What's the Answer?

Track Capacity

"Based on your experience, what would you say is the maximum number of trains that can be handled under practical conditions over a single-track division of say 60 to 100 miles?"

Depends Upon Method of Dispatching

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Many factors are to be considered in arriving at an answer to this question, among which are grade and curvature characteristics of the line; number, location and capacity of passing sidings; number of block offices; rating and speed of locomotives; and the number of passenger, perishable freight and drag freight trains and their spacing, during the 24-hour period.

In 1923 we made a study of a 42-mile section of single track on a 136-mile division. This 42-mile section was operated at that time under a manual block signal system; there being 14 block offices located at lap sidings. The average length of a block was 4.08 miles, the shortest block being 1.35 miles, and the longest, 5.45 miles.

At that time we operated a total of 59 trains in this territory, 35 being freight trains and 24 being passenger trains. Only 22 of the freight trains and 16 of the passenger trains covered this entire distance, so that really only 38 passenger and freight trains covered this entire 42-mile section. Even with the liberal use of No. 19 train orders, the delays in this territory were excessive, and while it was quite possible to operate a large number of trains over this territory under these intensified methods of operation, the cost of operation was high.

Diagrammatic charts of this section were made, showing trains as they were actually operated under the above conditions. Curves were then plotted on this chart showing what the train operation would be if a C.T.C. system were in use on this same section. Proposed trains were then plotted on the same chart in order to attempt to determine the capacity of this single-track section with a C.T.C. system installed.

Under this method of procedure, it was found that, after operating the 59 freight and passenger trains originally plotted on the chart, 35 additional freight trains could be operated over the same territory with the C.T.C. system without excessive delay and at a higher average speed than the first 35 freight trains were operated with the manual block system. The additional 35 freight trains were considered as being reasonably spread over the 24-hour period.

To Be Answered in a Later Issue

(1) In C. T. C. installations, what special equipment and what precautions are required to avoid the transmission of indications when the maintainer is testing OS track circuits?

(2) What are your instructions regarding the division of responsibility between signal maintainers and section foremen in the matter of maintaining spring switches?

(3) What are the advantages or disadvantages of using glass insulators, as compared with porcelain insulators, for signal-control open-line circuits? For a-c. power lines up to 440 volts?

(4) What is your opinion regarding the use of train recorders in automatic interlocking plants?

Thus, it is evident that 59 trains, of which 35 were freight and 24 passenger, caused excessive delays and high operating costs even under intensified methods of manual block operation. It is also evident that, by installing centralized traffic control, not only the excessive delays would be eliminated, but sufficient capacity would be available to add 35 additional freight trains with less delay than encountered under the manual block system.

This leads us to believe that approximately 90 trains, of which 25 per cent are passenger trains, can be efficiently and economically operated over this single track during a 24-hour period, if properly signaled.

Only a Rough Approximation Is Possible

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The maximum number of trains that may be dispatched simultaneously over a single-track section of railroad is equal to the number of stretches between passing tracks. For continuous occupation this would represent a number of train-hours equal to 24 times the number of stretches. It is not feasible to spread the traffic uniformly over the 24-hour period; the trains must be dispatched as they arrive at each end of the district. Nor is it practical to reoccupy each section immediately after it is vacated. Hence, the maximum practical occupation would be considerably less than the maximum train-hours just referred to.

An analysis of a single-track line in valley territory during peak-day performance indicated a load factor of 62 per cent; that is, the average use was only 62 per cent of the theoretical maximum. In another study where light helper movements were involved, the load factor was 73 per cent. The higher load factor in the helper territory is possible because of the greater flexibility of the light helpers whose movements may be adjusted as conditions dictate.

The number of trains that may be dispatched is then found by dividing the train hours by the average time through the district. The time of local or way freights occupied in actual switching may be disregarded if there is sufficient siding capacity to permit the free movement of all other trains.

Short of a detailed analysis of a particular locality, I would say that for a division of say 100 miles having 20 intermediate passing tracks, and therefore 21 stretches, with one local and four passenger trains per day, the practical capacity could be roughly estimated as follows:

		Train-Hours
Total occupation, 21x24x62 per cent		316
Less Local and Passenger Trains:		
Local train, 2x100 miles divided by 20 m. p. h.	10	
Passenger train, 8x100 miles divided by 40 m. p. h.	20	
Total Local and Passenger		30
Balance for Through Freight		286

Assuming a speed of 12½ m. p. m., the number of through freight trains would be 286x12½ divided by 100, or 36 trains. The capacity under these assumptions would be:

Local freight	2
Passenger	8
Through freights	36
Total trains	46

The low speed of 12½ m. p. h. for through freight trains is estimated on account of the many stops required on days when the practical capacity is reached; and local freight is figured at a higher rate because these trains are commonly dispatched at times when the interference to other trains is the least.

This estimate contemplates the capacity that may safely be counted upon during several consecutive days and not the ultimate that may be obtained on single days.

Centralized Traffic Control Increases Track Capacity

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As many as 54 trains a day have been run over our single-track C.T.C. section and the dispatcher stated that even more could have been handled. A study of this section, including the logging of freight-train runs and the charting of schedules to line capacity (See report of Economics Committee—Signal Section—Advance Notice, March, 1924, Page 404) indicated that, other things being equal, the daily capacity under C.T.C. would be about 50 freight trains in addition to 12 passenger trains and 2 local freights, or a total of 64 trains, with an average freight running time of 4.06 hours. The computed capacity at 12 m.p.h., based upon the method outlined below, is about 12 passenger trains, 2 local freight trains, and 58 through freight trains, or a total of 72 per day. This may be considered as the theoretical capacity. The first case, 64 trains, may be considered as the practical capacity to be realized in service on this section of railroad, at an average freight-train speed of 12 m.p.h. This sub-division, however, has four non-interlocked railroad crossings at which trains must make the safety stop, and this condition limits the capacity of the entire district and explains why the calculated and the charted methods do not match as to capacity and as to running time. Interlocking these four railroad crossings should bring the two results close together. If all cases were like this, we could assume that seven-eighths of the computed capacity would be the actual capacity (64/72). Prior to C.T.C., a test showed the average running time of 4.85 hours for 26 freight trains, and 4.5 hours for 21 freight trains. After C. T. C. had been installed, the average running time per freight train was 3.4 hours for 20 2/3 freights, with an average speed of 11.9 m.p.h.

A quick computation of the capacity of a single track may be made with a fair degree of accuracy for any given territory, if the conditions, such as track layout, free-running train-speed, grades and operating arrangement, are known. For example, consider the following case: The length of a single-track subdivision is 100 miles; there are 25 passing tracks; the maximum distance between adjacent passing tracks is 5 miles; freight-trai speed is 20 m.p.h.; there are 10 passenger trains each 24 hours; the average speed of passenger trains is 40 m.p.h.; the number of trains is approximately the same in both directions; the track layout and operating scheme, etc., are such that there is no restriction to the free running of the trains except interference between them on account of meeting or passing one another.

The question is: How many freight trains can be operated on this subdivision, in 24 hours? At maximum track capacity, a train will meet an opposing train at each passing track. If it is attempted to run more trains than this, the road will become blocked. At capacity, trains may follow one another at twice the distance between the two adjacent passing tracks farthest apart in point of time (10 miles), and at 20 m.p.h., the average speed, this means they may follow each other into the section from each end one-half hour apart or four trains per hour input, two from each end per hour. Necessarily, the output should be the same, making a total of 96 freight trains per day if everything works smoothly and no passenger trains are run.

The average running time for each freight train will be five hours, and the train-hour capacity at this speed and for this passing-siding arrangement will be 96 times 5, or 480.

The ten passenger trains will each require 2½ hours for the run, or a total of 25 train-hours per day. Deducting this from the total of 480 leaves 455 train-hours for use in operating freight trains. If each one requires 5 train hours this will provide a possibility of 91 freight trains or a total of 91 freight and 10 passenger trains, or 101 trains in 24 hours.

However, the average freight-train speed of 20 m.p.h. would require an average speed while in motion of about 60 m.p.h., on account of the time lost in making meets. Where train orders, manual block, and hand-operated passing-track switches are in use, the average time lost per train meet would be about 20 or more train minutes, or not less than 10 minutes per train. At 20 m.p.h. the running time from passing track to passing track (5 miles) is about 15 min. and the delay time is 10 min. per train per passing track. Therefore, only 5 min. are left to run the distance of 5 miles between passing tracks, which accounts for the 60-mile speed when actually the average is only 20 miles. While this speed under present operating conditions on most railroads is out of the question, this extreme case is purposely assumed in order to show the great advantage of reducing time lost in making meets and passes. It also shows that 100 trains in 24 hours could be operated on single track with freight trains making an average speed of 20 m.p.h., if no time is lost in making meets as against an average speed of 60 m.p.h. while running, if 10 train-minutes per train are lost in making each meet.

This capacity also presupposes the absence of train accidents and any other operating restrictions or practices which would interfere with the free movement of trains. If manual block is in use and it requires an absolute block surrounding passenger trains, this will necessarily reduce the 24-hour capacity on account of time lost to freight trains going into clear for a full manual block ahead of the passenger train and staying in the clear for a full manual block behind the train. Necessarily such movements on the part of one freight train will hold back all following and opposing freight trains at least as long as it takes the passenger train to run 10 miles—that is, at least 15 minutes. Since there would be about 20 freight trains in the section (at full capacity) this alone would cause at least 300 minutes or 5 train hours delay. It will be noted that this one pass cuts down the road capacity about one freight train each 24 hours. With automatic block or no block, instead of manual block, this delay time is necessarily shortened and the road capacity increased. It will also be noted that almost any condition that holds up capacity running 15 minutes in 24 hours cuts out one freight train. This may be due to non-interlocked crossings, water stations, local freights not in the clear, delay for orders, grades, etc., etc.

The use of centralized traffic control with power-operated passing-track switches should, according to our experience, show the effect of more than cutting in half the time lost at meeting points in capacity running. With a 10 minute loss at each of the 25 passing tracks, a freight train would lose 250 minutes, or more than four hours out of the five hours elapsed time to make the run, in making meets, or about 2.5 minutes per freight train mile. In actual cases so far reported in connection with centralized traffic control operation, the maximum time saved per freight train mile has been about 1.8 minutes. In none of these cases has the single-track capacity been reached and therefore it appears quite probable that the calculated values and the actual values of minutes saved per freight train mile will check each other—this for the reson that as more trains are run, approaching capacity, more time is lost and therefore it is possible to reclaim more by the CTC process.

In the above example suppose we assume that all conditions remain the same except that CTC is installed, superseding time-table and train-order operation, and train-crew operation of passing-track switches. The time lost per meet, as set forth above, should be reduced from about 10 minutes to about 5 minutes per train. At an average speed of 20 m.p.h. it will require 15 minutes to run the distance (5 miles) between adjacent passing sidings. Losing 5 minutes in making the meet leaves 10 minutes to make the run of 5 miles, which will require 30 m.p.h. instead of 60 m.p.h. train speed when 10 minutes per train per meet were lost in capacity running. This again shows how much the pressure on train speed is relieved by saving only 5 minutes per train per meet in capacity running. With the above mentioned change to CTC the 24 hour capacity of freight and passenger trains will remain 101 as before. It will be seen that this is much more in line with the present possibilities of freight train speeds and train loads, although it would still be difficult to make this 30-mile average speed from stop to stop in five miles unless the train loading is quite light or some "non-stop" meets are made as in CTC.

If business is such that trains may be fleeted so that 20 may be run in one direction and the operation then reversed and 20 sent in the other direction, assuming no passenger trains, and assuming the average speed is 20 m.p.h, trains may follow each other at about two mile intervals under clear signals, which would mean at 6 minute time intervals. Twenty trains in the fleet would require a speed of 120 minutes or two hours. At 20 m.p.h. the running time would be 10 hours, a total spread of 12 hours from the time the first train left the entering end until the last train arrived at the departure end. If the return fleet started immediately, two such fleets could be run in 24 hours, or a total of 40 trains per day. On such single track there would theoretically be no need for passing sidings, however, on account of break-downs, train accidents, and other difficulties the lack of passing sidings might at times cause serious traffic interruptions.

By the same reasoning, if these fleets were operated at 30 m.p.h., trains could follow each other every four minutes (2-mile headway) but the spread of the fleet would be 1 1/3 hours. The running time would be 3 1/3 hours and the elapsed time before turning, 4 2/3 hours. On this basis, if everything goes well, the 24-hour capacity would be about 103 trains.

It will be seen in both of these cases that the cost of road would be considerably less to secure the same theoretical capacity but actually it would be more difficult to realize that capacity on account of the lack of facilities, such as passing sidings, to make it possible to relieve any train accident if one should develop, as a wreck train could not get to a disturbance in the middle of the line until all trains on one side or the other had gotten out of the way. If the wreck train happened to be on the right end (ahead of the wreck) at the time it would help matters but all trains behind the wreck would still be badly tied up.

If grades, water stops on the main track, train-order delays, manual block delays, or other time losing elements are involved, they will slow up freight train movement and will have the effect of increasing the running time for each train and will set the ruling time for the sub-division if they occur between the two passing sidings which are the greatest distance (in time) apart. If there is more than one grade, the slower of the two will set the pace for the sub-division. If traffic is practically all in one direction, with the down grade, such grade will speed up the whole operation rather than retard it and produce the effect of shortening the running time between the two passing tracks in which the grade occurs in which case some other pair of passing tracks may determine the ruling time for the sub-division.

In capacity running of balanced traffic it will be seen that it is difficult to move a local freight from station to station unless it is done at a loss of running time of through freight. Even then such local must have some place other than the passing track upon which to clear the main track if it stays more than five minutes (the allotted time loss) at any meeting point.

It will also be seen that the best average running time per train will occur when the capacity number of trains is being operated and the running time will decrease as the number of trains decreases. This is on account of reducing the time lost due to meeting and passing of trains, etc. The number of meets varies approximately with the square of the number of trains, therefore, with a reduction in the number of trains, the time lost on account of meets alone is reduced very rapidly.

From a study of the foregoing I think that one can, with a fair degree of accuracy, answer the question as to the practical capacity of a given piece of single track line under given conditions.

Modern Equipment and Dispatching Methods Recommended

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The traffic capacity of a railroad depends upon several factors, including organization; motive power and equipment; track, yard, siding and terminal facilities; grades and curvature; train speed and spacing; classes of trains; coal and water stations; signaling and interlocking facilities; method of directing train movements; availability of traffic; and economy. Track capacity has been fully discussed in the reports of the Signaling Practice Committee, R.S.A. Proceedings, Vol. 12, 1915, pages 327-339 and Vol. 13, 1916, pages 211-234, and the report of Committee 21, A.R.E.A., Economics of Railway Operation, Vol. 32, Bulletin 334, Feb. 1931, pages 652-692.

The records of several railroads actually show short sections of single-track, 4 to 25 miles in length, with 50 to 87 trains per day and longer sections of single track, 25 to 97 miles in length, with 50 to 70 trains per day. On one installation, 23.6 miles in length, 10 trains were operated in a three-hour period, or at the rate of 80 trains per day, but more trains could have been dispatched in the same period without serious delay. In terminal and suburban areas, an actual operating capacity of 80 to 125 trains per track per day is not unusual, even though this capacity is based only on morning and evening rush-hour traffic conditions.

Therefore, it is my experience that a single-track division equipped with modern track and other facilities, and arranged for directing trains by signal indications by means of remote control or centralized traffic control, can economically handle 60 to 80 trains per day.

Exact Capacity Can Be Determined Only By Actual Demon tration

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Since I have never been confronted directly with this question of capacity, nor have I made a detailed study to determine the capacity of a given single-track line equipped with C.T.C., I can give only my personal opinion. I do not believe that there have been many C.T.C. installations which have been operated to within 60 per cent of their known or estimated capacity. Centralized-traffic-control installations have usually been instrumental in correcting difficult operating problems other than track-capacity problems, but at the same time there is no doubt that certain installations have forestalled the building of additional tracks. Unheard of accomplishments pertaining to train operation with C.T.C. equipment are performed daily. Recently, in a conversation with a signal engineer, I boasted of the fact that our operators perform six non-stop meets, in a certain territory, in a given 24-hour period. As usual, the first boaster hasn't a chance. I was informed that the accomplishment was nothing; that he, the other signal engineer, personally witnessed, on his single-track installation, two instances wherein one train passed another moving in the same direction, without stopping. Therefore, it is my opinion that the real capacity will never be determined except by actual demonstration. However, I would judge from experience that there would be no difficulty in, nor would any excessive delays result from dispatching 75 trains per 24-hour day on a 50-mile territory of single track equipped with C.T.C. where there were no extreme speed restrictions.

As to successfully accomplishing this performance on a 100-mile territory under the same operating conditions, I believe there would be a greater probability of approaching the capacity of the machine operator rather than of the track or apparatus. These opinions, as previously stated, are entirely personal, and are based on the unit wire system of C.T.C. where the response to various occurrences and happenings is instantaneous.

An Actual Problem on the Wabash

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The answer to this question as to the capacity of single track is applicable only to the particular section under consideration. The known capacity of a piece of single track must be derived by a study of that individual section. However, the method used to obtain this information may be used in general for solving the problem of capacity on any piece of single track.

Track capacity is affected by the number, location and length of passing sidings; grades and curvatures; number of block offices; block signals; yards; coal and water stations; station stops; rating and speed of locomotives; distribution and speed of traffic; etc. These factors when taken as a whole are so complex and have such a varying effect on traffic that individual consideration must be given to each case with due consideration to each factor.

Confronted with this very problem, we pursued the following method in arriving at a conclusion for a particular section of track: This section is 93 miles long. The grade is rolling with short grades ranging up to 0.8 per cent, one grade being 1.1 per cent. At one point there is a 5-deg. curve requiring a speed limit of 25 m. p. h., but at no other point is the curvature sharp enough to interfere with normal operation of trains. The stations with passing tracks averaged 4.8 miles apart. The line was equipped with automatic signals located approximately 1½ miles apart.

The traffic of 10 to 14 freight trains and 4 passenger trains each way daily, which made a total of from 28 to 36 through-train movements daily, sorely taxed the capacity of that section of track. The problem presented was to estimate the capacity of this section of the railroad if a centralized traffic control system were installed, assuming that all passing tracks were extended to hold capacity trains (125 cars) and that No. 20 turnouts were installed to permit moderate speed into and out of the passing tracks.

A dispatcher's train sheet was selected with 22 freight trains and 8 passenger trains, and from this information, together with the conductors' daily time slips, a graphic train sheet was prepared, showing the movement of trains as they were dispatched by written order.

The graphs were transposed to another chart to show the movement of the same trains as they would have