UNSECURED REELS ON WHEELS ARE A HAZARD

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ABSTRACT: *Road safety is the responsibility of all road users. As methods change securing systems must also keep pace. This paper sets out the reasons for and methods adapted in conducting a series of load restraint tests devised for securing News Print on Road Vehicles. Every effort was made to simulate, under test conditions the actual effects of violent manoeuvre at urban road speeds and during low speed roll-overs. The objective of the securing system was to contain the load within the confines of the conveying vehicle during the type of incidents specified above.*

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INTRODUCTION

Background

In 1982 Hammond Palmer Transport (H.P.T.) was successful in securing a 3 year contract from Australian Newsprint Mills Ltd. (A.N.M.) for transport by road of approximately 51,000 tonnes of Newsprint reels.

H.P.T. and their principal sub-contractor A.J. McLeish Pty. Ltd., (M.T.S.) sought detailed information upon securing reels on end and upon finding little suitable, approached A.N.M. seeking their participation in conducting a study.

Three simple criteria motivated the Companies to commission a detailed study. Firstly, the social responsibility that the Company's recognised was to ensure that when transporting substantial tonnage, as was proposed, by road that every precaution had been taken to protect the public.

Secondly, there were potential social consequences to both the Newsprint and Transport industries of being seen to cause, however indirectly, injury to persons or property.

Thirdly, the pure commercial aspects in the form of insurance costs and possibly substantial third party claims.

The reasons for developing reel loading on end was quite simple, that of efficiency. Newsprint reels are approximately 620 kgs. each. When loaded on the barrel, that is to say on the rolling surface, it is normal to achieve a payload of approximately 16 tonnes, however, loading these same reels one end, it is possible to improve the payload to around 21 tonnes, with obvious cost benefits. However, the process of inverting the reels from barrel to end, removed the opportunity to secure the reels individually by roping through the cores. Although there are methods suggested for securing reels using an insert into the core, this was not considered practical, taking into account the annual tonnage and the average loading of 35 reels.

It became clear to the three Companies that there existed a real need to set a new safety standard and the aforesaid group of concerned operators agreed that a detailed test programme would have to be conducted. The programme had to be privately financed.

Official Government agencies, under present restrictive conditions cannot aid service industries in productivity improvement research projects.

The following objectives were decided upon therefore -

(a) Quantified results by testing of existing equipment,

(b) Make recommendations as to improvements/modifications as deemed necessary.

(c) To conduct the test programme and qualify results in a manner such that the work could be included in the "Truck Loading Code" published by the Australian Department of Transport.

To conduct the test programme, Ken Baldock of Ken Baldock & Associates Pty. Ltd., was appointed Project Co-Ordinator and Dr. Harold Nolle was commissioned to design and conduct a test programme. Then get out in report form the results, conclusions and recommendations for an improved security system.

THE NEED FOR REGULATION

The road transport industry, has an unfortunate history of a minority of unsafe operators running ill-maintained vehicles, some of which are extremely dangerous. These vehicles, when carrying badly stowed and secured loads, constitute a menace on the highway. Some such loads constitute a latent risk of havoc particularly if involved in an accident situation.

Most potentially dangerous cargoes, such as explosives, inflammable fuels or chemicals, are generally carried by responsible operators and usually packaged safely in accordance with organised rules or regulations.

However, with solid cargoes most commonly carried on open platform type vehicles and indeed possibly by the railway system, if security is insufficient in a crash situation, loads can become missile like projectiles.

For example, a newsprint reel weighing 650 kgs. travelling at 80 kph. on the highway, due to its momentum, has its mass amplified in a crash situation. The impact effect in itself, could be sufficient to crush an oncoming motor car - to destroy it, and its occupants completely.

Imagine 35 of these reels let loose simultaneously. Hence the need for the safest possible equipment and most importantly, the need to set minimum safety standards by regulation, covering operating practices, speeds, maximum loadings; and design regulations requiring minimum safe performance standards applicable to all modes of transport. It is only in recent years that a "Truck Loading Code": has been published by Transport Australia in order to educate operators as to their minimum responsibilities.

PROJECT AIM

This is set as follows -

"To establish the security of the load restraint system against inadvertant spillage of reels from vehicles in normal highway operations during low speed lateral roll-over, or in an emergency stop situation.

It was not intended to simulate a serious high speed impact in which a normal vehicle could not be expected to survive. The aim is to provide euqipment which will maximize absorption of the kinetic energy of the load, and to reasonably meet the safety requirements of the "Truck Loading Code".

PROJECT LOGISTICS AND PLANNING

Preliminary road testing during 1982 found that the use of traditional lashings by webbing, ropes or chains, was physically adequate but commercially unacceptable. This early finding was due to the excessive labour time required to adequately secure the individual reels when stacked on end whether single or double tiered. Also, because the degree of lashing pressure required to contain the reels securely, edge crushing occurred unless each reel perimeter was individually protected.

It was concluded therefore that the only commercially acceptable vehicle would be a platform complete with a secure gate system, or alternatively a fully enclosed box or container type vehicle. Whichever vehicle is used, it is known that initial slip of any load within the system must be avoided, hence payloads must always be stowed "snugly" within the securing system.

A stowed mass once moving requires much greater strength of securing equipment than does a static mass. Existing side gate and end rack systems were found to be inadequate for the purpose of safely containing the payload and that a redesign of some key features were highly desirable.

Based on the project objectives, a test programme was developed which required the acquisition of, equipment, test cargo, special equipment for handling and safe lifting, a suitable location, and personnel. A data base had to be established - one fundamental factor was determining the frictional characteristics between typical types of vehicle deck materials, and various payload materials. Other factors were checking the individual strengths of lashing materials, and basic equipment such as gates and racks, webbing and ropes.

The tests required that two comparative types of complete semi trailer vehicles had to be lifted fully loaded to stand almost on their ends (end tilt) and sideways (side tilt) in order to demonstrate the combined capability of the securing system.

We were fortunately able to obtain the use of vacant Commonwealth Government premises with large overhead cranes, at Port Melbourne, and also obtain the co-operation and services of "Australian Road Research Board" scientists and technicians and their laboratories measuring equipment.

Preliminary testing of equipment took place over a three month period early in 1983, and the main test programme was completed within a three week period, mid. 1983.

FINDINGS

A complete report by Dr. H. Nolle has been published and a video film recorded the test series. The abridged text of Dr. Nolle's report forms the major text of this paper. (see Note 1. Page 4)

The fundamental recommendations for a secure side gate system are five fold.

1. A secure diagonally braced front end rack system tied into the side gates.
2. Side gates which are anchored to the vehicle side rails to prevent disengagement.
3. A top spreader system which prevents the spreading of the sides with respect of the load, and also provides the means of supporting encapsulating tarpaulins.
4. A full perimeter horizontal interlocking "banding"system between each side gate and the end racks, each securely tied to each other to restrain the "bursting out" of the payload in a crash situation.

5. A valuable load securing and weather protection medium was proved to be the traditional encapsulating tarpaulin system, lashed by ropes to the vehicle body around the full perimeters.

The sponsors of the tests, hope that these findings can be promulgated in the public's interests, and become a valued addition to the Truck Loading Code. Included therefore is a summary drawing depicting the chief points that were proven to be significant.

(refer included drawing No. 20883/1) :

Note 1:

Copies of the full report including the data set out in table form are available. Anyone wishing a copy should apply in writing to N.W. Willcock, ammond Palmer Transport, P.O. Box 203, Footscray. Victoria. 3011.

UNSECURED REELS ON WHEELS ARE A HAZARD

ABRIDGED "REPORT ON SECURITY OF PAPER REELS ON ROAD VEHICLES FITTED WITH GATES"

By: H. Nolle, B Mech.E., M. Eng. Sc., Ph.D., F.I.E., Aust.

Despite a history of transport of paper reels on road vehicles, there appears to be no precedent - in Australia and, it seems, for that matter overseas - of full-scale investigations into the security and stability of semi-trailers fitted with removable steel gates for lateral and fore/aft security. The tests were to provide data on the margin of safety of the operations in relation to inadvertent spills of reels from such vehicles in normal highway operations, low speed lateral roll-over or during emergency stops or manoeuvres involving sudden braking or swerve.

The present investigation complements previous full-scale tests and equipment safety assessments carried out by the writer in 1979 and 1980 for Australian Paper Manufacturers Ltd. This work culminated in the issue of an in-house safety code to which all APM product carriers adhere. It does not, however, provide an assessment of trailers fitted with removable gates which are the subject of this investigation.

This report provides an analysis and engineering assessment of the results and findings of a series of trailer tilt tests simulating the effects of acceleration of the vehicle on the road, both in the lateral and fore/aft directions. Wherever possible, geneneralizations have been made based on specific results so as to widen the applicability of the information for future design of gated systems. Where possible or relevant, results have also been compared with previous data contained in and requirements of the Department of Transport, Australia, Truck Loading Code.

The work described herein has been brought to its successful conculsion with the assistance of the principal sponsoring parties to the project: Australian News Print Mills Ltd. (ANM), Hammond Palmer Transport (HPT) and A.J. McLeish Pty.Ltd. (MTS) and their active participation during the preparation and conduct stages of the tests is gratefully acknowledged. The strain measurements on the trailer assemblies during testing were mounted by the Australian Road Research Board.

SCOPE OF INVESTIGATIONS

In view of complexity of the system to be tested - comprising the payload, gate restraints and trailer deck - the decision was made to test, as far as possible, full-scale set-ups of the HPT and MTS transports respectively. Apart from the assessment of the behaviour of fully loaded decks subjected to forward and lateral tilting (simultating corresponding acceleration forces encountered in on-the-road conditions), the restraint of the reels due to friction has been determined and the contributions to overall safety of the gates, other restraints and the construction of the trailer deck have been evaluated.

Preceding investigation the objectives of the project were broadly defined:

1. To suggest practical improvements to the HPT and MTS systems currently in use.

2. To prove the effectiveness of the security measures as proposed for transport by road of reels stowed on end.

3. To compare the level of security of the equipment and the method of loading (including any improvements) with that of loads secured in accordance with the relevant provisions of the above "Truck Loading Code", when reels are carried on the barrel.

OBJECTIVE OF THE INVESTIGATION AND CODE REQUIREMENTS

The objective of this investigation is to predict the limits of safety and hence ensure, through recommendations for safe practices, that these limits are not exceeded. The dividing line between "safe" conditions and "disaster" has been tested empirically on rare occasions only, and consequently there is very limited driver experience to fall back on. The limits of safety would therefore have to be determined by some other means.

Code Strength Requirements of Restraints

The aforementioned Truck Loading Code [1] requires that the load restraint system must be capable of preventing movement of the load under three particular conditions. [2]

(a) Forward deceleration under emergency braking conditions when the combined restraining forces must be at least equal to the payload masses (i.e. a force of 1.0 g).

(b) Rearward deceleration when braking during reversing when the combined restraining forces must be at least 50% of the payload masses (i.e. 0.5 g).

(c) Sideways or lateral acceleration when cornering when the combined restraining forces must be at least 50% of the payload masses (i.e. 0.5 g).

These requirements have been adopted as a reference for assessing the viability of the two gate restraint system under test.

Notes:

1. 'Recommended Code of Practice for the Safety of Loads on Road Vehicles', Commonwealth of Australia, 1981.

2. The three conditions are quotations taken from the Code where unfortunately the relationship between force, mass and acceleration has been denoted by 1 g (= 10 m/sec^2 approximately)

Longitudinal and Lateral Security

Concerning the means for meeting the above Code requirements, the gate system offers one solution. The problems associated with longitudinal and lateral security, respectively, may be dealt with in a like manner as their differences are largely differences in degree and not kind. The front, rear and side gates are in concept similar constructions, supported in similar ways, and when the reels are stowed on end the inertial and friction forces on the reels in the two principal directions are also of a similar kind.

On the highway or road the main factor affecting longitudinal security is acceleration, and to a lesser extent slope of the road. Vertical accelerations (due road surface condition and vibration generally)of the deck dimish the friction forces and may contribute to gradual drift of unsecured reels. Lateral security is further affected by possible tilting of the deck which is the combined effect of truck body roll, axle roll, road camber and possible uneven loading of the axles.

In the tilt test procedure no dynamic effects are reproduced which could under certain conditions lead to significant discrepancies on the road under aggravating conditions. However, some provisions for neutralizing this effect have been built into the method of conversion of tilt angle to equivalent acceleration on the road and this matter is elaborated on later in this report.

DESCRIPTION OF TRAILER AND LOAD

Preamble

Both the HPT and the MTS trailers have been subjected to similar test sequences. The conditions of testing have been maintained the same as far as possible, but for practical reasons some variations in the construction of the trailer decks and the respective loads of reels have been unavoidable. However, such variations should not significantly influence the comparison of the respective performances of the two set-ups, and, where deemed necessary, the appropriate allowances have been made in the evaluation of the results.

Description of HPT Trailer

The test deck is a foreshortened version of a HPT flush deck trailer of approximately 10 m length.

The deck surface is finished with plywood (unpainted). Each side of the deck is fitted with four gates constructed of welded 25 nominal bore steel pipe having three uprights, plywood panels and infill secured to the flush coaming in three oval sockets to allow a small longitudinal adjustment of the gate. The sockets are provided with locking screws which, however, were not applied in the tests.

The front and rear gates are constructed of heavy steel pipe (50 NB) and (40 NB) respectively, reinforced by three horizontal bolsters to provide additional strength and stiffness. Each gate is located in four sockets in the coaming. To provide circumferential continuity of restraint and bending resistance, all gates are linked by a set of special links along their tops and by steel pin connections at the four corners (similar to those for the MTS trailer.) The latter (at the front end only) have been reinforced by steel braces welded diagonally to the first side gates.

Preceding the tests it had been HPT practice to apply a webbing strap around the front gate and tie this down diagonally on the sides in lieu of the steel pin and brace which are prototype additions. This alternative method of restraint has been assessed separately.

To support the tarpaulin placed over the top of the load, and to add to overall structural integrity, a steel hoop is fitted over each pair of side gates. These are removable and are fitted into special attachment points in the top member of the side gate.

It has further been HPT practice to apply a crossed pair of webbing straps over the top of each hoop and side gate but placed under the tarpaulin. These straps are pulled down on the tie-rails by means of special buckles sewn into the straps.

Description of MTS Trailer

The MTS test deck is of 9 m length, has a raised coaming all round and is provided with a plywood floor finished with antislip paint similar to the surface applied to MTS steel decks.

The gate and hoop arrangement is in concept similar to that of the HPT system except for variations in the construction of the gates and the hoops and sizes of their steel members.

Front and rear racks have four uprights of 32 NB steel pipe and siz cross bolsters of 20 NB pipe. The horizontal tension flat is 50 x 8. Side gates have an outer frame of 20 NB heavy steel pipe and seven uprights of 15 NB steel pipe. Bottom rail is 50 x 25 x 3.2 wall thickness RHS tube. Front diagonal brace 50 x 8 flat two horizontal intermediate bolsters of 40 x 5 flat, pocket spades of 45 x 10 flat with bottom bayonets.

The spades of the side gates fit into rectangular slots cut into the coaming. The spades have on their ends a welded projection (facing forward) so as to engage under the slot and secure the gate against accidental lift out.

Description of Paper Reels

All reels of paper used in these tests were standard units of newsprint manufactured by "ANM". These reels are fully wrapped and are produced in a range of widths and diameters. In the present tests two sizes of reels were supplied, their respective dimensions being:

Reel Diameter	Reel Width	Weight	
900 mm	850 mm	331 kg	Used on HPT system
1060 mm	890 mm	463 kg	Used on MTS system

The weights and dimensions are averages and nominal values respectively, there being some variation between most reels in each size category.

LOAD SECURITY TESTS

Scope of Tests

The test program comprised the following range of investigations:

(a) Measurement of surface friction.

(b) Lateral pull tests on gates.

(c) Lateral tilt tests.

(d) Forward tilt tests.

(e) Rearward restraint test.

The tests were performed late in May 1983. All testing was conducted under cool atmospheric conditions and in air of average humidity.

Method of Testing

All above tests except (b) were carried out using the tilting method whereby horizontal inertial forces arising out of horizontal accelerations of the vehicle on the road are simulated by tilting the deck. The gravity forces due to the weight of the reels then provide the sideways thrust on whatever restraints have been applied. It is a quasi-static method which does not account for a number of aggravating on-the-road conditions and therefore provides a less severe test than the real circumstances would demand. On the other hand, when friction resistance against slide of the reels is involved, the tilt test produces a slightly more conservative result in terms of equivalent g-level (that is acceleration level) to which the tilt refers. That is to say when the tilt angle is converted to g-level by simply taking the sine of the angle the result (in g's) is somewhat less than the exact solution, especially at large angles of tilt. These two effects therefore counteract and the tilt should provide a fair experimental approach to establishing both lateral and fore/aft security.

The load configuration chosen in the final four (full load) tilt tests is based on a triangular pitch close-packed array which is the normal arrangement for road transport of ANM product. Reels are stowed hard up against the raised coaming or, in its absence , bearing against the bottom rails of the gates. As the two-high configuration of narrow reels on end places a more severe demand on the restraints than a one-high load of wide reels, the former alternative was selected for the tests.

Tilting of the test decks was effected by means of a 50 ton overhead crane, the tilt generally proceeding in short steps to give time for making checks and observations and to ensure safety to test personnel.

Angles of tilt were recorded by means of a liquid level gauge affixed to the deck. Forces and strains mentioned in this report were measured by calibrated force links and resistance strain gauges respectively.

Schedule of Tests

A schedule of all tests with the exception of the surface friction measurements is shown in Appendix 2. Table 3 [1]. provides further detailed information on the load and test conditions and observations on movements of the load during tilt.

The computed results of the friction tests are given in Table 1 where for purposes of comparison other related test data are also included.

1. Refer Note 1. Page 4 for details of how to obtain full report.

Experimental Data

Surface Friction

Static friction coefficients for various surface combinations are given in Table 1 of the full report. (See note 1. Page 4.)

Horizontal Force on Gate (Refer Appendix I)

The linearized bending strain on the HPT front and rear gates subjected to horizontal pull is shown in Fig. 1. Results are given for the inner and outer pipes at points of maximum stress (just above deck level). The force required to stress the smaller 40 NB diameter peg of the front gate to yield point is shown on the graph. The results apply to steel Grade 250 having a yield stress of 250 MPa and ultimate tensile strength of 420 MPa.

Strain in Side Gates Under Lateral Load

The bending strains (and hence stresses) in the HPT side gates measured during Tests 10 and 11 are shown in Fig. 2. The strain measurements referred to points on the vertical pipes just above the spade. Load conditions and details relating to security measures for tests 10 and 11 are given in Table 3. of the full report.

Onset of Slide and Maximum Tilt Angles

Tilt angles at onset of slide of the reels and angles at termination of test are summarized in Appendix II. This table gives also the calculated equivalent acceleration levels. As the restraint systems were not tested to failure the terminal tilt angles are not known and their estimates would have to be based on observed performance of the system.

From the measurements the following averaged values have been calculated for the angle at which lateral slide first commences:

Condition of Load	Onset of Lateral Slide	
	Tilt Angle	g-Level
Unrestrained	19°	0.32
Restrained by gates, tarpaulin	22°	0.38

The difference between the two values is small, indicating only a marginal effect on the onset of slide of applying the tarpaulin (and the webbing, in the case of the HPT system).

Force In Webbing and Steel Brace On Front Gate

In the forward tilt Tests 6 and 14 the efficacy of webbing strapped around the front gate was tested. Apart from webbing no other restraint was applied. Both MTS and HPT gates were thus examined and compared with the corresponding results when the webbing is replaced by steel (Tests 5 and 13). The results are summarized below:

Restraint	Gate	Tilt Angle	Tensile Force in Webbing or Brace (kg/tonne of reels)
Webbing at 45^{o} to horizontal	MTS HPT	50^{o} 45^{o}	40 26
Steel brace at 30^{o} to horizontal	MTS HPT	50^{o} 45^{o}	214 134

When the webbing is applied it is also pre-tensioned so that the total force in the strap is the sum of the value shown in the above table plus the pre-load which is estimated to have been close to 250 kg.

Two significant points are noted from a comparison of the figures:

1. That the load carried by the brace/webbing on the HPT gate is only about one-half of that for the MTS gate. The reasons for this are firstly the relatively stiffer HPT gate construction which would carry at larger portion of the total load; and, secondly, a diminishing thrust against the front gate exerted by the reels further back in the load (Table 3 shows the respective load configurations on the two different test set-ups).

2. The webbing, due to its much lower stiffness, supports only about 20% of the load carried by the steel brace. This means of course that the remaining 80% is transferred to the gate sockets.

Further strain measurements on the gate braces have provided figures for forward thrust on the front gate at different tilt angles. These data have been tabulated below and may be interpreted as total horizontal force acting on the gate at the point 1275 mm above the trailer deck. The values shown apply to trailers secured by the restrains listed in the test schedule, Table 3, full reports for Tests 15 and 16 respectively.

The observed difference in the thrust for the HPT and MTS trailers respectively is ascribed to variations in the frictional properties, the presence in one case of a raised coaming, different deformation patterns of the side gates and different diameter and number of reels in the respective loads. For design purposes the higher of the two respective figures shown in the table should be used.

	Thrust (kg/tonne of payload)			
Tilt Angle	30°	40°	50°	60°
g-Level	0.50	0.64	0.77	0.87
HPT MTS	40 10	130 54	160 110	225 165

EVAULATION OF RESTRAINT SYSTEM

The following comments and design pointers describe the observed performance and role played by the various components making up the restrain system.

Trailer Floor

The main role of the floor in context is to provide a slip-resistant surface. In this regard the MTS deck which is finished with antislip paint showed a significant improvement over the untreated plywood deck of the HPT trailer.

The benefits of high friction on the floor may be limited in the presence of multiple interfaces, e.g. where reels are stowed two-high and where a steel disc is interposed between the bottom reel and the floor. In such cases slip will occur at the face where there is lowest friction. Thus the MTS system will be only as good as the slip resistance of paper on the iron sheet, and there would be little benefit in treating the floor unless the latter is known to be more slippery than the sheet steel when in the unpainted condition. The HPT deck/steel combination in fact produced such a result, namely a friction coefficient of only 0.32 which was the lowest recorded in the tests. Notwithstanding the above, the results represent quite acceptable frictional conditions which are important to the control of onset of slide. As a guideline for design purposes a friction coefficient of 0.4 and greater constitutes entirely satisfactory conditions. If friction drops below 0.3 the beneficial effects of adherence to the floor are rapidly lost and have to be compensated by alternative means of restraint. Friction forces have the further characteristic of being able to dissipate energy when slide commences -- an extremely important aspect in considerations relating to load stability and control of load movements generally. Thus friction restraint is not always replaceable by simple alternative means. Moreover, it is usually more economical to upgrade the safety rating of a system by adding friction than by alternative methods and it therefore makes good sense -- both technically and economically -- to explore and apply all possible options in respect of antislip treatments as a first step towards greater safety of the equipment.

Coaming

The raised coaming has confirmed its important role in providing load security at deck level. In two-high loads the lower reels are almost entirely restrained by the coaming, and in the case of one-high loads of wide reels, say 1700 mm wide, at least 50% of the lateral restraint is provided at deck level.

To be effective and reliable the coaming should be not less than 25 mm high. In the absence of this facility the bottom rails of the gates have to take over, which places additional strain on the gate system whose more important role is to provide security of load at higher levels. The severity of lateral pressures on the gate under these conditions is where a reel plastically deformed the steel bar and nearly burst through the plywood panel above.

Side Gates

The side gates can provide adequate restraint only when linked together near the top so as to form a circumferentially continuous barrier to horizontal thrust. Both the HPT and MTS gates are fabrications of relatively light section steel pipe which has ample tensile strength but very limited resistance to bending. Thus permanent distortion and deformation of individual member of the gate or the gate as a whole can easily occur. The lateral pull test on a fully secured side gate has demonstrated that a force as small as 550 kg (Test 1) applied to the main frame can bring the gate to a state of permanent deformation. But this need not necessarily be interpreted as a condition of failure of the gate in the context of a safety assessment. In case of a collision or roll-over on the road, the gates will certainly suffer gross deformation, but this need not necessarily be interpreted as failure per se of the load restraining system as long as the structural continuity of the gate system is preserved. This continuity in the present designs depend on:

(a) the top links between adjacent side gates,

(b) the pinned connections at the corners, and

(c) the security of the spades in the sockets,

and further comment on these is made below.

In the free condition, that is with the top links and hoop removed the side gates have virtually no resistance to lateral bending forces, such resistance depending entirely on the three spades which are capable only of resisting shear and tension (pull out). So the viability of the side gate is absolutely dependent on the support coming from the top links.

Under lateral tilt conditions the bending stress in the side gates varies with position of the gate along the length of the trailer. Stresses are highest at mid-length and reduce gradually towards the front and rear. Fig. 2, which applies to specific points on a four-gate arrangement, probably is typical of the general stress pattern for corresponding points on successive gates. The result confirms not only the presence of larger lateral loads near mid-length (due to tilting and the generally greater instability of reels) but also the relatively greater prospects of failure of the system at mid-length. In general, the greater the number of side gates the less the support coming from the end gates; correspondingly the longitudinal catenary and hence the bending stresses increase. Restraint failure under such circumstances -- should it occur -- would most likely involve instability of the centrally placed upper reels which would slide into the catenary and eventually cause vehicle roll-over.

The comparison Tests 3 and 4 for the MTS trailer were included with the notion that the tests would reveal shortcomings, if any, peculiar to the construction of the MTS gates currently in use. The design of these gates (designated for identification purposes by "old" versus the specially prepared set of gates labelled as "new") shows differences in the construction of the top link and the bottom rail and some other details of lesser significance. The inclusion of one such gate in the otherwise "new" set did not reveal any observable special effects up to a tilt angle of 29° at which point the test was terminated. Following the conclusion of all subsequent tests and data evaluation, it may now be said that the comparison was inclusive for two reasons, namely (1) insufficient applied load (only 4600 kg), and (2) insufficient tilt angle. For example, failure of the top link, should it have occurred, would have been sudden and comes without much prior warning. Up to this point of failure the behaviour of the system would expectedly be similar to both tests. No further conclusions may be drawn from the performance of one gate that apply to the system as a whole. It is possible, however, to assess the 'old" gate design and for that matter also the "old" gate system in the light of the results and conclusions drawn from the other tests in this program.

The HPI gate revealed one potential structural weakness in the arrangement of the plywood panels. It was found that under certain conditions, when a reel is placed centrally opposite such a panel, there is a significant likelihood for the panel to fracture and the reel to burst through. Recommendations in this regard for some changes in the design have been made below.

Front and Rear Gates

MTS Gates

The construction of the gates appeared adequate, though note should be taken of the fact that the gate performance was tested only on a deck provided with a raised coaming. As already pointed out, the bending resistance of the gates without lateral support at the top is insignificant. The real strength of the gate is derived from the bracing on both sides which limits the stresses and controls forward tilt of the gate in case of a slide forward of the entire load.

When the gate is supported by the steel brace, the stress measurements for forward tilt showed good stress distribution in the pipes, stress being held within acceptable levels relative to the yield stress of the material. As front and rear gates are constructed identically, except for the horizontal tie added in the front, the results obtained from forward tilt may be applied also to the rear gate whose security level is stipulated at only 0.5 g versus 1.0 g for the front gate.

HPI Gates

The front gate of heavier construction was found by forward tilt test to fully satisfy strength requirements when braced by the steel braces on both sides. Moreover, the results suggest that some economy in the steel, and hence weight, might be achieved by reducing the size of some of the structural members without compromising strength and safety requirements; but this aspect would involve a separate design investigation and falls outside the scope of this report.

The socket and peg construction as tested featured a smaller diameter peg (pipe) inserted in the end of the main frame vertical members. The step-down in diameter at the most highly stressed zone of the main frame constitutes a weak link in the structural design which may be overcome by enlarging the sockets to the size of the main frame verticals. No weight penalty would be involved but the pipe bending stress would thereby be reduced by some 40%.

Steel Brace

The brace on the front gate constitutes the key indispensible support member for forward security. Its effectiveness depends on structural continuity and safe anchorage. The prototype design used in these tests showed adequate strength capacity to an equivalent acceleration of 0.88 g, securing a payload of 17.9 tonnes. Without the brace the gate would have collapsed at less than 0.5 g (30^o tilt angle) by simply bending over at the pegs.

The prototype brace features what are probably the best dimensions for the class of payload under investigation. These include the height of the pin connection above deck level which should be maintained at 1250 mm and a slope of 30^o with respect to horizontal for the braces on both sides. The clearance between the welded bosses of the pin joints as also the clearance of the pin hole should be kept to a minimum.

Of crucial importance to forward security of the load is the fixation of the anchor points of the braces to the trailer frame. The reliability of this fixation depends to a large extent on the locking arrangement provided on the spades of the side gates in their sockets. The natural tendency for the side gates to be pulled up at the rear spade was repeatedly observed in the forward tilt tests and would be even more pronounced under on-the-road conditions. This matter is elaborated on below.

Webbing Brace

While webbing in this application will provide additional forward security, its extensibility limits its effectiveness. Even when fully pre-tensioned the webbing loop will extend too readily to take its fair share of the forward load and the main part of the load is thus thrown back on the vertical members of the gate. Measurements of the loads carried by the steel and webbing braces, respectively, as quoted in Section headed "Force in Webbing and Steel Brace on Front Gate", show that the latter takes up no more than 20% of the load carried by the steel. This is not to be interpreted that failure of the forward restraint is necessarily imminent. It does mean, however, that under severe exposure the gate may collapse in part allowing a spill of part of the load, The tendency for forward movement was demonstrated in a test of a relatively lightly loaded gate.

Side Gate Spades

The tests revealed no shortcomings in the design of the spades per se. As structural members resisting mainly shear and tensile forces they appeared adequate both in their rectangular and circular versions.

In forward tilt the side gates would quite generally tilt forward, hinging on their front spades and pulling up at the rear. Accordingly, the rear spade should be provided with some means or device that positively locks the spade in the socket and makes accidental withdrawal impossible. The rear spade of the first side gate performs the vital function of anchor for the diagonal bracing bar for the front gate. For these reasons the provision of adequate spade anchorage is mandatory for the first gate on each side and advisory on the others. The design of the arrangement should further take into account the propensity for the gates to be pulled forward when the vehicle decelerates. This means that in the MTS design, such as was tested, adequate forward clearances in the front and central sockets must be provided to enable the rear spade to move into its locked position in its socket (a matter requiring specification of adequate dimensional tolerances on both gate and trailer, and quality control during manufacture).

Top Ties On Side Gates

Ideally the top ties should carry a tensile load only; however, in practice some bending may also be applied due to the method of securing the tie to the cleat. The function of the ties is to restrict separation of adjacent gates due to the formation of a catenary. Stress measurements on the ties have shown that a substantial load is developed not only during lateral tilt but also in the forward tilt mode when the reels commenced to squeeze out sideways.

Generalizing the strain measurements, such as are available, the stress in the link during forward tilt was found to be approximately 60% of that developed during lateral tilt given the same tilt angle and payload. This percent figure is expected to rise as forward movement of the reels and telescoping of the load progress. The inference drawn is that the side gates play an important role in forward security when the inertial forces from the load have both longitudinal and lateral components. (In this case the lateral thrust arises from the triangular pitch of the array of reels and would not be present had the reels been stowed in a square pitch array.) It is moreover quite possible under the circumstances that failure of the restraints -- should it occur -- in a forward collision of the vehicle on the road could result from the collapse of the side gates and not the front gate.

At 60° forward tilt angle the links were found to be strained to about 50% of yield stress which confirms the adequacy of the link cross-section, and the viability of the prototype link design generally.

Apart from strength considerations, the efficacy of the link is dependent on its ability to fix the gap between adjacent gates. It is necessary, therefore, that links and their supporting fittings are manufactured precisely, and that their assemblies have the correct tolerances and can be interchanged. This applies in particular to the positioning of the welded stop on the link which engages with the cleat. The prototype design, such as was tested, could further be improved if designed to link the gates in a symmetrical fashion with respect to the gate thickness.

The above ties form only one part of a horizontal steel "belt" along the tops of all gates. This belt provides the major structural member for security of the load and includes part of the gates, the pin joints at the four corners, and any other horizontal reinforcing members placed at the height of the belt. The criterion for correct positioning of the members making up the belt is explained with reference to a rope that is stretched tightly around the perimeter of the gates. Such a rope -- which can resist tension only -- represents the centre line for the steel to follow. On this basis it is seen that several improvements in the existing MTS and HPT designs are possible. For example, in the former case the upper horizontal cross-ties of the side gates, the corner joints and the top ties should ideally be located at the same level. The same may be said about the HPI design; also, the plywood panels require the addition of a steel backing strip placed across the full width of the side gate, such strip providing also the back-up against possible panel fracture mentioned elsewhere.

<u>Hoops</u>

Both the MTS and HPT hoop designs proved adequate and effective. The hoops are highly stressed members which may be bent (widened) under extreme load conditions. The hoops proved effective in transmitting lateral loads thereby loading also the gates on the upper side in the lateral tilt tests and significant catenary effect was noted. Likewise, in the forward tilt mode, the side gates were well supported at the top and pulled inwards against the lateral push of reels squeezing outwards.

The tilt tests showed that with a tarpaulin fitted tight over the top, the hoops remain well secured at their attachment points. There appears to be some danger for the hoop to come off when the hoop is not loaded (stretched), but once stretched the friction in the attachment points seems to be sufficient to prevent slip. Under severe loading the hoops are likely to suffer permanent deformation which will of course limit effectiveness to transfer load from one gate to the other. From a safety point of view, such deformation is not necessarily objectionable provided that it does not lead to detachment of the hoop from the gate. This appears more likely in the case of the MTS design; however, no failures in this regard were observed in the tilt tests.

Webbing Straps Over Top (HPT System Only)

The beneficial aspects of applying the crossed webbing over the hoops were investigated and may be summed up as follows:

1. Reduction of stresses in side gates on the loaded side during lateral tilt.
2. Partial transfer of load to gates on opposite side.
3. Reduction of hoop stresses generally.
4. General firming of lateral restraint system.

The use of webbing does not, however, delay onset of slide of the load.

Overall, the additional security and strength achieved by the webbing does make it a worthwhile component of the total system. Its contribution under extreme conditions involving roll-over of the load was not tested but it is likely to be significant in both containing individual reels and in providing a structural back-up for the hoops. In other words, the webbing has the versatility to contribute to top security which becomes equivalent to lateral security when the trailer deck has tipped sideways.

As is the case with all securing devices which rely on human effort for their application, the effectiveness of the straps is dependent on their correct placement and pre-tightening to the required level, and the above remarks apply only to circumstances where these operational requirements have been fulfilled.

Rearward Restraint

Restraint other than the rear gate is required only when the rearmost reels are positioned clear of the gate. As precise filling of the loading space cannot be expected, a full load would normally have some clearance at the back and up to a point this may in practice be acceptable. However, if an excessive clearance space is left at the rear, the possible consequences are several:

(a) The entire load may spread out or slide back which creates a major hazard condition with regard to forward safety.

(b) Rear unsecured reels may slide back and suffer damage.

(c) Upper rear reels may become unstable and topple compromising lateral security.

Such undesired movements may occur as early as 22° lateral tilt, equivalent to 0.37 g acceleration, and were witnessed in Test 15.

A possible design for strapping the rear reels to ensure a tight load configuration during transport was tested. The restraint remained effective to the end of the test, that is 45° or 0.71 g acceleration, though tested under partial load only. The measured forces in the webbing suggest that the design would have adequate strength under full load conditions providing under the circumstances sufficient security against excessive movement of load. The webbing is still backed up by the rear gate which retains its role as the primary restraint. At this stage the tests have demonstrated the desirability of securing the rear of the load against possible movements and, second, the viability of a simple strapping device which fulfils the desired function of a secondary restraint. Strapping is not the only solution and practical alternatives clearly exist.

There is no simple formula for determing the largest acceptable clearance between the rear reel and the gate before positive restraint against movement is indicated. On the basis of the test results and further considerations relating to the capacity of the rear gate to absorb the kinetic energy of the sliding reels, it is suggested that the reels need to be secured in cases where the clearance exceeds 300 mm.

* * *

CONCLUSIONS

Concerning Surface Friction

(1) The frictional characteristics of the HPT and MTS systems tested were found to be satisfactory.

(2) The frictional characteristics of the ANM reels stowed on end are satisfactory and comparable with those of a range of different paper products investigated previously (ref. Table 1).

(3) The onset of slide of reels in the lateral direction occurred at a tilt angle of 22° (average) or equivalent acceleration of 0.37 g (3.7 m/s^2).

(4) The onset of slide (and slide) is controlled by the surface combination having the lowest coefficient of friction; this was found to be between steel disk and untreated wooden floor (HPT system).

(5) There is a distinct incentive (both in the economic and technical senses) to upgrade the safety rating of the trailer by anti-slip surface treatment. Quite generally, surface combinations having a static coefficient of friction less than 0.30 indicate a need for treatment and should be avoided.

Concerning System Lateral Security

(6) Both the HPT and MTS simulated trailers under full load conditions were proved secure when tested to the tilt angles shown below. The systems therefore have satisfied Code requirements.

	Total Load (kg)	Longitudinal Load Density (kg/m)	Lateral Tilt Angle	Equivalent Acceleration (g's)	Code Requirement (g's)
HPI	19,200	1940	50°	0.77	0.50
MIS	13,900	1640	51°	0.78	0.50

(7) The proven margin of security above 0.50 g, as indicated in (6), suggests that full length trailers to 12.5 m overall length and fitted with the "new" MTS and HPT gates, should also be able to meet the Code requirement.

(8) The use of more than five gates on each side of a trailer is to be avoided. An increasing number of gates is likely to downgrade system security.

(9) To ensure lateral stability loads with a rearmost reel (or pairs of reels) separated from the rear gate by more than 300 mm must be secured by secondary restraints.

(10) Provision and use of a device positively locking the hoop to the gate was found to be desirable, but not essential.

(11) Testing of a single "old" MTS gate implanted in the "new" gate system did not provide a satifactory data base for predicting the performance of the "old" system in toto.

Concerning System Forward Security

(12) In the presence of friction forces, the first 0.5 g of the 1.0 g Code requirement for forward security places comparatively small demands on the gate system; but the second 0.5 g represents a severe test of structural integrity. Predictions, therefore, of security at higher g-levels, outside the test range, must be made with caution and with due regard to possible load instabilities under extreme conditions.

(13) The fully loaded HPT and MTS simulated trailers were proved secure when tested to the tilt angles shown below.

	Total Load (kg)	Longitudinal Load Density (kg/m)	Forward Tilt Angle	Equivalent Acceleration (g's)	Code Requirement (g's)
HPT	17,900	1800	62^{o}	0.88	1.0
MTS	13,900	1620	61^{o}	0.87	1.0

For practical reasons the Code loading requirement to 1.0 g cannot be simulated by tilt test. However, the evidence of this investigation suggests that both test trailers should have been able to satisfy the Code.

(14) Forward security of a full length trailer, fully loaded to 21 tonnes and secured by the respective "new" gate systems, is conditional upon:

(a) satisfactory load stability at 1.0 g, and

(b) adequate ultimate breaking strength of the restraints.

The results of this investigation indicate that both restraint systems should satisfy condition (b). (Note, however, Recommendations below.) The results of this investigation cannot be extrapolated to provide an unequivocal answer to (a). In particular, the shortfall in payload on the MTS test trailer (13.9 tonnes vs. 21.0 tonnes, say, on a full length deck) indicates that the test conditions stopped short at less than 65% of 1.0 g equivalent. Under the circumstances, any conclusion drawn with regard to performance to 1.0 g must be based on probability. Accordingly, the likelihood of compliance with the Code requirement of full length trailers is confirmed with a certainty of 90% for HPT and a certainty of 75% for MTS.

(15) The steel bracing of the front gate, and a guaranteed anchorage for the brace at the rear spade of the side gate are mandatory for forward security. Likewise anchorage for other side gates is recommended.

(16) Due to lateral "squeezing" action of the reels in forward slide load security under forward deceleration of the vehicle depends critically on the strength of the side gates.

Concerning System Rearward Security

(17) The results have confirmed that the HPT and MTS gate systems, as tested, would satisfy Code rearward security requirements of full length trailers.

(18) The requirement of conclusion (9) applies also in respect of rearward security.

Concerning System Components and Component Design

(19) A raised coaming (minimum 25 mm) on the trailer deck is highly beneficial to forward and lateral security and its provisions is recommended.

(20) Ihe chain of top links and pinned joints linking the top perimeter of the gates is an essential feature of the gate system. The links/joints should be designed to have a breaking strength in tension not less than 8000 kg force.

(21) A webbing brace on the front gate is of limited benefit and its use is not recommended.

(22) The crossed webbing straps over the hoops (HPT system only) are beneficial and their use is recommended.

(23) The HPT and MTS hoops were found to be effective and essential to forward and lateral security.

(24) A tight tarpaulin contributes as a means of controlling (limiting) movements of the load, in particular in the lateral direction; however, the non-destructive nature of the tests precluded demonstration of the value of the tarpaulin as an anti-slip device for the load.

FIG. 1.

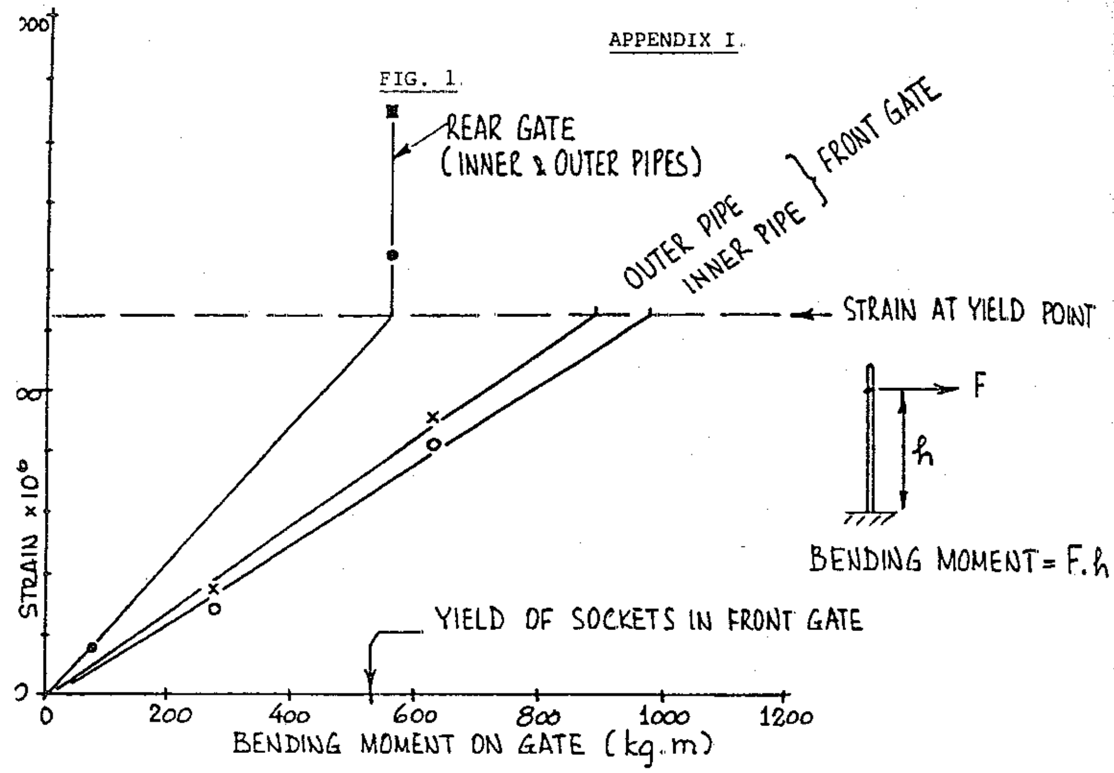


Fig. 1 Bending strain in HPT front and rear gates subjected to horizontal outward force

FIG. 2.

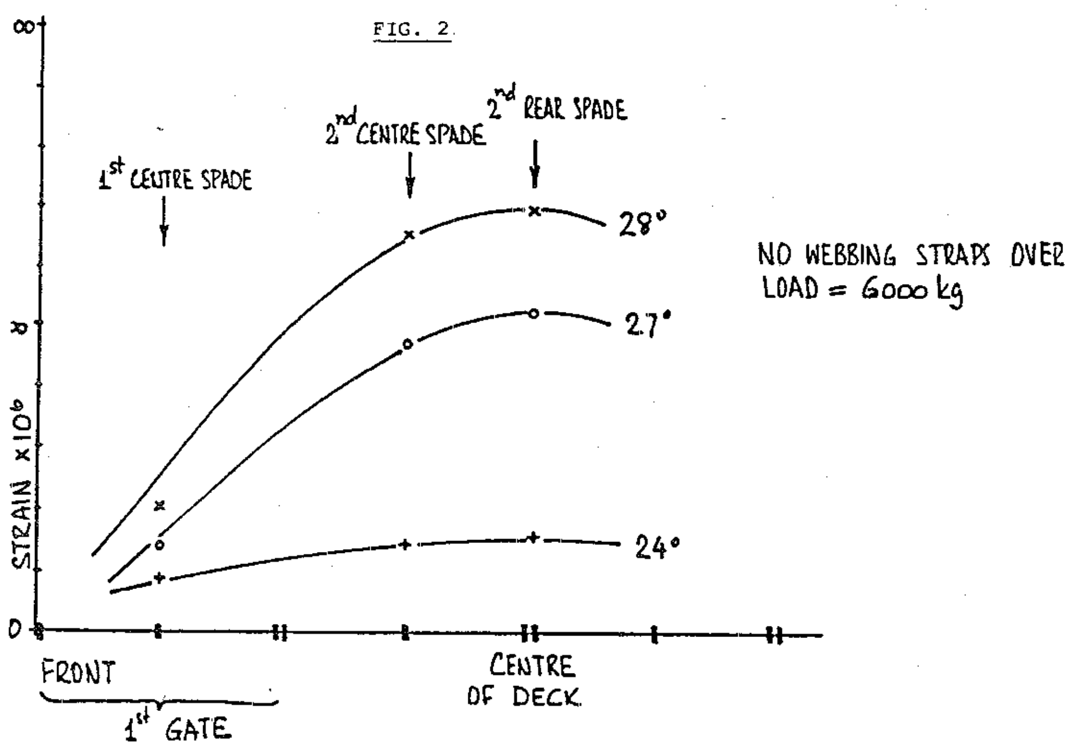


Fig. 2 Longitudinal variation of bending strain in HPT side gates under lateral tilt conditions.

APPENDIX 11

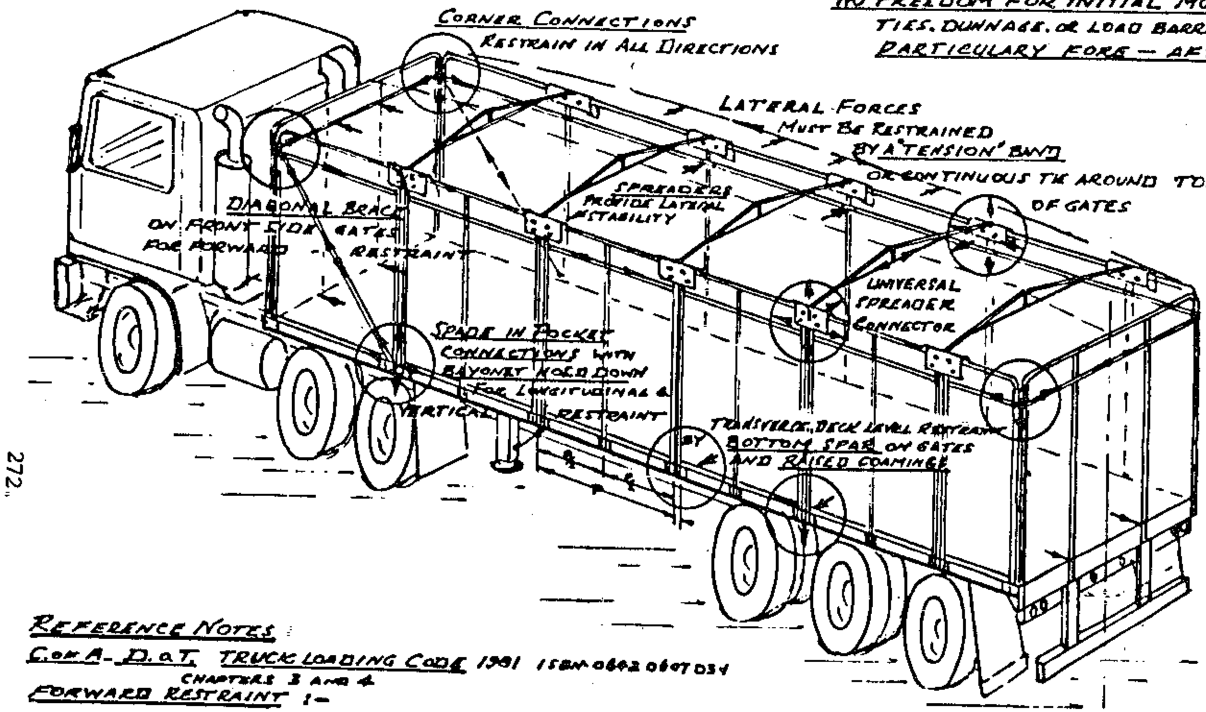
Acceleration Levels Corresponding to
Onset of Slide and Maximum Tilt

Type of Test	Test No.	Trailer	Tilt Mode	Load (kg)	Tilt Angle		Equivalent Acceleration (g's)	
					at first slip	tested to	at first slip	tested to
Preliminary (partially loaded)	1	MTS	-	horiz. force	-	-	-	-
	2	"	lateral	11,600	21°	24.5°	0.36	0.41
	3	"	"	4,600	18°	29°	0.31	0.48
	4	" *	"	4,600	19°	29°	0.33	0.48
	5	"	forward	5,600	27°	55.5°	0.45	0.82
	6	"	"	5,600	29°	50°	0.48	0.77
	7	"	rearward	5,600	28°	45°	0.47	0.71
	8	HPT	-	horiz. force	-	-	-	-
	9	"	-	"	-	-	-	-
	10	"	lateral	6,000	18°	28.5°	0.31	0.48
	11	"	"	6,000	17°	30°	0.29	0.50
	12	"	"	6,000	18°	30°	0.31	0.50
	13	"	forward	9,300	18°	45°	0.31	0.71
	14	"	"	9,300	20°	45°	0.34	0.71
Final (fully loaded)	15	MTS	lateral	13,900	22°	51°	0.37	0.78
	16	HPT	forward	17,900	25°	62°	0.42	0.88
	17	"	lateral	19,200	23°	50°	0.39	0.77
	18	MTS	forward	13,900	23°	61°	0.39	0.87

* With "old" MTS gate fitted.

AN EFFECTIVE DYNAMIC LOAD FORCE RESTRAINT SYSTEM

IS DEPENDANT ON CORRECT LOAD STUFFING WITHIN THE GATES ALLOWING ... NO FREEDOM FOR INITIAL MOVEMENT OR DISPLACEMENT. TIES, DUNNAGE, OR LOAD BARRIERS MUST SECURE LOAD PARTICULARY FORE – AFT DIRECTION.



DECK SURFACE MUST PROVIDE MAX. FRICTION AGAINST PAYLOAD. EITHER – UNPAINTED TIMBER SURFACES OR "NON-SLIP" APPLIED COATING ON FLAT METAL SURFACES.

POSTS & SPADES CONNECTING RACKS & GATES INTO COAMING POCKETS MUST BE NEAT FIT

FOR INTERCHANGABILITY POST & POCKET SPACING – PITCH TO BE WITHIN SPECIFIED TOLERANCES.

REFERENCE NOTES:

COM A – D.O.T. TRUCK LOADING CODE 1981 ISBN 0642 0607 034
CHAPTERS 3 AND 4

FORWARD RESTRAINT :–

THE COMBINED RESTAINING FORCES PROVIDED BY THE LOAD SECURING SYSTEM TO PREVENT LOAD MOVEMENT RELATIVE TO THE VEHICLE – DUE TO FORWARD DECELLERATION MUST EQUAL THE PAYLOAD MASS – 1 G.

REARWARD RESTRAINT :– 0·5 G.

LATERAL RESTRAINT :– 0·5 G.

AND OVERTURNING RESTRAINT > 0·5 G IS DESIRABLE

THE GATE SYSTEM SHOWN IS THE RECOMMENDED PRODUCT – – OUTCOME FROM LOAD SECURITY TESTS ** THIS IS AN ACCEPTABLE ALTERNATIVE TO ROPING METHOD TO SECURE 'REELS ON END' T.L.CODE CH. 14. CL 3. P. 94.

** REPORT ON "SECURITY OF PAPER REELS ON ROAD VEHICLES FITTED WITH GATES" DR. H. NOLLE JULY 1983 .

TITLE: ESSENTIAL FEATURES REQUIRED FOR SIDE GATE SYSTEMS.	HAMMOND PALMER TRANSPORT / McLEISH TRANSPORT SERVICE / AUSTRALIAN NEWSPRINT MILLS.
PROJECT: LOAD SECURITY TESTS RECOMMENDATIONS.	DATE: AUG. 83 · SCALE: – · SHEET SIZE: A3 · DRAWN: KWB. · TRACED: 1 OF 4 · CHECKED: · PASSED: · DRAWING NUMBER: 20883/1

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