HAZARDOUS MATERIAL TANK CARS - TANK HEAD PROTECTIVE "SHIELD" OR "BUMPER" DESIGN

AUGUST 1971

PREPARED FOR

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
WASHINGTON, D.C.

7111-144

The contents of this report reflect the views of the Association of American Railroads and the Railway Progress Institute, which are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification or regulation.

Availability is unlimited. Document may be purchased from the National Technical Information Service, Springfield, Virginia 22151, for $3.00 a copy.

61393

FINAL REPORT
(March 3, 1971)

Hazardous Material Tank Cars - Tank Head Protective "Shield" or "Bumper" Design
(Contract No. DOT - FR - 00035; RPI - AAR Project Phase 13)

ABSTRACT

The objective of this study program is to design a railroad tank car head protective device which will reduce the frequency of head punctures in accidents. Accident data were reviewed in detail for the years 1965 through 1970 to correlate head damage frequency and severity with various types of tank cars, to determine distribution patterns of damage over tank car head surfaces, and to assess the costs to the railroad shipping industry of head punctures. Full scale head impact tests, previously run were also reviewed. From these two reviews, design criteria were established and used to reduce an initial compilation of 74 concepts to a group of 15, which when applied to various classes of cars, comprised a semi-final total of 42 combinations, or schemes, as referred to in this report.

Designs for these 42 schemes were then detailed and cost estimated. Next, a comprehensive cost/benefit analysis was applied. In doing this, several important conservative assumptions were made. First, the six year accident record was assumed to be typical and totally representative of the future, notwithstanding the considerable distortion caused by several major accidents in two of the six years. Also, no potential reduction in head punctures was assumed attributable to other "overlapping" solutions, such as effective interlocking couplers or changes in train operation.

Finally, the design criteria were again applied to these 42 schemes and this, in combination with the cost/benefit analysis, led to the conclusions that three schemes appear attractive for the non-insulated pressure cars of the DOT 112A or 114A type and that no schemes are justified for any other class car. Recommendations are made that a test program be conducted to establish complete details of the final design and final performance specifications. The recommended test program is outlined, and a preliminary estimate of its cost is given.

TABLE OF CONTENTS

TABLE OF CONTENTS - Cont'd.

Page

APPENDIX C

APPENDIX D

TABLE OF CONTENTS - Concl'd.

Page

APPENDIX E

APPENDIX F

LIST OF FIGURES

LIST OF FIGURES - Cont'd.

APPENDIX B

APPENDIX C

LIST OF FIGURES - Cont'd.

APPENDIX D

LIST OF FIGURES - Concl'd.

Page

APPENDIX F

LIST OF TABLES

Page

MAIN BODY OF REPORT

APPENDIX A

LIST OF TABLES - Concl'd.

FINAL REPORT
(March 3, 1971)

Hazardous Material Tank Cars - Tank Head Protective "Shield" or "Bumper" Design
(Contract No. DOT - FR - 00035; RPI - AAR Project Phase 13)

I. INTRODUCTION

This is the final report on the subject DOT contract and covers all work done from 9/30/70 to 2/28/71, the technical period of the contract.

This contract has been handled administratively by the Association of American Railroads; however, technical performance has been carried out by the RPI-AAR cooperative team which is working on a more general tank car safety project under AAR administration. This RPI-AAR Project has been progressing under 12 technical phases, and the subject contract study has been carried out under newly added Phase 13.

The background, objectives, and work plan of this head shield study are described below. The work was divided into six tasks, and details of activity under the first three tasks have been reported on in the four monthly progress reports previously submitted. For completeness, all of this information, including updating where applicable, is repeated in this final report along with the details of the work since completed under the remaining three tasks.

To simplify the presentation, the complete discussions and results for each of the six tasks are given in the attached six appendices. A brief summary of each of these and final conclusions and recommendations are presented in this main body of the report.

II. BACKGROUND

Railroad tank car damage in derailments has been a railroad and tank car industry problem for many years. With the trend toward shipping increased quantities of certain hazardous products, particularly liquefied compressed gases, the problem has become more serious. In many of these accidents, a tank car head is punctured, a flammable hazardous product, either a liquefied compressed gas or a low vapor pressure liquid, is released, and substantial damage occurs as a result of the ensuing fire or violent tank rupture. The reduction of tank head punctures can lead to a reduction in both magnitude and frequency of such catastrophies.

The study program sought under this subject DOT contract covers a direct method of accomplishing this reduction.

The 12 technical phases of the RPI-AAR Project, which is progressing concurrently, are:

Phase 1 - Accident Review

Phase 2 - Derailment Environment Study

Phase 3 - Materials Study - Steels

Phase 4 - Review of Literature and Related Experience

Phase 5 - Head Study

Phase 6 - Safety Valve in Liquid Study

Phase 7 - Safety Relief Devices - General

Phase 8 - Reduced Scale Model Studies

Phase 9 - Design Study - Tanks and Attachments

Phase 10 - Design Study - Car

Phase 11 - Thermal Effects Study

Phase 12 - Vessel Failure Research

The Phase 1 effort was fairly well along at the time of initiating this subject head shield study and provided considerable input in the form of head damage statistics. Also, a preliminary series of full-scale impact tests had been completed under the Phase 5 study, and this information was also valuable as input.

III. OBJECTIVES AND WORK PLAN

The purpose of this head shield study as stated in the RFP is to develop a "shield", "bumper", or other possible protective structure which can be applied to the lower part of the heads of existing and new tank cars in order to significantly reduce the number of head punctures and end head contacts.

The objectives of the study are to include:

(1) A review of the characteristics of tank car head failures and determination of the approximate magnitude of probable tank head failure forces.

(2) The development of the criteria governing the design of the tank car head protective structure.

(3) The determination of the cost criteria for the addition of the protective structure including revenue loss due to increase of light weight of car, cost of structure, application and maintenance.

(4) The development of performance specifications, conceptual designs and application requirements for the protective tank head structure.

(5) The formulation of a performance test specification for the recommended design(s).

To accomplish these objectives, the work was divided into six tasks which are discussed briefly below. Complete discussions and results for each task are given in the appendices to this report.

TASK 1 - IDENTIFICATION OF TANK HEAD FAILURE CHARACTERISTICS

1.1 Accident Data Survey and Review
1.2 Identification of Primary Failure Parameters
1.3 Specification of Important Protection Features

Under Task 1, the major parameters associated with tank head punctures were evaluated using data obtained from a review of the RPI - AAR Project accident files. These files contain records of over 4500 cars which were damaged in accidents during the period 1965 through 1970. Of these, over 1200 cars suffered head damage, and 200 of these had punctured heads.

Based on the data for these 1200 + cars, the likelihood of head puncture was statistically analysed to assess the influence of several major parameters: type and size of car, location on the head, effect of load (vs empty), and insulation.

Next, that portion of the accident cost attributable to the head puncture of each car (loaded cars only) was estimated and tabulated by class of car. Also, statistics were tabulated on the number of cars of each class in service during the period 1965 through 1970. Both of these tabulations were used later in the cost/benefit analysis under Task 4.

TASK 2 - DESIGN CRITERIA

2.1 Tank Car Design Review
2.2 Head Failure Analysis and Correlation with Failure Data
2.3 Establishment of Protective Structure Design Criteria

This task was devoted to establishing design criteria for head protection devices based primarily on the full-scale head impact tests conducted previously under the RPI - AAR Project.

Semi-empirical equations were developed to "match" the test results and to permit analysis of the influence of various parameters on puncture phenomena.

Based on this analysis, the Task 1 accident review, and engineering judgement, a complete list of design criteria was then developed.

TASK 3 - DESIGN SPECIFICATIONS

3.1 Concept Formulation
3.2 Concept Analysis
3.3 Concept Review and Final Evaluation
3.4 Performance Specifications
3.5 Design Finalization and Drawings

This task comprised the generation of design concepts, their evaluation based on the above established design criteria, and development of performance specifications. The evaluation served as a screening process to reduce an originally lengthy list of concepts to a semi-final total of 15. Application of these to various classes of cars led to 42 combination schemes for design and cost estimating. Sketches of all 42 schemes are given in Appendix C.

TASK 4 - COST ANALYSIS

4.1 Cost Item Identification and Clarification
4.2 Structure Costs
4.3 Application Costs
4.4 Maintenance Costs
4.5 Cost-Affected Items
4.6 Cost/Benefit Analysis

The estimated installed cost for each of the 42 schemes was developed under this task. Analyses of less tangible cost affected items were also made.

At this point, each of the 42 schemes was evaluated on the basis of the economic benefit which would be realized from its application to a tank car. This was done using the estimates of installed cost and the Task 1 data on accident costs and number of cars in service.

Combining this economic benefit analysis with the Task 2 design criteria, a final scheme selection was made for each class of car. These are summarized in Table I which is discussed under Conclusions below.

TASK 5 - PERFORMANCE TEST SPECIFICATIONS

5.1 Test Parameter Identification
5.2 Relation of Performance Specifications to Test Parameters
5.3 Test Specification Formulation

The specifications for a prototype test program for the selected design were developed under this task.

TASK 6 - PROTOTYPE RESEARCH PROGRAM

6.1 Technical Design Requirements
6.2 Prototype Construction
6.3 Prototype Qualification
6.4 Cost Estimate

Based on the above test specifications, a complete prototype evaluation test program was outlined and cost estimated under this task.

IV. SCHEDULE

The project schedule was planned in detail during October, 1970, and technical activity followed in November through February, 1971.

With minor exceptions, the six tasks and sub-tasks listed above were conducted in sequence, but overlapping necessarily in some areas.

V. CONCLUSIONS

The following conclusions have been reached under this program:

The head protection schemes given in Table I have been identified as the economically and technically optimum of all schemes considered for each class of car listed.

This table does not include all classes of tank cars which are authorized to carry hazardous materials, although the first four classes listed cover approximately 97% of all new car types, and the latter four classes cover approximately 55% of existing car types. Class 103W, 104W, aluminum, and riveted cars constitute the balance and are fairly similar in design to the class 111 types listed.

This table also gives the estimated additional cost and benefit values for each scheme. The costs are, by our definition, those which would be incurred by a shipper-owner, excluding maintenance and less tangible related costs. The benefits are the maximum amounts which justifiably could be spent for each scheme and have been derived from estimated costs attributable to head punctures in past accidents, discounted to present value on a 10% annual rate of return on investment. Supporting details for these cost and

TABLE I

SUMMARY OF OPTIMUM HEAD PROTECTION CONCEPT BY CLASS OF CAR

Class Car	Optimum Head Protection Concept		Eff. of Scheme, % **	Est. Added Cost/ Car	Estimated Benefit/ Car	Estimated Economic Value (Benefit less Cost)
	Scheme*	Description				
New 112 & 114	O-1	1/2" butterfly plate	85	$430	$425	$ - 5
	P-1	1/2" vert. curv. plate	77	280	385	+105
	N-1	1/2" vert. straight pl.	55	200	275	+ 75
New 111 non-ins	N-2	1/2" vert. straight pl.	41	140	14	-126
New 111 ins.	J-3	3/8" jacket	75	270	13	-257
New 105 ins.	J-3	3/8" jacket	75	295	5	-290
Exist. 112 & 114	O-4	1/2" butterfly plate	85	500	425	- 75
	P-4	1/2" vert. curv. plate	77	335	385	+ 50
Exist. 111 non-ins.	N-5	1/2" vert. straight pl.	41	175	14	-161
Exist. 111 ins.	N-6	1/2" vert. straight pl.	79	200	10	-190
Exist. 105 ins.	N-6	1/2" vert. straight pl.	82	240	4	-236

* See Table C-2 for scheme identification code.

** Relative to a 1/2" steel plate covering entire head, see Table D-3, column labelled "B".

benefit values are given in Appendices A and D. The benefits were first derived in Appendix D on the assumption that head protection, had it been on cars which experienced head punctures, would have been 100% effective in preventing lading loss. The values shown in the benefit column of Table I are lower since the efficiency of the specific listed scheme is taken into account. These efficiencies are discussed in Appendix D, but noteworthy here is the fact that they are based on the assumption that a 1/2" steel plate, spaced away from, but covering the entire head, is 100% efficient. Variations in material, thickness, and head area covered (taking into account puncture distributions from accident data) lead to the estimated efficiencies.

There are two other important conservative assumptions underlying these benefit values. First, the accidents reviewed were for the six year period 1965 - 1970, and although the data was considerably distorted by several major accidents in two of the six years, 1968 and 1969, the assumption was made that the entire data set is typical and totally representative of the future. Second, no potential benefit has been assumed for other solutions which may overlap this head shield solution and which, therefore, would reduce the net benefit value of head shields.

Based on this approach and its associated assumptions, the estimated economic values given in Table I are finally established. From these, it is concluded that the head protection concepts, N, O, P or some combination design incorporating the best design and economic features of each, appear attractive for new and existing Class 112 and 114 cars. Conversely, no designs are justified for the balance of the cars.

VI. RECOMMENDATIONS

A. Prototype Test Program

The head shield concepts N, O, P or some optimum combination thereof, appear sufficiently attractive for class 112 and 114 cars to warrant a follow-up prototype test program. All of these concepts involve a 1/2" steel plate with slightly different shape and supporting structure. The test program is considered essential since the available data used to establish design criteria, though substantial, has not been sufficient to establish final performance specifications and the actual degree of protection offered by the concepts. This test program, outlined in Appendix F, has the direct objectives of:

- establishing quantitatively the degree of protection offered by the 1/2" steel plate design. This relates particularly to the values in the estimated benefit column in Table I which are based on the assumption that a 1/2" plate covering the entire head is 100% effective. For example, a 3/8" or 5/8" plate may be closer to being 100% effective; and, of course overriding all of this is the still undetermined "typical" impact speed and consist of impacting cars against which the shield is to protect. The test program is expected to provide a basis for establishing these unknowns.

- establishing a practical set of test performance specifications for the head shield and a set which can be used also for future submitted designs.
- establishing final design details and specifications for the recommended head shield and hence, final estimated additional cost.

Another benefit of the test program as proposed involves the evaluation of certain other energy absorbing materials which were considered under the present study, but which were discarded because of the uncertainty of their energy absorbing properties.

B. Overlapping Solutions to Overall Tank Car Safety Problem

Means other than a head shield, per se, can be instrumental in reducing the frequency of head punctures or ruptures. For example, an efficient interlocking coupler will reduce the frequency of head impact from couplers on adjacent cars. Operational changes such as speed reductions and/or car spacings will also tend to produce the desired result. While effective thermal shield coatings will not reduce the frequency of head punctures, they can affect the total benefit by reducing the magnitude of chain reactions initiated by head punctures. The estimated benefit values given in Table I do not take these overlapping solutions into account; instead, they are based on the assumption that only head shields will be available to produce the stated benefits.

With other potential solutions to the overall problem of improving tank car safety being studied under the RPI - AAR Project, it would be premature at this time to incorporate the head shield solution on actual cars. Fortunately, by the time the prototype head shield test program is completed, more will be known concerning these other solutions, and all can be considered simultaneously. Since the overall goal of the entire tank car safety program is to achieve improved safety as soon as practical, attractive potential solutions, whether overlapping or not, must be studied simultaneously; thus, speedy persuance of the outlined test program, is recommended.

VII. ACKNOWLEDGMENTS

Credit is due the following Project team members for their efforts in supervising the activities under their respective tasks:

R. A. Westin, UTC, Task 1
J. C. Shang, GARD, Task 2
J. E. Everett, GAT, Task 3

A. M. Skogsberg, NAC, Task 4
J. E. Everett, GAT, Task 5
C. E. Reedy, ACF, Task 6

Acknowledgment is also due to Dr. W. J. Harris, Jr., Vice President, AAR Research and Test Department; R. Byrne, AAR Research Director, L. L. Olson, AAR Senior Research Engineer; and others of the AAR staff for their cooperative assistance in many of the technical and administrative activities.

Mr. Everett, Principal Investigator of this subject study, has also been in charge of the full scale test work under the RPI - AAR Project Phase 5, and Mr. Westin has been in charge of the RPI - AAR Phase 1 Accident Review, both of which activities supplied input to the development of design criteria under Task 2 of this study.

For much of the design and cost estimating input under Tasks 3 and 4, we obtained certain services from the design and estimating departments of four tank car builders, and appreciation is expressed for this aid and for the liaison efforts of the following people:

D. Gruner (Amcar Division, ACF Industries)
J. Everett (General American Transportation Corp.)
A. M. Skogsberg (North American Car Corp.)
F. Brown (Union Tank Car Company)

Respectfully submitted,

Earl A. Phillips

E. A. Phillips
RPI - AAR Project Director

Approved:

W. J. Harris, Jr
Vice President
AAR Research & Test Department

Attachments:
Appendices A, B, C, D, E, F.

APPENDIX A

TASK 1

IDENTIFICATION OF TANK HEAD FAILURE CHARACTERISTICS

I. INTRODUCTION

The purpose of this task was to evaluate the major parameters associated with tank car head punctures using data obtained from a review of accidents. An attempt was made to accurately estimate for the major classes of cars: (1) the likelihood of head puncture as a function of several parameters; (2) the distribution pattern of punctures over the heads; (3) the economic loss resulting from head punctures, and (4) the average number of such cars in service. This effort was divided into two phases:

(1) Task 1.1 - Accident Data Survey and Review

(2) Tasks 1.2 and 1.3 - Identification of Primary Failure Parameters and Specification of Important Protection Features

II. TASK ACTIVITY

A. Task 1.1 - Accident Data Survey and Review

To obtain a base for the evaluation of various engineering and cost parameters associated with tank car head damage, relevant accident data were extracted from the accident files of the RPI - AAR Railroad Tank Car Safety, Research and Test Project. The sources of these data were the accident reports and car damage records of the AAR Bureau of Explosives, the Bureau of Railroad Safety of the Federal Railroad Administration, the major United States and Canadian tank car companies, and approximately 35 railroads.

The RPI - AAR files contained information on over 4,500 tank cars that were damaged in accidents during the six years 1965 through 1970. Of these, 1,256 cars suffered head damage, and data on these constituted the input to this study.

The specific data gathered under this task are presented in the following four sections.

1. Data on tank cars suffering head damage during the period of 1965 - 1970

The subject data is given in Tables A-1 and A-2; however, the list is not complete because some source files have been destroyed since 1965, not all records were specific as to the location of dents and punctures, and not all tank car owners and railroads have been contacted by the RPI - AAR Project personnel. Therefore, these data constitute a random, but large, sample of all tank cars which received head damage during the six-year period, although the statistics are probably skewed by the inclusion of nearly all cars that were damaged while loaded with hazardous commodities. This is because almost all such accidents were reported to the Bureau of Explosives.

Because much of these data were taken from defect cards and owners' damage reports, the speed of the car at the time of the accident, the train consist, and the identity of the striking object that damaged the head are not known for the majority of the cars. Therefore, no attempt was made to include this information in the data base. However, review of those accidents where the cause of the head damage is known indicates that the damage is often caused by coupler impact from the adjacent car.

Under its Phase 1 Accident Review activity, the RPI - AAR Project is still contacting railroads to obtain some of this missing information. However, this has not been completed in time for inclusion under this subject contract. Nevertheless, the data presented herein, and which has constituted the input to the head shield design and cost/benefit analysis, is considered sufficiently complete to be statistically significant.

2. Location of Head Punctures

In many cases, available records indicated only that there was a head puncture without specifying the location. However, in those cases where known, the location of the impact that resulted in a puncture was recorded as an X on the appropriate summary sheet in Figs. A-1 through A-6. In the case of riveted cars, the entire puncture was sketched on the sheet.

The overlying lines on Figs. A-2, A-3, and A-5 are outlines of various head shields which are discussed in detail in Appendix D.

3. List of Accidents Involving Head Punctures of Loaded Cars

The data in Tables A-3 through A-8 cover all cars found to have suffered a punctured head while loaded. Loss figures include the estimated cost of lading lost because of the head puncture and the estimated other costs incurred by chain reaction effects attributable to the lading lost due to the head puncture. Where there were other causes of lading loss besides the head puncture, the addition of a head shield as the only change in car design would not have prevented the loss of lading, and no loss is attributed to the absence of a head shield. In a few cases, the presence of a head shield and other changes in car design may have together resulted in a saving. However, the economic evaluation of combinations of head shields and other design changes is beyond the scope of this specific project on head shields.

The application of a head shield will reduce the likelihood of a head puncture, but it is assumed that it will not reduce the cost of the damage caused by an impact. That is, the cost of repairing a head damaged in the absence of a shield and a damaged shield is assumed to be equal. The correctness of this assumption is a function of the head shield design. While the assumption may be debatable, we nevertheless adopt it in the interest of simplicity and also because it will not significantly affect the conclusions.

It is quite likely that there were cars that suffered head punctures that do not appear on these lists in Tables A-3 through A-8. However, since all accidents involving hazardous materials are reported to the Bureau of Explosives, we are confident that the list includes almost all loaded pressure cars which suffered head punctures and other cars which carried ladings whose loss caused considerable other damage. Therefore, the number of cars listed may be low, but is still probably fairly close to the actual total.

The cost data in Tables A-3 through A-8 are partitioned to allow the Appendix D economic analysis to be separately applied to major categories of cars.

4. Number of Cars of Each Major Type - Estimate of Average Number in Service 1965 - 1970

For proper overall perspective of tank car design, it is essential to have some indication of the quantities of each type of tank car now in service and in current production. Since 1929, the AAR Committee on Tank Cars has published in its annual minutes a listing of new tank cars by specification class which were approved for service during each previous year. We have run cumulative totals on these, interpolating for the year 1932, 1933, 1937, 1941, 1943, 1944 and 1953 for which there were no data at the time of writing this report. 1/ The totals for the years 1928-1964 and 1965-1969 are shown in Table A-9. The values in the AAR Approvals column do not truly represent cars in service because of interpolation inaccuracies and the exclusion of cars destroyed or converted from

---

1/ We have recently obtained data for the missing years and will subsequently publish the total statistics under the RPI - AAR program; however, deviations in data are not significant for the purposes of this report. Even more relevant are statistics on car exposure by year, class of car, size, construction, commodity, etc. This information is also being developed under the RPI - AAR Project for later publication.

one class to another and of cars built prior to 1928 which are still in service. The results, of course, do not reflect usage which is essential in determining total exposures of cars by types. Nevertheless, the information can serve as a rough guide of quantities, particularly for the more modern classes of cars.

An independent check on the number of cars in each class is furnished by the records of the AAR Universal Machine Language Equipment Register (Umler). The figures from this source for the tank car fleet at the end of 1970 are also presented in Table A-9. Unfortunately, this record contains many cars that have been destroyed and are no longer in service.

The average number of cars of each type in service between 1965 and 1970 has been estimated by careful consideration of the two independent sources of data. These estimates are also shown in Table A-9.

B. Tasks 1.2 and 1.3 - Identification of Primary Failure Parameters and Specification of Important Protective Features

The accident data presented above was analyzed to determine the relative importance of various parameters associated with tank car head failures. A total of 1,256 reports were used in the analysis.

No conclusions can be drawn from this data as to the likelihood of head damage for various classes of cars as we do not have in this data base a description of all of the cars involved in accidents. We have data on only those that experienced head damage. Therefore, the allowable area for legitimate questions can be defined as follows: Given that a group of cars experienced damage to their heads, what was the distribution of the location of the head punctures, what was the probability of puncture, and how were these parameters affected by such factors as insulation, lading, underframe design, class of car, size of car, head thickness and material, etc.

1. Distribution of Head Punctures by Location

The cumulative distribution of head punctures as a function of height and segment size was calculated from the data presented in Figs. A-1 through A-6. These cumulative distribution curves are presented in Figs. A-7 and A-8 as a function of car class.

There does not appear to be any significant difference in distribution of punctures by type of car except that the punctures for the 112A and 114A pressure cars are slightly more concentrated in the lower center section of the head than are punctures of other types of cars. The 112A and 114A cars are generally stub sill cars, but the difference in distribution of punctures may be due to the large size of these cars since a slightly inverse effect appears for the stub sill design of non-pressure cars.

2. Distribution of Head Punctures by Parameters Other Than Location

The distributions of head punctures vs. class of car, insulation, size, and lading are given in Fig. A-9.

3. Statistical Analysis of Likelihood of Punctures of Welded Steel Cars

A number of combinations have been investigated to determine the effect of various parameters, the significance of each being determined by a chi-squared test of the deviation from a hypergeometric distribution. The results and conclusions are given in Figs. A-10 through A-13. A 90% confidence level is assumed to indicate significance. The statistic, degrees of freedom, and probability value are listed for each case (+.75 -.9 means probability value above .75 but below .9, etc.).

TABLE A - 1

DATA FORMAT

(for Table A-2)

Column	Information	Coding
1-4	Car Owner	Alpha - UTLX, GCX, etc.
5-10	Car number	Numeric - right justified
11-13	DOT class	Numeric: 3 for ARA 111, etc. 999 for USG and misc.
14-16	Pressure	Safety valve start to discharge pressure for DOT 112A and 114A. Nominal for other classes.
17-20	Head material	Steel: ASTM or AAR designation Col. 17-19 numeric - type Col. 20 alpha-numeric for grade Aluminum: 111A Nickel: 111N Stainless Steel: 111S
21-23	Joint efficiency	Col. 21 - 1 for riveted Col. 22 - 1 for .9 weld efficiency 2 for forge welded Col. 23 - 1 for 1.0 weld efficiency
24-26	Head thickness	Decimal inches x 1000 999 for 1" or greater
27-28	Tank capacity	US Gallons x .001
29-30	Truck capacity	Nominal - tons: 140 for dual 70, etc.
32-33	Insulation	Col. 32: 1 for insulated Col. 33: 1 for non-insulated
34-35	Underframe	Col. 34: 1 for full length underframe Col. 35: 1 for stub sills
36-37	Loaded at time of accident	Col. 36: 1 if loaded Col. 37: 1 if empty
38-42	Condition of worst damaged head	Col. 38: 1 if not damaged Col. 39: 1 if small dent (less than 36" diam. and/or 6" deep)

TABLE A-1 (cont'd)

Column	Information	Coding
		Col. 40: 1 if large dent (greater than 36" diam. and/or 6" deep) Col. 41: 1 if head punctured. Note: "puncture" is defined as any failure of a head due to impact that would result in lading loss. Col. 42: Location of damage shown in RPI - AAR files. Note: Col. 38 to 41 - All blank but one showing worst damage.
43-47	Conditon of other head	Col. 43: Same as Col. 38 Col. 44: " " " 39 Col. 45: " " " 40 Col. 46: " " " 41 Col. 47: " " " 42
48+	(Not significant)	

TABLE A-2 DATA: HEAD DAMAGE SURVEY - (1965-1970)

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head	Other Head
SEAX 27	112	300	212B			32	100	1		1	1 1	1
PSPX 153	111	100	285C			19	100	1		1	1	1
HOCX 154	111	100		1		10	50				1	
HOCX 155	111	100		1		10	50			1	1	1
UTLX 220	111	60	285C	1	500	20	70	1	1	1	1	1
UTLX 225	111	60	285C	1	500	20	70	1	1	1	1	1
UTLX 226	111	60	285C	1	500	20	70	1	1	1	1	1
UTLX 228	111	60	285C	1	500	20	100	1	1		1	1
PSPX 280	111	100	285C			19	100	1		1	1 1	1
ACFX 283	105	500	212B	1	875	11	70	1	1	1	1	1
ACFX 285	105	500	212B	1	875	11	70	1	1		1	1
MKT 310	103			1		19			1	1	1 1	1
UTLX 320	111	60	285C	1	500	20	70	1	1	1	1	1
UTLX 326	111	60	285C	1	500	20	70	1	1	1	1	
CCLX 349	203			1		8	50				1	1
SHPX 397	105	500	212B	1	875	11	70	1	1	1	1 1	1
UTLX 469	111	60	285C	1	500	21	100	1	1	1	1 1	1
GALX 557	112	280	128B		687	34	100	1	1	1	1	
UTLX 554	111	60	285C	1	500	20	70	1	1	1	1	1
SANX 632	103			1				1	1		1	
SFTX 713	105	300		2		11		1	1	1	1	
SFTX 746	105	300		2		11		1	1	1	1	
SFTX 749	105	300		2		11		1	1	1	1 1	1
UTLX 777	111	60	5157	1	437	20	100	1	1		1 1	1
UCLX 803	103			1		8	50			1	1	1
UTLX 917	111	100		1		5		1		1	1	
EBDX 961	105	300	285C			9	70	1		1	1 1	1
NATX 992	3			1		8	40	1	1		1 1	1 1
GATX 1001	111	100	212B	1	500	20	100	1	1	1	1 1	1
CELX 1025	111	60	111A	1		21	100	1	1	1	1	1
UTLX 1030	111	60	285C	1	500	22	100	1	1		1	1
UTLX 1038	111	100	285C	1	500	21	100	1	1		1 1	1
UTLX 1039	111	100	285C	1	500	21	100	1	1	1	1 1	1
UTLX 1040	111	100	285C	1	500	20	100	1	1		1 1	1
CGTX 1081	3			1		10	50	1	1		1 1	1 1
GATX 1111	103			1	500	6	40	1	1	1	1 1	1
CELX 1114	111	100	111A	1		10	50		1	1	1	1
SACX 1136	105	500		1		11		1	1	1	1	1
CGTX 1160	3			1				1	1	1	1	1
GATX 1205	103			1	500	6	40	1	1	1	1	1 1
CNTX 1213	112	280	212B	1	692	33	100	1	1	1	1 1	1
TCX 1606	111	60	285C	1	437	8	40	1	1	1	1 1	1
TCX 1620	111	60	285C	1	437	8	40	1	1	1	1 1	1
NATX 1657	3			1		10	50	1	1		1 1	1
NATX 1733	3			1				1	1	1	1	1
EORX 1749	105	300	285C			11	50	1		1	1	1
CGTX 1761	103			1		10	50	1	1	1	1 1	1
NATX 1801	3			1	500	8	40	1	1		1 1	1
GATX 1802	111	100	212B	1	437	20	100	1	1	1	1 1	1
CONX 1910	111	100									1 1	1
CGTX 1983	103			1		10	50	1	1		1 1	1 1

TABLE A-2

cont'd

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head	Other Head
GATX 2008	111	100	212B	1	500	20	100	1	1		1 1	11
CELX 2019	111	100	212B	1		20	100		1	1	1	1
CELX 2025	111	100	212B			20	100	1		1	11	1
MOBX 2207	111	100	212B	1	437	24	100	1	1		1	
CCBX 2271	3			1				1		1	11	1
CGTX 2278	3			1		8	40	1	1	1	1	
CCBX 2299	3			1				1	1	1	1 1	
GATX 2437	105	500	212B	1	937	10	70	1	1	1	1 1	1
ZIPX 2456	111	100	212B	1		25	100	1	1	1	1	1
KCPX 2502	103									1	1	1
GATX 2513	111	100	212B	1	437	20	100	1	1	1	1 1	1
NATX 2707	3			1		10	50	1	1		1 1	1
SDEX 2732	111	100		1		24	100	1		1	1	
CGTX 2826	3			1		10		1	1		11	1
SHPX 2996	105	300	115	1	875	11	50	1	1	1	1	
SOEX 3046	112	280	128B			34	100	1	1	1	1	1
KPCX 3267						10	50	1			1	
SACX 3502	111	100		1		8	50				1	
SACX 3516	111	100	285C	1	500	8	50	1		1	11	1
SRDX 3561						8	40	1		1	1	
NATX 3754	3			1		8	40	1	1		1 1	1
UTLX 3905	103		115	1	500	7	40	1	1	1	1 1	1
DOWX 4218	111	60	111A	1		10	50			1	1	1
GATX 4572	111	100	285C	1	437	4	40	1	1	1	1 1	1
DOWX 4672	111	100	5157	1	500	10	70	1	1	1	11	1
GATX 4719	103		285C	1	500	8	50	1	1	1	1 1	1
UTLX 4720	3		115	1	500	8	40	1	1	1	1	
ESMX 4803	114	280	128B	1		48	200	1	1		1 1	1
ESMX 4808	114	280	128B	1		48	200	1	1	1	1	1
NATX 5374	103			1	500	8	40	1	1		1	
UTLX 5565	3		115	1	500	10	40	1	1		1	
UTLX 5589	3			1					1		1	1
NATX 5923	103			1	500	8	40	1	1	1	1	1
GATX 6094	111	100	212B	1	437	20	100	1	1	1	1 1	1 1
SHPX 6110	103		285C	1	500	6		1	1		1	1
GATX 6205	103		285C	1	500	8	50	1	1	1	1 1	1 1
GATX 6215	103		285C	1	500	8	50	1	1	1	1 1	1
EBAX 6355	105	300	285C			6	50	1	1	1	1	1
EBAX 6383	105	300	285C			6	50	1		1	1	1
GATX 6437	111	100	212B	1	437	15	100		1	1	1 1	1
CGTX 6529	3			1		6	30	1	1	1	1 1	1
CGTX 6541	3			1		6	30	1	1	1	1	1
SHPX 6656	105	300	212	1	875	11	70	1	1	1	1	
GATX 7094	103			1		9	50	1	1	1	1 1	1
SHPX 7538	103		212A	1	500	8	50	1	1		1	1
NATX 7511	111	100	285C	1	437	8	50	1	1		1 1	1
GATX 7676	111	60	5157	1	500	10	50	1	1	1	1 1	1
NATX 8020	3			1		8	40	1	1		1 1	1
GATX 8119	111	60	285C	1	437	8	50	1	1		1 1	1
TCX 8130	103			1	500	10	50		1	1	1 1	1
GATX 8131	111	60	285C	1	500	8	50	1	1	1	1 1	1
SWTX 8191	103			1	500	8	40	1	1	1	1 1	1
CONX 8202	105	300				11	50	1	1	1	11	1
AESX 8323	111	100	5157			20	100	1			1 1	1 1
GATX 8381	111	60	111A	1	500	10	50	1	1	1	1 1	1

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head	Other Head
GATX 8527	103			1	562	7	50	1	1	1	1 1	1
GATX 8541	111	60		1	687	10	50	1	1	1	1 1	1
CGTX 8787	3			1			50	1	1		1 1	1
CGTX 8795	3			1				1	1		1 1	1 1
ACDX 8901	103			1					1	1	1 1	1
BECX 8913	103		111A			8	40		1		1	
DUPX 8919	105	300	212B			19	100	1	1	1	1 1	1
DUPX 8926	105	300	212B			19	100	1		1	1	1
GATX 8928	111	100	212B	1	437	20	100	1	1		1	1
SACX 9036	112	280	128B		599	26	100	1	1	1	1	
NATX 9085	3			1		10	50	1	1		1 1	1
CGTX 9166	3			1				1	1		1 1	1 1
GATX 9208	3			1					1	1	1 1	1
GATX 9509	111	60	212B	1	437	8	50	1	1	1	1 1	1 1
NATX 9817	3			1		10	50	1	1		1 1	1
PPGX 9948	112	280	128B	1	687	32	125	1	1	1	1 1	1
GATX 10065	111	100	5157	1	437	20	100	1	1	1	1 1	1
GATX 10197	111	60	5157	1	500	8	50	1	1	1	1 1	1
GATX 10500	111	60	5157	1	500	10	50	1	1	1	1 1	1
GATX 10525	111	100	5157	1	500	20	100	1	1	1	1 1	1 1
GATX 10613	111	100	5157	1	437	21	100	1	1	1	1 1	1
GATX 10624	111	100	5157	1	437	20	100	1	1	1	1 1	1
GATX 10645	111	60	5157	1		20	100	1	1		1 1	1
GATX 10788	111	100	5157	1	500	21	100	1	1	1	1 1	1
GATX 10884	103			1	500	13	100	1	1	1	1 1	1
GATX 10983	111	100	5157	1	500	20	100	1	1		1 1	1
GATX 11068	111	100	5157	1	500	21	100	1	1	1	1 1	1
GATX 11078	120	300	128B	1	312	34	100	1	1	1	1 1	1
UTLX 11125	103		115	1	500	6	30	1	1	1	1	1
GATX 11688	112	280	128B	1	653	34	100	1	1	1	1 1	1 1
GATX 11826	111	100	5157	1	562	26	100	1			1 1	1 1
GATX 11832	111	100	5157	1	562	27	100	1			1 1	1
SHPX 12136	111	100	212B	1	437	20	100	1	1		1	1
SHPX 12423	111	100	212B	1	437	20	100	1	1	1	1 1	1
SHPX 12426	111	100	212B	1	437	20	100	1	1		1	1
SHPX 12467	111	100	212B	1	437	18	100	1	1	1	1	1
SHPX 12471	111	100				18		1	1	1	1	
SHPX 12529	111	100	212B	1	437	20	70	1	1	1	1 1	1 1
ACFX 12566	111	100		1		21		1		1	1	
GATX 12588	103		285C	1		10	50	1	1	1	1 1	1
NATX 12607	111	60	111A	1	500	20	100	1	1		1 1	1
NATX 12623	111	60	111A	1	500	21	100	1			1 1	1 1
SHPX 12737	111	100	212B	1	437	20	100	1	1		1	
ACFX 12796	111	100	212B	1	437	20	100	1	1		1	1
GATX 12803	105	100	5157	1	625	23	100	1	1	1	1 1	1
SHPX 12886	111	100	212B	1	437	20	100	1	1	1	1	1
SHPX 12995	111	100	212B	1	437	20	100	1	1	1	1	1
UTLX 13007	111	100		1		14	100	1	1	1	1 1	1
UTLX 13064	111	100	285C	1	687	11	70	1	1	1	1 1	1
CGTX 13286	111	100	212B	1	437	13	100	1	1		1 1	1
CGTX 13294	111	100	212B	1	437	13	100	1	1	1	1	1
UTLX 13301	111	100	285C	1	500	15	100	1	1		1 1	
UTLX 13472	111	100	285C	1	500	15	100	1	1	1	1 1	1
UTLX 13523	111	100	5157	1	468	15	100	1	1	1	1 1	1 1
UTLX 13606	111	100	212B	1	437	15	100	1	1	1	1 1	1
WRNX 13657	3			1		8				1	1	

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head				Other Head			
UTLX 13690	111	100	285C	1	500	14	100	1	1	1		1		1	1			
UTLX 13866	111	100	5157	1	500	14	100	1	1	1		1		1		1		1
UTLX 13874	111	100	515	1	500	15	100	1	1	1			1	1	1			
UTLX 13959	3		115	1	500	7	50	1	1				1	1		1		1
UTLX 13988	3		115	1	500	7	50	1			1			1	1			
DODX 14011	111	100	5157	1		20	125	1	1		1			1	1			
CGTX 14056												1		1			1	1
CGTX 14091		30	285C	1	500	10	70	1	1	1	1				1			
GATX 14102	111	100	5157	1	500	21	100	1	1	1		1		1	1			
SHPX 14197	103		285C	1	500	10	50	1	1	1			1					
GATX 14204	111	100	5157	1	437	21	100	1	1	1	1			1	1			
CGTX 14333	111	100	212B	1		14	100	1	1	1	1			1	1			
UTLX 14347	103		285C	1	500	8	50	1			1					1		
GATX 14358	112		128B		625	34	100	1	1	1			1					
CGTX 14378	111	100	5157	1	437	14	100	1	1	1		1		1	1			
GATX 14721	3			1	500	8	40	1	1	1		1		1	1			
GATX 14877	3			1		8	40	1	1	1		1		1	1			
UTLX 14922	111	100	285C	1	500	15	100	1	1	1	1			1	1			
UTLX 14926	111	100	285C	1	500	15	100	1	1	1			1		1			
FMLX 15010	111	100		1		15	100				1							
VMCX 15018	111	100		1		15	100			1	1				1			
VMCX 15021	111	100		1		15	100			1	1					1		
NATX 15322	105	400	285C	1	875	11	50	1	1			1		1	1			
SHPX 15482	103		285C	1	500	10	70	1	1	1			1		1			
NATX 15545	111	100	285C	1	703	11	70	1	1	1	1				1			
SHPX 15809	103		285C	1	500	10	70	1	1	1	1				1			
SHPX 15831	103		285C	1	500	10	70	1	1			1			1			
GATX 15835	103		285C	1	500	8	50	1	1	1		1		1	1			
ACFX 15890	103		285C	1	500	10	70	1	1	1		1				1		
GATX 15908	111	100	5157	1	500	20	100	1	1	1	1			1	1			
GATX 15966	105	500	5167	1	937	19	100	1	1	1	1			1	1			
GATX 16145	103			1	500	10	50	1	1	1	1				1			
DODX 16438	103			1						1	1				1			
STAX 17029	103			1		7	50		1	1			1		1			
ACFX 17093	112	280	128	1	599	33	100	1	1	1			1	1			1	1
NATX 17105	112	300	212B	1	750	23	100	1	1		1			1	1			
NATX 17122	112	300	212B	1	750	23	100	1	1		1			1	1			
ACFX 17145	112	280	128		599	33	100	1	1	1		1		1		1		1
SHPX 17163	112	280	128	1	599	33	100	1	1	1	1					1		
NATX 17179	112	300	212B	1	750	23	100	1	1			1		1	1			
SHPX 17454	111	100	5157	1	437	20	100	1	1	1	1							
PSPX 17500	105	300	285C			11	50	1		1	1			1	1			
ACFX 17549	112									1		1				1		
SHPX 17594	112	300	212B	1	812	32	100	1	1			1					1	
SHPX 17602	112	300	212B	1	812	32	100	1	1		1				1			
SHPX 17603	112	300	212B	1	812	32	100	1	1			1			1			
SHPX 17608	112	300	212B	1	812	32	100	1	1		1					1		
SHPX 17610	112	300	212B	1	812	32	100	1	1		1							
SHPX 17611	112	300	212B	1	812	32	100	1	1		1				1			
SHPX 17614	112	300	212B	1	812	32	100	1	1				1		1			
SHPX 17619	112	300	212B	1	687	32	100	1	1		1							
SHPX 17720	112	280	128B	1	599	34	100	1	1	1	1					1		
SHPX 17722	112	280	128B	1	599	34	100	1	1	1	1				1			
UTLX 17830	103		285C	1	500	8	50	1	1	1			1	1	1			
SHPX 17873	112	300	212B	1	813	30	100	1	1	1	1				1			
SHPX 17939	112	280	128B	1	599	34	100	1	1		1					1		

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head	Other Head
GATX 18120	112	280	128B	1	687	34	100	1	1	1	1 1	1
NATX 18193	103		285C	1	500	8	50	1	1		1 1	1
GATX 18675	111	100	5157	1	500	20	100	1	1	1	1 1	1 1
ACFX 18718	112						100	1		1	1	
ACFX 18791	112						100	1			1	
ACFX 18815	112	280	128B	1	599	34	100	1	1	1	1	1
GATX 19195	3			1		10	50		1	1	1 1	1
GATX 19279	3			1		10	50	1	1	1	1 1	1
NATX 19310	111	100	285C	1	437	8	50	1	1		1 1	1
SHPX 19396	105	500	128B	1	753	11	50	1	1	1	1	1
NATX 19442	111	100	212B	1	437	12	100	1	1		1 1	1
NATX 19566	103		285B	1	500	10	70	1	1		1 1	1 1
UTLX 19726	3		115	1	500	8	40	1	1	1	1	
SHPX 19809	103		111A	1	687	8	50	1	1		1	1
UTLX 19888	103		285C	1	500	8	50	1	1	1	1 1	1
ACFX 19939	112	280	128B	1	599	34	100	1	1	1	1	1
NATX 19948	111	100	212B	1	437	13	100	1	1		1 1	1
NATX 19961	111	100	212B	1	437	13	100	1	1		1 1	1 1
GCX 20001	112							1	1	1	1	1
TCX 20020	111	100		1	437	20	100	1	1	1	1 1	1
NATX 20023	103			1		8	50	1	1		1 1	1
NATX 20101	111	60	111A	1	500	20	100	1	1		1 1	1
CGTX 20109	111	100	285C	1		20	100	1	1		1 1	1
DUPX 20109	111	100	285C	1		20	100	1	1	1	1	1
CGTX 20123	111	100	212B	1	437	20	100	1	1		1 1	1
CGTX 20139	111	100	212B	1	437	20	100	1	1		1 1	1 1
CGTX 20247	111	100	5157	1	437	20	100	1	1	1	1	
TCX 20307	111	60	5157	1	500	7	100	1	1	1	1 1	1
CGTX 20403	111	100	212B	1	437	20	100	1	1	1	1 1	1 1
CGTX 20426	111	100	212B	1	437	20	100	1	1	1	1 1	1
CGTX 20427	111	100	212B	1	437	20	100	1	1	1	1 1	1 1
CGTX 20434	111	100	212B	1	500	20	100	1	1	1	1 1	1
NATX 20568	111	100	5157	1	437	13	100	1	1		1 1	1
NATX 21011	111	100	212B	1	500	21	100	1	1	1	1 1	1 1
DUPX 21023										1	1 1	1
NATX 21035	111	100	212B	1	500	21	100	1	1		1 1	1 1
MCPX 21061	105	300		1		21		1	1	1	1	1
NATX 21098	111	100	212B	1	500	21	100	1	1	1	1	1
NATX 21108	111	100	212B	1	500	20	100	1	1		1 1	1 1
NATX 21132	111	100	212B	1	500	20	100	1	1		1 1	1
NATX 21149	111	100	212B	1	500	21	100	1	1		1 1	1
NATX 21220	111	100	212B	1	500	21	100	1	1		1 1	1
NATX 21237	111	100	212B	1		21	100	1	1		1	1
NATX 21245	111	100	212B	1	500	21	100	1	1		1 1	1
NATX 21253	111	100	212B	1	500	21	100	1	1		1 1	1
NATX 21268	111	100	212B	1	500	21	100	1	1		1 1	1
NATX 21274	111	100	212B	1	500	21	100	1	1		1 1	1
NATX 21296	111	100	212B	1	500	20	100	1	1		1 1	1
NATX 21359	111	100	212B	1	500	21	100	1	1	1	1 1	1
NATX 21400	111	100	212B	1	500	21	100	1	1		1 1	1
AESX 21506	111	100	212B	1		21	100	1		1	1 1	1
NATX 21567	111	100	5157	1	500	21	100	1	1		1 1	1
GATX 21581	103		285C	1	500	10	50	1	1	1	1 1	1
GATX 21584	103		285C	1	500	10	50	1	1	1	1 1	1
NATX 21615	111	100	212B	1	500	21	100	1	1	1	1 1	1
NATX 21703	111	100	212B	1	500	21	100	1	1	1	1 1	1

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head				
NATX 21716	111	100	212B	1	500	21	100		1	1				1			1	1				
NATX 21740	111	100	212B	1	500	21	100		1	1		1				1		1				
NATX 21826	111	100	212B	1	500	21	100	1		1				1			1	1				
NATX 21906	111	100	212B	1	500	21	70		1	1				1			1	1				
NATX 21922	111	100	212B	1	500	21	70		1	1				1			1	1				
NATX 21952	111	100	212B	1	500	21	100		1	1						1					1	1
NATX 21956	111	100	212B	1	500	21	100		1	1		1			1			1				
NATX 22126	111	100	212B	1	500	20	100		1		1			1				1				
NATX 22215	111	100	212B	1		21	100		1			1		1			1	1				
NATX 22303	111	100	212B	1	500	21	100		1	1					1		1			1		1
NATX 22330	111	100	212B	1	500	21	100		1	1				1			1	1				
NATX 22473	111	100	212B	1	500	21	100		1	1					1		1	1				
SHPX 22559	103		285C	1	500	8	50		1	1						1		1				
NATX 22647	111	100	212B	1	500	21	100		1	1					1		1	1				
NATX 22663	111	100	212B	1	500	21	100		1	1					1		1	1				
NATX 22861	111	100	5157	1	500	21	100		1	1				1			1		1			1
NATX 22889	111	100	5157	1		21	100		1					1			1		1			1
NATX 22956	111	100	212B	1	500	21	100		1	1		1		1			1	1				
SHPX 22965	103		285C	1	500	8	50		1	1				1								
GATX 22993	103			1	500	6	40		1	1			1	1			1	1				
NATX 23004	111	100	212B	1	500	21	100		1	1					1		1			1		1
MCPX 23025	111	100	212B	1		23	150	1			1	1				1	1			1		
MCPX 23028	111	100	212B				150	1				1			1		1	1				
RSPX 23118	111	100		1		23	100						1	1				1				
MOBX 23120	105	300				11		1				1			1		1	1				
NATX 23245	111	100	5157	1	437	21	100		1	1				1			1	1				
NATX 23408	111	100	5157	1	437	20	100		1		1		1	1				1				
NATX 23609	111	100	212B	1	437	21	100		1	1				1			1	1				
SHPX 23620	103		285C	1	500	8	50		1	1					1			1				
GATX 23749	3			1		8	50		1	1			1		1		1	1				
SHPX 23758	103		285C	1	500	8	70	1		1		1			1			1				
UTLX 23764	111	100	285C	1	500	23	100	1			1				1			1				
UTLX 23773	111	100	285C	1	500	23	100	1			1			1			1		1			1
UTLX 23785	111	100	285C	1	500	20	100	1			1		1	1				1				
CGTX 24000			111A	1	625	20	100	1		1					1			1				
NATX 24002	111	100	212B	1	500	21	100		1	1		1		1			1	1				
NATX 24003	111	100	212B	1	500	21	100		1	1		1			1		1	1				
UTLX 24224	3		115	1	500	10	50		1	1				1								
NATX 24247	111	100	5157	1	500	21	100	1		1					1		1			1		1
GATX 24409	105	500	128B	1	812	17	100	1			1	1		1								
SHPX 24482	103		285C	1	500	8	50		1	1				1								
NATX 24729	111	100	285C	1	500	10	70	1		1				1			1		1			1
GATX 24797	103			1	500	8	50		1	1		1				1	1	1				
PSPX 25042	112	300	212B				50		1			1			1		1		1			1
NATX 25078	111	100	5157	1	500	24	100		1	1				1			1	1				
NATX 25127	111	100	212B	1	500	18	100		1	1		1		1			1	1				
PSPX 25175	112	300												1								
NATX 25239	111	100	5157	1		24	100	1						1			1	1				
NATX 25372	111	100	5157	1	500	23	100	1		1				1			1	1				
NATX 25377	111	100	5157	1		25	100		1			1				1	1		1			
NATX 25394	111	100	5157	1	437	24	100		1	1				1			1		1			1
SRDX 25512	111	100	515B			26	100	1				1				1	1	1				
UTLX 25532	104		285C	1	500	10	70	1		1				1			1	1				
UTLX 25535	104		285C	1	500	10	70	1		1		1			1		1	1				
UTLX 25685	111	100	285C	1	500	20	100	1			1				1		1		1			1
GATX 25929	103		285C	1	500	6	40		1	1		1		1				1				

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged	Head	Other	Head
GATX 25941	103		2850	1	500	8	50	1	1	1	1			1	
GATX 26119	103		2850	1	500	10	50	1	1	1	1			1	
GATX 26177	103		2850	1		10	50	1	1		1		1	1	
NATX 26444	105	200	111A	1	625	10	50	1	1		1		1	1	
NATX 26634	111	100	2850	1	437	10	70	1	1		1		1	1	
GATX 26653	103			1	500	6	40	1	1	1	1			1	
RTCX 26701	111	100	5157			21	100			1		1	1	1	
RTCX 26706	111	100	5157			21	100	1		1		1	1	1	
UTLX 27168	103		115	1	500	10	40	1	1		1			1	
UTLX 27413	103		115	1	500	10	50	1	1		1				
UTLX 27550	103		2850	1	500	10	50	1	1	1		1	1	1	
NATX 27716	105	200	111A	1	625	10	50	1	1		1			1	
DUPX 28002	114	300				28	125	1		1		1	1	1	
NATX 28016	111	100	111S	1	437	19	100	1	1	1	1				
NATX 28020	111	100	111S	1	437	19	100	1	1	1	1			1	
UTLX 28025	105	500	128B	1	812	17	100	1	1		1				
DUPX 28040	114	300								1	1			1	
GATX 28667	103			1		8	50	1	1	1		1			
GATX 28969	103			1	500	8	50	1	1	1		1		1	
CGTX 29036							70			1		1		1	
CGTX 29083	111	100	212B	1	437	20	70	1	1			1	1	1	
CGTX 29106	111	100	212B	1	437	21	100	1	1	1	1			1	
CGTX 29128	111	100	212B	1	437	21	100	1	1			1	1	1	
CGTX 29207	111	100	212B	1	437	21	100	1	1	1		1	1	1	1
CGTX 29233	111	100	212B	1	437	20	70	1	1		1		1		1
CGTX 29319	111	100	212B	1	437	21	100	1	1	1	1				
CGTX 29333	111	100	212B	1	437	21	100	1	1	1		1	1	1	
CGTX 29409	111	100	5157	1	437	21	100	1	1	1		1			
DUPX 29414	111	100				38						1	1	1	
DUPX 29624	111	100	5157	1		42	150	1	1	1		1	1	1	
DUPX 29642	111	100	5157			42	150	1	1	1	1		1	1	
UTLX 29730	3			1		10	50	1	1	1		1		1	
NATX 29911	111	100	5157	1	500	29	100	1	1			1		1	
NATX 29972	111	100	128B	1	500	30	100	1	1		1		1	1	
WRNX 30003	112	300		1		32	100	1	1		1			1	
NATX 30026	112	300	212B	1	733	30	100	1	1	1		1	1	1	1
NATX 30031	112	300	212B	1	733	30	100	1	1		1		1	1	
NATX 30032	112	300	212B	1	733	30	100	1	1			1	1	1	1
UTLX 30064	3		115	1	500	10	50	1	1	1	1		1	1	
WRNX 30098	112	280	212B			33	100	1	1	1		1	1	1	
WRNX 30173	112	280	212B			33	100	1	1	1	1		1	1	
GATX 30643	103			1	500	13	50	1	1	1	1			1	
GATX 30669	103			1	500	13				1		1	1	1	
GATX 30751	112		128B		608	31	125	1	1	1		1			
GATX 30758	112	280	128	1	608	31	125	1	1	1		1	1	1	
GATX 30767	112	280	128	1	608	31	125	1	1	1		1	1	1	
GATX 30998	103			1	500	10	70	1	1	1	1			1	
NATX 31021	112	300	212B	1	773		100	1	1	1		1	1	1	
NATX 31025	112	300	212B	1	750	31	100	1	1	1		1	1	1	
NATX 31039	112	300	212B	1	750	31	100	1	1		1		1	1	
CSOX 31118	112	280	212B			33	100	1	1	1		1	1	1	
GATX 31690	103			1	500	7	50	1	1	1	1			1	
NATX 32015	112		212B		693	33	100	1	1	1		1			
NATX 32028	112	280	212B	1	693	33	100	1	1	1		1	1	1	
GATX 32029	105	400	2850	1	938	11	50	1	1	1	1		1	1	
NATX 32061	112	280	212B	1	693	33	100	1	1		1			1	

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head	Other Head
NATX 32069	112	280	212B	1	693	33	100	1	1	1	1 1	1
NATX 32105	112	280	212B	1	693	31	100	1	1		1 1	1
NATX 32111	112	280	212B	1	693	33	100	1	1	1	1 1	1
NATX 32138	112	280	212B	1	693	33	100	1	1	1	1 1	1
NATX 32152	112	280	212B	1	695	33	100	1	1		1 1	1 1
UTLX 32502	3		115	1	500	10	50	1	1		1 1	1 1
TGPX 32802	112	280	128B			33	100	1	1	1	1 1	1
UTLX 32870	3		115	1	500	10	50	1	1		1 1	1
GATX 33003	111	60	285C	1	437	8	50	1	1	1	1	1
MCPX 33004	112	255	128B	1		33	125	1	1	1	1	1
GATX 33008	111	60	285C	1	437	8	50	1	1	1	1	1
PSPX 33019	114	280	212B			33	100	1		1	1 1	1 1
NCTX 33036	112	280	212B	1	693	33	100	1	1	1	1	1
PSPX 33087	114	280	212B			33	100	1		1	1 1	1
NCTX 33107	114	280	128B	1	669	34	100	1	1	1	1	1
GATX 33151	103			1					1	1	1	1
PSPX 33578	112	280	128B			34	100	1	1	1	1	1
PSPX 33620	112	280	128B	1	653	34	100	1	1	1	1 1	1
PSPX 33624	112	280	128B	1	653	34	100	1	1	1	1	
UTLX 33786	3			1		10	50		1		1	1
NATX 33859	112	280	128B	1	692	34	100	1	1	1	1 1	1 1
NATX 33877	112	280	128B	1	692	34	100	1	1		1 1	1
NATX 33903	112	280	128B	1	692	34	100	1	1	1	1 1	1
NATX 33913	112	280	128B	1	603	34	100	1	1		1	1
NATX 33916	112	280	128B	1	603	34	100	1	1		1	1
GATX 33939	203		212B	1	500	10	50	1	1	1	1	1
NATX 33954	112	280	128B	1	603	34	100	1	1		1	1
NATX 33961	112	280	128B	1		34	100	1	1		1 1	1
UTLX 34022	3		115	1	500	10	50	1	1		1 1	1
NATX 34038	114	280	128B	1	669	34	100	1	1		1 1	1
GATX 34068	111	100	5157	1		20	100	1	1		1 1	1 1
NATX 34103	112	280	128B	1	669	34	100	1	1	1	1 1	1 1
NATX 34106	112	280	128B	1	669	34	100	1	1	1	1 1	1
NATX 34119	112	280	128B	1	669	34	100	1	1		1	1
NATX 34228	112	280	128B	1	603	34	100	1	1	1	1	1
NATX 34305	112	280	128B	1	603	34	100	1	1	1	1	1
NATX 34372	112	280	128B	1	603	34	100	1	1		1	1
NATX 34440	112	280	128B	1	603	34	100	1	1	1	1 1	1
GATX 34445	103		285C	1	500	6	50	1	1	1	1	1
NATX 34473	112	280	128B	1	603	34	100	1	1	1	1 1	1
GATX 34531	111	60	5157	1	500	10	50	1	1	1	1 1	1
GATX 34631	103			1		7	50	1	1	1	1	1
NATX 34672	112	280	128B	1	603	34	100	1	1	1	1	1
GATX 34675	103		285C	1	562	7	50	1	1	1	1	1
NATX 34703	112	280	128B		603	34	100	1	1	1	1	1
GATX 34995	105	300		1				1	1	1	1	
GATX 35163	103			1		10	50	1	1	1	1	1
UTLX 35718	3		115	1	500	10	50	1	1		1	
GATX 35941	999			1	375	10	50				1 1	1
GATX 36227	111	60		1	687	10	70	1	1	1	1	1
RTCX 36576	112	280	128			33	100	1	1	1	1	
RTCX 36801	112	280	128B		599	34	100	1	1	1	1 1	1
UTLX 37210	3		115	1	500	10	50	1	1		1	1
UTLX 37271	3		115	1	500	10	50	1	1		1 1	1
NATX 37529	112	280	128B	1	669	34	100	1	1		1 1	1
NATX 37531	112	280	128B	1	669	34	100	1	1		1 1	1

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged	Head	Other	Head
NATX 37532	112	280	128B	1	669	34	100	1	1		1		11		
NATX 37535	112	280	128B	1	669	34	100	1	1		1		1	1	1
UTLX 37934	3		115	1	500	10	50	1	1		1		1		
NATX 38021	114	255	128B	1	603	39	150	1	1	1		1	11		
NATX 38033	114	255	128B	1	603	39	150	1	1	1	1		1	1	1
NATX 38046	114	255	128B			39	150	1				1	1	1	1
UTLX 38046	112	280	128B	1	603	34	100	1	1	1		1			
UTLX 38047	112	280	128B	1	687	34	100	1	1	1		1	1	1	1
GATX 38066	103			1		7	50	1	1	1		1	11		
GATX 38138	103		285C	1	562	7	50	1	1	1	1		1		
GATX 38145	103		285C	1	562	7	50	1	1	1	1		11		
GATX 38308	103		285C	1	562	7	50	1	1	1		1	11		
GATX 38310	103		285C	1		8	50	1	1	1		1	1		11
GATX 38311	103		285C	1	562	7	50	1	1	1		1	11		
UTLX 38661	112	280	128B	1	625	34	100	1	1	1		1	1		
GATX 38753	111	100	212B	1		20	100	1	1	1	1		11		
GATX 38763	111	100	212B	1	437	15	100	1	1	1	1		11		
GATX 38764	111	100	212B	1	437	15	100	1	1	1		1	11		
GATX 38765	111	100	212B	1	437	14	100	1	1	1	1		11		
UTLX 38773	112	280	128B	1	687	34	100	1	1	1		1	1	1	1
GATX 38793	103		285C	1	500	13	100	1	1	1	1		1		
GATX 38802	111	100	212B	1	500	18	100	1			1		11		
GATX 38828	111	100	212B	1	437	15	100	1		1		1	11		
GATX 38828	111	100	212B	1	437	15	100	1		1	1		11		
GATX 38848	111	100	212B	1	437	20	100	1	1	1		1	11		
GATX 38932	103		285C	1	500	13	100	1	1	1	1		11		
GATX 38992	111	60	212B	1	437	20	100	1	1	1	1		11		
UTLX 39012	103		115	1	500	10	50	1	1		1		1		
MCPX 39043	112					33	100	1	1	1		1	11		
UTLX 39059	103		115	1	500	10	50	1	1	1	1		11		
GATX 39079	111	100	212B	1	437	20	100	1	1	1		1	11		
GATX 39083	111	100	212B	1	437	20	100	1	1	1		1	11		
UTLX 39113	103		285C	1	500	10	50	1	1		1		1		
UTLX 39137	103		115	1	500	10	50	1	1		1		11		
UTLX 39137	103			1	500	10	50	1	1			1	1		
GATX 39152	111	100	212B	1	437	20	100	1	1	1	1				
GATX 39196	111	100	212B	1	437	20	100	1	1	1		1	1	1	1
GATX 39211	111	100	285C	1	625	20	100	1	1	1		1	1		
GATX 39344	111	100	212B	1	437	20	100	1	1	1		1	11		
UTLX 39344	103		285C	1	500	10	50	1	1		1		11		
UTLX 39356	103		285C	1	500	10	50	1	1		1		11		
UTLX 39366	103		115	1	500	10	50	1	1			1	11		
UTLX 39385	103		285C	1	500	10	50	1	1			1	11		
GATX 39433	111	100	212B	1	437	20	100	1	1	1	1		11		
GATX 39440	111	100	212B	1	562	20	100	1	1	1		1	11		
GATX 39449	111	100	212B	1	625	20	100	1	1	1	1		1		
GATX 39457	111	100	212B	1	437	20	100	1	1	1	1		1	1	1
GATX 39463	111	100	212B	1		20	100	1		1	1		11		
GATX 39498	111	100	212B	1	437	20	100	1	1	1		1	11		
UTLX 39521	103		285C	1	500	10	50	1	1		1		11		
UTLX 39524	103		285C	1	500	10	50	1	1		1		11		
GATX 39549	111	100	212B	1	437	20	100	1	1	1		1	11		
GATX 39551	111	100	212B	1	437	70	100	1	1	1		1	1	1	1
GATX 39552	111	100	212B	1	437	20	100	1	1	1	1		11		
UTLX 39605	103		285C	1	500	10	50	1	1		1		1		

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged		Head		Other		Head	
UTLX 39691	103		285C	1	500	10	50	1	1		1			1	1				
UTLX 39781	103		285C	1	500	10	50	1	1		1								
UTLX 39788	103		285C	1	500	10	50	1	1		1			1	1				
GATX 39821	111	100	212B	1	437	16	100	1	1	1	1			1	1				
UTLX 39847	103		285C	1	500	10	50	1	1	1	1			1	1				
GATX 39851	111	100	212	1		20	100	1				1		1	1				
UTLX 39857	103		285C	1	500	10	50	1	1	1	1			1	1				
GATX 39903	111	100	212B	1	500	20	100	1	1	1		1		1	1				
UTLX 39980	103		285C	1	500	10	50	1	1	1	1					1			
UTLX 40025	103		285C	1	500	10	50	1	1		1				1				
UTLX 40091	103		285C	1	500	10	50	1	1		1			1	1				
UTLX 40104	103		285C	1	500	10	50	1	1		1								
UTLX 40185	103		285C	1	500	10	50	1	1		1								
UTLX 40246	103		285C	1	500	10	50	1	1			1		1			1		1
UTLX 42060	206		111S	1		12		1	1	1	1								
UTLX 42205	206		111S	1	307	12	100	1	1			1		1	1				
UTLX 45435	103		115	1	500	6	40	1	1		1					1			
UTLX 45843	3		115	1	500	8	40	1	1		1				1				
UTLX 46155	103		285	1	500	8	40				1			1	1				
UTLX 47133	103		285C	1	500	8	50	1	1	1		1		1	1				
UTLX 47263	103		285C	1	500	8	50	1	1		1				1				
UTLX 47265	103		285C	1	500	8	50	1	1		1				1				
UTLX 47284	103			1	500	8	50	1	1	1		1							
UTLX 47408	111	100	285C	1	437	8	50	1	1	1			1	1	1				
UTLX 47927	111	60	285C	1	500	20	70	1	1	1	1					1			
UTLX 48042	103		115	1	500	12	50	1	1	1		1		1	1				
UTLX 48701	111	100	5157	1	500	21	100	1	1			1		1	1				
UTLX 48732	111	100	5157	1	500	20	100	1	1				1					1	
UTLX 48743	111	100	5157	1	500	29	100	1	1	1	1				1				
UTLX 48768	111	100	5157	1	500	30	100	1	1	1			1	1					
UTLX 48862	111	100	5157	1	500	21	100	1	1		1			1	1				
UTLX 48904	111	100	285C	1	500	20	100	1	1			1		1	1				
UTLX 48907	111	100	285C	1	500	20	100	1	1			1		1		1			1
UTLX 49145	103		115	1	500	12	50	1	1	1			1	1		1			1
UTLX 49220	103		115	1	500	12	50	1	1	1	1			1	1				
UTLX 49247	103		115	1	500	12	50	1	1				1	1			1		1
UTLX 49407	103		115	1	500	12	50	1	1		1								
UTLX 49425	103		115	1	500	12	50	1	1	1		1		1		1			1
UTLX 49471	103		115	1	500	12	50	1	1		1								
UTLX 49577	111	100	212B	1	468	29	100	1	1	1	1			1	1				
UTLX 49585	111	100	212B	1	468	29	100	1	1	1		1		1	1				
UTLX 49596	111	100	285C	1	500	20	100	1	1		1				1				
UTLX 49598	111	100	285C	1	500	20	100	1	1	1		1		1	1				
UTLX 49720	111	100	285C	1	500	20	70	1	1	1			1				1		
UTLX 49849	111	100	285C	1	500	20	100	1	1		1			1	1				
UTLX 49867	111	100	285C	1	500	21	100	1	1	1	1			1	1				
UTLX 49931	111	100	285C	1	500	21	100	1	1			1		1		1			1
UTLX 49985	111	100	285C	1	500	21	100	1	1	1	1				1				
UTLX 49996	111	100	285C	1	500	21	100	1	1		1			1	1				
UTLX 50090	111	100	285C	1	500	20	100	1	1		1			1	1				
UTLX 50111	111	100	285C	1	500	20	100	1	1				1		1				
UTLX 50191	111	100	285C	1	500	21	100	1	1	1			1	1	1				
UTLX 50372	3		115	1	500	10	50	1	1	1			1		1				
GATX 50395	111	100	5157	1	500	21	100	1	1				1	1	1				
UTLX 50399	3		115	1	500	10	50				1			1	1				
GATX 50407	111	100	5157	1	500	21	100	1	1			1		1	1				

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head				Other Head			
UTLX 51229	3		115	1	500	10	50	1	1		1			1	1			
UTLX 51237	3		115	1	500	10	50	1	1		1				1			
UTLX 51336	3		115	1	500	10	50	1	1	1			1	1	1			
UTLX 51378	103		285C	1	500	10	50	1	1				1	1	1			
UTLX 51526	3			1					1	1	1			1	1			
UTLX 51849	3		115	1	500	10	50	1	1		1				1			
UTLX 52824	103		115	1	500	12	50	1	1			1			1			
UTLX 53113	103		285C	1	500	10	50	1	1		1				1			
UTLX 53207	103		285C	1	500	10	50	1	1				1	1	1			
UTLX 53300	103		285C	1	500	10	50	1	1		1			1	1			
UTLX 53573	3		115	1	500	10	50				1			1	1			
UTLX 53763	3		115	1	500	10	50	1	1		1				1			
UTLX 54268	2		115	1	500	10	40	1	1		1				1			
GATX 54644	103			1	500	8	50	1	1	1	1			1	1			
GATX 54647	103			1	500	8	50	1	1	1	1			1		1		
GATX 54663	103			1	500	8	50	1	1	1		1		1	1			
GATX 54863	103		111A	1	687	10	50	1	1	1	1			1		1		
UTLX 55006	103		285C	1	500	10	50	1	1			1		1		1		1
UTLX 55093	103		285C	1	500	10	50	1	1	1			1	1	1			
UTLX 55132	103		285C	1	500	10	50	1	1		1				1			
UTLX 55136	103		285C	1	500	10	50	1	1			1		1	1			
CGTX 55245												1		1			1	1
CGTX 55284	105	300	212B	1	938	11	70	1	1	1	1			1	1			
GATX 55460	112	280	128B	1	653	34	100	1	1		1			1	1			
UTLX 55555	3		115	1	500	10	50	1	1				1					
UTLX 55615	3		115	1	500	10	50	1	1			1		1	1			
UTLX 55731	3		115	1	500	10	50	1	1	1	1				1			
UTLX 55962	3		115	1	500	10	50			1	1				1			
GATX 56598	3			1	500	10	50	1	1	1	1			1	1			
GATX 56786	3			1	500	10	50	1	1	1			1		1			
GATX 57208	3			1	500	10	50	1	1	1			1	1	1			
GATX 57294	103			1	500	8		1	1	1		1		1	1			
UTLX 57434	3		115	1	500	10	50	1	1		1				1			
GATX 57754	3			1					1	1	1							
UTLX 58245	2		115	1	500	7	40	1	1		1							
GATX 59047	103		115	1	500	10	50	1	1	1	1			1	1			
UTLX 59196	3		115	1	500	10	50	1	1	1	1				1			
UTLX 59315	103		285C	1	500	10	50	1	1	1			1	1	1			
UTLX 59353	111	100	5157	1	500	20	100	1	1			1		1	1			
UTLX 59354	111	100	5157	1	500	20	100	1	1		1			1		1		1
UTLX 59355	111	100	5157	1	500	20	100	1	1				1	1	1			
UTLX 59418	111	100	5157	1	500	20	100	1	1	1	1			1	1			
UTLX 59432	111	100	285C	1	500	17	100	1	1		1			1	1			
UTLX 59440	111	100	285C	1		17	100	1	1			1		1	1			
UTLX 59444	111	100	285C	1	500	17	100	1	1				1	1		1		1
UTLX 59521	111	100	285C	1	500	20	100	1	1		1			1		1		1
UTLX 59537	111	100	5157	1	500	23	100	1	1			1		1		1		1
UTLX 59557	111	100	5157	1	500	27	100	1	1	1			1	1	1			
GATX 59559	103			1	562	7	50	1	1	1	1			1		1		
UTLX 59595	111	100	5157	1	500	20	100	1	1		1			1	1			
GATX 59622	103			1	562	8	70	1	1	1	1			1	1			
UTLX 59630	111	100	5157	1	500	20	100	1	1		1				1			
GATX 59868	112	280	128B	1	687	44	125	1	1	1	1				1			
UTLX 59895	3		115	1	500	10	50	1	1	1	1				1			
GATX 60026	103			1	500	4	40	1	1	1	1			1	1			
UTLX 60312	3		115	1	500	10	50	1	1		1			1	1			

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency		Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head				
GATX 60343	3			1		500	6	40			1		1				1	1	1				
UTLX 60502	111	100	285C		1	500	12	100	1			1	1				1	1	1				
UTLX 60509	111	100	285C		1	500	12	100	1			1	1				1	1				1	1
UTLX 60510	111	100	285C		1	500	12	100	1			1	1				1	1	1				
UTLX 60515	111	100	285C		1	500	12	100	1			1	1		1				1				
UTLX 60516	111	100	285C		1	500	12	100	1			1	1				1		1				
UTLX 60519	111	100	285C		1	500	12	100	1			1	1				1		1				
UTLX 60579	111	100	285C		1	500	12	100	1			1	1		1					1			
UTLX 60725	111	100	285C		1	500	10	70	1		1		1			1		1	1				
UTLX 60731	111	100	285C		1	500	10	70	1			1			1			1	1				
UTLX 60732	111	100	285C		1	500	10	70	1		1		1			1		1	1				
GATX 60898	103		115		1	562	7	50		1	1		1		1			1	1				
GATX 60959	103				1	562	7	50		1	1		1		1			1	1				
GATX 61214	103				1	562	7	50		1	1			1		1		1	1				
GATX 61346	103				1	500	10	50	1		1			1		1		1	1				
GATX 62401	103				1	500	10	50	1		1			1		1		1	1				
GATX 62413	103				1	500	10	50	1		1			1	1			1	1				
UTLX 62558	3		115	1		500	10	50	1		1						1		1				
UTLX 62615	3		115	1		500	10	50	1		1				1				1				
GATX 62637	203		285C			500	10	50	1		1			1		1		1	1				
GATX 62674	111	60	285C		1	437	8	50	1							1		1	1				
GATX 62856	103				1	500	8	50	1		1			1		1		1	1				
GATX 62865	103				1	500	8	50	1		1				1			1		1			1
GATX 63000	103		285C		1	500	10	50	1		1			1		1		1	1				
GATX 63018	103		285C		1	500	10	50	1		1		1			1		1	1				
UTLX 63145	111	100	285C		1	500	13	100	1			1					1		1				
GATX 63174	111	60			1	703	10	50		1	1			1	1				1				
CGTX 63223	112	280	212B		1	633	33	100		1		1	1		1								
UTLX 63255	111	100	285C		1	500	12	100	1			1		1	1			1	1				
CGTX 63505	112	280	212B		1	633	34	100		1		1		1		1			1				
UTLX 63679	103		115		1	500	7	40	1		1						1		1				
CGTX 63744	112	280	128B		1	653	34	100		1		1	1		1								
GATX 63767	105	300			1	750	6	50	1		1		1		1			1	1				
UTLX 63925	111	100	285C		1	500	20	100	1			1				1			1				
UTLX 63928	111	100	285C		1	500	20	100	1			1				1		1		1			1
UTLX 63942	111	100	285C		1	500	21	100	1			1				1			1				
GATX 63946	111	100				687	10								1			1	1				
UTLX 63980	111	100	285C		1	500	20	100	1			1		1		1		1	1				
UTLX 63995	111	100	285C		1	500	20	100	1			1				1			1				
GATX 64147	111	100	5157		1	500	14	100		1		1			1			1		1			1
UTLX 64313	3		115	1		500	10	50	1		1				1				1				
GATX 64463	103		285C		1	500	10	70	1		1			1	1			1					
GATX 64608	103				1	500	8	50		1	1			1	1			1	1				
GATX 64752	105	300	285C		1	999	10	70	1		1			1	1			1	1				
GATX 65146	103			1		500	8	40		1	1		1			1		1	1				
GATX 65197	103		285C		1		8	50		1	1				1			1	1				
GATX 65238	3			1		500	10		1		1			1	1				1				
GATX 65384	103			1		500				1	1		1				1	1			1		
UTLX 65406	111	60	285C		1	500	20	100	1			1				1		1		1			1
GATX 65623	3			1		500	10	50		1	1		1			1			1				
UTLX 65830	111	100	285C		1	500	13	100	1			1		1	1			1	1				
UTLX 65982	3		115	1		500	8	40	1		1				1				1				
UTLX 66341	3		115	1		500	10	50	1		1					1			1				
UTLX 66462	3		115	1		500	10	50	1		1			1	1					1			
UTLX 66601	3		115	1		500	10	50	1		1		1		1			1	1				
UTLX 66663	3		115	1		500	10	50	1		1					1		1	1				

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency		Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head		
GATX 66791	103		285C		1	500	8	50		1	1			1			1	1	1		
UTLX 66976	3		115	1		500	8	50	1		1			1			1				
UTLX 67146	3		115	1		500	10	50	1		1					1		1	1		
GATX 67479	105	300			1	875	10	50	1		1		1		1			1	1		
GATX 67489	105	300			1	875	10	50	1		1			1		1		1	1		
UTLX 67582	3		115	1		500	10	50	1		1		1		1				1		
UTLX 68419	3		115	1		500	10	50	1		1		1		1				1		
GATX 68587	111	100			1	500	10	50		1					1			1	1		
GATX 69066	103				1	500	8	50		1	1			1	1			1	1		
UTLX 69320	3		115	1		500	10	50	1		1		1			1		1	1		
UTLX 69458	3		115	1		500	10	50	1		1		1		1			1	1		
UTLX 69610	103		285C		1	500	10	50	1		1				1					1	
UTLX 69624	103		285C		1	500	10	50	1		1		1			1			1		
UTLX 69661	111	100	285C		1	500	10	70	1			1			1						
GATX 69662	201	70	111A		1	812	10	50		1	1					1		1	1		
UTLX 69668	111	100	285C		1	500	10	70	1			1	1				1	1		1	1
GATX 69849	201	70	111A		1	812	10	50	1		1			1			1	1	1		
UTLX 69909	103		285C		1	500	10	50	1		1					1			1		
UTLX 69994	111	100	285C		1	500	20	100		1		1				1		1	1		
UTLX 69997	111	100	285C		1	500	21	100	1			1	1		1			1	1		
UTLX 70011	103		115	1		500	10	50		1	1					1		1	1		
UTLX 70040	3		115	1		500	10	50		1	1				1			1	1		
GATX 70105	103		285C		1	500	8	50	1		1		1		1			1	1		
GATX 70637	103			1		500	10	50	1		1			1	1				1		
GATX 70751	105	100	111A		1	844	10	50			1					1		1	1		
GATX 71087	103		285C		1	562	7	50		1			1				1		1		
GATX 71262	103		285C		1	562	7	50		1	1		1			1		1	1		
GATX 71264	103		285C		1	562	7	50		1	1			1	1			1	1		
UTLX 71469	3		115	1		500	8	40		1	1		1				1				
GATX 71509	103		285C		1	500	10	70	1		1		1		1			1	1		
GATX 71604	103		285C		1	500	8	50		1	1		1		1			1	1		
GATX 71711	203		285C		1	500	8	50		1	1						1	1		1	
GATX 71783	103		285C		1	500	8	50		1	1				1					1	
UTLX 72039	3		115	1		500	8	40		1	1				1						
GATX 72191	105	500	285C		1	939	11	70	1		1			1	1						
GATX 72467	103		285C		1	500	8	50		1	1			1	1			1	1		
UTLX 72554	3		115	1		500	8	40		1	1						1		1		
GATX 72556	105	100	285C		1	687	11	50	1		1			1		1		1	1		
GATX 72730	103		285C		1		10	50		1	1		1		1			1	1		
GATX 72732	103		285C		1	500	10	50		1	1		1				1	1		1	
GATX 72745	103		285C		1	500	10	50	1		1			1	1			1	1		
GATX 72838	103		285C		1	500	8	50	1		1			1		1		1		1	1
GATX 72860	111	60	285C		1	500	8	40	1			1		1	1			1	1		
UTLX 73213	3		115	1		500	8	50			1				1				1		
GATX 73292	103		285C		1	500	10	70	1		1					1		1	1		
GATX 73464	103		285C		1	500	10	70	1		1		1		1				1		
GATX 73468	103		285C		1	500	10	70	1		1		1				1	1	1		
GATX 73469	103		285C		1	500	10	70	1		1		1		1			1	1		
GATX 73534	103		111A		1	625	8	50		1	1			1	1			1	1		
GATX 73846	103		285C		1	562	7	50		1	1						1		1		
GATX 73951	103				1	562	7	50		1	1			1			1	1	1		
GATX 74304	103				1	500	10	70	1		1		1		1			1	1		
UTLX 74410	3		115	1		500	8	50		1	1				1						
GATX 74456	103		285C		1	500	10	70	1		1		1		1			1	1		
GATX 74583	103		285C		1	500	10	50		1	1			1	1			1	1		
GATX 74608	103		285C		1	500	10	50		1	1		1		1			1	1		
GATX 75113	103		285C		1	500	8	50		1	1				1			1	1		

TABLE A- 2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency		Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head		
GATX 75162	103		285C		1	500	8	50		1	1		1		1			1	1		
GATX 75171	103			1		500	8	50		1	1		1		1			1	1		
GATX 75199	103		285C		1	500	8	50		1	1			1	1			1	1		
UTLX 75231	111	100	5157		1	500	21	100	1			1			1			1	1		
UTLX 75237	111	100	5157		1	468	17	100	1			1					1			1	
UTLX 75317	3		115	1		500	8	40		1	1						1		1		
UTLX 75342	3		115	1		500	8	40		1	1				1				1		
GATX 75401	103				1	500	10	50		1	1				1			1		1	1
GATX 75444	103		285C		1	500	10	50		1	1					1		1		1	1
GATX 75553	105	300	285C		1	682	11	50	1		1			1		1		1	1		
UTLX 75620	3			1			8	40		1	1		1				1				
GATX 75741	111	60	285C		1	682	11	50		1	1		1			1		1	1		
GATX 75771	111	60	285C		1	632	11	50	1		1		1		1			1	1		
GATX 76080	104		285C		1	500	10	70	1		1					1		1	1		
GATX 76036	104		285C		1		10	50	1		1		1		1			1	1		
GATX 76138	103				1	500	10	50	1		1		1		1			1	1		
GATX 76166	103		285C		1	500	10	50	1		1		1		1			1	1		
GATX 76294	105	500	212B		1	737	11	70	1		1				1			1	1		
UTLX 76496	3		115	1		500	8	40		1	1				1			1	1		
GATX 76571	103		285C		1	500	8	50		1	1			1		1		1	1		
UTLX 76913	111	60	5157		1	500	10	50	1			1			1				1		
GATX 76997	103		285C		1	500	8	50		1	1			1		1		1	1		
GATX 77105	103				1						1			1	1						
GATX 77284	205	300	285C		1	812	8	50		1	1		1		1			1	1		
GATX 77319	109	300	285C		1	812	8	50		1	1			1		1		1	1		
UTLX 77355	111	100	5157		1	500	22	100	1			1			1						
GATX 77464	103				1	500	10	50	1		1			1		1		1	1		
GATX 77586	111	100	285C		1	812	8	50	1		1			1	1						
UTLX 78032	111	100	5157		1	500	13	100	1			1			1				1		
UTLX 78144	111	100	5157		1	500	13	100	1			1			1				1		
GATX 78166	111	60			1	875	10	50	1		1		1		1			1	1		
UTLX 78356	111	60	5157		1	500	10	50	1			1				1		1	1		
UTLX 78433	111	100	5157		1	500	22	100	1			1			1			1	1		
UTLX 78543	111	60	285C		1	500	10	70	1			1	1		1				1		
UTLX 78586	111	60	285C		1	500	10	70	1			1			1			1	1		
UTLX 78593	111	60	5157		1	437	16	100	1			1		1	1			1	1		
UTLX 78620	111	60	5157		1	437			1			1				1		1		1	1
UTLX 78692	111	100	5157		1	437			1			1				1				1	
GATX 78712	111	60	285C		1	937	10	50	1		1		1			1		1	1		
UTLX 78788	111	100	285C		1	500	20	100	1			1		1		1					
UTLX 78932	111	100	285C		1	500	14	100	1			1			1				1		
UTLX 78955	111	100	285C		1	500	20	100	1			1		1		1			1		
UTLX 79026	111	100	285C		1	500	10	70	1		1				1				1		
UTLX 79081	111	100	212B		1	437	16	100	1			1					1	1	1		
UTLX 79113	111	100	212B		1	500	23	100	1			1	1			1		1	1		
UTLX 79171	111	60	285C		1	500	21	125	1			1				1		1	1		
GATX 79190	111	60	285C		1	682	11	50	1		1		1			1		1	1		
GATX 79260	105	300	285C		1	682	11	50	1		1		1		1			1	1		
UTLX 79264	111	60	285C		1	500	22	100	1			1				1		1	1		
UTLX 79293	111	100	212B		1	437	22	100	1			1			1				1		
GATX 79294	105	300	285C		1	632	11	50	1		1		1			1		1		1	1
UTLX 79363	111	100	285C		1	500	10	70	1			1			1					1	
GATX 79379	105	500	285C		1	999	10	70	1		1			1	1			1	1		
UTLX 79380	111	100	5157		1	437	22	100	1			1	1		1			1	1		
GATX 79420	105	300	285C		1	999	10	70	1		1		1		1			1	1		
UTLX 79432	111	100	285C		1	500	13	100	1			1			1			1			

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head		
UTLX 79443	111	100	285C	1	500	13	100	1			1			1						
UTLX 79448	111	100	285C	1	500	13	100	1			1			1			1	1		
UTLX 79571	111	60	5157	1	437	16	100	1			1			1						
UTLX 79671	111	100	285C	1	500	20	100	1			1		1			1	1	1		
UTLX 79876	111	100	285C	1	437	8	50	1			1			1			1		1	1
UTLX 79960	111	100	5157	1	437	22	100	1			1			1			1	1		
UTLX 80021	204	70	111S	1	312	17	100	1			1			1					1	
UTLX 80029	204	70	111S	1	312	17	100	1			1			1					1	
UTLX 80055	204	70	111S	1	312	17	100	1			1			1				1		
GATX 80144	103		285C	1	500	8	50		1	1			1		1		1	1		
GATX 80155	103		285C	1	500	8	50		1	1			1	1			1	1		
GATX 80156	103		285C	1	500	8	50		1	1			1	1			1	1		
GATX 80193	103		285C	1	500	8	50		1	1				1						
GATX 80293	103		285C	1	500	8	50		1	1		1			1		1	1		
GATX 80296	103		285C	1	500	8	50		1	1		1			1		1	1		
UTLX 80509	112	280	212B	1	718	33	100		1		1	1			1		1		1	1
UTLX 80512	112	280	212B	1	718	33	100		1		1	1			1		1	1		
UTLX 80518	112		212B		719	34	100		1		1	1				1				
UTLX 80557	112	280	285B	1		34	100		1		1			1				1		
UTLX 80561	112	280	285B	1	718	34	100		1		1	1		1			1	1		
UTLX 80567	112	280	212B	1	718	34	100		1		1					1		1		
UTLX 80596	112	280	212B	1	718	34	100		1		1				1		1		1	1
GATX 80690	103		285C	1	500	10	50		1	1		1			1			1	1	
UTLX 80694	112	280	128B	1	625	34	100		1		1	1			1		1	1		
UTLX 80701	112	280	128B	1	625	34	100		1		1	1		1			1	1		
UTLX 80740	112	280	128B	1	625	34	100		1		1				1		1	1		
GATX 80749	103		285C	1	500	10	70		1	1						1	1			
GATX 80802	111	100	212B	1	437	14	100		1				1	1			1	1		
UTLX 80811	112	280	128B	1	625	34	100		1		1			1			1	1		
UTLX 80860	112	280	128B	1	687	34	100		1		1			1			1		1	1
UTLX 80882	112	280	128B	1	687	34	100		1		1			1				1		
GATX 80920	111	100	212B	1	437	20	70		1	1			1	1			1	1		
GATX 80939	111	100	212B	1	437	20	100		1	1			1		1		1	1		
GATX 80959	111	100	212B	1	437	20	100		1	1			1		1		1	1		
UTLX 80990	112	280	128B	1	687	34	100		1		1	1		1				1		
UTLX 80997	112	280	128B	1	687	34	100		1		1			1			1	1		
UTLX 81040	105	500	128B	1	718	17	100	1			1			1				1		
GATX 81060	103		285C	1	500	8	50		1	1			1		1		1	1		
GATX 81061	103		285C	1	500	8	50		1	1					1		1	1		
SHPX 81107	111	100	212B	1	437	21	100		1	1		1		1				1		
GATX 81110	103		285C	1	500	10	70		1	1				1			1	1		
GATX 81134	103		285C	1	500	10	70		1	1			1			1	1	1		
UTLX 81193	112					34	100		1		1	1				1				
SHPX 81223	111	100	212B	1	437	20	100		1	1		1				1	1		1	
GATX 812[illegible]0	103		285C	1	500	10	50		1	1			1	1			1	1		
GATX 81287	111	100		1	437	20	100		1		1		1	1			1	1		
SHPX 81295	111	100	212B	1	437	20	100		1	1		1		1					1	
GATX 81300	111	100	212B	1	437	15	100		1		1		1	1			1	1		
SHPX 81310	111	100	212B	1	437	20	70		1	1		1				1		1		
SHPX 81337	111	100		1									1	1						
GATX 81369	111	100	212B	1	437	14	100		1		1			1			1	1		
GATX 81383	111	100	212B	1	437	14	100		1		1		1	1					1	
GATX 81389	111	100	?12B	1	437	14	100		1		1		1		1			1		
GATX 81394	111	100	212B	1	437	15	100		1		1		1	1			1	1		
UTLX 81406	112	280	128B	1	687	34	100		1		1				1		1	1		
SHPX 81412	111	100	212B	1	437	20	100		1	1				1					1	

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head				
GATX 81420	103		285C	1	500	10	70		1	1			1	1			1	1				
SHPX 81420	111	100	212B	1	437	20	100		1	1				1				1				
SHPX 81432	111	100	212B	1	437	20	100		1	1						1				1		
SHPX 81434	111	100	212B	1	437	20	100		1	1		1		1				1				
GATX 81469	111	100	212B	1	500	17	100		1		1	1		1				1				
GATX 81477	111	100	5157	1		18	100		1		1			1			1	1				
GATX 81492	111	100	5157	1	500	20	100		1		1		1	1			1	1				
GATX 81509	103		285C	1	500	10	70		1	1			1	1			1	1				
GATX 81514	103		285C	1		10	70		1	1		1		1			1	1				
SHPX 81525	111	100	212B	1	437	20	100		1	1				1				1				
SHPX 81529	111	100	212B	1	437	21	100		1	1				1					1			
GATX 81536	103		285C	1	500	10	70		1	1		1		1			1		1			1
UTLX 81571	112	280	128B	1	687	34	100		1		1	1		1			1	1				
UTLX 81583	112	280	128B	1	687	34	100		1		1	1			1		1	1				
SHPX 81633	111	100	212B	1	437	20	100		1	1		1				1		1				
GATX 81662	111	100	5157	1	500	20	100	1			1		1	1			1		1			1
UTLX 81747	112	280	128B	1	687	34	100		1		1	1			1		1	1				
GATX 81750	111	100	5157	1		10	50		1		1	1			1		1	1				
UTLX 81751	112	280	128B	1	687	34	100		1		1	1		1			1	1				
SHPX 81760	111	100	212B	1	437	20	100		1	1				1				1				
UTLX 81815	112	280	128B	1	687	34	100		1		1			1				1				
UTLX 81834	112	280	128B	1	687	34	100		1		1			1				1				
SHPX 81876	111	100	212B	1	437	21	100		1	1						1			1		1	
UTLX 81978	112	280	128B	1	687	34	100		1		1			1				1				
UTLX 81916	112	280	128B	1	687	33	100		1		1	1		1			1	1				
SHPX 82005	111	100	212B	1		20	100		1	1					1			1				
SHPX 82115	111	100	212B	1	437	20	100		1	1				1				1				
SHPX 82252	111	100	212B	1	437	20	100		1	1				1								
UTLX 82481	105	300	212B	1	625	24	100	1			1	1		1			1	1				
UTLX 82482	105	300	212B	1	625	24	100	1			1			1				1				
SHPX 82490	111	100	212B	1	437	21	100		1	1		1				1	1	1				
UTLX 82528	112	280	128B	1	687	26	100		1		1			1				1				
SHPX 82634	111	100	5157	1	437	21	100		1	1				1					1			
SHPX 82692	111	100	5157	1	437	20	100		1		1			1				1				
ACFX 82735	111	100	5157	1	437	21	100		1		1	1			1		1	1				
GATX 83008	105	500	212B	1	937	10	70	1		1		1		1			1	1				
UTLX 83024	112	300	212B	1	782	30	100		1		1			1			1	1				
UTLX 83035	112	300	212B	1	782	30	100		1		1		1	1			1	1				
UTLX 83096	112	300	212B	1	750	30	100		1		1			1			1	1				
GATX 83240	105	500	212B	1		10	70	1		1		1		1				1				
UTLX 83241	112	280	212B		719	34	100		1		1	1				1						
UTLX 83283	112	300	212B	1	750	31	100		1		1			1			1	1				
UTLX 83284	112	300	212B	1	750	31	100		1		1				1		1	1				
GATX 83285	112	280	212B	1	664	33	100		1		1	1		1			1	1				
UTLX 83293	112	300	212B	1	750	30	100		1		1	1				1	1		1			1
GATX 83305	112	280	212B	1	664	33	100		1		1		1	1				1				
GATX 83310	112	280	212B	1	664	33	100		1		1	1			1		1		1			1
GATX 83335	112	280	212B	1	664	33	100		1		1		1	1			1	1				
GATX 83370	112	280	128B	1	653	34	100		1		1		1		1		1	1				
GATX 83385	112	280	128	1		34	100		1		1			1			1	1				
UTLX 83390	112	300	212B	1	750	30	100		1		1	1		1			1	1				
UTLX 83424	112	300	212B	1	750	30	100		1		1					1	1	1				
UTLX 83427	112	300	212B	1	750	30	100		1		1	1			1		1	1				
GATX 83464	105	300	212B	1	625	20	100	1		1			1	1			1	1				
GATX 83486	105	300	212B	1	625	20	100	1		1			1		1		1	1				
UTLX 83516	112	300	212B	1	781	20	70		1		1			1			1	1				

TABLE A-2

cont'd

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head				Other Head			
UTLX 83537	112	300	212B	1	782	23	70	1	1		1			1	1			
GATX 83562	105	100	212B	1	625	21	100	1	1	1	1				1			
GATX 83603	112	300	212B	1	812	30	100	1	1	1		1		1		1		1
GATX 83615	112	300	212B	1	812	30	100	1	1	1		1		1	1			
GATX 83626	112	300	212B	1	813	30	100	1	1	1	1				1			
UPCX 83631	112	300	212B	1		33	100	1	1	1	1			1	1			
UTLX 83634	112	280	5157	1	782	34	100	1	1	1	1			1	1			
GATX 83641	112	300	212B	1	812	30	100	1	1		1			1	1			
GATX 83642	112	300	212B	1	812	30	100	1	1	1	1			1		1		1
UTLX 83647	112	280	128B	1	687	34	100	1	1			1		1		1		1
UTLX 83678	112	280	5157	1	718	34	100	1	1		1							
UTLX 83681	112	280	212B	1	718	34	100	1	1		1			1	1			
UTLX 83721	112	280	212B	1	718	34	100	1	1	1		1		1	1			
GATX 83758	112	300	212B	1	812	30	100	1	1	1		1		1			1	1
GATX 83762	112	300	212B	1	812	30	100	1	1	1	1			1	1			
UTLX 83766	112	280	212B		687	31	100	1	1	1			1					
UTLX 83838	105	300	212B	1	625	24	100	1	1			1		1	1			
GATX 83841	112	300	212B	1	812	30	100	1	1	1	1			1	1			
UTLX 83850	105	300	212B	1	625	23	100	1	1		1			1	1			
UTLX 83852	105	100	212B	1	625	23	100	1	1		1			1	1			
UTLX 83863	105	300	2128	1	625	23	100	1	1			1		1	1			
UTLX 83876	105	300	212B	1	625	23	100	1	1			1		1	1			
UTLX 83889	105	300	212B	1	625	23	100	1	1	1	1			1	1			
GATX 83891	112	300	212B	1	742	32	100	1	1	1			1		1			
GATX 83895	112	300	212B	1	742	32	100	1	1	1	1							
GATX 83911	112	300	212B	1	774	32	100	1	1	1	1			1	1			
UTLX 83959	105	300	212B	1	625	21	100	1	1			1		1			1	1
GATX 83972	112	280	212B	1	664	33	100	1	1	1		1		1	1			
GATX 83972	112	280	212B	1	664	33	100	1	1	1	1			1	1			
GATX 83982	112	280	212B	1	664	33	100	1	1	1	1			1	1			
GATX 83990	112	280	212B	1	664	33	100	1	1	1	1			1	1			
UTLX 83991	105	100	212B	1	625	21	100	1	1	1		1		1	1			
GATX 84059	112	280	212B	1	664	33	100	1	1	1	1			1		1		1
GATX 84064	112	280	212B	1	664	33	100	1	1	1		1		1	1			
GATX 84148	112	300	212B	1	774	32	100	1	1		1			1	1			
GATX 84159	112	300	212B			32	100	1	1	1			1	1	1			
UTLX 84161	105	200	111A	1	702	10	50	1	1	1			1		1			
GATX 84314	112	280	212B	1	664	33	100	1	1		1			1	1			
GATX 84339	112	280	212B	1	664	33	100	1	1	1	1			1	1			
GATX 84358	112	280	212B	1	664	33	100	1	1	1	1			1	1			
GATX 84374	112	280	212B	1	664	33	100	1	1	1	1			1	1			
GATX 84398	112	280	212B	1	664	33	100	1	1	1	1			1	1			
GATX 84460	112	280	212B	1	664	33	100	1	1	1			1	1	1			
UTLX 84461	105	200	111A	1	871	10	50	1	1	1	1			1	1			
GATX 84481	112	280	212B	1	664	33	100	1	1	1		1		1		1		1
UTLX 84607	109	200	111A	1	702	10	50	1	1			1		1	1			
UTLX 84649	109	200	111A	1	702	10	50	1	1	1		1					1	
GATX 84661	105	200	111A	1	782	10	50	1	1	1	1			1	1			
UTLX 84703	109	200	111A	1	702	10	50	1	1		1			1	1			
GATX 84710	105	100	212B	1	625	20	100	1	1	1	1			1	1			
GATX 84711	105	100	212B	1		21	100	1	1		1				1			
GATX 84725	105	100	212B	1	625	20	100	1	1	1	1			1	1			
GATX 84728	105	100	212B	1	625	20	100	1	1	1		1		1	1			
UTLX 84811	206	60	111S	1	250	8	50	1	1			1			1			
SHPX 85020	105	300	212B	1	692	23	100	1	1	1		1			1			
UTLX 85023	111	100	2850	1	500	10	50	1	1		1				1			

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head			
UTLX 85037	111	100	285C	1	500	10	70	1			1			1			1		1		1
UTLX 85086	111	60	285C	1	437	10	70	1		1				1			1	1			
GATX 85087	111	100	212B	1	437	20	100		1		1		1	1			1	1			
UTLX 85096	111	100	285C	1	500	10	50	1			1	1			1		1		1		1
SHPX 85132	105	200	212B	1	599	25	100	1			1	1			1			1			
SHPX 85154	105	200	5157	1	599	25	100	1			1	1			1					1	
SHPX 85155	105	200	5157	1	599	25	100	1			1	1			1					1	
GATX 85191	103		285C	1	500	8	50		1	1			1	1			1	1			
ACFX 85195	105	200	5157	1	599	25	100	1			1	1		1					1		
ACFX 85197	105	200	5157	1	599	25	100	1			1	1		1				1			
GATX 85199	103		285C	1	500	8	50		1	1		1			1		1	1			
UTLX 85210	111	100	285C	1	500	10	50	1			1				1		1	1			
ACFX 85212	105	200	5157	1	599	25	100	1			1	1				1	1	1			
GATX 85262	111	100		1	437	20	100		1		1		1	1			1	1			
GATX 85281	111	100	212B	1	437	20	100		1		1		1	1			1	1			
UTLX 85296	111	100	285C	1	437	8	50	1			1				1		1	1			
UTLX 85329	111	100	285C	1	500	14	100	1			1				1			1			
UTLX 85373	111	100	285C	1	500	16	100	1			1				1			1			
UTLX 85392	111	100	285C	1	437	8	50	1			1	1		1			1		1		1
GATX 85417	103		285C	1	500	10	50		1			1			1		1	1			
GATX 85421	103		285C	1	500	10	50		1	1			1	1			1	1			
GATX 85422	103		285C	1	500	10	50		1	1			1		1		1	1			
UTLX 85434	111	100	285C	1	437	8	50	1			1			1							
UTLX 85435	111	100	285C	1	437	8	50	1			1			1			1	1			
UTLX 85443	111	100	285C	1	437	8	50	1			1		1	1			1		1		1
UTLX 85446	111	100	285C	1	437	8	50	1					1	1			1	1			
GATX 85456	111	100	212B	1	437	20	100		1		1		1	1			1	1			
UTLX 85473	111	100	285C	1	437	8	50	1							1		1	1			
UTLX 85500	104		285C	1	500	10	70	1		1					1		1	1			
ACFX 85537	105	200	5157	1	599	25	100	1			1	1		1					1		
UTLX 85569	111	100	285C	1	500	10	70	1			1			1				1			
GATX 85578	111	100	212B	1	437	20	100		1		1		1			1	1	1			
GATX 85585	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 85618	103		212B	1	437	8	50		1		1	1		1				1			
GATX 85644	103		212B	1	437	8	50		1		1		1		1		1	1			
GATX 85666	111	100	212B	1		17	100		1		1				1		1	1			
GATX 85674	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 85675	111	100	212B	1	437	20	100		1		1				1		1	1			
GATX 85675	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 85704	111	100	212B	1	437	20	100		1	1			1		1		1	1			
GATX 85714	111	100	212B	1	437	20	100		1	1		1		1			1	1			
UTLX 85722	111	60	285C	1	500	10	70	1			1		1	1			1	1			
GATX 85752	111	100	212B	1	437	20	100		1	1			1	1			1	1			
UTLX 85776	111	100	285C	1	500	17	100	1			1			1			1	1			
GATX 85785	111	100	212B	1	437	20	100		1	1			1	1			1		1		1
GATX 85814	111	100	212B	1	437	20	100		1	1		1			1		1	1			
GATX 85826	111	100	212B	1	437	20	100		1	1		1		1					1		
GATX 85874	111	100	212B	1	437	20	100		1	1			1	1			1		1		1
GATX 85903	103		285C	1	500	10	70	1		1		1			1		1	1			
UTLX 85930	111	60	5157	1	500	10	50	1			1				1		1	1			
GATX 85976	103		285C	1	500	10	70	1		1			1	1			1	1			
SHPX 86005	111	100	212B	1	437	29	100		1	1		1				1		1			
GATX 86010	103		285C	1	500	10	70	1		1			1	1			1	1			
SHPX 86023	111	200	212B	1	437	29	100		1		1			1				1			
SHPX 86035	111	100	212B	1	437	29	100		1		1				1						
UTLX 86067			111A	1		20	100	1		1			1	1					1		

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head			
UTLX 86083	111	60	111A	1	500	20	100		1	1		1		1			1		1		1
UTLX 86084	111	60	111A	1	500	20	100		1	1		1				1					
GATX 86097	103		285C	1	500	10	70	1		1			1	1			1	1			
GATX 86382	103		285C	1	500	10	70	1		1			1	1			1		1		1
GATX 86415	103		285C	1	500	10	70	1		1			1	1			1	1			
GATX 86467	111	100	212B	1	437	24	100		1		1				1		1	1			
GATX 86472	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 86474	111	100	212B	1	437	20	100		1		1		1			1	1	1			
UTLX 86497	103		111A	1	625	10	50	1		1			1	1			1	1			
GATX 86542	103		285C	1	500	10	70	1			1		1	1			1	1			
GATX 86751	111	100	285C	1	562	20	100		1		1			1			1	1			
GATX 87040	103		111A	1	687	10	50		1	1			1	1			1		1		1
UTLX 87041	105	100	111A	1	812	10	50	1		1				1							
GATX 87111	111	60	111A	1		20	100		1	1					1		1	1			
GATX 87227	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 87265	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 87267	111	100	212B	1	437	20	100		1		1		1	1			1	1			
GATX 87276	111	100	212B	1	437	20	100		1		1	1		1				1			
GATX 87286	111	100	212B	1	437	20	100		1		1			1			1	1			
GATX 87314	111	60	111A	1	687	20	100	1		1		1				1	1		1		1
UTLX 87316	105	200	111A	1	702	10	50	1		1			1	1			1	1			
GATX 87349	111	60	111A	1	687	20	100		1	1		1			1		1	1			
GATX 87408	111	100	212B	1	437	20	100		1	1			1			1	1		1		1
UTLX 87427	105	200	111A	1	957	10	50	1		1		1			1		1			1	1
GATX 87447	111	100	212B	1	437	20	100		1	1			1		1		1	1			
UTLX 87473	105	200	111A	1	957	10	50	1		1				1			1	1			
GATX 87539	103		111A	1	687	10	50	1		1		1				1		1			
GATX 87550	111	60	111A	1	500	20	100		1	1			1	1			1	1			
GATX 87556	111	60	111A	1	500	20	100		1	1		1		1			1		1		1
UTLX 87608	105	300	212B	1	875	11	70	1		1				1				1			
GATX 87663	103		285C	1	500	10	50	1		1			1	1			1	1			
UTLX 87672	105	500	212B	1	875	11	70	1		1			1		1			1			
UTLX 87690	105	500	212B	1	875	11	70	1			1		1	1							
GATX 87816	111	100	285C	1	562	20	100		1	1			1	1			1		1		1
GATX 87824	111	100	212B	1	437	20	100		1	1			1	1			1		1		1
GATX 87880	111	100	212B	1	437	20	100		1	1			1	1			1	1			
GATX 87906	111	100	212B	1	437	20	100		1	1		1			1		1	1			
GATX 87924	111	100		1	437	18	100		1		1		1	1			1	1			
GATX 87941	111	100	212B	1	437	20	100		1	1		1				1	1	1			
GATX 87950	111	100	212B	1	437	20	100		1	1			1		1		1	1			
GATX 87957	111	100	212B	1	437	20	100		1	1			1	1			1	1			
SHPX 88004	111	100	212B	1	437	19	100		1	1		1				1		1			
UTLX 88034	112	280	128B	1	687	34	100		1		1			1							
UTLX 88083	105	300	285C	1	687	11	50	1		1		1		1				1			
UTLX 88173	112	280	128B	1	687	34	100		1		1			1			1	1			
SHPX 88189	111	100	5157	1	437	29	100		1		1					1	1	1			
UTLX 88203	112	280	128B	1	687	34	100		1		1	1		1			1	1			
UTLX 88223	112	280	128B	1	687	34	100		1		1			1			1	1			
GATX 88259	103		212B	1	500	8	50		1	1			1		1		1	1			
GATX 88270	111	60	212B	1	437	8	50		1		1		1	1			1	1			
UTLX 88278	112	280	128B	1	687	34	100		1		1				1		1		1		1
UTLX 88294	112	280	128B	1	687	34	100		1		1				1		1			1	1
GATX 88294	103		212B	1	500	8	50		1		1		1			1	1	1			
UTLX 88300	112	280	128B		687	34	100		1		1	1				1					
UTLX 88439	112	280	128B	1	687	34	100		1		1		1		1		1		1		1
SHPX 88476	111	60	5157	1	437	16	100	1			1			1					1		

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head			
SHPX 88487	111	60	5157	1	437	16	100	1			1			1				1			
GATX 88599	105	300		1	640	11	50	1		1			1	1			1	1			
ACFX 88797	111	100	5157	1	437	16	100	1		1		1				1			1		
UTLX 88870	105	300	285C	1	687	11	50	1				1		1					1		
ACFX 88875	111	100	128B	1	468	29	100		1		1	1		1			1	1			
ACFX 88902	111	100	5157	1	437	21	100		1		1	1				1	1	1			
UTLX 89048	105	200	115	1	500	12	50	1		1		1				1	1				
GATX 89055	104		212B	1	500	8	40	1		1			1		1		1	1			
ACFX 89109	111	100	5157	1	437	16	100		1		1	1			1		1	1			
UTLX 89116	112	280	128B	1	688	34	100		1		1			1			1	1			
GATX 89223	104			1	500	8	40	1		1			1	1			1	1			
ACDX 89241	103			1								1		1				1			
GATX 89304	104			1	500	8	40	1		1		1		1					1		
GATX 89429	104		115		640	8	40	1		1			1	1			1	1			
UTLX 89447	105	300	128B	1	687	24	100	1			1				1		1	1			
UTLX 89449	105	300	128	1	562	23	100					1		1					1		
GATX 89912	112	280	128	1	653	34	100		1		1		1	1			1	1			
GATX 89920	112		128B		653	34	100		1		1	1				1					
GATX 89921	112	280	128	1	653	34	100		1		1	1		1			1		1		1
GATX 89925	112		128B		653	34	100		1		1		1			1					
GATX 89976	112	280	128	1	653	34	100		1		1		1	1			1	1			
GATX 89999	112	280	128B	1	653	34	100		1		1		1	1			1	1			
UTLX 90024	112	280	128B	1	687	34	100		1		1	1		1			1	1			
SHPX 90227	111	100	115	1	875	11	70	1		1		1			1					1	
SHPX 90344	111	100	115	1	937	11	50	1		1			1		1			1			
UTLX 90680	112	280	128B	1	687	34	100		1		1			1				1			
UTLX 90738	105	300	115	1	687	11	50	1		1		1		1			1	1			
UTLX 90889	112	280	128B	1	688	34	100		1		1			1			1	1			
UTLX 90943	105	300	285C	1	687	11	50	1		1				1			1	1			
GATX 91050	112	300	128B	1	768	33	100		1		1	1				1	1	1			
GATX 91109	112	300	128B	1	768	33	100		1		1	1		1			1	1			
GATX 91116	112	300	128B	1	768	33	100		1		1		1	1			1	1			
GATX 91122	112	300	128B	1	768	33	100		1		1		1	1			1	1			
GATX 91197	112	280	128B	1	653	34	100		1		1	1		1			1	1			
GATX 91264	112	280	128B	1	653	34	100		1		1	1		1			1	1			
GATX 91267	112	280	128B	1	653	34	100		1		1		1		1		1	1			
GATX 91285	112	280	128B	1	653	34	100		1		1	1		1							
ACDX 91316	105	300		1		11		1				1		1							
GATX 91371	111	60	5157	1	500	8	50	1			1		1	1			1	1			
GATX 91410	112	280	128B	1	653	34	100		1		1		1	1			1	1			
GATX 91413	112	280	128B	1	653	34	100		1		1		1		1		1	1			
GATX 91424	112	280	128B	1		34	100		1		1	1			1		1			1	1
GATX 91562	112	280	128B	1	653	34	100		1		1		1	1			1		1		1
GATX 91693	112	280	128B	1	625	34	100		1		1		1	1			1	1			
GATX 91743	111	100	5157	1	500	20	100		1		1	1				1	1	1			
GATX 91767	112	280	128B	1	625	34	100		1		1	1		1			1		1		
UTLX 91837	105	300	285C	1	687	11	50	1		1				1			1	1			
GATX 91935	111	60	5157	1	500	10	50		1		1	1			1		1		1		1
GATX 92192	111	100	5157	1		20	100		1		1				1		1	1			
GATX 92732	112	280	128B	1	687	34	100		1		1		1	1			1	1			
UTLX 92975	105	300	115	1	687	11	50	1		1		1		1				1			
GATX 93161	111	100	5157	1	500	13	100	1						1			1	1			
UTLX 93202	105	300	115	1	687	11	50	1		1				1			1	1			
GATX 93352	111	100	5157	1	500	20	100		1		1		1		1		1				
GATX 93366	111	100	5157	1	500	20	100		1		1			1			1		1		1
GATX 93389	112	280	128B	1	687	34	100		1		1			1			1	1			

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged	Head	Other	Head
GATX 93396	112	280	128B	1	687	34	100	1	1	1	1		1 1		
GATX 93451	112	280	128B	1		34	100	1	1		1		1 1		
GATX 93995	111	100	5157	1	500	23	100	1			1		1 1		
UTLX 94339	105	300	115	1	687	11	50	1	1	1	1		1 1		
UTLX 94369	105	300	115	1	687	11	50	1	1		1		1		
GATX 94403	112	280	128B	1	687	34	100	1	1	1	1		1 1		
GATX 94411	112		128B		687	34	100	1	1	1		1			
GATX 94425	112	280	128B	1	687	34	100	1	1	1	1		1 1		
GATX 94461	112	280	128B	1	687	34	100	1	1		1		1 1		
UTLX 94647	105	300	115	1	687	11	50	1	1		1		1		
GATX 94650	112		128B		653	38	150	1	1	1		1			
GATX 94674	112		128B		653	38	150	1	1	1		1			
GATX 94686	112		128B		653	38	150	1	1			1			
GATX 94698	112	280	128B	1	653	38	150	1	1		1		1 1		
GATX 94701	112	280	128B	1	653	38	150	1	1		1		1	1	1
GATX 94814	114	255	212B	1		12	50	1			1		1 1		
UTLX 94977	105	300	115	1	687	11	50	1	1		1		1		
GATX 94999	111	60	212B	1	437	17	100	1	1	1	1		1 1		
GATX 95085	111	60		1	687	10	70	1	1	1	1		1 1		
GATX 95414	111	100		1		10	50	1			1		1 1		
GATX 95456	111	60	285C	1	719	10	50	1	1	1	1			1	
UTLX 95557	105	300	115	1	687	11	50	1	1		1		1 1		
GATX 96367	112	280	212B	1	664	33	100	1	1		1		1 1		
GATX 96419	112	280	212B	1	664	33	100	1	1	1	1		1	1	1
UTLX 96432	105	300	115	1	687	11	50	1	1	1	1		1		
GATX 96453	112		212B		664	33	100	1	1	1		1			
UTLX 96502	105	300	115	1	687	11	50	1	1		1		1 1		
GATX 96525	112	280	128	1	653	34	100	1	1		1		1 1		
GATX 96534	112		128B		653	34	100	1	1	1		1			
GATX 96545	112	280	128	1	653	34	100	1	1	1	1		1		
GATX 96781	112	280	128	1	653	34	100	1	1		1		1 1		
GATX 96803	111	100	212B	1	437	20	100	1	1	1	1		1 1		
GATX 96842	111	100	5157	1		20	100	1			1		1 1		
GATX 96857	112	280	212B	1	703	33	100	1	1	1	1		1 1		
GATX 96872	112	280	212B	1	703	33	100	1	1	1	1		1 1		
GATX 96909	112	280	212B	1	703	33	100	1	1		1		1 1		
GATX 96930	112	280	212B	1	703	33	100	1	1		1		1 1		
GATX 96945	112	280	212B	1	703	33	100	1	1	1	1		1 1		
GATX 96965	112	280	128	1	653	34	100	1	1	1	1		1		
GATX 97026	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97041	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97076	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97162	112	280	128B	1	687	34	100	1	1	1	1		1 1		
UTLX 97255	105	300	115	1	687	11	50	1	1		1		1		
GATX 97296	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97316	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97326	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97382	112	280	128	1		34	100	1	1		1		1 1		
GATX 97417	112		128B		653	34	100	1	1	1		1			
GATX 97423	112		128B		653	34	100	1	1	1		1			
GATX 97455	112	280	128	1	653	34	100	1	1	1	1		1	1	1
GATX 97465	112	280	128	1	653	34	100	1	1	1	1		1 1		
GATX 97476	112		128B		653	34	100	1	1	1		1			
UTLX 97497	111	100	115	1	697	11	50	1	1	1	1		1 1		
GATX 97493	112	280	128	1	653	34	100	1	1	1	1		1 1		
UTLX 97548	105	300	115	1	687	11	50	1	1			1			

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged	Head	Other	Head
SHPX 88487	111	60	5157	1	437	16	100	1	1		1			1	
GATX 88599	105	300		1	640	11	50	1	1	1	1		1	1	
ACFX 88797	111	100	5157	1	437	16	100	1	1	1		1		1	
UTLX 88870	105	300	285C	1	687	11	50	1		1	1			1	
ACFX 88875	111	100	128B	1	468	29	100	1	1	1	1		1	1	
ACFX 88902	111	100	5157	1	437	21	100	1	1	1		1	1	1	
UTLX 89048	105	200	115	1	500	12	50	1	1	1		1	1		
GATX 89055	104		212B	1	500	8	40	1	1	1		1	1	1	
ACFX 89109	111	100	5157	1	437	16	100	1	1	1		1	1	1	
UTLX 89116	112	280	128B	1	688	34	100	1	1		1		1	1	
GATX 89223	104			1	500	8	40	1	1	1	1		1	1	
ACDX 89241	103			1						1	1			1	
GATX 89304	104			1	500	8	40	1	1	1	1			1	
GATX 89429	104		115		640	8	40	1	1	1	1		1	1	
UTLX 89447	105	300	128B	1	687	24	100	1	1			1	1	1	
UTLX 89449	105	300	128	1	562	23	100			1	1			1	
GATX 89912	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 89920	112		128B		653	34	100	1	1	1		1			
GATX 89921	112	280	128	1	653	34	100	1	1	1	1		1	1	1
GATX 89925	112		128B		653	34	100	1	1	1		1			
GATX 89976	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 89999	112	280	128B	1	653	34	100	1	1	1	1		1	1	
UTLX 90024	112	280	128B	1	687	34	100	1	1	1	1		1	1	
SHPX 90227	111	100	115	1	875	11	70	1	1	1		1		1	
SHPX 90344	111	100	115	1	937	11	50	1	1	1		1		1	
UTLX 90680	112	280	128B	1	687	34	100	1	1		1			1	
UTLX 90738	105	300	115	1	687	11	50	1	1	1	1		1	1	
UTLX 90889	112	280	128B	1	688	34	100	1	1		1		1	1	
UTLX 90943	105	300	285C	1	687	11	50	1	1		1		1	1	
GATX 91050	112	300	128B	1	768	33	100	1	1	1		1	1	1	
GATX 91109	112	300	128B	1	768	33	100	1	1	1	1		1	1	
GATX 91116	112	300	128B	1	768	33	100	1	1	1	1		1	1	
GATX 91122	112	300	128B	1	768	33	100	1	1	1	1		1	1	
GATX 91197	112	280	128B	1	653	34	100	1	1	1	1		1	1	
GATX 91264	112	280	128B	1	653	34	100	1	1	1	1		1	1	
GATX 91267	112	280	128B	1	653	34	100	1	1	1		1	1	1	
GATX 91285	112	280	128B	1	653	34	100	1	1	1	1				
ACDX 91316	105	300		1		11		1		1	1				
GATX 91371	111	60	5157	1	500	8	50	1	1	1	1		1	1	
GATX 91410	112	280	128B	1	653	34	100	1	1	1	1		1	1	
GATX 91413	112	280	128B	1	653	34	100	1	1	1		1	1	1	
GATX 91424	112	280	128B	1		34	100	1	1	1		1	1	1	1
GATX 91562	112	280	128B	1	653	34	100	1	1	1	1		1	1	1
GATX 91693	112	280	128B	1	625	34	100	1	1	1	1		1	1	
GATX 91743	111	100	5157	1	500	20	100	1	1	1		1	1	1	
GATX 91767	112	280	128B	1	625	34	100	1	1	1	1		1	1	
UTLX 91837	105	300	285C	1	687	11	50	1	1		1		1	1	
GATX 91935	111	60	5157	1	500	10	50	1	1	1		1	1	1	1
GATX 92192	111	100	5157	1		20	100	1	1			1	1	1	
GATX 92732	112	280	128B	1	687	34	100	1	1	1	1		1	1	
UTLX 92975	105	300	115	1	687	11	50	1	1	1	1			1	
GATX 93161	111	100	5157	1	500	13	100	1			1		1	1	
UTLX 93202	105	300	115	1	687	11	50	1	1		1		1	1	
GATX 93352	111	100	5157	1	500	20	100	1	1	1		1	1		
GATX 93366	111	100	5157	1	500	20	100	1	1		1		1	1	1
GATX 93389	112	280	128B	1	687	34	100	1	1		1		1	1	

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency			Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head			
GATX 93396	112	280	128B			1	687	34	100		1		1	1		1			1	1			
GATX 93451	112	280	128B			1		34	100		1		1			1			1	1			
GATX 93995	111	100	5157		1		500	23	100	1						1			1	1			
UTLX 94339	105	300	115		1		687	11	50	1		1		1		1			1	1			
UTLX 94369	105	300	115	1			687	11	50	1		1				1				1			
GATX 94403	112	280	128B			1	687	34	100		1		1	1		1			1	1			
GATX 94411	112		128B				687	34	100		1		1	1				1					
GATX 94425	112	280	128B			1	687	34	100		1		1	1		1			1	1			
GATX 94461	112	280	128B			1	687	34	100		1		1			1			1	1			
UTLX 94647	105	300	115		1		687	11	50	1		1				1				1			
GATX 94650	112		128B				653	38	150		1		1		1			1					
GATX 94674	112		128B				653	38	150		1		1		1			1					
GATX 94686	112		128B				653	38	150		1		1					1					
GATX 94698	112	280	128B			1	653	38	150		1		1			1			1	1			
GATX 94701	112	280	128B			1	653	38	150		1		1				1		1		1		1
GATX 94814	114	255	212B		1			12	50		1					1			1	1			
UTLX 94977	105	300	115		1		687	11	50	1		1				1				1			
GATX 94999	111	60	212B		1		437	17	100	1			1		1		1		1	1			
GATX 95085	111	60			1		687	10	70	1		1			1		1		1	1			
GATX 95414	111	100			1			10	50	1						1			1	1			
GATX 95456	111	60	285C		1		719	10	50	1		1		1		1					1		
UTLX 95557	105	300	115		1		687	11	50	1		1				1			1	1			
GATX 96367	112	280	212B		1		664	33	100		1		1			1			1	1			
GATX 96419	112	280	212B		1		664	33	100		1		1	1			1		1			1	1
UTLX 96432	105	300	115		1		687	11	50	1		1		1			1			1			
GATX 96453	112		212B				664	33	100		1		1	1				1					
UTLX 96502	105	300	115		1		687	11	50	1		1				1			1	1			
GATX 96525	112	280	128		1		653	34	100		1		1			1			1	1			
GATX 96534	112		128B				653	34	100		1		1	1				1					
GATX 96545	112	280	128			1	653	34	100		1		1	1			1			1			
GATX 96781	112	280	128		1		653	34	100		1		1			1			1	1			
GATX 96803	111	100	212B		1		437	20	100	1			1		1	1			1	1			
GATX 96842	111	100	5157		1			20	100	1						1			1	1			
GATX 96857	112	280	212B		1		703	33	100		1		1	1		1			1	1			
GATX 96872	112	280	212B		1		703	33	100		1		1	1		1			1	1			
GATX 96909	112	280	212B		1		703	33	100		1		1			1			1	1			
GATX 96930	112	280	212B		1		703	33	100		1		1				1		1	1			
GATX 96945	112	280	212B		1		703	33	100		1		1		1	1			1	1			
GATX 96965	112	280	128		1		653	34	100		1		1		1	1				1			
GATX 97026	112	280	128		1		653	34	100		1		1	1			1		1	1			
GATX 97041	112	280	128		1		653	34	100		1		1	1			1		1	1			
GATX 97076	112	280	128			1	653	34	100		1		1	1		1			1	1			
GATX 97162	112	280	128B			1	687	34	100		1		1	1		1			1	1			
UTLX 97255	105	300	115		1		687	11	50	1		1				1				1			
GATX 97296	112	280	128			1	653	34	100		1		1		1	1			1	1			
GATX 97316	112	280	128			1	653	34	100		1		1		1		1		1	1			
GATX 97326	112	280	128			1	653	34	100		1		1	1		1			1	1			
GATX 97382	112	280	128		1			34	100		1		1			1			1	1			
GATX 97417	112		128B				653	34	100		1		1	1				1					
GATX 97423	112		128B				653	34	100		1		1	1				1					
GATX 97455	112	280	128			1	653	34	100		1		1		1	1			1		1		1
GATX 97465	112	280	128			1	653	34	100		1		1	1		1			1	1			
GATX 97476	112		128B				653	34	100		1		1	1				1					
UTLX 97487	111	100	115		1		687	11	50	1		1			1		1		1	1			
GATX 97493	112	280	128			1	653	34	100		1		1		1		1		1	1			
UTLX 97548	105	300	115		1		687	11	50	1		1						1					

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged	Head	Other	Head
SHPX 88487	111	60	5157	1	437	16	100	1	1		1			1	
GATX 88599	105	300		1	640	11	50	1	1	1	1		1	1	
ACFX 88797	111	100	5157	1	437	16	100	1	1	1		1		1	
UTLX 88870	105	300	285C	1	687	11	50	1		1	1			1	
ACFX 88875	111	100	128B	1	468	29	100	1	1	1	1		1	1	
ACFX 88902	111	100	5157	1	437	21	100	1	1	1		1	1	1	
UTLX 89048	105	200	115	1	500	12	50	1	1	1		1	1		
GATX 89055	104		212B	1	500	8	40	1	1	1		1	1	1	
ACFX 89109	111	100	5157	1	437	16	100	1	1	1		1	1	1	
UTLX 89116	112	280	128B	1	688	34	100	1	1		1		1	1	
GATX 89223	104			1	500	8	40	1	1	1	1		1	1	
ACDX 89241	103			1						1	1			1	
GATX 89304	104			1	500	8	40	1	1	1	1			1	
GATX 89429	104		115		640	8	40	1	1	1	1		1	1	
UTLX 89447	105	300	128B	1	687	24	100	1	1			1	1	1	
UTLX 89449	105	300	128	1	562	23	100			1	1			1	
GATX 89912	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 89920	112		128B		653	34	100	1	1	1		1			
GATX 89921	112	280	128	1	653	34	100	1	1	1	1		1	1	1
GATX 89925	112		128B		653	34	100	1	1	1		1			
GATX 89976	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 89999	112	280	128B	1	653	34	100	1	1	1	1		1	1	
UTLX 90024	112	280	128B	1	687	34	100	1	1	1	1		1	1	
SHPX 90227	111	100	115	1	875	11	70	1	1	1		1		1	
SHPX 90344	111	100	115	1	937	11	50	1	1	1		1		1	
UTLX 90680	112	280	128B	1	687	34	100	1	1		1			1	
UTLX 90738	105	300	115	1	687	11	50	1	1	1	1		1	1	
UTLX 90889	112	280	128B	1	688	34	100	1	1		1		1	1	
UTLX 90943	105	300	285C	1	687	11	50	1	1		1		1	1	
GATX 91050	112	300	128B	1	768	33	100	1	1	1		1	1	1	
GATX 91109	112	300	128B	1	768	33	100	1	1	1	1		1	1	
GATX 91116	112	300	128B	1	768	33	100	1	1	1	1		1	1	
GATX 91122	112	300	128B	1	768	33	100	1	1	1	1		1	1	
GATX 91197	112	280	128B	1	653	34	100	1	1	1	1		1	1	
GATX 91264	112	280	128B	1	653	34	100	1	1	1	1		1	1	
GATX 91267	112	280	128B	1	653	34	100	1	1	1		1	1	1	
GATX 91285	112	280	128B	1	653	34	100	1	1	1	1				
ACDX 91316	105	300		1		11		1		1	1				
GATX 91371	111	60	5157	1	500	8	50	1	1	1	1		1	1	
GATX 91410	112	280	128B	1	653	34	100	1	1	1	1		1	1	
GATX 91413	112	280	128B	1	653	34	100	1	1	1		1	1	1	
GATX 91424	112	280	128B	1		34	100	1	1	1		1	1	1	1
GATX 91562	112	280	128B	1	653	34	100	1	1	1	1		1	1	1
GATX 91693	112	280	128B	1	625	34	100	1	1	1	1		1	1	
GATX 91743	111	100	5157	1	500	20	100	1	1	1		1	1	1	
GATX 91767	112	280	128B	1	625	34	100	1	1	1	1		1	1	
UTLX 91837	105	300	285C	1	687	11	50	1	1		1		1	1	
GATX 91935	111	60	5157	1	500	10	50	1	1	1		1	1	1	1
GATX 92192	111	100	5157	1		20	100	1	1			1	1	1	
GATX 92732	112	280	128B	1	687	34	100	1	1	1	1		1	1	
UTLX 92975	105	300	115	1	687	11	50	1	1	1	1			1	
GATX 93161	111	100	5157	1	500	13	100	1			1		1	1	
UTLX 93202	105	300	115	1	687	11	50	1	1		1		1	1	
GATX 93352	111	100	5157	1	500	20	100	1	1	1		1	1		
GATX 93366	111	100	5157	1	500	20	100	1	1		1		1	1	1
GATX 93389	112	280	128B	1	687	34	100	1	1		1		1	1	

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst	Damaged	Head	Other	Head
GATX 93396	112	280	128B	1	687	34	100	1	1	1	1		1	1	
GATX 93451	112	280	128B	1		34	100	1	1		1		1	1	
GATX 93995	111	100	5157	1	500	23	100	1			1		1	1	
UTLX 94339	105	300	115	1	687	11	50	1	1	1	1		1	1	
UTLX 94369	105	300	115	1	687	11	50	1	1		1			1	
GATX 94403	112	280	128B	1	687	34	100	1	1	1	1		1	1	
GATX 94411	112		128B		687	34	100	1	1	1		1			
GATX 94425	112	280	128B	1	687	34	100	1	1	1	1		1	1	
GATX 94461	112	280	128B	1	687	34	100	1	1		1		1	1	
UTLX 94647	105	300	115	1	687	11	50	1	1		1			1	
GATX 94650	112		128B		653	38	150	1	1	1		1			
GATX 94674	112		128B		653	38	150	1	1	1		1			
GATX 94686	112		128B		653	38	150	1	1			1			
GATX 94698	112	280	128B	1	653	38	150	1	1		1		1	1	
GATX 94701	112	280	128B	1	653	38	150	1	1			1	1	1	1
GATX 94814	114	255	212B	1		12	50	1			1		1	1	
UTLX 94977	105	300	115	1	687	11	50	1	1		1			1	
GATX 94999	111	60	212B	1	437	17	100	1	1	1		1	1	1	
GATX 95085	111	60		1	687	10	70	1	1	1		1	1	1	
GATX 95414	111	100		1		10	50	1			1		1	1	
GATX 95456	111	60	285C	1	719	10	50	1	1	1	1			1	
UTLX 95557	105	300	115	1	687	11	50	1	1		1		1	1	
GATX 96367	112	280	212B	1	664	33	100	1	1		1		1	1	
GATX 96419	112	280	212B	1	664	33	100	1	1	1		1	1	1	1
UTLX 96432	105	300	115	1	687	11	50	1	1	1		1		1	
GATX 96453	112		212B		664	33	100	1	1	1		1			
UTLX 96502	105	300	115	1	687	11	50	1	1		1		1	1	
GATX 96525	112	280	128	1	653	34	100	1	1		1		1	1	
GATX 96534	112		128B		653	34	100	1	1	1		1			
GATX 96545	112	280	128	1	653	34	100	1	1	1		1		1	
GATX 96781	112	280	128	1	653	34	100	1	1		1		1	1	
GATX 96803	111	100	212B	1	437	20	100	1	1	1	1		1	1	
GATX 96842	111	100	5157	1		20	100	1			1		1	1	
GATX 96857	112	280	212B	1	703	33	100	1	1	1	1		1	1	
GATX 96872	112	280	212B	1	703	33	100	1	1	1	1		1	1	
GATX 96909	112	280	212B	1	703	33	100	1	1		1		1	1	
GATX 96930	112	280	212B	1	703	33	100	1	1			1	1	1	
GATX 96945	112	280	212B	1	703	33	100	1	1	1	1		1	1	
GATX 96965	112	280	128	1	653	34	100	1	1	1	1			1	
GATX 97026	112	280	128	1	653	34	100	1	1	1		1	1	1	
GATX 97041	112	280	128	1	653	34	100	1	1	1		1	1	1	
GATX 97076	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 97162	112	280	128B	1	687	34	100	1	1	1	1		1	1	
UTLX 97255	105	300	115	1	687	11	50	1	1		1			1	
GATX 97296	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 97316	112	280	128	1	653	34	100	1	1	1		1	1	1	
GATX 97326	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 97382	112	280	128	1		34	100	1	1		1		1	1	
GATX 97417	112		128B		653	34	100	1	1	1		1			
GATX 97423	112		128B		653	34	100	1	1	1		1			
GATX 97455	112	280	128	1	653	34	100	1	1	1	1		1	1	1
GATX 97465	112	280	128	1	653	34	100	1	1	1	1		1	1	
GATX 97476	112		128B		653	34	100	1	1	1		1			
UTLX 97487	111	100	115	1	687	11	50	1	1	1		1	1	1	
GATX 97493	112	280	128	1	653	34	100	1	1	1		1	1	1	
UTLX 97548	105	300	115	1	687	11	50	1	1			1			

TABLE A-2

cont'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency		Thickness	Gallons	Truck Capacity	Insulation		Underframe		Loaded		Worst Damaged Head				Other Head			
GATX 97663	111	100	5157	1		500	20	100		1		1		1	1			1	1			
GATX 97685	111	100	5157	1		500	20	100		1		1	1		1			1	1			
GATX 97724	111	100	5157	1		500	20	100		1		1		1	1			1	1			
GATX 97748	111	100	5157	1		500	20	100		1		1		1	1			1	1			
GATX 97855	112	280	128B		1	653	34	100		1		1		1		1		1			1	1
GATX 97871	112	280	128B	1			34	100		1		1			1			1	1			
GATX 97873	112	280	128B		1	653	34	100		1		1		1		1		1		1		1
GATX 97878	112	280	128B		1	653	34	100		1		1		1	1			1	1			
GATX 97887	112	280	128B	1		653	33	100		1		1		1		1		1	1			
GATX 97889	111	100	5157	1			20	100							1			1	1			
GATX 97904	111	100	5157	1		500	20	100		1		1		1		1		1	1			
GATX 97907	111	100	5157	1		500	20	100		1		1		1	1			1	1			
UTLX 97946	105	300	115	1		687	11	50	1		1				1				1			
GATX 98091	111	100	5157	1		500	22	100		1				1	1					1		
GATX 98095	111	100	5157	1		500	22	100		1		1		1	1			1	1			
GATX 98146	111	100	5157	1		500	22	100		1			1				1		1			
GATX 98257	111	100	5157	1		500	15	100		1		1		1		1		1	1			
GATX 98276	111	100	5157	1		500	15	100		1		1		1		1			1			
GATX 98296	111	100	5157	1		500	20	100		1		1	1		1			1	1			
UTLX 98314	112	280	128B	1		687	34	100		1		1		1	1							
GATX 98335	111	100	5157	1			13	100		1		1					1	1	1			
GATX 98603	111	100	5157	1		500	20	100		1		1	1			1		1	1			
RTCX 98621	103		111A	1			8	50	1		1		1		1					1		
GATX 98637	111	100	5157	1		500	20	100	1			1		1	1			1	1			
UTLX 98670	105	300	115	1		687	11	50	1		1		1			1			1			
GATX 98780	111	100	5157	1		500	20	100		1		1	1				1		1			
GATX 98896	111	100	5157	1		500	20	100		1		1		1	1			1	1			
GATX 98938	111	100	5157	1		500	20	100		1		1		1	1			1	1			
GATX 98940	111	100	5157	1		500	20	100		1		1	1			1		1			1	1
UTLX 98958	105	300	115	1		687	11	50	1		1		1			1		1	1			
UTLX 99026	112	280	5157	1		718	34	100		1		1				1			1			
UTLX 99042	112	280	5157	1		719	34	100		1		1			1			1	1			
UTLX 99056	112	280	212B	1		718	34	100		1		1			1			1	1			
UTLX 99066	112	280	128B	1		718	34	100		1		1				1		1	1			
GATX 99091	111	100	212B	1		437	20	100		1	1			1	1			1	1			
GATX 99127	111	100	212B	1		437	20	100		1	1			1		1		1	1			
UTLX 99159	112	280	128B	1		625	31	125		1		1					1	1	1			
UTLX 99176	112	280	128B			625	31	125		1		1	1				1					
GATX 99180	111	100	212B	1		437	20	100		1	1			1	1			1	1			
GATX 99221	111	100	212B	1		437	20	100	1			1		1	1			1	1			
UTLX 99252	112	280	128B	1		718	34	100		1		1	1			1		1		1		1
UTLX 99274	112	280	212B	1		718	34	100		1		1			1							
GATX 99290	111	60	212B	1		437	20	100	1			1	1			1		1	1			
UTLX 99300	112	280	212B			719	33	100		1		1	1				1					
GATX 99312	111	100	212B	1		437	12	100	1			1		1		1		1	1			
GATX 99321	111	100	212B	1		437	13	100	1								1	1	1			
UTLX 99325	112	280	212B			719	34	100		1		1	1				1					
UTLX 99373	112	280	212B	1		718	34	100		1		1			1			1	1			
GATX 99381	111	100	212B	1		437	12	100	1			1		1	1			1	1			
UTLX 99398	112	300	212B	1		782	30	100		1		1			1			1	1			
UTLX 99420	112	280	285B	1		718	34	100		1		1	1			1			1			
UTLX 99446	112	280	212B	1		718	34	100		1		1		1	1			1	1			
GATX 99463	111	60	212B	1		687	20	100							1			1	1			
UTLX 99466	112	280	212B	1		718	34	100		1		1		1		1		1	1			
UTLX 99489	112	280	128B				34	100		1		1					1					
GATX 99500	111	100	212B	1		437	20	100		1		1		1	1			1	1			

TABLE A-2 - concl'd.

Car Number	DOT Class	Pressure	Material	Joint Efficiency	Thickness	Gallons	Truck Capacity	Insulation	Underframe	Loaded	Worst Damaged Head	Other Head
GATX 99513	111	100	212B	1	437	20	100	1	1	1	1 1	1
GATX 99619	111	100	212B	1	437	20	100	1	1	1	1	1
GATX 99620	111	100	212B	1	437	20	100	1	1		1 1	1
GATX 99626	111	100	212B	1	437	20	100	1	1		1	1
GATX 99664	111	100	212B	1	437	20	100	1	1	1	1 1	1 1
GATX 99688	111	100	212B	1	437	20	100	1	1	1	1 1	1 1
GATX 99703	111	100	212B	1	437	20	100	1	1	1	1 1	1
GATX 99741	111	100	212B	1	437	20	100	1	1	1	1 1	1
GATX 99743	111	100	212B	1	437	20	100	1	1	1	1	1
GATX 99767	111	60	5157	1	500	20	100	1	1	1	1 1	1
GATX 99845										1	1	1
GATX 99852	111	100	5157	1	500	29	100	1	1	1	1 1	1
GATX 99864	111	100	5157	1	500	29	100	1	1	1	1 1	1
GATX 99946	111	60		1	437	8	50	1	1	1	1 1	1
UTLX 99997	105	300	115	1	687	11	50	1	1		1	1
HPLX102039	111	100		1		10	50	1	1	1	1	1
HPLX102056	111	100		1		10	50		1	1	1	1
HPLX102064	111	100		1		10	50		1	1	1	1
HPLX102069	111	100		1		10	50	1	1	1	1	1
TLDX114006	111	100	5157	1	437	15	100	1	1	1	1 1	1
TLDX114054	111	100	5157	1		15	100	1	1		1	1
TLDX211003	111	100									1 1	1
GCX310209	103		285C	1	500	10	70	1		1	1 1	1
HPLX355106	111	100		1		23	100			1	1	
GCX417021	105	300	128B			17	100	1		1	1 1	1
GCX 741610	112	255	128B			42	140	1	1	1	1 1	1
GCX741645	112					42	150	1	1		1	1
ACSX932003	112	300	212B	1	774	32	100	1	1	1	1	
ACSX932175	112	280	212B	1		33	100	1	1	1	1	
ACSX933024	112	280	212B	1		33	100	1	1	1	1	

TABLE A-3

LOSS CAUSED BY HEAD PUNCTURES - LOADED RIVETED CARS
(CLASS ARA II, ARA III, ICC 103, ICC 104)

Date & Place	Car #	Lading Loss this Car (Note 1)	Other Loss Due to Lading Loss This Car	Comments
4/2/65 Stewarton, Pa.	CCBX 2271	1,000	0	
7/13/65 El Dorado, Ark.	WRNX 13657	1,000	5,000	Lading fire (gasoline) damaged subject car and four adjacent cars.
10/23/65 Brit. Col., Can.	CGTX 1160	1,000	29,000	Fire spread thru wreck.
10/23/65 Brit. Col., Can.	UTLX 75620	1,000	0	
1/18/66 Okesa, Okla.	UTLX 71469	1,000	67,500	Fire spread to 6 other cars.
1/18/66 Okesa, Okla.	NATX 5923	1,000	0	
1/18/66 Okesa, Okla.	UTLX 4720	1,000	0	
8/15/66 Owassa, Ala.	UTLX 50372	5,000	0	
12/29/67 Holiday, Kan.	GATX 1205	2,300	0	
3/27/69 Buffalo, N.Y.	GATX 60343	1,000	0	

TABLE A-3 - cont'd.

Date & Place	Car #	Lading Loss this Car (Note 1)	Other Loss Due to Lading Loss This Car	Comments
5/16/69 Lardeau, B. C.	CGTX 1761	1,500	0	
7/6/69 Manitoba	CGTX 2278	1,200	0	
8/19/69 Amarillo, Tex.	GATX 56786	1,600	0	
2/18/70 La Rose, Ill.	UTLX 29730	1,000	1,000	
6/19/70 Britt., Ont.	UTLX 51336	0	0	Also shell & fittings leaks.
7/27/70 Mumford, Tex.	GATX 65384	0	0	Shell also leaking from seams.
TOTAL	16 cars	$20,600	$102,500	TOTAL LOSS = $123,100

TABLE A-4

LOSS CAUSED BY HEAD PUNCTURES - LOADED INSULATED WELDED STEEL NON-PRESSURE CARS

(CLASS DOT 103W, 104W, 111A-, AAR 203W, ETC.)

Date & Place	Car #	Lading Loss	Other Loss	Comments
11/27/65 N. Maine Jct., Maine	UTLX 69668	600	0	2/3 load sulfur lost -- rest solid or recoverable.
2/10/66 E. St. Louis, Ill.	GATX 73468	3,100	0	
2/1/67 Pelahatchie, Miss.	SHPX 15482	0	0	Also shell puncture
7/18/67 Rotave, Sask.	CGTX 13294	1,000	250,000	Spilled sulfur started major fire.
12/22/67 Wetumka, Okla.	SRDX 25512	6,000	0	
2/27/68 Brit. Col., Can.	UTLX 60502	0	0	Sulfur -- solid in car and recoverable.
"	UTLX 60509	100	0	Sulfur -- almost solid in car and recoverable.
"	UTLX 60510	900	0	3/4 load sulfur lost.
"	UTLX 60516	100	0	Sulfur -- almost solid in car and recoverable.
"	UTLX 60519	100	0	Sulfur -- almost solid in car and recoverable.
9/2/68 Hodge, Mo.	MCPX 23025	81,000	4,000	Fire caused additional damage to car.
3/2/69 Lake Grennell, N.J.	ACFX 88797	5,000	0	
TOTALS	12 cars	$97,900	$254,000	TOTAL LOSS = $351,900

TABLE A - 5

LOSS CAUSED BY HEAD PUNCTURES - LOADED NON-INSULATED WELDED STEEL NON-PRESSURE CARS

(CLASS DOT 103W, 104W, 111A-, AAR 203W, ETC.)

Date & Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
1/10/65 Poplarville, Miss.	CELX 2025	4,000	0	
2/8/65 Livingston, Ala.	CELX 2019	5,400	0	
2/28/65 Central Mills, Ala.	SHPX 81310	5,000	0	
3/27/65 Clifton Forge, Va.	SHPX 14197	1,500	0	
4/17/65 Perdido, Ala.	DUPX 21023	0	0	Also shell punctured.
10/31/65 Elkton, Md.	SHPX 88004	9,500	$100,000	See Note 2.
"	SHPX 12471	9,500		See Note 2.
11/9/65 Ideville, Ind.	PSPX 153	2,000	0	
11/10/65 Tecumseh, Kan.	GATX 38066	1,000	0	
11/25/65 Chicago, Il.	GATX 24797	100	0	Slight leak.
1/5/66 West Lake, La.	GATX 71087	1,800	0	
1/7/66 Bainbridge, N.Y.	UTLX 50191	4,400	0	Fire, but due to naptha car with shell puncture.
7/8/66 Brocket, Alberta	UTLX 14926	6,000	0	

TABLE A-5 - cont'd.

Date & Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
1/31/67 Philadelphia, Pa.	UTLX 17830	7,500	0	
3/19/67 Albany, N. Y.	UTLX 55093	3,000	0	
4/11/67 Connemaugh, Pa.	SHPX 82490	5,000	0	
4/27/67 Coosa Pine, La.	SHPX 81633	2,000	0	
9/30/67 Long Beach, Miss.	GATX 87941	17,000	0	
10/9/67 Bridgeport, Tenn.	UTLX 13472	0	0	Also shell puncture.
1/1/68 Dunreith, Ind.	RTCX 26706	0	0	Also shell puncture.
1/8/68 Blacksburg, S. C.	GATX 38310	2,000	0	
2/14/68 Lamison, Ala.	GATX 72732	1,600	0	
2/27/68 Dola, W. Va.	SACX 3516	4,000	3,000	Fire from this car damaged car itself.
4/23/68 Walker Siding, Maine	UTLX 49145	1,000	0	
5/4/68 Northridge, Ca.	STAX 17029	2,100	0	
5/4/68 Northridge, Ca.	UTLX 59315	7,500	0	
5/11/68 Nacogdoches, Tex.	NATX 21740	15,370	0	

TABLE A-5 - cont'd.

Date & Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
5/20/68 McHenry, Ky.	DUPX 20109	19,600	0	
7/8/68 Ontario	CGTX 29207	2,000	0	
9/1/68 Lake Bronson, Minn.	SOEX 2732	3,000	0	
9/6/68 Madison, Ill.	UTLX 47408	6,400	0	
12/10/68 Leslie, Md.	SHPX 81876	1,160	0	Partial loss of lading.
12/15/68 E. St. Louis, Ill.	UTLX 59557	11,000	0	
1/13/69 Battelle, Ala.	SHPX 81223	12,000	0	Did not create chain reaction. Rocketing of tank cars caused by fire due to shell puncture of LPG car.
5/26/69 E. St. Louis, Ill.	MKT 310	7,000	0	
6/2/69 Selma, Ala.	SHPX 86005	0	0	Bottom outlet also broken open.
7/6/69 Manitoba	CGTX 29409	2,000	16,000	Fire.
7/ 6 /69 Manitoba	UTLX 49720	2,000	0	
7/15/69 Medina, Wisc.	GATX 99513	19,500	0	
7/17/69 Fackler, Ala.	GATX 98146	21,000	0	Other loss attributable totally to four other cars which lost lading from shell and fittings damage. Major fire. Total wreck - $535,000.

TABLE A-5 - cont'd.

Date & Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
9/17/69 Shelby, Ohio	GATX 39549	11,000	0	
10/28/69 Charleston, Il.	NATX 21615	25,000	0	
12/30/69 St. Louis, Mo.	GATX 10065	100	0	Slight leak.
1/1/70 Palestine, Tex.	NATX 21098	66,000	200,000	Fire spread through wreck.
2/4/70 Corpus Christi, Texas	GATX 91743	12,000	300,000	Fire spread through wreck.
2/4/70 Sarah, Miss.	RTCX 26701	31,000	0	
2/4/70 Harpi, Va.	UTLX 13874	1,700	0	
2/18/70 La Rose, Il.	NATX 25377	2,000	3,000	Fire from this car damaged car itself.
3/8/70 Mumford, Tex.	HPLX 355106	5,000	0	
4/9/70 New Athens, Il.	TLDX 114006	6,000	0	
4/26/70 Morrisville, N.J.	NATX 21359	25,000	0	
4/28/70 Union Furnace, Pa.	GATX 98780	0	0	Shell also punctured.
5/30/70 Selmer, Tenn.	DUPX 29624	15,000	0	

TABLE A-5 - concl'd.

Date & Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
6/18/70 Redwood, Miss.	ACFX 88902	17,000	0	
7/27/70 Mumford, Tex.	HPLX 102069	0	0	Shell also punctured.
8/6/70 Boligee, Ala.	UTLX 48768	8,000	0	
10/27/70 Ft. St.John, B.C.	UTLX 226	2,000	0	One end of 2 compartment car.
TOTALS	57 cars *	$451,730	$622,000	Total Loss = $1,073,730

* Where details of insulation were not known, cars were assumed to be non-insulated. Several cars were included in this group although their DOT class is now known; the class of these cars was inferred from the lading.

TABLE A-6
LOSS CAUSED BY HEAD PUNCTURES - LOADED INSULATED STEEL PRESSURE CARS
(Class DOT 105A)

Date and Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
10/13/65 Elkton, Md.	SFTX 713	700		See Note 2.
10/31/65 Elkton, Md.	SFTX 746	700		See Note 2.
6/16/66 Crawfordsville, Ga.	UTLX 89048	5200	0	Major fire, but several other cars had shell punctures. This car was last of 32 derailed.
9/1/66 Winters Siding, Ill.	CONX 8202	10,000	0	
11/23/67 Ceders, Miss.	EBAX 6383	5,000	0	
4/4/68 Stillwell, Okla.	EORX 1749	1,600	0	
9/11/69 Black Bayou Jct. (Glendora), Miss.	ACFX 85212	9,000	140,000	Fire from this car caused one other car to rocket and destroyed several other cars.
10/18/69 Troup, Tex.	GATX 12803	11,000	60,000	Fire from this car caused rupture of ethylene oxide car.
3/3/70 Danbury, Tex.	GATX 34995	12,000	0	
TOTALS	9 cars	$55,200	$200,000	TOTAL LOSS = $255,200

TABLE A-7
LOSS CAUSED BY HEAD PUNCTURES - LOADED NON-INSULATED STEEL PRESSURE CARS
(CLASS DOT 112A-W, 114A-W)

Date and Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
1/13/65 Wautubee Hills, Miss.	NATX 31025	2,000	0	
8/28/66 Verona, Ky.	PSPX 33620	2,000	100,000	See Note 3.
1/15/67 Ardmore, Ga.	ACSX 932175	2,500	0	
3/16/67 Ontario, Can.	UTLX 99325	1,500	0	
9/30/67 Hurtsboro, Ala.	ACSX 933024	2,000	150,000	Fire spread through wreck.
11/18/67 Waterford, Ala.	GATX 89920	4,500	0	
1/1/68 Dunreith, Ind.	GATX 30751	10,000	1,000,000	Caused rupture of ethylene oxide car which damaged town.
1/25/68 Pemberton, B.C.	UTLX 83241	2,000	108,000	Fire caused rupture of two other LPG cars, damage of other equipment.
4/21/68 Kelley, Iowa	GATX 96534	4,500	1,000	270 people evacuated, 2 people slightly injured by ammonia fumes.
10/18/68 Houston, Tex.	DUPX 28002	60,000	2,000	50 people evacuated. 28000 gal. HF lost.
11/12/68 Dalby, Mo.	MCPX 39043	4,500	0	

TABLE A-7 - cont'd.

Date and Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
11/18/68 Mt. Vernon, Ill.	UTLX 99176	11,000	0	
12/27/68 Needles, Calif.	UTLX 99300	2,000	0	
1/5/69 Geary, Okla.	GATX 97476	2,000	100,000	Fire caused two other LP cars to rocket and damag other cars.
1/6/69 Squilox, B. C.	NATX 32028	2,000	0	
1/13/69 Springville, Ala.	RTCX 36801	2,000	700,000	See Note 4.
1/25/69 Laurel, Miss.	ACSX 932003	2,000	800,000	See Note 5.
1/25/69 Laurel, Miss.	GALX 557	2,000		
2/18/69 Crete, Nebr.	GATX 18120			See Note 6.
3/4/69 Pringle, Tex.	GATX 97417	2,000	50,000	Fire caused two other LP cars to rocket. Damage limited to these cars.
3/4/69 Pringle, Tex.	GATX 97423	2,000		
3/17/69 Powder Springs, Ga.	UTLX 83293	2,000	0	
4/25/69 Germantown, Ind.	GATX 84159	8,000	170,000	Fire spread through wreck.

TABLE A-7 - cont'd.

Date and Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
5/7/69 Alhambra, Ill.	GATX 91050	2,000	150,000	See Note 7.
5/28/69 Stockton, Calif.	PSPX 33624	2,000	0	
7/3/69 Preston Hollow, La.	SACX 9036	13,000	0	
7/17/69 Fackler, Ala.	UTLX 80518	4,500	5,000	$5000 estimate of damage to fish when 33,000 gal. ammonia spilled into river.
7/26/69 Florence, Kan.	GATX 96453	2,000	0	
11/19/69 Lehigh, Kan.	GATX 14358	2,000	85,000	Fire from head puncture caused 4 LPG cars to rocket.
11/26/69 Rockwell, Tex.	GATX 94411	4,500	0	
12/8/69 Celeron, N. Y.	CNTX 1213	2,000	0	
1/1/70 Palestine, Tex.	GATX 83891	3,000	0	
1/21/70 Dickinson, W. Va.	UTLX 88300	4,500	10,000	Very rough estimate. 27 people slightly injured by ammonia fumes, horses killed.
1/21/70 Forest River, N. D.	NATX 33903	2,000	0	

TABLE A-7 - concl'd.

Date and Place	Car #	Lading Loss (Note 1)	Other Loss	Comments
1/21/70 Forest River, N. D.	UTLX 83766	2,000	0	
4/7/70 New Athens, Ill.	UTLX 38046	0	0	Also shell puncture in this car.
6/19/70 Britt, Ont.	UTLX 81193	2,000	38,000	Fire spread to other cars
6/21/70 Crescent City, Ill.	NATX 32015	2,000	0	
7/30/70 Corbin, La.	GATX 84460	2,000	80,000	Fire spread and destroye 5 loaded cars.
8/27/70 S. Byron, N. Y.	PPGX 9948	11,000	31,000	See Note 8.
10/25/70 Farmers, Ky.	ACFX 17093	2,000	8,000	Fire spread to several nearby sheds.
12/22/70 Newberry, Calif.	UTLX 38661	2,000	0	
TOTALS	42 Cars	$197,000	$3,588,000	TOTAL LOSS = $3, 785,000

TABLE A-8

LOSS CAUSED BY HEAD PUNCTURES- LOADED MISCELLANEOUS CARS

(Aluminum, Stainless Steel, Cryogenic, etc. but Excluding Helium cars, Tank in Box Cars, etc.)

Date & Place	Car #	Class	Lading Loss (Note 1)	Other Loss	Comments
1/13/65 Wautubee Hills, Miss.	GATX 87539	103 ALW	9,500	0	
6/17/67 Hume, Ohio	GATX 87314	111A60ALW	7400	0	
1/21/68 Chambersburg, Pa.	KCPX 2502	103 (?) ins. (?)	250	0	Partial loss of lading
1/21/69 Nobel, La.	UTLX 84161	105A200 AL-W	2,000	0	
7/23/69 Schiller Park, Ill.	UTLX 86084	111A60 AL-W	25,000	0	
TOTAL	5 cars		$44,150	0	Total Loss = $44,150
TOTAL ALL CARS (Tables A-3 thru A-8)	141		$866,580	$4,766,500	

Grand Total = $5,633,080

NOTES TO TABLES A-3 THROUGH A-8

NOTE 1: Lading loss in most cases based on car gallonage x current published bulk cost/gallon; otherwise simply estimated, see p. A-2.

NOTE 2: Elkton, Md. Four cars suffered head punctures, but almost all the fire damage was due to fire spreading from the two punctured carbon disulfide cars, SHPX 88004 and 12471.

NOTE 3: Verona, Ky. Fire from lost lading caused rupture of one other LPG car which injured 7 people and caused other property damage. The loss value of $100,000 is simply a rough estimate based on our general knowledge of this accident.

NOTE 4: Springville, Ala. The total reported accident loss was $808,000. Fire due to the head puncture of RTCX 36801 caused 3 other cars to rocket resulting in damage to the town. Cost of this accident would conservatively have been $100,000 had there been no fire. The difference is therefore attributed to the head puncture.

NOTE 5: Laurel, Miss. Our estimate and analysis is as follows: The head of ACSX 932003 was punctured by the coupler of GALX 557. The impact also damaged the head of GALX 557. The loss of LPG from ACSX 932003 resulted in a fire which caused the pressure to build up in GALX 557. The damaged head of GALX 557 then failed, and the car then rocketed into a nearby factory causing damage to one sheet metal wall. The resulting fire also caused ACSX 932178 to vent at the safety valve resulting in the loss of lading from this car.

Further back from these three cars was a general pile-up of 12 other LPG cars. POTX 109 suffered a shell puncture in the derailment which resulted in the other 11 cars being engulfed in intense flames. These eleven cars all ruptured and rocketed, resulting in two deaths, many injuries and extensive damage to the town.

The head puncture of ACSX 932003 resulted directly in the rocketing of one car, loss of three car loads of propane, and damage to the factory. This is estimated at $100,000. Thus, the head puncture is the cause of the lading loss of three of the 15 cars which lost lading in the accident. Rather than assign only the $100,000 cost to the head puncture, in this case we have taken the more conservative approach of assigning a portion of the total cost of the accident to the head puncture, prorated in proportion to the cars which lost lading due to the head puncture. Based on our estimate that the total cost of the accident was $4,000,000, the cost attributable to the head puncture is 3/15 x 4,000,000 = 800,000. The total cost is not yet available from any official source and may exceed the $4,000,000 cited.

NOTE 6: Crete, Nebraska While standing on a siding, GATX 18120 was hit on the edge of the head by a derailing freight car traveling about 50 mph. Careful examination of the fracture patterns indicated that the head was punctured and that the force of the collision was sufficient to initiate a second failure in the shell. Both propagated in a brittle manner resulting in the fragmentation and rocketing of this car with resulting lading loss and the subsequent deaths of eight people.

Head shields of the types considered in this study probably would not have prevented the head puncture, and head shields of any design might not have prevented the shell failure. Therefore, since this study is concerned only with the effect of the addition of a head shield, it is difficult to assign a portion of the cost of this accident to the head puncture. Only if other design ohanges were to be considered to prevent the failure of the shell, the presence of a head shield in addition to these changes would be revelant to assignment of the costs of this accident. The final estimate of damages due to the head puncture is therefore left open to question, and this accident should be considered only if the final economic decision of head shields is marginal.

NOTE 7: Alhambra, Ill. GATX 91050 suffered a head puncture, and two other LPG cars had their shells punctured. The resulting fire caused two other cars to lose lading. The cost assigned to the head puncture was arbitrarily estimated to be 1/5 of the total accident cost of $750,000.

NOTE 8: South Byron, N.Y. Loss of lading from head puncture of PPGX 9948 caused a fire resulting in the rupture and total loss of one other car. Fire damage was confined to these two cars. No deaths or injuries resulted from the fire.

TABLE A-9

NUMBER OF CARS OF EACH MAJOR TYPE - ESTIMATE OF AVERAGE NUMBER IN SERVICE 1965-1970

Construction	Material	Type-Class	AAR Approvals[1] 1928-1964	AAR Approvals[1] 1965-1969	AAR Approvals[1] Total	Dec. 1970[2] Total UMLER	Estimated Average 1965-1970
Riveted	Steel	II, III 103, 104, 201, 203	28,796	0	28,796	52,517	52,500
Welded Non-Pressure	Steel	103W, 104W 111A, 201W, 203W	50,934	30,370	81,304	95,459[3]	Insulated 21,000 [4] Non-Ins. 49,000[4]
Pressure - Insulated	Steel	105A, 109A 111A100W,4 205A, 120A	38,931	4,219	43,150	33,736[3]	39,000
Pressure - Non-Insulated	Steel	112A, 114A	5,720	11,903	17,623	19,764	12,000 [5]
Other	Alum., Stainless, Nickel, etc.	206W, 113A, etc.	5,914	1,576	7,490	9,097	6,500
			130,295	48,068	178,363	210,573	180,000

Notes: [1] AAR approvals do not reflect cars built prior to 1928, conversions, scrapped cars, also, the published summary of approvals appears 6 to 18 months after cars go into service.

[2] UMLER (AAR Universal Machine Language Equipment Register) includes many cars that have been retired from service.

[3] A considerable number of 105A cars have been converted to Class 111A.

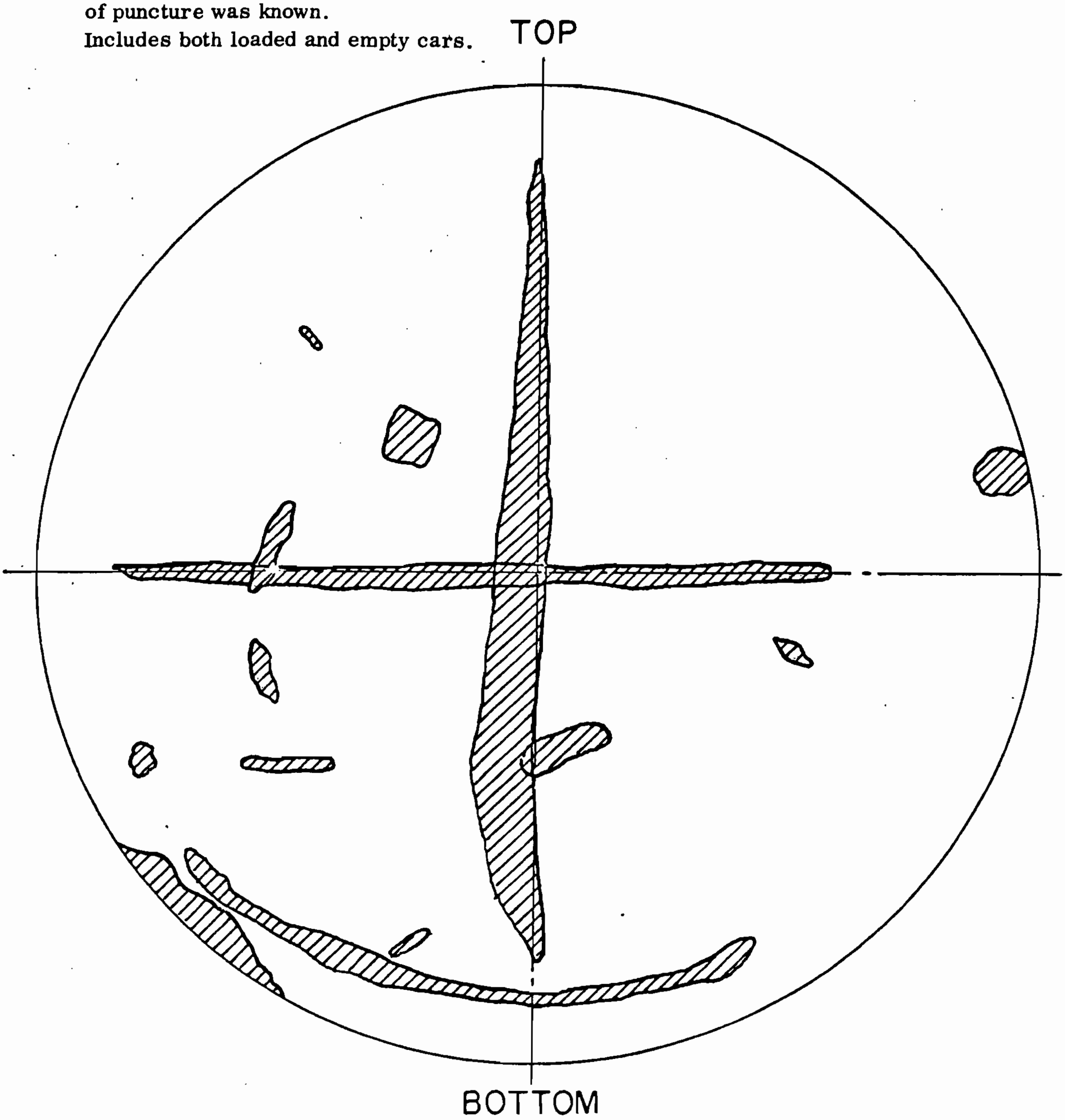
[4] Assuming 30% of all non-pressure welded cars are insulated.

[5] Estimated on basis 5720 + 11,903/2 = 11,671, rounded to 12,000.

FIGURE A-1

Head Punctures: Riveted Cars (ARA 111, 1CC 103)
(All have flanged and dished heads and full underframes)

Includes all cars where location
of puncture was known.
Includes both loaded and empty cars.

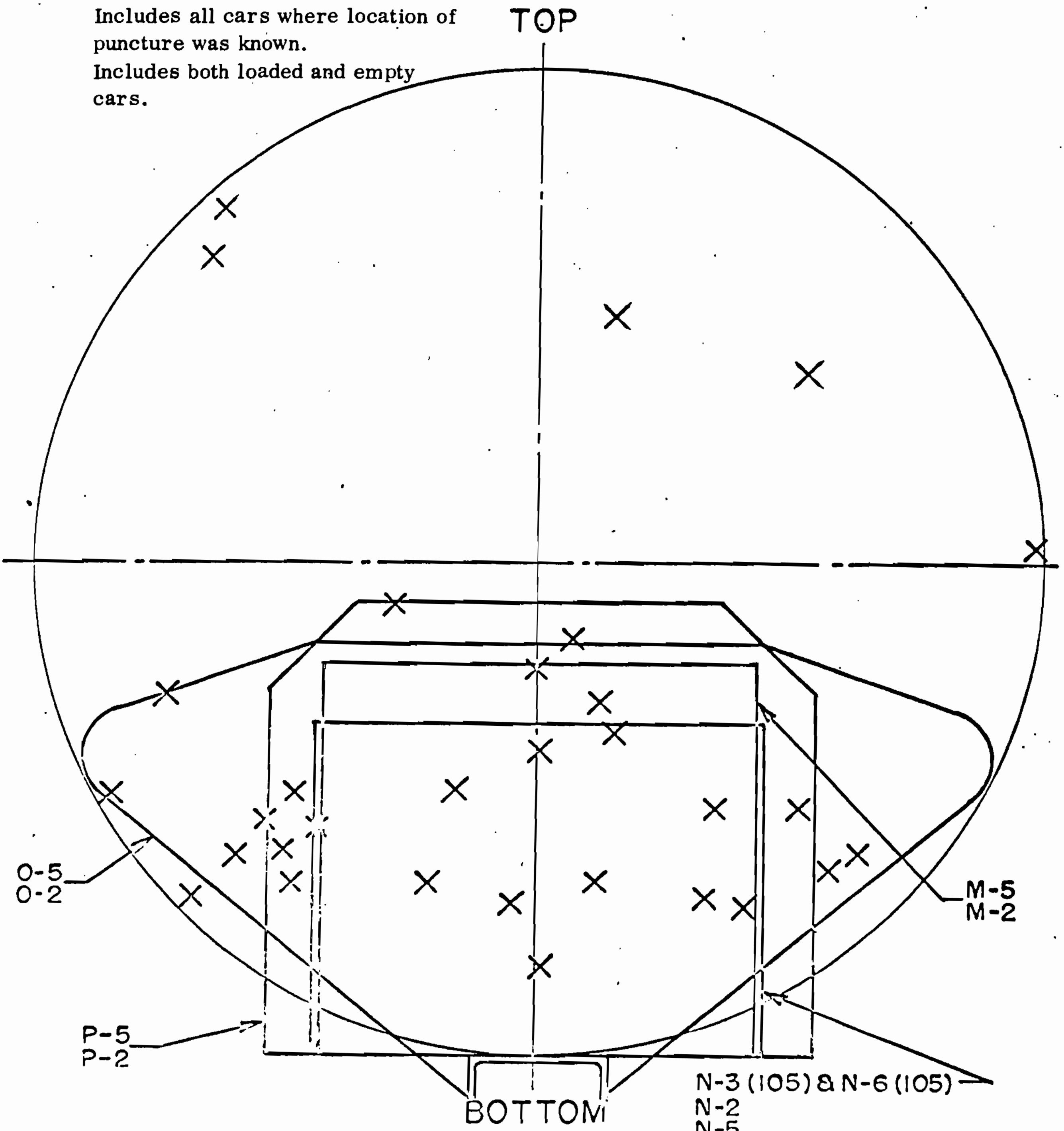


Note: Each shaded area describes a separate head puncture.

FIGURE A-2

Head Punctures: Non Pressure Cars (DOT 103W, 111A-) with Full Underframe. (X marks center of puncture)

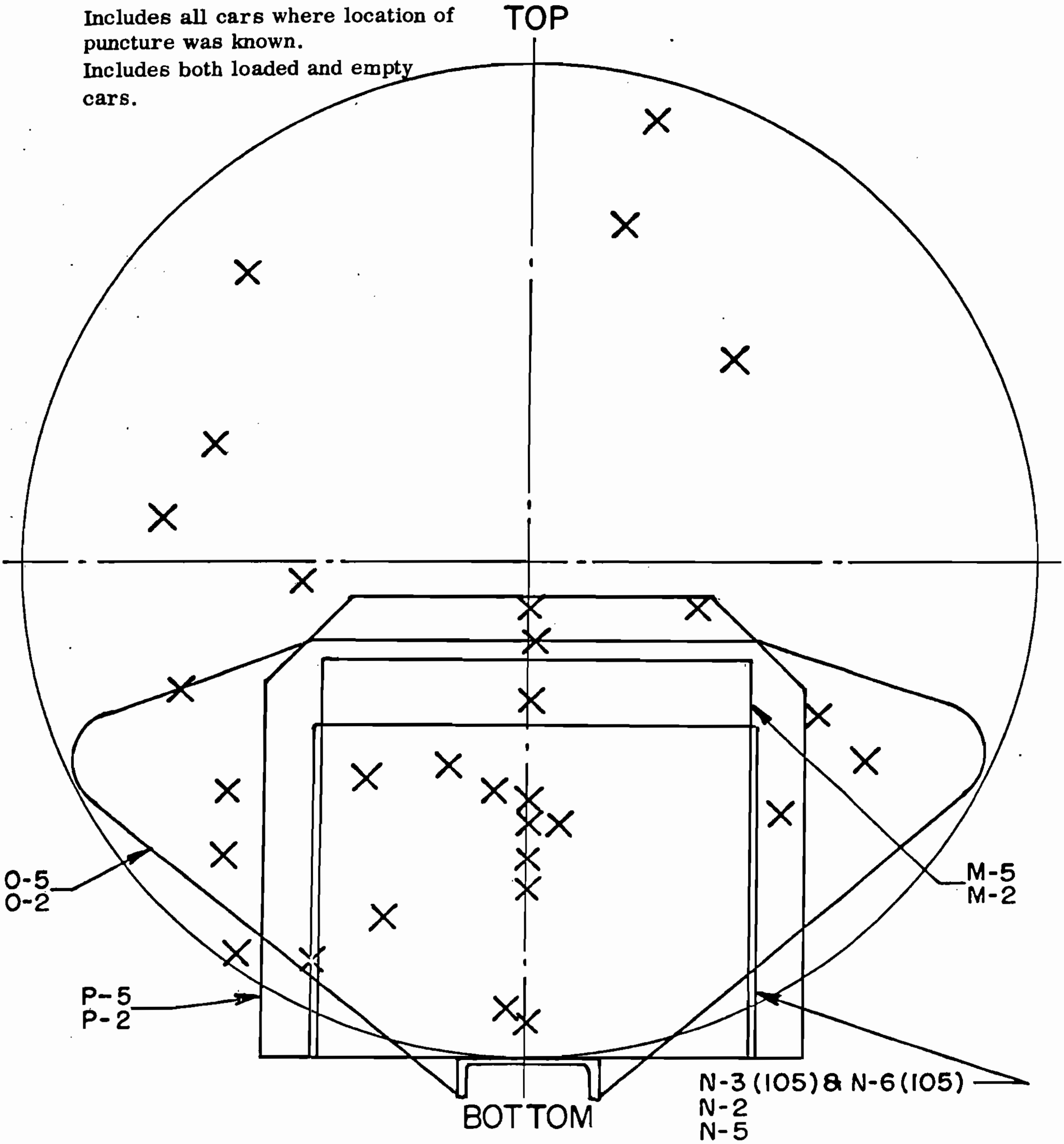
Includes all cars where location of puncture was known.
Includes both loaded and empty cars.



Note: Code numbers and outlines refer to head shield schemes evaluated in Appendix D.

FIGURE A-3

Head Punctures: Non Pressure Cars (ICC 103W, 111A-) with Stub Sills
(X marks center of puncture)



Note: Code numbers and outlines refer to head shield schemes evaluated in Appendix D.

FIGURE A-4

Head Punctures: Pressure Cars (DOT 105A-) with Full Underframe. (X marks center of puncture.)

Includes all cars where location of puncture was known.
Includes both loaded and empty cars.

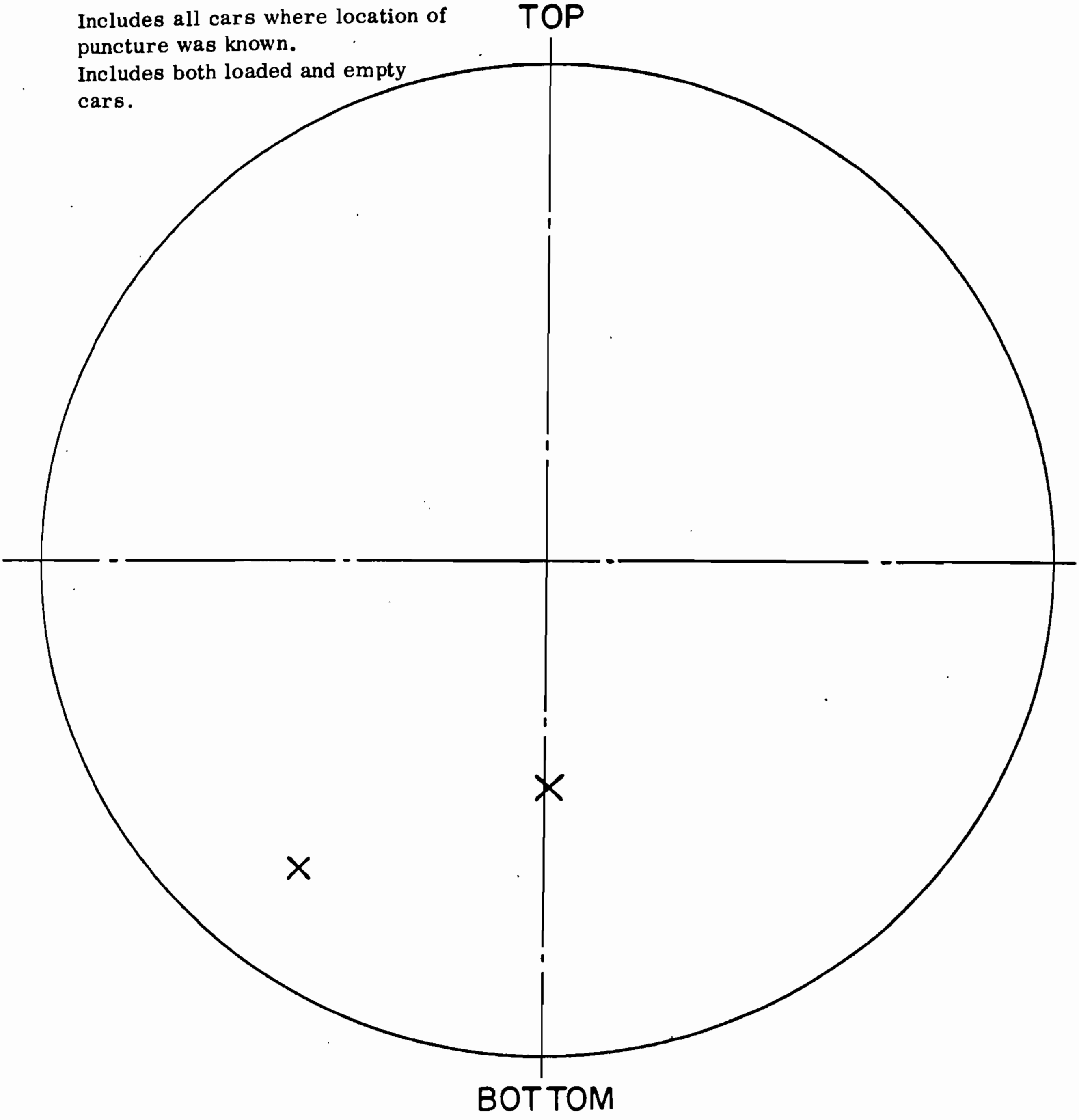
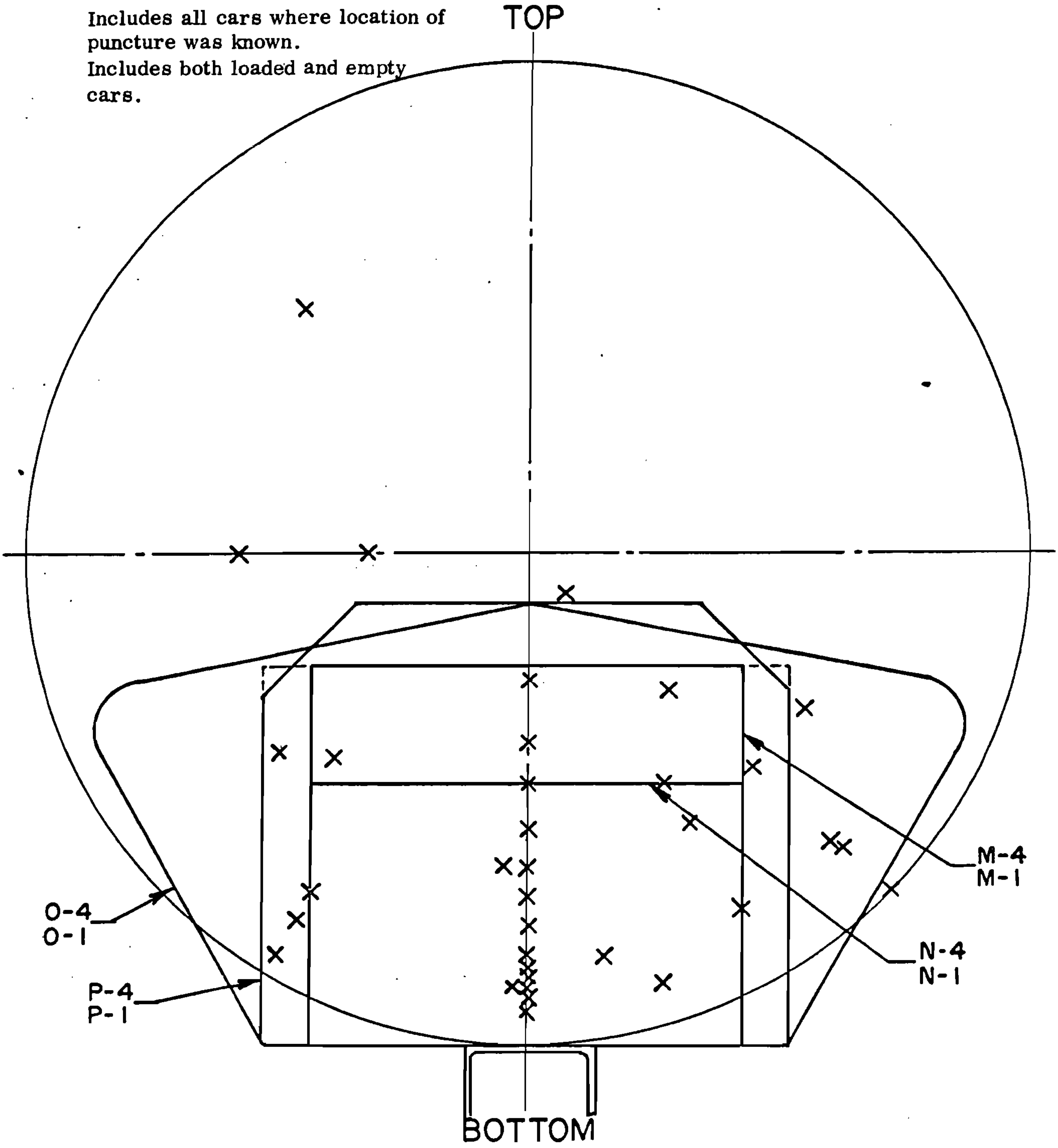


FIGURE A-5

Head Punctures: Pressure Cars (DOT 112A340W, 114A340W) Generally With Stub Sills. (X marks location of puncture.)

Includes all cars where location of puncture was known. Includes both loaded and empty cars.



Note: Code numbers and outlines refer to head shield schemes evaluated in Appendix D.

FIGURE A-6

Head Punctures: Pressure Cars (DOT 112A400W, 114A400W)
With Stub Sills

Includes all cars where location of puncture was known. Includes both loaded and empty cars.

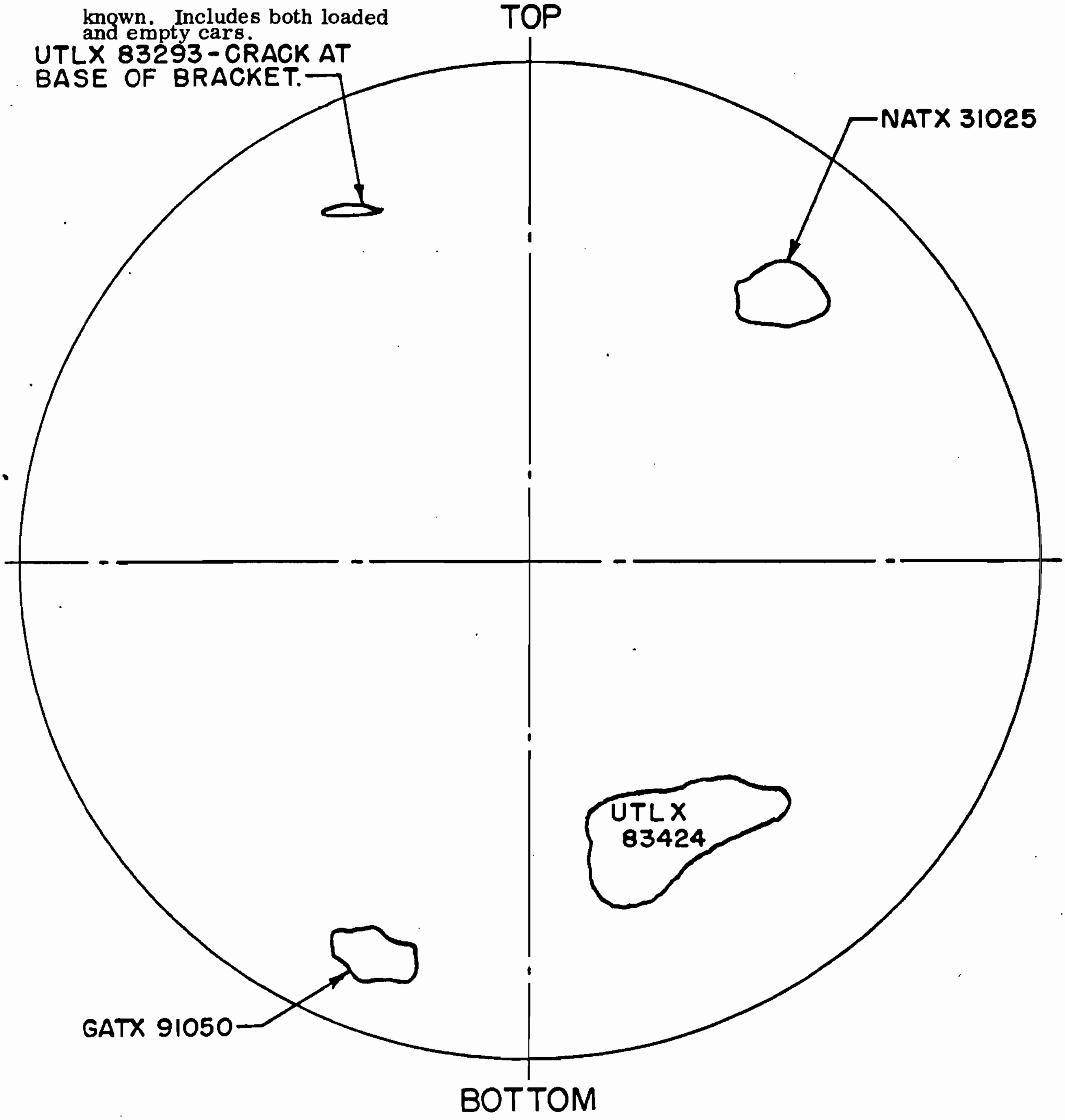
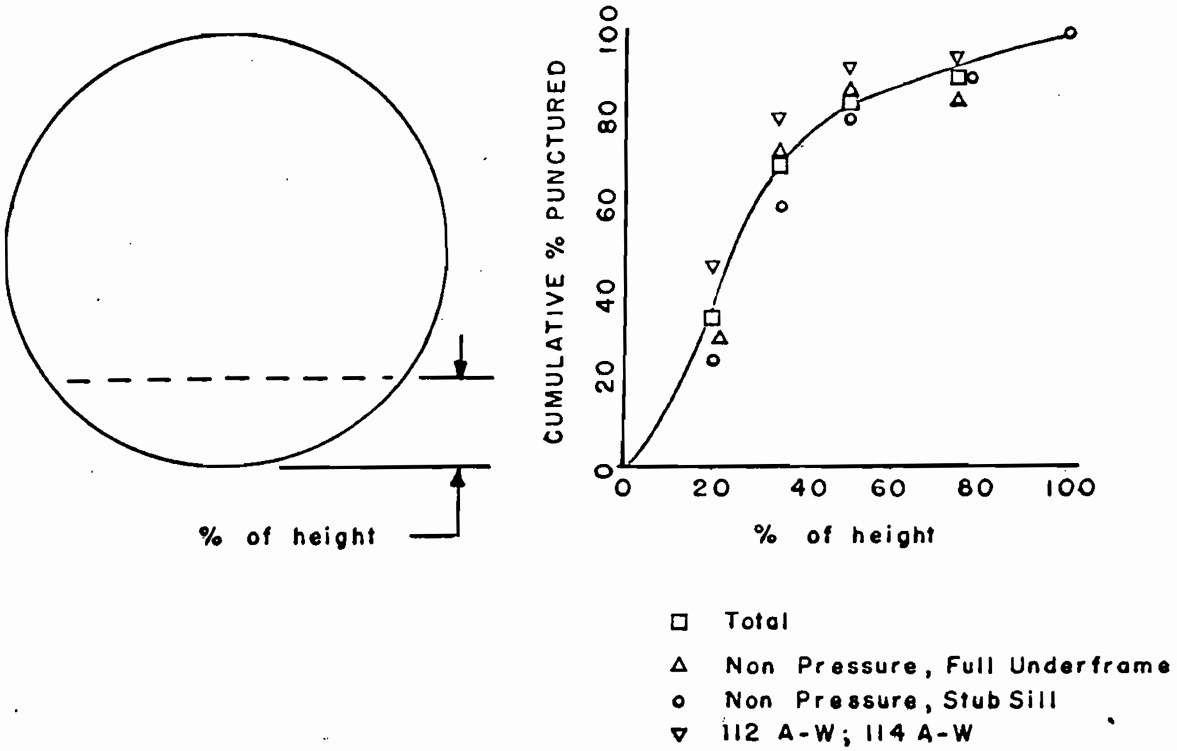


FIGURE A-7

DISTRIBUTION OF PUNCTURES BY HEIGHT ON HEAD

(Summary of Fig. A-1 thru Fig. A-6 data)



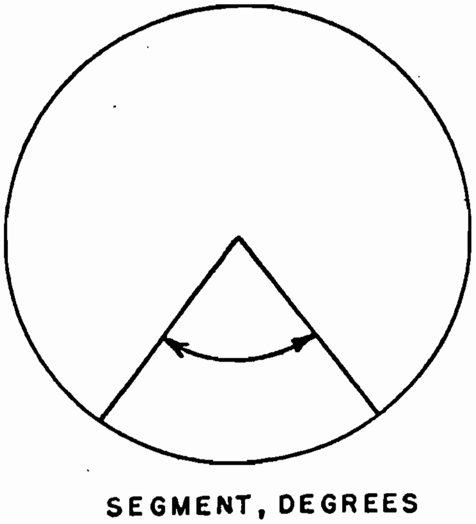
Height	Riveted*	Non Pressure Full Underframe	Non Pressure Stub Sill	105A-W	112A-W 114A-W	TOTAL
20%	2	11	8	1	18	40
35%	5	22	18	2	31	78
50%	7	26	24	2	36	95
75%	11	27	27	2	36	103
100%	11	31	30	2	39	113

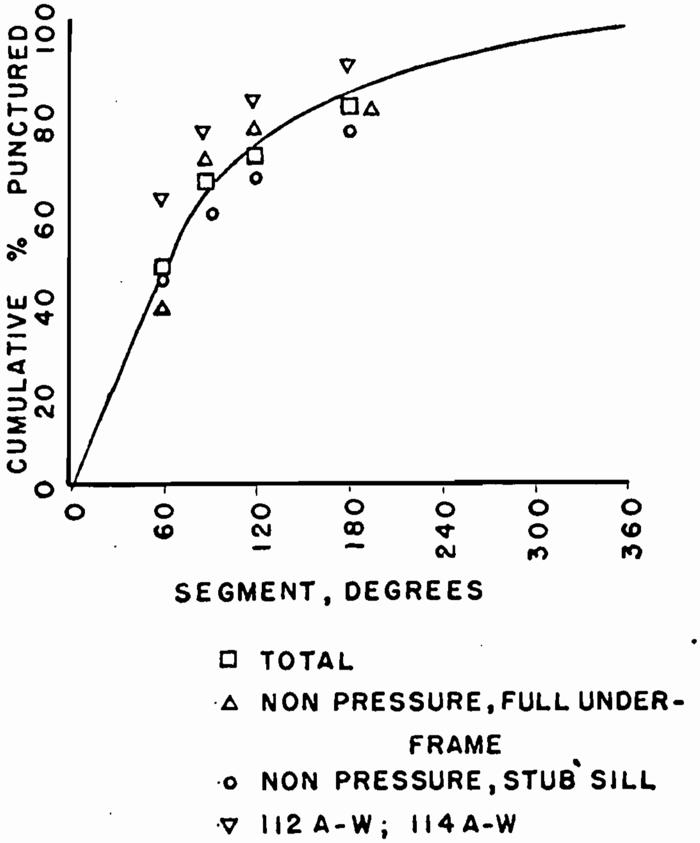
* Excluding major splits.

FIGURE A-8

DISTRIBUTION OF PUNCTURES BY SIZE OF SEGMENT

(Summary of Fig. A-1 thru Fig. A-6 data)





Segment, Degrees	Riveted*	Non Pressure Full Underframe	Non Pressure Stub Sill	105A-W	112A-W 114A-W	TOTAL
60	2	12	14	1	25	54
90	3	22	18	2	30	75
120	4	24	21	2	32	83
180	7	26	24	2	36	95
360	11	31	30	2	39	113

* Excluding major splits.

FIGURE A - 9

DISTRIBUTION OF PUNCTURES BY PARAMETERS OTHER THAN LOCATION

(Summary of Table A-2 data)

RIVETED STEEL CARS:

	Small Dent *	Major Dent *	Punc.	TOTAL
Insulated	15	6	3	24
Non-Insulated	42	18	24	84
Unknown Whether Insulated	12	0	4	16
TOTAL	69	24	31	124

105A-W PRESSURE CARS:
(all insulated)

Loaded	32	14	9	55
Empty	10	6	0	16
Unknown Whether Loaded	19	6	1	26
TOTAL	61	26	10	97

112A-W, 114A-W PRESSURE CARS:
(all non-insulated)

Loaded	56	35	41	132
Empty	34	17	5	56
Unknown Whether Loaded	67	21	7	95
TOTAL	157	73	53	283

MISCELLANEOUS CARS:
(aluminum, other classes, etc.)

TOTAL	33	19	11	63

* See Table A-1 for definitions.

FIGURE A-9 (cont'd)

INSULATED WELDED NON-PRESSURE CARS: 103W; 111A-W	Small Dent	Major Dent	Punc.	TOTAL
Loaded:				
10M-12M gal, 50 ton	7	5	0	12
20M-24M gal, 100 ton	3	6	0	9
Other	16	13	12	41
SUB-TOTAL	26	24	12	62
Empty:				
10M-12M	3	6	0	9
20M-24M	8	5	1	14
Other	27	10	0	37
SUB-TOTAL	38	21	1	60
Unknown Whether Loaded or Empty:				
10M-12M	4	4	0	8
20M-24M	14	12	0	26
Other	34	14	6	54
SUB-TOTAL	52	30	6	88
TOTAL INSULATED	116	75	19	210

FIGURE A - 9 (cont'd)

NON-INSULATED
WELDED NON-PRESSURE CARS:
103W, 111A-W

	Small Dent	Major Dent	Punc.	TOTAL
Loaded:				
10M - 12M gal, 50 ton	9	7	5	21
20M - 24M gal, 100 ton	26	17	22	65
Other	24	20	22	66
SUB-TOTAL	59	44	49	152
Empty:				
10M - 12 M	9	2	0	11
20M - 24 M	46	16	6	68
Other	36	17	8	61
SUB-TOTAL	91	35	14	140
Unknown Whether Loaded or Empty:				
10 M - 12 M	23	5	5	33
20 M - 24 M	45	28	11	84
Other	26	6	9	41
SUB-TOTAL	94	39	25	158
TOTAL NON-INSULATED	244	118	88	450

FIGURE A - 9 (concl'd.)

UNKNOWN WHETHER INSULATED WELDED NON-PRESSURE CARS: 103W; 111A-W	Small Dent	Major Dent	Punct.	TOTAL
Loaded:				
10 M - 12 M gal, 50 ton	3	0	0	3
20 M - 24 M gal, 100 ton	0	0	3	3
Other	3	0	3	6
SUB- TOTAL	6	0	6	12
Empty:				
10 M - 12 M	0	1	0	1
20 M - 24 M	1	0	0	1
Other	5	1	0	6
SUB- TOTAL	6	2	0	8
Unknown Whether Loaded or empty				
10 M - 12 M	1	0	0	1
20 M - 24 M	2	0	0	2
Other	4	2	0	6
SUB- TOTAL	7	2	0	9
TOTAL-UNKNOWN WHETHER INSULATED	19	4	6	29
TOTAL-ALL WELDED STEEL NON-PRESSURE CARS	379	197	113	689
GRAND TOTAL - ALL CARS	699	339	218	1256

FIGURE A-10

EFFECT OF CLASS OF CAR ON LIKELIHOOD OF PUNCTURE

(Based on Table A-2 and Fig. A-9 data)

Loaded:

	Punc.	TOTAL
Non Pressure, Insulated	12	62
Non Pressure, Non Insulated	49	152
105A-W	9	55
112A-W; 114A-W	41	132
TOTAL	111	401

Significant

Sta. = 6.67738

D.F. = 3

Prob. v. +.9 -.95

Empty:

	Punc.	TOTAL
Non Pressure, Insulated	1	60
Non Pressure, Non Insulated	14	140
105A-W	0	16
112A-W; 114A-W	5	56
TOTAL	20	272

Not significant

Sta.= 3.61009

Eliminating Effect of Car Size:

50 Ton Trucks, Loaded	Punc.	TOTAL	
Non Pressure, Insulated	0	12	Not Significant
Non Pressure, Non-Insulated	5	21	Sta. = 1.73189
105A-W	3	17	
TOTAL	8	50	

100 Ton, Loaded			
Non Pressure, Insulated	0	9	Not Significant
Non Pressure, Non-Insulated	22	65	Sta. = 3.3703
105A-W	1	8	
112A-W; 114A-W (all)	41	132	
TOTAL	64	214	

50 Ton, Empty			
Non Pressure, Insulated	0	9	Not Significant
Non Pressure, Non-Insulated	0	11	
105A-W	0	5	
TOTAL	0	25	

100 Ton, Empty			
Non Pressure, Insulated	1	14	Not Significant
Non Pressure, Non- Insulated	6	68	Sta. = .201509
105A-W	0	4	
112A-W; 114A-W (all)	5	56	
TOTAL	12	142	

CONCLUSION: Eliminating the effect of car size, the class of a car has no significant effect on the probability of head puncture regardless of whether the car is loaded or empty.

FIGURE A-11

EFFECT OF SIZE OF CAR ON LIKELIHOOD OF PUNCTURE OF NON-PRESSURE AND 105A CARS

(Based on Table A-2 and Fig. A-9 data)

	Punc.	TOTAL	
Loaded:			
50 Ton Trucks	8	50	Not Significant
100 Ton Trucks	23	82	Sta. = 1.882
TOTAL	31	132	
Empty:			
50 Ton Trucks	0	25	Not Significant
100 Ton Trucks	7	86	Sta. = 1.0177
TOTAL	7	111	

CONCLUSION: The size of a car has no significant effect on the probability of head puncture regardless of whether the car is empty or loaded. (Class 112A cars omitted from this analysis as almost all such cars have 100 ton trucks).

FIGURE A-12

EFFECT OF LADING (WHETHER LOADED OR EMPTY) ON LIKELIHOOD OF PUNCTURE

(Based on Table A-2 and Fig. A-9 data)

50 Ton Trucks

	Punc.	TOTAL
Empty	0	25
Loaded	8	50
TOTAL	8	75

Significant

Sta. = 2.95592

D. F. = 1

Prob. V. = +.9 - .95

100 Ton Trucks

Empty	12	142
Loaded	66	214
TOTAL	78	356

Very Significant

Sta. = 24.09807

D. F. = 1

Prob. V. + .995

EFFECT OF LADING ELIMINATING EFFECT OF CLASS OF CAR

Non Pressure - Insulated

Empty	1	60
Loaded	12	62
TOTAL	13	122

Very Significant

Sta. = 8.24889

D. F. = 1

Prob. V. + .995

Non Pressure - Non Insulated

Empty	14	140
Loaded	49	152
TOTAL	63	292

Very Significant

Sta. = 20.0034

D. F. = 1

Prob. V. + .995

FIGURE A-12 (concl'd.)

105A-W Cars

	Punc.	TOTAL	
Empty	0	16	Not Significant
Loaded	9	55	Sta. = 1.70216
TOTAL	9	71	

112A-W; 114A-W Cars

Empty	5	56	Very Significant
Loaded	41	132	Sta. = 9.25779
TOTAL	46	188	D. F. = 1
			Prob. V. + .995

EFFECT OF LADING
ELIMINATING EFFECT OF WEIGHT
(Loaded 50 Ton Cars weight slightly more than empty 100 Ton Cars)

Non Pressure - Insulated

Loaded 50 Ton	0	12	Not Significant
Empty 100 Ton	1	14	
TOTAL	1	26	

Non Pressure - Non Insulated

Loaded 50 Ton	5	21	Not Significant
Empty 100 Ton	6	68	Sta. = 2.08696
TOTAL	11	89	

CONCLUSION: Loaded cars are more likely to be punctured than are empty cars.

FIGURE A-13

EFFECT OF INSULATION ON LIKELIHOOD OF PUNCTURE

(Based on Table A-2 and Fig. A-9 data)

Loaded Non-Pressure Cars:

	Punc.	TOTAL
Insulated	12	62
Non-Insulated	49	152
TOTAL	61	214

Significant

Stat. = 2.98162

D. F. = 1

Prob. V. = + .9 - .95

Empty Non-Pressure Cars:

	Punc.	TOTAL
Insulated	1	60
Non-Insulated	14	140
TOTAL	15	200

Significant

Stat. = 3.0888

D. F. = 1

Prob. V. = +.9 -.95

All Loaded Cars:

	Punc.	TOTAL
Insulated	21	117
Non-Insulated	90	284
TOTAL	111	401

Significant

Stat. = 7.14409

D. F. = 1

Prob. V. = + .99 - .995

All Empty Cars:

	Punc.	TOTAL
Insulated	1	76
Non-Insulated	19	196
TOTAL	20	272

Significant

Sta. = 4.48

D. F. = 1

Prob. V. = + .95 - .975

CONCLUSION: Insulated cars are less likely to suffer punctured heads than are non-insulated cars.

APPENDIX B
TASK 2
DESIGN CRITERIA

I. INTRODUCTION

In sequence under this task, a review is made of tank car designs, an analysis is made of the results of the full scale impact tests conducted under Phase 5 of the RPI - AAR Project, and a list of design criteria is developed which is based on this analysis and on the results of the accident review under Task 1.

The factors controlling the failure of tank car heads are:

1. head properties: thickness, geometry, material.
2. commodity: outage, internal pressure, commodity weight.
3. impact characteristics: force and duration, impact velocity, location, and orientation.
4. tank car design and attachment construction details.
5. characteristics of draft gear (coupler impact only).
6. insulation: material, thickness.

Since no direct observations or recordings of head impact phenomena have been made in accidents, indirect methods must be employed to evaluate the influence of these important parameters.

As will be seen, the analysis of the full scale test results treats the first four of these factors. The fifth is not treated as a variable since it is generally the same for all cars, and changes to it are not considered practical for the purpose of reducing head vulnerability. The sixth factor has been treated in the analysis of accident data in Section II B of Appendix A.

II. TASK ACTIVITIES

A. Task 2.1 - Tank Car Design Review

The formulation of design criteria must take into account the various designs and types of tank cars now in service. These are:

Pressure Car - A tank car whose tank is designed and fabricated under the provisions of Paragraph 179.100 of the DOT Regulations. These cars are characterized by tanks whose designs are primarily governed by internal pressure loads. Tank wall thicknesses are therefore greater than in non-pressure car tanks, typically being between 9/16" and 15/16". Design, fabrication and inspection requirements for these tanks are also more stringent. Such cars may or may not be insulated.

Non - Pressure Car - A tank car whose tank is designed and fabricated under the provisions of Paragraph 179.200 of the DOT Regulations. These tanks are required to handle a small amount of internal pressure, up to 35, 45, and 75 psig in various cases. Normally, the tank wall thickness required to handle these low pressures is below that which is required to handle the mechanical loads of rail transportation; hence, such tanks are built thicker than required for the pressure load only. Typically, non-pressure tank car tanks have wall thicknesses between 7/16" and 1/2". These cars also may or may not be insulated.

Underframe Car - A tank car built with a center sill running continuously from end to end. The tank is attached to this "underframe" by a center "anchor" for longitudinal support, and is held down by steel bands on cradles over each truck for vertical support. The cradles provide no longitudinal support other than that produced by friction. In this construction, steady train loads are transmitted directly through the underframe, and longitudinal dynamic loads causing the tank to accelerate or decelerate are transmitted through the anchor. These cars may be built to a pressure or non-pressure car specification.

Underframeless Car or Car Without Continuous Center Sill - A tank car built with end "stub" sills only. The stub sills are similar to an underframe in cross section but merge into the tank at a point inboard of each truck. There is no center anchor. Longitudinal support is achieved by welding the tank solid to the cradles. In this construction, both steady and dynamic longitudinal train loads pass through one stub sill, through the tank, and then through the other stub sill. Special design requirements are specified by the AAR Committee on Tank Cars for this construction to provide for the safe transmittal of loads by the tank. These cars also may be built to a pressure or non-pressure car specification.

Insulated Car - A tank car that has a layer of insulation around the tank shell and heads. The most common insulation consists of 4" of fiberglass covered with a metal jacket, ranging from 1/8" to 3/16" in thickness, which is flashed with metal around all openings for weather tightness.

Sketches (to scale) of several of the common types of cars are given in Figures C-1 through C-12 in Appendix C.

B. Task 2.2 - Head Failure Analysis and Correlation With Failure Data

It is difficult, or even rather impossible, to conduct a full-scale analytical investigation of the head impact phenomena within the time span of this contract. Consequently, the analysis must be simple but still fairly accurate. It is begun by first identifying the problem areas related to tank car head failures.

1. Identification of Problem Areas Related to Head Failures

Problem areas related to the development of design criteria involve the general physical characteristics of head failures and mechanics considerations.

The dissipation of the kinetic energy of a projectile (coupler, sill, etc.) impacting a tank car head produces various effects, their nature depending on the physical characteristics of the colliding bodies (such as rigidity, mass, material) and the magnitude of the relative velocity.

There are two fundamental types of damage which can be considered: (1) dent without rupture and (2) puncture (dent with local rupture or complete piercing). When an impact occurs, initially the impact energy is primarily converted into elastic energy stored in the unyielded zone of the head and in the energy of plastic deformation of the head material surrounding the indentation. Smaller amounts of energy are absorbed in wave propagations, the rebound of the striking object, friction and heat.

In the case of pressurized tank cars, the internal pressure stiffens the head and reduces the flexibility to cushion the impact. Nevertheless, the general laws of conservation of momentum, energy and other laws of mechanics hold for all cases.

2. Methods of Solution

This study will be specifically focused on finding answers to the following questions:

- How can the type of tank head damage, dent or puncture, be predicted as a result of a projectile striking a tank head when the initial velocities and the masses of both colliding cars, the head geometry, the head material and the commodity condition are known?

- How can the maximum impacting force developed during the impact be estimated from direct observation of head damage?

- How can impact failure criteria be established if some analytical tools, such as those obtained in the answers to the above two questions, are available?

Realizing the difficulty of formulating the problem entirely on an analytical basis, a semi-theoretical method was sought. The procedure is comprised of a theoretical analysis of influential dimensionless parameters from the full scale test data and employment of the Hertz force-indentation law for collision problems.

The results of the full scale tests are shown in Table B-1. It must be immediately noted that these tests involved old tank cars which were of riveted construction and whose heads were of different contour and material than more current cars. The tests were conducted primarily to gain insight into test procedures and instrumentation and to gain only approximate knowledge of the head puncture phenomena.

Observation of the impressions made by the striking coupler clearly indicates that shear deformations were produced at the impressed areas which corresponded to the perimeter of the striking coupler. This was evident from the tests where the head was struck near its center. The degree of shear deformation increased with an increase in the striking speed, with failure occuring eventually under the more severe impacts.

The vulnerability of tank heads to puncture also increased with increasing internal pressure. The pressure offers considerable resistance to deformation of the tank head. Consequently, the applied force produces a deformation which is highly localized around its area of application. Because of this concentration, the tank head fails with less deformation and at a lower energy level.

A typical example of a failure under pressure is shown in Figure B-1 for the test impact No. 14. The primary failure was attributed to the plug formation caused by the high shear force applied by the top edge of the coupler knuckle. The secondary failure which took place at the lower edge was due to the dishing and overstress in tension.

The magnitude of the maximum force which the tank head can sustain will be estimated on the basis of this primary mode of failure by shear developed around the contour of the impressed area.

For the case of impacts at the lower portion of the heads, the deformation characteristics are substantially different from the case of central impacts. Generally on new welded cars, the knuckle area is reinforced by some structure which provides restraint against

TABLE B-1

FULL SIZE HEAD IMPACT TEST RESULTS SUMMARY

Impact No.	Impact Speed (mph)	Outage (%)	Internal Pressure (psi)	Striking Car Wt. (lbs)	Struck Car Wt. (lbs)	Head Size (in.)	Impact Location	Head Damage	
								Permanent Indentation (in.)	Failure
1	4.3	2	0	128,900	96,500	78 x 1/2	Center	30 x 2-3/4	
4	7.2	2	0	"	107,300	80 x 7/16	"	40 x 6-1/2	
6	10.2	2	0	"	128,900	88 x 7/16	"	60 x 11-1/4	
8	8.7	2	20	"	128,200	88 x 7/16	"	48 x 8-1/4	
10	11.0	2	40	"	108,400	80 x 7/16	"	42 x 7-1/2	
12	14.0	2	40	"	107,500	83 x 7/16	"	36 x 8	
14	16.0	2	40	"	130,000	88 x 7/16	"	*	Puncture
15	14.9	2	20	"	128,800	88 x 7/16	"	60 x 16	
16	15.0	2	20	"	127,000	88 x 7/16	"	60 x 14-1/2	
17	15.7	2	30	"	127,400	88 x 7/16	"	60 x 14-1/2	Shear
18	15.7	2	20	"	107,600	83 x 7/16	"	66 x 15-1/2	Shear
19	16.0	2	0	"	107,300	80 x 7/16	"	72 x 16	
20	8.5	100	0	"	40,900	83 x 7/16	"	51 x 9	
22	16.0	2	0	"	96,600	78 x 1/2	Knuckle	40 x 12	
23	16.1	2	20	"	108,400	80 x 7/16	"	*	Puncture
24	16.1	2	10	"	128,300	88 x 7/16	"	*	Shear[+]
25	16.1	100	0	"	48,000	88 x 7/16	"	*	Puncture

* No data.

\+ Threshold puncture.

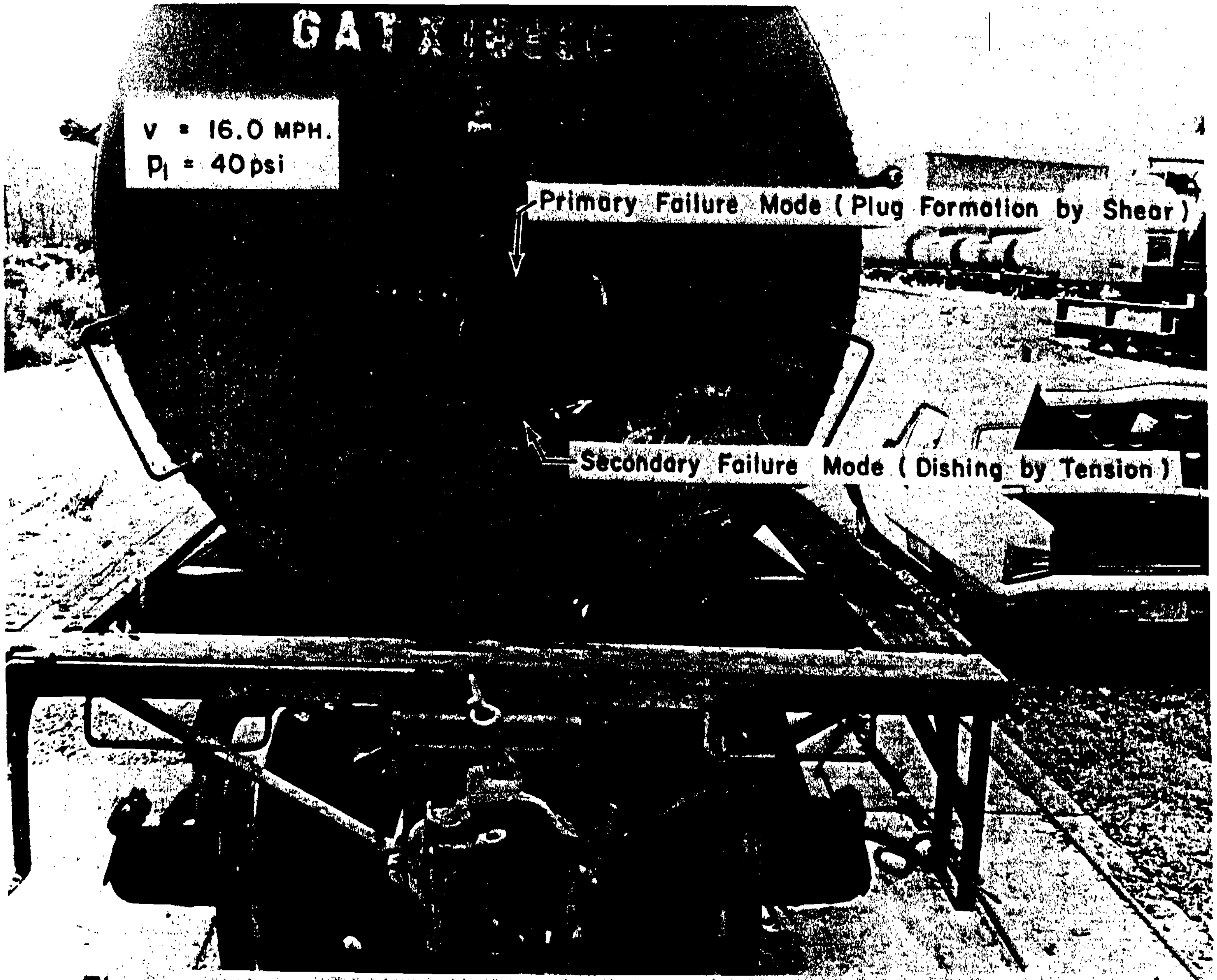


Figure B-1 TANK HEAD IMPACT FAILURE (Complete Puncture) deformation. Thus, the tank head can be torn at the reinforcement weld area where excessive shear force is developed. Such phenomenon can be appreciated by observing Figure B-2 for test impact No. 23. The primary failure of the tank head in this case is in shear developed at the tank head attachment area, and the secondary failure of the tank head is in tension by the dishing of the area above the knuckle.

3. Results

Renoting that tank car head damage (therefore, dent depth before puncture) is a function of the factors outlined in the introduction to this appendix, the phenomena can be expressed mathematically by the following equation:

(B-1)

$$d = K\phi\left(m_1V_1, \frac{m_1V_1^2}{2}, \frac{m_2}{m_1}, \frac{P_i}{P_o}, \frac{D}{t}, \text{outage}, \text{etc.}\right)$$

where: d = dent depth
K = constant to be determined
m_1V_1 = initial momentum prior to impact
$m_1V_1^2/2$ = initial kinetic energy prior to impact
m_1 = mass of striking car
m_2 = mass of struck car
P_i = internal pressure
P_o = 15 psi
D = tank head diameter
t = tank head thickness

The test data when plotted in Figure B-3 reveal that the dent depth is roughly linearly proportional to the initial momentum, Thus, no attempt was made to correlate the dent depth with the initial kinetic energy. In other words, the energy criteria is discarded in favor of the momentum criteria.

In Figure B-3, the data also indicate that a modification is required to accommodate the internal pressure variation in terms of the ratio P_i/P_o. This modification factor is designated a "B" and is found to be

(B-2)

$$B = e^{-0.018e^{P_i/P_o}}$$

where: e = natural logarithm base

To include the effects of other influential factors, the indentation parameters were then plotted against the geometric (D/t) and the mass m_2/m_1 parameters on log-log scales. These are shown in Figures B-4 and B-5.

The exponent to be applied to each individual parameter can be found without any difficulty through a direct measurement of the slope of these curves. The constant K also can be determined from the log-log plots in Figures B-4 and B-5. The drawing of straight lines on these log-log plots is a standard procedure in dimensional analysis for establishing exponents.

A similar process was employed to determine the impact force-internal pressure relationship and is shown in Figure B-6. The results of this analysis leads to the following more definitive form of equation B-1:

$$d = 5\times10^{-6}(D/t)^{2}(W_2/W_1)^{0.25}(W_1V_1/g)e^{-0.018e^{P_i/P_0}} \qquad \text{(B-3)}$$

where:

d = estimated permanent indentation (in.)
D = diameter of tank head (in.)
t = thickness of tank head (in.)
W_1 = weight of striking car (in 1000 lbs.)
W_2 = weight of struck car (in 1000 lbs.)
V_1 = striking velocity (in/sec.)
g = 386 in/sec.^{2}
P_i = internal pressure (psia)
P_0 = 15 psi

The maximum impact force is given by:

$$F = 35\times10^{6}(d)^{1.5}(t/D)^{3}\left(\frac{P_i+P_0}{P_0}\right)^{0.6} \qquad \text{(B-4)}$$

where: F = estimated maximum impact force (kips)

d, D, t, P_i, P_0 = as defined above

The failure criteria is given by the equations:

$$\tau = \frac{F}{CtL} \geq \tau_\mu \qquad \text{(for central impact) (B-5)}$$

$$\tau = \frac{1.81\,F}{CtR} \geq \tau_\mu \qquad \text{(B-6) (for impact near bottom of head)}$$

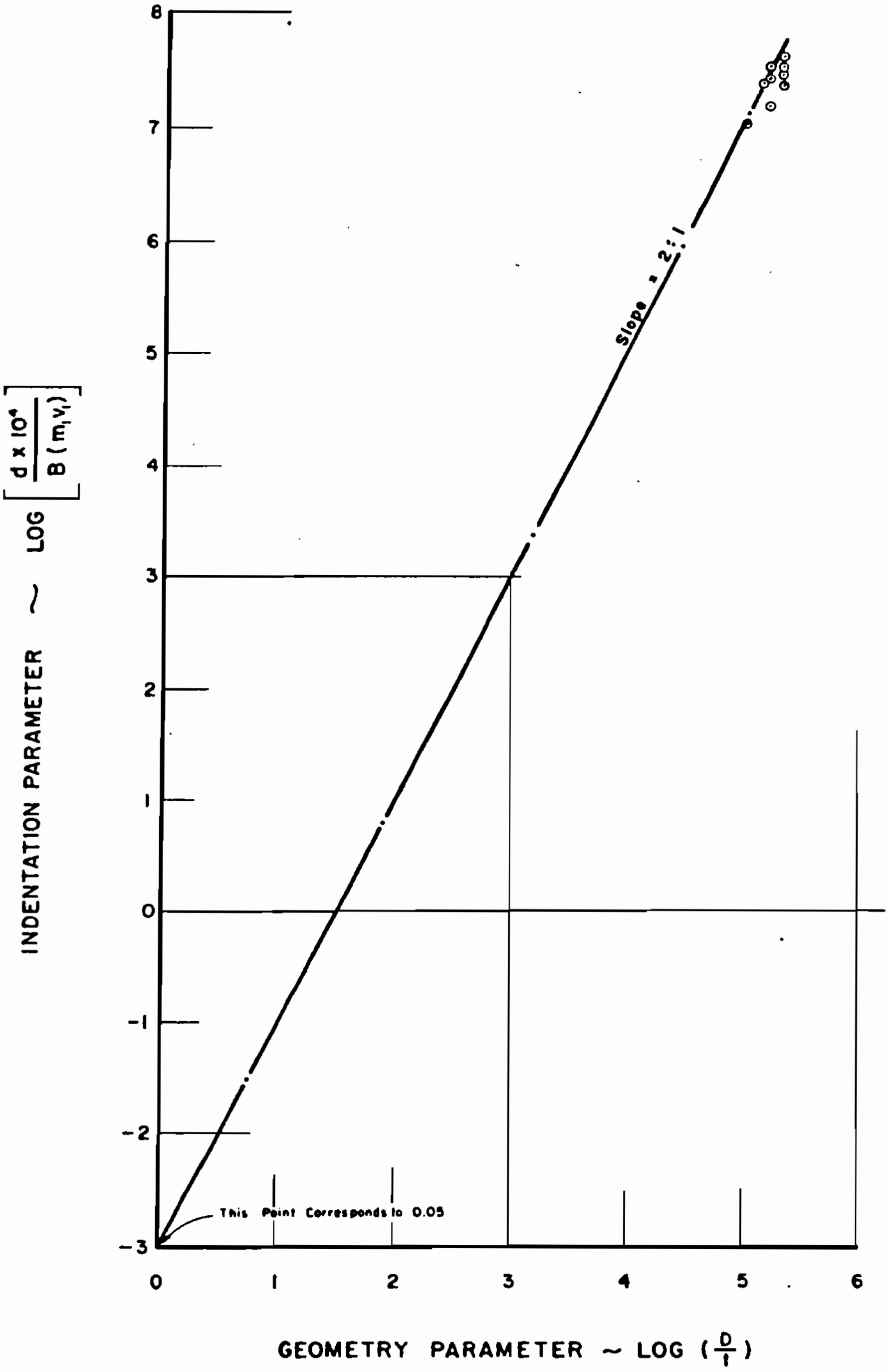


Figure B-4 GEOMETRY PARAMETER VS INDENTATION PARAMETER

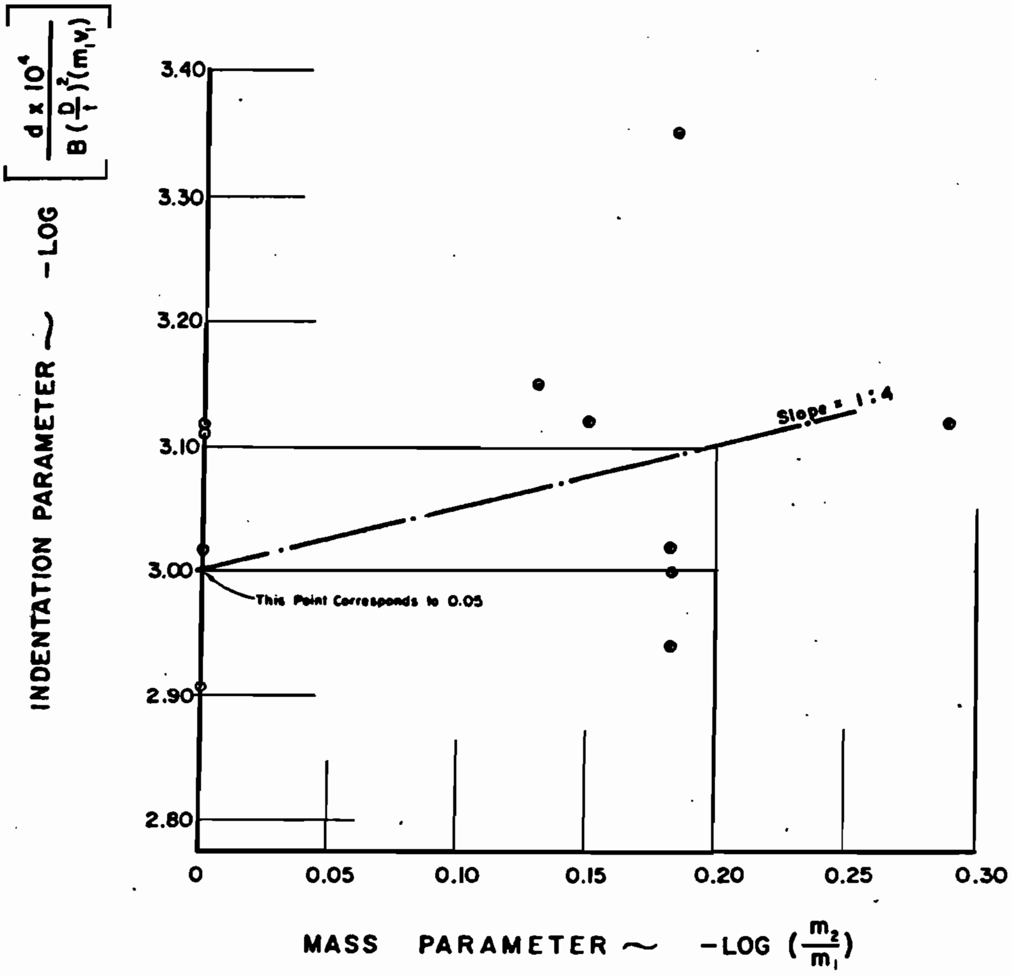


Figure B-5 MASS PARAMETER VS INDENTATION PARAMETER

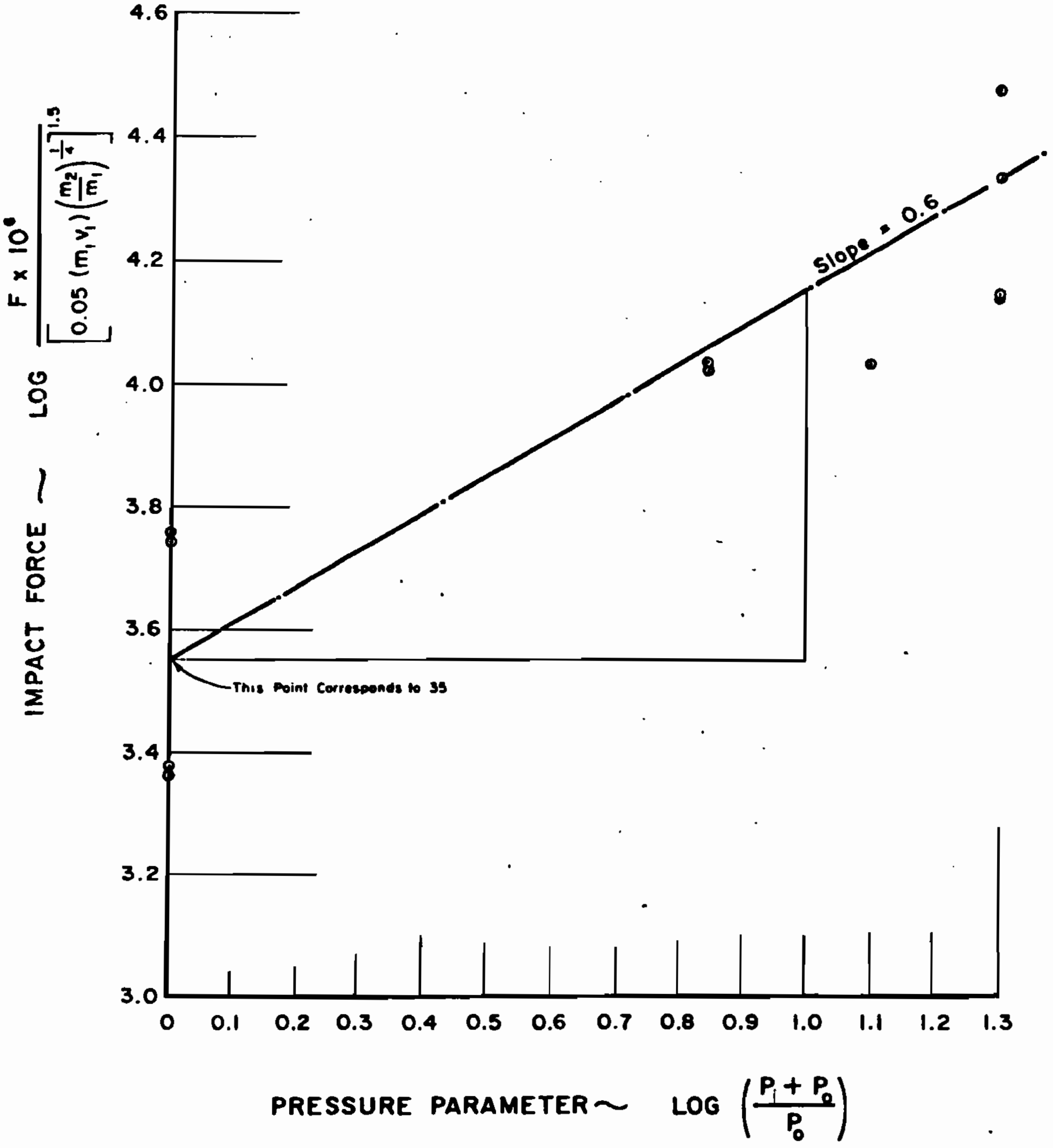


Figure B-6 PRESSURE PARAMETER INFLUENCE VS IMPACT FORCE where: F = maximum impact force (kips)

C = constant which depends on the environmental condition inside the tank, taken as unity for full tanks and 0.5 for empty tanks respectively.

τ_u = ultimate shear strength of tank head material (ksi)

t = head thickness (in.)

L = perimeter of impressed area (in.)

R = tank radius (in.)

4. Discussion - Correlation with Failure Data

Despite the fact that the tests involved a limited number of old cars which had been subjected to fatigue and corrosive environments over a great number of years, this analysis yields results which correlate well with the specific experimental failure data within engineering accuracy.

Table B-2 shows the comparison between the calculated permanent indentation with that measured in the tests. Table B-3 shows a similar comparison for the maximum impact force and also shows the criteria under which the tank heads fail. Finally, the theoretically calculated failure force is compared to the measured force in Table B-4.

As can be seen in these tables, the analytical results compare well with the test results, with a few exceptions. It can be concluded that the assumption of plug failure due to shear as the primary failure mechanism appears to be correct.

With only two tests conducted for the case of empty tanks, no decisive conclusion can be drawn with regard to this parameter. However, a comparison of impact Nos. 23 and 25 indicates that tanks can resist only half of the impact force when empty than when full. Both of these impacts were at the lower knuckle portion of the head. For the case of central impact, the maximum endurable force can be estimated to be about 1.6 times that for the lower knuckle location impact. Finally, the maximum endurable impact force can be estimated to decrease with increasing internal pressure by the factor

$$\left[P_o/(P_i + P_o)\right]^{0.6}$$

TABLE B-2
FULL SCALE HEAD IMPACT TESTS
PERMANENT INDENTATION

Test No.	Outage (%)	Internal Pressure Pi (psi)	Head Damage			
			Permanent Indentation, d (in.)		Maximum Indentation Recorded (in.)	Failure
			Calculated	Measured		
1	2	0	2.84	2.75	4.35	
4	2	0	6.35	6.50	5.0	
6	2	0	11.60	11.25	13.0	
8	2	20	9.65	8.25	9.5	
10	2	40	8.04	7.50	12.8	
12	2	40	10.53	8.00	*	
14	2	40	13.00	*	19.4	Puncture
15	2	20	16.00	16.00	18.6	
16	2	20	16.67	14.50	*	
17	2	30	16.70	14.50	*	Shear
18	2	20	14.35	15.50	*	Shear
19	2	0	15.75	16.00	*	
20	100	0	7.05	9.00	*	
22	2	0	10.70	12.00	*	
23	2	20	14.25	*	*	Puncture
24	2	10	16.00	*	*	Shear +
25	100	0	14.90	*	*	Puncture

*No data.

+ Threshold puncture.

TABLE B-3

FULL SCALE HEAD IMPACT TESTS - FAILURE CRITERIA

Test No.	Outage (%)	Internal Pressure Pi (psi)	Maximum Impact Force, F (kips)			Failure Criteria		
			Calculated			Shear Stress (ksi)		
			Based on d Estimated	Based on d Measured	Measured	τ*** Theoretical	Minimum Ultimate τ_u	Failure Mode
1	2	0	44	42	55	2.9	38.5	Dent
4	2	0	100	103	89	7.6	38.5	Dent
6	2	0	169	158	141	12.9	38.5	Dent
8	2	20	210	165	201	16.1	38.5	Dent
10	2	40	288	256	283	22.0	38.5	Dent
12	2	40	381	255	454	29.2	38.5	Dent
14	2	40	525	*	429	40.1	38.5	Puncture
15	2	20	448	448	360	34.3	38.5	Dent
16	2	20	477	368	375	36.5	38.5	Dent
17	2	30	560	427	465	42.9	38.5	Shear
18	2	20	496	580	462	38.0	38.5	Shear
19	2	0	361	368	410	27.6	38.5	Dent
20	100 Empty	0	103	139	118	13.8**	38.5	Dent
22	2	0	324	384	381	30.1	38.5	Dent
23	2	20	496	*	314	51.3	38.5	Puncture
24	2	10	446	*	365	41.9	38.5	Shear+
25	100 Empty	0	241	*	258	45.2**	38.5	Puncture

* No data.

** C = 0.5 for empty tanks; otherwise, C = 1.0.

\+ Threshold puncture.

*** per Eqs (B-5) or (B-6) using values of F based on d estimated. For central impact L assumed to be 30". Note good correlation of failure criteria $\tau > \tau_u$ and actual failures.

TABLE B-4

FAILURE FORCE AND FAILURE MODES

Test	Estimated Failure Force (kips)	Maximum Measured Force (kips)	Failure Mode
1	800	55	Dent
4	800	89	Dent
6	800	141	Dent
8	481	201	Dent
10	366	283	Dent
12	366	454	Dent
14	366	429	Puncture
15	481	360	Dent
16	481	375	Dent
17	414	465	Shear
18	481	462	Shear
19	800	416	Dent
20	400	118	Dent
22	507	321	Dent
23	301	314	Puncture
24	367	365	Shear +
25	256	258	Puncture

+ Threshold puncture.

Note good correlation of actual failures and cases where measured force exceeds that estimated for failure.

It is important to note that the maximum force F developed during impact would appear to be independent of the tank geometry D/t when Eq (B-3) is substituted into Eq (B-4). This is misleading for the following reason:

The heads of fifteen out of seventeen tanks tested were 7/16" thick; the others were 1/2" thick. Moreover, the diameters of the tanks tested ranged from 78" to 88". With such a narrow variation in these tests in the geometric parameter D/t, its influence cannot be accurately assessed. Since tank car design criteria allow more freedom for altering the thickness than the diameter, a larger range in the head plate thickness is recommended for the future experiments.

In addition, these formulas should be considered engineering approximations since the exponents applied to all the influential parameters included in the indentation and force formulas contain only two significant digits.

C. Task 2.3 - Design Criteria

The ultimate criteria for evaluating proposed design concepts is a combination of economics and satisfaction of functional objectives. The design requirements set forth for evaluating conceived design ideas comprise six categories: 1) design, 2) structure, 3) construction and installation, 4) materials, 5) application, and 6) maintenance. Many of these requirements will have constraints imposed by practical considerations, such as space allocation, material or device availability. Although many aspects are involved in the evaluation of proposed designs, the optimum design of such protective systems will require simultaneous consideration of all factors.

The specific design criteria derived from the Tasks 1.2, 1.3, 2.2 and from certain principles of common sense are given below with comments on their input influence. They are not listed in any order of importance.

1. The class of car has no significant effect on the probability of head puncture, regardless of whether the car is empty or loaded (from Tasks 1.2 and 1.3). This confirmed that we should initiate, for later consideration, designs for all classes of cars.

2. The size of a car has no significant effect on the probability of head puncture regardless of whether the car is empty or loaded (from Tasks 1.2 and 1.3). This directed us to consider the same design for a given class car, regardless of its size. This fact is probably a reflection of the importance of the inertia of the impacting car or of cars backing up the impacted and/or impacting car.

3. Loaded cars are more likely to be punctured than empty cars (from Tasks 1.2 and 1.3). The significance of this result is that head protection may be more efficiently provided by a shield concept which has no liquid backup; e.g. one spaced forward of the tank head.

4. Insulated cars are less likely to suffer punctured heads than non-insulated cars (from Tasks 1.2 and 1.3). We feel that this fact derives from the protective influence of the steel jacket, commonly 1/8" or 3/16" in thickness. This led us to consider heavier steel plates (e.g. 1/2") in many cases.

5. The primary mode of failure is shear; the secondary mode is tension at the extremities of an indented area (from Task 2.2). This fact provides a guide (approximate) for assessing the effectiveness of a steel plate shield, which is that its puncture resistance increases proportionally with the product of its strength and thickness.

6. Sharp projections of impacting objects are influential in lowering threshold puncture forces or energies. This has been evident in the Task 1 accident review and was also derived from the RPI - AAR Phase 5 tests which employed the standard E coupler as the striking object. While not directly related to the design of specific protection devices, this fact suggests that an alternate approach for improvement may be through incorporation of more generous radii along the forward edges of standard coupler components.

7. The likelihood of puncture increases as internal pressure increases (from Task 2.2). This, like point 3, implies that concepts involving shields spaced forward of the tank head will be more efficient.

8. The lower portion of the head is far more susceptible to being punctured than the upper (from Tasks 1.2 and 1.3). This fact is used in a number of shield concepts as will be seen.

9. The device should particularly protect areas of heads where structural restraints are attached (from Task 2.2). This point also emphasizes the importance of shielding the lower portions of heads, particularly for stub sill cars.

10. Attachments to heads are to be reduced or avoided (from accident review in Task 1 and from Task 2.2). This fact directed us away from shield concepts which required attachments to the head for a portion of their support.

11. Heads are capable of absorbing considerable energy before rupture (from Task 2.2). This fact (somewhat along with with item 4) has directed us to consider that, typically, 1/2" thick plates would be effective for those concepts involving shields spaced forward of the tank head.

12. The cases of extensive head damage appear to be primarily caused by coupler impact (from Task 1). This fact stresses the importance of preventing coupler separation.

13. The device should be easy to fabricate and install.

14. The device should have adequate strength and corrosion resistance to maintain integrity for many years.

15. The device should not adversely affect the normal operating functions of the car.

16. The head protection concept should not require a long term research effort to evaluate.

17. The device should not create additional hazards, such as the potential to puncture adjacent cars.

APPENDIX C
TASK 3
DESIGN SPECIFICATIONS

I. INTRODUCTION

The purpose of this task is best described by reviewing its five sub-tasks:

3.1 Concept Formulation - The generation of concepts for head shields.

3.2 Concept Analysis - The screening of the concepts.

3.3 Concept Review - Further development of the most promising concepts through engineering drawings and design calculations.

3.4 Performance Specifications - Development of the performance specifications for the head protective device(s).

3.5 Design Finalizations and Drawings - Finalization of designs and drawings for optimum head shield concepts for each class of car. This work actually followed Task 4 in the project sequence, and drawings of the final designs are given in Appendix D, Figures D-1 through D-10.

II. TASK ACTIVITY

A. Task 3.1 - Concept Formulation

This sub-task began with a "brainstorming" session attended by eight team members. No design or performance restraints were applied, and all conceived ideas were admitted. This was in line with the philosophy of such a session where many seemingly ridiculous concepts can lead to more practical ones, either directly, or in combination. In total, 74 ideas were logged during this meeting.

B. Task 3.2 - Concept Analysis

The 74 ideas were next reviewed by the Project Leader, the Principal Investigator, and engineering representatives of the participating companies. They were reduced to 19 concepts which were graded as to their feasibility. These are listed in Table C-1.

TABLE C - 1

CONCEPTS FOR HEAD PROTECTION

Rating

A - Promising
B - Less Promising

Function

1. Prevent blow to head
2. Allow blow but prevent puncture
3. Effective only if applied to all freight cars

Application

(N) New cars
(E) Existing cars

1.	A - 2 (NE)	Use wood for energy absorbing material.
2.	B - 2 (N)	Absorb energy by causing sill of struck car to be torn off.
3.	B - 2 (NE)	Use riveted plates that shear and collapse on impact.
4.	A - 2 - 3 (NE)	Improve outside shape of E couplers - provide blunt face for impact.
5.	B - 2 (NE)	Use rubber doughnut (similar to large tire) on sill in front of head. Cap with plates and fill with shock absorbing material.
6.	B - 1 - 3 (NE)	Design interlock to prevent E coupler from rising over F coupler on tank car.
7.	A - 1 (NE)	Provide attachment on sill to prevent coupler from rising to strike head.
8.	A - 2 (N)	Eliminate fittings on tank heads (important, but not directly related to project objective).
9.	A - 2 (NE)	Use double head - false head with void.
10.	A - 1 (NE)	Use vertical steel plate to act as energy absorber.
11.	A - 2 (N)	Use thicker head on non-insulated cars.
12.	A - 2 (N)	Use thicker jacket head on insulated cars.

TABLE C - 1 - cont'd.

13.	B - 2 (NE)	Interleaf different materials as laminates.
14.	A - 2 (NE)	Provide a contoured steel jacket head (11 gage) over all or part of pressure head and fill or partially fill with shock absorbing material. Includes applying shock absorbing material under jacket heads of normally insulated cars.
15.	B - 1 (NE)	Change impacting point so that head will impact head before coupler impacts head.
16.	B - 2 (NE)	Use corrugated steel plate in front of head.
17.	A - 2 (NE)	Use contoured vertical steel plate as energy absorber and force deflector.
18.	B - 1 (NE)	Use steel deflector at end of sill.
19.	B - 1 (N)	Redesign sill by moving rearward so heads contact first.

The design criteria provided by Tasks 1 and 2 and which are listed in Section II - C, Appendix B, were used during this refinement process.

One of the concepts in the original group of 74 involved an internal bladder designed to seal a punctured hole, but this was discarded for several reasons:

- High cost
- Inaccessibility for periodic inspection
- Potential high maintenance cost
- Incompatibility with certain commodities
- Inability to prevent, or reduce the severity of, the blow to the head
- Requires fairly long term research or trial evaluation

C. Task 3.3 - Concept Review and Final Evaluation

At this point, the Project Leader, the Principal Investigator, and representatives from the AAR and each of the five participating tank car builders conducted a final review of the Table C-1 concepts, discarded some for reasons given below, and prepared a preliminary set of designs and design specifications for the remainder.

Concepts 2, 3, 13, 15 and 19 were discarded in view of design criterior No. 16* which speaks against a long term research effort.

Concepts 7, 16 and 18 were discarded in view of design criterion No. 17 which states that an additional hazard should not be created.

Concept 5 was discarded as being impractical in contour (round) and thus not protecting the lower area of the head as efficiently as other designs.

Concepts 4, 6, and 8 are considered important but were not included in our selection at this point since they constitute solutions alternate to that of adding a shield or deflector. These three concepts are being investigated separately under our RPI - AAR Project. In particular, concepts 4 and 6 are being reviewed with coupler manufacturers and the AAR, and concept 8 is being pursued under our RPI - AAR Project Phase 9, particularly in regard to the head mounted handbrake. These are discussed further in Section III of this appendix.

The remaining concepts, Nos. 1, 9, 10, 11, 12, 14 and 17, were refined into actual designs using sketches and a 1/12th scale model tank car. Minimum design specifications were also established for each. These resulting designs and design specifications are shown in Table C-2 and in Figures C-1

---

* See list in section II - C, Appendix B

TABLE C - 2

HEAD PROTECTION SCHEMES

CATEGORY →	1	2	3	4	5	6
CONCEPT ↓	New DOT 112 & 114	New DOT 111 Non-Ins.	New DOT 111 & 105 Ins.	Exist. DOT 112 & 114	Exist. DOT 111 Non-Ins.	Exist. DOT 111 & 105 Ins.
A - Add full 11 ga.* steel jacket hd. filled w/sand.	ACF +	NAC +	-	-	-	-
B - Same as "A" except filled w/20# foam.**	ACF +	NAC +	-	-	-	-
C - Same as "B" except foam lower half only.**	ACF +	NAC +	-	-	-	-
D - Add 120 sector 11 ga. steel jacket fill w/20 lb. foam.	GAT +	UTC +	-	-	-	-
E - Substitute 20# foam for dual head ins. (1)	-	-	ACF(111 only)GAT (105 only) +	-	-	-
F - Same as "E" foam lower half. (1)	-	-	ACF(111 only)GAT (105 only) +	-	-	-
G - Same as "E" except use cork. (1)	-	-	ACF(111 only)GAT (105 only) +	-	-	-

* 7 gage jacket also considered as an alternate Scheme A-2-1.

** 6# foam also considered as alternate Schemes B-1-1, B-2-1, C-1-1, and C-2-1

+ = Concept applies to category.
- = Concept does not apply to category.
(1) = May not be practical for elevated temperatures.

TABLE C - 2 - Cont'd.

CATEGORY →	1	2	3	4	5	6
CONCEPT ↓	New DOT 112 & 114	New DOT 111 Non-Ins.	New DOT 111 & 105 Ins.	Exist. DOT 112 & 114	Exist. DOT 111 Non-Ins.	Exist. DOT 111 & 105 Ins.
H - Same as "F" except use cork. (1)	-	-	ACF(111 only) GAT (105 only) +	-	-	-
J - Substitute 3/8" for 11 gage jacket head.	-	-	NAC(111 only) UTC (105 only)	-	-	-
K - Add 7/16" double head	ACF +	GAT +	-	-	-	-
L - Substitute thicker tank head same material	NAC + (112A 500W)	UTC + (111A 150W)	-	-	-	-
M - Add wood tie assembly	ACF +	GAT +	-	NAC +	UTC +	-
N - Add 1/2" vert. steel plate w/ vert. bends.	ACF +	GAT +	NAC(111 only)UTC (105 only) +	ACF +	GAT +	NAC(111 only)UTC (105 only) +
O - Same as "N" except extended.	ACF +	GAT +	-	NAC +	UTC +	-
P - Add 1/2" vert. steel plate w/ horiz. bend lines	ACF +	GAT +	-	NAC +	UTC +	-

+ = Concept applies to category.
- = Concept does not apply to category.
(1) = May not be practical for elevated temperatures.

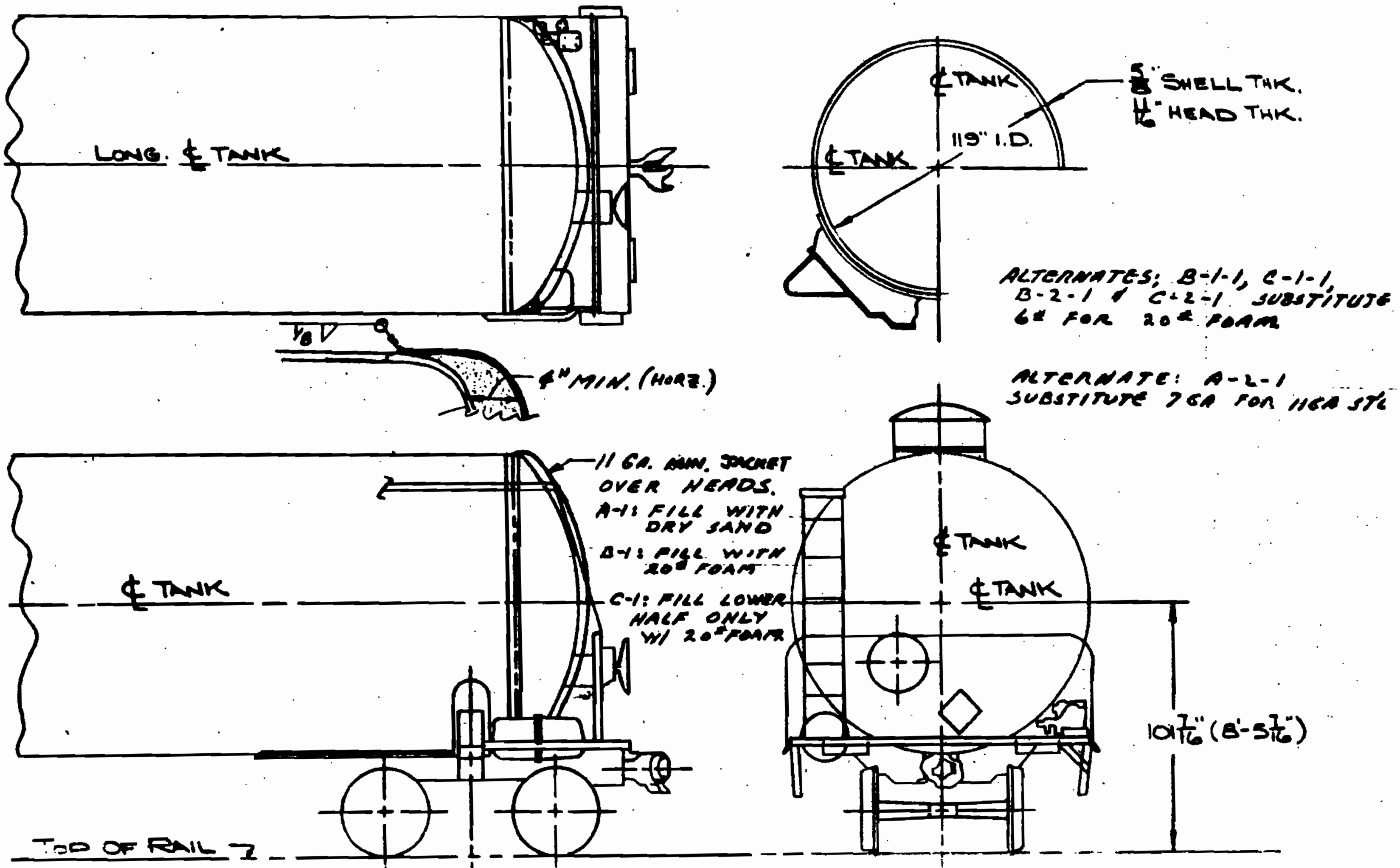


FIGURE C-1

HEAD PROTECTION SCHEMES A-1, B-1, C-1 SHOWN 33,500 GALLON CLASS DOT-112A340-W & 114A

(SCHEMES A-2, B-2, C-2 SAME EXCEPT FOR CLASS DOT 111 CARS.)

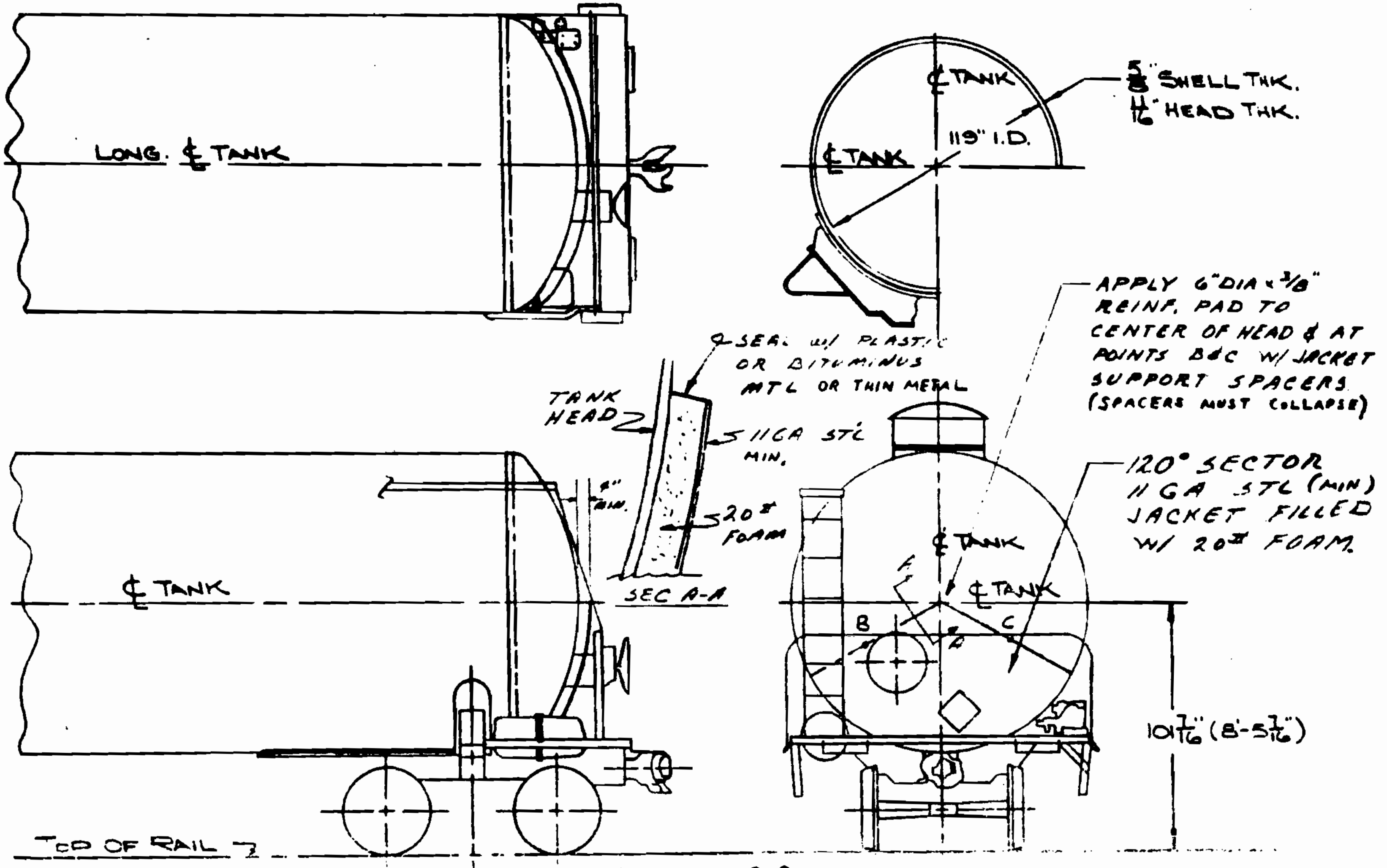
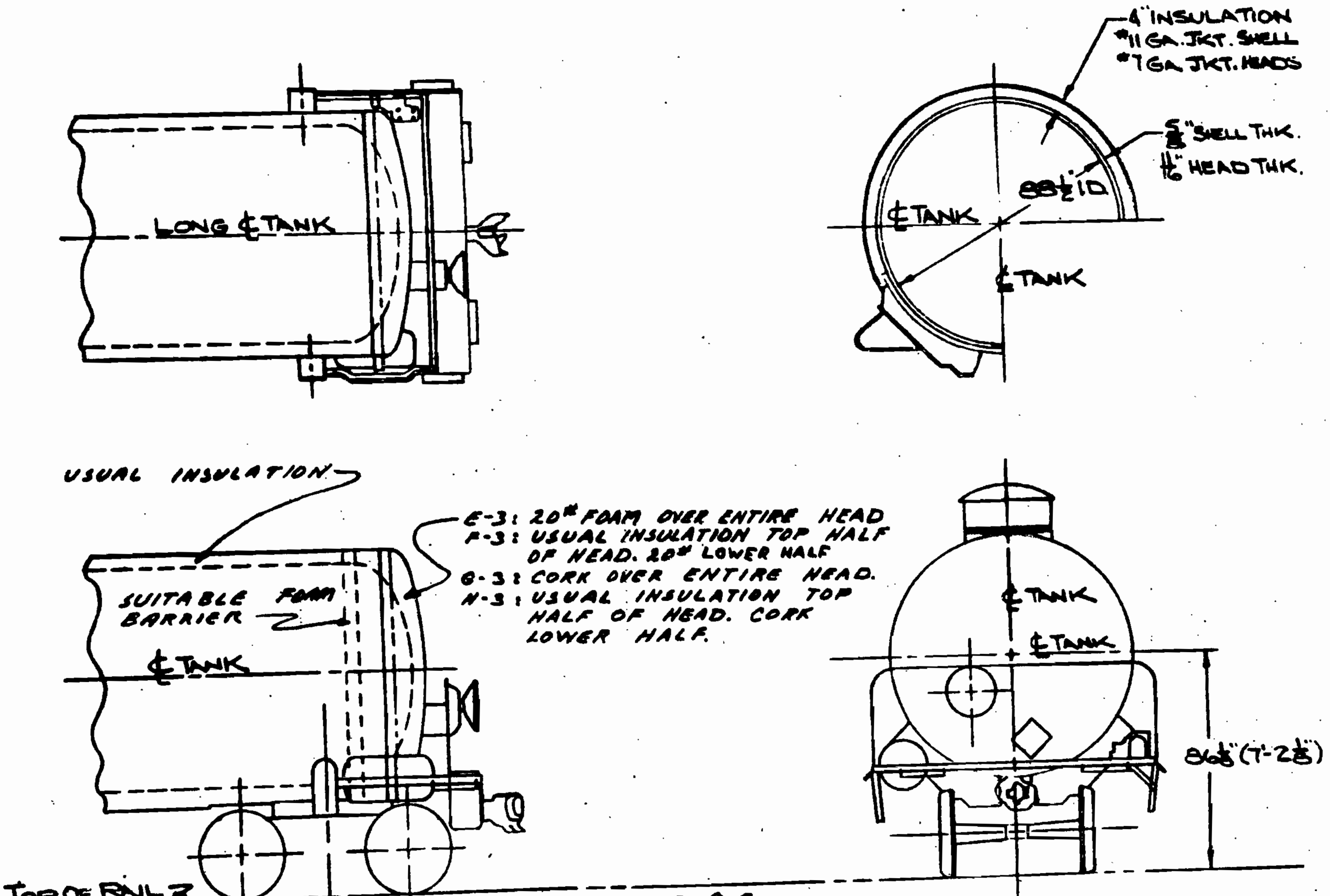


FIGURE C-2

HEAD PROTECTION SCHEME D-1 SHOWN

SCHEME D-2 SAME EXCEPT FOR CLASS 111 CARS.

33,500 GALLON
CLASS DOT-112A340-W
& 114A340-W



E-3: 20# FOAM OVER ENTIRE HEAD
F-3: USUAL INSULATION TOP HALF OF HEAD. 20# LOWER HALF
G-3: CORK OVER ENTIRE HEAD.
H-3: USUAL INSULATION TOP HALF OF HEAD. CORK LOWER HALF.

FIGURE C-3

HEAD PROTECTION SCHEME E-3, F-3, G-3, H-3

(ALSO APPLIES TO CLASS III TYPE CARS-NOT SHOWN)

11,200 GALLON
CLASS ICC 105A300-W

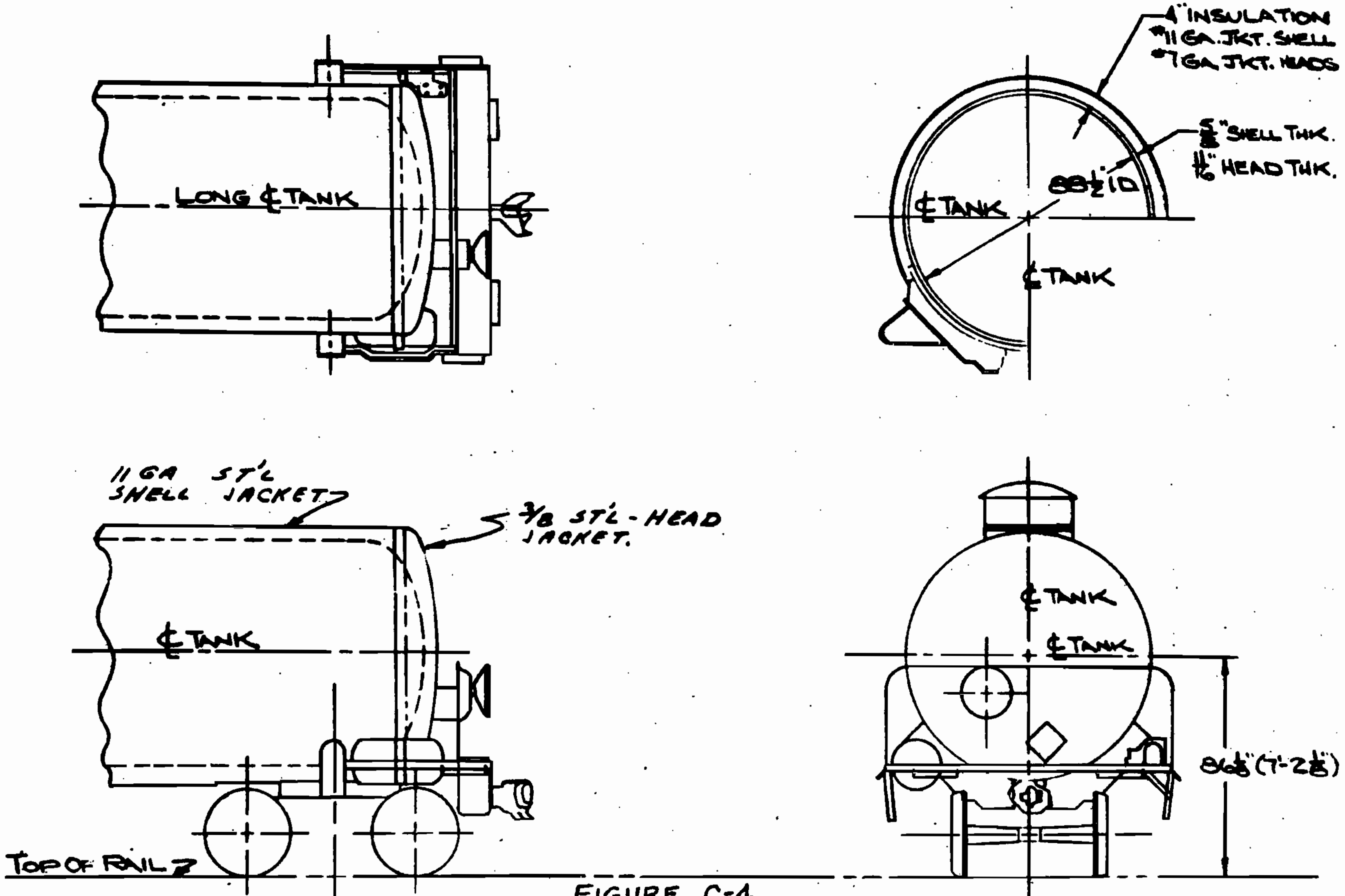


FIGURE C-4

HEAD PROTECTION SCHEME J-3 (105)

ALSO APPLIES TO CLASS III TYPE CARS-NOT SHOWN

11,200 GALLON
CLASS ICC 105A300-W

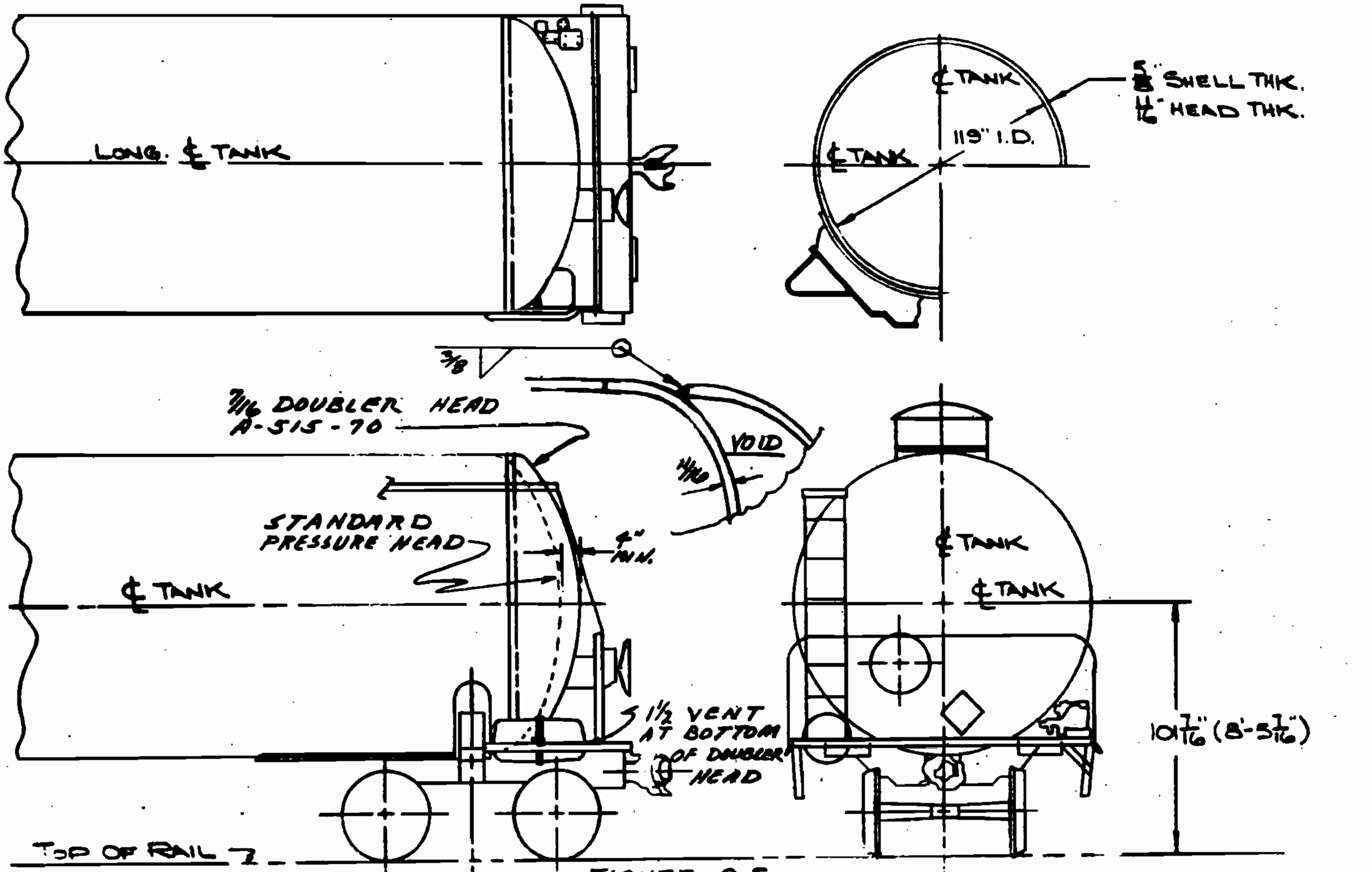


FIGURE C-5

HEAD PROTECTION SCHEME K-1 SHOWN

SCHEME K-2 SAME EXCEPT FOR CLASS 111 CARS NOT SHOWN

33,500 GALLON
CLASS DOT-112A340 W
& 114 A

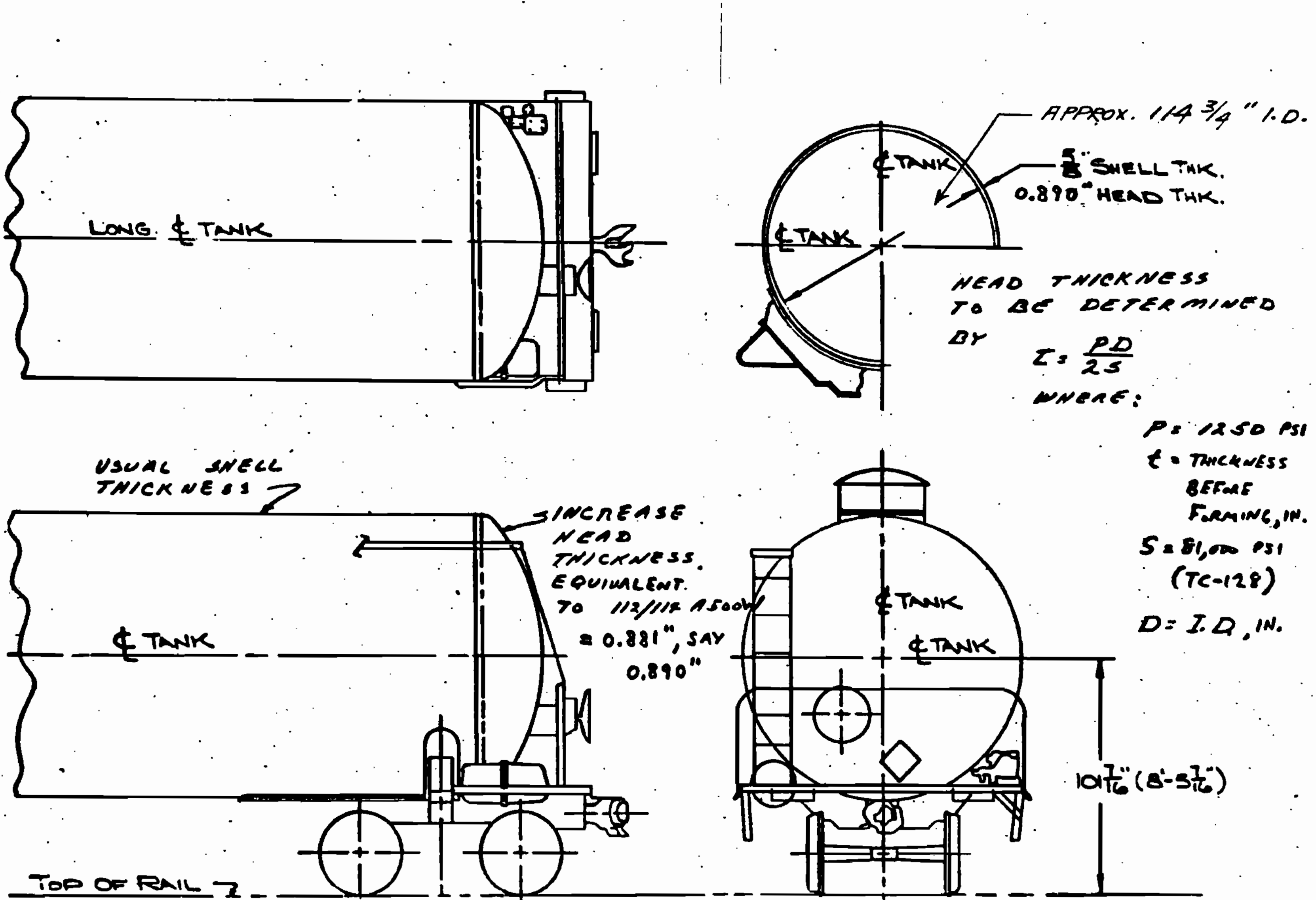
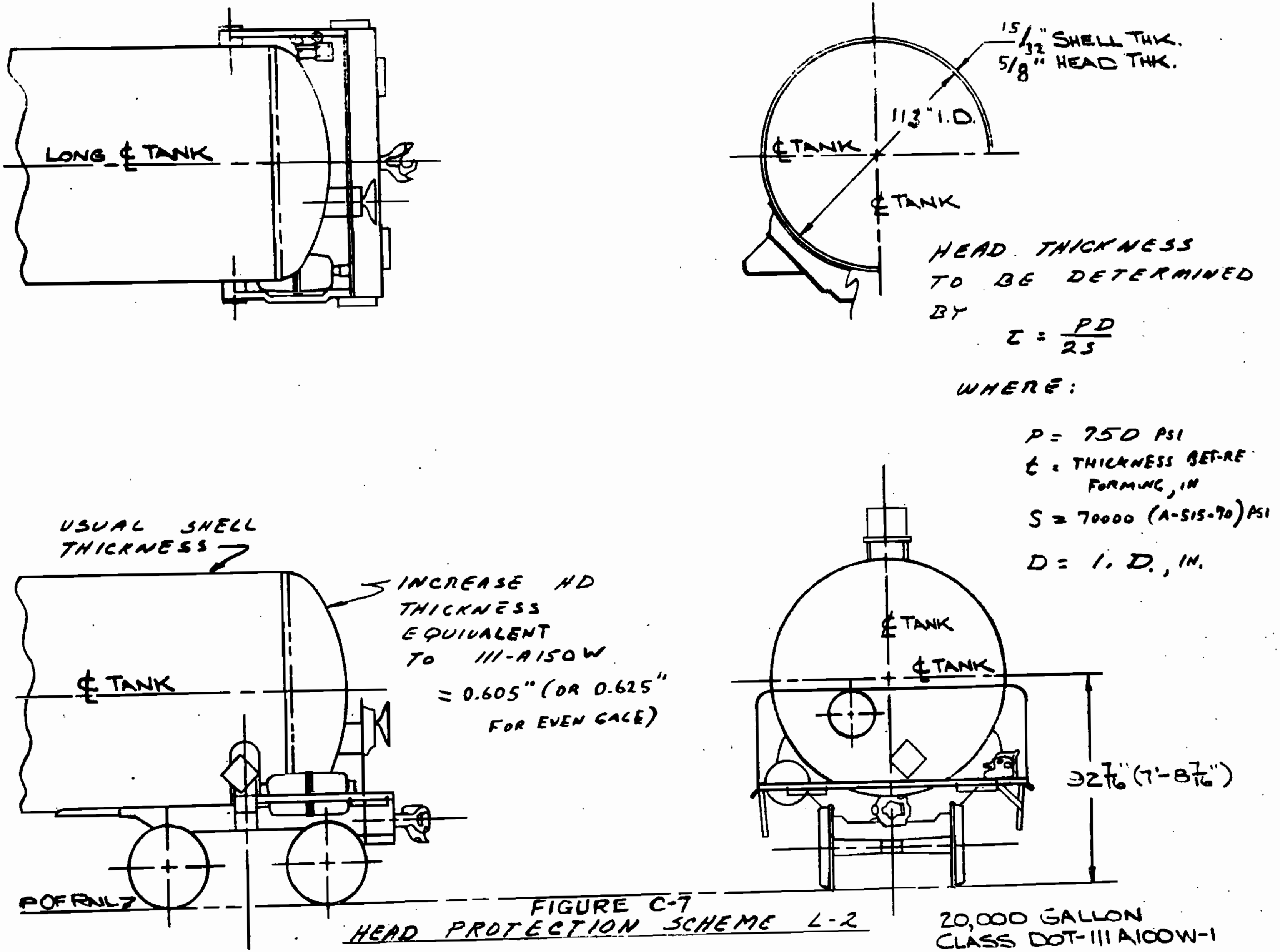


FIGURE C-6

HEAD PROTECTION SCHEME L-1

33,500 GALLON
CLASS DOT-112A340W
& 114-A



HEAD THICKNESS TO BE DETERMINED BY

$$t = \frac{PD}{2S}$$

WHERE:

P = 750 PSI
t = THICKNESS BEFORE FORMING, IN
S = 70000 (A-515-70) PSI
D = I. D., IN.

FIGURE C-7
HEAD PROTECTION SCHEME L-2

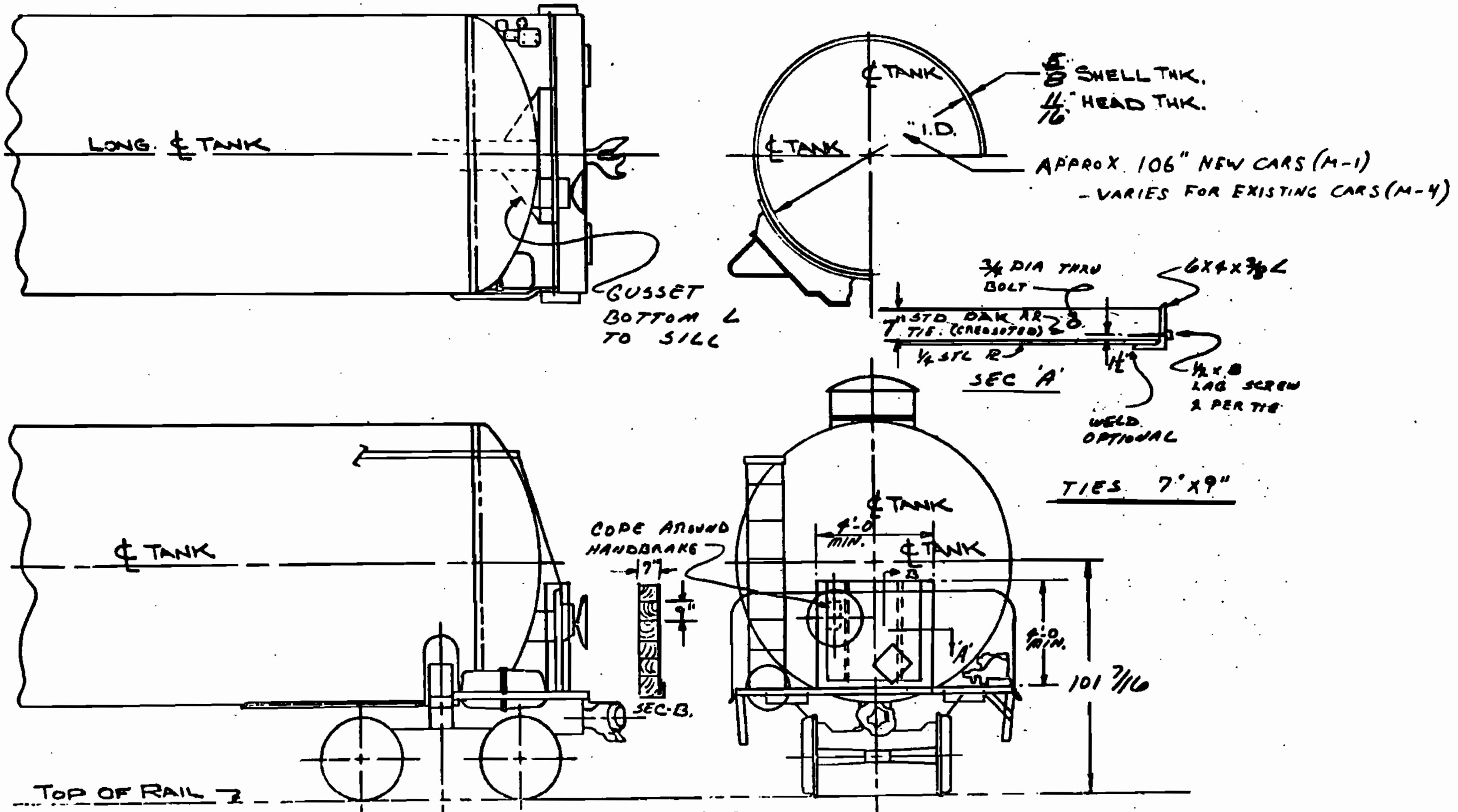


FIGURE C-8

HEAD PROTECTION SCHEME M-1 & M-4

33,500 GALL
DOT 112 A-340 W
& 112

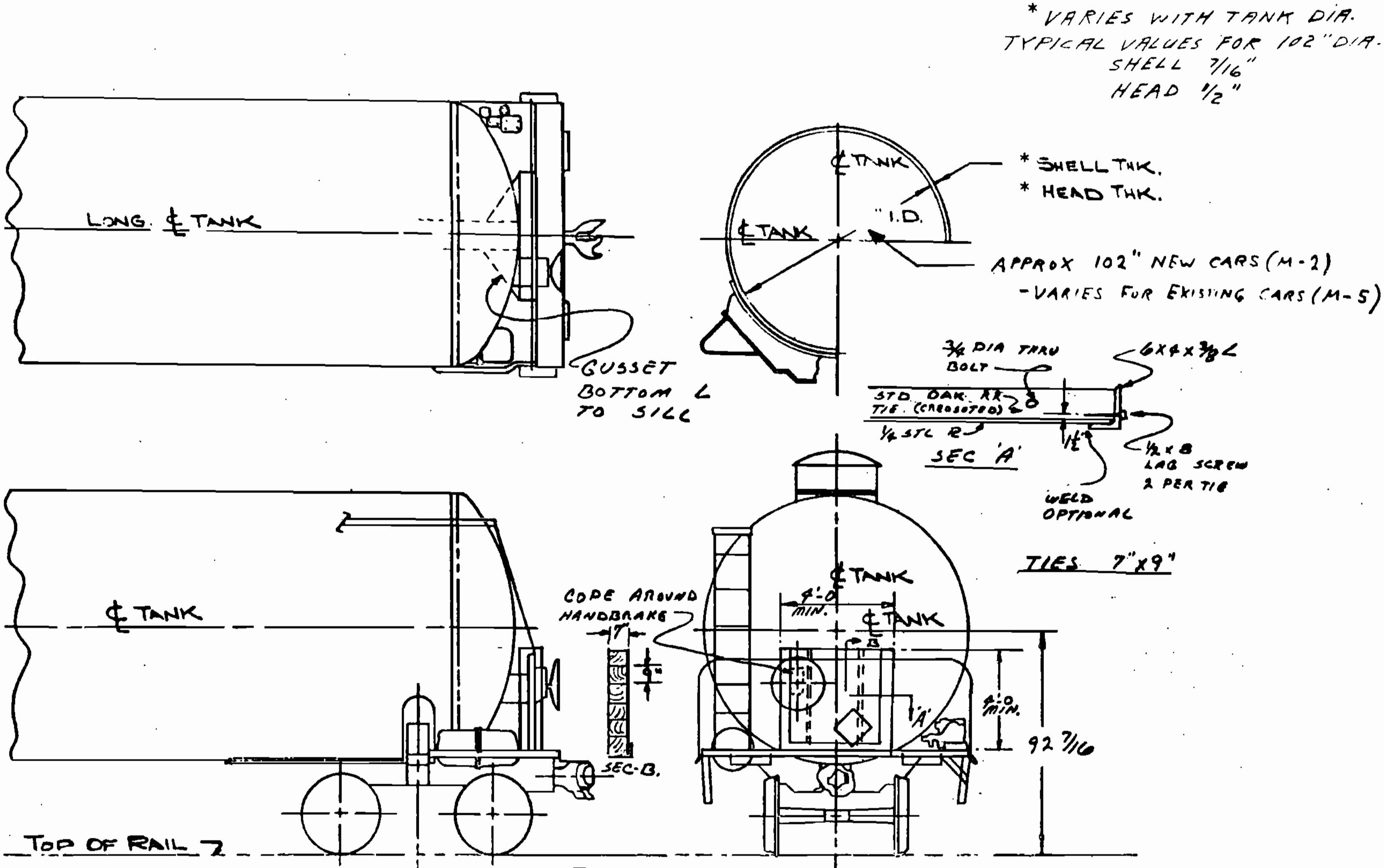


FIGURE C-9

HEAD PROTECTION SCHEME M-2 & M-5 DOT 111A100-W1

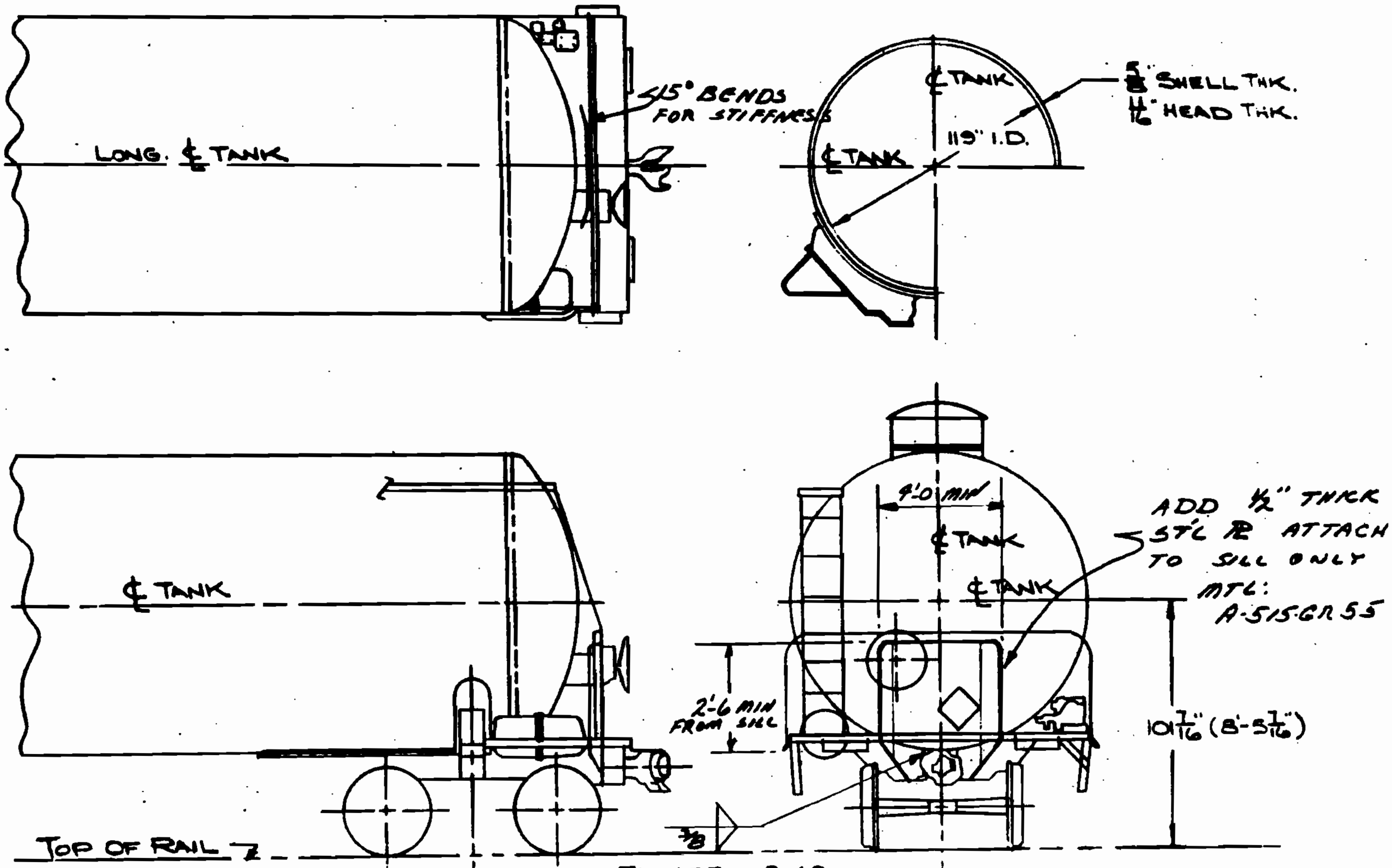


FIGURE C-10

HEAD PROTECTION SCHEME N-1 & N-4 SHOWN.
(N-2 N-3 N-5 & N-6 SIMILARILY APPLIED TO APPROPRIATE DOT CARS.)

33,500 GALLON
CLASS DOT 112A340-W

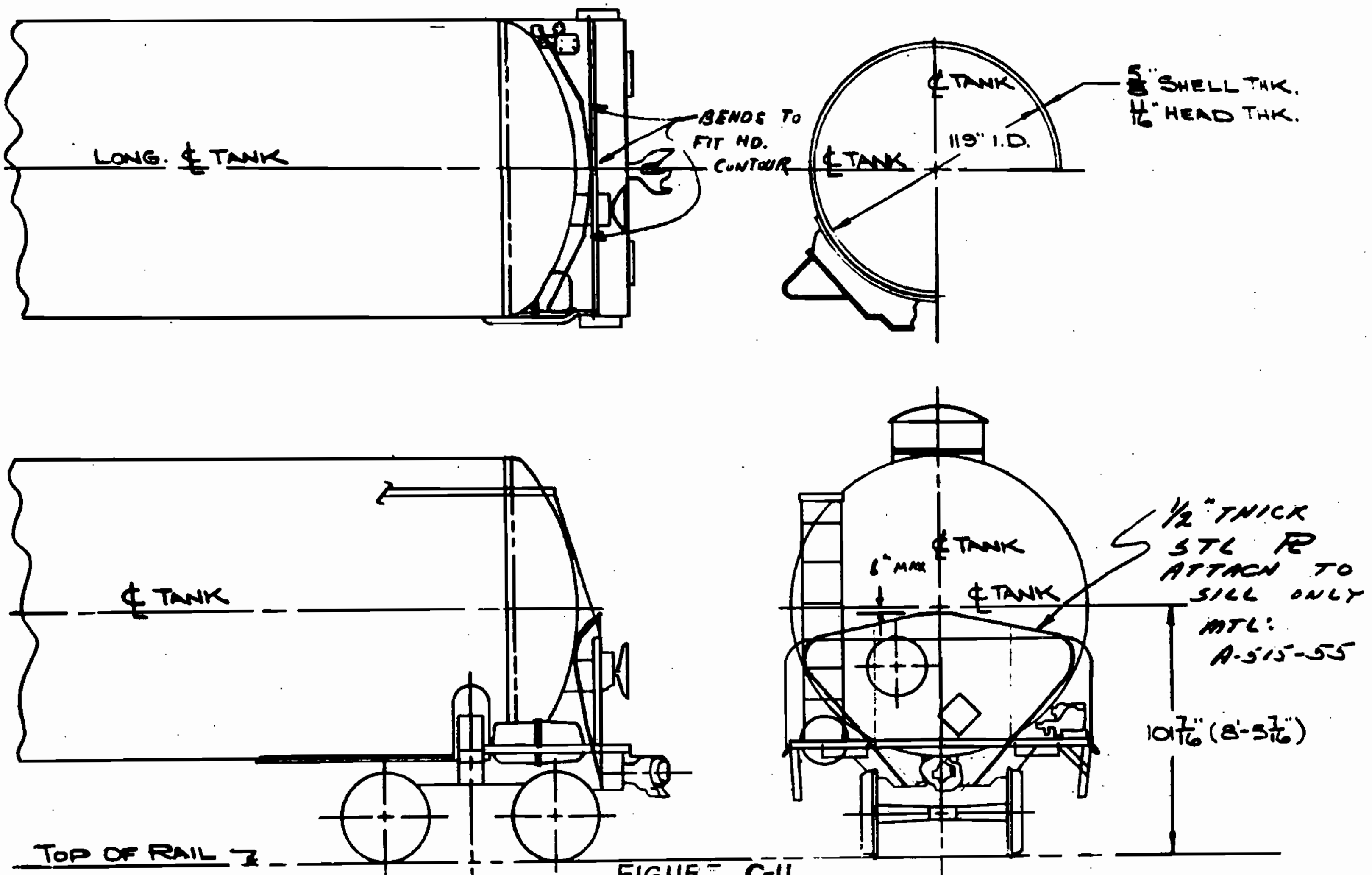


FIGURE C-11
HEAD PROTECTION SCHEME 0-1 & 0-4 SHOWN
(0-2, & 0-5 SIMILARILY APPLIED
TO APPROPRIATE DOT CARS)

33,500 GALLON
CLASS DOT-112A340-W

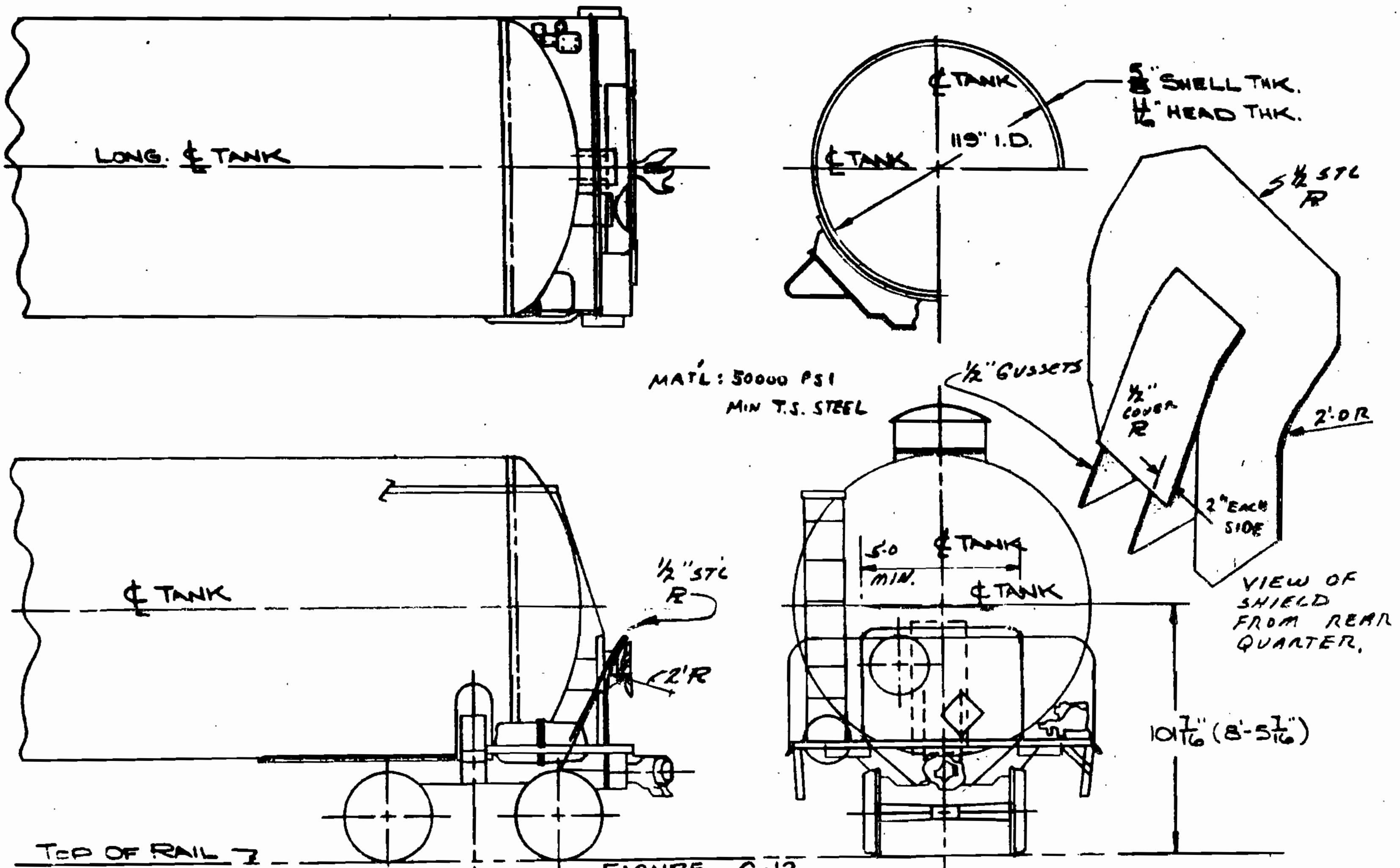


FIGURE C-12

HEAD PROTECTION SCHEME P-1 & P-4 SHOWN
(P-2 & P-5 SIMILARILY APPLIED
TO APPROPRIATE DOT CLASS CARS)

33,500 GALLON
CLASS DOT-112A340-W

through C-12. Fifteen concepts are listed which are more than the above stated remainder, but this is because some involved several variations and alternates.

Table C-2 also shows the class of car to which each would apply. For various reasons, most of which are obvious, certain concepts are not practical for certain classes of cars. For example, the addition of a second head (concept K) is not applicable for existing cars because welding on existing tank shells and heads should be avoided wherever possible. As another example, concept E applies by definition only to insulated cars; and here only new cars were considered (Class 3) since we felt that existing insulated cars (Class 6) could be protected more efficiently by other concepts. The only concepts considered feasible for existing cars were M, N, O and P which involve the attachment of a shield to the sill, but not to the head.

The design effort for these concepts were divided between four tank car builders as shown by the initials in each block in Table C-2. Note that each concept was treated by more than one company, all four in some cases, but never for an identical class car. This assured added design input while avoiding duplication.

D. Task 3.4 - Performance Specifications

1. General Considerations

Two distinct sets of specification requirements for tank car head protection devices must be considered. One relates to the test program for evaluation of prototype concepts and the other to applications on operational tank cars. The former should be primarily performance in nature and the latter primarily design in nature, with its requirements derived in great part from the prototype test program.

It would be practical, for example, to employ a performance specification in the test program which required prevention of head punctures under a certain prescribed set of conditions, but this would not be practical for devices applied for actual service. In the event of an accident, it could never be determined if the specification requirements were met.

These two sets of specifications are discussed separately below.

2. Specifications for Prototype Test Program

The objectives of a prototype test program should be to:

- establish performance requirements
- establish that selected designs meet these requirements
- establish design requirements for possible later use in regulations covering actual applications.

It is difficult at this point to derive meaningful performance requirements for the test program. This is because the "base" upon which performance is to be measured is not yet definable in precise terms. There are too many variables; and, further, the desired degree of improvement from this base is not easily determined. The problem is so complex, in fact, that numerous assumptions are required which, once made, will make the solution simple.

One performance yardstick might be based on the relative behavior of empty vs. loaded cars. As concluded in Fig. A-12, empty cars are less vulnerable to punctures from head impacts than loaded cars. We could assume the performance requirement that head protection devices reduce loaded car vulnerability to that of empty cars not equipped with head shields.

The difficulty of using this empty car criterion in the prototype test program is that empty car puncture threshold will vary with the class of car (e.g., empty pressure 112A340W car will be stronger than empty non-pressure 111A100W car, etc.). Also, we are not confident that empty car performance constitutes a sufficiently sound base. We propose a different and simpler approach as will be seen.

A second yardstick might be based on the dimensions of head dents. The threshold for puncture could be first established for, say, a loaded pressurized car. Then with the same car equipped with a candidate head protection device, an identical impact would be repeated and the dent geometry measured. If the improvement equaled or exceeded a certain value, the device would be accepted. The difficulty here is that the head device may behave in a manner which would lead to head damage, though acceptable, of an entirely different nature than a simple dent; and the correlation between the two damage conditions would be hard to define.

A third, and we feel most promising, approach is to treat the matter more philosophically as follows. Assume first that the damage received by any given car during impact increases with an increase in the speed of the impacting car (or cars) as a function of this speed raised to an exponential power n where $1 \leq n \leq 2$.

If momentum is the governing factor, then n = 1. If kinetic energy governs, then n = 2. Note that the analysis of the full scale tests given in Section II-B, Appendix B, predicted (of course, for those particular test runs only) that the depth of a dent varies with the speed of impact to the first power (n = 1) and that the force of the impact on the head varies with the speed to the 1.5 power (n = 1.5). On the other hand, the laws of conservation of energy and momentum* show that the total energy absorbed during the impact varies with the square of the speed (n = 2).

---

* See original proposal.

Consider next that two series of tests are conducted:

Test Series 1: Cars without a head protection device are impacted at increasing speeds until a speed V_p is reached that is just high enough to cause a puncture. Call D_p the damage at puncture. By our assumption, the damage D to each car will be proportional to the impact speed V raised to the nth power. Assume that in one of the lower speed tests, say at a speed V_d the damage D_d is acceptable.

Let:

$$V_d = V_p / \alpha \tag{C-1}$$

where $\alpha \geq 1$ and is simply defined as the ratio V_p/V_d

Also:

$$D_d = C V_d^n = C (V_p/\alpha)^n \tag{C-2}$$

$$D_p = C V_p^n \tag{C-3}$$

where C is a constant of proportionality.

Test Series 2: With the head shield applied to the same design car used in Test Series 1, impact the car at speed V_p. Let the performance specification be that if the resulting head damage is equal or less than the acceptable damage D_d, previously established, the shield is adequate.

During the second test the shield will be damaged an amount D_s. The total damage will be:

$$D_d + D_s = C V_p^n \; * \tag{C-4}$$

We are now done, except that it would be of interest to determine, without necessarily testing, the highest speed V_h that the car with the head shield can sustain without puncture. At this speed V_h the head will just be punctured, so its damage will be D_p, and we can characterize the shield damage by the term:

$$D_s \beta$$

where $\beta \geq 1$ is defined as a factor denoting the additional capability of the head shield to absorb damage above the speed V_p.

Total damage will be

$$D_p + D_s \beta = C V_h^n \tag{C-5}$$

Solving the equations for V_h we find

$$V_h = V_p \left(1 + \beta - \frac{\beta}{\alpha^n} \right)^{1/n} \tag{C-6}$$

Consider an example case where n = 2 (kinetic energy governs), $\beta = 1$ (shield not capable of absorbing significant additional damage above an impact speed of V_p), $\alpha = 2$, and $V_p = 16$ mph (head puncture speed without a shield). Saying that $\alpha = 2$ is equivalent to saying that an 8 mph

---

* These equations are more expressions of philosophy than exact engineering relationships.

speed produced acceptable damage without the shield. Then the speed at which puncture will occur with the shield will be, from eq. (C-6),

$$V_h = 16\left(1+1-\frac{1}{4}\right)^{1/2} \cong 16(1.3) \cong 21 \text{ mph}$$

Note the importance of β. If the shield is capable of absorbing considerable additional damage at speed V_h over that absorbed at speed V_p, then β is large. If in the above example, $\beta = 10$ then:

$$V_h = 16\left(1+10-\frac{10}{4}\right)^{1/2} \cong 16(2.9) \cong 46 \text{ mph}$$

If very little head damage is considered acceptable, V_α will be small and α large. In the above example, assume $V_\alpha \to 0$ so $\alpha \to \infty$. With $\beta = 1$, the speed at which puncture will occur with the shield will be:

$$V_h = 16\left(1+1-\frac{1}{\infty}\right)^{1/2} \cong 16(1.4) \cong 23 \text{ mph}$$

This is slightly higher than the first example where $V_h = 21$ mph because more is required of the shield.

Note further that if momentum governs (n = 1) instead of kinetic energy (n = 2), the three speeds V_h determined in the above examples become respectively:

$$V_h = 16\left(1+1-\frac{1}{2}\right) = 24 \text{ mph}$$

$$V_h = 16\left(1+10-\frac{10}{2}\right) = 96 \text{ mph}$$

$$V_h = 16\left(1+1-\frac{1}{\infty}\right) = 32 \text{ mph}$$

The 96 mph value is absurd, but this is only because of the fictitiously absurd value of 10 assumed for β. The speeds 24 and 32 are slightly higher than their counterparts of 21 and 23 because speed is not as influential when momentum governs, as would be expected.

Of interest is the fact that, except when β is large, the value selected for n does not have a very significant effect on V_h. We can probably assume a value of n = 1.5 with little deviation from reality.

3. Specifications for Applied Devices

As stated previously, most of the design specifications for applied devices can only be derived after the final selection of recommended designs is made and testing is performed. An example of one which can be stated beforehand, however is:

- The head protection device shall not be attached to both the sill and head. This is to avoid overstressing the head because of relative motion between these two components which occurs during normal and abnormal operating conditions.

It is also possible to state some performance specifications at this time:

- The head protection device shall be capable of meeting the impact test requirements of paragraph AAR . 24. 5 in the "Specifications for Tank Cars" Standard, effective January 1, 1970. The acceptance criterion shall be that the device and any supporting structure shall not exhibit visual evidence of permanent damage after each and all tests are completed. As defined in the AAR Specifications for Design, Fabrication and Construction of Freight Cars, permanent damage is that which would require the car be shopped for repairs. The object of this requirement is to assure that the device has adequate strength to remain attached and not constitute an additional hazard during normal operation.

- The head protection device should meet all of the requirements of the AAR Specifications for Design, Fabrication, and Construction of Freight Cars related to workmanship.

- While not a requirement on the device itself, the rules should require inspection of the device at interchange points to assure secure attachment.

E. Task 3. 5 - Design Finalization and Drawings

It was anticipated originally that the schedule sequence would lead to the final selection of designs under this Task 3. 5 prior to conducting the cost analysis under Task 4. It developed that the number of candidate designs, when combined with the various classes of cars, was much larger than anticipated, the total being those listed in Table C-2. Because we were able to obtain assistance from four companies simultaneously and thus handle this large number of schemes, we proceeded at this point to have drawings and cost estimates made for all 42 schemes. We then used the cost estimates as an additional guide in the final selection of designs, an activity which was transferred to Task 4 and is discussed in Appendix D.

III. DISCUSSION OF SEVERAL ALTERNATE APPROACHES TO REDUCE HEAD PUNCTURES

As stated in II - C above, concepts 4, 6 and 8 in Table C-1 are considered important and merit further discussion.

Concept No. 4 states, "Improve outside shape of E couplers - provide blunt face for impact". This was derived from the full scale impact tests where the primary mode of failure was observed to be shear around the periphery of the impacting coupler knuckle. This was accentuated along areas where the knuckle edges were relatively sharp. The rounding of these corners would reduce the stresses in these areas and raise the threshold impact speed for puncture. It is our recommendation that this matter be reviewed with coupler manufacturers. Possibly with no loss of functionality and no additional cost, these changes could be adopted as standard on all new couplers.

Concept No. 6 states, "Design interlock to prevent E coupler from rising over F coupler on tank car". The interlocking F coupler is only fully interlocking when mated with another F coupler. When the F coupler on a new tank car is mated with an E coupler, the E coupler can disengage upward and constitute a hazard to the head of the tank car. It is not feasible to change the couplers on existing cars from type E to F because of the coupler spring carrier arrangement and the difference in the key and butt design. A "modified E" coupler with a top and bottom shelf has been under development which, if applied to new tank cars and found functionally effective, would reduce the frequency of head punctures because of its ability to prevent vertical separation in either direction.

We recommend that this be pursued since, in the respect discussed, it is superior to the F coupler. Note, also, that if E couplers were equipped with bottom shelves only, vertical separation in either direction would be prevented when such couplers were mated.

Concept No. 8 states "Eliminate fittings on tank heads". The accident review data revealed several tank head ruptures which occurred adjacent to attachments. If the attachments are eliminated, then the failures can be reduced in frequency. This matter is being investigated under Phase 9 of the RPI-AAR Project.

APPENDIX D

TASK 4

COST ANALYSIS

I. INTRODUCTION

Under Task 3, 42 combinations of head protection concepts and car classes were selected. The estimated additional cost per car and the assessment of the protection capabilities of each are developed under Task 4. Under Task 1, the estimated additional cost of accidents attributable to the lack of head protection has been made. These costs, benefits, and degree of protection assessments have been combined under this Task 4 to determine the economic value of these 42 schemes.*

II. TASK ACTIVITY

A. TASK 4.1 - COST ITEM IDENTIFICATION AND CLARIFICATION

The cost estimates made include all items of cost that could be confidently estimated. Other cost items where the dollar value could not be practically assigned are discussed in general terms in this appendix.

Preliminary drawings of the 42 schemes were reviewed for ease of application to new and existing cars and to insure that there were no insoluble conflicts with existing and new car designs. This review was done before the drawings were submitted to the various tank car companies for cost estimates.

B. TASKS 4.2 & 4.3 - STRUCTURE COSTS AND APPLICATION COSTS

The same specific head protection schemes listed in Table C-2, which were assigned to the four tank car companies, ACF, GAT, UTC and NAC, for the preparation of preliminary designs and drawings were submitted to them for cost estimating. The following instructions were given:

1. Estimate the total cost for each design, including the cost of fabrication, application, overhead and markup. Do not furnish a breakdown for these categories.

2. In each case, furnish the cost that represents the differential between cars equipped with the head protection concept and cars as currently built or existing without the concept. For example, Scheme

---

* Actually, 42 plus 5 alternates were evaluated, see Table D-3.

L-1 is not to include the total cost of the thicker head, but is to cover only the added cost.

3. For new cars, assume for the quantities involved that any given design which is estimated will apply to all new cars under the particular category involved. For example, Scheme A-2 should be considered to be applied to every new non-insulated Class 111 car built.

4. For quantities relative to application of the concepts on existing cars, assume also that all existing cars of the involved category are to be equipped with the scheme, but for uniformity, assume a modification rate of 10 per week per company.

5. Provide all costs on a per car basis.

6. Do not consider the cost of maintenance, out-of-service time for existing cars, or less tangible costs such as loss of commodity carrying capacity due to the added weight of the device. These will be handled separately.

The estimated costs for these schemes as furnished by these companies are given later in Table D-3.

C. TASK 4.4 - MAINTENANCE COSTS

It is not possible to estimate quantitatively the maintenance costs of the various head protection schemes. Some judgement on this is expected from the prototype test program.

Certain preliminary conclusions can, however, be drawn. For example, only slightly increased maintenance costs (over ordinary maintenance) may be incurred with the concepts involving the addition of a jacket, thicker head or second head, whether filled with special energy absorbing material or the usual insulation or only filled with air. However, in each of these cases, the cost of repairing cars involved in minor wrecks may be increased considerably. These conclusions apply to concepts A through L.

It is expected that maintenance costs for schemes D-1 and D-2 may be further increased because these would be subjected to more than ordinary abuse by persons working on or around car.

Slightly higher costs for repairs to cars involved in minor wrecks might also be incurred with concepts M, N, O, and P unless their methods of attachment and support are evaluated properly in tests. If the design is not adequate and the device broke loose in service, then maintenance costs would be excessive, and the device would not be economically practical, not to mention the associated increase in hazard.

D. TASK 4.5 - COST AFFECTED ITEMS

None of the selected concepts involve designs which are internal to the tank shell; therefore the volumetric capacity of the cars is not affected from this standpoint. On the other hand, the addition of any of the selected concepts to a car increases the lightweight of the car, and in some cases this will, and in other cases will not, have an effect on the commodity carrying capacity of the car. This is best illustrated by the data in Table D-1 which has been developed for some typical cars of the classes involved.

As an example, if ammonia is to be shipped in a 112A340W car equipped with protective scheme A-1, the maximum filling density to avoid exceeding the rail load limit will be 60.7%. The maximum filling density allowed by DOT regulations is 57 and 58.8% for summer and winter loading respectively. Since the allowables are less than 60.7%, there would be no affect on the ammonia carrying capacity of this particular example car.

Since propane has a lower density than ammonia, the propane carrying capacity of the example car also would not be reduced.

For vinyl chloride, however, the maximum allowable filling density is 86%. This means that for the given car, every pound added by the shield will lead to a one pound reduction in carrying capacity. For new design cars there would be a tendency to affect this reduction somewhat by designing the tank slightly smaller.

With other commodities not affected by filling density regulations, the effect of the added weight on car carrying capacity must be treated separately for each. Because of the very extensive list of different commodities, it has not been practical to tabulate these effects for each one.

In any event, it is clear that it is very important to keep the light weight of the protective shield to a minimum. This will help minimize increases in shipping costs associated with smaller containers.

TABLE D - 1

EFFECT OF HEAD PROTECTION SCHEME ON CAR CARRYING CAPACITY

Class of Car	Head Shield Scheme	Shell Capacity Gallons	Max. Gross Wt. x 1000 Lbs.	Light Weight Lbs.	Shield Weight Lbs.	Max. Effective Commodity Lbs. B - C - D	Max. Effective Commodity Gals. 0.98 x A	Max. Filling Density H/8.328	Max. Weight Per Gal. E/A(or F)
		A	B	C	D	E	F	G	H
112A340W	None	33687	263	84700	0	178300		.635	5.29
112A340W	A-1	33687	263	84700	8000	170300		.607	5.06
111A100W1	None	20850	263	58700	0	204300	20433	1.200	9.99
111A100W1	A-2	20850	263	58700	10600	193700	20433	1.140	9.48
111A100W1	A-2-1	20850	263	58700	11000	193300	20433	1.140	9.46
112A340W1	B-1	33687	263	84700	2720	175580		.625	5.21
112A340W1	B-1-1	33687	263	84700	1800	176500		.629	5.24
111A100W1	B-2	20850	263	58700	3550	200750	20433	1.180	9.82
111A100W1	B-2-1	28850	263	58700	2240	202060	20433	1.190	9.89
112A340W1	C-1	33687	263	84700	2060	176240		.628	5.23
112A340W1	C-1-1	33687	263	84700	1600	176700		.630	5.25
111A100W1	C-2	20850	263	58700	2610	201690	20433	1.185	9.87
111A100W1	C-2-1	20850	263	58700	1960	202340	20433	1.190	9.90
112A340W	D-1	33687	263	84700	1450	176850		.630	5.25
111A100W1	D-2	20850	263	58700	1160	203140	20433	1.190	9.94
111A100W1	None	20850	263	68600	0	194400	20433	1.140	9.51
111A100W1	E-3	20850	263	68600	1900	192500	20433	1.130	9.42
105A500W	None	17369	263	81200	0	181800		1.256	10.47
105A500W	E-3	17369	263	81200	1960	197840		1.243	10.35
111A100W1	F-3	20850	263	68600	950	193450	20433	1.137	9.46
105A500W	F-3	17369	263	81200	980	180820		1.250	10.41
111A100W1	G-3	20850	263	68600	660	193740	20433	1.140	9.48

TABLE D - 1- cont'd.

Class of Car	Head Shield Scheme	Shell Capacity Gallons	Max. Gross Wt. x 1000 Lbs.	Light Weight Lbs.	Shield Weight Lbs.	Max. Effective Commodity Lbs. B - C - D	Max. Effective Commodity Gals.	0.98 x A Max. Filling Density H/8.328	Max. Weight Per Gal. E/A(or F)
		A	B	C	D	E	F	G	H
105A500W	G-3	17369	263	81200	690	181110		1.252	10.43
111A100W1	H-3	20850	263	68600	330	194070	20433	1.140	9.50
105A500W	H-3	17369	263	81200	340	181460		1.254	10.45
111A100W1	J-3 11ga	20850	263	68600	1650	192750	20433	1.133	9.44
111A100W1	J-3 3/16	20850	263	68600	1240	193160	20433	1.135	9.45
105A500W	J-3	17369	263	81200	1725	180075		1.244	10.37
112A340W	K-1	33687	263	84700	4260	174040		.620	5.17
111A100W1	K-2	20850	263	58700	3060	201240	20433	1.183	9.85
112A340W	L-1	33687	263	84700	2740	175560		.626	5.20
111A100W1	L-2	20850	263	58700	1080	203220	20433	1.194	9.94
112A340W	M-1	33687	263	84700	1960	176340		.628	5.23
111A100W1	M-2	20850	263	58700	2650	201650	20433	1.185	9.87
112A340W	M-4	32870	263	97700	1700	163600		.597	4.98
111A100W1	M-5	20850	263	58700	1760	202540	20433	1.190	9.91
112A340W	N-1	33687	263	84700	675	177625		.633	5.27
111A100W1	N-2	20850	263	58700	700	203600	20433	1.196	9.96
111A100W1	N-3	20850	263	68600	740	193660	20433	1.140	9.48
105A500W	N-3	17369	263	81200	670	181130		1.252	10.43
112A340W	N-4	32870	263	97700	675	164625		.601	5.01
111A100W1	N-5	20850	263	58700	875	203425	20433	11.954	9.96
111A100W1	N-6	20850	263	68600	580	193820	20433	11.162	9.30

TABLE D-1 — concl'd.

Class of Car	Head Shield Scheme	Shell Capacity Gallons	Max. Gross. Wt. x 1000 Lbs.	Light Weight Lbs.	Shield Weight Lbs.	Max. Effective Commodity Lbs. B - C - D	Max. Effective Commodity Gals. 0.98 x A	Max. Filling Density H/8.328	Max. Weight Per Gal. E/A(or F)
		A	B	C	D	E	F	G	H
105A500W1	N-6	17369	263	81200	670	181130		1.252	10.43
112A340W	O-1	33687	263	84700	1355	176945		.631	5.25
111A100W1	O-2	20850	263	58700	1040	203260	20433	1.194	9.95
112A340W	O-4	32870	263	97700	1500	163800		.598	4.98
111A100W1	O-5	20850	263	58700	1120	203180	20433	1.194	9.94
112A340W	P-1	33687	263	84700	1200	177100		.631	5.26
111A100W1	P-2	20850	263	58700	940	203360	20433	1.195	9.95
112A340W	P-4	32870	263	97700	1210	164090		.599	4.99
111A100W1	P-5	20850	263	58700	890	203410	20433	1.195	9.95

In the case of existing cars, the addition of the protective shielding should be done when the cars are in shops for other work or testing so that out of service costs will be minimized. This is essential, since, for the head shielding alone, it is estimated that the required out of service time would be typically 30 days or more to: shop the cars, clean the interiors if necessary; place the cars in the production line; apply the head shielding and return the cars to service. Other expenses involved in modifying existing cars include, for example, the cost to clean the car interior ($60.00 per car and up) and switching charges (typically, $10 to $30 per switch).

E. TASK 4.6 - COST/BENEFIT ANALYSIS

The economic benefit that can be expected from the application of a head shield to a tank car is equal to the total expected reduction in costs over the life of the car discounted to present value minus the cost of the application of the head shield. In this analysis it is assumed, nor is it practical to do otherwise, that no correlation exists between the location of a head puncture (on the head surface) and the loss due to the puncture. The following relationship is used:

$$V = (L-M) \cdot E_A \cdot (R \cdot E^*) \cdot (1-E_O) \cdot \frac{e^{rt} - 1}{re^{rt}} - C \quad \text{(Eq. D-1)}$$

Where: V = Present economic value of the head shield.

L = Estimated annual losses from head punctures per car due to absence of head shield.

M = Added maintenance cost of head shield, per car, per year.

E_A = Area effectiveness of head shield (number of expected punctures within area protected by head shield divided by total expected punctures over head).

$R \cdot E^*$ = Mechanical effectiveness of head shield where E^* is the ratio of punctures which would be prevented by a 1/2" thick steel shield covering the entire head to the total expected with no shield, and R = estimated mechanical efficiency of the proposed design compared to a 1/2" steel shield.

E_O = Effectiveness toward reducing frequency of head punctures due to changes other than application of head shields (e.g. interlocking couplers, lower train speeds, etc.).

C = Estimated additional cost of applying head shield. The term $\frac{e^{rt} - 1}{re^{rt}}$ = annuity factor discounting a uniform stream cash flow to present value where r = annual rate of return on investment.

t = Years of cash flow (expected remaining service life of car).

e = Base of natural logarithums.

Calculation of Estimated Annual Losses: L

The calculation of estimated annual losses is summarized in Table D-2 below:

TABLE D-2

ESTIMATED ANNUAL LOSSES BY CLASS OF CAR

	Riveted Steel	103W, 111A-W Insulated	103W, 111A-W Non. Ins.	105A	112A 114A	Other
Total loss due to head punctures 1965-1970 (Tables A-3 through A-8)	$123,100	$351,900	$1,073,730	$255,200	$3,785,000	$44,150
Average total loss/year	20,517	58,650	178,955	42,533	630,830	7,358
Average number of cars in service 1965-1970 (Table A-9)	52,500	21,000	49,000	39,000	12,000	6,500
Average loss/car/year	$ .39	$2.79	$3.65	$1.09	$52.57	$1.13

Estimate of Maintenance Costs: M

Maintenance costs are discussed previously in this appendix. We will take the conservative approach in the following analysis of assuming that the addition of a head shield will not increase maintenance costs.

Estimate of Area Effectiveness: E_A

The area effectiveness of each head protection scheme was calculated by overlaying each design over the appropriate puncture location plots shown in Figures A-2, A-3 and A-5. The ratio of the punctures covered to the total was to be taken to be the area effectiveness, E_A.

Because of scarcity of data on Class 105 cars, the distribution of head punctures for these cars was assumed to be the same as for non-pressure welded cars.

The calculated area effectiveness for each design is summarized in Table D-3.

Estimate of Mechanical Effectiveness of Head Shield: $R \cdot E^*$

No absolute values of the effectiveness of any design can be estimated without considerable experimental effort. However, by conservatively assuming that $E^* = 1$, the relative effectiveness of each design can be estimated with a fair degree of confidence.

In assessing steel plate or sheet thinner than 1/2", the assumption is made that the effectiveness is directly proportional to thickness, and this is supported somewhat by tests. The assumptions as to the effectiveness of materials other than steel had not been verified, and true values would have to be determined in tests.

Our assumed effectiveness values for the various materials (compared to 1/2" steel plate) are as follows:

A.	Sand	35%
B.	20 lb. foam	60%
C.	6 lb. foam	15%
D.	Cork	15%
E.	Railroad track ties	60%
F.	Steel sheet or plate	thickness x 100 divided by 1/2"

The calculation of the relative protection afforded, $E_A \cdot R$, for each head protection scheme is summarized in Table D-3. Where the total head protection is the result of contributions by several components of designs, the effectiveness of the individual components is assumed to be additive with each weighted by its own area effectiveness.

Primary shield protection in Table D-3 refers to that part of the shielding device that is intended to provide the major portion of the head protection.

Secondary shield protection in Table D-3 refers to that part of the shielding device that is essential to the device or car and which provides a significant amount of head protection. This would include the jacket of an insulated car or one placed over a shielding material.

TABLE D-3

ECONOMIC VALUE CALCULATION FOR THE PROPOSED HEAD SHIELD DESIGNS

			HEAD SHIELD PROTECTION										
			Primary		Secondary					LxD	ExB	F-C	C/F
Scheme --- Type Car Description	Estimated Added Cost		% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Af'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$	Loss $/year	Annuity Factor	Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
A-1 --- New 112, 114 **Press.** **Add full** 11 gage **steel jacket over tank** heads only. **Fill/sand.**	$ 780	8,000	35	1.00	25	1.00	.60	$ 52.57	9.5	$ 500.	$ 300.	$ -480	2.60
A-2 --- New 111 **Non-Insl. Add full** 11 gage **steel jacket over tank** heads only. **Fill/sand.**	560	10,000	35	1.00	25	1.00	.60	3.65	9.5	34.68	20.81	-539.19	26.9
A-2-1 --- New 111 **non-insl. Add full** 7 gage **steel jacket over tank** heads only. **Fill/sand.**	650	11,000	35	1.00	37	1.00	.72	3.65	9.5	34.68	24.97	-625.03	26.0
B-1 --- New 112, 114 **Press. Add full** 11 gage **steel jacket over tank heads only. Fill with 20 lb. foam.**	1800	2,720	60	1.00	25	1.00	.85	52.57	9.5	500.	425	-1375.	4.24
B-1-1 --- New 112, 114 **Press. Add full 11 gage steel jacket over tank** heads only. **Fill with 6 lb. foam.**	1115	1,800	15	1.00	25	1.00	.40	52.57	9.5	500.	200.	-915.	5.6

TABLE D-3 - cont'd.

			SHIELD PROTECTION										
			Primary		Secondary					LxD	ExB	F-C	C/F
Scheme --- Type Car Description	Estimated Added Cost	Added Weight	% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $\frac{R_1 \times E_{A1}}{+ R_2 \times E_{A2}}$	Loss $/year	Annuity Factor	Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
B-2 --- New 111 Non-insl. Add full 11 gage steel jacket over tank heads only. Fill with 20 lb. foam.	$ 1690	3,550	60	1.00	25	1.00	.85	$ 3.65	9.5	$ 34.68	$ 29.48	$ -1660.52	57.3
B-2-1 --- New 111 non-insl. Add full 11 gage steel jacket over tank heads only. Fill with 6 lb. foam.	1070	2,240	15	1.00	25	1.00	.40	3.65	9.5	34.68	13.87	-1056.13	77.1
C-1 --- New 112,114 Press. Add full 11 gage steel jacket over tank head only. Fill lower half with 20 lb. foam.	1280	2,060	60	.92	25	1.00	.80	52.57	9.5	500.	400.	-880	3.2
C-1-1 --- New 112,114 Press. Add full 11 gage steel jacket over tank heads only. Fill lower half with 6 lb. foam.	960	1,600	15	.92	25	1.00	.39	52.57	9.5	500.	195.	-765	4.92

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F-C	C/F
			Primary		Secondary								
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$			Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
C-2 --- New 111 Non-insl. Add full 11 gage steel jacket over tank heads only. Fill lowere half with 20 lb. foam.	$ 1270	2,610	60	.82	25	1.00	.74	$ 3.65	9.5	$ 34.68	$ 25.66	$ -1244.34	49.5
C-2-1 -- New 111 Non-Insl. Add full 11 gage steel jacket over tank heads only. Fill lower half with 6 lb. foam.	840	1,960	15	.82	25	1.00	.37	3.65	9.5	34.68	12.83	-827.17	65.5
D-1 --- New 112, 114 Press. Add 120 sector of 7 gage steel jacket covering lower portion of tank head, symmetrical to vertical center line, & with Apex at center of head. Fill with 20 lb. foam.	1090	1,450	60	.82	37	.82	.80	52.57	9.5	500.	400.	-690	2.72

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION							LxD	ExB	F-C	C/F
			Primary		Secondary								
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $\frac{R_1 \times E_{A1}}{R_2 \times E_{A2}}$	Loss $/year	Annuity Factor	Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
D-2 --- New 111 Non-Insl. Add 120 sector of 7 gage steel jacket covering lower portion of tank head, symmetrical to vertical center line and with Apex at center of head. Fill with 20 lb. foam.	$ 915	1,160	60	.74	37	.74	.71	$ 3.65	9.5	$ 34.68	$ 24.62	$ -890.38	37.2
E-3 --- New 111 Insl. Substitute 20 lb. foam for usual insualtion between jacket and tank head.	1550	1,900	60	1.00	19	1.00	.79	2.79	9.5	26.51	15.91*	-1534.09	97.4
E-3 --- New 105 Insl. Substitute 20 lb. foam for usual insulation between jacket and tank head.	1890	1,960	60	1.00	19	1.00	.79	1.09	9.5	10.36	6.22	-1883.78	304.

* Benefit of head shield on insulated cars is based on the additional relative protection of the shield ($R_1 \times E_{A1}$). The protection afforded by the jacket is reflected in the loss, L.

TABLE D-3 - cont'd.

Scheme --- Type Car Description			SHIELD PROTECTION							LxD	ExB	F-C	C/F
			Primary		Secondary								
	Estimated Added Cost	Added Weight	% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$	Loss $/year	Annuity Factor	Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
F-3 --- New 111 Insl. Substitute 20 lb. foam for usual insualtion in lower half of space between jacket & tank heads. Usual insulation to be used in upper half.	$ 810	950	60	.82	19	1.00	.68	$ 2.79	9.5	$ 26.51	$ 13.04*	$ -796.96	62.1
F-3 --- New 105 Insul. Substitute 20 lb. foam for usual insulation in lower half of space between jacket & tank heads. Usual insulation to be used in upper half.	1120	980	60	.82	19	1.00	.68	1.09	9.5	10.36	5.10*	-1114.90	220.
G-3 --- New 111 Insl. Substitute Cork Insulation for usual insulation between jacket and tank head.	280	660	15	1.00	19	1.00	.34	2.79	9.5	26.51	3.98*	-276.02	70.4

* Benefit of head shield on insulated cars is based on the additional relative portection of the shield ($R_1 \times E_{A1}$). The protection afforded by the jacket is reflected in the loss, L.

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F - C	C/F
			Primary		Secondary								
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$			Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
G-3 --- New 105 Insl. Substitute Cork Insulation for usual insulation between jacket and tank head.	$ 540	690	15	1.00	19	1.00	.34	$ 1.09	9.5	$ 10.36	$ 1.55*	$ -538.45	348.
H-3 --- New 111 Insl. Substitute cork for usual insulation in lower half of space between jacket & tank head. Usual insulation to be used in upper half.	140	330	15	.82	19	1.00	.31	2.79	9.5	26.51	3.26*	-136.74	42.9
H-3 --- New 105 Insl. Substitute cork for usual insulation in lower half of space between jacket & tank head. Usual insulation to be used in upper half.	450	340	15	.82	19	1.00	.31	1.09	9.5	10.36	1.27*	-448.73	354.

* Benefit of head shield on insulated cars is based on the additional relative protection of the shield ($R_1 \times E_{A1}$). The protection afforded by the jacket is reflected in the loss, L.

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F-C	C/F
			Primary		Secondary					Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$						
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
	$							$		$	$	$	
J-3 --- New 111 Insl. Substitute 3/8" jacket for 11 gage jacket, over tank heads only.	270	1650	75	1.00	-	-	.75	2.79	9.5	26.51	13.26**	-256.74	20.4
J-3 ---- New 105 Insl. Substitute 3/8" jacket for 11 gage jacket, over tank heads only.	295	1725	75	1.00	-	-	.75	1.09	9.5	10.36	5.18*	-289.82	56.9
K-1 --- New 112, 114 Press. Build tank with two heads on each end, with air space between, second head to be 7/16".	1110	4260	87	1.00	-	-	.87	52.57	9.5	500.	435.	-675	2.55
K-2 --- New 111 Non-Insl. Build tank with two heads on each end, with air space between -- second head to be 7/16".	732	3060	87	1.00	-	-	.87	3.65	9.5	34.68	30.17	-701.83	24.3

* Benefit of head shield on insulated cars is based on the additional relative protection of the shield ($R \times E_{A1}$). The benefit is adjusted for the contribution of a 1/8" thick steel jacket which is reflected in the loss, L.

** Benefit adjusted for contribution of 1/3" thick jacket.

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F-C	C/F
			Primary		Secondary					Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$						
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
L-1 --- New 112, 114 Press. Increase head thickness by approx. 40% to .890".	$ 525	2740	55	1.00	-	-	.55	$ 52.57	9.5	$ 500.	$ 275.	$ -250	1.91
L-2 ---- New 111 Non-Insl. Increase head thickness by approx. 33% to 0.625".	190	1080	31	1.00	-	-	.31	3.65	9.5	34.68	10.75	-179.25	17.7
M-1 --- New 112, 114 Press. Add wood tie assembly in front of but not attached to tank heads.	460	1960	60	.69	-	-	.41	52.57	9.5	500.	205	-255	2.24
M-2 --- New 111 Non - Insl. Add wood tie assembly in front of but not attached to tank heads.	195	2650	60	.42	-	-	.25	3.65	9.5	34.68	8.67	-186.33	22.5
M-4 --- Exist 112, 114 Add wood tie assembly in front of but not attached to tank heads.	305	1700	60	.69	-	-	.41	52.57	9.5	500.	205.	-100	1.49

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F-C	C/F
			Primary		Secondary					Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$						
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
M-5 --- Exist. 111 Non-Insl. Add wood tie assembly in front of but not attached to tank heads.	$ 345	1760	60	.42	-	-	.25	$ 3.65	9.5	$ 34.68	$ 8.67	$ -336.33	39.8
N-1 --- New 112, 114 Press. Add 1/2" steel plate assembly in front of tank head but not attached to head.	200	675	100	.55	--	-	.55	52.57	9.5	500.	275.	75.	.73
N-2 --- New 111 Non-Insl. Add 1/2" steel plate assembly in front of tank head but not attached to head.	140	700	100	.41	-	-	.41	3.65	9.5	34.68	14.22	-125.78	9.85
N-3 --- New 111 Insl. Add 1/2" steel plate assembly in front of tank head but not attached to head.	285	740	100	.38	41	1.00	.79	2.79	9.5	26.51	10.07*	-274.93	28.3

* Benefit of head shield on insulated cars is based on the additional relative protection of the shield ($R_1 \times E_{A1}$). The protection afforded by the jacket is reflected in the loss, L.

TABLE D-3 - cont'd.

			SHIELD PROTECTION										
			Primary		Secondary					LxD	ExB	F-C	C/F
Scheme --- Type Car Description	Estimated Added Cost	Added Weight	% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$	Loss $/year	Annuity Factor	Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
N-3 --- New 105 Insl. Add 1/2" steel plate assembly in front of tank head but not attached to head.	$ 270	670	100	.41	41	1.00	.82	$ 1.09	9.5	$ 10.36	$ 4.25*	$ -265.75	63.5
N-4 --- Exist. 112 Press. Add 1/2" steel plate assembly in front of but not attached to head.	350	675	100	.55	-	-	.55	52.57	9.5	500.	275.	-75	1.27
N-5 --- Exist. 111 Non-Insl. Add 1/2" steel plate assembly in front of but attached to head.	175	875	100	.41	-	-	.41	3.65	9.5	34.68	14.22	-160.78	12.3
N-6 --- Exist. 111 Insl. Add 1/2" steel plate assembly in front of but not attached to head.	200	580	100	.38	41	1.00	.79	2.79	9.5	26.51	10.07*	-189.93	19.9

* Benefit of head shield on insulated cars is based on the additional relative protection of the shield ($R_1 \times E_{A1}$). The protection afforded by the jacket is reflected in the loss, L.

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F-C	C/F
			Primary		Secondary								
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$			Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
N-6 --- Exist. 105 Insl. Add 1/2" steel plate assembly in front of but not attached to head.	$ 240	670	100	.41	41	1.00	.82	$ 1.09	9.5	$ 10.36	$ 4.25 *	$ -235.75	56.5
O-1 --- New 112 & 114 Press. Add 1/2" vertical steel plate assembly "butterfly" design	430	1355	100	.85	-	-	.85	52.57	9.5	500.	425.	-5	1.01
O-2 --- New 111 Non-Insl. Add 1/2" vertical steel plate assembly "butterfly" design	400	1040	100	.71	-	-	.71	3.65	9.5	34.68	24.62	-375.38	16.2
O-4 --- Exist. 112 & 114 Pres. Add 1/2" vertical steel plate assembly "butterfly" design	500	1500	100	.85	-	-	.85	52.57	9.5	500.	425.	-75	1.18

* Benefit of head shield on insulated cars is based on the additional relative protection of the shield $(R \times E_{A1})$. The protection afforded by the jacket is reflected in the loss, L.

TABLE D-3 - cont'd.

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION					Loss $/year	Annuity Factor	LxD	ExB	F-C	C/F
			Primary		Secondary					Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$						
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
O-5 --- Exist. 111 Non-Insl. Add 1/2" vertical steel plate assembly "butterfly"design	$ 355	1120	100	.71	-	-	.71	$ 3.65	9.5	$ 34.68	$ 24.62	$ -330.38	14.4
P-1 --- New 112 & 114 Press. Add 1/2" vertical steel plate assembly with horizontal bend lines.	280	1200	100	.77	-	-	.77	52.57	9.5	500.	385.	105.	.73
P-2 --- New 111Non-Insl. Non-Press Add 1/2" vertical steel plate assembly with horizontal bend lines.	225	940	100	.56	-	-	.56	3.65	9.5	34.68	19.42	-205.58	11.6
P-4 --- Exist 112 & 114 Press. Add 1/2" vertical steel plate assembly / horizontal bend lines	335	1210	100	.77	-	-	.77	52.57	9.5	500	385.	50	.87

TABLE D-3 - concl'd,

Scheme --- Type Car Description	Estimated Added Cost	Added Weight	SHIELD PROTECTION							LxD	ExB	F-C	C/F
			Primary		Secondary								
			% Effective	Fraction of Puncture	% Effective	Fraction of Puncture	Relative Prot. Aff'd. $R_1 \times E_{A1} + R_2 \times E_{A2}$	Loss $/year	Annuity Factor	Benefit if 100% effective	Benefit of this design	Value of this design	Cost/Benefit Ratio
	C		R_1	E_{A1}	R_2	E_{A2}	B	L	D	E	F		
P-5 --- Exist. 111 Non-Insl. Non-Press. Add 1/2" vertical steel plate assembly with horizontal bend lines.	$ 405	890	100	.56	-	-	.56	$ 3.65	9.5	$ 34.68	$ 19.42	$ -385.58	20.9

Estimate of Reduction of Head Punctures from Changes Other Than Application of Head Shields: E_O

It is possible that the incidence of head punctures will decrease in the future even if no head shields are applied due to the use of interlocking couplers on new tank cars and because of a general reduction in number and severity of accidents due to changes in operating practices by the railroads. However, this analysis will conservatively assume that no such improvement will occur and that therefore $E_O = O$.

Calculation of Annuity Factor:

Assume: Annual rate of return on investment r = 10%

New Car life = 30 years

Existing welded car life = 30 years (This simplification may not only be realistic, but has little effect on the results since the annuity factor does not drop off rapidly until remaining life becomes low, see Table D-4)

Table D-4 lists the results of this calculation for various economic lives

TABLE D-4

Annuity Factors

Remaining Life	Annuity Factor
30	9.5
25	9.2
20	8.6
15	7.8
10	6.3
5	3.9
0	0

Estimate of Cost of Application of Head Shield: C

The cost estimates for each head protection scheme are given in Table D-3. These costs reflect only the direct cost of the shield and its application as would be incurred by a shipper-owner. The other less tangible costs discussed previously in this appendix are assumed to be zero. Apparent cost discrepancies between similar designs applied to different classes of cars are due to the fact that each was treated by a different company with associated variations in car design and engineering, estimating, fabrication and other policies. We did not attempt to rectify or explain these variances because of the large number of head shield schemes involved and because of knowing that only a few could be considered in the final analysis.

III. DETAILED DRAWINGS OF OPTIMUM HEAD PROTECTION SCHEMES

Detailed drawings have been made of those head protection schemes which have the most attractive economic values for each class of car. These are given in Figures D-1 through D-10 and are referred to in the summary under IV B below.

IV. DISCUSSION

A. Comments on all Schemes

Many of the head protection schemes that were subjected to the cost/benefit analysis have specific features that are or may be undesirable. Discussion of real and potentially undesirable features that can be recognized prior to actual testing of the devices is included in the following comments:

Schemes A-1, A-2, A-2-1 Sand is employed in these schemes as the energy absorber, filling the space between the tank head and a steel jacket. Because the density of sand is high, the weight added to the car in each case is considerable, and this would result in a large loss in carrying capacity for most commodities. Sand also presents a potential problem in that a small hole in the jacket near its bottom would permit leakage, resulting in a considerable loss in head protection. Such a hole could exist for a long period before discovery. Further, none of these head protection schemes is justified on a cost/benefit basis.

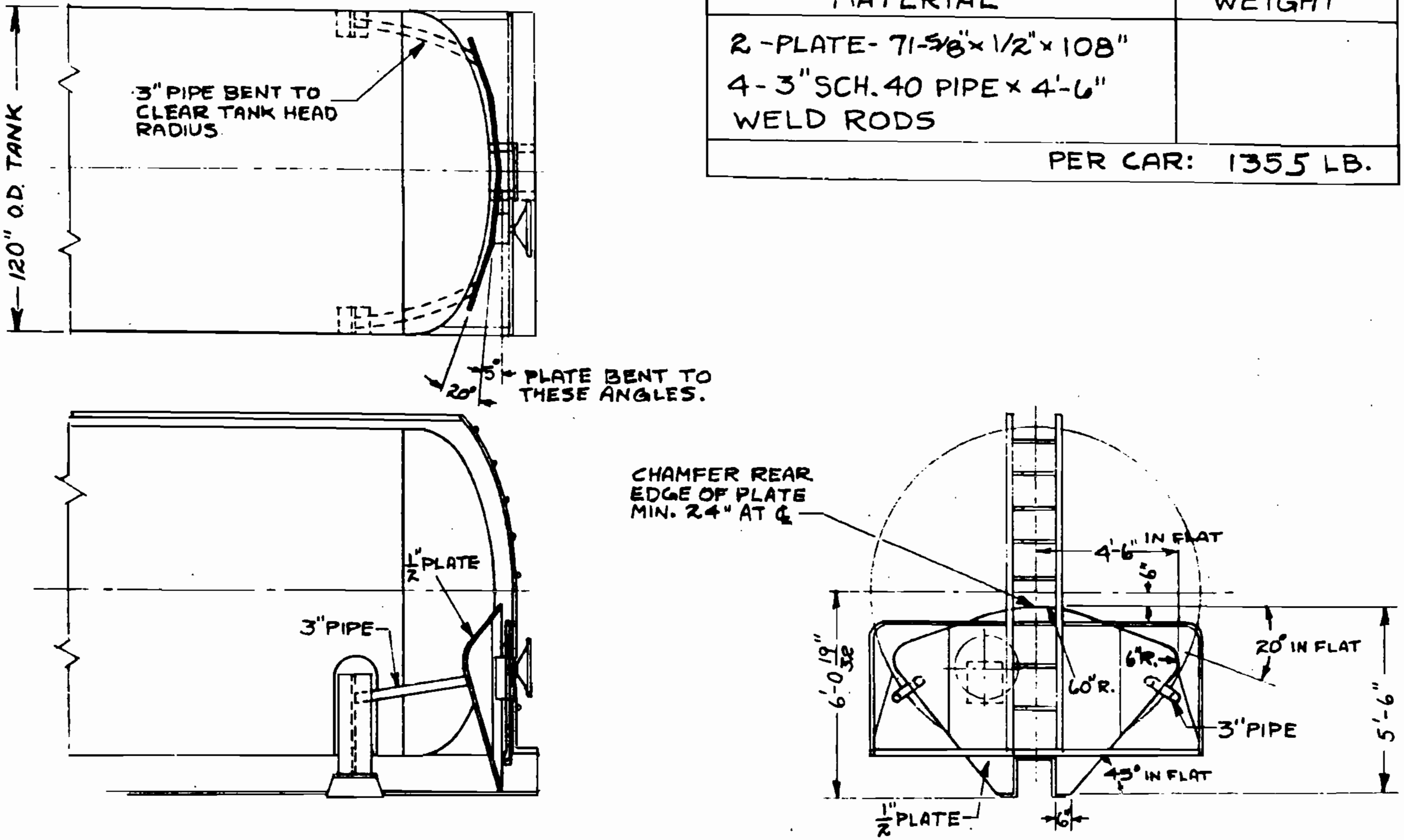
Schemes B-1, B-2, B-1-1, B-2-1 Urethane foam is used in these schemes as the energy absorber. Twenty lb. density foam is used in Schemes B-1 and B-2 and is quite heavy. The 6 lb. density foam in alternate schemes B-1-1 and B-2-1 results in lower weight; however, the amount of protection is also considerably lower. Further, none of these head protection schemes is justified on a cost/benefit basis.

Schemes C-1, C-2, C-1-1, C-2-1 The same comments apply here as for the B series of schemes above.

Schemes D-1, D-2 The same comments apply here as for schemes B-1 and B-2 above. Also, it is anticipated that higher than normal maintenance would be incurred.

Scheme E-3 This scheme involves the substitution of 20 lb. density foam for the usual insulation between the tank head and jacket. This is not justified on a weight and on a cost/benefit basis.

Scheme F-3 This involves the substitution of 20 lb. density foam for the usual insulation in the lower half of the space between the jacket and the tank head. This is not justified on a cost/benefit basis.



MATERIAL	WEIGHT
2 -PLATE- 71-5/8" × 1/2" × 108" 4 - 3" SCH. 40 PIPE × 4'-6" WELD RODS	
PER CAR:	1355 LB.

RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

HEAD PROTECTION DEVICE
NEW DOT 112A & 114A TANK CARS

DATE: 2-24-71	DWG. NO. RA-13-1
DRAWN: C. KNOBLOCK	APPROVED:

FIGURE D-1
SCHEME O-1

MATERIAL	WEIGHT
2-PLATE - 54 1/8" × 1/2" × 60" 4-GUSSET-10 5/8" × 1/2" × 39" 2-GUSSET COVER PLATE - 21" × 1/2" × 40 3/4" WELD RODS	
PER CAR:	1200 LB.

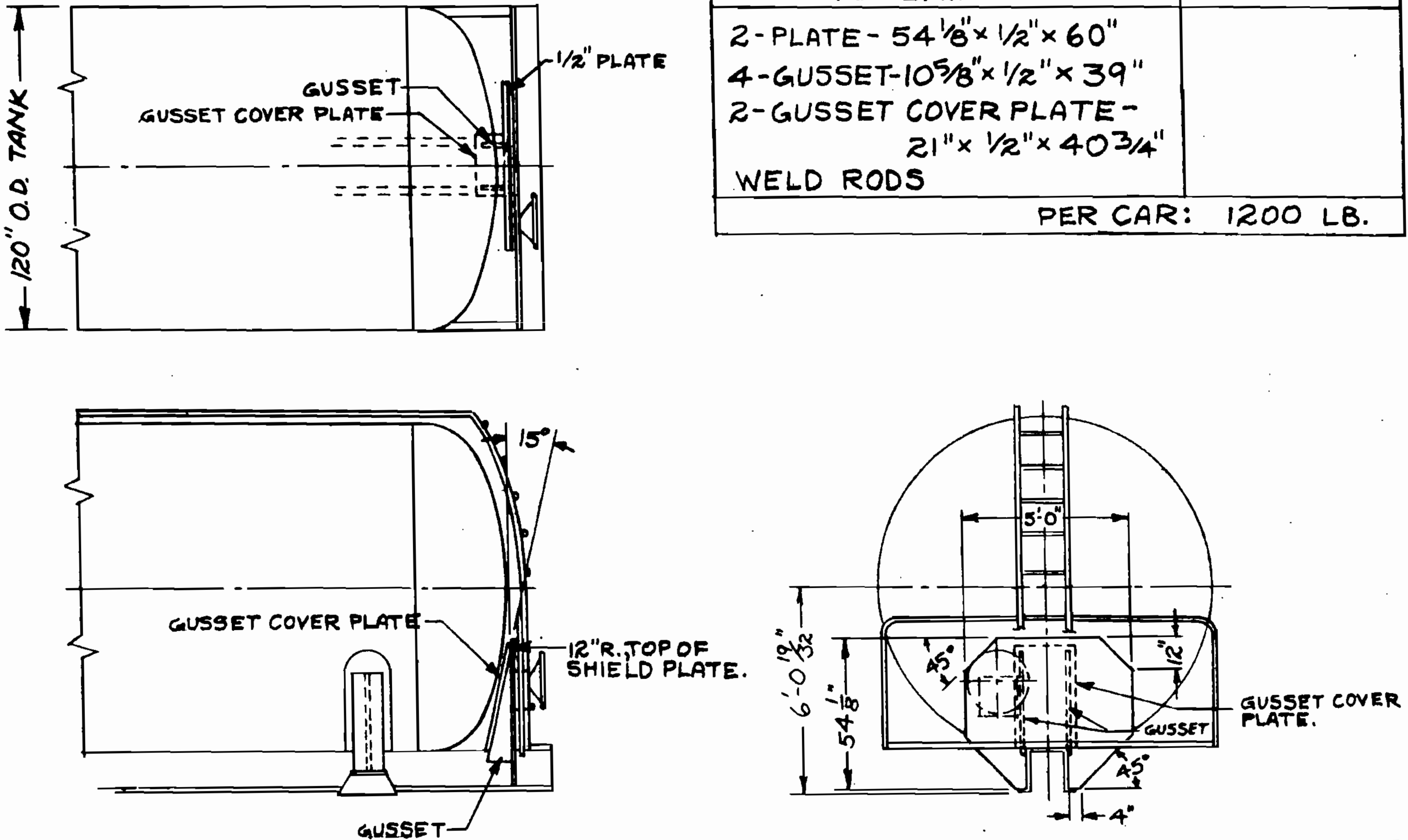
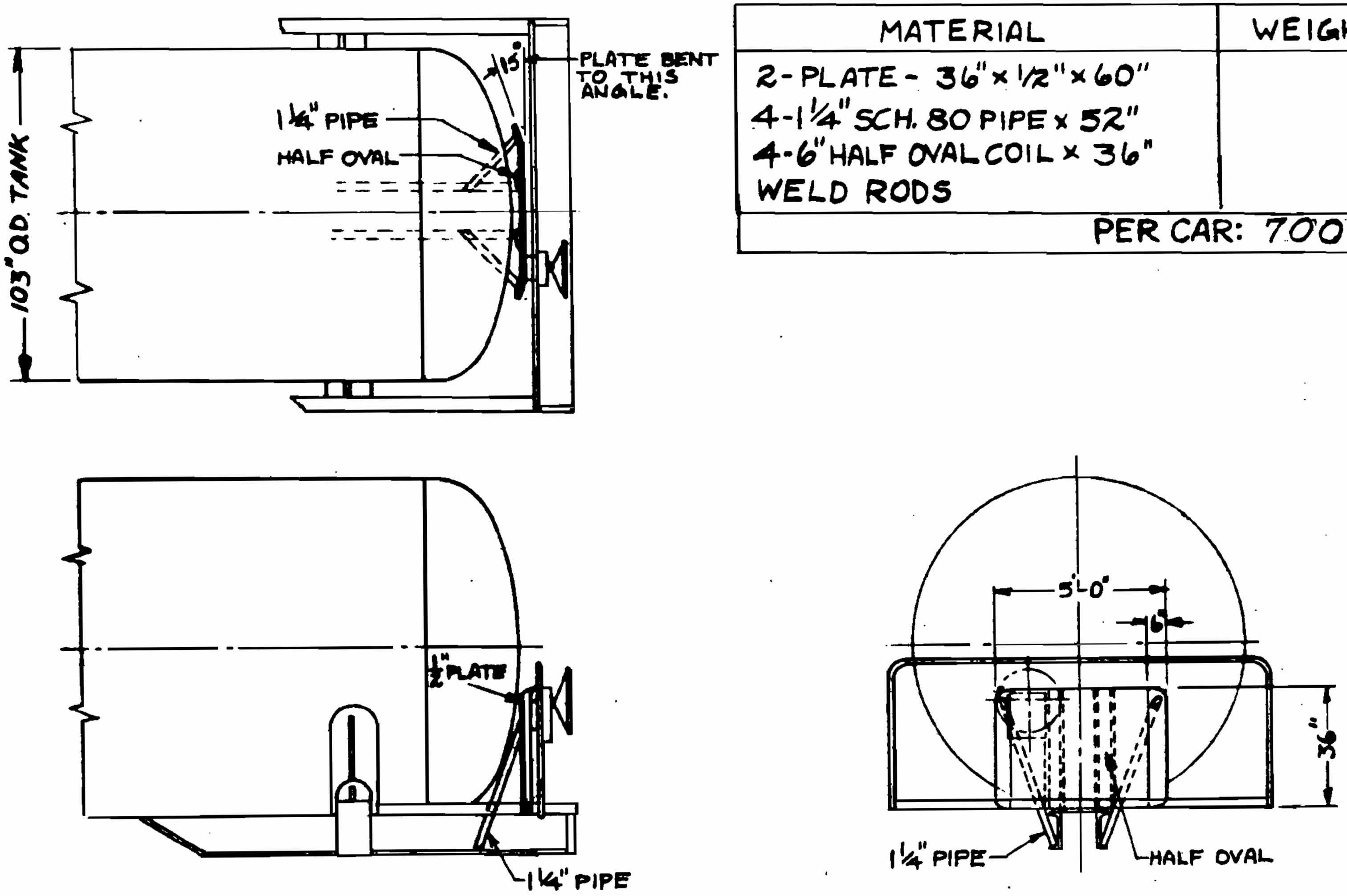


FIGURE D-2
SCHEME P-1

RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

HEAD PROTECTION DEVICE
NEW DOT 112A & 114A TANK CARS

DATE: 2-24-71	DWG. NO. RA-13-2
DRAWN: O. KNOBLOCK	APPROVED:



MATERIAL	WEIGHT
2-PLATE - 36" × ½" × 60" 4-1¼" SCH. 80 PIPE × 52" 4-6" HALF OVAL COIL × 36" WELD RODS	
PER CAR: 700 LB.	

RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

HEAD PROTECTION DEVICE
NEW DOT 111A TANK CARS, NON-INS.

DATE: 2-24-71	DWG. NO. RA-13-3
DRAWN: O. KNOBLOCK	APPROVED:

FIGURE D-3
SCHEME N-2

MATERIAL	WEIGHT
3/8" INSULATED JACKET HEAD IN PLACE OF 3/16", (7 GA.), HEAD	
PER CAR:	1236 LB.
3/8" INSULATED JACKET HEAD IN PLACE OF 1/8", (11 GA.), HEAD.	
PER CAR:	1650 LB.

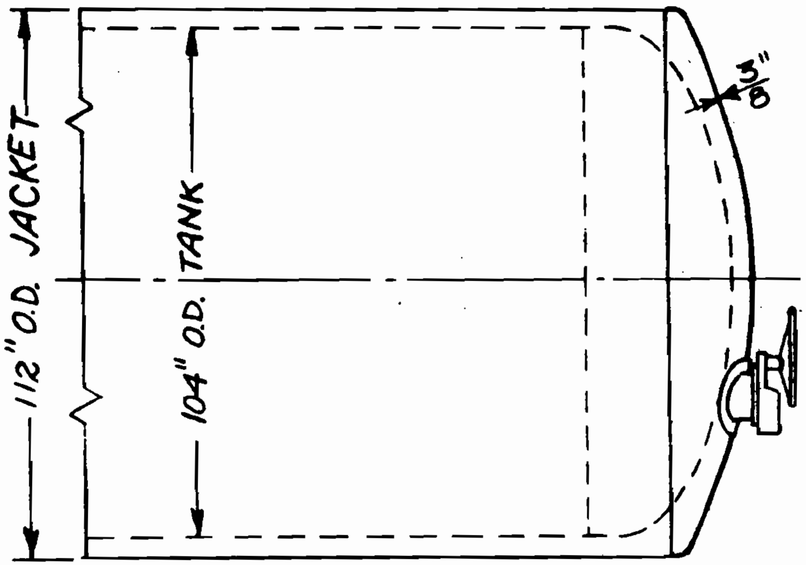


FIGURE D-4
SCHEME J-3

RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT
HEAD PROTECTION DEVICE
NEW DOT 111A TANK CAR, INS.
DATE: 2-24-71 DWG. NO. RA-13-4
DRAWN: O. KNOBLOCK APPROVED:

MATERIAL	WEIGHT
3/8" INSULATION JACKET HEAD IN PLACE OF 1/8",(11GA.),HEAD	
PER CAR:	1725 LB.

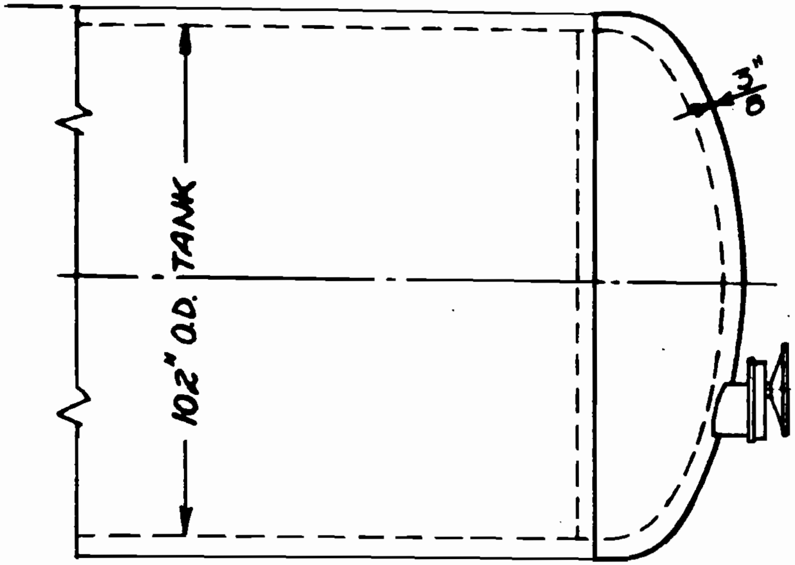


FIGURE D-5

SCHEME J-3

RPI-AAR RAILROAD TANK CAR SAFETY RESEARCH AND TEST PROJECT	
HEAD PROTECTION DEVICE NEW DOT 105A TANK CARS, INS.	
DATE: 2-24-71	DWG. NO. RA-13-5
DRAWN: O. KNOBLOCK	APPROVED:

MATERIAL	WEIGHT
2 - ∠s- 6"×4"×1/2"×5'-0"	162 LB.
2 -PLATES-50"×T/2"×8'-8" FINISHED WEIGHT	1250 LB.
4- 2" SCH. 80 PIPE×3'-6"	70 LB.
WELD RODS	18 LB.
PER CAR: 1500 LB.	

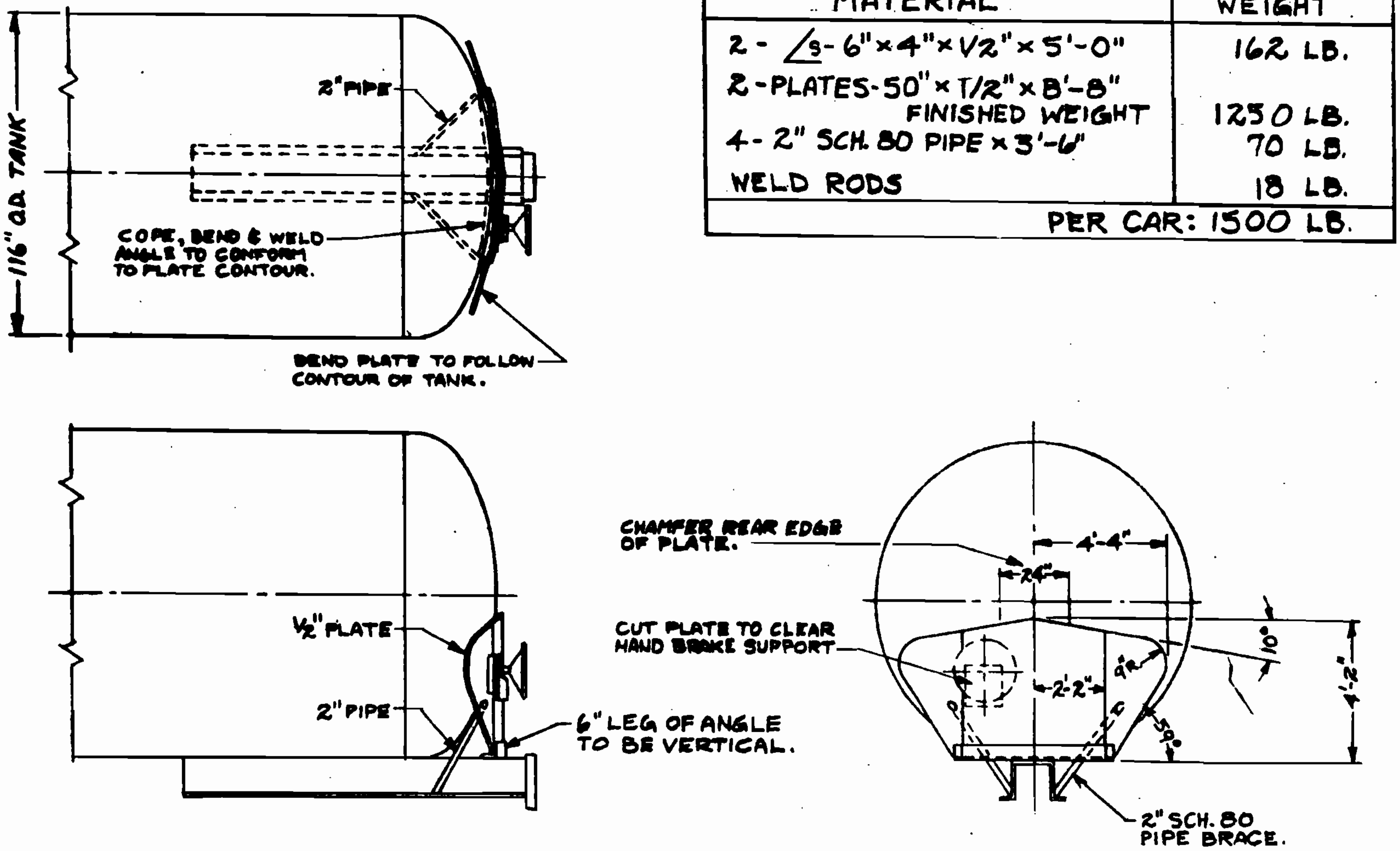


FIGURE D-6

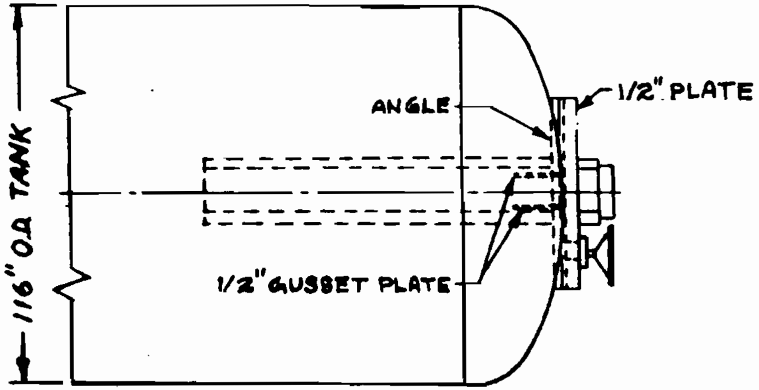
SCHEME O-4

RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

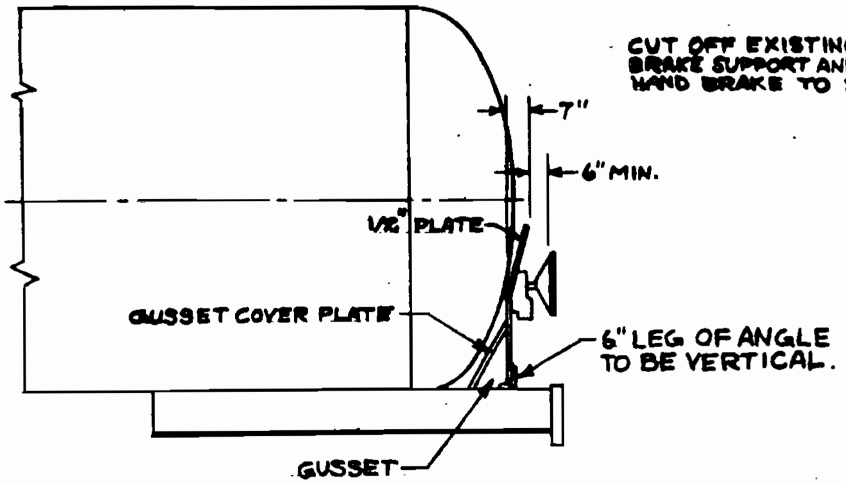
HEAD PROTECTION DEVICE
EXISTING DOT 112A & 114A TANK CARS

DATE: 2-24-71 DWG. NO. RA-13-6

DRAWN: O. KNOBLOCK APPROVED:



MATERIAL	WEIGHT
2-∠s-6"×4"×1/2"×5'-0"	162 LB.
2-PLATES-52"×1/2"×5'-0"	843 LB.
4-GUSSETS-12"×1/2"×1'-10"	75 LB.
2-GUSSET COVER PLATES-16"×1/2"×1'-11"	104 LB.
WELD RODS	22 LB.
PER CAR:	1210 LB.



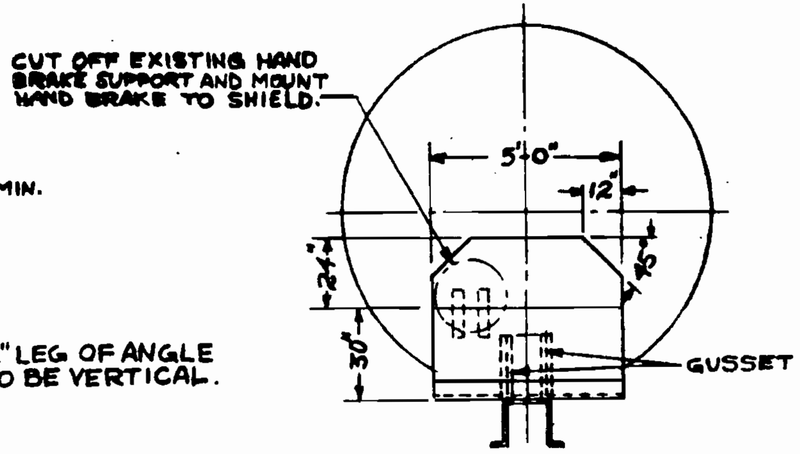


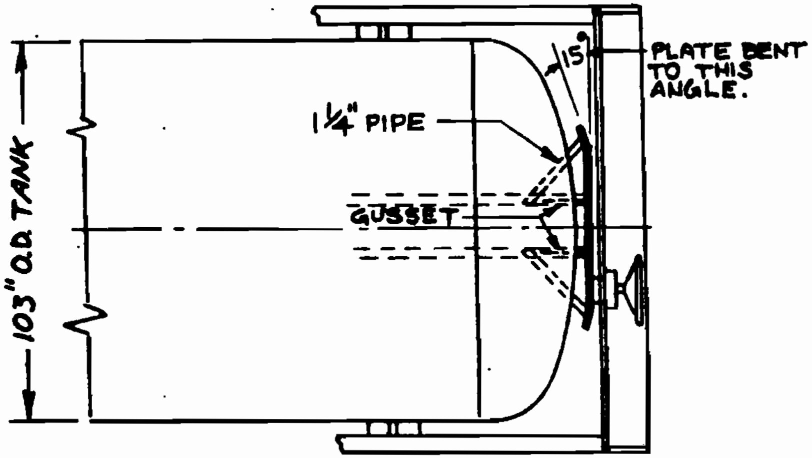
FIGURE D-7

SCHEME P-4

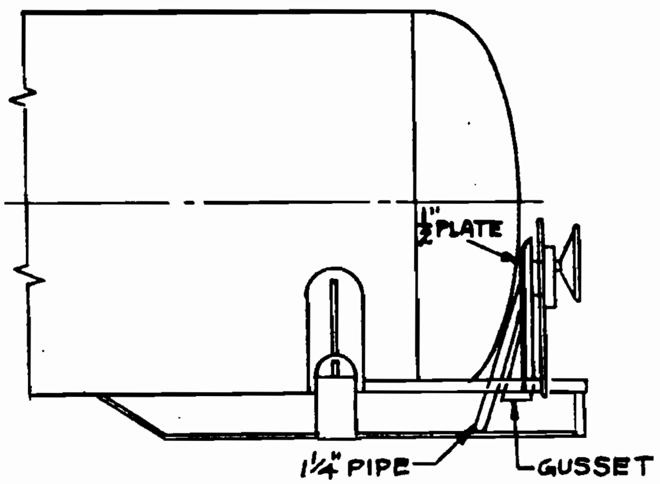
RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

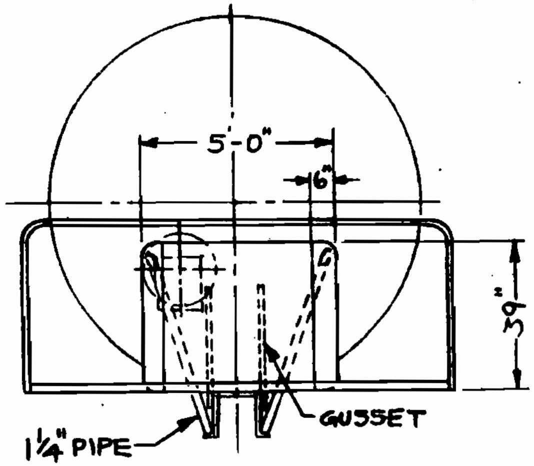
HEAD PROTECTION DEVICE
EXISTING DOT 112A & 114A TANK CARS

DATE: 2-24-71
DWG. NO. RA-13-7
DRAWN: O. KNOBLOCK
APPROVED:



MATERIAL	WEIGHT
2-PLATE- 39"×½"×60" 4-1¼" SCH. 80 PIPE × 62" 4-GUSSET-18"×½"×30" WELD RODS	
PER CAR:	875 LB.



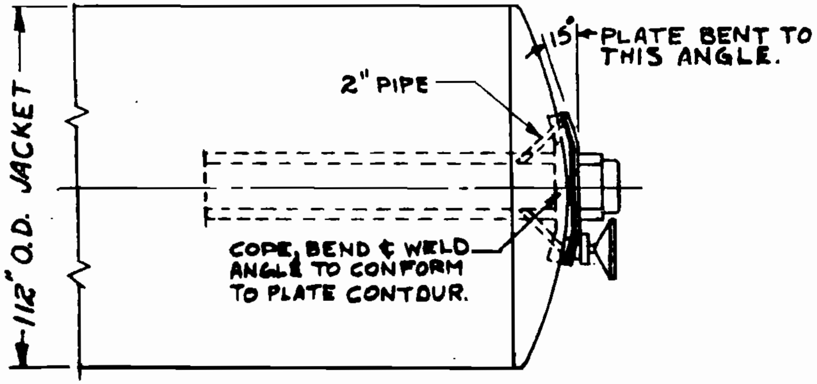


RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

HEAD PROTECTION DEVICE
EXISTING DOT 111A TANK CARS, NON-INS.

DATE: 2-24-71 | DWG. NO. RA-13-8
DRAWN: O. KNOBLOCK | APPROVED:

FIGURE D-8
SCHEME N-5



MATERIAL	WEIGHT
2- ∠s-6"×4"×1/2"×4'-0"	
2- PLATES-32"×1/2"×4'-0"	
4-2" SCH. 80 PIPE ×3'-1"	
WELD RODS	
PER CAR:	580 LB.

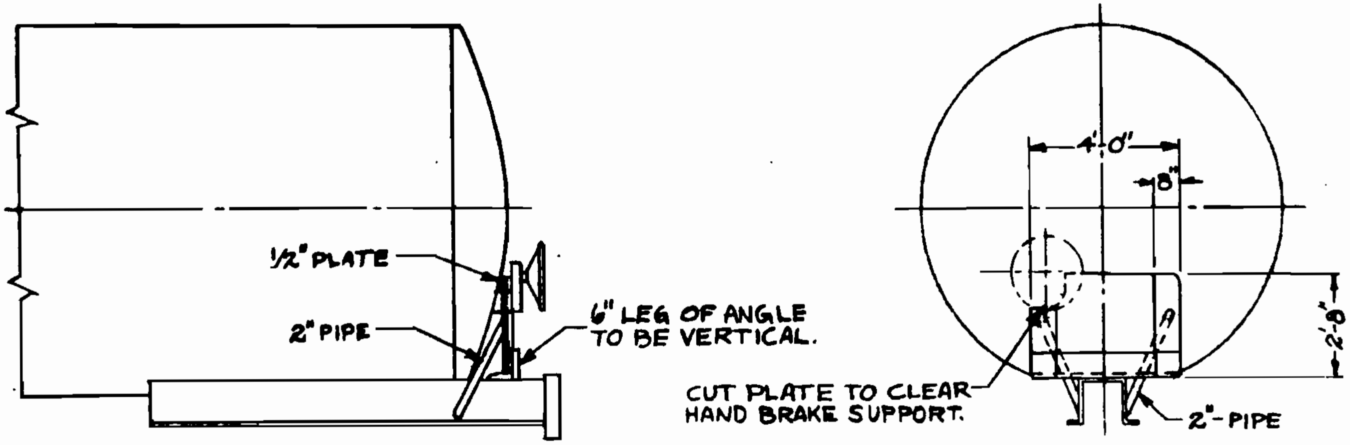


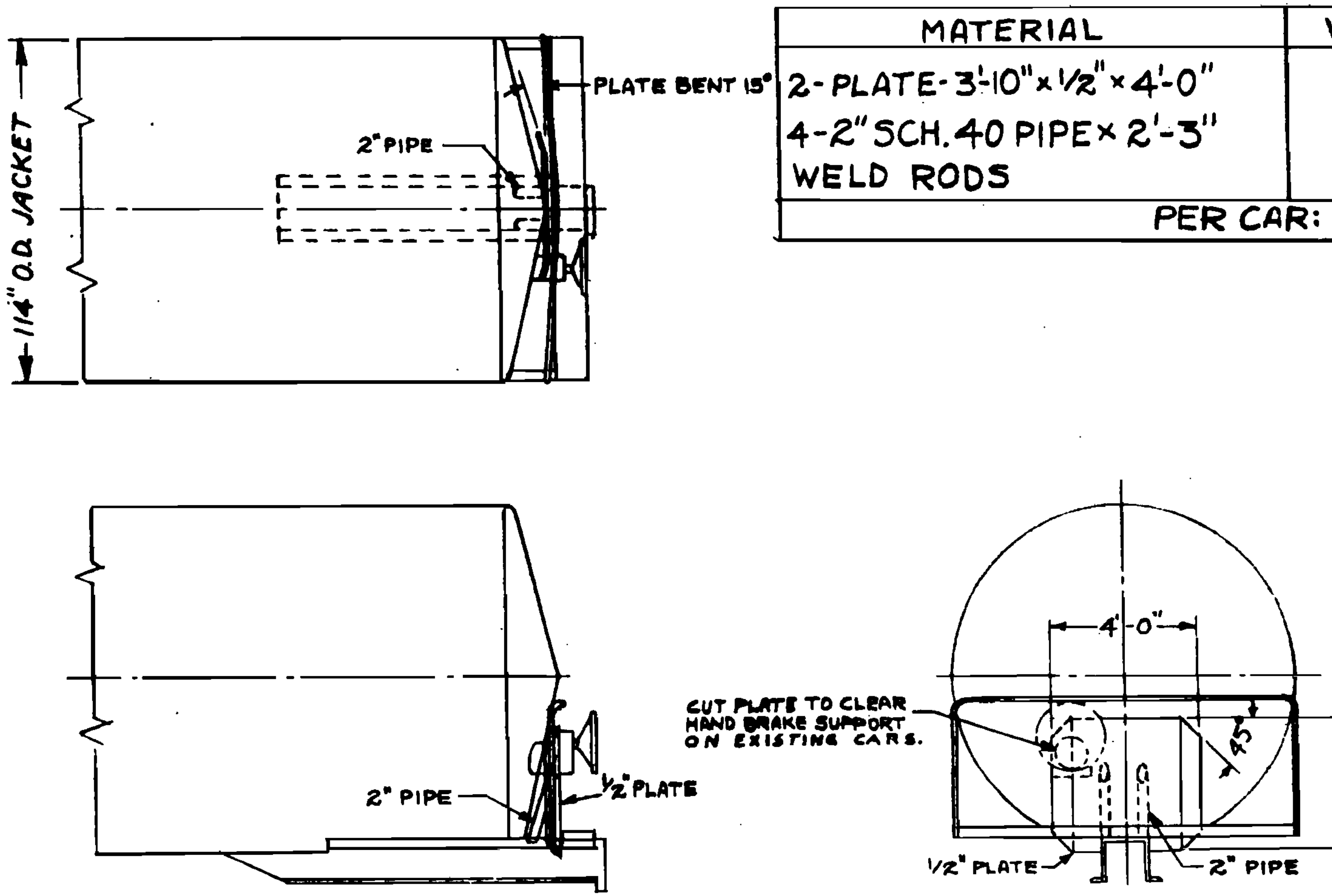
FIGURE D-9

SCHEME N-6

RPI-AAR RAILROAD TANK CAR
SAFETY RESEARCH AND TEST PROJECT

HEAD PROTECTION DEVICE
EXISTING DOT 111A TANK CARS, INS.

DATE: 2-24-71 | DWG. NO. RA-13-9
DRAWN: O. KNOBLOCK | APPROVED:



MATERIAL	WEIGHT
2-PLATE-3'-10" × 1/2" × 4'-0" 4-2" SCH. 40 PIPE × 2'-3" WELD RODS	
PER CAR: 670 LB.	

FIGURE D-10

SCHEME N-6

RPI-AAR RAILROAD TANK CAR SAFETY RESEARCH AND TEST PROJECT	
HEAD PROTECTION DEVICE - NEW & EXISTING DOT 105A TANK CARS, INS.	
DATE: 2-24-71	DWG. NO. RA-13-10
DRAWN: O. KNOBLOCK	APPROVED:

Scheme G-3 This involves the substitution of cork insulation for the usual insulation between the tank head and jacket. The amount of protection provided is relatively small,and it is not justified on a cost/benefit basis.

Scheme H-3 The same comments apply here as for scheme G-3 above, however, the cost of the scheme for new Class 111 cars is low, and it has the least unattractive economic value. More should be learned about cork as an energy absorbing material in the test program.

Scheme J-3 This involves the substitution of 3/8" jacket for the usual 1/8" jacket. This scheme is not justified on an absolute cost/benefit basis, but it is a standoff with scheme N-3 as the least unattractive. This is preferred to N-3 since it comprises a relatively standard approach to tank car design.

Schemes K-1, K-2 These involve the welding of a 7/16" thick second head over the tank head. The added weight is high. A serious drawback is that inspection of the tank head is precluded for the life of the car. Considerable corrosion or even cracks could develop in the tank head along the attachment weld that would not be discovered. Further, the scheme is not justified on a cost/benefit basis.

Schemes L-1, L-2 These involve the employment of heads that are thicker than now required by specification. The increased weight is quite high. Also, test data indicate that a greater degree of protection can be obtained from this weight of added steel through other means, such as a spaced added jacket or shield. The cost/benefit analysis further indicates that this scheme is not justified.

Schemes M-1, M-2, M-4, M-5 These involve the installation of wooden shields in front of the tank heads. Maintenance costs are expected to be fairly high; further, this scheme is not justified on a cost/benefit basis.

Schemes N-1, N-2, N-3, N-4, N-5, N-6 These involve the addition of 1/2" steel plate shields in front of the tank heads. Only N-1 is justified on a cost/benefit basis. Its cost is also low, and it should be considered in the last analysis.

Schemes O-1, O-2, O-4, O-5 These also involve the addition of 1/2" steel plate shields in front of the tank heads. These plates cover most of the lower half of the tank heads and extend to the side nearly the full width of the tank. Of these schemes, O-1 and O-4 are the least unattractive on a cost/benefit basis.

Schemes P-1, P-2, P-4, P-5 These also involve the addition of 1/2" steel plate shields in front of the tank heads. Of these schemes, P-1 and P-4 are justified on a cost/benefit basis.

It should be recognized that all of the basic data used to arrive at the cost and benefit values in Table D-3 are estimated; and, therefore, the final yardsticks (such as economic benefit values, costs, and benefits) referred to in the previous and following discussions of the head protection schemes are only as valid as the estimates. With this understanding, the discussions are carried out, for simplicity, on the basis that the values are final and absolute. Judgement must, of course, then be employed in interpretation.

B. Summary

In summary, only the following designs may be justified on the basis of a positive economic value:

New 112 and 114 cars: N-1, O-1, P-1. Scheme N-1 involves the lowest cost, scheme O-1 provides the greatest benefit, and scheme P-1 produces the highest economic benefit value (benefit minus cost). Only drawings of schemes O-1 and P-1 have been prepared (Figures D-1 and D-2) since concept N is reflected in the drawings for existing insulated cars under scheme N-6 and new non-insulated cars under scheme N-2.

New 111 Non-insulated cars: None. Excluding all schemes except N, O, and P because of disadvantages discussed, scheme N-2 involves the lowest cost, scheme O-2 provides the greatest benefit, and scheme N-2 produces the best, though negative, economic benefit value. A drawing of scheme N-2 is given in Figure D-3.

New 111 and 105 Insulated cars: None. Schemes J-3 and N-3 are a standoff relative to economic values, costs, and benefits. Scheme J-3 is preferred as the least unattractive, and drawings of it applied to 111 and 105 cars are given in Figures D-4 and D-5.

Existing 112 and 114 cars: O-4, P-4. Scheme O-4 provides the greatest benefit, while scheme P-4 involves the lowest cost and produces the highest economic benefit value. Drawings of these are given in Figures D-6 and D-7. Scheme N-4 may ultimately be in contention also, although in this analysis it exhibits a negative economic value.

Existing 111 Non-insulated cars: None. The same comments apply here as made above for new 111 non-insulated cars. A drawing of the best selection, scheme N-5 is given in Figure D-8.

Existing 111 and 105 insulated cars: None. Only scheme N-6 was in contention, and drawings of it for both type cars are given in Figures D-9 and D-10.

APPENDIX E

TASK 5

PERFORMANCE TEST SPECIFICATIONS

I. INTRODUCTION

Task 3, Design Specifications, included a discussion of test performance specifications under Task 3.4. Generally, for a given set of test conditions (e.g. number of backup cars, weights of cars, etc.), two series of tests are recommended:

Test Series 1.

This series of tests would subject cars without the head protective device to impacts of increasing speeds to determine head damage characteristics versus speed and the minimum speed, called V_p, at which head puncture occurs.

Test Series 2.

This series of tests would subject similar cars, but with the head protective device installed, to impacts at speed V_p. For qualification of the shield, the resulting damage to the tank car head must be equal to or less than a certain selected acceptable damage which occurred during one of the lower speed impacts in Test Series 1, say at speed V_d.

This Task 5 will describe the test conditions, instrumentation and procedures to be employed in performing these tests. It will also describe certain preliminary tests to be conducted on various other shield concepts which have been developed under Tasks 3 and 4, but which were recommended only for further study. It will also describe other preliminary tests to be performed on reduced scale and full scale scrap tank cars. The objective of these preliminary tests is to gain knowledge to more efficiently conduct the final and more expensive tests involving full scale cars of current design.

The cost/benefit analysis under Task 4 dictates that the test effort be directed toward DOT 112A340W type cars and for head shield concepts, N, O, or P, or some optimum combination thereof. The following specifications are written on the basis of evaluating one such optimum design.

II. SPECIFICATIONS

A. Outline of Tests

1. Basic Shield Material Investigations

- a) 1/2" plate, A515-55
- b) 1/2" plate, A515-70
- c) 3/8" plate, A515-70
- d) 3/16" plate, A515-70
- e) 11 ga. steel sheet
- f) 20 lb. foam w/11 ga. steel jacket
- g) 20 lb. foam w/7 ga. steel jacket
- h) 6 lb. foam w/11 ga. steel jacket
- i) 6 lb. foam w/7 ga. steel jacket
- j) Cork w/11 ga. steel jacket
- k) Cork w/7 ga. steel jacket

2. Reduced Scale Model Tests

- a) Test Series No. 1 (as defined above under Introduction)
  - 1) Establish V_d and D_d
  - 2) Establish V_p and D_p
- b) Test Series No. 2
  - 1) With head shield applied, determine head damage at V_p.
  - 2) Repeat with improved shield if required.

3. Full Scale Tests on Old Tank Cars

- a) Conduct Test Series No. 1 per II-A-2-a above.
- b) Conduct Test Series No. 2 per II-A-2-b above.

4. Full Scale Tests on Current Design DOT 112A340W cars

- a) Conduct Test Series No. 1 per II-A-2-a above.
- b) Conduct AAR .24-5* Impact Tests
- c) Conduct Test Series No. 2 per II-A-2-b above.

---

* AAR specifications for Tank Cars, paragraph.24-5, Impact Test

B. Description of Tests

1. Basic Shield Material Investigations

The purpose of these tests is to study the behavior of the several materials that have been considered under Task 3, but not recommended because of lack of knowledge of their characteristics. This will permit assessing their future feasibility as head protection means.

A minimum of three specimens of each of the 11 materials listed above should be fabricated to a size comparable to an actual head shield. Each specimen is to be attached to a sill mounted on one end of a railroad flat car modified for the purpose. Each specimen of each set of three is to be impacted once at a different speed with an E coupler mounted on a ram car. The damage in each case is to be graded as to the effectiveness of the material.

2. Reduced Scale Model Tests

These tests have the purpose of establishing a preliminary evaluation of the chosen head shield concept prior to testing full scale cars. All model tank cars should be of the DOT 112A340W class and should be loaded and pressurized to 100 psig.

The scale model cars without the head protective device are to be impacted with a scale car equipped with a scale E coupler. Each head is to be struck only once at increasing speeds until V_d and V_p are established. The scale model cars are then to be fitted with a scaled-down head shield and struck with the E coupler at speed V_p. In all tests described here, the head damage is to be measured after each impact and its degree is to be characterized as D_d and D_p.

3. Full Scale Tests on Old Tank Cars

These tests also have the purpose of establishing a preliminary evaluation of the chosen head shield scheme by using less expensive old (scrap) full size tank cars.

These tests should permit closer definition of V_d and V_p which is required for efficient performance of the final tests on current design DOT 112A340W cars.

These tests should also permit verification of certain results of the reduced scale tests as they relate to full scale tests. It is possible, for example, that future tests on additional shield concepts can be performed on reduced scale model cars.

In these tests, a number of 8,000 to 10,000 gallon tank cars destined to be scrapped should be used. Each car should be impacted at a point 1/3 down from the horizontal center line of the head, on the vertical center line, and with an E coupler. The E coupler should be attached and adequately supported on a "ram" car built for the purpose. Under Test Series No. 1, each car should be struck only once at increasing speeds until speed V_p is attained. The degree of damage and the striking speed should be measured in each case so that V_d and D_d can be determined.

With V_p now known, additional test cars should then be fitted with the chosen head shield and subjected to Test Series No. 2. The shield should be struck at the same location as in test series No. 1. The resulting degree of head damage shall then be compared to the acceptable degree of damage D_d established during Test Series No. 1. If it is less than, or equal to D_d , then the shield shall have passed the performance requirement.

4. Full Scale Tests on Current Design DOT 112A340W Cars

The purpose of this test is to establish final acceptance criteria for the chosen head shield.

First, a test car without the head shield should be impacted at one end at speed Vp, now fairly well established. If the head is punctured, the car should be repaired (or replaced) and struck at the other end at a speed V_p-. If it is not punctured, the car should be repaired and struck at the other end at a speed V_p+. In either case, a better estimation of V_p will be possible.

In these tests, the impact location and test procedure should be similar to that described for the full scale old car tests.

Next, a DOT 112A340W car shall be equipped with the chosen head shield and subjected to the AAR .24-5 test to insure the adequacy of the shield design and its attachment means.

Following successful completion of this AAR test, the car shall then be subjected to Test Series No. 2. This shall entail striking the shield with an E coupler at the same point as the head was struck in test series No. 1 and at speed V_p. The resulting head damage shall then be compared with D_d which will not be obtained from these tests with current cars, but which will be fairly well definable from the previous tests. If this damage is equal to or less than D_d, the shield shall have passed the performance required.

C. Parameters for Tests

1. Class of Test Car

Scale models	-	DOT 112A340W
Scrap cars	-	Nonjacket riveted cars
Current cars	-	DOT 112A340W

2. Size

Scale models	-	20,000 gallon *
Scrap cars	-	8,000 - 10,000 gallon
Current cars	-	20,000 gallon *

3. Tank Outage

Scale models	-	fill w/water to scale rail load for a 100 ton car, but ≥ 2% outage.
Scrap cars	-	fill w/water to 2% outage.
Current cars	-	fill w/water to maximum rail load for a 100 ton car, but ≥ 2% outage.

4. Tank Pressures (Compressed Air)

Scale models	-	100 psi
Scrap cars	-	40 psi
Current cars	-	100 psi

5. Impact Point and Angularity (All Tests)

On vertical center line 1/3 of the radius down from the horizontal center line, and parallel to longitudinal center line.

---

* 20,000 gallon is recommended because, when loaded with water, such a car approaches the rail load limit of a 33,000 gallon car carrying propane.

6. Speeds

AAR .24-5 Impact Test - 14 mph or 1,250,000 lb.
coupler force, whichever
first.

Other tests - To be determined, but probably not over
16 mph from a practical standpoint.

7. Consist for AAR .24-5 Tests

Ram car (220,000 lbs.), test car, three cars backing up test car. Backup cars to be loaded as prescribed in AAR .24-5.

8. Consist for Head Shield Impact

Ram car, test car, three cars backing up test car. The ram car to be 10,000 gallon car filled to 2% outage with water.* The test car to be coupled to the three coupled backup cars, each weighing 177,000 lbs. (nominally) and with draft gear open and brakes set.

9. Striker

Use E head coupler mounted in typical sill. Draft gear not essential since results will be conservative with draft gear omitted.

D. Instrumentation

1. Dynamometer on striking coupler shank and oscilligraphs to record forces.
2. Recorder to measure striking speeds.
3. Means to measure displacements of each car during impact as a function of time (including backup cars).

E. Data To Be Recorded

1. Coupler force during impact as a function of time.
2. Speed of impact.
3. Displacements and hence speeds (by differentiation) as a function of time during impact for all cars (including backup cars).
4. Weight of each car in consist.
5. Damage measurements (size and shape of dents or punctures)
6. Motion pictures of impacts.
7. Still photographs of damage.

---

* Or a car of equivalent loaded weight.

APPENDIX F
TASK 6
PROTOTYPE RESEARCH PROGRAM

I. INTRODUCTION

Under Task 4, three head protection schemes N-1, O-1 and P-1 were selected as being potentially justifiable for DOT 112A and 114A pressure cars (see section IV-B, Appendix D). In the main body of this report recommendations are made that one of these schemes, or some optimum combination thereof, be tested for the 112A and 114A class cars.

The recommended research program to accomplish this is outlined in this appendix along with an estimate of its cost.

This Task 6 activity was originally divided into four sub-tasks; but essentially, the first three cover the outline of the recommended research program, and the fourth covers its estimated cost. The following presentation will, therefore, cover only these two main topics.

II. RECOMMENDED RESEARCH PROGRAM

A. Objectives

The objectives of the program are:

- To establish quantitatively the degree of protection offered by the selected design.
- To establish a set of performance specifications for qualifying the selected, or any future submitted, design.
- To establish design specifications for the selected, or any future submitted design.

B. Description of Program

A five phase program is envisioned:

- Phase A - Review of designs and final selection for testing.
- Phase B - Head shield material tests.
- Phase C - Reduced scale tests.
- Phase D - Full scale tests - old cars.
- Phase E - Full scale tests - new cars.

1. Phase A - Review of Designs and Final Selection for Testing

Under this phase, a comprehensive review of the work conducted under this current head shield study should be made in order to refine and optimize the recommended head protection schemes N - 1, O - 1 or P - 1. The objective is to arrive at one design for testing. This review should include consultation with the major tank car builders.

2. Phase B - Head Shield Material Tests

The objective of these tests is to establish performance criteria of various basic shield materials, particularly as related to the recommended 1/2" steel plate material.

The eleven materials and material combinations listed in section II-A-1, Appendix E, should be tested.

The test set-up and procedure would consist of mounting a minimum of three approximately 4 feet square specimens of each of the eleven materials and material combinations on a typical end sill, mounted in turn on one end of a railroad flat car modified for the purpose, and impacting these with a ram car. The schematic drawing in Fig. F-1 illustrates the arrangement. The ram car should employ a full scale standard type E coupler and sill striker.

Each of the three specimens of each material should be impacted only once at three respective different speeds, probably in the range of 6, 10, and 16 mph. After each impact, the specimen shall be graded for its energy absorption capabilities and its effectiveness in protecting the 5/8" back-up plate which is spaced 4" behind the test specimen.

The instrumentation and data to be recorded are listed in section II-D and II-E, Appendix E.

It would be too speculative at this writing to detail the form of the expected results and the manner in which they would be used as input to subsequent tests or as input to other future head protection concepts. Suffice it to say that these tests appear attractive both technically and economically; and although the chances are remote, such an arrangement may even possibly be ultimately employed as an acceptance test for new designs.

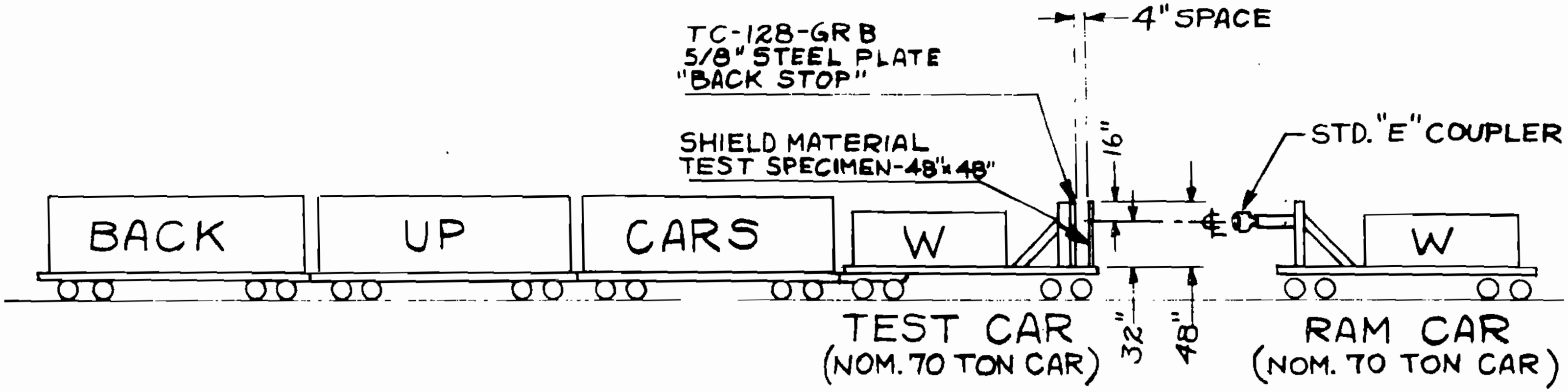


FIGURE: F-1

SETUP FOR HEAD SHIELD MATERIAL TESTS -PHASE B

3. Phase C - Reduced Scale Tests

This phase comprises the second of three sets of tests (Phases B and D cover the other two) which **have the objective** of improving the efficiency of the final and expensive full scale tests.

Here, reduced scale models of a ram car and 20,000 gallon DOT 112A340W pressure cars are to be built, giving particular attention to details of the head scaling. The tests described in paragraph II-A-2 of Appendix E should be conducted, with instrumentation and recorded data also as described in Appendix E. The test arrangement is sketched in Fig. F-2. The test cars should be loaded with water* and pressurized to 100 psig.

In order to estimate the number of model cars required, an anticipated reasonable test sequence has been developed and is shown in Fig. F-3. This sequence involves 8 impacts, one at each end of 4 model tanks. By the end of these tests, the adequacy of the head shield and speed at which it so performs should be known.

4. Phase D - Full Scale Tests - Old Cars

The sequence of tests to be run, the instrumentation, and data to be recorded in these tests are described in Appendix E and are all similar to those described above for the reduced scale tests in Phase C. The only differences are:

- Tank pressure to be 40 psig vs. 100 psig.
- Two cars per impact to be employed vs. one.
- Impacts at speeds greater than 16 mph probably will not be practical.

5. Phase E - Full Scale Tests - New Cars

Here also, the sequence of tests to be run, the test arrangement, instrumentation, and data to be recorded are described in Appendix E; but the sequence of the tests is changed so that only two cars need be employed. The sketch in Fig. F-4 shows the anticipated sequence.

III. ESTIMATED COST OF PROTOTYPE RESEARCH PROGRAM

Following is our preliminary estimate of the cost of the recommended prototype research program. The costs are developed separately for the 5 Phases which in total constitute, in our estimate, a complete and maximum program. A minimum program incorporating only Phases A, D and E could conceivably accomplish the program objectives, but with possible added cost to Phase E.

---

* This will provide approximately the required reduced scale rail load limit for a 100 ton car.

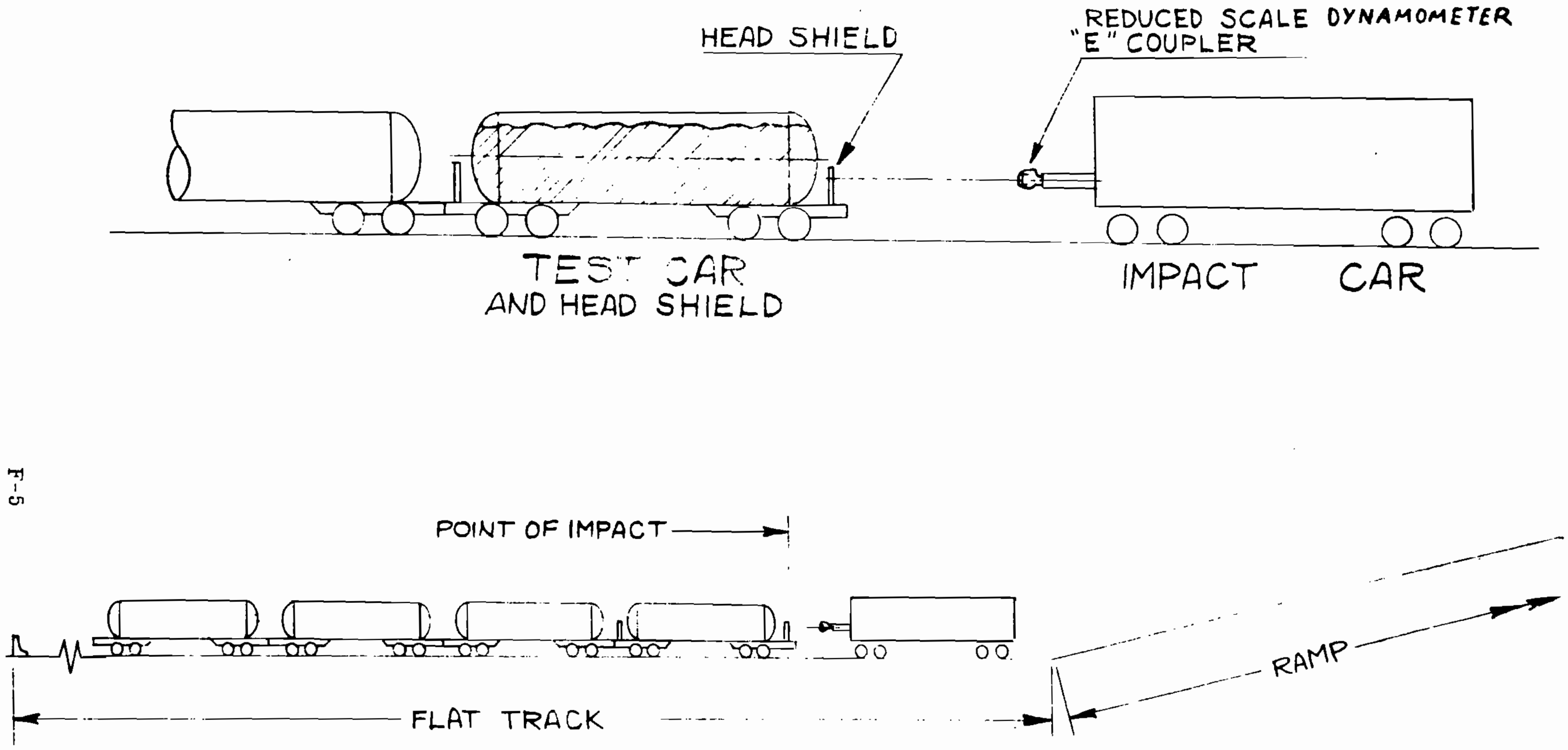
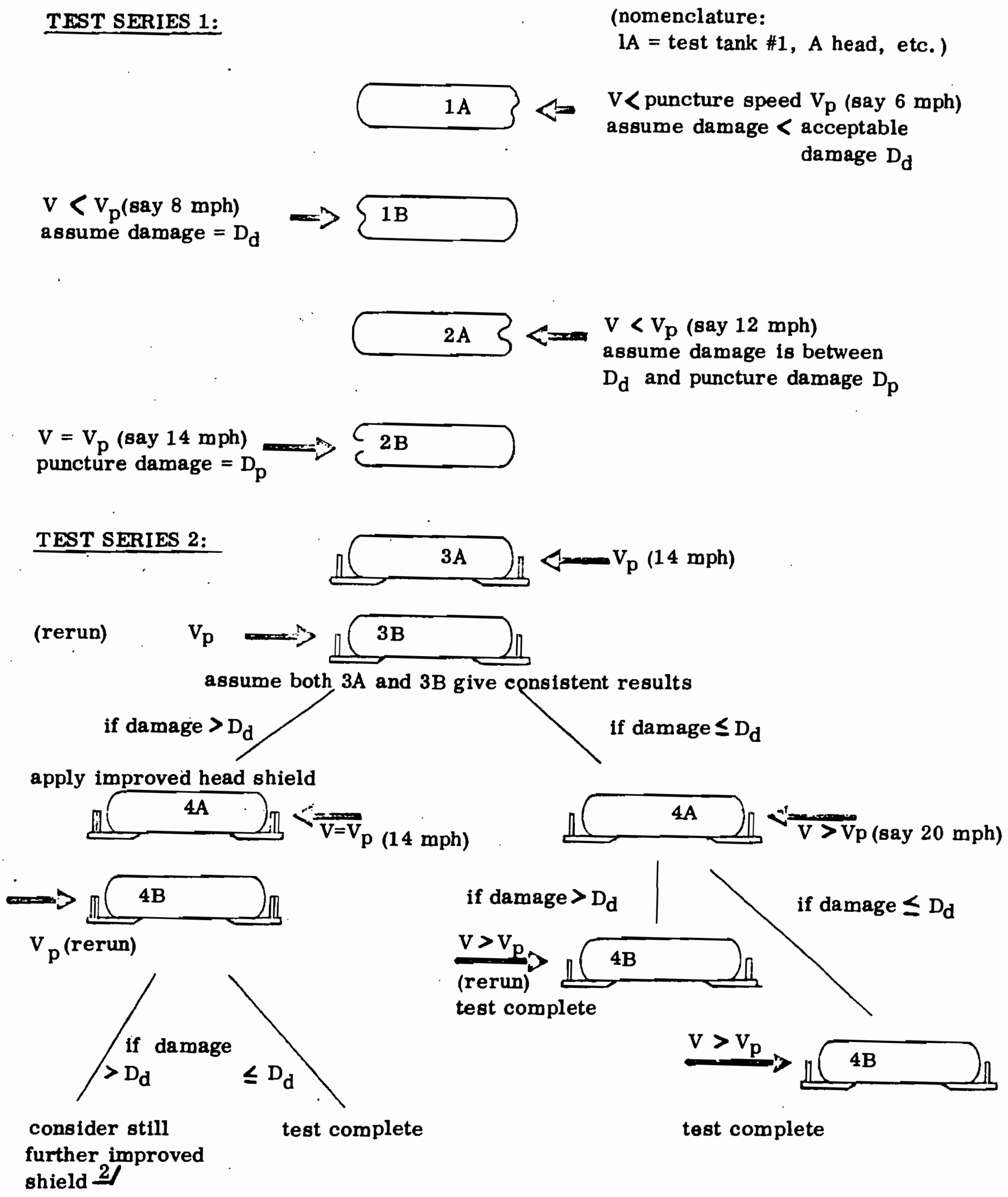


FIGURE F2

SETUP FOR REDUCED SCALE TESTS – PHASE C

FIGURE F - 3

SCHEMATIC OUTLINE - REDUCED SCALE TESTS [1]



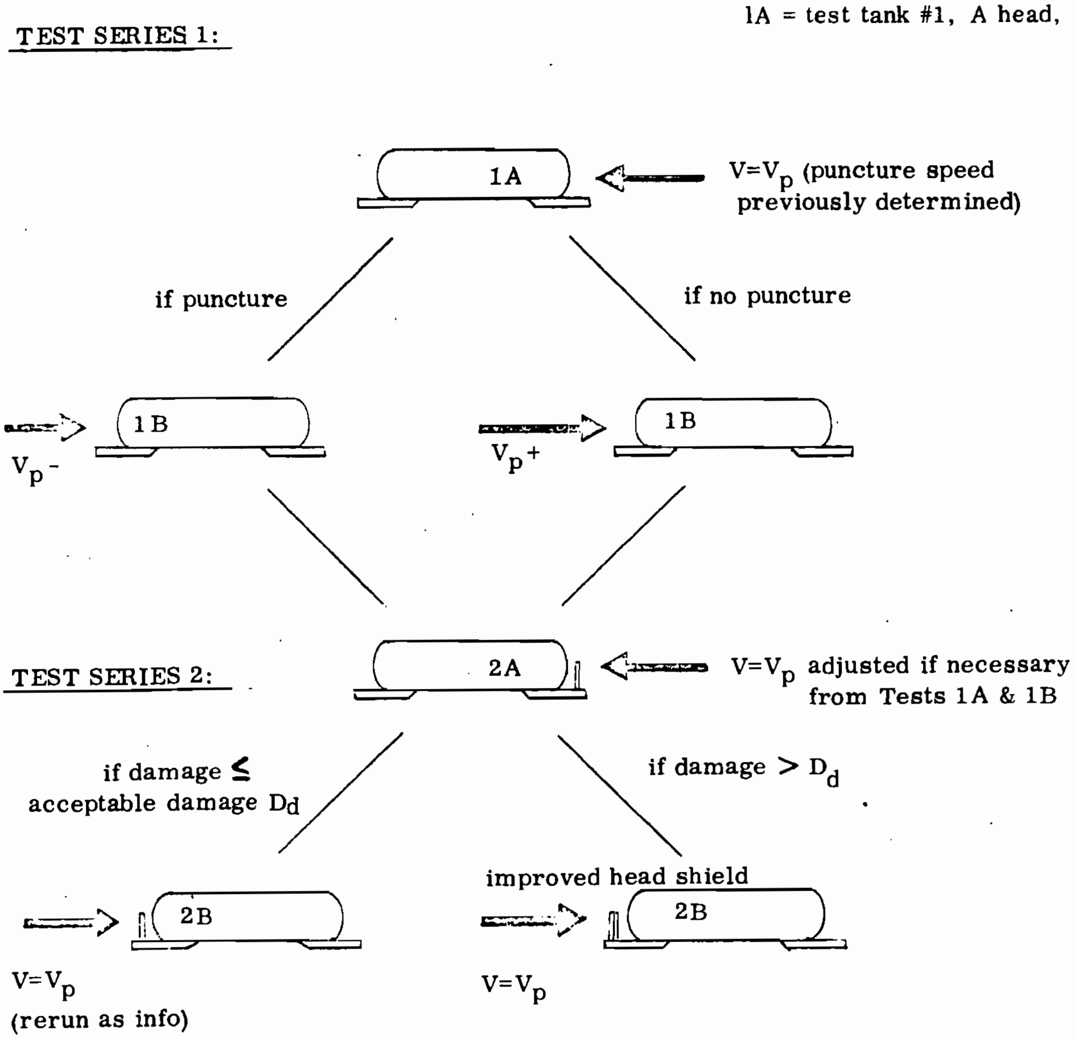
---

[1] Also applied to full scale old car tests except for tests with V >16 mph.

[2] For purpose of outlining and estimating the cost of the test program, assume this point will not be reached.

FIGURE F - 4
SCHEMATIC OUTLINE
FULL SCALE NEW CAR TESTS

(nomenclature:
1A = test tank #1, A head, etc.)



Phase A - Review of Design and Final Selection for Testing

It is anticipated that three man-months of technical effort would be required to arrive at final detail drawings for the optimum head shield design. This assumes contributed assistance on the part of tank car industry companies or organizations consulted under this phase.

Phase B - Head Shield Material Tests

Equipment Costs

Eleven materials and material combinations x 3 specimens each @ $200/ each	$ 6,600
5/8" back-up plates (assume 20) @ $200/each	4,000
Ram car (including instrumented E Coupler)	10,000
Flat car with test frame	8,000

Manpower

Preparation and conduction of 33 impact tests, reduce data - - 6 man-months

Phase C - Reduced Scale Tests

Based on our experience on some 1/5th scale model impact tests which we are preparing to conduct on 18 scale cars, we estimate the total cost of this Phase C test program (starting new) to be $30,000. This includes technical manpower.

Phase D - Full Scale Tests - Old Cars

Equipment Costs

Eight test cars @ $1,000/each	$ 8,000
Ram Car test (cost under Phase B)	(10,000)
Eight head shields, installed	10,000

Manpower

Preparation and conduction of 16 impact tests, reduce data - - 8 man-months

Phase E - Full Scale Tests - New Cars

Equipment Costs

Repairs of damaged cars after tests; @ $2,000/repair	$ 8,000
Preparation of two cars for return to service @ $1,500/car	3,000
Out of service cost, two cars	1,600
Ram car (cost under Phase B)	(10,000)
Two head shields installed	3,000

Manpower

Preparation and conduction of two impacts under test series No. 1 - one man-month

Preparation and conduction of AAR .24.5 impact tests (assume 25 strain gage locations, assume minor alterations in design required after first impact and therefore, one rerun) - 3 man-months.

Preparation and conduction of two impacts under test series No. 2, reduce data - 2 man-months.

Data Analysis and Final Report - All Tests

Technical effort - 4 man-months.

Contingencies

Assume 20% on both equipment cost and manpower estimates. This covers, for example, instrumentation.

Summary

The following cost and manpower estimates include the 20% contingencies:

Equipment costs, all phases	$ 110,600

Manpower, all phases, except Phase C (manpower included in $30,000) 32 man-months	
Equipment Cost, Phases A, D and E only	$ 52,300
Technical effort, Phases A, D and E only 25 man-months.	

(Note: Phase E may cost more if only Phases A, D and E are included in the program.)

GPO 915-694