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COST/BENEFIT ANALYSIS OF HEAD SHIELDS FOR 112A/114A SERIES TANK CARS

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16. Abstract

A Cost/Benefit analysis of head shields installed on new and existing 112A/114A railroad tank cars was performed.

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FOREWORD

The work of this technical report was performed under Contract No. DOT-FR-20069 by the Systems Research Department of Calspan Corporation for the U.S. Department of Transportation, Federal Railroad Administration. This special report deals with only a portion of a more comprehensive cost/benefit analysis of head shields for 112A/114A tank cars conducted by Calspan Corporation which is reported in "Rail Hazardous Material Tank Car Design Study, Interim Report", May 1973. This work was monitored by Mr. Donald Levine of the Rail Systems Division of the Federal Railroad Administration.

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I. SUMMARY

A cost/benefit analysis of head shields installed on new and existing 112A/114A series pressure tank cars was performed based on a redistribution of accident dollar losses. Head shields are designed to prevent puncture of a tank car head during an accident with resulting loss of lading and possibly extensive fire damage. The design of the head shields and data for the analysis were obtained from Railway Progress Institute (RPI) - Association of American Railroads (AAR) cooperative research program reports. The RPI/AAR considered accident data for the years 1965-1970 and assigned accident dollar losses during that period according to the tank element that failed. That is, if during an accident, a tank head was punctured with a resulting loss of lading and subsequent fire, the damage caused by the lost lading was assigned to the category of head puncture. Similarly, if the tank shell was punctured, the losses were assigned to the category of shell punctures. Using this rationale with the relatively small amount of historical data available, RPI/AAR determined that shell punctures which accounted for only 18% of the lading spills were responsible for 68% of the dollar losses. The historical data are too limited to provide the correct distribution of losses between head and shell punctures. If enough tank car accidents were investigated over a long period of time, the dollar loss distribution would be expected to match the puncture distribution, inasmuch as shell punctures do not inherently produce more costly losses than head punctures. Supporting evidence is presented ~~in the main body of this report~~ indicating that dollar losses are strongly related to puncture distribution for a more extensive set of data including all classes of tank cars.

The following table shows the results of statistically distributing dollar losses. Also shown are the results of the two original RPI/AAR studies. In the first RPI/AAR study, the efficiency of head shields in preventing head punctures was determined to be 77%. In the second study the efficiency was downgraded to 50% and the cost of a head shield installation and accident losses were updated. Other than the distribution of losses, the Calspan data utilize the same data and analytical techniques as the second RPI/AAR report.

HEAD SHIELD COST/BENEFIT STUDIES

STUDY	INSTALLATION	SHIELD EFFICIENCY	SHIELD COST	ECONOMIC BENEFIT
RPI/AAR-DOT HEAD SHIELD STUDY, AUG. 71, REF.1	NEW 112A/114A's	77%	$280	+$105
	EXISTING 112A/114A's	77%	$335	+$50
RPI/AAR REPT. RA-00-1-22, OCT. 72, REF.2	NEW 112A/114A's	50%	$272	-$8
	EXISTING 112A/114A's	50%	$474	-$210
CALSPAN DISTRIBUTION OF LOSSES	NEW 112A/114A's	50%	$272	+$407
	EXISTING 112A/114A's	50%	$474	+$205

Note that, if the economic benefit is positive for a given change, it will be profitable to make that change over the long term. It can be seen in the table that head shields produce a substantial economic benefit when evaluated with the proper distribution of losses between head and shell punctures.

Conclusion: Installation of properly designed head shields on new and existing 112A/114A pressure type tank cars would be cost beneficial.

II. INTRODUCTION

About 20,000 railroad tank cars of the 112A and 114A series are presently in service. The 112A/114A cars are used in pressurized service mainly for transporting compressed liquefied gases. A number of the tanks have been punctured during derailments or other accidents, resulting in substantial dollar losses and casualties in large part due to fires of spilled lading. Tank punctures are caused by striking couplers, trucks, and other objects. Several methods have been proposed for decreasing the likelihood of tank punctures. Among these are shields covering a portion or all of the tank heads primarily to prevent couplers from preceding or following cars from puncturing the tank during an accident.

This report deals with a cost/benefit analysis of head shields for new and existing 112A/114A series tank cars. A cost/benefit analysis is composed of three key factors, namely:

(1) The magnitude of expected dollar losses.

(2) The cost per car of implementing a proposed modification.

(3) The "efficiency" of the modification in reducing the dollar losses.

The amount of expected losses can be estimated from statistical review of historical data on losses. The cost of implementing a proposed modification can be determined from engineering estimates of costs. The efficiency of the modification can be determined from analysis combined with available experimental test data. The term "efficiency" as expressed here is a dimensionless factor determined by dividing expected overall losses with modified cars by losses anticipated with unmodified cars. The reduction in losses by adoption of the modification results from a reduced frequency of occurrence of head puncture. Reduction in the magnitude of loss for a given accident for which a puncture occurs is not implied.

The amount of expected losses times the efficiency determines the reduction in losses, i.e., savings, that can be expected. These savings can be utilized to pay for the modification plus interest over a number of years. The amount at 100% efficiency that could be paid back, including interest, from the expected savings is termed present value. Any reduction in efficiency of the modification reduces the present value proportionately. The economic benefit is the cost of the modification subtracted from the present value at the efficiency of the modification. If the economic benefit is positive, it is then economically justifiable to make the modification.

The Railway Progress Institute (RPI) and the Association of American Railroads (AAR) in a cooperative research program have already investigated head shields and the losses occurring in tank car accidents,[1,2]. The RPI/AAR reports list all tank cars known to have lost lading due to mechanical damage incurred in accidents during the period from 1965 to 1970. Incidents of loss are sorted by class of tank car and cause of loss. Loss figures are composed of two parts: (1) cost of lost lading and (2) other losses caused by the loss of this lading, including fire damage to equipment, real property, and loss of life. The RPI/AAR has reported the accident loss data due to punctures of 112A/114A tank cars. A review is given in Table I.

TABLE I

LOSSES DUE TO PUNCTURES OF 112A/114A TANK CARS*

	Cause	
	Head Puncture	Shell Puncture
Losses, $	3,997,633	8,610,791
No. of Cases	40	9
No. of Years	6	6
Avg. No. of Cars in Service	12,000	12,000
Losses, $/Car/Year	55.52	119.59
Total Losses - $12,608,424		

*Data taken from Ref. 3, p. D-11.

The RPI/AAR has developed designs of head shields for reducing head punctures on new or existing 112A/114A tank cars. The design chosen as being the most cost effective consists of a 4 ft. high (above top of sill) by 5 ft. wide, 1/2 in. thick A-36 steel plate. The costs of this shield were determined to be $272/car on new 112A/114A cars and $474/car on existing 112A/114A cars. It was estimated by RPI/AAR from a review of all known cases of 112A/114A head punctures that this type of head shield would prevent 50% of the head punctures of 112A/114A tank cars. (Ref. 2, p. 14-15.)

III. COST/BENEFIT ANALYSIS

The RPI/AAR, in their review of tank car accidents, determined what the immediate cause of a fire was and then assigned accident dollar losses according to the tank element which failed. For instance, if during an accident, a tank head was punctured with a resulting loss of lading and/or fire, the damage caused by the lost lading was assigned to the category of head puncture. Similarly, if a tank shell was punctured, causing damage, these costs were assigned to the category of shell puncture. ("Shell" is considered to include only the cylindrical portion of the tank and "head" only the ends of the tank.) In this way, the losses were assigned to a particular tank element and an estimate was made of the potential savings which could be realized if the frequency of occurrence for that type of failure could be reduced. The RPI/AAR results for all head and shell puncture accidents involving tank cars are summarized in Table I (Introduction).

Historically, there were 40 head punctures and 9 shell punctures which caused damage during the six-year period of 1965-1970. Intuitively, this is the type of distribution which would be expected. The tank head is exposed to the coupler of the adjoining car during the early phase of a derailment when the cars are still relatively well in line. During this period the high compressive forces existing between cars, in conjunction with the vertical motion between cars, allows the coupler of an adjoining car to contact the tank head.

Later in the derailment sequence, once the cars are no longer in line, contact between cars can occur, but there is a substantially smaller chance of a concentrated force being applied to the shell. Coupler-shell and truck-shell contacts occur, but so do the more acceptable shell-shell contacts. As a result, the distribution of shell punctures presented in Table I is as expected. The distribution of dollar losses presented in Table I is <u>not</u>, however, consistent with the puncture data.

The historical data imply that only 18% of the punctures are responsible for 68% of the dollar losses, while the other 82% of the punctures are responsible for only 32% of the losses. Calspan is of the opinion that simply relying on the relatively small amount of historical data introduced a fallacy into the RPI/AAR cost/benefit analysis. If enough tank car accidents were investigated over a long period of time, the loss distribution should match the shell puncture distribution. Shell punctures do not inherently produce more costly losses than head punctures. Since head punctures occur five times as often as shell punctures, in the long run, dollar losses due to head punctures should approach five times the losses due to shell punctures. In fact, it might be expected that head punctures would be more costly than shell punctures because head punctures may tend to occur more frequently during yard accidents near heavily populated areas. Accident data since 1970 have tended to agree with the revised distribution, i.e., the East Saint Louis, Illinois, accident on January 22, 1972, which was caused by a head puncture and resulted in $7½ million property damage plus 19 people injured enough to be hospitalized[4].

In support of the argument that losses should be proportional to the frequency of puncture occurrence, the puncture data for all classes of cars are summarized in Table II. There are two entries for the 112A type of car. The first includes the losses at Laurel, Mississippi, and Crescent City, Illinois. The second excludes those losses. The effect of deleting these two accidents is shown in Table II to reduce the total losses by 60%, indicating that these two accidents have a large distorting effect. In particular, the losses due to shell punctures are decreased 85% by eliminating these two accidents. The nature of this distortion can be determined by the last two entries in Table II. Using all the accidents, the losses are inversely proportional to puncture frequency. When the two accidents are not included, the opposite results occur and accident losses become more directly proportional to puncture frequency, as would be expected.

Calspan has recomputed the cost/benefit analysis for head shields, applied to 112A/114A cars, using the statistically correct losses. Hence,

TABLE II

LOSS DUE TO PUNCTURES OF TANK CARS*[3]

	Cause			
	Head Punctures		Shell Punctures	
	$ Loss	No.	$ Loss	No.
Riveted Steel Cars	293,000	20	425,860	22
103-W Non-Insulated	50,000	15	78,700	11
103-W Insulated	3,100	1	30,665	3
111A-W Full Frame Non-Ins.	680,530	15	66,300	4
111A-W Full Frame Ins.	9,000	3	3,400	1
111A-W Stub Sill Non-Ins.	841,650	29	158,500	10
111A-W Stub Sill Ins.	292,550	12	30,000	3
105A-W Insulated	403,000	8	110,840	4
112A-W	3,918,000	40	8,439,265	9
112A-W Minus Laurel, Miss. and Crescent City, Ill.	2,356,000	38	297,265	7
113	50,240	5	34,060	8
Total	6,541,070	148	9,674,855	75
Total Minus Laurel, Miss. and Crescent City, Ill. Data	4,979,070	146	1,532,855	73

*Values are slightly different from those in Table I because in Table I losses due to unknown causes were proportionately distributed among the known causes.

head punctures were assigned 82% of the losses due to punctures, while shell punctures were assigned 18%. The redistributed losses are shown in Table III using the same format as in Table I.

Applying the correct loss distribution, the cost benefit of head shields is recomputed as shown in Table IV. Note that the cost of capital, head shield life, and the shield efficiency are unchanged from those used by RPI/AAR. Head shields are now found beneficial by +$407 on new cars and by +$205 on existing cars. Therefore, there is a net economic benefit to be derived from installing head shields on both new and existing 112A/114A tank cars.

TABLE III

REDISTRIBUTED LOSSES DUE TO PUNCTURES OF 112A/114A TANK CARS

	Cause	
	Head Puncture	Shell Puncture
Losses, $	10,338,908	4,791,201
No. of Cases	40	9
No. of Years	6	6
Avg. No. of Cars in Service	12,000	12,000
Losses, $/Car/Year	142.95	32.16

Total Losses - $12,608,424

TABLE IV

HEAD SHIELD COST/BENEFIT ANALYSIS - REDISTRIBUTED LOSSES

Cost of Capital: 10%
Assumed Life: 30 yrs.
112A/114A Tank Cars

Present Value = Losses/Car/Year x Present Value Factor*	
= $142.95 x 9.5 =	$1358
Shield Efficiency (RPI/AAR estimate)	50%
Present Value at Stated Efficiency = Present Value x Efficiency	
= $1358 x .50 =	$ 679
Cost of Shield (RPI/AAR estimate)	
New Cars	$ 272
Existing Car	$ 474
Economic Benefit = Present Value at Stated Efficiency	
- Cost of Shield	
New Cars: $679 - $272 =	$ 407
Existing Cars: $679 - $474 =	$ 205

*Present value of a stream of payments of $1/year for 30 years discounted continuously at an annual rate of 10%.

The results of this cost/benefit analysis are compared with those of RPI/AAR in Table V. In the first RPI/AAR study, the efficiency of the head shields in preventing head punctures was determined to be 77%. In the second study, the efficiency was downgraded to 50% and the cost of a head shield installation and accident losses were updated. Other than the redistribution of losses, the Calspan data utilize the same data and analytical techniques as the second RPI/AAR report. Analysis similar to that in Table IV would show that head shields would be cost beneficial at efficiencies as low as 20% on new cars and 35% on existing cars.

TABLE V

HEAD SHIELD COST/BENEFIT STUDIES

STUDY	INSTALLATION	SHIELD EFFICIENCY	SHIELD COST	ECONOMIC BENEFIT
RPI/AAR-DOT HEAD SHIELD STUDY, AUG. 71, REF.1	NEW 112A/114A's	77%	$280	+$105
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The above necessarily brief cost benefit analysis deals chiefly with distribution of losses resulting from head and shell punctures and the effect on the cost benefit analysis. Greater detail with regard to cost benefit analyses and other related factors can be found in the Calspan Report "Rail Hazardous Material Design Study, Interim Report" (Reference 5).

IV. REFERENCES

1. "Hazardous Material Tank Cars - Tank Head Protective 'Shield' or 'Bumper' Design," RPI/AAR Project Phase 13, Contract No. DOT-FR-00035, August 1971.

2. "Overall Project Summary Report," Railroad Tank Car Safety Research and Test Project, RPI/AAR Report No. RA-00-1-22, October 6, 1972.

3. "Final Phase 02 Report on Accident Review," Tank Car Safety Research and Test Project, RPI/AAR Report No. RA-02-2-18, August 14, 1972.

4. "Hazardous Materials Railroad Accident in the Alton and Southern Gateway Yard in East Saint Louis, Illinois, January 22, 1972," National Transportation Safety Boards, RAR 73 1 SSR 18, January 31, 1973.

5. "Rail Hazardous Material Tank Car Design Study, Interim Report," by J. S. Patten, Calspan Corporation, Contract No. DOT-FR-20069, May 1973.