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CORRELATION OF ACCIDENT DATA WITH PHYSICAL CHARACTERISTICS OF DERAILED FREIGHT VEHICLES

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PROJECT MEMORANDUM

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PREFACE

The Federal Railroad Administration (FRA) is sponsoring research to provide improved safety of the rail transportation system at reduced life-cycle costs. The Transportation Systems Center is supporting the FRA in their efforts by developing analytical tools and conducting analytical, actuarial and experimental studies under the Improved Track Structures Research Program to provide a technological base for meeting these objectives. These studies are aimed at developing important relationships between track design construction, and maintenance parameters and the safety and performance of the fleet of railcars operating over the track system.

To meet these objectives, engineering descriptions of track and the fleet of U.S. railway rolling stock operating over the nation's track system have been developed for use in vehicle/track dynamics simulation modeling. Quantification of the relationships between track roughness, train operating speeds and physical characteristics of rolling stock will permit development of improved performance-based standards for track geometry which will limit vehicle/track dynamic interactions to safe and tolerable levels at reduced life-cycle costs.

Because of the scope of this problem, it is desirable to prioritize analytical studies, to the extent possible, by conducting vehicle-accident correlation studies of railcar derailments and defining sets of conditions leading to these derailments. This report describes actuarial studies correlating FRA accident data, physical characteristics of derailed freight vehicles and related fleet characterization data to identify:

(a) Freight vehicle configurations having a disproportionately high incidence and (estimated) frequency of derailment on a per-mile basis, and

(b) Commonly occurring derailment scenarios implying specific modes of vehicle/track dynamic interactions leading to derailment.

Results of this study should aid in prioritizing analytical studies in rail systems dynamics to develop improved performance based standards for track which should have large and near-term benefits to railroad operations.

The author would like to acknowledge and thank: Mr. John Bannick of the System Development Corporation for his dedicated and careful effort in constructing and interrogating the data base in this study; Dr. Herbert Weinstock of TSC for his helpful suggestions in organizing the report; and Mr. Donald McConnell of TSC for his educated review and comments.

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SUMMARY

The Improved Track Structures Research Division, Office of Rail Safety Research of the Federal Railroad Administration is sponsoring analytical and experimental research activities to provide a technical data base for the establishment of improved performance-based safety standards for track construction and maintenance. These efforts are aimed at providing improved safety of the rail transportation system at reduced life-cycle costs. Because of the large scope of this effort, it is desirable to identify correlated sets of vehicle, track and accident factors which imply underlying vehicle/track dynamic interactions associated with large numbers of derailments. Identification of such derailment "scenarios" should aid in prioritizing research activities to produce improved performance-based standards, for tracks, which have large and near term benefits in reducing the number of derailments experienced in railway operations.

The Transportation Systems Center has conducted actuarial studies of freight vehicle derailments, which comprise the bulk of derailments experienced in the United States. These studies were initiated to:

- o Identify typical freight vehicle derailment scenarios, expressed in terms of a set of specific conditions including causal factors, typical speeds and track conditions, and physical characteristics of derailed freight vehicles;
- o Identify freight vehicle configurations which experience an unusually large number of derailments and;
- o Select and prioritize rail vehicle configurations and derailment scenarios for analytical studies in rail systems dynamics.

A data base was developed to meet these objectives by (a) assembling accident data from the FRA's Railroad Accident/Incident Reporting System (RAIRS) data tapes, (b) concatenating accident

data with physical characteristics of derailed freight vehicles through use of the AAR's Universal Machine Language Equipment Register (UMLER) and (c) appending more detailed freight vehicle descriptors, population data, and freight vehicle mileage estimates using fleet characterization data developed under related contract activities.

In constructing the data base, all freight vehicle derailments attributed to causal factors (i.e., cause codes) which implied vehicle/track dynamic interaction were considered. The data base contains principal vehicle and accident attributes on over 16,000 freight vehicle derailments, covering calendar years 1976, 1977 and the first three quarters of 1978.

In order to emphasize derailments associated with excessive vehicle/track dynamic interaction on track having reasonable structural and geometric integrity, this study considered, primarily, derailments occurring at speeds greater than 10 mph on Class 2-6 main line track. For these conditions, a total of 4,230 correlated vehicle/accident data base records were available for analysis.

Analysis of this data has resulted in the following principal conclusions:

- A specification for track geometry variations in cross-level which is capable of controlling or minimizing the carbody harmonic roll derailment process has the greatest potential for reducing derailments attributed to vehicle/track dynamic interaction. This is particularly applicable to Class 2 and 3 track.
- Since several other derailment scenarios imply harmonic roll as a principal factor, an effective crosslevel specification will probably have a spill-over effect on reducing the number of derailments attributed to other causal factors.

- The second most important track geometry parameter with respect to freight vehicle derailments is variation in track alinement, especially on Class 2 and 3 track. An integrated specification for track alinement and crosslevel variations should be investigated as a possible improvement to the current requirement which specifies independent limits on each of these track geometry parameters.
- The number of derailments on Class 2-6 main line track at speeds above 10 mph which are attributed to (a) variations in track superelevation, (b) track surface irregularities, and (c) gage widening is relatively small and does not indicate a correlation between freight vehicle derailments and these speed and track conditions.
- The most frequently derailed freight vehicles include loaded, 100-ton cars having high centers-of-gravity and truck center spacings between 35 and 45 feet. Loaded, 100 ton covered hopper cars are typical of this group and have the highest derailment frequency (i.e. number of derailments per mile traveled).
- Loaded freight vehicles have a substantially higher incidence and frequency of derailment than unloaded cars, with some major exceptions.

Additional results include definition of principal dynamics-related derailment scenarios and a profile of freight vehicle derailments in terms of numbers of derailments and estimates of mileage-weighted derailment frequency for freight vehicles described by (a) cartype and truck capacity and (b) by similar physical attributes such as truck center spacing, axle load, truck capacity and center-of-gravity height.

Table S-1 contains a summary of related factors involved in freight vehicle derailments corresponding to each principal cause code group identified. These factors include: functional and generic physical descriptions of the most frequently derailed

TABLE S-1. SUMMARY OF ASSOCIATED FACTORS IN FREIGHT VEHICLE DERAILMENTS

PRINCIPAL CAUSE CODE GROUP.	DESCRIPTION OF MOST FREQUENTLY DERAILING VEHICLE CONFIGURATION		ASSOC. TRACK CLASS	STATISTICS OF SPEED DISTRIBUTION (Speed - mph) 15 20 25 30 35 40 45 50 55	NO. OF DERAILMENTS	RANK
(4) Alinment	100 ton open and covered hoppers	o med. lgth., med. c.g. ht. o med. lgth., high c.g. o long, high c.g.	2,3		244	6
(7) Crosslevel	(same as above)		2,3		539	1
(14) Coupler and Draft System	Low platform vehicular flatcars	o very long, med. c.g. ht.	3,4		317	3
(15) Side Bearings	70 and 100 ton covered hoppers	o med. lgth., high c.g.	2,3		233	7
(17) Plain Journals Overheated	70 ton gondolas & 70 ton covered hoppers	o short, med. c.g. ht. o medium length, low c.g.	3,4		307	4
(19) Broken Wheels	Low platform flat and vehicular flat cars.	o long, med. c.g. ht. o very long, low c.g. o very long, med. c.g.	3,4,5		255	5
(25) Excessive Buff/Slack Action	100 ton covered hoppers	o med. length, high c.g.	2,3,4		233	8
(29) Rail Head	(same as groups 4 and 7)		2,3		367	2

● average speed
Δ median speed
|—| standard deviation

freight vehicles involved in each derailment-cause group; associated track class(es); statistics describing derailment speed distribution; total number of derailments represented by cause code group*; and, rank of principal cause code group based on total number of derailments incurred. These sets of associated derailment factors serve to identify typical vehicle/track derailment scenarios which may be used to imply underlying derailment mechanisms associated with each major group of accidents.

It should be noted that minor differences between certain types of data utilized in this report may be observed in comparison with similar data contained in other reports which use the same basic data files. These differences are most probably due to variations in the methodology used to develop mileage data by cartype and/or small differences in cartype definitions. Overall trends however, should be quite similar.

*Data is for 2.75 years of RAIRS data.

1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The Improved Track Structures Research Program is aimed at reducing the number of track-related derailments by development of improved, performance-based safety standards for track construction and maintenance which will improve safety at reduced life-cycle costs. A major factor in establishing such standards involves the characterization of vehicle/track dynamic interaction in order to (a) quantify wheel/rail loads affecting the life and integrity of track and (b) limit derailments resulting from excessive vehicle/track dynamic interaction.

To accomplish these goals detailed analytical studies are necessary to provide a characterization of vehicle/track dynamic interaction associated with the range of rail systems operations, track conditions and current rolling stock designs in operation over the existing track system network. Statistical descriptions of generically similar track conditions and engineering data characterizing the fleet of U.S. railway rolling stock have recently been completed by TSC for use in these studies.[1] A wide range of analytical tools and computer simulation models of the vehicle track system have also been developed over the past several years. A recent survey of existing analytical tools and an assessment of the applicability of these tools to meeting the objectives of the Truck Design Optimization Program (TDOP) is contained in Reference 2. Analytical simulation models are typically used to predict railcar stability, carbody dynamic response to steady state or transient excitation due to track irregularities, forces and/or displacements developed at the wheel-rail interface, and railcar curving performance.

Bounds on safe and acceptable regimes of operating speed and track roughness may be established by limiting vehicle dynamic responses in accordance with safety-related performance criteria for principal derailment modes. Establishment of these regimes must consider the range of track conditions, operating speeds and the fleet of railway rolling stock configurations currently in operation over the track system. Analytical simulations must also contend with a range of rail system non-linearities associated with vehicle suspension systems, wheel/rail guidance forces, and equipment design characteristics. These non-linearities, together with other potentially influential factors such as carbody flexibility and/or track compliance, tend to increase the cost and complexity of analytical simulation models unless reasonable trade-offs are established between model accuracy and execution costs.

The scope of rail system dynamics analysis is sufficiently broad that selective application of resources to problems which have potentially large and immediate benefits, is desirable.

Over the past year and a half, actuarial studies of freight vehicle derailments, which comprise the bulk of the derailments experienced in the United States, have been initiated. Freight vehicle derailment profile data has been generated by identifying important physical characteristics of derailed freight vehicles which influence dynamic behavior, with associated accident data such as speed, track conditions (type and class), and causal factors which imply derailment modes associated with excessive vehicle/track dynamic interaction.

These studies were aimed at:

(a) Identification of freight vehicle configurations having an unusually high incidence and frequency of derailment;

(b) Identification of typical freight vehicle derailment "scenarios," expressed in terms of a set of specific conditions, including causal factor, speed range, track conditions and physical characteristics of derailed freight vehicles; and

(c) Selecting and prioritizing vehicle configurations and derailment modes for analytical studies in rail system dynamics.

Results of a combined actuarial and analytical approach using analytical simulation modelling should lead to improved performance-based standards for those track construction and maintenance factors which have the largest and most immediate effect in reducing the number and rate of freight vehicle derailments. In addition, identification of railcar designs which have a disproportionately high derailment incidence and frequency will help to uncover potential vehicle equipment-related problems affecting rail transportation safety.

1.2 OVERVIEW OF APPROACH

In order to conduct analytical studies relating freight vehicle dynamic response to various operating speeds and track conditions, engineering data is required in sufficient scope and detail to characterize virtually any railcar design with and without typical ladings, in the freight vehicle fleet. The parameters include all principal freight car dimensions, masses and inertias and truck suspension characteristics. For the actuarial studies, a profile of the physical characteristics and composition of the U.S. freight vehicle fleet is required along with estimates of total annual mileage traveled by empty and loaded freight vehicles. This data has recently been assembled and indicates that the fleet of approximately 1.7 million U.S. freight vehicles may be described by a total of 198 major and distinctive railcar design groups.[1] These groups represent "standard" or "equivalent" vehicle designs describing the fleet of box, stock, refrigerator, covered hopper, open hopper, gondola, flat (including TOFC/COFC),* vehicular flat and tank cars. Detailed engineering data has been developed to characterize each major freight vehicle design group and group populations. Representative ladings carried by each group, and operational data describing approximate mileage traveled, have also been defined. The mileage data has been used to estimate mileage-weighted derailment frequencies for various railcar configurations in the

*Trailer on Flat Car (TOFC) and Container on Flat Car (COFC) actuarial study of vehicle-accident correlations described herein. A profile of the composition and physical characteristics of the freight vehicle fleet is contained in Appendix A.

Figure 1-1 illustrates the number and relative populations of distinctive freight vehicle design groups by car type. Since these design groups represent families of vehicles which are similar in terms of dimensional features (as well as other design characteristics) they are also referred to as Dimensional Vehicle Categories, or DVCs.

A data base has been developed for performing actuarial studies of freight car derailments by linking: (a) accident data contained in the FRA's Railroad Accident/Incident Reporting Systems (RAIRS); (b) physical attributes of derailed freight vehicles as contained in the AAR's Universal Machine Language Equipment Register (UMLER); and (c) more detailed freight vehicle attributes (i.e., engineering parameter data) developed in Reference 1.

Under the FRA's Railroad Accident-Incident Reporting System, railroads are required to submit monthly reports on railroad accidents and incidents resulting from rail transportation operations. For reporting purposes, the following categories of reportable accidents have been defined: (a) Rail-Highway Grade Crossings; (b) Rail Equipment; and (c) Death, Injury and Occupational Illness. This study is concerned with Rail Equipment-related derailments involving freight vehicles in motion and which result in track and equipment damages exceeding a threshold value for reporting purposes. Accident data such as causal factor, train speed, track class and type, hazardous material transportation and train consist data, vehicle load condition, vehicle and track damages and vehicle initials (i.e. owner's markings) and serial number, have been taken from the RAIRS data files. In using the accident data, it should be noted that the validity of accident attributes such as causal factor and vehicle speed are, in many cases, difficult to judge. Although the assigned accident attributes may not always be strictly correct, in total, the accident

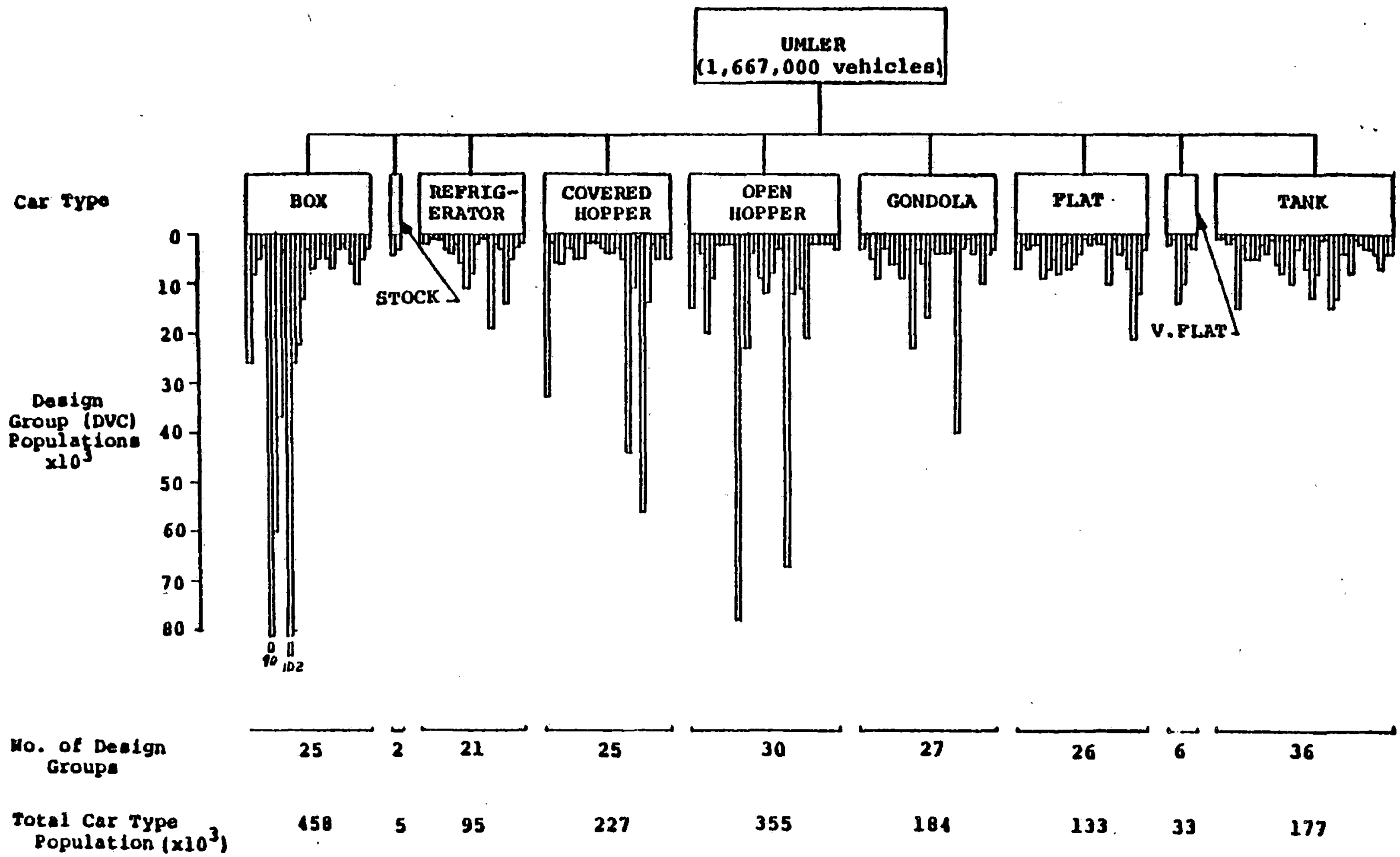


FIGURE 1-1. NUMBER AND RELATIVE POPULATIONS OF DISTINCTIVE FREIGHT VEHICLE DESIGN GROUPS (BY CAR TYPE)

data is considered very useful in establishing basic trends for evaluation and is the only publically available, industry wide report of derailment incidents.

The ULMER file contains data on car type, dimensions and design-related factors for each freight vehicle in the fleet of approximately 1.7 million U.S.-owned vehicles. This data includes lengths, heights, special features, volumetric and weight capacities, tare weight, vehicle initials and serial number etc. The accident data from RAIRS was linked with freight vehicle data taken from UMLER by using the vehicles' identification markings (i.e. initials and serial number).

For the purposes of this study, the freight vehicle data contained in UMLER is of limited use because it does not describe vehicle parameters which are expected to have a significant influence on vehicle dynamics. For this reason, each derailed freight vehicle has been associated with a more fully described design group characterized in relative depth.[1] Each of the design groups was originally defined by sorting and grouping UMLER design data, hence the linkage between UMLER data from each vehicle/accident record and the more fully described design group is easily accomplished by matching vehicle data. Having made this association, information such as carbody weight, c.g. height, truck capacity, truck center spacing and carbody flexibility, group population data and annual mileage estimates may readily be added to the data base. The mechanics of this process and the development of the data base used in the following discussion of vehicle/accident correlation, is described in more detail in Appendix B. Table 1-1 illustrates information contained in the data base for each freight vehicle derailment record and the sources used to compile the data.

Approximately 16,000 vehicle/accident records have been assembled by linking accident data contained in CY 1976, 1977 and the first 9 months of CY 1978 RAIRS with an UMLER file which was

TABLE 1-1. ACCIDENT DATA AND PHYSICAL ATTRIBUTES OF DERAILED FREIGHT VEHICLES (RAIS/UMLER/ROLLING STOCK DATA FILE CONCATENATION)

CAUSE CODE		ACCIDENT ATTRIBUTES FROM RAILROAD ACCIDENT/INCIDENT REPORTING SYSTEM (RAIRS)
VEHICLE INITIALS & SERIAL NO.		
POSITION IN CONSIST		
LOADED/UNLOADED		
NO. OF HAZARDOUS MAT'L CARS		
NO. OF HAZARDOUS MAT'L CARS DERAILED		
HAZARDOUS MATERIAL RELEASED ?		
SPEED		
EQUIPMENT CONSIST		
TRACK CLASS		
TRACK TYPE (MAIN,YD, ETC.)		
EQUIPMENT DAMAGE		
RR ACCIDENT NO.		
RR RESPONSIBLE FOR TRACK MAINTENANCE		
TRAILING TONS		
ANNUAL TRAFFIC DENSITY		
TRACK DAMAGE		
NO. INJURED		
NO. KILLED		
BEARING TYPE (R vs. P)		VEHICLE ATTRIBUTES FROM UNIVERSAL MACHINE LANGUAGE EQUIPMENT REGISTER (UMLER)
DRAFT GEAR		
AAR CAR TYPE CODE		
INSIDE LENGTH		
OUTSIDE LENGTH		
EXTREME HEIGHT		
DOOR WIDTH		
DOOR TYPE		
NOMINAL CAPACITY		
LIGHT WEIGHT		
VOLUMETRIC CAPACITY (ETS)		
DUPLICATE ACCIDENT RECORD (FLAG)		
DIMENSIONAL VEHICLE CATEGORY (CODE)		DIMENSIONAL VEHICLE CATEGORY (DVC) PHYSICAL ATTRIBUTES AND POPULATION DATA
DVC WEIGHT DESCRIPTOR		
DVC SECOND DESCRIPTOR (FT, GAL, FT^3)		
DVC POPULATION		
DVC ANNUAL MILEAGE (EMPTY)		
DVC ANNUAL MILEAGE (LOADED)		
DVC TRUCK CODE		
LENGTH BETWEEN TRUCK CENTERS		
LENGTH OF COUPLER PINS		
CAR MASS	EMPTY	
CG HEIGHT	EMPTY	
GROSS WEIGHT ON RAILS	EMPTY	
AXLE LOAD	EMPTY	
VERTICAL BENDING FREQUENCY	EMPTY	
CAR MASS	AVERAGE LOADED	
CG HEIGHT	AVERAGE LOADED	
GROSS WEIGHT ON RAILS	AVERAGE LOADED	
AXLE LOAD	AVERAGE LOADED	
VERTICAL BENDING FREQUENCY	AVERAGE LOADED	
% ROLLER VS. PLAIN BEARINGS		
GENERIC VEHICLE FAMILY		
DVC % OF MECHANICAL TYPE		

last updated in December 1977.* Only freight vehicle derailments attributed to cause codes which imply excessive dynamic interaction between vehicle and track were considered in the study. Because a great number of derailments happen at low speed (10 mph or less) and/or in yards, sidings etc., the data base was partitioned to include only derailments occurring at speeds greater than 10 mph on Classes 2 through 6 main line track. This was done to highlight and study derailments associated with excessive track/train dynamic interaction on track having reasonable structural and geometric integrity. This resulted in a total of 4230 data base records available for analysis of freight vehicle derailments.

It should be noted that minor differences between certain types of data utilized in this report (e.g. annual mileage data and derailment frequency by cartype and truck capacity) may be observed in comparison with similar data contained in other reports which use the same basic data files. These differences are most probably due to: variations in assumptions and/or approximations made in developing mileage data by cartype; minor differences in cartype definitions; differences in speed, track class and causal factors considered; and approximations associated with developing and appendixing the more detailed physical descriptions of freight vehicles. Overall trends however, should be quite similar.

*At the time of the analysis, these were the most complete and current files available.

2.0 A PROFILE OF FREIGHT VEHICLE DERAILMENTS

2.1 DEFINITION OF DERAILMENT CAUSE CODE GROUPS

The data base outlined in Section 1.0 and described in Appendix B has been assembled to study freight vehicle derailments which imply excessive vehicle/track or vehicle/vehicle dynamic interaction. Accident data and vehicle identification markings (Reference Table 1-1) were assembled from the FRA's Railroad Accident/Incident Reporting System (RAIRS) data tapes for those derailment accidents of interest. To separate these derailments from those arising from other probable causes such as human factors, signal or communication malfunction, irregularities in operational procedures, etc., the list of Rail Equipment Accident/Incident Cause Codes[3] was screened to select those cause codes which implied excessive vehicle/track dynamic interaction. Table 2-1 indicates the principal causal factors considered in the freight vehicle derailment studies. The derailment causes considered fall into four main categories including (1) track geometry and structural failure-related causes; (2) carbody and running gear mechanical failures; (3) train-operations related causes which indicate excessive speed or train-action forces; and (4) selected miscellaneous cause codes which indicate or imply the development of large dynamic forces between vehicles or vehicle and load.

Several of the mechanical failure and track structural failure cause codes could be the result of poor maintenance rather than a result of accumulated wear or fatigue of components resulting from dynamic effects. However, if this is the case, derailments attributed to these cause codes should be fairly evenly distributed among the freight vehicle population. Should a strong correlation exist between a particular mechanical failure and freight vehicle configuration, this information may suggest an underlying relationship between vehicle dynamics and equipment components.

TABLE 2-1. PRINCIPAL CAUSE CODE GROUPS

Derailments corresponding to the following Rail Equipment Accident/Incident Cause Codes have been included:

TRACK ROADBED AND STRUCTURES

- Roadbed Defects
- Track Geometry Defects
  - a. Wide Gage
  - b. Alinement
  - c. Profile
  - d. Superelevation
  - e. Crosslevel
- Rail and Joint Bar Defects
  - a. Rail-Head Defects
  - b. Rail End and Joint Bar Defects
  - c. Welds
- Frogs Switches and Appliances
  - a. Frogs
  - b. Switches
  - c. Applicances

MECHANICAL AND ELECTRICAL FAILURE

- Trailer or Container on Flat Car
- Carbody
- Coupler and Draft System

CONSIDERED IN RAIL VEHICLE DERAILMENT STUDIES

- Truck Components
  - a. Side Bearing Defects
  - b. Other Truck Failures
- Axles and Journal Bearings
  - a. Plain Journal Failure from Overheating
  - b. Roller Bearing Failure from Overheating
- Wheels
  - a. Broken Wheel Component (Flange Rim or Plate)
  - b. Other Wheel Related Failures
- Locomotives

TRAIN OPERATION, HUMAN FACTORS

- Speed
  - a. Switch Movement, Excessive Speed
  - b. Excessive Speed, Clear Block, Outside Yard Limits
- Miscellaneous
  - a. Buff or Stock Action Excessive
  - b. Lateral Drawbar Force on Curve Excessive

OTHER MISCELLANEOUS

- Load Shifted or Fallen, improperly or Overloaded Car
- Interaction of Lateral and Vertical Forces

Many individual but related cause codes selected from the Rail Equipment Accident/Incident cause codes can be lumped together to form distinctive "cause code groups." This has been done where possible, and Table 2-2 summarizes the principal cause code groups used in this study. In some instances, a group may consist of a single cause code.

In general, the cause code groups have been structured to (a) identify those causal factors which are responsible for a large percentage of dynamics-related derailments and (b) yet retain some distinctiveness between cause groups in order to assess or hypothesize the role of vehicle/track dynamic interaction in these derailments. Each of these (33) cause groups, in conjunction with accident data such as vehicle speed and track class and physical attributes of derailed freight vehicles, may be quite useful in assessing an underlying derailment process which might be controlled by improved performance-based standards for track.

2.2 DISTRIBUTION OF FREIGHT VEHICLE DERAILMENTS WITH SPEED AND TRACK TYPE

Considering derailments attributed only to those causal factors described above, Figure 2-1 illustrates the distribution of freight vehicle derailments with speed on various classes of main line track. Figure 2-2 shows similar data for derailments on yard track, sidings or industry track. This data is illustrated in terms of the total number of derailments occurring below a given speed range (with the upper bound inclusive). Approximately 16,000 derailment records, resulting from two and three-quarter years of accident data, are represented. These figures indicate that about 50 percent of all derailments occurred on mainline track while the remaining 50 percent of derailments occured at very low speeds (10 mph or less) on sidings, industry tracks or in yards. Of the derailments occurring on main line track, about 3,400 occurred at very low speeds and another 230 derailments occurred on Class 1 track at reported speeds greater than 10 mph. Figure 2-1 indicates that the preponderance of derailments at or below 10 mph occur on Class 1 track.

TABLE 2-2. DEFINITION OF CAUSE CODE GROUPS

Group No.	Cause Code Numbers (low-high)	Cause Code Descriptor (Abbreviated)
1	101-101	ROADBED, SOFT
2	102-102	ROADBED, FLOODED ETC
3	110-113	WIDE GAGE
4	114-115	ALIGNMENT
5	116-116	PROFILE
6	117-118	SUPERELEVATION
7	119-120	CROSSLEVEL
8	132-133	BROKEN WELD
9	160-166	SWITCH
10	167-169	FROG
11	171-176	TRACK APPLIANCE
12	411-413	TOFC EQUIP.
13	420-426	CAR BODY
14	430-436	COUPLER/DRAFT SYST
15	440-442	SIDE BEARINGS
16	443-447	OTHER TRACK COMP.
17	451-451	PLAIN JOURNAL (OHTD)
18	452-452	ROLLER BEARING (OHTD
19	460-463	BROKEN WHEEL
20	464-464	WORN FLANGE
21	465-465	WORN TREAD
22	466-467	OTHER WHEEL
23	470-477	LOCOMOTIVE
24	555-555	EXCESSIVE SPEED
25	570-570	EXCESSIVE BUFF/SLACK
26	572-572	EXCESS LAT FORCE ON
27	706,702	OVERLOADED CAR
28	713-713	INT. OF L & V FORCES
29	NOTE1	RAIL HEAD FAILURE
30	NOTE2	RAIL END & J.B. FAIL
31	450,453	OTHER AXLE/JOURNAL
32	704,5,7	LOAD RELATED
33	NOTE3	MISC.

NOTE1: 131-143 EXCEPT 132,133,137,140
NOTE2: 144-148 PLUS 130,137
NOTE3: 109,129,149,179,419,429,439,449,459,469,479

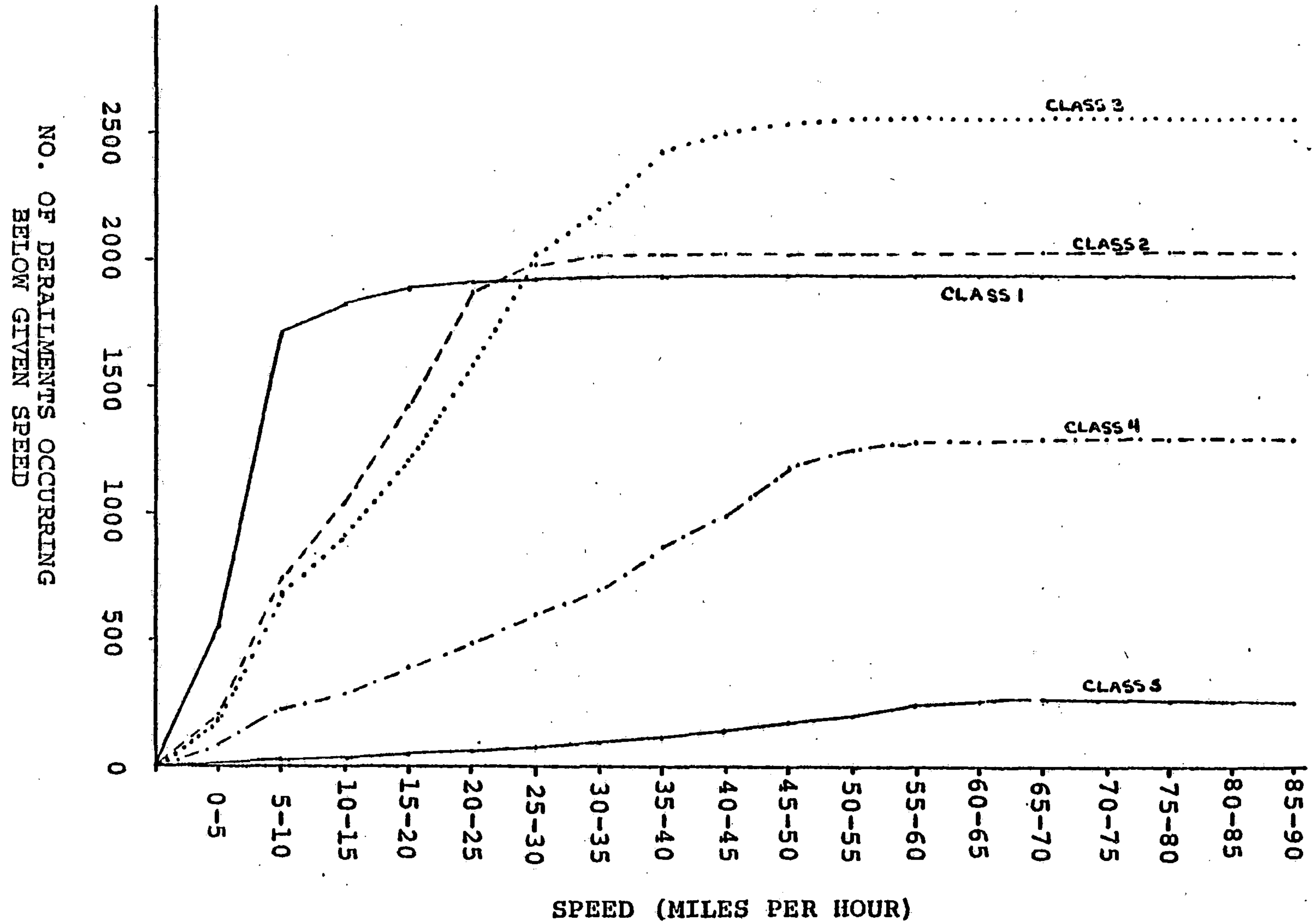


FIGURE 2-1. DISTRIBUTION OF FREIGHT VEHICLE DERAILMENTS WITH SPEED AND TRACK CLASS FOR MAIN LINE TRACK

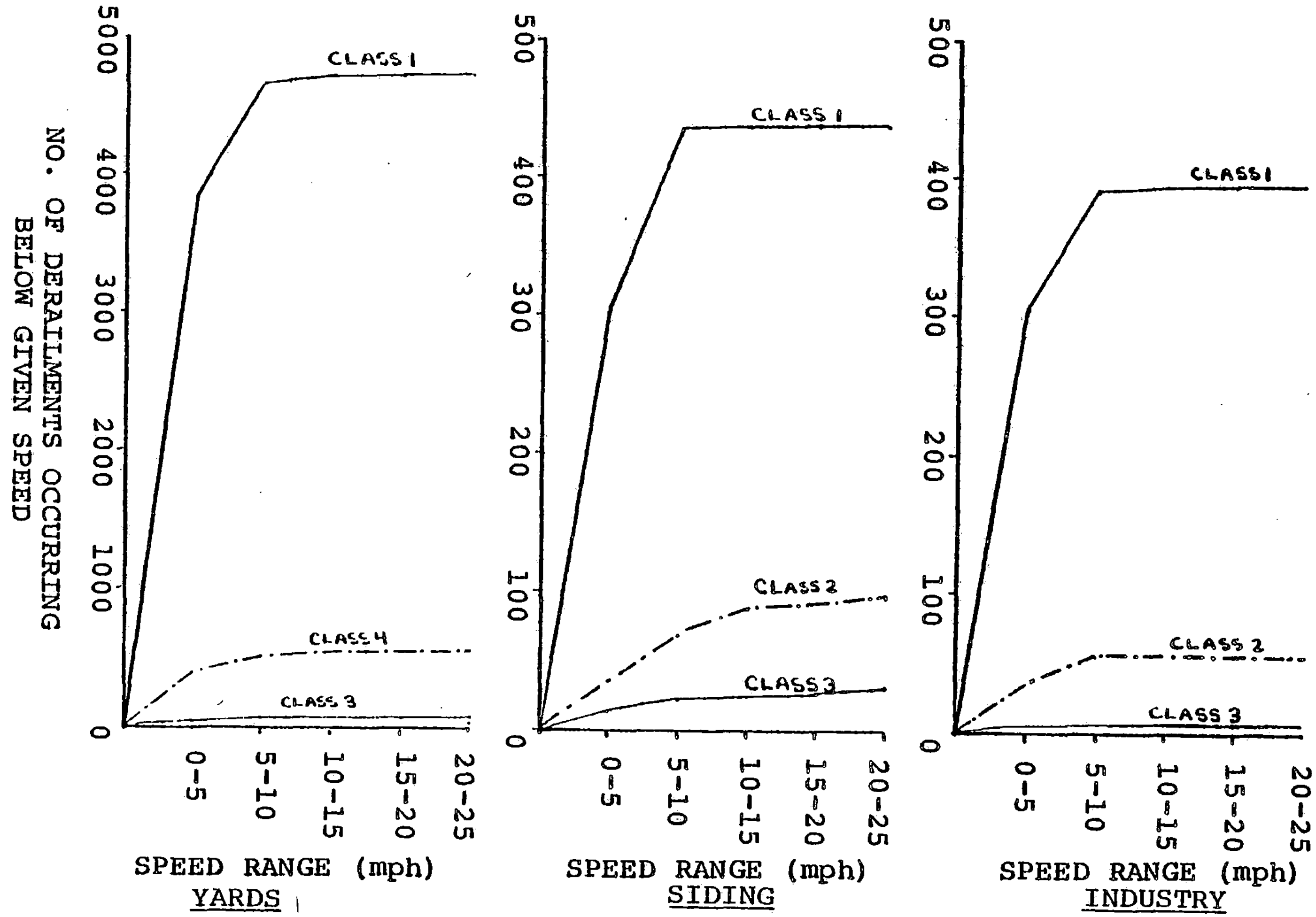


FIGURE 2-2. DISTRIBUTION OF FREIGHT VEHICLE DERAILMENTS WITH SPEED AND TRACK CLASS ON YARD, SIDING AND INDUSTRY TRACK

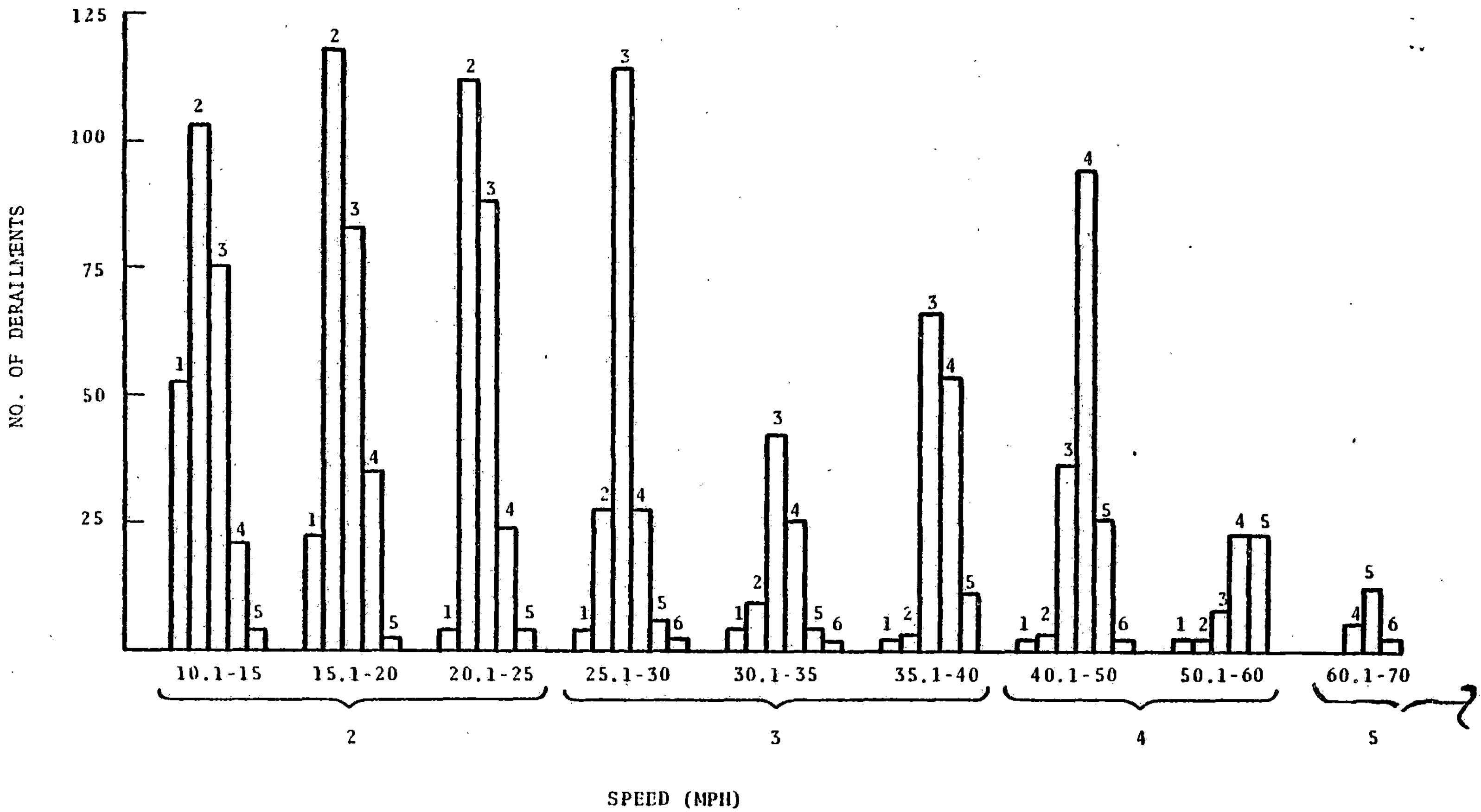
In order to emphasize derailments associated with excessive vehicle/track dynamic interaction on track having reasonable structural and geometric integrity, only those derailments occurring at speeds greater than 10 mph on track Class 2 through 6 main line track are considered in developing the following derailment profile data unless otherwise specified. Derailments ocurring on industry track, on sidings or in yards and derailments associated with Class 1 main line track generally occur at very low speeds and cause relatively little damage per derailment. These derailments probably result from lateral forces produced by poor track geometry and/or relatively poor track structural integrity resulting in inadequate rail restraint capability. The most common low-speed derailments typically involve gage widening and wheel drop or rail roll-over as a result of inadequate rail restraint, or large track alinement variations.

A small number of records were eliminated because of missing data or because they could not be adequately linked to vehicle data. The following is an accounting of derailment records included in subsequent analyses:

Number of derailments (2.75 years of accident data)*	: =	16,060
Number of derailments (yards, sidings industry track)	: =	(7,940)
Number of main line derailments	: =	8,120
Number of main line derailments at 10 mph or below	: =	(3,390)
Main line derailments above 10 mph	: =	4,730
Main line derailments, Class 1 track above 10 mph	: =	(230)
Main line derailments, Classes 2-6 above 10 mph	: =	4,500
Unacceptable linkages, bad or incomplete records	: =	(270)
Total Data Base Records		4,230

Figure 2-3 shows the distribution of derailments in 5 mph speed bands on Class 1-6 main line track for speeds greater than 10 mph. It is of interest to note that for speeds corresponding to the operating speed ranges for Class 3 and 4 track (25-40 mph

*For selected rail equipment cause codes.



Note: In 5 mph speed bands on main line track.

FIGURE 2-3. NUMBER OF DERAILMENTS BY SPEED RANGE AND TRACK CLASS and 40 to 60 mph respectively), derailments occurring on Class 3 and 4 track do not tend to be evenly distributed or to cluster at the upper bound of the allowable track class speed limit. In fact, these derailments tend to cluster at lower speeds. This may be a result of a relatively high percent of car-miles traveled at the lower end of the allowable speed for these track classes although an opposite argument might be made that the actual percent-mileage distribution should be weighted towards the higher operational speed limit since this would result in greater efficiency. Based on available information, either assumption is purely conjectural. Assuming the percent-mileage distribution with speed (within a track class operational speed range) is somewhat uniform, Figure 2-3 implies that reducing the track class speed limit would not have a substantial effect in reducing the number of derailments on Class 3 or 4 track. Moreover, the track-class/derailment speed profile implies the existence of speed-related derailment scenarios where large numbers of derailments may be attributed to a particular derailment mode. Figure 2-4 illustrates the distribution of derailment speeds for the 4,230 records in the data base, in terms of percent of total derailments in 5 mph speed bands.

2.3 DISTRIBUTION OF DERAILMENTS BY CAUSE CODE GROUPS AND TRACK CLASS

The number and percent distribution of derailments by cause code groups is illustrated in Figure 2-5. It can be seen that several of these cause code groups are very small. Group numbers 5, 8, 10, 11, 12, 20, 21 and 23 all contain fewer than twenty derailments. These cause code groups were not considered further because of their very small size. Many other groups have somewhat larger populations but are still small for the purpose of developing derailment scenarios because of the large number of factors which must be considered. These factors involve a large number of distinctive vehicle configurations, a number of speed ranges and five track classes. In order to define a derailment scenario, a significant number of derailments must correlate

Speed Band	Total Derailments	
10.1-15.0	(13)	*************
15.1-20.0	(18)	******************
20.1-25.0	(21)	*********************
25.1-30.0	(15)	***************
30.1-35.0	(07)	*******
35.1-40.0	(10)	**********
40.1-45.0	(05	*****
45.1-50.0	(06)	******
50.1-55.0	(02)	**
55.1-60.0	(02)	**
60.1-65.0	(00)	
65.1-70.0	(00)	
70.1-75.0	(00)	
75.1-80.0	(00)	
80.1-85.0	(00)	
85.1-90.0	(00)	

EACH * = 1%   Total Derailments = 4,231

FIGURE 2-4. PERCENT DISTRIBUTION OF DERAILMENTS IN 5 MPH SPEED BANDS

Cause Code Descriptor	Cause Group No.		Number of Derailments		
ROADBED, SOFT	1.00	I	(64	02)	**
ROADBED, FLOODED ETC	2.00	I	(34	01)	*
WIDE GAGE	3.00	I	(84	02)	**
ALIGNMENT	4.00	I	(244	06)	******
RROFILE	5.00	I	(15	00)	
SUPERELEVATION	6.00	I	(80	02)	**
CROSSLEVEL	7.00	I	(540	13)	*************
BROKEN WELD	8.00	I	(8	00)	
SWITCH	9.00	I	(29	01)	*
FROG	10.00	I	(7	00)	
TRACK APPLIANCE	11.00	I	(3	00)	
TOFC EQUIP.	12.00	I	(14	00)	
CAR BODY	13.00	I	(197	05)	*****
COUPLER/DRAFT SYST	14.00	I	(321	08)	********
SIDE BEARINGS	15.00	I	(235	06)	******
OTHER TRACK COMP.	16.00	I	(91	02)	**
PLAIN JOURNAL (OHTD)	17.00	I	(306	07)	*******
ROLLER BEARING (OHTD)	18.00	I	(123	03)	***
BROKEN WHEEL	19.00	I	(255	06)	******
WORN FLANGE	20.00	I	(19	00)	
WORN TREAD	21.00	I	(1	00)	
OTHER WHEEL	22.00	I	(22	02)	**
LOCOMOTIVE	23.00	I	(2	00)	
EXCESSIVE SPEED	24.00	I	(40	01)	*
EXCESSIVE BUFF/SLACK	25.00	I	(226	05)	*****
EXCESS LAT FORCE ON	26.00	I	(26	01)	*
OVERLOADED CAR	27.00	I	(37	01)	*
INT. OF L & V FORCES	28.00	I	(71	02)	**
RAIL HEAD FAILURE	29.00	I	(366	09)	*********
RAIL END & J.B. FAIL	30.00	I	(150	04)	****
OTHER AXLE/JOURNAL	31.00	I	(34	01)	*
LOAD RELATED	32.00	I	(175	04)	****
MISC.	33.00	I	(351	08)	********

EACH * = 1% 1.02

NOTE: For Derailments on Class 2-6 Main Line Track st Speeds Greater Than 10 mph. (also percentages are rounded and may not total exactly 100 percent)

FIGURE 2-5. PERCENT DISTRIBUTION OF DERAILMENTS BY CAUSE CODE GROUPS with a specific vehicle configuration, speed range and track class. For these reasons, the following principal cause code groups have been emphasized in this study:

Principal Cause Code Groups

Causal Factor	Group No.	No. Derailments	Rank
Alinement Deviations	(4)	244	6
Crosslevel Variations	(7)	540	1
Coupler and Draft System	(14)	321	3
Side Bearing Failures/Defects	(15)	235	7
Plain Journals Overheating	(17)	306	4
Broken Wheel Components	(19)	255	5
Excessive Buff/Slack Action	(25)	226	8
Rail Head Failures	(29)	366	2

These eight groups account for about 58 percent of all non-miscellaneous derailments included in the data base. Cause code group No. 33 represents miscellaneous "unlisted cause codes" which although non-specific, are associated with the cause code categories listed in Table 2-1. Although these derailments are not specifically useful in developing derailment scenarios they are considered important, along with the smaller cause code groups, in establishing freight vehicle derailment incidence and frequency as described in later sections.

Considering the principal cause code groups listed above, it can be seen that variations in track crosslevel geometry is the leading dynamics-related causal factor, representing about 14 percent of all (non-miscellaneous) derailments. Variations in track alinement is another important track geometry related accident cause. Referring to Figure 2-5, cause code groups 3 through 7 represent the relative number of derailments attributed to track geometry related factors. At speeds greater than 10 mph the number of derailments due to wide gage, profile and superelevation (Nos. 3, 5 and 6 respectively) are quite small. If all speeds and track types were being considered, a large number of low speed, wide gage derailments would mask the trends described above, i.e., with respect to track geometry, crosslevel and alinement variations have the most significant impact on vehicle dynamics.

For the principal cause code groups defined above, Table 2-3, Part A, indicates the distribution of these accidents by track class and Part B summarizes track classes associated with each cause code group and indicates that track class having the highest number of derailments. Row and column percentages are provided in the upper right-hand corner and the lower left hand corner of each cell to indicate the percent distribution of derailments with respect to track class for each cause code group and the percent distribution of derailments with principal cause groups for each track class. It can be seen that a significant number of derailments occur on Class 3 track with very few derailments occurring on Class 6 track for all cause code groups. These trends are probably the result of a relatively high proportion of car miles logged on Class 3 track and the superior quality of Class 6 track. In addition to these trends, it can also be seen that most cause code groups can be associated with one or several track classes as indicated in Part B of Table 2-3. Alinement, crosslevel, side bearing, and rail head failures are associated with track Classes 2 and 3 which implies a relatively low average speed. Coupler failures, plain journals overheating and broken wheels are associated with higher track classes and average speeds. Excessive buff/draft (train-action forces) are associated with track Classes 2, 3 and 4. This is discussed further in the following section.

2.4 DISTRIBUTION OF DERAILMENTS WITH SPEED BY PRINCIPAL CAUSE CODE GROUP

For each principal cause code group defined above, the distribution of these derailments with speed has been developed along with selected statistics in order to bound the primary speed regimes at which these derailments occur. Table 2-4

TABLE 2-3. PART A. DISTRIBUTION OF FREIGHT VEHICLE DERAILMENTS BY TRACK CLASS AND PRINCIPAL CAUSE CODE GROUPS

	Principal Cause Code Groups	TRACK CLASS 2	3	4	5	6	Total
Alinement	4	(25) 60 (8)	(53) 130 (13)	(20) 49 (8)	(2) 5 (4)	0	244
Crosslevel	7	(43) 229 (32)	(47) 256 (25)	(10) 52 (9)	2 (2)	0	539
Couplers Etc.	14	(13) 41 (6)	(33) 104 (10)	(44) 138 (23)	(10) 33 (24)	1 (20)	317
Side Bearings	15	(39) 92 (13)	(39) 92 (9)	(19) 45 (7)	(1) 3 (2)	1 (20)	233
Plain Journals Overheated	17	(12) 38 (5)	(45) 138 (13)	(37) 112 (19)	(6) 17 (12)	2 (40)	307
Broken Wheel	19	(6) 15 (2)	(27) 70 (7)	(43) 109 (18)	(24) 60 (44)	1 (20)	255
Exc. Buffer Slack	25	(34) 75 (10)	(39) 88 (9)	(22) 49 (8)	(5) 11 (8)	0	223
Rail Head	29	(46) 170 (24)	(39) 144 (14)	(13) 47 (8)	(2) 6 (4)	0	367
	Total	720	1022	601	137	5	2485

Legend = ( ) = Row percentage:
XX = No. of derailments
( ) = Column percentage

TABLE 2-3. PART B. ASSOCIATED AND MOST FREQUENT TRACK CLASS

Principal Cause Code Groups	Cause Code Group No.	Associated Track Class (*)		Most Frequent Track Class (*)	
Alinement	(4)	2,3	(78)	3	(53)
Crosslevel	(7)	2,3	(90)	3	(47)
Couplers Etc.	(14)	3,4	(77)	4	(44)
Side Bearings	(15)	2,3	(78)	2 and 3	(39)
Plain Journals Overheated	17	3.4	(82)	3	(45)
Broken Wheel	19	3,4,5	(94)	4	(43)
Exc. Buffer Slack	25	2.3,4	(95)	3	(39)
Rail Head	29	2,3	(85)	2	(46)

*Indicates % of derailments on these track classes for indivdual cause code groups.

TABLE 2-4. STATISTICAL DESCRIPTION OF THE DISTRIBUTION OF DERAILMENTS WITH SPEED BY PRINCIPAL CAUSE CODE GROUPS

Cause Code Group (No. & Descriptor)	STATISTICS OF SPEED DISTRIBUTION				REFERENCE FIGURE (APP. C)
	Average Speed	Median	Mode	Standard Deviation	
(4) Alinement	28.7	27.3	25	10.2	C-1
(7) Crosslevel	22.9	21.6	20	8.0	C-2
(14) Coupler/Draft System	34.2	34.7	40	12.9	C-3
(15) Side Bearings	23.9	21.7	20	9.6	C-4
(17) Plain Journals (overheated)	33.6	32.6	30	11.4	C-5
(19) Broken Wheel Components	40.8	40.3	50	12.7	C-6
(25) Exc. Buff/Slack Action	25.6	22.8	15	11.5	C-7
(29) Rail Head Failures	25.5	24.9	25	8.4	C-8

Note: For derailments on Class 2-6 Main Line Track Speeds Greater than 10 mph.

presents a statistical description of the distribution of derailments with speed for each of the major cause code groups. (These statistics include only those derailments which occurred at speeds greater than 10 mph.)

In addition to the statistics, Figures C-1 through C-8 have been included (in Appendix C) to illustrate the percent distributions of accidents in 5 mph speed bands for each principal cause code group. Comparison of each distribution with the aggregate distribution (Figure 2-4) provides a further indication of whether these derailments tend to occur in distinct speed ranges. A single speed profile roughly equal to the aggregated accident speed distribution implies that a particular causal factor does not correlate with an identifiable speed range.

Derailments attributable to excessive variations in track crosslevel geometry (group 7) are the largest single cause code category for the conditions of interest. It can be seen from Figure 2-6 (Figure C-2 from Appendix C) that 91 percent of all crosslevel derailments occur at speeds below 30 mph. Of the principal cause code groups considered, crosslevel derailments have the lowest derailment speed profile. From Figure 2-7 (Figure C-4 from Appendix C) it can be seen that side bearing derailments (group 15) also occur at low speeds and have a derailment speed distribution very similar to that for track geometry variations in crosslevel. About 85 percent of these derailments occur below 30 mph. Derailments resulting from excessive buff or slack action (Figure C-7 in Appendix C) also occur at somewhat lower speeds (78 percent below 30 mph).

Side bearing failures and derailments associated with track geometry variations in crosslevel are both symptomatic of the harmonic roll derailment process where excessive car roll is induced by track geometry variations in crosslevel. These variations cause the carbody to rock off the centerplate and onto the side bearing, thus requiring the side bearing to support the entire car weight for brief intervals. Since side bearings are not designed to carry the entire car weight, car rocking in this manner would be

roll due to track geometry → load shift

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	20********************
15.1		20.0	29*****************************
20.1		25.0	29*****************************
25.1		30.0	13*************
30.1		35.0	03***
35.1		40.0	03***
40.1		45.0	01*
45.1		50.0	01*
50.1		55.0	00
55.1		60.0	00
60.1		65.0	00
65.1		70.0	00
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 543 derailments
Average derailment speed = 22.9 mph.

FIGURE C-2. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 7, CROSSLEVEL

FIGURE 2-6. EXHIBIT FIGURE C-2 FROM APPENDIX C

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	22**********************
15.1		20.0	25*************************
20.1		25.0	26**************************
25.1		30.0	12************
30.1		35.0	03***
35.1		40.0	05*****
40.1		45.0	03**
45.1		50.0	02**
50.1		55.0	01*
55.1		60.0	01*
60.1		65.0	00
65.1		70.0	00
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 236 derailments
Average derailment speed = 23.9 mph

FIGURE C-4. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 15, SIDE BEARINGS

FIGURE 2-7. EXHIBIT FIGURE C-4 FROM APPENDIX C expected to accelerate side-bearing failures. Because of the similarities in derailment speed profile and the dynamics associated with harmonic roll, the two cause categories, side bearing failures and crosslevel geometry variations, may be interrelated. Together they account for about 19 percent of all derailments considered herein (a total of 775 derailments over 2.75 years).

Referring to Figure C-8 in Appendix C, the derailment speed profile for derailment resulting from rail-head failures is similar to that for the aggregate distribution but shifted slightly toward lower speeds. These results imply that rail-head failures may not be induced as much by vehicle speed as by other mechanisms such as accumulated damage from loads developed as a result of track geometry variations.

The speed distribution for derailments resulting from coupler and draft system failures (Figure C-3 in Appendix C) is relatively uniform from 15 to 50 mph. These derailments tend to occur at relatively high speeds. Large relative motions between adjacent vehicles, such as those which might be induced by carbody hunting at higher speeds, may be an underlying factor in these derailments. Derailments attributed to plain journals overheating (Figure C-5 in Appendix C) occur at speeds which are moderately higher than the aggregate speed distribution. These derailments would be expected to occur at relatively high speeds. Derailments resulting from broken wheels also show a pronounced tendency to occur at higher speeds (Figure C-6 in Appendix C). The most frequent derailment speed is 45-50 mph which falls squarely into the speed range associated with carbody hunting dynamics. Derailments resulting from broken wheel components probably result from thermal stresses developed during braking in conjunction with mechanical stresses developed in curves or during hunting. The speed profile of derailments associated with track geometry deviations in alinement (Figure C-1 in Appendix C) is very similar to the aggregate derailment speed distribution.

2.5 INCIDENCE AND FREQUENCY OF DERAILMENT FOR FREIGHT VEHICLES DESCRIBED BY CAR TYPE AND TRUCK CAPACITY

The freight vehicle fleet is composed of nine mechanical car types including box, stock, refrigerator, covered hopper, open hopper, gondola, flat (including TOFC/COFC vehicles), vehicular flats and tank cars (see Appendix A). Several equipment types include cars outfitted with special equipment or construction features pertaining to car operational function while other cars of the same type are built for more general usage. For the purposes of this study, the "equipped" and "general service" cars have been aggregated since overall configurational differences between the two groups are generally small. Each vehicle is also equipped with a carset of trucks designed to carry a maximum gross rail load consisting of the weight of carbody and trucks (i.e., the vehicle lightweight) and the maximum permissible load (or vehicle weight capacity). There are three principal truck designs in use. These are the familiar 50, 70 and 100 ton truck designs. The fleet population includes a small number of open hopper cars equipped with 125 ton trucks. However, the small population and small derailment sample available for these cars precludes a statistical analysis of this group. In addition, a specialized, low-profile truck is in use with certain low-level flat cars and vehicular flat cars. The latter truck design is simply referred to as a low level (LL) truck design in this report. This truck has a gross rail load limit which is slightly higher than that of a 50 ton truck. Table A-6 in Appendix A contains information on populations of freight vehicles described by nine mechanical equipment types and the four principal truck capacity groups described above (i.e., 50, 70, 100 and low level truck designs).

While describing vehicles in this manner effectively groups cars of similar function and weight class, large variations in car configuration may exist in these groups. For example, 70 ton boxcars* may have truck center spacings ranging from approximately

*i.e., boxcars equipped with 70 ton trucks. This convention is used throughout the report.

39 to 64 ft, while for 100 ton open hopper cars, truck center spacings range from about 25 ft to 59.5 ft with corresponding volumetric capacities ranging from about 2100 cubic ft to 7000 cubic ft. Since these (as well as other) physical attributes may influence a vehicle's dynamic response and susceptibility to various derailment modes, analyzing the derailment pattern of freight vehicles described by car type and truck capacity may aggravate trends as a result of the large variations in key physical descriptors which may exist. Nonetheless, describing freight vehicles in this manner provides useful and familiar descriptions of the fleet in terms of a total of 29 distinctive vehicle configurations (27 for 50, 70 and 100 ton truck capacities and 2 for 55 ton truck capacities) as defined in Table A-6 in Appendix A.

The data base has been exercised to define the aggregate number of derailments for both loaded and unloaded vehicles, experienced on Class 2-6 main line track at speeds above 10 mph, for the freight vehicle fleet described in terms of car type and truck capacity. For each of these vehicle configurations, Table 2-5 contains (a) an estimate of the total annual mileage traveled by the population of cars constituting each group, (b) the incidence or total number of derailments experienced by each group and, (c) an estimated mileage-weighted, annual derailment frequency (i.e. number of derailments per 10^8 car miles).

The derailment incidence and frequency data contained in Table 2-5 (and in subsequent tables) indicates both the absolute number of derailments experienced (i.e., incidence) and the relative derailment tendency based on aggregate, loaded plus unloaded car miles traveled.* In reviewing these tables, vehicle configurations having both high incidence and frequency of derailment are of particular interest since this suggests vehicle configurations prone to derailments. Table 2-5 indicates that 100 ton hopper cars have both the highest incidence and frequency of derailment.

*And for the cause-code, track type, track class and speed conditions under consideration.

TABLE 2-5. MILEAGES, DERAILMENT COUNTS, AND DERAILMENT FREQUENCIES

MECHANICAL CAR TYPE		TRUCK CAPACITY 50 TON	70 TON	100 TON	125 TON	LOW-LEVEL	TOTAL
BOX	1.	3448448.	3598942.	735713.	0.	0.	7784103.
		460	546	68	0	0	1074
		4.85	5.52	3.36	0.00	0.00	5.02
STOCK	2.	33279.	0.	0.	0.	0.	33279.
		0	0	0	0	0	0
		0.00	0.00	0.00	0.00	0.00	0.00
REFRIGERATOR	3.	258189.	1503594.	200143.	0.	0.	1961926.
		22	219	28	0	0	268
		3.10	5.27	5.09	0.00	0.00	4.97
COV. HOPPER	4.	0.	812567.	2661905.	0.	0.	3474472.
		0	226	909	0	0	1135
		0.00	10.11	12.42	0.00	0.00	11.89
OP. HOPPER	5.	281456.	1509570.	1211303.	20782.	0.	3023111.
		51	234	269	0	0	554
		6.59	5.64	8.08	0.00	0.00	6.66
GONDOLA	6.	87287.	793069.	1097472.	0.	0.	1977829.
		24	194	116	0	0	334
		10.00	8.90	3.84	0.00	0.00	6.14
FLAT (+TOFC)	7.	446851.	2235951.	247803.	0.	89137.	3019742.
		45	411	30	0	4	490
		3.66	6.68	4.40	0.00	1.63	5.90
VEH. FLAT	8.	0.	513067.	0.	0.	437043.	950110.
		0	21	0	0	111	132
		0.00	1.49	0.00	0.00	9.24	5.05
TANK	9.	607390.	124474.	993548.	0.	0.	1725412.
		74	33	157	0	0	264
		4.43	9.64	5.75	0.00	0.00	5.56
	MILES	5162900.	11091734.	7148888.	20782.	526180.	23949984.
	COUNT	476	1883	1577	0	115	4251
	FREQ	4.76	6.17	8.02	0.00	7.95	6.45

Note 1. **Each Cell:** a. **Estimated Carmiles** x10^3 (per year)
b. **No. of Derailments (2.75 years acc. data)**
c. **Estimated Derailment frequency per 10^8 annual carmiles**

2. Derailments on Class 2-6 Main Line Track at Speeds Greater than 10 mph (includes Loaded and Unloaded Vehicles)

The derailment frequency (number of derailments per 10^8 car-miles) is seen to be approximately twice the derailment frequency for all (loaded and unloaded) freight vehicles.

Other cartypes having high derailment incidence include:

50 and 70 ton boxcars
70 ton refrigerator cars
70 ton covered hoppers
70 and 100 ton open hoppers and
70 ton flatcars

To provide another perspective on these derailments, the derailment incidence data from Table 2-5 has been normalized by the corresponding car group populations (from Table A-6 in Appendix A) to estimate a "population weighted" derailment frequency (number of annual derailments per thousand freight vehicles in each group) as shown in Table 2-6. Using population weighting, low-level vehicular flat cars display the highest derailment frequency.

The mileage weighted derailment frequencies are considered more useful for the purposes of this study because they take into account the relative usage of each vehicle group and are more indicative of relative vehicle safety than population-weighted statistics. In computing mileage-weighted derailment frequencies, an implicit assumption is made that the mileage logged by each vehicle configuration at speeds below 10 mph is a small percentage of the vehicle's total mileage. It is further assumed that there is no discrimination against a particular vehicle configuration by considering only main line derailments on Class 2 - 6 track. This is tantamount to assuming that all vehicle configurations travel

(a) a relatively equal and small percentage of total mileage at speeds equal to or below 10 mph and,

(b) a relatively equal and large percentage of total mileage on Class 2 - 6 main line track.

TABLE 2-6. POPULATION WEIGHTED DERAILMENT FREQUENCY BY CARTYPE AND TRUCK CAPACITY

MECHANICAL CAR TYPE	50 TON	70 TON	100 TON	125 TON	LOW-LEVEL	Aggregate
BOX	1.97	2.8	2.2	-	-	2.35
STOCK	-	-	-	-	-	-
REFRIGERATOR	1.69	2.95	4.0	-	-	2.82
COV. HOPPER	-	4.26	5.22	-	-	5.00
OP HOPPER	1.46	1.33	1.86	-	-	1.56
GONDOLA	1.2	1.86	1.97	-	-	1.82
FLAT (+TOFC)	1.55	4.47	3.33	-	1.33	3.68
VEH. FLAT	-	1.17	-	-	7.40	4.00
TANK	1.18	2.75	1.54	-	-	1.49
TOTAL	1.70	2.60	2.99	-	6.39	2.55

* Based on 2.75 years of accident data involving derailments on Class 2-6 mainline track at speeds greater than 10 mph. Ratios are expressed in terms of number of derailments per 1000 vehicles

From Tables 2-5 and 2-6, it can be seen that the following vehicle configurations have both high incidence and mileage or population weighted derailment frequencies.

Mileage Weighted (Ref. Table 2-5)	Population Weighted (Ref. Table 2-6)
o 70 and 100 ton covered hoppers	o 70 and 100 ton covered hoppers
o 100 ton open hoppers	o 70 ton flatcars
o low-level vehicular flatcars	o low-level vehicular flatcars

2.6 DISTRIBUTION OF DERAILMENTS BY LOADED AND UNLOADED CARTYPES

The derailment data shown in Table 2-5 has been disaggregated for loaded and unloaded freight vehicles as shown in Tables 2-7 and 2-8 respectively. Mileage-weighted derailment frequencies were based on loaded or unloaded car mileage estimates as appropriate.

Table 2-9 contains ratios of derailment incidence for loaded and unloaded freight vehicles by mechanical cartypes and truck capacity. This data indicates that in the aggregate there are 3.3 loaded freight vehicle derailments for each derailment of an unloaded car. The ratio of loaded to unloaded car miles is also shown in Table 2-9 for each cartype to provide an indication of relative mileage traveled in loaded and unloaded conditions.

From this data and Tables 2-7 and 2-8 it can be seen that on a per-mile basis, essentially all cars are more likely to derail in the loaded condition. In particular, 70 and 100 ton truck covered and open hopper cars have high derailment incidences, mileage weighted derailment frequencies and loaded to unloaded derailment ratios. For unloaded vehicles, low level vehicular flatcars have the highest mileage weighted derailment frequency although the data indicates, relatively equal probabilities of derailment for loaded and unloaded conditions. Figure 2-8 provides a graphical summary of relative derailment incidence and frequency by cartype, for loaded and unloaded conditions.

TABLE 2-7. MILEAGES, DERAILMENT COUNTS, AND DERAILMENT FREQUENCIES

MECHNICAL CAR TYPE		TRUCK CAPACITY 50 TON	70 TON	100 TON	125 TON	LOW-LEVEL	TOTAL
BOX	1.	2152600.	2210600.	439400.	0.	0.	4802600.
		322	375	37	0	0	734
		5.44	6.17	3.06	0.00	0.00	5.56
STOCK	2.	15200.	0.	0.	0.	0.	15200.
		0	0	0	0	0	0
		0.00	0.00	0.00	0.00	0.00	0.00
REFRIGERATOR	3.	163200.	884700.	113200.	0.	0.	1161100.
		17	131	19	0	0	167
		3.79	5.38	6.10	0.00	0.00	5.23
COV. HOPPER	4.	0.	402239.	1317704.	0.	0.	1719943.
		0	196	800	0	0	996
		0.00	17.72	22.08	0.00	0.00	21.06
OP. HOPPER	5.	147350.	790312.	634138.	10880.	0.	1582680.
		45	205	234	0	0	484
		11.11	9.43	13.42	0.00	0.00	11.12
GONDOLA	6.	51800.	461200.	645800.	0.	0.	1158800.
		16	158	97	0	0	271
		11.23	12.46	5.46	0.00	0.00	8.50
FLAT (+TOFC)	7.	246800.	1431891.	103100.	0.	61000.	1842791.
		35	312	23	0	3	373
		5.16	7.92	8.11	0.00	1.79	7.36
VEH. FLAT	8.	0.	256531.	0.	0.	218521.	475052.
		0	11	0	0	54	65
		0.00	1.56	0.00	0.00	8.99	4.98
TANK	9.	289811.	60127.	470006.	0.	0.	818944.
		57	26	89	0	0	172
		7.18	15.72	6.89	0.00	0.00	7.64
	MILES	3065761.	6497600.	3723348.	10880.	279521.	13577110.
	COUNT	497	1414	1299	0	57	3262
	FREQ	5.84	7.91	12.69	0.00	7.42	8.74

Note: Derailments on Class 2-6 Main Line Track at Speeds Greater Than 10 mph (For Loaded Vehicles)

TABLE 2-8. MILEAGES, DERAILMENT COUNTS, AND DERAILMENT FREQUENCIES

MECHANICAL CAR TYPE		TRUCK CAPACITY 50 TON	70 TON	100 TON	125 TON	LOW-LEVEL	TOTAL
	1.	1295848.	1388342.	297313.	0.	0.	2981503.
BOX		138	171	31	0	0	340
		3.87	4.48	3.79	0.00	0.00	4.15
	2.	18079.	0.	0.	0.	0.	18079.
STOCK		0	0	0	0	0	0
		0.00	0.00	0.00	0.00	0.00	0.00
	3.	94989.	618894.	86943.	0.	0.	800826.
REFRIGERATOR		5	87	9	0	0	101
		1.91	5.11	3.76	0.00	0.00	4.59
	4.	0.	410328.	1344201.	0.	0.	1754529.
COV. HOPPER		0	30	109	0	0	139
		0.00	2.66	2.95	0.00	0.00	2.88
	5.	134106.	719258.	577165.	9902.	0.	1440431.
OP. HOPPER		6	29	35	0	0	70
		1.63	1.47	2.21	0.00	0.00	1.77
	6.	35487.	331869.	451672.	0.	0.	819029.
GONDOLA		8	36	19	0	0	63
		8.20	3.94	1.53	0.00	0.00	2.80
	7.	200051.	804060.	144703.	0.	28137.	1176951.
FLAT (+TOFC)		10	99	7	0	1	117
		1.82	4.48	1.76	0.00	1.29	3.61
	8.	0.	256536.	0.	0.	218522.	475058.
VEH. FLAT		0	10	0	0	57	67
		0.00	1.42	0.00	0.00	9.49	5.13
	9.	318579.	64347.	523542.	0.	0.	906468.
TANK		17	7	68	0	0	92
		1.94	3.96	4.72	0.00	0.00	3.69
	MILES	2097139.	4593634.	3425540.	9902.	246659.	10372874.
	COUNT	184	469	279	0	58	989
	FREQ	3.19	3.71	2.95	0.00	8.55	3.47

Note: Derailments on Class 2-6 Main Line Track at Speeds Greater Than 10 mph (For Unloaded Vehicles)

TABLE 2-9. RATIO OF DERAILMENT INCIDENCE FOR LOADED AND UNLOADED FREIGHT VEHICLES BY CARTYPE AND TRUCK CAPACITY

MECHANICAL CAR TYPE	TRUCK CAPACITY						Ratio of Loaded to Unloaded Carmiles
	50 TON	70 TON	100 TON	125 TON	LOW-LEVEL	Total	
BOX	2.33	2.19	1.19	-	-	2.16	1.66
STOCK	-	-	-	-	-	-	0.84
REFRIGERATOR	3.4	1.5	2.1	-	-	1.66	1.45
COV. HOPPER	-	6.5	7.33	-	-	7.16	0.98
OP HOPPER	7.5	7.1	6.68	-	-	6.9	1.09
GONDOLA	2.0	4.4	5.1	-	-	4.3	1.4
FLAT (+TOFC)	3.5	3.15	3.28	-	3.0	3.2	1.56
VEH. FLAT	-	1.1	-	-	0.94	0.97	1.0
TANK	3.35	3.7	1.3	-	-	1.87	0.91
TOTAL	2.67	3.0	4.67	-	1.0	3.3	1.3

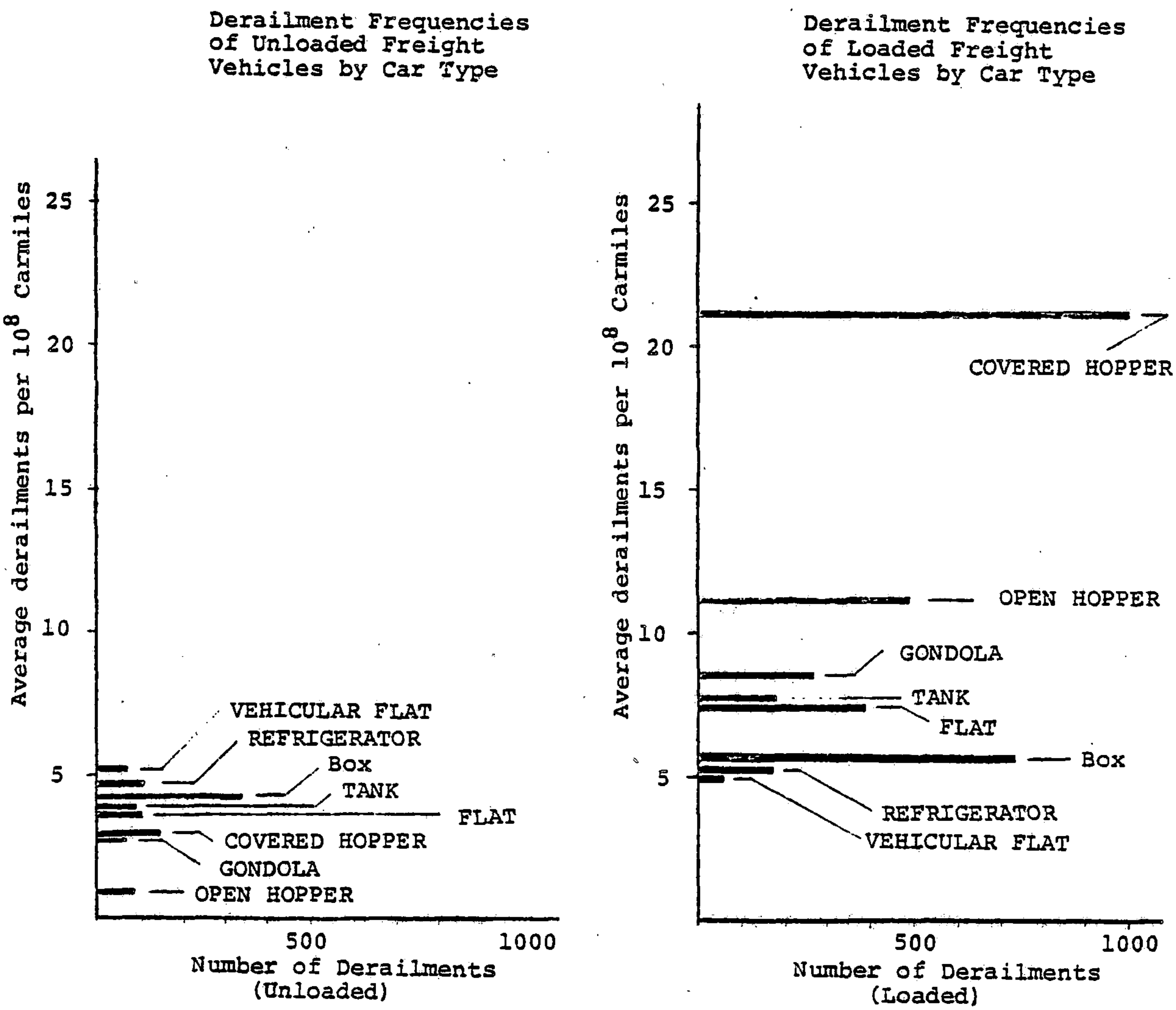


FIGURE 2-8. SUMMARY OF DERAILMENT INCIDENCE AND FREQUENCY BY CAR TYPE

2.7 DISTRIBUTION OF DERAILMENTS BY CARTYPE AND PRINCIPAL CAUSE CODE GROUPS

In order to determine if correlations exist between the principal cause code groups and freight vehicle configurations discussed above, the data base was exercised to compute individual derailment distributions and mileage weighted derailment frequencies by cartype and truck capacity for each principal cause code group. Both loaded and unloaded vehicle derailments are included. This data is contained in Tables C-1 through C-8 (of Appendix C) and relative derailment frequencies are summarized in Table 2-10. The first column of Table 2-10, contains an aggregated derailment frequency for each cause group which is based on the total number of derailments of that kind experienced by the freight vehicle fleet, and the total fleet mileage logged by all cartypes. Subsequent columns contain similar computations disaggregating derailments and mileage based on groups of vehicles described by truck capacity; major cartype; and major population vehicle groups described by both cartype and truck capacity. In instances where the sample size (i.e., number of derailments) was small the derailment frequency may not be very meaningful and is therefore not included in the summary table. The last rows of Table 2-10 indicate aggregated derailment frequencies which are based on all thirty-three cause code groups included in the data base. This data provides a useful indication of the relative percent of total derailments represented by the eight principal cause code groups for a particular vehicle configuration.* For example, it can be seen that 48 percent of all derailments involving low-level vehicular flat cars result from either coupler and draft system failures or broken wheel components (groups 14 and 19).

*This is determined by summing derailment frequencies for the eight principal cause code groups and dividing by the derailment frequency for all derailments. This may be done because the denominator (i.e., annual miles traveled) is always the same for a particular vehicle configuration.

TABLE 2-10. SUMMARY OF RELATIVE DERAILMENT FREQUENCIES BY CAUSE GROUPS AND VEHICLE CONFIGURATION

VEHICLE DESCRIPTOR

Cause Code Group (No. & Descriptor)		TRUCK CAPACITY			CARTYPE									TRUCK CAPACITY/CARTYPE (MAJOR POPULATIONS)													
	All Vehicles	All 50 Ton Cars	All 70 Ton Cars	All 100 Ton Cars	All Box	All Stock	All Refrigerator	All Covered Hoppers	All Open Hoppers	All Gondolas	All Flats	All V. Flats	All Tank	50T Box	70T Box	70T Refrigerator	70T Cov. Hopper	100T Cov. Hopper	70T Open Hopper	100T Open Hopper	70T Gondola	100T Gondola	70T Flat	LL Veh. Flat	100T Tank	REFERENCE TABLE
(4) Alinement	.37	.20	.24	.72	.23	-	.20	.89	.51	.37	.19	.08	.42	.23	.25	.24	.45	1.02	.24	.87	-	.60	.23	-	.55	C-1
(7) Crosslevel	.82	.44	.67	1.37	.66	-	.85	2.17	.85	.29	.22	.42	.70	.44	.94	.89	.98	2.53	.51	1.23	-	-	.26	-	.81	C-2
(14) Coupler	.49	.54	.52	.27	.50	-	.37	.26	.20	.39	1.0	.42	.21	.65	.41	.34	.45	.20	-	-	-	-	1.19	2.58	-	C-3
(15) Side Bearings	.36	.14	.33	.56	.25	-	.41	1.18	.22	.09	.11	.23	.21	.16	.35	.48	.03	1.23	.24	-	-	-	-	-	-	C-4
(17) Plain Journals	.47	.71	.66	.04	.28	-	.09	.63	.46	1.49	.22	-	.99	.58	-	-	2.51	-	.79	-	3.44	-	.20	-	-	C-5
(19) Broken Wheels	.39	.27	.44	.31	.36	-	.50	.39	.31	.24	.49	.92	.21	.27	.46	.46	-	.41	.43	-	-	-	.59	1.83	-	C-6
(25) Exc. Buff/Slack	.34	.25	.32	.46	.31	-	.30	.65	.37	.15	.33	.15	.23	.21	.33	.34	.49	.70	.26	.45	-	-	.36	-	-	C-7
(29) Rail Head	.56	.42	.41	.91	.42	-	.35	.99	.88	.51	.39	.19	.57	.44	.45	.41	-	.17	.55	1.17	-	.53	.37	-	.77	C-8
Aggregate Derailments	6.45	4.76	6.17	8.03	5.02	-	4.97	11.88	6.66	6.14	5.90	5.05	5.56	4.8	5.5	5.3	10.1	12.4	5.6	8.1	8.9	3.8	6.7	9.2	5.8	2-5
PERCENT (2)	58	62	58	58	60	-	62	60	57	55	50	74	64	62	58	60	59	59	59	46	39	30	48	48	37	

(1) Derailments per ten million carmiles.

(2) "Percent" = percentage of total derailments represented by principal case code groups.

(-) Indicates fewer than 10 derailments in all.

The relative distribution of a particular derailment group with vehicle configuration is indicated by the corresponding derailment frequencies computed for various vehicle configurations as outlined in Table 2-10. For example, considering derailments attributed to variations in track alinement, it can be seen that the following vehicle configurations have significantly higher derailment frequencies when compared with that of the entire fleet:

Alinement Cause Code Group

Vehicle Descriptor	Derailment Frequency	Relative Frequency Compared with Fleet Average
Fleet (all vehicles)	0.37	1.0
100 Ton Cars	0.72	1.95
Covered Hoppers	0.80	2.40
100 Ton Covered Hopper	1.02	2.76
100 Ton Open Hopper	0.87	2.35

In a similar manner, associations may be made between other principal cause code groups and vehicle configurations by comparing (and ratioing) derailment frequencies for specific vehicle configurations with that for the entire fleet, treating each cause code group separately. These associations are indicated in Table 2-11, based on derailment frequency ratios which are significantly larger than 1.0. Large derailment frequency ratios indicate strong associations.

2.8 DEFINITION OF GENERICALLY SIMILAR VEHICLE CONFIGURATIONS

The previous section describes associations made between freight vehicle configurations described in terms of cartype and truck capacity and principal cause code groups. As illustrated above, large variations in physical properties may exist for vehicles which are described on the basis of cartype only. A second and perhaps more useful method of assessing such relationships, is by analyzing groups of vehicles on the basis of similar

TABLE 2-11. ASSOCIATIONS BETWEEN PRINCIPAL CAUSE CODE GROUPS AND VEHICLE CONFIGURATIONS

Cause Code Group (No. & Descriptor)	All 50 ton cars	All 70 ton cars	All 100 ton cars	All covered hoppers	All open hoppers	All Gondolas	All Flats	All Veh. Flats	All Tanks	70 Ton Cov. Hop.	100 Ton Cov. Hop.	100 Ton Open Hop.	70 Ton Gondolas	70 Ton Flats	L.L Veh. Flats	100 Ton Tank	
(4) Alinement			1.95	2.40							2.76	2.35					
(7) Crosslevel			1.67	2.64							3.09	1.5					
(14) Coupler, etc.							2.04	2.89						2.43	5.27		
(15) Side Bearings			1.56	3.28						2.86	3.42						
(17) Plain Journals	1.51	1.40				3.17			2.11	5.34			7.32				
(19) Broken Wheels								2.36							4.69		
(25) Exc. Buff/Slack											2.06						
(29) Rail Head			1.63	1.77	1.57						2.09	2.09				1.38	

* Expressed in terms of ratio of derailment frequency for specific vehicle configuration to fleet derailment frequency for each principal cause code groups.

overall physical characteristics. In this approach, generic vehicle families have been defined in terms of a matrix of ranges of key physical attributes which influence vehicle dynamic response to various track and operations-related excitations. Several cartypes may be included in the same generic family depending on similarities of key physical attributes as discussed below.

Generic vehicle familes have been defined based upon the key vehicle descriptors and a system of Generic Family Codes (GFCs) has been developed to facilitate reference to each configuration as discussed below.

(a) Truck Suspension Characteristics and Truck Capacity - The vehicle/truck suspension system design involves the maximum permissible gross weight on rails and the cushioning of vertical and lateral forces generated from dynamic interactions with the track. The first descriptor used to define generically similar vehicle designs is, therefore, truck capacity. The principal truck capacity groups are indexed as shown below.

Truck Type	Truck Capacity	Rail Load Limit	Typical Vehicles
1	50 tons	177,000 lbs	all types
2	70 tons	220,000	all types
3	100 tons	263,000	all types
4	55 tons (low level)	179,000	low level flat and vehicular flat cars

The 125 ton group is not included here because of the small sample of derailment data available and because only a small number of cars are equipped with this truck.

(b) Truck Center Spacing

Trucks of a given capacity may be used on different freight vehicles with differing truck center spacings, c.g. height, load conditions, and other principal physical characteristics. The first additional descriptor used to group distinctive vehicle configurations is truck center spacing. This characteristic is important because it acts as a chordal filter on track geometry, effectively permitting certain modes of excitation to be transmitted, while filtering or attenuating others.

There is particular interest in vehicles having truck center spacings corresponding to the 39 ft rail length used in track construction. Depending upon the mode of excitation, these vehicles may be strongly excited by the 39 ft wavelengths associated with bolted-joint rail. Truck center spacing groups have been established to include a range fairly centered about the 39 ft spacing. The following table summarizes these groups and assigns qualitative descriptors to various truck center spacings.

First Descriptor	Range on Truck Center Spacing	Qualitative Descriptor	Corresponding Truck Capacity 50T	70T	100T	55T(LL)
1	15-25	very short	X	X		
2	25-35	short	X	X	X	
3	35-45	medium	X	X	X	
4	45-55	long		X	X	
5	55-70	very long		X	X	X

The medium length truck spacing is the most populous for 70 and 100 ton vehicles. Fifty (50) ton vehicles fall about equally into short and medium length categories.

(c) Axle Loads

The second additional descriptor considered is the estimated vehicle axle load. Axle loads have a strong influence on the vertical dynamic forces generated from vehicle/track dynamic interaction. In addition, higher axle loads are likely to aggravate problems associated with track and running gear structural integrity. Three load ranges are considered here which are intended to distinguish, in a gross sense, the effect of loads. These groups are indicative of empty and lightly loaded vehicle configurations, and vehicles carrying moderate and heavy loads, as described below.

Second Descriptor	Axle Load Range - lbs	Qualitative Descriptor
1	0-22,000	empty
2	22,000-46,000	moderate
3	46,000-70,000	heavy

Relating loads to specific truck capacities results in the following

Axle Load	Qualitative Descriptor	Truck Capacity 50T	70T	100T	55T (LL)
0-22,000	very light*	X	X	X	X
22,000-33,000	light	X	X	X	X
33,000-46,000	medium	X	X	X	X
46,000-55,000	heavy		X	X	
55,000-70,000	very heavy			X	

*empty vehicles

Most of the loaded car mileage logged by 70 ton cars falls into the "medium" axle load range, while mileage logged by 50 ton vehicles is about equally split between "light" and "medium" axle loads. The largest mileage component for 100 ton cars falls in the "very-heavy" axle load range.

(d) Center-of-Gravity Height

The vehicle center of gravity height is the third principal physical attribute used in defining the generic vehicle families. This descriptor is primarily a function of load weight and density, and mechanical car configuration. Center of gravity height has a strong influence on a vehicle's lateral/roll dynamics. The harmonic roll problem is probably most sensitive to a combination of vehicle attributes including: truck suspension characteristics, truck center spacing, roll inertia and center of gravity height. The following ranges on c.g. height are used in defining generically similar vehicle families.

Third Descriptor	C.G. Height* Range	Qualitative Descriptor	Truck Capacity 50T	70T	100T	55T(LL)
1	30-65	low	X	X	X	
2	65-90	medium	X	X	X	
3	90-120	high	X	X	X	

*Height of carbody only above top of rail surface.

The center of gravity heights of empty carbodies cuts across each of the above categories although about two-thirds of these vehicles have c.g. heights in the medium c.g. height range. Most of the (loaded plus unloaded) mileage logged by vehicles in the 50, 70 and 100 ton truck categories have c.g. heights in the intermediate range. Most of the mileage logged by high center of gravity vehicles is logged by 100 ton truck cars. The lowest center of gravity heights are associated with low level flatcars in TOFC/COFC service.

2.9 DISTRIBUTION OF DERAILMENTS BY GENERICALLY SIMILAR VEHICLE CONFIGURATIONS AND ESTIMATED AXLE LOADS

Table 2-12 indicates derailment incidence (COUNT), estimated mileage traveled (MILES), and mileage-weighted derailment frequency (FREQ) for groups of vehicles having generically similar configurations. Each generic family description is identified by a series of four digits and three "truck types". Truck types 1, 2 and 3 indicate 50, 70 and 100 ton truck capacity groups respectively for each generic family. Vehicles equipped with low-level trucks are fairly uniform in physical characteristics. These are adequately represented by cartype and truck capacity, hence these

TABLE 2-12. DERAILMENT COUNTS AND FREQUENCIES BY GENERIC FAMILY AND TRUCK TYPE FOR DERAILMENTS ON CLASS 2-6 MAIN LINE TRACK AT SPEEDS GREATER THAN 10 MPH

PART	GFC	TRUCK TYPE 1 COUNT	TRUCK TYPE 1 MILES	TRUCK TYPE 1 FREQ	TRUCK TYPE 2 COUNT	TRUCK TYPE 2 MILES	TRUCK TYPE 2 FREQ	TRUCK TYPE 3 COUNT	TRUCK TYPE 3 MILES	TRUCK TYPE 3 FREQ
A	1 0 0 0	21.	169703.	4.50	33.	222692.	5.39	0.	0.	0.00
	2 0 0 0	385.	2984519.	4.69	396.	2205005.	6.53	185.	679219.	9.90
	3 0 0 0	270.	2008678.	4.89	971.	5853323.	6.03	973.	3990985.	8.87
	4 0 0 0	0.	0.	0.00	144.	619023.	8.46	384.	2289718.	6.10
	5 0 0 0	0.	0.	0.00	339.	2191191.	5.63	35.	137796.	9.24
B	0 0 1 0	53.	487000.	3.96	417.	2465282.	6.15	59.	856527.	2.50
	0 0 2 0	601.	4584564.	4.77	1415.	8225825.	6.26	818.	4472633.	6.65
	0 0 3 0	22.	91336.	8.76	51.	400127.	4.63	700.	1766558.	14.41
C	1 0 1 0	0.	0.	0.00	5.	99544.	1.83	0.	0.	0.00
	1 0 2 0	16.	126743.	4.59	24.	109537.	7.97	0.	0.	0.00
	1 0 3 0	5.	42960.	4.23	4.	13611.	10.69	0.	0.	0.00
	2 0 1 0	24.	179643.	4.86	21.	328061.	2.33	0.	41120.	0.00
	2 0 2 0	354.	2765800.	4.65	367.	1875465.	7.12	133.	427734.	11.31
	2 0 3 0	7.	39076.	6.51	9.	1479.	196.69	52.	210365.	8.99
	3 0 1 0	29.	307357.	3.43	256.	1303450.	7.14	40.	680207.	2.14
	3 0 2 0	231.	1692021.	4.96	695.	4494048.	5.62	524.	2414397.	7.89
	3 0 3 0	10.	9300.	39.10	20.	55825.	13.03	409.	896381.	16.59
	4 0 1 0	0.	0.	0.00	51.	142245.	13.04	15.	120260.	4.54
	4 0 2 0	0.	0.	0.00	93.	476778.	7.09	137.	1528581.	3.26
	4 0 3 0	0.	0.	0.00	0.	0.	0.00	232.	640877.	13.16
	5 0 1 0	0.	0.	0.00	84.	591982.	5.16	4.	16940.	8.59
	5 0 2 0	0.	0.	0.00	236.	1269997.	6.76	24.	101921.	8.56
	5 0 3 0	0.	0.	0.00	19.	329212.	2.10	7.	13935.	13.44

vehicles are not re-analyzed in this section. The four digit generic family codes (GFC) describe groups of vehicles in terms of ranges on:

Truck center spacing	(1st digit)
Axle load	(2nd digit)
Carbody c.g. height	(3rd digit) and
Carbody vertical stiffness	(4th digit)*

The ranges on each descriptor have been defined and numbered in the preceding discussion. In instances where a zero appears in the four digit code, this indicates the corresponding descriptor has not been used in the family definition. For example, the first four digit code (1000) shown in Table 2-12 indicates a group of vehicles which have truck center spacings of 15 to 25 ft. The vehicle family is not characterized by any other physical details and all vehicles having very short truck center spacings are grouped together within the 50, 70 and 100 ton truck groups. The corresponding mileage data is summed for all vehicles having the 15-25 ft truck center spacing as are the number of derailments experienced by vehicles having this configuration. As before, mileage-weighted derailment frequencies were computed by dividing derailments by the corresponding mileage for each generic family within each truck capacity group. As a second example of this coding system, a 70 ton vehicle described by GFC 2220 would indicate a vehicle having a short truck center spacing (25 to 35 ft), a moderate (estimated) axle load (22,000 to 46,000 lbs), and a medium center of gravity height (65 to 90 in).

The data shown in Table 2-12 has been organized to assist in examining overall trends in derailment tendency for groups of vehicles having generically similar physical attributes. Table 2-13 contains qualitative descriptions of the generic vehicle configurations analyzed in Table 2-12. In Part A of Table 2-12 all freight vehicles are grouped into categories according to truck

*This descriptor was included in the structuring of the data base but was not used in this study.

TABLE 2-13. DESCRIPTION OF GENERIC FREIGHT VEHICLE FAMILIES IN EACH TRUCK CAPACITY GROUP (50, 70 AND 100 TON)

	FOUR DIGIT (GFC) CODE	FAMILY DESCRIPTION ALL VEHICLES HAVING:	
	1000	Very Short Truck Center Spacings	(15 to 25 feet)
	2000	Short Truck Center Spacings	(25 to 35 feet)
PART A	3000	Medium Truck Center Spacings	(35 to 45 feet)
	4000	Long Truck Center Spacings	(45 to 55 feet)
	5000	Very Long Truck Center Spacings	(55 to 70 feet)
	0010	Low c.g. Height	(30-65 in)*
PART B	0020	Medium c.g. Height	(65-90 in)*
	0030	High c.g. Height	(90-120 in)*
	1010	Very Short Truck Center Spacings and Low c.g. Height	
	1020	Very Short Truck Center Spacings and Medium c.g. Height	
	1030	Very Short Truck Center Spacings and High c.g. Height	
	2010	Short Truck Center Spacings and Low c.g. Height	
	2020	Short Truck Center Spacings and Medium c.g. Height	
	2030	Short Truck Center Spacings and High c.g. Height	
	3010	Medium Truck Center Spacings and Low c.g. Height	
	3020	Medium Truck Center Spacings and Medium c.g. Height	
PART C	3030	Medium Truck Center Spacings and High c.g. Height	
	4010	Long Truck Center Spacings and Low c.g. Height	
	4020	Long Truck Center Spacings and Medium c.g. Height	
	4030	Long Truck Center Spacings and High c.g. Height	
	5010	Very Long Truck Center Spacings and Low c.g. Height	
	5020	Very Long Truck Center Spacings and Medium c.g. Height	
	5030	Very Long Truck Center Spacings and High c.g. Height	

****

* Carbody only, above top of rails; does not include carset of trucks.

center spacing. In Part B, vehicles are grouped only on the basis of c.g. height and in Part C, vehicles are grouped on the basis of both truck center spacing and c.g. height. The relative sizes of various groups is indicated by the estimated annual mileage column (MILES). A zero in this column indicates a null group.

For these generic vehicle configurations, the derailment frequencies do not indicate large variations due to truck center spacing (within the same truck capacity group). Trends toward higher derailment frequencies for heavier weight classes (i.e., truck capacity groups) are observed, however. For vehicles described only by c.g. height (a total of nine families in Part B), these trends indicate a strong trend toward higher derailment frequencies for 100 ton high c.g. cars. This trend is not observed for 70 ton cars, however. Considering vehicles described by both truck center spacing and c.g. height (Part C), 50 ton vehicle derailments do not indicate much sensitivity to vehicle configuration except for the medium length high c.g. family (3030). For 70 ton cars, there is a general increase in derailment frequency with higher c.g. heights for very short, short and medium length cars. The trend for longer 70 ton cars appears to reverse itself however. For 100 ton cars, there is a trend toward an increasing number of derailments with higher c.g. height for medium to long cars. This is <u>opposite</u> to the trend exhibited by 70 ton cars. These results imply that a fundamental relationship may exist between derailment probability and basic railcar configuration described in terms of truck center spacing, c.g. height and truck suspension characteristics.*

Tables C-9, 10 and 11 in Appendix C disaggregate the derailment data of Table 2-12 into three axle load ranges as defined by the second digit of the generic family code. For relatively light axle loads (Table C-9 in Appendix C) the only vehicle

*In general derailment frequencies for "low-mileage" generic families are computed based on a relatively small number of derailments. In these situations there is an element of uncertainty about trends indicated for these groups.

configuration exhibiting high incidence and frequency of derailment is the long, light, low c.g. 70 ton vehicle group (No. 4110). For moderate axle loads (Table C-10 in Appendix C) none of the generic family configurations indicate both high incidence and derailment frequency. For heavy axle loads (Table C-11), the following configurations indicate both high incidence and frequency of derailment:

- medium length, heavy, medium c.g., 70 ton cars (3320)
- short, heavy, medium c.g., 100 ton cars (2320)
- medium length, heavy, medium c.g. 100 ton cars (3320)
- medium length, heavy, high c.g. 100 ton cars (3330)
- long, heavy, high c.g., 100 ton cars (4330)

Table 2-14 summarizes relative derailment frequencies for major generic families of freight vehicles in 50, 70 and 100 ton truck capcity groups. These twelve families (two 50 ton, six 70 ton and four 100 ton) represent 86, 90 and 77 percent, respectively of all mileage logged by 50, 70 and 100 ton cars. These results indicate significantly higher derailment incidence and frequency with heavier axle loads.

2.10 DISTRIBUTION OF DERAILMENTS BY GENERIC VEHICLE FAMILY AND PRINCIPAL CAUSE CODE GROUPS

In order to determine if relationships exist between principal cause code groups and groups of freight vehicles having generically similar physical attributes, the data base was exercised to generate the distribution of derailments for each principal cause code group, among the generic freight vehicle families discussed above. These distributions are contained in Tables C-12 through C-19 of Appendix C and summarized in Table 2-15 for the major generic vehicle families. The relative distribution of a particular derailment cause group with vehicle configuration is indicated by the corresponding derailment frequencies for various vehicle configurations. Table 2-16 indicates vehicle configurations which have significantly higher derailment frequencies when compared with the fleet average, for each of the principal cause

TABLE 2-14. SUMMARY OF RELATIVE DERAILMENT FREQUENCIES VS. ESTIMATED AXLE LOADS FOR GENERICALLY SIMILAR FREIGHT VEHICLE CONFIGURATIONS

AXLE LOAD RANGE	50T		70T						100T				REF TABLE
	2020	3020	2020	3010	3020	4020	5010	5020	3020	3030	4020	4030	
All Loads	4.65	4.96	7.12	7.14	5.62	7.09	5.16	6.76	7.89	16.59 (409)	3.26	13.16 (232)	2-12
Light axle loads	2.83	4.43	2.16	4.51	3.72	7.23	3.77	-	2.69	4.21	2.55	8.64	C-9
Medium axle loads	5.83	5.27	7.39	10.23 (159)	5.92	7.03	17.15 (29)	6.82	3.27	-	4.82	-	C-10
Heavy axle loads	-	-	11.56 (282)	*	22.59 (85)	-	-	-	17.03 (407)	19.55 (389)	3.58	13.35 (226)	C-11

* small sample

( ) indicates number of derailments.

TABLE 2-15. SUMMARY OF RELATIVE DERAILMENT FREQUENCIES BY CAUSE GROUPS AND GENERICALLY SIMILAR FREIGHT VEHICLE CONFIGURATIONS

TRUCK CAPACITY AND GENERIC VEHICLE FAMILY (CODES)

Cause Code Group (No. & Descriptor)	All Vehicles	50T		70T						100T				REF. TABLE
		2020	3020	2020	3010	3020	4020	5010	5020	3020	3030	4020	4030	
(4) Alinement	.37	0.20	0.26	0.35	-	0.28	0.23	-	0.26	0.72 (48)	1.34 (33)	0.21	1.87 (33)	C-12
(7) Crosslevel	.82	0.47	0.49	0.62	-	0.96	0.84	0.18	0.49	1.24 (82)	3.85 (95)	0.52	1.76 (31)	C-13
(14) Coupler System	.49	0.42	0.75	0.27	0.78	0.37	-	0.61	1.12 (39)	0.30	-	0.29	-	C-14
(15) Side Bearings	.36	0.13	-	0.45	-	0.45	-	-	-	0.39	1.95 (48)	-	0.57	C-15
(17) Plain Journals	.47	0.80 (61)	0.54	1.65 (85)	1.98 (71)	0.19	-	-	-	-	-	-	-	C-16
(19) Broken Wheels	.39	0.24	0.37	0.43	-	0.40	0.99 (13)	0.68 (11)	0.74 (26)	0.33	-	-	0.57	C-17
(25) Exc. Buff/Slack	.34	0.25	0.21	0.21	0.31	0.28	-	-	0.31	0.50	1.01 (25)	0.39	-	C-18
(29) Rail Head	.56	0.43	0.28	0.48	0.42	0.42	-	-	0.29	1.08 (72)	1.05 (26)	0.24	2.21 (39)	C-19

Note: Sample size and frequency small (i.e., less than 10 derailments).
Data for derailment per ten million car miles.

TABLE 2-16. ASSOCIATION BETWEEN PRINCIPAL CAUSE CODE GROUPS AND GENERICALLY SIMILAR VEHICLE CONFIGURATIONS

TRUCK CAPACITY AND GENERIC VEHICLE FAMILY CODE

Cause Code Group (No. & Descriptor)	50 Ton		70 Ton						100 Ton			
	2020	3020	2020	3010	3020	4020	5010	5020	3020	3030	4020	4030
(4) Alinement									1.94	3.62		5.05
(7) Crosslevel									1.51	4.69		2.15
(14) Coupler System								2.29				
(15) Side Bearings										5.42		
(17) Plain Journals	1.70		3.51	4.21								
(19) Broken Wheels						2.53	1.74	1.89				
(25) Exc. Buff/Slack										2.97		
(29) Rail Head									1.98	1.88		3.95

code groups. The associations outlined in Table 2-16 are expressed in terms of the ratio of derailment frequency for a specific vehicle configuration to that of the entire fleet, considering each principal cause code group separately. Only derailment frequency ratios significantly larger than 1.0 are indicated, with larger ratios indicating stronger associations.

A comparison of Table 2-16 with Table 2-11 provides insight into specific vehicle configurations which have relatively high derailment frequencies for accidents attributed to each principal cause group studied. In some instances these configurations are best described by cartype and truck capacity while in others the generic vehicle description provides a stronger association with a particular cause code group. These associations are summarized in the following discussion.

For the track alinement cause code group, 100 ton, long, high c.g. cars (described by GFC 4030) have the highest derailment frequency ratio as indicated in Table 2-16. (That is, the derailment frequency considering all vehicles in the fleet for this particular cause code group is considerably higher than for all other vehicle configurations). While many of the cars in this group are 100 ton covered and open hopper cars as suggested by Table 2-11, there is a more generic group of 100 ton vehicles (i.e., group 4030 in Table 2-16) as described above which is independent of cartype and has a higher derailment frequency ratio (5.05) than that for either 100 ton covered hoppers (2.76) or 100 ton open hoppers (2.35). The 100 ton medium length high c.g. group (no. 3030) also has a higher derailment frequency ratio (3.62).

Considering the crosslevel derailment group, 100 ton, medium length, high c.g. cars have the highest derailment frequency ratio (4.69). This same group of cars also has the highest derailment frequency ratio for the Side Bearings cause group (5.42) and the Excessive Buff/Slack Action derailment group (2.97).

For Coupler and Draft System Failures, low platform vehicular flatcars have the highest derailment frequency ratio (5.27). These cars are quite uniform in terms of their overall physical chacteristics and can be basically described as a very long, medium c.g. height vehicle configuration. Derailments attributed to Plain Journals Overheated are most strongly associated with 70 ton gondolas (7.32) and 70 ton covered hoppers (5.34). In terms of generic vehicle configuration these derailments also correlate with 70 ton short, medium c.g. height cars with 70 ton medium length, low c.g. height cars.

The Broken Wheel derailment group is primarily associated with low platform vehicular flat cars and Rail Head failure derailments are primarily associated with 100 ton, long, high c.g. height cars.

The distribution of derailments with speed and track class for these cause groups and associated vehicle configurations are quite similar to the aggregate distributions defined in Tables 2-3 and 2-4.

2.11 SUMMARY OF RELATED FACTORS INVOLVED IN FREIGHT VEHICLE DERAILMENTS

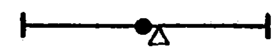
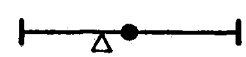
Table 2-17 contains a summary of related factors involved in freight vehicle derailments corresponding to each principal cause code group identified. These factors include: functional and generic physical descriptions of the most frequently derailing freight vehicles involved in each derailment-cause group; associated track class(es); statistics describing derailment speed distribution; total number of derailments represented by each cause code group; and, rank of principal cause code based on total number of derailments incurred. These factors imply the following relationships between track conditions, speed, vehicle configuration, mileage weighted derailment frequency and derailment mode.

2.11.1 Alinement Related Factors

Derailments resulting from excessive variation in track alinement most frequently involve heavy, high c.g. cars having truck center spacings in the 35 to 45 ft range. These cars include 100

*For 2.75 years of accident data.

TABLE 2-17. SUMMARY OF ASSOCIATED FACTORS IN FREIGHT VEHICLE DERAILMENTS

PRINCIPAL CAUSE CODE GROUP.	DESCRIPTION OF MOST FREQUENTLY DERAILING VEHICLE CONFIGURATION		ASSOC. TRACK CLASS	STATISTICS OF SPEED DISTRIBUTION (Speed - mph) 15 20 25 30 35 40 45 50 55	NO. OF DERAILMENTS	RANK
(4) Alignment	100 ton open and covered hoppers	o med. lgth., med. c.g. ht. o med. lgth., high c.g. o long, high c.g.	2,3		244	6
(7) Crosslevel	(sams as above)		2,3		539	1
(14) Coupler and Draft System	Low platform vehicular flatcars	o very long, med. c.g. ht.	3,4		317	3
(15) Side Bearings	70 and 100 ton covered hoppers	o med. lgth., high c.g.	2,3		233	7
(17) Plain Journals Overheated	70 ton gondolas & 70 ton covered hoppers	o short, med. c.g. ht. o medium length, low c.g.	3,4		307	4
(19) Broken Wheels	Low platform flat and vehicular flat cars.	o long, med. c.g. ht. o very long, low c.g. o very long, med. c.g.	3,4,5		255	5
(25) Excessive Buff/Slack Action	100 ton covered hoppers	o med. length, high c.g.	2,3,4		233	8
(29) Rail Head	(same as groups 4 and 7)		2,3		367	2

● average speed

△ median speed

├─┤ standard deviation

ton covered and open hoppers, some gondolas and tank cars and certain heavily loaded 100 ton 50 ft (outside length) box cars. These derailments occur primarily on Track Classes 2 and 3 (78%), at an average speed of about 28.7 mph. About 70 percent of these derailments occur at speeds between 15 and 35 mph.

This combination of vehicle configuration, average derailment speed, associated track class, and derailment cause codes implies derailments resulting from large amplitude carbody lateral and roll oscillations induced by periodic lateral track geometry irregularities. The harmonic roll problem is usually associated with variations in track crosslevel geometry (see below). However, the same effects may be produced by periodic track geometry irregularities in alinement since the lateral and roll motions of the vehicles are strongly coupled for vehicles which have high center of gravity heights.

2.11.2 Crosslevel Related Factors

Derailments resulting from excessive variations in track crosslevel geometry most frequently involve the same vehicle configurations as discussed above. Heavy, high c.g. cars with a truck center spacing between 35 and 45 ft are strongly associated with this cause group. These derailments occur primarily on Track Classes 2 and 3 (90 percent) at an average derailment speed of about 23 mph. About 78 percent of these derailments occur at speeds between 10 and 25 mph which corresponds to the carbody lateral/roll resonance speed range. The mechanics of the resonance involves the build-up of carbody roll oscillations, due to variations in track crosslevel geometry, until the carbody begins to rock off the center plate onto the side bearings. At this point severe roll oscillations and wheel-lift may occur as a result of non-linear kinematic effects associated with changes in carbody restraint after center plate separation occurs.[4*]

*Information is also to be found in the following internal document on file at the Transportation Systems Center. Railcar Harmonic Roll Response to Periodic Trade Crosslevel Variations, H. Weinstock, and H. Lee, WP No. 743-C-15-075, Transportation Systems Center, Cambridge MA, December 1979.

2.11.3 Coupler and Draft System-Related Factors

Derailments resulting from coupler and draft gear failures are primarily associated with very long vehicles with c.g. heights falling in the intermediate range. Low platform vehicular flatcars are the most common cartype identified with the cause group. The average derailment speed is about 34 mph but the percent distribution of these derailments is fairly uniform over the speed range from 15 to 50 mph. About 77 percent of these derailments occur on Class 3 and 4 track. These derailments probably result from a combination of lateral/yaw hunting motions and train action forces which impose relatively high stresses on the coupler and draft gear system.

2.11.4 Side Bearing-Related Factors

Derailments resulting from side bearings (missing, broken or improper clearance) are again most frequently associated with heavy, medium length, high c.g. cars, principally 70 and 100 ton covered hoppers. The average speed for these derailments is about 24 mph and 78 percent of these derailments occur on Track Classes 2 and 3. These vehicles, track classes and speed factors are very similar to those for the alinement and crosslevel cause groups previously discussed. Side bearing related failures and derailments are also symptomatic of the harmonic roll derailment process discussed above. In this process the carbody rocks off the centerplate and onto the side bearings, thus requiring the side bearings to support the entire carbody weight for brief intervals. Since side bearings are not designed to carry these loads, car-rocking in this manner would be expected to accelerate side-bearing failures. Because of similarities in derailment speed profiles, track classes, associated vehicle configurations and the dynamics associated with harmonic roll, the side bearing type of derailment is classed with those attributed to alinement and crosslevel track geometry variations. Together these three cause groups account for 41 percent of all derailments considered in this study.

2.11.5 Plain Journal-Related Factors

Derailments resulting from plain journal bearings overheating are most frequently associated with 70 ton gondola and 70 ton covered hoppers. There is also some correlation with 50 ton vehicles as a group. These cars are primarily short and medium length vehicles with low or medium c.g. heights. The average derailment speed is about 33.6 mph and about 82 percent occur on Track Classes 3 and 4. As expected, plain journal bearing failures due to overheating occur at relatively higher speeds and cartypes involved principally include 50 to 70 ton vehicles which tend to be equipped with plain rather than roller bearing trucks. These derailment factors do not suggest any particular derailment mode other than mechanical equipment failure.

2.11.6 Broken Wheel-Related Causes

Derailments resulting from broken wheels are most frequently associated with very long, low and medium c.g. height flatcars, especially low-platform vehicular flatcars. These derailments occur on higher classes of track (66 percent on Class 4 and 5 track) and have an average derailment speed of about 41 mph. The most frequent 5 mph speed band is 45 to 50 (see Figure C-6 in Appendix C) which falls squarely into the speed range associated with carbody hunting dynamics. Long light flatcars are also known to have a propensity to hunt in this speed range. The large dynamic motions and wheel/rail forces induced by hunting produce mechanical stresses in the wheel plate and tread which, in conjunction with larger thermal stresses which can be developed during braking, are probably responsible for these mechanical failures. Hunting motions and braking actions may represent principal factors in these derailments.

2.11.7 Excessive Buff/Slack Action-Related Factors

Derailments attributed to excessive buff and slack action are most frequently associated with heavy, high c.g. vehicles such as 100 ton covered hopper cars. This was a surprising result since train action forces were expected to have the greatest effect on very long, light cars which have long overhang distances between bolster and end of car. The average derailment speed is about 26 mph with about 66 percent of the derailments occurring at speeds between 10 and 25 mph. About 70 percent of the derailments occur on Track Classes 2 and 3. These speed, track class, and vehicle factors are all very similar to those for the harmonic roll derailment process as discussed above. However, the speed range associated with harmonic roll also coincides with a speed range in which much braking and tractive effort are applied. It may be possible that some combination of train handling factors and harmonic roll of heavy, high c.g. cars may be responsible for many of these derailments. This hypothesis may be reinforced by an unusual aspect of the harmonic roll response which arises from the non-linear kinematic behavior of this process. As train speed is increased into the roll resonance speed range of heavy, high c.g. cars, carbody roll angles begin to increase. If this roll motion is observed by the train crew, action may be taken to reduce train speed. Because of the unusual nature of the harmonic roll process, decreasing speed can often lead to an increase in roll amplitude. The combination of train action forces and harmonic roll of heavy, high c.g. cars may act together as an underlying, causal factor in these derailments.

2.11.8 Rail Head Failure-Related Factors

Derailments resulting from rail head failures are most frequently associated with medium length, medium and high c.g. cars, and long, high c.g. cars such as 100 ton covered hoppers. The average derailment speed is about 26 mph and 82 percent of these derailments occur between 10 and 30 mph. About 85 percent occur on Track Classes 2 and 3. These factors imply that rail-head failures may not be induced so much by speed as by other mechanisms such as accumulated damage resulting from lower-speed, vehicle track dynamic interaction. These derailments are logically associated with the relatively heavy axle loads typical of 100 ton cars. The generic, physical characteristics of freight vehicles involved in this derailment group and speed and track class factors again suggest that harmonic roll of high c.g. vehicles may contribute to these derailments. In this process, under severe rocking, the vertical springs of the truck suspension may bottom out on one side of the freight truck while wheel-lift, or largely reduced vertical wheel loads, may occur on the opposite side. This wheel lift condition could approximately double the static vertical wheel load and increase the lateral wheel/rail load for the wheel which remains in contact with the rail for relatively long periods, approaching 1 sec. in duration. This means that for vehicles traveling at speeds of about 20 mph, the heavy wheel load would be sustained for about 30 ft of track which implies the possibility of accelerating rail flaw growth through an increased exposure of rail flaws to heavy loads. In addition, since the suspension system is bottomed out under these circumstances, other deviations in track geometry could cause even higher vertical loads to occur.

2.12 FREIGHT VEHICLE CONFIGURATIONS HAVING HIGH INCIDENCE AND FREQUENCY OF DERAILMENT

From the preceeding discussion and the data contained in Tables 2-5 and 2-12, and in Appendix C, it is apparent that heavy 100 ton freight vehicles, having truck center spacings in the range of 35-45 ft and carbody c.g. heights greater than 90 inches (above top of rail), have an unusually high derailment incidence and mileage weighted derailment frequency. This class of vehicle includes a substantial percentage of covered hopper cars and relatively small percentages of open hopper, gondola and box cars. A substantial number of tank cars is also included in this category; however, these cars do not show up as strongly in the overall derailment statistics. This suggests that there may be some physical distinction between tank cars and others having higher derailment frequencies. It may be quite significant that the roll inertia of 100 ton tank cars (with truck spacings of 35 to 45 ft and comparable c.g. heights over 90 inches) is approximately 50 percent of typical roll inertias for similar 100 ton covered hopper cars. It may also be possible that motion of the fluid cargo aids in damping roll oscillations. No difference in truck suspensions are known to exist.

Long and very long freight vehicles having truck center spacings between 45 to 55 and 55 to 70 ft respectively, also have a high relative frequency of derailment. These cars include low platform vehicular flatcars typically 93 ft in length, and with 63 to 66 ft truck center spacings. The following table summarizes cartypes having both high incidence and frequency of derailment (Ref. Table 2-5) relative to the fleet average of 6.45 derailments per 10^8 miles.

Cartype and Truck Capacity	Number of Derailments (Loaded & Unloaded)	Derailments per 10^8 Miles
100 Ton Covered Hopper	909	12.4
70 Ton Covered Hopper	226	10.1
70 Ton Tank	33	9.6
70 Ton Gondola	194	8.9
Low Platform Vehicular Flat	111	9.2
100 Ton Open Hopper	269	8.1
70 Ton Flatcar	411	6.7

The following cartypes have a relatively low derailment frequency compared to the fleet average

Cartype and Truck Capacity	Number of Derailments (Loaded & Unloaded)	Derailments per 10^8 Miles
100 Ton Tank	157	5.8
70 Ton Box	546	5.5
All Refrigerator Cars	268	4.97
50 Ton Box	460	4.8
50 Ton Tank	74	4.4
100 Ton Gondola	116	3.8
100 Ton Box	68	3.4

As previously discussed, the derailment frequencies associated with loaded vehicles as compared to unloaded ones is substantially higher for virtually every cartype or generic vehicle configuration (Ref. Tables 2-7 and 2-14).

Each of the following cartypes has a relatively high incidence and frequency of derailment per loaded carmile compared to the fleet average of 8.79 derailments per 10^8 loaded vehicle miles.

Cartypes and Truck Capacity	Number of Derailments (Loaded)	Loaded Derailments per 10^8 Carmiles
100 Ton Covered Hopper	800	22.1
70 Ton Covered Hopper	196	17.7
70 Ton Tank	26	15.7
100 Ton Open Hopper	234	13.4
70 Ton Gondola	158	12.5

Each of the following cartypes has a relatively low frequency of derailment per loaded carmile compared to the fleet average.

Cartypes and Truck Capacity	Number of Derailments (Loaded)	Loaded Derailments per 10^8 Carmiles
70 Ton Boxcars	375	6.2
100 Ton Gondola	97	5.5
50 Ton Boxcar	322	5.4
70 Ton Refrigerator	131	5.4

2.13 CONCLUSIONS

The foregoing discussions regarding freight vehicle derailment scenarios and vehicle configurations having relatively high derailment incidence and mileage weighted frequencies of derailment suggest the following considerations in establishing improved performance based safety standards for track.

- A specification for track geometry variations in cross-level which is capable of controlling or minimizing the harmonic roll process has the greatest potential for reducing derailments attributable to excessive vehicle/track dynamic interaction. This is particularly applicable to Class 2 and 3 track which may have a relatively large percentage of track constructed of 39 ft staggered joint rail. Since a number of other derailment scenarios also imply the strong involvement of the harmonic roll process, the potential benefits to be derived from such a specification could have a positive effect on reducing the number of derailments attributed to other causal factors such as side bearing failures. Rail head failures and derailments which may involve combined train action and harmonic roll dynamics might also be reduced.

- The next most important track geometry parameter with respect to the freight vehicle derailments is variation in track alinement. From the scenario discussed for these derailments, it appears that many of these derailments are also a result of a harmonic roll process excited by lateral track irregularities. This process whether excited by track geometry variations in crosslevel or alinement, appears to be a significant influence in many of the principal dynamics-related cause group scenarios discussed above. A specification for track geometry variations in alinement which is capable of controlling or minimizing harmonic roll oscillations resulting from lateral track irregularities, especially on Class 2 and 3 track, is desirable.

- Development of specifications for controlling variations in track crosslevel geometry and for alinement deviations as discussed above should be coordinated and/or integrated such that an effective level of control is attained. Control of either track geometry parameter without the other may not produce the desired effect. In order to accomplish this, extended parametric studies of freight car rocking response to crosslevel and/or alinement track irregularities vs speed should be conducted. Analytical tools suitable for both detailed and parametric analysis of freight car lateral/roll response and engineering data characterizing the freight vehicle fleet (Ref. Appendix A) have been developed under the AAR/Track-Train Dynamics Program and FRA sponsored research activities. The AAR has long recognized the severity of the harmonic roll problem and has completed a limited but fairly detailed study for selected cases*. Initial parametric studies have been conducted at TSC to develop a pilot specification for track crosslevel geometry.

Interrelationships between freight vehicle physical characteristics, speed, and combinations of track alinement and/or crosslevel variations should be determined. Principal physical characteristics affecting harmonic roll include: truck suspension and carbody/bolster interface parameters, truck center spacing, carbody mass, roll inertia and center of gravity height. This study should provide information suitable for developing improved track geometry standards and may also be useful to carbuilders and equipment manufacturers in designing freight vehicles and components with improved dynamic response characteristics.

- The number of freight vehicle derailments experienced on Class 2-6 main line track, at speeds above 10 mph, which are attributed to (a) variations in track superelevation, (b) track surface irregularities, and (c) gage widening is relatively small and does not indicate a correlation between freight vehicle derailments and their speed and track conditions.

  Gage widening is primarily associated with low speed derailments on Class 1 main line track or derailments on yard, siding or industrial track. These statistics imply that improved specifications for track geometry variations in gage and rail restraint specifications would be best applied to this track.

  There is some data[5] which indicates that gage widening on certain classes of main line track may be

* Harmonic Roll Series, International Government--Industry Research Program on Track-Train Dynamics, AAR-FRA-RPI-TDA.

associated with heavy six-axle locomotives in curve negotiation. This class of derailments was beyond the scope of this study and is not discussed herein. A future study of locomotive derailments would provide useful insight into gage and rail restraint requirements for reducing locomotive derailments.

- The most frequently derailing freight vehicles include loaded, 100 ton cars having high center of gravity heights (i.e., greater than 90 inches) and truck center spacings of 35 to 45 ft. Loaded 100 ton covered hopper cars are typical of this configuration but certain groups of fully loaded 100 ton box, gondola tank and open hopper cars also fit this category. These cars have been associated with derailments attributed to variations in track alinement and crosslevel geometry, and derailments related to side-bearing failures, excessive buff and slack train action and rail-head failures. All of these principal cause categories may be related to large carbody motions and wheel-rail forces arising from harmonic roll.

  Very long, low and medium center-of-gravity height cars, typically flatcars and vehicular flatcars also have relatively high derailment frequencies on a miles-traveled basis. Typical causal factors include coupler and draft system failures and broken wheel components. The derailment speed profiles indicate that these derailments generally occur at higher speeds with the largest percentage occurring on Class 4 track. These causal factors and derailment speed profiles may imply excessive car hunting and associated lateral/yaw dynamics.

  A substantial number of derailments have resulted from plain journal bearing failures due to overheating. Associated cartypes include smaller 70 ton truck gondolas and covered hopper cars and cars equipped with 50 and 70 ton trucks in general. These cars are probably older vehicles. Newer cars are being equipped with roller bearing trucks.

- Loaded freight vehicles have a substantially higher incidence and frequency of derailment than unloaded cars with the exception of vehicular flat cars, 100 ton box and tank cars and 70 ton truck refrigerator cars. This trend is particularly applicable to covered and open hopper cars and heavier gondolas. These cars are bulk carriers and are usually loaded to full volumetric (and weight) capacity. The mileage weighted derailment frequency for loaded 100 ton tank cars is lower than the average for all loaded freight vehicles and is about 50% of the average for all 100 ton cars (Ref. Table 2-7).

  The group of cars having the highest derailment frequency in the unloaded condition is vehicular flatcars equipped with low level trucks.

- The mileage weighted derailment frequencies computed in this study must be regarded as estimates since the annual mileage data developed for each distinctive vehicle design group (refer to the discussion of Appendix A) is an estimate. While the mileage data is not exact, it is considered to be a good approximation of relative vehicle utilization. Small differences in derailment frequency should not be considered significant; however, larger ratios of derailment frequency between two vehicle configurations may be considered a good indicator of relative derailment frequency. An outline of the approximations used in this study is contained in Appendix B.

- This analysis is limited to the study of derailments which imply excessive vehicle/track and vehicle/vehicle dynamic interaction at speeds greater than 10 mph on Class 2-6 main line. Because of inherent limitations and uncertainties associated with using the RAIRS accident data, and the approximations required to develop physical characteristics of the fleet of railcars and associated loading and average mileage data, the derailment incidence and mileage-weighted derailment frequency data contained herein should be considered as an indicator of relative derailment frequency between various groups of vehicles rather than an absolute indicator of derailment frequency. For a more complete discussion of the nature of these limitations and uncertainties, refer to the discussions in Appendix B.

APPENDIX A

A PROFILE OF THE PHYSICAL CHARACTERISTICS AND COMPOSITION OF THE U.S. FREIGHT VEHICLE FLEET

Under contract DOT/TSC-1362, entitled "Engineering Data for Characterization of Railway Rolling Stock and Representative Ladings and Wheel Profiles," Pullman Standard R&D of Hammond Indiana has provided a physical characterization of the current fleet of U.S. railway rolling stock including locomotives, freight and passenger vehicles. For each vehicle type, major categories were defined which are dimensionally similar in terms of overall configuration and as such, are representative of "standard" or "equivalent" vehicle design groups having large populations. The AAR's Universal Machine Language Equipment Register (UMLER) was sorted and analyzed to define dimensionally equivalent groups of freight vehicles and associated populations. A similar approach was used for locomotive and passenger vehicle characterizations. However, the relatively small number of these vehicles allowed a more direct definition of distinctive vehicle design groups. The remainder of this section contains:

(a) An overview of the methodology used to generate the freight vehicle data, and

(b) A profile of the physical characteristics and composition of the U.S. freight vehicle fleet as abstracted from the data developed by Pullman Standard.

A.1 METHODOLOGY OVERVIEW

To model the dynamic response of railcars to vertical and lateral track geometry and stiffness variation, and to assess railcar stability, curving performance and other measures of performance, a physical description of each (distinctive) railcar configuration and suspension is needed in sufficient detail to characterize all principal physical attributes which influence the various excitation/response modes of interest. Table A.1

TABLE A-1. ENGINEERING PARAMETERS FOR FREIGHT VEHICLE CHARACTERIZATION AND PRINCIPAL DATA SOURCES

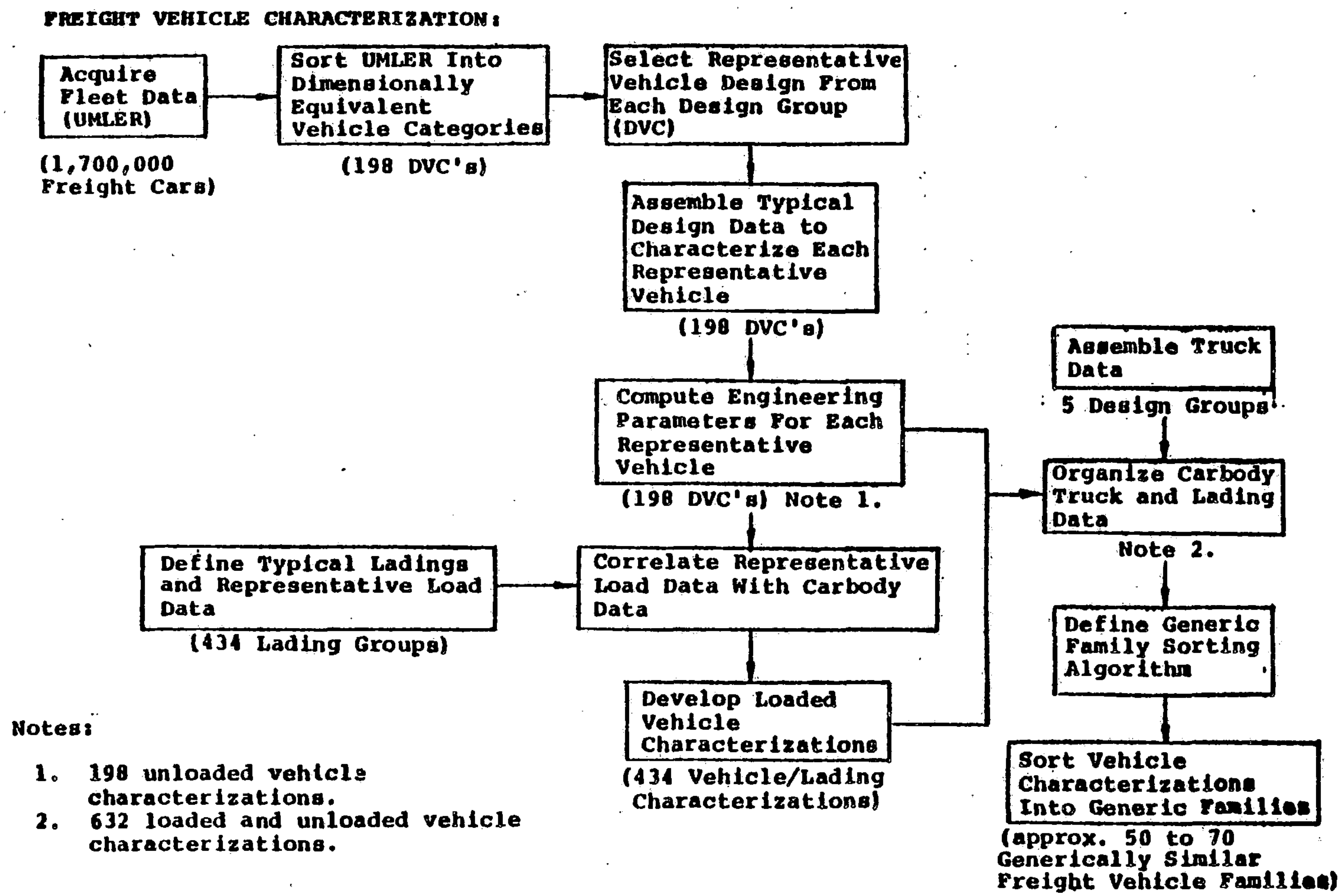
PARAMETER DESCRIPTION	PRINCIPAL SOURCES
Carbody Mass	Published Literature
Carbody Geometric Configurations	Published Literature
Loaded Car Mass	Published LIterature
Length of Coupler	Published Literature
Carbody Center of Gravity	Computation
Lading Center of Gravity, Density, Stiffness, Mass	Published Literature
Carbody Moments of Inertia (roll, pitch, yaw)	Computation
Carbody Stiffness (vertical, lateral, torsional)	Computation
Carbody First Bending Mode Frequency (vertical, lateral, torsional)	Computation
Assembled Truck Mass	Manufacturers Data
Truck Geometric Configuration	Manufacturers Data
Assembled Truck Moment of Inertia (roll, pitch, yaw)	Published Literature
Assembled Truck Centerplate to Rail Stiffness (vertical, lateral, roll, pitch, yaw)	Manufacturers Data & Computation
Truck Bolster to Sideframe Stiffness (vertical, lateral, roll, pitch, yaw)	Manufacturers Data & Computation
Truck Sideframe to Wheelset Stiffness (vertical, Lateral)	Manufacturers Data & Computation
Truck Bolster to Sideframe Damping	Manufacturers Data & Published Literature
Centerplate Yaw Friction	Published Literature
Truck Bolster to Sideframe Clearance (vertical, lateral, longitudinal)	Manufacturers Data & Computation
Truck Sideframe to Axle Yaw Clearance	Manufacturers Data &
Side Bearing Distance from Centerline and Clearance	Published Literature
Bolster Bowl Diameter and Center Pin Height	Published Literature
Centerplate-Bolster Bowl Net Clearance	Manufacturers Data

contains an overview of the information required for vehicle simulation modeling.

The fundamental problem associated with developing such data for the fleet of 1.7 million U.S. freight vehicles at this level of detail, involves making reasonable tradeoffs between extremes of detail and accurate representation. Figure A-1 illustrates the basic methodology used to develop detailed engineering descriptions for major and distinctive vehicle design groups. These groups are representative of "standard" or "equivalent" vehicle designs which have significant populations in the freight vehicle fleet. In the aggregate, these vehicle descriptions and associated group populations, representative lading data, empty and loaded car mileage data, and engineering data describing freight vehicle trucks approximates the composition, physical characteristics and relative utilization of the fleet of U.S. freight vehicles. This data has been developed with sufficient accuracy and scope for use in analytical simulation modeling to predict vehicle/track dynamic interactions for the range of freight vehicles in operation over the nation's track system. The data has also been useful to approximate more detailed physical characteristics of derailed freight vehicles as described in Appendix B.

A.1.1 Definition of Major and Distinctive Groups of Freight Vehicles

Fleet register data contained in UMLER provided basic dimensional and design-related data describing 1.7 million U.S. freight vehicles. The UMLER data was initially sorted to group vehicles on the basis of similar mechanical design and function. Separate groups were thus established for box, stock, refrigerator, covered hopper, open hopper, gondola, flat (including TOFC), vehicular flat and tank cars. Since each of these car types has a significant population and individual cars (within a mechanical car type) exhibit large variations in lengths, capacities and other design-related factors it was necessary to establish subgroups within each mechanical car type whose members would have relatively small design vari-



Notes:

1. 198 unloaded vehicle characterizations.
2. 632 loaded and unloaded vehicle characterizations.

FIGURE A-1. OVERVIEW OF METHODOLOGY USED IN FREIGHT VEHICLE CHARACTERIZATION ations. This is an important consideration, necessary to provide reasonable characterizations of vehicles in each subgroup and the fleet as a whole. The subgroups were developed by re-sorting the vehicles in each car type category into a matrix of ranges on primary and secondary vehicle design characteristics describing each car type, based on data contained in UMLER. Initial subgroup definitions were developed based on car-builder's knowledge of fleet composition and construction practices and on manual screening of fleet register data. This process was repeated for each car type until subgroup definitions were completed. Each design group identified in this manner essentially represents a "standard" or "equivalent" vehicle design having a significant population. Further sorting yielded dimensional data and populations for 198 distinctive vehicle configurations describing box, stock, refrigerator, covered hopper, open hopper, gondola, TOFC and general flat, vehicular flat and tank cars. Approximately 96 percent of the 1.7 million U.S. freight vehicles are represented by the 198 categories. For each cartype, the number and relative populations of distinctive vehicle design categories is indicated in Figure 1-1 (of Section 1).

A single railcar design was selected from each of the dimensionally similar design groups, which was representative of the entire group population. A more detailed physical description was then developed for this particular vehicle by assembling detailed structural data from design drawings and by assimilating data from the literature, the fleet register, equipment manufacturers, FRA and AAR/TTD sponsored test programs and/or by computational methods. Nominal values of all principal dimensions, masses, inertias and suspension characteristics were developed for each representative vehicle. Since each design group definition is based largely on dimensional data, these groups may alternatively be referred to as Dimensional Vehicle Categories (DVCs). Table A-2 indicates typical DVC definitions for box cars in terms of ranges of principal dimensions or design-related parameters and the corresponding nominal data describing a vehicle design repre-

TABLE A-2. DVC DEFINITIONS

WEIGHT CAPACITY			TARE WEIGHT	
LOW	N	HIGH	LOW	N
100.	110.	120.	50.0	32.0
100.	110.	120.	50.0	52.0
100.	100.	110.	47.0	47.0
88.	110.	116.	60.0	62.0
100.	110.	120.	43.0	47.0
100.	110.	120.	54.0	58.3
100.	110.	120.	54.0	58.3
95.	100.	107.	70.0	73.0
140.	149.	160.	56.0	63.5
140.	149.	160.	56.0	63.5
140.	149.	160.	56.0	63.5
130.	140.	174.	75.0	78.0
130.	140.	174.	75.0	78.0
140.	150.	150.	64.0	69.0
130.	134.	140.	75.0	81.0
180.	188.	200.	66.0	73.0
180.	188.	200.	66.0	73.0
125.	133.	155.	80.0	85.0
125.	133.	155.	80.0	85.0
180.	182.	200.	69.0	76.0
180.	182.	200.	69.0	76.0
165.	173.	181.	81.0	87.0
165.	173.	181.	81.0	87.0
100.	102.	110.	108.0	113.0
140.	142.	150.	110.0	114.0

(N

FOR BOX CARS (WITH CORRESPONDING NOMINAL DATA)

	OUTSIDE LENGTH			INSIDE LENGTH		
HIGH	LOW	N	HIGH	LOW	N	HIGH
56.0	44.0	44.5	45.9	40.0	40.5	40.9
56.0	44.0	44.5	45.9	40.0	40.5	40.9
56.0	47.0	48.0	48.9	40.0	40.5	40.9
67.0	44.0	44.5	45.9	40.0	40.5	40.9
49.0	44.0	44.5	44.9	40.0	40.5	40.9
64.0	54.0	54.5	54.9	50.0	50.5	50.9
64.0	54.0	54.5	54.9	50.0	50.5	50.9
80.0	54.0	54.5	58.9	50.0	50.5	50.9
71.0	54.0	54.5	55.9	50.0	50.5	50.9
71.0	57.0	58.0	58.9	50.0	50.5	50.9
71.0	57.0	58.0	58.9	50.0	50.5	50.9
82.0	57.0	58.0	58.9	50.0	50.5	50.9
82.0	57.0	58.0	58.9	50.0	50.5	50.9
74.0	59.0	60.4	60.9	50.0	50.5	52.9
85.0	59.0	60.4	60.9	50.0	52.5	52.9
82.0	55.0	55.4	56.9	50.0	50.5	50.9
82.0	57.0	58.0	60.9	50.0	50.5	50.9
98.0	67.0	68.1	68.9	60.0	50.5	60.9
98.0	67.0	68.1	68.9	60.0	60.8	60.9
79.0	67.0	68.1	68.9	60.0	60.8	60.9
79.0	67.0	68.1	68.9	60.0	60.8	60.9
95.0	67.0	68.1	68.9	60.0	60.8	61.9
95.0	67.0	68.1	68.9	60.0	60.8	61.9
120.0	92.0	93.5	93.9	86.0	86.5	86.9
120.0	92.0	92.9	93.9	86.0	86.5	86.9

= nominal DVC descriptor)

sentative of the entire group. It can be seen from this table that the variations in principal dimensions and design-related features between vehicles in each design group are generally small. Variations from the representative railcar design are also generally small.

A.1.2 Freight Vehicle Truck Characterizations

Data was compiled to describe the principal physical characteristics of 50, 70, 100, 125 ton capacity trucks and a special (low-level) truck design used with certain flat cars. These descriptions characterize the preponderance of truck designs in current use in terms of principal masses, inertias and suspension characteristics in suitable detail for analytic simulation modeling. The 50, 70 and 100 ton capacity trucks account for approximately 24 percent, 43 percent and 32 percent respectively, of the freight vehicle truck population. Truck designs have been correlated with carbody designs, i.e., the Dimensional Vehicle Categories, by summing the vehicle's lightweight and weight capacity and comparing this total with the rail load limits for various truck capacities. This permits a single and valid correlation. Vehicle weight classes are typically described in terms of their corresponding truck capacities since this provides a much better indication of total (loaded) vehicle weight than by simply using the nominal carbody weight capacity. The ratio of nominal weight capacity to vehicle tare weight can vary from about 0.8 (for an enclosed vehicular flat car) to about 3.7 (for an open hopper car) for common railcar designs. The large variation in this ratio indicates that information on both carbody weight capacity and tare weight is necessary to properly establish a vehicle's weight class in terms of total rail weight.

A.1.3 Definition of Representative Ladings and Freight Car Mileage Data

Representative ladings and loaded freight car mileage data have been defined for each mechanical car type through analysis of the FRA's Waybill Sampling Tapes supplemented by ICC Freight Commodity Statistics and Pullman's knowledge of car commodity relationships. A detailed description of this methodology is contained in Ref. 1. Because this data has been used extensively in this study and is central to the results, a fairly detailed overview of the methodology used to approximate mileage data and average load conditions is presented in the following paragraphs. It should be noted that this data has been developed as part of a fleet characterization effort to provide engineering data on vehicles and ladings for studies in rail systems dynamics. The form and completeness of the data makes it useful to the study at hand although it has not been developed specially for this purpose.

The waybill data is a one percent sample of all carloads originating on Class 1 railroads. Principal data taken from the waybill records includes: commodity data (as defined by Standard Transportation Commodity Codes), AAR car types, carload weight, and carload mileage information. The ICC data provided information on total annual carloadings by commodity.

For each car type, carload-weight distributions were developed for principal commodities carried by that car type. This distribution was developed through analysis of the 1 percent waybill data and indicates number of carloads of a specific commodity shipped in various load-weight ranges. Commodities having similar densities were generally aggregated and handled together in "commodity density groups."

A similar carload-mileage distribution was developed for the corresponding commodity group and used to estimate an average mileage per carload for that car type/commodity combination. Analysis of the waybill data typically considered 85 to 90 percent of all commodities carried by each mechanical car type.

Analysis of the resulting car type/commodity data indicated that certain mechanical car types such as covered hopper, open top hopper, vehicular flat, stock and tank cars (about 50 percent of the DVCs) were essentially commodity and load dependent and, as such, "typical ladings" could be characterized by a single average load, volume, and average trip length per carload. Commodity density groups tend to correlate with vehicle weight and volumetric capacity since many of these cars were designed to carry bulk commodities having a specific density. Other mechanical car types such as box, refrigerator, gondola and flat car tend to be commodity independent, hence multiple "representative" ladings are required to describe typical loads carried by these vehicles. In many instances however, a single commodity density group is dominant for these vehicles also. The following discussion outlines the methodology used in developing representative lading data for commodity independent cars such as boxcars. Variations in the methodology as applied to other car types are described in Reference [1].

After developing the carload-weight distributions from the 1 percent waybill data for commodity density groups, the total number of carloads shipped in each carload-weight (and carload mileage) distribution was then "scaled" to equal the total annual carloads shipped as reported by the annual carload-commodity statistics published by the ICC Freight Commodity Statistics, Class I Railroads. The actual mechanics of this approximation involves taking the carload-weight distribution as obtained from the 1 percent waybill and converting it to a "percentage carload distribution." This is done by dividing the number of carloads carried in each weight range by the total carloads carried as found from the 1 percent waybill.* The "percentage carload distribution" is then multiplied by the carload total (for that commodity) as reported by the ICC to obtain a "total" carload-weight distribution. The resulting total carload-weight distribution is intended to be more representative of total carloads shipped, than that obtained by simply multiplying the 1 percent waybill distributions by 100.

An average mileage per carload was computed for each commodity group (from the carload-mileage distribution) by summing the

*For the particular cartype/commodity group combination being considered.

product of carloads times mileage in each mileage range and dividing by number of carloads.

The next step in the methodology disaggregated the carload weight distribution into separate distributions corresponding to major vehicle weight capacity groups. For commodity independent cartypes, an assumption was made that the number of carloads carried by each vehicle weight capacity group was proportional to the number of vehicles available to carry a load in a particular load range.

For example, the fleet of boxcars has three distinct weight capacities typically described by vehicles equipped with 50, 70 and 100 ton trucks.*

Carloads in excess of 154,000 lbs were assigned entirely to 100 ton cars since these loads typically exceed the weight capacities of 50 and 70 ton cars. Similarly, carloads in the 120,000 to 154,000 lb range were assigned to 70 and 100 ton cars in proportion to their relative populations, and carloads less than 120,000 lbs were assigned to 50, 70 and 100 ton cars in proportion to the percent population of 50, 70 and 100 ton cars. Boxcar truck capacity groups, approximate weight capacity ranges, percent populations and carload distribution factors are described in the following table.

			Carload Distribution Factors		
Truck Capacity Group	Approximate Vehicle Weight Capcity Range	Percent of Box-Car Population	0-120,000 lbs	120,000 to 154,000 lbs	154,000 to 210,000 lbs
50 tons	0-120,000 lbs	50.9%	50.9%	-	-
70 tons	0-154,000 lbs	42.3%	42.3%	86%	-
100 tons	0-210,000 lbs	6.8%	6.8%	14%	100%

* For the purpose of correlating loads with vehicle design groups, the vehicle weight capacity is the parameter which has been used in making the correlation. For boxcars, the three vehicle weight capacity groups correspond very closely to vehicles equipped with 50, 70 and 100 ton trucks. However, there are some small exceptions.

For each car-commodity group, an estimate of total annual mileage traveled by each vehicle weight capacity group was computed based on total carloads carried by that group (determined by summing carloads in the disaggregated carload-weight distribution), times the average mileage per carload computed for the car commodity group.

For box cars, five commodity density groups were defined and typical loads were characterized in terms of average density, weight per carload, volume per carload and mileage per carload. Table A-3 contains average boxcar lading data for five principal commodity density groups in three vehicle weight capacity ranges. Specific load characterizations are correlated with vehicle design groups (i.e., DVCs) according to weight capacity (for boxcars). Carloads (and estimated annual mileage) are allocated to various design groups having similar weight capacities, in proportion to design group populations. The empty car mileage shown in Table A-3 was estimated using ratios of empty to loaded freight car mileage for various mechanical car types. These ratios were taken from data published by the ICC Bureau of Accounts. Similar data has been developed for other commodity-independent car types (refrigerator, gondola and flat cars). The remaining car types are essentially commodity-dependent and typical loads may be characterized by a single representative load description.

Representative lading descriptions and estimated mileage data have been used in this study to approximate the physical characteristics of derailed freight vehicle carrying loads and to approximate total annual mileages traveled by empty and loaded freight vehicle configurations. This is discussed further in Appendix B.

A.2 COMPOSITION AND PHYSICAL CHARACTERISTICS OF THE U.S. FREIGHT VEHICLE FLEET

To summarize the discussion of Section A.1, the U.S. freight vehicle fleet may be described by a total of 198 major and distinctive vehicle design groups characterizing the nine mechanical

TABLE A-3. BOX CAR LADING DATA SUMMARY - AVERAGE CONDITIONS

WEIGHT CAPACITY	LADING CODE	DENSITY RANGE	AVERAGE DENSITY	AVERAGE WT. PER CARLOAD	AVERAGE VOL. PER CARLOAD	NO. OF CARLOADS (1000's)	AVERAGE MILES PER CARLOAD	TOTAL MILES (1000's)
0-120 k	1	Empty	—	—	—	—	—	1,325,133
	2	11-19	16.6	34.5	2078	686.53	780.82	536,056
	3	24-40	33.1	72.04	2176	1259.22	778.66	980,504
	4	44-60	51.6	89.58	1736	509.69	476.59	242,913
	5	61-100	97.6	54.47	558	87.48	500.58	42,791
	6	101-155	138.9	75.62	544	163.18	650.95	106,222
0-154 k	7	Empty	—	—	—	—	—	1,392,596
	8	11-19	16.6	37.32	2248	585.75	780.82	457,365
	9	24-40	33.1	91.86	2775	1271.84	778.66	990,331
	10	44-60	51.6	109.93	2130	729.84	476.59	347,834
	11	61-100	97.6	64.09	657	82.04	500.58	41,069
	12	101-155	138.9	192.67	739	239.06	650.95	155,616
0-210 k	13	Empty	—	—	—	—	—	273,215
	14	11-19	16.6	43.07	2595	98.43	780.82	76,856
	15	24-40	33.1	105.95	3201	256.91	778.66	200,046
	16	44-60	51.6	114.69	2223	154.02	476.59	73,404
	17	61-100	97.6	99.09	1015	18.73	500.58	9,376
	18	101-155	138.9	121.87	877	52.23	650.95	33,999

0-154 k

LIST OF COMMODITIES BY LADING CODE

LADING CODE	CHARACTERISTIC COMMODITIES	DENSITY lbs/cu.ft.
1	Empty Car Code	—
2	Furniture, Textiles, Tobacco Products, Rubber & Plastic Products, Transportation Equipment	11-19
3	Food & Kindred Products, Lumber, Pulp & Paper, Machinery	24-40
4	Field Crops, Chemicals, Stone, Clay, Glass	44-60
5	Non-Metallic Minerals, Fabricated Metal Products	61-100
6	Metallic Ores, Primary Metal Products, Waste & Scrap	101-155
7	Empty Car Code	—
8	Same as 2	—
9	Same as 3	—
10	Same as 4	—
11	Same as 5	—
12	Same as 6	—
13	Empty Car Code	—
14	Same as 2	—
15	Same as 3	—
16	Same as 4	—
17	Same as 5	—
18	Same as 6	—

cartypes. Each design group contains a significant number of vehicles whose physical characteristics usually have very small deviations (e.g., less than 10 percent) from a nominal vehicle design selected to represent the entire group. Expanded physical descriptions of each representative vehicle have been developed, and these descriptions have been used to approximate the physical characteristics of the respective design groups. Representative ladings, average load conditions, and estimates of total annual miles traveled by commodity dependent and commodity independent cartypes have also been defined. This data is used to (a) provide a profile of the physical characteristics of the fleet of U.S. freight vehicles (b) approximate physical characteristics of loaded or empty freight vehicles involved in derailments and (c) approximate freight vehicle derailment rates on a per-miles-traveled basis for various freight vehicle configurations. The following discussion outlines the data developed in Reference 1 to describe the composition and physical characteristics of the fleet of U.S. freight vehicles. This description is a prerequisite to interpreting a profile of freight vehicle derailments. Approximations of the physical characteristics and derailment incidence and frequency of derailed freight vehicles are discussed in subsequent chapters.

Table A-4 and Figure 1-1 (in Section 1) summarize the number of major and distinctive freight vehicle design groups (DVCs) and vehicle/lading combinations developed to characterize various mechanical cartypes. Empty car data is contained in Part A of Table A-4 and indicates population and relative population data for various car types. Loaded car data is shown in Part B. Table A-5 illustrates typical data assembled to characterize each of the DVCs using covered hopper cars as an example (only data describing two of the twenty-five covered hopper DVCs is shown). The descriptions are composed of UMLER-related data and parameters developed by computational methods. Similar descriptions have been developed for each of the 198 design groups. Most of the computed parameters are load-dependent and are recomputed for each load condition

TABLE A-4. DIMENSIONAL VEHICLE CATEGORY SUMMARY DATA

PART A.- UNLOADED FREIGHT VEHICLES

MECHANICAL CAR TYPE	NO. OF DVC's	POPULATION (ALL DVC's)	RELATIVE POPULATION (%)	ANNUAL MILAGE (ALL DVC's)	ANNUAL MILAGE (%)
BOX	25	458.2×10^3	27.5	2577.2×10^6	40.1
STOCK	2	4.9×10^3	0.3	8.2×10^6	0.1
REFRIG	21	94.4×10^3	5.7	451.6×10^6	7.0
COVERED HOPPER	25	226.8×10^3	13.6	868.5×10^6	13.5
OPEN HOPPER	30	355.9×10^3	21.4	753.5×10^6	11.7
GONDOLA	27	183.8×10^3	11.0	444.0×10^6	6.9
FLAT w/END BULKHEAD	11	42.3×10^3	2.5	133.5×10^6	2.1
FLAT w/o END BULKHEAD	15	89.9×10^3	5.4	534.2×10^6	8.3
VEHICULAR FLAT	6	33.0×10^3	2.0	237.6×10^6	3.7
TANK	36	177.4×10^3	10.6	421.9×10^6	6.6
TOTALS	198	1666.6×10^3*	100.0%	6430.2×10^6	100.0%

PART B - LOADED FREIGHT VEHICLES

MECHANICAL CAR TYPE	NO. OF DVC/ LADING COMBINATIONS	ANNUAL MILAGE (LOADED DVC's)	ANNUAL MILAGE (%)
BOX	150	4808.0×10^6	35.5
STOCK	2	15.2	0.1
REFRIG	42	1161.0	8.6
COVERED HOPPER	25	1719.8	12.7
OPEN HOPPER	30	1582.7	11.7
GONDOLA	75	1159.4	8.5
FLAT w/END BULKHEAD	29	338.0	2.5
FLAT w/o END BULKHEAD	39	1509.7	11.1
VEHICULAR FLAT	6	475.1	3.5
TANK	36	793.4	5.8
TOTALS	434	13562.3×10^6	100.0%

* THIS POPULATION REPRESENTS ABOUT 95% OF ALL UMLER VEHICLE RECORDS.

TABLE A-5. ENGINEERING PARAMETER DESCRIPTIONS OF COVERED HOPPER CARS BY DIMENSIONAL VEHICLE CATEGORIES

	PARAMETER OR DESCRIPTOR	UNITS	COVERED HOPPER CAR DIMENSIONAL VEHICLE CATEGORY NO.		
			1	2	25
SORTED UMLER DATA	VOLUMETRIC CAPACITY	ft^3	2000	2000	5280
	INSIDE LENGTH	ft-in	29'-3"	27	63'-6"
	OUTSIDE LENGTH	ft-in	36'-0"	44	68'-3"
	EXTREME HEIGHT	ft-in	13'-2"		15'-6"
	WEIGHT CAPACITY	kip	149		194
	LIGHT WEIGHT	kip	51.2		68.6
	DRAFT GEAR	-	STD		STD
	TRUCK CENTERS	ft-in	25'-0"		54'-0"
	POPULATION	-	33,151		4546
	% POPULATION	%	13.7		1.9
	% TRUCK BEARINGS R-ROLLER; P-PLAIN	-	R - 76 P - 24		R - 100 P - 0
LADING	LOADED/UNLOADED	-	UNLOADED		UNLOADED
	LADING CODE	-	N/A		N/A
	ANNUAL MILAGE	mi	126×10^6		10.5×10^6
COMPUTED ENGINEERING PARAMETERS	CARBODY MASS	lb-sec^2/in	84.6		125.8
	CARBODY YAW INERTIA	in-lb-sec^2	1.15×10^6		6.84×10^6
	CARBODY PITCH INERTIA	in-lb-sec^2	1.15×10^6		6.94×10^6
	CARBODY ROLL INERTIA	in-lb-sec^2	2.76×10^5		5.55×10^5
	c.g. HEIGHT	in	74.1		80.8
	LENGTH B. COUPLER PINS	in	402.8		789.8
	LENGTH OF COUPLER	in	29.3		29.3
	VERTICAL BENDING FREQ.	Hz	59		24.2
	LATERAL BENDING FREQ.	Hz	46.5		20.8
	TORSIONAL FREQUENCY	Hz	21.3		12.3
	TRUCK CODE	-	2		3
	DVC CODE	-	4-1		4-17
	GENERIC FAMILY CODE	-	N/A		N/A

identified with each design group. This results in an additional 434 loaded vehicle characterizations. One of the five truck descriptions discussed in Section A.1 has also been associated with each design group. This is an important descriptor since it is indicative of loaded vehicle gross rail weight. The vast majority of freight vehicles are designed such that the sum of the vehicle's lightweight and nominal weight capacities is approximately equal to the rail load limit for 50, 70 and 100 ton trucks. This relationship is described below:

Truck Type (Vehicle Weight Class)	Rail Load Limit
50 tons	177,000 lbs.
70 tons	220,000 lbs.
100 tons	263,000 lbs.
125 tons	315,000 lbs.
55 tons (low-level)	179,000 lbs. (approximate)

Comparisons have been made[1] between the fleet characterization data discussed above and five specific railcar characterizations available in the literature. For each vehicle description, a corresponding DVC was selected based on comparisons of principal dimensional and car-capacity descriptors, which closely approximated each car's characteristics. The comparisons indicated that, in each case, a DVC could be selected which closely approximated each of these vehicles in terms of carbody weights, dimensions, volumetric and weight capacities, c.g. height, and mass moments of inertia. Since the basic DVC definitions were developed by sorting and analyzing the UMLER file based on primary and secondary physical descriptions of railcars and, since these definitions cover approximately 96 percent of the freight vehicle fleet, virtually all freight cars can be identified with a particular DVC in this manner.

Table A-6 contains fleet population data by car type and principal vehicle weight classes (as defined by truck capacity) while Table A-7 contains estimates of total annual mileage traveled, in

TABLE A-6. FLEET POPULATION DATA BY MECHANICAL CAR TYPE AND TRUCK CAPACITY

TRUCK CAPACITY / CAR TYPE	POPULATION IN THOUSANDS					
	50T	70T	100T	LL*	TOTALS	% FLEET
BOX	233	194	31	-	458	27.6
STOCK	5	-	-	-	5	0.3
REFRIGERATOR	13	74	7	-	95	5.7
COVERED HOPPER	-	53	174	-	227	13.6
OPEN HOPPER	35	176	145[1]	-	355	21.4
GONDOLA	20	105	59	-	184	11.0
FLAT (incl TOFC)	29	92	9	3	133	8.0
VEHICULAR FLATS	-	18	-	15	33	1.2
TANK	63	12	102	-	177	10.6
TOTALS	398	724	527	18	1667	
% FLEET	24.0	43.5	31.7	1.0		

*Indicates special low-level truck used with low platform-height flat cars.

(1) Includes approximately 2000 125 ton cars

(2) Totals may not be exact due to rounding

TABLE A-7. ESTIMATED TOTAL FLEET MILEAGE BY MECHANICAL CAR TYPE AND TRUCK CAPACITY

	Car Mileage--Total Empty + Loaded In Millions				
CARTYPE \ TRUCK CAPACITY	50T	70T	100T	LL*	TOTALS
BOX	3,448.4	3,598.9	736.7	-	7,784.1
STOCK	33.3	-	-	-	33.3
REFRIGERATOR	258.2	1,503.6	200.1	-	1,961.9
COVERED HOPPER	-	812.6	2,661.9	-	3,474.5
OPEN HOPPER	281.4	1,509.6	1,211.3	-	3,023.1[1]
GONDOLA	87.3	793.1	1,097.5	-	1,977.8
FLAT (incl TOFC)	446.9	2,235.9	247.8	89.1	3,019.7
VEHICULAR FLATS	-	513.1	0	437.0	950.1
TANK	607.4	124.4	993.5	-	1,725.4
TOTALS:	5,162.9	11,091.2	7,148.9	526.1	23,949.9[1,2]

*Indicates special low-level truck used with low platform-height flat cars.

[1]Includes approximately 20.7 million carmiles for 125 ton freight vehicles.

[2]Totals may not be exact due to rounding.

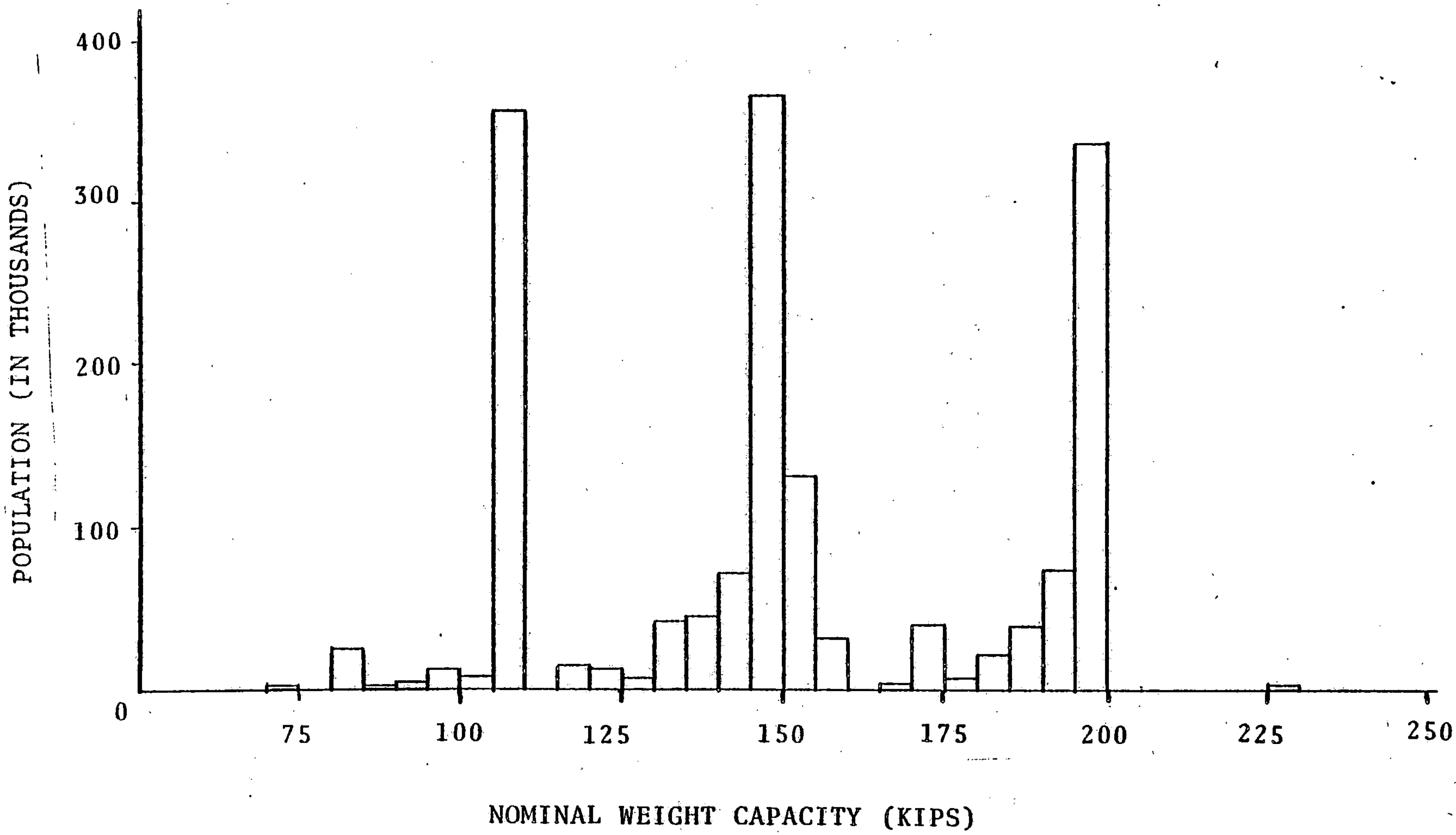
both loaded and unloaded configurations, for the corresponding vehicle groups.

From Table A-6, it can be seen that open and covered hopper cars make up approximately 35 percent of the fleet, and over half of them are 100 ton cars. Box cars represent another major group (27.5 percent of the fleet). Percent populations for 50, 70 and 100 ton weight classes are also indicated in Table A-6 and indicate that approximately 99 percent of all freight vehicles fall in these weight classes.

PRINCIPAL PHYSICAL CHARACTERISTICS OF THE FREIGHT VEHICLE FLEET

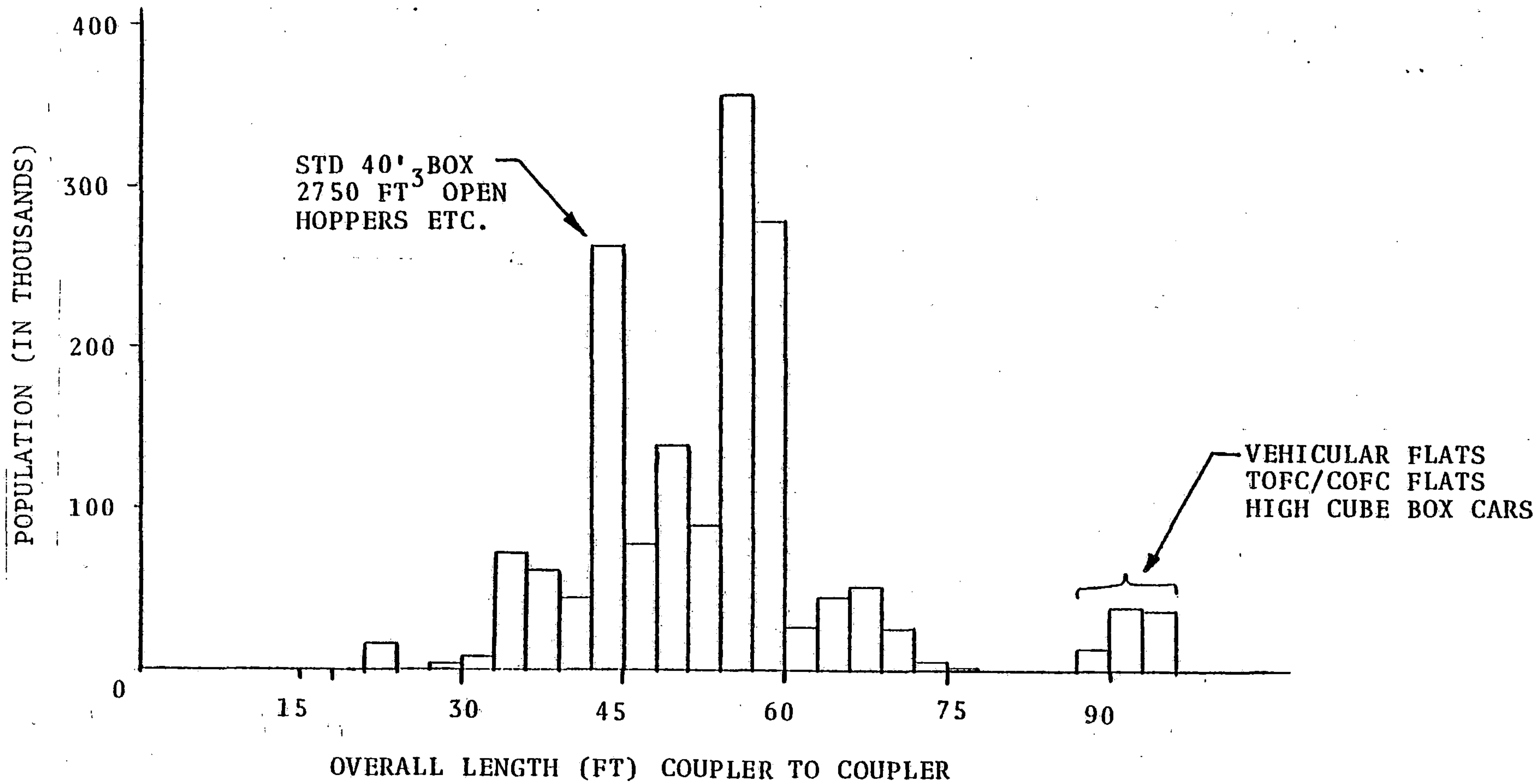
Figures A-2 through A-5 are histograms illustrating the distribution of some principal physical characteristics for the fleet of freight vehicles. These include vehicle weight capacity, outside length and volumetric capacity. Figure A-6 illustrates the distribution of coupler lengths within the fleet. The vast majority of cars are equipped with the standard 29 inch long coupler with smaller numbers of "long" couplers in service with longer vehicles such as flat, vehicular flat and long, cushioned underframe box cars. Figures A-7, 8 and 9 illustrate vehicle populations vs vehicle inside length, length between coupler pins and truck center spacing, respectively. Referring to Figure A-9, the large number of vehicles having a truck center spacing between 39 and 42 feet should be noted in conjunction with the typical 39 foot rail length used in track construction.

Figures A-10 and A-11 illustrate vehicle populations as a function of vehicle light (tare) weight and extreme height respectively. The large number of vehicles having an extreme height of 15 to 15.5 feet (Figure A-11) is noteworthy. This implies that a large percentage of the freight vehicle fleet will have high center of gravity heights in either the loaded or unloaded configuration. This is an important consideration in the harmonic roll process associated with the dynamic response of high c.g. vehicles to track having moderate to large crosslevel track geometry irregularities.



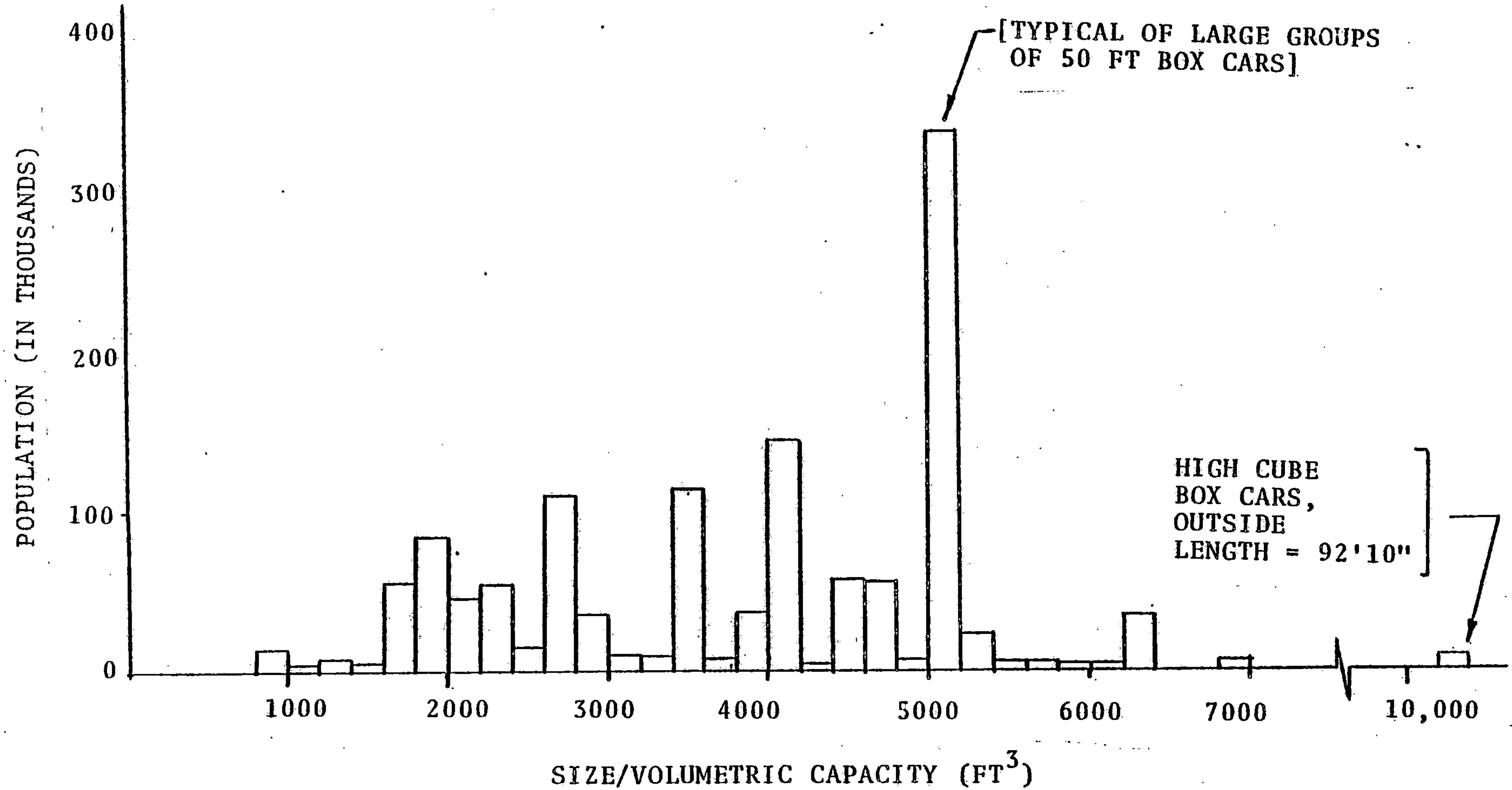
Note: All mechanical car types

FIGURE A-2. NUMBER OF VEHICLES VS WEIGHT CAPACITY, U.S. RAIL FREIGHT VEHICLE FLEET



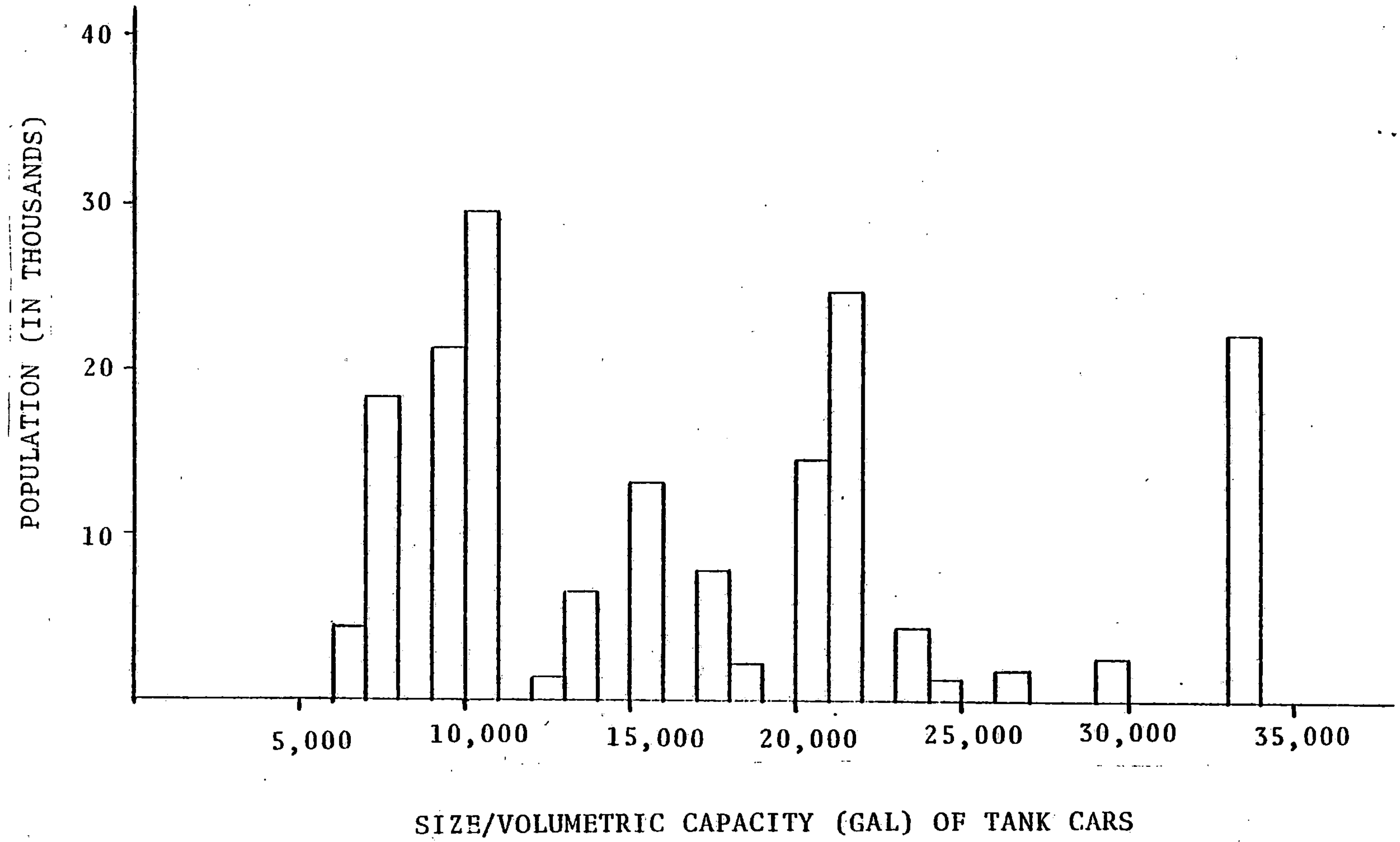
Note: All mechanical car types

FIGURE A-3. NUMBER OF VEHICLES VS OUTSIDE LENGTH, U.S. RAILWAY FREIGHT VEHICLE FLEET



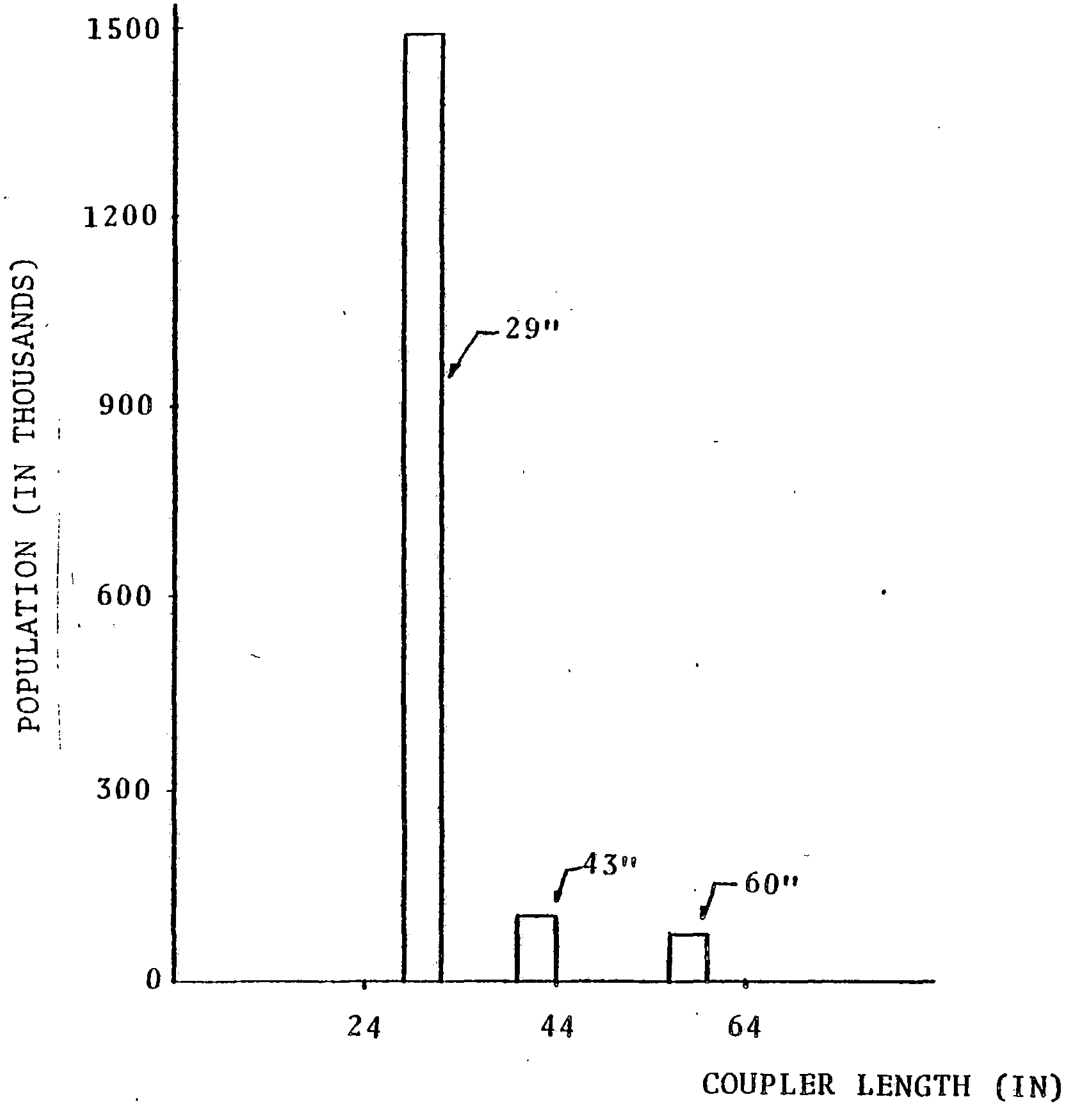
Note: Includes box, stock, refrigerator, covered hopper, open hopper & gondolas

FIGURE A-4. NUMBER OF VEHICLES VS SIZE (VOLUMETRIC CAPACITY), U.S. RAILWAY FREIGHT VEHICLE FLEET



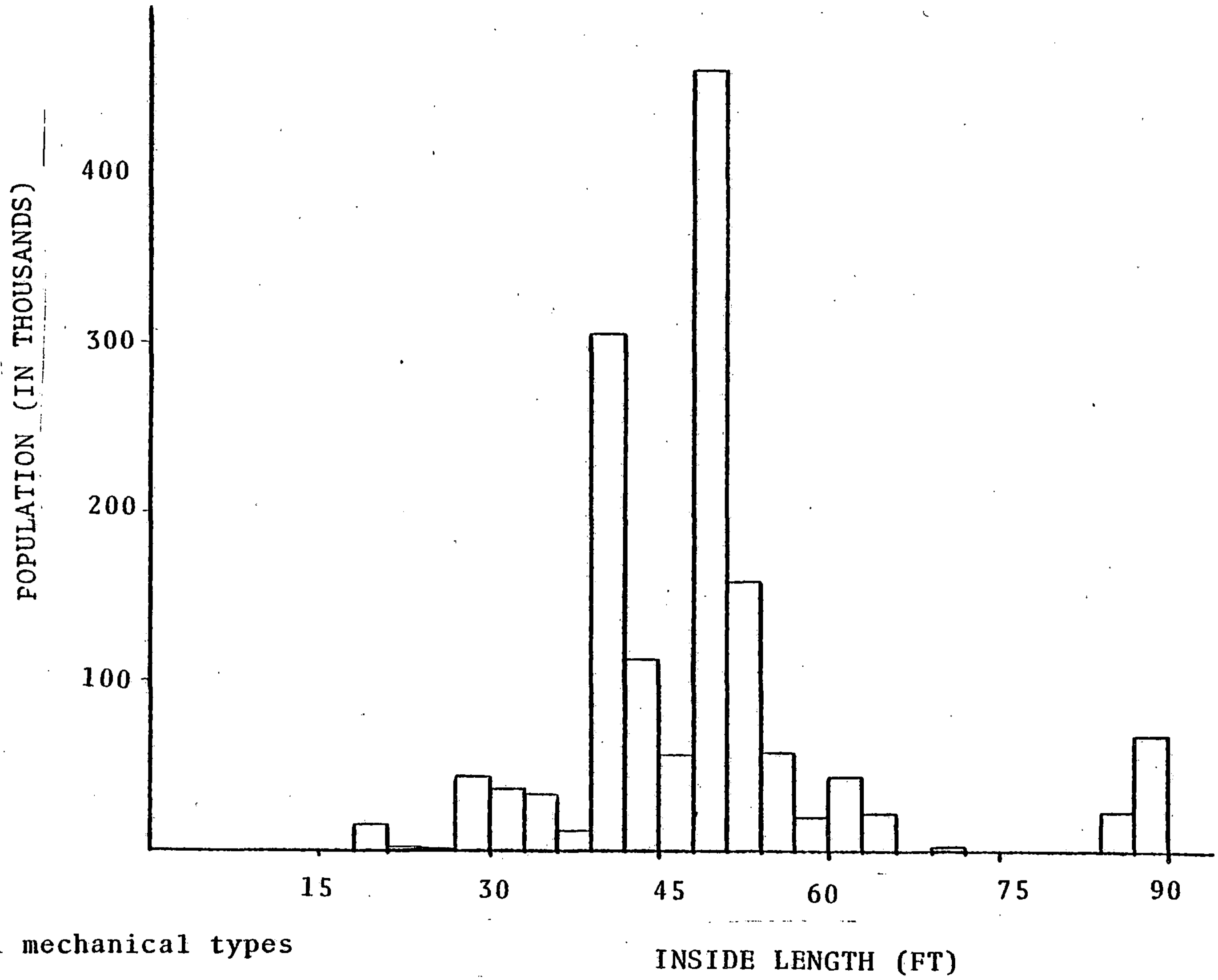
Note: Includes tank cars only

FIGURE A-5. NUMBER OF VEHICLES VS SIZE (VOLUMETRIC CAPACITY), U.S. RAILWAY FREIGHT VEHICLE FLEET



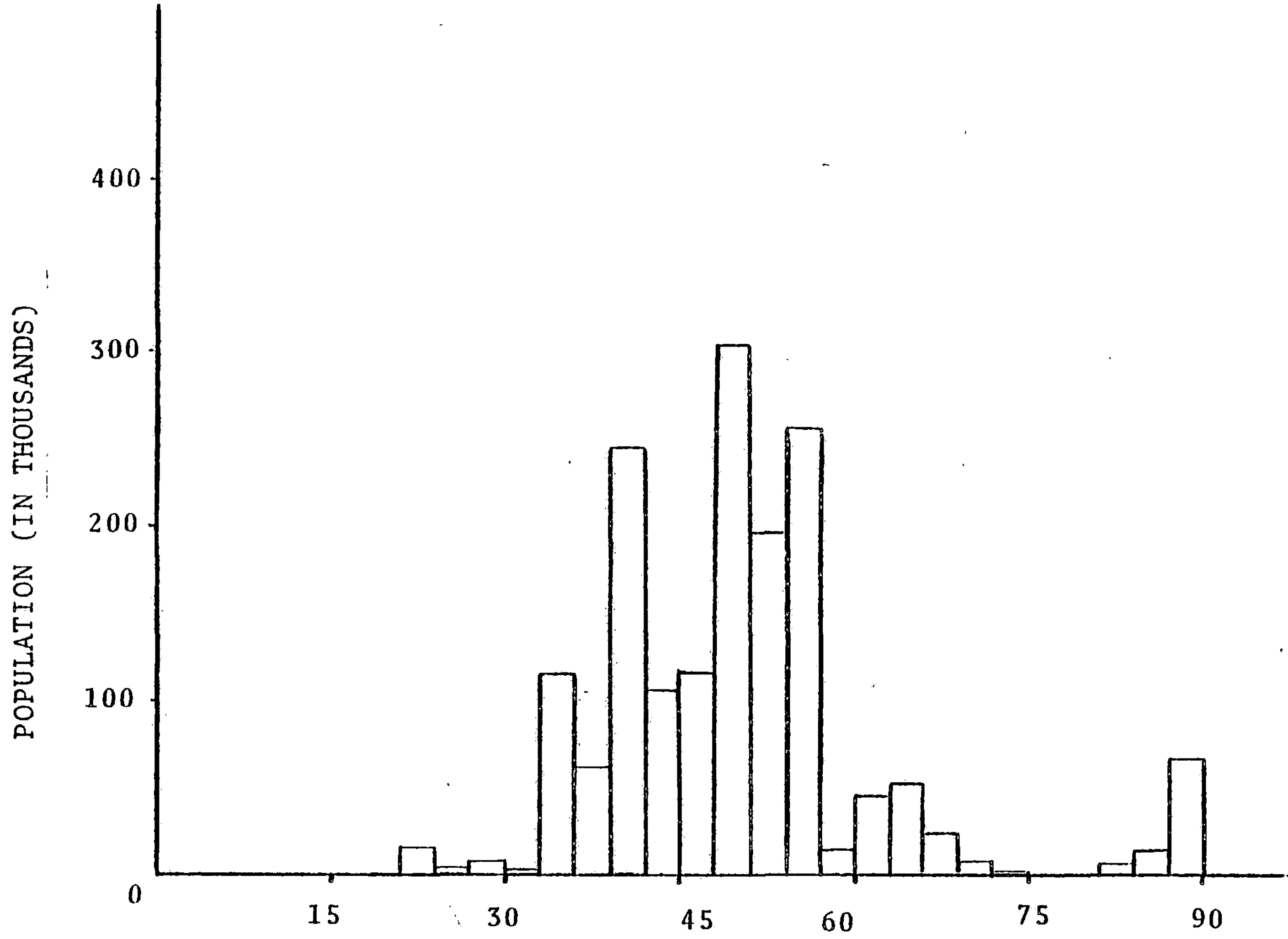
Note: All mechanical types

FIGURE A-6. NUMBER OF VEHICLES VS COUPLER LENGTH OF U.S. RAILWAY FREIGHT VEHICLE FLEET



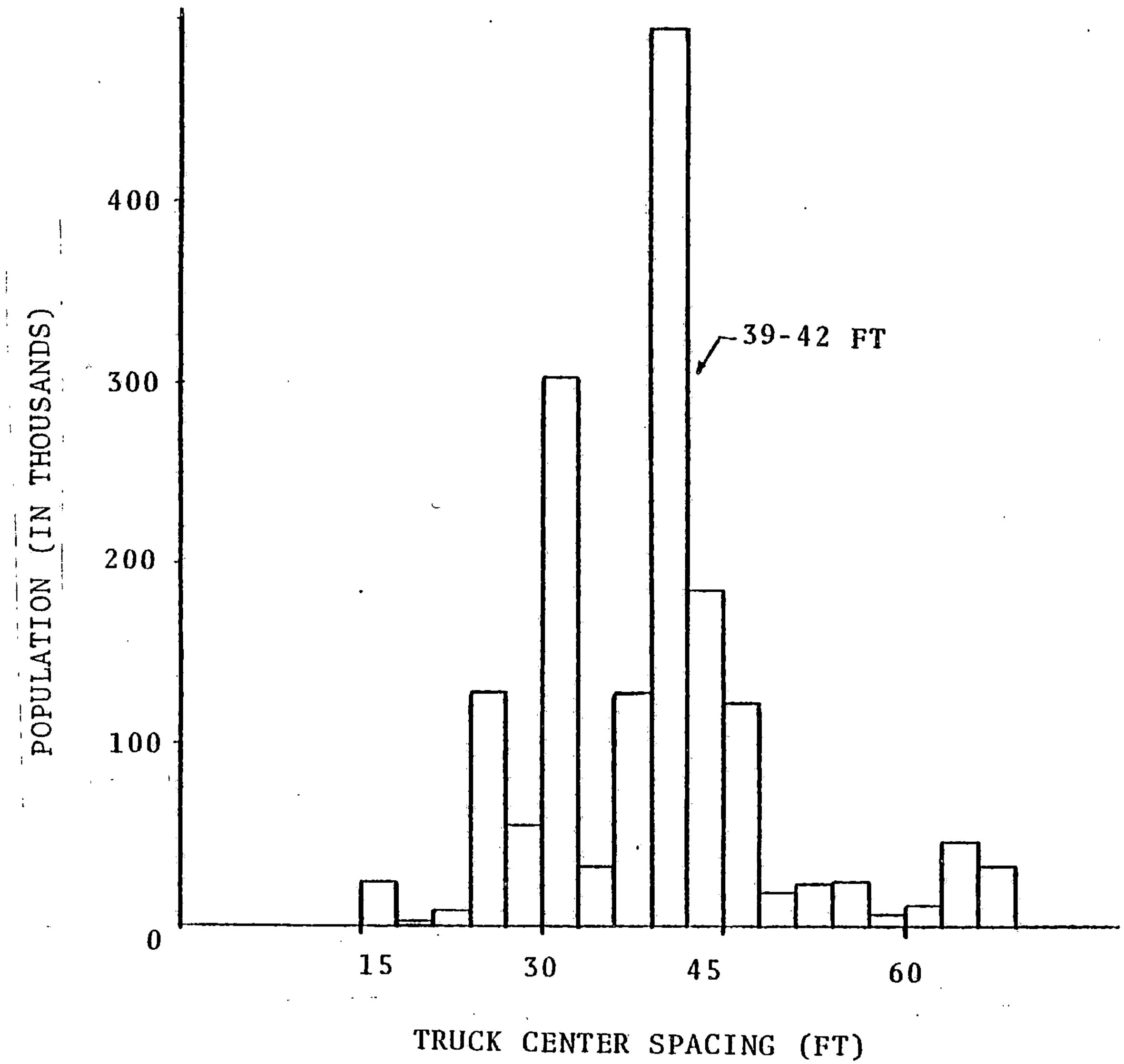
Note: All mechanical types

FIGURE A-7. NUMBER OF VEHICLES VS INSIDE LENGTH OF U.S. RAILWAY FREIGHT VEHICLE FLEET



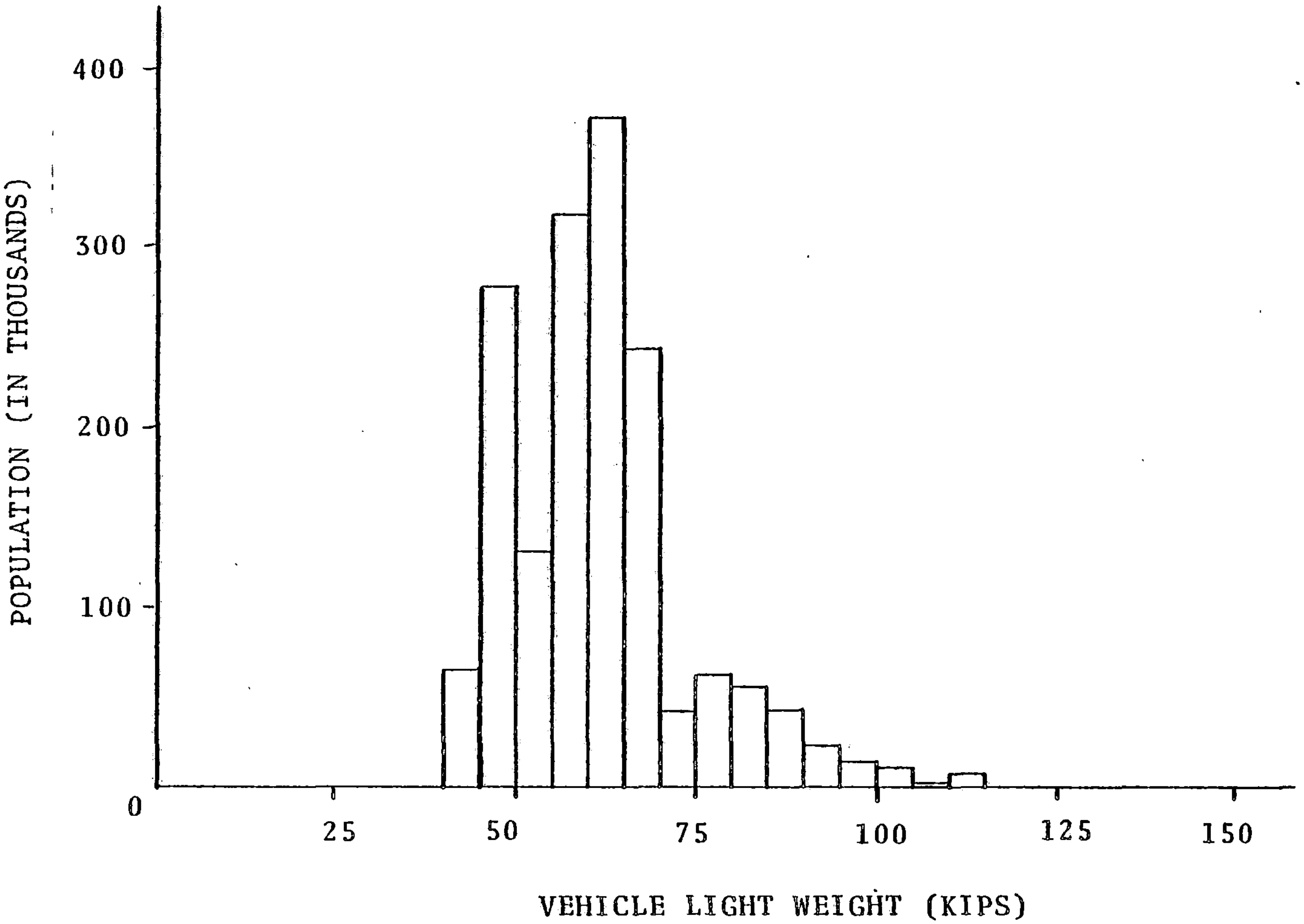
Note: All mechanical types LENGTH BETWEEN COUPLER PINS (FT)

FIGURE A-8. NUMBER OF VEHICLES VS LENGTH BETWEEN COUPLER PINS OF U.S. RAILWAY FREIGHT VEHICLE FLEET



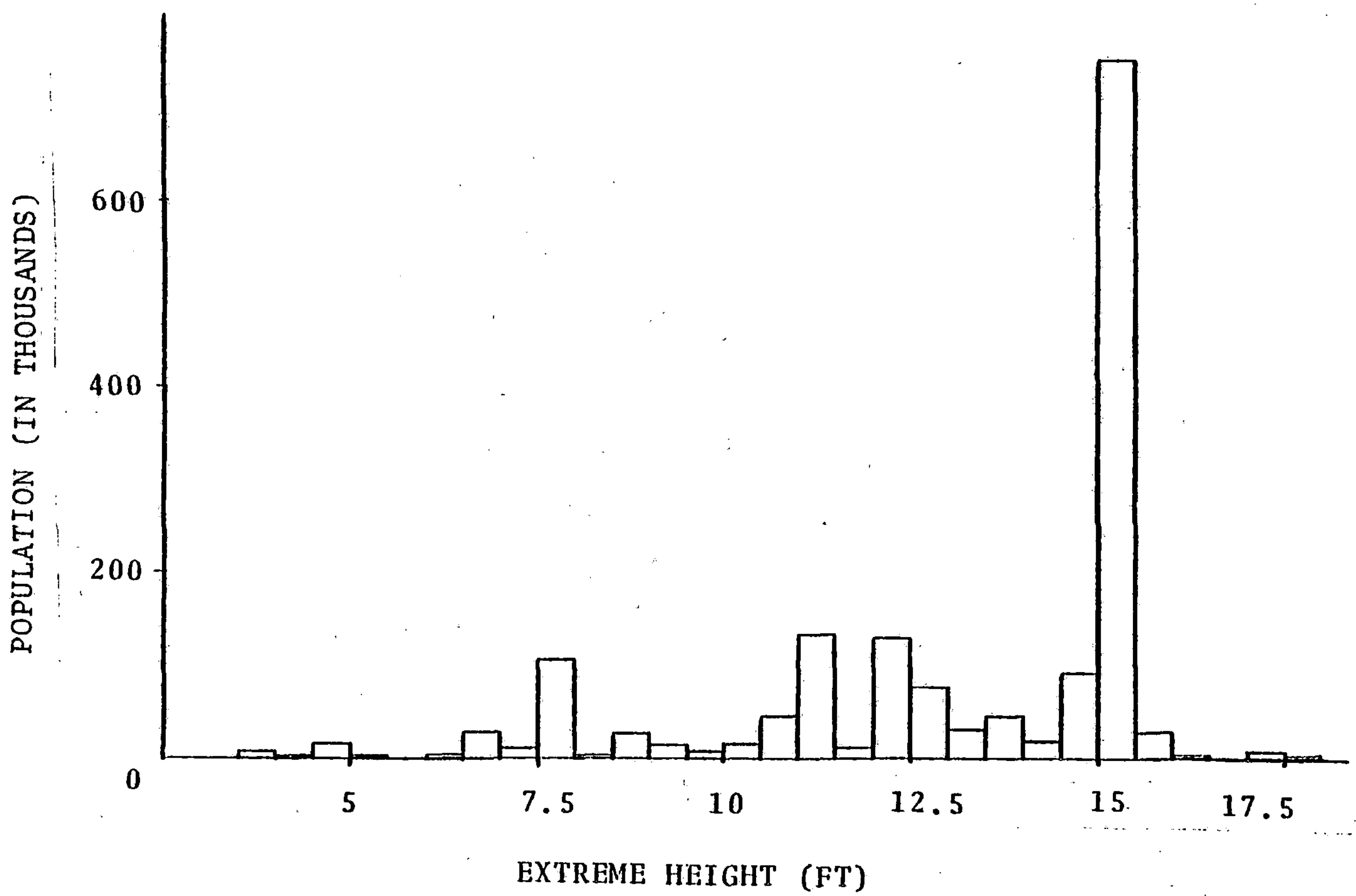
Note: All mechanical types

FIGURE A-9. NUMBER OF VEHICLES VS TRUCK CENTER SPACING OF U.S. RAILWAY FREIGHT VEHICLE FLEET



Note: All mechanical types

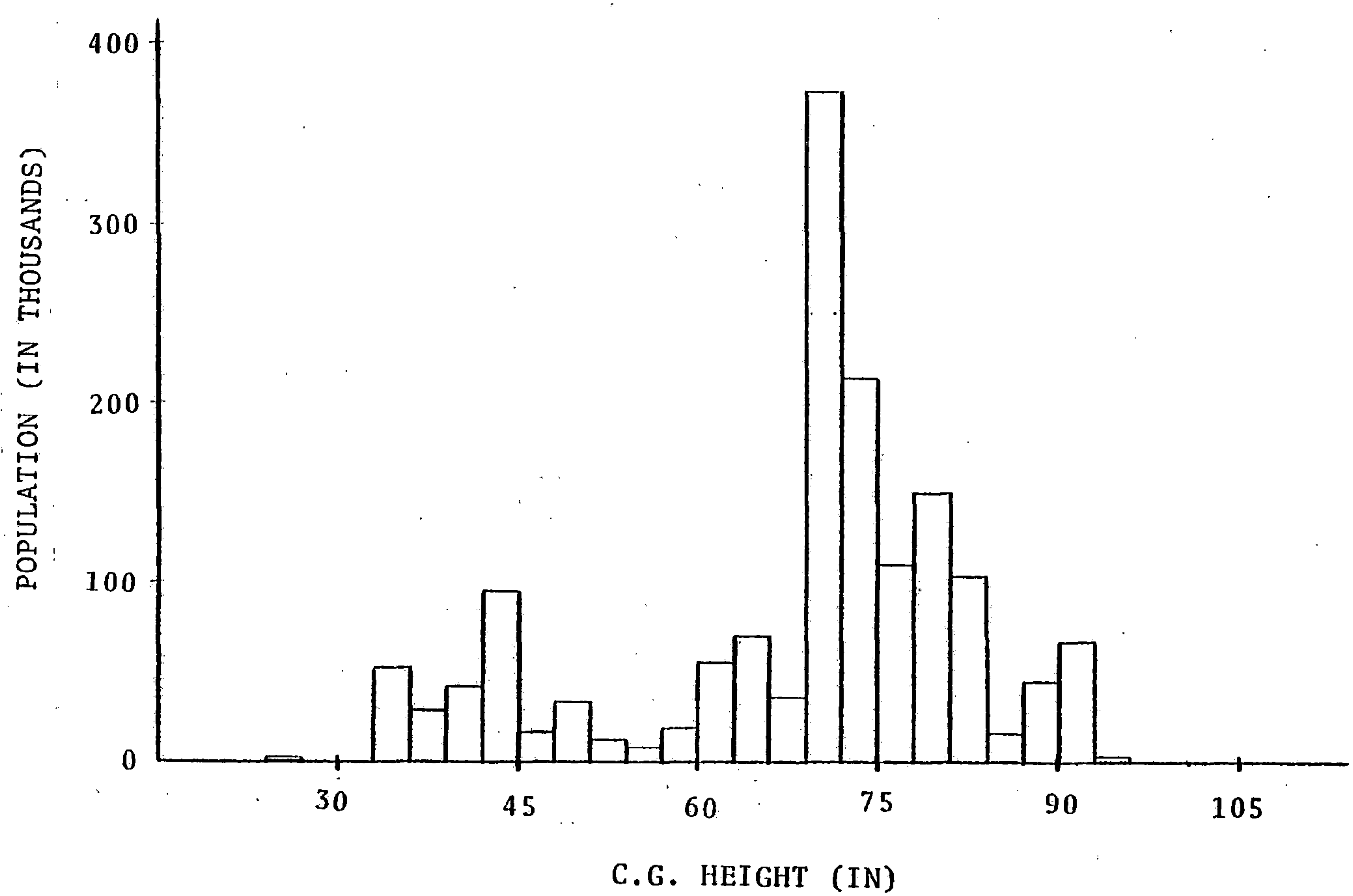
FIGURE A-10. NUMBER OF VEHICLES VS LIGHTWEIGHT OF U.S. RAILWAY FREIGHT VEHICLE FLEET



Note: All mechanical types

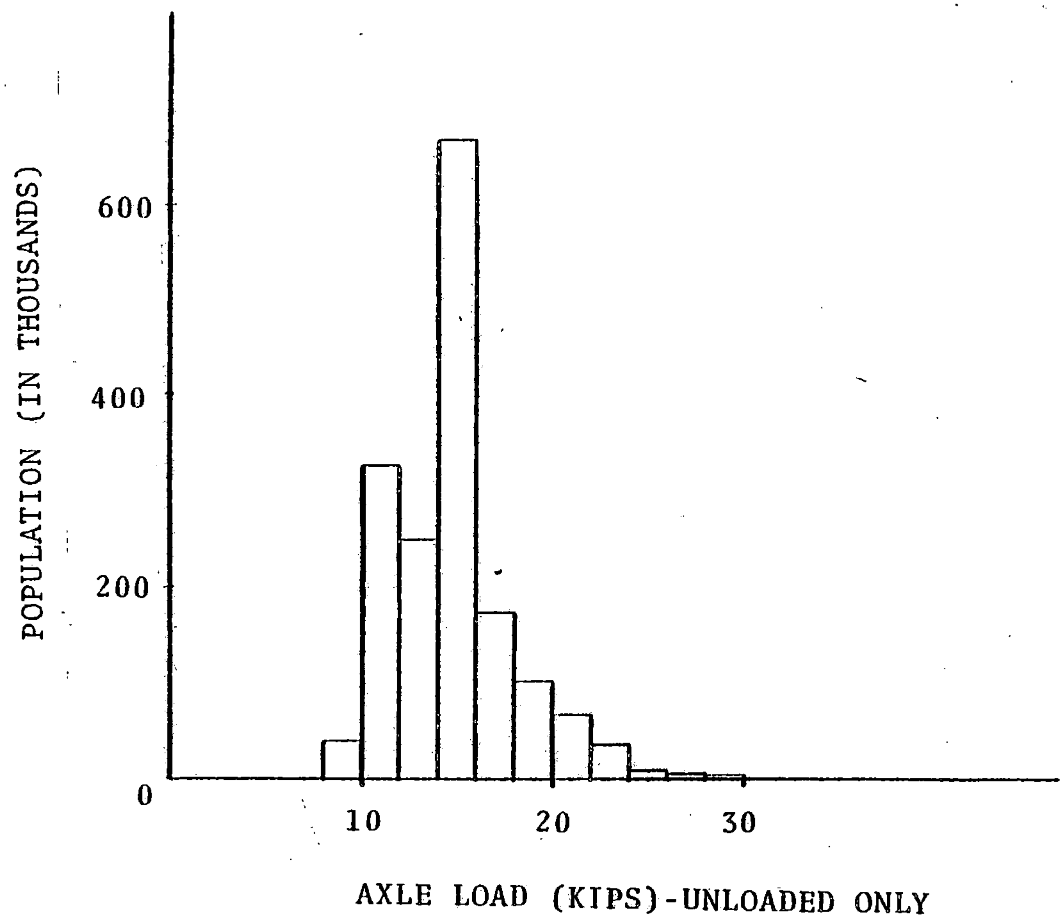
FIGURE A-11. NUMBER OF VEHICLES VS EXTREME HEIGHT OF U.S. RAILWAY FREIGHT VEHICLE FLEET

Figures A-12 through A-15 contain population histogram data on important vehicle configurational parameters which are affected by loads. These histograms approximate the distributions of empty carbody c.g. heights and axle loads, carbody roll inertias, and carbody vertical bending frequency, respectively. These parameters influence a railcar's vertical and lateral response to variations in track geometry and structural compliance. Note that the population histogram data contained in Figures A-12 through A-15 are for unloaded freight vehicles only. In order to characterize the relative distributions of physical attributes which are influenced by load, mileage histograms have been estimated for (a) unloaded (b) total (unloaded plus loaded) mileage conditions. These histograms approximate the relative frequency of occurrence of load dependent vehicle descriptors over the range of possible values, with and without typical loads carried. For example, Figures A-16A and A-16B approximate the relative frequency of occurrence of c.g. heights in terms of total annual miles traveled by (a) unloaded freight vehicles and (b) loaded and unloaded freight vehicles. Similar approximations are presented for axle load distributions (Figures A-17A and A-17B), carbody roll inertias (Figures A-18A and A-18B), and carbody vertical bending frequencies (Figures A-19A and A-19B).



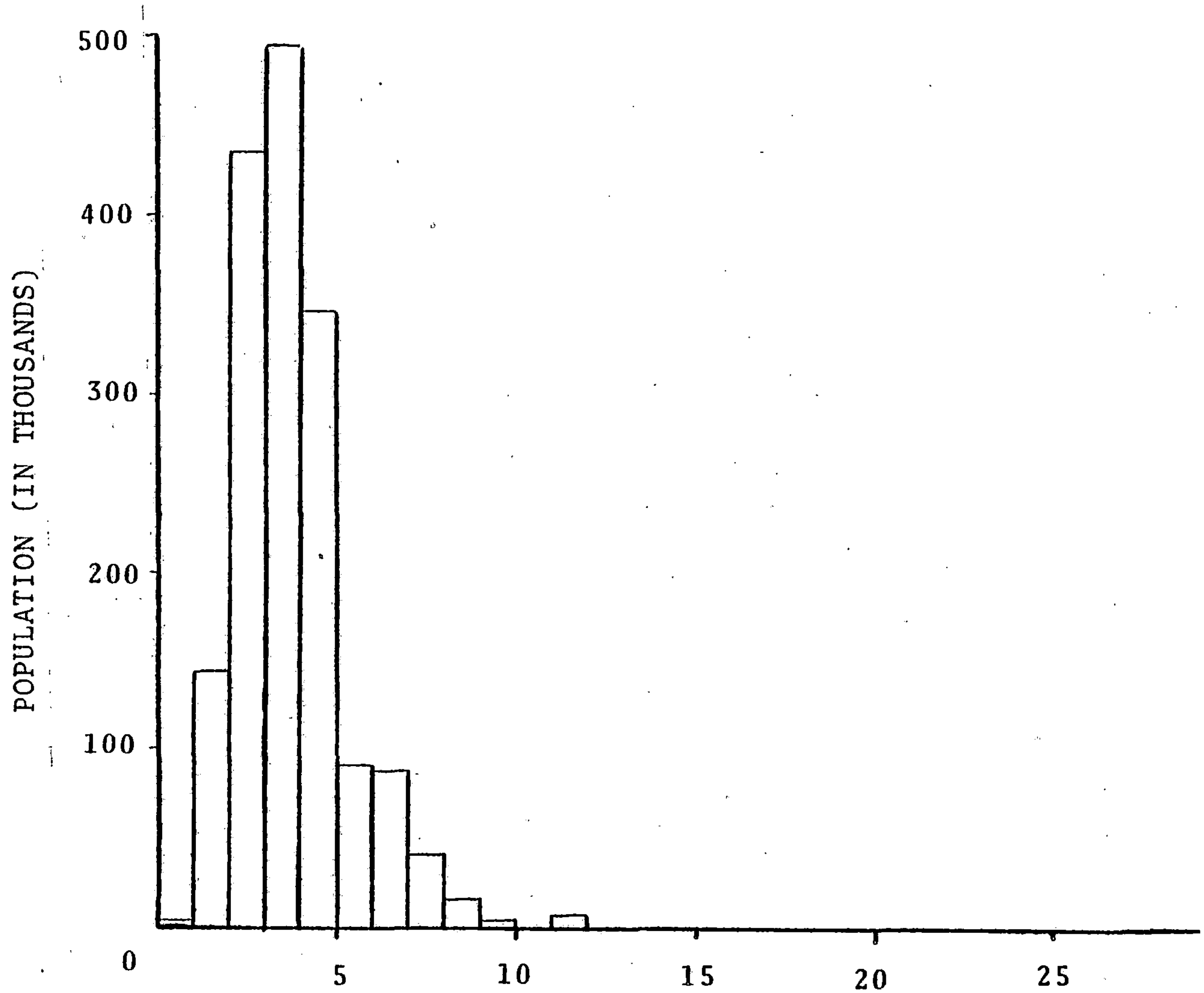
Note: All mechanical types, unloaded

FIGURE A-12. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(NUMBER OF VEHICLES VS C.G. HT. IN)



Note: All mechanical types, unloaded

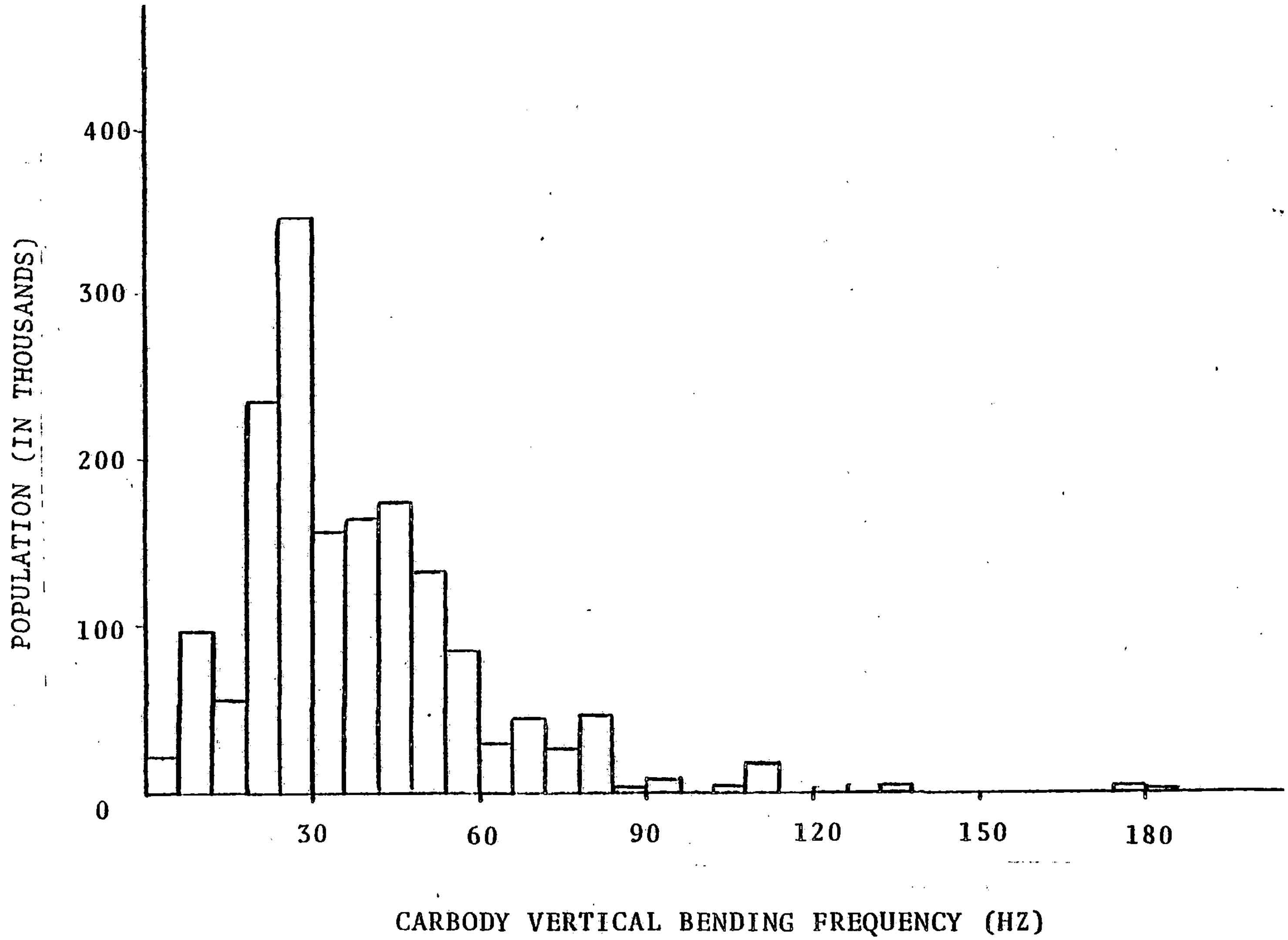
FIGURE A-13. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(NUMBER OF VEHICLES VS AXLE LOAD (KIPS)



Note: All mechanical types, unloaded

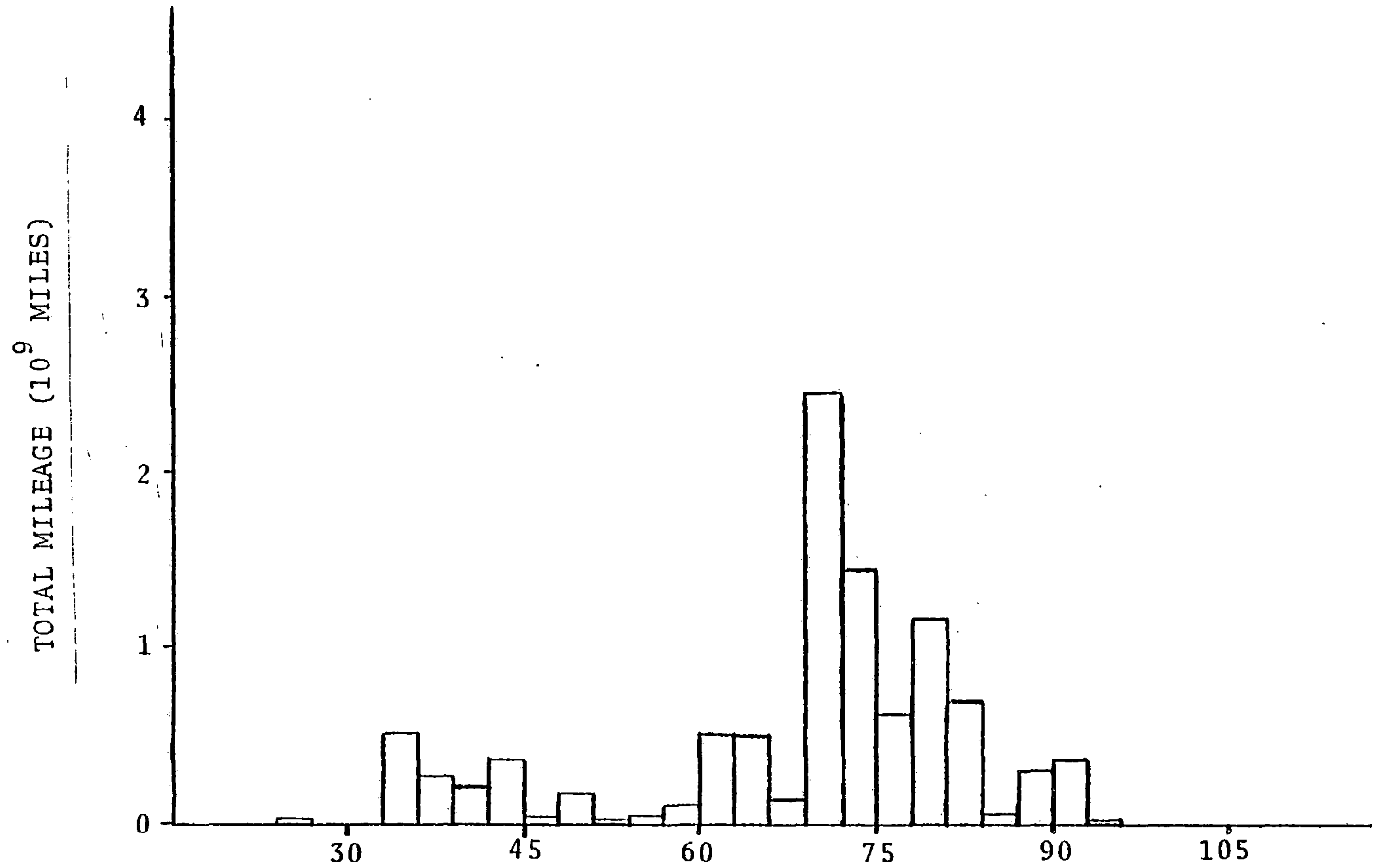
MOMENT OF INERTIA - ROLL (lb-in-sec^2)x10^5

FIGURE A-14. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(NUMBER OF VEHICLES VS ROLL MOMENT OF INERTIA LB-IN-SEC^2)



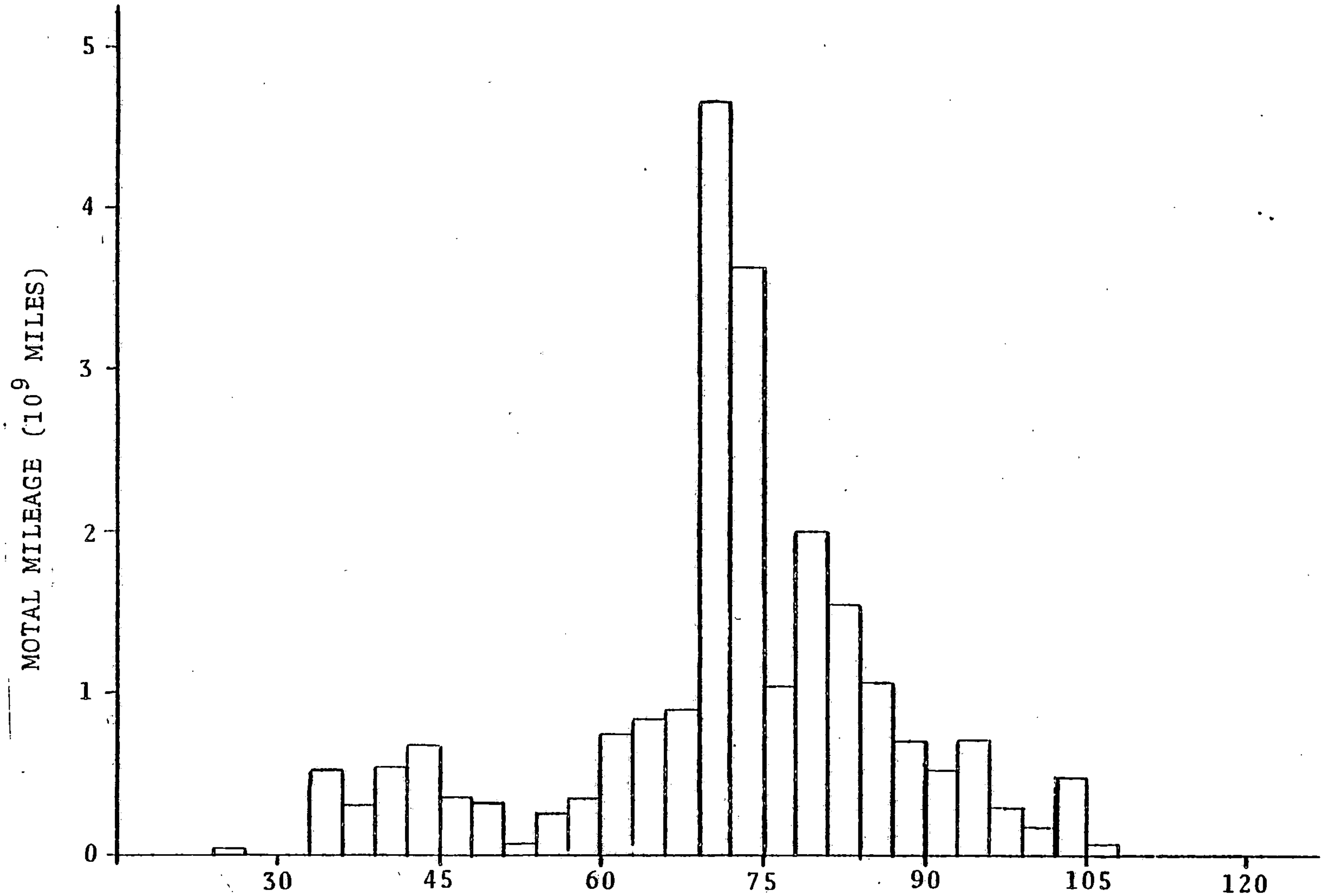
Note: All mechanical types, unloaded

FIGURE A-15. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(NUMBER OF VEHICLES VS VERTICAL FREQUENCY-Hz)



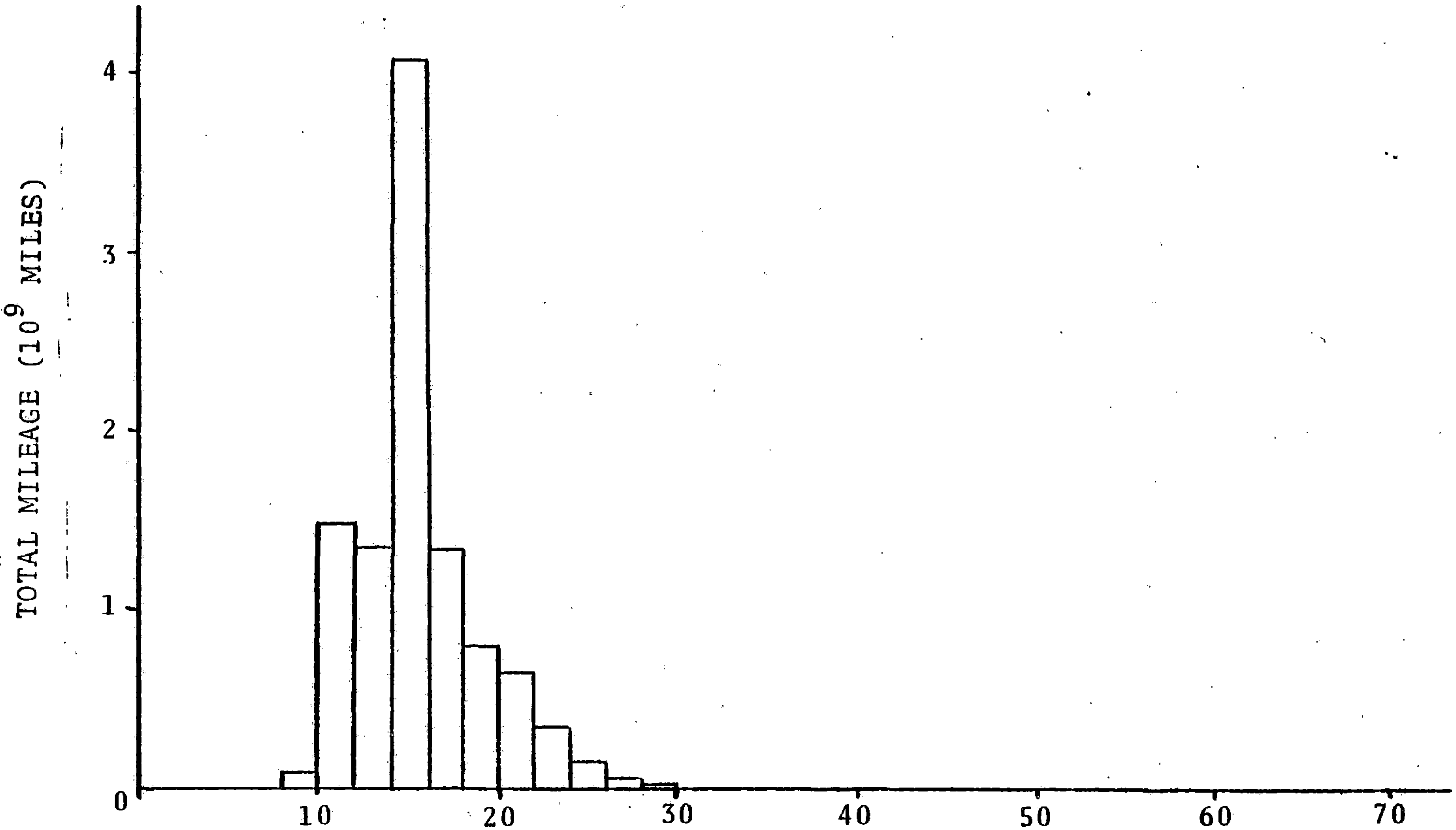
Note: All mechanical types

FIGURE A-16A. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-TOTAL ANNUAL MILES TRAVELED IN UNLOADED CONDITION VS CENTER OF GRAVITY HEIGHT-IN)



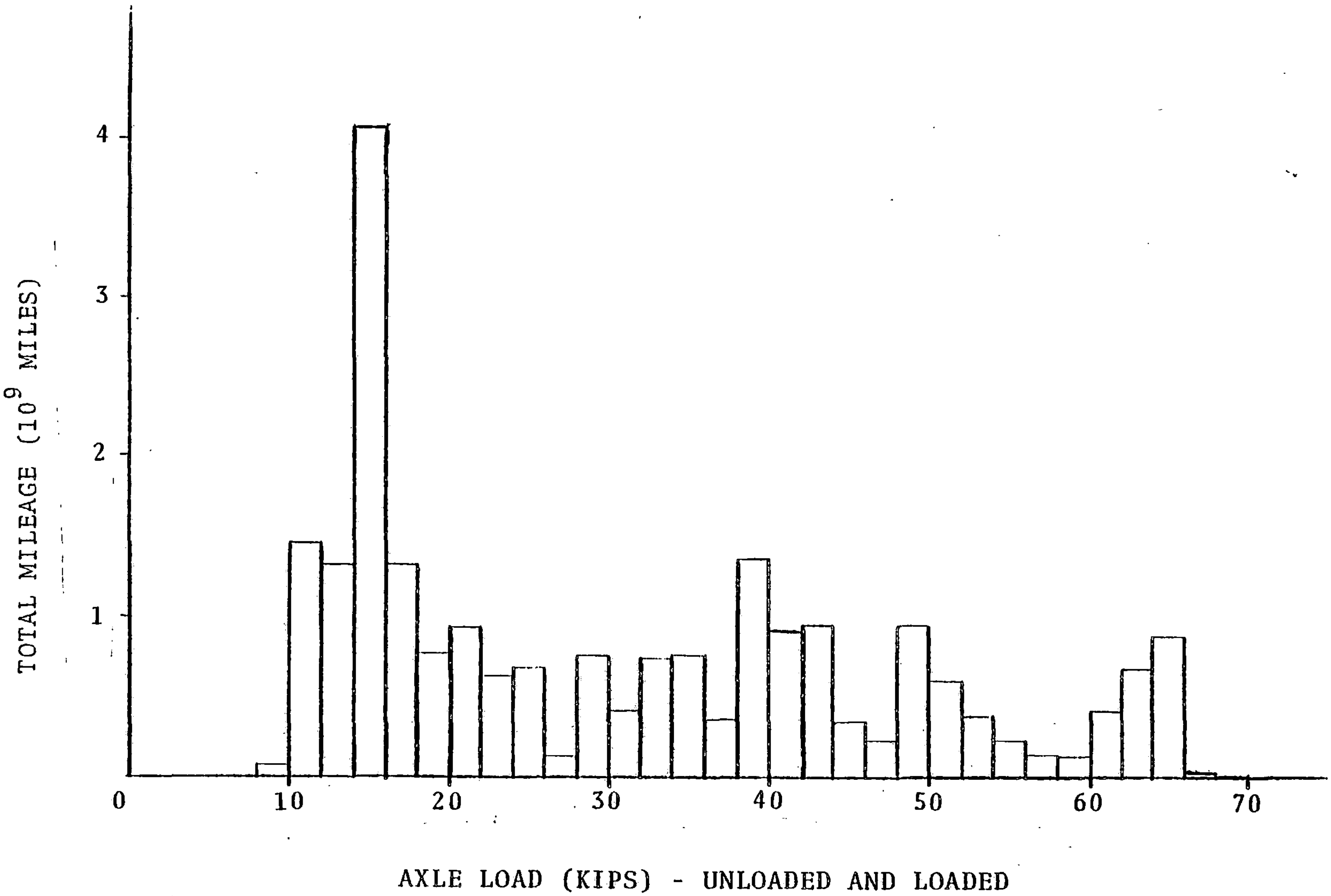
Note: All mechanical types   CENTER OF GRAVITY HEIGHT (IN)

FIGURE A-16B. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN LOADED AND UNLOADED CONDITION VS CENTER OF GRAVITY HEIGHT-in)



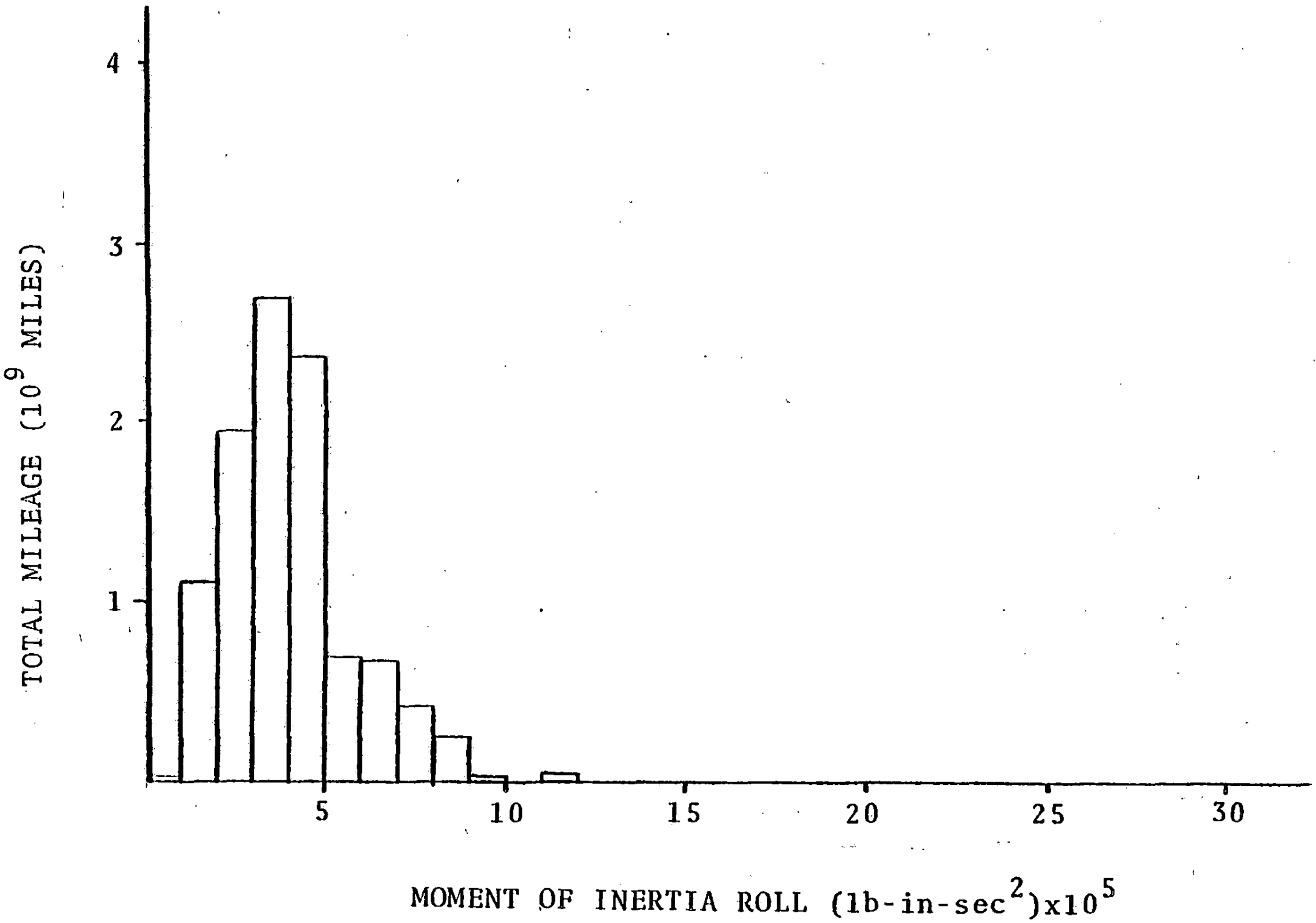
Note: All mechanical types

FIGURE A-17A. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN UNLOADED CONDITION VS AXLE LOAD-KIPS)



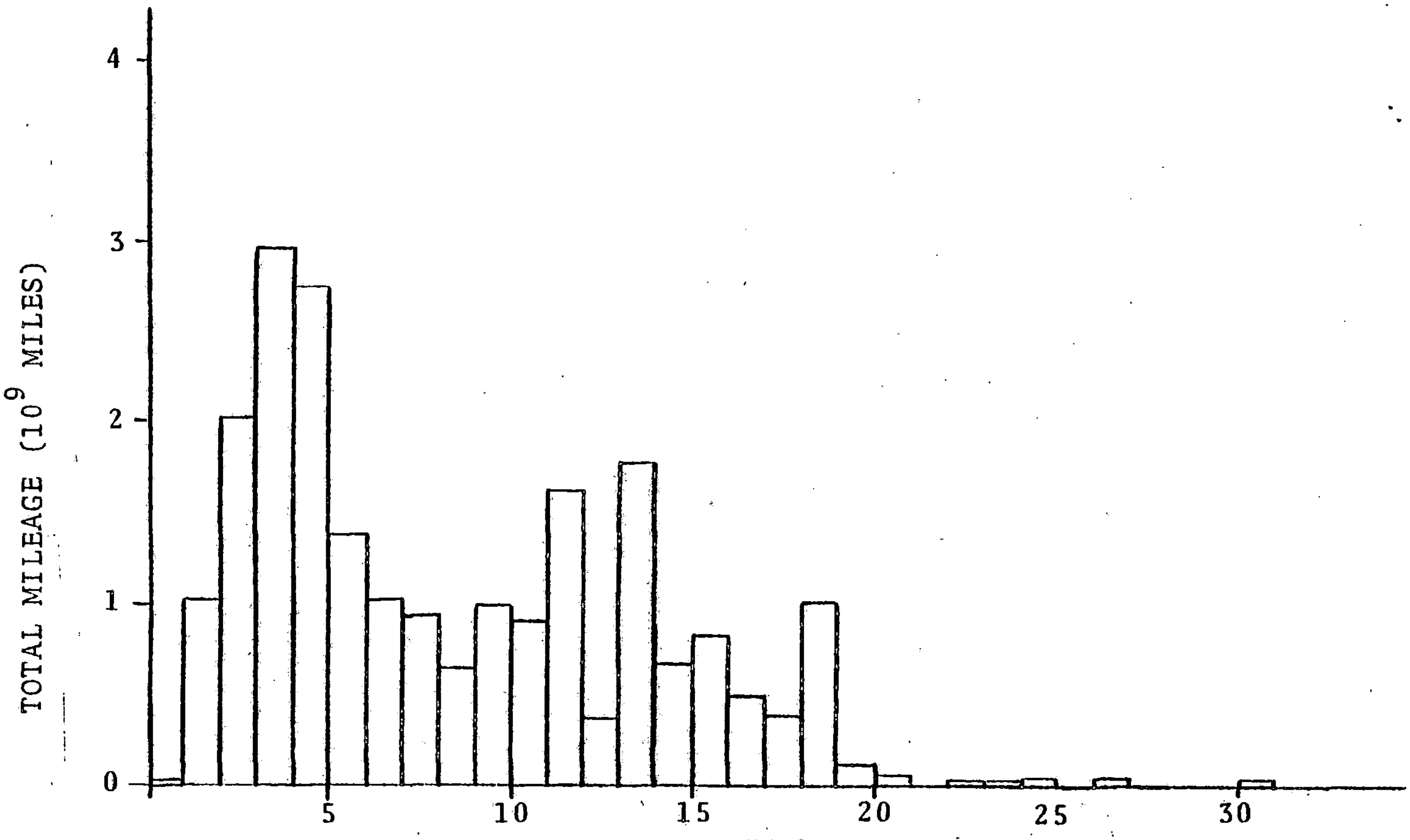
Note: All mechanical types

FIGURE A-17B. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN LOADED AND UNLOADED CONDITION VS AXLE LOAD-KIPS)



Note: All mechanical types

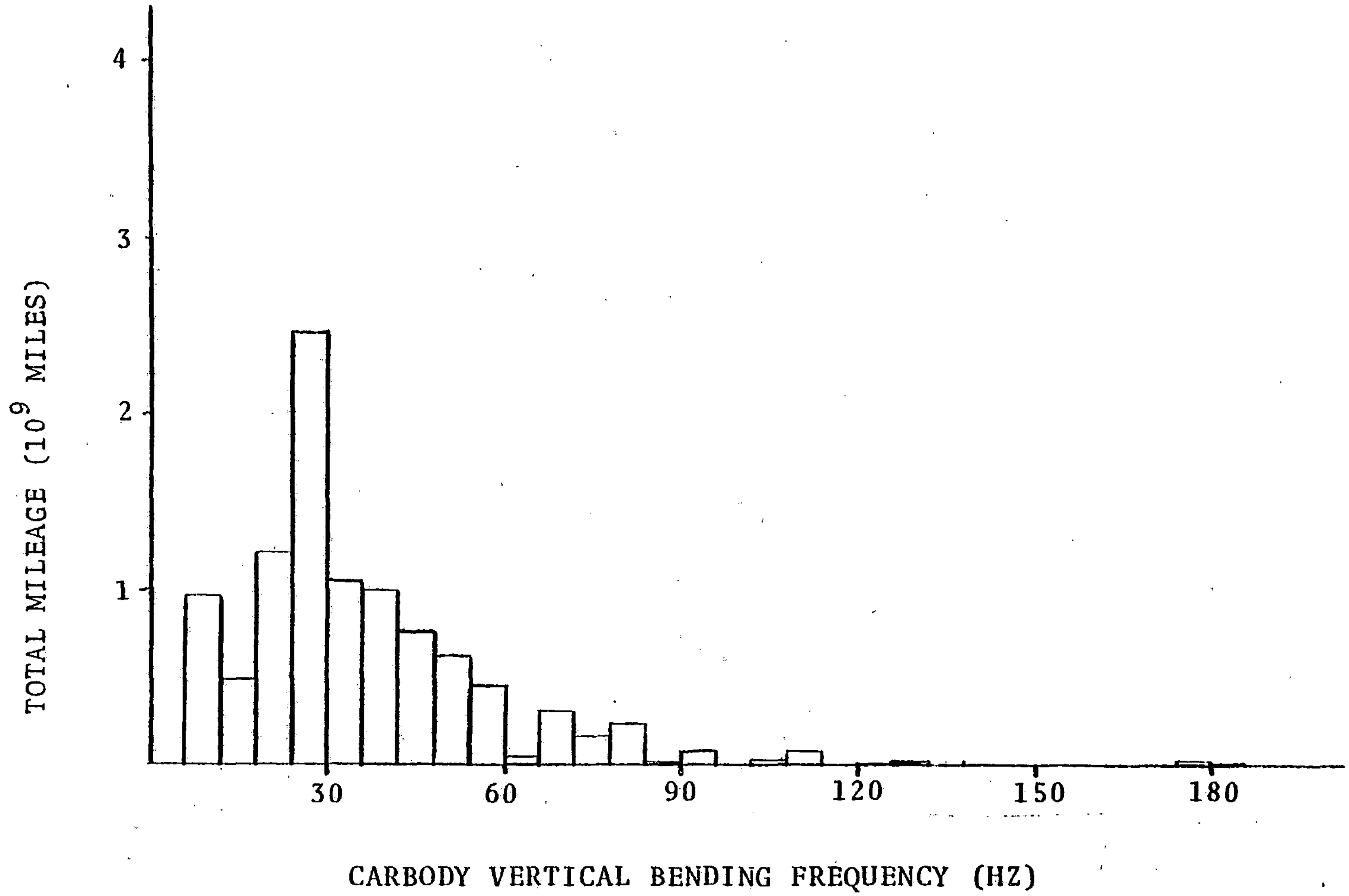
FIGURE A-18A. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN UNLOADED CONDITION VS ROLL MOMENT OF INERTIA LB-IN-SEC^2)



MOMENT OF INERTIA (lb-in-sec^2)x10^5

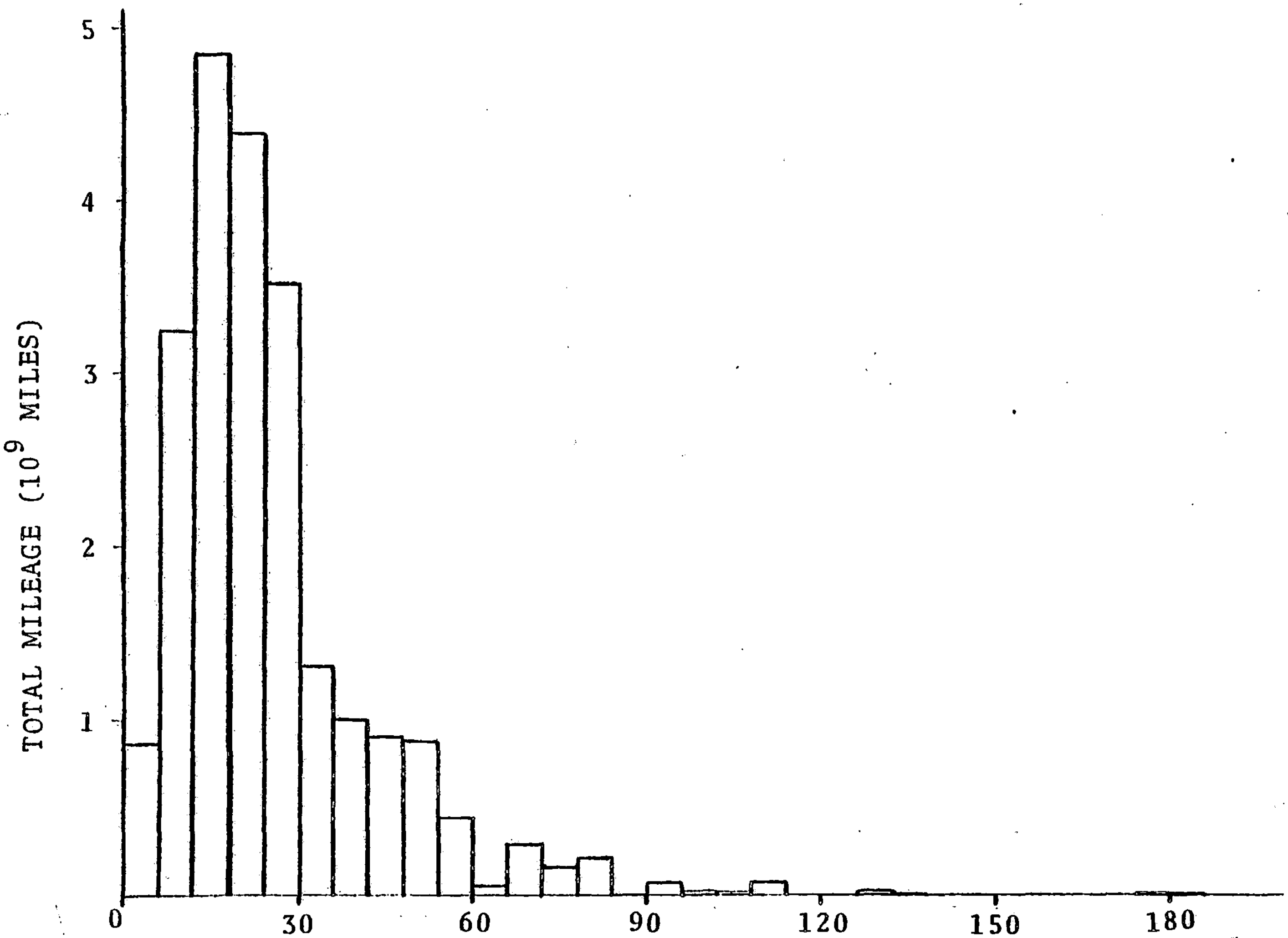
Note: All mechanical types

FIGURE A-18B. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN LOADED AND UNLOADED CONDITION VS ROLL MOMENT OF INERTIA - LB-IN-SEC^2)



Note: All mechanical types

FIGURE A-19A. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN UNLOADED CONDITION VS VERTICAL FREQUENCY-Hz)



Note: All mechanical types CARBODY VERTICAL BENDING FREQUENCY (Hz)

FIGURE A-19B. PHYSICAL CHARACTERISTICS, U.S. FREIGHT VEHICLE FLEET-(TOTAL ANNUAL MILES TRAVELED IN LOADED AND UNLOADED CONDITION VS VERTICAL FREQUENCY-Hz)

APPENDIX B

DEVELOPMENT OF DATA BASE FOR VEHICLE ACCIDENT CORRELATION STUDIES

Under the FRA's Railroad Accident Incident Reporting System (RAIRS), railroads are required to submit monthly reports on railroad accidents and incidents resulting from rail transportation operations. For reporting purposes the three following categories of reportable accidents are defined[3]:

<u>Group I - Rail-Highway Grade Crossings</u> - All accidents and incidents at grade crossings are to be reported, regardless of injury or level of equipment damage.

<u>Group II - Rail Equipment</u> - These accidents include derailments, collisions, fires or other events involving railroad on-track equipment (standing or moving). Accident/incidents resulting in track and equipment damages exceeding about $2,300 are reportable under this category.

<u>Group III - Death, Injury and Occupational Illness</u> - Death and injuries resulting from railroad operations are reported under this category.

For these categories, reports on individual accidents and incidents are filed which contain information describing accident conditions such as location, type of accident, environmental conditions, operational data, equipment involved, property damage, casualties, hazardous material involvement and a set of codified causal factors. These reports are compiled periodically on magnetic tapes and provide an automated data file suitable for statistical analysis of accidents associated with railway operations.

From a rail systems dynamics point of view, the accident data, correlated with information describing the physical characteristics of derailed freight vehicles, provides a more comprehensive data base for assessing derailment scenarios and to quantify the incidence and mileage weighted derailment frequencies of various railcar configurations. The data base described below has been assembled for this purpose.

This study is concerned with rail equipment related accidents and specifically with freight vehicle derailments attributed to causal factors such as truck geometry defects, rail component failures, vehicle running gear and other component failures, excessive speed, excessive train action or curving forces, and other related factors implying excessive vehicle/track dynamic interaction. Tables 2-1 and 2-2 in Section 2 summarize principal cause-code categories considered herein. Accidents attributable to grade crossing incidents, signal and control equipment failures, human error or related human factors are not germane to the objectives of this study and accidents of this nature are not included.

Figure B-1 illustrates the reporting from used for reporting rail equipment type derailments. Information considered useful to this study is indicated. Accident data from calendar years 1976, 1977 and the first three quarters of 1978 was used to generate an accident data file containing this information, for all freight vehicle derailments attributed to causal factors such as those described above.

The accident data file was then linked with the FRA's Universal Machine Language Equipment Register (UMLER), using the vehicle initials and serial number (common to both files), in order to add basic vehicle design and configurational attributes for each derailment record.

The UMLER is a master file containing data on the entire fleet of freight vehicles and on highway trailers and containers used in TOFC/COFC service. The principal purpose of the UMLER file is to provide a basic source of vehicle data for improving car utilization and to provide a means of listing per diem and

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

RAIL EQUIPMENT ACCIDENT/INCIDENT REPORT

FORM APPROVED
OMB NO 04R4006

1. Name of reporting railroad: East West Railroad Company (Amtrak [X] Autotrain [ ])	1a. Alphabetic Code: EWRC	1b. Railroad Accident/Incident No.: 12345
2. Name of other railroad involved in train accident/incident: Amtrak	2a. Alphabetic Code: ATK	2b. Railroad Accident/Incident No.: 6789
3. Name of railroad responsible for track maintenance (single entry): North South Railroad Company	3a. Alphabetic Code: NSRC	3b. Railroad Accident/Incident No.: A7654
4. U.S. DOT-AAR grade crossing identification number: N/A	5. Date of accident/incident: month 01, day 01, year 77	6. Time of accident/incident: 12:35 am [ ] pm [X]

7. Type of accident/incident (enter number in code box, single entry): 1. Derailment 2. Head on collision 3. Rear end collision 4. Side collision 5. Raking collision 6. Broken train collision 7. Rail-Hwy crossing 8. RR grade crossing 9. Obstruction 10. Explosion-Detonation 11. Fire or violent rupture 12. Other (specify) — CODE: 3

HAZARDOUS MATERIALS (number of)

8. Cars carrying	9. Cars damaged or derailed	10. Cars which released haz. mat.	11. People evacuated (est.)
0	0	0	0

LOCATION

12. Division	13. Nearest station	14. Milepost (to nearest tenth)	15. State (two letter code) — CODE
Eastern	Gooberville	25.2	DC

ENVIRONMENTAL CONDITIONS

16. Temperature (specify if minus)	17. Visibility (single entry): 1. Dawn 2. Day 3. Dusk 4. Dark — CODE	18. Weather (single entry): 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — CODE
-02 °F	2	1

OPERATIONAL DATA

19. Method (place X in appropriate box(es)): 1 [ ] Manual block; 2 [ ] Interlocking; 3 [ ] Cab signal; 4 [ ] Automatic block; 5 [ ] Traffic control; 6 [ ] Auto. train stop; 7 [ ] Yard rules; 8 [X] Time table; 9 [ ] Radio; 10 [ ] Auto. train control; 11 [ ] Verbal permission; 12 [X] Train orders; 13 [ ] Other (specify)

20. Speed (recorded speed, if available)	21. Train number	22. Time table direction: 1. North 2. South 3. East 4. West — CODE
45 MPH — Est. [ ] Recorded [X]	32	3

EQUIPMENT

23. Trailing tons (gross tonnage, excluding power units)	24. Type of equipment consist (single entry): 1. Freight train 2. Passenger train 3. Mixed train 4. Work train 5. Single car 6. Cut of cars 7. Yard/switching 8. Light loco(s) — CODE	25. Was the equipment identified in item 24 unattended? 1. Yes 2. No — CODE
N/A	2	2

26. Track number or name	27. FRA track classification	28. Annual track density (gross tons in millions)	29. Type of track: 1. Main 2. Yard 3. Siding 4. Industry — CODE
ABC Siding	1	N/A	3

30. Principle car/unit	30a. Initial and Number	30b. Position in Train	30c. Loaded (yes or no)
(1) First involved (derailed, struck, striking, etc.)	EWR 7220	1	N/A
(2) Causing (mechanical failures)	N/A	N/A	N/A

31. Locomotive units (no. of)	a. Head End	Mid Train b. Manual	Mid Train c. Remote	Rear End d. Manual	Rear End e. Remote
(1) Total in Train	2	0	0	0	0
(2) Total Derailed	2	0	0	0	0

32. Cars (no. of)	Loaded a. Freight	Loaded b. Pass.	Empty c. Freight	Empty d. Pass.	e. Caboose
(1) Total in Equipment Consist	0	10	0	0	0
(2) Total Derailed	0	3	0	0	0

PROPERTY DAMAGE (estimated cost, including labor, to repair or replace)

33. Equipment damage (to be reported for this equipment consist only)	34. Track, signal, way and structures damage (to be reported by railroad in item 1 only)
$ N/A	$ N/A

ACCIDENT/INCIDENT CAUSE CODE

35. Primary cause — CODE	36. Contributing cause — CODE	37. If no code available, explain cause.
702	N/A	N/A

CASUALTIES

38. Number of persons injured	39. Estimated total days disability	40. Number of fatalities
9	86	1

CREW (no. of) / HOURS ON DUTY

41. Engineers	42. Firemen	43. Conductors	44. Brakemen	45. Engineer	46. Conductor
1	1	1	1	Hrs: 3 Mins: 05	Hrs: 3 Mins: 05

47. Typed name and title	48. Signature	49. Date
John R. Henry, Superintendent of Safety		02/15/77

50. Narrative description – Describe the cause, nature and circumstances of accident/incident:
Siding switch lined by person or persons unknown resulting in rear-end collision with standing cut of cars.

FORM FRA F 6180-54 (12 74) REPLACES FORM FRA F 6180-35 (11 72) WHICH IS OBSOLETE

FIGURE B-1. FRA ACCIDENT/INCIDENT REPORT FORM mileage billing rates for each car. A discussion of the UMLER file and a discussion of typical data contained in the file is presented in Appendix A.

It should be noted that the UMLER file used in correlating accident data with physical attributes of derailed freight vehicles, is the identical file used to generate the fleet characterization (i.e., the DVC populations, and extended physical characterizations) data described in Appendix A. The UMLER file used was last updated in December 1977 and has been very compatible in terms of successful linkages with the accident data file discussed above. Successful linkages were obtained for approximately 95 percent of all rail-equipment related derailments reported for the two and three quarter accident years considered. A small number of derailments involving locomotives or passenger vehicles were omitted since these vehicles could not be linked with the UMLER file.

The concatenated file of RAIRS/UMLER data was then erroneous, or contained duplicate accounts of the same accident (arising from situations where separate accident reports were required from more than one railroad in reporting the same accident). A total of approximately 16,000 vehicle/accident records were assembled for the 2.75 years of accident data studied.

Additional data on more detailed vehicle physical characteristics was then added to each record contained in the RAIRS/UMLER file by appending selected freight vehicle characterization data previously described in Appendix A. The freight vehicle configurational and design data contained in UMLER is useful, but this data does not describe physical attributes of freight vehicles which are likely to influence the dynamic response of vehicles to various track related excitations over the range of railcar operational speeds. Parameters such as estimated axle loads, carbody mass moments of inertia and c.g. heights, truck center spacings, carbody flexibilities and truck suspension characteristics are physical attributes of known importance in assessing vehicle dynamic response to various modes of excitation. For example, parameters such as truck spacing, carbody mass, truck vertical suspension characteristics, carbody vertical bending mode and pitch inertia would dominate and distinguish a vehicle's vertical dynamics; carbody c.g. height and roll inertia, side bearing clearance, and truck roll suspension characteristics would dominate roll response; while lateral response and hunting stability are primarily controlled by truck suspension and carbody mass and inertia characteristics in addition to more complicated and detailed considerations involving wheel/rail interaction mechanics.

The linking mechanism used to append the more descriptive vehicle characterization data involved identifying each derailed freight vehicle with a particular DVC by using the physical attributes available from the UMLER file.

As outlined in Appendix A, the DVCs were developed by sorting the UMLER file into major and distinctive vehicle categories based on these physical attributes. Variations between vehicles constituting each design group are generally small, hence, if a derailed freight vehicle can be identified with a particular design group, the physical descriptors which characterize the group should provide a good estimate of the physical characteristics of the derailed vehicle. Since important design, population and utilization data has been developed for each major and distinctive vehicle group, it is useful to "re-associate" the vehicle described in each RAIRS/UMLER record with its appropriate DVC group and to append this useful data to the data base. This has been done for all vehicle/accident records by matching primary and secondary UMLER attributes used to develop the DVCs.

Table B-1 contains a sample listing of UMLER attributes from concatenated vehicle/accident records which were associated with DVC no. 11, a 4750 ft^3, 100 ton covered hopper car. The first row of data indicates the nominal DVC physical description including weight capacity, tare weight, volumetric capacity, inside length and outside length. This data implies that there is very little variation between the representative vehicle characterization used to describe the group (as indicated by the nominal

TABLE B-1. CONCATENATED ACCIDENT RECORDS ASSOCIATED WITH COVERED HOPPER CAR NO, (i.e. DVC NO)

WEIGHT CAPACITY	TARE WEIGHT	VOLUME CAPACITY	OUTSIDE LENGTH	INSIDE LEGNTH	Notes
$200x10^3$	$61.6\ x10^3$	$4750ft^3$	59ft	55 ft	Nominal DVC Descriptor
200.	54.0	4750.0	58.8	54.1	Typical TMLER Descriptors for Derailed Vehicles Associated With This Design Group. Total of Records
200.	61.0	4750.0	60.8	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	62.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
198.	64.0	4700.0	57.8	53.5	
197.	65.0	4700.0	57.8	53.5	
197.	65.0	4700.0	57.8	53.5	
197.	65.0	4700.0	57.8	53.5	
200.	61.0	4740.0	59.3	54.5	
200.	60.0	4740.0	59.3	54.5	
200.	61.0	4740.0	59.3	54.5	
200.	62.0	4740.0	59.3	54.5	
200.	62.0	4700.0	57.1	53.5	
199.	64.0	4740.0	59.3	54.5	
200.	63.0	4700.0	59.3	54.5	
200.	64.0	4700.0	59.3	54.5	
199.	64.0	4700.0	59.3	54.5	
200.	62.0	4700.0	59.3	54.5	
200.	63.0	4740.0	59.3	54.5	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	62.0	4700.0	59.3	54.5	
195.	65.0	4785.0	59.1	54.5	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	62.0	4750.0	60.0	55.3	
202.	60.0	4750.0	60.0	55.3	
198.	63.0	4740.0	58.3	54.5	
198.	63.0	4740.0	59.3	54.5	
200.	61.0	4750.0	60.0	55.3	
195.	68.0	4740.0	59.3	54.5	
198.	64.0	4740.0	59.3	54.5	
200.	62.0	4740.0	59.3	54.5	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	61.0	4750.0	60.0	55.3	
200.	60.0	4750.0	60.0	55.3	
200.	61.0	4750.0	59.9	55.3	
200.	61.0	4750.0	60.0	55.3	
198.	65.0	4740.0	58.3	54.5	

DVC descriptors in the 1st row) and individual vehicles constituting the group (as indicated in subsequent rows listing actual physical characteristics of derailed freight vehicles as taken from the UMLER file).

The mechanics of "associating" each UMLER record with an appropriate DVC involved one or more steps as described below.

The UMLER data from each vehicle/accident record is first compared with each DVC definition (a matrix of ranges on primary and secondary physical attributes) for the cartype being considered. If all primary and secondary parameters fit one and only one DVC definition, the vehicle is identified with this DVC (group). Approximately 75% of all linkages are made using the criterion. If the vehicle fits more than one DVC group (which is an unlikely event) a "best-fit" algorithm is used to assign the vehicle to the most appropriate group. The best-fit algorighm computes a normalized rms deviation between the set of UMLER attributes (from a particular vehicle/accident record) and the corresponding set of nominal attributes describing candidate DVCs for the car type being considered. The following equation illustrates the process where RMS(i) equals the normalized rms deviation;

$$RMS(i) = \sqrt{\sum_{j=1}^{n} \left[\frac{XN(i,j) - XU(j)}{XN(i,j)} \right]^2}$$

where j = no. of primary and secondary physical attributes compared

i = no. of DVC definitions which a record satisfies

XN = nominal value of DVC attribute

XU = UMLER value for attribute corresponding to XN

If RMS(i) exceeds 0.10 or if any [(XN(i,j) - XU(j))/XN(i,j)] exceeds 0.40, the record is flagged and separated from the main data base as a poor fit. If these criteria are not exceeded, the record is assigned to a DVC group based on minimum rms deviation from nominal values describing the DVC.

The second step involves situations where all primary attributes fit one and only one DVC but a single secondary attribute is not satisfied. These records were assigned to the appropriate DVC and hand checked to insure that a reasonable association had been made. If a large variation was noted, the record was flagged and separated from the main data base.

Table B-2 provides information pertaining to the linking of derailed boxcar records using the algorithm discussed above. An RMS value of 0.0 indicates that the set of physical attributes describing a derailed freight vehicle satisfies the definition of a single DVC and is assigned to that DVC. Values between 0.01 and 0.09 indicate that the derailment record may be associated with more than one DVC definition or that one of the matching parameters lies slightly outside of its corresponding range of values for a best fit DVC. This occurs fairly frequently because of the narrow definition of most DVCs. About 6 percent of the records had an ERMS equal to or greather than 0.10. Although these cars were identified with a DVC, there was enough variation from the normal DVC definition to regard these cars as improperly represented by the DVC, hence these records were flagged and omitted from the main data base. A value of 9.99 indicates that DVC associations were not made because of missing UMLER data needed for the linking process. Table B-2 indicates that good associations were made with boxcar DVCs for 93 percent of all derailed boxcar records. This is typical of assignments for other cartypes also.

The third step involved manual linking of certain car types based on UMLER attributes and AAR Car Type Code. This technique is particularly necessary in making associations for vehicular flat cars. These cars are long and fairly uniform in length and are basically composed of bi-level or tri-level racks atop a low-deck or high-deck flat car. Typical rack weights vary from approximately 15,000 to 45,000 lbs depending upon features such as number of tiers or enclosure partitions. Typical flat car weights (without racks) are approximately 60,000 to 70,000 lbs. In developing the DVCs, UMLER sorting indicated that light weights contained in UMLER for vehicular flat cars, typically include the rack weight. In many cases however, the listed weight capacity is

TABLE B-2. SUMMARY OF BOXCAR DVC ASSIGNMENTS

RMS	Number of Records	Cumulative Percent
0.00	1184	64
0.01	36	66
0.02	49	68
0.03	63	72
0.04	78	76
0.05	138	83
0.06	78	88
0.07	36	89
0.08	26	91
0.09	26	93
0.10 to 0.24 (1)	113	99
9.99 (2)	27	100
Total	1854	

(1) These records represent marginal "fits" and have been excluded from the data base.

(2) These records represent "non-linked" records, usually as a result of missing UMLER data.

not de-rated by the rack weight. This causes difficulty in making comparisons of vehicle weight capacities. The following example provides a useful illustration:

from UMLER:
- AAR Car type Code = V681
- Weight Capacity = 118,000 lbs
- Light Weight = 86,000 lbs
- Platform Height = 2 ft 6 in.

- Gross Vehicle Weight (WT Cap + Tare Wt) = 204,000 lbs
- Rail Load Limit (for low profile trucks) ≅ 179,000 lbs

- Approximate Weight Bi-Level of Rack: 30,000 lbs

The AAR Car Type Code indicates this vehicle is a bi-level, low deck flat car. This is corroborated by the 2 ft 8 in. platform height. These low deck cars are equipped with specialized low profile trucks which have a rail load limit of approximately 179,000 lbs as indicated above. Based upon the listed UMLER values for light weight and weight capacity, this vehicle would exceed the rail load limit for a car equipped with these trucks by an amount which is approximately equal to the rack weight in this example. Considering the vehicle weight capacity to be 88,000 lbs, i.e., subtracting the estimated rack weight from the vehicle weight capacity, this vehicle can readily be identified with its appropriate design group, i.e., DVC.

In addition to the methods described above, each set of UMLER values was checked to ensure that it had been assigned to a DVC having an appropriate weight class. This was done by summing the vehicle weight capacity and light weight and comparing this total with the rail load limits for 50, 70 and 100 ton truck vehicles as shown below.

Vehicle Weight Class	Rail Load Limit
50 tons	177,000 lbs
70 tons	220,000 lbs
100 tons	263,000 lbs

125 tons*	315,000 lbs
55 tons**	179,000 lbs

Finally, a visual screening of all UMLER attributes for each vehicle/accident record was made against the corresponding nominal atriibutes for the assigned DVC to eliminate any incompatible assignments.

In expanding the physical descriptions of derailed freight vehicles to include engineering descriptors which influence vehicle dynamic response characteristics, it is necessary to make some assumptions about derailments of loaded freight vehicles for certain cartypes. This is because the accident data only indicates whether the vehicle involved in the derailment was loaded or unloaded. Information describing the commodity and load weight carried is not available. Of the derailments analyzed in this report, approximately 23 percent involved unloaded cars. Another 40 percent involved loaded cars, such as covered and open hopper cars, vehicular flats and tank cars. To a great extent, these cars are commodity dependent and characteristic loads have been defined. Most of the remaining derailments involve loaded box, refrigerator, gondola and flat cars. These cars generally carry a wide range of commodities and in different load ranges. For example, up to six representative load characterizations have been developed to describe the range of loads carried by box cars, in the fleet characterization effort described in Appendix A. Two to three representative loads were typically identified for the other "commodity independent" car types (refrigerator, gondola and flat car).

A review of these representative loads for the commodity dependent car types discussed above indicate that, in many instances one of the typical load groups is dominant in terms of total number of carloads carried and car miles traveled. In other instances, differences between representative loads are small. These considerations led to the following assumption regarding loaded

*very small population

**low profile truck used with low deck flatcars.

freight car characteristics for the car types discussed above. Table B-3 contains typical information describing the number of lading groups associated with certain commodity independent car-types and the corresponding annual mileage and carbody parameters associated with each vehicle/lading combination.

Freight vehicles involved in derailments are first associated with an appropriate DVC as discussed above. For the commodity independent cartypes, in instances where one DVC load condition, (i.e., commodity density group) is predominant, that vehicle/lading combination is assumed for all of that vehicle's loaded car mileage. Part A of Table B-3 illustrates this process for a typical loaded box car configuration. Loaded carbody parameters corresponding to lading group (b) and a total loaded car mileage of 244 million miles, are assumed for all loaded boxcars identified with boxcar group no. 2A. Part B of Table B-3 illustrates a condition where two representative loads have been identified to characterize loads carried by a particular flat car design (DVC No. 1A). Each load is similar to the extent that variations in loaded carbody properties are small. Loaded carbody parameters corresponding to lading group (a) are assumed for loaded freight car derailments associated with flat car group no. 1A and the associated loaded car mileage used is 23.1×10^6 miles. The latter approximations should generally result in very good load estimates.

The assumptions outlined above are considered reasonable for the purposes of this study although an assumed "most frequent" load configuration must be used to characterize loads for commodity-indpendent car types. The load approximations used are not considered gross and are made in a relatively small percentage of the data base records (about 20 percent). This approximation also seems reasonable in the sense that the most frequently carried load configuration is assumed for these cases.

A complete description of the resulting file of accident data and associated physical attributes of derailed freight vehicles is contained in Table 1-1 in Section 1. This data is an abstract of the most salient information contained in RAIRS, UMLER and the

TABLE B-3. SELECTION OF TYPICAL LOAD FOR COMMODITY INDEPENDENT CARS

Part A: Box Car Example; DVC No. 2A

Lading Group No.	Total Annual Mileage (X10^6 mi)	Loaded Carbody Properties: Mass (# sec^2/in)	Roll Inertia (X10^5 in lb sec^2)	C.G. Height (in)	Vert. Freq. (Hz)
a.	59	188	8.4	73.8	17
b.	108	285	9.8	74.9	14
c.	27	330	10.2	70.2	13
d.	5	239	8.9	60.1	15
e.	12	294	9.6	58.2	14
f.	33	373	12.6	86.6	12
	244				

Representative lading group = no. b.
Total loaded car miles = 244 x 10^6

Part B: Flat Car Example; DVC No. 1A

Lading Group No.	Total Annual Mileage (X10^6 mi)	Loaded Carbody Properties: Mass (# sec^2/in)	Roll Inertia (X10^5 in lb sec^2)	C.G. Height (in)	Vert. Freq. (Hz)
a.	12.5	338	12.2	96.8	20
b.	10.6	353	13.5	100.5	20
	23.1				

Representative lading group = no. 147
Total loaded car miles = 23.1 x 10^6

fleet characterization data for the purpose of conducting an actuarial study of the relationship between causal factors (implying derailment mode), equipment designs and operating conditions. The data file, is composed of 16,000 records covering 2.75 years of accident reports and considers each derailment attributed to the selected cause code groups listed in Tables 2-1 and 2-2 of Section 2.

Referring to Table 1-1 in Section 1, it can be seen that each data base record contains a set of actual vehicle attributes (from UMLER) and a corresponding set of attributes which is assigned when each vehicle is identified with a DVC. Parameters such as outside length, inside length, weight capacity, volumetric capacity and lightweight are common descriptors. Since a relatively small number (198) of DVCs are used to characterize about 1.7 million U.S. freight vehicles, the range of possible values which a particular DVC descriptor may take is more discretized (in the sense that the number of possible values is limited) when a vehicle is represented by the DVC descriptors rather than those of the actual vehicle design.

To develop a qualitative sense of how representative the DVC descriptors are of the actual freight vehicle fleet, the vehicle/accident records have been used to generate cumulative distribution diagrams indicating the distribution of a particular vehicle attribute when represented by the actual vehicle parameter and its corresponding assigned (DVC) values.

Figure B-2 and B-3 indicate the cumulative number of derailments as a function of outside length (Figure B-2) and vehicle weight capacity (Figure B-3) using both the actual vehicle data taken from UMLER and the assigned values resulting from associating each derailed freight vehicle with a DVC. It can be seen that the overall distributions are very similar. These results imply that physical characteristics of derailed freight vehicles may be reasonably approximated by the fleet characterization data described in Appendix A.

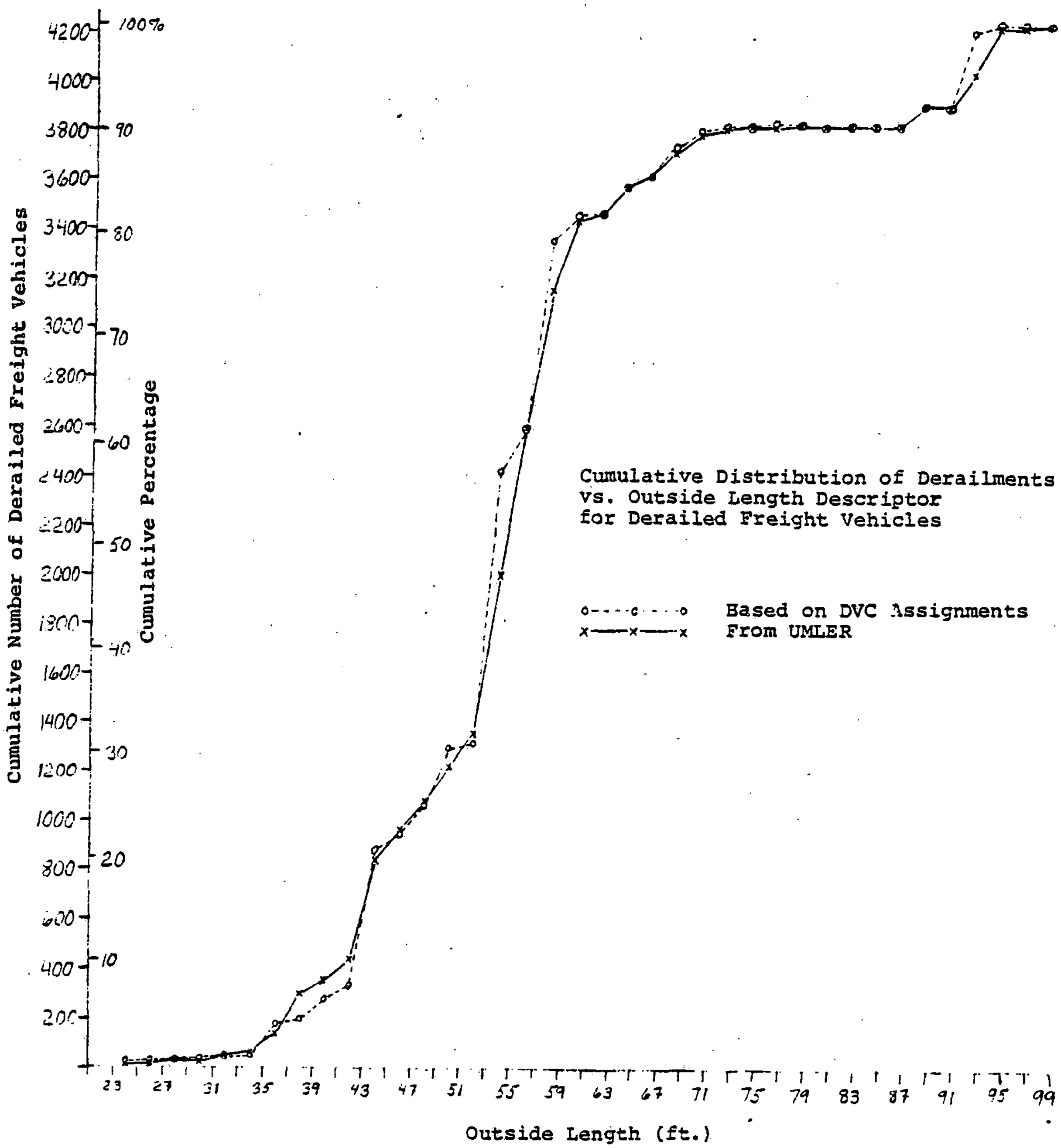


FIGURE B-2. CUMULATIVE DISTRIBUTION OF DERAILMENTS VS OUTSIDE LENGTH DESCRIPTOR FOR DERAILED FREIGHT VEHICLES

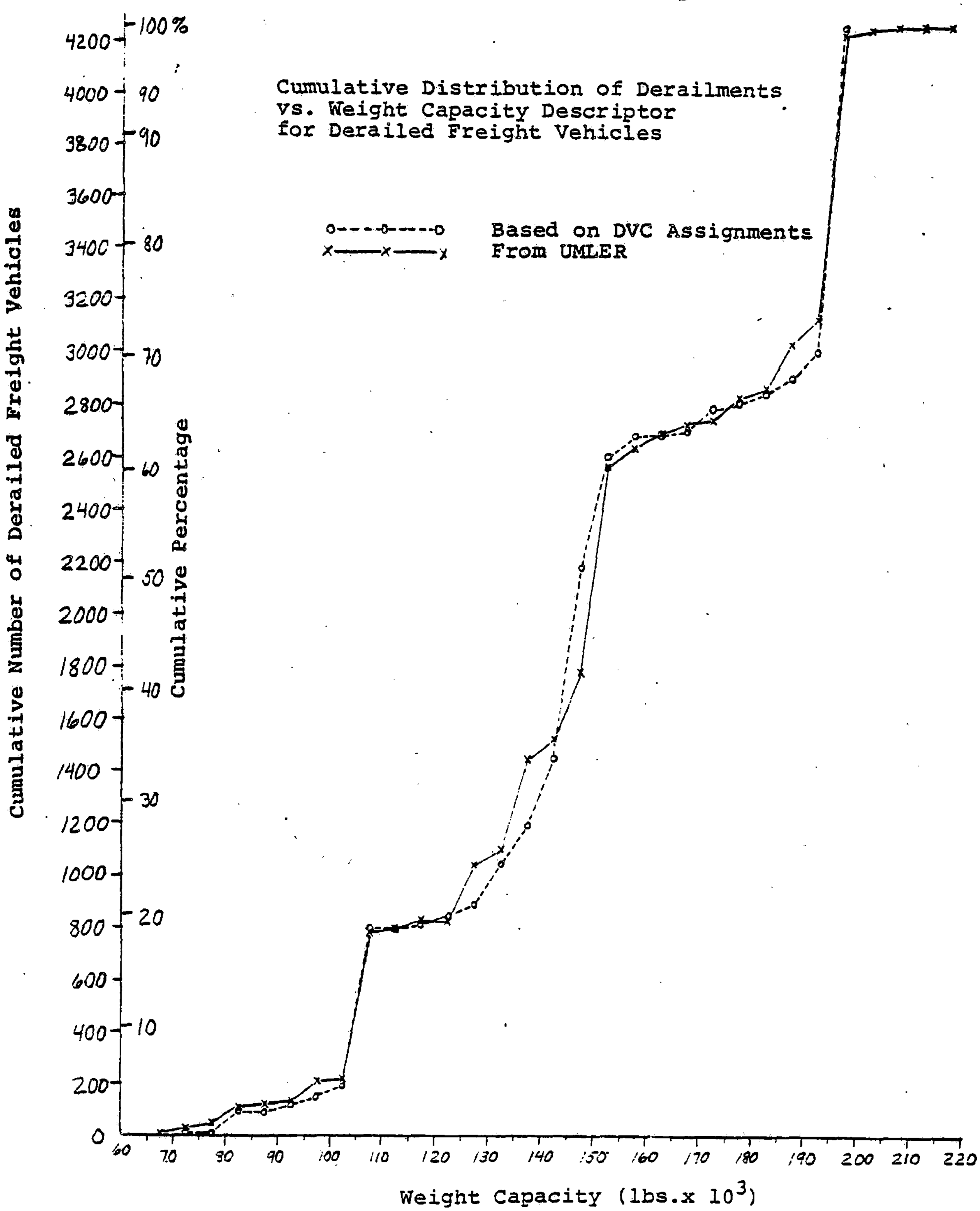


FIGURE B-3. CUMULATIVE DISTRIBUTION OF DERAILMENTS VS WEIGHT CAPACITY DESCRIPTOR FOR DERAILED FREIGHT VEHICLES

As a second qualitative check, the vehicle/accident records were sorted into groups according to combinations of parameters describing various vehicle configurations. In this process a matrix of relatively large ranges on vehicle outside length, nominal weight capacity and volumetric capacity were defined such that the entire fleet would be represented by a small number of vehicles described by these three descriptors. Three ranges were selected for each descriptor resulting in a total of twenty-seven combinations.

Vehicle/accident records were first sorted into this matrix of physical configurations using actual UMLER attributes for length, weight and volumetric capacity and then resorted using the corresponding values resulting from identifying each vehicle with a DVC. Tables B-4 and B-5 illustrate the number of (derailment) records falling into each vehicle configuration using actual (UMLER) and DVC values respectively. In each of these tables, flatcars are broken out separately since volumetric capacity does not apply to these cars. From a comparison of these tables it can be seen that the resulting derailment distributions are very similar. This is an important finding because these results imply that derailment profile data (extracted from analysis of the data appended to each record as a result of identifying each vehicle with a DVC), is very similar to the results one would obtain if the actual vehicle data were analyzed. Although results are not expected to be exact, the observed differences are considered small enough to suggest that the DVC assignments are reasonable representations of derailed freight vehicle configurations. Although freight vehicle fleet derailment profiles can be generated based on either the UMLER or DVC descriptions, the physical data available from UMLER is not very detailed for the purposes of this study. On the other hand, the DVC data is very detailed, including useful population data and mileage estimates for each major and distinctive vehicle design representing about 96 percent of the freight vehicle fleet, and can readily be associated with individual freight vehicle designs which have been involved in derailments. For these reasons, the

TABLE B-4. DISTRIBUTION OF FREIGHT VEHICLE DERAILMENTS AMONG VEHICLES DESCRIBED BY LENGTH, WEIGHT AND VOLUMETRIC CAPACITY ATTRIBUTES USING UMLER DATA

PART A, FLAT & VEHICULAR FLAT CARS

		WEIGHT CAPACITY (KIPS)		
		70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	11	0	0
LENGTH	47.1-62 (MED)	34	98	4
(FT)	62.1-80 (LONG)	0	64	27

PART B, ALL MECHANICAL TYPES EXCEPT FLATS & VEHICULAR FLATS

1. SMALL VOLUMETRIC CAPACITY (600-1300 FT^3 OR 5000-16500 GAL)

		WEIGHT CAPACITY (KIPS)		
		70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	130	401	112
LENGTH	47.1-62 (MED)	3	170	67
(FT)	62.1-80 (LONG)	0	27	3

2. MEDIUM VOLUMETRIC CAPACITY (3100-4900 FT^3 OR 16500-25500 GAL)

		WEIGHT CAPACITY (KIPS)		
		70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	262	22	24
LENGTH	47.1-62 (MED)	19	71	1132
(FT)	62.1-80 (LONG)	0	17	7

3. LARGE VOLUMETRIC CAPACITY (4900-7100 FT^3 OR 25500-34500 GAL)

		WEIGHT CAPACITY (KIPS)		
		70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	0	1	0
LENGTH	47.1-62 (MED)	206	628	66
(FT)	62.1-80 (LONG)	0	99	118

PART C, VERY LARGE FREIGHT VEHICLES

(IN TERMS OF LENGTH, WEIGHT CAPACITY AND/OR VOLUMETRIC CAPACITY)

		TYPICAL VEHICLES
WEIGHT CAP. (225-230 KIPS)	0	OPEN HOPPER (125 TON)
OVERALL LENGTH (27-96 FT)	423	BOX, FLAT & VEHICULAR FLAT
VOLUMETRIC CAPACITY (10,000 FT^3)	39	HIGH CUBE BOX

TABLE B-5. DISTRIBUTION OF FREIGHT VEHICLE DERAILMENTS AMONG VEHICLES DESCRIBED BY LENGTH, WEIGHT AND VOLUMETRIC CAPACITY ATTRIBUTES USING DVC DATA

PART A, FLAT & VEHICULAR FLAT CARS

		WEIGHT CAPACITY (KIPS) 70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	14	0	0
LENGTH	47.1-62 (MED)	31	100	0
(FT)	62.1-80 (LONG)	0	63	30

PART B, ALL MECHANICAL TYPES EXCEPT FLATS & VEHICULAR FLATS

1. SMALL VOLUMETRIC CAPACITY (600-3100 FT^3 OR 5000-16500 GAL)

		WEIGHT CAPACITY (KIPS) 70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	113	431	105
LENGTH	47.1-62 (MED)	4	170	63
(FT)	62.1-80 (LONG)	0	22	0

2. MEDIUM VOLUMETRIC CAPACITY (3100-4900 FT^3 OR 16500-25500 GAL)

		WEIGHT CAPACITY (KIPS) 70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	248	15	22
LENGTH	47.1-62 (MED)	17	48	1148
(FT)	62.1-80 (LONG)	0	22	6

3. LARGE VOLUMETRIC CAPACITY (4900-7100 FT^3 OR 25500-34500 GAL)

		WEIGHT CAPACITY (KIPS) 70-120 (LT)	120.1-165 (MED)	165.1-210 (HEAVY)
OVERALL	21-47 (SHORT)	0	0	0
LENGTH	47.1-62 (MED)	218	650	67
(FT)	62.1-80 (LONG)	0	88	133

PART C, VERY LARGE FREIGHT VEHICLES

(IN TERMS OF LENGTH, WEIGHT CAPACITY AND/OR VOLUMETRIC CAPACITY)

		TYPICAL VEHICLES
WEIGHT CAP. (225-230 KIPS)	0	OPEN HOPPER (125 TON)
OVERALL LENGTH (87-96 FT)	423	BOX, FLAT & VEHICULAR FLAT
VOLUMETRIC CAPACITY (10,000 FT^3)	39	HIGH CUBE BOX

DVC descriptions have been used primarily in this study unless otherwise specified.

As a result of linking each derailed freight vehicle with a distinctive vehicle group (DVC), an estimate of the total annual miles traveled by vehicles having a particular physical characteristic or combinations of physical characteristics is available (including both loaded or unloaded conditions). This permits the calculation of estimated derailment frequencies for various combinations of accident and/or vehicle physical attributes. For example, consider the question of the relative derailment tendency of different vehicles, each having a different center of gravity height. Also consider the range of c.g. heights in the fleet to be represented by the following groups.

GROUP	C.G. HEIGHT
1	25 - 50 in.
2	50 - 70 in.
3	70 - 90 in.
4	90 - 110 in.

A derailment incidence vs c.g. height could be determined by counting, for each group, the number of derailed freight vehicles which have a c.g. height lying within that group. The corresponding mileage weighted derailment frequency can be estimated by summing the total mileage traveled by vehicles having c.g. heights in each of the four ranges. Derailment frequencies can then be calculated on a per mile basis by dividing total number of derailments by total miles traveled. This process is outlined in Figure B-4. Figure B-5 shows the results of this exercise and indicates that while the highest incidence of derailment occurs for vehicles having c.g. heights in the 70 to 90 inch range, the highest frequency of derailment is associated with the high c.g. (90 - 110 inch) cars.

The above example is typical of the derailment frequency computations made in Section 2.0. Principal assumptions and approximations used in the vehicle/accident correlation studies are outlined below.

SELECT COMBINATIONS OF VEHICLE ACCIDENT AND PHYSICAL ATTRIBUTES OF INTEREST

OPERATE ON UMLER/RAIS DATA BASE TO PROVIDE:

DERAILMENT COUNTS ON UMLER/RAIS RECORDS HAVING THIS COMBINATION OF ACCIDENT AND PHYSICAL ATTRIBUTES

MILEAGE COUNT ON ALL DVC GROUPS HAVING THE COMBINATION OF PHYSICAL ATTRIBUTES OF INTEREST

$$\text{DERAILMENT FREQUENCY} = \frac{\text{DERAILMENT COUNT}}{\text{MILEAGE COUNT}}$$

FIGURE B-4. BASIS FOR DERAILMENT FREQUENCY CALCULATIONS

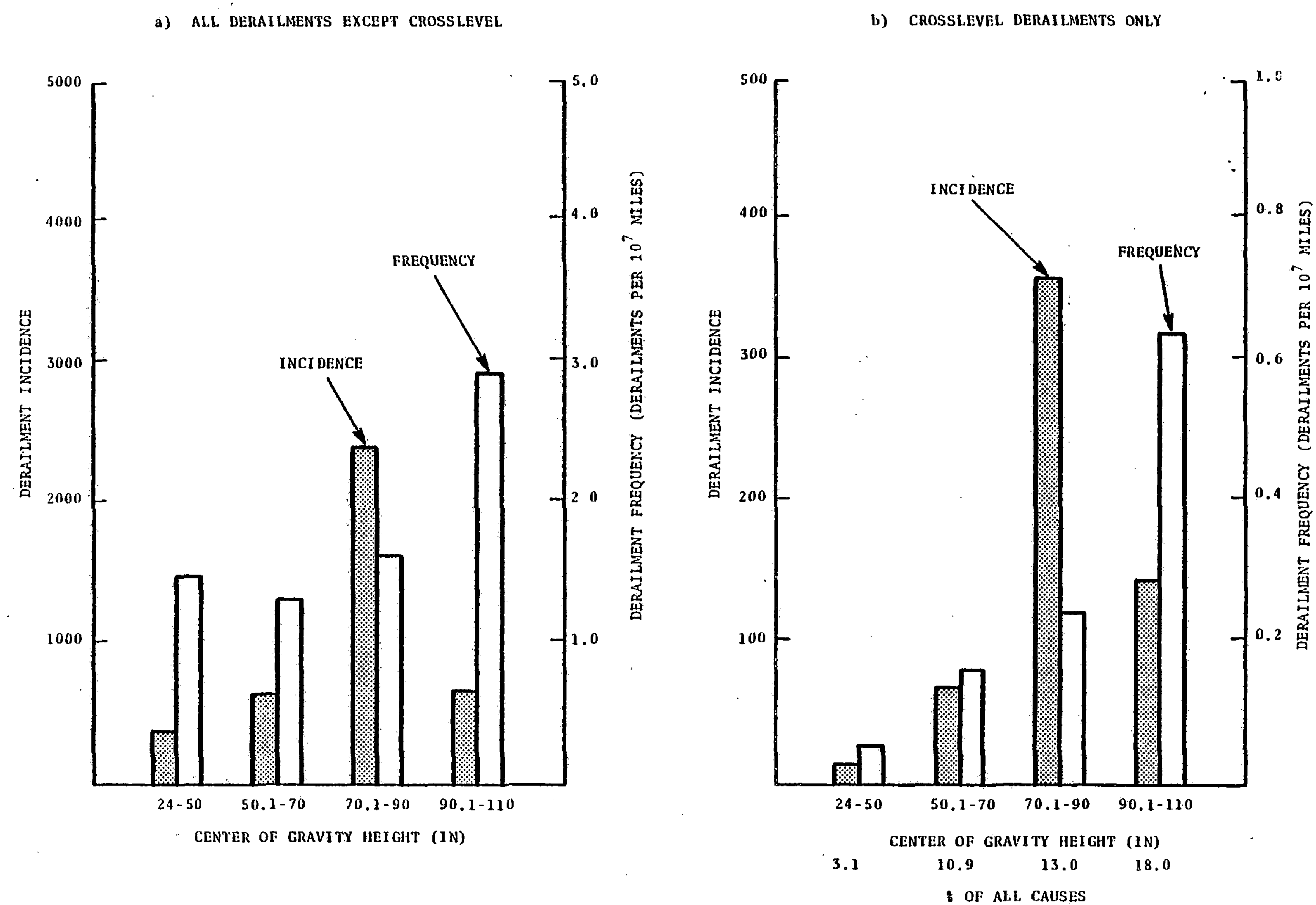


FIGURE B-5. DERAILMENT INCIDENCE AND FREQUENCY VS CENTER OF GRAVITY HEIGHTS

APPROXIMATIONS

The information contained in the data base should not be taken as exact because of (a) assumptions implicit in using the limited accident data contained in RAIRS and (b) approximations in developing engineering parameter descriptions of distinctive vehicle design groups and associated mileage estimates. Nevertheless, many of the assumptions and/or approximations used are considered reasonable for the purposes of this study. Principal approximations and/or simplifying assumptions used in this study include:

- In using the RAIRS data, a "first involved" or "causing" vehicle is identified. Information on other derailed freight vehicles is not included, hence the analysis is limited to vehicles identified in the accident records.
- Even though the validity of accident attributes such as accident cause and vehicle speed are, in many cases, difficult to judge. the validity of assigned accident attributes is assumed correct.
- It is assumed that unknown physical characteristics of derailed freight vehicles are quite similar to those of the design groups with which the derailed vehicle has been identified. This is a reasonable assumption because the design group definitions are usually very narrow and represent large populations of railcars which have relatively small variations from a nominal representative value. The assumption is based on the fact that an element of approximation is inherent in matching a derailed freight vehicle configuration to one of the 198 "distinctive vehicle design groups" in order to expand the physical descriptions of derailed freight vehicles. In most instances, only small differences exist in matching parameters.
- Several approximations were necessary in developing mileage data used for computing mileage-weighted derailment frequencies of various vehicle configurations. This is discussed in more detail in later sections.

- For certain car-types which carry a wide variety of commodities and load weights, an approximate or "averaged" load condition has been established in the absence of more detailed information. This assumption is necessary because the accident data only indicates if a vehicle is loaded and does not indicate commodity or load weight carried. In many cases, load conditions can be assumed with confidence because of known car-commodity relationships.
- In developing derailment scenarios it is implicitly assumed that all vehicles in the fleet experience relatively equal exposure to track of varying quality (i.e., track classes) and have relatively equal mileage speed distributions such that the probability of derailment for any group of vehicles in the fleet is not overly influenced by a disproportionate amount of exposure to such factors when compared to the overall utilization profile of other groups of vehicles.

APPENDIX

C

SPEED RANGE MPH		PERCENT DISTRIBUTION
10.1 to	15.0	09*********
15.1	20.0	18******************
20.1	25.0	21*********************
25.1	30.0	17*****************
30.1	35.0	13*************
35.1	40.0	10**********
40.1	45.0	06******
45.1	50.0	03***
50.1	55.0	00
55.1	60.0	00
60.1	65.0	00
65.1	70.0	00
70.1	75.0	00
75.1	80.0	00
80.1	85.0	00
85.1	90.0	00

Average derailment speed = 28.7 mph.
Each * = 1% Based on 246 derailments

FIGURE C-1. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 4, ALINEMENT

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	20********************
15.1		20.0	29*****************************
20.1		25.0	29*****************************
25.1		30.0	13*************
30.1		35.0	03***
35.1		40.0	03***
40.1		45.0	01*
45.1		50.0	01*
50.1		55.0	00
55.1		60.0	00
60.1		65.0	00
65.1		70.0	00
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 543 derailments
Average derailment speed = 22.9 mph.

FIGURE C-2. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 7, CROSSLEVEL

SPEED RANGE MPH		PERCENT DISTRIBUTION
10.1 to	15.0	07*******
15.1	20.0	13*************
20.1	25.0	13*************
25.1	30.0	13*************
30.1	35.0	09*********
35.1	40.0	14**************
40.1	45.0	13*************
45.1	50.0	11***********
50.1	55.0	03***
55.1	60.0	03***
60.1	65.0	00
65.1	70.0	01*
70.1	75.0	00
75.1	80.0	00
80.1	85.0	00
85.1	90.0	00

Each * = 1% Based on 321 derailments
Average derailment speed = 34.2 mph

FIGURE C-3. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 14, COUPLER AND DRAFT SYSTEM FAILURE

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	22**********************
15.1		20.0	25*************************
20.1		25.0	26**************************
25.1		30.0	12************
30.1		35.0	03***
35.1		40.0	05*****
40.1		45.0	03**
45.1		50.0	02**
50.1		55.0	01*
55.1		60.0	01*
60.1		65.0	00
65.1		70.0	00
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 236 derailments

Average derailment speed = 23.9 mph

FIGURE C-4. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 15, SIDE BEARINGS

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	06******
15.1		20.0	10**********
20.1		25.0	14**************
25.1		30.0	18******************
30.1		35.0	14**************
35.1		40.0	16****************
40.1		45.0	08********
45.1		50.0	08********
50.1		55.0	04****
55.1		60.0	02**
60.1		65.0	01*
65.1		70.0	00
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 309 derailments
Average derailment speed = 33.6 mph

FIGURE C-5. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 17, PLAIN JOURNALS, OVERHEATED

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	04****
15.1		20.0	07*******
20.1		25.0	07*******
25.1		30.0	11***********
30.1		35.0	11***********
35.1		40.0	13*************
40.1		45.0	09*********
45.1		50.0	18******************
50.1		55.0	06******
55.1		60.0	09*********
60.1		65.0	02**
65.1		70.0	03***
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 256 derailments
Average derailment speed = 40.8 mph

FIGURE C-6. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 19, BROKEN WHEELS

SPEED RANGE MPH			PERCENT DISTRIBUTION
10.1	to	15.0	24************************
15.1		20.0	19*******************
20.1		25.0	23***********************
25.1		30.0	12************
30.1		35.0	03***
35.1		40.0	08********
40.1		45.0	02**
45.1		50.0	03***
50.1		55.0	03***
55.1		60.0	02**
60.1		65.0	00
65.1		70.0	00
70.1		75.0	00
75.1		80.0	00
80.1		85.0	00
85.1		90.0	00

Each * = 1% Based on 226 derailments
Average derailment speed = 25.6 mph

FIGURE C-7. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 25, EXCESSIVE BUFF/SLACK ACTION

SPEED RANGE MPH	PERCENT DISTRIBUTION
10.1 to 15.0	13*************
15.1 20.0	21*********************
20.1 25.0	28****************************
25.1 30.0	20********************
30.1 35.0	08********
35.1 40.0	05*****
40.1 45.0	03***
45.1 50.0	01*
50.1 55.0	01*
55.1 60.0	00
60.1 65.0	00
65.1 70.0	00
70.1 75.0	00
75.1 80.0	00
80.1 85.0	00
85.1 90.0	00

Each * = 1% Based on 368 derailments

Average derailment speed = 25.5 mph

FIGURE C-8. PERCENT DISTRIBUTION OF DERAILMENTS VS FIVE MPH SPEED BANDS FOR CAUSE CODE GROUP 29, RAIL-HEAD FAILURES

TABLE C-1. DERAILMENT DATA VS CARTYPE AND TRUCK CAPACITY FOR ALINEMENT CAUSE CODE GROUP

Cause Code Group-- 4. (Alinement)

MECH-CAR TYPE	TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level	TOTAL
Box	3448448.	3598942.	736713.	0.	0.	7784103.
	22	25	3	0	0	50
	0.23	0.25	0.15	0.00	0.00	0.23
Stock	33279.	0.	0.	0.	0.	33279.
	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerator	258189.	1503594.	200143.	0.	0.	1961926.
	0	10	1	0	0	11
	0.00	0.24	0.18	0.00	0.00	0.20
Cov. Hopper	0.	812567.	2661905.	0.	0.	3474472.
	0	10	75	0	0	85
	0.00	0.45	1.02	0.00	0.00	0.89
Open Hopper	281456.	1509570.	1211303.	20782.	0.	3023111.
	3	10	29	0	0	42
	0.39	0.24	0.87	0.00	0.00	0.51
Gondola	87287.	793069.	1097472.	0.	0.	1977829.
	0	2	18	0	0	20
	0.00	0.09	0.60	0.00	0.00	0.37
Flat (incl. TOFC)	446851.	2235951.	247803.	0.	89137.	3019742.
	1	14	1	0	0	16
	0.08	0.23	0.15	0.00	0.00	0.19
Vehicular Flat	0.	513067.	0.	0.	437043.	950110.
	0	1	0	0	1	2
	0.00	0.07	0.00	0.00	0.08	0.08
Tank	607390.	124474.	993548.	0.	0.	1725412.
	3	2	15	0	0	20
	0.18	0.58	0.55	0.00	0.00	0.42
MILES	5162900.	11091234.	7148888.	20782.	526180.	23949984.
COUNT	29	74	142	0	1	246
FREQ	0.20	0.24	0.72	0.00	0.07	0.37

TABLE C-2. DERAILMENT DATA VS CARTYPE AND TRUCK CAPACITY FOR CROSSLEVEL CAUSE CODE GROUP

Cause Code Group-- 7. (Crosslevel)

MECH-CAR TYPE		TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level		TOTAL
Box	I	3448448.	3598942.	736713.	0.	0.	I	7784103.
	I	42	93	6	0	0	I	141
	I	0.44	0.94	0.30	0.00	0.00	I	0.66
Stock	I	33279.	0.	0.	0.	0.	I	33279.
	I	0	0	0	0	0	I	0
	I	0.00	0.00	0.00	0.00	0.00	I	0.00
Refrigerator	I	258189.	1503594.	200143.	0.	0.	I	1961926.
	I	2	37	7	0	0	I	46
	I	0.28	0.89	1.27	0.00	0.00	I	0.85
Cov. Hopper	I	0.	812567.	2661905.	0.	0.	I	3474472.
	I	0	22	185	0	0	I	207
	I	0.00	0.98	2.53	0.00	0.00	I	2.17
Open Hopper	I	281456.	1509570.	1211303.	20782.	0.	I	3023111.
	I	9	21	41	0	0	I	71
	I	1.16	0.51	1.23	0.00	0.00	I	0.85
Gondola	I	87287.	793069.	1097472.	0.	0.	I	1977829.
	I	0	9	7	0	0	I	16
	I	0.00	0.41	0.23	0.00	0.00	I	0.29
Flat (incl. TOFC)	I	446851.	2235951.	247003.	0.	89137.	I	3019742.
	I	1	16	1	0	0	I	18
	I	0.08	0.26	0.15	0.00	0.00	I	0.22
Vehicular Flat	I	0.	513067.	0.	0.	437043.	I	950110.
	I	0	2	0	0	9	I	11
	I	0.00	0.14	0.00	0.00	0.75	I	0.42
Tank	I	607390.	124474.	993548.	0.	0.	I	1725412.
	I	8	3	22	0	0	I	33
	I	0.48	0.88	0.81	0.00	0.00	I	0.70
MILES	I	5162900.	11091234.	7148087.	20782.	526180.	I	23949904.
COUNT	I	62	203	269	0	9	I	543
FREQ	I	0.44	0.67	1.37	0.00	0.62	I	0.82

TABLE C-3. DERAILMENT DATA VS CARTYPE AND TRUCK CAPACITY FOR COUPLER/DRAFT SYSTEM

Cause Code Group-- 14. (Coupler/Draft System)

MECH-CAR TYPE		TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level		TOTAL
Box	I	3448448.	3598942.	736713.	0.	0.	I	7784103.
	I	62	41	5	0	0	I	108
	I	0.65	0.41	0.25	0.00	0.00	I	0.50
Stock	I	33279.	0.	0.	0.	0.	I	33279.
	I	0	0	0	0	0	I	0
	I	0.00	0.00	0.00	0.00	0.00	I	0.00
Refrigerator	I	258189.	1503594.	200143.	0.	0.	I	1961926.
	I	1	14	5	0	0	I	20
	I	0.14	0.34	0.91	0.00	0.00	I	0.37
Cov. Hopper	I	0.	812567.	2661905.	0.	0.	I	3474472.
	I	0	10	15	0	0	I	25
	I	0.00	0.45	0.20	0.00	0.00	I	0.26
Open Hopper	I	281456.	1509570.	1211303.	20782.	0.	I	3023111.
	I	5	7	5	0	0	I	17
	I	0.65	0.17	0.15	0.00	0.00	I	0.20
Gondola	I	87287.	793069.	1097472.	0.	0.	I	1977829.
	I	3	9	9	0	0	I	21
	I	1.25	0.41	0.30	0.00	0.00	I	0.39
Flat (incl. TOFC)	I	446851.	2235951.	247803.	0.	89137.	I	3019742.
	I	4	73	5	0	1	I	83
	I	0.33	1.19	0.73	0.00	0.41	I	1.00
Vehicular Flat	I	0.	513067.	0.	0.	437043.	I	950110.
	I	0	6	0	0	31	I	37
	I	0.00	0.43	0.00	0.00	2.58	I	1.42
Tank	I	607390.	124474.	993548.	0.	0.	I	1725412.
	I	1	0	9	0	0	I	10
	I	0.06	0.00	0.33	0.00	0.00	I	0.21
MILES	I	5162900.	11091234.	7148888.	20782.	526180.	I	23949984.
COUNT	I	76	160	53	0	32	I	321
FREQ	I	0.54	0.52	0.27	0.00	2.21	I	0.49

TABLE C-4. DERAILMENT DATA VS CARTYPE AND TRUCK CAPACITY FOR SIDE BEARINGS

Cause Code Group-- 15. (Side Bearings)

MECH-CAR TYPE	TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level	TOTAL
Box	3448448.	3598942.	736713.	0.	0.	7784103.
	15	35	3	0	0	53
	0.16	0.35	0.15	0.00	0.00	0.25
Stock	33279.	0.	0.	0.	0.	33279.
	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerator	258189.	1503594.	200143.	0.	0.	1961926.
	1	20	1	0	0	22
	0.14	0.48	0.18	0.00	0.00	0.41
Cov. Hopper	0.	812567.	2661905.	0.	0.	3474472.
	0	23	90	0	0	113
	0.00	1.03	1.23	0.00	0.00	1.18
Open Hopper	281456.	1509570.	1211303.	20782.	0.	3023111.
	2	10	6	0	0	18
	0.26	0.24	0.18	0.00	0.00	0.22
Gondola	87287.	793069.	1097472.	0.	0.	1977829.
	0	2	3	0	0	5
	0.00	0.09	0.10	0.00	0.00	0.09
Flat (incl. TOFC)	446851.	2235951.	247803.	0.	89137.	3019742.
	0	9	0	0	0	9
	0.00	0.15	0.00	0.00	0.00	0.11
Vehicular Flat	0.	513067.	0.	0.	437043.	950110.
	0	2	0	0	4	6
	0.00	0.14	0.00	0.00	0.33	0.23
Tank	607390.	124474.	993548.	0.	0.	1725412.
	2	1	7	0	0	10
	0.12	0.29	0.26	0.00	0.00	0.21
MILES	5162900.	11091234.	7148888.	20782.	526180.	23949984.
COUNT	20	102	110	0	4	236
FREQ	0.14	0.33	0.56	0.00	0.28	0.36

TABLE C-5. DERAILMENT DATA VS CARTYPE AND TRUCK CAPACITY FOR PLAIN JOURNALS OVERHEATED

Cause Code Group-- 17. (Plain Journals Overheated)

MECH-CAR TYPE	TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level	TOTAL
Box	3448448.	3598942.	736713.	0.	0.	7784103.
	55	5	0	0	0	60
	0.58	0.05	0.00	0.00	0.00	0.28
Stock	33279.	0.	0.	0.	0.	33279.
	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerator	258189.	1503594.	200143.	0.	0.	1961926.
	3	2	0	0	0	5
	0.42	0.05	0.00	0.00	0.00	0.09
Cov. Hopper	0.	812567.	2661905.	0.	0.	3474472.
	0	56	4	0	0	60
	0.00	2.51	0.05	0.00	0.00	0.63
Open Hopper	281456.	1509570.	1211303.	20782.	0.	3023111.
	4	33	1	0	0	38
	0.52	0.79	0.03	0.00	0.00	0.46
Gondola	87287.	793069.	1097472.	0.	0.	1977829.
	5	75	1	0	0	81
	2.08	3.44	0.03	0.00	0.00	1.49
Flat (incl. TOFC)	446851.	2235951.	247803.	0.	89137.	3019742.
	6	12	0	0	0	18
	0.49	0.20	0.00	0.00	0.00	0.22
Vehicular Flat	0.	513067.	0.	0.	437043.	950110.
	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00
Tank	607390.	124474.	993548.	0.	0.	1725412.
	28	17	2	0	0	47
	1.68	4.97	0.07	0.00	0.00	0.99
MILES	5162900.	11091234.	7148080.	20782.	526180.	23949984.
COUNT	101	200	8	0	0	309
FREQ	0.71	0.66	0.04	0.00	0.00	0.47

TABLE C-6. DERAILMENT VS CARTYPE AND TRUCK CAPACITY FOR BROKEN WHEEL COMPONENTS

Cause Code Group-- 19. (Broken Wheel Components)

MECH-CAR TYPE		TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level		TOTAL
Box	I	3448448.	3598942.	736713.	0.	0.	I	7784103.
	I	26	46	6	0	0	I	78
	I	0.27	0.46	0.30	0.00	0.00	I	0.36
Stock	I	33279.	0.	0.	0.	0.	I	33279.
	I	0	0	0	0	0	I	0
	I	0.00	0.00	0.00	0.00	0.00	I	0.00
Refrigerator	I	258189.	1503594.	200143.	0.	0.	I	1961926.
	I	7	19	1	0	0	I	27
	I	0.99	0.46	0.18	0.00	0.00	I	0.50
Cov. Hopper	I	0.	812567.	2661905.	0.	0.	I	3474472.
	I	0	7	30	0	0	I	37
	I	0.00	0.31	0.41	0.00	0.00	I	0.39
Open Hopper	I	281456.	1509570.	1211303.	20782.	0.	I	3023111.
	I	1	18	7	0	0	I	26
	I	0.13	0.43	0.21	0.00	0.00	I	0.31
Gondola	I	87287.	793069.	1097472.	0.	0.	I	1977829.
	I	2	6	5	0	0	I	13
	I	0.83	0.28	0.17	0.00	0.00	I	0.24
Flat (incl. TOFC)	I	446051.	2235951.	247003.	0.	89137.	I	3019742.
	I	2	36	3	0	0	I	41
	I	0.16	0.59	0.44	0.00	0.00	I	0.49
Vehicular Flat	I	0.	513067.	0.	0.	437043.	I	950110.
	I	0	2	0	0	22	I	24
	I	0.00	0.14	0.06	0.00	1.83	I	0.92
Tank	I	607390.	124474.	993548.	0.	0.	I	1725412.
	I	0	1	9	0	0	I	10
	I	0.00	0.29	0.33	0.00	0.00	I	0.21
MILES	I	5162900.	11091234.	7148008.	20782.	526180.	I	23949984.
COUNT	I	30	135	61	0	22	I	256
FREQ	I	0.27	0.44	0.31	0.00	1.52	I	0.39

TABLE C-7. DERAILMENT VS CARTYPE AND TRUCK CAPACITY FOR EXCESSIVE BUFF/SLACK ACTION

Cause Code Group-- 25. (Excessive Buff/Slack Action)

MECH-CAR TYPE	TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level	TOTAL
Box	3448448.	3598942.	736713.	0.	0.	7784103.
	20	33	13	0	0	66
	0.21	0.33	0.64	0.00	0.00	0.31
Stock	33279.	0.	0.	0.	0.	33279.
	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerator	258189.	1503594.	200143.	0.	0.	1961926.
	0	14	2	0	0	16
	0.00	0.34	0.36	0.00	0.00	0.30
Cov. Hopper	0.	812567.	2661905.	0.	0.	3474472.
	0	11	51	0	0	62
	0.00	0.49	0.70	0.00	0.00	0.65
Open Hopper	281456.	1509570.	1211303.	20782.	0.	3023111.
	5	11	15	0	0	31
	0.65	0.26	0.45	0.00	0.00	0.37
Gondola	87287.	793069.	1097472.	0.	0.	1977829.
	0	6	2	0	0	8
	0.00	0.28	0.07	0.00	0.00	0.15
Flat (incl. TOFC)	446851.	2235951.	247803.	0.	89137.	3019742.
	4	22	1	0	0	27
	0.33	0.46	0.15	0.00	0.00	0.33
Vehicular Flat	0.	513067.	0.	0.	437043.	950110.
	0	1	0	0	3	4
	0.00	0.07	0.00	0.00	0.25	0.15
Tank	607390.	124474.	993548.	0.	0.	1725412.
	6	0	6	0	0	12
	0.36	0.00	0.22	0.00	0.00	0.25
MILES	5162900.	11091234.	7148008.	20782.	526180.	23949984
COUNT	35	98	90	0	3	226
FREQ	0.25	0.32	0.46	0.00	0.21	0.34

TABLE C-8. DERAILMENT VS CARTYPE AND TRUCK CAPACITY FOR RAIL HEAD FAILURES

Cause Code Group-- 29. (Rail Head Failures)

MECH-CAR TYPE		TRUCK CAPACITY 50 Ton	70 Ton	100 Ton	125 Ton	Low Level	TOTAL
Box		3448448.	3598942.	736713.	0.	0.	7784103.
		42	45	2	0	0	89
		0.44	0.45	0.10	0.00	0.00	0.42
Stock		33279.	0.	0.	0.	0.	33279.
		0	0	0	0	0	0
		0.00	0.00	0.00	0.00	0.00	0.00
Refrigerator		258189.	1503594.	200143.	0.	0.	1961926.
		1	17	1	0	0	19
		0.14	0.41	0.18	0.00	0.00	0.35
Cov. Hopper		0.	812567.	2661905.	0.	0.	3474472.
		0	9	86	0	0	95
		0.00	0.40	1.17	0.00	0.00	0.99
Open Hopper		281456.	1509570.	1211303.	20782.	0.	3023111.
		1	23	49	0	0	73
		0.13	0.55	1.47	0.00	0.00	0.88
Gondola		87287.	793069.	1097472.	0.	0.	1977829.
		4	8	16	0	0	28
		1.67	0.37	0.53	0.00	0.00	0.51
Flat (incl. TOFC)		446851.	2235951.	247803.	0.	89137.	3019742.
		6	23	3	0	0	32
		0.49	0.37	0.44	0.00	0.00	0.39
Vehicular Flat		0.	513067.	0.	0.	437043.	950110.
		0	0	0	0	5	5
		0.00	0.00	0.00	0.00	0.42	0.19
Tank		607390.	124474.	993548.	0.	0.	1725412.
		5	1	21	0	0	27
		0.30	0.29	0.77	0.00	0.00	0.57
	MILES	5162900.	11091234.	7148888.	20782.	526180.	23949984.
	COUNT	59	126	178	0	5	368
	FREQ	0.42	0.41	0.91	0.00	0.35	0.56

TABLE C-9. DERAILMENT COUNTS AND FREQUENCIES BY GENERIC FAMILY AND TRUCK TYPE--FOR AXLE LOADS REPRESENTATIVE OF EMPTY FREIGHT CARS (0 to 22,000 lbs)

		TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
	GFC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
(a)	1 1 0 0	5.	87728.	2.07	9.	105278.	3.11	0.	0.	0.00
	2 1 0 0	94.	1225533.	2.79	56.	1069663.	1.90	31.	340738.	3.31
	3 1 0 0	85.	783878.	3.94	258.	2369801.	3.96	136.	1866775.	2.65
	4 1 0 0	0.	0.	0.00	66.	255632.	9.39	70.	952108.	2.67
	5 1 0 0	0.	0.	0.00	55.	530482.	3.77	4.	18877.	7.71
(b)	0 1 1 0	21.	312900.	2.44	195.	1720857.	4.12	20.	382824.	1.90
	0 1 2 0	162.	1754371.	3.36	247.	2602963.	3.45	193.	2561096.	2.74
	0 1 3 0	1.	29868.	1.22	2.	7036.	10.34	28.	234578.	4.34
(c)	1 1 1 0	0.	0.	0.00	4.	[illegible]	1.69	0.	0.	0.00
	1 1 2 0	4.	65520.	2.22	3.	12298.	8.87	0.	0.	0.00
	1 1 3 0	1.	22208.	1.64	2.	7036.	10.34	0.	0.	0.00
	2 1 1 0	10.	136843.	2.66	8.	263327.	1.10	0.	6620.	0.00
	2 1 2 0	84.	1081030.	2.83	48.	806336.	2.16	29.	297749.	3.54
	2 1 3 0	0.	7660.	0.00	0.	0.	0.00	2.	36369.	2.00
	3 1 1 0	11.	176057.	2.27	90.	726250.	4.51	13.	303951.	1.56
	3 1 2 0	74.	607021.	4.43	168.	1643551.	3.72	103.	[illegible]	[illegible]
	3 1 3 0	0.	0.	0.00	0.	0.	0.00	20.	[illegible]	4.21
	4 1 1 0	0.	0.	0.00	38.	114854.	12.03	3.	55313.	1.97
	4 1 2 0	0.	0.	0.00	28.	140778.	7.23	61.	871535.	2.55
	4 1 3 0	0.	0.	0.00	0.	0.	0.00	6.	25260.	8.64
	5 1 1 0	0.	0.	0.00	55.	530482.	3.77	4.	16940.	8.59
	5 1 2 0	0.	0.	0.00	0.	0.	0.00	0.	1937.	0.00
	5 1 3 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00

Note: Track Type 1 Track Class 2-6 SPEEDS GT 10 MPH

TABLE C-10. DERAILMENT COUNTS AND FREQUENCIES BY GENERIC FAMILY AND TRUCK TYPE--FOR MEDIUM WEIGHT AXLE LOADS (22,000 to 46,000 lbs)

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GFC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 2 0 0	16.	81975.	7.10	24.	117414.	7.43	0.	0.	0.00
2 2 0 0	291.	1758986.	6.02	54.	225507.	8.71	20.	96291.	7.55
3 2 0 0	185.	1224800.	5.49	616.	3333200.	6.72	14.	155631.	3.27
4 2 0 0	0.	0.	0.00	78.	363391.	7.81	51.	372957.	4.97
5 2 0 0	0.	0.	0.00	273.	1589009.	6.24	17.	60784.	10.17
0 2 1 0	32.	174100.	0.68	211.	709491.	10.81	7.	40747.	6.25
0 2 2 0	439.	2830193.	5.64	790.	4528164.	6.34	75.	548625.	4.97
0 2 3 0	21.	61468.	12.42	44.	391666.	4.09	20.	96291.	7.55
1 2 1 0	0.	0.	0.00	1.	13600.	2.67	0.	0.	0.00
1 2 2 0	17.	61223.	7.13	21.	97239.	7.85	0.	0.	0.00
1 2 3 0	4.	20752.	7.01	2.	6573.	11.06	0.	0.	0.00
2 2 1 0	14.	42800.	11.09	9.	41900.	7.81	0.	0.	0.00
2 2 2 0	270.	1684776.	5.83	37.	182128.	7.39	0.	0.	0.00
2 2 3 0	7.	31416.	8.10	8.	1479.	196.69	20.	96291.	7.55
3 2 1 0	18.	131300.	4.99	159.	565100.	10.23	0.	0.	0.00
3 2 2 0	157.	1084200.	5.27	442.	2713700.	5.92	14.	155631.	3.27
3 2 3 0	10.	9300.	39.10	15.	54400.	10.03	0.	0.	0.00
4 2 1 0	0.	0.	0.00	13.	27391.	17.26	7.	40747.	6.25
4 2 2 0	0.	0.	0.00	65.	330000.	7.03	44.	332210.	4.82
4 2 3 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00
5 2 1 0	0.	0.	0.00	29.	61500.	17.15	0.	0.	0.00
5 2 2 0	0.	0.	0.00	225.	1199097.	6.82	17.	60784.	10.17
5 2 3 0	0.	0.	0.00	19.	329212.	2.10	0.	0.	0.00

Note: Track Type 1 Track Class 2-6 Speeds GT 10 MPH

TABLE C-11. DERAILMENT COUNTS AND FREQUENCIES BY GENERIC FAMILY AND TRUCK TYPE--FOR HEAVY AXLE LOADS (46,000 to 70,000 lbs)

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GFC	CCUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 3 0 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00
2 3 0 0	0.	0.	0.00	286.	909835.	11.43	134.	242190.	20.12
3 3 0 0	0.	0.	0.00	97.	150322.	23.46	823.	1960579.	15.20
4 3 0 0	0.	0.	0.00	0.	0.	0.00	263.	964653.	9.91
5 3 0 0	0.	0.	0.00	11.	70900.	5.64	14.	58135.	8.76
0 3 1 0	0.	0.	0.00	11.	34934.	11.45	32.	434956.	2.68
0 3 2 0	0.	0.	0.00	378.	1094698.	12.56	550.	1362912.	14.67
0 3 3 0	0.	0.	0.00	5.	1425.	127.59	652.	1435609.	16.51
1 3 1 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00
1 3 2 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00
1 3 3 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00
2 3 1 0	0.	0.	0.00	4.	22834.	6.37	0.	34500.	0.00
2 3 2 0	0.	0.	0.00	282.	887001.	11.56	104.	129985.	29.09
2 3 3 0	0.	0.	0.00	0.	0.	0.00	30.	77705.	14.04
3 3 1 0	0.	0.	0.00	7.	12100.	21.04	27.	376256.	2.61
3 3 2 0	0.	0.	0.00	85.	136797.	22.59	407.	068891.	17.03
3 3 3 0	0.	0.	0.00	5.	1425.	127.59	389.	723432.	19.55
4 3 1 0	0.	0.	0.00	0.	0.	0.00	5.	24200.	7.51
4 3 2 0	0.	0.	0.00	0.	0.	0.00	32.	324036.	3.58
4 3 3 0	0.	0.	0.00	0.	0.	0.00	226.	615617.	13.35
5 3 1 0	0.	0.	0.00	0.	0.	0.00	0.	0.	0.00
5 3 2 0	0.	0.	0.00	11.	70900.	5.64	7.	39200.	6.49
5 3 3 0	0.	0.	0.00	0.	0.	0.00	7.	18935.	13.44

Note: Track Type 1 Track Class 2-6 Speeds GT 10 MPH

TABLE C-12. DERAILMENTS DATA BY GENERIC VEHICLE CONFIGURATION AND ALINEMENT CAUSE CODE GROUP

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GPC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 0 0 0	1.	169733.	0.21	0.	222692.	0.00	0.	0.	0.00
2 0 0 0	15.	2994519.	0.18	21.	2205005.	0.35	10.	679219.	0.54
3 0 0 0	13.	2008678.	0.24	41.	5853323.	0.25	86.	3390985.	0.78
4 0 0 0	0.	0.	0.00	3.	619923.	0.18	43.	2289718.	0.68
5 0 0 0	0.	0.	0.00	9.	2191191.	0.15	3.	137796.	0.79
0 0 1 0	1.	487000.	0.07	8.	2465282.	0.12	6.	858527.	0.25
0 0 2 0	27.	4584564.	0.21	64.	8225825.	0.28	65.	4472633.	0.53
0 0 3 0	1.	91336.	0.80	2.	400127.	0.18	71.	1766558.	1.46
1 0 1 0	0.	0.	0.00	0.	90544.	0.00	0.	0.	0.00
1 0 2 0	0.	126743.	0.00	0.	109527.	0.00	0.	0.	0.00
1 0 3 0	1.	42950.	0.85	0.	13611.	0.00	0.	0.	0.00
2 0 1 0	0.	179643.	0.00	3.	328061.	0.33	0.	41120.	0.00
2 0 2 0	15.	2765890.	0.20	18.	1975465.	0.35	6.	427734.	0.51
2 0 3 0	0.	39076.	0.00	0.	1479.	0.00	4.	210365.	0.69
3 0 1 0	1.	307357.	0.12	5.	1103450.	0.14	5.	680207.	0.27
3 0 2 0	12.	1592021.	0.26	34.	4494048.	0.28	48.	2414397.	0.72
3 0 3 0	0.	9330.	0.00	2.	55925.	1.30	33.	896381.	1.34
4 0 1 0	0.	0.	0.00	0.	142285.	0.00	1.	120260.	0.10
4 0 2 0	0.	0.	0.00	3.	476770.	0.23	9.	1528581.	0.21
4 0 3 0	0.	0.	0.00	0.	0.	0.00	33.	640877.	1.87
5 0 1 0	0.	0.	0.00	0.	591982.	0.00	0.	16940.	0.00
5 0 2 0	0.	0.	0.00	9.	1269997.	0.26	2.	101921.	0.71
5 0 3 0	0.	0.	0.00	0.	329212.	0.00	1.	18935.	1.93

STOP

Note: Cause Code Group = 4, (Alinement)

FIGURE C-13. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND CROSSLEVEL CAUSE CODE GROUP

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
SPC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 0 0 0	3.	169733.	0.64	3.	222692.	0.49	0.	0.	0.00
2 0 0 0	36.	2984519.	0.44	36.	2205005.	0.59	34.	679219.	1.82
3 0 0 0	23.	2008678.	0.42	131.	5853323.	0.81	178.	3990985.	1.62
4 0 0 0	0.	0.	0.00	12.	619023.	0.70	53.	2289718.	0.84
5 0 0 0	0.	0.	0.00	21.	2191191.	0.35	4.	137796.	1.06
0 0 1 0	0.	487000.	0.00	15.	2465282.	0.22	1.	858527.	0.04
0 0 2 0	62.	4584564.	0.49	190.	8225825.	0.80	133.	4472633.	1.08
0 0 3 0	0.	91336.	0.00	8.	400127.	0.73	135.	1766558.	2.78
1 0 1 0	0.	0.	0.00	1.	99544.	0.37	0.	0.	0.00
1 0 2 0	3.	126743.	0.86	1.	109537.	0.33	0.	0.	0.00
1 0 3 0	0.	42960.	0.00	1.	13611.	2.67	0.	0.	0.00
2 0 1 0	0.	179643.	0.00	1.	328061.	0.11	0.	41120.	0.00
2 0 2 0	36.	2765800.	0.47	32.	1875465.	0.62	25.	427734.	2.13
2 0 3 0	0.	39076.	0.00	3.	1479.	73.76	9.	210365.	1.56
3 0 1 0	0.	307357.	0.00	9.	1303450.	0.25	1.	680207.	0.05
3 0 2 0	23.	1692021.	0.49	119.	4494048.	0.96	82.	2418397.	1.24
3 0 3 0	0.	9300.	0.00	3.	55825.	1.95	55.	896381.	3.85
4 0 1 0	0.	0.	0.00	1.	142245.	0.26	0.	120260.	0.00
4 0 2 0	0.	0.	0.00	11.	476778.	0.84	22.	1528581.	0.52
4 0 3 0	0.	0.	0.00	0.	0.	0.00	31.	640877.	1.76
5 0 1 0	0.	0.	0.00	3.	591982.	0.19	0.	16940.	0.00
5 0 2 0	0.	0.	0.00	17.	1269997.	0.49	4.	101921.	1.43
5 0 3 0	0.	0.	0.00	1.	229212.	0.11	0.	18935.	0.00

Note: Cause Code Group = 7 (Cross Level)

TABLE C-14. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND COUPLER/DRAFT SYSTEM CAUSE CODE GROUP

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GPC I	COUNT	MILES	FREQ I	COUNT	MILES	FREQ I	COUNT	MILES	FREQ I
1 0 0 0 I	1. I	169703. I	0.21 I	1. I	222692. I	0.16 I	0. I	0. I	0.00 I
2 0 0 0 I	35. I	2984519. I	0.43 I	14. I	2205005. I	0.23 I	6. I	679219. I	0.32 I
3 0 0 0 I	40. I	2008678. I	0.72 I	74. I	5053323. I	0.46 I	25. I	3090995. I	0.23 I
4 0 0 0 I	0. I	0. I	0.00 I	16. I	619023. I	0.94 I	18. I	2289718. I	0.29 I
5 0 0 0 I	0. I	0. I	0.00 I	55. I	2191191. I	0.91 I	4. I	137796. I	1.05 I
0 0 1 0 I	6. I	487000. I	0.45 I	47. I	2465282. I	0.69 I	5. I	858527. I	0.21 I
0 0 2 0 I	58. I	4584564. I	0.54 I	107. I	8225825. I	0.47 I	36. I	4472633. I	0.29 I
0 0 3 0 I	2. I	91336. I	0.80 I	6. I	400127. I	0.55 I	12. I	1766558. I	0.25 I
1 0 1 0 I	0. I	0. I	0.00 I	1. I	99544. I	0.37 I	0. I	0. I	0.00 I
1 0 2 0 I	1. I	126743. I	0.29 I	0. I	109537. I	0.00 I	0. I	0. I	0.00 I
1 0 3 0 I	0. I	42960. I	0.00 I	0. I	13611. I	0.00 I	0. I	0. I	0.00 I
2 0 1 0 I	2. I	179643. I	0.40 I	0. I	320061. I	0.00 I	0. I	41120. I	0.00 I
2 0 2 0 I	32. I	2765800. I	0.42 I	14. I	1875465. I	0.27 I	2. I	427734. I	0.17 I
2 0 3 0 I	1. I	39076. I	0.93 I	0. I	1479. I	0.00 I	4. I	210365. I	0.69 I
3 0 1 0 I	4. I	307357. I	0.47 I	28. I	1303450. I	0.78 I	0. I	680207. I	0.00 I
3 0 2 0 I	35. I	1692021. I	0.75 I	46. I	4494048. I	0.37 I	20. I	2414397. I	0.30 I
3 0 3 0 I	1. I	9210. I	3.91 I	0. I	55825. I	0.00 I	5. I	896381. I	0.20 I
4 0 1 0 I	0. I	0. I	0.00 I	8. I	142245. I	2.05 I	3. I	120260. I	0.91 I
4 0 2 0 I	0. I	0. I	0.00 I	8. I	476770. I	0.61 I	12. I	1528501. I	0.29 I
4 0 3 0 I	0. I	0. I	0.00 I	0. I	0. I	0.00 I	3. I	640877. I	0.17 I
5 0 1 0 I	0. I	0. I	0.00 I	10. I	591982. I	0.61 I	2. I	16940. I	4.29 I
5 0 2 0 I	0. I	0. I	0.00 I	39. I	1269997. I	1.12 I	2. I	101921. I	0.71 I
5 0 3 0 I	0. I	0. I	0.00 I	6. I	329212. I	0.66 I	0. I	18935. I	0.00 I

STOP

Note: Cause Code Group = 14 (Coupler & Draft System)

TABLE C-15. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND SIDE BEARINGS CAUSE CODE GROUP

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GFC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 0 0 0	1.	169713.	0.21	1.	222602.	0.16	0.	0.	0.00
2 0 0 0	11.	2994519.	0.13	26.	2205005.	0.43	16.	679219.	0.86
3 0 0 0	8.	2008678.	0.18	59.	5953323.	0.37	75.	3393585.	0.68
4 0 0 0	0.	0.	0.00	7.	619023.	0.41	18.	2289718.	0.29
5 0 0 0	0.	0.	0.00	9.	2151191.	0.15	1.	137756.	0.26
0 0 1 0	1.	487000.	0.07	9.	2465282.	0.13	1.	859527.	0.04
0 0 2 0	15.	6584564.	0.15	89.	8225825.	0.39	48.	4472633.	0.39
0 0 3 0	0.	91376.	0.00	8.	800127.	0.36	61.	1766558.	1.26
1 0 1 0	0.	0.	0.00	0.	30544.	0.00	0.	0.	0.00
1 0 2 0	1.	126743.	0.29	1.	109537.	0.33	0.	0.	0.00
1 0 3 0	0.	42950.	0.00	0.	13118.	0.00	0.	0.	0.00
2 0 1 0	1.	179643.	0.20	1.	320061.	0.11	0.	41120.	0.00
2 0 2 0	10.	2765800.	0.13	23.	1975465.	0.45	13.	427734.	1.11
2 0 3 0	0.	39376.	0.00	2.	1473.	49.17	3.	210365.	0.52
3 0 1 0	0.	307157.	0.00	3.	1303450.	0.08	1.	680207.	0.05
3 0 2 0	3.	1692031.	0.17	56.	4494049.	0.45	26.	2414397.	0.39
3 0 3 0	0.	5300.	0.00	0.	55825.	0.00	48.	896381.	1.55
4 0 1 0	0.	0.	0.00	3.	142245.	0.77	0.	120260.	0.00
4 0 2 0	0.	0.	0.00	4.	476770.	0.31	8.	1528581.	0.19
4 0 3 0	0.	0.	0.00	0.	0.	0.00	10.	640877.	0.57
5 0 1 0	0.	0.	0.00	2.	591982.	0.12	0.	16940.	0.00
5 0 2 0	0.	0.	0.00	5.	1260997.	0.14	1.	101921.	0.36
5 0 3 0	0.	0.	0.00	2.	329212.	0.22	0.	18935.	0.00

Note: Cause Code Group = 15 (Side Bearings)

TABLE C-16. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND PLAIN JOURNALS OVERHEATED CAUSE CODE GROUP

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GFC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	CCUNT	MILES	FREQ
1 0 0 0	4.	169703.	0.86	2.	222692.	0.33	0.	0.	0.00
2 0 0 0	68.	2984519.	0.83	86.	2205005.	1.42	4.	679219.	0.21
3 0 0 0	29.	2008678.	0.52	59.	5853323.	0.62	3.	3990585.	0.03
4 0 0 0	0.	0.	0.00	2.	619023.	0.12	1.	2269718.	0.02
5 0 0 0	0.	0.	0.00	11.	2191191.	0.18	0.	137796.	0.00
0 0 1 0	9.	487000.	0.67	81.	2465282.	1.19	0.	858527.	0.00
0 0 2 0	88.	4504564.	0.70	114.	8225825.	0.50	4.	4472633.	0.03
0 0 3 0	4.	91336.	1.59	5.	400127.	0.45	4.	1766558.	0.08
1 0 1 0	0.	0.	0.00	0.	99544.	0.00	0.	0.	0.00
1 0 2 0	2.	126743.	0.57	1.	109537.	0.33	0.	0.	0.00
1 0 3 0	2.	42960.	1.69	1.	13611.	2.67	0.	0.	0.00
2 0 1 0	5.	179643.	1.01	1.	328061.	0.11	0.	41120.	0.00
2 0 2 0	61.	2765800.	0.80	85.	1875405.	1.65	2.	427734.	0.[illegible]
2 0 3 0	2.	39076.	1.86	0.	1479.	0.00	2.	210365.	0.35
3 0 1 0	4.	307357.	0.47	71.	1303450.	1.98	0.	680207.	0.00
3 0 2 0	25.	1692021.	0.54	24.	4494048.	0.19	2.	2414397.	0.03
3 0 3 0	0.	9300.	0.00	4.	55825.	2.61	1.	896381.	0.04
4 0 1 0	0.	0.	0.00	0.	142245.	0.00	0.	120260.	0.00
4 0 2 0	0.	0.	0.00	2.	476778.	0.15	0.	1520501.	0.00
4 0 3 0	0.	0.	0.00	0.	0.	0.00	1.	640877.	0.08
5 0 1 0	0.	0.	0.00	9.	551562.	0.55	0.	16940.	0.00
5 0 2 0	0.	0.	0.00	2.	1269997.	0.06	0.	101921.	0.00
5 0 3 0	0.	0.	0.00	0.	329212.	0.00	0.	18935.	0.00

Note: Cause Code Group = 17 (Plain Journals Overheated)

TABLE C-17. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND BROKEN WHEEL COMPONENTS CAUSE CODE GROUP

	TRUCK TYPE								
	1			2			3		
GEC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 0 0 0	0.	169733.	0.00	2.	222692.	0.33	0.	0.	0.00
2 0 0 0	20.	2394519.	0.29	34.	2205305.	0.40	7.	675219.	0.37
3 0 0 0	19.	2008678.	0.33	55.	5953333.	0.34	30.	3990985.	0.27
4 0 0 0	0.	0.	0.00	15.	619023.	0.88	20.	2289718.	0.32
5 0 0 0	0.	0.	0.00	39.	2191191.	0.65	4.	137796.	1.06
0 0 1 0	3.	497000.	0.22	22.	2465282.	0.32	3.	958527.	0.13
0 0 2 0	35.	4580564.	0.28	111.	8225825.	0.49	37.	4472633.	0.30
0 0 3 0	0.	91336.	0.00	2.	400137.	0.18	21.	1766558.	0.43
1 0 1 0	0.	0.	0.00	1.	93544.	0.37	0.	0.	0.00
1 0 2 0	0.	126743.	0.00	1.	109537.	0.33	0.	0.	0.00
1 0 3 0	0.	42950.	0.00	0.	13631.	0.00	0.	0.	0.00
2 0 1 0	2.	179647.	0.40	2.	328061.	0.22	0.	41120.	0.00
2 0 2 0	18.	2765870.	0.24	22.	1875865.	0.43	4.	427734.	0.34
2 0 3 0	0.	39076.	0.00	0.	1879.	0.00	3.	210365.	0.52
3 0 1 0	1.	307357.	0.12	6.	1303459.	0.17	1.	680207.	0.05
3 0 2 0	17.	1692021.	0.37	49.	4498048.	0.40	22.	2414397.	0.33
3 0 3 0	0.	[illegible]	0.00	0.	55925.	0.00	7.	996381.	0.28
4 0 1 0	0.	[illegible]	0.00	2.	142345.	0.51	2.	120260.	0.60
4 0 2 0	0.	[illegible]	0.00	13.	476778.	0.99	8.	[illegible]	0.19
4 0 3 0	0.	[illegible]	0.00	0.	0.	0.00	10.	640877.	0.57
5 0 1 0	0.	[illegible]	0.00	11.	591983.	0.68	0.	16940.	0.00
5 0 2 0	0.	[illegible]	0.00	26.	1269997.	0.74	3.	101921.	1.07
5 0 3 0	0.	0.	0.00	2.	332213.	0.22	1.	18935.	1.92

Note: Cause Code Group = 19 (Broken Wheel Components)

TABLE C-18. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND EXCESSIVE BUFF/SLACK ACTION CAUSE CODE GROUP

	TRUCK TYPE								
				2			3		
SPC I	COUNT	MILES	FREQ I	COUNT	MILES	FREQ I	COUNT	MILES	FREQ I
1 0 0 0 I	1. I	169703. I	0.2[illegible] I	4. I	222652. I	0.65 I	0. I	0. I	0.00 I
2 0 0 0 I	20. I	2984519. I	0.24 I	13. I	2205905. I	0.21 I	5. I	679219. I	0.27 I
3 0 0 0 I	10. I	2008678. I	0.2[illegible] I	47. I	5953333. I	0.29 I	60. I	3990985. I	0.55 I
4 0 0 0 I	0. I	0. I	0.00 I	13. I	619023. I	0.76 I	24. I	2289718. I	0.38 I
5 0 0 0 I	0. I	0. I	0.00 I	21. I	2191191. I	0.35 I	1. I	137796. I	0.26 I
0 0 1 0 I	3. I	487000. I	0.2[illegible] I	26. I	2465283. I	0.38 I	2. I	858527. I	0.08 I
0 0 2 0 I	30. I	4584558. I	0.24 I	70. I	8225825. I	0.31 I	54. I	4472633. I	0.44 I
0 0 3 0 I	2. I	91376. I	0.80 I	2. I	400127. I	0.10 I	34. I	1766558. I	0.70 I
1 0 1 0 I	0. I	0. I	0.00 I	0. I	99544. I	0.00 I	0. I	0. I	0.00 I
1 0 2 0 I	1. I	126703. I	0.[illegible] I	4. I	100537. I	1.33 I	0. I	0. I	0.00 I
1 0 3 0 I	0. I	42960. I	0.00 I	0. I	13611. I	0.00 I	0. I	0. I	0.00 I
2 0 1 0 I	1. I	179643. I	0.20 I	2. I	320061. I	0.22 I	0. I	41120. I	0.00 I
2 0 2 0 I	1[illegible]. I	2765800. I	0.25 I	11. I	1875465. I	0.21 I	5. I	427734. I	0.43 I
2 0 3 0 I	0. I	39076. I	0.00 I	0. I	1479. I	0.00 I	0. I	210365. I	0.00 I
3 0 1 0 I	2. I	307357. I	0.24 I	11. I	1302859. I	0.31 I	2. I	680207. I	0.11 I
3 0 2 0 I	10. I	1692097. I	0.21 I	35. I	4994049. I	0.29 I	33. I	2414397. I	0.59 I
3 0 3 0 I	2. I	[illegible]390. I	7.83 I	1. I	55025. I	0.65 I	25. I	896391. I	1.04 I
4 0 1 0 I	0. I	[illegible] I	0.00 I	4. I	10[illegible]45. I	[illegible] I	[illegible]	[illegible]	[illegible]
4 0 2 0 I	0. I	[illegible] I	0.00 I	9. I	476779. I	0.69 I	15. I	1528501. I	0.36 I
4 0 3 0 I	0. I	[illegible] I	0.00 I	0. I	0. I	0.00 I	9. I	640877. I	0.51 I
5 0 1 0 I	0. I	[illegible] I	0.00 I	9. I	551982. I	0.55 I	0. I	16940. I	0.00 I
5 0 2 0 I	0. I	[illegible] I	0.00 I	11. I	1269997. I	0.31 I	1. I	101921. I	0.36 I
5 0 3 0 I	0. I	0. I	0.00 I	1. I	329212. I	0.11 I	0. I	18935. I	0.00 I

STOP

Note: Cause Code Group = 25 (Excessive Buff/Slack Action)

TABLE C-19. DERAILMENT DATA BY GENERIC VEHICLE CONFIGURATION AND RAIL HEAD FAILURE CAUSE CODE GROUP

	TRUCK TYPE 1			TRUCK TYPE 2			TRUCK TYPE 3		
GFC	COUNT	MILES	FREQ	COUNT	MILES	FREQ	COUNT	MILES	FREQ
1 0 0 0	3.	169703.	0.64	3.	222692.	0.49	0.	0.	0.00
2 0 0 0	38.	2984519.	0.46	28.	2205005.	0.46	24.	679219.	1.28
3 0 0 0	18.	2008678.	0.33	69.	5853323.	0.43	1C2.	3990985.	0.93
4 0 0 0	0.	0.	0.00	11.	619023.	0.65	49.	2289718.	0.78
5 0 0 0	0.	0.	0.00	15.	2191191.	0.25	3.	137796.	0.79
0 0 1 0	7.	487000.	0.52	25.	2465282.	0.37	5.	858527.	0.21
0 0 2 0	48.	4584564.	0.38	97.	8225825.	0.43	57.	4472633.	0.79
0 0 3 0	4.	91336.	1.59	4.	400127.	0.36	76.	1766558.	1.56
1 0 1 0	0.	0.	0.00	0.	99544.	0.00	0.	0.	0.00
1 0 2 0	2.	126743.	0.57	2.	109537.	0.66	0.	0.	0.00
1 0 3 0	1.	42960.	0.85	1.	13611.	2.67	0.	0.	0.00
2 0 1 0	5.	179643.	1.01	2.	320061.	0.22	0.	41120.	0.00
2 0 2 0	33.	2765200.	0.43	25.	1875465.	0.48	14.	427734.	1.19
2 0 3 0	0.	39076.	0.00	1.	[illegible]	24.59	10.	210365.	1.73
3 0 1 0	2.	307357.	0.24	15.	1303450.	0.42	4.	680207.	0.21
3 0 2 0	13.	1692021.	0.28	52.	4494048.	0.42	72.	4414397.	1.08
3 0 3 0	3.	9300.	11.73	2.	55825.	1.30	26.	056381.	1.05
4 0 1 0	0.	0.	0.00	3.	142245.	0.77	0.	120260.	0.00
4 0 2 0	0.	0.	0.00	8.	476778.	0.61	10.	1528581.	0.24
4 0 3 0	0.	0.	0.00	0.	0.	0.00	39.	640877.	2.21
5 0 1 0	0.	0.	0.00	5.	591902.	0.31	1.	16540.	2.15
5 0 2 0	0.	0.	0.00	10.	1269997.	0.29	1.	[illegible]	0.34
5 0 3 0	0.	0.	0.00	0.	329212.	0.00	1.	18935.	1.92

Note: Cause Code Group = 29 (Rail Head Failures)

REFERENCES

1. F.P. Di Masi, "Engineering Data Characterizing the Fleet of U.S. Railway, Rolling Stock" Vol 1, Users Guide, U.S. Department of Transportation, Federal Railroad Administration, Washington DC,

2. "Truck Design Optimization Project, Phase II, Analytical Tool Assessment Report," Wyle Laboratories, FRA/ORD-79/36, August 1979.

3. FRA Guide for Preparing Accident/Incident Reports, DOT/FRA

4. B.E. Platin et al, "Computational Methods to Predict Railcar Response to Track Crosslevel Variations", from where, FRA-ORD-76-293, September 1976.

5. P. Tong et al, "Tests of the Amtrak SDP-40F Train Consist Conducted and Chessie System Track", U.S. Department of Transportation, Federal Railroad Administration, Washington DC, June 1980,

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