FREIGHT CAR TRUCK DESIGN OPTIMIZATION

VOLUME VI — CRITIQUE OF PHASE I — TEST SERIES RESULTS REPORTS

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FINAL REPORT

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Abstract

The Test Results Reports, Final Report, and Math Model Reports from Phase I of the Truck Design Optimization Project (TDOP) are reviewed. Recommendations for Phase II resulting from this review are given. See also:

Vol. I - Executive Summary, FRA/ORD-78/12.I
Vol. II - Phase I Final Report, FRA/ORD-78/12.II
Vol. III - Phase I Frequency Domain Model, FRA/ORD-78/12.III
Vol. IV - Critique of Frequency Domain Model - Solution Techniques, FRA/ORD-78/12.IV
Vol. V - Critique of Frequency Domain Model - Equations of Motion, FRA/ORD-78/12.V

Also available in microfiche and photocopy form from NTIS:

Vol. VII - Results Report for Test Series 1, FRA/ORD-78/12.VII
Vol. VIII - Results Report for Test Series 2 and 5, FRA/ORD-78/12.VIII
Vol. IX - Results Report for Test Series 4, FRA/ORD-78/12.IX
Vol. X - Results Report for Test Series 3 and 5, FRA/ORD-78/12.X
Vol. XI - Performance Guidelines for Type I Trucks, FRA/ORD-78/12.XI
Vol. XII - TDOP Postprocessing Program Manual, FRA/ORD-78/12.XII
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1.0 INTRODUCTION

The major output resulting from the Phase I effort which is of interest to railroads, suppliers, and the Phase II contractor was the series of Test Results Reports, which contained summary commentary and selected processed data from the field testing. Because of the importance of the content of these collections of data and the quantity of data involved, these reports are addressed in considerable detail in this report.
2.0 BACKGROUND

The SOW for Phase I did not specify a format for the submission of field data. As a result, the contractor chose to submit data in several forms, of which the Test Results Reports constitute one.

After the data from the five series of field tests had been processed, selected results were compiled into drafts of four Test Results Reports and formally submitted for review prior to publication. At the end of the contract, final drafts of these documents were submitted for publication. The final volumes did not purport to present all the data from the program. Additional data, processed into graphical form but uncatalogued and apparently unanalyzed, appears as appendices to the main body of the reports.
3.0 THE REPORTS

3.1 General

The Test Results Reports quite naturally have many common features, and these will be examined before specific discussion of each report. There are two major aspects to the reports: the content of the report and the presentation of the content. The former is concerned with the purposes of the report, the material selected for the report, and how well the material presented serves those purposes. The latter is concerned with how well the selected material is organized and presented in order to serve the avowed purposes. It is believed that consideration of both of these aspects in this report is essential to an understanding of the extent of the accomplishments of Phase I and the appropriateness with which they are described within the reports.

The tests whose results are described in these reports were run in most instances varying three basic parameters: rail type (jointed or continuously welded), load conditions, and speed. These parameters were varied under several track conditions deemed to be a representative spectrum of conditions encountered in normal operations: high-speed tangent track, low- and medium-speed tangent track, and curved track. Forty-eight channels of data were normally recorded during each of these runs. In addition to data on these parameters recorded directly, there is data on calculated parameters, those not measured directly but calculable from others which were. Parameter conditions for each test are not included in the Test Series Reports but can be found in Appendix I of the Phase I Final Report.

A great deal of material was collected, processed, and prepared for analysis under these five series of test runs. For practical reasons however, only selected portions were included in the main bodies of the reports. The remainder was relegated in most cases to an appendix, or was not reduced to graphical form and reposes on
magnetic tapes available from NTIS. The result was nevertheless that the number of plots of various types in the appendix of each report averaged over one hundred fifty.

The fact that so much data was collected and only certain portions included in the reports is certainly troublesome. It is difficult to avoid the conclusion that the selection process was subjective. In most cases it was generally clear from the report that the data collected corresponded with the purposes of the report and was reasonably adequate to fulfill them. However, because the rationale for the selection process by which certain results were included and others omitted was not given, it was impossible to determine whether the omitted data had any significance. To select data to be omitted means in effect that other data were tacitly selected to be included. A firm defense of the selectivity rationale would have alleviated some of the doubts generated by omission of such an apparently large proportion of the data collected.

Another common feature of the reports which was also subjective was the type of plot selected for presentation. Many different forms of plots were available from the post-processing computer program intended to perform the function of analyzing and reducing the voluminous data; in that respect the program is certainly to be commended for its capabilities. To defend the particular choice of plot for each of the many hundreds of plots included in the reports would have been impossible; however, the preferred format for data presentation was never satisfactorily determined.

The vast amount of data collected presented another problem which was never adequately solved during the course of the project. How does one find the data processed in a particular way from certain test conditions or determine whether or not it had actually been
processed? The accessibility of the data throughout the reports is poor. Take a hypothetical example: find plots showing the effect upon the PSD of the carbody vertical acceleration of changing side bearing clearance when an empty car is run at high speed over continuously welded rail with nominal gib clearances on the truck. The Final Report must be examined to find that comparison of data from tape 0033 of test 1-2-2 with data from tape 0036 of test 1-2-3 is sought. Plots from data processed from these tapes should be found in the Series 1 Test Results Report, but there is no way of determining whether the desired plots actually exist other than by examining the list of the 75 plots in the main body of the report or leafing through the 139 miscellaneous plots in the rear. The probability that such particular plots are included in the report is small, and therefore it is normally necessary that the interested party acquire the tapes for the tests of interest and process the data. This system is not without merit, as there are obviously thousands of plots which might be made from the data, but within the reports themselves finding data of particular interest is a formidable task. Such considerations regarding the general inaccessibility of the data from a given test run are regarded as constituting a serious shortcoming of the report and an impediment to an understanding of what was accomplished by the series of tests.

The data have not been related in the Test Results Reports to even the simplest of mathematical models, even though the reports contain many comments purporting to explain unusual behavior observed during testing or after the data has been processed. It would have been more informative if conclusions formed by observation of data plots could be validated by and correlated with model behavior directly in the same discussion. Because no quantitative information was included on the track condition in the Test Results Reports, it is impossible for the user to confirm these observations through
exercising of models. The closest approach to quantifying the track is the statement that the runs were made over "high speed tangent track" or "medium and low speed tangent track." Some indication of track parameters, since they were actually measured by the FRA track geometry cars during the course of Phase I and constituted some of the information stemming from the program, should have been made.

An important technical point which pervades the plots and which requires explanation was unfortunately ignored throughout. A plot typical of those presented in the Test Results Reports is shown in Figure 1. On a plot of this type, the RMS value of the signal for each speed is plotted. The points vertically above and below a given data point are a measure of the spread of the data about that point. Specifically, as explained during Phase I, but not pointed out in the Test Results Reports, the vertical spread corresponds with the standard deviation of the rectified signal. It should have been explained on the plots themselves what the vertical lines superimposed over the curves mean, and an explanation of the significance of plotting the standard deviation of the rectified signal, in addition to the RMS value, should have been given. In at least one of the volumes of the Test Series Reports, and preferably in every volume in which such plots appear, a statement indicating what parameter is plotted on these curves (e.g., std. deviation of the rectified signal), a rigorous definition of it, and an explanation of its significance should have been given. In addition, if such a procedure was used in the calculation of other plotted parameters, this should have been duly noted and rigorously explained.

A final comment with regard to data collection, presentation, and general philosophy of testing seems appropriate. Much was made during the program of testing trucks under a wide variety of
conditions. However, of equal importance is a similar collection of data plots showing how repeatable the data are from the same truck when an effort has been made to make the test conditions as identical as possible. Such a comparison would have shed considerable light on the validity of conclusions drawn from the data plots. Repeatability of data is the essence of credibility in the testing domain. This problem was not addressed in depth during the project.

Before the introduction of comments on specific reports, some comments of an editorial nature which apply to all the data reports should be made. There is often awkwardness and inconsistency in titling of data plots. Too often, plots of data from tests in which conditions were identical have dissimilar titles. A page of definitions in each volume for all abbreviations used in titles would have been useful. The justification for apparently bad data is troublesome. It is unfortunate that data plots are printed with curves that in the text are admitted to be erroneous but with no such indication on the plot itself. As a minimum, in such cases a note to that effect and/or a reference to the applicable commentary in the text should be supplied. Sometimes there is something wrong with the scaling factor of the PSD plots, where the curves go off the paper. In other cases it is difficult, if not impossible, to determine the standard deviations of the several curves plotted together when the curves are near the top of the plot, as the other end of the vertical bar representing the spread of the data is off the paper. See Figure 1.

The lack of a separate summary and conclusions section to each of the reports is a final troublesome shortcoming. The textual material is too often filled with what are mere observations. The few conclusions which were drawn were relegated to the Final Report.
Since these were not accompanied by any definitive plots, one is left with the feeling that one is to accept them on faith.

In summary, the Test Results Reports have been found in many ways to have fallen short of what might be expected of data reports, both in content and in presentation. However, it should be remembered that the reports were not the objectives of the program and were only ancillary benefits.

3.2 Series 1 Test Results Report

The purposes of the Series 1 Test were two-fold:

- To characterize the dynamic behavior of a nominal freight car truck by operating it under a wide variety of conditions which are representative of those which might be encountered under normal operating conditions.

- To characterize the effects of variations of gib and side bearing clearances on the behavior of the same truck under the same conditions.

Implicit in the first purpose was the preparation of the performance guidelines for Type I trucks. The collection of the data was made in order to quantify the dynamic behavior of the base line or typical Type I truck.

The tests structured for this series therefore attempted to reflect these purposes, and tests were run over the previously mentioned variety of tracks under various conditions. Six gib and side bearing configurations were tested, including nominal ones.

The report consists of a main text and its accompanying plots plus three appendices. Appendix A describes the data reduction and analysis procedure and the different plot types; Appendix B contains miscellaneous information on the instrumentation and computation of the calculated parameters; Appendix C contains numerous miscellaneous
but uncatalogued plots. The portion of the report which is of most concern is the main text with its accompanying plots and the miscellaneous plots of Appendix C.

The number of tests run under this series and the variety of operational conditions appear to have been more than adequate. The six gib and side bearing configurations tested in Test Series 1 were sufficient to permit the drawing of valid conclusions.

A shortcoming of a serious nature was that the relationship of the data to the performance guidelines later generated during the program was never presented. The purpose of running the tests was to relate the data to the performance specification. The data from the tests should have flowed logically towards that goal, and the method used to determine the figures for the performance guidelines should have been explained.

Finally, the report presented few conclusions drawn from the tests. Occasionally, apparently valid conclusions are interspersed throughout the report, such as "one can deduce that the forcing function of the rail joints influences the truck swivel, but that on welded rail the swivel exhibits its natural vibration at a slightly higher frequency and slightly less amplitudes." The others were more difficult to understand. For instance, it is not clear why the similarity of the shapes of the histograms of lateral carbody and lateral axle accelerations "roughly correlate(s) the relationship between axle lateral and carbody lateral accelerations." Conclusions of this nature were not responsive to the purposes of the test. Conclusions were expected with regard to the significance of side bearing clearance or the tightness of the gibs. Instead, the report offered what could be more accurately termed "observations." For example, "the tight truck gives
slightly more truck swivel than the nominal truck, but the loose truck indicates significantly less swivel through the 70 mph speed level." The preface of the report stated that "little has been said about the comparison between the loose, nominal, and tight trucks," then continued by stating that the difference in behavior was so small as to be inconclusive. It is not clear whether this is intended to mean that nothing was gained from the test runs or that gib and side bearing clearance are not related to truck behavior in a significant fashion. At one point the reader is cautioned to be careful in drawing conclusions. In general, the lack of definitive conclusions and the absence of a separate summary and conclusions section for each chapter or for the complete report detract considerably from the quality of the report and demonstrate that the report is mainly a compilation of data.

3.3 Series 2 and 5 Test Results Report

The purpose of the Series 2 tests was to investigate the effects of worn wheel profiles and reduced springing and snubbing. It was found during Series 2 testing that the effects of certain springing and snubbing changes were being masked by the effects of the worn wheel profiles. A subsequent Series 5 was devised to eliminate these effects by utilizing cylindrical wheel profiles in the evaluation of springing and snubbing characteristics.

As with the previous series, the tests described in this report were conducted over three different types of track representing normal railroad operating conditions: high-speed tangent track, medium and low speed tangent track, and curved track of different degrees of
curvature. Primary operational parameters which were varied during the testing included wheel profiles and springing and snubbing characteristics. Not all possible combinations of the variations in these and other parameters were tested, however.

This report consisted of the main text, its accompanying plots, and an appendix of approximately 108 miscellaneous unlisted and unindexed plots.

In general, conclusions in this report are more evident from the data plots than in the report for Test Series 1, in which series the investigation was more concerned with the characterization of existing behavior than the observation of changes in behavior as a consequence of altering single parameter values. The plots included are in general impressive. The effects of different spring sets and reduced snubbing (two-thirds of nominal) were also examined in this test series. The text of Section 1 of the report, discussing operation over high speed tangent track, states some plain conclusions which are in general supported by the plots but which are partially inconsistent with commonly accepted views. "The spring stiffness does not influence the lateral dynamics of the empty car to any important extent .... increasing the vertical compliance of the truck by reducing the snubbing or springing increases the effective level of truck swivel ... variations in springing and snubbing have very little effect on the vertical spring displacement or the vertical carbody accelerations, indicated by the bounce accelerations." In Section 2 there were no conclusions listed in the text and the results in the data plots were mixed; little was shown regarding the effect of reduced snubbing.
The main effort in this report is to distinguish the effects of wheel profile. In that respect, the particular plots selected for inclusion served the purpose very well, and in most instances the effects of wheel profile on performance were quite evident.

However, this report again omits a considerable portion of the results, and there is only the assurance of the contractor that the omitted data was observed to be of no interest or of less consequence. While purporting to investigate "lateral dynamics of the freight car" and "truck motions that accompany hunting," the contractor chose in Section 1 to show data from an empty car only, but it is not obvious that truck and body hunting will be of no interest with a loaded car. In Section 2 they chose to show data from a loaded car only. This was based upon tests run in Series 1, when it was noted that it was the higher inertia of the loaded car that produced greater roll angle and side bearing forces." It consequently seems justifiable with respect to the roll dynamics induced by the rail joints. However, this is not valid for the examination of vertical dynamics. Data depicting the corresponding phenomena for the alternate load configuration should have been included for comparative purposes.

Although the data in Section 3, Curve Negotiation, of this report are of some interest, it is difficult to draw any conclusions other than sharper curves create larger values of almost every measured parameter. A calculated parameter is used as a measure of curve negotiability, but no conclusions are drawn with regard to the effect of wheel profile on curve negotiability. A summary and conclusions section for each chapter and for this entire report, would have added much to the value of the report.
3.4 Series 4 Test Results Report

The tests described herein were intended to evaluate the effect upon dynamic behavior of modifications to the standard three piece freight car truck. The modifications were based upon the results of previous tests performed by the Japanese National Railways (JNR) in 1970. The Series 4 tests "examined the effects of a side frame intertie to rigidize the truck; use of hydraulic lateral dampers between the bolster and side frames to limit side frame motion; use of constant contact side bearings; application of a longitudinal control device between the roller bearing and the pedestal legs of the side frame; elastomeric adapter pads; and various amounts of centerplate friction." A final test combining several of these modifications used high centerplate friction, constant contact side bearings, and longitudinal pedestal control.

Since "truck hunting is primarily an empty car, high speed phenomenon," the variations of centerplate friction and the addition of pedestal shims intended to reduce truck hunting were run only over high speed tangent track. Other modifications and the final optimized combination were run over all three types of track.

The text of the report consists of six sections describing the base case and the five basic modifications, plus an additional section describing the operation of the "optimized" combination over the three types of track. Except for the material accompanying the last section, the textual material was minimal and the report consisted mainly of a series of plots. An appendix contained an additional eighty-two miscellaneous unsorted plots.

In general, the plots selected for inclusion in the report were effective in demonstrating the effect of the modifications. The base
case discussion was a useful collection of comparative data from two different trucks of the same manufacturer, and demonstrated data repeatability. This is indeed important and fills a needed role in the report of the test results for TDOP Phase I. The effects of several levels of friction of the carbody-bolster interface are clearly shown in the figures, which convey more information than the limited text accompanying them. The effects, or lack of effects, of the pedestal controls and of the side frame intertie are quite apparent in most of the plots. However, neither the discussion nor the plots presented for the other modifications were as clear cut in drawing or supporting conclusions.

The last portion of the report, which discusses the performance of the optimized truck, is of interest and appears meaningful. Throughout the discussion of this section the word "optimized" is prevalent and should be viewed with caution. What constitutes optimization of the current three-piece truck within the operational constraints of a given system is not obvious. Moreover, the properties of the optimum truck may be viewed differently by different railroads, according to their operating conditions. A railroad operating on good continuous welded rail at high speeds may be mainly concerned with preventing lading damage due to hunting, while another railroad, running in mountainous territory with many curves, may be more interested in lowering the cost of maintaining track and exchanging wheels. It may be difficult to improve the characteristics of a truck currently in general service to the point where it will perform much better under the full range of operating conditions. Therefore, in evaluating this report one should bear in mind that "optimized" in this case considers only the cessation of hunting or raising the critical speed.
The effects of "optimizing" the truck are readily apparent and are easily summarized: there was little or no effect in carbody bounce, pitch, and yaw, but substantial effect upon carbody lateral and roll acceleration and truck swivel. The remainder of the text again merely makes observations on the 45 figures in this section. This is an important section, as it is an attempt at utilizing the knowledge from previous JNR tests in synthesizing a new design. The rationale for the selection of the optimized truck parameters should have been explained, as favorable results were definitely obtained.

A summary and conclusions section, as with the other reports, would have been useful.

3.5 Series 3 and 5 Test Results Reports

The series 3 tests were performed primarily to extend the data base to truck operation with other types of freight cars. Specifically, a 70 ton boxcar, an 89 ft. flatcar modified for Stac-Pac service, a 100 ton covered hopper car, and 100 ton 60 ft. boxcar were tested. Several varieties of trucks were tested. The subsequent Series 5 tests also covered in this report were tests of the effects of different springing and snubbing combinations on the 100 ton boxcar with cylindrical wheels. The latter tests were run over the three standard track types and over a specially modified shimmed track for studies of resonant roll dynamics.

The report discusses the results of each type of car-truck combination in sequence. The report is voluminous and many plots are presented, but the textual material is minimal. Since the ostensible purpose of these tests was to extend the data base for the performance guidelines, few, if any, conclusions were drawn.
3.6 Mathematical Model

The contractor was required to create a mathematical model which in addition to its initial use and later refinement during Phase I of the TDOP program was to be compatible with the future needs of Phase II, TDOP, the Rail Dynamics Simulator at the Transportation Test Center, and truck and carbody manufacturers. A model purporting to fulfill these requirements was prepared by the contractor during the final stages of Phase I.

The math modeling effort was reported in two volumes, one of which serves as an introduction to the Frequency Domain Model and ultimately as a user's manual for the program. The kinds of outputs one can extract from the program and the limitations of the model are also discussed. The second volume contains in various appendices the derivation of the equations of motion and a number of associated parameters, in addition to a comparison of theoretical predictions with field data.

A requirement of the TDOP research project was the creation, validation, and refinement of a mathematical model for use during the program for the prior evaluation of innovative modifications to the trucks which were to be tested. While such a model was ultimately created, it was done so after completion of the field tests. This was clearly contrary to the intent to develop an analytical tool for use in the evaluation of field test data during this project. The present utility of the model can only be determined through actual manipulation by the intended users.

It has been determined that several of the equations of motion entered into the computer program contained errors. While it is possible that the impact of several minor errors in sign affecting one term among many might be small, one error affecting three
different equations was thought to be considerable. The Phase I contractor, however, reported that use of the corrected equations failed to alter any of the plots in a significant manner and none of the plots for publication were changed. It must therefore be noted that the comparison between test and analysis appearing in this report was made with a program now known to have contained errors, and all of the plots which resulted from use of this model are subject to some question.

Two basic reports prepared by The MITRE Corporation for FRA are available which analyze and review in detail aspects of the Phase I mathematical model. These are useful for a clear understanding of the model. They should be used in conjunction with this report. There are:


In the first of these reports a complete derivation of the equations of motion for the linear model using simpler and less computer-oriented nomenclature is presented. Free body diagrams illustrating the thirteen degrees of freedom are also presented.

In the second of these reports the computer program which utilizes these equations and a forcing function derived from actual track data to generate time- and frequency-domain responses is reviewed and analyzed in detail. In particular the substitution of equivalent viscous damping for coulomb damping and subsequent calculation of power spectral densities and the validity of superposition under these
circumstances is explored. The reader is cautioned to exercise judgment and discretion in interpreting results from the program, since they are only valid within specified parameter ranges.

3.7 Phase I Final Report

A final report, consisting mainly of appendices, was furnished at the conclusion of the program. Because no tests which were run were specifically described in this report, the following discussion is directed toward the content of the report alone.

The bulk of the Final Report consists of appendices containing a wealth of background material necessary to a complete understanding of the program. Although occasional deficiencies in the content of these appendices were noted, in general the coverage and scope of the material was quite satisfactory.

However, a certain number of technical inaccuracies which are worth mentioning unfortunately permeate the report. For instance, the "comprehensive testing" was not in fact "supported by analytical and modeling studies;" the math modeling was all after the fact. In particular, the definitions offered of technical terms used throughout the various reports and during the project leave much to be desired. It should have been made clear that the definitions given apply only to the particular usage to which they have been put in the TDOP and its associated reports. Many of the definitions are technically inaccurate as well as being applicable only to the TDOP.

Although the material in the appendices is broad in scope and in most cases more than adequate, basic numerical information used in the math model has not been included in the final report. Although the torsional stiffnesses are reported in Appendix E, the tables of carbody characteristics in Appendix B omit the bending and torsional
stiffness of the cars. These data are essential to any modeling of the dynamic behavior. There is no indication that bending stiffnesses were ever determined. Moments of inertia are also lacking. Similarly, in the tables of truck characteristics, a number of properties of trucks deemed necessary for proper mathematical modeling have been omitted; for example, moments of inertia and masses of separate parts, bending stiffnesses, friction levels, heights of c.g.'s of certain parts, etc. While there appears to be adequate information in Appendix B about the spring constants of all groups used, it is awkward to relate a particular group to a particular test. The most meaningful section of the report, Appendix A, which deals with conclusions reached as a result of the project, forms only a small portion of it.

Since this was the final report from this phase of the project, some indication of the degree to which the project met its goals should have been presented. One measure of the degree of success of Phase I is the relationship of the conclusions to the purposes of the program, namely, how they were related to truck behavior and what recommendations were made regarding future designs or design modifications to existing trucks on the basis of these conclusions.

One purpose of the several series of tests was to characterize the behavior of Type I trucks under varied operational conditions. A conclusion of this program should relate to the behavior or the changes in the behavior of the trucks and carbodies or their components when these conditions were normal or modified from normal. A number of the conclusions, however, are concerned with considerations which may be of interest but whose relationship to truck behavior is indirect, at best. A good example of this is the conclusion that "at speeds up to 79 mph, not all empty cars exhibit hunting. Furthermore, not all loaded cars exhibit lateral stability over the same speed range."
Most of the conclusions related to carbody behavior when various parameters of the truck were changed. Although these are also of interest it is not clear how the conclusions should be utilized to modify truck designs in order to improve truck or carbody behavior.

The characterization of truck behavior was to have also served the purpose of establishing a data base from which performance guidelines quantifying the behavior of the Type I truck in numerical terms could be prepared. Although occasional references to the truck hunting threshold are made, the procedure through which this huge data base was related to the preparation of such a performance guideline was not included in the Final Report. This is regarded as a serious shortcoming of the project.

Finally, the third objective of the TDOP was to perform certain economic analyses, and one would expect the Final Report on this project to discuss economic considerations in some detail. Instead, the existence of separate economic reports is acknowledged with a one-sentence summary of the content of each of the three reports, and the reader is referred to the reports in the bibliography.

The Phase I Final Report seems to reflect the feeling that it was better that the reader draw the conclusions, having considered the data which was gathered. This is felt to be contrary to the original intent of the program.
4.0 RECOMMENDATIONS

Much material was generated during Phase I, in the form of both reports and data, processed and unprocessed. The report resulting from the literature search is self-explanatory. The economic report and the survey and appraisal of Type II trucks stand independently. As recommended by the Phase I contractor, the Type II truck survey should be utilized as a starting point for the later work in Phase II involving Type II trucks, and, similarly, the Phase I economics report should be utilized as a starting point for the Phase II economic analysis.

It has been noted throughout this document that the amount of data collected during Phase I was voluminous. A considerable amount was processed into numerical or graphical form. The very volume of material contributes to its inaccessibility, and as a result it is not clear to those other than the Phase I contractor that sufficient data or the appropriate data were taken to characterize the behavior of Type I trucks or modifications thereto, or to supply information for the performance guidelines. Since such a large volume of information exists, it seems highly desirable to utilize as much of it as possible in Phase II in order to avoid needless duplication of effort. With this thought in mind, the following recommendations are made to utilize the results of Phase I testing in a meaningful way and to assist the Phase II contractor in avoiding any pitfalls whose existence has come to light as a result of the Phase I experience.

4.1 Applicability of Phase I Data

The volume of the data collected makes it imperative that only for good reason should material be discarded or unutilized in Phase II. A determination should be made of the extent and applicability of both the data taken and the data processed. Such a determination would
naturally involve both the processed data and uncatalogued material and the unprocessed data on the tapes. The Phase II contractor will have to decide the relevance of all such material to Phase II. Such a determination of relevance might be made by comparing material available with material to be generated from a similar Test Plan with identical goals.

As a part of the above determination of the extent and applicability of the data base, the adequacy of the original instrumentation and the sufficiency of the tests actually run must also be considered to satisfy the Phase II contractor that sufficient and valid data of an appropriate nature was collected. The list of tests run and the conditions under which they were run must be examined so that the contractor is satisfied that an adequate data base now exists. If tests are deemed to be lacking, or if data seemed to be erroneous, the existing data base must be supplemented by additional effort and testing on the part of the Phase II contractor. However, this should be regarded as supplementary work by the Phase II contractor, not work to replace the wealth of data that exists.

4.2 Validity of Phase I Data

The Phase II contractor should establish the validity of the test data collected and determine its applicability and relevance so that the data may be utilized for the purposes of fulfilling the requirements of the Phase II SOW. As a part of this aspect of the Phase I evaluation, the data post-processing program developed in Phase I should be studied and utilized for processing the necessary data from the magnetic tapes. The capabilities of this program are quite large; data can be reduced to many different forms, such as amplitude vs. frequency, amplitude vs. velocity, PSD plots, histograms, etc. This program can be a valuable tool for use in Phase II in assessing the data stored on the tapes. The problem will be to determine what
forms are most meaningful. It is likely that the program might ultimately have to be modified to accommodate processing of data from merged tapes, or processing data so that results from different tapes are shown in the same plot. There are occasional references throughout the Phase I Test Results Reports to erroneous data, anomalies and inconsistencies in the data, lack of repeatability, or faulty signals. The Phase II contractor should be assured through appropriate assessment that what was done with the relevant data was in fact performed correctly; e.g., instruments were generating signals of appropriate magnitude and correct sign, signal conditioning amplifiers treated the incoming signal appropriately, etc. This could be accomplished by the spot checking of individual runs; e.g., a selection of representative runs from the series, preferably one from each should be made, and at minimum cost, runs as identical as possible with the original ones should be made, and the results processed by the Phase I post processing program and compared with the original results. If anomalies or inconsistencies between such data and data from new Phase II test runs later develop, the particular runs from Phase I can be reexamined. In such a fashion and by such means, all of the data from Phase I can be made useful to the purposes of Phase II. This should save the Phase II contractor considerable effort in his requirement to finalize the performance specification for Type I trucks.

4.3 **Repeatability of Phase I Data**

The repeatability of data from these tests, both from time to time and from truck to truck, should be established early in the program. Spot-checking of the data from Phase I will partially accomplish this goal. Supplementary tests should be run so that the contractor has assured himself that the spread of the data derived from Phase I is sufficiently small that the data are meaningful. Such repeatability
was not established during Phase I and is essential in determining the value of the existing data base.

4.4 Relationship to Performance Guidelines

Having established the validity and repeatability of the relevant data base acquired from Phase I and supplemented as deemed appropriate to establish its adequacy, the Contractor should then rigorously establish the relationship of this data base to the performance guidelines. The flow of data to the figures used should be made clear, and if data from all tests was not used, the selectivity process should be rationalized. It must be made clear how the data collected and the process of collection meaningfully relate to the final product.

4.5 Evaluation of Conclusions

The conclusions resulting from the Phase I effort as given in the Final Report should be evaluated in the light of this report and should be used as a guide as to what was done throughout Phase I of the project. However, the Phase II contractor should not regard these conclusions as proven with respect to efforts in the first portion of Phase II. The flow of data leading to conclusions must be clearly established. While a number of conclusions were voiced in the Phase I Final Report, the test results upon which they were based were not made clear. The data were described elsewhere, and the conclusions voiced in the Test Results Reports themselves were not as concise. Although the validity of the conclusions reached is not necessarily disputed, certainly they would have been more credible had the flow of evidence leading to them been more evident. Their proof lies buried in the mass of data which the Phase I contractor has assimilated to arrive at them. If these conclusions are to be furthered, the data should be exercised and reported so as to substantiate them rigorously. As an example, although from the results of Phase I,
hunting seems related to both the load condition of the car and the speed of operation, the apparent contrary conclusion, also of Phase I, that not all empty cars exhibit hunting and not all loaded cars exhibit lateral stability over the same speed range should be investigated further, especially with regard to the distinction between body hunting and truck hunting.

4.6 Relationship to Track Data

It would be desirable during Phase II and the reduction and analysis of any data that its relationship to the track data be established. The track roughness serves as the forcing function both to the physical system and the mathematical model. In the Phase I Test Results Reports, the only mention of the track condition was that the data were taken when the train was run over high speed tangent track, jointed rail, or the like, in a qualitative sense. A more quantitative relationship should be established between the data from the instrumented car and the data recorded by the track survey vehicle.

4.7 Form for Data Reduction

It should be established early in the program through consultation with the Industry Consultants what kind of data will be considered most meaningful and what they would like to see in the Interim and Final Reports. The purposes of displaying the processed data should be made clear: how they relate to the performance specification, how they relate to the relationship of truck parameters to performance indices, and how they relate to conclusions drawn from the first portion of Phase II. Such considerations would involve what types of plots will be most meaningful, what variables will be compared with which or what effects will be shown on the same variable on the same plot; in particular their relation to the track parameters must be established, both from a static numerical standpoint (RMS level) and from a dynamic standpoint (behavior across a frequency band).
4.8 Quality of Reports

Improvement of an editorial nature over the quality of the Phase I reports is desirable if the Phase II reports are to be received with approval throughout the industry. Such things as a list of definitions of terms used consistently throughout the reports both in the text and in particular by the data post-processing program, and lists of fundamental car, truck, and track data essential to the modeling effort and its validation should be included in the basic reports.
Freight Car Truck Design Optimization,
Volume VI: Critique of Phase I Test Series
Results Reports (Final Report), 1978
US DOT, FRA