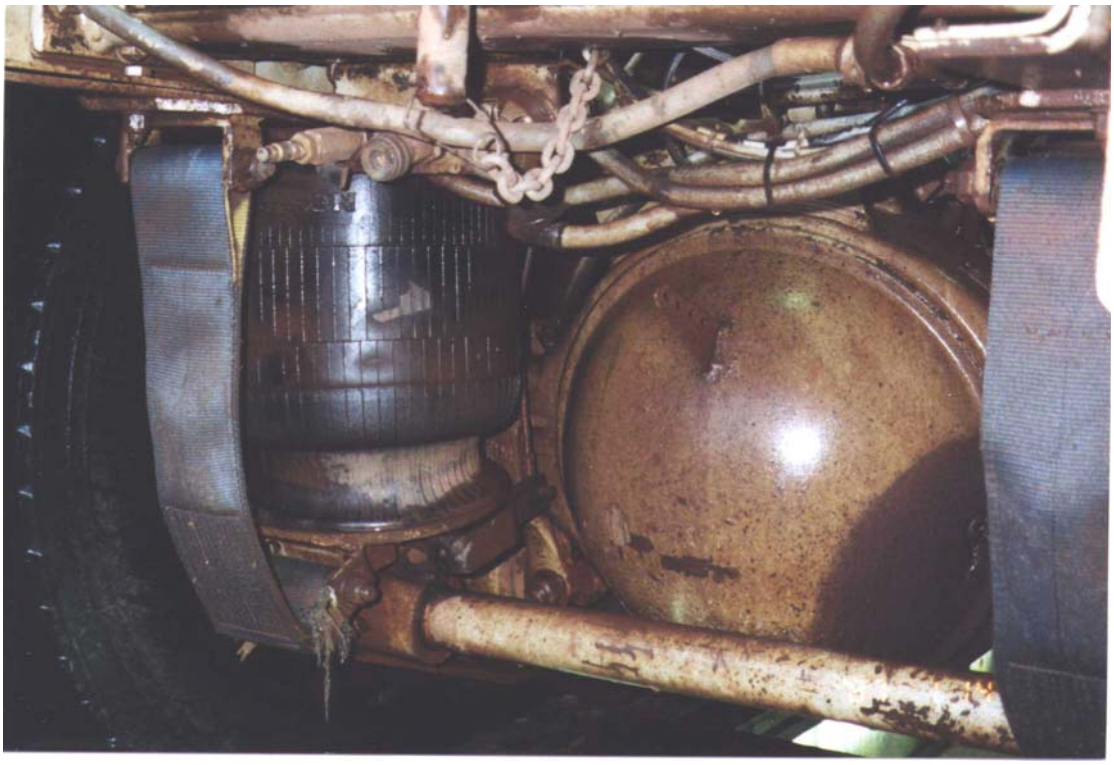
Operational Stability and Performance of Air Suspension on Various Vehicle Configurations



Report prepared for the
Department of Transport
and Works, Northern Territory

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Executive Summary

This report has been undertaken at the request of the Northern Territory Government, Department of Transport and Works and the National Road Transport Commission Remote Area Group (RAG). The study resulted from comments expressed by heavy multi-combination vehicle drivers in regard to unusual vehicle behaviour being experienced in some combinations using Airbag suspension on prime movers and trailers.

Both State and National Agencies recognise the economic contribution of heavy multi-combinations vehicles in remote area transport and as a consequence have commissioned this investigation into driver concerns.

The report found some evidence of safety concerns with vehicles using airbag suspension, but they are largely confined to remote areas. Assessment of a limited number of accident records from one State did not indicate that vehicles using airbag suspension are over represented in accident statistics or have a higher accident rate than other vehicles. As such they do not represent a major safety risk. However, Agencies agreed that further action will be taken to address the concerns identified in this review and provide remedial action.

In effect, this report outlines findings of a road transport industry survey undertaken to collect and evaluate specific experience and knowledge from operators on the performance of air suspensions on various vehicle configurations.

The aim of this study was to interview key personnel, operators, drivers and maintenance providers within the transport industry to gather data on the operational stability and on-road performance of various vehicle configurations fitted with air suspensions.

The list of companies to be interviewed was prepared by a sub-committee convened by the National Road Transport Commission Remote Area Group. The companies spanned a wide range of transport operations and vehicles within the transport industry located in the Northern Territory, Queensland, South Australia and Western Australia. The identified sample included operatives involved in transporting livestock, frozen foods, fuel, bulk cement and bulk commodities. The list was then supplemented with additional companies as the opportunity arose during the field survey and were industry requested input.

Thirty-five transport operators provided "industry feedback" on the operational issues associated with the introduction of air suspension, especially in remote areas via the survey questionaire process. The survey

was undertaken during face to face interviews with owners, managers, drivers and maintenance personnel. Where it was not possible to meet with these representatives in person, telephone interviews were conducted. To ensure consistency of interview, all interviewees were taken through the same questionaire with company specific comments being recorded individually.

In a number of questions the respondents offered "no response" either because of no experience with or in that area or not operating vehicles that complied to the question. In these cases tables show entries under the heading of "no experience".

Eighty six percent of respondents who specified their length of experience in the transport industry had between 15–30 years experience driving spring suspension and between 5-10 years experience driving air suspension. In all cases, experience with single units and multi-combination configurations was also evident.

Discussions confirmed that spring suspension was ***generally*** preferred by respondents as it provided better stability, performance and steering and less movement in the trailer.

Air suspension was found to have a number of operational issues including stability problems because of increased roll, sway and lurch of the vehicle, making it difficult for the driver to hold the combination in a straight line.

Where air prime movers were preferred, the majority indicated the main reason for fitting air was to gain increased mass and decreased commodity damage. Also all respondents identified increased driver comfort, less body stress and noise reduction relating to air suspension. Furthermore respondents stated that they preferred an air prime mover combination with spring trailers and dollies to lessen any sway or roll with the trailers.

The suspension of the prime mover was identified as critical in the overall stability of the vehicle combination. Spring suspension on both the dolly and trailer was found to positively effect the stability of the overall vehicle combination while air suspension was identified as negatively impacting on stability.

Drivers experience was that prime movers with air suspension follow every little indentation in the road and 'wallow' from side to side thus requiring countermeasures to the steering to keep them straight. These counter measures were reported to have adverse effects causing the configuration to lose stability and roll (in some cases) or 'lurch' to a new position on the road.

Drivers of high centre of gravity loads (eg. livestock/freezer) also reported greater lean and roll with air prime movers. The stability of high centre of

gravity vehicles is effected by the roll that is set up from the levelling of the air bags, which effects the total performance of the overall combination.

In relation to cornering, the majority of drivers agreed that prime movers (fitted with air) lean considerably more when going into a corner and hence cause the driver to correct, which effects the second and third trailer with roll and sway. Discussions with all operators reported that tandem air dollies move around more than the spring dolly and under braking behave erratically. As a result, most operators identified a preference for spring dollies as they were found to keep the combination straight.

In relation to on road performance, drivers commented that vehicles were more difficult to control with air prime movers. As a result, drivers on air reported that they drove with more caution, particularly when entering corners and rough undulating patches.

Nearly all drivers commented that air suspension was "load friendly not road friendly" and that drivers were more confident when driving on spring suspension as it provided a "better feel" for how the vehicle was performing.

In the majority of cases operating on air suspension prime movers, super single tyres have been installed on the front steers to give wider tyre footprint and better handling and stability. Super singles were also reported to promote greater recovery when returning from the unsealed hard shoulder to the sealed pavement.

The majority of respondents stated that air suspension required more maintenance than spring suspension. Twenty seven companies out of a possible 35 stated that vehicles were more expensive to maintain with air suspension.

From the data collected during this study, unsatisfactory driving experiences have occurred were air bag suspension have been installed in multi vehicle combinations especially prime movers. At the same time there are structural issues relating to suspension design and regulatory issues that need addressing to ensure that long combinations operating in remote areas with air suspensions and especially those with high centre of gravity operate satisfactorily and therefore further work and research is necessary.

The following recommendations are made:

1. Additional field research be undertaken in relation to the performance and stability of air suspensions when used in multi-combination configuration in relation to:

- Configurations with 2 or more trailers;
- Operation on rough sealed and unsealed roads;
- Stability on narrow pavements tracking on and off the sealed section;
- Effect on Stability using low profile and Super Single tyres fitted to steer axles;
- Stability on close curved road alignment;
- Determining centre of gravity(C of G) height limits;
- Trailer movement/on road characteristics for configurations incorporating air prime movers versus spring prime movers; and
- Effect of Speed and C of G on configurations with air suspensions versus configurations with steel suspensions.

2. Investigate and evaluate "After market improvements" to air suspensions.

3. Encourage manufacturers to work with the transport industry in developing best design practice ie location of shock absorbers, ride height valves etc to improve performance of air suspensions applicable to multi-combination configurations.

4. Improve accident collection techniques to include suspension types in accident questionnaire to develop a history file on accident patterns.

1. Introduction

1.1 Purpose

The Northern Territory Government Department of Transport and Works and the National Road Transport Commission (NRTC) Remote Area Group have recently received a number of comments and concerns from industry regarding the stability of combination vehicles where air suspension has been introduced, particularly their application to prime movers. The introduction of air suspension on all axle groups (with the exception of the steer axle) has reportedly introduced a different vehicle performance than previously occurred with mechanical suspension.

As a result, the Northern Territory Government, Department of Transport and Works has taken a lead agency role in commissioning Estill and Associates to conduct a road transport industry survey. In particular, the survey was to collect and evaluate specific experience and knowledge from operators of multi-combination vehicles fitted with air suspensions.

Both State and National Agencies recognise the economic contribution of heavy multi-combinations vehicles in remote area transport and as a consequence have commissioned this investigation into driver concerns. Agencies agree that currently there is no major road safety issue with these vehicles and advise that further action will be taken to address the concerns identified in this review.

In collecting this information, industry raised a number of other issues relating to air suspensions. This report includes further information regarding these other key issues and concerns outlined by transport operators in consultations conducted throughout the Northern Territory, South Australia and Western Australia and is provided to further clarify issues and concerns outlined by industry.

1.2 Scope

This Review of Operational Stability and Performance of Air Suspension on Various Vehicle Combinations project has involved consultation with operators, drivers and maintenance personnel. These groups were targeted as "hands on" people to establish any change in vehicle performance characteristics attributable to vehicles or combinations fitted with air suspensions. Consultation with the transport industry in various locations in remote area states was undertaken to establish comment and opinions on operational issues.

1.3 Objectives

The aim of the project was to interview key personnel and gather data on the operational stability and on-road performance of vehicles fitted with air suspensions with the following objectives:

- Identify any consistent adverse operational vehicle performance characteristics due to the installation of air suspension;
- Sample the effect of air suspensions on Remote Area regulation vehicles and other combinations such as:
    - ⇒ 6/7 axle articulated
    - ⇒ truck/5 axle dog trailers
    - ⇒ road trains – double/triple
    - ⇒ other combinations
- Document and assess the survey information and make recommendations.

The project was essentially an opportunity for the transport industry to provide "feedback" to the Northern Territory Government and the NRTC Remote Area Group on the live operational daily occurrences associated with the introduction of air suspensions, especially in remote areas.

2. Background

In 1993 the National Road Transport Commission (NRTC) initiated a working group to conduct a Review of Mass Limits. The review considered all mass limits on all axle groups and recommended an increase in mass limits. In April 1998 the Ministerial Council on Road Transport approved the findings of the working group and recommended increased mass limits nationally. A significant condition attached to the introduction of the increased mass was that the increased limits would only apply to vehicles fitted with road friendly suspensions. The Mass Limit Review (MLR) identified air suspension as road friendly because it had been reported from research in Europe (discussed below) that road friendly suspension could operate with the increased mass without an adverse impact on road maintenance.

In 1992 the Organisation of Economic Cooperation and Development (OECD) undertook a substantial international coordinated research program known as the Dynamic Interaction of Vehicle and Infrastructure Experiment (DIVINE). DIVINE consisted of six research elements addressing different aspects of the vehicle infrastructure system. Element 1 in this research was an accelerated pavement test conducted at a Pavement Testing indoor facility in Christchurch New Zealand. This work identified parameters for road friendly suspension as well as performance criteria which are listed in the Vehicle Standards Bulletin (VSB) "Certification of Road Friendly Suspensions

Systems" issued by the Australian Federal Department of Transport and Regional Services and based on the Council of the European Union Directive 95/53/EC 25 July 1996.

The Certification of Road Friendly Suspensions Systems states that for suspension to be road friendly, they must comply with:

- A sprung mass frequency no greater than 2Hz;
- Minimum critical damping of 20 percent;
- Static load sharing to within 5 percent; and
- Dual tyres

The increased mass limits applied to steer axles, tandem axles and tri-axles associated with road friendly suspensions are as follows:

Existing		**Review of Mass Limits**
Axle	**Mass**	
Steer	6.0T	6.7t on a rated road train prime mover
Tandem	16.5t	17.0t
Tri	20.0t	22.5t

Since the announcement of the increased mass limits in 1993 industry geared itself up to take advantage of the increased productivity on road friendly suspensions and have installed air bag suspension on trailer dollies and prime movers.

3. Methodology

In undertaking this project, Estill and Associates designed an "Industry Feedback Survey" (***Appendix 1***) to gather data on industry knowledge and experiences with air suspension as compared to mechanical suspensions. The survey was particularly targeted to remote area locations as stability factors reported by Industry were effecting multi-combination vehicles more than single unit configurations.

The Survey was designed to collect qualitative and quantitative data, in particular industry opinion, experience and views. In a number of questions the respondents offered "no response" either because of no experience with or in that area or not operating vehicles that complied to the question. In these cases tables show entries under the heading of "no experience".

The following key elements were included in the survey:

- Vehicle and biographical details
- Drivers experience
- Maintenance costs and criteria
- Current fleet composition (including percentage of prime movers, trailers, dollies) and air/spring breakdowns
- Issues associated with stability, suspension and other key concerns
- Preferred vehicle configurations

A list of companies to be interviewed was prepared by a sub-committee convened by the National Road Transport Commission Remote Area Group. The list includes a wide range of transport operations across the Northern Territory, Queensland, South Australia and Western Australia. The identified sample included operatives involved in transporting livestock, frozen foods, fuel, bulk cement and bulk commodities. The list was then supplemented with additional companies as the opportunity arose.

Thirty five companies were formally surveyed and discussions were undertaken with a number of other company representatives during the project. ***Appendix 2*** provides details on those companies who responded to the survey and those who provided additional comment only.

The survey was undertaken at company depots during face to face interviews with owners, managers, drivers and maintenance personnel. Where it was not possible to meet with these representatives in person, telephone interviews were conducted.

It is important to note that the majority of operators run large fleets encompassing different vehicle models and combinations. In completing the survey operators were asked to identify individual vehicle components on which to provide specific in-depth detail as well as assessing issues across their whole fleet.

4. Companies and Locations

A breakdown by State of the companies who participated in the survey is included in Table 4.1 below:

State	NT	QLD	SA	WA
No. of Companies	11	9	7	8

Table 4.1: Breakdown by State of Participating Companies

Approximately 65 people of varying positions within the transport industry were involved in the interviews, originating from locations such as Darwin, Alice Springs, Mount Isa, Toowoomba, Adelaide and Perth.

The breakdown of company operations involved in the survey is shown in Table 4.2:

Product	Livestock	Tanker	Bulk Commodities	General	Freezer/ General
No	10	6	3	7	9

Table 4.2 Breakdown of Company Operations

All companies were asked to provide a percentage breakdown of the composition of air and spring suspension across their entire fleet. Their responses indicate a higher proportion of spring prime movers and trailers and a definite preference for spring dollies. Table 4.3 provides information on these percentages.

Prime Movers		Trailers		Dollies	
Springs	Air	Springs	Air	Springs	Air
55%	45%	55%	45%	95%	5%

Table 4.3 Proportion of Spring and Air Suspension in Companies Surveyed

Not all companies reported actual numbers relating to the size of their fleet. For the 25 companies who did provide details, it was apparent that there were over 600 prime movers, 1800 trailers and 650 dollies in operations. These figures demonstrate the broad ranging experience those interviewed had, in relation to multiple vehicle configurations.

4.1 Vehicle Combinations Normally Driven

Respondents identified that they were operating the following types of vehicle combinations:

- Single/Artic
- Truck/Trailer
- Double RT/Triple RT
- "B' Double
- "B" Triple
- Double "B" Triple
- 2AB2
- Rigid Plus 2/3

4.2 Respondent's Experience in the Industry

Eighty six percent of respondents who specified their length of experience in the transport industry had between 15 – 30 years experience driving spring suspension and between 5-10 years experience driving air suspension. In all cases, experience with single units and multi-combination configurations was also evident.

4.3 Operator Ratings and Preference for Air and Spring

Respondents were asked to rate a number of vehicle combinations and to identify their particular preferences (as outlined in Tables 4.3.1 and 4.3.2). Typical comments received from operators identified a preference for spring suspension with some strong support as identified in the following representative comments.

Typical Comments Received
"Anything over a double road train should be on springs because it is better controlled by the driver for stability"
"Air prime movers should not be used on multi-combination configurations"

As can be seen from Table 4.3.1 below, the majority of owners and drivers preferred a multi-combination to consist of spring suspensions on each vehicle. Discussions confirmed that spring suspension provided better stability, performance and steering and less movement in the trailer. Where air prime movers were preferred, the majority of operators indicated that the combination should include spring trailers or dollies, to lessen any sway or roll created from the air prime mover within the trailers.

Prime Mover Trailer Dolly	**Air, Air, Air**	**Air, Spring, Air**	**Air, Spring, Spring**	**Air, Air, Spring**	**Spring, Air, Spring**	**Spring, Spring, Spring**	**Spring, Spring, Air**
Preference	6	1	4	5	2	17	0

Table 4.3.1 Preference of Combinations

Table 4.3.2 indicates respondents rating of each of the various vehicle combinations (double and Triple road train) with a strong preference for spring suspension evident.

Prime Mover	Trailer	Dolly	Trailer	Poor	Fair	Good	No Experience
Air	Air	Air	Air	9	10	10	6
Air	Air	Spring	Air	4	13	7	11
Air	Spring	Air	Spring	8	12	2	13
Air	Spring	Spring	Spring	0	10	15	10
Spring	Air	Air	Air	9	7	4	15
Spring	Air	Spring	Air	3	9	11	12
Spring	Spring	Air	Spring	11	8	2	14
Spring	Spring	Spring	Spring	0	2	25	8

Table 4.3.2 Qualitative Rating of Vehicle Combinations

Respondents were also asked why air suspension might be preferred over any other type of suspension. The main reasons identified (as outlined in Table 4.3.3 below) related to increased mass and decreased commodity damage.

	Yes	No	No Experience
Increased mass	19	3	13
Better stability	5	6	24
Decreases commodity damage	17	1	17
Better quality ride	8	3	24
Less maintenance	7	5	23

Table 4.3.3 Reasons why air bag suspension is preferred over other types of suspension

5. Key Issues

During the course of the interviews a number of key issues were identified from the study and are grouped below into issues relating to preference for spring/air, operational stability, suspension design, on-road performance and other issues.

5.1 Operational Stability

A review of the literature suggests that the operational stability of a vehicle is effected by a number of factors including: the overall height of the vehicle, its centre of gravity, the cross fall of the road, and the configuration of the vehicle combination. It is clear that multi vehicle combinations will effect the overall performance and stability of the vehicle.

Where vehicles have additional height such as livestock vehicles and freezer vans, the centre of gravity is higher. This has been found to impact on the overall stability and moveability of the vehicle. In addition, where the load involves a moving load with livestock, a decrease in overall stability of the combination can and does result.

Given the above factors, respondents were asked to specifically identify operational stability issues effecting multi vehicle combinations for both air and spring suspension. Firstly, operators were asked to identify changes in stability due to the introduction of air suspension. Of the 22 responses received, 67% identified that the stability of the prime mover became worse, due to the introduction of air suspension (see Table 5.1.1). The suspension of the prime mover was identified as critical in the overall stability of the vehicle combination as it effected the steering input, with some differences of opinion relating to air suspension on the dolly and trailer. Four companies indicated that they will not be purchasing any more air bag suspension prime movers due to a range of factors including: instability, poor road handling, increased vehicle maintenance, increased tyre wear and driver's complaints regarding steering.

The high response of "no change" to trailer performance from introducing air suspension is reflected in that the majority of these returns are from companies already operating air trailers as freezer pans or existing air bag livestock trailers.

With regard to the change in stability from the use of air suspensions on prime movers the majority of the major livestock companies rated the use of air suspensions on prime movers as having a "worse" effect on vehicle stability

	Better	**Worse**	**No Change**	**No Experience**
Prime Mover	4	16	4	11
Dolly	3	9	5	18
Trailer	5	6	14	10

Table 5.1.1 Changes in Stability from introducing air suspension

Tables 5.1.2 and 5.1.3 identify a variety of dolly and trailer axle groups and suspension types and their effect on stability. From these tables it is clear that spring suspension with the exception of the single axle group on both the dolly and trailer, have a greater support towards improving the stability of the overall vehicle combination while air suspensions have a much lesser support. Figure 1 shows a typical spring suspension.

Type of Dolly axle group and suspension	Better	Worse	No change	No Opinion
Single Axle (spring)	0	***12***	1	22
Tandem Axle (spring)	***22***	0	0	13
Tandem Axle (air)	3	***13***	0	19
Tri Axle (spring)	***12***	0	0	23
Tri Axle (air)	6	2	0	27

Table 5.1.2 Dolly Suspension Effect on Stability

Type of Trailer axle group and suspension	Better	Worse	No change	No Opinion
Single Axle (spring)	0	14	1	20
Tandem Axle (spring)	9	9	0	17
Tandem Axle (air)	1	13	0	21
Tri Axle (spring)	25	0	2	8
Tri Axle (air)	17	4	13	11

Table 5.1.3 Trailer Suspension Effect on Stability

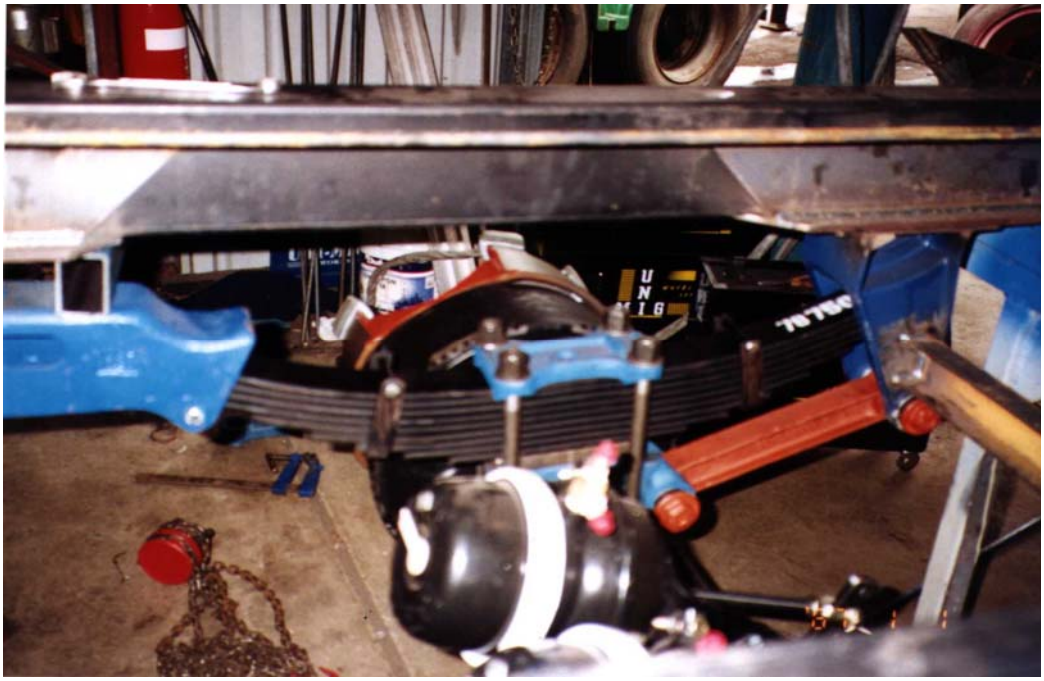

Figure 1: Typical Spring Suspension

5.1.1 Sway and Roll of the Vehicle

Feedback was also received in relation to the increase in sway and roll with air suspension. Although some respondents did not identify any difference between air and spring, the majority of respondents identified some concerns with air suspension.

Drivers experience is that prime movers with air suspension follow every little indentation in the road and 'wallow' from side to side thus requiring countermeasures to the steering to keep them straight. These countermeasures were reported to have adverse effects causing the configuration to lose stability and roll (in some cases) or 'lurch' to a new position on the road which, in some instances, has caused drivers to be in the middle of the road without knowing why. Furthermore on successive right or left hand corners compensation of the vehicles' air bags does not appear to be quick enough to straighten the vehicle and hence a reverse lean is created going into the next corner. Drivers experience that the rear drive wheels on air tends to steer the vehicle as the air bags compensate for every dip and hole in the road and therefore change position on the road rather than sitting firmly. Under braking, dolly "lock ups" occur due to the reaction times of the air which causes instability in the trailers.

As a result of the above factors, drivers (on air) reported that they drove with more caution, particularly when entering corners and rough undulating patches. Some rollovers were reported by drivers as being caused by "all of a sudden" losing control on the corners as the vehicle dipped into the corner and then rolled over. Drivers also commented that it was more difficult to hold an air prime mover combination in a straight line. Some comment was received that this may have been due to the slower reaction time of air when straightening the vehicle. One driver reported that when he had dropped off the edge of the seal with a longer combination (and an air prime mover) it was difficult to bring the vehicle back on the road without rollover and was further complicated by being a high centre of gravity vehicle. This was due to the fact that the air suspension compensated with the drive wheels being on different levels.

A further comment was made that drivers on air suspension using cruise control can get into difficult situations as the vehicle leans more with speed on the corners and overriding the cruise control can be too slow to correct the lean. Cornering with springs on the prime mover does not pose the same problems as the vehicle 'stands up' straight.

It is interesting to note that the owner of a company has now changed all air suspensions back to spring suspensions and made it a company policy so that drivers can feel what the combination is doing.

The following types of comments were received

Typical Comments Received
"More sway in the air trailers than there is with the spring trailers"
"It is more difficult to keep a prime mover with air in line, tends to wander across the road when it hits any undulations"
"On pavements with crossfall it is more difficult to handle triple road trains with air bags".
"More correction in the steering wheel with an air prime mover effecting the sway of the trailers"
"On rough roads air is seen to be easier on stability"
"Vehicles lean more on air than on springs"
"6 rod suspension helps keep the combination on the ground and reduces rolling"

In fact one operator identified that there was an estimated 25% increase in the trailer swing due to air suspension.

It is significant that the comments received on the stability of vehicles have mainly been raised by those operators and drivers that are engaged in multi combination operations in remote areas. This configuration combined with reduced pavement standards (ie. sealed and unsealed, greater cross fall, edge wear, gravel shoulders, rougher surfaces etc) make stability of multi combination configurations a greater concern in remote areas.

It is important to note that drivers also differentiated between sealed and unsealed roads in addressing stability issues. Air on wide fully sealed roads was less dramatic in performance than air on narrower pavements in remote locations that require drop-off from the seal to gravel and returning to seal.

5.2 Suspension Design

Generally all the literature regarding road friendly suspension and air bag suspension emphasise that shock absorbers must be maintained and kept at high quality performance. The shock absorbers by nature of their design absorb the harsh/violent movement of the axle and reduces the reaction to a smoother one to improve impact to the chassis and road.

In examining the various suspensions it was noted that shock absorbers had a mounting range (see Figure 2) from being vertically positioned to the extreme position of 60° from the vertical. The functionality of dampers is critical and

all companies interviewed remarked that maintenance and replacement of shock absorbers was a significant element in the performance of the air bag suspension.

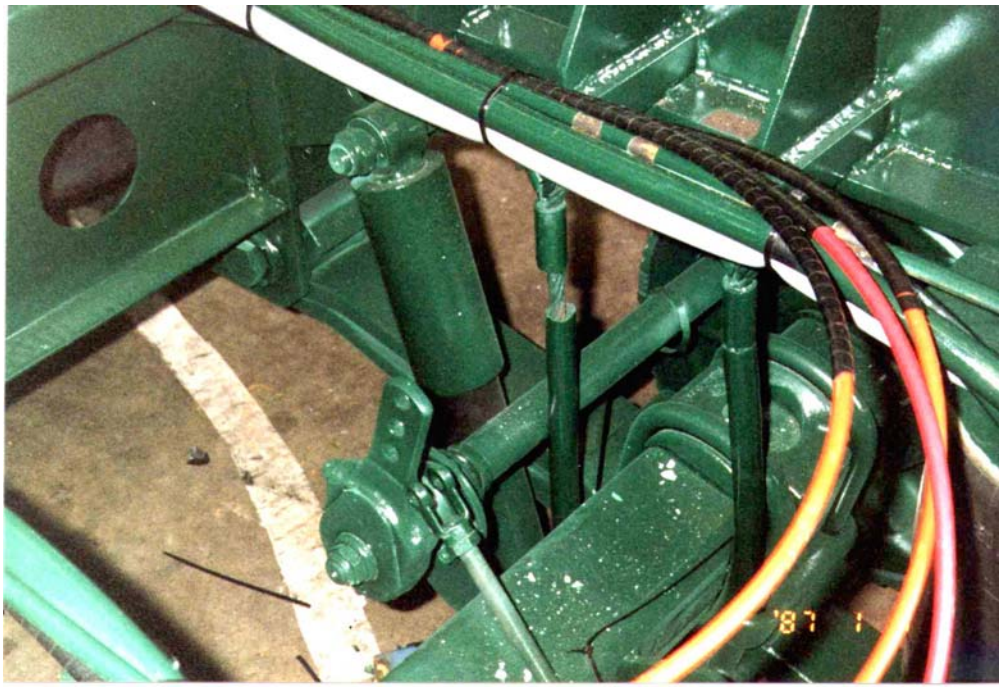

Figure 2: Shock Absorber Mounting Angle

One driver reported an extreme case where in a 3000 km trip on gravel roads, 18 shock absorbers were replaced. Drivers indicated that shock absorbers effect the stability as well as reducing the impact transmitted to the road surface. It was therefore considered essential that regular maintenance was conducted. Without the shock absorbers functioning properly, drivers indicated that "roll" and "wandering" of the prime mover and trailers increased and axle oscillation increased dramatically.

In relation to cornering, the majority of drivers agreed that prime movers (fitted with air) lean considerably more when going into a corner and hence cause the driver to correct which effects the second and third trailer with roll and sway. A number of operators have fitted a second air ride height control valve on the tandem drive axles to make the air delivery and exhaust to the air bag faster and hence improve air bag reaction time and keep the vehicle more level. This in turn however nullifies the load sharing technique within the suspension. In this regard, height control valve setting on the air bag suspension is critical and the set up is vital to the stability of the vehicle combination. In comparison, a six rod spring suspension prime mover sits down on the road and the driver feels the movement as the vehicle behaves to the drivers control which increases control of the stability in the trailers.

One company has installed a modification "the Haire System" which replaces the small bore pipes going to the air bags with larger diameter pipes to supply and exhaust air flow to the bag quickly and hence improve the response time of the air bag. This modification also reduces the roll and has improved stability.

Two companies specifically mentioned modifying the operation of the fifth wheel by reducing movement, both longitudinally and transversely, by inserting rubber bushes to reduce roll and increase stability and tracking. This practice has been implemented across their fleet as a result of their experience with air bag suspension prime movers.

Comments were received that the position of the shock absorbers within the suspension affects the life of the shock absorbers and also the stability of the vehicle. In inspecting different designs it has been pointed out that some shock absorbers have been relocated by the maintenance personnel to improve stability and efficiency as the effectiveness of the original angle of location did nothing towards the working operation of the shock absorber. Industry comment is that as close to vertical as possible gives the most satisfactory result.

5.3 On Road Performance

In relation to on road performance, drivers commented that vehicles were more difficult to control with air prime movers although the air bag did provide a more comfortable ride.

5.3.1 Vehicle Design

A range of comments listed below were received relating to vehicle design:

- Separate ride height valves have been installed on drive axle to improve stability;
- Wide spread tri-axles help stability and reduces lateral movement of rear trailers;
- With air bag suspension the attachment to the axles is narrower than it is with springs which may effect stability;
- Set up of the ride height valve is most important to ensure correct stability;
- Super singles used on the steer axle to get greater steering ability and stability in the combination;
- Shock absorbers on some air suspensions are mounted at steep angles and do not appear to work efficiently;
- Double compensating turntables have been replaced with restricted single oscillating turntables on the air prime movers to try and get extra stability;
- Larger air bags help stability;
- "Haire" modifications added to air suspension to improve stability;

- Air leaks and low pressure in air bags cause instability;
- Rubber bushes have been added to the turntables so that the longitudinal movement is reduced and all turntables are single oscillating to improve performance;
- Air bag trailer lateral movement is greater than with spring trailers; and
- Angle of dampers was changed to vertical to improve performance.

In the majority of cases operating on air suspension prime movers, super single tyres have been installed on the front steers to give wider footprint of tyre and better handling and stability. The super singles make it easier to correct the steering and recover from the gravel shoulder back onto the bitumen.

5.3.2 Driver Comfort

All respondents identified increased driver comfort, less body stress and noise reduction relating to air suspension. Drivers commented that "the person in the cab is floating on air" which was considered by all to be a very positive factor in "switching to air suspension" (see Figure 3). Two-up drivers indicated that they could sleep better when the prime mover was on air suspension rather than mechanical. However, drivers did note that as a result, "there was less feel for how the vehicle was behaving" and "what is happening behind is 'unknown'.
In some cases, drivers believe that the vehicle speed has also increased because of the driver comfort and less sensation of what's happening behind.

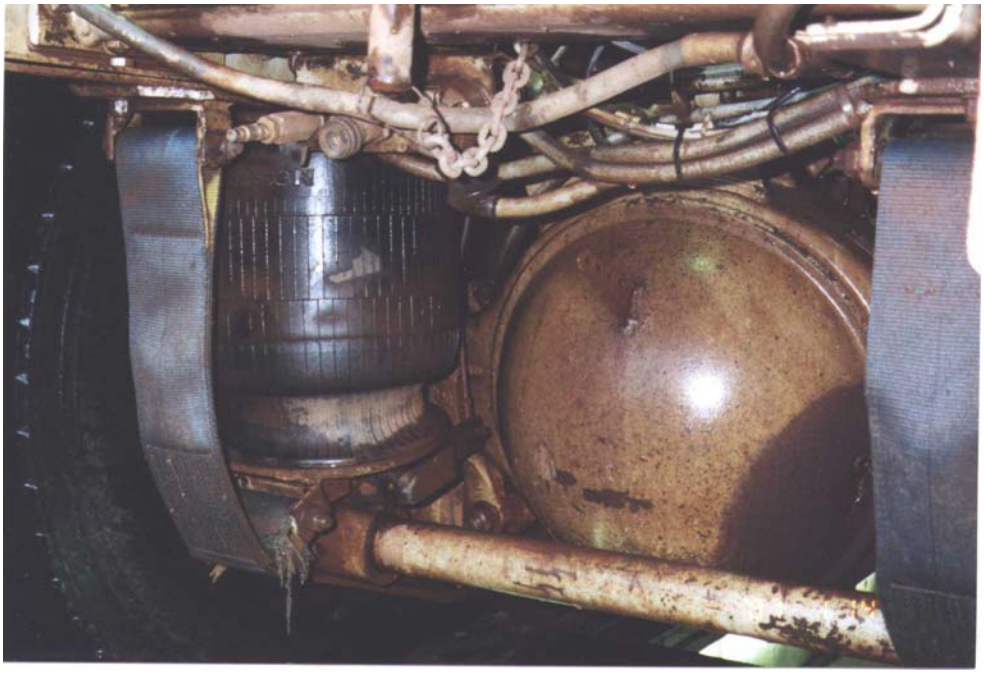

Figure 3: Typical Air Suspension

5.3.3 Driver Confidence and Concentration

The majority of respondents commented that they were more confident when driving on springs as they had a "better feel" for how the vehicle was performing. Alternatively, when on air, they were unaware of what was happening behind them and had reduced sensitivity to the performance of the combination. As a result, the driver needed to concentrate more when on air, and tended to become more fatigued. Drivers also commented that they tended to "mistrust" air suspension because of the exaggerated lean.

5.4 Maintenance

The majority of respondents (68%) stated that air suspension requires more maintenance than spring suspension while there was differing opinion as to which type of suspension causes more overall structural damage to vehicles.

The following comments were received relating to the requirement for additional maintenance for air suspension:

- Shock absorbers need to be inspected more often;
- Trailer maintenance is greater;
- Maintenance below the air bag is greater;
- More maintenance is required on air compressors;
- Air is more complicated to fix and effects all axles;
- Maintenance time over the pit is increased;
- Air bags require more attention and more finer tuning;
- Ring feeders, king pins, draw bar eyes and fifth wheels need constant maintenance and have had to be replaced;
- Ride height valves keeping the torque on the bushes and replacing shock absorbers frequently is a must for air suspension;
- Additional maintenance required on wheel bearings, brakes and ancillary gear, bushes, pins, bolts with air than with springs;
- Tyre blow outs and animals under the vehicle damage air suspension gear, ride height valves, air bags etc and are costly to repair;
- Aligning air suspension is more difficult;
- Air suspension needs more regular maintenance to prevent leaks and longer to diagnose the problem; and
- More preventative maintenance required and more time spent on maintaining vehicles.

All maintenance personnel (operating air) said that ride height valves were important to set and require continuous checking to ensure constant height. They reported that ride height effected stability and tyre wear. Furthermore, checking for air leaks was a constant activity.

A number of companies indicated that any under-vehicle damage from hitting animals was extensive and sometimes stopped the trip as air bags and pipework were so extensively damaged that repairs needed to be done by experienced mechanics.

In regard to running repairs, most drivers preferred springs as it is easier to get back to the depot if a spring breaks than if the air system is damaged. A significant number of maintenance personnel commented that it is easier to align and maintain springs than air and therefore cheaper to fix.

5.4.1 Cost of Maintenance

Twenty seven companies out of a possible 35 stated that vehicles were more expensive to maintain with air suspension. This increase in cost ranged from 15% to 150% in extreme cases. One company reported that on a 3000 km journey they had to replace 18 shock absorbers. They also stated that maintenance on air vehicles was considerable with a total expenditure of $80,000 for repairs. Another company reported having to change all shock absorbers on 2 triple road trains within 18 months.

Companies reported that the cost of air bags is high compared to spring packs. Furthermore the frequency of shock absorbers and air bag replacement is costly.

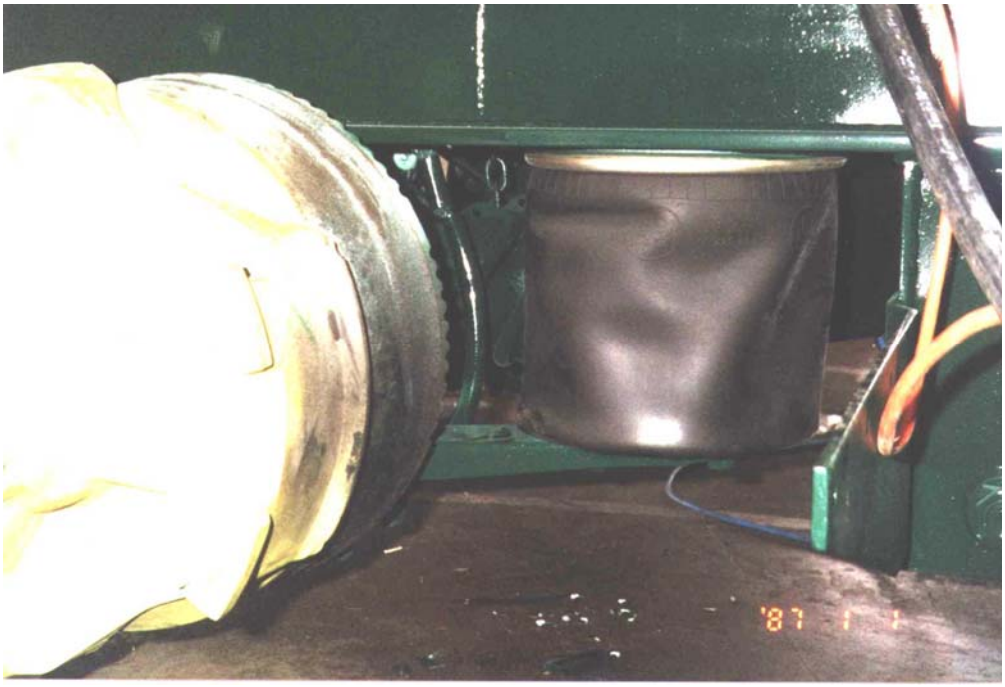

Figure 4: Deflated Air Bag

Air leaks in air suspensions are a major problem for companies. Vehicles left standing without the engine idling to maintain air pressure results in trailers sitting down on the air bag that can cause damage (see Figure 4). On a triple road train, over 15 minutes can be spent pumping up the bags before moving. One company reported having lowered the height of the vehicle on the air bags for loading and unfortunately the driver started his trip and forgot to pump the bags up to full pressure. The vehicle rolled from excessive lean on the first corner causing extensive damage to the prime mover and trailers. Drivers commented "It is just another thing to remember to do".

However, one fuel company commented that when doing mechanical suspension repairs that required welding, the cost to degas the tanks is quite expensive whereas with air suspension, no hot work is required so therefore maintenance costs are reduced.

5.4.2 Maintenance on Gravel

Companies operating on all bitumen roads had less maintenance problems than those operating on unsealed roads. Operators on rough roads have found that maintenance costs increase and some have reverted back to mechanical suspensions. Companies reported increased wear on brakes, draw bars, fifth wheels, king pins, more frequent replacement of air bags and shock absorbers and some cracking to the frame of trailers on gravel roads. One company replaced 17 shock absorbers during one trip.

5.4.3 Tyres

Differing comments were received on tyre wear, ranging from no additional tyre wear , due to the introduction of air suspension, to significant increase in tyre wear. Tyre wear pattern was also reported as more abnormal on air suspension than on springs. Scalloping or chattering pattern appears predominant with air.

From those companies reporting greater tyre life with springs, the range was between 24% - 100%. In these cases, tyre life operating with springs was in the order of 140,000km per tyre. The equivalent tyre life for air reduced to 70,000km per tyre in some operations.

Some companies did report an increase in tyre life with air however these companies were mainly operating on sealed roads. A number of companies reported no difference in tyre life.

The majority of companies with air bag prime movers (used on multi combination vehicles) had fitted super single tyres on the front steer to increase driver control, improve stability and improve tyre life. Up to 300% increase in tyre life was reported from one company when using super single

on steer axles with air suspension. Also, as super singles are a higher rated mass tyre, companies have fitted super singles to achieve the increased mass limit of 6.7 tonne on the steer. Standard tyres were found to have significantly less tyre life when fitted on steer axles of prime movers on air suspension, than when used on spring suspension prime movers.

Fuel companies also indicated that super single tyres on trailers greatly improved stability due to the wider wheel track but recognise that increased mass was not available for these type of tyres and hence were moving out of super single tyre trailers.

In general, super singles were fitted to the steer axle to improve, handling, provide better steering quality and promote greater recovery when returning from the unsealed hard shoulder to the sealed pavement. Comments were also received from drivers stating that when super singles were fitted to the steer axle there was less movement from the steer that reduced the ripple effect throughout the combination.

Drivers commented that super singles can skid more in the wet but did provide better handling for prime movers with air suspension. In regard to recovery from falling off the seal or having to pass with one side of the vehicle on the gravel shoulder, super singles were cited as more effective.

Tyre consultants attached to one company reported that tyre pressure is very significant when operating on air suspension as ride height is effected by uneven roll or flexing of tyres and consequently tyre wear is effected.

5.4.4 Operational Safety

Drivers operating single units or 'B' Doubles comment that little difference is experienced with prime movers on either air or mechanical suspensions.
Multi combination drivers of double and triple road trains however, indicate that combinations fitted with air suspension (drive axle, trailers) have more roll and trailer movement than on mechanical suspensions. Drivers on air suspension report that the vehicle "wallows" indicating that it follows the road pattern and therefore has more movement than vehicles fitted with mechanical suspensions. High centre of gravity loads (eg. livestock/freezer) experience greater lean and roll with air prime movers.

One company has taken the step to replace all air suspension on their equipment with springs as their vehicle combinations pulling bulk commodities were reportedly uncontrollable and unsafe. Efforts were made to try and correct the movement effects but these were unsuccessful.

Operators reported that the inclusion of spring dollies with air trailers and prime movers steadies the roll and sway of the combination. Most operators included a sprung vehicle in the combination for a steadying effect.

All drivers indicated that with multi combination configurations knowing what the 'rig' is doing comes "through the seat". In the controlled environment of an air mounted cab, air drive axle and seat, the feel of the combination was lost.

Fifteen respondents stated that they had experienced rollover or bad experiences with their current vehicle combination. These experiences are outlined in table 5.4.4.1 below. Of the 24 respondents who answered this question, 9 or 38% stated that they had not experienced any difficulties which indicates that they did not have a safety issue with their existing combination.

Problems	**Yes**
Prime Mover	10
Trailer	4
Dolly	1
Vehicle Set-up	5
Vehicle Characteristics/Performance	4
Road Surface	5
Road Width	1
Driver Error	5
Traction	1
Lack of Air in Tag Trailer	1
Driver Confidence	1
Driver dropped off the edge and the vehicle rolled	1

Table 5.4.4.1 Difficulties Reported with Current Vehicle Combinations

In order of occurrence the majority of experiences were attributable to the prime mover. No explanations were received as to the type of reaction of the prime mover in these experiences. Vehicle set up and vehicle characteristics/performance were also significant relating to handling, feel and rear trailer sway. Driver error accounted for a high incident rate.

5.4.5 Incidence of Accidents

Conclusive evidence was not available concerning the incidence of accidents since the introduction of air bag suspension however a case study from one company of 8 accidents is reported in ***Appendix 3*** showing 75% of the accidents reported involved prime movers fitted with airbag suspensions.

Approximately 50% of respondents stated that more accidents had occurred with prime movers with air bags while the remaining 50% commented that there had been no increase. Likewise in relation to trailers and dollies fitted with air bag suspension there was no substantive evidence that accidents had increased in vehicle combinations fitted with air or springs. Comments received indicate that tandem air dollies are low in numbers and little experience has been gained. Those drivers that have experience indicated that they "duck and dive" and create additional movement. Also under braking they behave erratically.

5.5 Other Issues

5.5.1 Manufacturer's Comments

Manufacture guidelines, issued from the late 1970's, are extremely relevant to this review of air suspension.

There has been general Manufacturer awareness of the different characteristics of air suspensions to leaf spring suspensions since their introduction into Australia. Initial product releases in the 1970's were usually under strict manufacturer application guidelines.

Wider adoption of air suspensions in the 1990's, encouraged by pending higher Road Friendly suspension allowable mass limits, resulted in a greater number of air suspension vehicles being utilized.

Manufacturer's guidelines were issued during this period to highlight the need for careful review of each application before placing an air suspended truck into an unfamiliar application.

The example guideline, which updated one manufacturer's general suspension guidelines, was given to dealer principals, sale managers and sales representatives and relevant parts are copied below.

> *Air Suspension Application Guidelines*
>
> *"The suspension is an on-highway suspension and will usually only be approved for 100% on-highway use. Limited approval for use off-highway may be given in individual cases on receipt of complete and accurate details etc …"*
>
> *The suspension is not suitable for high centre of gravity loads. Applications which constitute high centre of gravity loading will be closely scrutinized, etc. The suspension is not approved for application with volume livestock transport employing trailers higher than 4.3m. This includes but is not limited to, 2 deck crates and 4 deck sheep crates.*

Log carriers and grain carters may also result in an effective high centre of gravity application. Details of trailers, load, etc may be requested to enable an accurate analysis.

Tippers involve greater than usual twisting and turning motions. These applications place greater strain on the suspension bushes and accelerated wear may occur.

In summary, air suspensions by their nature have lower roll resistance than mechanically sprung suspensions. The combination of truck air suspensions, trailer air suspensions and high centre of gravity loads can lead to undesirable ride characteristics and consequently customer dissatisfaction. If the application falls within the above criteria or is new for the suspension obtain full details as requested above. In these instances the use of a mechanical sprung suspension should be the first consideration."

From these comments it is obvious that the manufacturer had investigated stability concerns associated with air systems and re-emphasized the parameters within which the vehicle must operate. The introduction of other forms and designs of air suspensions on prime movers could then attract the same questions in terms of loading and centre of gravity of the load.

5.5.2 Prime Mover Traction

All drivers have commented that driver traction with air prime movers is less dependable than mechanical suspension. Problems cited included:

- Suspension does not equalise properly to load share and causes loss of traction;
- Spring prime movers sit down more on the road to give greater traction;
- Air bags start to compensate then they are losing traction on the second axle;
- Drivers have experienced loss of traction as the air bag stretches and wheels lift;
- Where there is any slight dip in the road or undulation traction can be lost as the air bags compensate;
- Less traction with air as it skips on jump ups and any small rise. Air bags compensate and you lose traction, especially when the vehicle is empty; and
- Traction is found to be a problem with air when you are on a rough road or dips in the road.

In all cases the expression "the prime mover sits down on the road" is used when talking of 6-rod mechanical suspension and is more solid on the road. On air, pot holes, close undulations or corrugations effect the pressure in the

air bags and traction is lost. In some cases reported wheel spin has occurred due to one wheel being lodged in a small hole.

A number of examples of traction being lost were reported by a company operating out of Toowoomba where prime movers with air suspension had recently failed to negotiate a mountain range due to poor traction. Drivers also agree that once a traction failure occurs, no amount of trying will correct the problem.

5.5.3 Speed

Drivers comments on whether they drove faster or slower when driving a combination fitted with air suspension varied. Twelve respondents stated that they would drive slower and with more care while 10 stated they would not, 3 reported no change and the remaining 10 respondents did not answer this question. Reasons cited by industry for driving slower include:

- More concentration and care required by driver;
- Took a lot of getting used to;
- Vehicle lean particularly on corners and rough spots; and
- Prime mover slower to become level with more roll on cornering

In relation to cornering, drivers commented that they "don't throw an air prime mover into the corners as much as mechanical as the lean from the air gives the feeling of rollover and trailers sway more". Also on exiting the corner, the air does not compensate quick enough and the lean is the wrong way if you have to take a reverse direction corner in an 'S' bend situation.

In relation to speed, seven operators stated their prime mover was limited to 90km per hour, six commented that they were limited to 95 while the majority of drivers cited 100km as their prime mover limit.

5.5.4 Road Damage

Nearly all drivers commented that air suspension was "load friendly not road friendly". Constant comment was made that "if the freight is not getting damaged and the suspension has high maintenance the damage below the air bag has to be going into the road".

Drivers on Adelaide to Darwin and Adelaide to Melbourne runs all commented on the road corrugations and believe that it is attributable to the introduction of air suspension. Drivers generally commented that with air there was greater banging from the axle oscillations on the pavement. Therefore the heavier thumps from the impact of the axle on the road surface had to be causing road damage. Major damage under the air bag was attributed to increased road damage.

Some drivers indicated that they could feel when shock absorbers had gone as the axle hop was greater effecting the movement of the combination. Drivers also indicated that unless shock absorbers were kept in good condition and renewed, the axle vibrations increased and road damage had to occur.

5.5.5 Increased Mass

All companies were asked the main reason for installing air suspension on equipment and the majority indicated that it was only to "achieve extra mass". A number of companies commented that if increased mass applied to any suspension type, they would return to springs. A further company has taken the decision to replace all 'B' double prime mover and trailers with spring suspensions as they believe extra mass (in Queensland) will be a long time coming and the economic and operational benefits are not there. The company drivers applauded management's decision, as the drivers believed springs suspension was a safer option.

Those companies involved in perishable or easily damaged goods indicated that the change to air suspension, was primarily to improve commodity transport. However, one company commented that if a vehicle is packed properly, springs were just as effective as air.
All companies indicated that air suspensions were heavier than spring suspensions as axles needed to have thicker walls and air bag arms were heavy. Up to 500kg difference in weight was reported.

5.6 Industry Innovations

Industry reported that they are currently trialing different combinations of spring and air across their prime movers, trailers and dollies to develop a solution applicable to their transport task. Mixtures of air prime movers with spring trailers and dollies have been tried as well as spring prime movers with air trailers and spring dollies, in an attempt to assemble the safest, most efficient and highly productive combination. This is reinforced by the comment "one glove does not fit all hands" which demonstrates that industry are increasingly introducing flexibility into their operations and tailoring their vehicle combinations to suit their own task. It is clear that no two tasks are the same.

In some cases industry have implemented innovative solutions to improve the performance of multi-combination vehicles. One company has modified the operation of the 'fifth wheel' by inserting rubber bushes to reduce movement and hence improve trailer stability. These combinations utilise prime movers with air suspensions.

Another company has installed a market modification to the piping system of the prime mover air bags to increase airflow. This modification increases the

rate of change of the air and decreases compensation time between air bags. Companies have also installed extra air ride valves on axles to decrease compensation time. This type of modification has the effect of cancelling load sharing principles within the axle group. Industry is therefore adjusting manufacturers designs to make operational environments work. Larger air bags are being installed to help stability. Shock absorbers are being re-positioned from steep angles of mounting to vertical or near vertical to improve performance stability and handling. This modification however increases the frequency of replacement of shock absorbers.

An outcome of this survey and report is the documentation of these additional ideas that industry are trying and developing. A number of operators stated that shock absorbers on spring suspension should be tested for compliance with the "road friendly" certification parameters and if successful, marketed as a suitable suspension. Some prime movers seen during the course of the survey had shock absorbers fitted to a 6 rod suspension and the drivers believed the result was better than air for performance.

A further comment on tandem air dollies indicates that there was no extra mass benefit for the 25% increase in extra cost and therefore it was not economical to change.

One company since fitting air on prime movers and trailers has experienced additional "fall over" whilst tipping and are currently investigating the issue to determine the exact cause.

Industry has continued to be innovative and with experience, knowledge and in general with a hands on approach has continued to develop "best practice", particularly in response to changing transport regulations.

6. Concluding Comments

From the survey it is evident that no one combination or "set up" of the combination "outshines" any other. Combinations fit the transport task and what works for one task does not necessarily work for another. Furthermore, what operates in the more metropolitan environment does not necessarily operate successfully in the remote areas. An excellent example was provided in relation to two identical prime movers (same year, model and engine) where it was reported that one pulled a set of trailers perfectly, yet when hooked to the other, the trailers were all over the road.

The most common factor across all operators is that air dollies were not well accepted within multi vehicle combinations. Discussions with all operators reported that tandem air dollies move around more than the spring dolly and under braking behaves erratically. The additional movement is reflected in

the "ripple" effect down the combination and hence the rear trailer movement is greater.

Most operators prefer to incorporate a spring suspension vehicle, dolly or trailer, within the combination to keep the combination straight and therefore an influence on the tracking and reduce trailer movement. The preference for a spring suspension vehicle in the combination is reflected in the "Rating of the Preferred Vehicle Combination" at Table 4.3.2. The majority of preferred "Good" rated combinations shown in the table include a spring suspension vehicle. Furthermore of all combinations preferred in Table 4.3.1 an all spring combination was favoured.

An outcome from the survey indicates that any mandatory requirements for the inclusion of air suspensions in the operation of multi-combination vehicles to utilise higher mass limits in remote areas should address the allowance of some components within the combination to have spring suspensions on the prime mover and other components , e.g. dollies or trailers to improve safety and operational performance.

The survey indicates that a number of operators of air suspended prime movers are experiencing operational problems relating to stability, tyre wear and maintenance which should be brought to the attention of manufacturers so that options for solving these issues could be developed.

Livestock transporters, freezer operators and other remote area road transport businesses who operate high centre of gravity trailers have experienced significant vehicle control and stability problems with long combinations which have air suspensions on prime movers, trailers and dollies. In practice, these problems have largely been solved by substituting spring suspensions prime movers or other units with spring suspensions within the combination.

Operators have commented that the levelling techniques used to inflate and deflate air bags on air suspension appear to inject roll into the vehicle as each air bag or set of air bags compensates for each other. The mechanism used to, inject air when the axle falls, and dissipate air as the axle lifts, is considered by operators to be too slow and results in unevenness between airbags which can cause roll motion. Drivers opinion is that this type of operation gives them excessive lean characteristics on corners and a "waddle" effect in straight driving as the suspension tries to find an even ride height.

In single unit operation air suspension trailers are reported as behaving adequately however in multi-combination configurations the movement of any part of the vehicle influences the remainder and consequently air related combinations have more rear movement than spring combinations. Furthermore the stability of high centre of gravity vehicles is effected by the

roll that is set up from the levelling of the air bags on the trailers, which effects the total performance of the overall combination.

From information collected a major reason for shifting to air suspension was to gain the extra mass approved in the ***Review of Mass Limits on Road Friendly Suspensions.*** Data collected indicates that without the incentive of gaining extra mass only those operators using air suspension to reduce commodity damage would have stayed on air and the remainder indicated that they would have stayed on mechanical suspensions. This is further supported from Table 5.1.1 were from the introduction of air suspensions the highest number of positive responses indicates that the effect on stability is "worse" on prime movers and dollies.

The report found some evidence of safety concerns with vehicles using airbag suspension, but they are largely confined to remote areas. Assessment of a limited number of accident records from one State did not indicate that vehicles using airbag suspension are over represented in accident statistics or have a higher accident rate than other vehicles. As such they do not represent a major safety risk.

The survey results raise a number of questions regarding the performance of air suspension including air on prime movers that suggests further investigation into using air suspension on prime movers should be undertaken.

Furthermore the evidence collected in the survey aligns with that published by the Department of Transport Regional Services in their report "Investigation into the Specification of Heavy Trucks and Consequent Effect on Truck Dynamics and Drivers", in that drivers are experiencing "darting" "wandering " and "vibration" with prime movers on air suspensions.

7. Recommendations

This study focused on collecting information regarding the stability of multi-combination vehicles hauled by prime movers fitted with air bag suspensions. A number of other issues were raised relating to tyre wear, maintenance of suspensions, stability, and tracking performance.

From the data collected during this study, unsatisfactory driving experiences have occurred were air bag suspension have been installed in multi vehicle combinations. At the same time there are structural issues relating to suspension design and regulatory issues that need addressing to ensure that h long combinations operating in remote areas with air suspensions and especially those with high centre of gravity operate satisfactorily and therefore further work and research is necessary.

The following recommendations are made:

1. Additional field research be undertaken in relation to the performance and stability of air suspensions when used in multi-combination configuration in relation to:

   - Configurations with 2 or more trailers;
   - Operation on rough sealed and unsealed roads;
   - Stability on narrow pavements tracking on and off the sealed section;
   - Effect on stability using low profile and Super Single tyres fitted to steer axles;
   - Stability on close curved road alignment;
   - Determining centre of gravity (C of G) height limits;
   - Trailer movement/ on road characteristics for configurations incorporating air prime movers versus spring prime movers; and
   - Effect of speed and C of G on configurations with air suspensions versus configurations with steel suspensions.

2. Investigate and evaluate "After market improvements" to air suspensions.

3. Encourage manufacturers to work with the transport industry in developing best design practice ie location of shock absorbers, ride height valves etc to improve performance of air suspensions applicable to multi-combination configurations.

4. Improve accident collection techniques to include suspension types in accident questionnaire to develop a history file on accident patterns.

APPENDIX 1

QUESTIONNAIRE

PRIME MOVER

Make	Model	Year	H.P.	G.C.M.	Gear Box

STEER AXLE

Single	Twin

TYRES

Std	Low Profile	Super Single

DRIVE AXLE GROUP

Single	Tandem	Tri

TYRES

Dual Tyres	Tyre Size

SUSPENSION DRIVE AXLE

Air Bag		Number of dampers	
Springs		Number of dampers	

AIR SUSPENSION	**Make**		**Model**	

TRANSVERSE DISTANCE BETWEEN CENTRE OF AIRBAGS	

RIGID TRAILING ARM	**Over Axle**		**Under Axle**	

DAMPER POSITION FACING	**Forward**	**Vertical**	**Rear**	**Side**	**Approx angle**
No. of dampers					

LEAF SPRING	**Walking Beam**	**4 Spring**	**6 Spring**
No of leafs			

AXLE SPACING	**Extreme axles**	**Centre of group to centre of steer**

PRIME MOVER SPEED LIMITED:	80 85 90 95 100 kph

Further Comments:

TRAILER

MAKE	Flat Bed	Freezer	Cattle	Curtain Side	Tanker

AXLE GROUP	Single	Tandem	Tri Axle

TYRES	Dual	Std	Low Profile	Super Single

AXLE GROUP SPREAD	Standard	Wide Spread
Distance between axles		

HEIGHT OF TRAILER (M)	0 – 1	>1 – 2	>2 – 3	>3 – 4	>4	>4.3
Est C of G						

WHEEL BASE

KING PIN – Centre of Axle Group (M)	4 – 5	>5 – 6	>6 – 7	>7 – 8	>8 – 9	>9

AIR SUSPENSION

AIR	MAKE	MODEL
Transverse distance between airbags		
RIGID TRAILING ARM	Over Axle	Under Axle
Transverse distance between centre of airbags		

DAMPER POSITION FACING	Forward	Vertical	Rear	Side	Approx angle
No. of dampers					

SPRING SUSPENSION

WALKING BEAM	4 SPRING	6 SPRING	SEMI ELIPTIC
No of Leafs			
Transverse distance between centre of springs			
No of Dampers			

Further Comments:

DOLLIES

AXLE GROUP

Single	Tandem	Triaxle
Distance between axles		

TYRES	Dual	Std	Low Profile	Super Singles

AIR SUSPENSIONS

Air	Make	Model	No. of dampers
Transverse distance between airbags			

RIGID TRAILING ARM	Over Axle	Under Axle

DAMPER POSITION FACING	Forward	Vertical	Rear	Side	Approx angle

SPRINGS

Walking Beam	4 Spring	6 Springs
No. of Leafs:		
No. of Dampers:		
Transverse distance between centre of springs		

AXLE GROUP SPREAD	Standard	Wide Spread
Distance between axles		

DRAWBAR LENGTH (centre of axle group to eye)	

Further Comments:

DRIVERS – In your Experience

- **What suspension types/combinations give you improved stability/control of your vehicle combination:**

(a)	Air Bag Prime Mover	Air Bag Trailers/Dollies	Y	N
(b)	Air Bag Prime Mover	Spring Trailers/Dollies	Y	N
(c)	Spring Prime Mover	Air Bag Trailers/Dollies	Y	N
(d)	Spring Prime Mover	Spring Trailers/Dollies	Y	N
(e)	Other suspension combinations (please specify)			

- **Which of the following dollies effect stability?**

Single Axle	Better	Worse
Tandem Axle (Spring)	Better	Worse
Tandem Axle (Air)	Better	Worse
Tri Axle (Spring)	Better	Worse
Tri Axle (Air)	Better	Worse

- **Which of the following trailers effect stability?**

Single Axle	Better	Worse
Tandem Axle (Spring)	Better	Worse
Tandem Axle (Air)	Better	Worse
Tri Axle (Spring)	Better	Worse
Tri Axle (Air)	Better	Worse

- **How would you rate the following combinations of suspension and the effect on stability?**

Prime Mover	Trailer	Dolly	Trailer	Dolly	Trailer	Poor	Fair	Good
Air	Air	Air	Air	Air	Air			
Air	Air	Spring	Air	Spring	Air			
Air	Spring	Air	Spring	Air	Spring			
Air	Spring	Spring	Spring	Spring	Spring			
Spring	Air	Air	Air	Air	Air			
Spring	Air	Spring	Air	Spring	Air			
Spring	Spring	Air	Spring	Air	Spring			
Spring	Spring	Spring	Spring	Spring	Spring			

- **What combination do you normally drive?**

Single/Artic	Truck/ Trailer	Double RT/ Triple RT	'B' Double
'B' Triple	Double 'B' Doubles	2AB2	Rigid plus 2/3

- **Have you had any rollover or bad experience with the combination?**
  Yes No

- **What in your opinion was the problem:**
  - Prime Mover
  - Trailer
  - Dolly
  - Vehicle Setup
  - Vehicle characteristic/performance
  - Road surface
  - Road width
  - Other please explain?

_____
_____
_____
_____

- **How long have been driving heavy transport?**

SPRING: ..……. years AIR: ……. years

- **Have you experienced any change in stability from introducing Air Suspension:**

  - Prime Mover Better Worse No change
  - Dolly Better Worse No change
  - Trailer Better Worse No change

- **If a change occurred, what problems have you experienced?**

  - Roll over tendency
  - Difficult to steer
  - No feel for the reaction of the vehicle
  - Problems cornering high speed/low speed
  - Trailer movement
  - Other - Please explain

_____

_____

_____

- **Any specific effects from the combination:**

  - Vibration Yes No
  - Trailer Lurching Side/Side Yes No
  - Trailer Roll Side to Side Yes No

- **Do you prefer to drive:**

  - Prime Mover With Air Bag Yes No
  - Combination With Air Bag Yes No
  - Combination With Springs Yes No
  - Mixture of Both Yes No
  - State reason::

_____

_____

_____

- **Do you drive slower/with more care when driving a combination fitted with Air Suspension?** Yes No
  - State reason:

_____

_____

_____

MAINTENANCE MANAGER

- **Which suspension requires more maintenance?**
  Air Spring

- **Which suspension causes more structural damage to your vehicles?**
  Air Spring

- **How often do you change dampers for:**

AIR (km)	2000-5000	>5000-10,000	>10,000-20,000	>20,000-50,000	>50,000-100,000	>1,000,000
Gravel road						
Bitumen road						

SPRING (km)	2000-5000	>5000-10,000	>10,000-20,000	>20,000-50,000	>50,000-100,000	>1,000,000
Gravel road						
Bitumen road						

- **How often do you change airbags/springs?**

REPLACE AIRBAGS (km)	2000-5000	>5000-10,000	>10,000-20,000	>20,000-50,000	>50,000 - 100,000	>1,000,000
Gravel road						
Bitumen road						

REPLACE SPRING LEAVES (km)	2000-5000	>5000-10,000	>10,000-20,000	>20,000-50,000	>50,000 - 100,000	>1,000,000
Gravel road						
Bitumen road						

- **Are the vehicles more or less costly to maintain with air suspensions?**
  More Less

- **Have more accidents/incidents occurred since introducing air suspension on:**

  - Prime Movers Yes No
  - Trailers Yes No
  - Dolly Yes No

  Details of accident/incident:

  _____

  _____

  _____

  _____

- **What in your opinion would be the best vehicle combination:**

Prime Mover	Air	Spring
Trailer	Air	Spring
Dolly	Air	Spring
Trailer	Air	Spring

- State reason:

OWNERS / TRANSPORT MANAGERS

- **What percentage of your fleet has airbag suspension?**

Prime Movers	10%	20%	30%	40%	50%	60%	>70%	State %:
Trailers	10%	20%	30%	40%	50%	60%	>70%	State %:
Dollies	10%	20%	30%	40%	50%	60%	>70%	State %:

- **Do you favour air bag suspension over other types?**

  Yes No

  Reason:

Increased mass	Yes	No
Better stability	Yes	No
Decreases commodity damage	Yes	No
Better Ride Quality	Yes	No
Less maintenance	Yes	No

- **If your transport task has remained the same, have you had an increase in accidents/incidents/problems with the introduction of air suspension on:**

➢ Prime Movers	Yes	No
➢ Trailers	Yes	No
➢ Dollies	Yes	No
➢ Mixing Air and Springs	Yes	No

  If yes, please detail:

  _____

  _____

  _____

- **Does the increase mass provided for under the Mass Limits Review have an effect on the performance of vehicle combinations with air suspensions?**

  Yes No

  Reason:

  _____

  _____

  _____

- **If increased mass was granted <u>to any suspension type</u>, which would you prefer:**

➢ Prime Movers	Air	Spring
➢ Dolly	Air	Spring
➢ Trailer	Air	Spring

Reason:

_____

_____

_____

- **What are your prime movers speed limited to:**

80 85 90 95 100 kph

APPENDIX 2

LIST OF COMPANIES INTERVIEWED

Air Suspension Survey

Companies Interviewed

LOCATION	COMPANY	COMMODITY
Darwin	Gulf Transport	Bulk Materials
Darwin	Road Trains Australia	Livestock
Darwin	Frontline	General
Darwin	Ascot Transport (NTFS)	Freezer
Darwin	Linfox	Fuel
Darwin	Titan	Cement
Darwin	AFD	Fuel Distributors
Alice Springs	G & S Transport	Bulk
Alice Springs	Titan	Bulk Cement
Alice Springs	Northern Territory Fuels	Fuel Distributors
Alice Springs	Tanami	Livestock
Alice Springs	McBride Transport	General
Mt Isa	Road Trains Australia	Livestock
Mt Isa	Haulmark	Manufacturer
Mt Isa	Ross Kiernan Transport	Bulk Material
Toowoomba	Frasers Transport	Livestock
Toowoomba	Johnston's Transport	Livestock
Toowoomba	Strasburg Bros	Livestock
Toowoomba	Robertson's Transport	Livestock
Toowoomba	Baskett Transport	General/Fuel
Toowoomba	Rural Freighters	General
Toowoomba	Westrans	Freezer/General
Toowoomba	Young & Land	General
Adelaide	Gilberts Transport	Freezer
Adelaide	Transport Connection	Manufacturer
Adelaide	Titan Bulk	Bulk Cement
Adelaide	Niteflite	General
Adelaide	Collins Transport	Freezer/General
Adelaide	Gilberts Transport	Freezer/General
Adelaide	Bulls Transport	Freezer/General
Adelaide	Lamont Transport	General
Perth	Marley Transport	Livestock
Perth	Fyfe Transport	Bulk Commodities
Perth	Giacci Bros Transport	Bulk Commodities

LOCATION	COMPANY	COMMODITY
Perth	Centurion Transport	Freezer
Perth	Mitchell Logistics	Fuel
Perth	Symington Transport	Livestock
Perth	Brambles	Freezer
Perth	Westfarmers	Freezer

APPENDIX 3

CASE STUDY

APPENDIX 3

CASE STUDY - AIR SUSPENSIONS IN DRIVE APPLICATIONS

Introduction

During the consultative process, one company identified that they had operated air suspension in drive axle over a four-year period and had collected performance and accident data during that period. During this time, the company had identified a number of concerns relating to the handling characteristics of air suspension as opposed to mechanical spring suspensions. The following incidents were reported by drivers:

Incident 1
Two experienced drivers reported rollovers as a result of a lack of response from the steering when trying to maintain control of a multi-combination configuration hauled by an air suspension prime mover. One incident occurred when a vehicle combination was passing another vehicle on a narrow road, and was required to pull over onto the hard shoulder, causing the rollover.

Incident 2
The second incident occurred when the multi-combination vehicle dropped off the edge of the bitumen while negotiating a bend, thus causing a rollover.

Other
Company drivers also report lack of steering control and handling for no apparent reason.

Operators therefore have doubts on the ability of air bags in a drive suspension to maintain a balanced pressure and thus suitable stability in high centre of gravity loading vehicles.

Operators also have concerns about the load sharing ability of air suspensions in motion and the impact on pavement loading. They commented that the transfer of air from one air bag to another, through small bore piping in sufficient time, is considered not possible and therefore creates uneven pavement loading.

Accident history was recorded over a 7 month period between September 1998 and March 2000, and the results are shown below.

No. of Accidents	Loaded	% Rollover				Prime Mover Air Suspension
		Prime Mover	Semi	1st Trailer	2nd Trailer	
8	100%	50%	50%	63%	75%	75%

These statistics demonstrate that the probability of the rear trailer to rollover is higher than the prime mover. Of all of the accidents recorded, 75% of the prime mover hauling these units, were on air bag suspension.