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THE PERFORMANCE OF RAILROAD TRACK SCALES

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A Statistical Study Based on 1000 Tests Made With Bureau of Standards' Track Scale Testing Equipment No. 3, from May 4, 1918, to July 1, 1922, With Specific Reference to the Application of Certain Tolerances as a Criterion for Grading Weighing Performance.

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INTRODUCTION

The matter of proper tolerances to be applied to the weighing performance of railroad track scales is one productive of much discussion. Certain tolerances have been in use for a number of years and their application is generally conceded to have wielded a great influence for good in commercial weighing. At the time they were drawn there was no comprehensive body of test data so correlated as to enable one to frame conclusions, and thus the tolerances naturally grew out of the experience of practical men who knew conditions as they existed at that time and of men who had definite ideas as to what the conditions should be. In the process of time, since the issuance of these tolerances, much pertinent data has accumulated and is now available for study. Specifically it is the purpose of this paper to present, in succinct form, data accumulated in the Bureau of Standards' investigation of track scales in order that competent minds may form judgments towards such final conclusions as the circumstances justify.

TOLERANCES IN CURRENT USE

Tolerances originating from two sources are applied in grading track scale weighing performance. One is that used by the Bureau of Standards in grading weighing performance to the exclusion of all other methods and set forth in Bureau of Standards Forms 565 and 566, "Supplements to Track Scale Reports"; others appear in Section III, paragraph 5, American Railway Association "Rules for the Location, Maintenance, Operation and Testing of Railroad Track Scales". For the sake of convenience a statement of these tolerances is given in the following paragraphs. These will hereafter be designated as the "Bureau of Standards" tolerance and the "American Railway Association" or "A. R. A." tolerances, respectively.

Bureau of Standards' Tolerance:

Forms 565 and 566, "Supplements to Track Scale Reports" relating to the error of weighing and tolerance to be applied read as follows:-

> "Maximum Indicated Error of Weighing - Since the errors found with the test truck in general correspond to those that would be produced by one truck of a freight car, it is apparent that the largest algebraic sum of any two errors found that may be duplicated by the two trucks of a freight car corresponds to a possible error of weighing a freight car whose gross weight is twice the weight of the test load, or instead, the mean of these two errors may be used if the weight of the freight car is considered equal to the weight of the test load.

"Since the distances between the two trucks of freight cars of various types differ greatly, any two of the normal positions of the test truck on the scale except those which are at the same section, such as 2R and 2L, etc., may be duplicated by the trucks of some car, but on account of the improbability that the two trucks of a car can assume a position on the same span of the scale the Bureau does not use in the computation of the maximum error two errors found on opposite ends of the same span.

"Therefore, in computing the maximum indicated error of weighing of the scale for the load applied, the largest mean of any two errors corresponding to normal positions of the test truck not closer together than similar points on adjacent spans is used."

"Tolerance - A tolerance of two-tenths of one per cent (0.20 per cent) on the 'maximum indicated error of weighing' for any test load applied to the scale has been adopted by the Bureau. A tolerance of 0.20 per cent applied to a load of 100 000 pounds amounts to 200 pounds. The test loads used by the Bureau are in no case less than 40 000 pounds."

American Railway Association Tolerance:

Section III, paragraph 5, American Railway Association "Rules for the Location, Maintenance, Operation, and Testing of Railroad Track Scales" reads as follows:

"Adjustment: Track scales should be kept in the closest possible adjustment, and a scale should be considered inaccurate when it cannot be adjusted, and such adjustment maintained to within two (2) pounds to one thousand (1000) pounds, in excess or deficiency, when distributed test is made with two or more test loads. When only concentrated sectional tests are made, the maximum error for any position of the test load should not exceed three (3) pounds to each one thousand (1000) pounds of test load used."

DESCRIPTION OF BUREAU OF STANDARDS' TESTING EQUIPMENT

Bureau of Standards' track scale testing Equipment No. 3 consists of two cars, one weighing 40 000 pounds and the other weighing 80 000 pounds. The body of each car is cast in one piece and provided with suitable means for carrying adjusting material and necessary supercargo. The cars have a seven foot wheel base. Each car is mounted on two pairs of wheels, the axle of each pair of wheels being provided with roller bearing journals to facilitate movements during testing.

DESCRIPTION OF TEST

Both cars of equipment No. 3 are always used in making a test, that is to say, the prescribed routine consists of applying the 40 000 pound car in a certain manner specified below, of applying the 80 000 pound car in a similar manner, and then usually applying both cars at the same time.

Test Routine:

Briefly the test routine for a four section scale is as follows:

Points are marked on the deck directly over the center of each section, (i.e., directly over the center of each main lever load pivot) which are numbered 1, 2, 3, and 4 beginning at the left hand end of the deck as the observer stands at the beam and faces the deck. If the ends of the live rails do not reach to the center of the end sections, i.e., if the scale has a "protective overhang", points 1 and 4 are marked about three inches from the ends of the live rails.

The beam is then balanced and the 40 000 pound car moved on the scale, say on the No. 1 end, until the rear pair of wheels is directly over position No. 1. The car is then weighed and the results recorded as the weight of the car at position 1R. The car is moved up until the front pair of wheels is directly over position No. 2, is then weighed and the result recorded as the weight of the car at position 2L. The car is then moved up until the rear pair of wheels is directly over position No. 2, is then weighed and the result recorded as the weight of the car at position 2R. Progress across the scale is continued in this manner until a position is reached when the front pair of wheels is directly over position No. 4, for which a result is recorded as the weight of the car at position 4L. The car is then run off the scale, the condition of the balance noted and the balance corrected if necessary. The car is then run across the scale and results recorded as above in the reverse order.

The above process is repeated with the 80 000 pound car. In all 12 observations are made on the weight of each car as indicated by the scale. Both cars are then placed on the scale in such positions as circumstances justify and the results recorded. Adjustments may be then made if necessary. It is the rule not to make any adjustments or correct any conditions until the completion of the test.

A typical test record follows:

Table I
Track Scale Test Record Made With Bureau of Standards' Equipment No. 3

First Run

Load on platform lb.	Position of load	Beam readings lb.	Error lb.	Sensibility reciprocal lb.
0	---	0	---	40
40 000	1R + 12	39 980	-20	
"	2L	40 020	+20	
"	2R	40 040	+40	
"	3L	40 040	+40	
"	3R	40 020	+20	
"	4L - 12	40 010	+10	
0	---	0	---	

Second Run

Load on platform lb.	Position of load	Beam readings lb.	Error lb.	Sensibility reciprocal lb.
0	---	0	---	
40 000	1R + 12	39 990	-10	
"	2L	40 030	+30	
"	2R	40 040	+40	
"	3L	40 040	+40	
"	3R	40 020	+20	
"	4L - 12	40 010	+10	
0	---	0	---	

Third Run

Load on platform lb.	Position of load	Beam readings lb.	Error lb.	Sensibility reciprocal lb.
0	---	0	---	
80 000	1R + 12	79 980	-20	50
"	2L	80 060	+60	
"	2R	80 080	+80	
"	3L	80 060	+60	
"	3R	80 040	+40	
"	4L - 12	80 020	+20	
0	---	0	---	

Fourth Run

Load on platform lb.	Position of load	Beam readings lb.	Error lb.	Sensibility reciprocal lb.
0	---	0	---	
80 000	1R + 12	79 980	-20	
"	2L	80 060	+60	
"	2R	80 060	+60	
"	3L	80 060	+60	
"	3R	80 040	+40	
"	4L - 12	80 020	+20	
0	---	0	---	

Fifth Run

(Combined Load Test)

Load on platform lb.	Position of load	Beam readings lb.	Error lb.	Sensibility reciprocal lb.
0	---	0	---	
120 000	1R+12(80 000) 4L--12(40 000)	120 000	0	
120 000	1R+12(80 000) 3R (40 000)	120 000	0	
120 000	1R+12(80 000) 3L (40 000)	120 020	+20	
120 000	1R+12(80 000) 2R (40 000)	120 020	+20	
0	---	0	---	

SOURCE OF DATA

The data herein submitted were compiled from the results of 1000 tests of railroad track scales made with Bureau of Standards' Equipment No. 3 from May 1918 when the equipment was put into service until July 1, 1922. The tests were distributed over a large number of different railroads. Both railroad-owned and industry-owned scales are represented.

CLASSIFICATION OF SCALES

For the purpose of this study, scales are separated into four classes, this classification being made according to their mechanical condition as reported by the inspector making the tests., viz., Good scales, Fair scales, Deficient scales, and Indeterminate scales.

Good Scales:

In the class Good Scales were placed all those which were in good condition of repair and in a general way conformed to the requirements of Bureau of Standards' Circular 83, Specifications for the Manufacture and Installation of Railroad Track Scales. Minor deficiencies such as the live rails being a few inches shorter than specification requirements, or lack of a ventilator system, or refinements of a similar nature not intimately associated with the weighing function, were not considered as sufficient grounds for exclusion from this class. A few five section scales are included.

Fair Scales:

The class, Fair Scales, includes all those scales which were in a reasonably good condition of repair but whose design, or construction, did not meet the Circular 83 specifications in some notable feature, or scales which, while not in proper condition of repair, were not in such a condition as to justify placing them in the deficient class next following. A very light scale, but well installed and maintained might be classed as a Fair scale. Also a scale of adequate design and installation with slightly worn pivots, or one loose main lever, or similar defects of a minor nature might be classed as a Fair scale.

Deficient Scales:

The class, Deficient Scales includes all those which had some notable inherent defect that prevented proper performance, such as binding of parts, excessive wear, timber construction under the deck, inadequate design and maintenance, or other similar defect.

Indeterminate Scales:

The class, Indeterminate Scales includes all those for which for any reason no inspection record was made. Failure of the inspector to make this part of his record may have been due to such causes as an inaccessible pit, pit full of water, lack of time, or other reason.

PRESENTATION OF DATA

In presenting these data, emphasis is placed upon the following features: (I) Determination of the extent to which the results of a "Distributed Load" test may be predicted from the results of a single load sectional test. (II) Comparison of percentages of scales tested that passed the different tolerances given above: (III) Proportionality of error to load.

I. TO DETERMINE THE EXTENT TO WHICH THE RESULTS OF A DISTRIBUTED LOAD TEST MAY BE PREDICTED FROM THE RESULTS OF A SINGLE LOAD SECTIONAL TEST.

In single load sectional tests with short wheel base test cars, the performance of the scale upon the application of a single loaded truck comparable in length to a single freight car truck is developed. In practical weighing the scale is, of course, loaded with both trucks of a freight car. The degree of variation in the performance of a scale when loaded with two trucks at the same time and when loaded with a single truck placed successively in different positions has been much discussed, particularly by those charged with the care of a number of scales of light design. Typical of the nature of the discussion is the following extract from a letter which came to the Bureau several years ago from a railroad supervisor of scales.

"I have noticed in your various report, as well as actual observation at the various track scales, that some scales are showing very bad results with the individual cars on sectional tests, but when both test cars are placed on the scales and weighed as an ordinary box car would be weighed, that the results are considerably better than the sectional test results."

Of the group of 1000 scales herein reported, both sectional tests and distributed tests were made on 794 scales. In comparing the results of sectional tests against distributed load tests the procedure was as follows:

The positions occupied by the 40 000 pound and 80 000 pound cars in the Distributed Load test were noted in the Inspector's record. (See Distributed Load test in sample test record above.) The weight indication under this loading was compared against the sum of the errors obtained in the single load tests with the 40 000 pound and 80 000 pound cars in the corresponding positions. If this sum and the weight indication for the distributed load did not differ by more than 60 pounds, (one-fourth the A. R. A. Distributed Load Tolerance on 120 000 pound load) it was considered that the results of the Distributed Load test checked the results computed for a load of 120 000 pounds from the results of the Single Load tests. See following example.

Note: Two reasons appeared for selecting 60 pounds as the limiting difference when the observed and computed errors for the Distributed Load might be considered a check. (1) If a variation of one beam division (20 lb.) is equally likely to occur plus or minus in any of the three readings the odds are one to three that the difference due to accidental errors of observation will be 60 pounds (2). 60 pounds is 25% of the tolerance on the 120 000 distributed load, which it is believed will appeal to most minds as being a sufficiently close check for the purpose at hand.

Table II

Example of Comparison of Results of Distributed and Single Load Tests

Position 40 000 lb. car	Position 80 000 lb. car	Error in Weight Indication	Errors obtained in Single Load tests. Cars spotted in same positions as in Distributed load tests. 40 000 lb. car	80 000 lb. car	Sum of Single Load test Errors	Distributed load errors minus sum of Single load Test Errors
4L - 12	1R + 12	0	+10 lb.	- 20 lb.	- 10 lb.	+10 lb.
3R	1R + 12	0	+20 lb.	- 20 lb.	0	0
3L	1R + 12	+20 lb.	+40 lb.	- 20 lb.	+20 lb.	0
2R	1R + 12	+20 lb.	+40 lb.	- 20 lb.	+20 lb.	0

The values in the last column show almost an exact check between the results obtained in the Distributed Load test and those computed from the Single Load tests. Had one or more of the values in the last column exceeded 60 pounds, it would have been held for the purposes of this analysis that the observed and computed values did not check.

The above method of reduction was carried out for each of the 794 test records which contained both Distributed Load and Single Load test results.

Table III

Comparison of Results of Distributed Load and Single Load Tests

The key to the column headings is as follows:

A. Number and percentages of scales for which the errors of the Distributed Load tests checked the errors computed from the Single Load Tests.

B. Number and percentages of scales for which the errors of the Distributed Load Tests were greater than the errors computed from the Single Load tests.

C. Number and percentages of scales for which the errors of the Distributed Load tests were less than the errors computed from the Single Load tests.

D. Number and percentages of scales for which some of the errors of the Distributed Load tests were greater than those computed from the Single Load tests and others were less.

Total number of scales, 794.

	Good Scales Total number 147				Fair Scales Total Number 155			
	A	B	C	D	A	B	C	D
Number	130	3	14	0	118	12	25	0
Percent	88.4	2.0	9.5	0	76.1	7.7	16.1	0

	Deficient Scales Total Number 457				Indeterminate Scales Total Number 35			
	A	B	C	D	A	B	C	D
Number	143	64	212	38	15	6	12	2
Percent	31.3	14.0	46.4	8.3	42.9	17.1	34.3	5.7

The above table presents forcefully the fact that a good scale can be expected to yield a uniform weighing performance whether a Distributed or Sectional load is applied.

Attention is directed to the values under the headings B and C, respectively. The greater values under the headings indicate that there is a marked tendency for the readings under a distributed load to be less than those under sectional or single loads.

II. COMPARISON OF PERCENTAGES OF SCALES THAT PASSED DIFFERENT TOLERANCES IN CURRENT USE

The tolerances in current use are given above under the designation of "Bureau of Standards" tolerance, and "A. R. A." tolerance. The effect of applying these tolerances for the purpose of grading track scale performance is shown in the following tables.

Table IV

Numbers and Percentages of 1000 Scales That Passed Different Tolerances

	Bureau of Standards' Tolerance		A.R.A. 0.3% Sectional Tolerance	
	Passed	Failed	Passed	Failed
Number	477	523	570	430
Percent	47.7	52.3	57.0	43.0

Thus it is seen that the A. R. A. 0.3% sectional tolerance passed 9.3% more scales than the Bureau of Standards' tolerance.

Of these 1000 scales there were 794 on which a Distributed Load Test was made. The following table gives a comparison of the different percentages of these latter scales passed by the current tolerances.

Table V

Results of Applying Different Tolerances to Tests of 794 Scales

	Bureau of Standards Tolerance		A.R.A. 0.3% Sectional Tolerance		A.R.A. 0.2% Distributed Load Tolerance	
	Passed	Failed	Passed	Failed	Passed	Failed
Number	419	375	496	298	562	232
Percent	52.8	47.2	63.5	37.5	70.8	29.2

In comparing this table with Table IV, it will be noted in Table IV that 47.7% of 1000 scales passed the Bureau of Standards' tolerance, and 57% of 1000 scales passed the A.R.A. 0.3% sectional tolerance, as compared to 53.8% and 63.5% of 794 scales, respectively, in Table V although the 1000 scales in Table IV include the 794 scales of Table V. This discrepancy is due to the fact that scales on which Distributed Load tests were not made were usually poor scales, which had large errors, and were of light design and construction. Therefore, taken as a whole, the 794 scales of Table V consist of a better class of scales than those of Table IV.

Table VI

Results of Applying Different Tolerances to Tests of 794 Scales, (Scales Graded with Respect to Mechanical Condition).

	Good Scales Total 147 Passed	Good Scales Failed	Fair Scales Total 155 Passed	Fair Scales Failed	Deficient Scales Total 457 Passed	Deficient Scales Failed	Indeterminate Scales Total 35 Passed	Indeterminate Scales Failed
	BUREAU OF STANDARDS TOLERANCE							
Number	137	10	127	28	137	320	18	17
Percent	93.2	6.8	81.9	18.1	30.0	70.0	51.4	48.6
	A. R. A. 0.3% SECTIONAL LOAD TOLERANCE							
Number	147	0	143	12	180	277	26	9
Percent	100	0	92.3	7.7	39.4	60.6	74.3	25.7
	A. R. A. 0.2% DISTRIBUTED LOAD TOLERANCE							
Number	145	2	146	9	246	211	27	8
Percent	98.6	1.4	94.2	5.8	53.8	46.2	77.2	22.8

79 Scales failed Bureau of Standards' Tolerance and passed A.R.A. 0.3% Sectional tolerance.
2 Scales passed Bureau of Standards' Tolerance and failed A.R.A. 0.3% Sectional tolerance.
Discrepancies include 10 "Good" Scales, 16 "Fair" Scales, 47 "Deficient" Scales, and 8 "Indeterminate" Scales. Total Discrepancies 81.
147 Scales failed Bureau of Standards' Tolerance and passed A.R.A.0.2% Distributed load tolerance.
4 Scales passed Bureau of Standards' Tolerance and failed A.R.A. 0.2% Distributed load tolerance.
Discrepancies include 8 "Good" Scales, 17 "Fair" Scales, 115 "Deficient" Scales, and 11 "Indeterminate" Scales. Total discrepancies 151.
92 Scales failed A.R.A. 0.3% Sectional Tolerance and passed A.R.A. 0.2% Distributed Load Tolerance.
16 Scales passed A.R.A. 0.3% Sectional Error provision and failed A.R.A. 0.2% Distributed Load Error provision.
Discrepancies include 2 "Good" scales, 5 "fair" Scales, 94 "Deficient" Scales, and 7 "Indeterminate" Scales. Total discrepancies, 108.

III. PROPORTIONALITY OF ERROR TO LOAD

Theory shows that the error in weighing on a track scale should be proportional to the load, that is to say, the error at 80 000 pounds load should be twice as great as the error at 40 000 pounds load. The question has often been asked whether the results found in practice check the theoretical results.

The matter of proportionality of error to load was given some consideration in this investigation. The study was restricted to the class "Good" Scales, as there was no reason to believe that a "Deficient" scale could be expected to check any theory.

The average percent errors at 40 000 pounds load, and at 80 000 pounds load for each of 147 good scales were computed by adding all the errors found at all the positions in the test at 40 000 pounds load and dividing by the number of readings, and doing the same for the errors obtained at the same position with the 80 000 pounds load. In the case of scales having errors proportional to the load, the percent errors for 40 000 pounds load and 80 000 pounds load should be equal.

The average difference between the percent errors at 80 000 pounds load and 40 000 pounds load was found to be -0.01% for 147 scales. That is to say, on the average the percent error at 80 000 pounds load was 0.01%, or 8 pounds less than the error at 40 000 pounds load. The maximum variation from the mean was 0.11% and the odds were 9 to 1 that the percent error at 80 000 pounds load would not differ from the percent error at 40 000 pounds load by more than 0.05%. It appears therefore, that the theory can be expected to hold up in practice in the case of good scales.