U.S. Department
of Transportation
**Federal Railroad
Administration**

SAFETY MARGIN TESTING OF A 70-TON BOXCAR WITH SHIFTED PLYWOOD LADING

Office of Research and
Development
Washington DC 20590

TEST RESULTS DATA

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DOT/FRA/ORD-84/15.02

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Final Report

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03 - Rail Vehicles &
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16. Abstract

Tests were performed at the Transportation Test Center, Pueblo, Colorado, in a joint Association of American Railroads (AAR) and Federal Railroad Administration (FRA) effort in the April-May-June period of 1982. AAR objectives were to perform a "pilot" test on the Vibration Test Unit (VTU) as a demonstration that the facility could meet their requirements for lading damage prevention testing. Pilot test results have been reported by the AAR.

The FRA performed "Safety Margin Tests" of a plywood lading that is suspected of being a derailment cause factor, with the objectives of determining conditions that cause the plywood to shift and the effect of the shifted plywood on derailment margins. Volume 1 presents a summary of the safety margin tests performed and test results. Volume 2 contains the data from which the summary was extracted.

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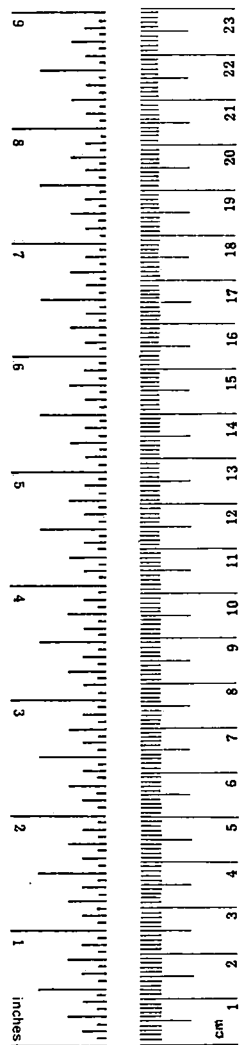
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

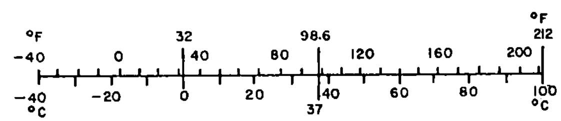
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

A cooperative test effort between the Association of American Railroads (AAR) and the Federal Railroad Administration (FRA) was conducted at the Transportation Test Center (TTC), Pueblo, Colorado in the April-May-June period of 1982. The test vehicle used was the DOTX 503, which is a 50-foot 70-ton boxcar. The testing performed was primarily on the Vibration Test Unit (VTU) but also included longitudinal impacting and over-the-road measurements. The AAR test requirement, presented in Reference 1, and the FRA requirements, presented in Reference 2, were incorporated into the Implementation Plan, Reference 3.(1) The AAR objectives were primarily concerned with evaluation of the performance and operation of the VTU and to determine the feasibility of using the VTU as a rail vehicle simulator for damage prevention testing. Results of the AAR tests are contained in References 4 and 5.

The FRA objectives centered on the investigation of derailment cause and prevention using a boxcar and lading configuration that has been a suspected contributing cause to several derailments. The FRA tests were performed between June 8 and June 30, 1982; they have been identified as Safety Margin Testing and are the subject of this report.

MITRE involvement in these tests has been in support of both the AAR and FRA phases of testing. This report, however, covers only the Safety Margin Testing conducted at the Transportation Test Center's Rail Dynamics Laboratory (RDL).

A review of freight car derailment statistics has shown that the combination of curved track with out-of-specification low joints and boxcars with plywood lading has been frequently involved in derailments.(2) It is suspected that in these cases the plywood lading had shifted laterally and was a major contributor to the cause of derailment.

The typical boxcar is 114 inches in inside width; thus there is a total lateral clearance of 18 inches with 4 x 8 plywood. AAR loading specifications require that the plywood be placed in

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(1)The List of References can be found at the end of this report.

(2)Discussions with members of the Association of American Railroads (AAR) Subcommittee on Freight Claim and Damage Prevention; Tom Schoenleben, Chessie, Baltimore, Md., Harry Grosso, AAR, and Peter Kiliani, CONRAIL.

the center (laterally) and that longitudinal wedging be effected with wooden spacers between each adjacent stack of plywood. Longitudinal preload is applied using air bags and held with wooden wedges. The objective of this AAR requirement is to minimize longitudinal dynamics and reduce the tendency for lateral shifting of the plywood.

The objectives of the Safety Margin Testing of this report are first to determine the threshold of track variations that will cause the plywood lading to shift and then to determine what track variations will result in wheel lift. The effect of various truck suspension systems, including hydraulic snubbers, on the response of the carbody and lading and the margin of derailment conditions were investigated.

This working paper is the second of a two volume report: Volume 1 was the basic report with summarized test data; Volume 2 contains the base test data and plots used in developing the final summary data and is in four sections. Section 1 contains carbody roll angle and vertical wheel load plots from the staggered rail tests ordered by run number. Sections 2, 3 and 4 contain Power Spectral Density (PSD) plots as summaries, as X and Z envelopes, and as comparisons of Configuration 1 and Configuration 2 responses.

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(Concluded)

1. STAGGERED RAIL TEST RESULTS

Staggered rail tests were performed using rectified sine profile shapes. Each run was with constant cross level amplitudes of low joints and with decreasing frequencies corresponding to a speed slow down from 35 to 11 miles per hour. Successive runs were made with increased cross level for each new run until the lading started to shift or zero wheel load occurred. Table 1-1 presents a summary of the runs made identifying configuration, test, run number, and input level. Table 1-2 defines the changes made for each configuration.

The data presented are plots of carbody roll angle as a function of frequency (speed) and corresponding plots of vertical wheel load. The load data shown is from the left and right wheels of axle 1. However, in performance of the tests, all vertical wheel loads were monitored through the computer controlling the shaker. The shaker was stopped (limit checked) when any of the eight strain readings approached zero.

TABLE 1-1
TEST MATRIX

CONFIG.*	INCREASED TRACK GEOMETRY RUN/SCALE FACTOR		STAGGERED RAIL RUN/AMPLITUDE (INCHES)		SUPERELEVATED RAIL NORTH SIDE HIGH STAGGERED RAIL RUN/AMPLITUDE (INCHES)	
	CENTERED	SHIFTED	CENTERED	SHIFTED	CENTERED	SHIFTED
1	49/1.25	56/1/25	54/0.2	60/0.2		83/0.2
	50/1.50	57/1.50	55/0.4	61/0.4		84/0.3
	52/1.75#	58/1/75		62/0.6		85/0.4
	53/2.00#	59.2.00#				
2	122/1.25	118/1.25	126/0.2	98/0.2	128/0.2	101/0.2
	123/1.50	119/1.50	127/0.4	99/0.4	129/0.3	102/0.3
	124/1.75	120/1.75		100/0.6		103/0.4
	125/2.00#	121/2.00#				
3				104/0.2		109/0.2
				106/0.4		108/0.3
				107/0.6		
4				111/0.2		113/0.2
				110/0.4		112/0.3
5				115/0.3		117/0.2
				114/0.4		116/0.3
6		130/1.25		132/0.2		135/0.2
		131/1.75		133/0.4		136/0.3
				134/0.6		137/0.4
7		138/1.25		140/0.2		143/0.2
		139/1.75		141/0.4		144/0.3
				142/0.6		145/0.4
8		146/1.25		148/0.2		151/0.2
		147/1.75		149/0.4		152/0.3
				150/0.6		

*Suspension configurations are as shown in Table 1-2.
#These tests are invalid due to an error in the input track geometry introduced by the computerized process when increasing the amplitude.

Note: Total runs made from run #48 through run #153. Runs not listed were aborted or gave inconclusive results.

TABLE 1-2
TRUCK CONFIGURATIONS, SAFETY MARGIN TESTING

CONFIGURATION NUMBER	FRICTION[1] SNUBBERS	HYDRAULIC[2] SNUBBERS	SPRING RATES PER NEST[3] (lb./in.)
1	High	None	18,000
2	Low	Low	15,000
3	Low	High	15,000
4	High	Low	16,000
5	High	High	16,000
6	None	Low	13,000
7	None	High	13,000
8	Low	None	15,000

[1] Friction snubber condition:
High = with inner and outer side springs
(force equal about 5,000 lb./spring nest)
Low = with outer side spring only
(force equal about 2,800 lb./spring nest)

[2] Hydraulic snubbers. See Figure 3-4 for force rates.

[3] Spring rates per spring nest based on the following values:
D5 outers: 2,140 lb./in. each
B-432 Side outers: 984 lb./in. each
B-433 Side inners: 439 lb./in. each

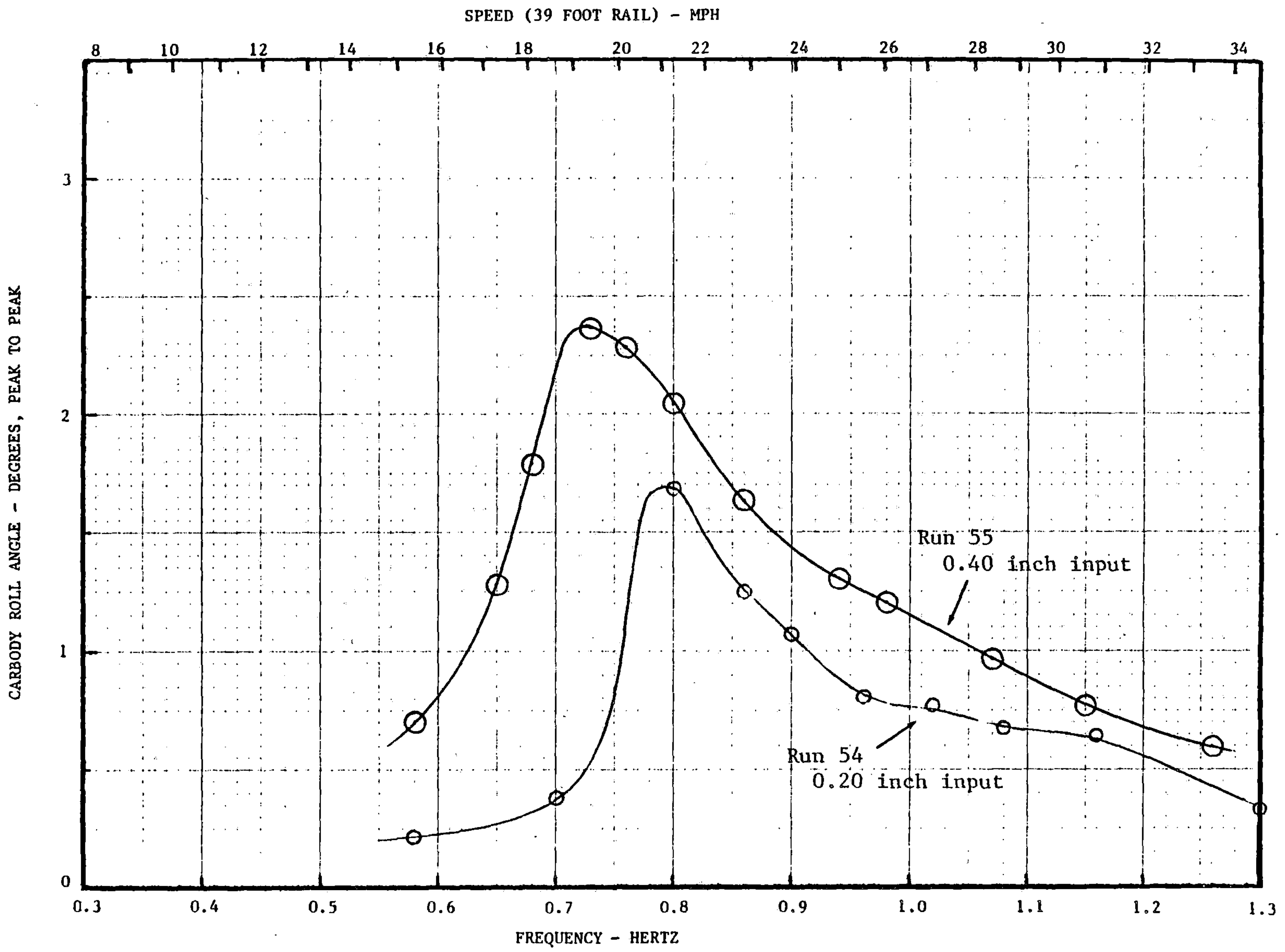

FIGURE 1-1
CARBODY ROLL ANGLES, CONFIGURATION 1, CENTERED LADING,
STAGGERED RAIL TEST, RUNS 54 AND 55

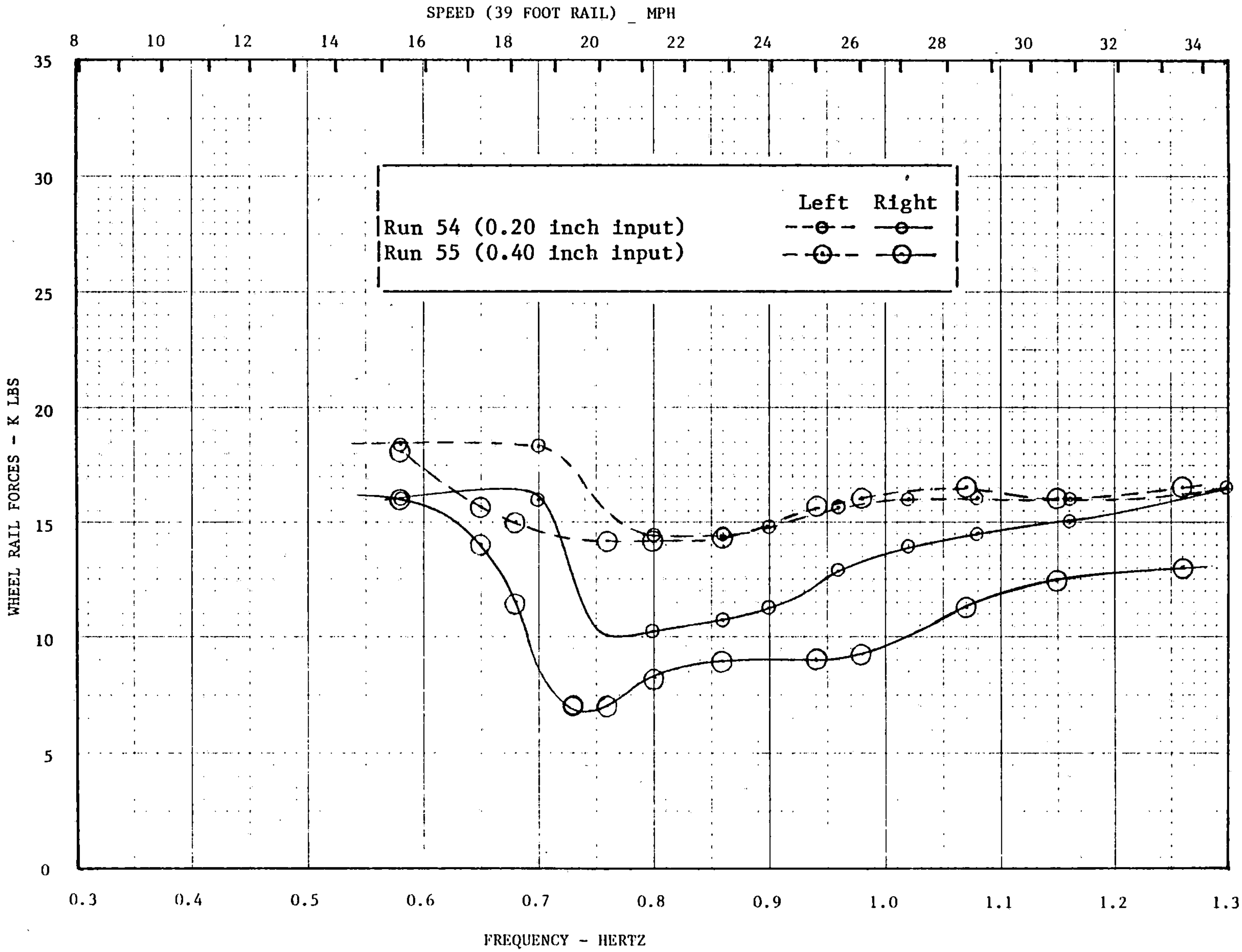

FIGURE 1-2
MINIMUM WHEEL VERTICAL LOAD, CONFIGURATION 1, CENTERED LADING, STAGGERED RAIL TEST RUNS 54 AND 55

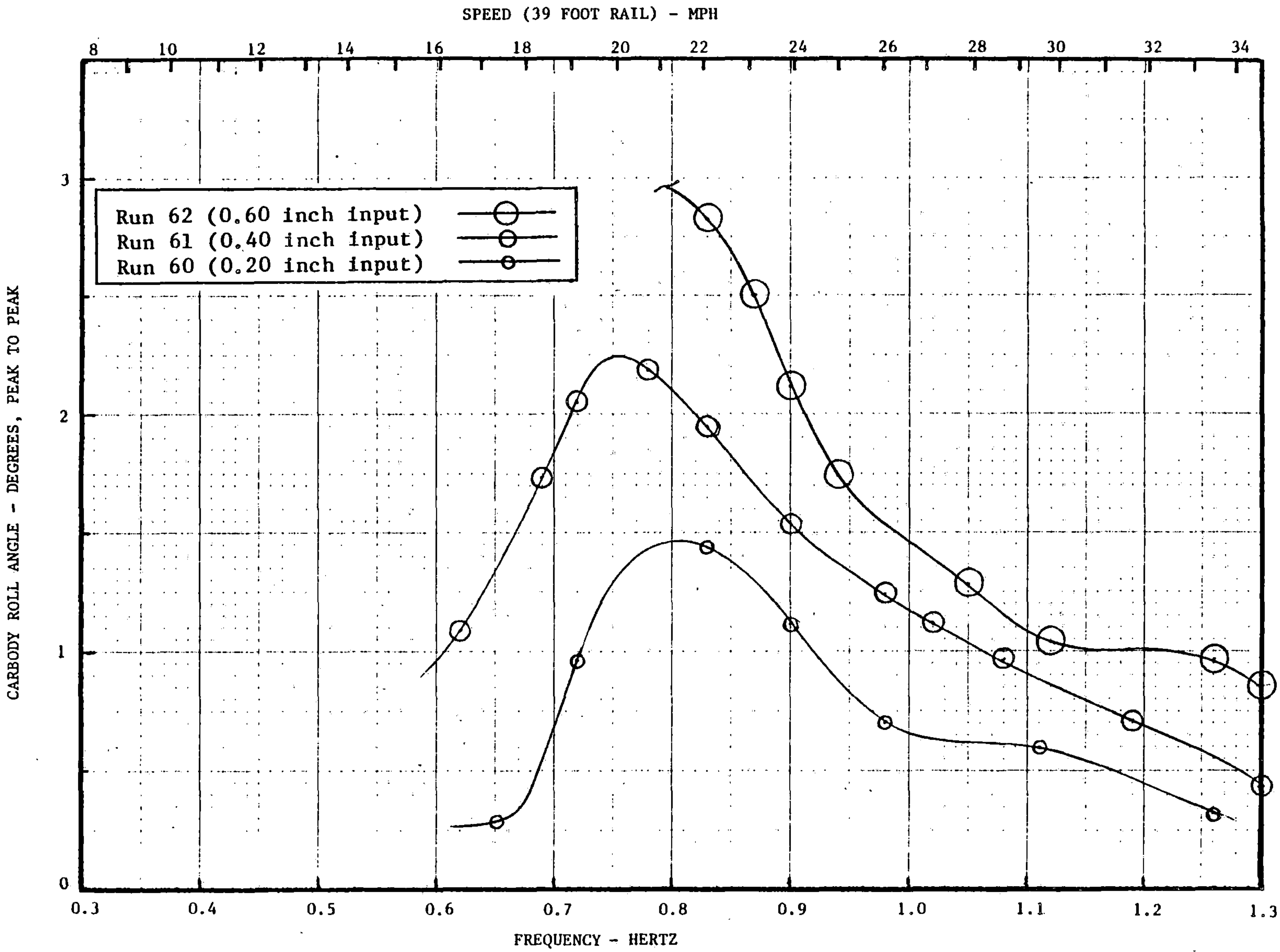

FIGURE 1-3
CARBODY ROLL ANGLES, CONFIGURATION 1, SHIFTED LADING,
STAGGERED RAIL TEST, RUNS 60, 61, and 62

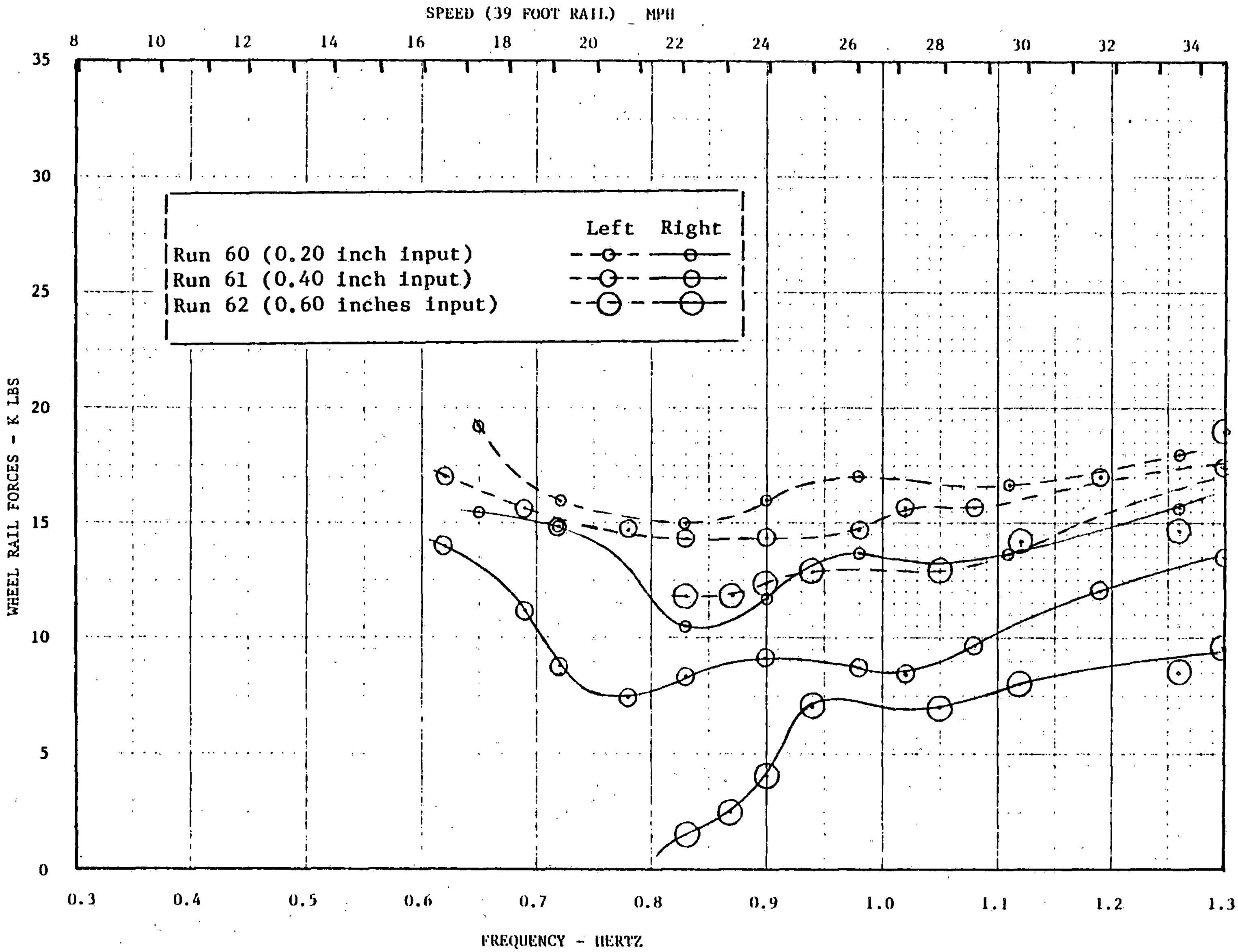

FIGURE 1-4
MINIMUM VERTICAL WHEEL LOAD, CONFIGURATION 1, LADING SHIFTED,
STAGGERED RAIL TEST, RUNS 60, 61, and 62

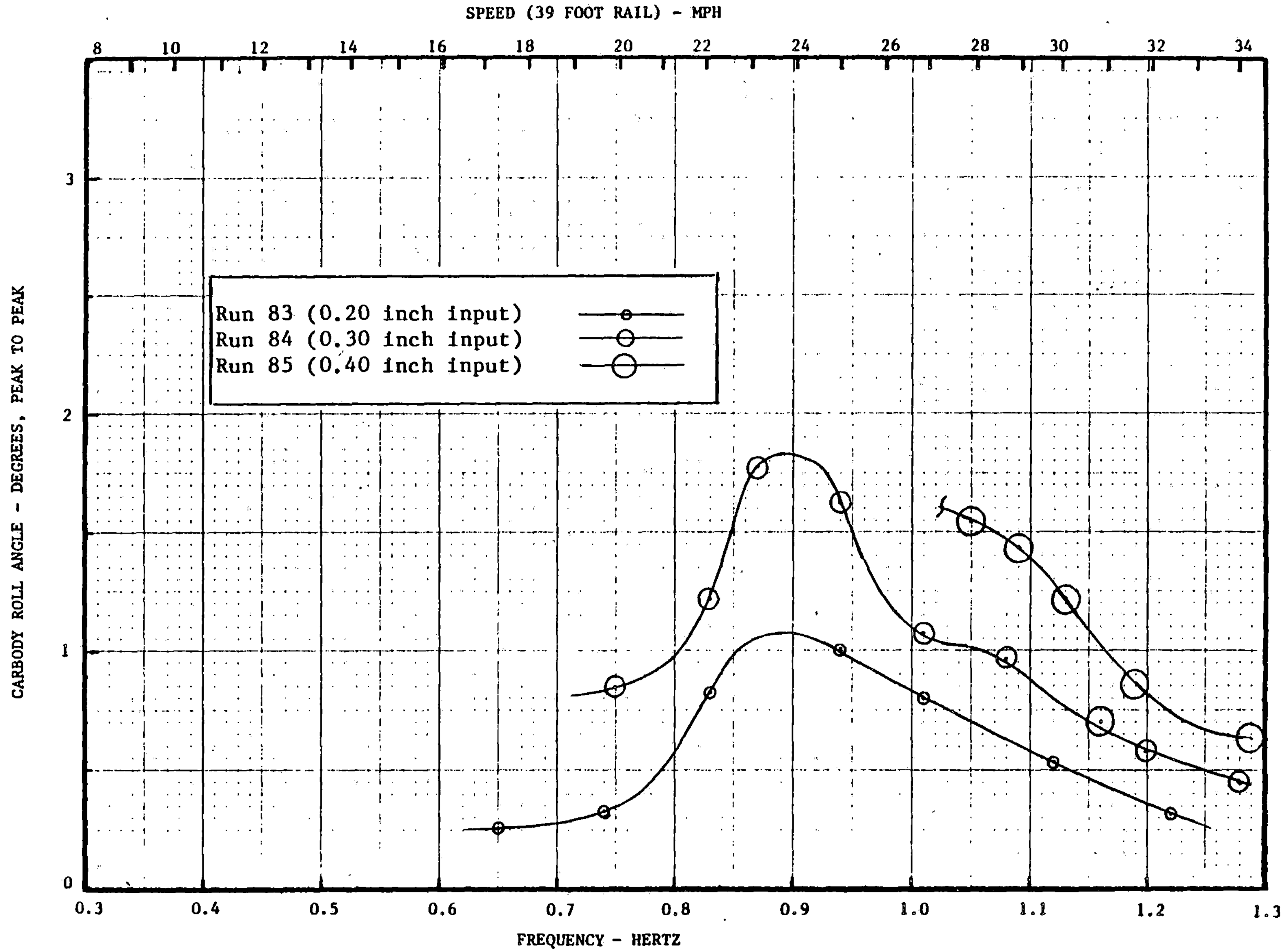

FIGURE 1-5
CARBODY ROLL ANGLES, CONFIGURATION 1, LADING SHIFTED, STAGGERED RAIL
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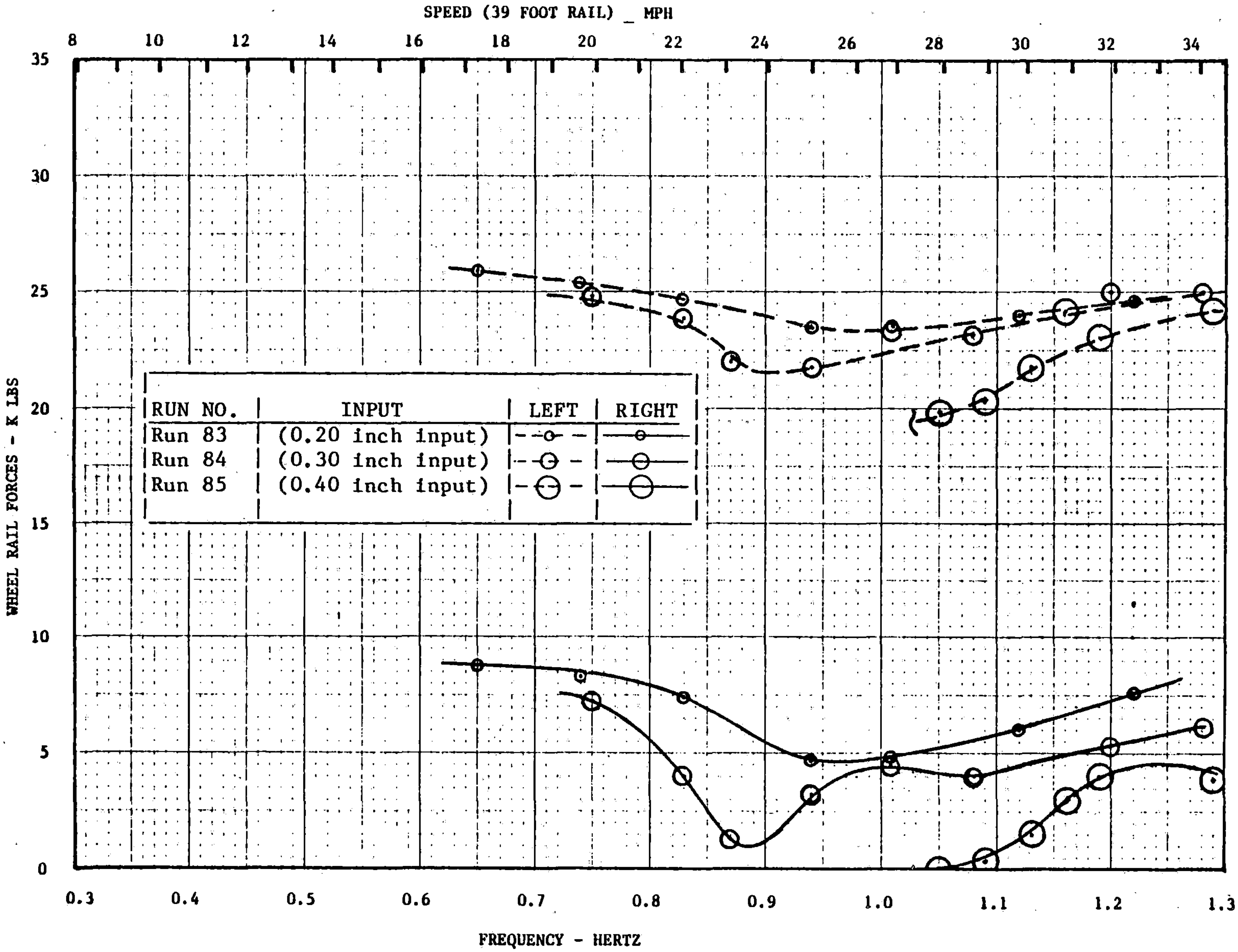

FIGURE 1-6
MINIMUM VERTICAL WHEEL LOAD, CONFIGURATION 1, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION,
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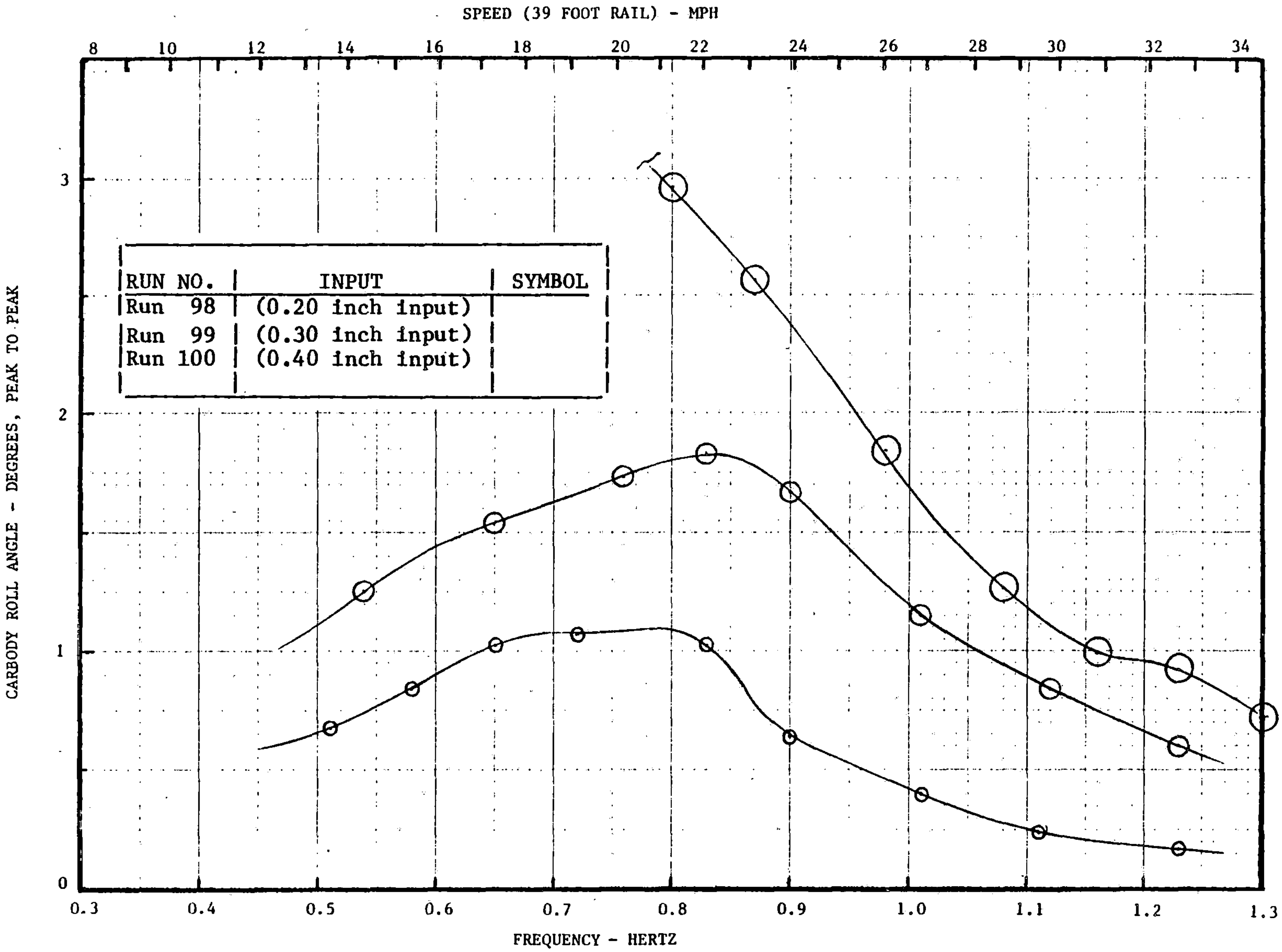

FIGURE 1-7
CARBODY ROLL ANGLE, CONFIGURATION 2, LADING SHIFTED,
STAGGERED RAIL TEST, RUNS 98, 99, and 100

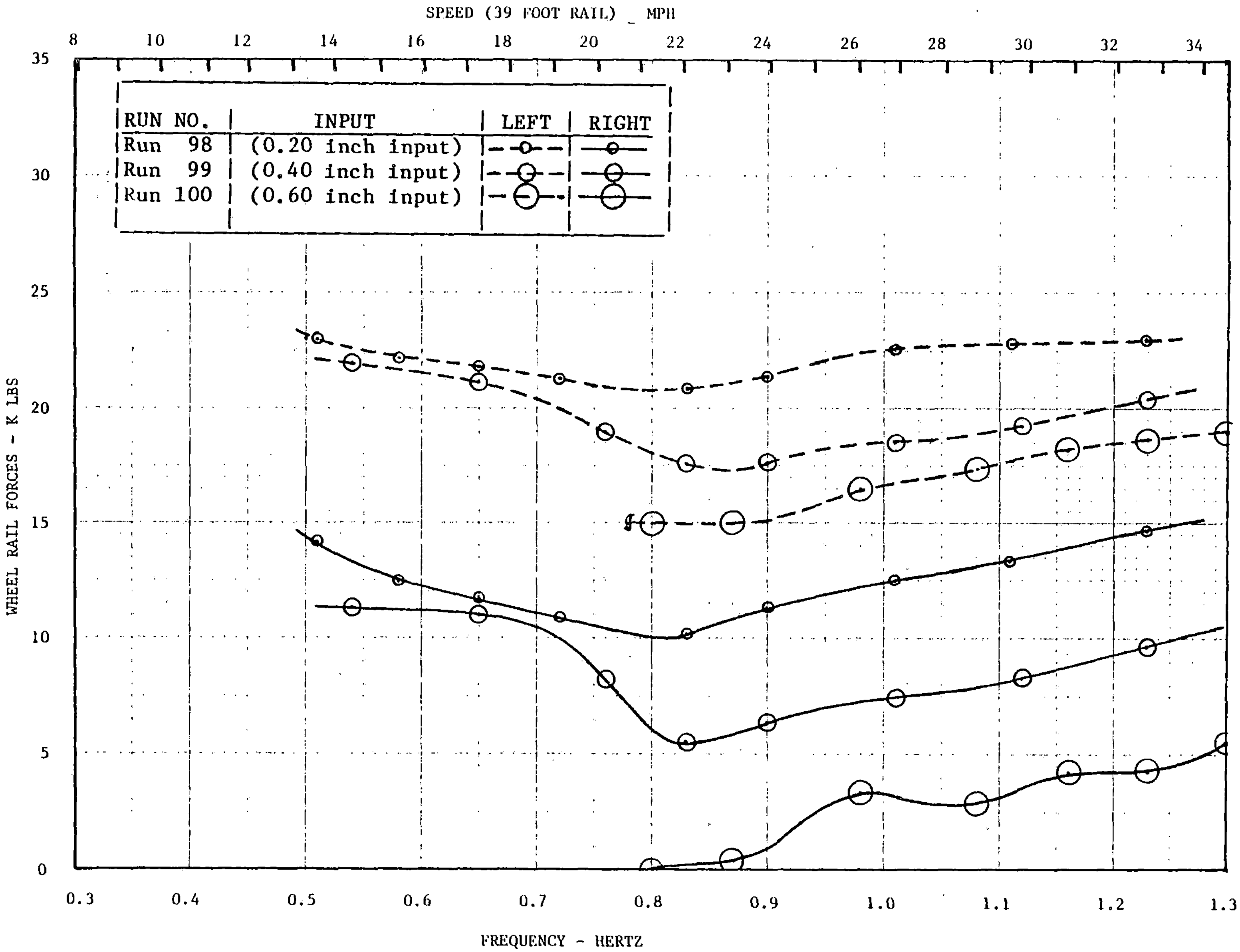

FIGURE 1-8
MINIMUM VERTICAL WHEEL LOADS, CONFIGURATION 2, LADING SHIFTED, STAGGERED RAIL TEST, RUNS 98, 99, and 100

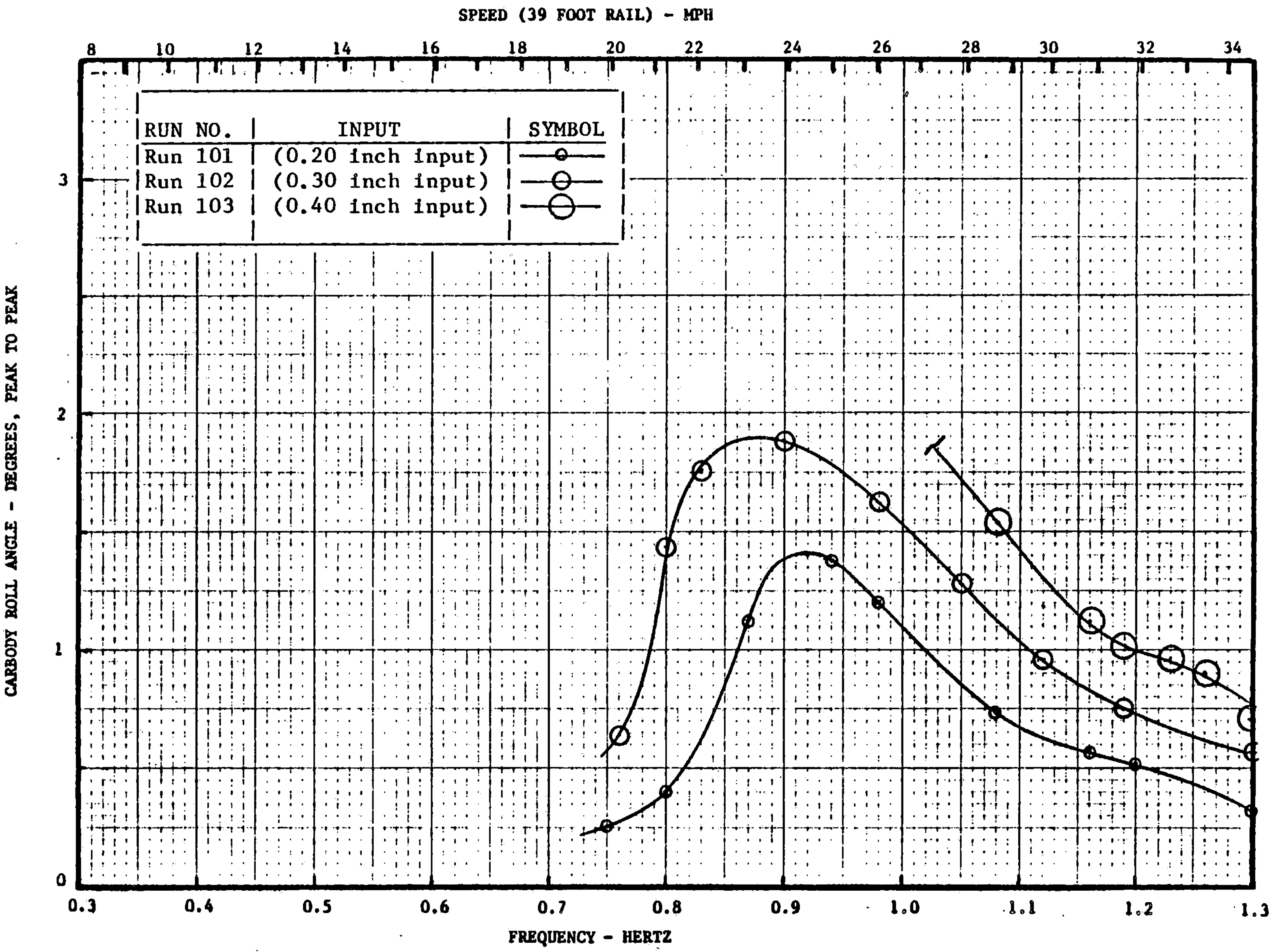

FIGURE 1-9
CARBODY ROLL ANGLES, CONFIGURATION 2, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION,
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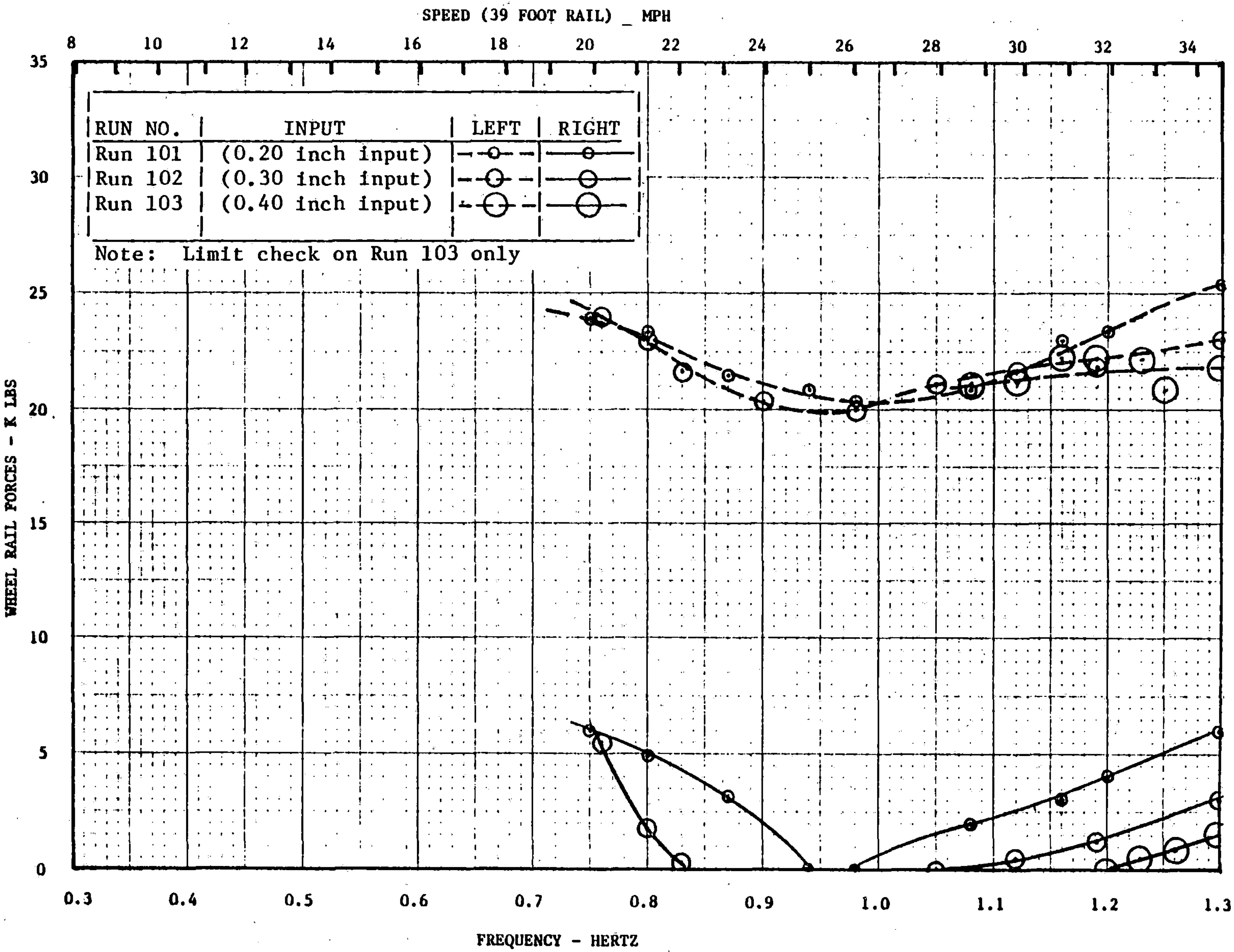

FIGURE 1-10
MINIMUM VERTICAL WHEEL LOAD, CONFIGURATION 2, LADING SHIFTED, STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION, RUNS 101, 102, AND 103

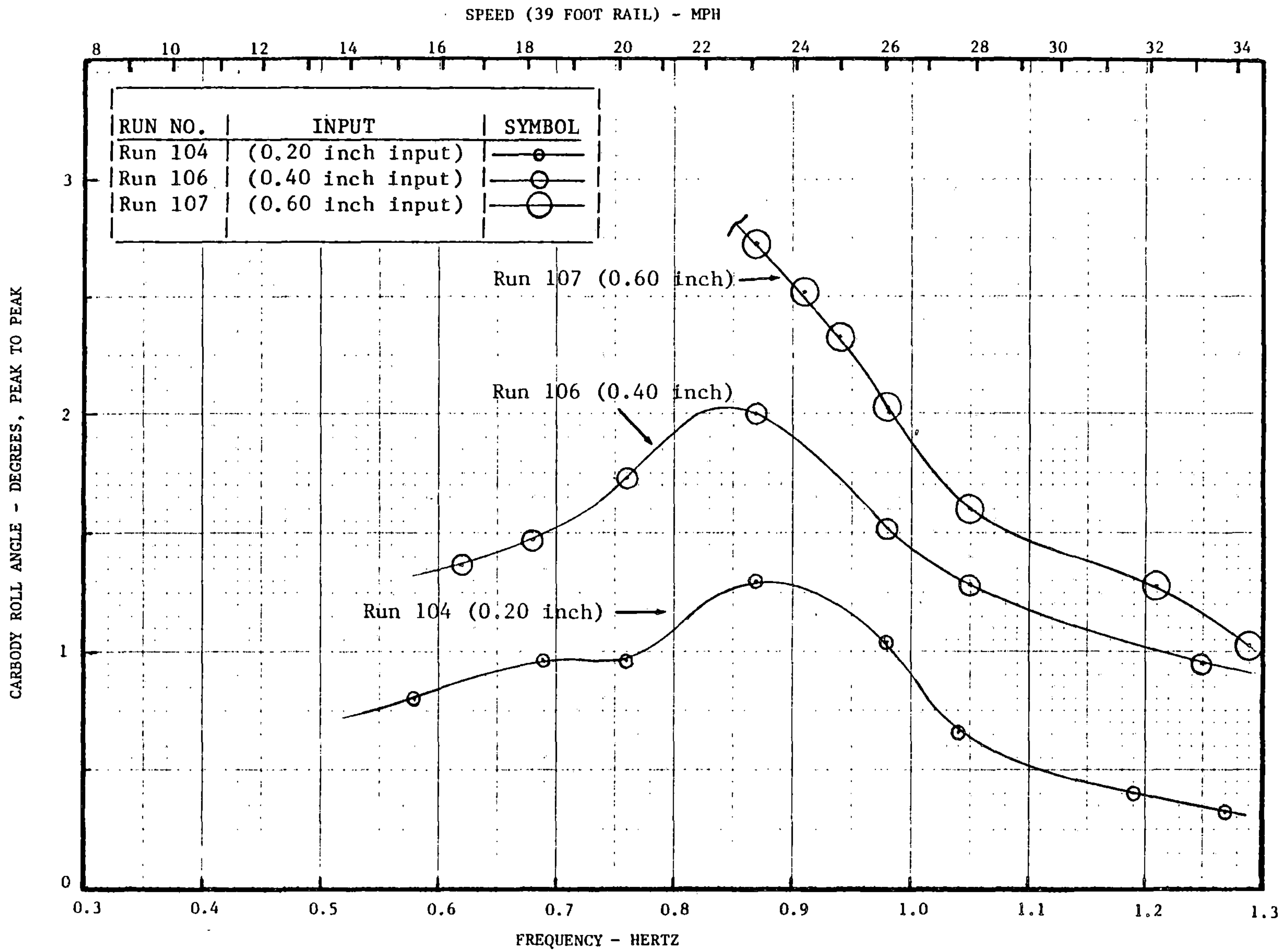

FIGURE 1-11
CARBODY ROLL ANGLES, CONFIGURATION 3, LADING SHIFTED, STAGGERED RAIL TESTS, RUNS 104, 106, and 107

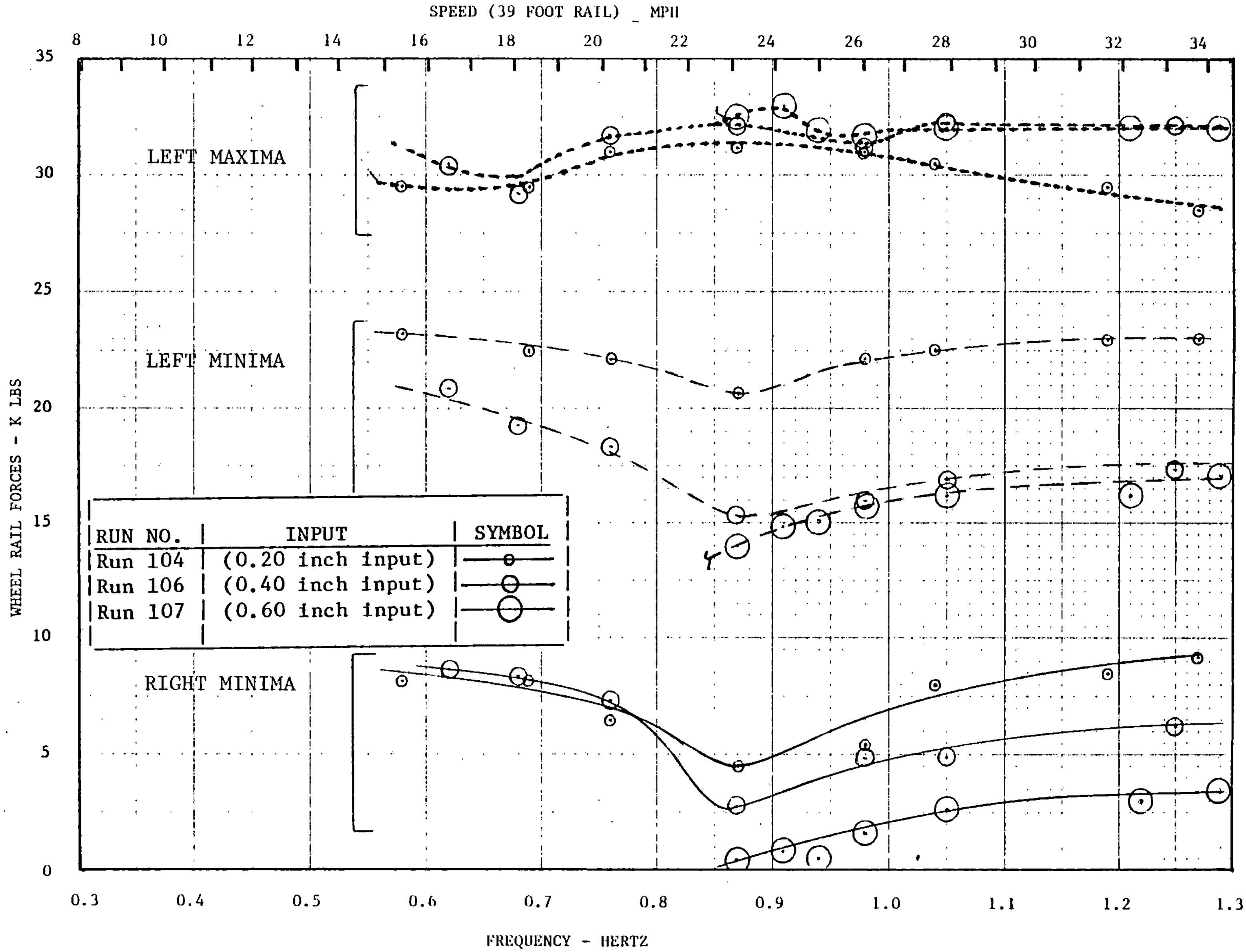

FIGURE 1-12
VERTICAL WHEEL LOADS, CONFIGURATION 3, LADING SHIFTED, STAGGERED RAIL TESTS, RUNS 104, 106, AND 107

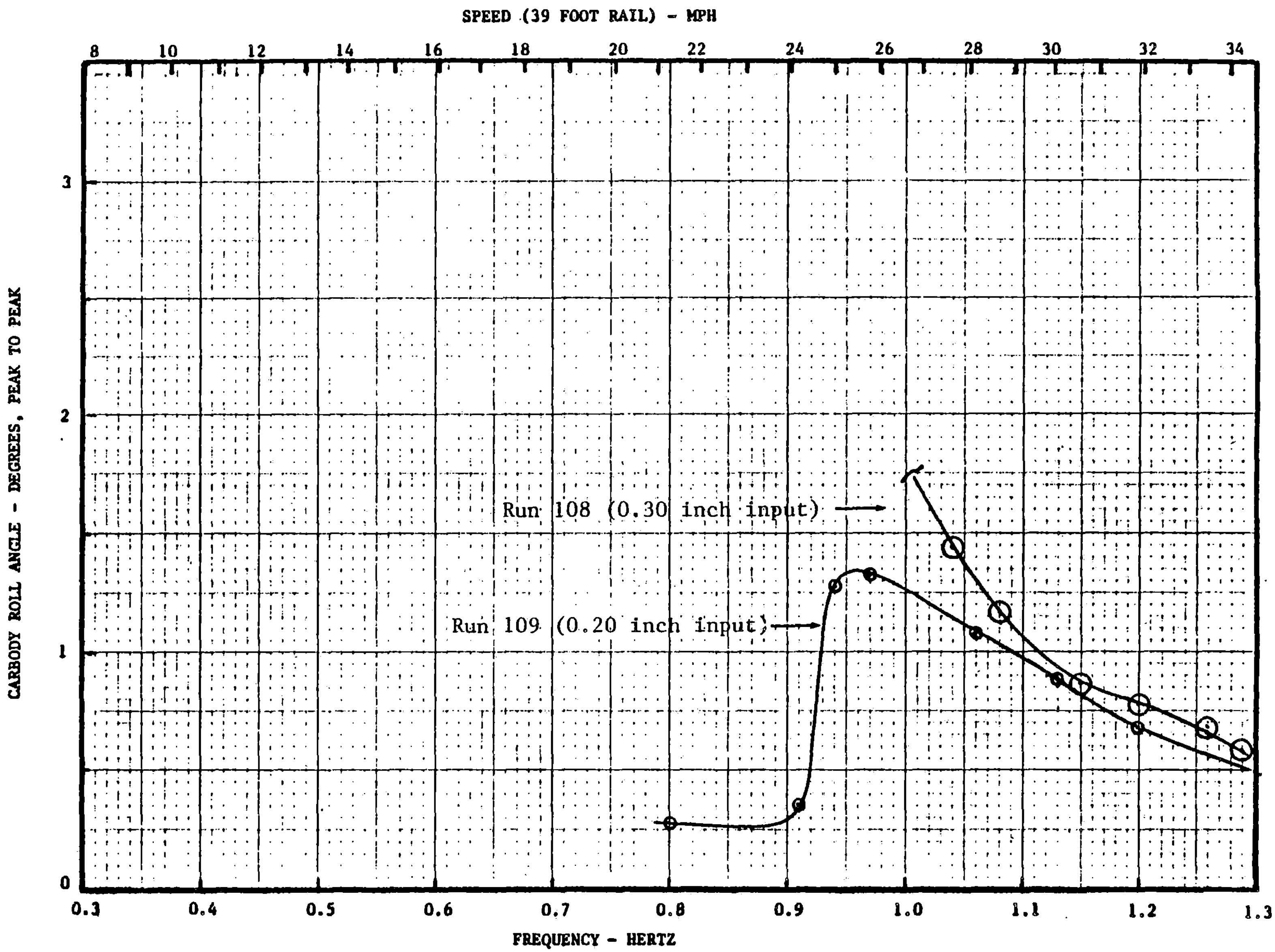

FIGURE 1-13
CARBODY ROLL ANGLES, CONFIGURATION 3, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION,
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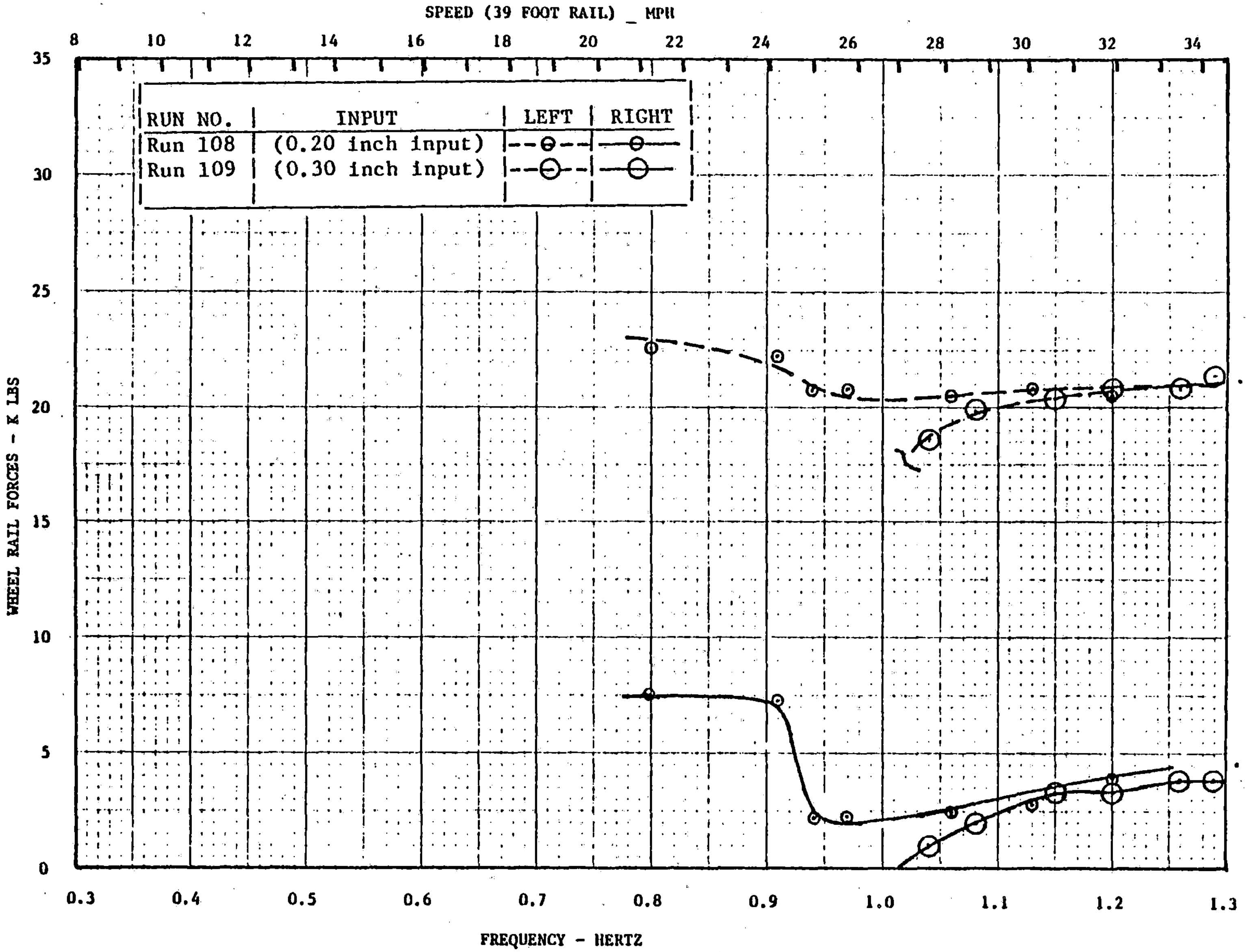

FIGURE 1-14
MINIMUM VERTICAL WHEEL LOADS, CONFIGURATION 3, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION,
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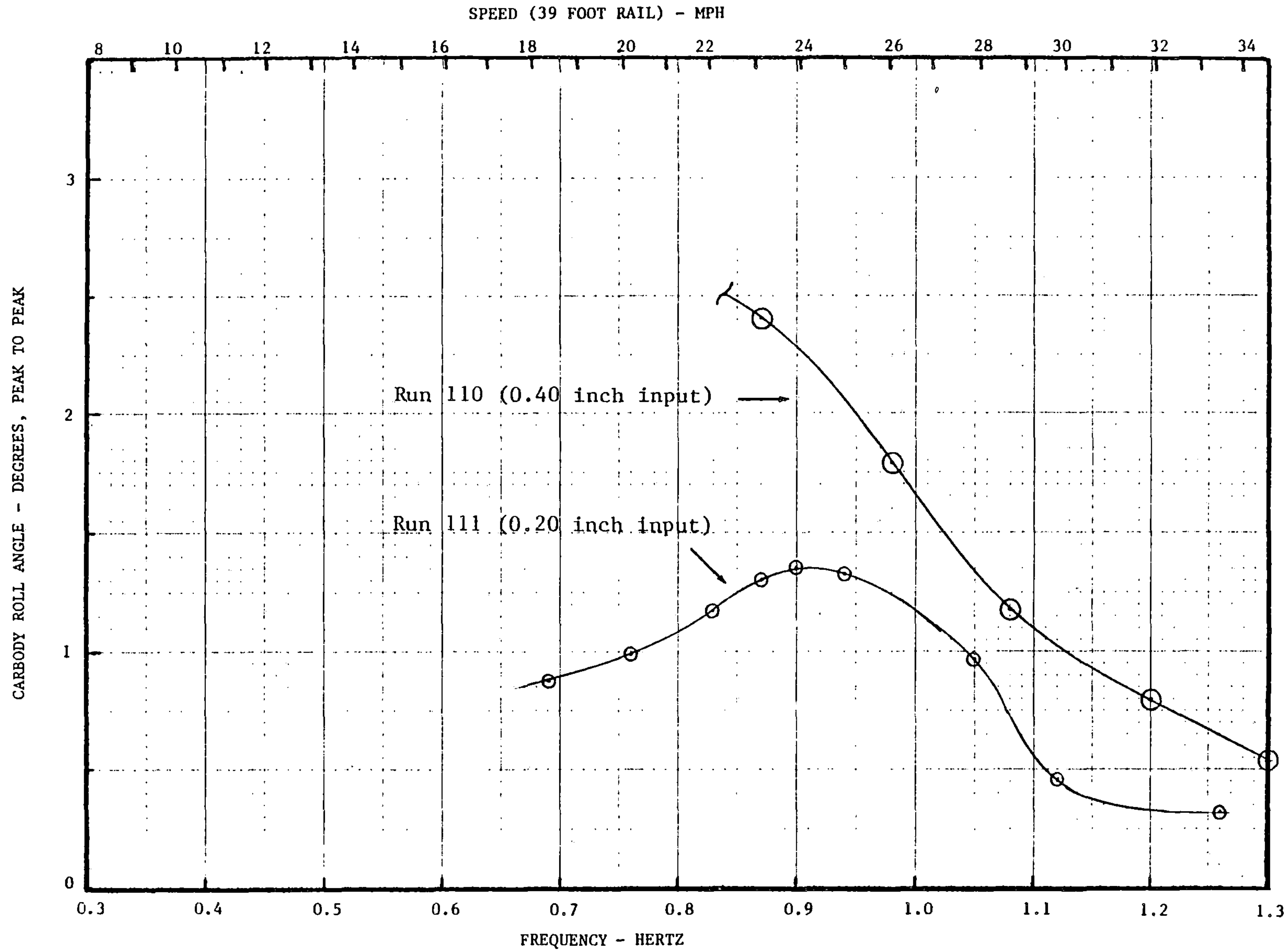

FIGURE 1-15
CARBODY ROLL ANGLES, CONFIGURATION 4, LADING SHIFTED, STAGGERED RAIL TESTS, RUNS 110 AND 111

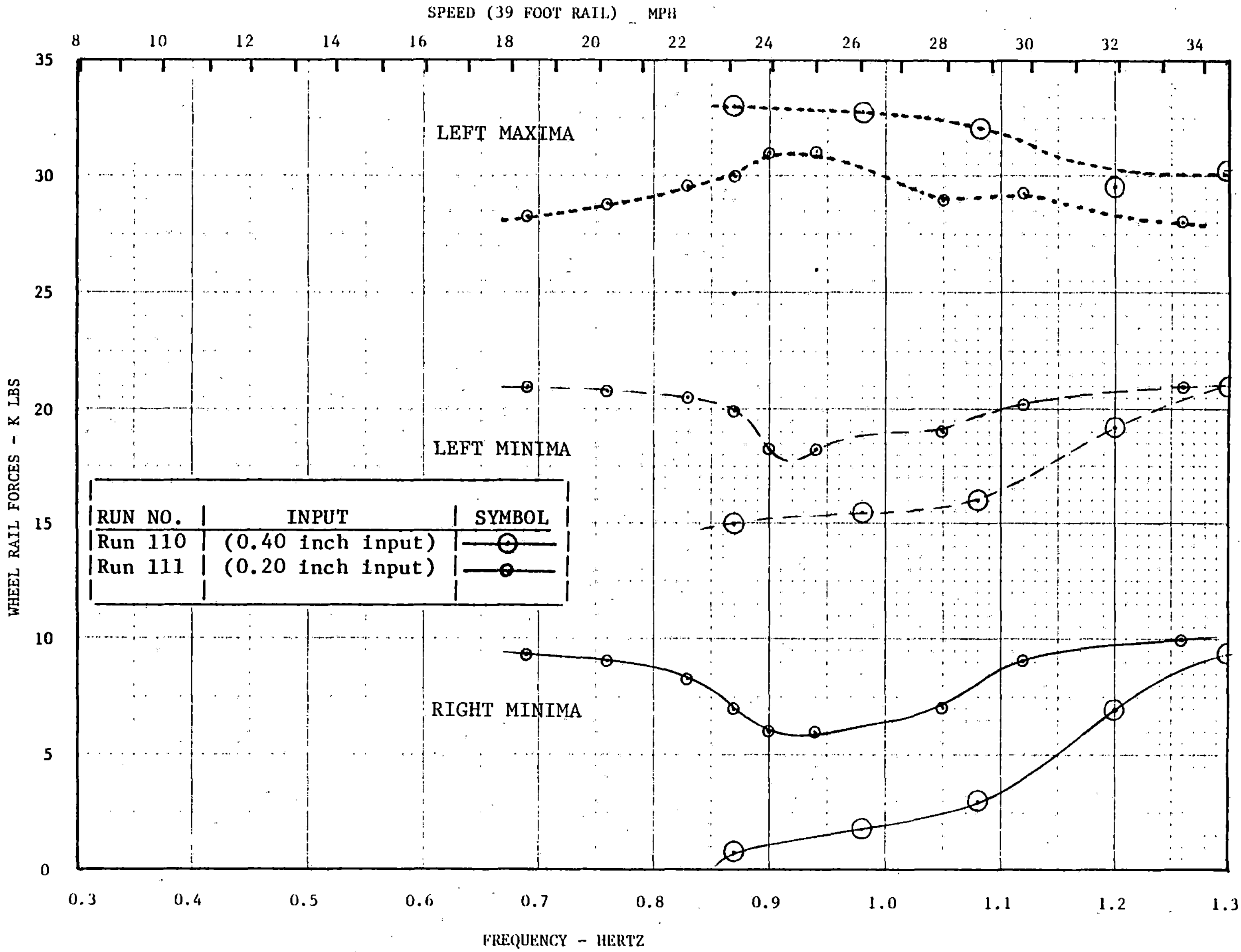

FIGURE 1-16
VERTICAL WHEEL LOADS, CONFIGURATION 4, LADING SHIFTED,
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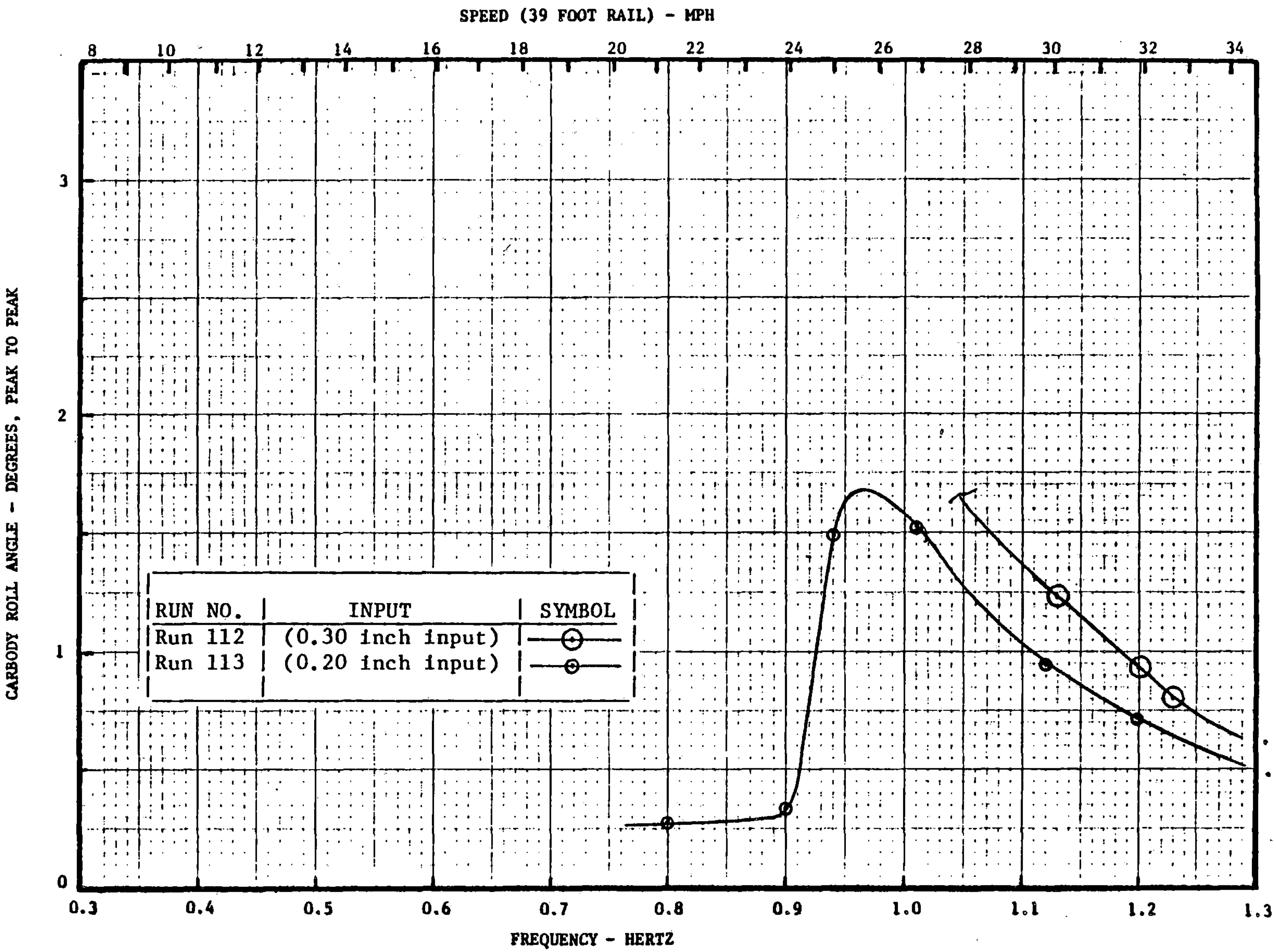

FIGURE 1-17
CARBODY ROLL ANGLES, CONFIGURATION 4, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION,
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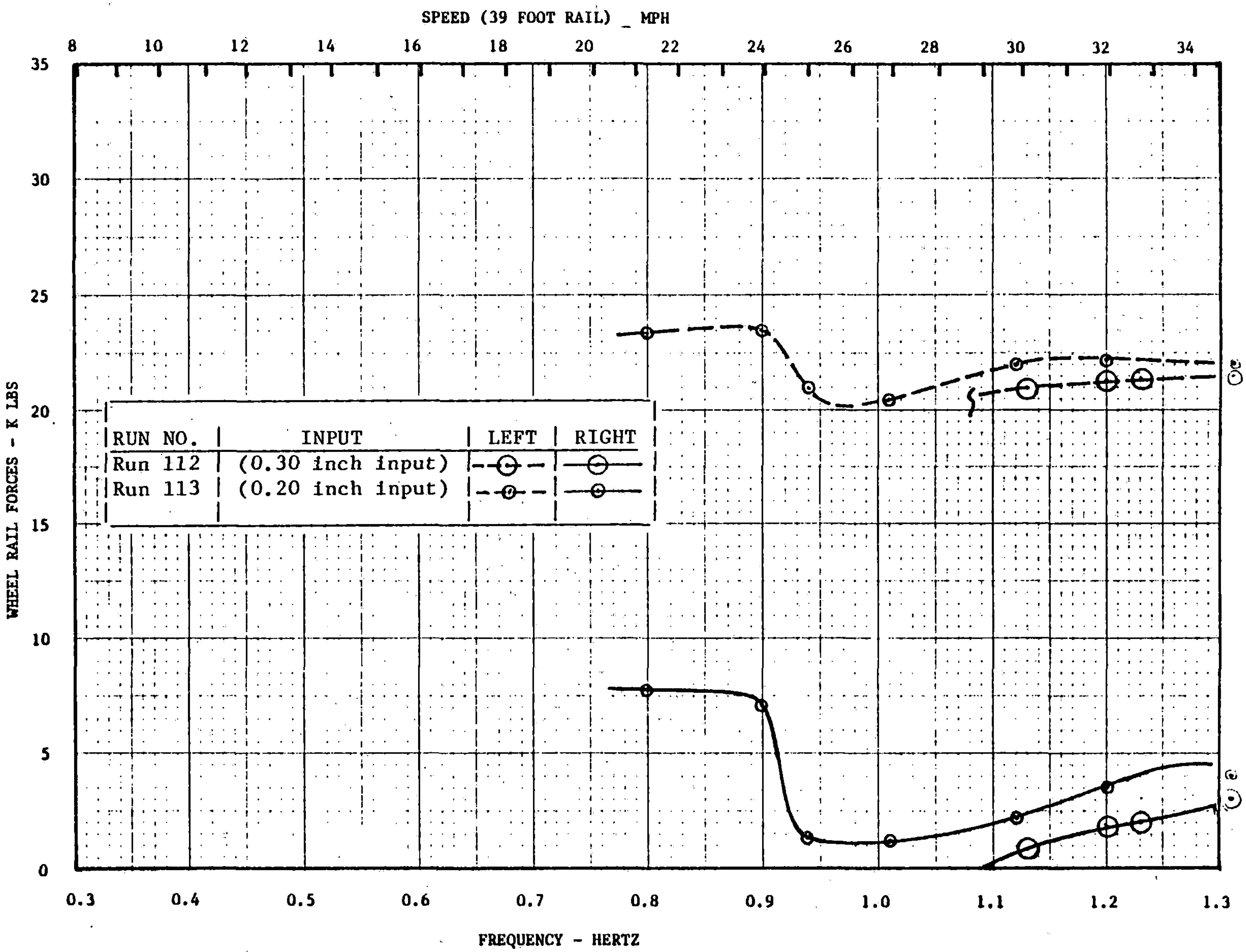

FIGURE 1-18
MINIMUM VERTICAL WHEEL LOADS, CONFIGURATION 4, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION,
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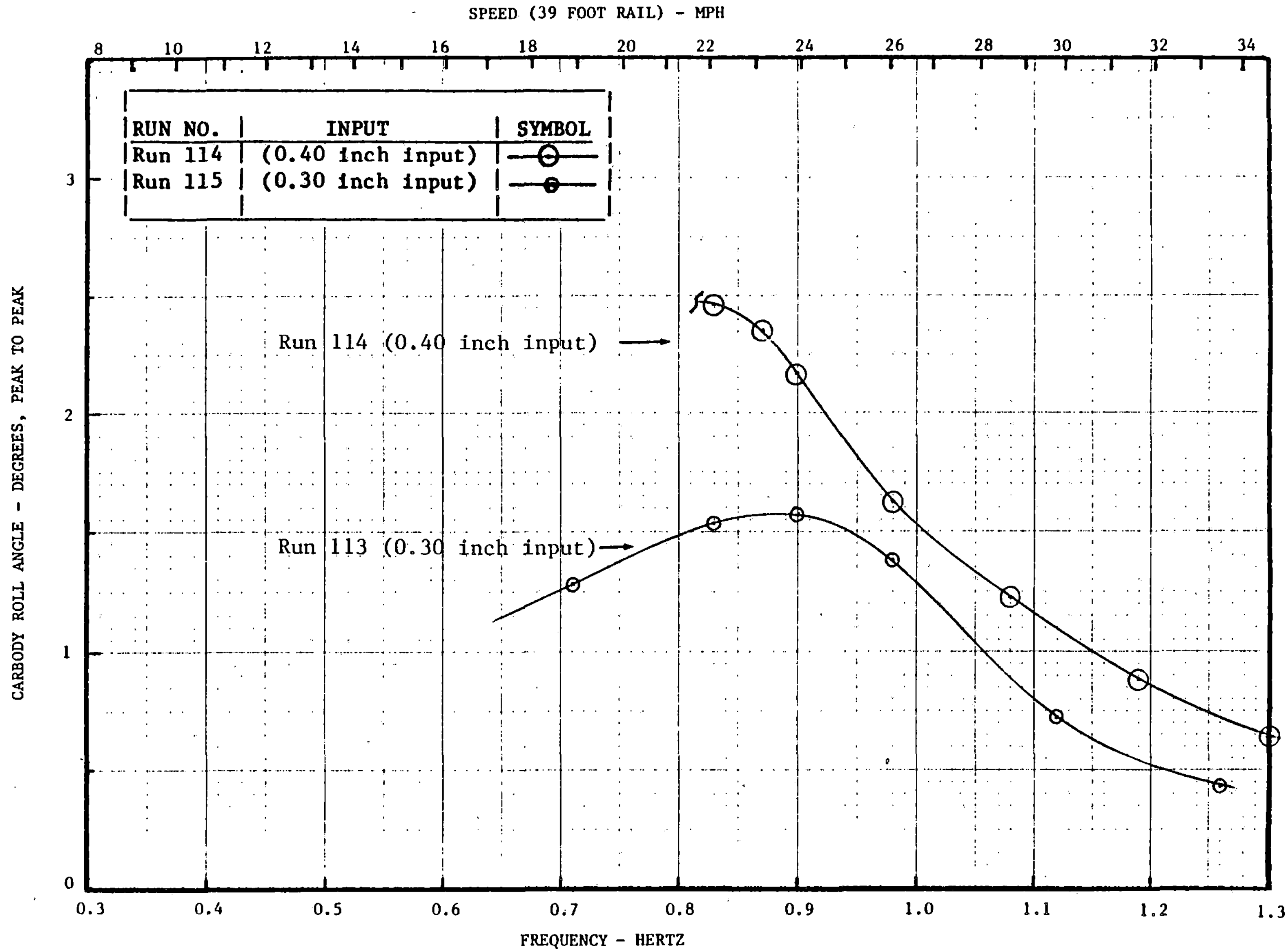

FIGURE 1-19
CARBODY ROLL ANGLES, CONFIGURATION 5, LADING SHIFTED,
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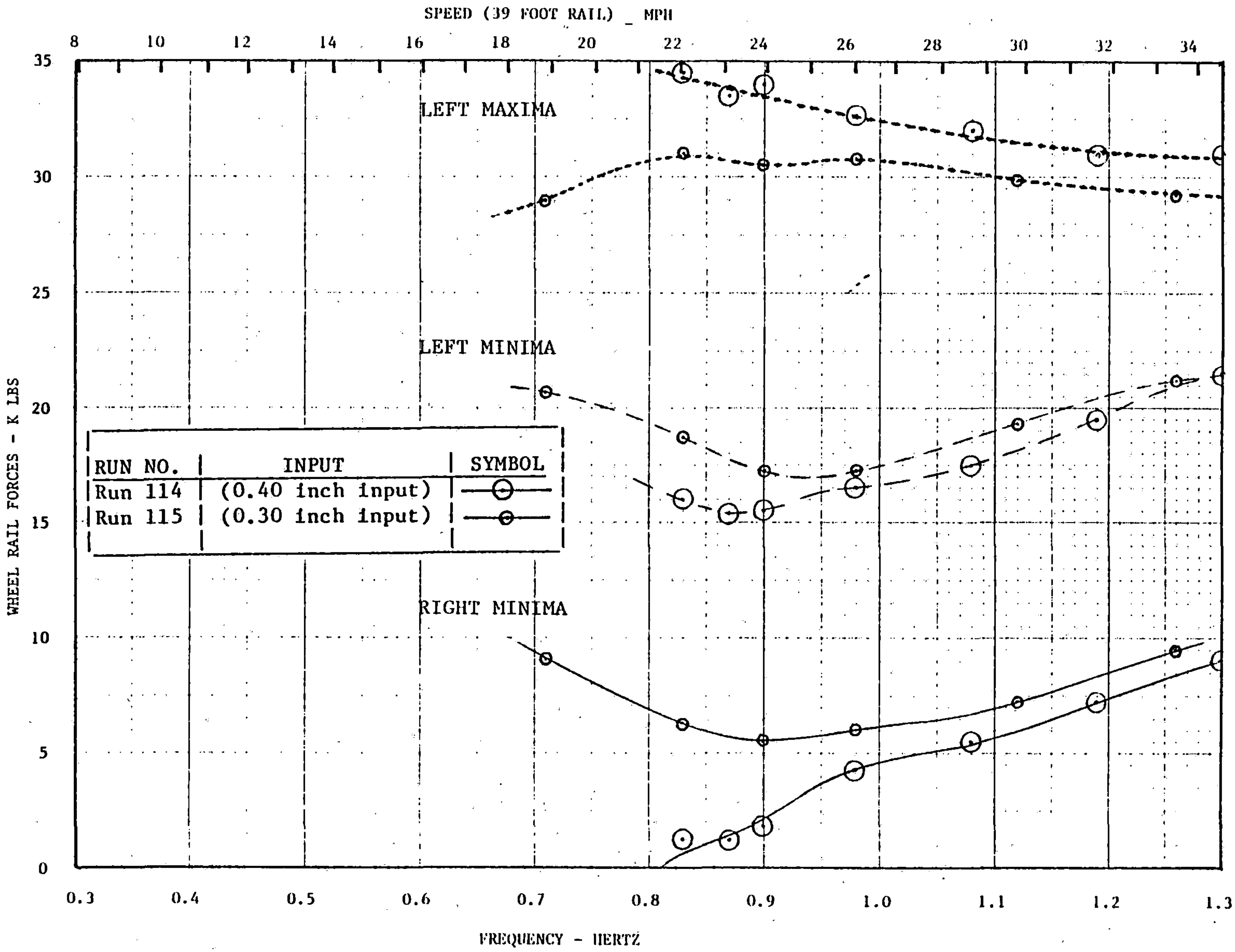

FIGURE 1-20
VERTICAL WHEEL LOADS, CONFIGURATION 5, LADING SHIFTED,
STAGGERED RAIL TEST, RUNS 114 AND 115

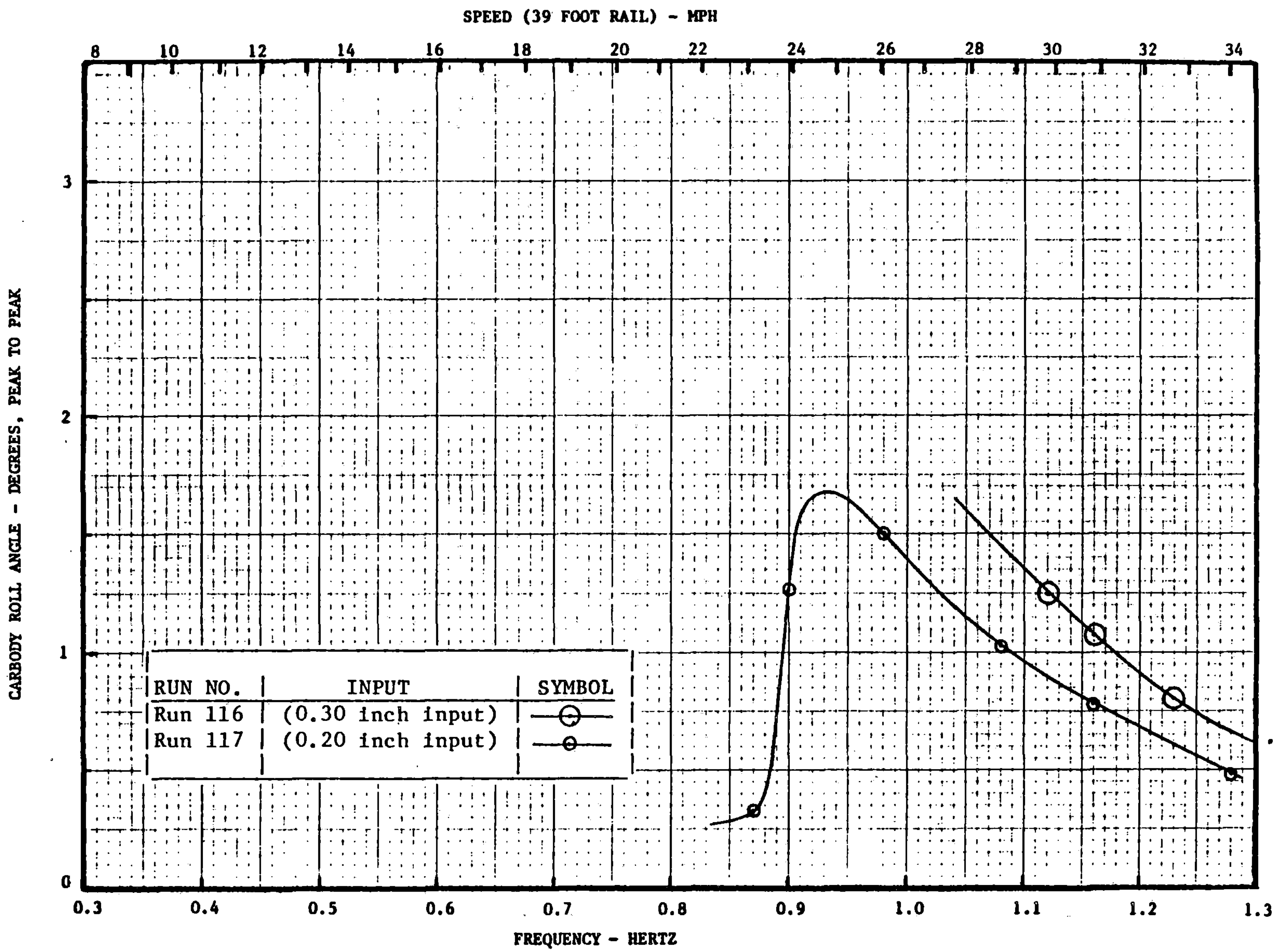

FIGURE 1-21
CARBODY ROLL ANGLES, CONFIGURATION 5, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION
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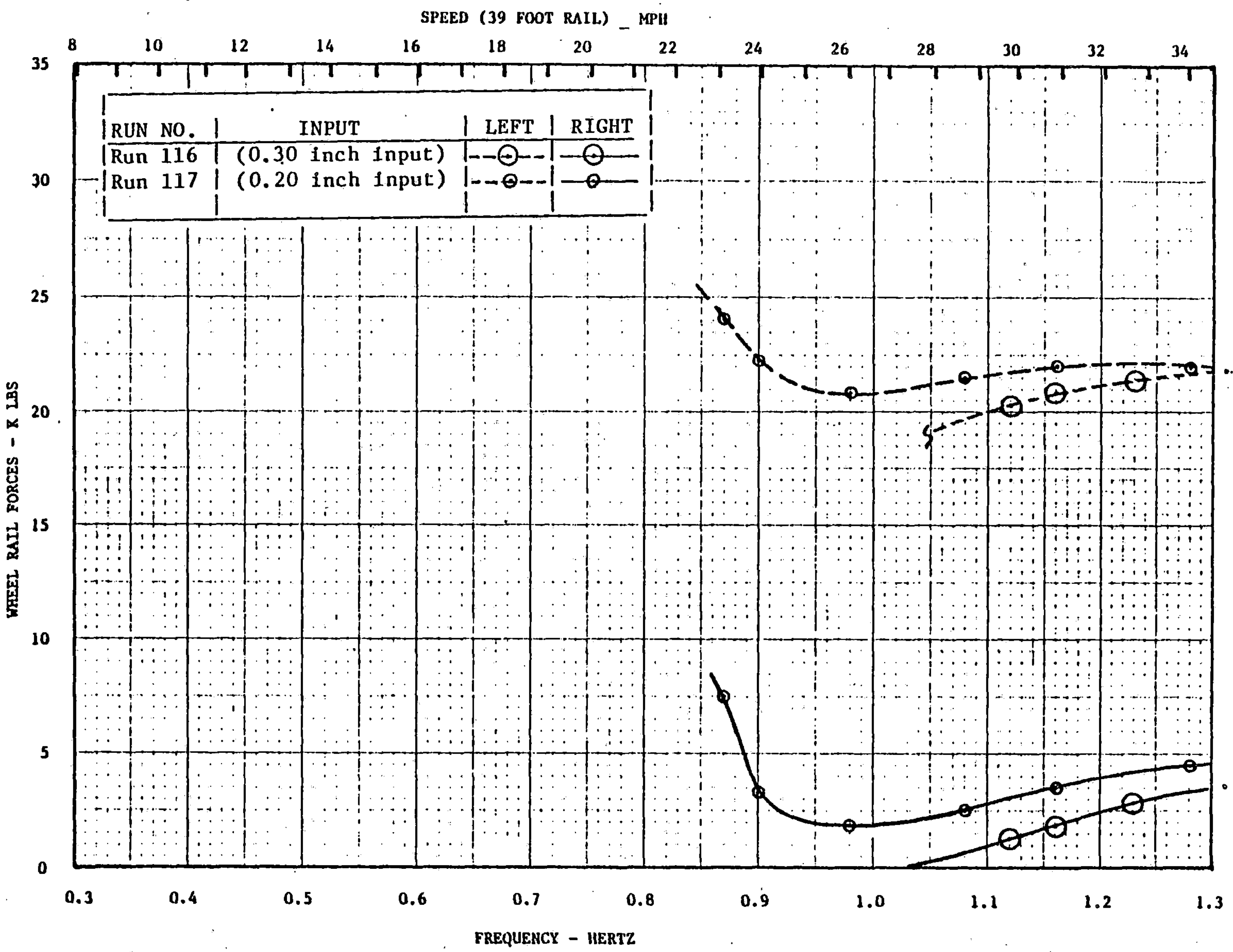

FIGURE 1-22
MINIMUM VERTICAL WHEEL LOADS, CONFIGURATION 5, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION
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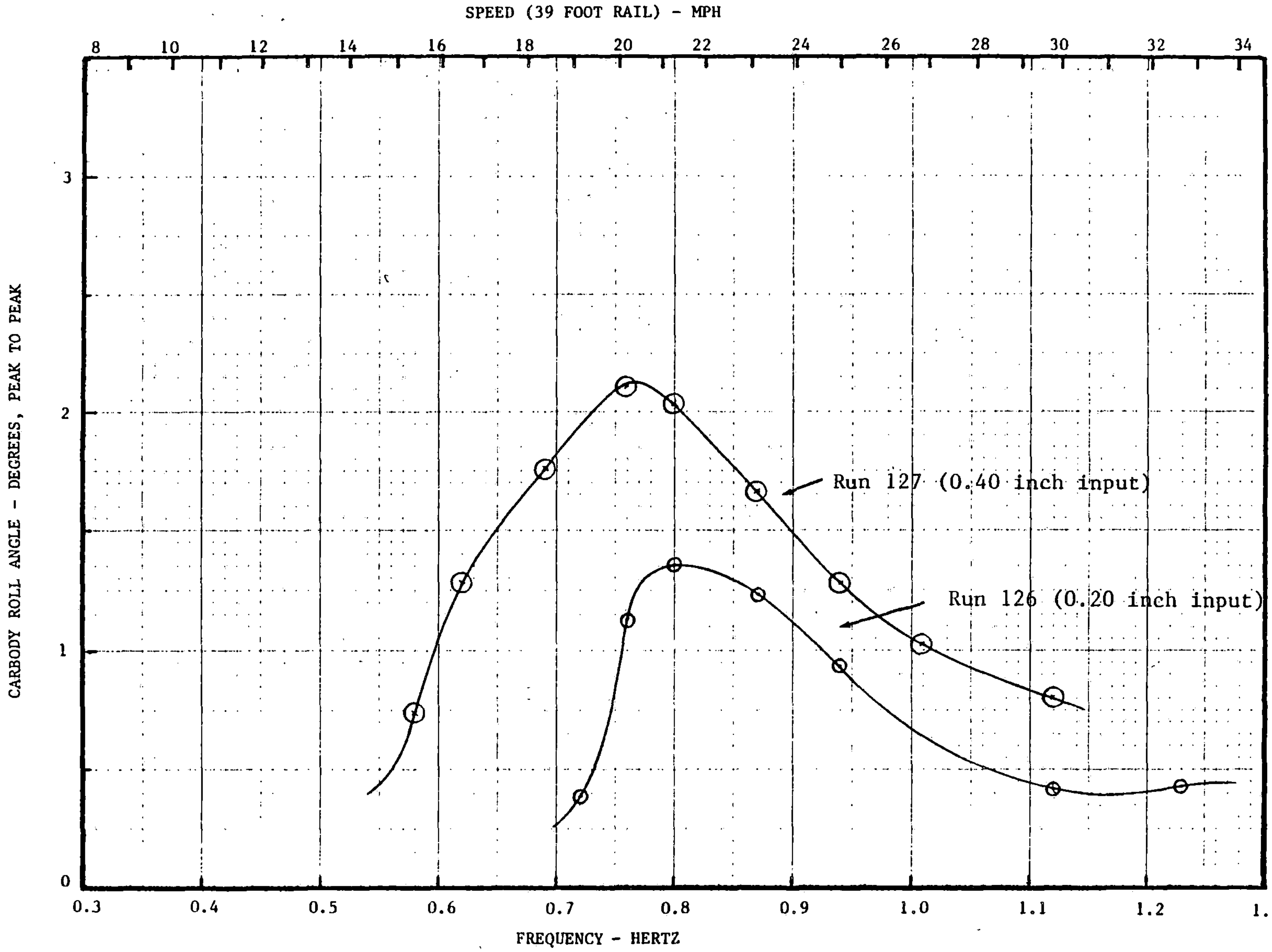

FIGURE 1-23
CARBODY ROLL ANGLES, CONFIGURATION 2, LADING CENTERED
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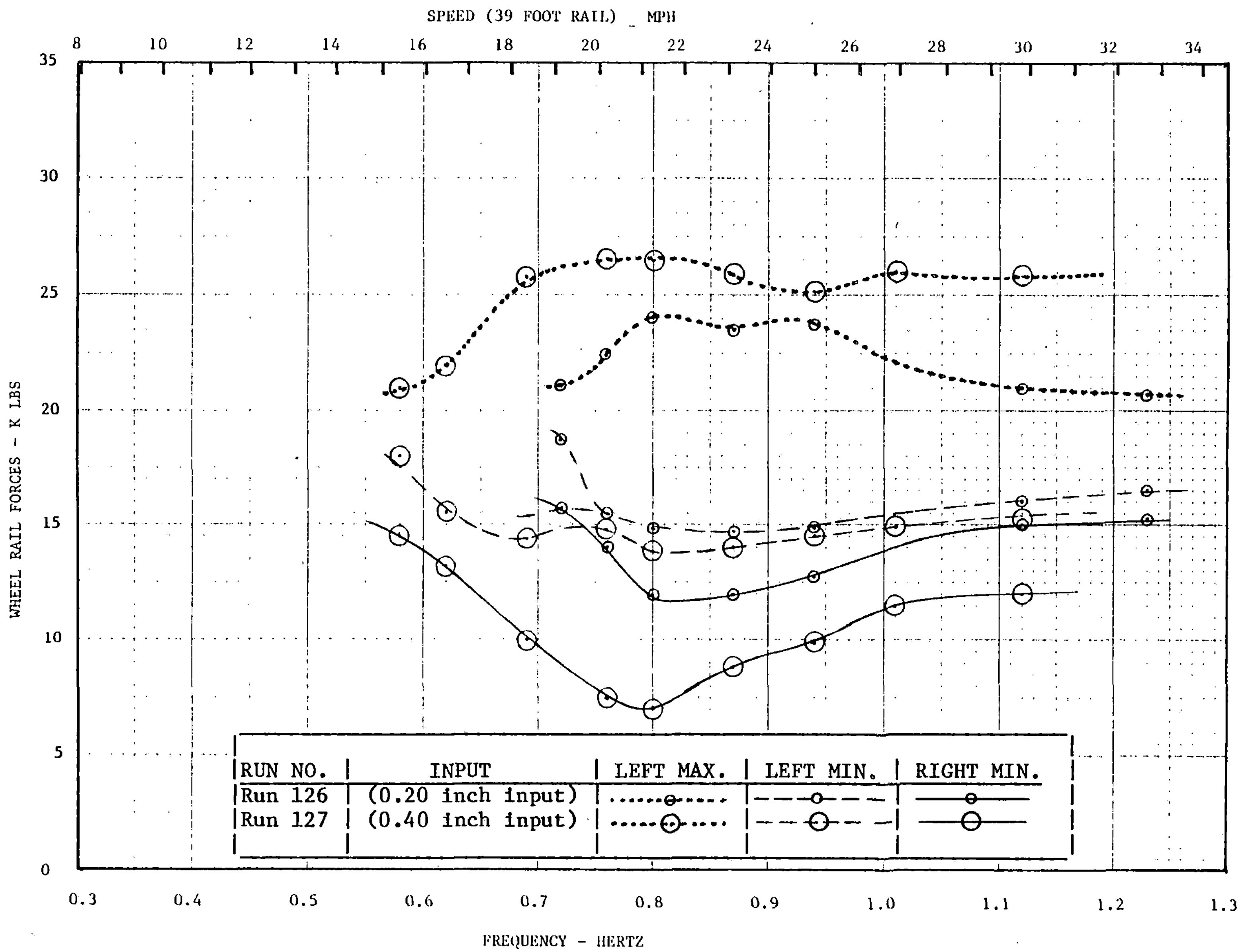

FIGURE 1-24
VERTICAL WHEEL LOAD, CONFIGURATION 2, LADING CENTERED,
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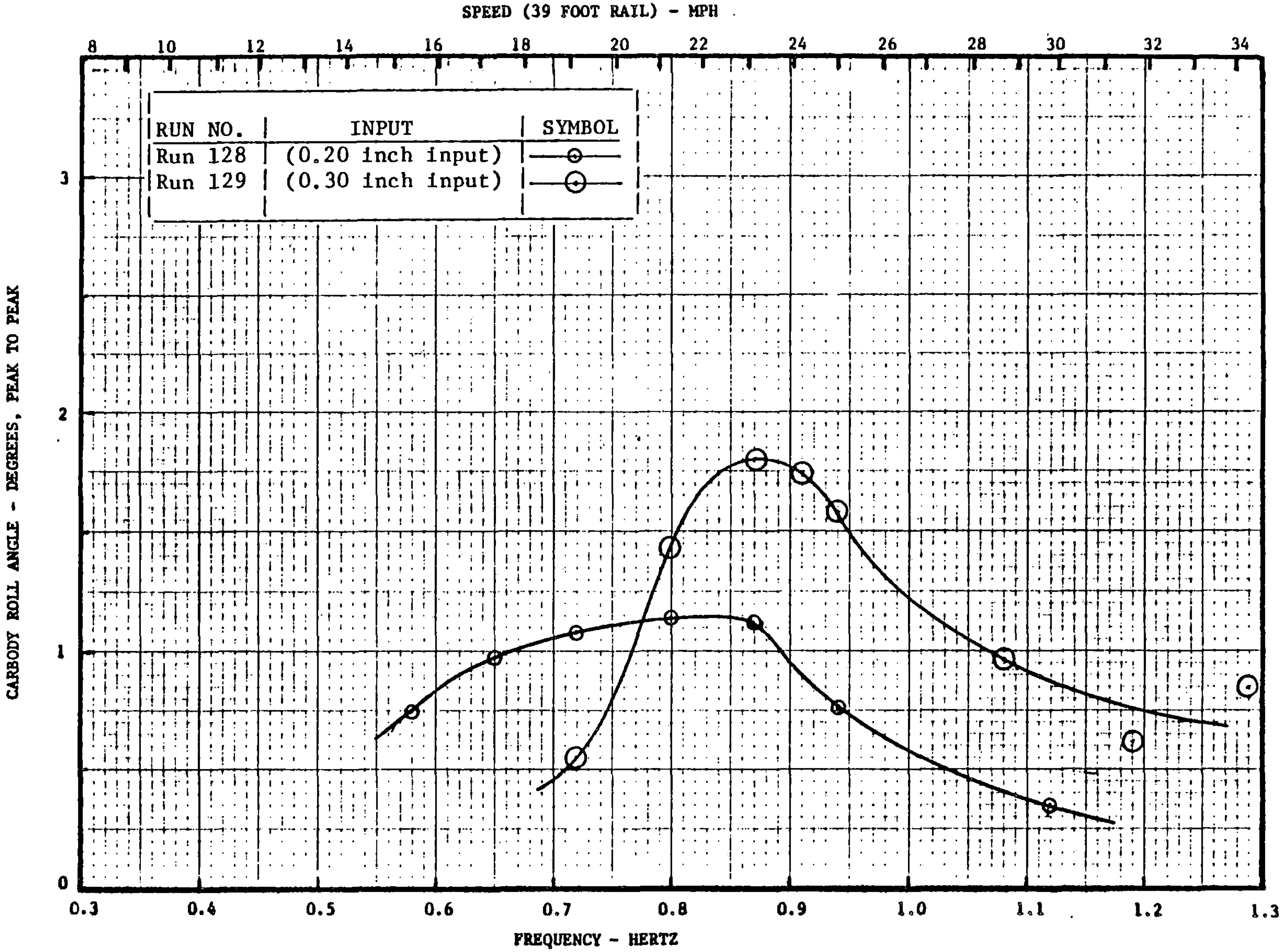


FIGURE 1-25
CARBODY ROLL ANGLE, CONFIGURATION 2, LADING CENTERED, STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION, RUNS 128 AND 129

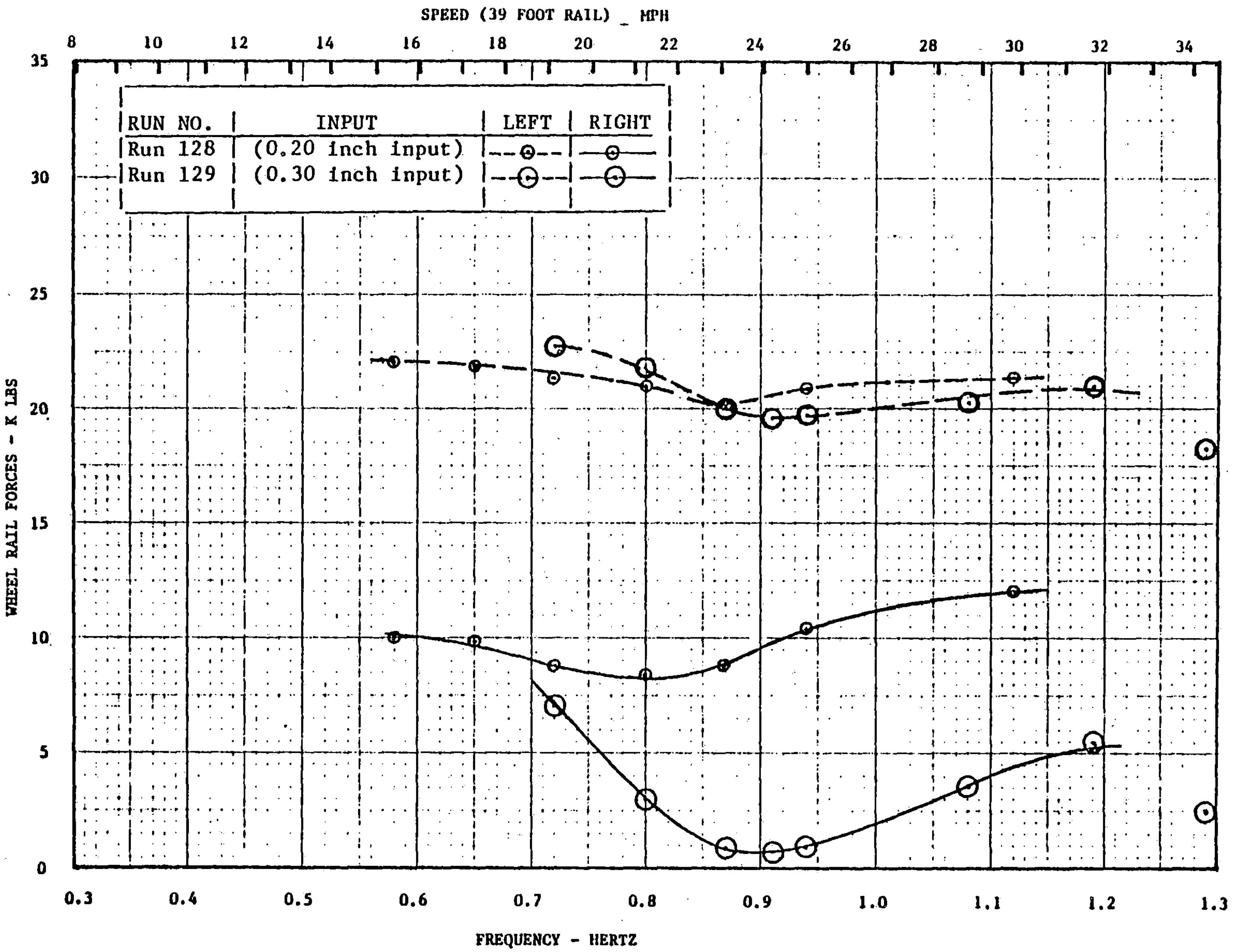


FIGURE 1-26
MINIMUM VERTICAL WHEEL LOAD, CONFIGURATION 2, LADING CENTERED, STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION, RUNS 128 AND 129

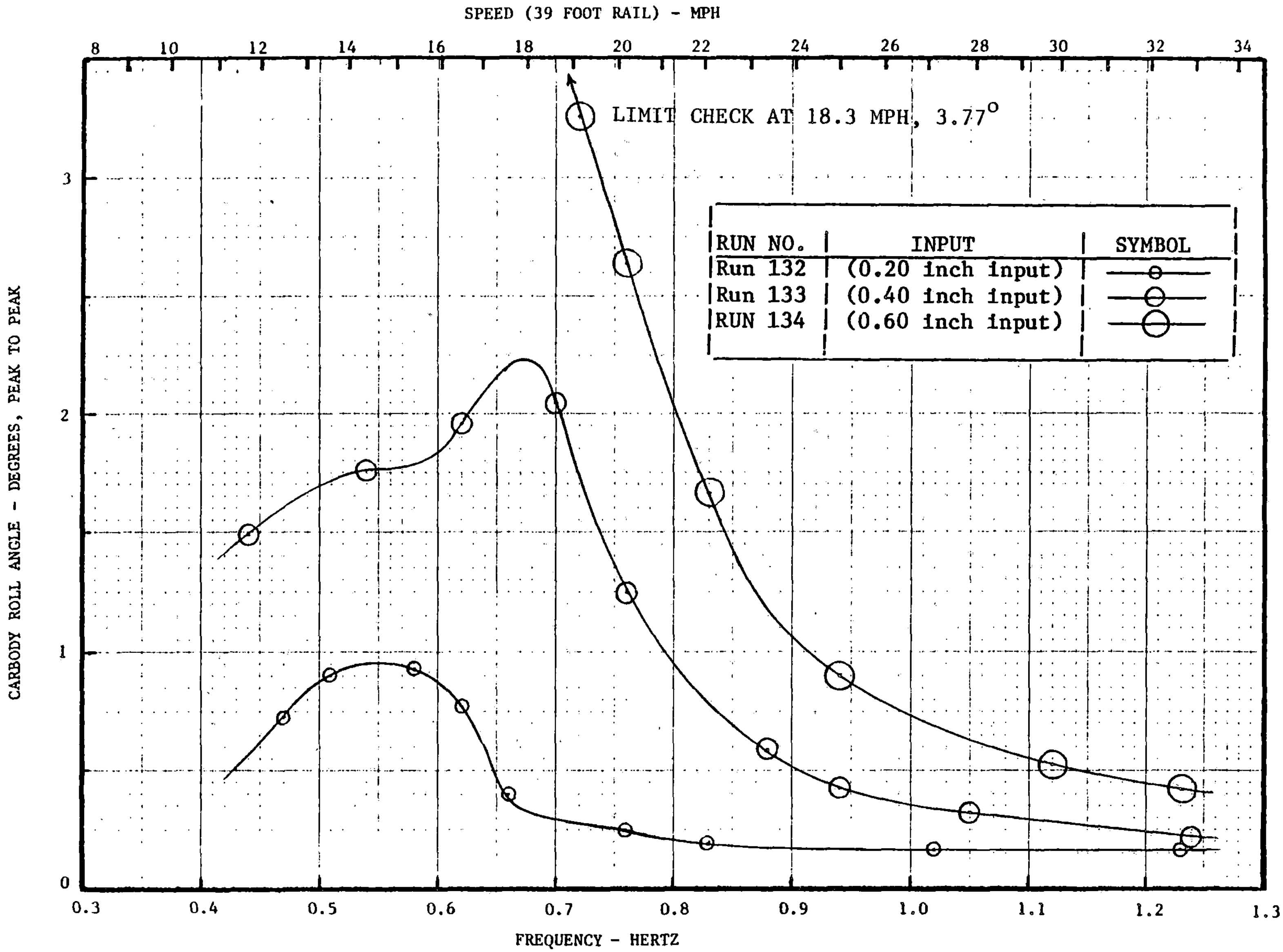


FIGURE 1-27
CARBODY ROLL ANGLE, CONFIGURATION 6, LANDING SHIFTED, STAGGERED RAIL TEST, RUNS 132, 133 AND 134

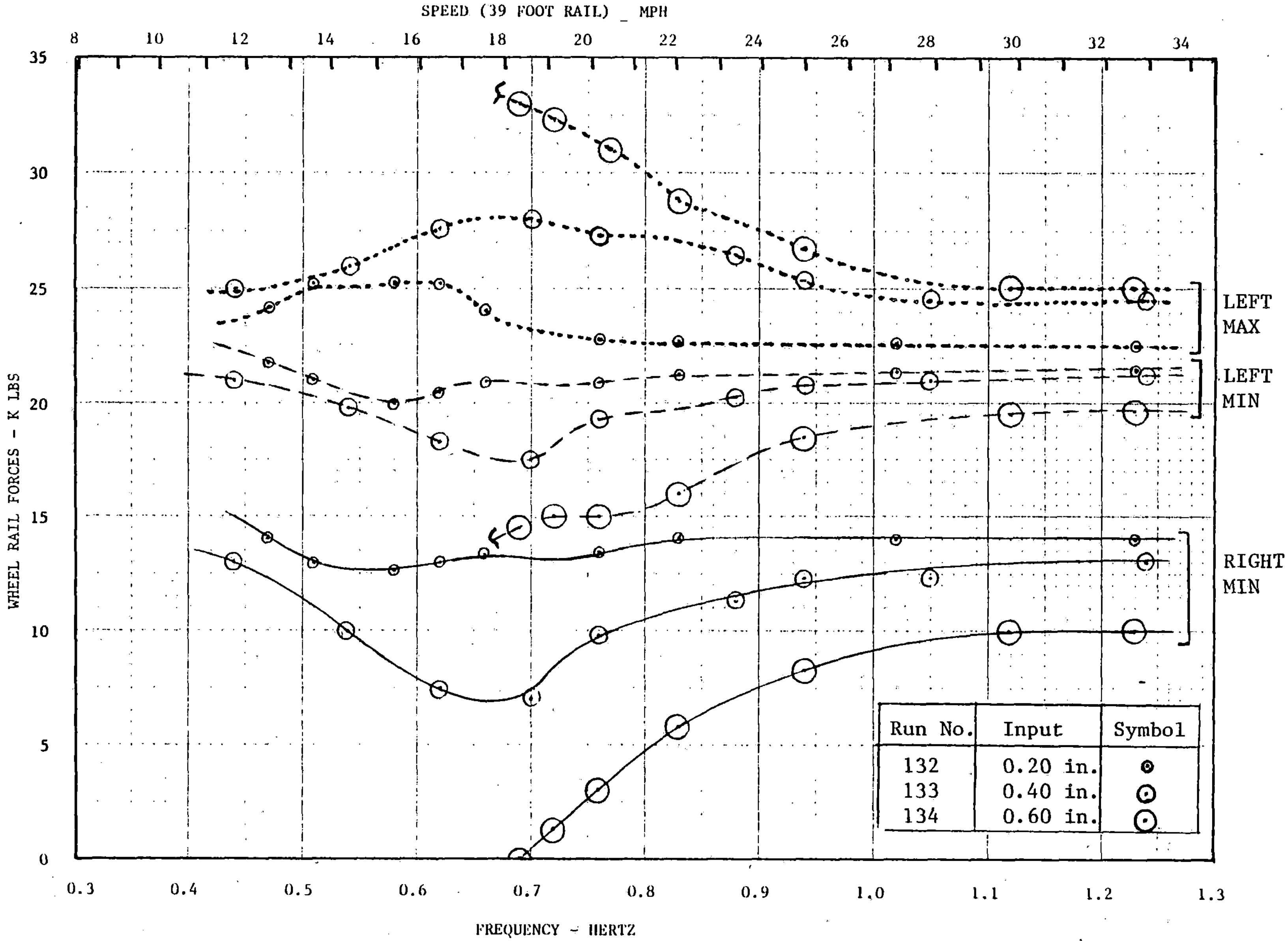


FIGURE 1-28
VERTICAL WHEEL LOADS, CONFIGURATION 6, LADING SHIFTED, STAGGERED RAIL TEST, RUNS 132, 133, AND 134

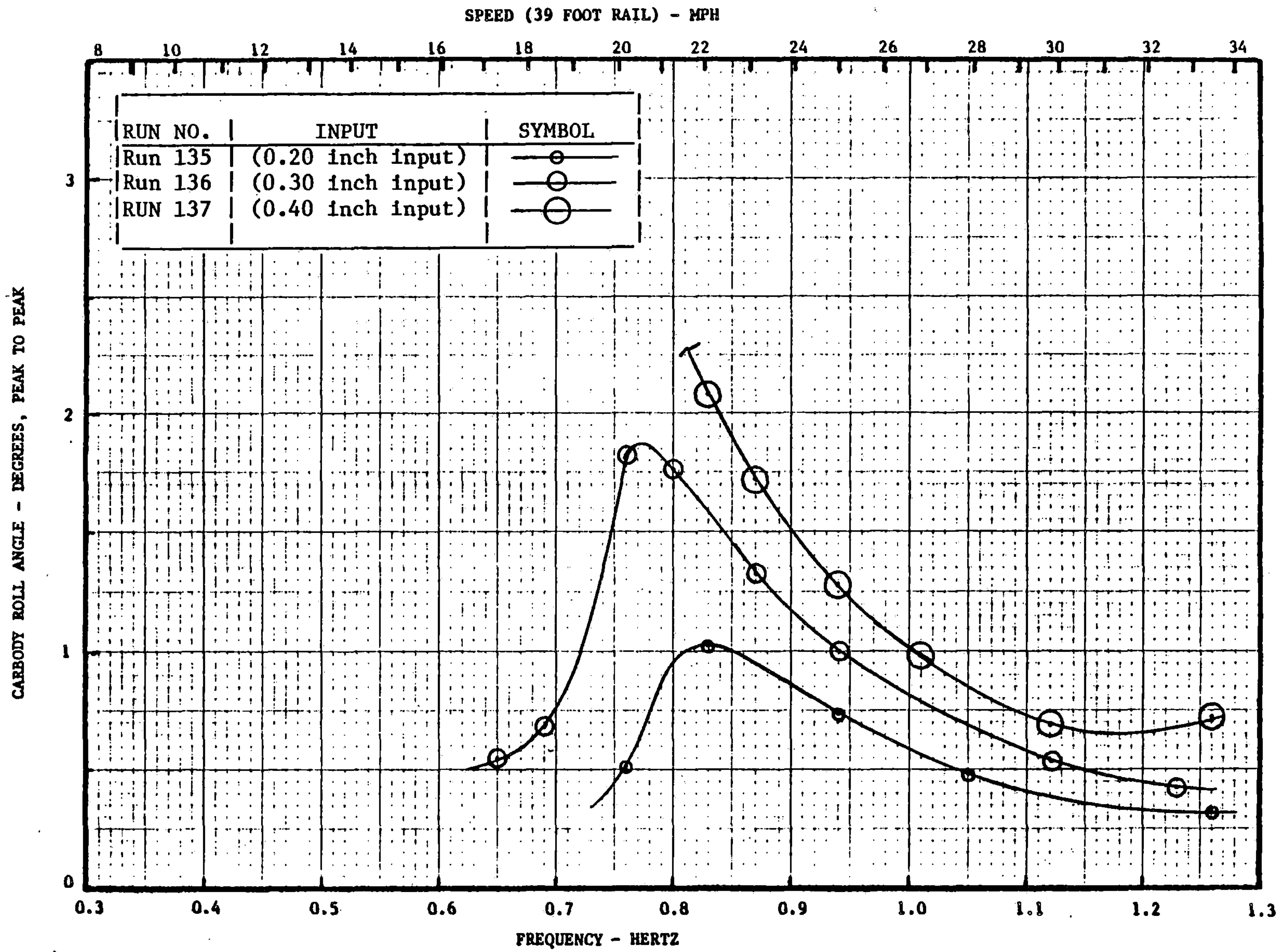


FIGURE 1-29
CARBODY ROLL ANGLE, CONFIGURATION 6, LADING SHIFTED, STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION, RUNS 135, 136, AND 137

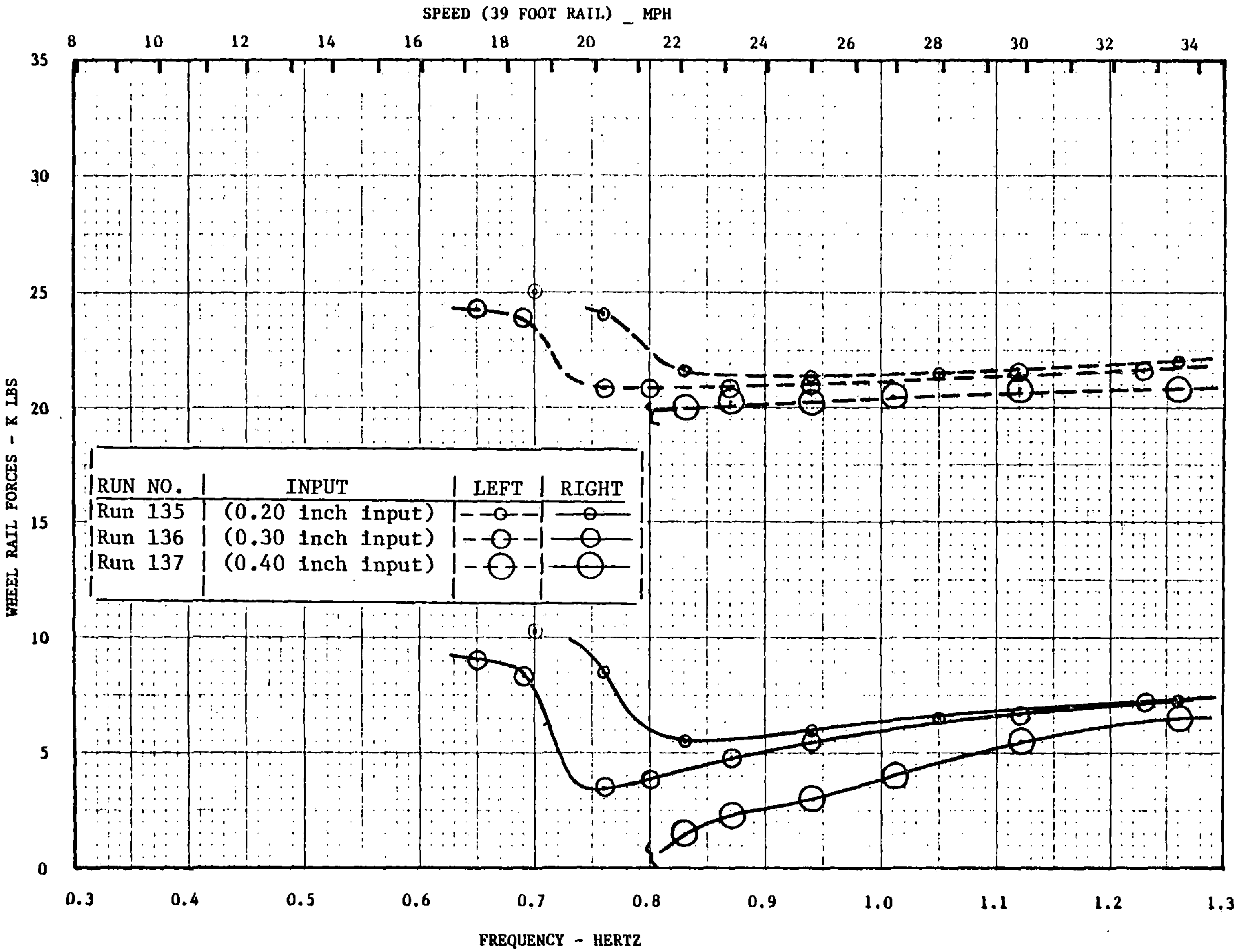


FIGURE 1-30
MINIMUM VERTICAL WHEEL LOADS, CONFIGURATION 6, STAGGERED
RAIL TEST WITH 3.0 INCH SUPERELEVATION, RUNS 135, 136 AND 137

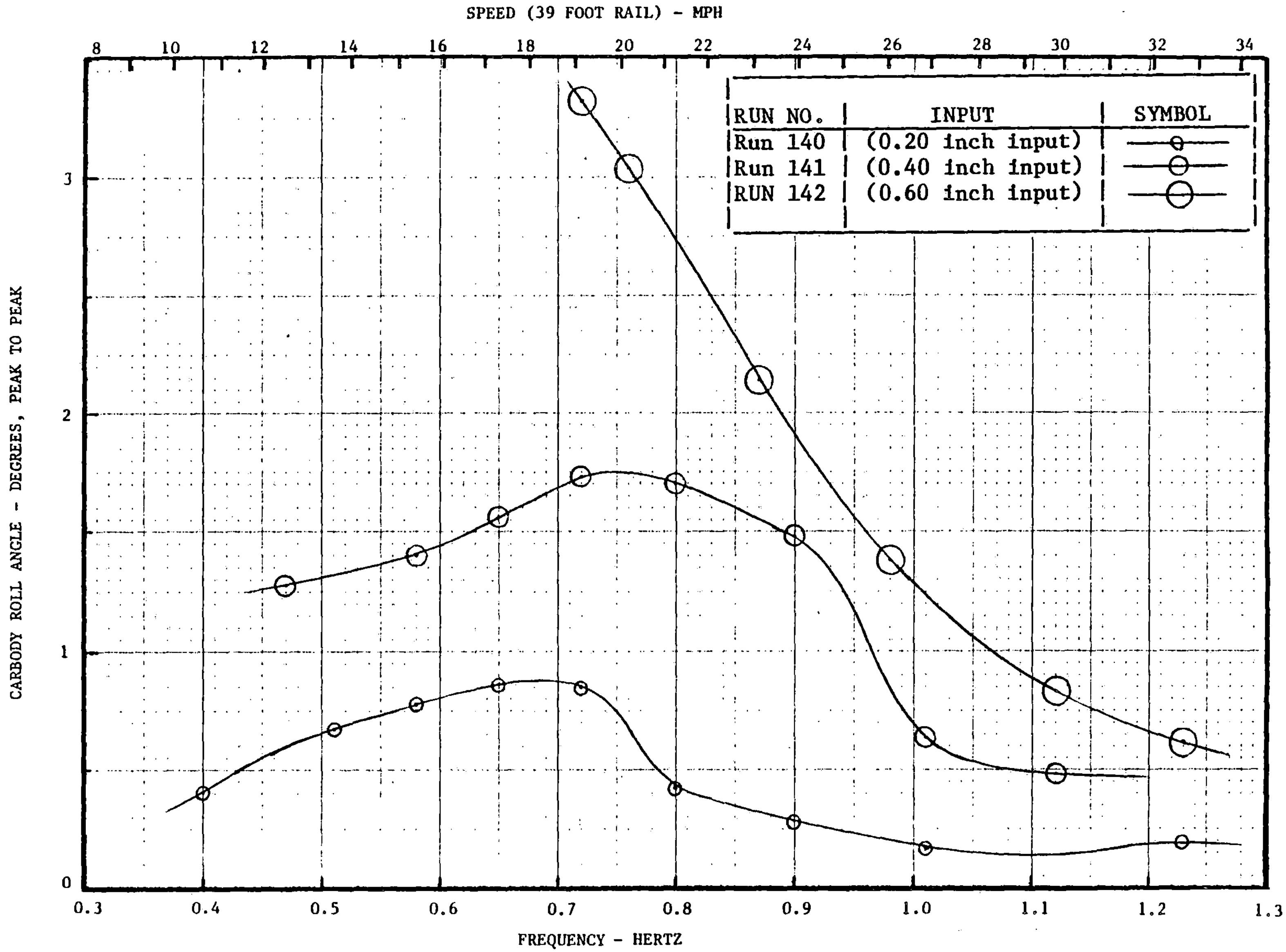


FIGURE 1-31
CARBODY ROLL ANGLE, CONFIGURATION 7, LADING SHIFTED,
STAGGERED RAIL TEST, RUNS 140, 141, AND 142

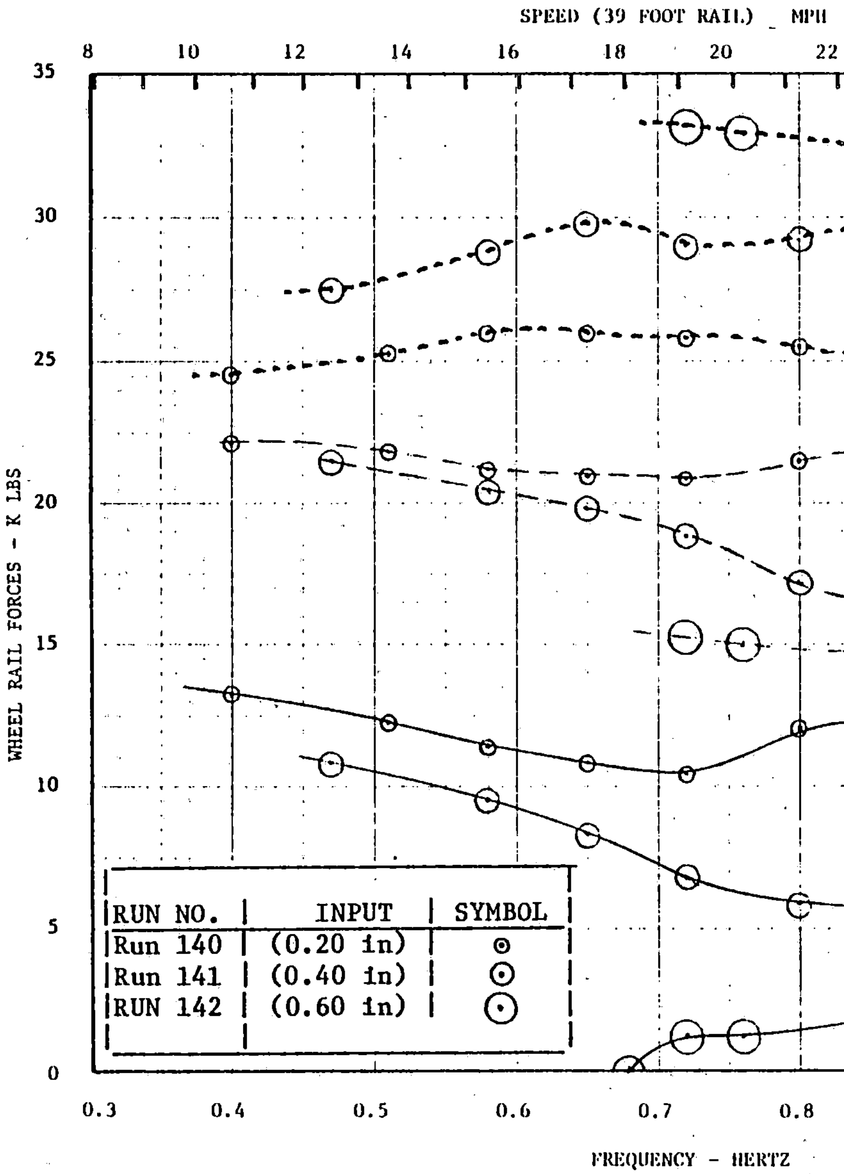
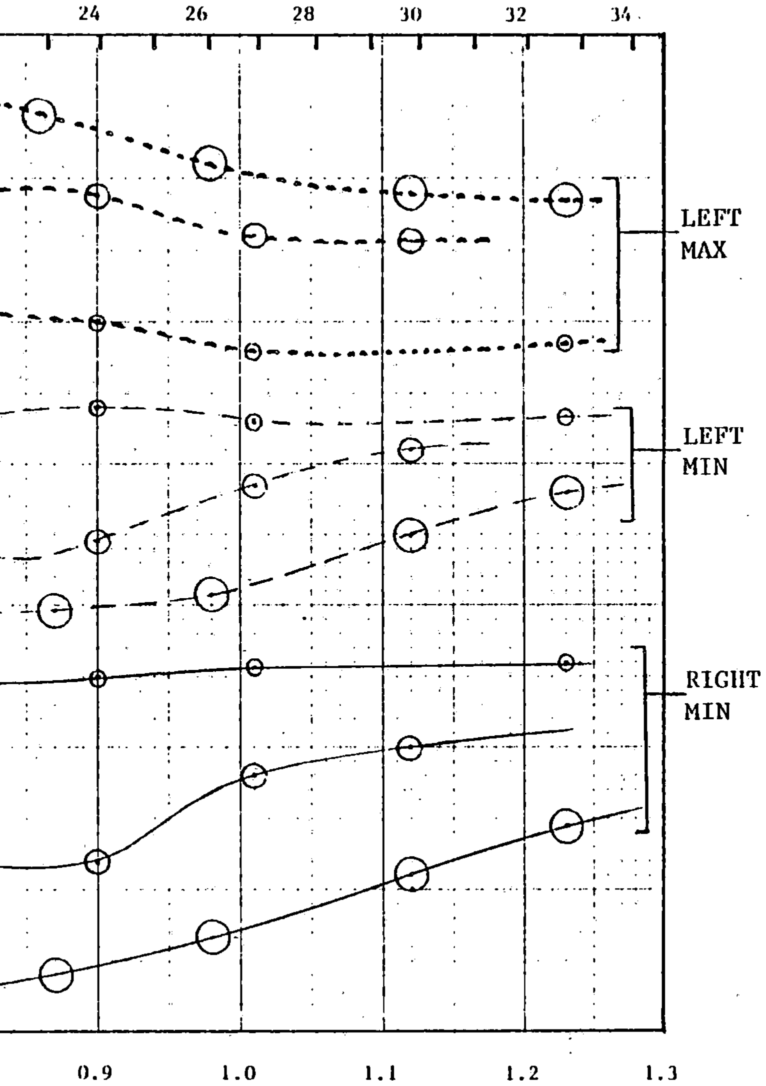


FIGURE 1-32
VERTICAL WHEEL LOAD, CONFIGURATION 7,
STAGGERED RAIL TEST



, LADING SHIFTED,

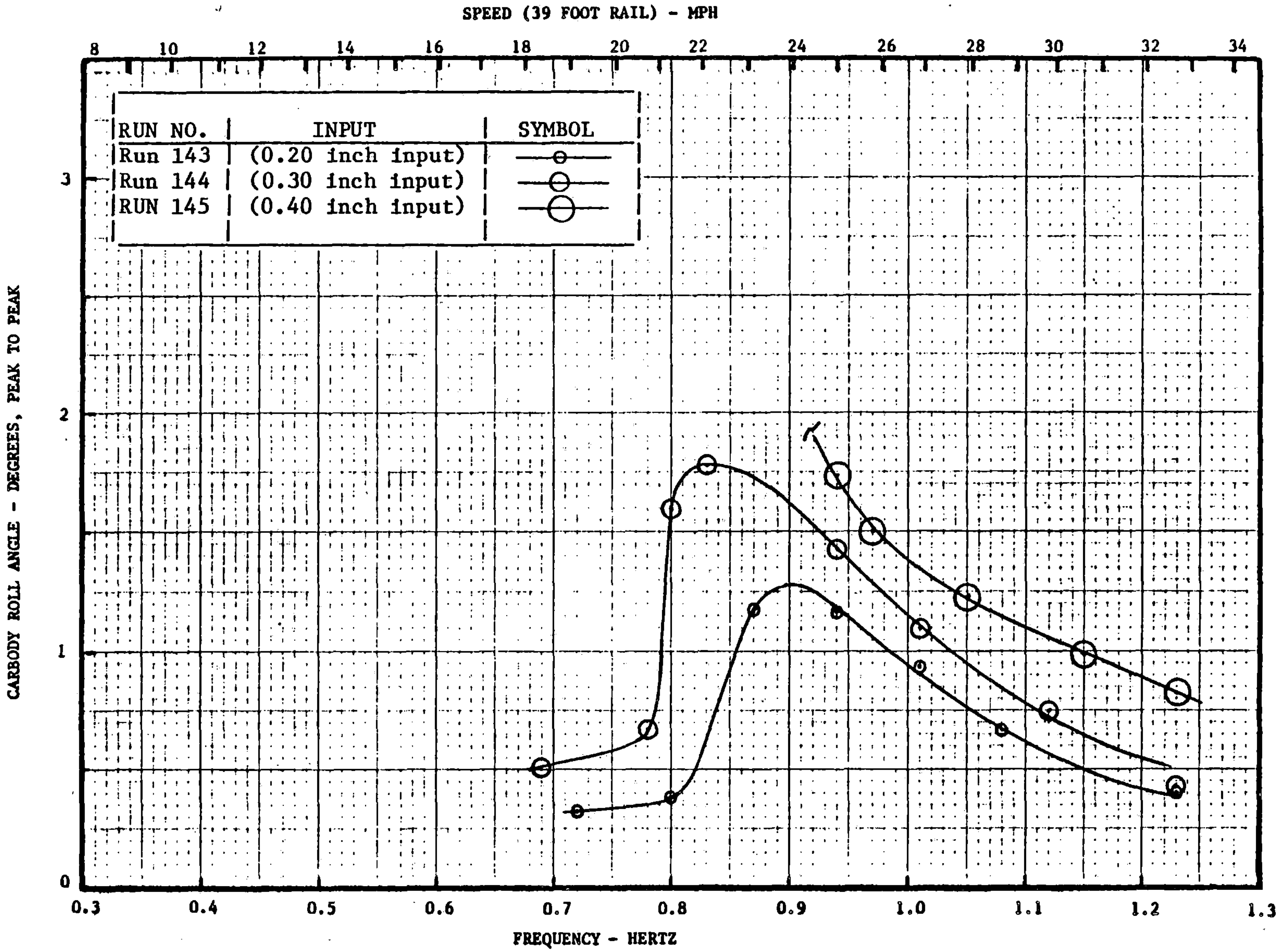


FIGURE 1-33
CARBODY ROLL ANGLE, CONFIGURATION 7, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION

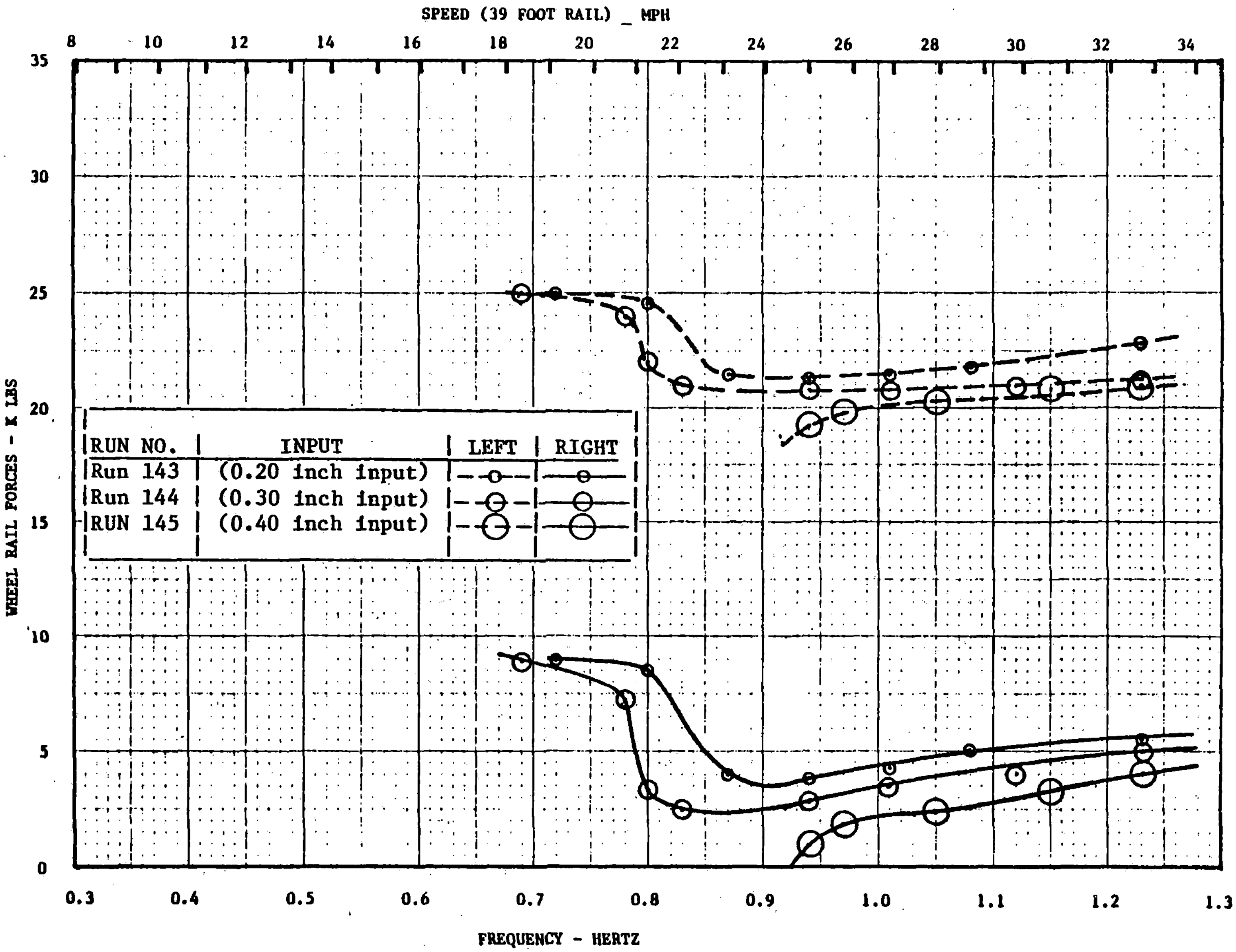


FIGURE 1-34
MINIMUM VERTICAL WHEEL LOADS, CONFIGURATION 7, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION

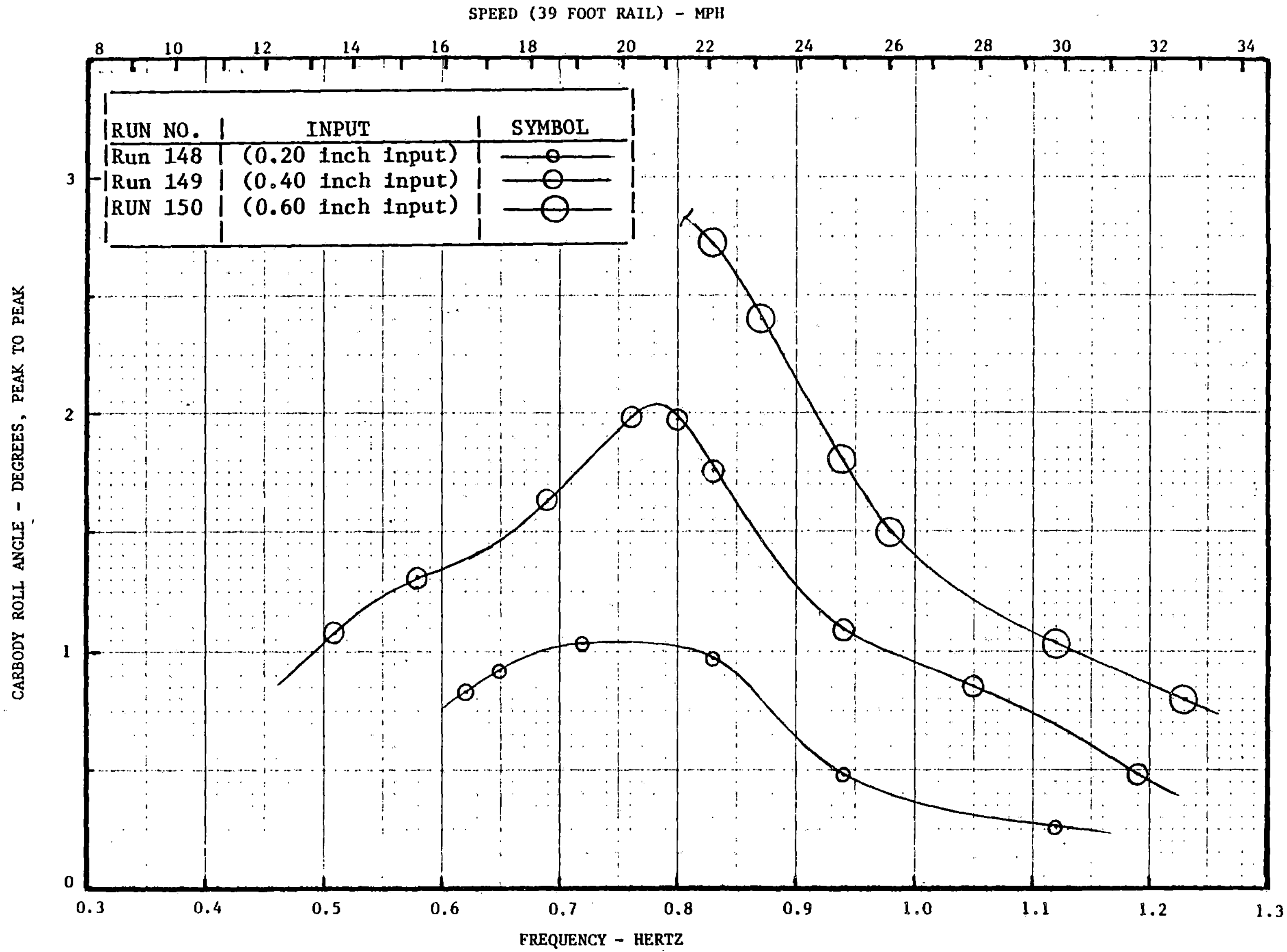


FIGURE 1-35
CARBODY ROLL ANGLE, CONFIGURATION 8, LADING SHIFTED,
STAGGERED RAIL TEST

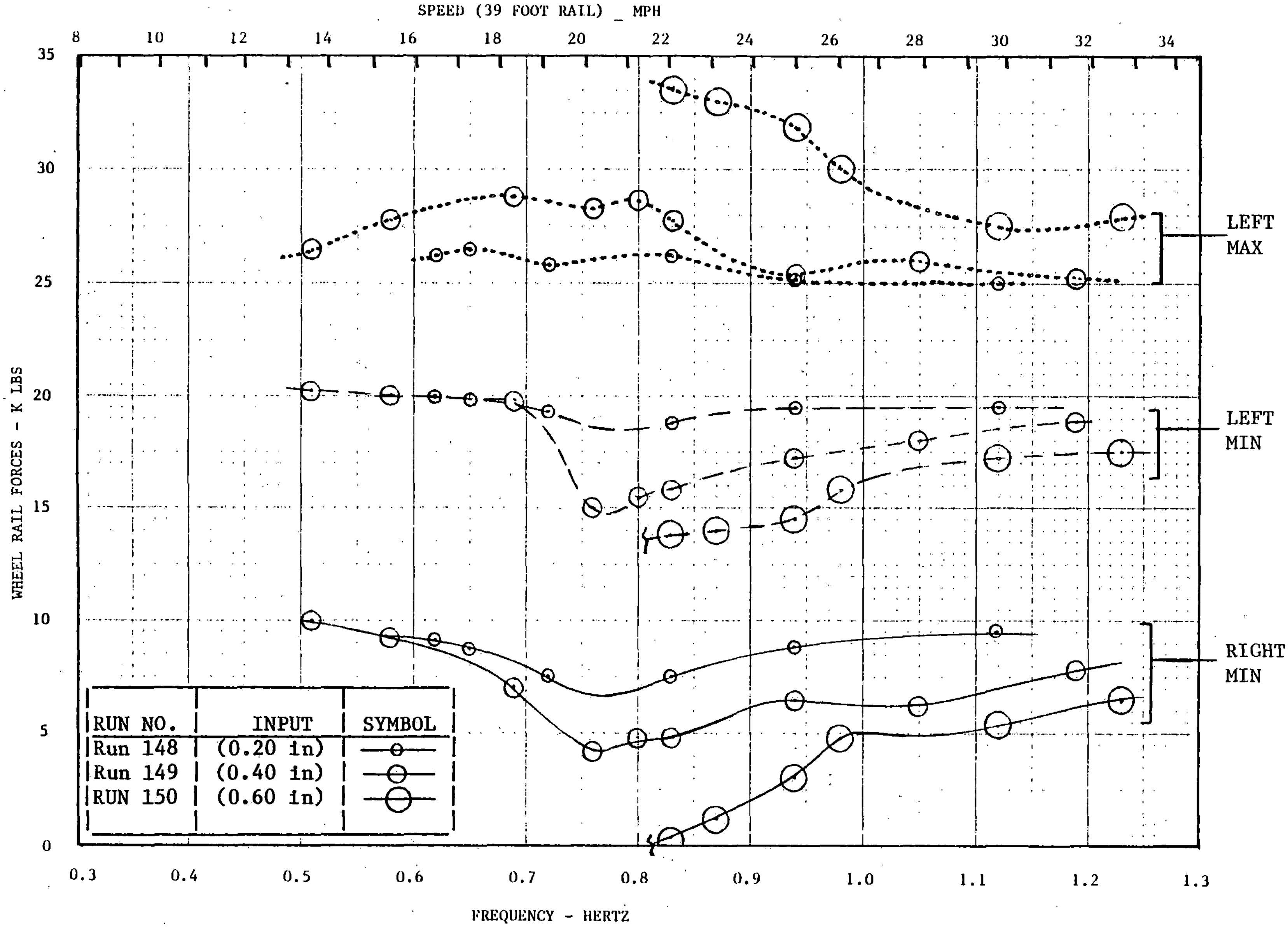


FIGURE 1-36
VERTICLE WHEEL LOADS, CONFIGURATION 8, LADING SHIFTED,
STAGGERED RAIL TEST

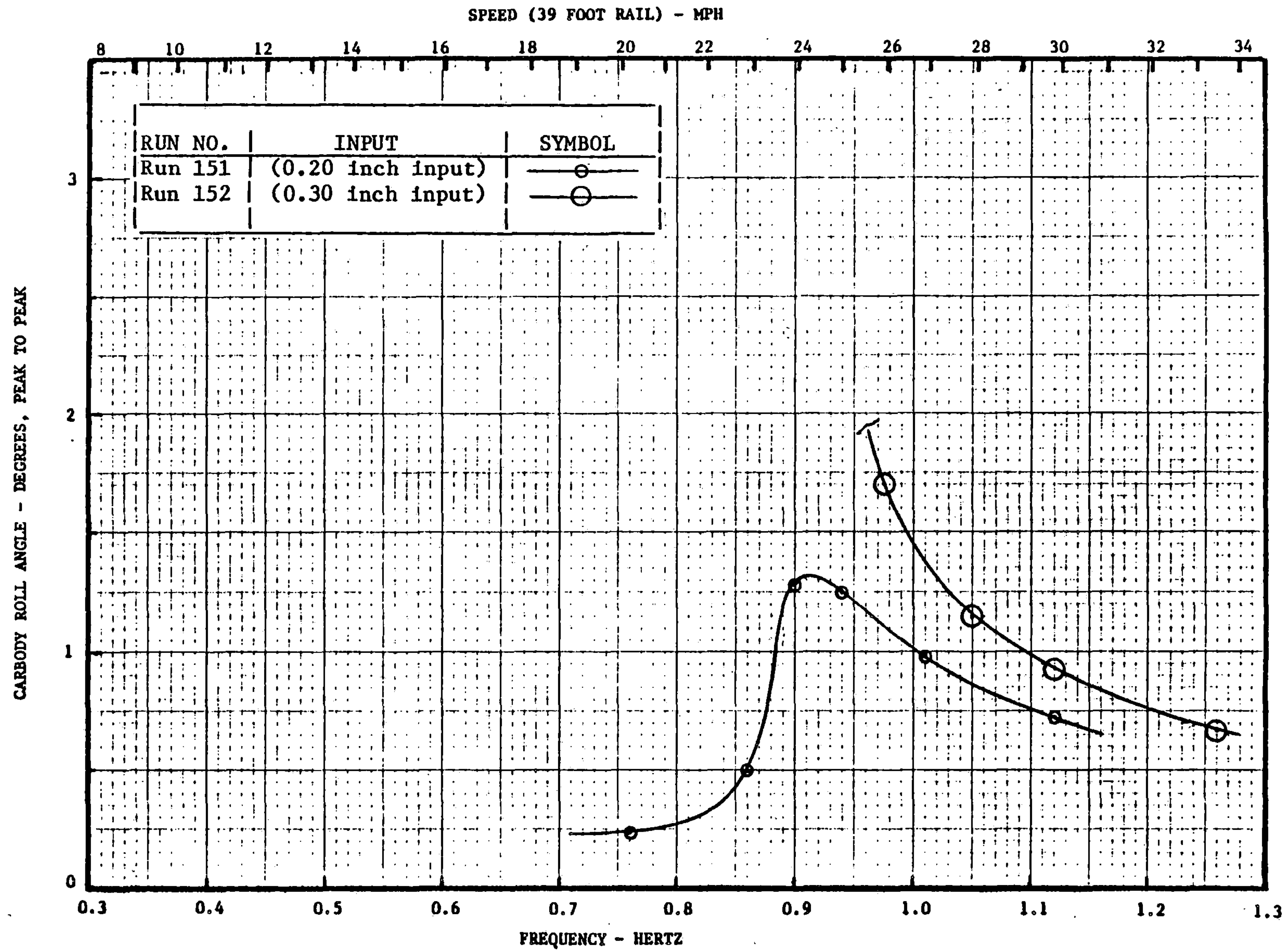


FIGURE 1-37
CARBODY ROLL ANGLES, CONFIGURATION 8, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION

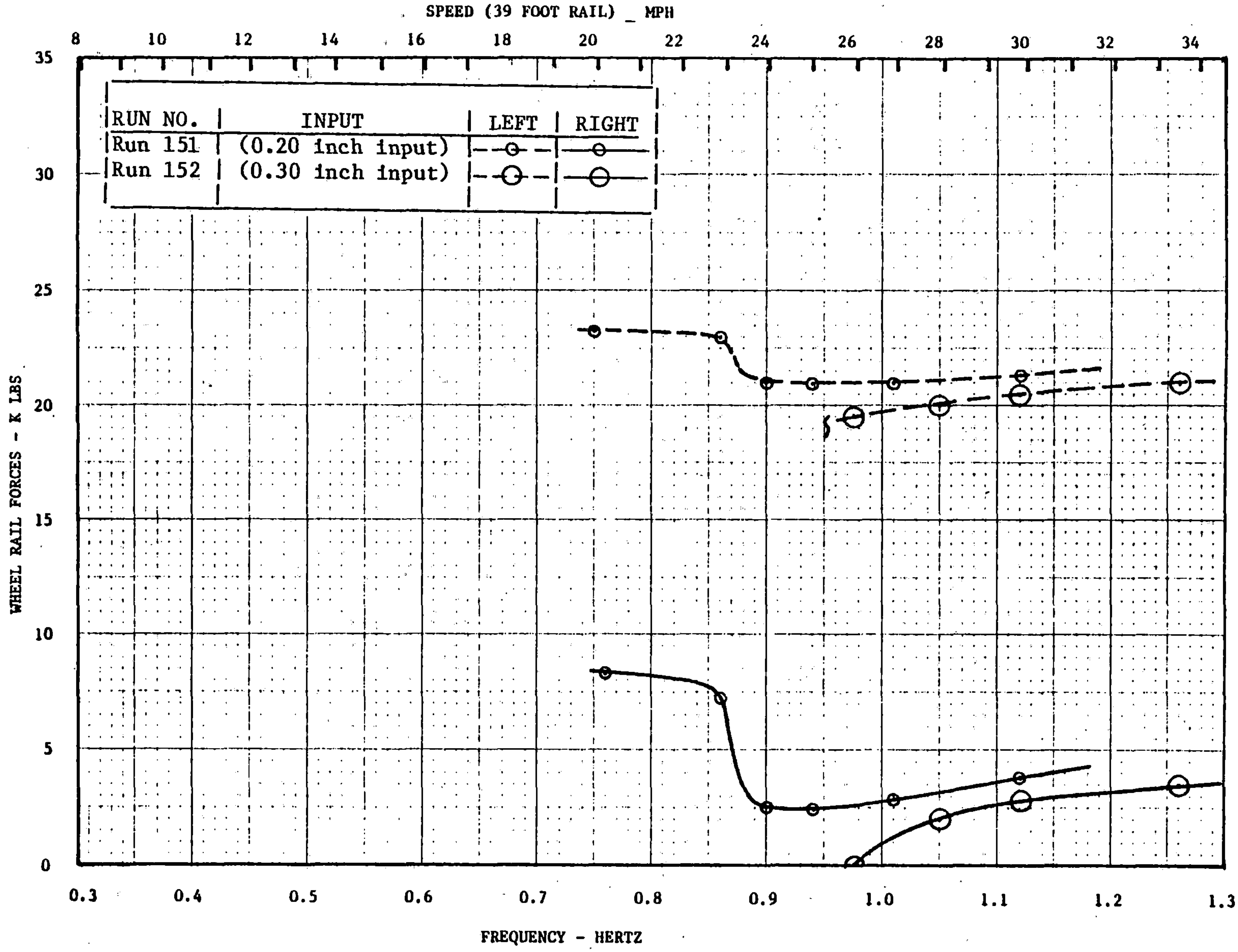


FIGURE 1-38
MINIMUM VERTICAL WHEEL LOAD, CONFIGURATION 8, LADING SHIFTED,
STAGGERED RAIL TEST WITH 3.0 INCH SUPERELEVATION

2. SUMMARY POWER SPECTRAL DENSITY PLOTS FROM TRACK GEOMETRY TESTS

This section contains summary plots of input displacements and response accelerations from the Track Geometry (TG) tests. The data is all in PSD spectra from measurements over the same 80 second sections of the TG test. The data is for the following measurements:

XE1A	Piston Displacement Actuator 1A, vertical, inches.
XE1C	Piston Displacement Actuator 1C, lateral, inches.
A8Z	Vertical acceleration of lading on top right side, A end of car, g's.
A9X	Lateral acceleration of lading on top right side, A end of car, g's.
A14Z	Vertical acceleration of carbody on bottom right side, A end of car, g's.
A15X	Lateral acceleration of carbody on bottom right side, A end of car, g's.
A17X	Lateral acceleration of carbody on top right side, B end of car, g's.

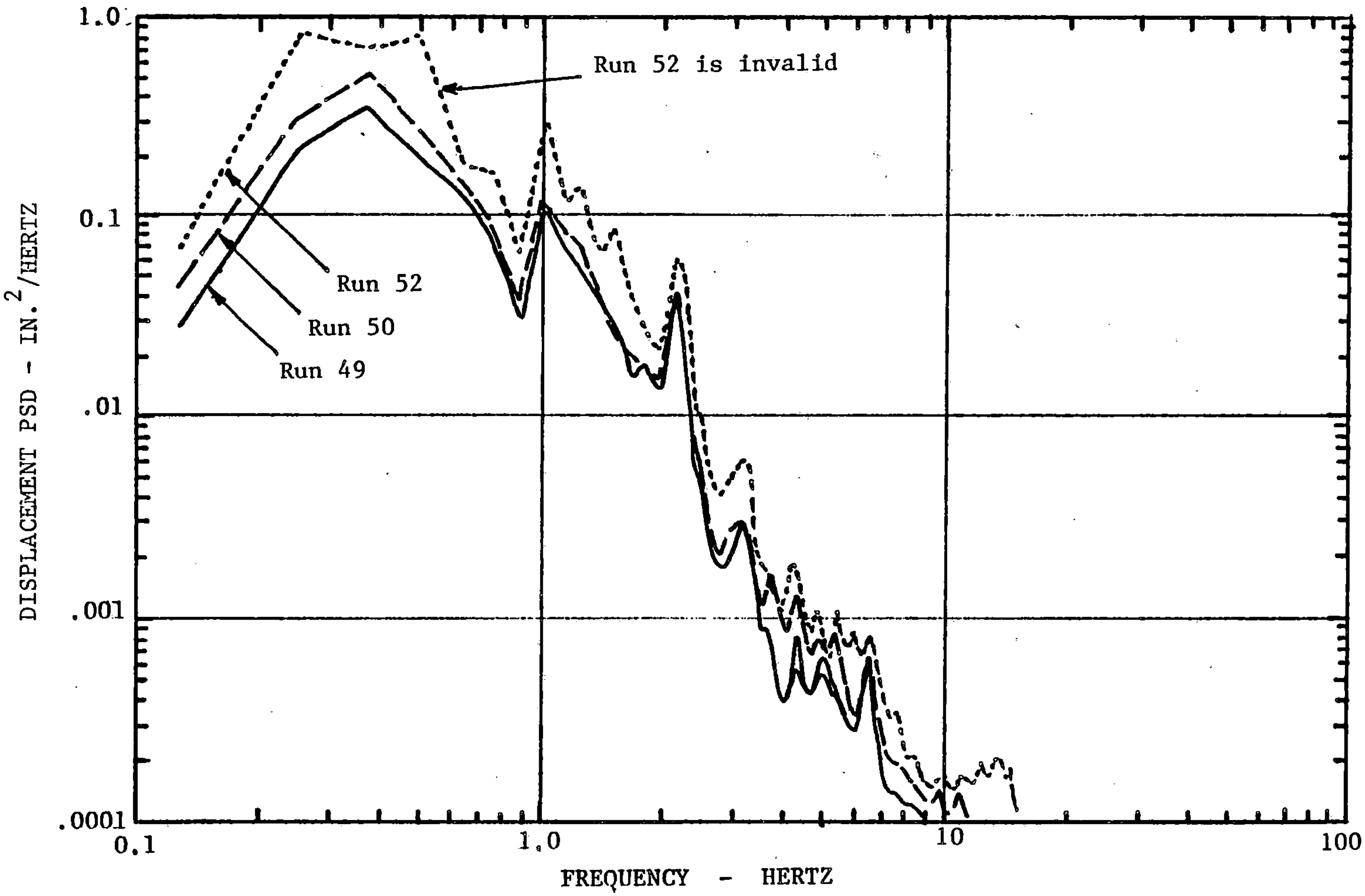


FIGURE 2-1
TRACK GEOMETRY INPUT SPECTRA, XE1A, CONFIGURATION 1,
LADING CENTERED, RUNS 49, 50, AND 52

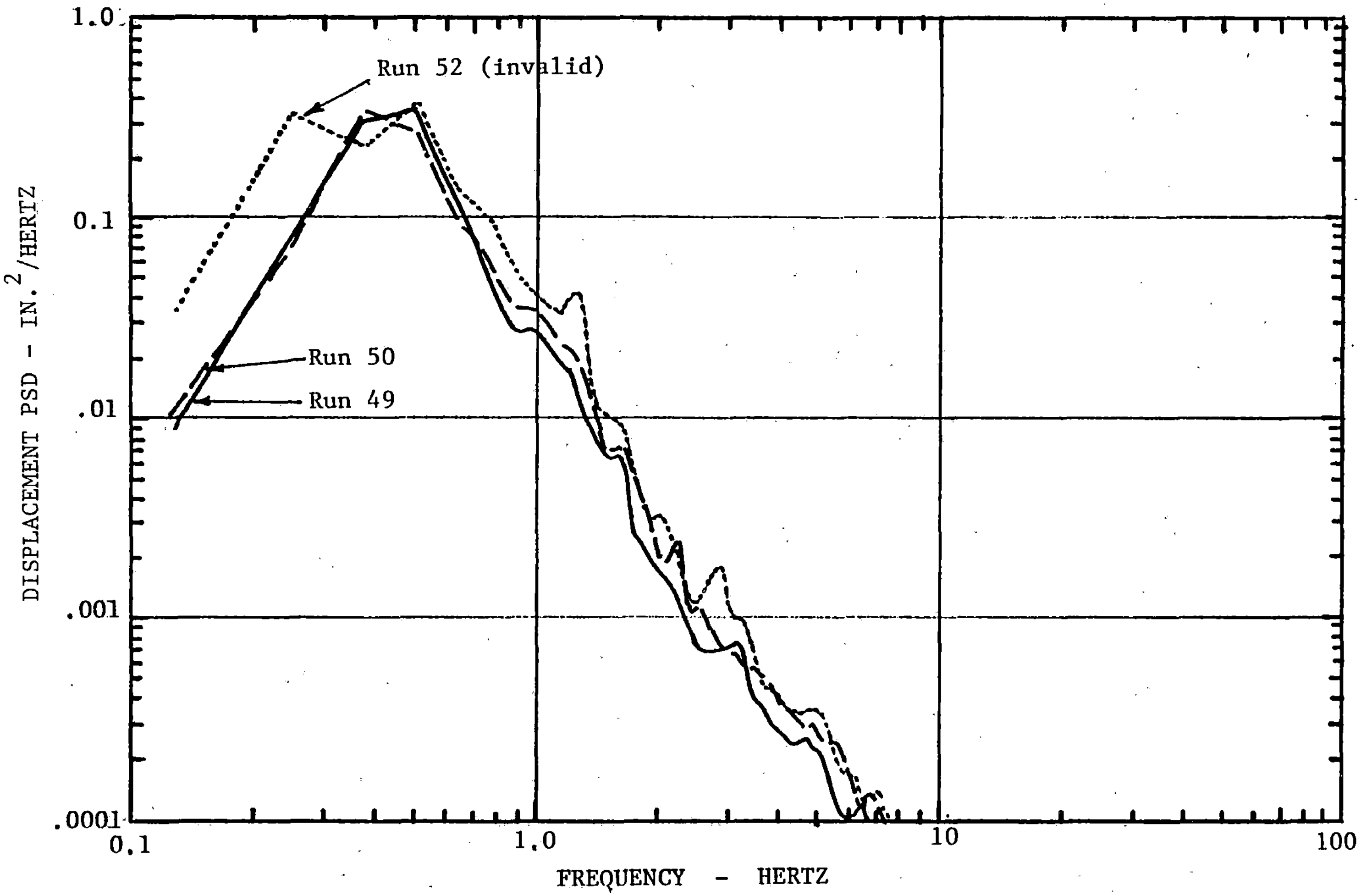


FIGURE 2-2
TRACK GEOMETRY INPUT SPECTRA, XE1C, CONFIGURATION 1,
LADING CENTERED, RUNS 49, 50, AND 52

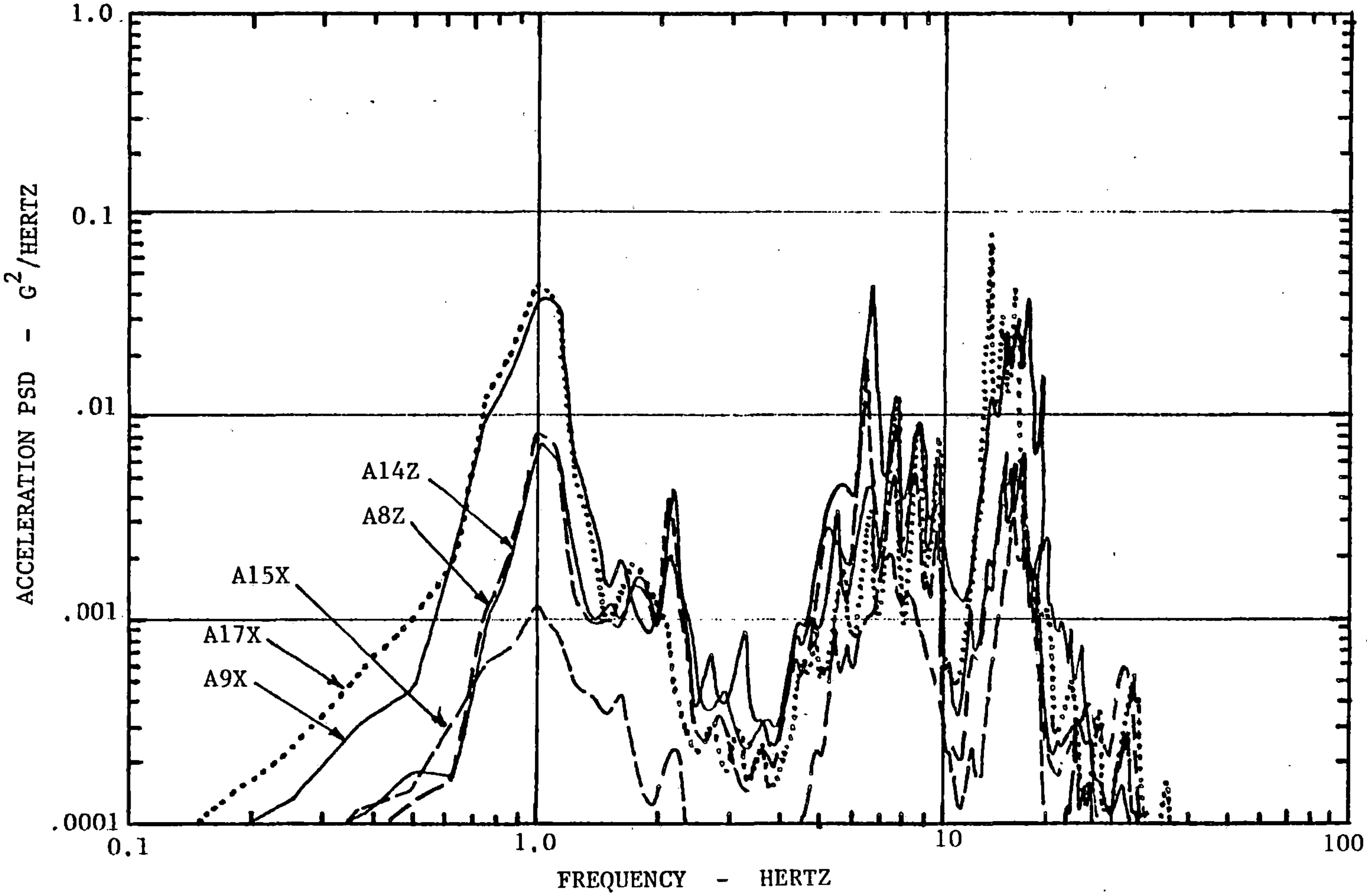


FIGURE 2-3
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1,
LADING CENTERED, RUN 49, 1.25 LEVEL

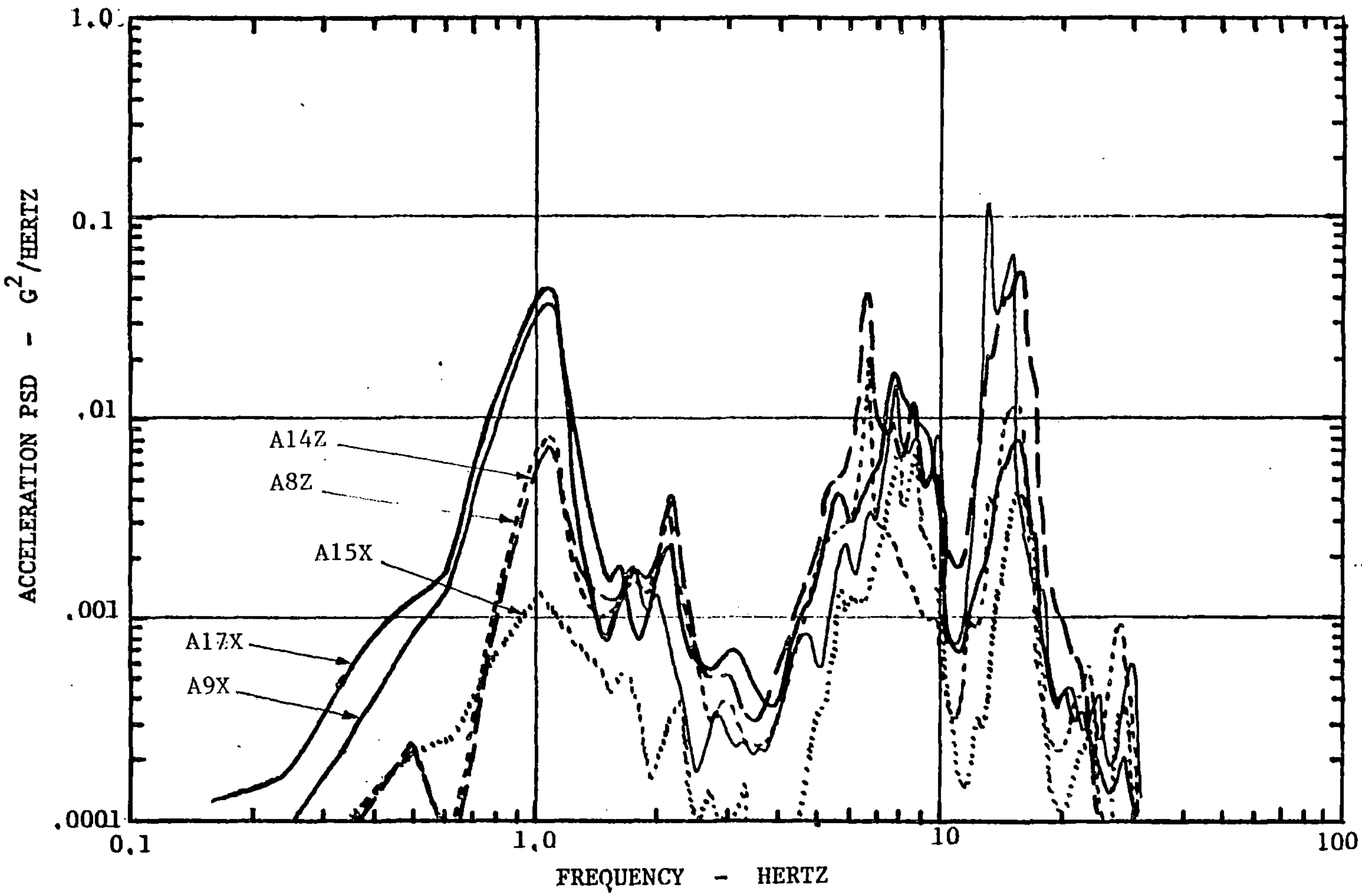


FIGURE 2-4
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1,
LADING CENTERED, RUN 50, 1.50 LEVEL

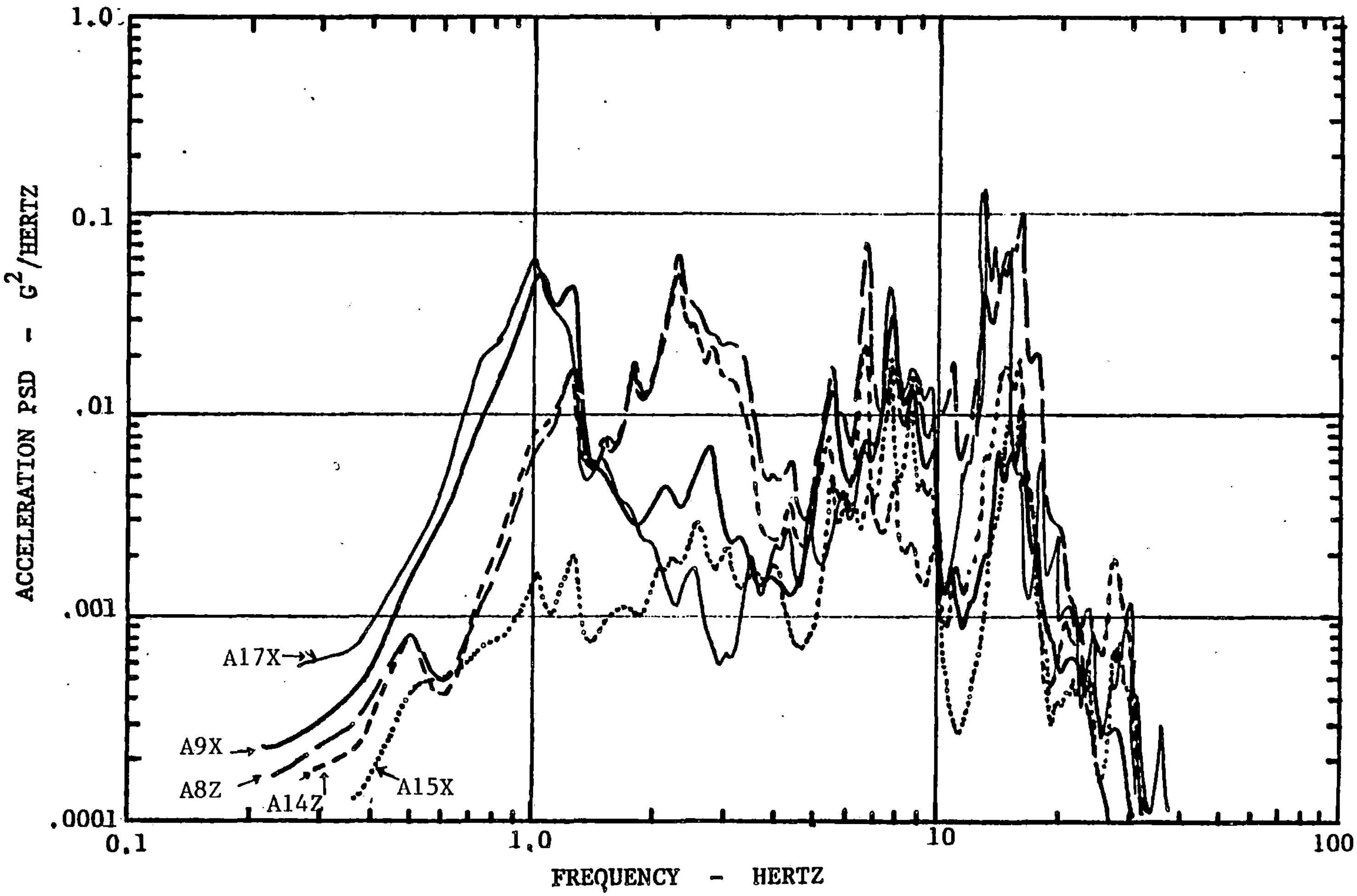


FIGURE 2-5
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1,
LADING CENTERED, RUN 52, 1.75 LEVEL

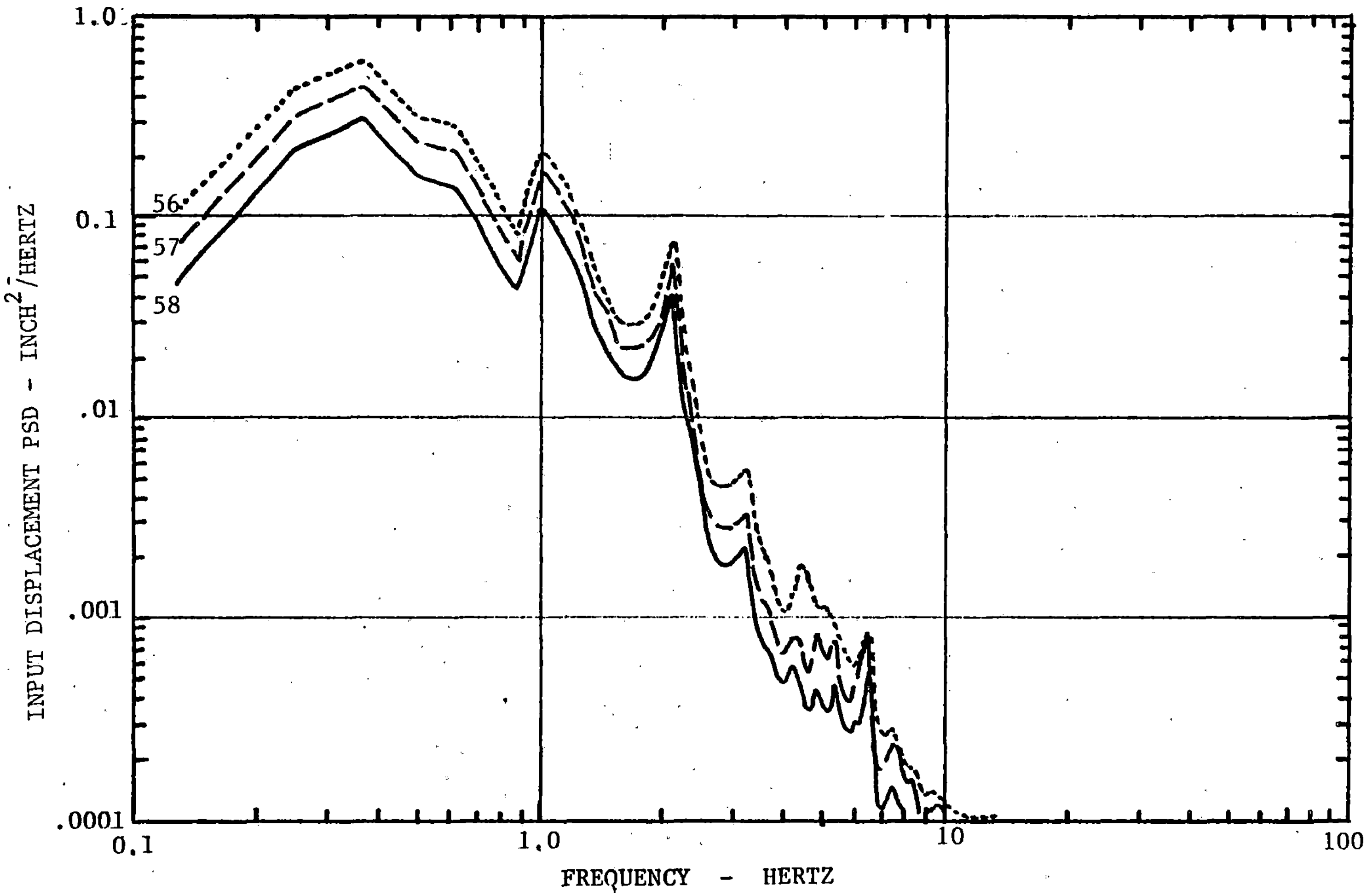


FIGURE 2-6
TRACK GEOMETRY INPUT SPECTRA, XE1A, CONFIGURATION 1,
LADING SHIFTED, RUNS 56, 57, AND 58

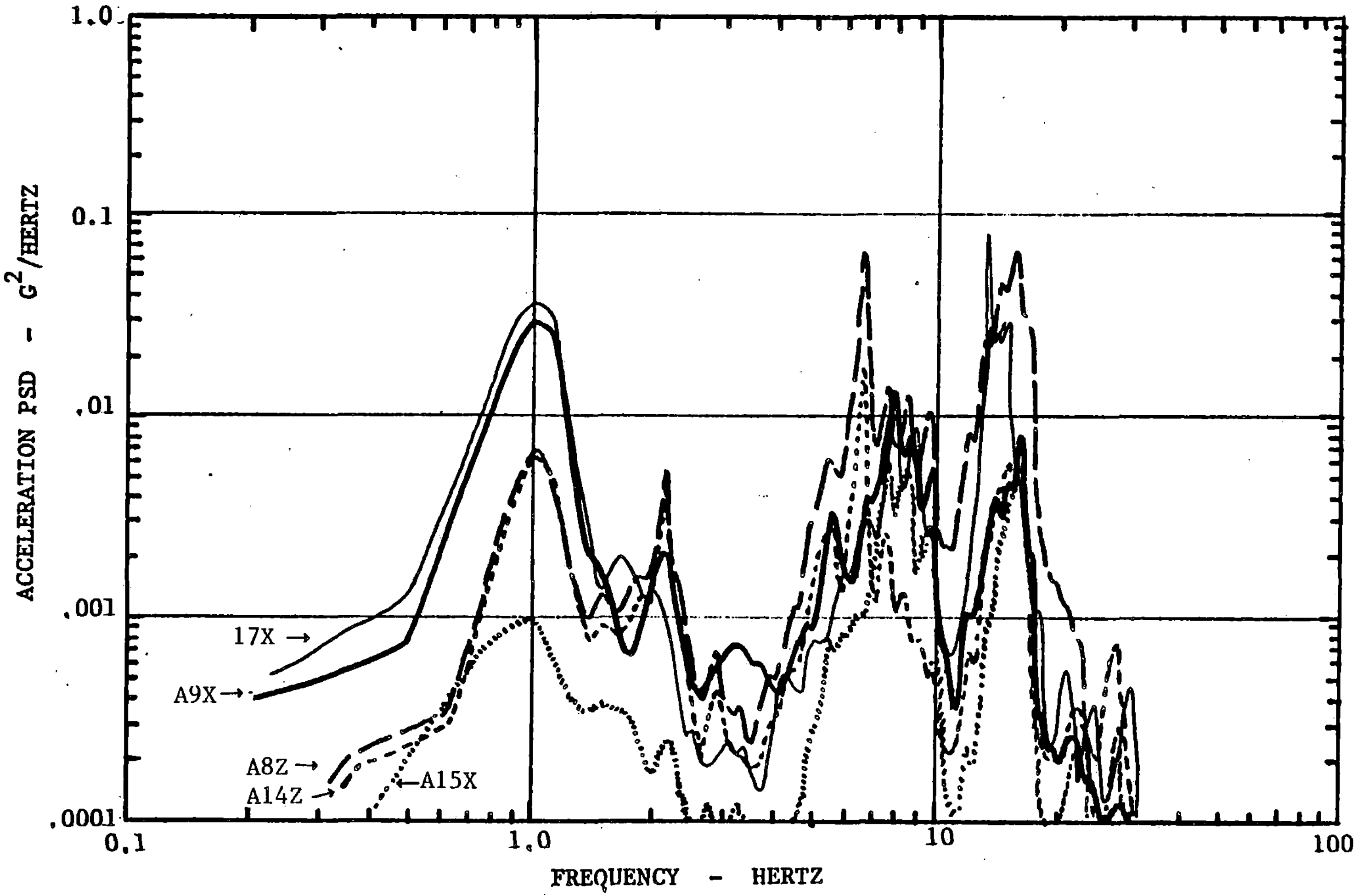


FIGURE 2-7
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1
LADING SHIFTED, RUN 56, 1.50 LEVEL

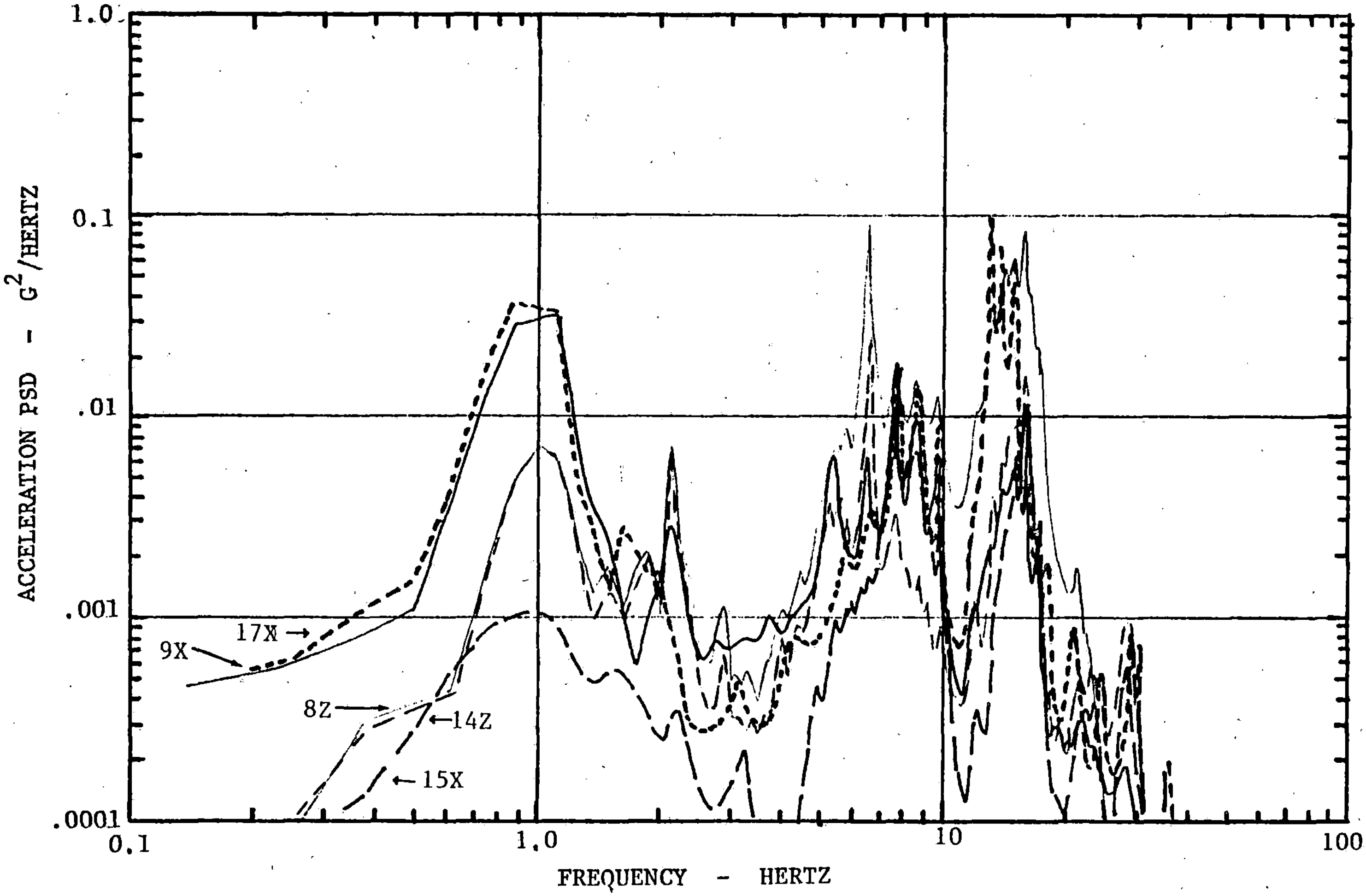


FIGURE 2-8
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1,
LADING SHIFTED, RUN 57, 1.50 LEVEL

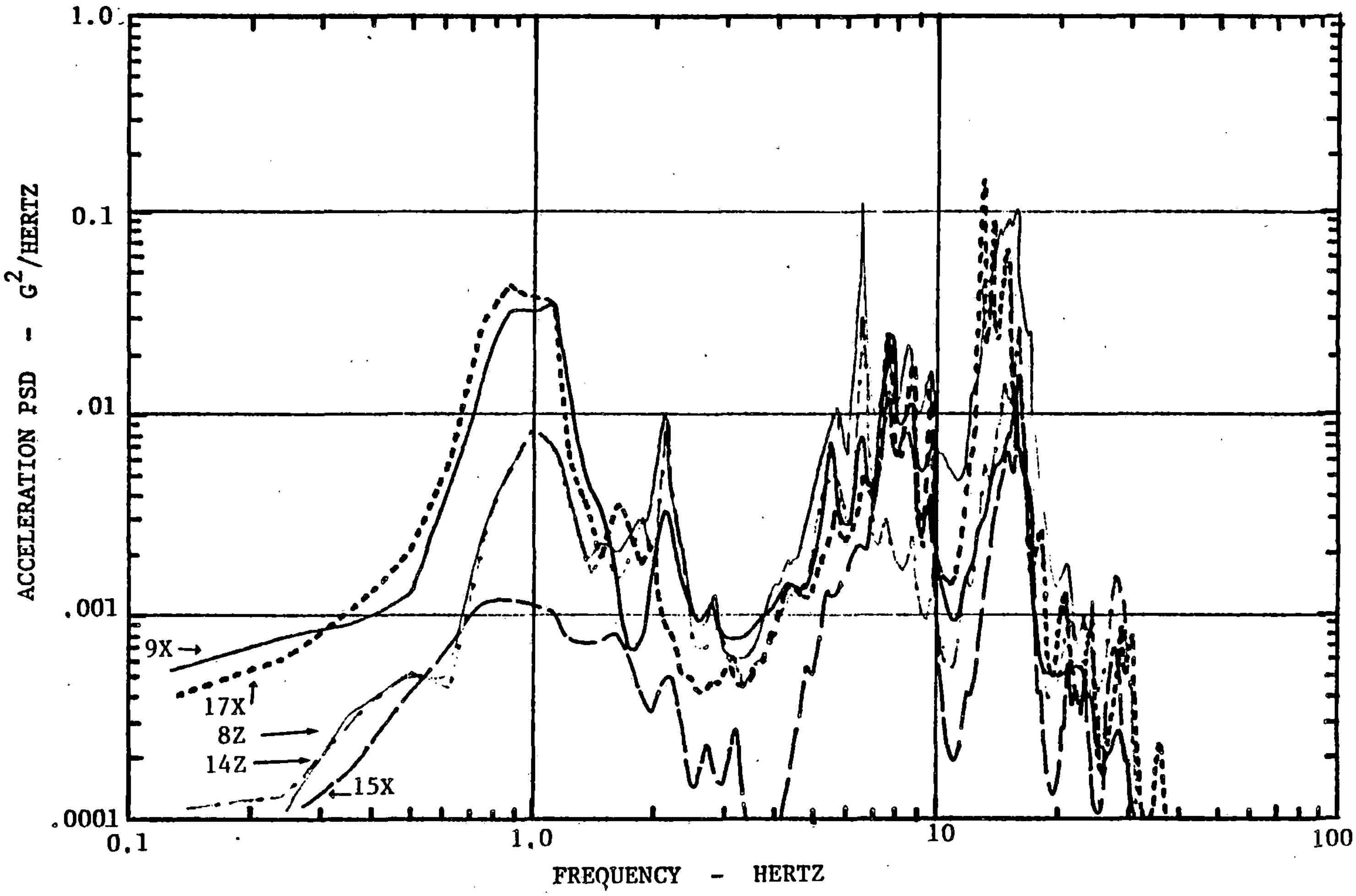


FIGURE 2-9
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1,
LADING SHIFTED, RUN 58, 1.75 LEVEL

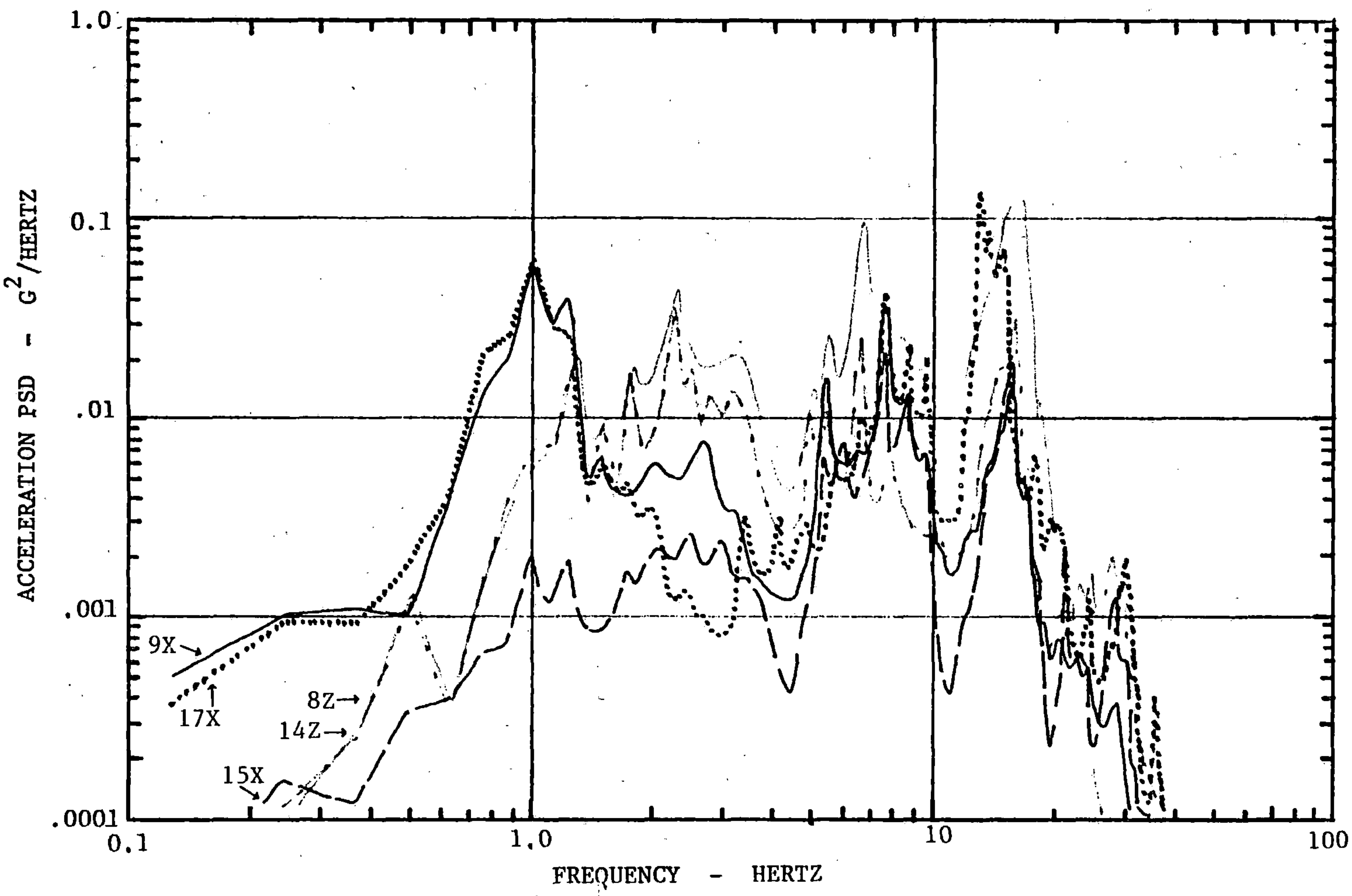
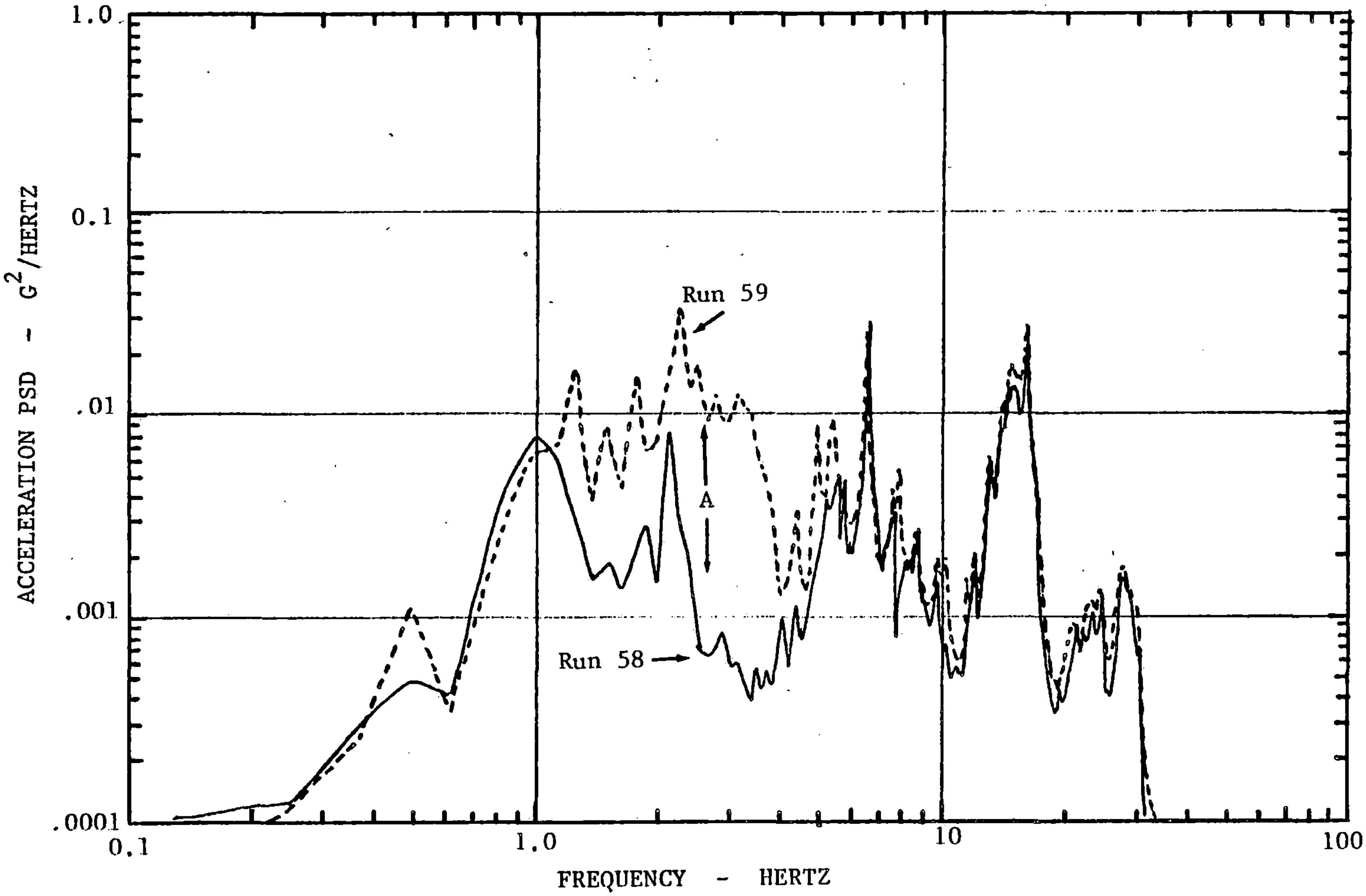


FIGURE 2-10
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 1,
LADING SHIFTED, RUN 59, 2.00 LEVEL



[A] This difference is due to error introduced by shaker control system when TG is amplified too far.

FIGURE 2-11
TRACK GEOMETRY RESPONSE SPECTRA COMPARISON BETWEEN RUNS 58 AND 59 SHOWING EFFECT OF ERROR IN RUN 59

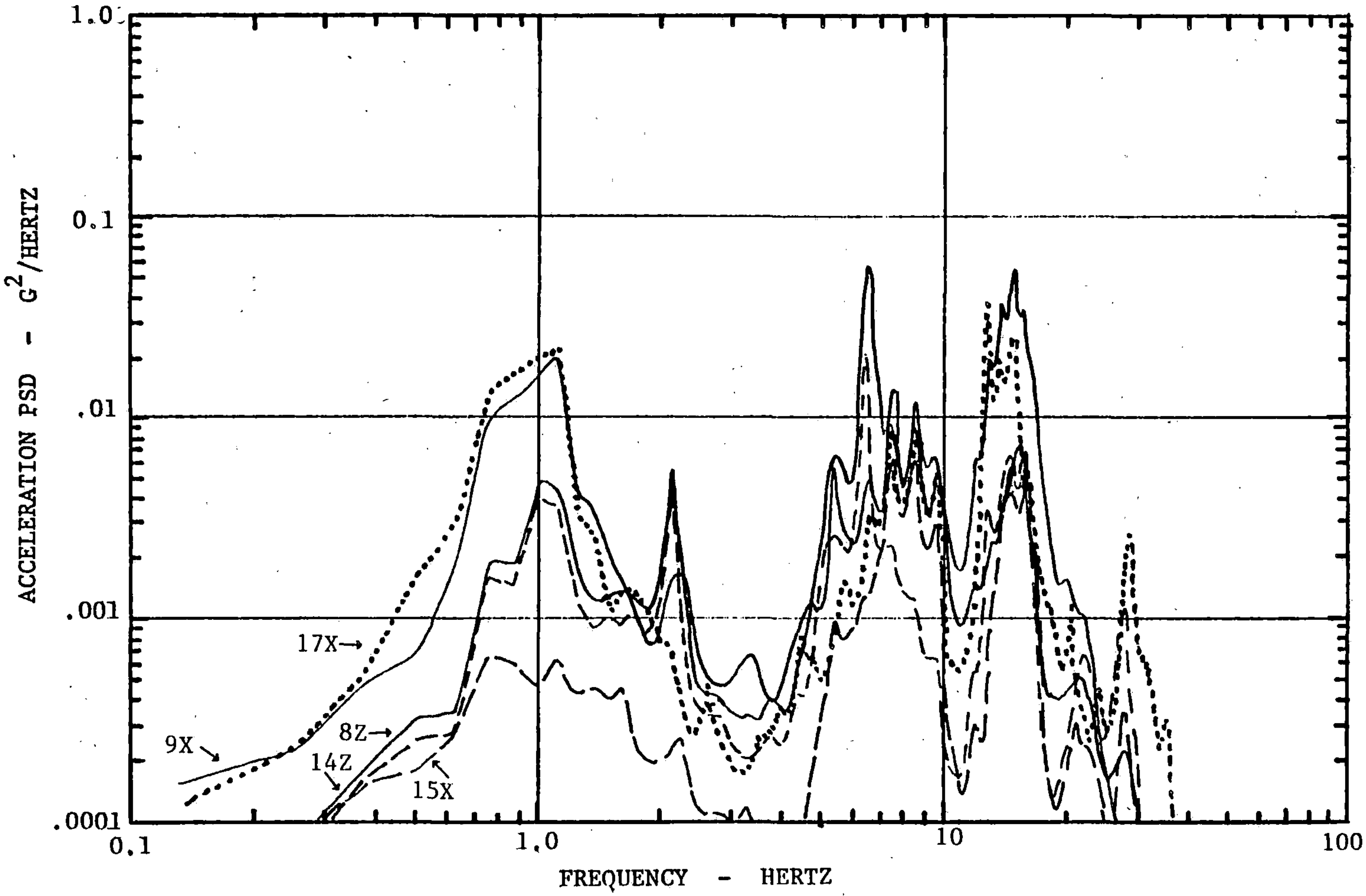


FIGURE 2-12
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 2,
LADING SHIFTED, RUN 118, 1.25 LEVEL

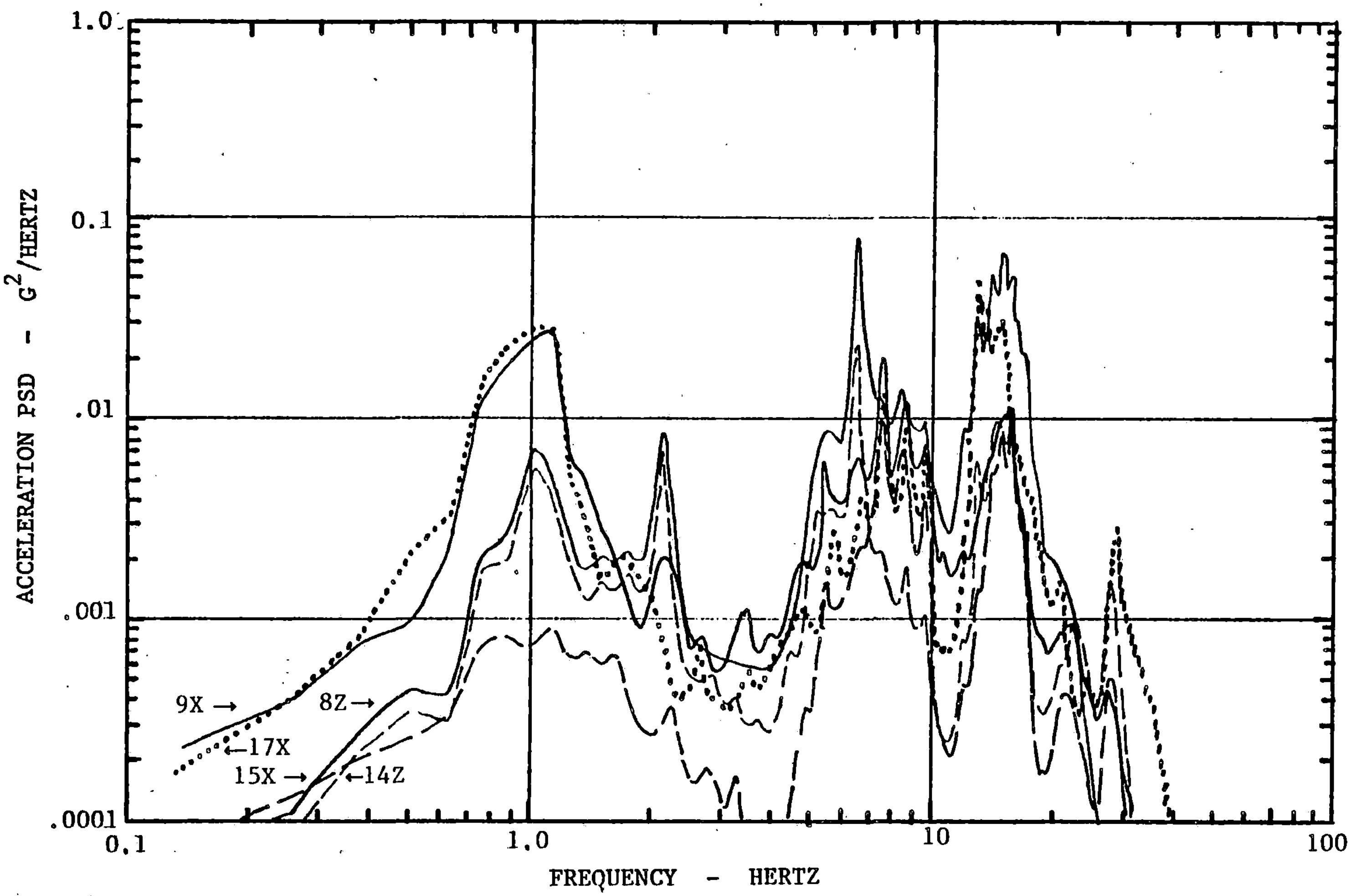


FIGURE 2-13
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 2,
LADING SHIFTED, RUN 119, 1.50 LEVEL

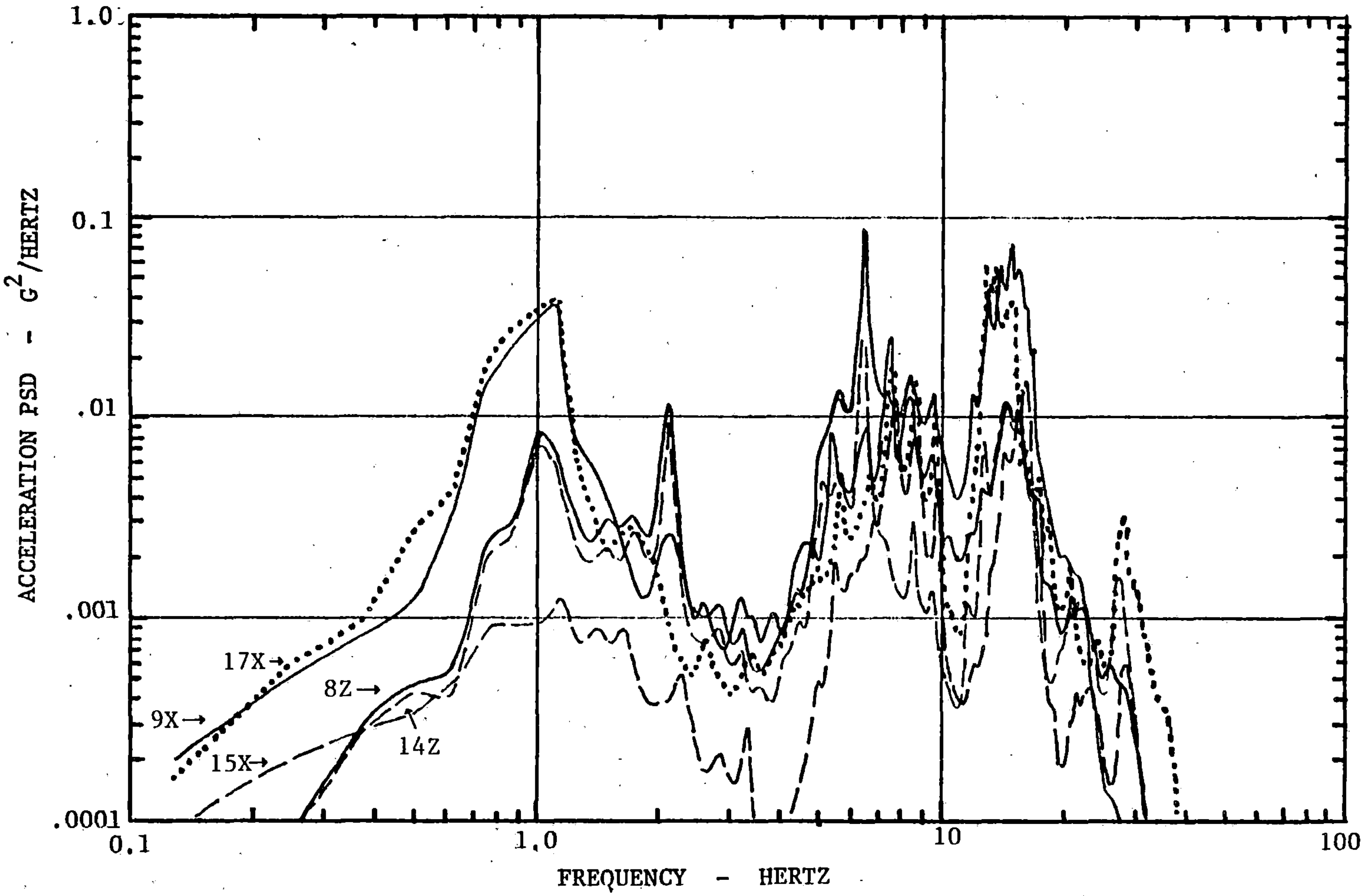


FIGURE 2-14
TRACK GEOMETRY SUMMARY OF RESPONSE SPECTRA, CONFIGURATION 2,
LADING SHIFTED, RUN 120, 1.75 LEVEL

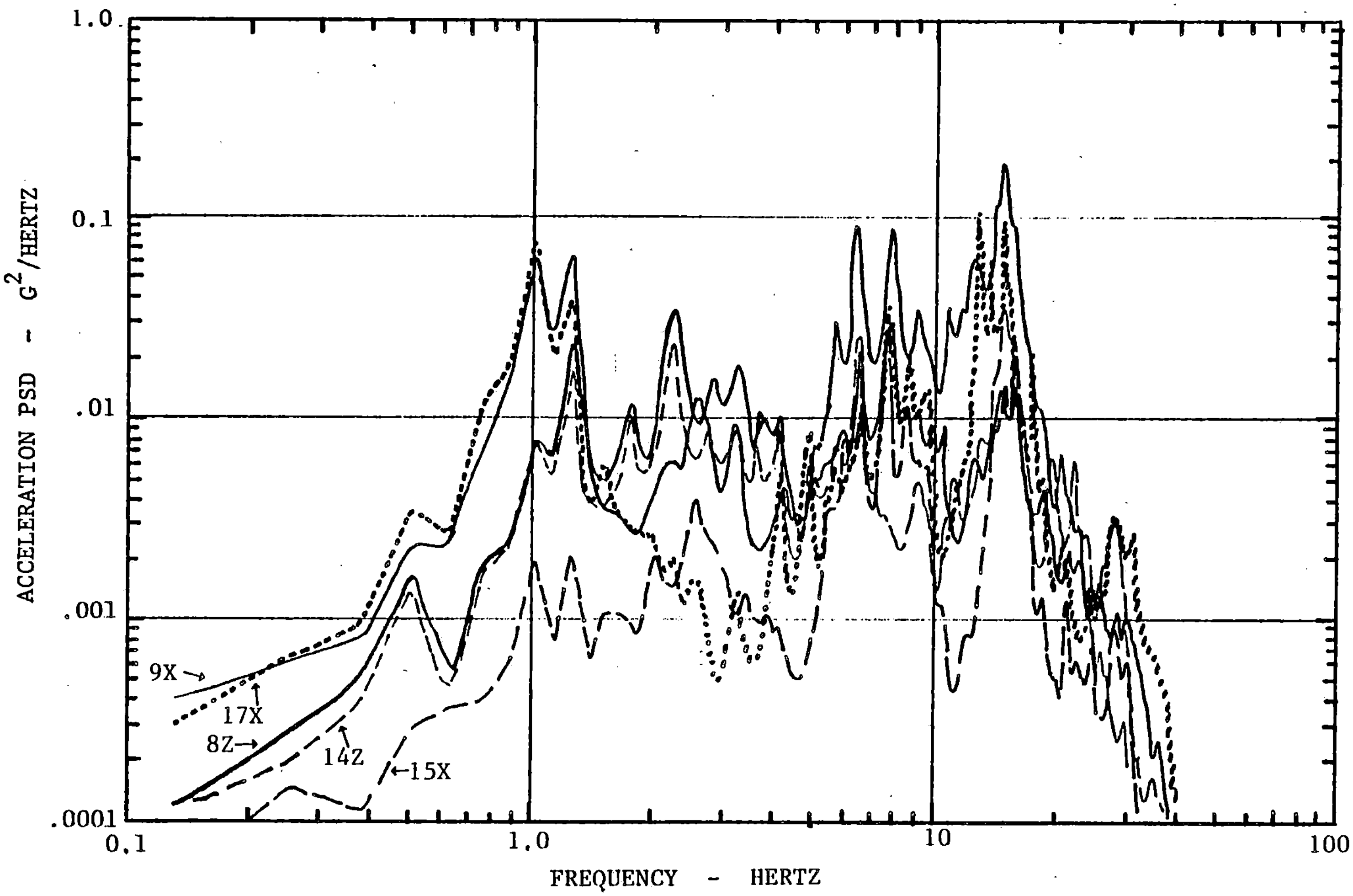


FIGURE 2-15
TRACK GEOMETRY SUMMARY OF RESPONSE SPECTRA, CONFIGURATION 2,
LADING SHIFTED, RUN 121, 2.00 LEVEL

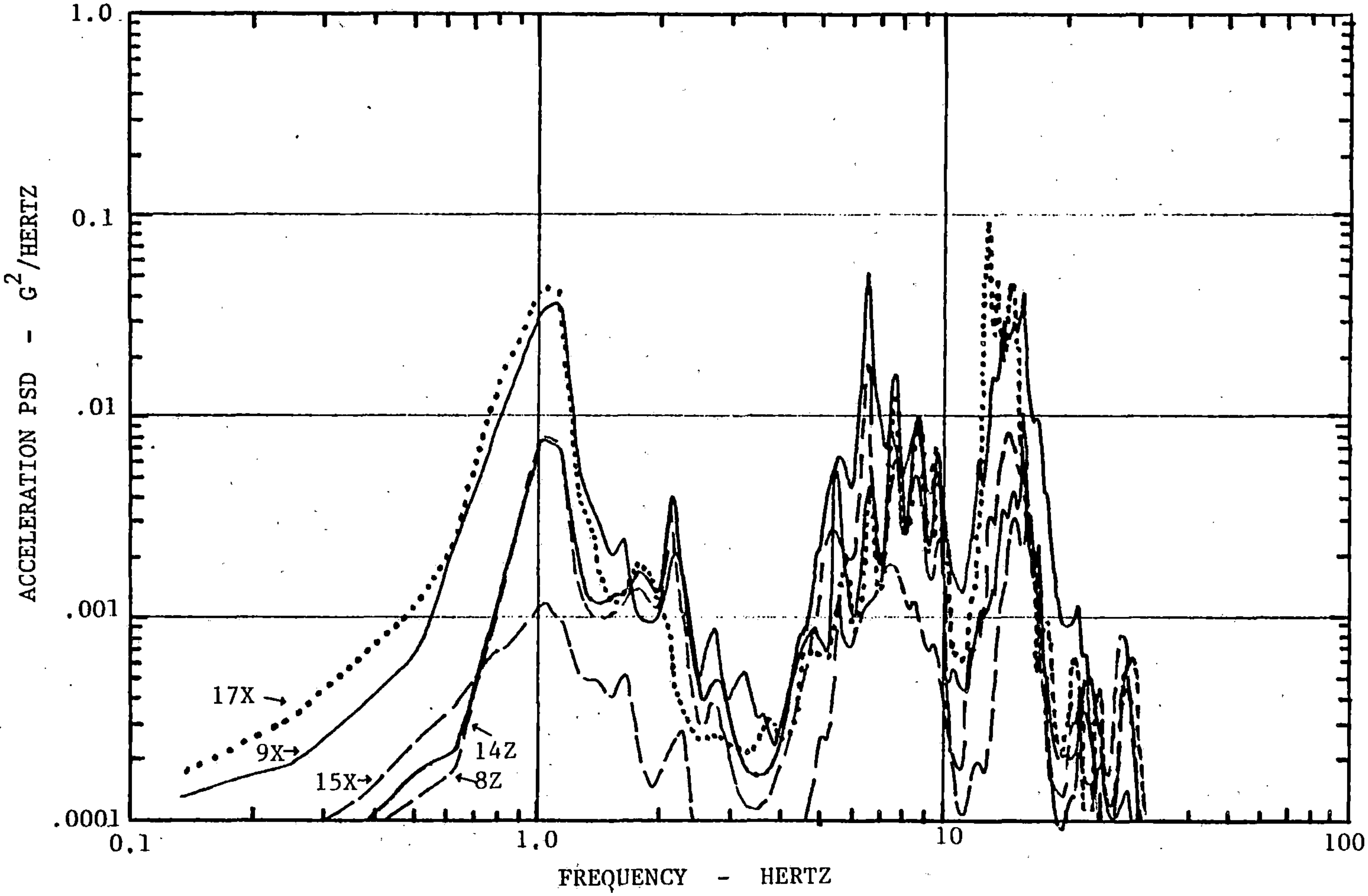


FIGURE 2-16
TRACK GEOMETRY RESPONSE SPECTRA SUMMARY, CONFIGURATION 2,
LADING CENTERED, RUN 122, 1.25 LEVEL

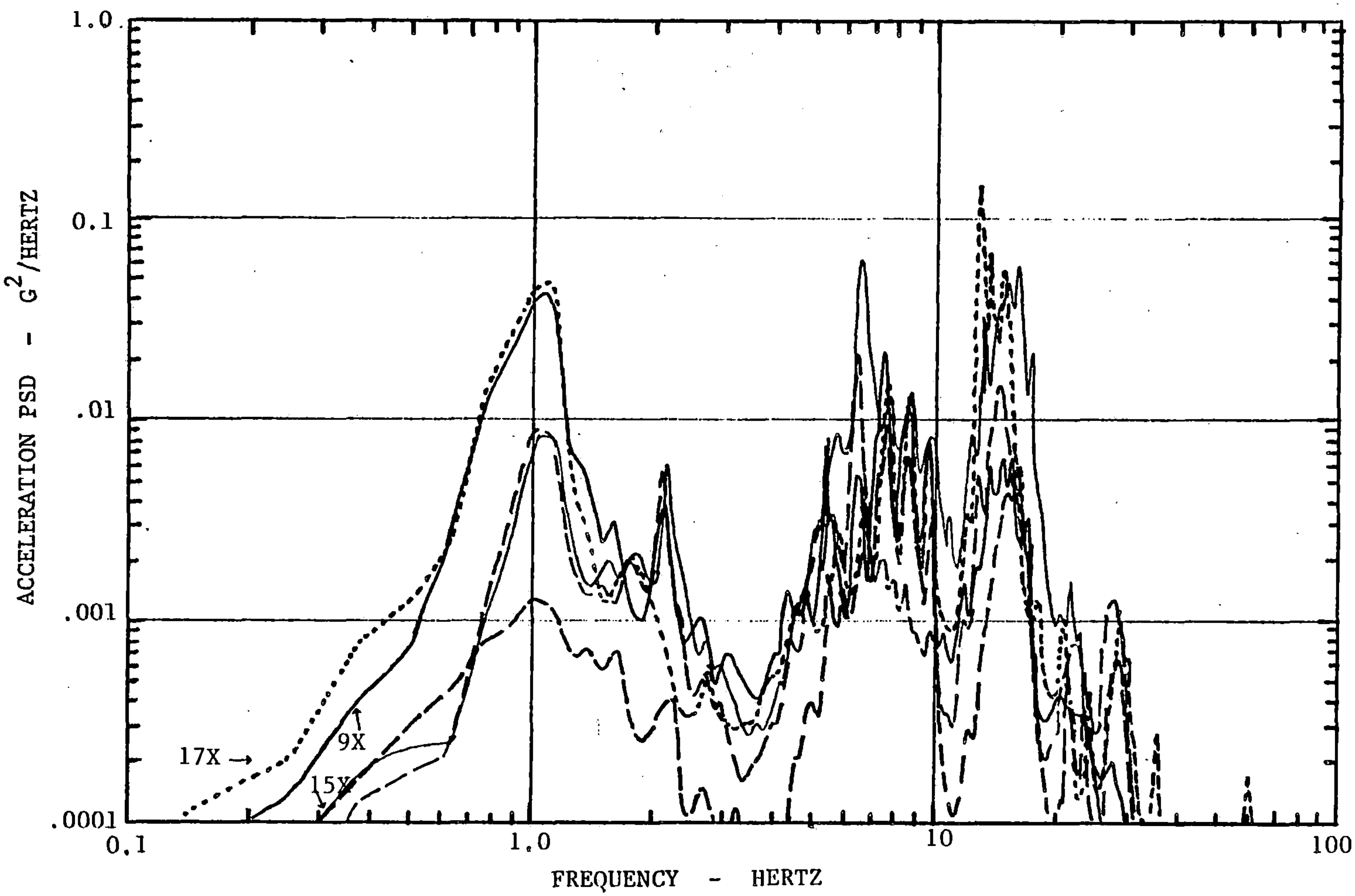


FIGURE 2-17
TRACK GEOMETRY RESPONSE SPECTRA SUMMARY, CONFIGURATION 2,
LADING CENTERED, RUN 123, 1.50 LEVEL

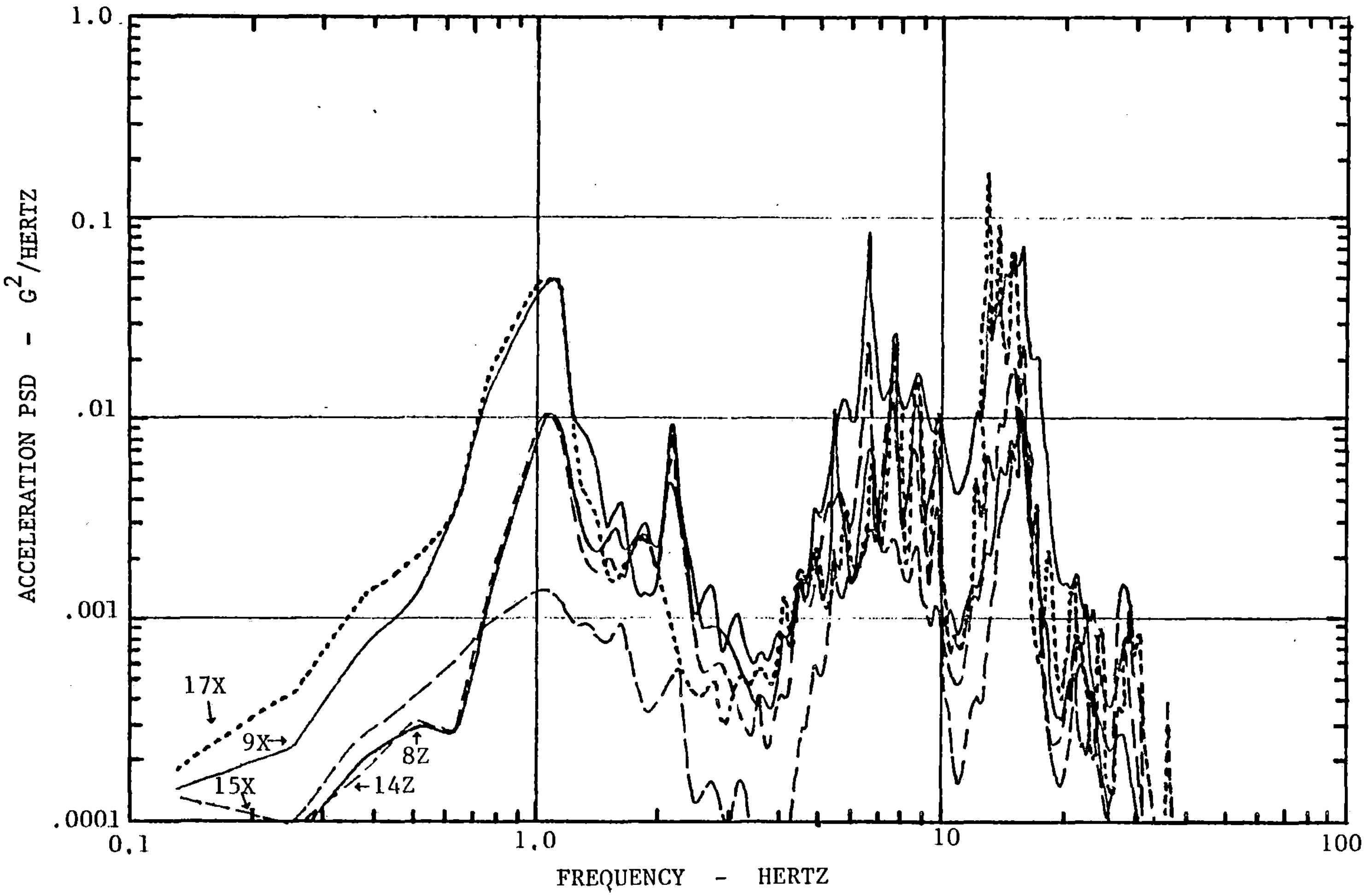


FIGURE 2-18
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 2,
LADING CENTERED, RUN 124, 1.75 LEVEL

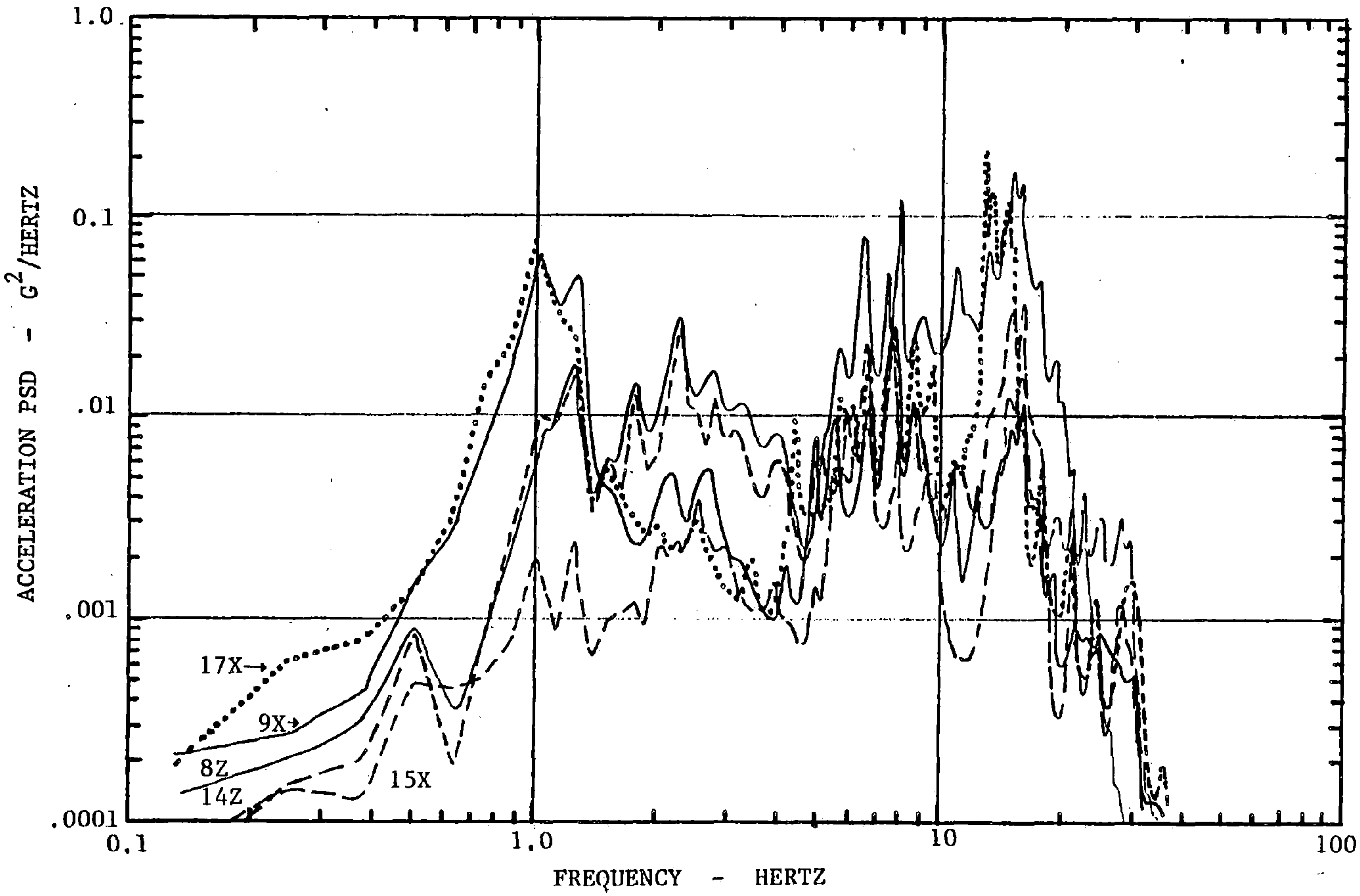


FIGURE 2-19
TRACK GEOMETRY RESPONSE SPECTRA, CONFIGURATION 2,
LADING CENTERED, RUN 125, 2.00 LEVEL

3. POWER SPECTRAL DENSITY ENVELOPES

Envelope PSD plots were made for the three lateral (X) and two vertical (Z) acceleration measurements for the four test conditions covering configurations 1 and 2 with the lading centered and shifted. The objective for presenting the data in this form was to show representative X and Z levels of accelerations PSD as an aid to interpretations of the test results and for possible future reference.

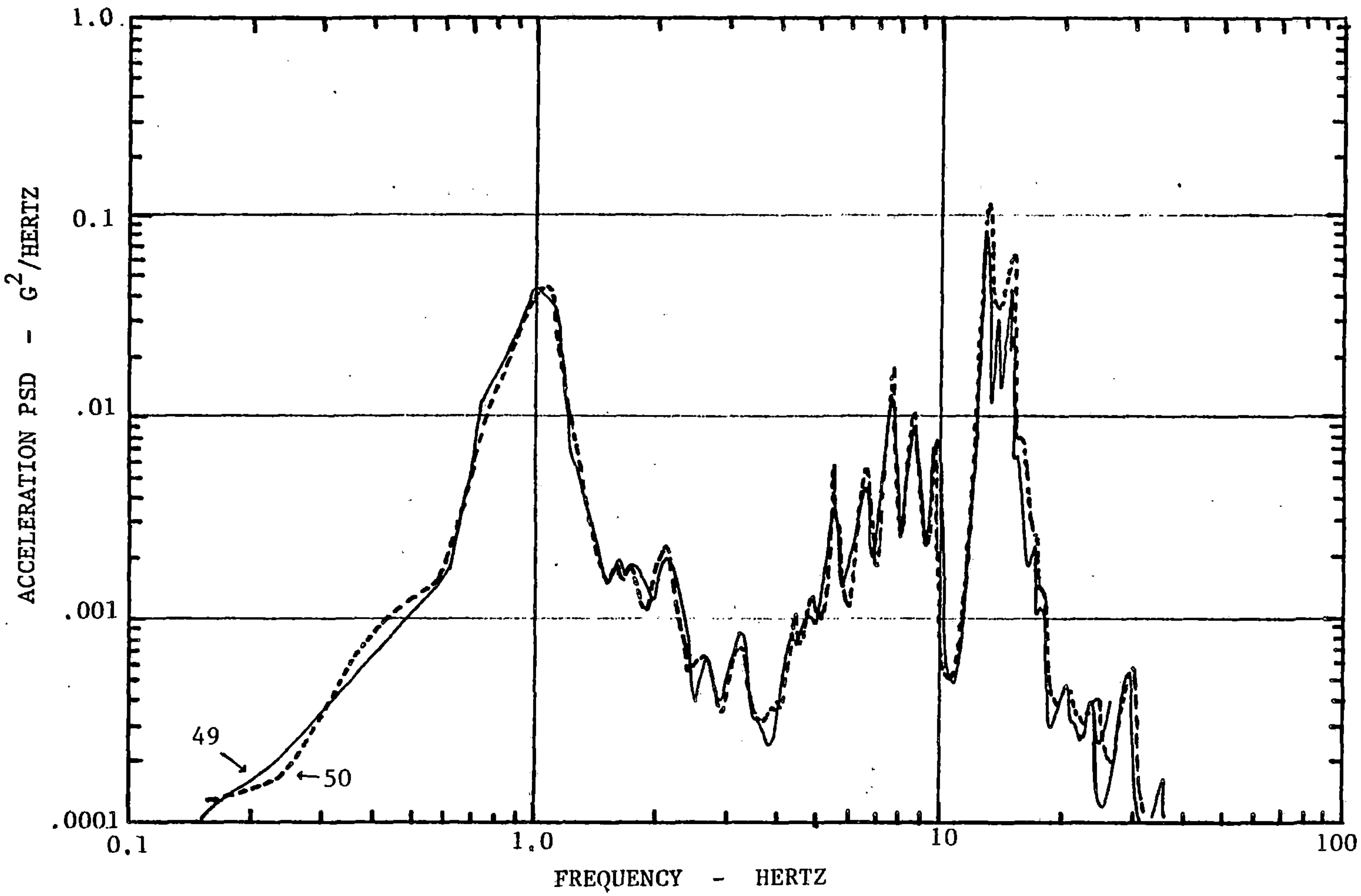


FIGURE 3-1
ENVELOP PSD OF X RESPONSES, CONFIGURATION 1,
LADING CENTERED, TRACK GEOMETRY TESTS

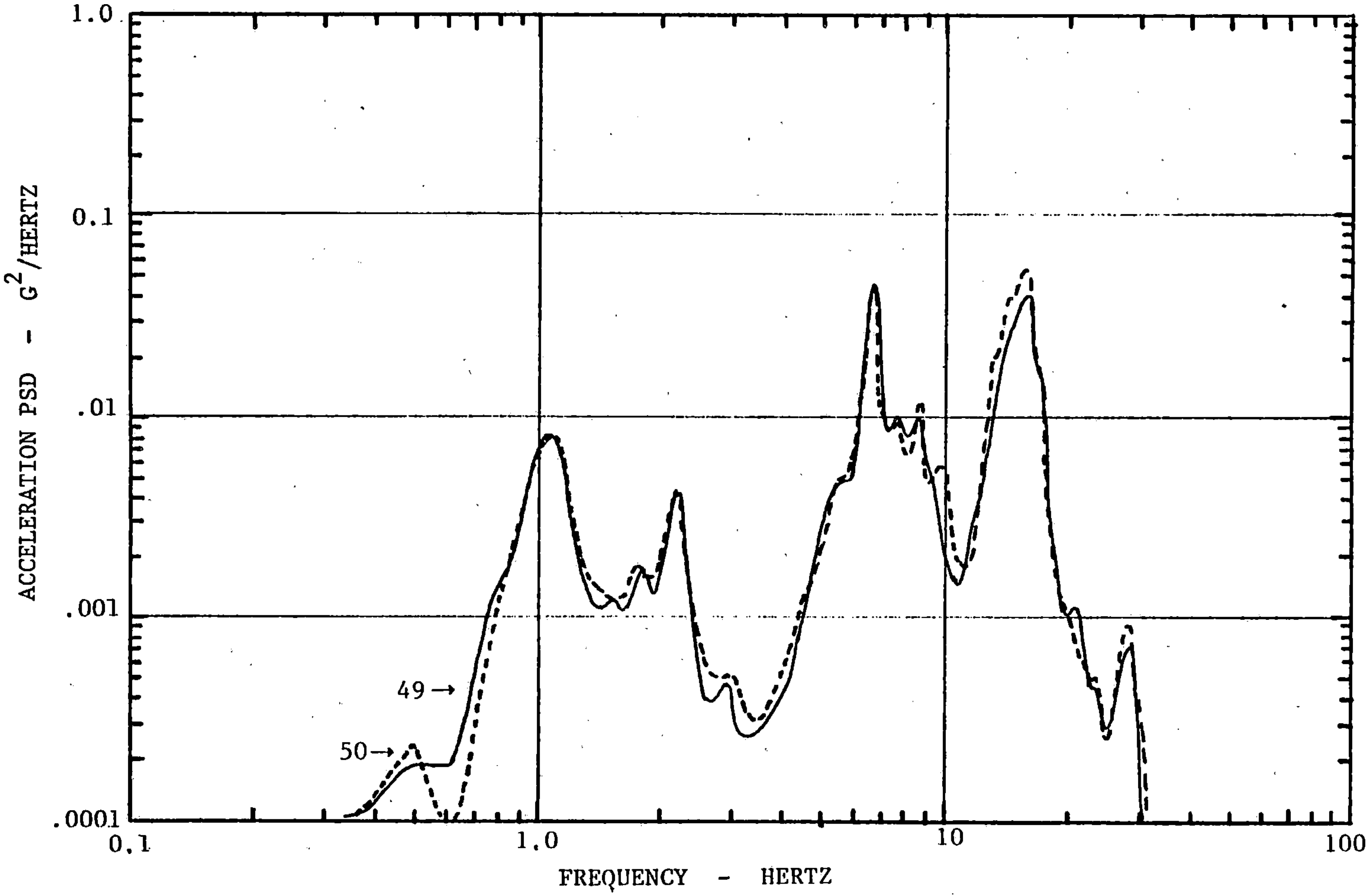


FIGURE 3-2
ENVELOP PSD OF Z RESPONSES, CONFIGURATION 1,
LADING CENTERED, TRACK GEOMETRY TESTS

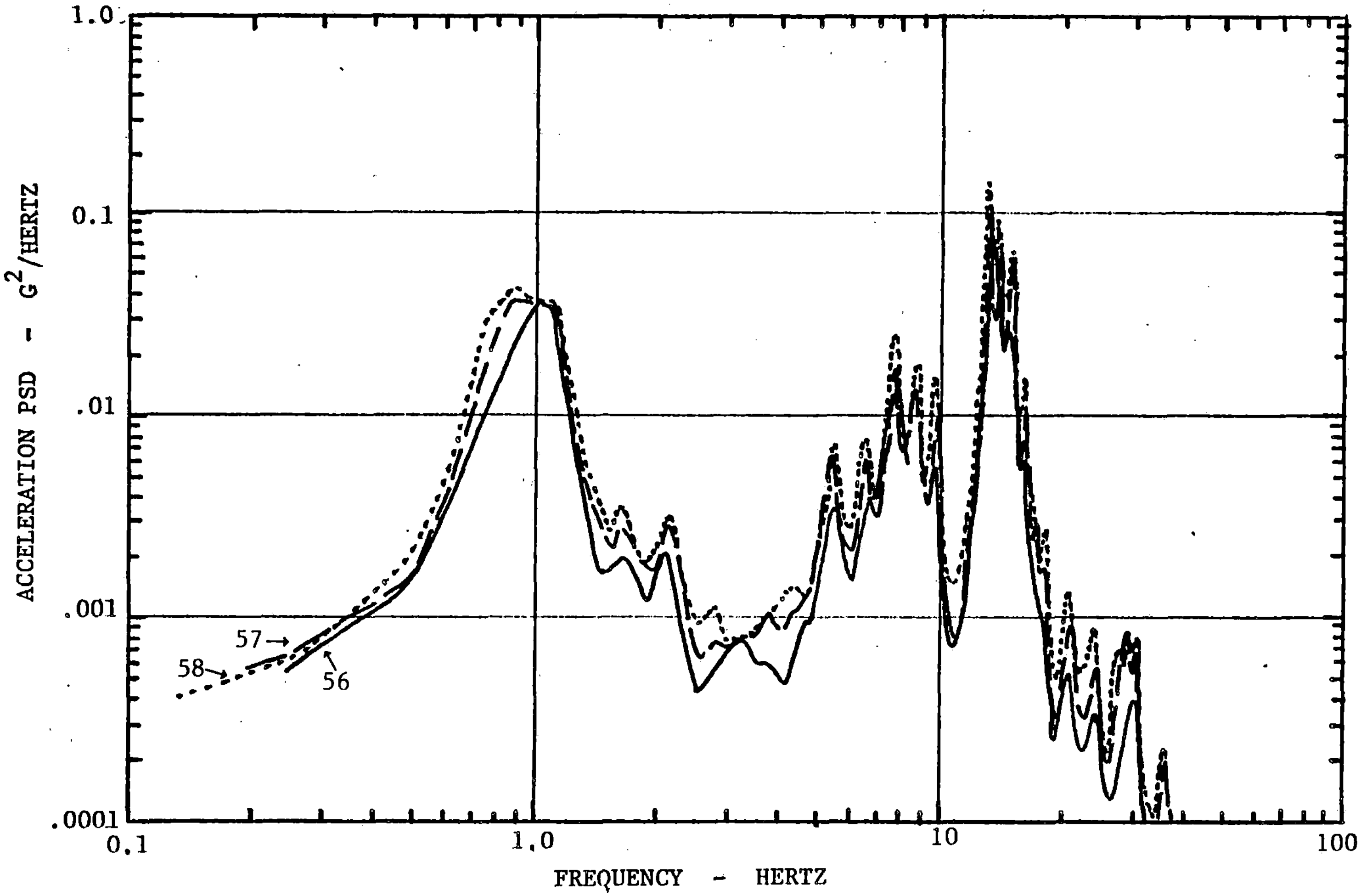


FIGURE 3-3
ENVELOP PSD OF X RESPONSES, CONFIGURATION 1, LADING SHIFTED, TRACK GEOMETRY TESTS

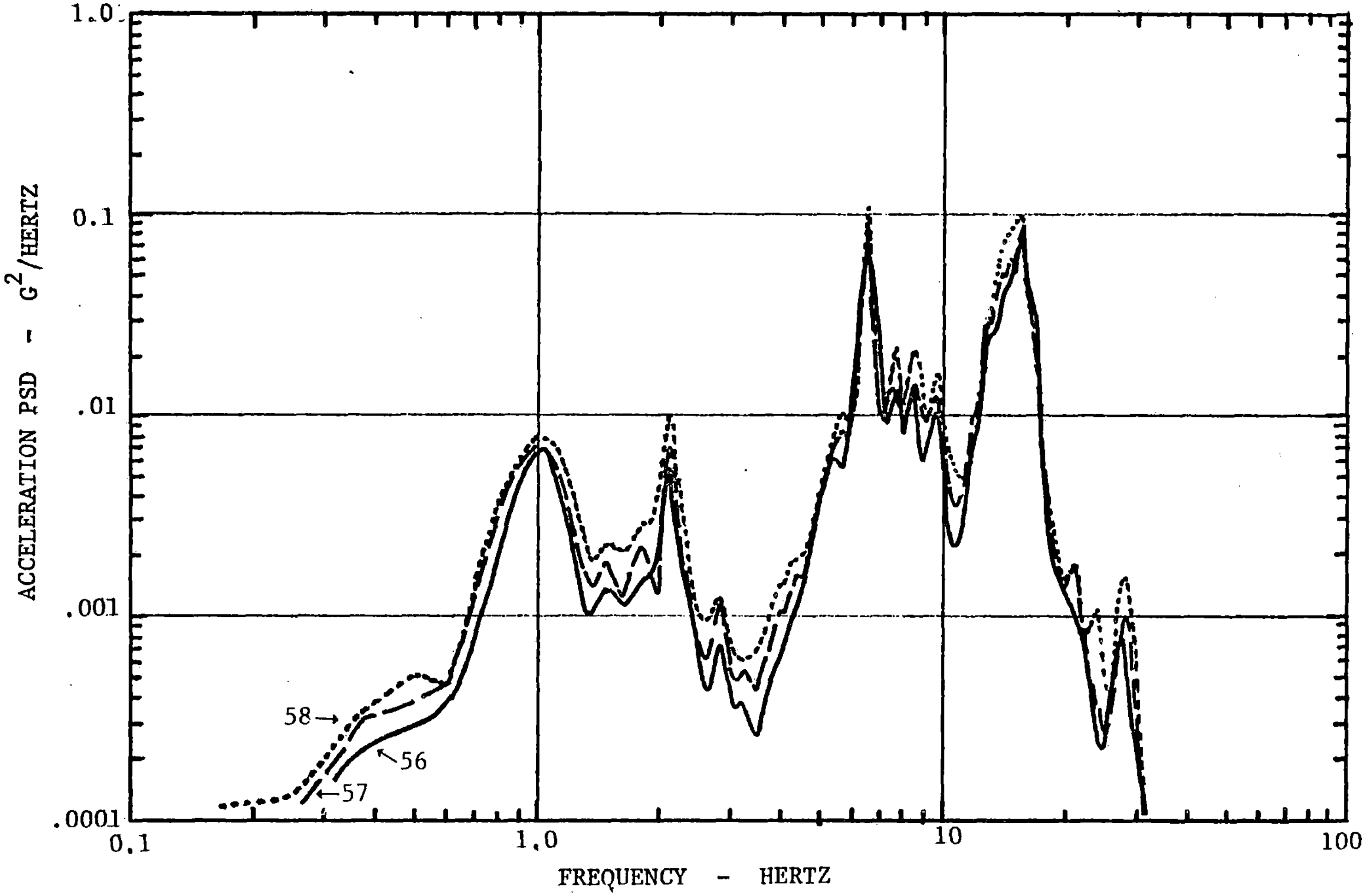


FIGURE 3-4
ENVELOP PSD OF Z RESPONSES, CONFIGURATION 1,
LADING SHIFTED, TRACK GEOMETRY TESTS

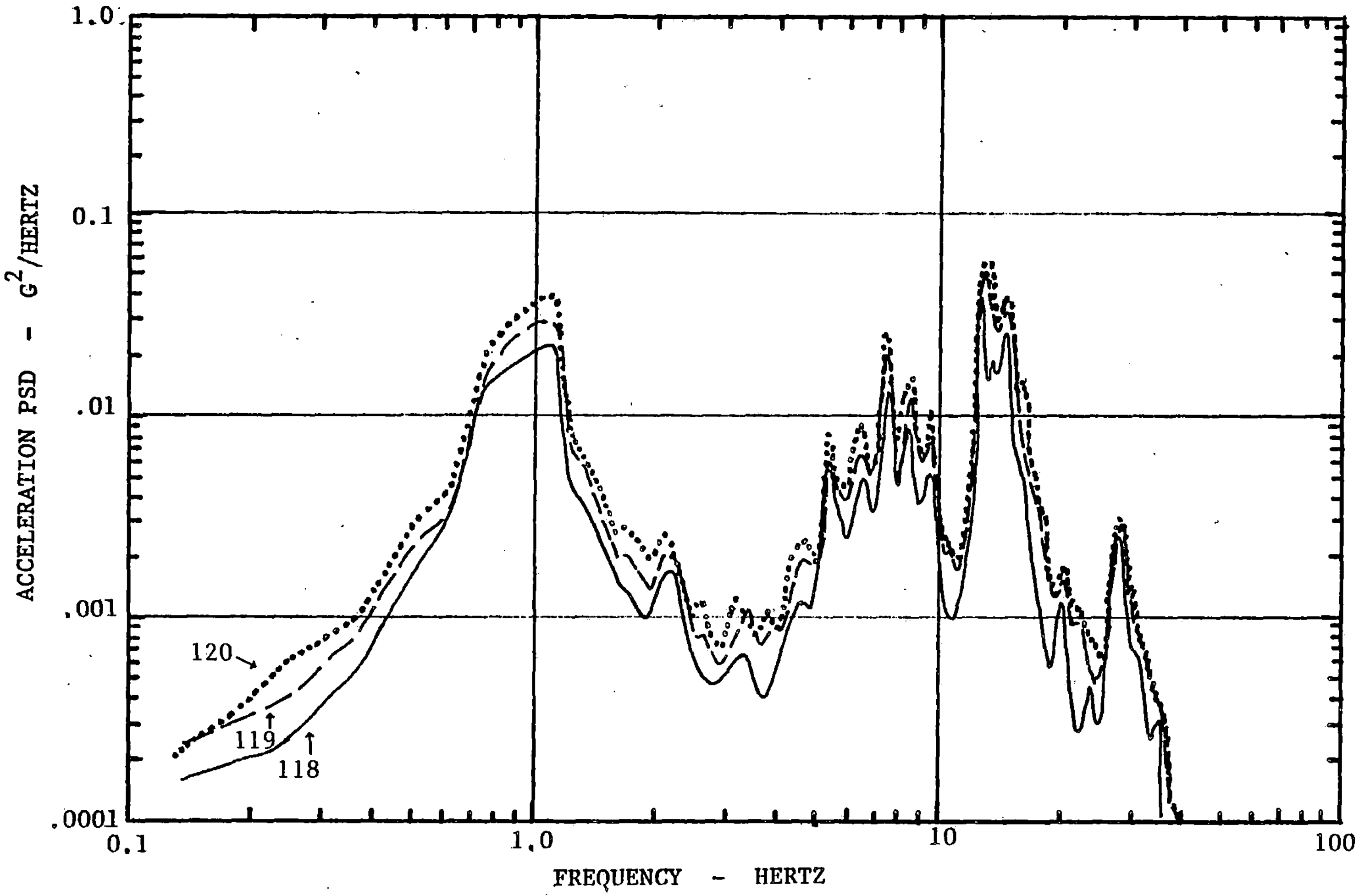


FIGURE 3-5
ENVELOP PSD OF X RESPONSES, CONFIGURATION 2,
LADING SHIFTED, TRACK GEOMETRY TESTS

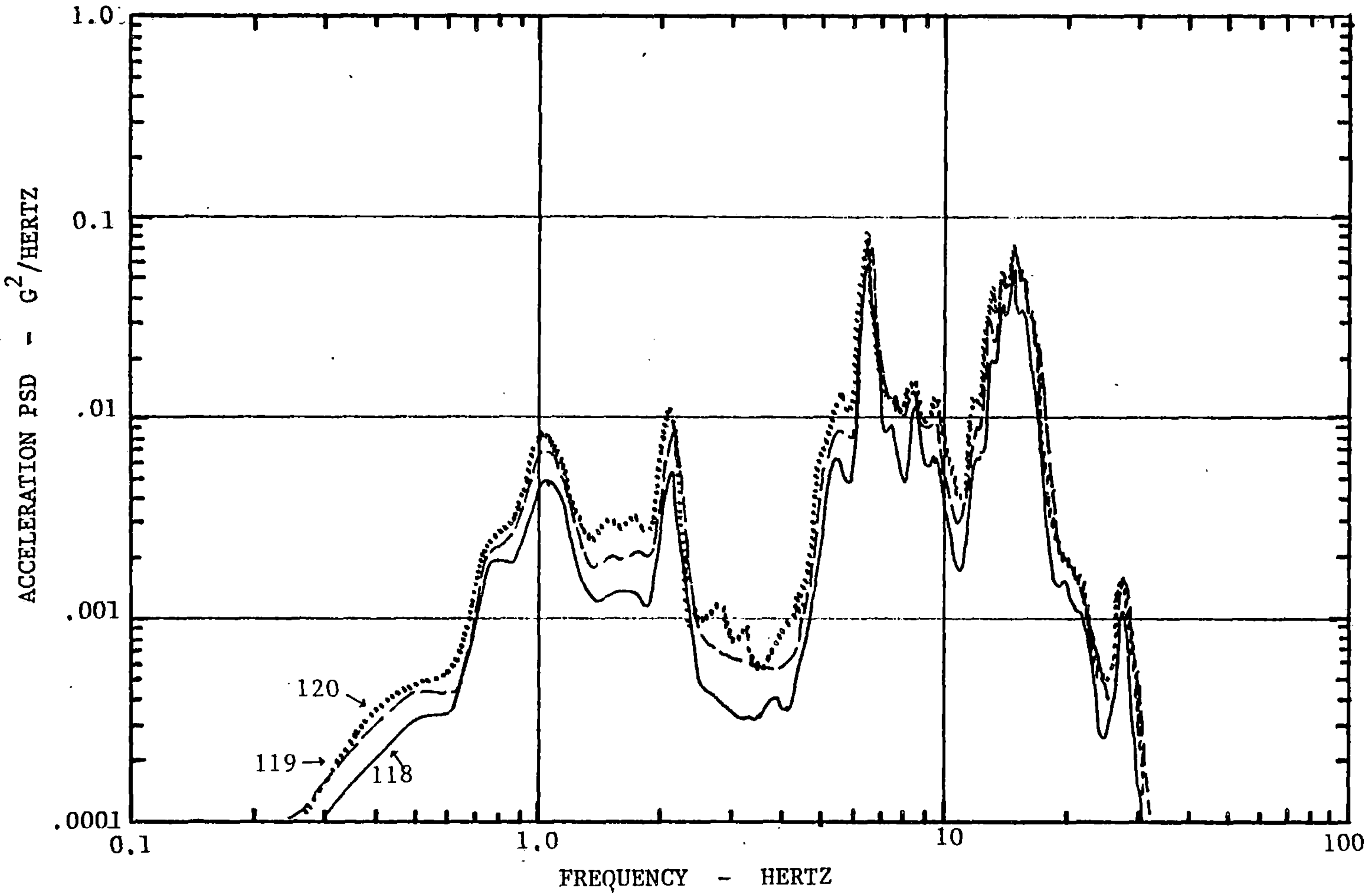


FIGURE 3-6
ENVELOP PSD OF Z RESPONSES, CONFIGURATION 2,
LADING SHIFTED, TRACK GEOMETRY TESTS

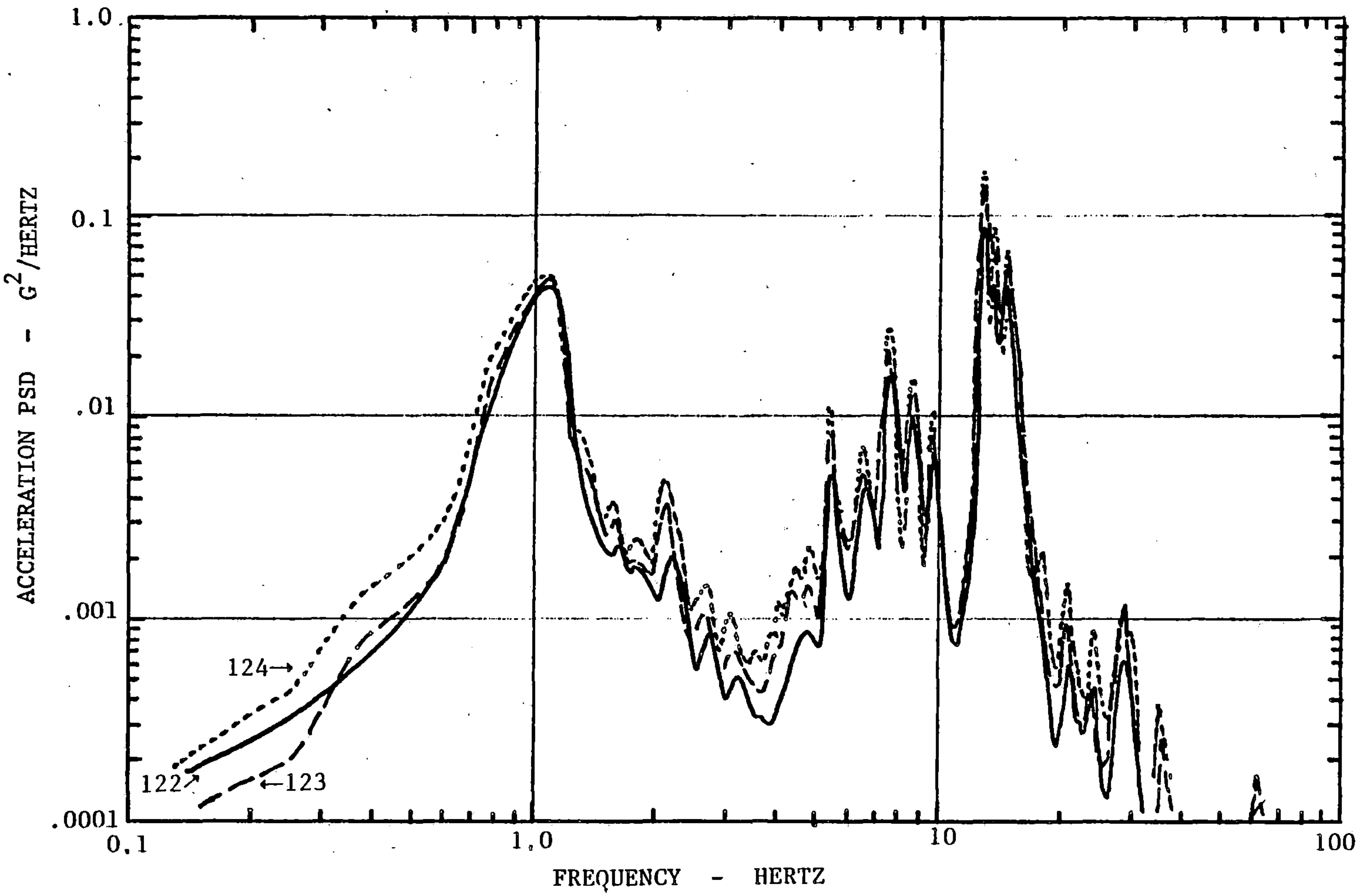


FIGURE 3-7
ENVELOP PSD OF X RESPONSES, CONFIGURATION 2,
LADING CENTERED, TRACK GEOMETRY TESTS

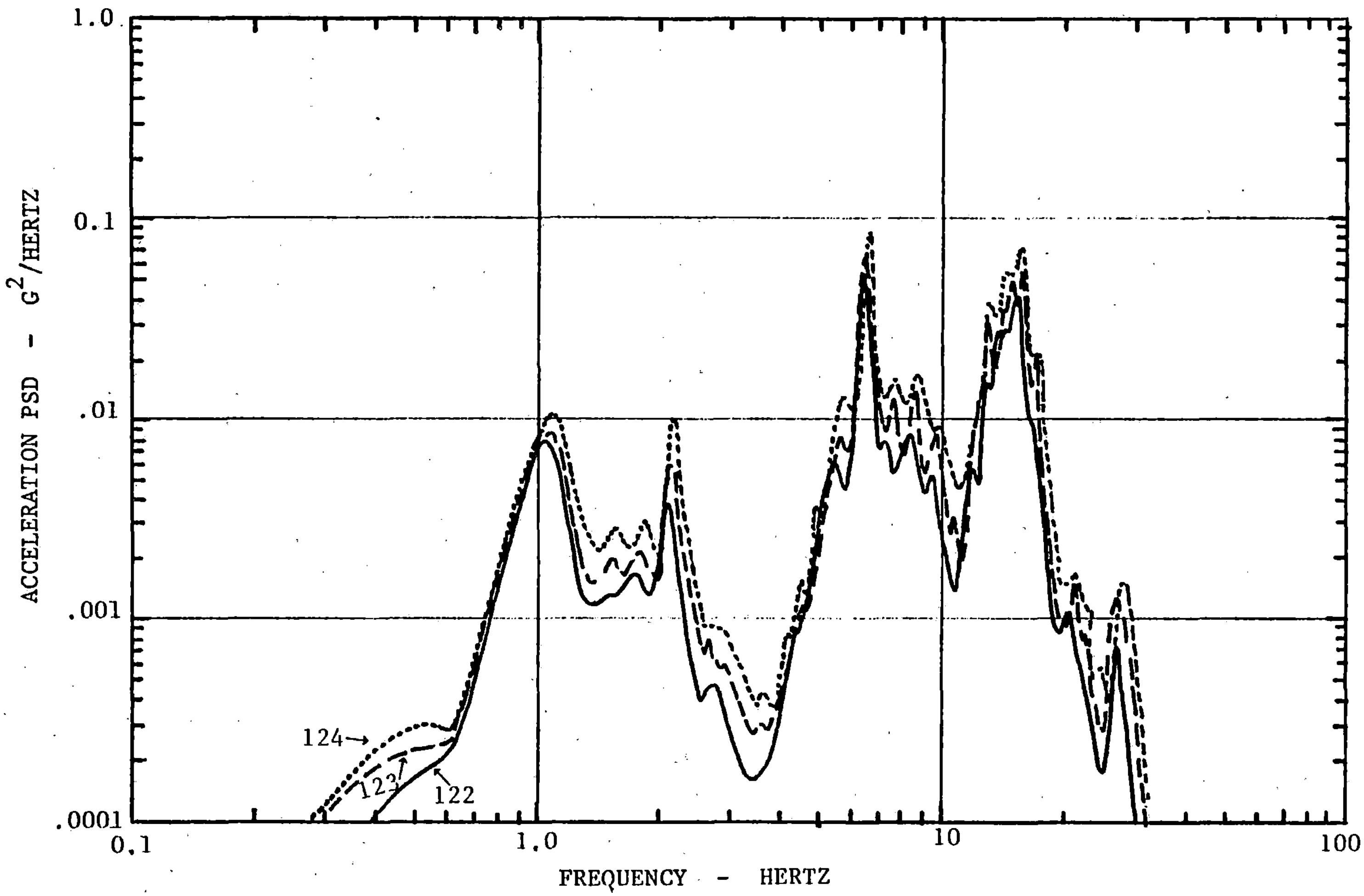


FIGURE 3-8
ENVELOP PSD OF Z RESPONSES, CONFIGURATION 2,
LADING CENTERED, TRACK GEOMETRY TESTS

4. COMPARISON OF CONFIGURATIONS 1 AND 2 IN TRACK GEOMETRY TESTS

The PSD spectrum for accelerometers 8AZ and 9AX were used to show the difference in responses of the plywood lading in configurations 1 and 2 in the lading centered and shifted conditions. No significant conclusions were drawn from this comparison, and the data is presented for reference purposes only.

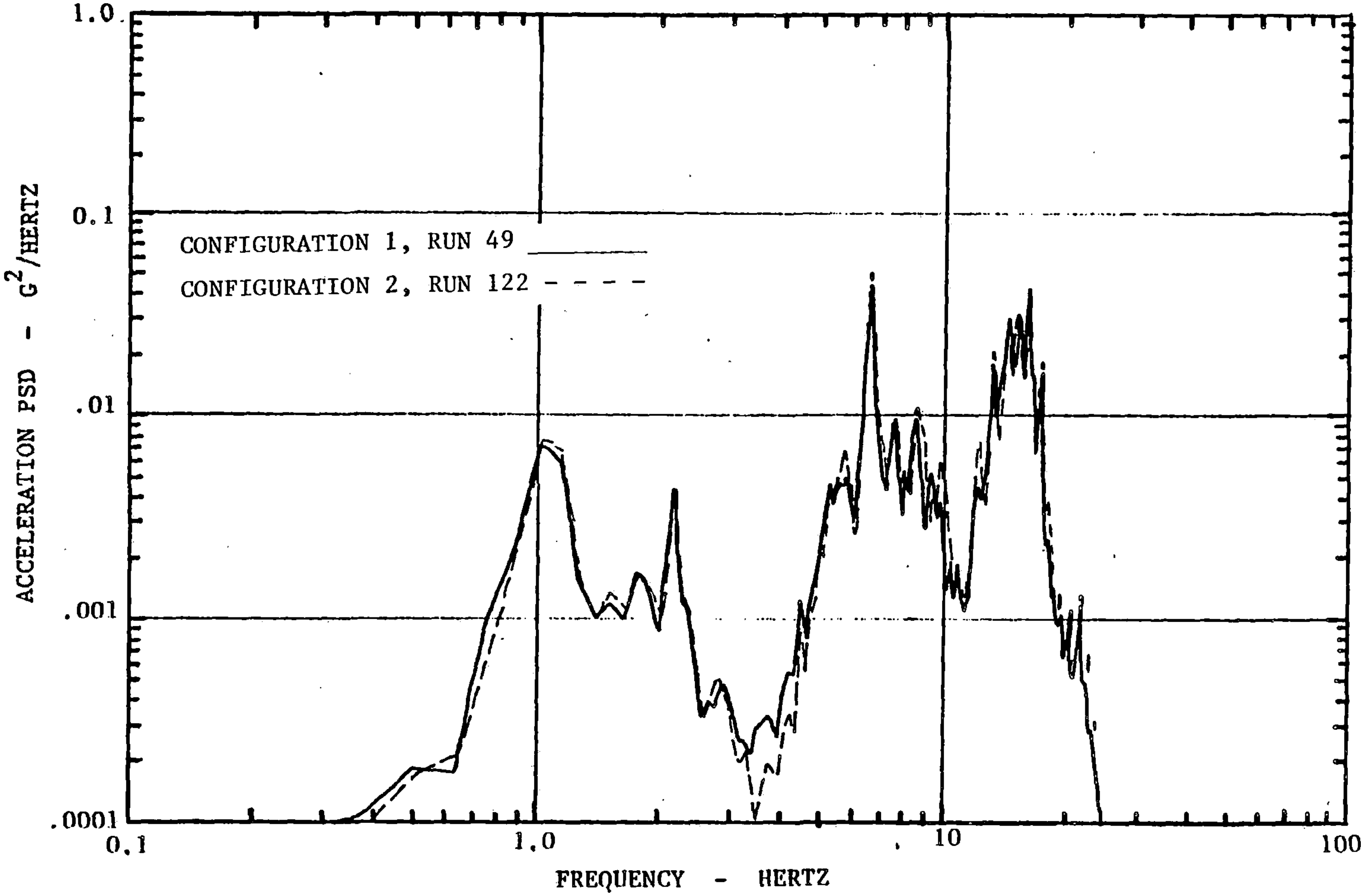


FIGURE 4-1
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A8Z, LADING CENTERED,
TRACK GEOMETRY TESTS, 1.25 INPUT LEVEL

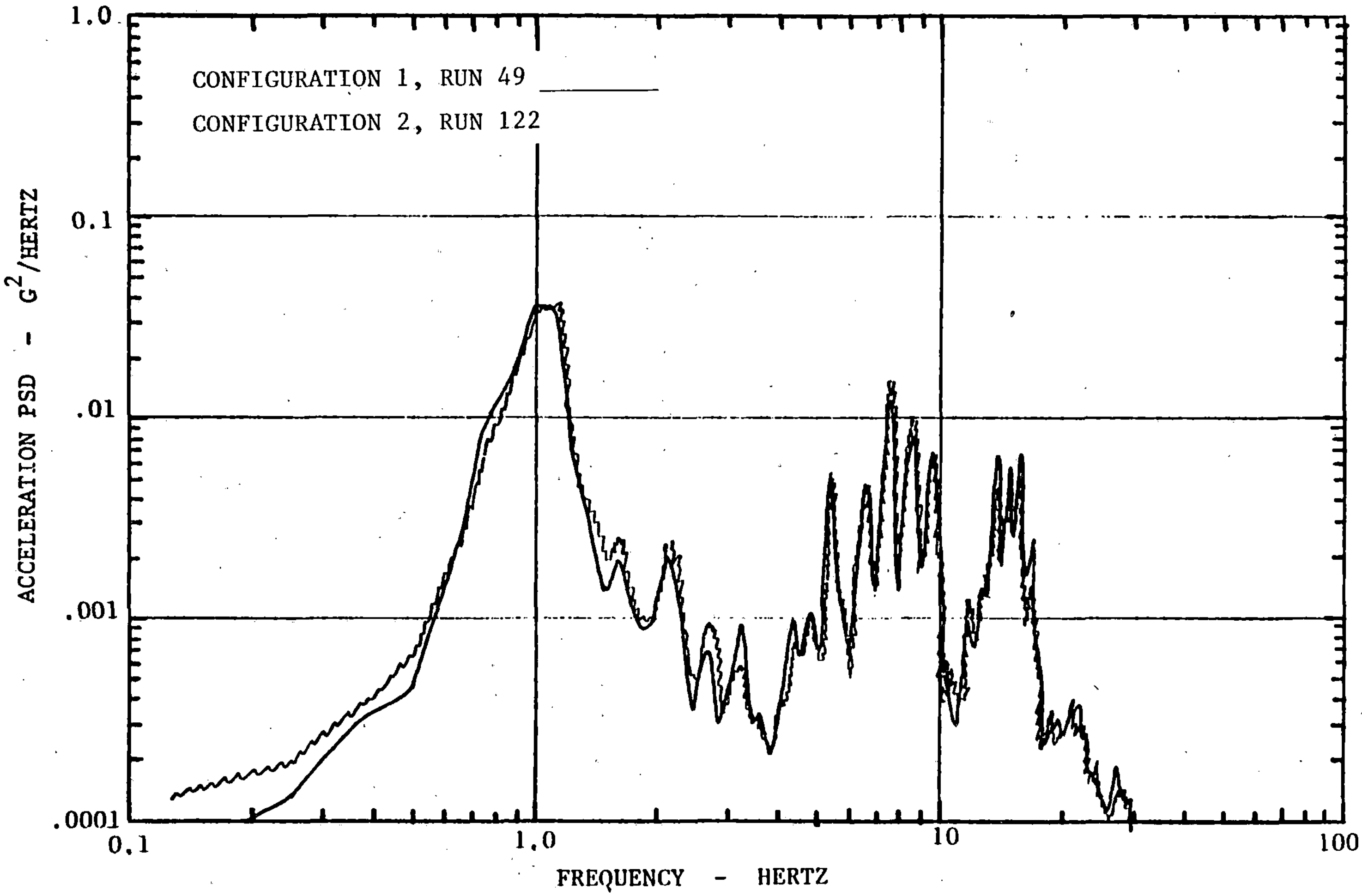


FIGURE 4-2
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A9X, LADING CENTERED,
TRACK GEOMETRY TESTS, 1.25 INPUT LEVEL

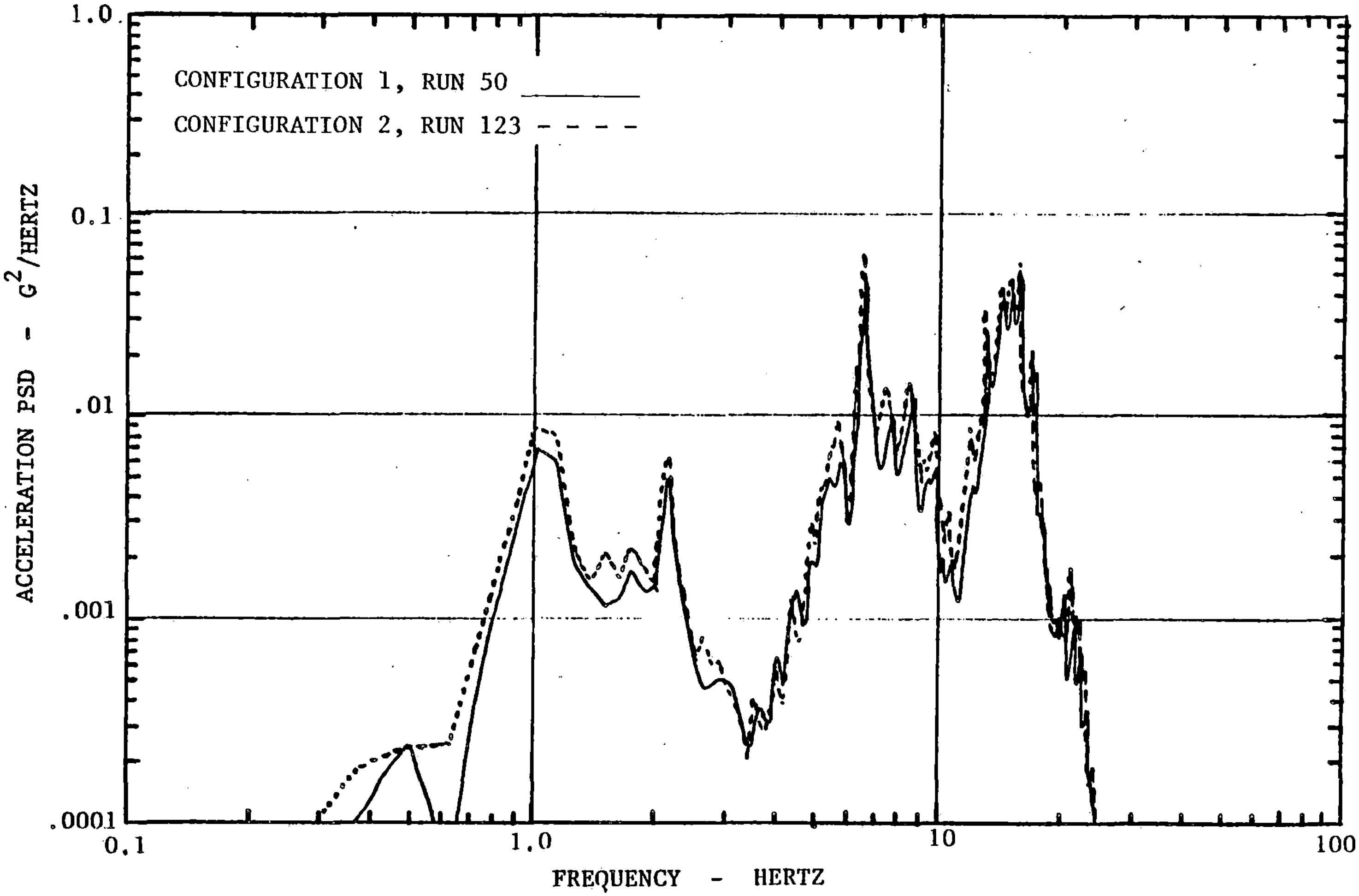


FIGURE 4-3
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A8Z, LADING CENTERED
TRACK GEOMETRY TESTS, 1.50 INPUT LEVEL

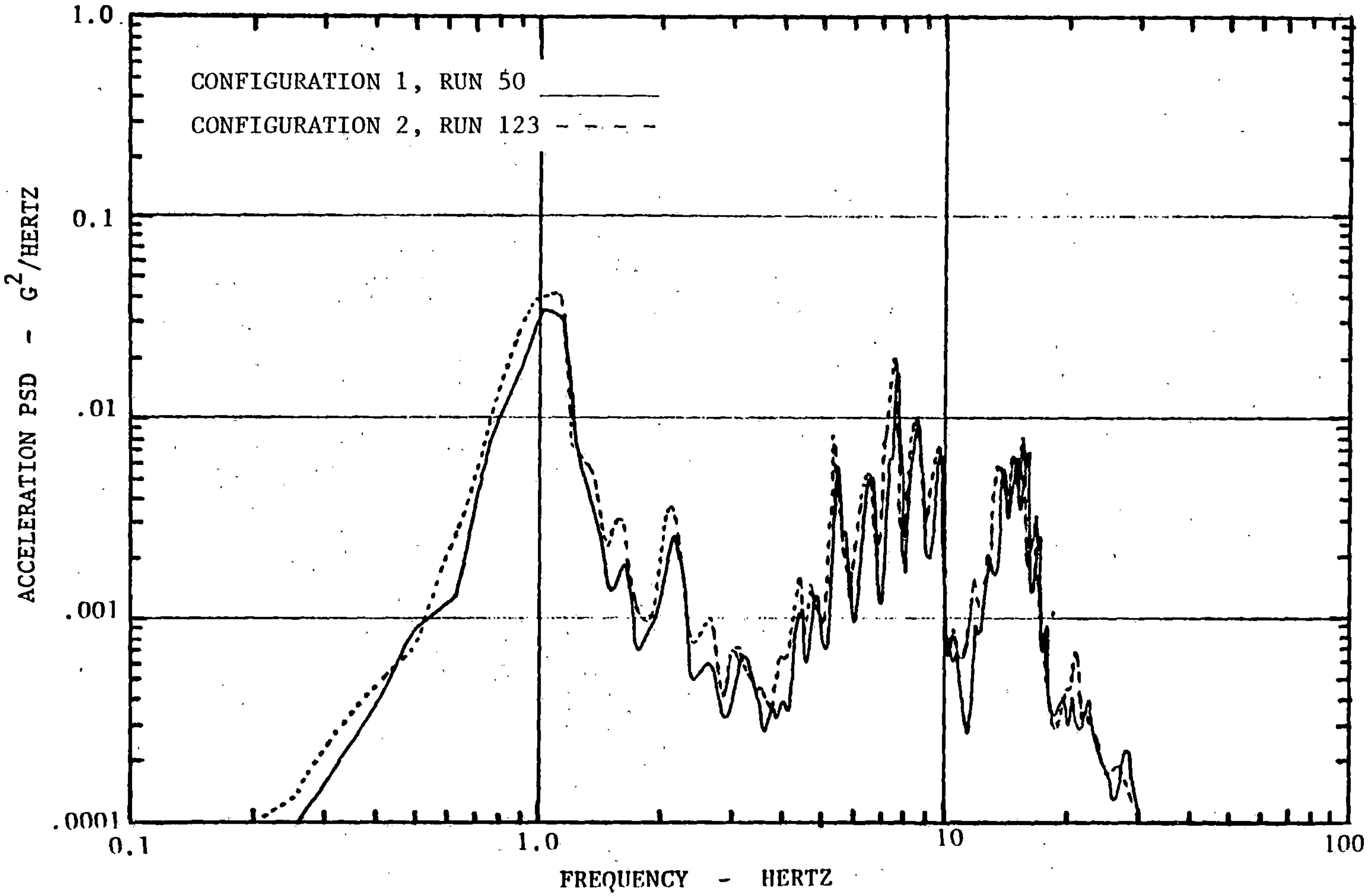


FIGURE 4-4
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A9X, LADING CENTERED,
TRACK GEOMETRY TESTS, 1.50 INPUT LEVEL

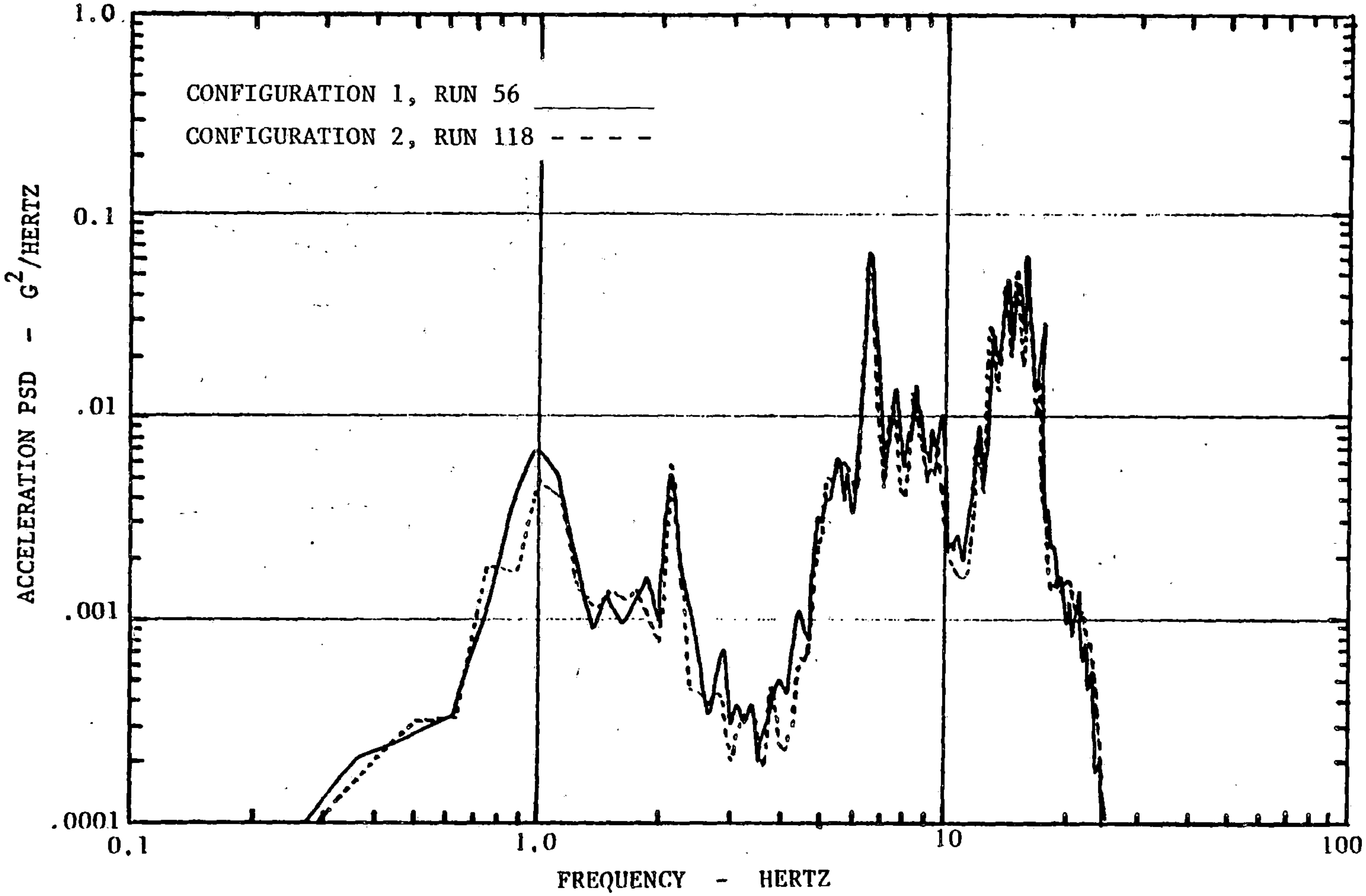


FIGURE 4-5
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A8Z, LADING SHIFTED,
TRACK GEOMETRY TESTS, 1.25 INPUT LEVEL

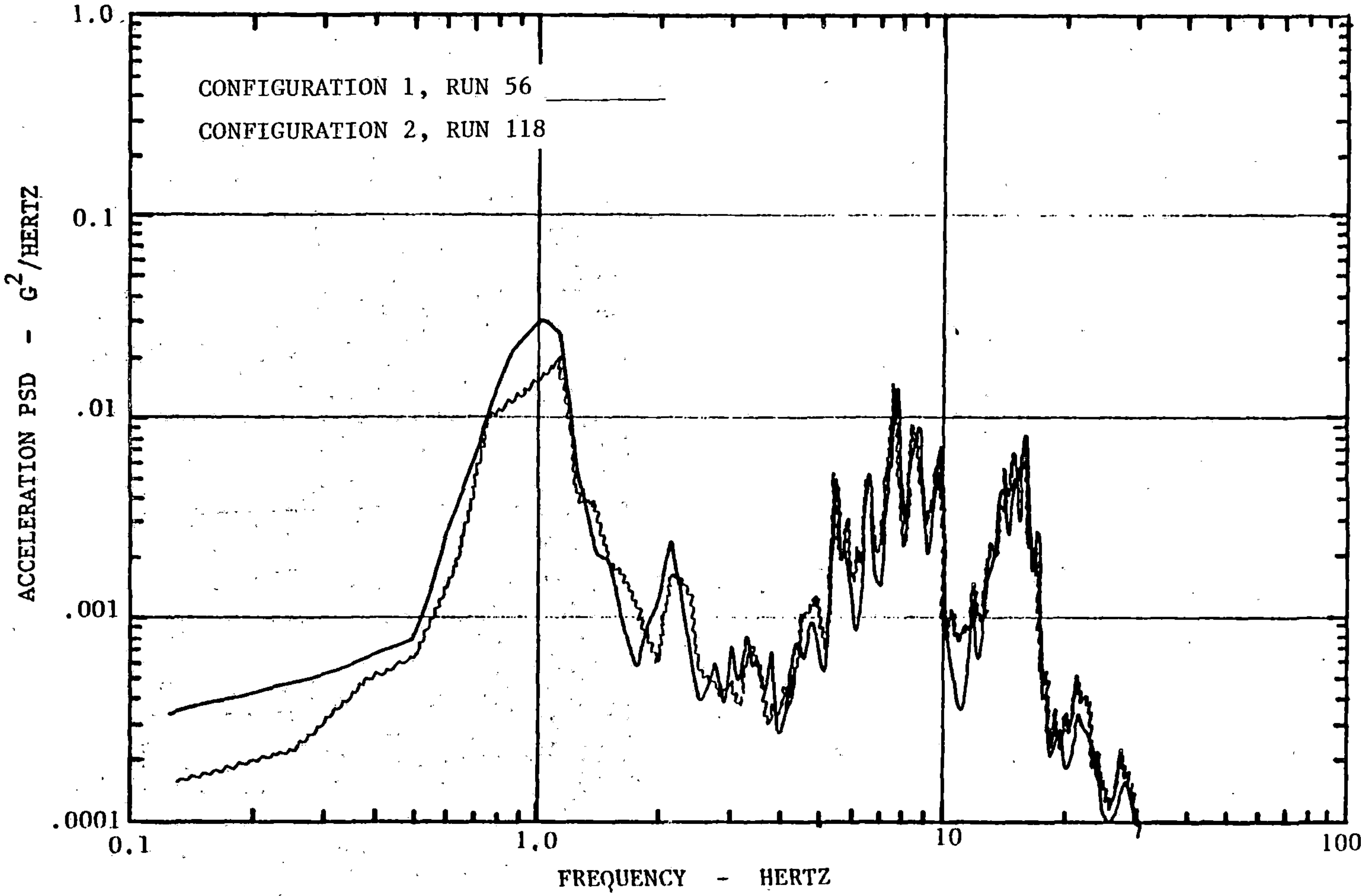


FIGURE 4-6
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A9X, LADING SHIFTED,
TRACK GEOMETRY TESTS, 1.25 INPUT LEVEL

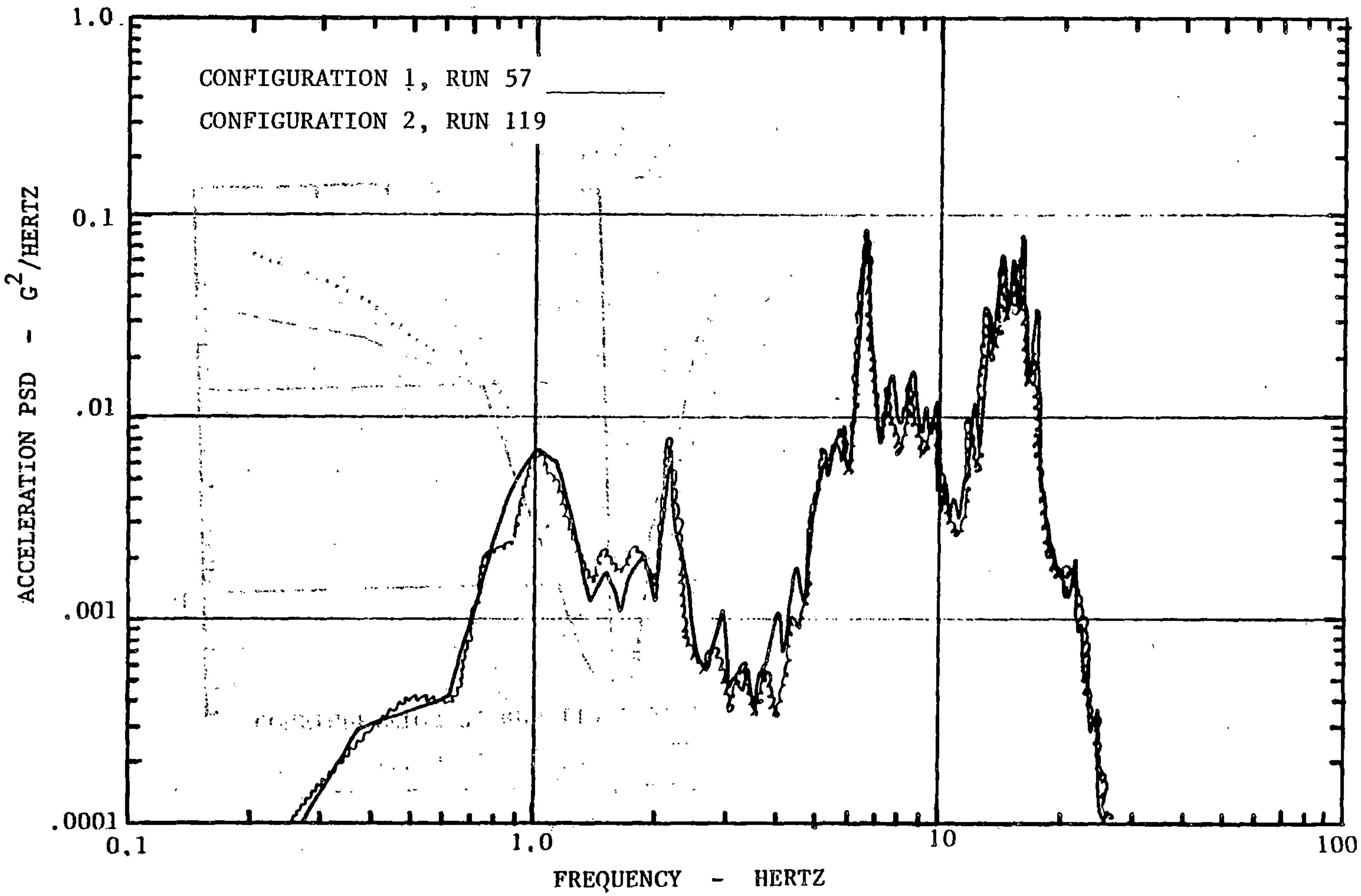


FIGURE 4-7
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A8Z, LADING SHIFTED,
TRACK GEOMETRY TESTS, 1.50 LEVEL

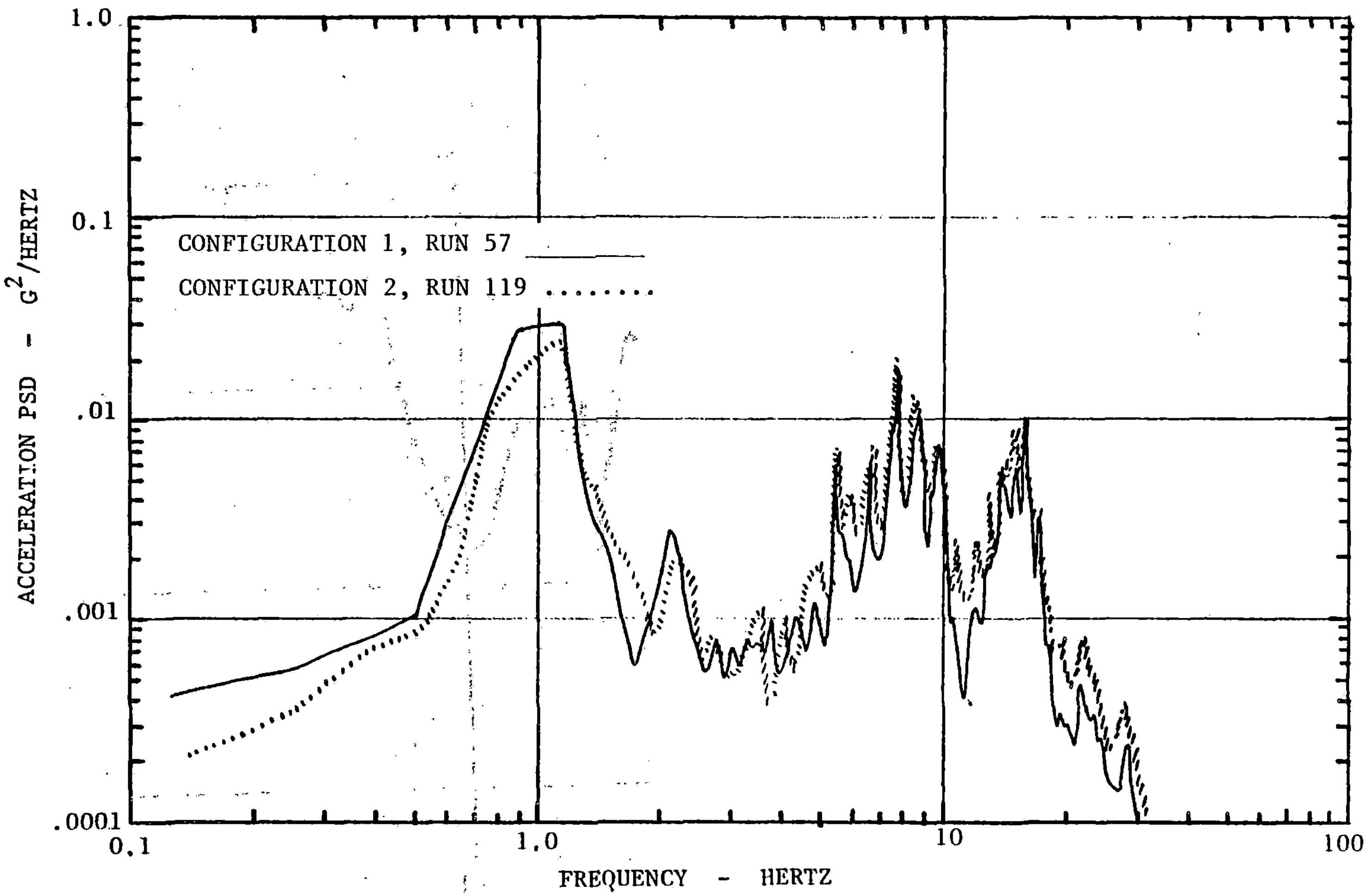


FIGURE 4-8
COMPARISON OF CONFIGURATIONS 1 AND 2 PSD,
MEASUREMENT A9X, LADING SHIFTED
TRACK GEOMETRY TESTS, 1.50 INPUT LEVEL

APPENDIX A

LIST OF REFERENCES

1. Harry A. Grosso, Vibrations Test Unit-Pilot Test, AAR Test Requirements, Association of American Railroads letter, January 27, 1982, File: G948.

2. George Kachadourian, FRA Test Requirements, VTU Pilot Test, MITRE Corporation Working Paper No. WP-82W00001, January 1982.

3. Wade D. Dorland et al, Implementation Plan, Rail Dynamics Laboratory, Vibration Test Unit Pilot Test, Report No. VTU-IP-82-03-03, March 1982.

4. Britto Rajkumar and Firdausi Irani, VTU Pilot Program, Validation of the Track Geometry Input to the Vibration Test Unit (VTU). Boeing Services International, Transportation Test Center, Pueblo, Colorado, July 26, 1982.

5. Britto Rajkumar and Firdausi Irani, Validation of the Vibration Test Unit Endurance Capability, Vibration Test Unit, Boeing Services International Transportation Test Center, Pueblo, Colorado, August 18, 1982.

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Safety Margin Testing of a 70-Ton Boxcar with Shifted Plywood Lading: Test Results Data, 1984
US DOT, FRA, George Kachadourian