1/84

TRAFFIC AUTHORITY N.S.W.
ORTA RECENS QUAM PURA NITES

ACCIDENTS INVOLVING ROAD TANKERS WITH FLAMMABLE LOADS

MICHAEL GRIFFITHS,
B.E. (Mech.), M.Biomed.E.,

DAWN R. LINKLATER
B.A. (Hons.) Ph.D.

TRAFFIC AUTHORITY OF NEW SOUTH WALES

The Traffic Accident Research Unit was established within the Department of Motor Transport, New South Wales, in May 1969 to provide a scientific approach to the traffic accident problem.

This paper is one of a number which report the results of research work undertaken by the Unit's team of medical, statistical, engineering and other scientists and is published for the information of all those interested in the prevention of traffic accidents and the amelioration of their effects.

Commissioner

ACCIDENTS INVOLVING ROAD TANKERS WITH FLAMMABLE LOADS

MICHAEL GRIFFITHS,
B.E. (Mech.), M.Biomed.E.,

DAWN R. LINKLATER,
B.A. (Hons.) Ph.D.

NOTE:

1. This study was completed in 1980 for the New South Wales Interdepartmental Tanker Committee. The results of each crash investigation were given to the Committee and were taken into account in the Committee's deliberations.

   Since that time a need has become apparent for a full report and this document has been prepared in response to that demand.

2. The views expressed in this report are those of the authors and are not necessarily endorsed by the Traffic Authority.

TRAFFIC ACCIDENT RESEARCH UNIT,
TRAFFIC AUTHORITY OF NEW SOUTH WALES.

ISSN 0313-2854
ISBN 0-7240-7035-4

RESEARCH REPORT 1/84
JANUARY, 1984.

ABSTRACT

An in-depth on-scene study of forty-two road tanker incidents with flammable loads was conducted in New South Wales over a period of fifteen months by teams each consisting of an Engineer and a Behavioural Scientist.

The report describes notification arrangements, site attendance and investigation techniques used in the study. Results include a listing of all the factors encountered. These are generally classified as mechanical, environmental and behavioural factors. Special mention is made of the potential for improvements in tanker stability, tanker design and tanker maintenance. An Appendix includes all the case histories.

CONTENTS

		PAGE NO.
ABSTRACT		i
1.	EXECUTIVE SUMMARY	1
2.	INTRODUCTION	3
3.	METHOD	5
	3.1 Sample	5
	3.2 Notification	5
	3.3 Team composition, Despatch and Kits	5
	3.4 On-Site Procedure	6
	3.5 Follow up and Debriefing	7
	3.6 Factor Classification	7
	3.7 Limitations of this Report	9
4.	RESULTS	11
	4.1 Factor Classification	11
	4.2 Mechanical Factors	11
	4.2.1 Stability	11
	4.2.2 Maintenance	12
	4.2.3 Design	12
	4.2.4 Incompatibility	13
	4.2.5 Labelling	13
	4.2.6 Miscellaneous	13
	4.2.7 Injuries	14
	4.2.8 Factors for other vehicles	14

4.3 Environmental Factors 14
4.3.1 Road Geometry 14
4.3.2 Roadside Furniture 14
4.3.3 Natural Roadside Environment 15
4.3.4 Surface Conditions 15
4.3.5 Traffic Controls 15
4.3.6 Miscellaneous 16

4.4 Behavioural Factors 16
4.4.1 Carelessness 16
4.4.2 Negligence 16
4.4.3 Misperception 16
4.4.4 Illness 17
4.4.5 Alcohol 17
4.4.6 Unfamiliarity 17
4.4.7 Education 17
4.4.8 Seat Belts 18
4.4.9 Stress 18
4.4.10 Fatigue 18

4.5 General Factors 18
4.5.1 Rollover 19
4.5.2 Leakage 19
4.5.3 Breakaway 19
4.5.4 Route Distance 20
4.5.5 Tanker Drivers 20
4.5.6 Miscellaneous 20

5. DISCUSSION 21

5.0 Additional Information 21
5.1 Tanker Stability 21
5.2 Tanker Design and Maintenance 23
5.3 The Road Environment 26
5.4 Salvage 27
5.5 Driver Behaviour 27
5.6 Miscellaneous 30

6. APPENDICES

6.1 Contributing Factors 38

6.1.1 Mechanical Factors Before Crash 38
6.1.2 Mechanical Factors In Crash 41
6.1.3 Mechanical Factors After Crash 43
6.1.4 Environmental Factors Before Crash 44
6.1.5 Environmental Factors In Crash 46
6.1.6 Environmental Factors After Crash 47
6.1.7 Behavioural Factors Before Crash 48
6.1.8 Behavioural Factors In Crash 51
6.1.9 Behavioural Factors After Crash 52

6.2 Case Histories 53

1. EXECUTIVE SUMMARY

This report describes the investigation of 42 incidents involving road tankers transporting flammable loads on New south Wales roads. An engineer and a behavioural scientist attended the scene of each incident to determine the vehicle, environmental and human factors that led to the accident and the resulting losses. These investigations revealed features of vehicle and road design and human behaviour which interacted to the detriment of traffic and community safety.

Roll instability was a common factor and rollover of the tankers occurred frequently. The reduced stability appeared to result from high centre of gravity, 'soft' roll stiffness from suspension and turntables, and sloshing of the liquid cargo.

Mechanical defects both in design and maintenance of the tankers appeared to be more frequent than has been the case in similar in-depth investigations of crashes involving other types of vehicles. Some mechanical factors noted were:

* Some braking systems simply not having the capacity to stop the trucks on the grades encountered; other instances where the use of spring brakes might have maintained braking capacity, after a loss of air pressure. (Sequenced braking and anti wheel lock systems might also have improved braking capacity,)

* Under-ride protection which was not provided,

* a lack of puncture protection of aluminium tankers,

* battery isolation switches which were non existent or difficult to find.

* no drain points for pumping out rolled over tanks,

* hatchgear that did not retain fluid on rollover.

Other mechanical problems occurred with mirrors, pipework, labelling, fire extinguishers and protective clothing.

Road geometry factors contributing to the forty-two incidents occurred nine times and included curvature, cross section, grade and width. Rough or slippery surface condition was reported six times as a factor contributing to the crash. Roadside furniture was a contributing factor in seven cases. The lack of controls (signs), or their inconspicuity or their unclear message played a contributing role in ten crashes. It was believed that raised pavement edge markers might, if provided, have alerted some fatigued drivers before their vehicles strayed completely off the sealed surface and lost control or rolled over. One case illustrated a problem with the existing regulations for right turning vehicles off two lane rural roads.

Common behavioural findings for tanker drivers were excessive speed for the conditions, fatigue and driving a vehicle with known defects. Tanker drivers did not report falling ill or being affected by alcohol whilst driving. Specific and general stresses on drivers were also found as factors in many of the crashes. Drivers and rescue workers were ignorant of the flame proof qualities of battery isolation switches. It appeared that improved education could have played a helpful role in familiarising drivers, rescuers and authorities with the tankers and salvage management.

Alternative methods of longhaul transport for flammable liquids may need further investigation, rail tankers being a possible solution in some cases.

2. INTRODUCTION

In 1978 a number of serious crashes involving road tankers with flammable loads attracted the Medias attention. These included one in Spain where 150 people died and another in Sydney, where fuel from a burning tanker entered the Airport's drainage system. As a result the Minister for Transport convened a meeting of representatives of the Ministry of Transport, Police, Main Roads, Motor Transport and Industrial Relations and Technology Departments and the Traffic Authority to discuss and examine the increasing incidence of tanker accidents in the State.

Subsequently, in March, 1979, the Road Tanker Committee, comprising the above officers together with representatives from the Australian Institute of Petroleum, the Transport Workers' Union, and the Board of Fire Commissioners, was established to "advise the Ministers for Transport and Industrial Relations on:

* the cause of the recent petrol tanker accidents (in New South Wales);

* any steps that needed to be taken in the short term to obviate a recurrence of the accidents;

* any action the Government needed to take to minimise dangers to the community from such accidents which was practicable and which was not being taken at the present time."

A summary of management practices of tanker companies was compiled during 1979 and 1980 (Linklater and Baker, 1982).

The Road Tanker Committee reported that there were about 3000 road tankers for flammable loads and 100 pressurised tankers on N.S.W. roads in 1979. Until recently the crash statistics for N.S.W did not clearly identify the load carried. This aspect of reporting has been changed and future monitoring of such crashes now includes load identification. However, when this study started some additional enquiries were made into all tanker crashes in a previous one year period. From this additional information it appeared that there had been 50 to 100 crashes per year recorded by the Traffic Accident Research Unit which involved tankers carrying flammable liquids*. These recorded crashes involved 3 to 5 fatalities per year. Product loss was frequent and there was fire in 5% of cases. The annual recorded crash rate for tankers for the number registered appeared to be about 2.5%, which was the same as the average annual recorded crash rate for all vehicles. Tankers did not appear to be overly represented in the total recorded traffic crashes. However, a tanker crash appeared to be two to three times more likely to result in fatal injury than other crashes and the Road Tanker Committee considered that "there remains a far greater potential for catastrophic consequences from crashes involving tankers".

This view caused the Minister for Transport to direct the Traffic Accident Research Unit (T.A.R.U.) to undertake a study. On-site in-depth investigations of road traffic crashes involving tankers carrying flammable products commenced in N.S.W. in May, 1979. The types of vehicles used to cart flammable liquids vary from table top trucks with drums strapped on the back, to sophisticated special design tankers. All such bulk carriers were included in the study.

During the course of this study, notification of a number of crashes involving other dangerous goods was received by TARU. The more notable of these were investigated as part of another project (Griffiths, 1984). It was observed that many of the problems of transporting flammable liquids are similar to those of transporting other dangerous goods.

---

* Crashes were recorded when they resulted in injury or sufficient damage to have at least one vehicle towed from the scene.

3. METHOD

3.1 SAMPLE

This in-depth study spanned a period of fifteen months from the 29th May, 1979 to the 30th September, 1980, during which 42 incidents involving vehicles carting bulk flammable liquids were investigated. During the study period another 12 incidents which were not attended came to the attention of the teams. These were generally minor or notification was received many hours after the crash had occurred.

3.2 NOTIFICATION

The sample was obtained by various means. Initially the Police were asked to notify TARU of any crashes involving road tankers with flammable loads. Selected radio news reports and newspapers were monitored as a back up. Outside office hours, Police were required to telephone people from a list of home phone numbers until they located a TARU officer and a Department of Industrial Relations and Technology officer. Generally, it was thought that this arrangement was not conducive to a good notification rate.

Later in the study a 24 hour answering service was arranged and a radio triggered paging unit (beeper) was leased. Police Radio, all Police Stations and the Fire Brigade Control Centre, were all given one telephone number. The frequency of notifications subsequently more than tripled. The notifying body was alway contacted immediately, firstly to verify the details and secondly to positively reinforce the notifying response.

3.3 TEAM COMPOSITION, DESPATCH AND KITS

Each team consisted of an Engineer, who investigated both the traffic and the mechanical factors, and a Behavioural Scientist who investigated the human aspects of the crash. Because the teams were required to attend crashes all over the state on an on-scene basis, special provisions had to be made for equipment etc. when a crash was too distant from Sydney to access quickly by car, the teams generally used scheduled airline services. By gaining a good knowledge of the operations of the multitude of smaller aeroplane services and using Departmental and hire car links it became possible to achieve a good rate of same-day, on-scene attendances even for crashes outside the Sydney Metropolitan Area. The more specialised recovery procedures required for tankers generally meant that salvage took longer than normal. This time factor gave the teams a better chance of arriving on-site before everything was cleared away. A sizeable portion of the crashes occurred in the early hours of the morning. In such cases, teams departed direct from their homes by car or on the earliest flights from Sydney that day. Teams were expected to take equipment kits home in readiness.

Kits were contained in a shock resistant, compartmentalised suit case. Each consisted of 35mm single lens reflex camera with standard and 35 to 105mm zoom lens, flash, chalk, measuring tape, measuring wheel, screw drivers, spanners, tyre pressure gauge, thread depth gauge, note-paper, cue sheets, inclinometer and a compass. A pendulum type road surface friction tester was used in some cases. Its bulkiness and weight discouraged it from being taken to those crash sites visited by aeroplane.

3.4 ON-SITE PROCEDURE

The general techniques used by the teams were developed after three years of in-depth work (Humphreys, 1981). The team utilised a cue sheet to prompt it to look for the various factors of interest.

On arriving at the scene the Engineer would examine the road and vehicles in an attempt to determine the causal factors for the crashes and crash loss. The Behavioural Scientist would interview those involved in the crash, witnesses, police, fire brigade, ambulance officers etc. Hence the teams hence frequently split up, as the engineer generally stayed on site and the Behavioural Scientist went into the nearby town for interviews at either the hospitals or other centres.

The on-site investigations were usually completed within one day.

3.5 FOLLOW-UP AND DEBRIEFING

After the visit to the site the team often continued to collect data by telephone. This was especially the case for the Behavioural Scientist who would conduct telephone interviews with those not available on location and monitor the subsequent progress of police investigations. A debriefing was conducted for each crash by a fellow researcher who was not on the team. This minimised the chance of a team accidentally overlooking any aspect of the crash.

3.6 FACTOR CLASSIFICATION

During the course of the study each case was investigated in an attempt to find all the contributing factors. However, it was possible that some bias could have occurred despite efforts to avoid situations where:-

1. After a factor had been identified several times it may have appeared less important to the study team to draw attention to this factor in subsequent case reports.

2. The identification of a factor in a later case may have been due to expertise developed during the study. The same factor may have been present, but not identified in earlier cases.

In an attempt to eliminate such possibilities and to optimise the reporting techniques, all the cases were reviewed together, upon the completion of the study. This led to a refinement of the factor classification and some changes to the way these factors had been classified in the progress report (Corben et al., 1980).

The factors were classified into a matrix (Figure 3.1) commonly attributed to Haddon and Brenner (1972).

Before crash (BC)
In crash (IC)
After crash (AC)

The areas into which the factors fell were further classified as Mechanical (M), Behavioural (B) and Environmental (E).

	BEFORE	IN	AFTER
Mechanical	BC - M	IC - M	AC - M
Behavioural	BC - B	IC - B	AC - B
Environmental	BC - E	IC - E	AC - E

FIGURE 3.1: HADDON MATRIX.

A further four assessments were made for each factor:

(a) An indication of the certainty with which the factor was present and hence had an opportunity to play a role.

D Definitely Present,
PB Probably Present,
PS Possibly Present,
U Uncertain if present

(b) The type of role that the factor played

S Sufficient,

N Necessary,

C Compounding,

P Present but no role,

U Role uncertain.

The extent of the contribution of a factor was measured within the time phase of the crash in which it manifested itself. For example, if it was before the crash then its contribution to crash cause was checked, if it was during or after the crash then its contribution to crash losses was checked.

(c) An indication of the assessors' certainty that the factor played the above role is recorded using the same codes as part (a), with a prefix of "R". Hence the codes are:-

RD Role definite,

RPB Role probable,

RPS Role possible,

RU Role unknown.

(d) Some factors, such as "not wearing seat belts in other involved vehicles" were not really specifically related to this crash type. These factors were distinguished from other factors that were specific to crashes involving road tankers with flammable loads, by assigning them a fourth code of INJ.

3.7 LIMITATIONS OF THIS REPORT

Many data were collected during each investigation, in an attempt to determine the factors underlying each crash and the injuries or other losses arising from the crash. A basic core of data was collected in each case and for economy investigations were terminated when the factors contributing to the losses appeared to have been identified. However, it may be possible that relevant data were not all collected with this method of terminating the investigations.

An attempt was made to attend all relevant crashes rather than to sample a few cases. However, the study was dependent upon notification of crashes by the Police, Fire Brigade or media. Some relevant crashes were not attended, even though notification was received (see section 3.1 above). It is possible that other relevant cases were not attended because notification of the crashes was not received.

The study was aimed at identifying the existence of factors, not at quantifying their extent. The sample of crashes attended was too small for that, and there were no associated controls, exposure checks or observational studies.

4. RESULTS

Summaries of the forty-two crashes studied are described in Appendix 2 of this report.

4.1 FACTOR CLASSIFICATION

Appendix 1 carries a list of the factors identified for each crash. They have been grouped according to the classification set out in Figure 3.1, and presented with the various assessment codes defined in Section 3.6.

In addition, Appendix 1 allocates each factor to a subgroup, and further details of the factors within each subgroup are given in Sections 4.2, 4.3, 4.4, and 4.5 following.

For ease of reporting, factors have been expressed as facts, even though in some cases they are based upon some conjecture by field teams and/or the authors. In some cases, the allocation of a factor (such as deteriorated gaskets) to one subgroup (such as 'design') rather than another (such as 'maintenance') reflects judgements for which the authors take responsibility. Another investigator, with different perspective might well reverse such allocations.

4.2 MECHANICAL

4.2.1 Stability

Of the forty two incidents stability compromised by a high centre of gravity, liquid load and soft suspension occurred as a factor thirteen times, nine pre-crash and four in-crash. In addition, two trucks had longitudinally oscillating skid plates, the driver of another reported no feedback that the trailer was leaning at a dangerous angle, another tanker had an undesirable prime mover and trailer suspension combination, and another had a loose king pin.

4.2.2. Maintenance

Instances of inadequate maintenance characterised by either infrequent inspections, non rectification of known faults, or both, occurred eleven times. Three such incidents concerned brakes; one concerned post repair inspection of steering; another post repair testing of pipework; and the remainder concerned tyres, framework, fuel injection line, steering, wheelbearing and one "general."

4.2.3 Design

There were sixteen tanker design details seen as contributing to crash losses. These were the relatively low puncture resistance of the aluminium tank walls, deteriorated gaskets or insufficient clip pressure on the hatch seals; pressure relief valves that by their design settings opened to leak the liquid load in a rollover, hatchgear that was not well protected by high enough or strong enough guards; a lack of electrical isolation switches; and inadequate access for pumping out rolled over tankers. There were four cases where turntable design failed. These included a joint with insufficient weld, a non foolproof hitching design, a king pin that failed to withstand the stresses imposed on it and a failed turntable race. In three cases the design of tankers provided inadequate under-ride protection which contributed to the crash losses. Two of these involved under-ride at the front by a car onto a vital component of the truck and the other concerned side under-ride of the tank's pipe work.

There were a further two cases where it was believed that hatch seals allowed vapour to escape and cause drowsiness of the driver before the crash.

4.2.4. Incompatibility

There were three cases of reduced turning ability and one of reduced hill climbing speed, leading to incompatibility with other vehicles and the road environment.

4.2.5 Labelling

There were two cases where Hazchem signs were not present and another one where the message was incomplete*.

4.2.6 Miscellaneous

There were two cases where it was felt that anti-jackknife devices may have delayed the onset of the jackknife and hence allowed better control. In one case a fire extinguisher had insufficient capacity and in another the fire extinguisher malfunctioned. In both cases total burn out subsequently occurred. It appeared possible in one of these cases, that fuel was ignited when it spilt on a turbo charger.

An effective aluminium tank puncture repair kit would have minimised fuel lost in a crowded site in one case. In another case it appeared that the driver had not been issued with sufficient protective clothing to deal with problems enroute.

4.2.7 Injuries

In one case a seat belt may have prevented injury of the car driver had the belt been intact and worn at the time of the crash (see 4.4.8 below for a further breakdown of the role of seat belts).

---

* In July 1978 placards displaying the type of flammable load carried by road tankers were made compulsory for all road tankers. In 1979 the oil companies agreed to have the Hazchem signs incorporated in the placard. However, during the period of the study, display of Hazchem signs was not compulsory.

4.2.8 Factors for other vehicles

For vehicles other than the tankers, there were three mechanical factors. One had a flat battery and only one headlight; another vehicle's steering linkages jammed; whilst one truck had only partially operative brakes.

4.3 ENVIRONMENTAL

4.3.1. Road Geometry

Road geometry occurred as a contributing factor in nine cases. These factors have been classified as Curvature, Cross-section, Grade and Width. Those cases in which curvature was involved included one tight curve, one tight "S" bend and one generally winding rough road. Cross-section defects included a negative camber on a sharp curve, an abrupt curve super-elevation, and a sudden (0.6m) drop off a road shoulder. A mild grade in a fuel discharge area allowed a tanker to roll away.

Narrow road width was a factor twice. In one case a narrow turnlane caused a tanker to mount an island and the fuel movement that resulted, contributed to the tanker rolling over. In the other case a country road was not wide enough to allow an evasive manoeuvre by a tanker.

4.3.2 Roadside Furniture

Overall there were seven cases where roadside furniture was a factor. In one, a support post for a guard rail punctured an aluminium tank during rollover. In three cases, power poles situated close to the road caused extensive damage. An abrupt ditch caused a tanker to trip over after it slid sideways. In one rollover, petrol drained into Sydney's airport drainage system. Fallen live wires from a power pole hampered salvage in one case.

4.3.3 Natural Roadside Environment

In one case an adjacent embankment led to a rollover when a truck left the road and ran up the embankment. In another case an uncovered deep culvert at the roadside bogged a tanker. In the third case insufficient intervisibility between intersecting roads contributed to a crash.

4.3.4 Surface Condition

Surface condition was reported six times as a factor. Two cases involved soft shoulders on a dirt road with one of them being aggravated by rain. Slippery road surfaces were caused by rain in one case and spilt diesel oil in another. A generally rough road route is believed to have contributed to one crash by loosening a turntable locking device. A stock grid with fractured joints partially collapsed and punctured an aluminium tank leading to a burnout.

4.3.5 Traffic Controls

There were ten instances where it was thought that controls were needed or were confusing or inconspicuous. In two cases the addition of raised road edge markers may have provided earlier warning to fatigued drivers that they were straying off the road. One tight curve needed a warning sign whilst another would have benefited from a special advisory speed sign for trucks. One 'Give Way' sign was difficult to see. Active warning lights at one rail crossing would probably have alerted one driver. There were two instances of confusing road markings. In one case a tanker driver strayed off the main road onto a light residential access road and found there was not enough room for his truck to manoeuvre. In the other case a truck slowing to turn right off a main rural highway confused a following driver.

4.3.6 Miscellaneous

The general hazardous nature of one road which was winding, hilly and had insufficient drainage, hence allowing pooling of water, was considered a factor. The rising sun caused 'blinding' glare to one driver who was ascending a hill towards the sun.

4.4. BEHAVIOURAL

4.4.1 Carelessness

In thirteen cases driver carelessness contributed to the crashes. Of these, six involved excessive speed for the conditions. In a further case a driver, aware he was fatigued, continued driving. Another driver was inattentive. In another five cases a lack of caution contributed to these crashes. The lack of caution occurred; (a) during an overtaking manoeuvre, (b) on an unsealed road, (c) while cutting a corner on an unsealed road, (d) at a rail crossing and (e) when a car driver was distracted by the passenger.

4.4.2 Negligence

In seven cases negligence contributed to the crash. One driver and his company decided to continue to operate a vehicle with defective brakes. Despite reports from one driver, a company did not correct a steering defect. One driver did not allow for the inadequate maintenance and general incompatibility of his vehicle with other vehicles using the road. One truck driver was following another too closely. Oone driver did not ensure Hazchem signs were attached to his vehicle. One driver did not use his horn as a warning. One car driver did not slow down when he drove into dense smoke.

4.4.3 Misperception

There were four reports of misperception. In one case a driver did not perceive a dangerous situation developing. In another instance a car driver reported having difficulty driving in the dawn light. One truck driver did not see an approaching motorcyclist. One tanker driver misperceived an approaching car's speed.

4.4.4 Illness

In two cases illness of car drivers contributed to tanker collisions. In one case a car driver was under treatment for diabetes and may have been in a coma when he went to the wrong side of the road. Another car driver had a heart attack.

4.4.5 Alcohol

This study was conducted before compulsory breath testing by Police in N.S.W. road crashes was introduced, and so many drivers were not breath tested. However, none of the tanker drivers were considered by the investigators to have been affected by alcohol. In one instance a car driver had a blood alcohol concentration level in excess of 0.08g of alcohol per 100 ml. of blood.

4.4.6 Unfamiliarity

In three cases drivers were not familiar with their vehicles, whilst another was not familiar with the locality he was driving in. One motor cyclist was inexperienced, whilst a car driver's inexperience combined with other factors, led to excessive speed.

4.4.7 Education

Inadequate education in three cases led to poor salvage management and hence unnecessarily extended delays. In one case a salvage worker was observed smoking during the recovery of a flammable vapour laden tanker. In four other cases, one driver used the wrong brakes for parking; one did not know how to correctly hitch his trailer; one did not know the amount of space he needed to turn in; whilst another did not know how to make a suitable crash avoidance manoeuvre.

4.4.8 Seatbelts

In five crashes, the fact that seat belts were not worn contributed to the injuries received. Of these five, three crashes involved fatalities and in the remaining two crashes, numerous injuries were sustained. In all, four people were killed and seven people injured who were not wearing seat belts. Although belts were known to be available in nineteen of the tankers, only three tanker drivers reported wearing them at the time of the crash.

4.4.9 Stress

In six instances stress contributed to the crash. In two cases the drivers were under personal stress prior to the crash (general stress), while in one case a combination of general and specific stresses occurred. In three cases specific stresses were involved. The specific stresses were a desire to urinate, a fear of jackknifing which stopped a driver from braking, and a car driver who was worried about known car defects.

4.4.10 Fatigue

There were seven instances of fatigue. Two of these occurred in drivers other than the tanker driver. Four of the tankers were carrying loads whose vapours could cause drowsiness if inhaled. In two of these it is believed that this may have contributed to driver fatigue although only one driver reported smelling such vapour prior to the crash. This driver was also known to have been driving for 15.5 hours.

4.5 GENERAL

Some aspects of the crashes may be a part of several contributory factors. The contributing factors that make up such aspects have generally been reported in the preceding parts of this report. This section is included to highlight such aspects of special interest to the industry or researchers.

4.5.1 Rollover

Rollover occurred in eighteen of the forty-two crashes. In some cases rollover resulted from mechanical factors, whilst in others it resulted from roadside characteristics. Behavioural factors such as driver education interacted with these other factors.

Five of the eleven non-articulated tankers or trucks with tanks rolled over. Thirteen of the thirty-one articulated tankers rolled over. Of the rigid tankers, two rolled over on soft road shoulders and another rolled over after being hit by a rail motor. Of the four pressurised vehicles, two rolled over. In one crash, only the prime mover rolled and that was after being hit by another vehicle. One unhitched trailer rolled over after its tyres and suspension were damaged by fire.

4.5.2 Leakage

In ten of the eighteen rollovers susbstantial leakage occurred. This came from hatch gear or vents in seven crashes, punctured tanks in six crashes, dislodged caps in three crashes and a hole burnt by a fire in one case. Neither of the two pressurised tankers that rolled over leaked, although one prime mover's fuel tank did. Two of the twenty four tankers which did not roll were punctured and burnt out. One tanker lost 'a lot' of product from a fractured pipe fitting and a fuel tanker lost part of its load from a discharge pipe that developed a leak. In another two crashes without rollover, fuel was also reportedly lost from the vents.

In eighteen of the crashes where the bulk load did not leak, three prime mover fuel tanks did leak.

4.5.3 Breakaway

In nine of the thirty-one articulated vehicle crashes, the trailer broke away, with eight overturning. In two of the nine cases it was the turntable failure with breakaway, that initiated the incident.

4.5.4 Route Distance

Of the forty-two tanker crashes attended, fourteen were on routes of less than 80 km, eleven were on routes between 90 km and 300 km, sixteen were on routes greater than 300 km, and one was unknown.

4.5.5 Tanker Drivers

Three of the thirty-four employee drivers and two of the eight owner drivers showed some unfamiliarity, or lack of education with their vehicle or load.

One of the eight owner drivers and nine of the thirty-four employee drivers,were driving vehicles where inadequate maintenance was a contributing factor to the crash. There was no significant relationship between vehicle ownership and level of maintenance (X^2 = 0.697, 1 d.f. p = 0.4).

4.5.6. Miscellaneous

Salvage personnel showed a lack of Hazchem knowledge in one case. After one crash a damaged trailer was towed more than 200 km with flammable liquid sloshing out through damaged hatches. In several cases water contaminated with flammable liquid was washed into drains. Battery isolation switches were difficult to find or hard to access. Some drivers and rescue workers reported a reluctance to operate these switches. They did not appreciate the safety of such switches' spark proof properties. In one recovery a salvage worker was observed smoking during the recovery of a flammable vapour laden tanker. One contractor had thirty-five petrol tanker trips per week from Victoria to Sydney petrol stations, to make up the refinery short fall. This appeared to be a long term practice with several other contractors also reputed to be organising at least a similar number of trips.

5. DISCUSSION

5.0 ADDITIONAL INFORMATION

Some of the information introduced in this discussion was gathered in interviews with drivers and operators following crashes. It was complemented by attendance at relevant seminars, meetings, committees and by first hand observation of road transport practices during the course of this report's preparation.

5.1 TANKER STABILITY

Amongst the factors that lead to tanker rollover are their high centre of gravity (C.G.), 'soft' roll stiffness and sloshing of the liquid load. A high centre of gravity results when the tank is mounted above the turn table and rear axle assembly. The low roll stiffness is a result of suspension being traditionally located on that part of the axle inside the wheel track, hence giving a small moment arm. This coupled with restricted spring stiffness gives a "soft" roll stiffness at the rear of the trailer. Similarly "soft" suspensions on the prime mover and/or soft mounted or laterally oscillating fifth wheels, lead to reduced roll stiffness at the front of the trailer. (more comment on soft turntables may be found on page twenty-five).

Stability can also be compromised by load movement, especially the sloshing of liquid. Sloshing can only occur when a tank is not full. Some allowance needs to be made for liquid expansion and it seems the simplest way to do this is to leave some room at the top of the tank (ullage). A possible alternative would be a small separate expansion chamber connected to the tank compartment top.

The recommended practice quoted at industry seminars is for tanks to be nearly completely full (minimum ullage space only) or completely empty. Observations of both crashed and non crashed vehicles manifests during the course of this study indicated that contrary to this loads, are often tailored to customers' requirements.

Another source of partial loading occurs because some tankers are designed to carry the maximum volume (i.e. maximum legal weight) of the least dense liquid they are likely to carry. When carrying more dense liquids the compartments cannot be filled if legal static axle loadings are to be adhered to, and hence sloshing may result. This problem may be more acute with pressurised gas tankers, where greater variations in the densities of potential loads occur.

Tanks of hybrid elliptical-rectangular cross section have come into use. In some cases they may not lower the centre of gravity because the larger diameter of the bottom pan of the tank limits how far the tank can drop into the space above the axles, between the left and right wheels. This space is limited in breadth by the traditional double wheel and suspension design. Professor Kore Rumar (National Road and Traffic Research Institute, Sweden) indicated that these hybrid rectangular elliptical cross-section tanks have about the largest amount of liquid sloshing of any current shape. This finding appears to have been based on small scale modelling over a range of roll frequencies. In an informal seminar of TARU, Rumar reported that the Swedish National Road and Traffic Research Institute recommended side baffles for road tankers.

It appears to be a common fallacy that tankers are fitted with side baffles. None of the tankers encountered in this study appeared to have had side baffles and in practice the knowledge that side baffles are not fitted appears to be confined to tank manufacturers and their purchasers. Certainly, during this study much anecdotal evidence suggested that many people believed that tankers had baffles fitted as a routine measure. The non-fitment of baffles may arise from both increased manufacturing costs and a lower subsequent payload in order to comply with weight restrictions.

The potential for more stable tanker designs by better suspension selections or better prime-mover and trailer suspension combinations is currently under investigation by Sweatman (1979) and Luan Mai (1982) both of the Australian Road Research Board. A research programme is being conducted to find out the roll stiffness and rollover angles of various trucks and trailer combinations, using a platform for static tilting of trucks and semi-trailers. This will quantify the comparative and absolute lateral static stability of available heavy vehicle suspensions. At this stage their preview reports (Luan Mai, 1982) recommend better selection of suspensions and improved designs.

The Australian Standard for fuel tankers A.S.2016 includes a limit on the static upright height of the centre of gravity. This appears to have been selected to suit contemporary tankers rather than seeking to increase rollover resistance. It takes no account of equally important factors such as roll stiffness.

5.2 TANKER DESIGN AND MAINTENANCE

Some gross examples of inadequate maintenance occurred in this study. The standard of maintenance did not vary significantly between owner drivers and company vehicles. During the study period special roving teams of Department of Motor Transport inspectors were operating. In one area they inspected 492 heavy vehicles and found that 167, i.e. about one third, had major defects (McDonnell, 1980).

Poor maintenance was a causal factor in nine cases and a compounding factor in one. Design was a crash causal factor in five cases and a compounding one in four cases. Out of the 42 cases poor maintenance occurred 10 times (24%) and poor design occurred 9 times (21%). These incidences of mechanical defects (24% and 21%) are high compared to those previously reported from in-depth studies for other vehicles (Humphries, 1981). Inadequate roll stability from poor design was not included in the categorisation of mechanical defects for this tanker study. If it were included, the incidence of mechanical defects would be even higher.

This study identified several factors, which had the potential to prevent traffic collisions or minimise the consequent damage. Some of these factors were underride bars, brakes, mirrors, puncture protection, battery isolation switches and access for pumping out rolled over tankers.

Regarding underride guards, of the three cases in the study where other vehicles underrode a tanker, two were to the front and one to the side. This sample was small and more information was needed to compare the various incidences of underride in the general population. An examination was made of TARU's coded records of all crashes where a car ran into the rear or front of a truck throughout N.S.W. during 1979 and 1980. A breakdown of this is shown in Table 5.1. It indicates that there were five times more fatalities and four times more serious injuries overall for frontal crashes than rear crashes.

TABLE 5.1 Car front and rear crashes with trucks for 1979 and 1980 totalled.

	FRONT	REAR
Fatalities	109	21
Serious Injuries	194	54
All reported crashes	465	564

The Australian Standard for road tank vehicles has provision for rear underride. An Australian Design Rule (ADR) is currently in draft for rear underride bars. However, front underride has a greater potential to allow a car to damage a tanker's steering with a possible loss of control or rollover and thus serious consequences to the tanker driver and those in the immediate vicinity of the crash. Furthermore, since the vehicles are travelling in the opposite direction, the closing speeds and consequent forces involved generally result in more devastating consequences for the other vehicle occupants. For maximum effect underride bars need to be tightly specified in height and strength to properly catch today's smaller cars.

With respect to brakes most of the problems were concerned with maintenance. However, in one instance a tanker using an engine brake jackknifed on a bend. It seems likely that this occurred because engine brakes operate on the drive axles only and it appears that such supplementary braking systems must be used with some discretion if control is to be maintained.

Inadequacies of rear view mirrors were reported three times. In one case they were not adequate on the other vehicle. On one tanker they obscured side vision, whilst on another tanker they were poorly positioned.

In five cases the low puncture resistance of aluminium tankers allowed penetration or rupture of the tank. The tankers are generally designed so that the tank forms an integral part of the trailer structure and this arrangement is often sufficiently strong to allow the use of relatively light partial chassis beams. Thus amongst other forces the tanks have to absorb much of the vertical and torsional dynamic loads. Such loads are reported to have caused non elastic strains around the turntable fittings on tanks (Sweatman, 1979 and IRTE, 1982).

In an effort to reduce these strains, turntables with some lateral oscillation freedom and vertical shock absorption have been introduced. In this they appear to be successful. However, in achieving this, they reduce the component of roll stiffness from the prime mover at the tank front. This changes the rig's roll stability from that of a four point object towards that of a three point object, and hence increases its proneness to rollover. Drivers have generally reported favourably on these soft turntables, probably because they transmit less of the trailer movement to them and so increase their ride comfort and sense of stability. This means the driver may receive less feedback on what is happening to his trailer and so may be lulled into a false sense of security that can further compound the likelihood of rollover.

In summary soft turntables may -

1. reduce dynamic stresses on the tanks
2. increase driver comfort
3. reduce the lateral stability of tanks
4. reduce the feedback to the driver of impending rollover

In reducing the torsional stresses by allowing some roll freedom, these soft turntables also make it possible to use lighter materials. A lighter tank can allow a greater legal payload. Where the long term costs of tank life and traffic crashes are ignored, such greater payloads can appear to offer short term economies.

In many cases battery isolation switches could not be found or were not used by the drivers or rescue workers. This study and subsequent attendance at gatherings of the trucking industry have made it clear to one of these authors that there is a widespread confusion concerning the flame proof attributes of battery isolation switches. It is not uncommon to hear rescue workers advise others not to operate such switches. The labelling of these switches and their accessibility could also be improved.

Fire extinguishers were found to have incorrect or missing labelling, insufficient capacity and to malfunction. These problems and those of insufficient protective clothing have fairly clear solutions.

The problems of jack-knifing have been studied by many other researchers and a number of countermeasures have been proposed. These include driver behaviour modification, caution with drive wheel braking on articulated units, sequencing of braking, friction discs and other mechanical stops to limit trailer swing (jack-knife). Braking improvement controls are desirable for other obvious reasons, but the specific anti-jack-knife devices may not be cost effective (Sweatman 1979).

The investigations of crashes reported here have shown that leakage from hatches, pressure relief vents and filler caps was common after rollover. Since this study, new standards have been applied to hatch gear, and several companies have retrospectively fitted equipment to these standards. It appears this aspect of tanker design may have improved, although only further crash studies could confirm this.

5.3 THE ROAD ENVIRONMENT

The specific problems of the environment have been referred to the Department of Main Roads (D.M.R.) and in several cases modifications have already occurred. The D.M.R. is in the process of upgrading one of N.S.W.'s main highways on which many of the crashes in this study have occurred. In particular, a completely new section is being built to replace a hilly, curved and narrow stretch of this highway.

With respect to roadside furniture and in particular power poles, there is now legislation authorising funding for relocation of those poles that are dangerously situated. However, at this time it appears few such relocationshave occurred. A model has been evolved which can be used to identify such poles (Fox, Good and Joubert 1979). This model takes into account such things as traffic volume, road curvature, surface friction etc.

Regarding right turns off rural highways into minor roads or lanes, none of the current controls seemed appropriate for the situation. As it does not seem practical to provide right turn bays for such turnoffs to minor roads, an additional control may be needed for this manoeuvre in rural areas. Further investigation of possible means of controlling such right turn manoeuvres appears justified. It may be more productive to place responsibility for making these turns in safety onto the turning vehicle, rather than the following vehicles. This may require the turning vehicle to pull to the left until the road is clear of all vehicles.

5.4 SALVAGE

Salvage methods continue to be an area of controversy. In this study every tanker that had rolled over was emptied before it was righted. The general industry advice is however that the flammable liquid transfer operations involve more hazards and time-associated costs than recovery of the tank and load together (Crowley 1982). The fuel transport industry generally recommends that vehicles be righted by specialist tow truck type vehicles. The authorities at crashes however tend to call for cranes. At a recent I.R.T.E. Seminar (1982) speakers recommended that operators should pre-plan their recovery procedures and authorise in advance salvage and towing contractors.

5.5 DRIVER BEHAVIOUR

Attempts to modify the behavioural factors of carelessness, negligence and stress could to be plagued with problems of high expense and low effectiveness (Avery 1973, Freedman and Rothman 1979). However, it may be that these traditional problems associated with driver training may not apply to a specialised group such as truck drivers. Perhaps the benefit of a more clearly defined target audience and possibly different motivation of professional drivers can be combined with other factors to give cost effective training. This is currently under investigation within the transport and insurance industries.*

Education problems and unfamiliarity could theoretically be dealt with by driver training programmes. Such programmes might involve owner drivers and small companies as well as large companies since in this study 40% of drivers showing such problems were owner drivers.

Better selection procedures for drivers of potentially dangerous vehicles may also yield some improvements in driver behaviour.

Tanker drivers were not tested for alcohol or medical fitness, although they were questioned about these matters by this study's interviewers. Evidence from police and witnesses was also sought. Neither illness nor alcohol were reported as a factor for tanker drivers. However, they were factors in some of these crashes for the other drivers involved.

Only three of the tanker drivers in the 42 incidents wore seat belts although in 19 cases they were available. This was surprising in the light of the overwhelming evidence that wearing seat belts prevents injuries in the case of traffic collisions (Herbert 1980). There are many reasons why tanker drivers may choose not to wear the available seat belts (Linklater 1977). Two commonly expressed reasons have been that the belts were thought to be dangerous and that they were uncomfortable. Henderson and Sims (1970) have described the probability of injury when truck drivers

---

* Some large road transport companies such as TNT and AZTEC were making claims of very effective driver education programmes with consequent crash reductions. Some insurance companies in N.S.W. are interested in offering premium discounts for companies whose drivers take courses approved or given by the insurance company.

do not wear seat belts as being higher than when they do, thus suggesting that the apparent safety related beliefs of some truck drivers are wrong. The comfort of belts is a special problem in trucks with air suspension seats and seat belt anchorages on the truck body. However, in the 1980s two seat belt systems became available that were suitable for air suspension truck seats. One system is optional overseas on some Volvo trucks and utilises two reelout and locking devices with electric actuation. The other system by Kangol Magnet uses electric actuation of a single reel from two differentiating sensors. (Volvo 1980, Kangol 1980). These systems have yet to be approved for use in Australia.

Seven instances of fatigue were reported. Raised road edge markers have been suggested as having some value for fatigued drivers to alert them when their vehicle strayed off the roadway (Linklater 1979). The driver would of course then have to heed the warning, stop driving, have a rest and preferably a sleep in order to dissipate the fatigue. Current controls and enforcement of driving hours and rest periods are apparently not sufficient to prevent fatigue. Since this study began, LPG carriers have been investigating the compulsory use of tachographs which might improve recording of actual driving hours over the present log books used in N.S.W. However, the permitted driving hours in N.S.W. (72 hours per week) are excessive when compared to those permitted in other countries. The European Economic Community has adopted an eight hour day for drivers or a 48 hour week. In the United States the code of Federal Regulations permits a maximum of ten hours driving time per day as against the twelve hours permitted in N.S.W. The International Labour Office (ILO) of the United Nations has recommended a maximum total working time for truck drivers of nine hours per day including overtime and a 48 hour week (ILO, 1980). Thus, N.S.W. and the rest of Australia which has the same provisions for long-distance driving hours would appear to expect more from its truck drivers than is expected in other countries. A reduction in hours is presently being discussed at the federal level.

5.6 Miscellaneous

At the time of this study, the practice of transporting petrol from Victoria to Sydney by road seemed to be well established. According to some reports, such movements could have accounted for over 100 round trips per week. This appeared to be due to a general shortfall of Sydney's refineries petrol output. Perhaps further investigation is required and alternatives such as rail transport may need to be considered, as well as long term resolution of the shortfall in Sydney petrol availability.

6. CONCLUSIONS

This study has shown that collisions involving tankers carting flammable loads may occur for many reasons. Of particular concern has been the loss of flammable liquid and consequent damage arising from factors occurring during and after the crash.

The investigations reported here have highlighted many factors which contribute to the crash losses arising from road tankers carrying flammable loads. It is heartening to note that the potential for improvements in either reducing the frequency or the severity of these crashes seems to be considerable.

These findings were referred to the Interdepartmental Tanker Committee and taken into consideration in their deliberations. At present the Australian Standard for fuel tankers is being merged into one common standard for all dangerous goods carried in bulk. The Traffic Authority of New South Wales has input into this Committee and anticipates that the results of this research will assist in the revision and compilation of the new Standard.

Of particular note in this study was the actual and/or potential contribution of the following factors to occurrence of the crashes or to their severity:

* lack of stability arising from tank shape; lack of side baffles; 'soft' suspension; mismatching of suspension and turntable; noncompliance with recommended loading practice.

* mechanical defects of tankers contributed to by design features and lack of maintenance.

* some braking systems simply did not have the capacity to stop the trucks on the grades encountered; there were other instances where the use of spring brakes might have maintained braking capacity; after a loss of air pressure, sequenced braking and anti wheel lock systems might also have improved braking capacity.

* rear view mirrors that were not used or did not provide adequate rear vision and in some cases impeded side vision.

* lack of puncture protection of aluminium tankers

* no drain points for pumping out rolled over tanks

* lack of under-ride protection

* hatches that did not retain fluid on rollover

* misunderstanding of spark-proof capacity of battery isolation switches and the failure of drivers and rescue workers to find such switches.

* roads with tight curves or narrow pavements that were difficult to negotiate with tankers.

* roadside furniture that caused tank damage to vehicles leaving the roadway

* fatigued drivers

* excessive speed for the road conditions

* illegal driving durations

* non-wearing of seat belts by tanker drivers

* longhaul road transport of petrol i.e. from Victoria to Sydney

REFERENCES

AUSTRALIAN STANDARDS ASSOCIATION 1982. "Road Tank Vehicles for Flammable Liquids". A.S. 2016 Revised 1982.

AVERY, G.C. 1973 "The Role of Communication and Propaganda in Traffic Safety". Report 3/73, Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

CORBEN, C., OSHLACK, C. AND LINKLATER, D. 1981. "In-Depth Study of Traffic Crashes involving Fuel Tankers (First Progress Report)". Report 2/80 Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

CROWLEY, L. 1982. "The Tanker Operators Angle". A paper presented to a seminar of the Institute of Road Transport Engineers, Sydney, N.S.W.

FREEDMAN, K. AND ROTHMAN, J. 1979. "The 'Slob' Campaign: An Experimental approach to Drink-Driving Mass Media Communications". Report 2/79, Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

FOX, J.C., GOOD M.C. and JOUBERT, P.N. 1979. 'Collisions with Utility Poles'. Department of Mechanical Engineering, Melbourne University.

GRIFFITHS, M.J. 1982 "In-depth Studies of Special Crashes" Traffic Accident Research Unit, Traffic Authority. An unpublished report.

HADDON, W. (Jnr.) 1972. "A Logical Frame Work for Categorising Highway Safety Phenomena and Activity". The Journal of Trauma U.S.A. Vol. 12, No.3 pp.193-207

HENDERSON, M. AND SIMS, A. 1970. "Heavy Vehicle Crash Injury". Report 2/70 Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

HERBERT, D.C. 1980. "Road Safety in the Seventies: Lessons for the Eighties" Report 4/80 Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

HUMPHREYS, M., 1981. 'The Collection and Analysis of In-depth Crash Data'. Ergonomics Vol. 29, No. 6. pp. 423-436.

ILO, 1980. "Driver Welfare". Commercial Motor, June 14, 1980 pp.40-41

I.R.T.E. (1982). "After the Accident". A seminar conducted by the Sydney Centre of the Institute of Road Transport Engineers. Copies available from I.R.T.E., P.O. Box 421, Auburn, N.S.W. 2144

KANGOL, 1980. Kangol Magnet Ltd., Norfolk Street, Carlisle, Cumbria, U.K.

LINKLATER, D.R. 1977. 'A Profile of Long Distance Truck Drivers' Report 9/77 Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

LINKLATER, D.R. 1978. 'Traffic Safety and the Long Distance Truck Driver'. Report 8/78 Traffic Accident Research Unit, Department of Motor Transport, Rosebery, N.S.W.

LINKLATER, D.R. AND BAKER, A., 1981. 'Traffic Safety and the Transport of Pressurised Gas Fuels'. Research Report 3/81, Traffic Accident Research Unit, Traffic Authority, Rosebery, N.S.W.

LINKLATER, D.R. AND BAKER, A., 1982. 'A Summary of Management Practices in Tanker Companies'. Research Note, Traffic Accident Research Unit, Traffic Authority, Rosebery, N.S.W.

LUAN MAI, 1982 'Articulated Vehicle Stability'. A progress report. Australian Road Research Board, Vermont South, Victoria. 3133.

McDONELL, G. 1980. Commission of enquiry into the New South Wales Road Freight Industry. vol. IV. Government Printer, N.S.W.

SWEATMAN, P. 1979. 'Articulated Vehicle Stability'. A summary report on the Australian Institute of Petroleum (A.I.P.) seminar conducted on 17/7/1979, Australian Road Research Board, Vermont South, Victoria. 3133.

VOLVO, 1980. Volvo Australia, Box 122, Sydney, N.S.W. Australia.

ACKNOWLEDGEMENTS

Our thanks for the notification of crashes go to the N.S.W. Fire Brigade and Police. We were assisted in getting to the crash sites by the N.S.W. Department of Motor Transport staff and the police. We are most grateful to all those who supplied information to our researchers during the course of our investigations. These include the vehicle occupants, witnesses, rescue workers, hospital staff, ambulance, police, fire brigade and members of the Australian Institute of Petroleum.

A core group of staff experienced in in-depth on-site studies led most of the investigations and assisted with the planning and training of other staff. They were:

Max Humphreys, B.Sc. (Hons.) (Ph.D.)
John Jamieson, B. Surv., M. eng. Sc., M.I.S., A.I.T.E.
Michael Griffiths, B.E. (Mech.), M. Biomed. E., M.I.E. (Aust)

Other staff involved in the planning or organisation and the occasional site investigations were:

Dawn Linklater, B.A. (Hons.), Ph.D.,
Principal Research Scientist, Behaviour Section.
Chris Corben, B.E. Crash Studies Manager.

The TARU staff who were involved in the bulk of the data collection included:

Jenny Young, B.E. (Civ.), Cert. T.P. & C.
Fred Schnerring, B.E. (Civ.), M. Eng. Sc.
Colleen Strotton, B.A.
Bruce Hartwig, B.E.
Louise Radford, B. Soc. Stud.
Christine Oshlack, B.A. (Hons.)
Lindy Hazelton, B.A.
Vicki Dendtler, B. Sc.

Colleen Strotton provided additional assistance with the compilation of the behavioural aspects of this report.

Studies of this nature place great demands on the field staff, who need to be on call 24 hours a day and often depart for distant parts of the state with little or no notice. For this, and a general enthusiasm from all the staff to get on with the job we are most grateful.

6.1 CONTRIBUTING FACTORS

6.1.1 MECHANICAL FACTORS BEFORE CRASH

Factor Contribution*	Description	Factor Classification
D, N, RD	Poor stability (from high Centre of Gravity (C.G.) and load movement).	Stability
D, N, RD	Longitudinally oscillating skid plate reduced roll stiffness.	Stability
D, U, RD	Air bag suspension possibly soft.	Stability
D, U, RD	Poorly maintained prime mover, brakes, tyres, etc.	Maintenance general
D, N, RD	Poor stability (high C.G., liquid movement).	Stability
D, N, RD	Brake failure from poor maintenance.	Maint., brakes
D, C, RD	High C.G. of load reduced stability.	Stability
PB, N, RD	Inadequate brakes for other truck. (NT)	Other vehicle.
D, N, RD	Reduced stability (high C.G., liquid load).	Stability.
D, N, RD	Brake airline leak, poor maintenance.	Maintenance, brakes
D, U, RD	Poor placement of brake control.	Design, brakes.
D, S, RD	Poor design of welded joint of turntable.	Design, turntable.
D, C, RPB	Defective headlights, battery (NT)	Other vehicle
RS, C, RPB	Vapour leaks which may have caused drowsiness.	Design
D, C, RD	No trailer tilt feedback to driver.	Stability feedback
PS, C, RPS	Prime mover/trailer suspension mismatched.	Stability
D, C, RD	No underride protection for fuel lines valves etc.	Design

* Codes are explained on pages 9 and 10.

Factor Contribution	Description	Factor Classification
D, C, RPS	Poor tread depth on prime mover tyres.	Maintenance general.
D, N, RD	Non foolproof turntable hitching design.	Design, turntable
D, S, RD	Poor maintenance of brakes' air pressure system.	Maintenance, brakes.
D, N, RD	Poor turning ability of articulated tankers.	Incompatability
D, S, RD	An inadequate repair procedure on a trailer linkage component allowed fatigue failure.	Maintenance, general
D, N, RD	Inadequate maintenance inspections.	Maint., General
D, N, RD	Isolation valves not directly at tank outlet.	Design.
D, N, RPB	Short period registration possibly influenced maintenance, hence allowing poor turn indicators and poor mirrors on other truck. (NT)	Other vehicle.
C, S, RPB	Injector line failed spraying tyres with diesel fuel.	Maintenance, general.
PB, C, RPS	Relative poor manoeuverability of tanker.	Incompatability
PS, C, RPS	Lack of containment of sleep inducing vapour.	Design
D, S, RD	Poor maintenance and inspection procedures.	Maintenance.
D, N, RPB	Inadequate design led to fracture of springs.	Design.
D, S, RD	Steering joint disconnected (Power steering ram from tie rod) following poor repairs.	Maintenance, steering.

Factor Contribution	Description	Factor Classification
D, N, RPB	Obscured side vision by large external mirror for truck driver.	Design
D, C, RD	Sloshing of fuel in 80% full containers gave reduced stability.	Stability.
D, C, U, RD	Poorly positioned mirrors on tanker.	Design.
D, C, RPB	Slow moving tanker on a main rural highway.	Incompatibility
D, N, RD	Bearing collapse on a tanker trailer wheel.	Maintenance.
D, N, RD	Car steering jammed. (NT).	Other vehicle.

6.1.2 MECHANICAL FACTORS IN CRASH

Factor Contribution	Description	Factor Classification
D, N, RD	Poor puncture resistance of aluminium.	Design.
D, N, RD	Prime mover mudguard strut punctured tank,	Design.
D, N, RD	Poor puncture resistance of aluminium tank.	Design.
D, N, RD	Instability from high C.G., fluid load movement, loose king pin.	Stability
PS, C, RPS	Truck steering damage from primary collision after underrun reduced stability.	Design.
D, N, RD	Fifth wheel king pin failed in crash allowing trailer rollover.	Design, turntable.
PB, C, RPB, INJ.	Seat belt not wearable.	Injury.
PR, C, RPB	No jack-knife prevention devices.	Miscellaneous
D, C, RD	Lack of puncture protection for aluminium tankers.	Design.
D, C, RD	Double oscillating turntable allowed reduced lateral stability.	Stability.
D, N, RD	Lack of puncture protection for aluminium tanks.	Design
D, C, RD	Double oscillating turntable allowed reduced lateral stability.	Stability.
D, N, RD	Lack of puncture protection for aluminium tanks.	Design
D, N, PRB	Poor puncture resistance of aluminium tank.	Design.
D, N, RD	Hatches tore off in rollover.	Design.
D, C, RD	No anti jack-knife devices.	Miscellaneous.
D, N, RD	High Centre of Gravity.	Stability
D, U, RPB	Possible lack of manoeuverability of tanker.	Incompatibility
D, N, RD	High Centre of Gravity	Stability.

Factor Contribution	Description	Factor Classification
U, C, RPS	Turntable race failed.	Design.
D, N, RD	Malfunctioning fire extinguishers.	Miscellaneous.
D, C, RD	No front underride bar on tanker to prevent car intrusion and damage to steering, turbo charger and fuel tank.	Design.
D, C, RD	Fire from damaged turbo charger probably ignited fuel from broken tank.	Miscellaneous.

6.1.3 MECHANICAL FACTORS AFTER CRASH

Factor Contribution	Description	Factor Classification
D, C, RD	Hatches leaked fuel.	Design.
D, C, RD	No effective tank puncture kits.	Design.
D, C, RD	Inadequate access for salvage pump out.	Design.
D, U, RD	Inadequate warnings of product vapour as hazard to health.	Labelling.
D, N, RD	Hatches leaked fuel	Design.
D, U, RD	No electrical isolation switches.	Design.
D, C, RD	Dislodged cap allowed major leaks.	Design.
D, C, RD	Pressure vents leaked fuel.	Design.
C, N, RPB	Insufficient capacity of fire extinguishers on truck.	Miscellaneous.
D, C, RD	Insufficient protective clothing for drivers of hazardous loads.	Miscellaneous.
D, C, RD	No Hazchem signs, so load not treated as volatile.	Labelling.
D, P, RD	No Hazchem signs although this made no contribution to crash losses.	Labelling.
D, C, RPB	Hatches leaked fuel.	Design.
D, N, RD	Hatches leaked fuel.	Design.
D, N, RD	Hatches leaked fuel	Design.
D, N, RD	Pressure vents leaked fuel.	Design.

6.1.4 ENVIRONMENTAL BEFORE CRASH

Factor Contribution	Description	Factor Classification
E, N, RD	Tight curve.	Curvature.
D, U, RD	No warning sign for tight curve.	Controls.
D, C, RD	Narrow lane, truck drove over island possibly inducing sloshing.	Width.
D, U, RD	Negative camber on a sharp corner.	Cross section.
D, N, RD	No audible road edge warning.	Controls.
D, N, RD	Roadside embankment.	Natural Road-side Environ-ment.
D, N, RD	Mild slope in fuel discharge area.	Grade.
D, C, RD	Winding roadway.	Curvature.
D, C, RPS	Ambiguous road markings.	Controls.
D, C, RPS	No special truck advisory speed signs for this tight bend.	Controls.
D, S, RD	Poorly maintained stock grid.	Surface con-dition.
D, C, RPB	Wet road surface.	Surface con-dition.
D, C, RPS	Abrupt curve super elevation.	Cross section.
D, N, RD	Route with generally rough roads.	Surface con-dition.
D, C, RPB	Lack of route controls for long heavy vehicles.	Controls.
D, C, RD	Drainage ditch at roadside not covered by grate or other.	Natural Road-side Environ-ment.
D, N, RD	Diesel, fuel spill on a corner from other users made road slippery.	Surface con-dition.
D, N, RD	Road Hazardous, winding, hilly, poor drainage.	Miscellaneous.
D, N, RPB	No special controls for right turning vehicles on rural highways.	Controls

Factor Contribution	Description	Factor Classification
D, C, RPB	Confusing road configuration.	Controls.
D, N, RD	Soft road shoulders on a primitive road deteriorated by rain.	Surface condition.
D. C. RPS.	Narrow road.	Width.
D. C. RPS	Poor visibility of give way signs.	Controls
D, C, RPB	Poor intervisibility of car and tanker.	Natural Roadside Environment.
D, C, N, RD	Soft shoulders on a primitive road.	Surface condition.
D, N, RD	Tight S bend on main road.	Curvature.
D, N, RD	No active warning signs of train approaching rail crossing.	Controls.
D, N, RPS	Low elevation of early morning sun coinciding with a hill.	Miscellaneous.
PB, C, RPB	No road edge audible warnings.	Controls.

6.1.5 ENVIRONMENTAL IN CRASH

Factor Contribution	Description	Factor Classification
D, N, RD	Guard rail support post punctured tank.	Roadside furniture.
D, N, RD, INJ	Power pole on bend exit.	Roadside furniture.
D, C, RD, INJ	Pole close to roadside.	Roadside furniture.
D, N, RD	Sudden drop off road shoulder (0.6m).	Cross section.
D, N, RPB	Tanker tripped over on a roadside ditch after sliding sideways.	Roadside furniture.
D, N, RD	Power poles near road hit by prime mover and damaged tanker.	Roadside furniture.

6.1.6 ENVIRONMENTAL FACTORS AFTER CRASH

Factor Contribution	Description	Factor Classification
D, C, RD	Petrol drained to airport drains system.	Roadside furniture.
D, C, RD	Live wires from fallen pole hampered salvage.	Roadside furniture.

6.1.7 BEHAVIOURAL FACTORS BEFORE CRASH

Factor Contribution	Description	Factor Classification
D, N, RD	Excessive speed for the conditions.	Carelessness.
D, N, RD	Driver unused to this vehicle.	Unfamiliarity (Vehicle).
D, N, RD	Driver & company agreed to continue driving a defective vehicle.	Negligence.
D, C, RD	Close following distance for other truck driver.	Negligence.
D, N, RD	Driver fatigue (fell asleep).	Fatigue.
D, N, RD	Driver inexperience and life stress.	General stress.
D, N, RD	Driver fatigue (lost attention or fell asleep).	Fatigue.
D, N, RD	Specific stress (haste to urinate).	Specific stress
D, N, RD	Incorrect brakes activated for parking (possibly driver education).	Driver Education.
D, S, RPB	Alcohol for car driver	Alcohol.
D, S, RPB	Fatigue for car driver	Fatigue
D, C, RPB	Specific stress regarding defective car for driver.	Specific stress
D, N, RPB	Tanker driver fatigue (possibly from benzene vapour).	Fatigue.
D, N, RD	Excessive speed for the bend.	Carelessness.
D, C, RPS	Driver unfamiliar with revised vehicle suspension	Unfamiliarity (Vehicle).
D, N, RD	Excessive speed in wet conditions.	Carelessness.
D, N, RD	Inadequate driver training in hitching procedures.	Driver Education.
D, C, RPS	Inadequate driver knowledge of his vehicle turning distance requirements.	Driver Education.
D, C, RPB	Hazchem signs were not displayed.	Negligence.
D, N, RD	Excessive speed by car driver.	Carelessness.

Factor Contribution	Description	Factor Classification
D, N, RPB	Driver did not allow for poor maintenance and incompatibility of his vehicle.	Negligence.
PB, C, RPB	Lack of caution before overtaking.	Carelessness.
D, C, RD	Driver's lack of perception of dangerous situation.	Misperception.
D, S, RD	Physiological manfunction of other vehicle driver (wrong side of road in possible diabetic coma).	Illness.
D, N, RD	Lack of caution by truck driver on primitive road.	Carelessness.
D, N, RD	Fatigue from 15-1/2 hours driving and possibly sleep inducing vapour.	Fatigue
PB, N, RPB	Fatigue for the other vehicle driver.	Fatigue.
D, C, RPB	Lack of warning use of horn by tanker driver.	Negligence.
PS, C, RPS	Possible dawn light sensory problems.	Misperception.
D, N, RD	Heart attack for the other vehicle driver.	Illness.
D, C, RPB	Car drivers lack of familiarity with area.	Unfamiliarity (Environ).
PS, U, RPS	Possible lack of familiarity of car driver with controls.	Unfamiliarity (Veh.)
PS, U, RPS	Possible distraction of car driver.	Carelessness.
D, N, RD	Driver careless, cut corner in known poor road conditions.	Carelessness.
D, N, RD	Poor maintenance checks on steering (in spite of driver's fault reports).	Negligence.
D, N, RPB	Misperception for truck drivers.	Misperception.
D, N, RPB	Stress for truck driver.	General stress
D, N, RPS	Inexperience for motor cyclist.	Unfamiliarity

Factor Contribution	Description	Factor Classification
D, C, RD	General excess speed for load.	Carelessness.
D, N, RD	Carelessness for truck driver (at rail crossing).	Carelessness.
D, N, RD	Excess speed from carelessness for car driver.	Carelessness.
D, C, RPS	Excess speed from inexperience for car driver.	Unfamiliarity
D, U, RPS	Excess speed from stress (late) for car driver.	Specific stress
D, N, RD	Route with difficult manoeuvres for tanker driver.	Unfamiliarity
D, C, RD	Tanker driver misperception.	Misperception.
U, C, RD	Tanker driver general specific stress.	General/ specific stress
D, S, RPB	Inattention of tanker driver.	Carelessness.
D, N. RD	Negligence of car driver in not slowing down in reduced visibility.	Negligence
D, N, RPB	Driver did not stop when fatigued	Carelessness
U, C, RPB	Predawn tiredness.	Fatigue.
D, N, RD	Road transport of petrol from Victoria to Sydney.	Miscellaneous

6.1.8 BEHAVIOURAL FACTORS IN CRASH

Factor Contribution	Description	Factor Classification
PB, C, RPB	Inappropriate driver reaction	Specific stress
D, C, RPB, INJ	Seat belt not worn.	Lack of seat belt wearing.
PB, C, RPB	Poor crash avoidance manoeuvre by driver of other vehicle.	Driver education.
D, N, RD, INJ	No seat belt wearing for car driver (fatal).	Lack of seat belt wearing.
D, N, RD, INJ	Lack of seat belt wearing for both car passengers (fatal).	lack of seat belt wearing.
D, N, RD, INJ	Seat belts not worn	Lack of seat belt wearing.
D, N, RD, INJ	No seat belt wearing in car (all passengers injured).	Lack of seat belt wearing.
PB, C, RPB	Fear of jackknifing stopped driver from braking.	Specific stress

6.1.9 BEHAVIOURAL FACTORS AFTER CRASH

Factor Contribution	Description	Factor Classification
D, C, RD	Poor salvage control, caused extended traffic blockage.	Education.
D, N, RD	Poor salvage management caused extended traffic blockage.	Education.
D,C, RPB	Poor salvage, caused extended traffic blockage.	Education.
D, P, RD	Salvage worker smoking near flammable vapour laden tanker.	Education