	68
Wilmington Jct. to Salem	132	121	85	68
Salem to Wilmington Jct.	160	147	85	69
Lowell to Ayer	146	134	85	67
Ayer to Lowell	147	135	90	75
Haverhill to Georgetown	114	105	85	68
Georgetown to Haverhill	114	105	85	68
Wakefield to Newburyport	114	105	85	68
Newburyport to Wakefield Jct. . .	114	105	85	69
Newton Jct. to Merrimac	114	105	85	70
Merrimac to Newton Jct.	110	101	85	70
Rollinsford to Somersworth	114	105	85	70
Somersworth to Rollinsford	114	105	85	70
Boston to Lynn via Saugus	114	105	84	69
Lynn to Boston via Saugus	114	105	85	68
Swampscott to Marblehead	115	105	85	69
Marblehead to Swampscott	114	105	85	70
Salem to Marblehead	115	105	85	70
Marblehead to Salem	114	105	85	71

Present Portland Division Ratings (Continued)

	115	105	85	70
H. & Wenham to Conomo	114	105	85	70
Conomo to H. & Wenham	118	105	85	70
Beverly to Rockport	114	105	85	69
Rockport to Beverly	114	105	85	69
Salem to Danvers	114	105	85	69
Danvers to Salem	115	105	84	69
Salisbury to Amesbury	114	105	85	68
Amesbury to Salisbury	114	105	85	69
Portsmouth to Dover	114	105	85	69
Dover to Portsmouth	114	105	85	69
Jewett to Sanbornville	114	105	85	69
Sanbornville to Intervale	115	105	84	69
Intervale to Sanbornville	115	105	84	69
Sanbornville to Rochester	114	105	85	69
Rochester to Jewett	114	105	85	69
Sanbornville to Wolfboro	114	105	85	69
Wolfboro to Sanbornville	114	105	86	70
Mean for Division	116	108	85	69
Upper Extreme	160	147	91	77
Normal High Figure	134	123	86	72
Normal Low Figure	113	104	83	67
Lower Extreme	110	101	78	63

System Tonnage Ratings

Class	175	115	105	85	80	70	65	45
Mean for System. . . .	179	116	107	84	79	67	64	44
Upper Extreme	218	160	147	104	85	79	69	48
Normal High Figure . .	186	128	116	87	82	73	66	46
Normal Low Figure . .	162	113	104	78	68	61	52	37
Lower Extreme	143	108	101	67	63	53	42	29

Note: In computing the normal high and normal low figures, the thirty extreme figures were used, instead of the ten extremes, as was done in the case of the divisional figures.

APPENDIX D

Adjusted Tonnage Ratings

The following adjusted tonnage ratings are in effect on the Boston and Maine:

200 class

	Car Factor	AA	A	B	C	D
McVille to No.Adams	7	4525	4254	4084	3921	3764
E.Deerfield to E.Gard.	5	2885	2712	2604	2500	2400
Ayer to East Deerfield	4	2325	2186	2099	2015	1934
E.Deerfield to McVille	5	2980	2801	2688	2580	2477
Concord to W.R.Jct.	5	2955	2778	2666	2559	2457
W.R.Jct. to Concord	5	2749	2584	2481	2382	2287

175 class

	Car Factor	AA	A	B	C	D
McVille to No.Adams	7	4025	3784	3633	3488	3348
E.Deerfield to E.Gard	5	2565	2411	2315	2222	2133
Ayer to East Deerfield	4	2067	1943	1864	1789	1717
E.Deerfield to McVille	5	2650	2491	2391	2295	2203
Concord to W.R.Jct.	5	2630	2472	2373	2278	2187
W.R.Jct. to Concord	5	2444	2297	2205	2117	2032

AA - Fair, dry, warm weather
A - Temperature above 40
B - Temperature 20 to 40
C - Temperature 0 to 20
D - Temperature below zero

APPENDIX E

A Short Method of Changing Flat Ratings to Adjusted Tonnage Ratings

In making a change from flat to adjusted tonnage ratings, it is necessary first to assume an average car weight for the district. On main line districts, the present flat ratings are based on the average car weight for the district in the direction involved. Elsewhere, a general average car weight is assumed.

If the original data on which the ratings are based is not available, it will be necessary to determine the present average car weight. To do this, a check should be made of all trains over a ten day period, dividing the gross tonnage handled over the district in a given direction by the number of cars moved. On branches, an average weight of 30 tons is probably not far enough off to make trouble.

Having determined the average car weight, divide this into the present 115-class rating to determine the number of cars in a tonnage train as handled by this class of power.

(Appendix E continued on next page)

Assign car factors in accordance with the following table:

Present Flat Rating	below	190	tons	Car Factor	0
	190 to	580	tons	Car Factor	1
	580 to	930	tons	Car Factor	2
	930 to	1250	tons	Car Factor	3
	1250 to	1560	tons	Car Factor	4
	1560 to	1850	tons	Car Factor	5
	1850 to	2110	tons	Car Factor	6
	2110 to	2380	tons	Car Factor	7
	2380 to	2600	tons	Car Factor	8
	2600 to	2830	tons	Car Factor	9
	2830 to	3040	tons	Car Factor	10
	3040 to	3250	tons	Car Factor	11
	3250 to	3450	tons	Car Factor	12
	3450 to	3610	tons	Car Factor	13
	3610 to	3800	tons	Car Factor	14
	3800 to	3950	tons	Car Factor	15
	3950 to	4100	tons	Car Factor	16

Multiply the number of cars as determined above by the car factor from the table, and add the result to the present flat rating for the 115-class. The result is the adjusted tonnage rating for the 115-class.

Consider the adjusted tonnage rating as determined above as 119%, and produce the ratings for the other classes, in accordance with the percentages as specified in the recommendations in the body of this thesis.

This method introduces some errors, for the following reasons:

1. It does not take account of the effect of train length on ruling grade.

2. The table of car factors is based on an average car weight of 30 tons, (i.e., a train resistance of 5.8 pounds per ton on straight level track). This will throw some error into the values in cases where other car weights are assumed, but these cases being comparatively few in number, it will probably be feasible to treat them as special cases, and carry through the regular computation from the basic figures of tractive effort and pull per adjusted ton.

3. It is assumed that the 115-class ratings are correct. If they are not, the same proportional error will appear in all the values.

APPENDIX F

Types of Tonnage Ratings

A Resume of Several Types in Common Use on Various Railroads of the United States and Canada

I. Canadian Pacific Railroad

The method in use on the Canadian Pacific Railroad appears to be rather laborious for general use. They make use of an "Equivalent Gross Tonnage", equal to the actual gross tonnage plus a percentage of the difference between the tare weight of the cars in the train and one-half of the weight of the contents. Three different percentages are used, depending on the ruling grade of the district; 30% being used on grades of 0.5% and less; 20% on grades between 0.5% and 1.25%; and 10% on all grades over 1.25%. The formula under the first of these percentages would be:

$$E = G + 30\% \text{ of } \left(T - \frac{C}{2}\right)$$

$$= T + C + 0.3\left(T - \frac{C}{2}\right)$$

where

E = the equivalent gross tonnage

G = the actual gross tonnage

T = the tare, or empty, weight of the cars in the train.

C = the weight of the contents, or lading.

Thus it is necessary for a yard clerk to draw off from the waybills the tare and lading separately, add the two for the gross tonnage, and also deduct half of the weight of the contents from the tare, take 30% of the difference, and add the result to the gross tonnage. While the mathematics involved is not complicated, it appears to be sufficiently so to frighten the average yard clerk.

Quoting from a letter from the Chief of Motive Power and Rolling Stock of the C.P.R.: "The system which we have followed was based on the assumption that the train which offers the least resistance is assumed to be that in which the lading is twice the tare weight and, in order that empty or not fully loaded tains may be handled under similar conditions, such trains are given an allowance which, added to their actual gross tonnage becomes what is known as equivalent gross tonnage, which corresponds to the actual gross tonnage of fully loaded trains. This allowance varies on the different subdivisions with the percentage of the grades encountered." This letter is under date of March 10, 1924, and another letter dated May 5, 1930, states that they are still employing the same method.

Provision for cold weather is made by reducing the rating by specified percentages, depending on the temperature. A total of 22 different reductions are given, eleven for slow freights and eleven for fast freights. The table of these reductions follows:

Rail and Weather Conditions	Where 30% Chart is Used		Where 20% Chart is Used	Where 10% Chart is Used
	Slow	Fast	All Trains	All Trains
Normal	Nil	Nil	Nil	Nil
Bad Rail	5%	5%	5%	5%
15 to 10 above	5%	5%	5%	5%
9 to 5 above	6%	10%	6%	6%
4 to 1 above	7%	12%	6%	6%
Zero to 4 below	10%	15%	7%	6%
5 to 9 below	12%	17%	9%	8%
10 to 14 below	14%	18%	11%	10%
15 to 19 below	16%	19%	13%	12%
20 to 24 below	17%	20%	15%	14%
25 to 30 below	20%	22%	17%	16%
More than 30 below with storm	25%	25%	20%	18%

It seems rather illogical to try to work to such close limits on a proposition that is purely empirical, particularly when no reduction is made until the temperature reaches 15 degrees above zero. It is much more customary to make the first reduction at a temperature of about 35 degrees.

II. Delaware and Hudson Railroad.

The Delaware and Hudson uses the common adjusted tonnage rating method, as outlined in Appendix C. They show four ratings at all points, reducing the rating to allow for weather conditions. These allowances are:

Temperature above 35 degrees	-	full rating
20 to 25 degrees	-	10% reduction
zero to 20 degrees	-	20% reduction
below zero	-	30% reduction

III. Chesapeake and Ohio Railroad.

The Chesapeake and Ohio uses the standard adjusted tonnage rating method, but instead of reducing the rating to allow for cold weather, they increase the car factor as the temperature drops. These changes are as follows:

Temperature above 35 degrees	-	car factor normal
20 to 35 degrees	-	car factor 150% of normal
zero to 20 degrees	-	car factor 200% of normal
below zero	-	car factor 250% of normal

IV. Norfolk and Western Railroad.

The Norfolk and Western used flat ratings.

V. Baltimore and Ohio Railroad.

The Baltimore and Ohio uses an adjusted tonnage rating system similar to that of the Chesapeake and Ohio - i.e., varying the car factor to compensate for weather changes.

VI. New York Central.

The New York Central employs two methods of rating locomotives. The adjusted tonnage ratings are used on two divisions which have comparatively heavy grades, and the "Mean Resistance Ratio", as applied by the Daly Machine, is used elsewhere. This latter method, theoretically, is more accurate than the adjusted tonnage rating method, but it requires special equipment in the form of a specially designed adding machine. As commonly used, the assumption is made that a 40-ton car has an average resistance. Quoting from the American Railway Master Mechanics' Association Proceedings for 1914 (Volume XLVII, Part 1, pages 291 to 323): "In this method a train of cars of some average weight is determined for a given locomotive and the actual tons in this train taken as the rating. In order to provide adjustment for lighter or heavier cars, a factor is added to the weight of lighter cars, and subtracted from the weight of heavier cars. The value of the factor is made to vary with the weight of the car, being equal to zero for cars of the average weight tested".

In practice this method is very laborious unless the special adding machine is used, as the figure corresponding to the car factor varies with the weight of the car, and may be added or subtracted, depending on whether the car is lighter or heavier than the average. This special adding machine is so designed that it is only necessary to add in the actual weight of the car, the machine automatically correcting this weight to the adjuted figure. For example, as used on the Philadelphia and Reading,* the machine registeredas follows:

Carsfrom 15 to 19 tons are registered 4 percent heavy
Cars from 20 to 24 tons are registered 3 percent heavy
Cars from 25 to 28 tons are registered 2 percent heavy
Cars from 29 to 33 tons are registered 1 percent heavy
Cars from 34 to 48 tons are registered actual weight
Cars from 49 to 53 tons are registered 1 percent light
Cars from 54 to 58 tons are registered 2 percent light
Cars from 59 to 64 tons are registered 3 percent light
etc. to
Cars from 83 to 85 tons are registered 9 percent light

Were it not for the expense of the machines, this is probably the simplest method to apply, as it is necessary only for the clerk to add the weights on the special adding machine, the total shown being the adjusted tonnage. However, these

* See Railroad #VIII for method used by Reading Company at Present.

percentages vary with the ruling grade, and with the speed at which it is intended that the train shall pass the ruling grade, as is shown in the table below, so that at a point where the ruling grades in different directions are different, it is either necessary to have more than one machine, or to adjust the machine to correspond with the direction of the train.

Percentage by which Weight of Car Should Be Changed to Compensate for Weight of Car

Grade	Speed	Weight of Car (Actual)	Percentage Change in Weight	Equivalent Weight of Car
0.0%	10 m.p.h.	20 tons	55.4%	31 tons
0.5	10 m.p.h.	20 tons	17.7%	24 tons
1.0	10 m.p.h.	20 tons	10.5%	22 tons
1.5	10 m.p.h.	20 tons	7.5%	21 tons
0.0	30 m.p.h.	20 tons	51.5%	30 tons
0.5	30 m.p.h.	20 tons	20.5%	24 tons
1.0	30 m.p.h.	20 tons	12.8%	23 tons
1.5	30 m.p.h.	20 tons	9.3%	22 tons
0.0	10 m.p.h.	70 tons	31.9%	48 tons
1.0	10 m.p.h.	70 tons	6.1%	66 tons
0.0	30 m.p.h.	70 tons	32.8%	47 tons
1.0	30 m.p.h.	70 tons	7.9%	64 tons

(Based on Schmidt's tables of freight car resistance)

Thus it is seen that the ruling grade has a large effect on the correct percentage to use, and the speed a small but definite effect, showing up in the higher cars especially.

VII. Pennsylvania Railroad.

Uses a standard adjusted tonnage rating, with a reduction in rating to cover adverse weather conditions.

VIII. Reading Company.

The Reading uses a variation of the adjusted tonnage rating method. This is outlined in a letter from Mr. R. B. Abbott, Assistant General Superintendent, as follows:

"Our train tonnages are assigned with relation to tonnage constants that are built up on the assumption that the total Summer tonnage rating of the engine is equal to the weight of the cars plus the load on the cars plus ten tons per car to cover frictional resistance, etc.

"The hauling capacity at 12 1/2 miles per hour of each locomotive has been found in practice to conform to the following formula:

$$HC = \frac{.16\ WD}{9 - 5 \times \frac{\text{weight loaded on cars}}{\text{capacity of cars}} + 20G}$$

"In above formula:

HC = hauling capacity of locomotive in long tons.
WD = total weight on locomotive drivers in pounds.
9-5 = a constant.
G = ruling grade in percent.

"It has been found in practice that it is uneconomical to load an engine with tonnage that it cannot handle at 12 1/2 miles per hour on the ruling grade and this fact has been brought out by a comparison of cost per 1000 gross ton miles under various sizes and weights of trains.

"After the hauling capacity has been ascertained by the preceding formula, the tonnage constant is built up by dividing the sum of the weights of the largest coal car and its lading (20 tons + 55 tons = 75 tons) into HC. This gives the total number of the largest loaded coal cars that could be hauled by the locomotive under study. This number of cars as ascertained should then be multiplied by 10 and this product should be added to HC and the sum = tonnage constant. The formula for this is:

$$\text{TC (tonnage constant)} = \text{HC} + \frac{10\text{HC}}{75}$$

"After TC is secured, it becomes a guide for the building up of trains in our classification yards and, when by adding the weights of the cars and contents plus 10 on any track or tracks in the yard, the total approximates TC, the proper cars and tonnage for the engine in question have been found.

"Our method for reducing the tonnage for cold weather conditions is as follows:

"No reduction when temperature is 35 deg. or higher.

"For every degree of temperature below 35 deg., we reduce tonnage constant one percent.

"Further reductions are of course made in connection with severe wind or snow storms but is left to the judgment of the local division people."

APPENDIX G

Explanation and Discussion of Adjusted Tonnage Ratings with Methods of Determining Such Ratings

The necessity of reducing the tonnage that is assigned to a locomotive if the train is composed of light cars, as against that assigned if the train is composed of heavy cars has been demonstrated in the text of this thesis, and a brief outline of the various methods in use is given in Appendix F. It is proposed in this Appendix to present a detailed discussion of the common adjusted tonnage rating, this being the method that is most widely used, and the simplest to apply.

Reference has been made frequently in this report to Schmidts tables of freight car resistance. This table is given on page 59. A number of other tests have been made by various railroads, among which is the Pennsylvania Railroad. Their tests were extended to include cars of a gross weight of 121 tons, and the curve extended to show the probable resistance of cars with gross weights running up to 140 tons. The results of their tests are published in their Test Department Bulletin No. 26, dated 1915. They consider the resistance practically uniform between 5 and 25 miles per hour. A comparison of their results with the Schmidt figures is given on the next page.

Comparison of P.R.R. Car Resistance Figures with Schmidt Figures

Car Weight	P.R.R.	Schmidt 5 m.p.h.	Schmidt 25 m.p.h.
20 tons	7.00#/ton	6.8#/ton	9.3#/ton
30 tons	6.13#/ton	5.4#/ton	7.4#/ton
40 tons	4.20#/ton	4.4#/ton	6.0#/ton
50 tons	3.64#/ton	3.7#/ton	5.0#/ton
60 tons	3.27#/ton	3.3#/ton	4.4#/ton
70 tons	3.00#/ton	3.1#/ton	4.1#/ton
80 tons	2.82#/ton	--	--

It will be noticed that P.R.R. figures are in general rather lower than Schmidt's. The following gives the P.R.R. figures for heavier cars:

Train Resistance for Heavy Cars

100 ton - four wheel trucks - 3.13 # per ton average
120 ton - six wheel trucks - 3.17 # per ton average

A typical example of the effect on hauling capacity of a locomotive of difference in weight of cars in a train is given in the text and in Appendix A. From this it is seen that it is necessary to substitute for actual tonnage, some fictitious value that will have a uniform resistance regardless of the weight of the cars in the train. Paradoxical as it may seem, this is accomplished by adding a constant to the weight of each car, this constant having a fixed value for any given ruling grade, but varying with the value of the ruling grade over which the train is to be hauled. The resulting figure is known as the adjusted tonnage of the train. The constant is commonly known as the

FREIGHT CAR RESISTANCE

SUMMER WEATHER

(From Bulletin #43, Univ. of Illinois Experiment Station)

Train Resistance - Pounds per Ton

Speed Miles per Hour	Average Weight per Car in Tons												
	15	20	25	30	35	40	45	50	55	60	65	70	75
5	7.6	6.8	6.0	5.4	4.8	4.4	4.0	3.7	3.5	3.3	3.2	3.1	3.0
6	7.7	6.9	6.1	5.5	4.9	4.4	4.1	3.8	3.5	3.3	3.2	3.1	3.0
7	7.8	7.0	6.2	5.5	5.0	4.5	4.1	3.8	3.6	3.4	3.2	3.1	3.1
8	8.0	7.1	6.3	5.6	5.0	4.6	4.2	3.9	3.6	3.4	3.3	3.2	3.1
9	8.1	7.2	6.4	5.7	5.1	4.6	4.2	3.9	3.6	3.4	3.3	3.2	3.1
10	8.2	7.3	6.5	5.8	5.2	4.7	4.3	4.0	3.7	3.5	3.3	3.2	3.2
11	8.3	7.4	6.6	5.9	5.3	4.8	4.3	4.0	3.7	3.5	3.4	3.3	3.2
12	8.4	7.5	6.7	6.0	5.4	4.8	4.4	4.0	3.8	3.6	3.4	3.3	3.3
13	8.6	7.6	6.8	6.1	5.5	4.9	4.5	4.1	3.8	3.6	3.5	3.4	3.3
14	8.7	7.8	6.9	6.2	5.5	5.0	4.5	4.2	3.9	3.7	3.5	3.4	3.4
15	8.8	7.9	7.0	6.3	5.6	5.1	4.6	4.2	3.9	3.7	3.6	3.5	3.4
16	9.0	8.0	7.1	6.4	5.7	5.1	4.7	4.3	4.0	3.8	3.6	3.5	3.5
17	9.1	8.1	7.2	6.5	5.8	5.2	4.8	4.4	4.1	3.9	3.7	3.6	3.5
18	9.3	8.3	7.4	6.6	5.9	5.3	4.8	4.5	4.1	3.9	3.7	3.7	3.6
19	9.4	8.4	7.5	6.7	6.0	5.4	4.9	4.5	4.2	4.0	3.8	3.7	3.6
20	9.6	8.5	7.6	6.8	6.1	5.5	5.0	4.6	4.3	4.0	3.9	3.8	3.7
21	9.7	8.7	7.7	6.9	6.2	5.6	5.1	4.7	4.3	4.1	3.9	3.9	3.8
22	9.9	8.8	7.9	7.0	6.3	5.7	5.2	4.8	4.4	4.2	4.0	3.9	3.8
23	10.0	9.0	8.0	7.1	6.4	5.8	5.3	4.9	4.5	4.3	4.1	4.0	3.9
24	10.2	9.1	8.1	7.3	6.6	5.9	5.4	4.9	4.6	4.3	4.2	4.1	4.0
25	10.4	9.3	8.3	7.4	6.7	6.0	5.5	5.0	4.7	4.4	4.2	4.1	4.0
26	10.5	9.4	8.4	7.5	6.8	6.1	5.6	5.1	4.8	4.5	4.3	4.2	4.1
27	10.7	9.6	8.5	7.7	6.9	6.2	5.7	5.2	4.8	4.6	4.4	4.3	4.2
28	10.9	9.7	8.7	7.8	7.0	6.3	5.8	5.3	4.9	4.7	4.5	4.4	4.3
29	11.1	9.9	8.8	7.9	7.1	6.5	5.9	5.4	5.0	4.8	4.6	4.5	4.4
30	11.3	10.0	9.0	8.0	7.3	6.6	6.0	5.5	5.1	4.9	4.7	4.5	4.5
31	11.4	10.2	9.1	8.2	7.4	6.7	6.1	5.6	5.2	5.0	4.8	4.6	4.5
32	11.6	10.4	9.3	8.3	7.5	6.8	6.2	5.8	5.3	5.0	4.9	4.7	4.6
33	11.9	10.5	9.4	8.5	7.6	7.0	6.3	5.9	5.4	5.2	5.0	4.8	4.7
34	12.0	10.7	9.6	8.6	7.8	7.1	6.5	6.0	5.5	5.3	5.1	4.9	4.8
35	12.3	10.9	9.7	8.8	7.9	7.2	6.6	6.1	5.7	5.4	5.2	5.0	4.9
36	12.5	11.1	9.9	8.9	8.0	7.4	6.7	6.2	5.8	5.5	5.3	5.1	5.0
37	12.7	11.2	10.0	9.0	8.2	7.5	6.9	6.4	5.9	5.6	5.4	5.2	5.1
38	12.9	11.4	10.2	9.2	8.3	7.6	7.0	6.5	6.0	5.7	5.5	5.3	5.2
39	13.1	11.6	10.4	9.4	8.5	7.8	7.1	6.6	6.2	5.8	5.6	5.4	5.3
40	13.4	11.8	10.6	9.5	8.6	7.9	7.3	6.8	6.3	6.0	5.7	5.6	5.5

"Car Factor" .

That this method will work is seen from the following hypothetical example:

Call the car factor "k". Then, if the level track resistance <u>per car</u> has the following values

20 ton car - 140# (These figures based on P.R.R.)
40 ton car - 168#
70 ton car - 210#

and the drawbar "Pull per Adjusted Ton" is constant, then on a level track.

$$\frac{140}{20 + k} = \frac{168}{40 + k} = \frac{210}{70 + k} .$$

Solving the first pair, we find k = 80; solving the second pair, k also equals 80, showing that the assumption of the "Pull per Adjusted Ton" being constant is correct. If Schmidt's figures are used, the results are not quite as good, as he does not make the initial assumption that the resistance per ton varies uniformly with the car weight; i.e., that the unit resistance is a straight line function of the gross weight of the car. The variation of this unit resistance from a straight line is small, even on level track, and when a constant grade resistance of 20 pounds per ton per percent of grade is added, the variation becomes even less (on a percentage basis). As the whole system of adjusted tonnage ratings is based on the assumption that a straight line relation does exist between the unit resistance and the weight of car, the following derivations will be founded on that assumption, and Pennsylvania figures for car resistance will be adopted unless otherwise specified.

If the unit resistance varies as a straight line function of the weight, then the total resistance per car will also be a straight line function of the weight of the car, and can be expressed by an equation of the form

$$y = ax + b, \quad \text{or} \quad r = fw + c, \; . \; . \; . \; . \; . \; . \; . \; (1)$$

where r is the total resistance of a car of weight w(in tons of 2000 pounds), and f and c are constants to be determined from tests. The Pennsylvania tests indicated that $f = 1.4$. It is a factor which involves such items as journal friction and rolling friction which vary with the weight of the car. On straight level track, c is found to have a value of 112. It embodies the items, such as flange friction and air resistance, which do not vary with the weight of the car. On grades the value of c varies somewhat, but not to any great extent.

It can be demonstrated mathematically that grade resistance is a constant per ton of weight, and equals 20 pounds per ton per percent of grade. If the rate of grade is expressed as G, and the total resistance as R, then

$$R = fw + c + 20\,Gw = w(f + 20\,G) + c$$

Substituting the single letter F for f + 20 G, we have

$$R = Fw + c \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (2)$$

Considering two trains as follows:

	First Train	Second Train
Number of cars	N	N_1
Weight per car (average) . . .	w	w_1
Gross weight of train (tons) .	W	W_1
Adjusted tonnage	T	T_1

As before, the car factor is K.

If the first train is composed of a small number of heavy cars, and the second of a larger number of light cars, so that the adjusted tonnage is equal, then

$$T = W + KN = T_1 = W_1 + KN_1$$

or $$W + KN = W_1 + KN_1$$

from which $$K = \frac{W - W_1}{N_1 - N} \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

From equation (2),

$$RN = (Fw + c)N$$

$$RN_1 = (Fw_1 + c)N_1$$

RN and RN_1 representing the drawbar pull of the two trains, and these being assumed equal, the right hand sides are also equal, and can be solved to produce

$$\frac{c}{F} = \frac{wN - w_1N_1}{N_1 - N}$$

but, as $wN = W$ and $w_1 N_1 = W_1$,

$$\frac{c}{F} = \frac{W - W_1}{N_1 - N} = K$$

To determine these values experimentally, it is necessary to make dynamometer car tests in the field over the section of the road to which it is desired to assign a rating. Several trains of empties, or light cars, of a tonnage such that the locomotive must be worked to full capacity in order to make its running time, are tested, the dynamometer pull on the ruling grade being recorded. This is corrected to allow for any acceleration or deceleration that may be taking place at the time, and is considered the train resistance over the ruling grade. The same is done for several trains of heavy cars.

The train resistances so determined are divided by the number of cars in the respective trains, giving the resistance per car for heavy and light cars. This figure is plotted against the weight per car, and the best representative straight line is drawn through the points.

This line represents equation (2), $R = Fw + c$, in which c is the intercept on the y-axis, and F the slope of the line, or the value of c divided by the intercept on the x-axis. Inasmuch as K is c divided by F, K is also equal to the intercept on the x-axis.

The value of F is called the pull per adjusted ton. Accordingly, from tests on one engine, it is easy to compute the adjusted tonnage rating for any other type of locomotive by the following method:

Determine the drawbar pull on level track by means of dynamometer tests. Correct this, for the effect of raising the weight of the engine up the grade, by the value of 20 pounds per ton per percent of grade. Divide the remaining available drawbar pull by the pull per adjusted ton determined above, and the result is the adjusted tonnage rating of the locomotive in question.

In case no dynamometer tests are available, the whole process can be carried out on paper, using standard values of car resistance, and computed tractive efforts, correcting the train resistance for grade and alignment from the known profile of the road.

An even shorter method, producing nearly as good results, is to assume a value of f as 1.4 and similarly assume c as 112, substitute in the equations $F = f + 20G$, and $K = c + F$, to develop the pull per adjusted ton and the car factor. The adjusted tonnage rating is then found by dividing the available drawbar pull corrected for grade resistance of the locomotive, by the pull per adjusted ton. It must also be remembered that the theoretical tractive effort, based on the standard formulae, must be corrected for mechanical resistance and rolling resistance of the engine and tender. This is customarily done by deducting from 25 to 30 pounds per ton of weight on the drivers, and deducting for weight on lead and trailing trucks and tender weight on a basis of the resistance per ton of a freight car with the same axle loads.

In all cases, it is customary to use the adjusted tonnage to not closer than the nearest ten tons, and the car factor to the nearest even ton. This introduces errors, of course, but the whole question of train resistance is so uncertain that one or two percent error makes little difference in the probable accuracy of the results.

The table following gives value of F and K for various grades. It should be noted that the values are approximate only, and may be materially different if actual tests are made on the grade in question. However, in the absence of tests results, they may be used, and having the drawbar pull of the locomotive at the speed it is desired to operate on the grade, the total adjusted tonnage may be computed with reasonable accuracy.

Most of the foregoing has been based on the Pennsylvania Railroad's Bulletin #26, referred to on the next page.

Appendix H gives a comparison of the various method in use for establishing tonnage ratings.

In connection with the second short method outlined above, it should be noted that, whereas the Pennsylvania shows values of f and c of 1.4 and 112, respectively, the New York Central tests indicate that these values should be 1.5 and

Values of F and K for Various Grades

Based on P.R.R. Bulletin #26.

Grade in Percent (G)	Pull per Adjusted Ton (F)	Car Factor (K)
Level	1.4	80
0.05	2.4	46.6
0.10	3.4	33.0
0.20	5.4	20.7
0.30	7.4	15.1
0.40	9.4	11.9
0.50	11.4	9.8
0.60	13.4	8.3
0.70	15.4	7.3
0.80	17.4	6.4
0.90	19.4	5.8
1.00	21.4	5.2
1.10	23.4	4.8
1.20	25.4	4.4
1.30	27.4	4.1
1.40	29.4	3.8
1.50	31.4	3.6
1.60	33.4	3.4
1.70	35.4	3.2
1.80	37.4	3.0
1.90	39.4	2.8
2.00	41.4	2.7
2.20	45.4	2.5
2.40	49.4	2.3
2.60	53.4	2.1

107, while the values based on Schmidt's figures would be 1.56 and 115, on the basis of 20 and 70 ton cars at 10 m.p.h. For further comparison, these three sets of figures on a 0.5% grade would produce ratings and car factors as follows:

(locomotive with 70,000 pounds tractive effort available on this grade - approximately a Boston and Maine class T-1a)

Values	Rating	Car Factor
Pennsylvania	6140	9.8 (use 10)
New York Central	6090	9.3 (use 9)
Schmidt	6050	9.9 (use 10)

Thus it will be seen that these differences cause little change even on flat grades, and on heavy grades the difference would be even less. With heavy power, a car limit would probably be the determining factor on flat districts. For example, in the above cases, if a car limit of 125 cars be assumed, the car limit would be the determining factor until the average car weight of the train reached 47.1 tons, in the first case, 46.7 in the second, and 46.4 in the third. To show that the differences above make little difference in actual tonnage handled, consider the effect in case of cars of 50 tons gross weight and of 100 tons gross weight. The results are as follows:

Values	50-ton cars		100-ton cars	
	Tonnage	Number	Tonnage	Number
Pennsylvania	5100	102	5500	55
New York Central	5150	103	5600	56
Schmidt	5050	101	5500	55

Thus there is a maximum variation of 2 cars in this flat grade case, showing that considerable variations in values of train resistance produce little real effect, from a practical standpoint, in the adjusted tonnage rating.

APPENDIX H

Comparison of Various Methods of Establishing Tonnage Ratings

In the following, P.R.R. figures for train resistance will be used throughout. The methods that will be compared are:

1. Flat Tonnage Rating
2. Adjusted Tonnage Rating
3. Canadian Pacific Formula
4. The actual tonnage that should be handled

will be computed to show the percent of error that is introduced by each method. The territory from East Deerfield to Ayer, on the Boston and Maine, with a ruling grade of 1.09% will be taken as the district in question, and a Boston and Maine class T-1b (2-8-4) locomotive will be considered.

This locomotive has a tractive effort of 81,400 pounds up to 15 miles per hour (with a booster cut in). The weight on drivers is 127.9 tons, and the lead and trailing truck and tender weight (tender half loaded) 191.1 tons, on 9 axles. This gives a total weight of 319 tons, with a level track resistance of 4500 pounds, leaving 76,900 pounds for level track drawbar pull at ten miles per hour. The grade resistance of the locomotive on a 1.09% grade will be

1.09 x 20 x 319 or 6950 pounds, leaving 70,000 pounds available tractive effort up the grade.

Basing the flat tonnage rating on 30 ton cars, a flat rating of 70,000 ÷ (5.8 + 1.09 x 20) or 2540 tons is produced.

Basing the adjustedtonnage rating on the second approximate method in the preceding appendix, the pull per adjusted ton is 23.2#, with a car factor of 4.84 (or 5 to the nearest ton). This gives an adjusted tonnage rating of 3010 tons.

For the Canadian Pacific Method, consider 3.3 pounds per ton a fair level track resistance for a loaded car. (It is the resistance for a 60 ton car, as indicated below). This value gives a tonnage rating of 2790 on the C.P.R. method. As the grade is 1.09%, this division falls in the "20%" range.

The actual tons for three trains will be computed, the first composed of cars of an average weight of 20 tons, the second of 40 tons, and the third of 60 tons. The first column in the table gives the average weight of car in the trim, the second the actual tonnage based on the following resistances - for 20 ton cars 7.0 pounds per ton; for 40 ton cars, 4.2 pounds per ton; and for 60 ton cars, 3.3 pounds per ton. The third column gives the actual tonnage handled according to the flat rating method, the fourth column giving the percentage error; the fifth and sixth similarly for the adjusted tonnage rating method, and the seventh and eighth for the Canadian Pacific Method.

Weight of Cars	Drawbar Pull	Flat Rating Tons	%	Adjusted Tons	%	C.P.R. Tons	%
Rating		2540 . . .		. 3010 . . .		2790	
20 tons	2430	2540	+4.9	2400	-0.1	2320	-0.3
40 tons	2690	2540	-5.6	2680	-0.0	2660	-0.1
60 tons	2790	2540	-9.0	2780	0.0	2790	0.0

Thus it is seen that the flat tonnage rating badly overloads the engine on light cars, and underloads them on heavy cars to an even greater extent, while the other two methods give results well within any reasonable limits; this being a fairly heavy grade territory, with a small car factor, the error in the flat rating is not as great as it would be in a more nearly level territory. Accordingly for further comparison, another territory with a ruling grade of only 0.4% will be assumed. Working on the above basis the following ratings are found:

Flat rating	5580 tons	
Adjusted tonnage rating .	7800 tons	Car Factor 11.9 (12)
Canadian Pacific rating .	6500 tons	30% territory

On this basis, the following results are secured:

Weight of Cars	Drawbar Pull	Flat Rating Tons	%	Adjusted Tons	%	C.P.R. Tons	%
Rating		5580		7800 . . .		6500	
20 tons	4900	5580	+13.9	4870	0.0	5000	+2.0
40 tons	6020	5580	- 7.3	6000	0.0	6050	0.0
60 tons	6500	5580	-14.2	6500	0.0	6500	0.0

This example, of course, borders on the absurd, as no train would be made up 279 empties (as called for by the flat rating) still the error continues in the figures for heavier cars, and

6500 tons is by no means a heavy train for roads in the coal section of the country, where 12,000 ton trains are not unheard of, and the example shows even more clearly the advantages of some sort of adjustment.

It was not considered practical to include the mean resistance ratio method in the above comparison, as it would have merely meant back-figuring the correct ratios to apply to the car weights, and then applying them, with the result that the answer would have come out exact in each case, and nothing would be proved. The principal advantage of this system is in trains made up of cars of varying weights (which, of course, always occur in practice) with the proper ratio applied to each individual car. It is probably more accurate than even the adjusted tonnage rating method in such cases.

APPENDIX I

Graphical Methods of Establishing Adjusted Tonnage Ratings

There are two or three feasible graphical methods available, which involve a considerable amount of preliminary work, but once the necessary curves have been made up, it is a very quick matter to establish a rating for any locomotive on any ruling grade.

In the first of these, involving the smallest amount of preliminary work, but more work in the application, involves two curves. The first of these is a car factor curve, in which the car factor is plotted against the rate of grade. In the second curve, the adjusted tonnage rating for 10,000 pounds available tractive effort behind the tender is plotted against the percent of grade. These two curves are shown in Plate I. To establish a rating, it is necessary to pick off from the curve the rating for the grade in question, and multiply this by the available tractive effort behind the tender of the locomotive in question. This latter figure is the net level track tractive effort at the desired speed, reduced by the grade resistance for the grade in question. For example, taking a Boston and Maine class T-1b locomotive at ten miles an hour, with an 0.8% ruling grade, we find the following:

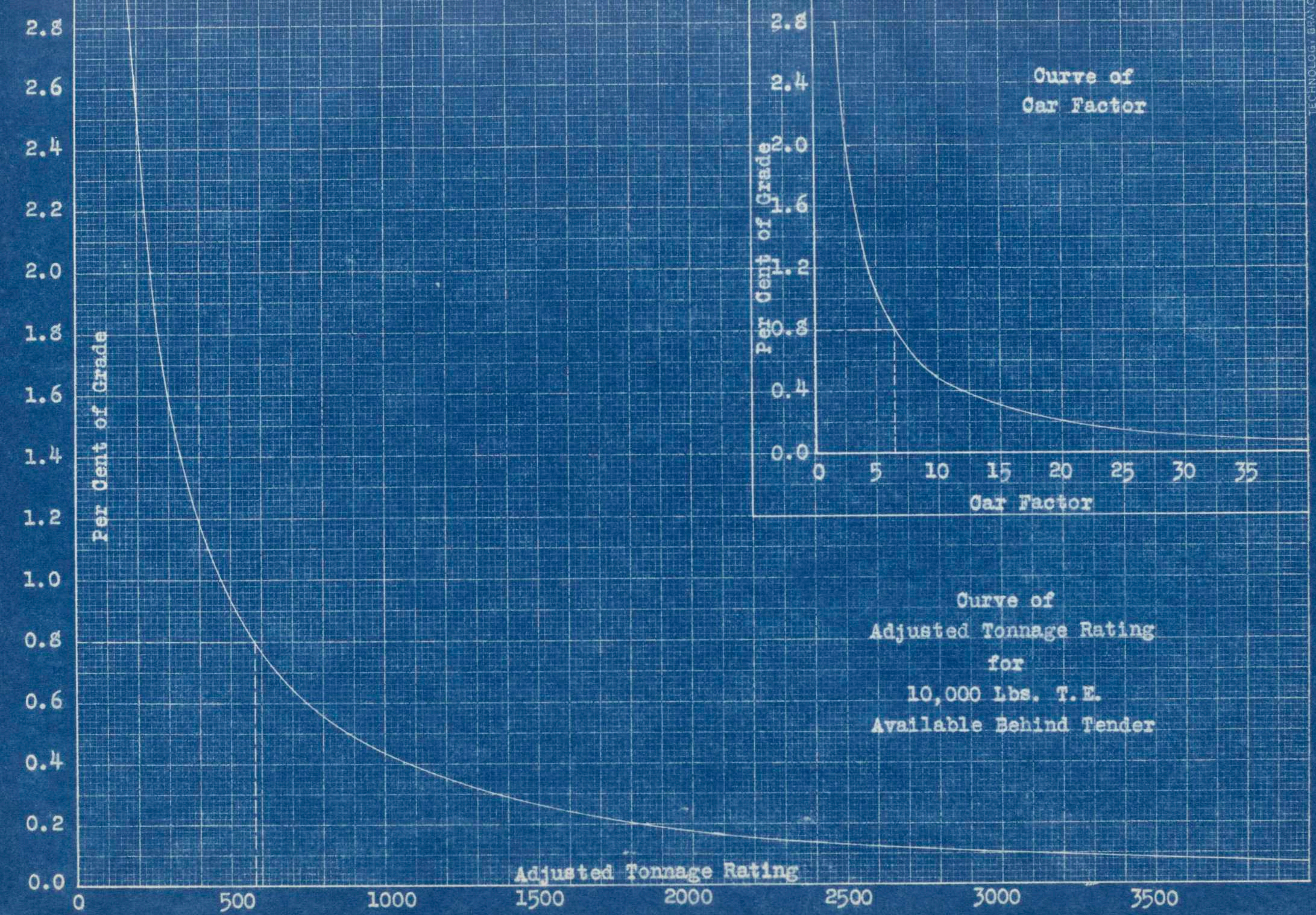
Curve of
Car Factor
Per Cent of Grade
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
5
10
15
20
25
30
35
Car Factor
Curve of
Adjusted Tonnage Rating
for
10,000 Lbs. T. E.
Available Behind Tender
Per Cent of Grade
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
500
1000
1500
2000
2500
3000
3500
Adjusted Tonnage Rating

PLATE I

Level track tractive effort	76,900 lb.
Grade resistance 0.8 x 20 x 319	5,100
Net available T.E. on 0.8% grade	71,800

From curves, as shown by dotted line, the adjusted tonnage rating for 10,000 lb. T.E. on an 0.8% grade is 575 tons. 575 times 7.18 gives 4130 tons, which would be the rating for a district with an 0.8% ruling grade, to be passed at 10 m.p.h. From the other curve, we find the car factor to be 6.4, (the correct value to use being 6).

The second readily applicable graphical method requires somewhat more preliminary work, but can be applied in a very few minutes to any ruling grade. The chart shown in Plate II is drawn up, one curve being drawn for each type of locomotive. The method of drawing the chart is as follows:

First, enter the scales of grade, pull per adjusted ton, and tonnage rating on the right hand edge, bottom, left hand edge of the chart, respectively. The scales used are immaterial, but should be as large as is convenient.

Second, draw the straight line marked "Grade Line", its slope being such that it indicates the relation between grade and pull per adjusted ton correctly - in other words, fits the equation

$$F = f + 20G$$

Third, from a table drawn up, as is the one at the end of Appendix H, divide the top margin to indicate the car

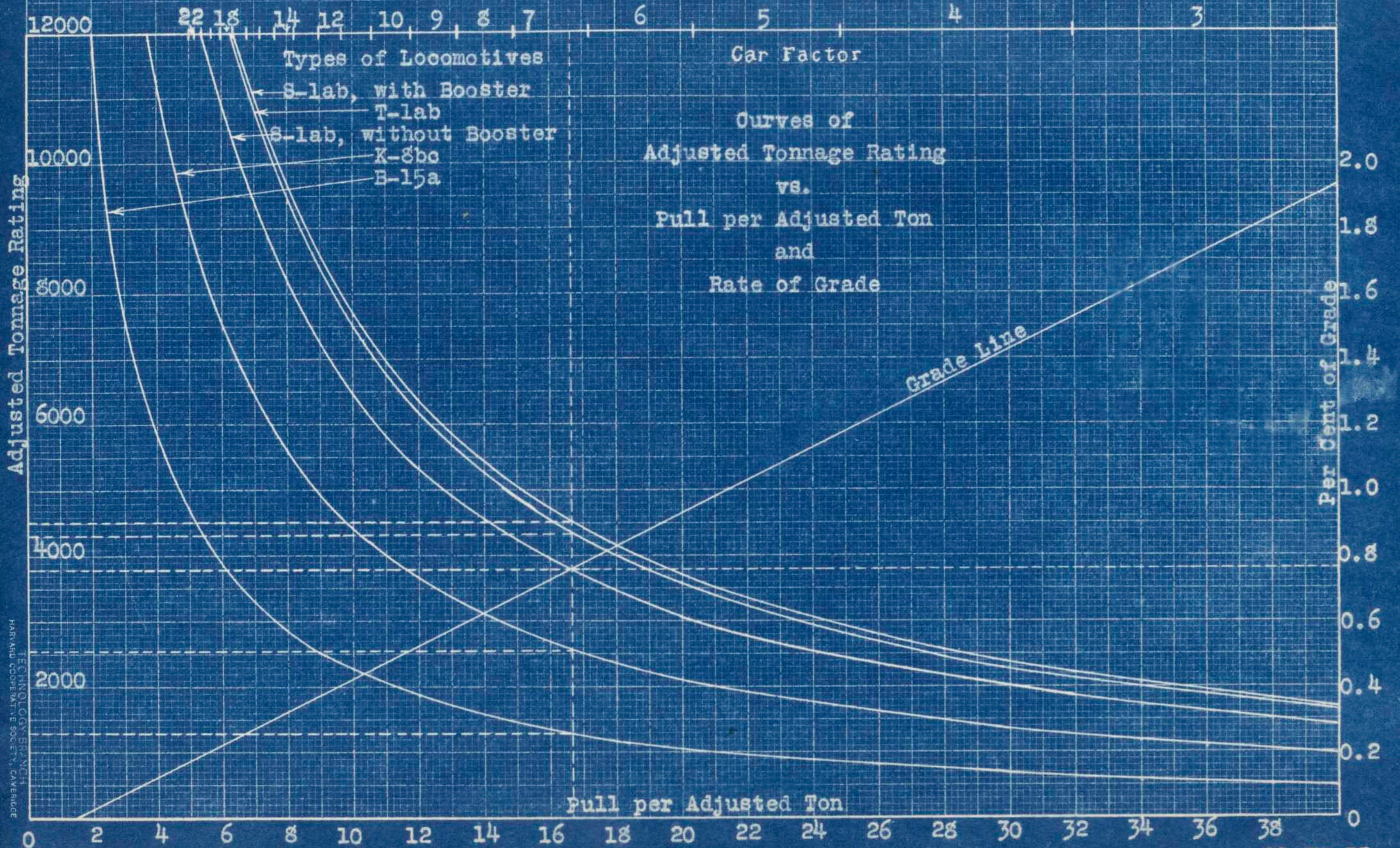
12000
22 18 14 12 10 9 8 7 6 5 4 3
Types of Locomotives
S-lab, with Booster
T-lab
S-lab, without Booster
K-8bc
B-15a
Car Factor
Curves of
Adjusted Tonnage Rating
vs.
Pull per Adjusted Ton
and
Rate of Grade
Adjusted Tonnage Rating
10000
8000
6000
4000
2000
Grade Line
Per Cent of Grade
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
Pull per Adjusted Ton
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38

PLATE II

factor corresponding to the various values of pull per adjusted ton. In this, the section shown for a car factor of 4 includes all values between 3.5 and 4.5, etc.

Fourth, compute the values of adjusted tonnage rating for the type of locomotive involved for different values of "Pull per Adjusted Ton" at the speed desired. The computations for this are shown in Appendix I-2 for five types - T-lab, S-lab, with and without booster, K-8bc (with 200# Boiler Pressure) and B-15a locomotives of the Boston and Maine R.R. A departure from standard practice of computation here greatly simplifies the work. Instead of calculating the actual straight level track drawbar pull from the rated tractive effort of the locomotive, the rated tractive effort is corrected only for machine friction by deducting the weight on drivers in tons times 25 pounds per ton. This gives a hypothetical straight level track drawbar pull, in which no allowance is made for the resistance of the locomotive, other than machine friction. Dividing this tractive effort by any given value of pull per adjusted ton gives the adjusted tonnage that the drive wheels will pull, and deducting the weight of the locomotive (in actual tons) gives the adjusted tonnage that the locomotive will handle behind the tender. The error introduced comes from assuming that the straight level track resistance of the locomotive (exclusive of machine friction) is equal to the pull per adjusted ton, but the error is much smaller than the other errors inherent in the adjusted tonnage rating method. The whole problem of locomotive resistance (particularly the machine friction) is empirical, and the actual amount that the tractive effort should be reduced to account for machine friction is variously placed from 20 to 30 pounds per ton on the drivers, and it is commonly assumed constant, regardless of speed, which is probably incorrect.

Fifth, plot the values of tonnage rating against pull per adjusted ton.

The chart is used as follows: To determine the adjusted tonnage rating and car factor for a run with a given ruling grade, enter the chart at the right hand edge, at the percent of grade specified. Go horizontally until the grade line is met. Vertically above this point will be found the car factor, and vertically below the pull per adjusted ton. Go vertically up or down until the curve for the locomotive in question is met, then horizontally to the left will be found the adjusted tonnage rating of the locomotive. The dotted lines on the chart indicate the method, the rating for a ruling grade of 0.76%, corresponding to the run from Mechanicville to North Adams, being shown for all five types of locomotive, as follows:

S-1ab with booster	4510
T-1ab	4300
S-1ab without booster	3790
K-8bc	2540
B-15a	1290

In this connection, it is of interest to note that the "A" (or normal) rating for the T-lab locomotive on this run as now published by the Boston and Maine is 4254, and that for the S-lab without booster is 3784, the difference being 46 tons in the first case, and only 6 tons in the second.

Comparing all of the published ratings with those derived from the chart, we find the following:

District	Grade	Rating Pub.	Rating Chart	Error
		T-lab Locomotive		
McVille to North Adams	0.76%	4254	4300	+ 3%
E.Deerfield to E.Gardner	1.10	2712	3000	+11%
Ayer to E.Deerfield	1.36	2186	2380	+ 9%
E.Deerfield to McVille	1.15	2801	2870	+ 3%
Concord to White River Jct.	1.25	2778	2620	- 2%
White River Jct. to Concord	1.24	2584	2630	+ 2%
Ayer to Portland	0.84	4418	3950	-10%
Portland to Lowell	0.80	4820	4150	-14%
		S-lab without Booster		
McVille to North Adams	0.76	3784	3790	0%
E.Deerfield to E.Gardner	1.10	2411	2590	+ 7%
Ayer to E.Deerfield	1.36	1943	2110	+ 9%
E.Deerfield to McVille	1.15	2491	2475	- 1%
Concord to White River Jct.	1.25	2472	2300	- 3%
White River Jct. to Concord	1.24	2297	2310	+ 1%
Ayer to Portland	0.84	3948	3420	-11%
Portland to Lowell	0.80	4332	3550	-18%
		K-8bc Locomotives		
Greenfield to White River Jct.	1.28	2143	1560	-27%
White River Jct. to Claremont	1.34	1715	1480	-15%
Claremont to East Northfield	0.88	2711	2200	-19%
Jefferson to Bowman	2.11	802	850	+ 6%
Berlin to Bowman	2.14	794	840	+ 6%

That these results are as close as they are, indicates that the method outlined is not seriously in error, and can be applied tentatively until definite operating results can be observed under the ratings so derived.

A factor entering into the results given is the small scale of the chart included herewith. It is difficult to plot it accurately and to read it closely. A chart intended for actual use should be at least double the size of this one, and preferably even larger.

A further point of error lies in the fact that the grades given were not properly corrected for length of train, as outlined in Appendix J. This could easily throw a considerable error in the results, particularly in the case of the heavy power, where the ratings are so high that the train would probably not all be on the ruling grade at the same time.

It is in the trial and error method of determining the equivalent grade that the chart here presented is most useful, saving as it does many laborious calculations.

APPENDIX I-1

Computations for 10,000 Pound Available Tractive Effort

Adjusted Tonnage Rating Curve. (Plate I).

Grade	Pull per Adjusted Ton (F)	Tons (10,000 ÷ F)	Car Factor (K) = $\frac{112}{F}$
Level	1.4	7140	80.0
0.05	2.4	4160	46.6
0.10	3.4	2940	33.0
0.15	4.4	2270	25.5
0.20	5.4	1850	20.7
0.30	7.4	1350	15.1
0.40	9.4	1060	11.9
0.50	11.4	875	9.8
0.60	13.4	745	8.3
0.70	15.4	650	7.3
0.80	17.4	575	6.4
0.90	19.4	515	5.8
1.00	21.4	465	5.2
1.10	23.4	425	4.8
1.20	25.4	395	4.4
1.30	27.4	365	4.1
1.40	29.4	340	3.8
1.50	31.4	320	3.6
1.60	33.4	300	3.4
1.70	35.4	280	3.2
1.80	37.4	268	3.0
1.90	39.4	254	2.8
2.00	41.4	242	2.7
2.20	45.4	220	2.5
2.40	49.4	202	2.3
2.60	53.4	187	2.1
2.80	57.4	174	2.0
3.00	61.4	163	1.8

APPENDIX I-2

Computations for General Ten Mile Per Hour Adjusted Tonnage Rating Curves

These curves will be drawn for the following locomotives:

1. B. & M. T-lab (There is a slight difference between these locomotives, but not enough to warrant separate curves).
2. B. & M. S-lab with booster.
3. B. & M. S-lab without booster.
4. B. & M. K-8bc with 200# boiler pressure.
5. B. & M. B-15a.

The following are the necessary specifications of these locomotives:

	T-lab	S-lab with booster	S-lab without booster	K-8bc 200# Press	B-15a
Type	2-8-4	2-10-2	2-10-2	2-8-0	2-6-0
Rated T.E.(85% B.P.) .	81400	84400	71300	48200 .	25300
Weight on drivers . .	304000	362300	308500	190600	125000
Total weight(E.& T.) .	609400	599900	579500	369100	252600

NOTE:- In computing weight on drivers, the weight on one trailing axle has been included in the T-lab, and a similar weight in the S-lab to cover machine friction in the booster.

Deduction for engine friction, to produce the hypothetical net level track drawbar pull referred to in Appendix I.

25 x Weight on drivers (in tons)

T-lab :	25 x 152.0	=	3800
S-lab :	25 x 181.2	=	4500
S-lab*:	25 x 154.3	=	3900
K-8bc :	25 x 95.3	=	2400
B-15a :	25 x 62.5	=	1600

*Without booster

Deducting these figures from the total tractive effort, we have the following new straight level track drawbar pulls:

T-lab . .	77600	Weight . .	304.7
S-lab . .	79900	Weight . .	300.0
S-lab'. .	67400	Weight . .	289.3
K-8bc . .	45800	Weight . .	184.6
B-15a . .	23700	Weight . .	126.3

On this page will be found the adjusted tonnage ratings for these locomotives for various values of pull per adjusted ton from which the curves in Plate II are drawn.

The following table of adjusted tonnage ratings for various locomotives is calculated as follows:

$$A.T.R = (T.E. \div P) - W$$

where A.T.R = adjusted tonnage rating
T.E. = hypothetical straight level track tractive effort as computed on previous page.
P = pull per adjusted ton
W = total weight, Engine and Loaded Tender, in tons

Adjusted Tonnage Rating

Pull per Adj.Ton	T-lab	S-lab with Booster	S-lab without Booster	K-8bc 200# B.P.	B-15a
T.E.:	77600	79900	67400	45800	23700
2.0	38500	39650	33410	22720	11720
4.0	19100	19680	16560	11270	5800
6.0	12630	13020	10840	7450	3820
8.0	9400	9690	8140	5540	2840
10.0	7460	7690	6450	4400	2240
12.0	6160	6360	5330	3630	1850
14.0	5240	5410	4520	3090	1570
16.0	4550	4690	3920	2680	1360
18.0	4010	4140	3460	2360	1190
20.0	3580	3700	3080	2110	1060
22.0	3230	3330	2770	1900	950
24.0	2930	3030	2520	1720	860
26.0	2680	2770	2300	1580	790
28.0	2470	2550	2120	1450	720
30.0	2280	2360	1960	1340	660
32.0	2120	2200	1820	1250	610
34.0	1980	2050	1690	1160	570
36.0	1850	1920	1580	1090	530
38.0	1740	1800	1480	1020	500
40.0	1640	1700	1400	960	470
42.0	1540	1600	1320	910	440

APPENDIX J

Ruling Grade Vs. Length of Train

In choosing the ruling grade of a district it must be remembered that the length of the train enters into the question to a considerable extent. For example, if the steepest grade of a district is one of 2.0%, 1000 feet long, between two long descending grades, this would be the ruling grade for a train of less than 25 cars, and might be so for longer trains, depending on the other grades of the district. However, with a long train of 125 cars, only one fifth of the train is on the ascending grade, and four-fifths is on the adjacent descending grades, and if the descending grades are 0.5% or steeper, the net effect is of level track, the 2.0% grade being eliminated from consideration for very long trains. This embodies no consideration of momentum grades, but merely the fact that only a small part of the train is on the steep grade.

The above is an extreme case, but illustrates the principle. In practice, the more normal case would be of a profile with grades as follows:

5000 feet of 0.5%
2000 feet of 0.7%
2000 feet of 0.8%
1000 feet of 1.0%
3000 feet of 0.8%
1000 feet of level

In a case such as this, it is necessary to arrive at the rating by a process of trial and error. First, assume an average car weight, which normally occurs on the run. Perusal of tonnage records for a period of time will disclose this figure. We will assume this to be 40 tons. Taking the steepest grade, determine the tonnage rating. For a T-lab, from Plate II, we find this, for a 1.0% grade to be 3300 tons, with a car factor of 5. With forty ton cars, this gives 73 cars, or a train length of 3000 feet, including the engine. Placing the train on the profile in the worst position, we have 1000 feet on the 1.0% grade, and 2000 feet on the 0.8%. This gives a total rise of (0.01 x 1000 - 0.008 x 2000) feet, or 26 feet in 3000, giving an "Equivalent Grade" of 0.87%. From the chart, we find the rating as 3800 tons, with a car factor of 6; giving 83 cars, or a train length of 3400 feet. The worst position is still with 1000 feet on the 1.0% grade, and 2400 feet on 0.8% grade, giving a total rise of 29.2 feet in 3400, or an equivalent grade of 0.86%. This grade shows 3850 tons, with a car factor of 6, and is probably close enough for practical purposes, until operating results can be observed. On the other hand, the track charts must be examined to be sure that there is no other grade steeper than 0.86% in the district, that may be the ruling grade.

Suppose now that the same profile is to be rated for a K-8bc locomotive. On the 1.0% grade, the chart gives 1970 tons, car factor 5; or 44 cars, making a length of 1850 feet. Placing this with 1000 feet on the 1.0%, and 850 on the 0.8% gives a rise of 16.8 feet in 1850, or an equivalent grade of

0.91%. The second approximation gives 2150 tons, car factor 6, producing an equivalent grade of 0.90%, close enough to try out in practice. However, this shows that the same profile produces a ruling grade of 0.86% for heavy power, and 0.90% for medium power.

Practical cases may be more complicated, if there are a series of very short grades differing quite widely in steepness, but the principle is the same:

1. Pick the probable ruling grade.

2. Find rating on this grade.

3. Determine probable train length, and place train of this length in worst position on grade.

4. Determine the net rise in this train length.

5. Calculate percent of grade corresponding to this rise and distance.

6. With this new grade, unless it is within 0.01% of the original assumption, repeat the process. Repeat as many times as is necessary to produce the desired accuracy.

After some experience, the third trial will usually be satisfactory.

APPENDIX K

Passenger Ratings

As outlined in the body of this thesis, a locomotive cannot handle freight tonnages at passenger train speeds. This is due to two causes, first, the train resistance increases rapidly with the speed, and secondly, the locomotive available tractive effort falls off even more rapidly as the speed increases.

Appendix B indicates that a locomotive operating at 45 miles per hour can handle only 42% of the tonnage it can handle at 14 miles per hour. The table following indicates the corresponding percentages for various types of Boston and Maine locomotives, the two speeds considered being 10 m.p.h. and 45 m.p.h. It is assumed that passenger trains will be scheduled to pass the ruling grade at the latter speed.

Type	Speed Factor	Tons Capacity 10 m.p.h.	Tons Capacity 45 m.p.h.	Percent at High Speed
A-41	0.502	1080	420	38.9
B-15	0.429	1530	470	31.4
C-15	0.456	1250	420	33.6
J-1	0.495	1270	470	37.0
P-2	0.461	1920	610	31.8
P-3	0.461	2210	754	33.9

The above assumes a 0.5% grade, and Schmidt's figures for passenger car resistance (65-ton cars) throughout. Accordingly, the results differ somewhat from those given in Appendix B, where freight car resistances were used for the low speed, and the low speed was taken at 14 m.p.h. instead of 10.

However, it is shown that the high speed capacity is in the vicinity of one-third of the low speed capacity. Thus, if the passenger ratings be taken as one-third of the flat freight ratings the error will not be large. It would, of course, be preferable to draw up an entirely new set of figures, basing the locomotive classification on the high speed tractiive efforts, which may not be in the same ratios as the tractive efforts at low speed, due to the differing speed factors (as indicated in the table above). In this case, the process would be exactly the same as that used for freight ratings, using 45 m.p.h. available tractive efforts, and passenger car resistances for that speed.

It is not considered worth while to use adjusted ratings for passenger work, as car weights are comparatively uniform. In fact, it is quite common to use a car rating, instead of a tonnage rating, publishing the number of coaches an engine will handle, with a ratio between pullman cars and coaches, if they are to be used. That is, six pullmans would be considered the equal of seven coaches. As passenger trains must maintain their schedule much more accurately than freight trains, a larger margin of safety to allow for unforseen delays being made up, etc., should be allowed. This would amount to a margin of one car, at least; i.e. if an engine should handle seven cars, it should be listed for six. This would allow of an extra car being put into the train if necessary, would allow for one or two pullmans in place of coaches, and would give a margin to allow for making up lost time if necessary.

APPENDIX L

Form for Keeping Record of Freight Train Performance

On the following page is shown a form which would be suitable for the keeping of a running record of the performance of freight trains, keeping each train separately, so that a quick check can be made if desired.

As outlined in the text of this thesis, it is desirable to break many of the runs into two or more portions, for greater ease in keeping track of the percentage of rating handled. This is the reason for the item "Sheet No." on the form.

In the event that the run is over a section of the road which has no adjusted tonnage ratings established, the word "Adjusted" would be crossed out in the heading, and the space for car factor would be left blank. The ratings entered in the space provided in the heading should be the limiting single engine rating for the portion of the run covered by the sheet.

Most of the column headings are self-explanatory. In the column headed "Total Rating" should be entered each day the limiting rating applying to the day, depending on the power used. This would be the sum of the ratings of the principal and helper engines, if that becomes the limiting rating. The entry for the column headed "Adjusted Tons" consists of the actual tons plus the car factor times the number of cars.

Train No.__________

FREIGHT TRAIN PERFORMANCE, MONTH OF ________________

Sheet No.____ From ____________To____________

Rating - 200 class________Adjusted Tons   Car Factor_________
175 class________ " "
115 class________ " "
___ class________ " "

Schedule time (Minutes)_______________

Date	Prin. Eng.		Helper		Helped		Total	No.	Tons		Time	Gain or Loss	
	No.	Class	No.	Class	From	to	Rating	Cars	Act	Adj			
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
Total													

Percentage of Rating Utilized___________

Remarks:

In the column headed "Time" is entered the actual running time for the day, and the columns headed "Gain or Loss" is for the number of minutes by which the train beat or exceeded its scheduled running time. Under remarks may be entered notes of any unusual delays, resulting in seriously large entries in the last column, or any other special incidents.

Probably it would be advisable to make the form on "Legal Length" paper, allowing more space per line for the entries in the main body of the form. If the form is on 8 1/2" by 13" paper, there is room for 1/4" per line in the body, with plenty of room for remarks at the bottom. This would give room for double entries of helpers, if two are used, etc.

If desired the form could be printed in Hektograph ink, and copying ink could be used for the entries. This would permit of several copies being made at the end of the month, for distribution to Superintendents, yard masters, etc.

The following page shows the form filled out with the data for PM-1 as given in Appendix M.

Train No. PM-1

FREIGHT TRAIN PERFORMANCE, MONTH OF November, 1930

Sheet No. 3 From E. Deerfield To McVille

Rating - 200 class 2801 Adjusted Tons   Car Factor 5
175 class 2491 " "
115 class 1665 " "
100 class 1415 " "

Schedule time (Minutes) 345

Date	Prin. Eng.		Helper		Helped		Total	No.	Tons		Time	Gain or Loss	
	No.	Class	No.	Class	From	to	Rating	Cars	Act	Adj			
1	4017	200	2670	115	E.D.	E.Por	4466	80	3001	3401	279	66	
2	4000	200	2660	115	"	"	4466	75	3370	3745	245	100	
3	4017	200	3018	175	"	J'ville	5292	67	2372	2707	237	108	
4	3028	200					2801	66	2175	2505	321	24	
5	4017	200					2801	79	2410	2805	245	100	
6	3022	175	2670	115	"	N.Ad.	4158	99	3166	3661	304	41	
7	3021	200	2732	115	"	E.Por.	4466	93	2985	3468	279	66	
8	3005	175	2720	115	"	N.Ad.	4158	87	3115	3550	328	17	
9	4017	200					2801	68	2136	2476	334	11	
10	3001	200	3009	175	"	McV.	5292	80	3234	3634	270	75	
11	4022	200					2801	77	2217	2602	221	124	
12	4017	200					2801	40	1126	1326	189	156	
13	3017	200					2801	69	2289	2634	295	50	
14	3016	200	2679	115	"	E.Por	4466	91	2700	3155	255	90	
15	3019	200					2801	68	2438	2778	327	18	
16	3026	175	2717	115	"	"	4158	88	3156	3596	225	120	
17	4012	200	3028	200	"	McV	5602	57	2442	2727	210	135	
18	4017	200					2801	35	1143	1318	205	140	
19	3021	200					2801	55	1566	1841	225	120	
20	4017	200					2801	64	2109	2429	200	145	
21	3021	200	2667	115	"	E.Por	4466	97	2994	3479	233	112	
22	4003	200	2605	100	"	"	4216	103	3003	3518	252	93	
23	4002	200	2703	115	"	McV	4466	110	2928	3478	284	61	
24	4017	200	4003	200	"	"	5602	67	2140	2475	197	148	
25	3011	175					2491	37	1135	1320	203	142	
26	3002	175					2491	60	1924	2224	237	108	
27	3005	175	2733	115	"	"	4158	87	2377	2812	236	109	
28	3027	—	—	—	—	—	—	—	—	—	—	—	—
29	3022	175					2491	49	1950	2195	230	115	
30	3002	175	2677	115	"	N.Ad	4158	81	3016	3421	304	41	
31	—												
Total	—	—	—	—	—	—	109073	2129	70627	81272	7370	2635	—

Percentage of Rating Utilized 74.51

Remarks:

Ave. running time 254 min.

Train delayed by wreck on 28th, so data did not appear on daily report.

APPENDIX M

Tabulation of Data of Performance of PM-1 for the Month of November, 1930

The tables on the following pages show the performance of train PM-1, operating from Rigby, Maine, to Mechanicville, New York, during November, 1930. The run is divided into three sections, the first being from Rigby to Ayer, the second from Ayer to East Deerfield, and the third from East Deerfield to Mechanicville. The two intermediate points are those at which tonnage is dropped or picked up, as indicated by the schedule, presented on page .

In the tables, the first column gives the date; the second the number of the principal engine; the third, the number of the helper, if any; the fourth the points between which a helper was used; the fifth the rating class of the principal engine; the sixth, the class of the helper; the seventh, the number of cars in the train; the eighth, the actual tonnage; the ninth, the adjusted tonnage; and the tenth, the adjusted rating, allowing for the helper.

PM-1 Rigby to Ayer

Date	Prin. Eng.	Helper	Between		Class Prin.	Class Helper	Cars	Act. Tons.	Adj. Ton.	Rating
1	4004				200		86	3157	3845	4820
2	3000				200		103	3997	4821	4820
3	4001				200		83	3175	3839	4820
4	3019				200		51	1599	2007	4820
5	3026				175		84	2752	3424	4332
6	2698	2634	Riby	Ayer	115	100	122	3982	4958	5278
7	3029				175		92	3215	3951	4332
8	4000				200		90	3124	3844	4820
9	3021				200		84	3135	3807	4820
10	3001				200		102	3804	4620	4820
11	4014				200		79	2416	3048	4820
12	3001				200		83	2606	3270	4820
13	4014				200		94	3286	4038	4820
14	4013				200		112	3644	4540	4820
15	4014				200		116	4120	5048	4820
16	4020				200		108	3916	4774	4820
17	3021				200		85	3165	3845	4820
18	2037				175		55	1867	2307	4332
19	3018				175		98	3509	4293	4332
20	4010				200		87	2853	3549	4820
21	3025				200		103	3530	4354	4820
22	3005				175		106	3478	4326	4332
23	4001				200		95	3346	4106	4820
24	4006				200		107	3645	4502	4820
25	4011				200		64	2109	2621	4820
26	4008				200		89	2945	3657	4820
27	3017				200		100	3560	4360	4820
28	3027				175		76	2989	3597	4332
29	4012				200		70	2486	3046	4820
30	4001				200		103	3777	4601	4820

Total tons from Rigby . . . 95247
Total Cars from Rigby . . . 2717
Total adjusted tons 116998
Potential adjusted tons . . 142130
Percentage of rating . . . 82.32

PM-1 Ayer to East Deerfield

Date	Prin. Eng.	Helper	Between		Class Prin.	Class Helper	Cars	Act. Ton.	Adj. Ton.	Rating
1	4017	?	Fitchburg	Gardner	200	230	95	3756	4136	4787
2	4000	2649	Ayer	Gardner						
		2643	Fitchburg	Gardner	200	230	93	3604	3976	4787
3	4017	3018	Ayer	E.Deer.	200	175	63	2281	2533	4132
4	3028	2667	Ayer	Gardner	200	115	81	2675	2999	3487
5	4017	2665	Fitchburg	Gardner	200	115	77	2374	2682	3487
6	3022	2708	Ayer	Gardner						
		2729	Fitchburg	Gardner	200	230	111	3758	4202	4787
7	4017	2677	Ayer	Gardner						
		2668	Fitchburg	Gardner	200	230	107	3819	4247	4787
8	3005	2698	Ayer	Gardner	200	230	106	3950	4374	4787
		2668	Fitchburg	Gardner						
9	4017	2668	Fitchburg	Gardner	200	115	79	2639	2955	3487
10	3001	3009	Ayer	E.Deer.	200	175	80	3234	3554	4132
11	4022				200		63	1950	2202	2186
12	4017				200		45	1354	1534	2186
13	3017	2712	Fitchburg	Gardner	200	115	75	2705	3005	3487
14	4017	2731	Ayer	Gardner	200	115	100	3069	3469	3487
15	3019	2678	Ayer	Gardner						
		2684	Ayer	Gardner	200	230	108	4028	4460	4787
16	4017	3028	Ayer	E.Deer.	200	200	100	3592	3992	4372
17	3011	2731	Ayer	Gardner	175	115	76	2709	3013	3246
18	4017				200		56	1905	2129	2186
19	3021	2642	Ayer	Gardner	200	115	82	2991	3319	3487
20	4017	2703	Ayer	Gardner	200	115	89	3060	3416	3487
21	3021	2712	Ayer	Gardner						
		2668	Fitchburg	Gardner	200	230	103	3610	4022	4787
22	4017	2717	Ayer	Gardner						
		2710	Fitchburg	Gardner	200	230	107	3956	4024	4787
23	4002	2668	Fitchburg	Gardner	200	115	82	2862	3190	3487
24	4017	4003	Ayer	E.Deer.	200	200	97	3198	3856	4372
25	3011	2668	Fitchburg	Gardner	175	115	60	2059	2299	3246
26	3002	2708	Fitchburg	Gardner	175	115	78	2639	2951	3246
27	3005	2641	Ayer	Gardner						
		2710	Fitchburg	Gardner	175	230	103	3754	4166	4547
28	3027	2708	Fitchburg	Gardner	175	115	61	2406	2650	3246
29	3022	2668	Fitchburg	Gardner	175	115	68	2594	2866	3246
30	2674	2703	Ayer	Gardner						
		2668	Fitchburg	Gardner	115	230	73	3416	3708	3902

Total cars 2518
Total flat tons . 89587
Total adj. tons . 99659
Total pot.adj.tons 114437

% of rating 87.08

PM-1 East Deerfield to Mechanicville

Date	Prin. Eng.	Helper	Between		Class Prin.	Class Helper	Cars	Act. Ton.	Adj. Ton.	Rating
1	4017				200	115	80	3001	3401	4466
2	4000	2660	E. Deer.	E. Portal	200	115	75	3370	3745	4466
3	4017	3018	E. Deer.	Johnson	200	175	67	2372	2707	5292
4	3028				200		66	2175	2505	2801
5	4017				200		69	2410	2805	2801
6	3022	2670	E. Deer.	No. Adams	175	115	99	3166	3661	4158
7	3021	2732	E. Deer.	E. Portal	200	115	93	2995	3460	4466
8	3005	2720	E. Deer.	No. Adams	175	115	87	3115	3550	4158
9	4017				200		68	2136	2476	2801
10	3001	3009	E. Deer.	McVille	200	175	80	3234	3634	5292
11	4022				200		77	2217	2602	2801
12	4017				200		40	1126	1326	2801
13	3017				200		69	2289	2634	2801
14	3016	2679	E. Deer.	E. Portal	200	115	91	2700	3155	4466
15	3029				200		68	2438	2778	2801
16	3026	2717	E. Deer.	E. Portal	175	115	88	3156	3596	4158
17	4012	3028	E. Deer.	McVille	200	200	57	2442	2727	5602
18	4017				200		35	1143	1318	2801
19	3021				200		55	1566	1841	2801
20	4017				200		64	2109	2429	2801
21	3021	2667	E. Deer.	E. Portal	200	115	97	2994	3479	4466
22	4003	2605	E. Deer	E. Portal	200	115	103	3003	3518	4216
23	4002	2703	E. Deer.	McVille	200	115	110	2928	3478	4466
24	4017	4003	E. Deer.	McVille	200	200	67	2140	2475	5602
25	3011				175		37	1135	1320	2491
26	3002				175		60	1924	2224	2491
27	3005	2733	E. Deer.	McVille	175	115	87	2377	2812	4158
28	3027				W	W	W	W	W	W
29	3022				175		49	1950	2195	2491
30	3002	2677	E. Deer.	No. Adams	175	115	81	3016	3421	4158

Total Cars 2129
Total Actual Tons 70627
Total Adjusted Tons 81272
Potential Adjusted Tons . .109073
Percent of Rating 74.51

W - Wreck at Charlemont resulted in so great a delay that data did not appear in daily report.

PM-1 Summary

	Act.Tons	Adj. Tons	Pot.Tons	% of Rat.
Portland to Ayer	95247	116998	142130	82.32
Ayer to East Deerfield	89587	99659	114437	87.08
East Deerfield to McVille	70627	81272	109323	74.34

Rigby to Ayer:

On one day the train exceeded the adjusted rating by 224 tons. On this day, it lost only 40 minutes on its schedule, and it did worse than that on many other days. On 4 other days the tonnage was within one car of the rating. However, on 15 days, a 200-class engine was used when a smaller one would have sufficed, while on 2 of these days a 115 class would have handled the train. One of the days when a 175-class engine was used, a 100-class would have sufficed.

Ayer to East Deerfield:

On one day the rating was exceeded by a few tons, and on two other days it was closely approached. In no case was a helper used unnecessarily, but there were many days when a 200-class was used as a principal engine when a 175-class would have sufficed, or when smaller helpers could have been used. On ten days two 115-class helpers were used. In every case one of these could have been replaced with a 100-class or smaller engine.

East Deerfield to McVille:

On one day the rating was exceeded by a few tons, and on one other day it was closely approached. However, 3 times helpers were used unnecessarily, although it appears that they were used rather than running them light from East Deerfield to McVille. This represents 6.62% of the 25.66% of potential tonnage unused. However, there were several instances of 200-class engines being used when smaller would have sufficed.

Following are the schedule and consist of PM-1, taken from Symbol Book #18:

Rigby	Lv.	9.45 P.M.
Ayer	Ar.	3.15 A.M.
Ayer	Lv.	4.30 A.M.
E. Deerfield	Ar.	8.00 A.M.
E. Deerfield	Lv.	8.45 A.M.
Mechanicville	Ar.	2.30 P.M.

Consist:	Cars for and via D&H-Mechanicville; Rutland-Bellows Falls; and NYC - Troy, filling out with cars for and via Ayer.
Ayer:	Pick up cars for and via D&H-Mechanicville and NYC, Troy. Connects with A-X 1 and L-R - 1.
E. Deerfield:	Drops all but cars for and via D&H, picking up cars for and via D&H. Connects with B-T 1.
Mechanicville:	Connects with D&H trains M-B 6 - 6.30 P.M., M-W 4 - 10.00 P.M.