FRA/TTC-82/03

HOPPER VS TANK CAR TRUCK LOADS

FAST Facility for Accelerated Service Testing

TRANSPORTATION TEST CENTER
PUEBLO, COLORADO 81001

Final Report

PREPARED FOR
THE FAST PROGRAM

AN INTERNATIONAL GOVERNMENT - INDUSTRY RESEARCH PROGRAM

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16. Abstract
This report describes the results of tests conducted at the Transportation Test Center (TTC) in Pueblo, Colorado to ascertain differences between the ride characteristics of a hopper car with D-5 and D-3 springs and those of a tank car with D-3 springs. Testing involved operating speeds of 10 to 60 mi/h on the Facility for Accelerated Service Testing (FAST) track and specially shimmed (perturbed) sections of the Railroad Test Track (RTT). Data thus obtained are presented in the format of curves and force tabulations to facilitate further analyses.

In addition, data obtained from the FAST measurements of truck forces are shown compared with data from measurements taken during operation on U.S. Western and Midwestern revenue service tracks, thus permitting an assessment of how well the FAST results compare with results obtained under actual revenue conditions.

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PREFACE

The authors wish to express their appreciation for the very great assistance received from the following groups: the Test Engineering Department of the Product Engineering Division of American Steel Foundries, responsible for instrumentation and data collection, and for the use of their instrumentation and hopper cars; the Federal Railroad Administration (FRA) and the Transportation Test Center (TTC), which made it possible to conduct these tests; the Illinois Institute of Technology Research Institute for their assistance as consultants, and for reduction of data and report presentation; and the Association of American Railroads staff for additional assistance in arranging for data reduction and reporting.

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ACRONYMS

AAR	Association of American Railroads
ALD	Automatic Location Detector
ALT	Accelerated Life Test
FAST	Facility for Accelerated Service Testing
FM	Frequency Modulation
FRA	Federal Railroad Administration
IIT	Illinois Institute of Technology
IITRI	Illinois Institute of Technology Research Institute
RPI/AAR	Railway Progress Institute/Association of American Railroads
RTT	Railroad Test Track
TTC	Transportation Test Center

ABBREVIATIONS AND METRIC EQUIVALENTS

°	degree	
%	percent	
", in	inch	= 2.54 cm
', ft	foot	= 0.305 m
gal	gallon	= 3.785 l
lb	pound	= 0.454 kg
mi	mile	= 1.609 km
ton		= 0.907 metric ton

EXECUTIVE SUMMARY

Forces acting on the truck components of a hopper car and tank car were measured while operating over test tracks at the Transportation Test Center (TTC). The program had two major objectives: The first was to measure freight car truck forces resulting from movement over specially shimmed track sections. The second was to measure freight car truck forces while operating on the Facility for Accelerated Service Testing (FAST) track and to compare these measurements with those taken in typical U.S. Western & Midwestern revenue service environments. The Railway Progress Institute/Association of American Railroads (RPI/AAR) Truck Research Safety and Test Project has conducted tests measuring hopper car truck forces while operating over a number of different eastern, midwestern and western railroads. These data show a wide variation in truck component loads depending upon the type of service and the place of operation. Other truck force measurements have indicated that large loads result when suspension springs are driven solid. Truck bounce forces exceeding 240,000 lbs were measured on one test involving a 33,000 gal, type 112A tank car.

The two cars used for this program were a 100-ton hopper and a tank car, both using 6-1/2x12" journals. Vertical forces acting through the side frames were measured on both cars. The hopper car also had instrumented side bearings.

Two sections of track were modified on the Railroad Test Track (RTT) at the TTC for this project. The modifications placed 3/4" shims between the tie plates and ties to change the vertical profile of the rail at staggered locations in one test section to excite the motions that would be expected from staggered rail joints. A second test section consisted of shims placed directly opposite one another under the rails, to excite car bounce and pitch motions.

Tests were conducted by running the test cars back and forth over the shimmed track sections. Two different springing systems were used in the hopper car: the conventional D-5 (3-11/16" travel), its original equipment, and stiffer D-3 (2-1/2" travel) springs. The tank car was equipped with D-3 springs for all of the tests. A second set of tests was conducted running cars over the FAST track at speeds of 20, 25, 35, and 45 mi/h. The hopper car was again operated with the two different types of springs: D-3 and D-5.

The data were collected on analog tape and digitized for computer processing. In addition to processing the side frame and side bearing load data, a truck bounce load parameter (instantaneous sum of two side frame channels) and a truck rock load parameter (instantaneous difference of two side frame load channels) were determined. Data were summarized by counting and classifying the intensity of the peak loads between crossings of the mean level.

Test results on the staggered shim test section show the hopper car rolling motion to be worse with D-3 springs than with D-5 springs. As might be expected, with tank versus hopper car centers of gravity differing 80" vs

94", the tank car showed less roll response than the hopper car over this test section. Tests on the opposite shimmed test section showed that the bounce response of the hopper car was not affected by the type of spring group. Peak truck bounce loads on the tank car were shown to be a function of speed, and did not approach the levels associated with the spring group going solid. Therefore, the tests did not develop the high magnitudes of truck bounce loads measured on earlier field tests.

A comparison of service data and FAST load spectra showed that the FAST track produced a level of truck loads similar to service data in the 30 to 45 mi/h speed range. It must be recognized, however, that service load data are substantially larger at higher speeds.

1.0 INTRODUCTION

In recent years, the forces acting on freight car truck components have been measured under various operating conditions. The Railway Progress Institute/Association of American Railroads (RPI/AAR) Truck Research Safety and Test Project published data[1] which summarized the forces acting upon the truck of a hopper car (loaded with coal) that was operated over six midwestern and eastern railroads. Data from 1,900 mi of operation were included in the summary. Similar data were obtained from the operation of this car for approximately 2,300 mi over western railroads. These operations are referred to as the "D-Series Test".

The Illinois Institute of Technology (IIT) Research Institute (IITRI) has participated in three test programs where freight car truck component loads were measured during the operation of 100-ton cars.[2] One program included the operation of a hopper car loaded with iron ore over a branch line of an eastern railroad. Data were obtained from 18 runs at 35 mi/h over a 4.1 mi test track containing numerous curves, several grade crossings, two turnouts, and several bridges. The second program covered the operation of a hopper car loaded with crushed stone. Data were obtained for 182 mi of operation on a mainline track of a western railroad. The third program covered the operation of a 33,000-gal, DOT classification 112A tank car loaded with water. Data were collected for 114 mi of operation on a mainline track of a midwestern railroad; large vertical truck bounce forces were measured on this test, and a number of peak loads exceeding twice the nominal static load were recorded at speeds over 45 mi/h. One possible explanation for these large forces is that the tank car truck was equipped with D-3 (2-1/2" travel) springs, whereas, all the hopper car data were obtained on trucks with D-5 (3-11/16" travel) springs.

Data recorded during the RPI/AAR and IITRI tests showed a wide variation in truck component loads, which made it desirable to measure truck forces during operation over track with known geometrical variations in order to isolate some of the factors affecting the development of truck component forces.

An opportunity to make such tests was presented when the test car which had been used in the RPI/AAR test series was at the Transportation Test Center (TTC) in August 1977. An instrumented 112A-type tank car, which had been used in the Accelerated Life Test (ALT) of thermally shielded cars, was also available.

The program had two major objectives: First, to measure freight car truck component forces resulting from traversing specially shimmed track sections.

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[1] Evans, R.A., and Johnson, M.R., Analysis of Environmental Truck Component Load and Bolster Fatigue Test Data, AAR Research and Test Report R-246, September 1976.

[2] Johnson, M.R., "Summarization and Comparison of Freight Car Truck Load Data," Transactions of the ASME, Journal of Engineering for Industry, Volume 100, No. 1, February 1978.

Measurements were designed to compare the responses of a hopper car and a tank car, and to compare hopper car truck forces with D-3 suspension springs and D-5 springs. Second, to measure the freight car truck forces while operating at the Facility for Accelerated Service Testing (FAST) and to compare these measurements with those taken in a typical service environment. This plan permitted assessment of how well FAST results compare with results from actual revenue service conditions.

2.0 TEST PROCEDURES

2.1 TEST CARS

Two cars were used for this program, a hopper car and a tank car, each having a nominal capacity of 100 tons (6-1/2x12" journals). The hopper car had been used in earlier RPI/AAR Truck Project tests.[1] It had an overall length of 50 ft with 37'-6" truck centers. The car was normally equipped with D-5 suspension springs. It was loaded with coal, which gave it a relatively high center of gravity--(approximately) 94" above the rail. The tank car (DOT classificaton 112A) was similar to the one used by IITRI in over-the-road tests where high truck loads were measured.[2] It had an overall length of approximately 64 ft, a truck center distance of approximately 53 ft, and was equipped with D-3 suspension springs. It was loaded with water to attain the allowable rail load for a 100-ton capacity car, which resulted in an outage of approximately 40% in the tank and a center of gravity approximately 80" above the rail.

2.2 TEST TRACK

Two sections of tangent track on the Railroad Test Track (RTT) (Figure 1) at the TTC were modified for this project. The modifications consisted of placing 3/4" shims between the tie plates and ties to change the vertical profile of the rail. One test section, designated the "rock" test section, consisted of 10 shimmed positions on each rail, 39 ft apart (Figure 2). The shimmed positions on each rail were offset by 19'6" to excite the type of carbody oscillations that would be expected from staggered rail joints.

The second test section consisted of five shimmed positions on each rail, again located 39 ft apart as illustrated in Figure 2, but in this case the shimmed positions on each rail were parallel. This section was referred to as the "bounce" test section, as its purpose was to excite bounce and pitch motions of the car.

Automatic Location Detector (ALD) markers were placed at the beginning and end of the test sections so that the entry and exit of the test cars from the test zones could be included on the data tape. Two additional ALD markers were placed 50 ft apart on an unmodified section of track between the two sections so that a reference level for dynamic behavior could be established.

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1 Evans, Op. cit.

2 Johnson, Op. cit.

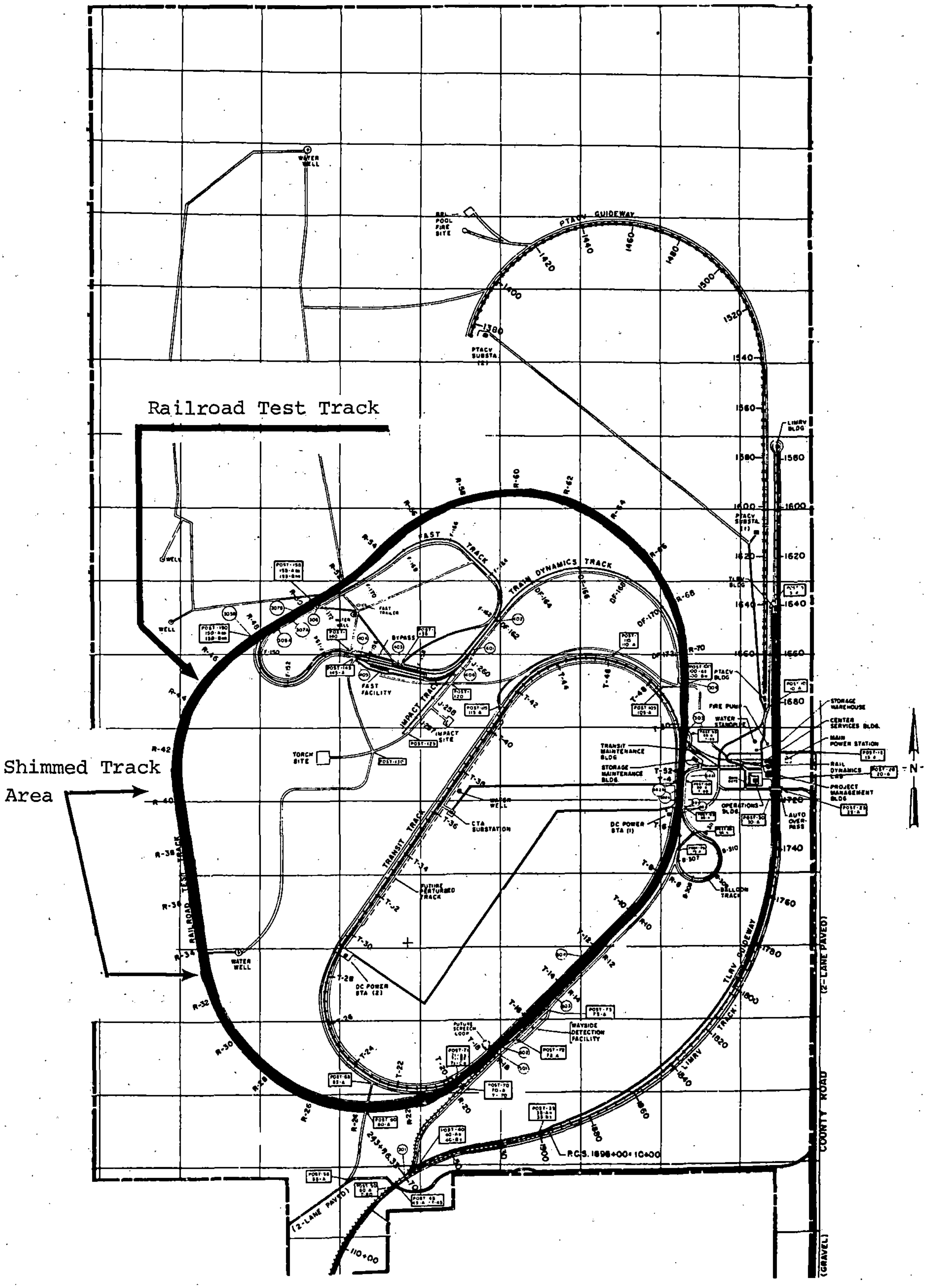
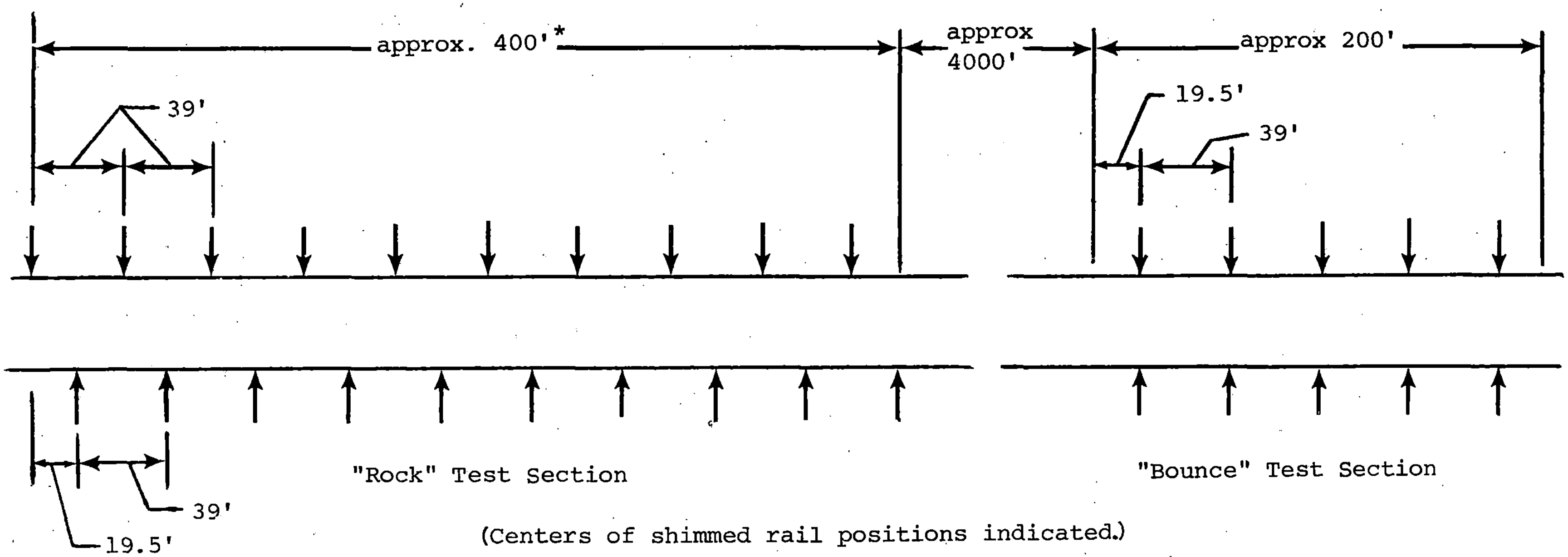


FIGURE 1. RAILROAD TEST TRACK (RTT) LAYOUT.



* Not drawn to scale.

Note: Each shimmed rail position consists of 20 shimmed tie plates: 2 each at 1/16, 1/8, 3/16, 5/16, 7/16, 9/16, 5/8, and 11/16 in. and 4 each at 3/4 in.

FIGURE 2. SHIMMED TEST TRACK SCHEME.

2.3 INSTRUMENTATION

Vertical forces acting through the side frames were measured on the B end truck of the hopper car and on both ends of the tank car. A four-arm, active strain gage bridge was used on each side frame, one gage on each of the two tension members, and one gage on each of the two compression members.

Accelerometer data were also obtained. One vertically oriented accelerometer was located on the body bolster adjacent to the centerplate of the instrumented hopper car truck; another was located at each end of the tank car near the centerplate.

Two side bearings on the B end of the hopper car were also instrumented to measure the vertical loads acting through the side bearings.

During the test runs, data from the transducers were continuously recorded. An FM analog tape recorder was set up in an instrumentation car that was run with the two test cars. The order of cars in the consist was: the locomotive, instrumentation car, hopper car, and tank car.

2.4 TEST RUNS

- Two test series were conducted running back and forth over the shimmed RTT track sections. The first, designated as the "10,000 test series", used standard D-3 springs in the tank car truck and D-5 springs in the hopper car truck. The first run was at 5 mi/h and was increased in 5 mi/h increments until the maximum speed of 60 mi/h was reached. The maximum speed of a backward run over the shimmed track sections was restricted to 30 mi/h.

  The second test series, designated as the "20,000 test series", was run in a similar manner except that the D-5 springs in the hopper car truck were replaced with D-3 springs.

- Following the runs on the shimmed RTT track sections, the test consist was moved to the FAST track (Figure 3). Two groups of tests were run: the first, the "30,000 test series", used D-3 springs in the hopper car. The second group of test runs, the "40,000 test series", used D-5 springs in the hopper car truck. D-3 springs were used in the tank car for both groups of tests. For each test group, the FAST Track was traversed at four different speeds: 20, 25, 35, and 45 mi/h; two laps were made at each speed.

2.5 DATA PROCESSING

Analog signals were digitized at 100 samples per second to facilitate computer data processing. This report describes results from the analysis of the six vertical side frame load channels and the two side bearing load channels on the hopper car.

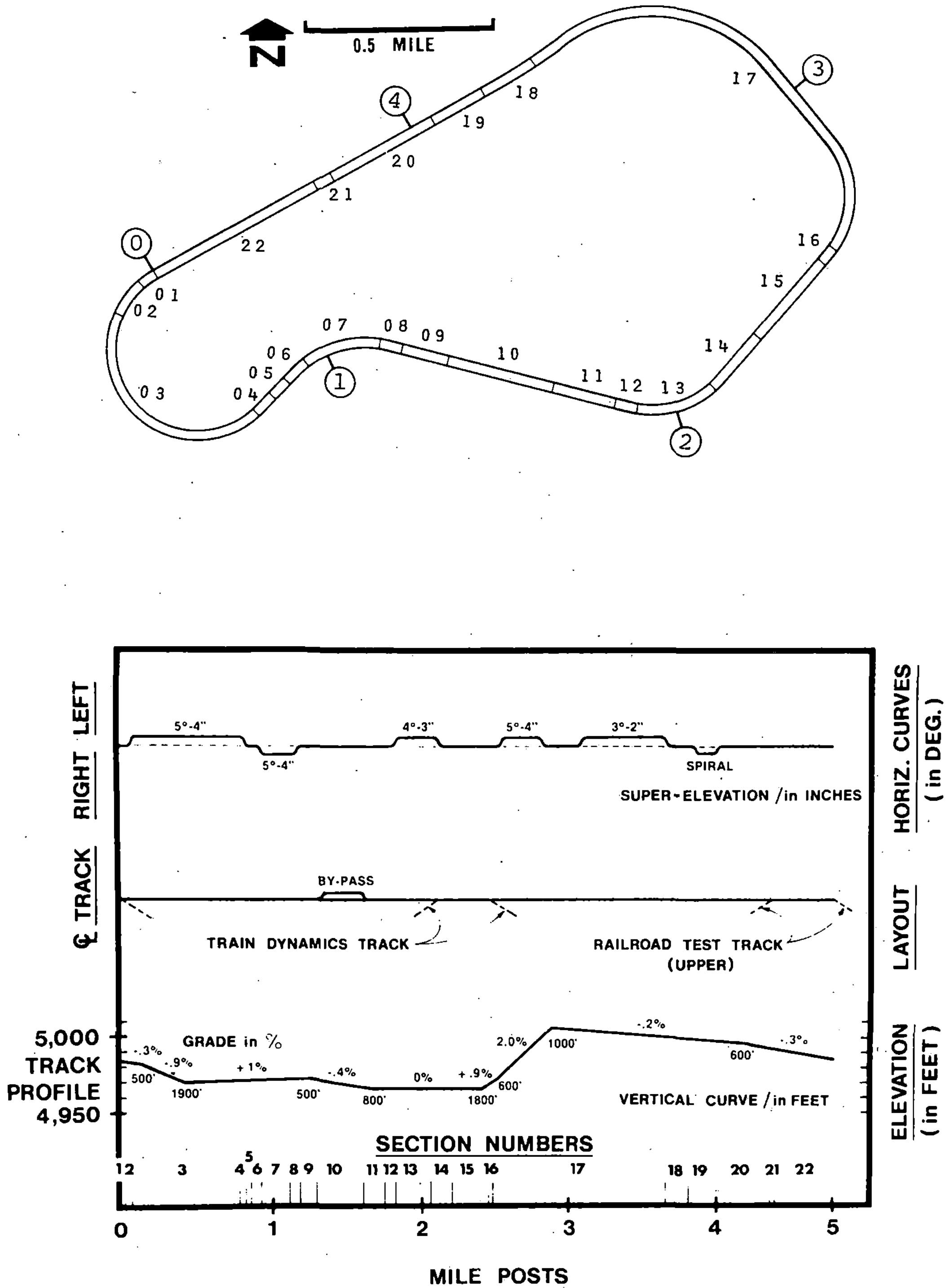


FIGURE 3. FACILITY FOR ACCELERATED SERVICE TESTING (FAST) TRACK LAYOUT.

In addition to the side frame and side bearing loads, two other load parameters were defined. These were the "truck bounce" and "truck rock" loads. Truck bounce load is defined as the instantaneous sum of the two side frame load channels; it describes the total load acting on the car through the truck. (In this report the truck bounce load data are presented with reference to the mean load level.) The truck rock load is defined as the instantaneous difference between the two side frame vertical loads. It is a measure of the weight transfer which occurs during rolling (rocking) motions of the car. There was a high correlation between side bearing loads and the rock loads.

Data were summarized by counting and classifying the intensity of the peak loads between crossings of the mean level. Both positive and negative peaks were identified about the mean load level. This procedure was used for the side frame load channels, truck bounce, and truck rock. A similar procedure was followed for the two side bearing load channels, except that the zero-load level was used as a reference. Data summaries were processed for each of the shimmed track sections and the short section of unmodified track adjacent to the shimmed track.

The most significant responses for the truck rock load and the side bearing load summaries occurred over the rock test section. For the truck bounce load, they occurred over the bounce test section. Tabulations of peak loads in various load ranges associated with these tests are presented in the appendix; the truck rock and the two side bearing loads are classified by 10,000-lb load ranges, truck bounce by 5,000-lb load ranges.

Peak load data were classified and summarized in a similar manner for the side frame, side bearing, truck bounce, and truck rock parameters for the test runs on the FAST track. These data were subsequently put in terms of counts-per-mile to allow comparison with other service load data.

3.0 RESULTS

3.1 LOAD VS. TIME PLOTS

Selected load vs. time plots are included to show the dynamic response phenomena associated with movement over the rock and bounce test sections. Figures 4 and 5 show data from the movement of the test cars over the rock test section at the speed where the greatest car body response motions were noted. The top two traces on each figure show the two side frame loads from the A truck on the tank car; note that the load oscillation is relatively small. The third and fourth traces show the side bearing loads on the hopper car. (Figure 4 shows data for the hopper car with D-5 springs; Figure 5 shows data obtained with D-3 springs.) Note that the rolling motion of the hopper car produces maximum side bearing loads of approximately 100,000 lbs. Also, the load intensity is slightly greater in Figure 5, where the stiffer springs were used on the hopper car. The fifth and sixth traces on Figures 4 and 5 show the side frame vertical forces on the hopper car; these traces show a high-amplitude, 180° out-of-phase relationship, indicative of severe rolling motion.

Figures 6 and 7 show typical data from the bounce test section; the data shown are from the 60 mi/h runs of the 10,000 and 20,000 series. This speed developed the largest truck bounce forces. The first two traces on these figures show the truck bounce load for the A and B ends of the tank car and the bottom trace shows the truck bounce load on the hopper car B end; the maximum tank car bounce load exceeded the maximum hopper car bounce load. There are relatively minor differences between the bounce loads for the hopper car on these two runs, indicating that the change in stiffness of the spring suspension had little effect on bounce load development.

Figures 8 and 9 show similar data for a 55 mi/h run over the bounce test section for the two test series. The bottom three curves show the same truck bounce load information indicated in Figures 6 and 7. There was only a slight reduction in the hopper car truck bounce resulting from the reduction in speed.

Two additional curves are shown on these figures. The second curve represents the total tank car bounce load, which was obtained by computing the instantaneous sum of the two tank car truck bounce loads. This curve is an indication of the vertical rigid body displacement motion of the tank car. The top curve on these figures shows a "pitch" load, which is defined as the instantaneous difference between the bounce loads on the A end truck and the B end truck, a measure of the pitching motion of the tank car. The tank car total bounce and pitch loads are about equal. The pitch load had a slightly higher frequency than the total bounce load. This would be expected theoretically and is an indication of the complex dynamic phenomena associated with the response of the tank car to track irregularities.

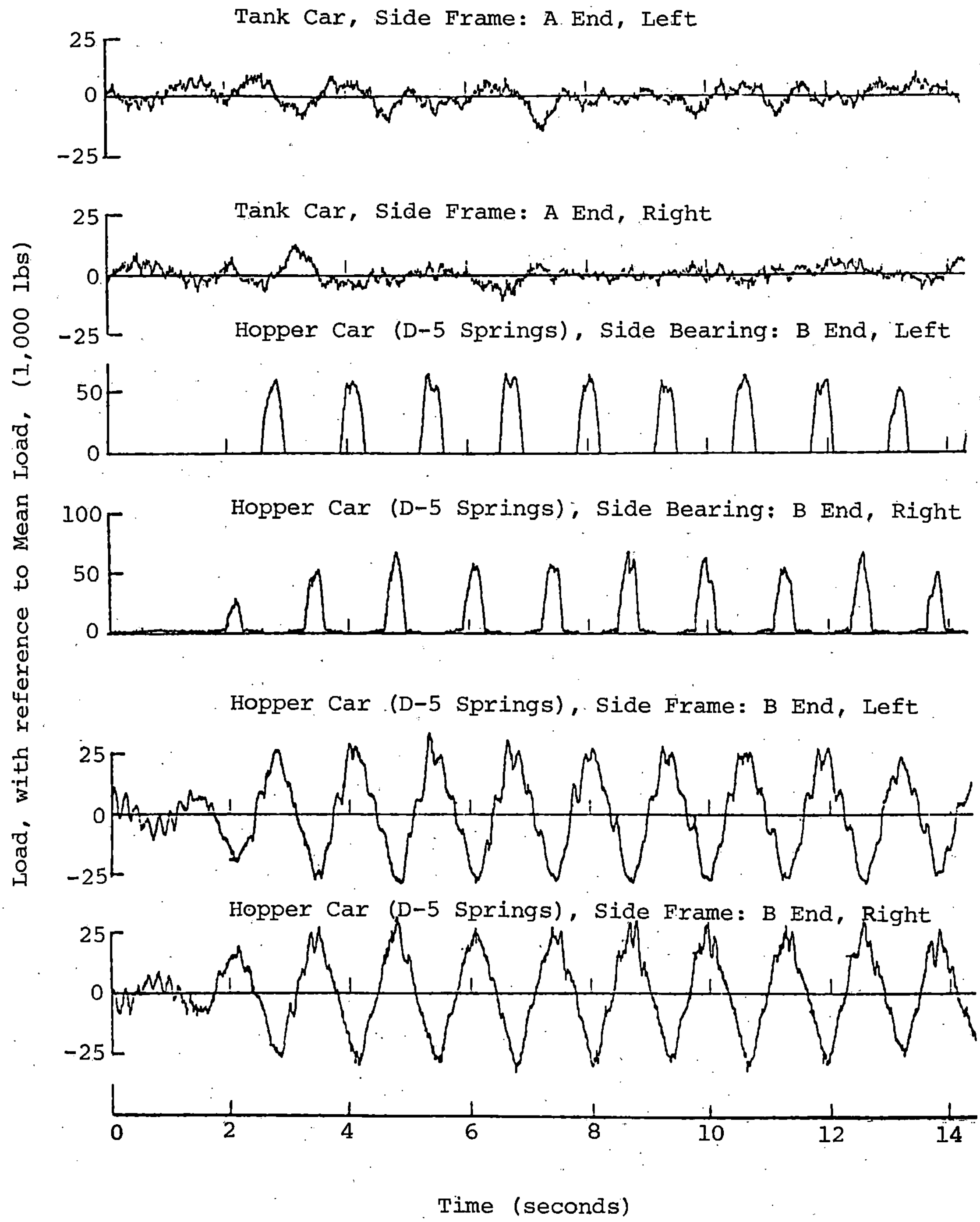


FIGURE 4. TRUCK LOAD PARAMETERS VS TIME, 20 MI/H FORWARD RUN (TEST 10016), ROCK TEST SECTION.

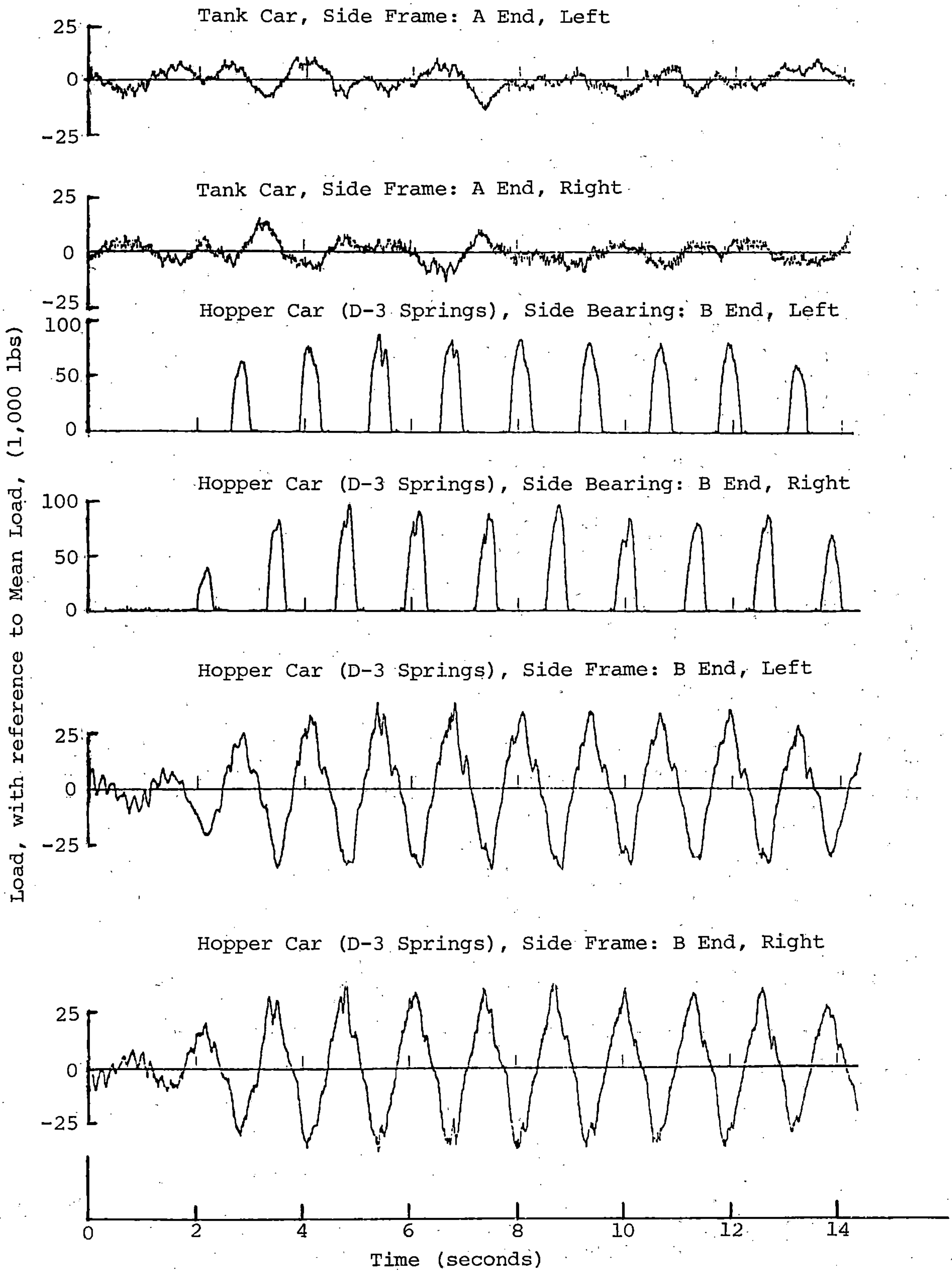


FIGURE 5. TRUCK LOAD PARAMETERS VS TIME, 20 MI/H FORWARD RUN (TEST 20016), ROCK TEST SECTION.

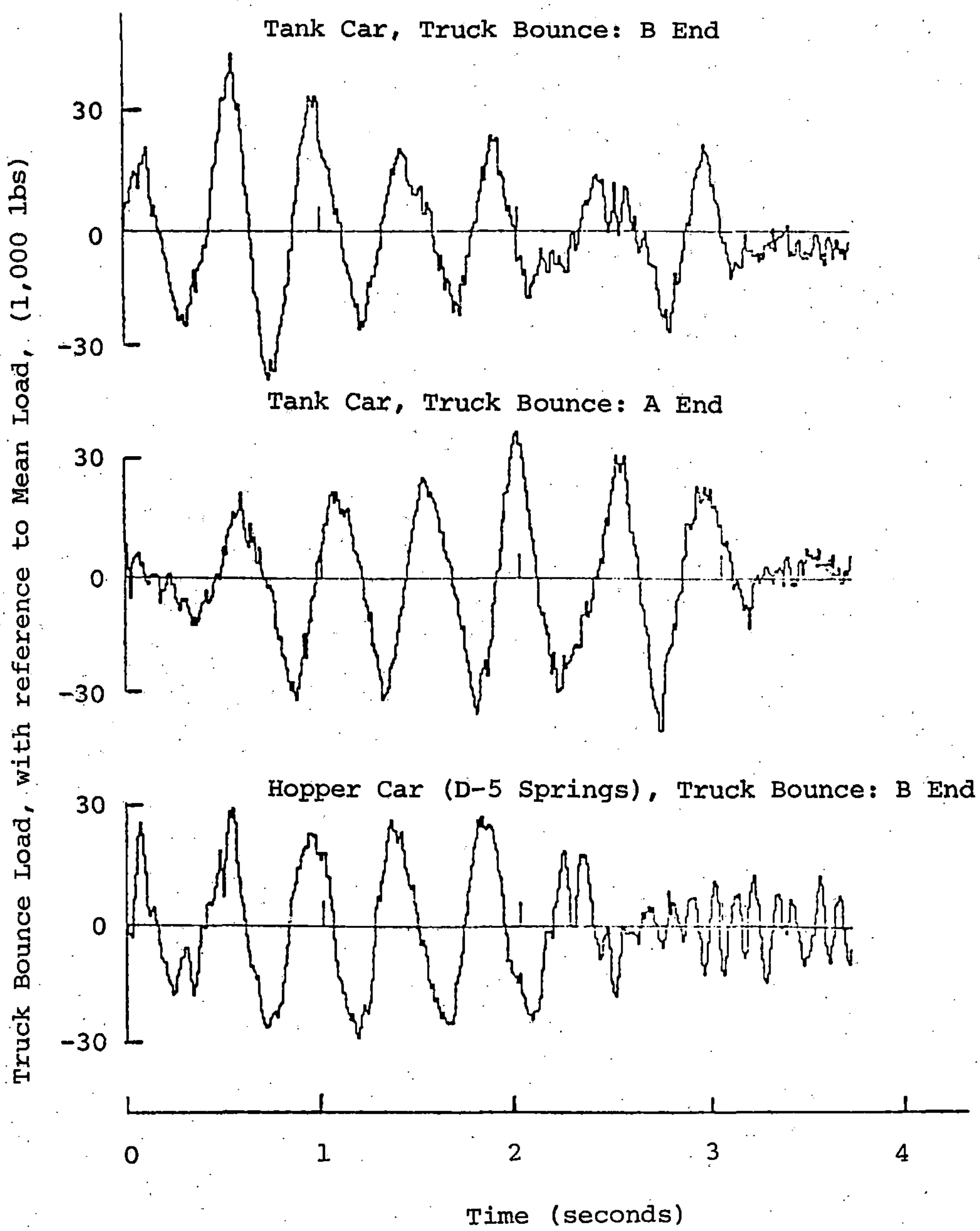


FIGURE 6. TRUCK LOAD PARAMETERS VS TIME, 60 MI/H FORWARD RUN (TEST 10045), BOUNCE TEST SECTION.

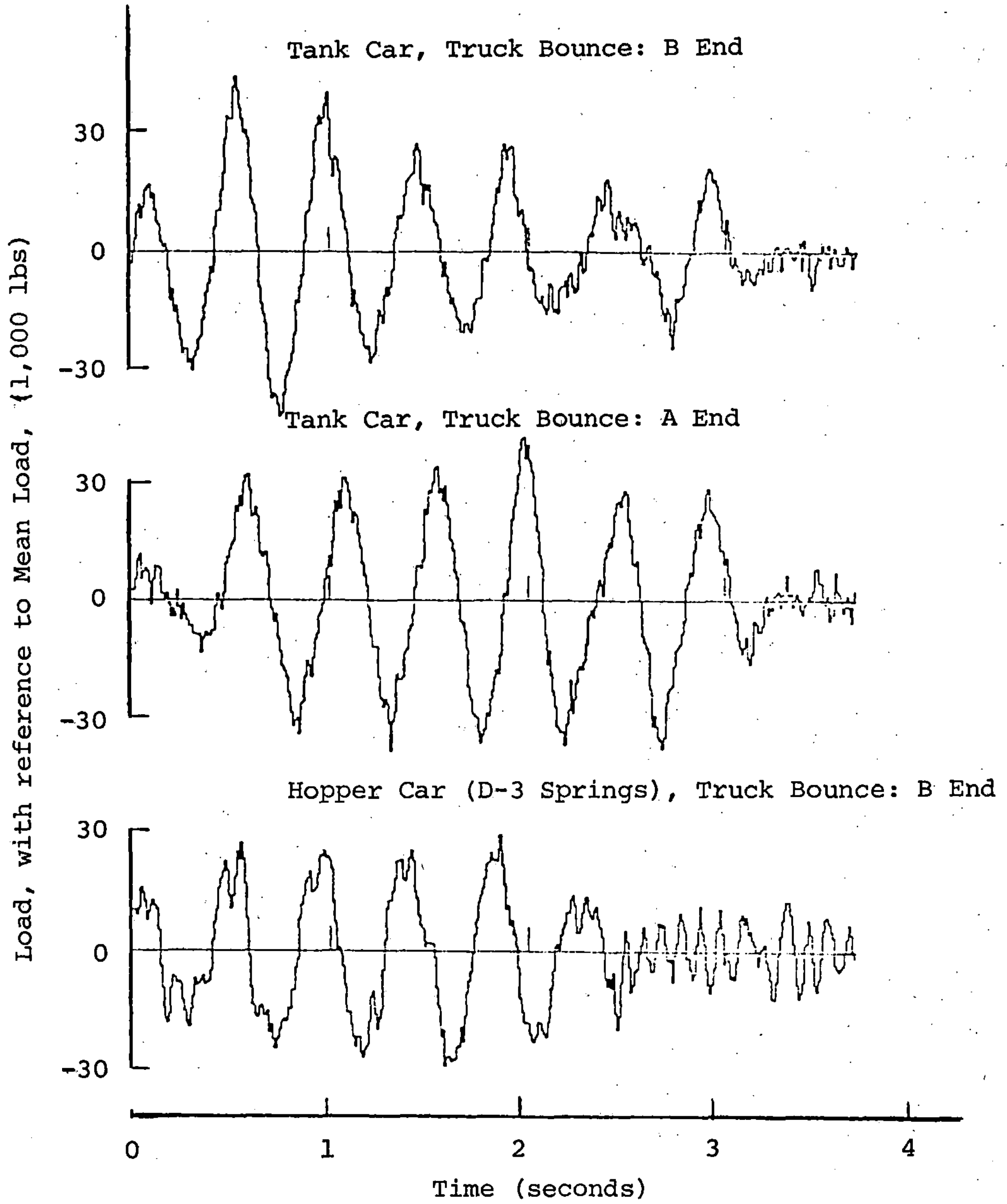


FIGURE 7. TRUCK LOAD PARAMETERS VS TIME, 60 MI/H FORWARD RUN (TEST 20036), BOUNCE TEST SECTION.

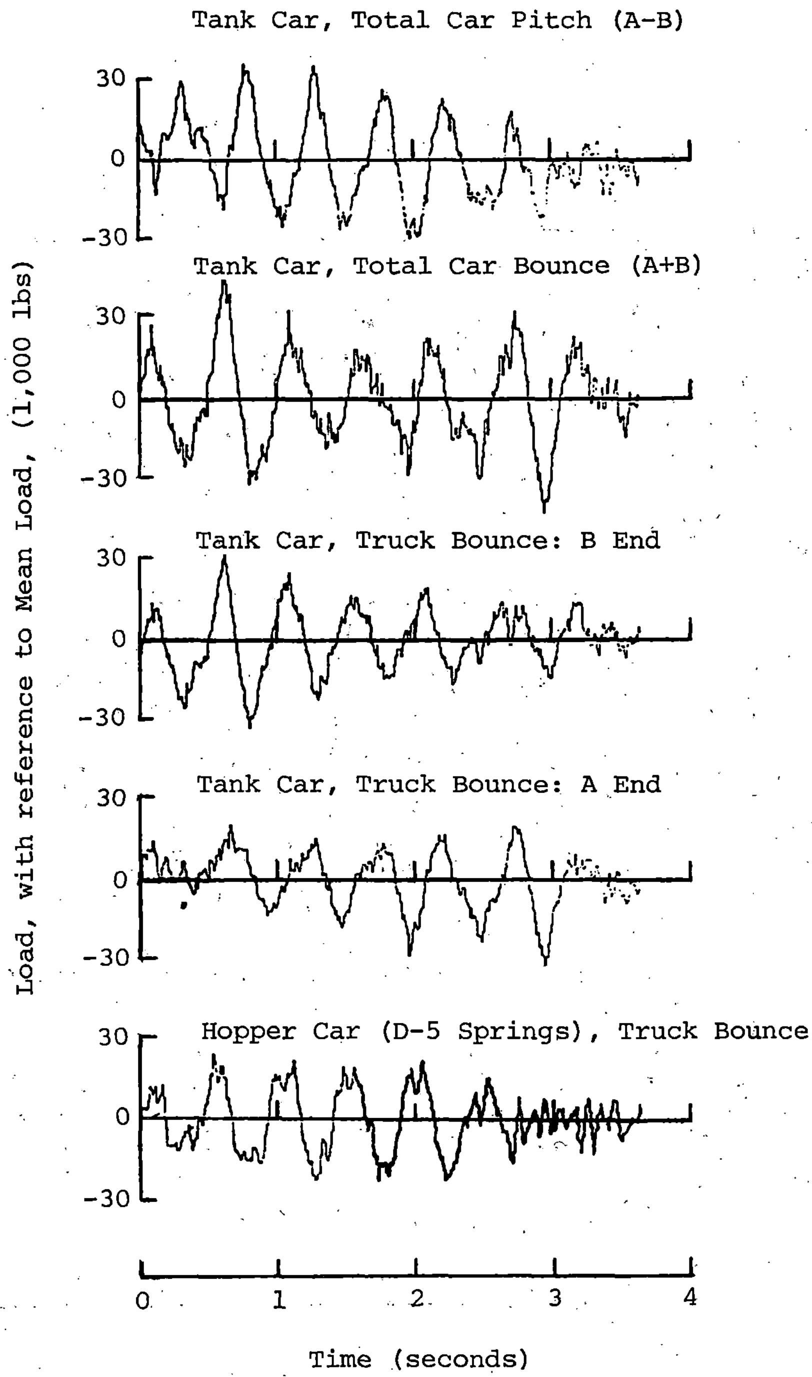


FIGURE 8. TRUCK LOAD PARAMETERS VS TIME, 55 MI/H FORWARD RUN (TEST 10036), BOUNCE TEST SECTION.

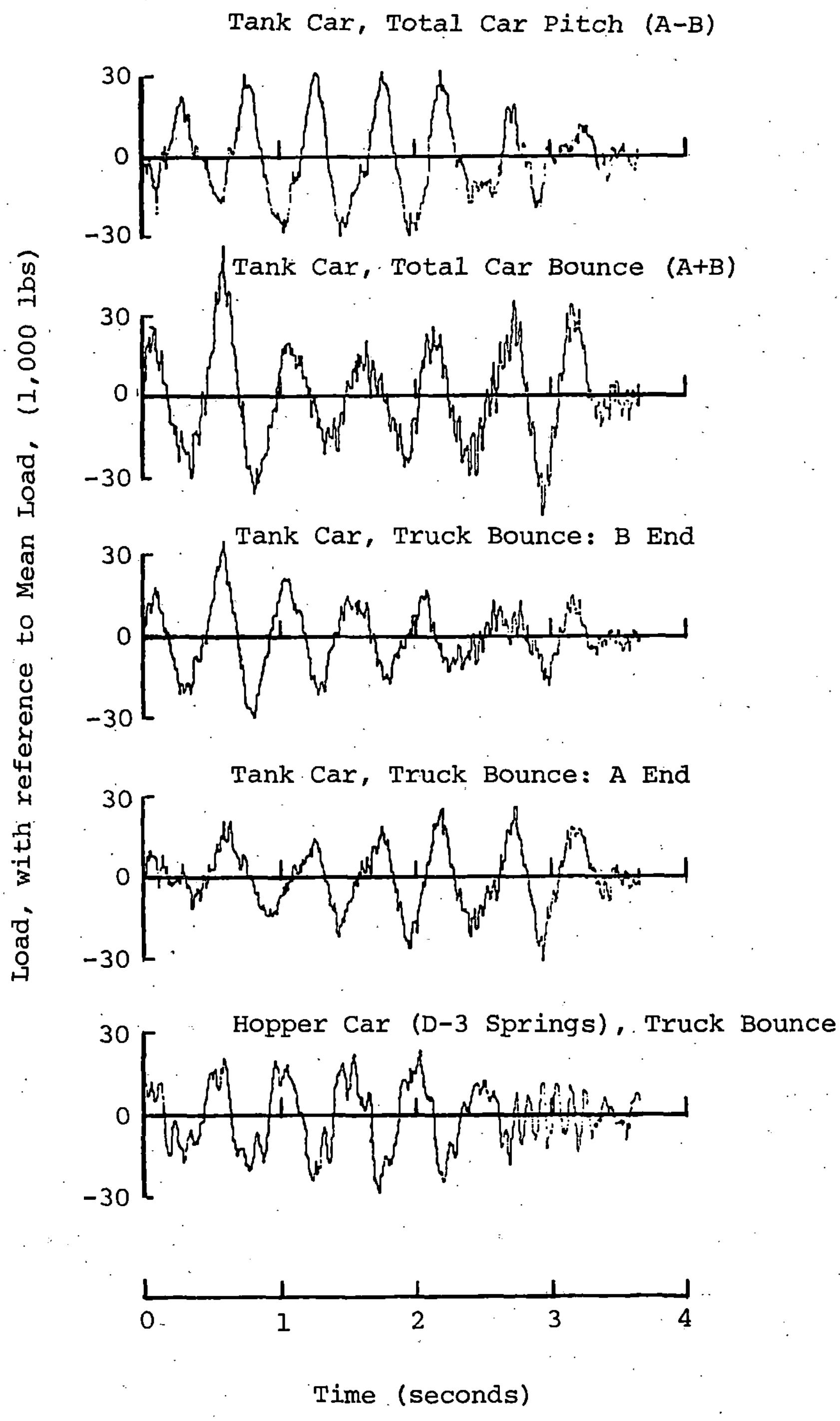


FIGURE 9. TRUCK LOAD PARAMETERS VS TIME, 55 MI/H FORWARD RUN (TEST 20042), BOUNCE TEST SECTION.

3.2 LOAD SPECTRA

The peak load data associated with the rock and bounce test track sections are summarized in the appendix. The most significant features of these data have been plotted on a series of figures to compare the different responses of the hopper car when equipped with different springs, and the differences between the response of the hopper car and the tank car. Data are depicted on a series of load spectra plots in Figures 10 through 14. The plots show the number of times a peak load level was exceeded while traversing the test sections. The curve was established by making a cumulative count; i.e., all values exceeding a given magnitude were included when plotting the number of exceedings. Figure 10 compares the rock load spectra for the hopper car, with D-5 and D-3 springs, on the rock test section. Note the greater intensity of the rock load when the D-3 springs were used.

Figure 11 compares the rock load spectra for the tank car and the hopper car on the rock test section. Hopper car data are for the D-5 springs. The tank car spectra were found by averaging the data from the two trucks and from the two different test series, since there were no changes in the tank car from one test series to the next. The hopper car spectra were much larger than the tank car spectra, indicating the relatively low excitation of the tank car to the staggered shim track irregularities, probably because the truck center distance of the tank car was not a critical dimension and the car had a lower center of gravity.

Figure 12 compares the hopper car side bearing load spectra on the rock test section for the two sets of suspension springs. The results correlate with the rock load test spectra shown in Figure 10. The larger load levels were associated with the stiffer D-3 springs.

Figures 13 and 14 show truck bounce load spectra for traversal of the bounce test section. Figure 13 compares bounce load spectra for the two hopper car spring conditions. Note the similarity of the two spectra; the change in springs produced no significant difference in the bounce load response of the car. The most severe bounce loads occurred on the 60 mi/h test runs. Figure 14 compares the bounce load spectra (averaged for the two tank car trucks and the two test runs) with the bounce load spectra from the hopper car when equipped with D-5 springs. The tank car showed much higher levels of bounce load than the hopper car. The bounce load response was quite speed-dependent, with the maximum loads being obtained at the highest test speed.

3.3 COMPARISON OF FAST DATA WITH THE TYPICAL SERVICE ENVIRONMENT

Figures 15 through 18 show load spectra developed from data taken as the test cars rolled along the FAST track. Figure 15 shows 20 mi/h hopper car rock load spectra for the two test series using different truck springs. The stiffer springs gave only a slightly more intense rock load spectra. Data were compared with RPI/AAR D-series test data in the 15 to 30 mi/h and 30 to 45 mi/h speed ranges (which included results from over 2,300 miles of western and midwestern railroads). These are representative of good mainline track conditions, and the FAST data compare closely with the D-series data.

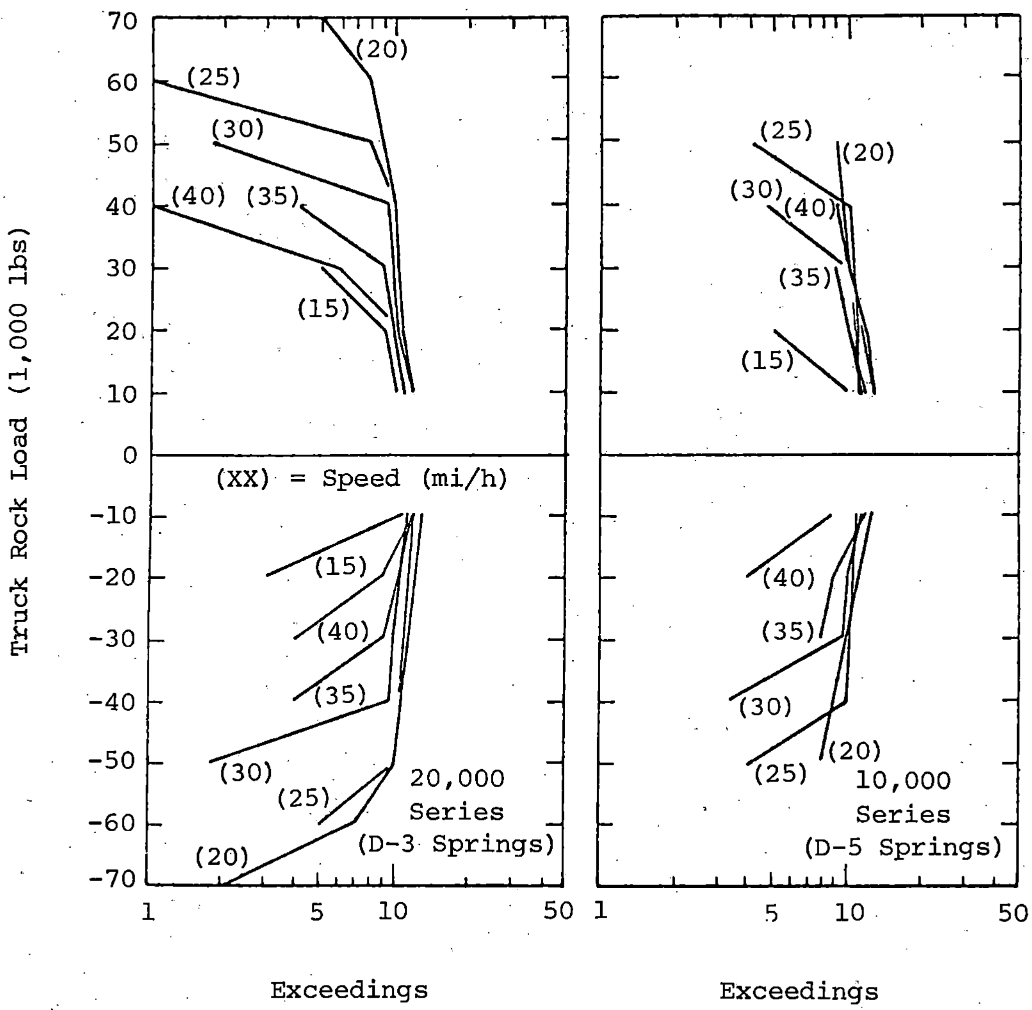


FIGURE 10. TRUCK ROCK LOAD SPECTRA FOR HOPPER CAR, COMPARING 10,000 and 20,000 TEST SERIES DATA.

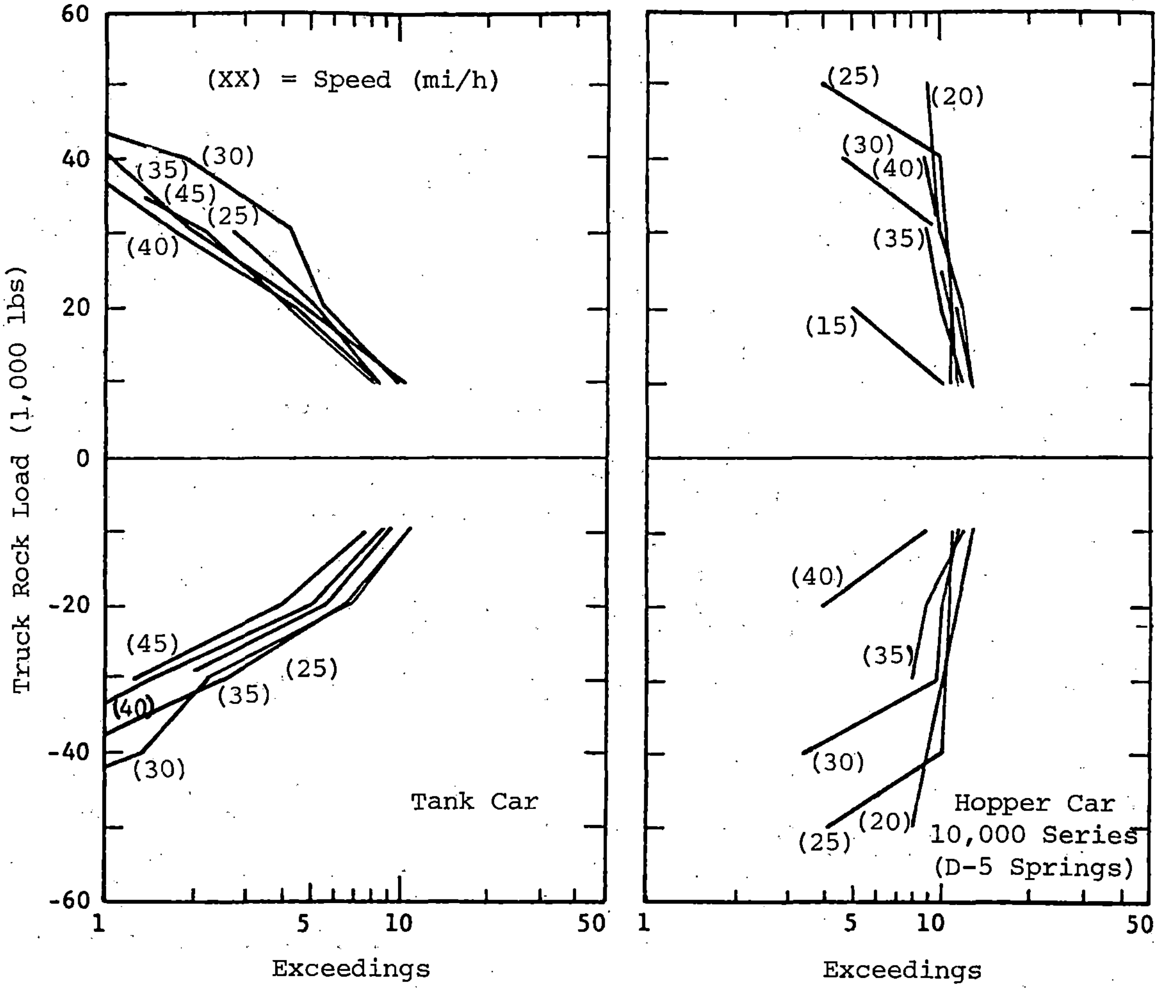


FIGURE 11. TRUCK ROCK LOAD SPECTRA, COMPARING AVERAGE TANK CAR DATA (BOTH TEST SERIES) WITH HOPPER CAR 10,000 TEST SERIES DATA.

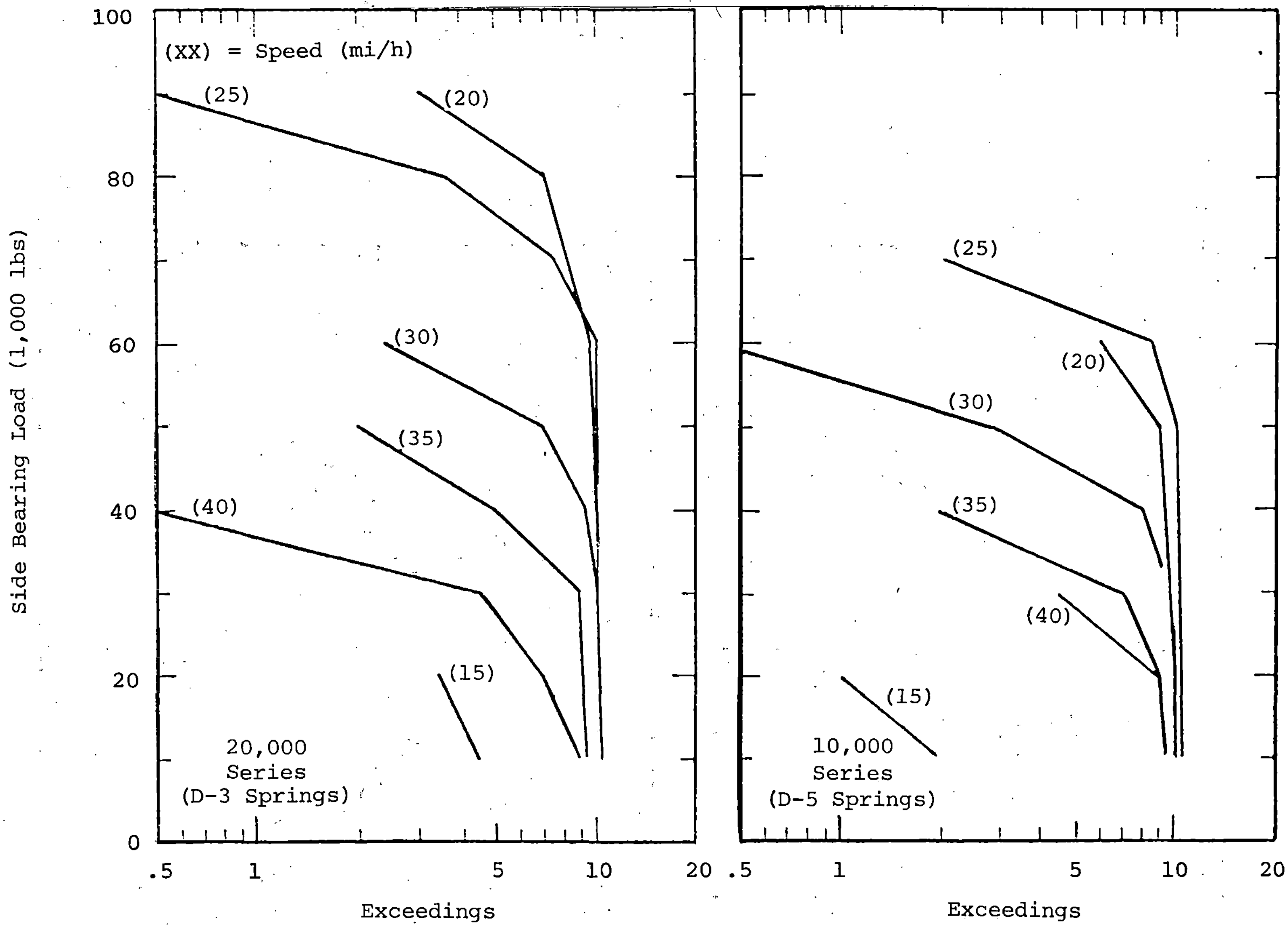


FIGURE 12. SIDE BEARING LOAD SPECTRA FOR HOPPER CAR, COMPARING 10,000 AND 20,000 TEST SERIES DATA.

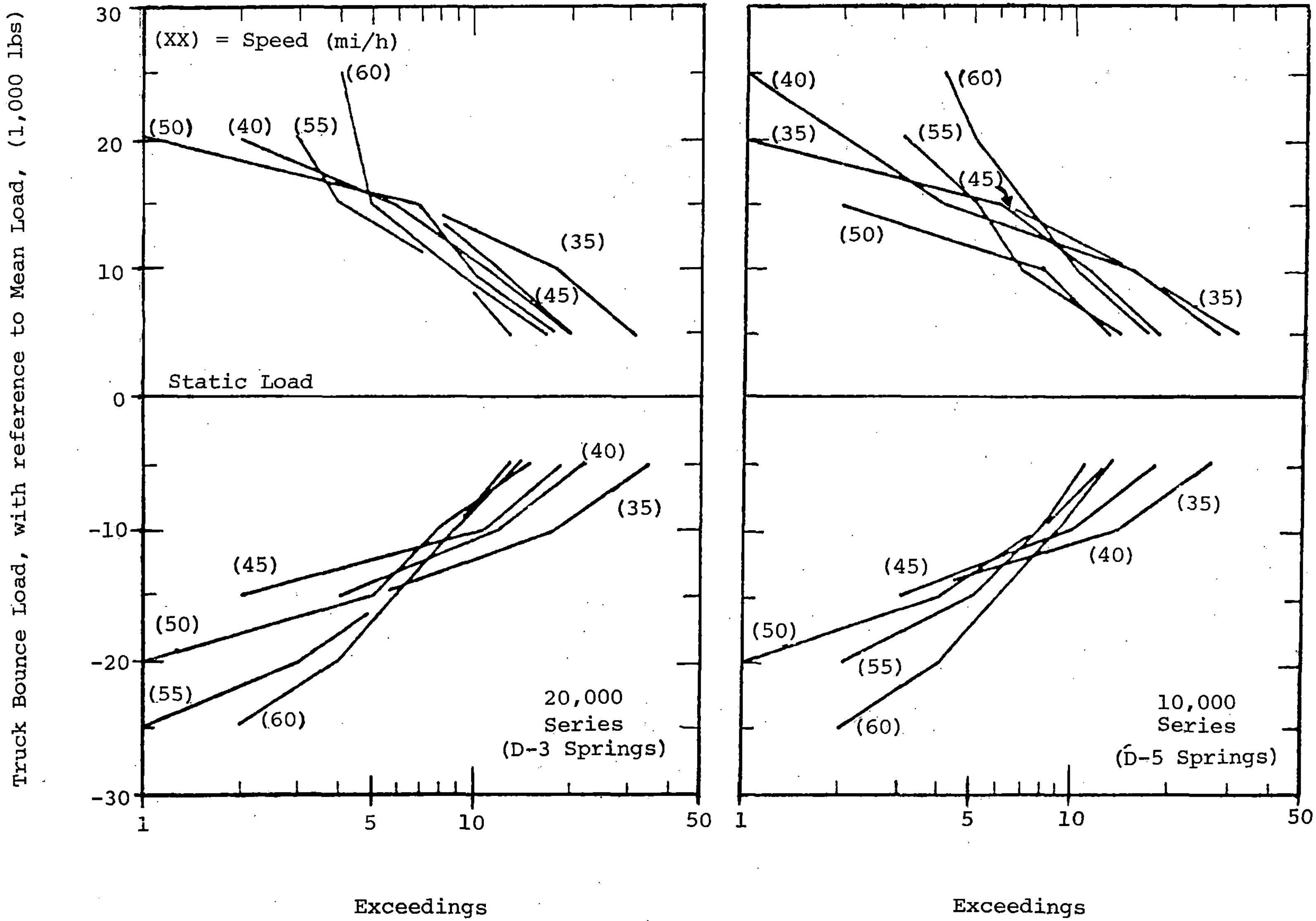


FIGURE 13. TRUCK BOUNCE LOAD SPECTRA FOR HOPPER CAR, COMPARING 10,000 and 20,000 TEST SERIES DATA.

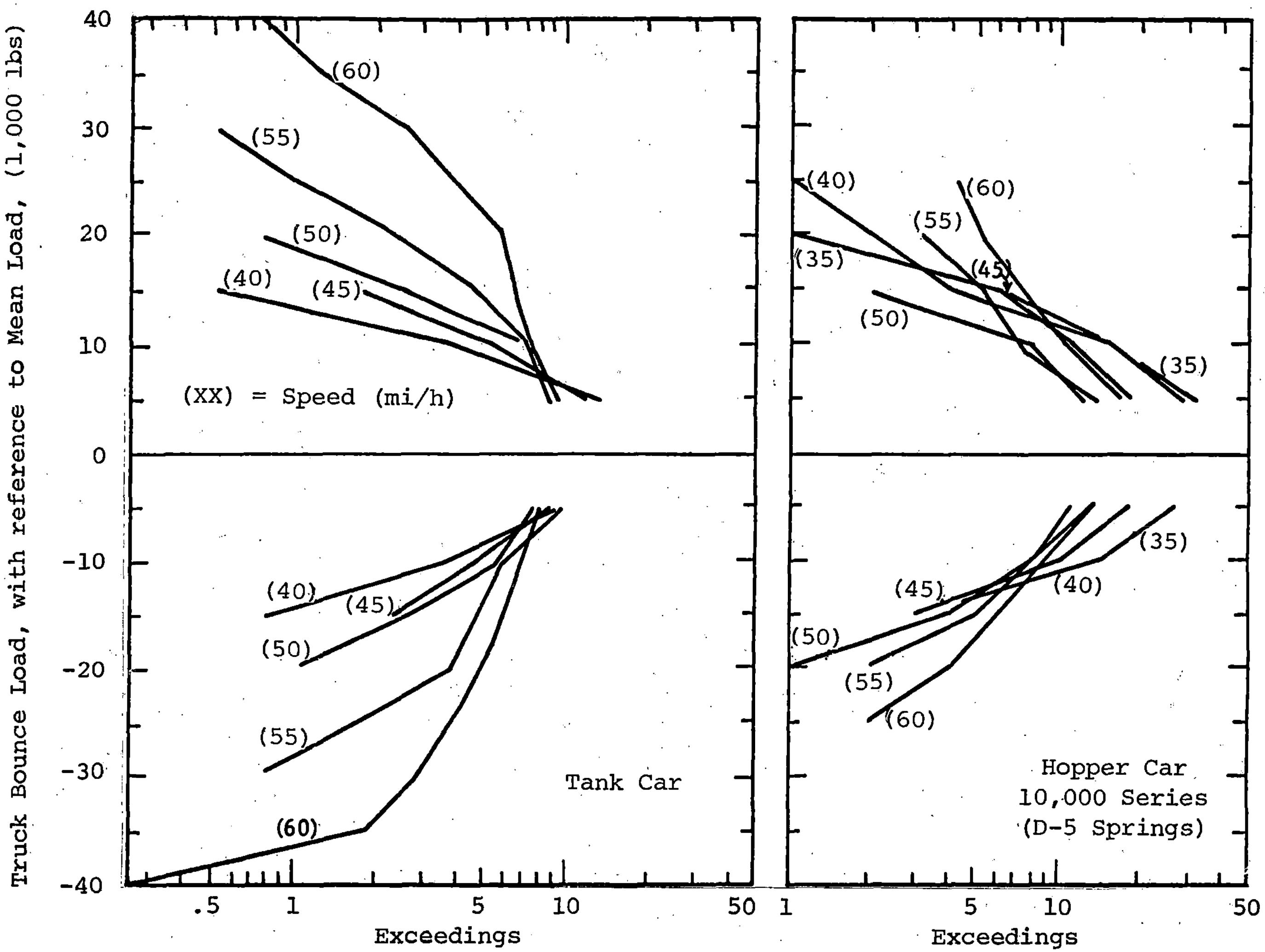


FIGURE 14. TRUCK BOUNCE LOAD SPECTRA, COMPARING AVERAGE TANK CAR DATA (10,000 and 20,000 TEST SERIES) WITH HOPPER CAR 10,000 TEST SERIES DATA.

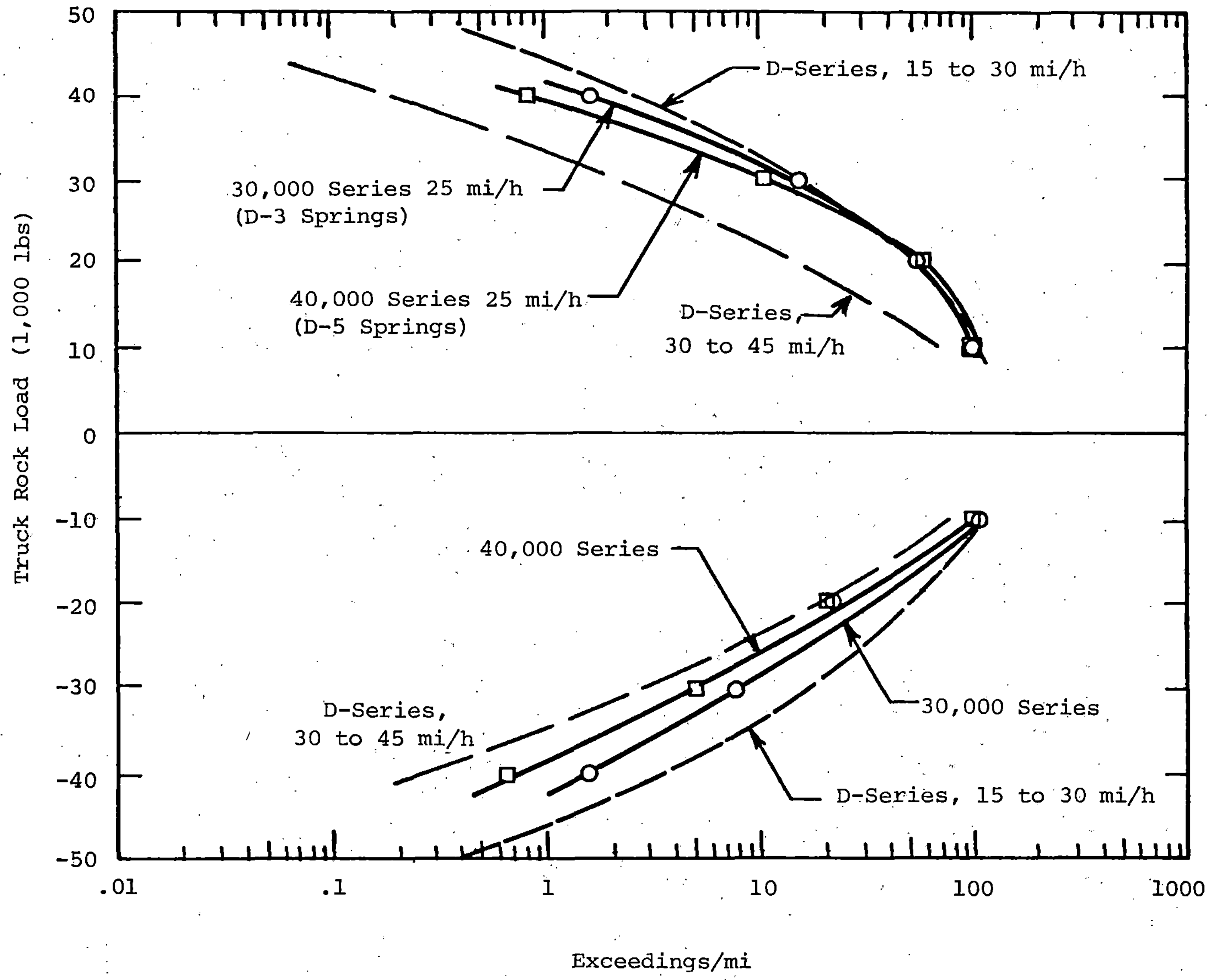


FIGURE 15. TRUCK ROCK LOAD SPECTRA, COMPARING HOPPER CAR DATA FROM D-SERIES TESTS AND FROM FAST OPERATIONS.

Figures 16 and 17 compare hopper car truck bounce load spectra from the FAST track with the D-series data. Figure 16 shows data for the D-3 truck springs and Figure 17 shows data for the D-5 springs. On each curve, points are plotted for 35 and 45 mi/h test runs; there is almost no difference between the bounce load data at those speeds, and there is only a small difference between intensity of the spectra of the two sets of springs. The D-series data for the 30 to 45 mi/h and 45 to 60 mi/h speed ranges are included. Note the similarity of the two spectra in the figures. The FAST data closely approximate the 30 to 45 mi/h service data. However, the service loads were substantially larger in the next higher speed range, 45 to 60 mi/h.

Figure 18 shows the average tank car truck bounce load spectra for test runs on FAST; there was greater speed-dependence than for the hopper car. However, the overall intensity at 45 mi/h was not much different than the hopper car data. Also, note that the comparison with D-series data shows agreement between the 45 mi/h FAST (entire loop) bounce load spectra and the D-series (tangent and curved track) spectra in the 30 to 45 mi/h range. However, the bounce load test spectra were still well below those indicated for the 45 to 60 mi/h speed range D-series data.

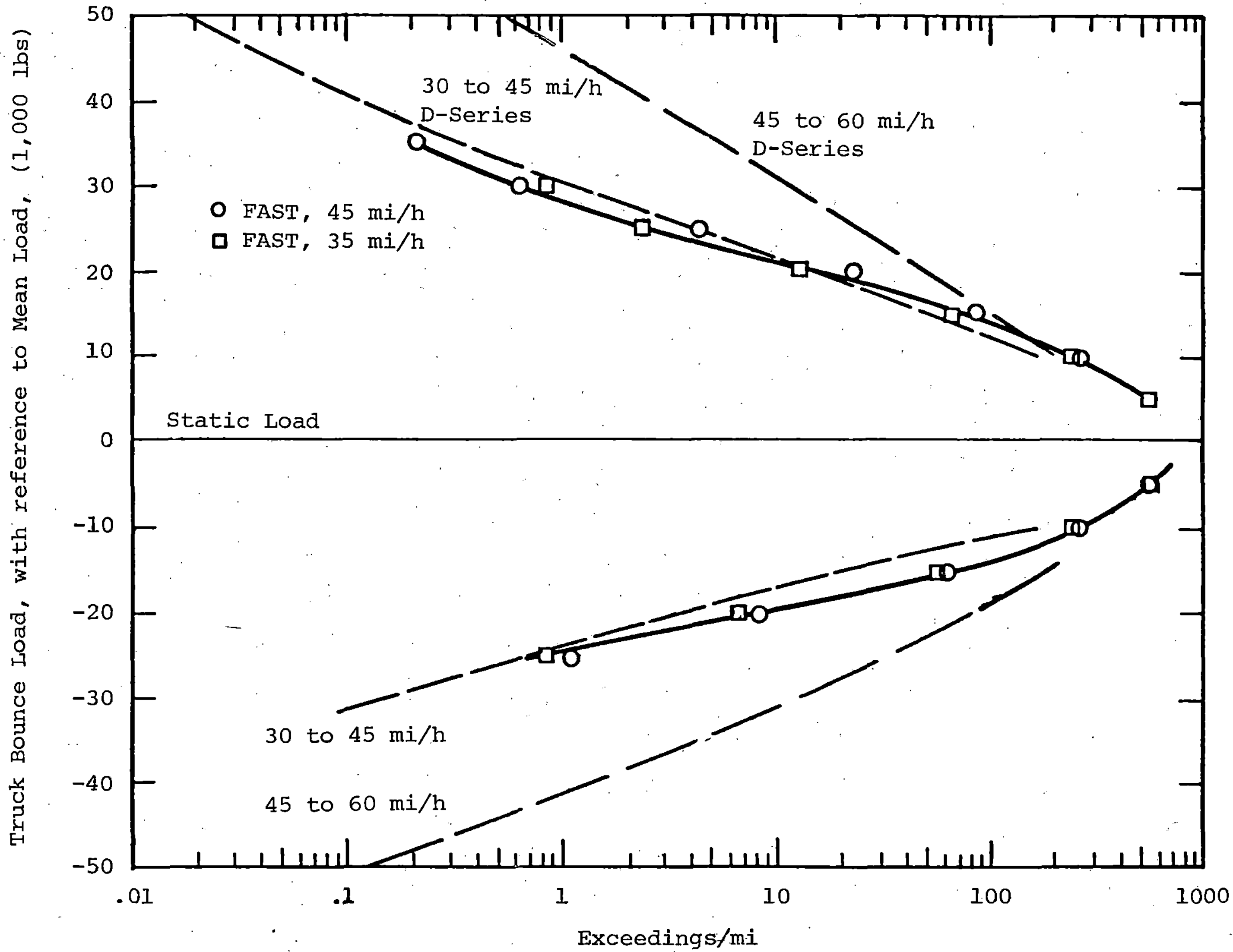


FIGURE 16. TRUCK BOUNCE LOAD SPECTRA, COMPARING HOPPER CAR DATA FROM D-SERIES TESTS AND FROM FAST OPERATIONS (30,000 TEST SERIES, D-3 SPRINGS).

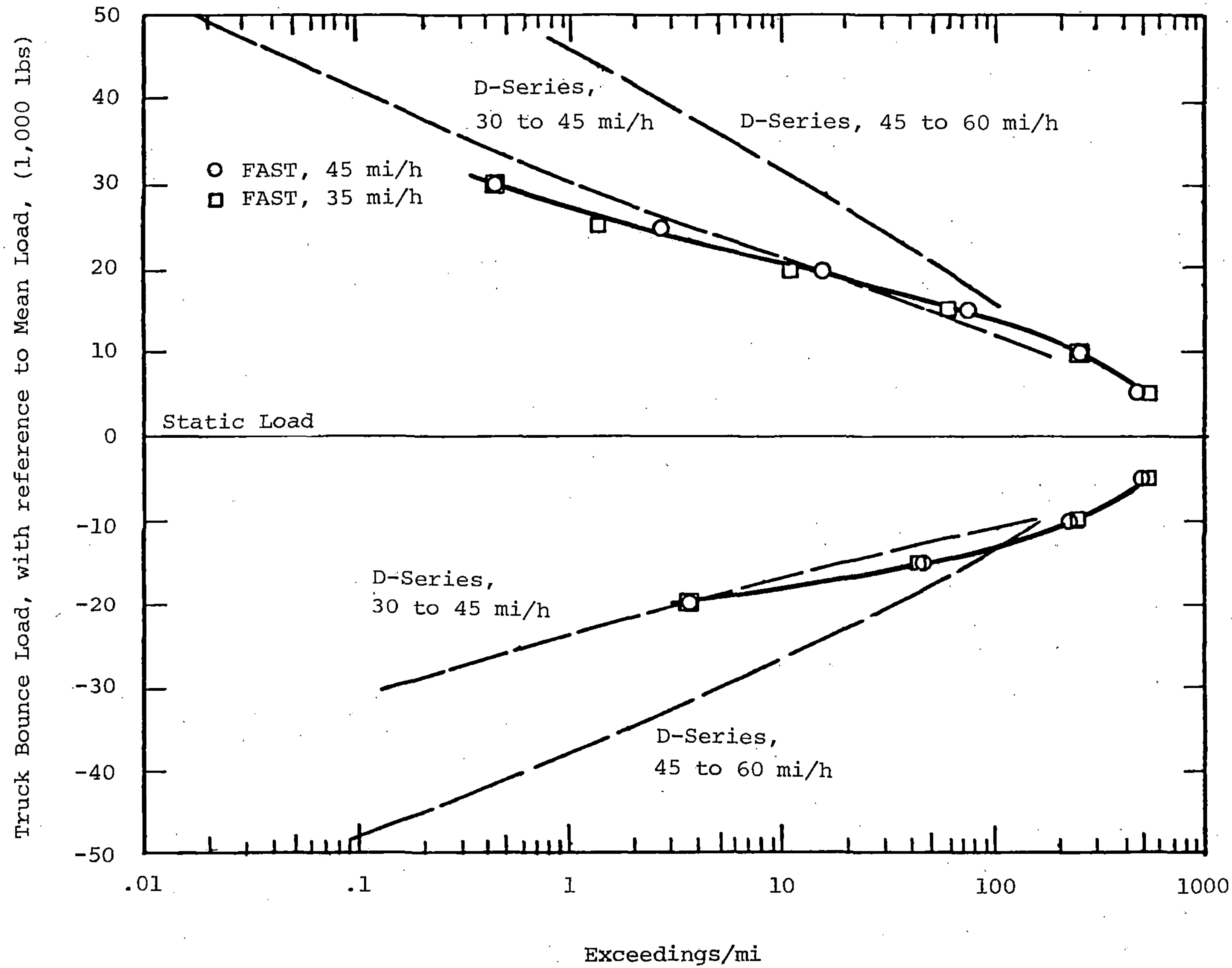


FIGURE 17. TRUCK BOUNCE LOAD SPECTRA, COMPARING HOPPER CAR DATA FROM D-SERIES TESTS AND FROM FAST OPERATIONS (40,000 TEST SERIES, D-5 SPRINGS).

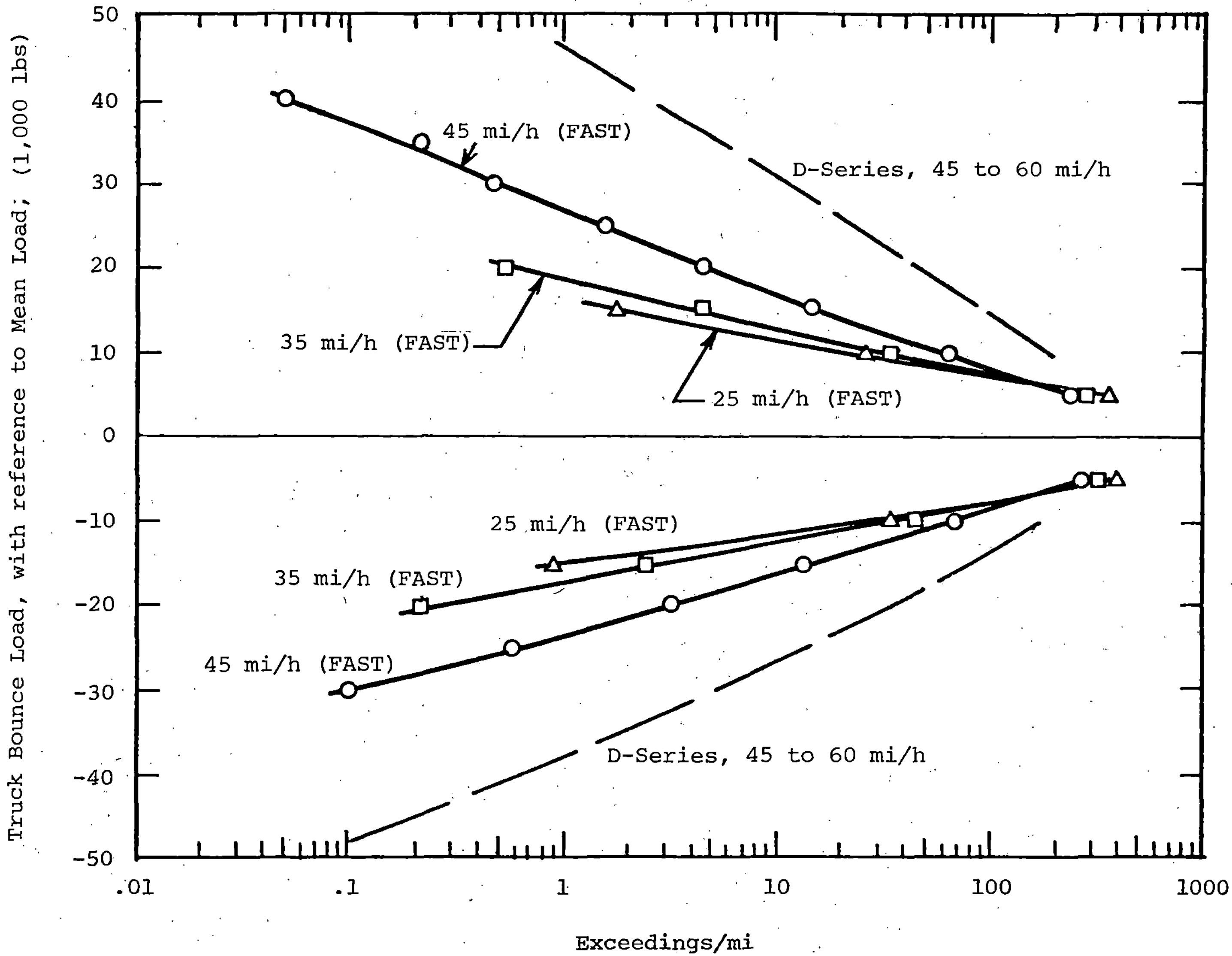


FIGURE 18. TRUCK BOUNCE LOAD SPECTRA, COMPARING TANK CAR DATA FROM FAST OPERATIONS WITH HOPPER CAR DATA FROM D-SERIES TESTS.

4.0 CONCLUSIONS

The substitution of D-3 springs for conventional D-5 springs increased the tendency of the hopper car to develop rock and roll motions when operating over a test track section that was shimmed to excite carbody roll motions. However, when operating over a test track section shimmed to excite carbody bounce and pitch motions, the substitution of D-3 springs for conventional D-5 springs produced no substantial differences in hopper car responses.

The response of the tank car to the rock test section was substantially less than that of the hopper car. On the bounce test section, tank car responses were shown to be more speed-dependent than the hopper car responses; maximum recorded truck bounce loads were as much as 40,000 lbs above the mean load level. These truck bounce loads were far less than loads that had been measured on tank cars in service tests, where peak bounce loads exceeding 120,000 lbs above the mean load had been measured.

Comparison of load spectra from the RPI/AAR D-series test with operations on the FAST track showed that FAST produced a level of truck loads similar to service data in the 30 to 45 mi/h speed range. It must be recognized, however, that service load data are substantially greater at higher speeds.

APPENDIX

TABULATION OF PEAK LOAD DATA

This section presents results from the classification and summarization of peak load data for test car travel on the shimmed track sections. In the analysis of the data, only the peak load occurring between crossings of the mean load value was counted. The values shown in the tables are the number of peak loads, within given load ranges, that occurred during runs over the test section.

TABLE A-1. HOPPER CAR RESPONSE, "BOUNCE" TEST SECTION, BOUNCE LOAD MAXIMA AND MINIMA CLASSIFIED BY LOAD RANGE, BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Ranges of Bounce Load, Measured with respect to Mean Load (1,000 lbs)															
		Positive Load Ranges								Negative Load Ranges							
		40/45	35/40	30/35	25/30	20/25	15/20	10/15	5/10	5/10/	10/15	15/20	20/25	25/30	30/35	35/40	40/45
10007	10B																
10013	15B								1	4							
10018	20F							9	33	34	4						
10019	25B						2	15	25	22	17						
10025	30B							8	20	25	4	1					
10031	30B							5	21	20	5	1					
10037	30B							5	22	20	4	2					
10006	35F					1	4	10	16	14	15						
10012	40F				1		3	11	13	12	10	4					
10024	45F						6	5	7	8	7	3					
10030	50F						3	5	5	5	4	3	1				
10036	55F					3	2	2	7	3	3	2	3				
10045	60F				4	1	2	3	7	4	3	2	2				
20007	10B								1								
20013	15B								6	4							
20018	20F							6	33	34	3						
20019	25B							13	26	20	15						
20025	30B							5	25	24	6	1					
20031	30B							19	13	22	11	2					
20037	30B						2	7	18	20	5	3					
20043	30B							7	19	20	5	1					
20006	35F					1	6	11	13	14	13	5					
20012	40F					2	4	5	9	10	8	4					
20024	45F					1	6	5	8	8	9	2					
20030	50F					1	6	3	8	7	3	4	1				
20042	55F					3	1	5	4	4	3	3	2	1			
20036	60F				4		1	4	8	5	3	2	2	2			

TABLE A-2. TANK CAR RESPONSE, "BOUNCE" TEST SECTION, BOUNCE LOAD MAXIMA AND MINIMA CLASSIFIED BY LOAD RANGE, A END BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Ranges of Bounce Load, Measured with respect to Mean Load (1,000 lbs)															
		Positive Load Ranges								Negative Load Ranges							
		40/45	35/40	30/35	25/30	20/25	15/20	10/15	5/10	5/10/	10/15	15/20	20/25	25/30	30/35	35/40	40/45
10007	10B								25	17							
10013	15B								15	18	2						
10018	20F								21	19	1						
10019	25B							1	25	23	7						
10025	30B							2	18	18	1						
10031	30B							2	24	18	2						
10037	30B							2	16	21							
10006	35F							1	17	10	4						
10012	40F						1	1	14	11	2						
10024	45F						1	3	11	4	2	2					
10030	50F						1	5	3	1	2	2	1				
10036	55F					2	2	2	3	4	1	1	1	1	1		
10045	60F		1	1	1	3			4	1	1			1	3	1	
20007	10B							1	36	33							
20013	15B							1	34	26							
20018	20F								16	24	1						
20019	25B								19	22							
20025	30B							5	14	6	5						
20031	30B							4	28	15	1	1					
20037	30B							4	16	8	6						
20043	30B							5	14	14	2						
20006	35F							1	20	16	2						
20012	40F							4	12	6	2	1					
20024	45F						1	4	5	8	3	1					
20030	50F					1	1	6	5	4	3	1	1				
20042	55F				2	1	2	1	2	2	2		2	1	1		
20036	60F	1		3	2			1	4	1	1	1			1	4	

TABLE A-3. TANK CAR RESPONSE, "BOUNCE" TEST SECTION, BOUNCE LOAD MAXIMA AND MINIMA CLASSIFIED BY LOAD RANGE, B END BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Ranges of Bounce Load, Measured with respect to Mean Load (1,000 lbs)															
		Positive Load Ranges								Negative Load Ranges							
		40/45	35/40	30/35	25/30	20/25	15/20	10/15	5/10	5/10/	10/15	15/20	20/25	25/30	30/35	35/40	40/45
10007	10B							1	18	34							
10013	15B								19	23							
10018	20F								20	16	1						
10019	25B							2	17	20	2						
10025	30B							2	14	13	6						
10031	30B							1	21	18	3						
10037	30B							2	18	20	5						
10006	35F							4	14	3	5						
10012	40F							4	8	6	6						
10024	45F						3	2	5	4	2	3					
10030	50F					1	2	4	2	2	1	2	2				
10036	55F			1		1	2	4	1	4	2	1	1	1	1		
10045	60F	1		1		4		3			1	1	3	1		1	
20007	10B								14	30							
20013	15B								9	24							
20018	20F								14	17	1						
20019	25B								18	21	2						
20025	30B							3	20	8	2						
20031	30B							4	17	25	2						
20037	30B							5	12	15	2						
20043	30B							1	14	10	5						
20006	35F							4	10	14	2						
20012	40F						1	3	3	2	1	2					
20024	45F						2	5	6	2	2	3					
20030	50F					1	3	3	2	2	6	1					
20042	55F			1		1	3	3		4	1	2	2	1			
20036	60F	1	1		2	1	2			2		2	1	2			1

TABLE A-4. HOPPER CAR RESPONSE, "ROCK" TEST SECTION, RIGHT SIDE BEARING LOAD MAXIMA CLASSIFIED BY LOAD RANGE, BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Load Range (10,000 lbs)								
		1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	9/10
10009	10B									
10015	15B	2	2							
10016	20F		1			5	4			
10021	25B	1				2	7	1		
10027	30B			1	5	4				
10033	30B			4	5	1				
10039	30B			4	3	3				
10004	35F	1	3	6						
10010	40F	1	5	4						
10022	45F	3	4	2						
10028	50F	1	5	2						
10034	55F	1	3	3	1					
10040	60F	1	4	2	1					
10043	60F	3	2	2	2					
20009	10B									
20015	15B	1	7							
20016	20F	1			1			1	3	5
20021	25B	1					4	4	1	1
20027	30B			1	4	4	1			
20033	30B				4	3	3			
20039	30B				4	5	1			
20045	30B			1	4	3	2			
20004	35F		1	5	3	1				
20010	40F	2	2	4	1					
20022	45F		7	2						
20028	50F	1	5	3						
20040	55F	2	3	3	1					
20034	60F	3	2	2		1				

TABLE A-5. HOPPER CAR RESPONSE, "ROCK" TEST SECTION, LEFT SIDE BEARING LOAD MAXIMA CLASSIFIED BY LOAD RANGE, BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Load Range (10,000 lbs) 1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	9/10
10009	10B									
10015	15B									
10016	20F			1		1	8			
10021	25B					1	6	3		
10027	30B		1		2	5	2			
10033	30B		1		8	1				
10039	30B		1		8	1				
10004	35F		1	4	4					
10010	40F		4	5						
10022	45F	1	5	3						
10028	50F		2	6						
10034	55F	1	2	5						
10040	60F	1	1	3	2					
10043	60F	2	1	4	1					
20009	10B									
20015	15B	1								
20016	20F						3	1	5	1
20021	25B						1	4	5	
20027	30B		1		2	6	1			
20033	30B			1		4	5			
20039	30B				1	6	3			
20045	30B				2	5	3			
20004	35F			3	3	3				
20010	40F	2	3	4						
20022	45F	3	2	4						
20028	50F	2	2	4						
20040	55F		2	4	2					
20034	60F	1	1	2	3					

TABLE A-6. HOPPER CAR RESPONSE, "ROCK" TEST SECTION, ROCK LOAD MAXIMA AND MINIMA CLASSIFIED BY LOAD RANGE, BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Rock Load Range (10,000 lbs)													
		Positive Load Ranges							Negative Load Ranges						
		7/8	6/7	5/6	4/5	3/4	2/3	1/2	1/2	2/3	3/4	4/5	5/6	6/7	7/8
10009	10B							6	7						
10015	15B						5	5	12						
10016	20F			9		1	1	1	3		2	1	8		
10021	25B			4	6		1		1			6	4		
10027	30B				7	3		2	2		5	5			
10033	30B				2	8		1	1		8	2			
10039	30B				5	5		2	1	1	6	3			
10004	35F					9	1	2	3	1	8				
10010	40F				9	1		2	5	4					
10022	45F					3	7		3	7	2				
10028	50F					5	5		4	6	2				
10034	55F					6	3	1	4	4	4				
10040	60F					4	5	2	5	2	5				
10043	60F				1	4	4	1	4	5	2				
20009	10B							6	7						
20015	15B					5	4	1	8	3					
20016	20F	5	3	1	1		1	1	3				3	5	2
20021	25B		1	7	2		1	1	2				5	5	
20027	30B			1	8	1		2	1		1	8	1		
20033	30B			3	6	1	1	1	2		1	7	2		
20039	30B			2	8			1	1		1	8	1		
20045	30B			2	6	2	1	1	1			9	1		
20004	35F				4	5	1	1	3		5	4			
20010	40F				1	5	4	1	3	5	4				
20022	45F					7	3		3	5	3				
20028	50F					5	5		4	4	4				
20040	55F					7	3		4	3	5				
20034	60F				1	3	5	1	5		6				

TABLE A-7. TANK CAR RESPONSE, "ROCK" TEST SECTION, ROCK LOAD MAXIMA AND MINIMA CLASSIFIED BY LOAD RANGE, A END, BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Rock Load Range (10,000 lbs)													
		Positive Load Ranges							Negative Load Ranges						
		7/8	6/7	5/6	4/5	3/4	2/3	1/2	1/2	2/3	3/4	4/5	5/6	6/7	7/8
10009	10B						8	5	9	1					
10015	15B						3	7	8	2					
10016	20F							6	6						
10021	25B					6	3	3	3	8	1				
10027	30B				4	4	3		1	3	3	4			
10033	30B				3	3	3	1	2	5	2	1	1		
10039	30B				4	5	1	1	2	4	3	1	1		
10004	35F		1			1	6	2	5	3	2				
10010	40F			1		2	1	5	3	4		1			
10022	45F				2	2	1	3	5	3	1				
10028	50F				2	3		1	5	1	1				
10034	55F				1	4		1	7	2					
10040	60F					1	4	5	8	3					
10043	60F						6	5	6	4					
20009	10B						7	2	11						
20015	15B						3	7	8	1					
20016	20F						3	6	7						
20021	25B				2	7	3	2	3	5	5				
20027	30B			1	1	7	1	2	3	3	3	1	1		
20033	30B			1	5	3	1	1	3	4	3	1	1		
20039	30B			1	2	4	2	1	2	6	1	2			
20045	30B			1	2	3	4	1	5	4		3			
20004	35F				1	2	3	4	5	6					
20010	40F				2	1	3	3	5	1	1		1		
20022	45F			1		3	3	4	6	5					
20028	50F				2	3		1	3	3	1				
20040	55F						4	7	8	2					
20034	60F						6	5	7	3					

TABLE A-8. TANK CAR RESPONSE, "ROCK" TEST SECTION, ROCK LOAD MAXIMA AND MINIMA CLASSIFIED BY LOAD RANGE, B END, BOTH TEST SERIES.

Test Number	Speed (mi/h) and Direction (F-forward B-backward)	Rock Load Range (10,000 lbs)													
		Positive Load Ranges							Negative Load Ranges						
		7/8	6/7	5/6	4/5	3/4	2/3	1/2	1/2	2/3	3/4	4/5	5/6	6/7	7/8
10009	10B							10	10						
10015	15B					1		8	5	5	1				
10016	20F							11	3	4	3	1			
10021	25B							3	6	1					
10027	30B						1	9	7	3		1			
10033	30B						1	7	5	3	2				
10039	30B						1	7	6	2	2				
10004	35F				1	1	1	8	3	3	3	2			
10010	40F					1	4	3	5	4	2				
10022	45F					1	2	4	7	2	2				
10028	50F					1	1	5	1	2	4				
10034	55F							7	2	2	3				
10040	60F							10	6	2					
10043	60F							9	6	2					
20009	10B							10	4	5					
20015	15B					1		9	5	5					
20016	20F						5	7	1	5	2	2			
20021	25B							5	3	1	1				
20027	30B						2	8	4	2	2	1			
20033	30B						2	8	5	4	2				
20039	30B						1	8	7	2	2				
20045	30B							9	6	3	2				
20004	35F				1		1	9	4	4	2	1			
20010	40F						3	5	2	5	1				
20022	45F						2	5	7	1	2				
20028	50F					1	1	5	1	4	2				
20040	55F						1	7	4	4					
20034	60F							10	9	2					

GPO 835-507

Hopper vs Tank Car Truck Loads, 1981
US DOT, FRA, MR Johnson, RA Evans, S Guins
(FRA/TTC 82/03)