DEVELOPING TRUCK - TRAILER BRAKE COMPATIBILITY STANDARDS

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ABSTRACT

Australian Design Rules have achieved a large degree of truck/trailer braking balance under emergency braking (new vehicles must comply with Australian Design Rules before registration). This results in safe, stable braking. But complete brake balance between trucks and trailers under all conditions has proved elusive.

Efforts to achieve compatibility at everyday braking levels have been frustrated by a lack of driver behaviour and vehicle performance knowledge. This paper covers a study which looks at the safety implications of this incompatibility and ways of reducing it.

By determining the pattern of brake use in routine service a typical brake usage pattern has been established. This pattern shows usual braking levels are much lower than was previously thought. Using this pattern to assess brake performance of compatible and incompatible combinations, a set of test requirements has been formulated to provide a means of improving compatibility.

To date, compatibility measures have concentrated on achieving equal retardation from each vehicle in the combination for a given air pressure in the truck to trailer coupling at relatively high retardations.

The results now obtained indicate that balance needs to be achieved at much lower retardations, starting at levels only marginally above rolling friction.

Additionally, the results show that distributing brake work per axle with wear and temperature patterns in mind is more important than relying on equal vehicle retardation in achieving compatibility under normal driver conditions..

TRUCK BRAKING PERFORMANCE is a major primary safety feature, playing an important role in assisting the driver avoid an impending crash. In Australia all new vehicles are required to comply with a number of Australian Design Rules (ADRs) which specify safety related design and construct requirements, one of which is braking performance.

Australian Design Rules for commercial vehicle braking (referred to as Australian Design Rule 35 for trucks {ADR35}, and ADR38 for trailers) lay down minimum service brake performance levels, requirements to guard against brake fade, parking brake requirements and measures to prevent a total loss of braking should a failure occur in the brake system.

ADR 35 was based on the United States Federal Motor Vehicle Safety Standard 121 (FMVSS 121), and does not have any explicit provisions for truck-trailer compatibility. In developing the Design Rule for trailer braking (ADR 38) the compatibility requirements from the United Nation's Economic Commission for Europe (ECE) Regulation 13 were adopted. However, unlike ECE 13, ADR 38 does not impose different compatibility requirements for drawbar trailers as opposed to semi-trailers. Nor does ADR 38 adjust the semi-trailer performance limits to reflect the different dynamic weight transfer characteristic of long and short semi-trailers.

Thus, all new trailers in Australia are designed to a common performance envelope (Figure 1).

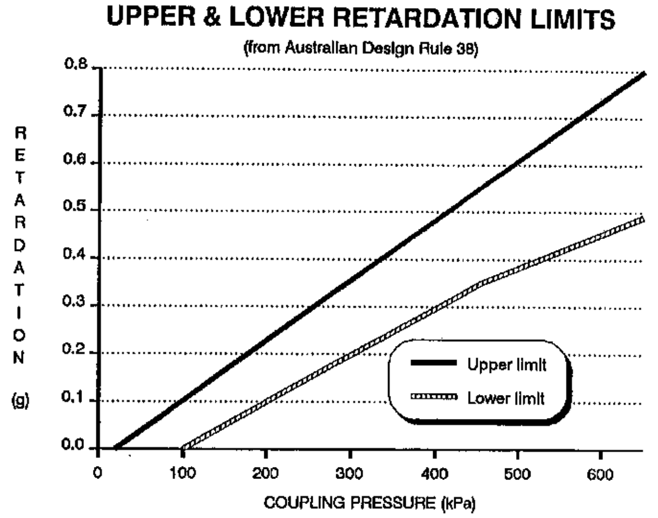

Figure 1

Prior to the introduction of ADR38, a validation study was conducted in 1982 to establish just what effect these performance limits would have on compatibility

The study concluded that ADR 38 would ensure combination stability tothe degree permitted by the truck's own stability *(1)

But stability and compatibility are not exactly the same. Stability relates to mainly high braking levels, and under those conditions the Design Rules and voluntary measures introduced by the truck manufacturers have achieved a large measure of balance and hence stability and safety.

But drivers and operators have continued to complain of inadequate brake performance and very uneven brake wear patterns.

Initial investigations indicated a marked degradation of braking performance was occurring in service due to a poor match of brake systems on the truck and trailer.

IN-SERVICE DEGRADATION

Operator complaints centred around excessively high brake lining wear, mainly on the truck's drive axles. Drivers complained of a feeling of "being pushed" by the trailer whilst braking.

In most cases nothing obviously wrong with the combination could be found. However, by observing the driver at work, and taking a few simple measurements, it appeared that drivers rarely reached the levels of braking addressed by the Design Rules and that the conventional brake testing procedures were inappropriate.

SAFETY IMPLICATIONS - In simple terms, brake wear could be looked upon as a maintenance issue and only a safety issue if correct maintenance procedures are not followed. Excessive heating is not so easily resolved, but could also be dismissed as an operational problem. The reality is somewhat more complicated than this.

Radlinski, Williams and Machey[2] found that the combined effect of increased stroke due to wear and increasing the initial brake temperature can result in an overall 34% reduction in torque.

*(1)Numbers in parenthesis designate references at end of paper

Rapid brake wear on one part of the combination may be conducive to lining glazing on another part, further reducing brake performance. This condition can easily go undetected.

One (extreme) case investigated showed an appreciable increase in truck drive axle brake chamber stroke and signs of trailer lining glaze during one 1,000 km trip, leading to a reduction of over 30% in combination brake performance.

Thus, even on well maintained vehicles, imbalance or incompatibility can have very real safety implications.

CONDITIONS UNDER WHICH DEGRADATION OCCURS

Although incompatibility between the brake systems of two vehicles in a combination is often considered as a major cause of in-service brake degradation, no objective measure of compatibility could be found. However, the operator's assessment, based on lining wear and heating/glazing tendencies, is adequate to identify those combinations where incompatibility is probably assisting or causing in-service brake degradation.

From earlier driver observations it was clear that traditional regulation based brake tests had little relevance to the investigation of service based degradation. Drivers appeared to use braking levels much lower than those specified in the regulations.

Before any analysis of vehicle behaviour could be made, the pattern of brake usage in normal service needed to be known. To establish this the Australian Road Research Board were commissioned to conduct a study of brake usage .

The results of that study are discussed in a separate paper by ARRB's Jim Jarvis.

In summary, a typical brake application was found to begin at 75 km/h, the air pressure would rise at around 130 kPa/sec until a deceleration level of 0.06g is reached. The pressure will then be held constant for about 5 seconds by which time the speed will have dropped 10 km/h or so to about 65 km/h.

EFFECT OF BRAKE USAGE PATTERN ON VEHICLE PERFORMANCE REQUIREMENTS

These results indicate that the previous emphasis on high retardation brake testing may not be a reliable indicator of in service brake balance, except for stability measures.

Clearly, balance needs to be achieved at both ends of the retardation range. In particular, attention needs to be given to the slow application of low pressures and balance of brake effort at low retardations.

In looking at the effect on vehicle design, the rationale adopted in draft American SAE standards[3] of specifying brake contact pressures becomes very relevant. Many operator complaints indicate that most of the routine braking is being done by one axle or axle group. Equal contact pressures on all axles of the combination should avoid this.

But it was felt that it is just as important to achieve equal retardation from each vehicle in the combination as the braking level rises.

However, achieving these requirements must not destroy the stability balance at high retardations.

To ascertain the validity of these assumptions, track tests were conducted using the data logged vehicles, and some additional combinations, to establish vehicle performance under the conditions found to be typical of normal service.

The tests concentrated on the two identified causes of incompatibility induced degradation; contact pressure imbalance and retardation performance imbalance.

CONTACT PRESSURE TESTS - The simple concept was to apply a specified, but relatively low, torque to each wheel on the combination and raise the air pressure in the actuator slowly at approximately the rise rates observed in normal driving until the applied torque was resisted. A torque of 137 Nm was found to overcome wheel bearing friction etc and gave consistent rotational speed.

As there was no evidence of significant air pressure modulation during a brake application, there appeared little validity in the American practice of taking "contact" pressure for both rising and falling pressure.

The required pressure rise rate was obtained by throttling the signal line to the relay valves in use, thus maintaining any crack pressure characteristics.

RETARDATION TEST PROCEDURE - The brakes were applied to each vehicle in the combination in turn (ie truck or trailer), starting at a speed slightly above the chosen starting speed, with recording starting at the selected speed. This gives a deceleration which can be described as established, ignoring any transient response characteristics in line with the normal braking patterns observed.

Any differences between combination test mass and the appropriate vehicle rated mass (maximum legal mass) were adjusted by applying the ratio "test mass/rated mass" to the measured deceleration. The resultant measure is referred to as "Established Retardation Coefficient" (ERC) as used in Australian Design Rule 38. ERC has units of 'g'.

TIME RESPONSE PROCEDURE - The time response as usually defined was not measured.

Instead traces of pressure against time were recorded for a number of different brake application rates and levels. At the slow rates used in service no significant time response effects were observed.

Although the air system could be expected to exhibit complete fidelity at these application rates, time lags in braking may still exist due to differences in contact pressure. In fact, the slow air pressure rise seen would exaggerate these lags as it would take longer to traverse from the lowest contact pressure to the highest.

ROAD TEST RESULTS

The following graphs show the results for each combination tested. In each case the air line coupling between truck and trailer is used as the reference point as this is the only common point. The retardations are stated as ERCs.

Details of the vehicles tested are provided in Appendix 2

ANSETT SCANIA 6x4 /MAXI-CUBE TANDEM SEMI

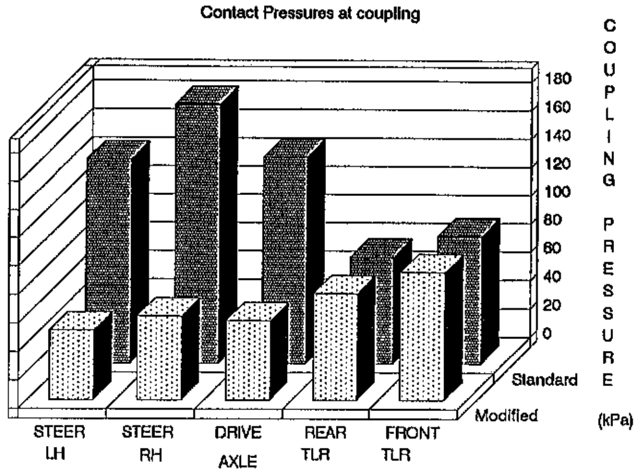

Figure 2

ANSETT SCANIA 6x4 /MAXI-CUBE TANDEM SEMI

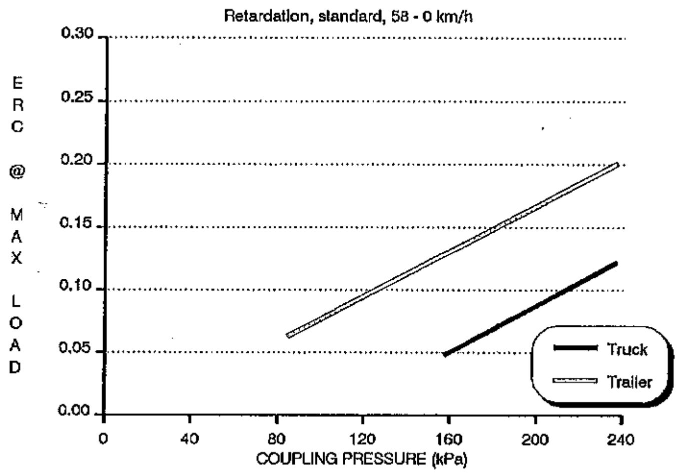

Figure 3

ANSETT SCANIA 6x4 /MAXI-CUBE TANDEM SEMI

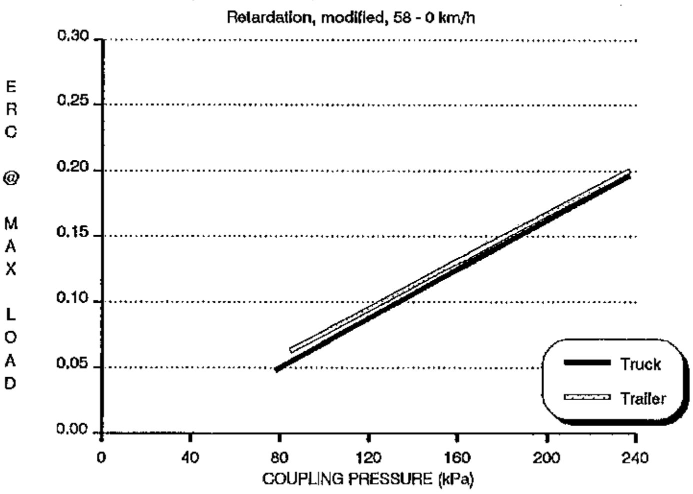

Figure 4

COMET FORD 6x4 / FREIGHTER TRIAXLE SEMI

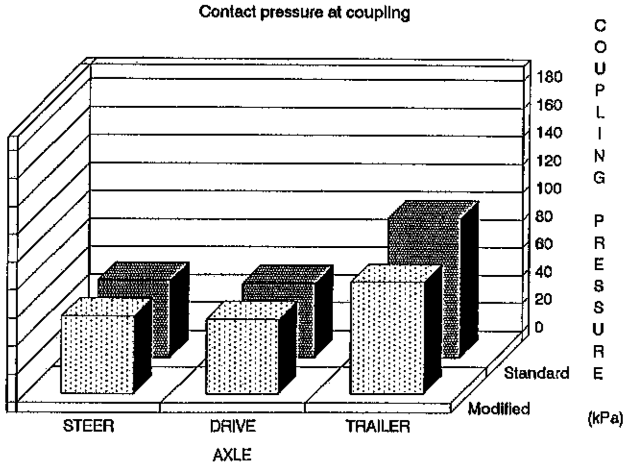

Figure 5

COMET FORD 6x4 / FREIGHTER TRIAXLE SEMI

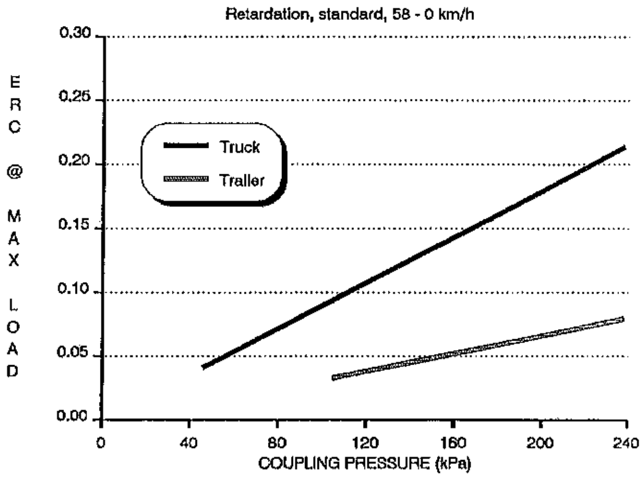

Figure 6

COMET FORD 6x4 / FREIGHTER TRIAXLE SEMI

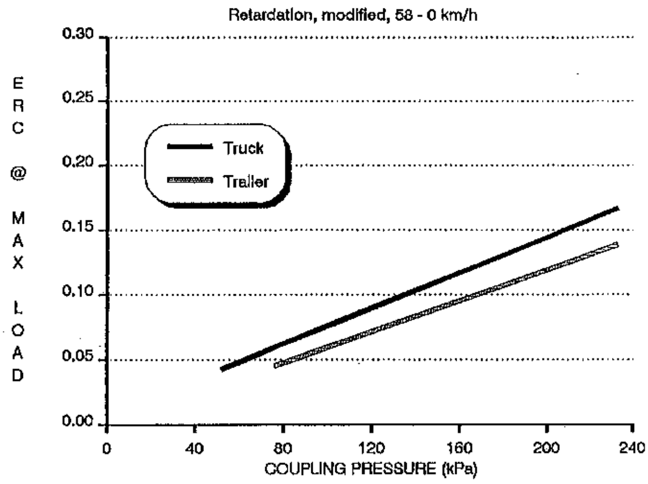

Figure 7

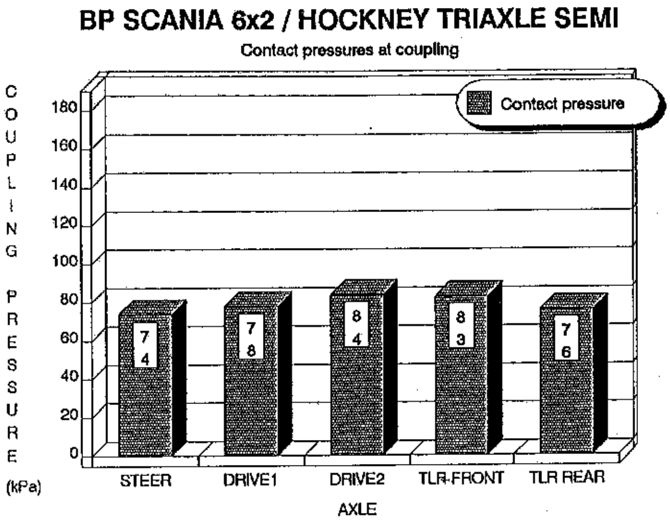

Figure 8

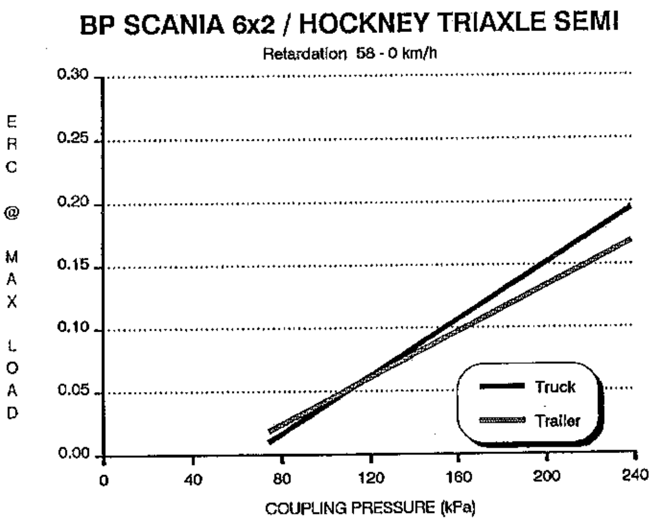

Figure 9

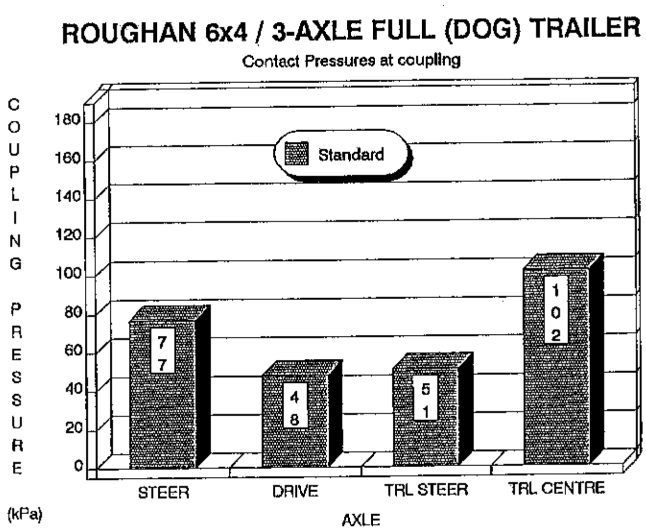

Figure 10

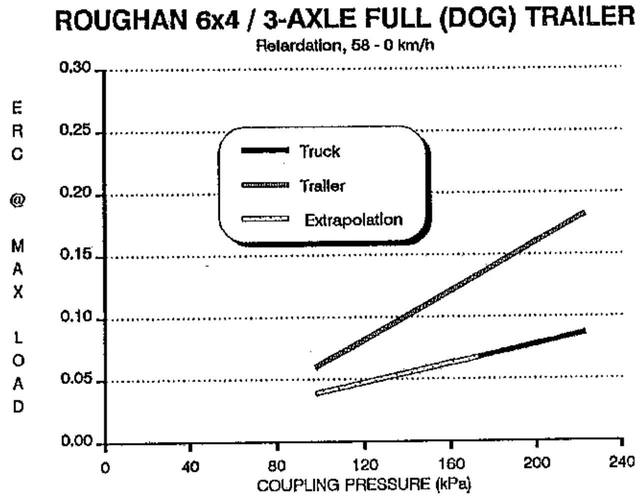

Figure 11

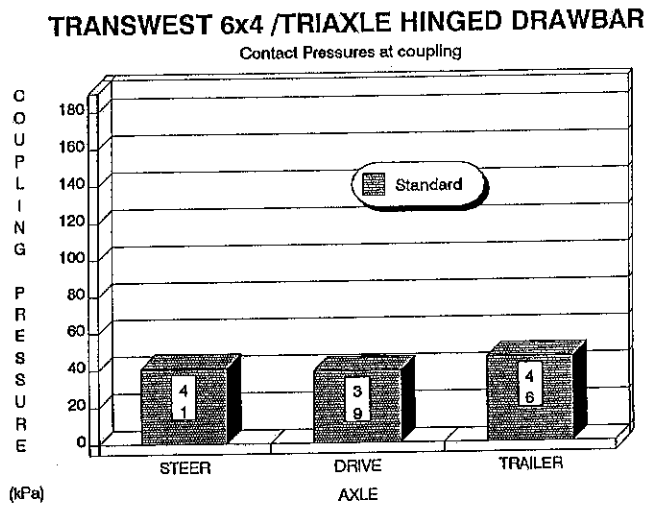

Figure 12

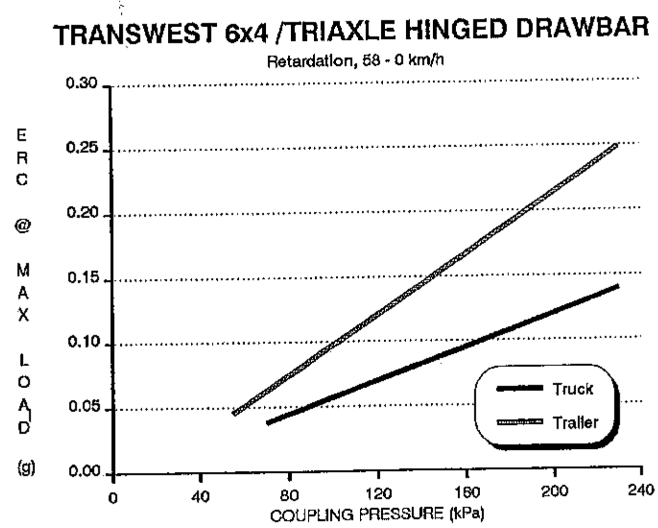

Figure 13

At the outset, it had been thought that differences in contact pressure in the combination allowed one or more axles to do all the braking work; the larger the gap in contact pressure the greater the degree of incompatibility.

The contact pressures measured at the coupling differ across the combination by between 5kPa to 40 kPa for compatible combinations, and from 47 to 115 kPa for incompatible combinations.

In looking at the retardation results, the expectation was that the greater the difference in retardation of the two vehicle at any given coupling pressure, the greater the degree of incompatibility.

At a coupling pressure equivalent to a combination retardation of 0.04 g, the difference in ERC for the truck and the trailer vary from 0.003 to 0.02 g for compatible combinations and from 0.02 to 0.052 g for incompatible combinations.

At a coupling pressure equivalent to a combination retardation of 0.1g, the ERC gaps for compatible combinations vary from 0 to 0.04 g, and from 0.07 to 0.1 for incompatible combinations.

Generally, the incompatible combinations have both higher contact pressure gaps and higher ERC gaps.

DEVELOPMENT OF ENGINEERING COUNTERMEASURES

The results appear to support the theory that, for compatibility, the brakes on axles of the combination must make initial contact at nearly the same coupling pressure.

The proposal that the retardation of each vehicle must exactly match for any coupling pressure does not appear to stand up so well.

However, it is still appropriate to develop a tolerance range for each of these parameters. In the case of retardation the tolerance will take the form of upper and lower bounds on the graph of retardation versus coupling pressure.

The expectation is that if the brake performance of all trucks and trailers falls within those tolerance limits, brake compatibility and interchangeability will ensue, and in service brake degradation will be eliminated or much reduced.

CONTACT PRESSURE LIMITS - Contact pressure results obtained using quasi-constant pressure show a test to test repeatability of 4 KPa (0.6 psi) and that a difference across the combination of up to 40 kPa still results in a compatible combination.

However, greasing of the camshafts on the Transwest pig trailer resulted in a contact pressure drop of approximately 20 kPa. Whether this vehicle represented recommended maintenance standards before greasing is debatable. It certainly serves to highlight a potential pitfall in implementing a contact pressure test.

Thus it would seem reasonable to specify a tolerance of +/- 20 kPa on contact pressure requirements. However, as the contact pressures determine the start points on the retardation graph, this was felt to be too wide. A figure of +/- 15 kPa was preferred to maintain reasonable limits on contact pressure in service.

In order to maintain compatibility between new and old vehicles, the contact pressures specified need to reflect mean values of existing vehicles. A figure of 70 kPa appeared a suitable compromise.

So, a criteria of 70 +/- 15 kPa seems appropriate .

RETARDATION LIMITS For compatible combinations, with the exception of the Comet Ford vehicle, the trailer generally has slightly higher retardation at any given coupling pressure. That is, the trailer appears higher on the graph of ERC vs pressure than the truck, rather than two co-incident plots as was expected. Although the margin by which Comet Ford truck was higher than its trailer was quite small, this appears to cause a disproportionate amount of truck brake wear. Combinations with the trailer above the truck by this much or more appeared very much more compatible.

Thus, it would appear that the trailer should sit above the truck on the ERC graph, and that the further the trailer falls below the truck, the greater the imbalance becomes. Having the truck and trailer coincident on the graph still appears to result in higher truck brake wear and heating.

Thus, the normally accepted aim of achieving equal retardation from each vehicle does not appear to give compatibility under normal service conditions.

The United Nation's ECE Regulations would have a semi-trailer fall below the truck on the ERC graph in order to achieve stability at high retardation levels. This would appear to conflict with compatibility in normal service.

In considering why this should be so the question of torque distribution per axle was raised. In various vehicle configurations each axle bears a different amount of the load and accordingly will have a different amount of torque. However, the brake does not wear in accordance with imposed load; developed torque causes wear.

Specifying a standard torque distribution seems appropriate, with the aim of achieving equal brake wear on each axle in the combination, with temperature effects accounted for; brake wear being, in part, temperature dependent.

Unlike some other torque distribution proposals which have proved unsuccessful before, the proposition here is to not use rated torque, but the torque actually developed at specified, low coupling pressures. This takes into account all the valve characteristics, the booster performance and the losses in the friction brake itself.

DEVELOPING REQUIREMENTS TO GIVE EQUAL BRAKE WEAR

TORQUE DISTRIBUTION - The above results indicate that trailers should have slightly higher torque levels per axle than trucks at the low retardation levels.

This may be because trailer axles generally have better cooling airflow than trucks' drive axles,. and a large number of trucks have smaller steer axle brakes than either drive or trailer axles.

Taking into account these effects, a simple torque ratio based roughly on drum sizes appeared to give good results, taking the common 178mm wide drum (7 inch) as having one notional "unit of torque".

For example, taking a triaxle semi trailer as having 3 units of torque (3 axles with 178mm wide drums), a 4x2 truck would have a total of 1.7 units of torque (for 1 axle with 178mm drums, 1 with 127 mm {5 inch} drums) and a 6x4 truck 2.7 units of torque (2 x 178mm, 1 x 127mm).

The results for the modified Ansett Scania (where, incidentally, all brakes were nearly the same size as on the trailer) has exactly the torque balance truck to trailer that this approach would indicate. That is, the truck is assigned 2.7 units of torque and the tandem trailer 2 units of torque. On this basis the truck should have 2.7/4.7 ths (57%) of the total combination torque. The road test results show the truck has 58% of combination torque. and was found to be very compatible.

CONVERTING TORQUE TO RETARDATION - As brake tests usually result in a measure of deceleration, not torque, the notional units of torque are converted into retardation (ERC) at maximum legal loads. From this a tolerance band can be developed which will keep the truck and trailer retardation in the appropriate ratio for in-service compatibility.

Whether the vehicle is operating laden, empty or somewhere in between, the thermal balance needs to be the same and, for any given coupling pressure, the brake temperatures will be independent of load.

By fixing the test mass, all other conditions are catered for in an equivalent fashion.

In developing upper and lower ERC bands, the upper bound from the existing Australian Design Rule 38 graph (equivalent to the base ECE 13 drawing vehicle graph) is used as a starting point. The lower bound is obtained by drawing a line parallel to the upper bound displaced approximately 30 kPa (contact pressure gap) in the critical compatibility area. Outside of the critical compatibility area the two bounds blend into the existing ADR 38 graph limits (Figure 14).

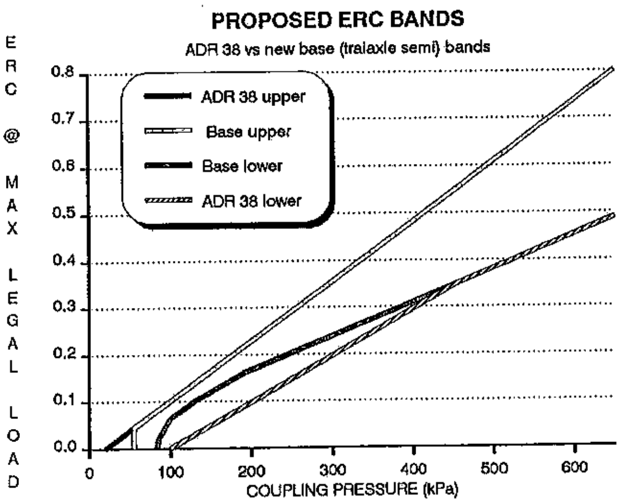

Figure 14

These bounds will be truncated at the upper and lower contact pressures respectively and will have the effect of providing tight specifications in the compatibility area but retain existing upper and lower limits at the higher braking levels where stability is the predominant requirement.

Each vehicle type (ie triaxle semi-trailer, 6x4 truck etc) will need its own set of upper and lower limits, to reflect the different allocation of notional torque and its maximum legal mass. Appendix 3 details how the retardation limits for each vehicle type is derived.

These upper and lower limits will ensure interchangeability and compatibility.

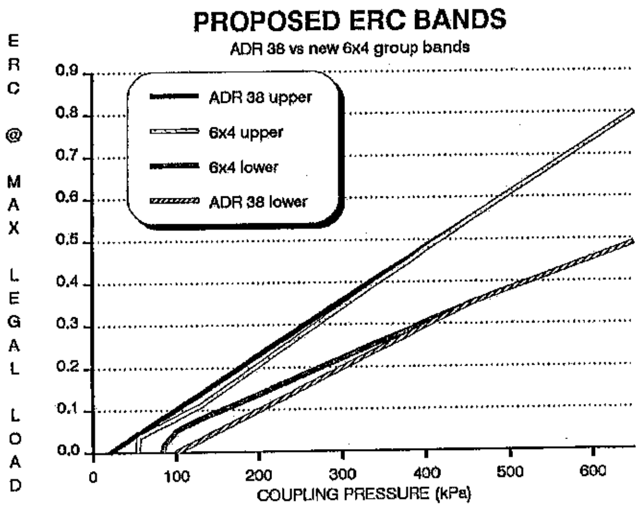

Figure 15

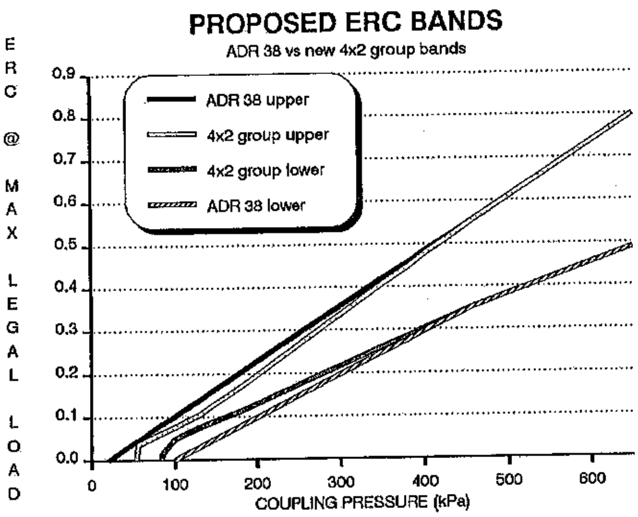

Figure 16

Rolling friction should be subtracted from test results as it is quite sensitive to the mass used for testing, rather than to the maximum certification mass.

EVALUATION

Test procedures using the requirements outlined above have been distributed to industry for evaluation (Appendix 4).

Whilst the response to date has been limited, some feed back from fleet operators has been encouraging. Vehicle combinations modified to meet, or nearly meet, these requirements have been found to have much better driver acceptance and more even brake wear patterns.

In-service brake degradation has reduced but stability at higher braking levels has not been compromised.

In some cases, meeting both contact pressure requirements and retardation requirements has proved extremely difficult, although vehicles which meet retardation but not quite meet contact pressures, appear to be satisfactory in service.

In a number of cases the contact pressure falls below the minimum value specified. Yet the vehicle appears perfectly compatible with a mating half which fully meets the proposed requirements.

This indicates that the lower contact pressure point is incorrectly specified.

The basis for this error probably lies in the assumed step change in brake torque at the instant of contact; the self-servo effect common to S-cam drum brake designs. The degree of self-servo appears to have been overestimated. It would appear that no significant torque (and thus heat or wear) is occurring in the period between actual contact and the lower contact limit.

To all intents and purposes, brake torque establishment commences above the lower contact point , as was intended.

Measuring the brake torque at these low pressures is extremely unreliable using over the road techniques. However, the existing static test clearly does not produce definitive results either.

Further exploration and evaluation of these requirements by industry will continue in parallel with the development of appropriate words for use in the Australian Design Rules. The experiences gained by industry will be used to modify the requirements as appropriate.

CONCLUSIONS

In routine service braking the driver applies the brakes slowly and continually up to the desired level, or close to it. This level is maintained with little modulation until the brakes are released completely.

The braking levels are low, typically around 0.1g or less. Correspondingly, the air pressures employed are also low, around 100 kPa. Thus, the brake balance on the combination is quite sensitive to small differences in brake performance at these levels.

Achieving equal contact pressures across the combination prevents one axle from doing the majority of the work at braking levels marginally above rolling friction. Just how this contact pressure should best be measured is yet to be determined.

Achieving equal retardation from each vehicle in the combination will not necessarily lead to good compatibility under normal driving conditions, although this remains important for high brake level stability.

Achieving equal brake work per axle appears to offer balance as the braking level builds up. However, the brake work done per axle appears to need correcting to take account of cooling, drum sizes etc.

A set of performance curves, measuring retardation against coupling pressure, have been developed for groups of vehicle types which should ensure appropriate brake work distribution for each vehicle in a combination. These curves are being evaluated by industry for potential inclusion in the mandatory Australian Design Rules.

ACKNOWLEDGEMENTS

The work described in this paper is the result of consultation, cooperation and participation by the technical committee members listed in Appendix 1.

The author thanks all those committee members and also the organisations who lent vehicles for testing and those who spent their time trying to arrange vehicle loans.

Particular thanks to International Harvester for extensive use of their test facilities.

The data logging of driver behaviour and initial analysis of the collected data was carried out by Jim Jarvis of the Australian Road Research Board.

Some track tests were conducted by Bisitecniks P/L, Ballarat, Victoria under contract.

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2. Radlinski, Williams and Machey, The importance of maintaining air brake adjustment. SAE paper 821263, Truck & Bus Meeting and Exposition, Indianapolis, Indiana USA November 1982.

3. SAE J1505 May 1985, Brake force distribution test code - commercial vehicles

APPENDIX 1

Membership of technical committee.

Lawrence Glynn Federal Office of Road Safety (Chair)

Harry Close TNT (representing ARTF)

Peter Edwards Kenworth (representing FCAI) up to May 1988 only

Ron Ellery Ford (representing FCAI)

Stuart Ironmonger International (representing FCAI)

Jim Jarvis ARRB (co-opted to manage data logging tests)

Andrew Reynoldson Kenworth (representing FCAI) May and June 1988 only

Bob Howell Kenworth (representing FCAI) from May 1988

Ross Deves Kenworth (representing FCAI) from July 1988

Keith Mackinlay Bisitecniks P/L (representing CVIAA)

APPENDIX 2
DETAILS OF TEST VEHICLES

BP Scania/Hockney Alcan triaxle tanker

Considered to have good compatibility after being modified to remove a boost to the trailer line built into the truck.

Truck
Make/Model Scania P112M 6x2
Built 5/87

Front axle	16.5 x 5	Type 24 on 165mm slack
Rear axle 1	16.5 x 7	Type 24 on 165mm slack
Rear axle 2	16.5 x 7	Type 24 on 152mm slack (York axle)

Tyres 275/80R22.5

Trailer
Make/Model Hockney Alcan TS-3-36
Built 12/86

Axle 1	16.5 x 7	Type 24 on 127mm slack (All
Axle 2	16.5 x 7	Type 30 on 127mm slack York
Axle 3	16.5 x 7	Type 30 on 127mm slack axles)

Tyres 15R22.5

Ansett Scania/Maxi-Cube tandem van

In modified form considered to have good compatibility. In standard form considered to be overbraked on the trailer. The modification entails removing the built in boost given to the truck's control line coupling.

Truck
Make/Model Scania T142 6X4
Built 1/86

Front axle	16.5 x 5	Type 24 on 165mm slack
Rear axle 1	16.5 x 7	Type 24 on 165mm slack
Rear axle 2	16.5 x 7	Type 24 on 165mm slack

Tyres 11R22.5

Trailer
Make/Model Maxi-Cube Tandem
Built 04/86

Axle 1	16.5 x 7	Type 24 on 150mm slack (BPW
Axle 2	16.5 x 7	Type 24 on 150mm slack axles)

Tyres 11R22.5

Comet Ford/Freighter triaxle tautliner

In modified form it is considered to have reasonable compatibility but the truck still tends to wear brakes faster.

In standard form the truck is considered to be doing too much of the routine braking.

The modification entails altering the feed from the foot valve to the trailer and drive axles, aiming to give the trailer more signal sooner than is the standard case. Also the slack adjuster length on the trailer has been increased from 120mm to 150mm.

Truck
Make/Model Ford LTL 9000
Built Not recorded
Front axle 15 x 5 Type 20 on 140mm slack
Rear axle 1 16.5 x 7 Type 24 on 152mm slack
Rear axle 2 16.5 x 7 Type 24 on 152mm slack
Tyres Not recorded

Trailer
Make/Model Freighter Triaxle
Built 10/85
Axle 1 16.5 x 7 Type 24 on 120mm slack (All
Axle 2 16.5 x 7 Type 24 on 120mm slack Fruehauf
Axle 3 16.5 x 7 Type 24 on 120mm slack axles)
Tyres Not recorded
Note: Slack adjuster changed to 150mm in modified form.

Transwest Kenworth/triaxle hinged drawbar pig

Considered to have good compatibility. As received for test the trailer had excessive travel at the slack adjusters which was corrected.

Truck
Make/Model KenworthSAR
Built Not recorded
Front axle 16.5 x 5 Type 20 on 140mm slack (All
Rear axle 1 16.5 x 7 Type 30 on 140mm slack Rockwell
Rear axle 2 16.5 x 7 Type 30 on 140mm slack axles)
Tyres 11R22.5

Trailer
Make/Model White
Built Not recorded
Axle 1 16.5 x 7 Type 30 on 152mm slack (All
Axle 2 16.5 x 7 Type 30 on 152mm slack Ingersol
Axle 3 16.5 x 7 Type 30 on 152mm slack axles)
Tyres 11R22.5

Roughan Kenworth/ 3 axle dog trailer

In the configuration presented for test, the operator is not really happy with the brake balance. The truck had been modified by fitting a "Williams" ratio valve to boost the coupling pressure and relieve high drive axle brake wear.

Also, the front axle on the trailer is reported to wear too quickly and suffer from greater heat build up effects.

Therefore, there may be a balance problem within the trailer, as well as between truck and trailer.

Truck
Make/Model Kenworth SAR
Built Not recorded
Front axle 16.5 x 5 Type 20 on 152mm slack
Rear axle 1 16.5 x 7 Type 30 on 140mm slack
Rear axle 2 16.5 x 7 Type 30 on 140mm slack
Tyres Not recorded

Trailer
Make/Model White
Built Not recorded
Axle 1 16.5 x 7 Type 30 on 150mm slack (All
Axle 2 16.5 x 7 Type 24 on 120mm slack BPW
Axle 3 16.5 x 7 Type 24 on 180mm slack axles)
Tyres Not recorded

APPENDIX 3
DEVELOPMENT OF RETARDATION LIMITS

The notional units of torque are to be converted to units of retardation. These can then be used to develop equivalent ERC bounds for each vehicle category at maximum legal loadings as follows.

First, taking a triaxle semi trailer laden to maximum legal loading (20 tonne) as the base case. 3 units of torque (ie three axles with 178mm wide drums) can be said to produce 100% retardation at 20 tonne load. This 100% has no particular units and is purely a relative measure. 100% retardation will be achieved at all nominated pressures and represents the upper bound from the ERC graph.

From this the upper limits for all other vehicles can be calculated by considering what percentage retardation they would have.

If 3 units of torque give 100% @ 20 tonne then each unit equals $\frac{100\% \times 20}{3}$,having notional units of % retardation x tonne/axle

Looking at the 4x2 truck with 1.7 units of torque and at 15 tonne maximum legal mass we have:

$$\text{4x2 retardation} = \frac{1.7}{15} \times 100\% \times \frac{20}{3} = 75.5\%$$

For a 6x4 truck with 2.7 units of torque and at 22.5 tonne maximum legal mass, we have

$$\text{6x4 retardation} = \frac{2.7}{22.5} \times 100\% \times \frac{20}{3} = 75.5\%$$

The relative performance of all other cases can be calculated in a similar way.

To reduce the number of different bands vehicles with similar performance can be grouped together. These groups would be:

4x2 group

- 4x2, single axle semi, 2 axle dog

6x4 group

- 6x4, 8x4, tandem semi.

triaxle semi group

- triaxle semi, 3 axle dog, triaxle pig and quad semi.

The upper bound for the 6x4 group will be 80% of that for the triaxle semi (Figure 20). The upper bound for the 4x2 group will be 75% of the triaxle semi group (Figure 21). The lower bounds are moved across accordingly

Remember that these different ERC boundaries take account of vehicle mass and actually produce equivalent torque per axle and similar brake temperatures and wear.

PROPOSED NEW REQUIREMENTS

APPLICABILITY

All heavy trucks (vehicles in the NC category, over 12 tonne GVM) and heavy busses (ME category, over 5 tonne GVM) which are equipped to tow a trailer, and medium and heavy trailers (TC and TD categories, over 3.5 tonne GTM).

DEFINITIONS

Motor Vehicle : Rigid, non-articulated vehicles in ADR categories NC or ME equipped to tow a trailer

Service coupling : The end fitting (eg glad hand or bayonet) of any air system connecting hose provided as part of the vehicle to connect a motor vehicle with a trailer, or a towed trailer to a towing trailer.

Rear service coupling: The end fitting (eg glad hand or bayonet) of any air system connecting hose provided as part of the trailer to connect a towing trailer to a towed trailer.

ERC : The retardation (in units of g) which would occur were the vehicle tested alone and laden to maximum legal load.

Maximum legal load : The lesser of :

- RoRVL Option C
- tyre capacity limits
- GVM determined for other ADRs.

Test load : The combination mass used during testing, which should be the minimum required to avoid wheel lock.

Combination : In the case of a trailer test or a motor vehicle tested with a trailer attached, a motor vehicle and a trailer. In the case of a motor vehicle tested alone, the motor vehicle.

Rise rate : The rate at which the pressure rises averaged over the time interval between when the pressure reaches 10 kPa and when it just exceeds the target pressure.

1. CONTACT PRESSURE TEST

1.1 PURPOSE

To ensure that all brakes commence working at approximately the same instant in an application.

Rapid brake applications to medium to high pressures are not of concern.

Typical applicatons have been found to have slow rise rates (around 130 kPa per second) to pressures in the range 60 to 140 kPa. It is these conditions that this test is intended to replicate. However, for accurate pressure measurement a rise rate substantially slower than this will be required.

1.2 PROCEDURE

Charge all air tanks on the vehicle to at least 650 kPa.

For trailers, connect a truck simulator (or equivalent signal source) as described in ADR 38/00 to the service coupling of the trailer.

Raise all wheels connected to one brake of the vehicle off the ground. Where drive train drag (differentials etc) may have an effect, raise both wheels on the axle under test or otherwise eliminate drive train drag.

Apply a torque of between 98 and 150 Nm to each brake in the direction of forward rotation in turn and slowly raise the service coupling pressure until the torque is resisted.

Record the service coupling presure (in the case of trailers equipped to tow another trailer also record the pressure at the rear service coupling) at which contact occurs.

Repeat the test on each brake to obtain three readings within a 4 kPa range.

Repeat the test for all other brakes on the vehicle.

1.3 EVALUATION

Contact shall occur at all brakes when the service coupling pressure is within the range 55 to 80 kPa.

For trailers equipped to tow another trailer, contact shall occur on all brakes when the rear service coupling pressure is within the range 50 to 85 kPa.

2. ERC TEST

2.1 PURPOSE

To specify the retardation of each part of a combination vehicle referenced to the common service coupling signal pressure at the low retardation levels typically found in routine braking.

Achievement of balanced friction utilisation is not the major concern of this test as the retardation levels are below those at which wheel lock would usually occur.

The aim is to achieve conditions which will encourage balanced brake wear on both motor vehicle and trailer under the braking conditions which are routinely used in service.

Note: Although retardation is used, by specifying the vehicle mass at which that retardation is calculated the measure becomes, effectively, torque.

2.2 PROCEDURE

2.2.1. Preparation.

The brakes should be burnished by repeated brake applications until stable friction conditions are achieved. During burnishing excessive brake temperatures should be avoided.

It is anticipated that between 100 and 1000 brake applications may be required to achieve burnished brakes. Comment on this aspect is sought.

The vehicle shall be laden to its test load with the load distributed to prevent wheel lock on any axle under test.

Instrument the vehicle so as to be able to measure speed, braking time or distance, and service coupling pressure.

Install a device (or other repeatable means) which allows the service coupling pressure be to raised to preset pressures ranging from 55 to 190 kPa.

In the case of a trailer test, application of the motor vehicle brakes is to be prevented.

For each sequence of tests, or with each significant change in test site conditions, establish the rolling resistance of the test track for the combination at test load by conducting a measured coast down (time or distance) from 75 to 60 km/h. If necessary this coast down can be conducted in a number of runs, each covering a part of the speed range and over the same stretch of test track.

Before each sequence of tests temperature condition the brakes using either of the following two procedures: -

i) conduct a number of repeated brake applications until the brakes reach a temperature of between 60 and 100 degrees C measured on the external face of the brake (drum/disc) in the middle of the lining swept path. The vehicle should travel a distance of approximately 1km at a maximum speed of 80 km/h after the last braked stop before measuring brake temperatures or stand for at least 5 minutes.

ii) perform 5 brake applications from 75 to 60 km/h at a retardation of approximately 0.1 g at intervals of approximately 1 km in between which the vehicle should not use its own brakes and should only be brought to rest for the purposes of turning around.

2.2.2. Retardation test.

The brake temperature during the sequence of tests shall be controlled using either of the following two procedures:-

i) before commencing each test the brake temperature measured on the external face of the brake in the middle of the linings swept path should be between 60 and 100 degrees C. The vehicle should travel a distance of approximately 1km at a maximum speed of 80 km/h after the last braked stop and before measuring brake temperatures or stand for at least 5 minutes. The procedure for the next brake application must commence immediately after measuring brake temperatures.

ii) by conducting a brake application as required below at approximately 1 km intervals in between which the vehicle should not use its own brakes and should only be brought to rest for the purposes of turning around.

Charge all air tanks on the vehicle to be tested to at least 650kPa.

Allow the combination to coast down, in neutral with brakes disengaged, to an speed of between 80 and 77 km/h.

Apply the brakes within this speed band.

Commence recording time or distance when the speed reaches 75 km/h. at which point a stable pressure, as specified below and maintained for the remainder of the application, should be reached.

Record the initial speed at which the brakes were applied, the service coupling pressure during the application, and the time or distance taken from instant of reaching the initial speed until the final speed specified below is reached.

The final speed (V) is calculated by :-

$$V = \sqrt{\left\{5625 - \frac{(\text{max. legal load} \times 2025)}{\text{test load}}\right\}}$$

The test is to be conducted using stable service coupling pressures within 5 kPa of : -

85 kPa

130 kPa

160 kPa

190 kPa.

2.2.3. Calculating ERC

Calculate the rolling resistance using the coast down results with the answer having the units of g using :-

where time was measured

$$\text{Rolling resistance} = \frac{0.0283 \times (U - V)}{t} \; g$$

where distance was measured

$$\text{Rolling resistance} = \frac{0.0039 \times U^2 - V^2}{s}$$

where, for the rolling resistance test,

U = initial speed (km/h)

V = final speed (km/h)

t = stopping time (sec)

s = stopping distance (m)

ERC can now be calculated using the brake application test results and : -

where stopping time is measured

$$ERC = \frac{0.0283 \times (U - V)}{t} - \text{rolling resistance}$$

$$\times \frac{\text{test load}}{\text{max. legal load}}$$

where stopping distance is measured

$$ERC = \frac{0.0039 \times U^2 - V^2}{s} - \text{rolling resistance}$$

$$\times \frac{\text{test load}}{\text{max. legal load}}$$

where, for the brake application,

U = initial speed (km/h)

V = final speed (km/h)

t = stopping time (sec)

s = stopping distance (m)

2.3 EVALUATION

Plot the ERC results obtained on the graph of ERC against service coupling pressure. All plotted points to be within the upper and lower bounds shown on the graph for the vehicle group appropriate to the test vehicle configuration.

Vehicle groups are :-

Group 1

2 axle motor vehicles, single axle semi, 2 axle dog

Group 2

3 axle motor vehicles, 4 axle motor vehicles, tandem semi.

Group 3

triaxle semi, 3 axle dog, triaxle pig and quad semi.

3. TRAILER REAR TOW SERVICE COUPLING AIR SYSTEM TEST

For trailers equipped to tow another trailer

3.1 PURPOSE

To ensure that the signal provided to the towed trailer is a faithful replica of that delivered to the towing trailer. Transient effects are not generally of concern, but ratio effects could allow severe contact pressure differences through a multiple trailer combination causing significant disparity in brake work done.

3.2 PROCEDURE

Charge all air tanks on the trailer to at least 650kPa.

Connect a truck simulator (or equivalent signal source) as described in ADR 38/00 to the service coupling of the trailer.

Connect an 800ml vessel to the rear service coupling of the trailer.

Apply a control signal at the service coupling with a rise rate of between 100 and 140 kPa per second.

Measure the pressures reached in the 800ml vessel attached to the rear service coupling when the pressure at the coulping is within 5 kPa of :-

85 kPa

130 kPa

160 kPa

190 kPa.

Repeat the above with a control signal rise rate of between 250 and 300 kPa per second.

The pressures are to be measured without interrupting the rise of service coupling control signal.

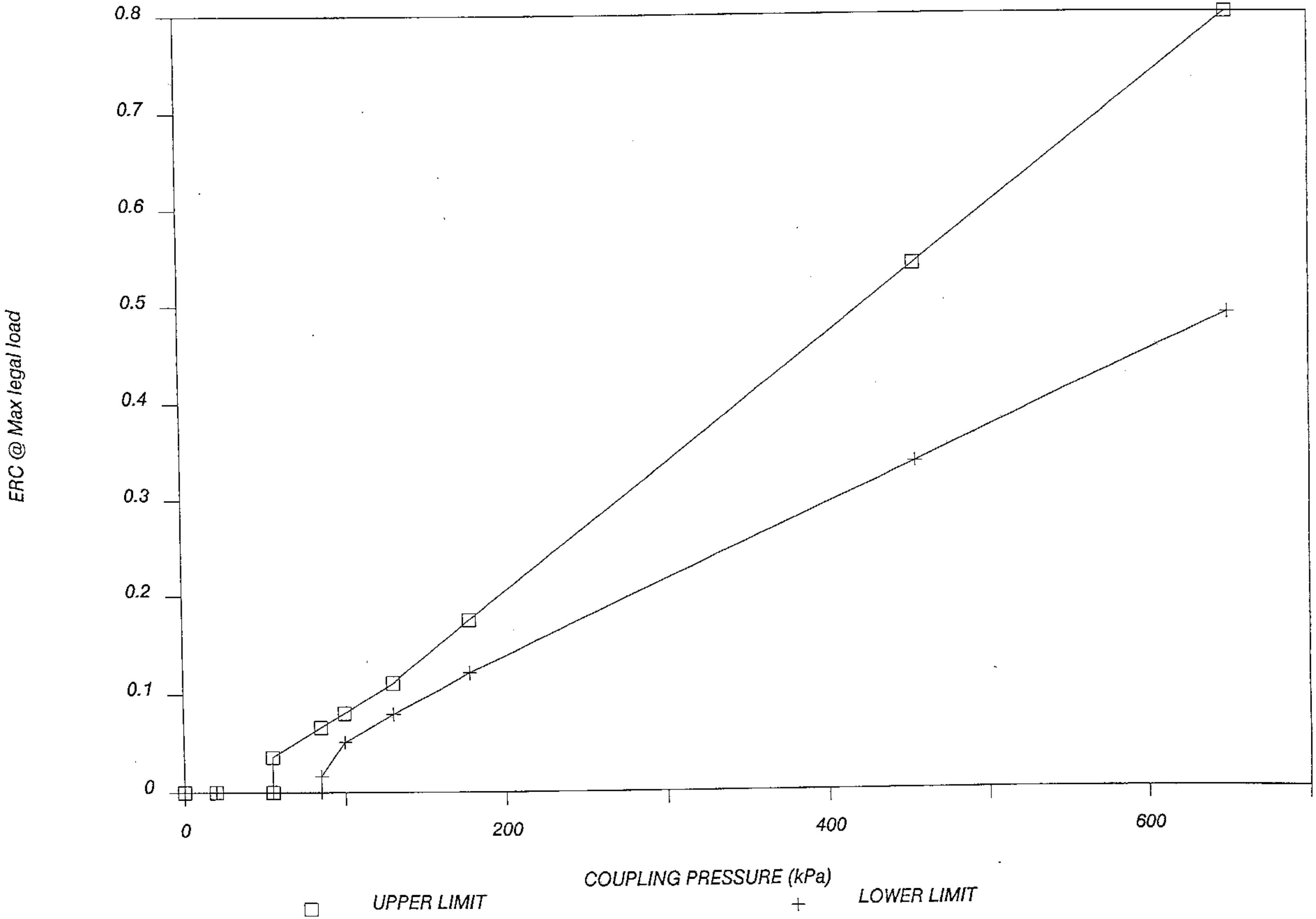
3.3 EVALUATION

For each test, the pressure measured in the 800ml vessel attached to the rear service coupling shall be within :-

> 5 kPa of the control signal at the service coupling when the rise rate is between 100 and 140 kPa per second
>
> 8 kPa of the control signal at the service coupling when the rise rate is between 250 and 300 kPa per second.

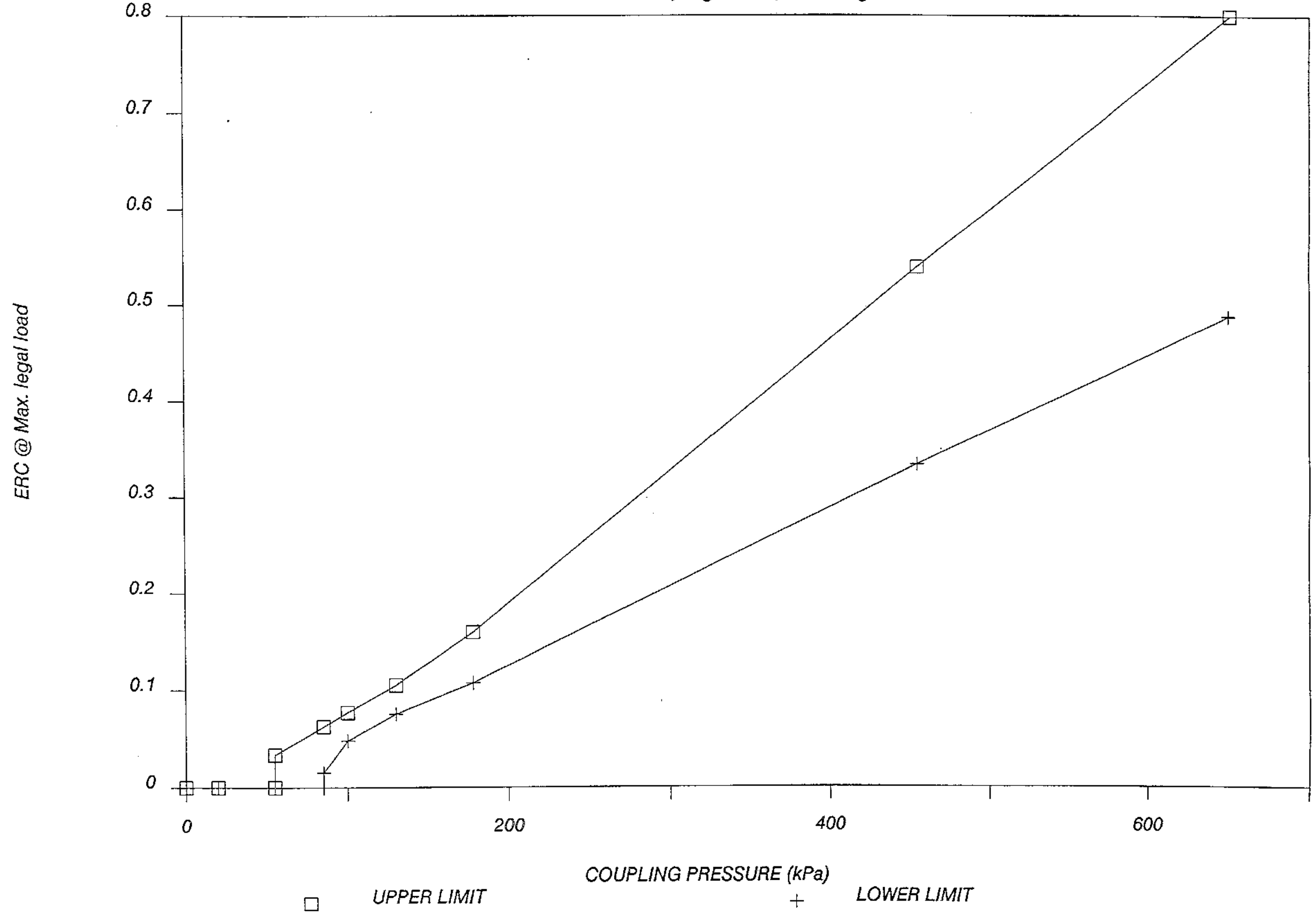
ERC BANDS GROUP 2

3 & 4 axle truck/bus, 2 axle semi



ERC B NDS GROUP 1

2 axle truck/bus,single semi,2 axle dog



ERC BANDS GROUP 3