



Load restraint for LP Gas cylinder distribution



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Australian Standard[®]

**Load restraint for LP Gas cylinder
distribution**

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-015, Storage and Handling—Liquefied Petroleum Gases. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

The objective of this Standard is to provide industry with specific requirements and guidance for load restraint systems for typical LP Gas cylinder loads that facilitate compliance with the National Transport Commission's Load Restraint Guide.

This Standard does not replace statutory regulations, which take precedence at all times. It should be read in conjunction with the latest edition of AS/NZS 1596, *The storage and handling of LP Gas*, and the National Transport Commission's *Load Restraint Guide* and *Australian Code for the Transport of Dangerous Goods by Road and Rail* (ADG Code).

Statements expressed in mandatory terms in notes to figures are deemed to be requirements of this Standard.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	4
1.2 REFERENCED DOCUMENTS.....	4
1.3 DEFINITIONS.....	4
1.4 REQUIREMENTS.....	4
1.5 FORCES ACTING ON LP GAS CYLINDER LOADS	5
SECTION 2 GENERAL VEHICLE BODY AND GATE CONFIGURATIONS	
2.1 DESIGNS OF VEHICLES AND GATES	9
2.2 GATE DESIGN LOAD CRITERIA.....	9
2.3 FAILURE ANALYSIS AND RESTRAINT SYSTEM REQUIREMENTS	9
2.4 DETAILED GATE DESIGN	12
2.5 DETAILED GATE DIMENSIONS	13
SECTION 3 RESTRAINT METHODS FOR DRIVERS	
3.1 STRAPPING LOAD RESTRAINT FOR CYLINDERS	15
3.2 LONG REAR OVERHANG	15
3.3 LEISURE CYLINDER CAGES AND STILLAGES	18

STANDARDS AUSTRALIA

Australian Standard

Load restraint for LP Gas cylinder distribution

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements and recommendations for the design and construction of load restraint systems for typical LP Gas cylinder loads to prevent loss of the load or movement of the LP Gas cylinders that affects stability of the vehicle. The requirements facilitate conformance with the requirements of the National Transport Commission's *Load Restraint Guide* to the transport of LP Gas cylinders.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Australian Standard:

AS/NZS

1596 The storage and handling of LP Gas

National Transport Commission (NTC)

Load Restraint Guide

1.3 DEFINITIONS

For the purpose of this Standard, the definitions given in AS/NZS 1596 and the *Load Restraint Guide* 2004 apply.

1.4 REQUIREMENTS**1.4.1 General load restraint performance requirement**

Loads shall be restrained to prevent unacceptable movement during all normal conditions of on road operation. The load restraint system shall, therefore, satisfy the following requirements:

- (a) The load shall not become dislodged from the vehicle.
- (b) Cylinders shall be restrained to remain upright.
- (c) Any load movement shall be limited, such that in all cases where movement occurs, the vehicle's stability and weight distribution are not adversely affected.

Loads that are permitted to move relative to the vehicle include loads that are effectively contained within the sides or enclosure of the vehicle body, such as loads that are restrained from moving horizontally. Limited vertical movement is permissible. Also see Clause 3.1.1.

To achieve this, the load restraint system shall be capable of withstanding the forces (see Figure 1.1) that would result if the laden vehicle were subjected to each of the following separately:

- (i) 0.8g deceleration in a forward direction.
- (ii) 0.5g deceleration in a rearward direction.
- (iii) 0.5g acceleration in a lateral direction.
- (iv) 0.2g acceleration relative to the load in a vertical direction.

NOTE: g is the acceleration due to gravity.

1.4.2 General requirements for load restraint

Every load shall be restrained to prevent unacceptable movement during all expected conditions of operation. The load restraint system shall meet the performance requirements detailed in Clause 1.4.

NOTE: Figure 1.1 shows typical road restraint forces.

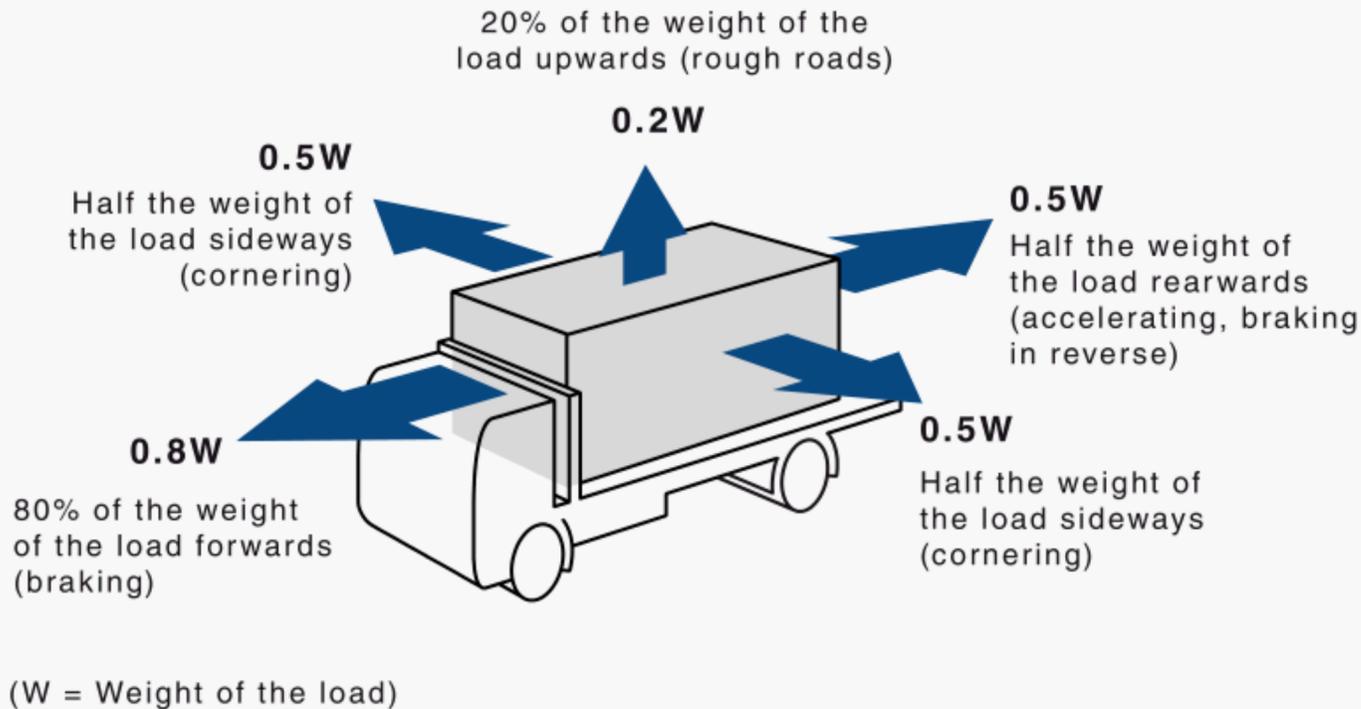


FIGURE 1.1 LOAD RESTRAINT FORCES

1.4.3 Means of restraint

The primary means of restraint is achieved by the use of strapping, wrapping or mechanical restraints.

The secondary means of restraint is achieved by the use of gates, fixed side panels, stillages or cages constructed to provide adequate strength to contain a load of filled cylinders.

NOTE: This is important where the gate is at the rear and vertical forces when driving over a bump may dislodge the gate.

To satisfy the above requirements, the gates shall—

- be tied down;
- have a locking device fitted that positively affixes the gates to the tray; or
- be hinged and permanently fixed to the tray.

1.5 FORCES ACTING ON LP GAS CYLINDER LOADS

1.5.1 General

The loads and modes of failure include the following:

- Cylinders sliding sideways when the vehicle is subjected to a lateral acceleration of $0.5g$.
- Cylinders tipping over sideways when the vehicle is subjected to a lateral acceleration of $0.5g$.
- Cylinders thrown upwards when the truck drives over a speed bump or similar giving a vertical acceleration of $0.2g$.
- Cylinders bending or shearing the headboard when the vehicle is subject to a braking deceleration of $0.8g$.

1.5.2 Tipping versus sliding—Single cylinder

Where a cylinder is subject to decelerations of 0.5g or 0.8g, a force is generated through the centre of mass and will result in either the cylinder sliding across the surface or tipping over.

The relevant forces are shown in Figure 1.2.

With a very low friction surface, all objects will tend to slide rather than tip. With a very high friction surface, almost all objects will tend to tip rather than slide.

Depending on the geometry of an object, there is a friction factor below which the object will slide, and above which the object will tip. Table 1.1 gives the relevant values for the typical range of cylinders. Table 1.1 shows the values when the LP Gas cylinders are full.

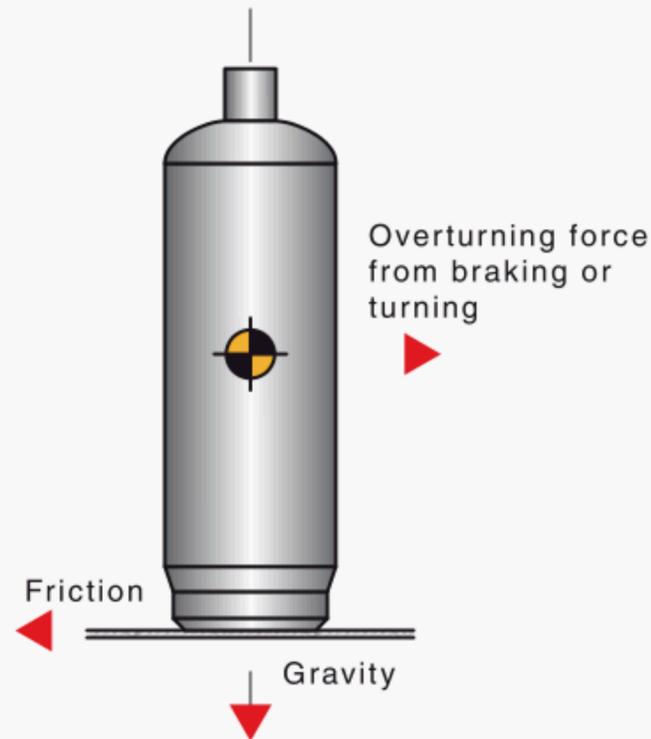


FIGURE 1.2 FORCES ON SINGLE CYLINDER

TABLE 1.1

CRITICAL FRICTION FACTORS FOR SINGLE CYLINDERS

Cylinder description	Height mm	Diameter mm	Tare kg	LP Gas kg	Gross kg	Centre of mass mm
2.15 kg	283	132	3.0	2.15	5.2	122
4 kg	310	260	5.0	4.0	9.0	132
9 kg	481	310	8.0	9.0	17.0	197
18 kg	840	310	18.0	18.0	36.0	357
18 kg steel forklift	840	310	21.0	18.0	39.0	361
15 kg aluminium forklift	840	310	10.0	15.0	25.0	301
45 kg domestic	1235	375	33.0	45.0	78.0	525
90 kg	1340	508	70.0	90.0	160.0	583
190 kg	1350	760	125.0	190.0	315.0	561
210 kg	1390	760	130.0	210.0	310.0	591

NOTE: With design friction factors greater than 0.4 cylinders would slide rather than tip if tested as a single cylinder. 45 kg cylinders will always tip rather than slide if tested as a single cylinder because its critical friction factor is below 0.36.

1.5.3 Tipping versus sliding—Multiple cylinders

With multiple cylinders the circumstances are altered because each cylinder pushes against the next introducing friction between the cylinders.

This friction provides additional resistance to tipping.

Experience has shown that a group of cylinders will not tip over when the cylinders are pulled together by a webbing strap or bound using industrial cling wrap material when palletised.

The relevant forces are shown in Figure 1.3.

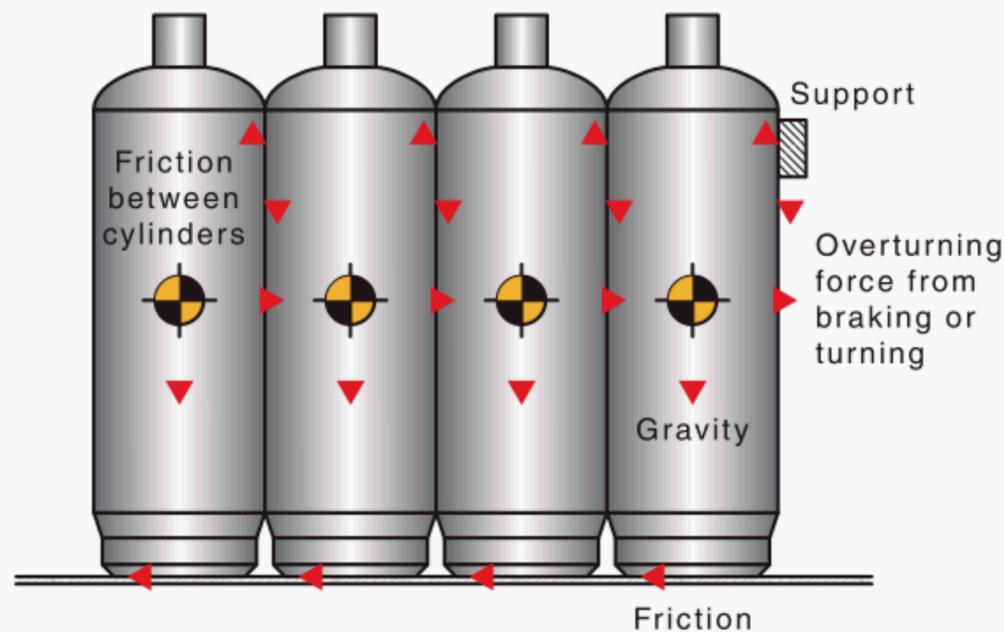


FIGURE 1.3 FORCES ON MULTIPLE CYLINDERS

1.5.4 Cylinders being thrown vertically

Legislation in Australia allows rear overhang to be a maximum of 3.7 m or 60% of the wheel base.

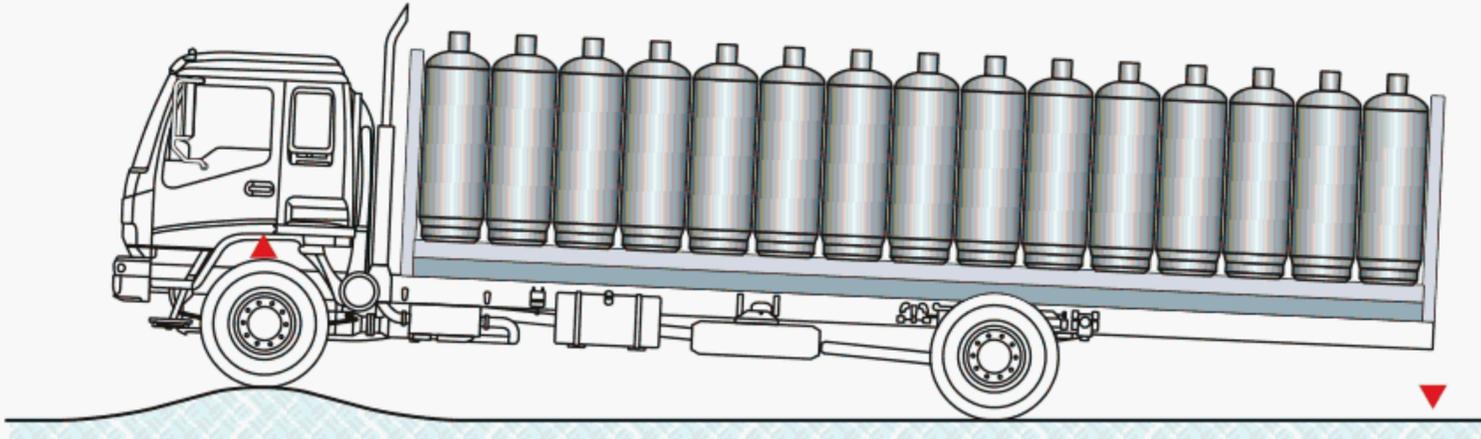
When designing and specifying LP Gas cylinder delivery vehicles, minimization of the rear overhang as a percentage of the wheel base shall be a primary consideration.

The two situations illustrated in Figure 1.4 show the differing effects when the front and rear axles go over a speed bump.

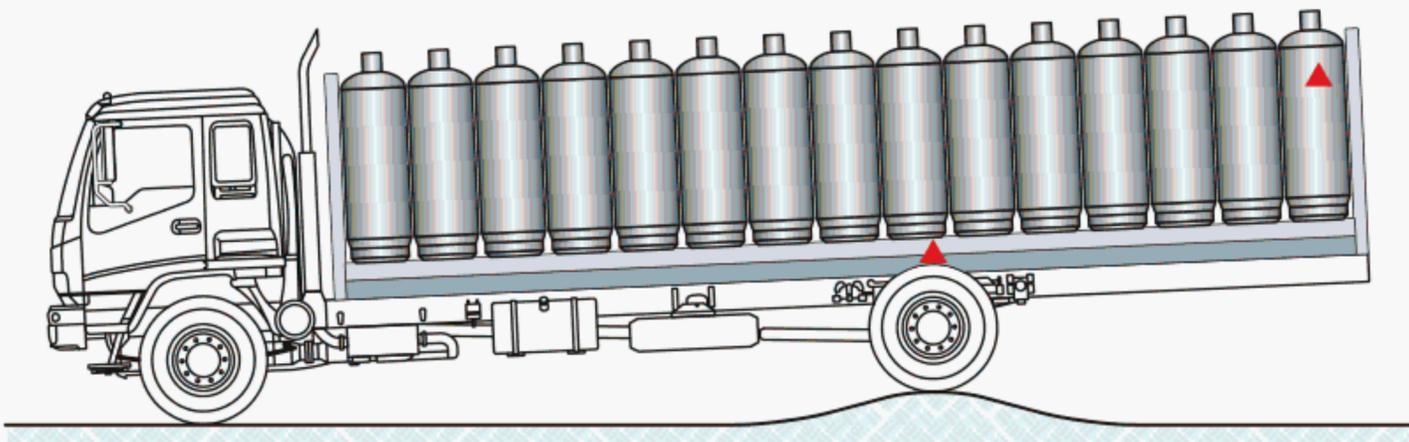
Where the steer axle goes over a speed bump so that the tyres and suspension are compressed, the front of the truck is driven upwards. Generally, drivers will drive at a speed that will avoid being propelled out of their seat and in this case the upward acceleration will be less than 1.0g.

In contrast, when the rear axle goes over the same bump the situation is very different. In this case, the upwards acceleration of the drive axle is increased by up to 60% at the rear of the tray. The upward acceleration of 0.4g to 0.6g will become $0.4g \times 160\%$ to $0.6g \times 160\%$, i.e. 0.64g to 0.96g. This is on the verge of propelling the cylinders at the rear into the air.

The photograph in Figure 1.5 illustrates cylinder dislodgement where the upwards 'g' force at the rear has been excessive.



(a) Front axle traversing speed bump



(b) Rear axle traversing speed bump

FIGURE 1.4 EXAMPLES OF AXLES TRAVERSING A SPEED BUMP



NOTE: All cylinders regardless of being carried in stillages, cages or whole load shall be restrained so that the relief valve always communicates with the vapour space of the cylinder.

FIGURE 1.5 CYLINDER DISLODGE­MENT WITH EXCESSIVE UPWARD FORCE AT REAR OF TRAY

SECTION 2 GENERAL VEHICLE BODY AND GATE CONFIGURATIONS

2.1 DESIGNS OF VEHICLES AND GATES

Where there is a gap within a load, cylinders shall be strapped together to prevent movement. This requires a horizontal webbing strap at, or slightly above, the centre of the cylinders.

Where webbing restraints are applied to gates, the gates shall be designed to resist the loads applied by the webbing. This design shall include requirements related to how the gate is attached to the tray.

2.2 GATE DESIGN LOAD CRITERIA

2.2.1 General

The design of gates or side panels shall be adequate to resist the loads generated by LP Gas cylinders whilst in transit and when the vehicle is subject to decelerations as defined in the performance standards of the *NTC Load Restraint Guide*. The appropriate loads and forces for LP Gas cylinder distribution are detailed in Clauses 2.2.2 to 2.2.4.

2.2.2 Cylinder masses

The design gross masses of cylinders (worst case is the larger full cylinders) is specified in Table 1.1. Friction factor design values shall be as follows:

- (a) For steel on steel.....0.20.
- (b) For steel on timber.....0.40.
- (c) For steel on rubber load mat0.60.

2.2.3 Stillages and cages

Design values for stillages and cages shall be the maximum combined mass of the cage or stillage and cylinders when full.

2.3 FAILURE ANALYSIS AND RESTRAINT SYSTEM REQUIREMENTS

2.3.1 General

Clauses 2.3.2 to 2.3.5 cover possible modes of vehicle body or gate failure and actual failure events that could result in non-compliance with the *NTC Load Restraint Guide* performance requirements. The circumstances covered relate to two-axle, single-drive trucks with a maximum payload of nominal 10 000 kg, as shown in Figure 2.1.

There shall be a minimum of one central gate support on each side. If gates are not hinged and are to be manually inserted and removed, the maximum gate length shall be 2 m to achieve a nominal gate weight of 16 kg.

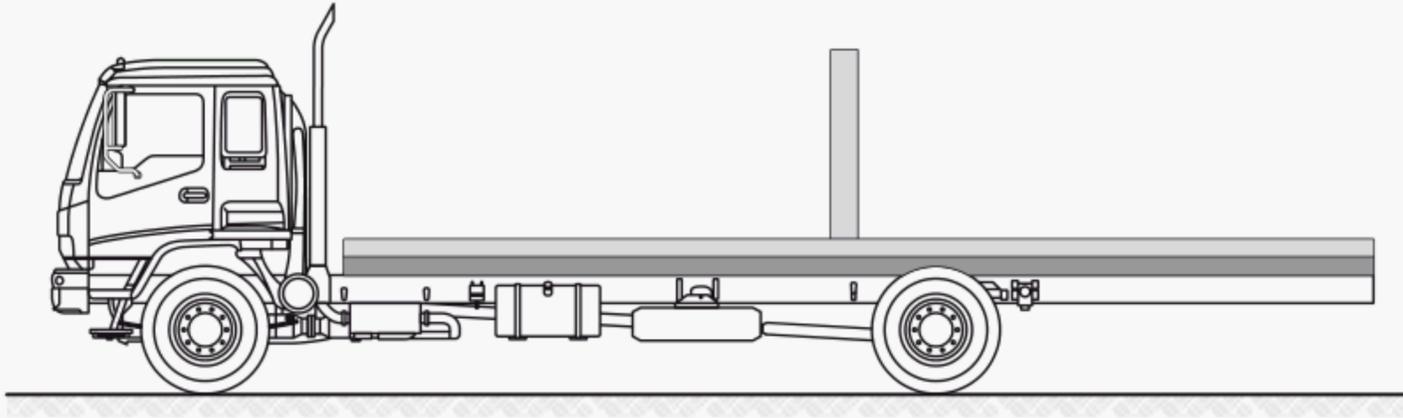


FIGURE 2.1 BASIC DISTRIBUTION TRUCK

2.3.2 Loss of cylinders through gate opening

This may occur through two modes—

- (a) failure of strapping, wrapping or mechanical restraint where the upper gate latching becomes loose resulting in a gap that a cylinder could pass through; or
- (b) failure of strapping, wrapping or mechanical restraint where a cylinder becomes loose on the tray, or unrestrained, particularly small cylinders, which move around until an opening is found.

To avoid these circumstances, the following load restraint requirements shall be complied with:

- (i) Gate latches shall positively lock in a manner that does not allow the latching mechanism to release during transit.
- (ii) Stillages used for small cylinders shall have openings that are less than the diameter of the smallest cylinder.
- (iii) Where small cylinders are not transported in stillages or cages, gates shall have openings that are less than the diameter of the smallest cylinder.

2.3.3 Loss of cylinders through gate failure

Loss of cylinders through gate failure may occur through two modes—

- (a) failure of the gate at the lugs or hinges as a result of the shear forces and bending forces applied to the gate; or
- (b) failure of the gate as a result of the gate bending outwards between the lugs or hinges and becoming detached at the locking points.

The gates and the headboard shall be designed to safely resist the forces in Table 2.1. It is normal practice to apply a safety factor of 2.5.

TABLE 2.1
DESIGN FORCES FOR RESTRAINT SYSTEM COMPONENTS

Component	Maximum shear force N/m	Maximum bending moment Nm/m
Side gates	2, 260	314
Headboard	34, 340 (85, 850 for a 2.5 m wide tray)	12, 250 (12, 250 for a 2.5 m wide tray)

2.3.4 Loss of cylinders through central support failure

For the cylinder truck design concept being covered in this Clause, 50% of side forces are resisted by the central support. The maximum length of the LP Gas storage space is 8.4 m; therefore, the central support shall resist the LP Gas cylinder-related forces with a safety factor of 2.5. These forces are—

- (a) a shear force of 18, 500 N; and
- (b) a bending moment force of 2, 510 Nm.

2.3.5 Other detailed design considerations to minimize the risk of failure

Where there is a sudden change in shape of a structural member, stress concentration will occur. The safety factor may be increased.

A weld joint shall be designed so forces are transferred through welds in shear. It is poor welding practice and not recommended that a weld be in pure tension.

For example, using rectangular hollow section (RHS) steel tubes for the central support for the headboard uprights, butt welding these against the top of the coaming rail and welding around the point of contact is not recommended. The minimum material that will resist the forces and provide the required safety margins is a 100 mm × 50 mm × 4 mm RHS tube with the 50 mm dimension lined up with the 50 mm width of the coaming rail.

The method in which this support is attached to the coaming rail is critical. The 100 mm × 50 mm × 4 mm RHS tube shall not be butted to the coaming rail and welded around its circumference. Any internal weld defect may crack and fail as maximum loads (tension plus shear plus bending moment) are applied to that weld.

Plates, angles or other devices shall be used to ensure that the welds resisting failure are not in tension.

Two possible arrangements are shown in Figure 2.2, with all edges and corners smoothed and rounded. Other detailed designs that achieve the same result may be used.

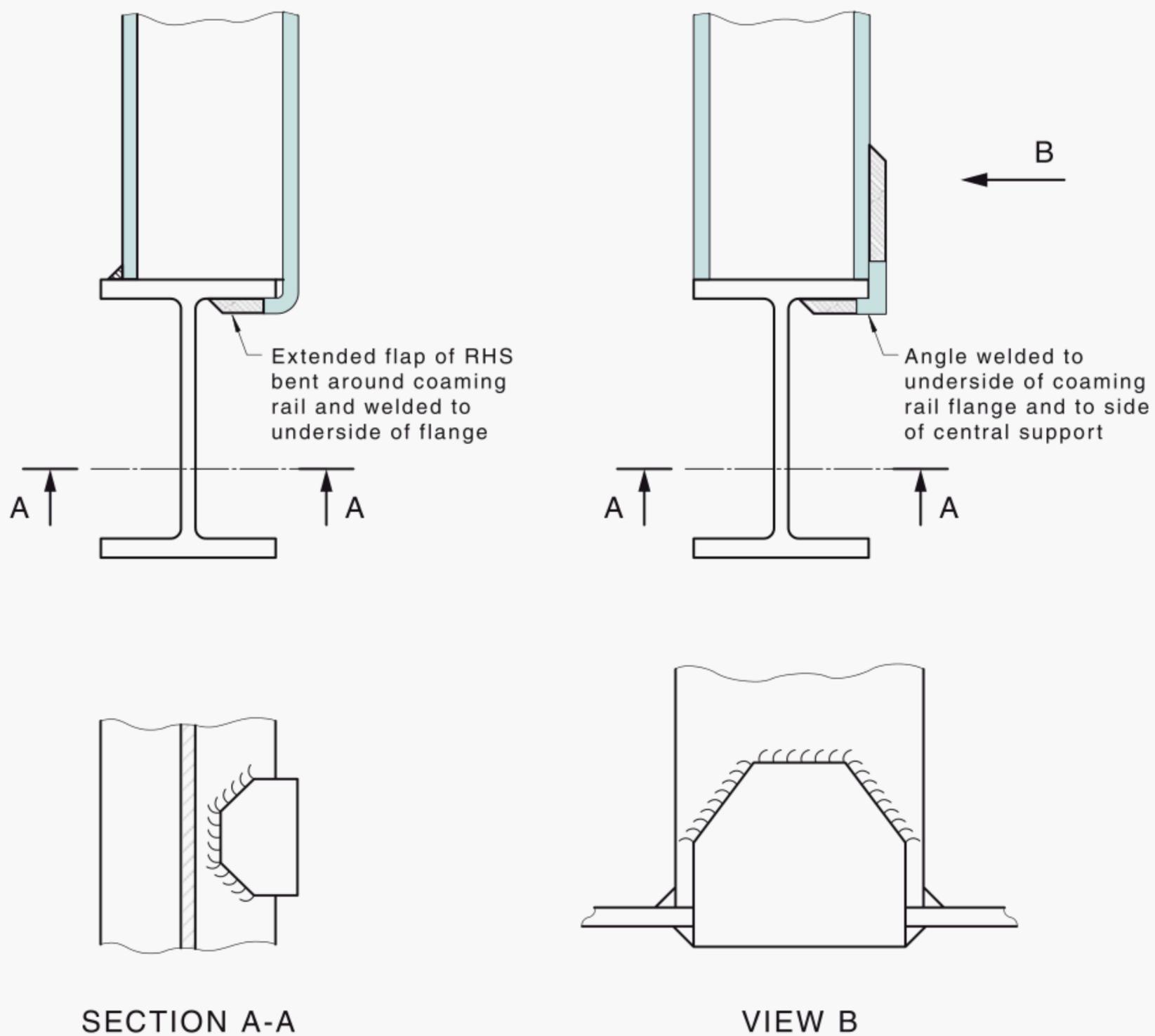


FIGURE 2.2 EXAMPLES OF PREFERRED WELDING METHODS

2.4 DETAILED GATE DESIGN

The following requirements shall apply for gates:

- The outer horizontal members shall be a minimum of 25 mm × 25 mm × 2.0 mm square hollow section (SHS) tube.
- Intermediate horizontal members shall be a minimum of 20 mm × 20 mm × 1.6 mm SHS tube.
- The vertical members at the hinges shall be a minimum of 20 mm × 20 mm × 1.6 mm SHS tube.

NOTE: Any verticals between those verticals may be 20 mm × 3 mm flat bar.

- The plates attaching the hinges to the gate structure shall be a minimum of 40 mm × 4 mm flats × 120 mm long.
- The minimum diameter of the pins forming the hinges shall be 10 mm.
- The pins shall have a locking device to prevent the gate sliding off when hanging down.

- (g) The pins shall be welded at the top flange of the coaming rail to give maximum gate clearance to the ground, and the length of welds to the coaming rail on each side shall be at least 40 mm.

NOTE: The tubing forming the other part of the hinge should be at least 40 mm long and either heavy 15 mm nominal bore circular hollow section (CHS) tube with an outside diameter of 21.3 mm and a wall thickness of 3.2 mm or machined tube with a minimum wall thickness of 4 mm.

- (h) Suitable top latches that positively lock the gates shall be fitted at each end of the gates. Such latches shall have pins, barrels or bars at least 10 mm in diameter if in close to pure shear, or larger if subject to bending moments.

NOTE: If the locking part is a flat plate style, it should be 40 mm wide and 4 mm deep or alternately around 25 mm wide and 5 mm thick.

- (i) Gates shall not exceed 3.2 m overall length.

2.5 DETAILED GATE DIMENSIONS

Table 2.2 shows the centre of mass of the various types of LP Gas cylinders regularly carried and recommended locations of gate cross members. These spacing are illustrated in Figure 2.3.

Gates shall be a minimum of 70% of the height of the cylinders they are used to contain or 55% of the height of any stillage they contain. Due consideration shall be given to ground clearance for gates that are hinged.

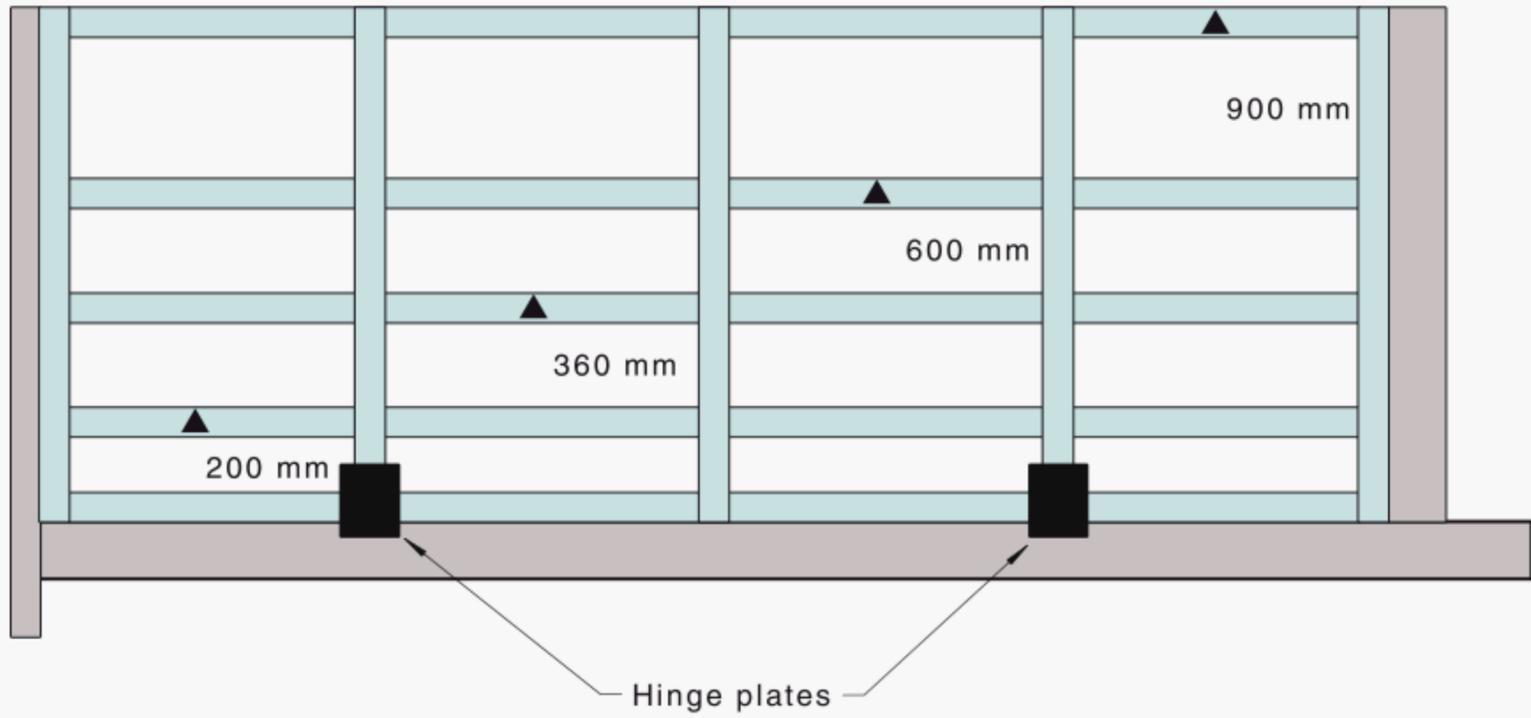
When in the 'down' position with a load of full cylinders and the suspension fully compressed, there shall be adequate clearance for the operator to close the gates and to provide ground clearance when manoeuvring the truck into depot load bays while the gates are down. For 45 kg cylinders, the optimum height is 900 mm.

For a 2000 mm long gate there shall be minimum two verticals between the two hinge verticals. The estimated weight of a 2000 mm gate is nominal 16 kg.

TABLE 2.2
GATE CROSS MEMBER LOCATIONS

Cylinder description	Height mm	Diameter mm	Centre of mass mm		Recommended restraint point height mm
			Full	Empty	
2.15 kg	283	132	122	139	See Note
4 kg	310	260	132	150	
9 kg	481	310	197	228	200
18 kg	840	310	357	412	360
18 kg steel forklift	840	310	361	411	
15 kg aluminium forklift	840	310	301	361	
45 kg domestic	1235	375	525	602	600
90 kg	1340	508	583	649	
190 kg	1350	760	561	634	
210 kg	1390	760	581	654	

NOTE: It is recommended that separate storage provisions be made for small cylinders where they are regularly carried.



SIDE VIEW

NOTE: All heights shown are measured from the tray.

FIGURE 2.3 EXAMPLES OF CROSS MEMBER SPACINGS

SECTION 3 RESTRAINT METHODS FOR DRIVERS

3.1 STRAPPING LOAD RESTRAINT FOR CYLINDERS

3.1.1 General

Webbing strap restraints shall comply with a relevant Australian Standard; shall be a minimum of 50 mm wide and of nominal 2000 kg load capacity. These shall be visually inspected at least weekly and replaced where signs of deterioration are observed.

Applying webbing around a corner formed by a vertical and horizontal member of a gate will significantly reduce the operational life of the strapping material.

The webbing will generally be horizontal to the tray surface or at right angles to the edge of the tray.

Where there is a gap within the load, cylinders shall be strapped together with horizontal strapping to prevent unrestrained movement; the webbing straps are to be applied horizontally at, or slightly above the centre of the cylinders.

The trucks design should incorporate anchor points that allow for the varying heights of the horizontal restraint.

If restraints are applied to gates, the gates shall be designed to resist the webbing loads. This includes requirements related to how the gate is attached to the tray.

LP Gas cylinders shall not extend more than 30% of their height above the gates. See Clause 2.5.

3.1.2 Incompatible dimensional cylinders in common load

Cylinders of different heights shall have a dedicated webbing strap fitted for each group of cylinders (each size of cylinder requires its own horizontal strapping).

Cylinders with vertical heights 500 mm or less shall be transported in enclosed cages or stillages.

3.2 LONG REAR OVERHANG

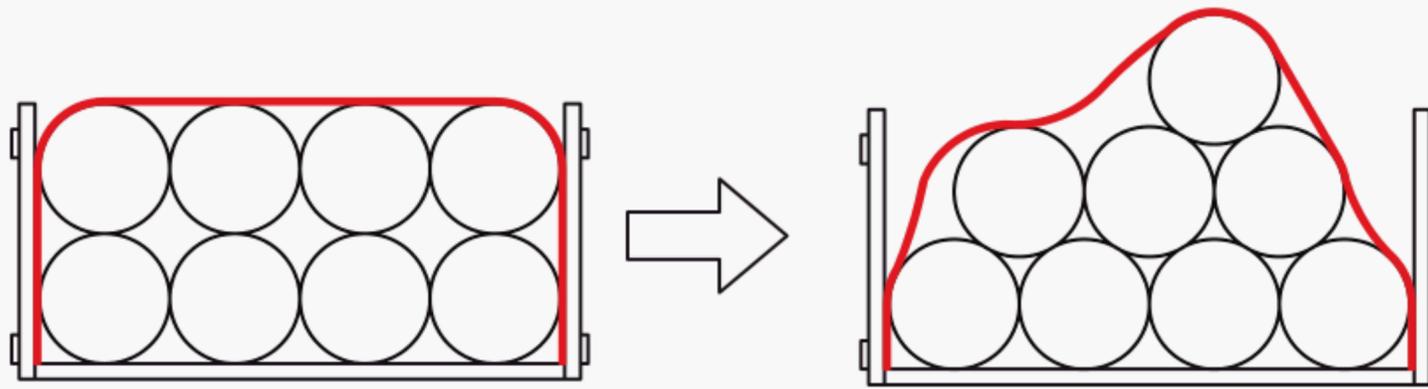
3.2.1 'Belly wrapped' 8 × 45 kg LP Gas cylinder arrangement

To prevent cylinders being propelled upwards, the cylinders shall be strapped together [see Figure 3.1(a)]. As loaded, these cylinders have friction between the cylinders themselves and the frame.

However, if subjected to a sliding force sideways during transit it is possible for cylinders to rearrange themselves as shown in Figure 3.1(b), resulting in loss of tension from the strapping and the cylinders becoming loose.

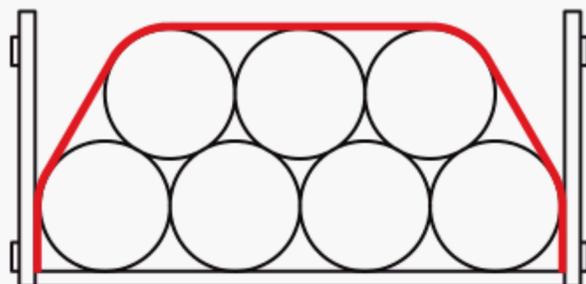
The total movement of the top cylinder is about 225 mm due to the rearrangement of the cylinders plus 50 mm due to the rearrangement the strap becoming loose. With this degree of movement, the outer cylinder would fall from the top layer and precipitate the other cylinders also falling as all strap tension is lost. A side load of 0.36g would be required to cause this situation. In normal truck operations this would not occur.

Changing the initial arrangement to that shown in Figure 3.1(c) would result in a more stable configuration but reduce the capacity of the truck.



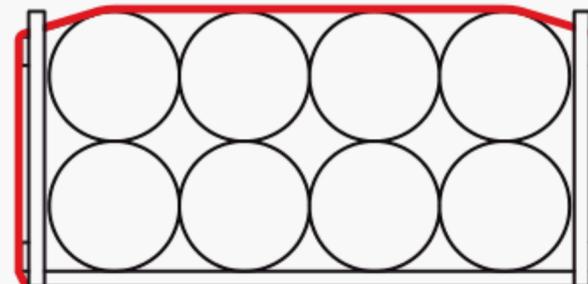
(a) NOT SUITABLE; straps not restrained by vertical member (attached inside the side gates)

(b) Effect of side load greater than 0.6g



(c) More stable load configuration

SUITABLE



(d) Strap restrained by vertical member

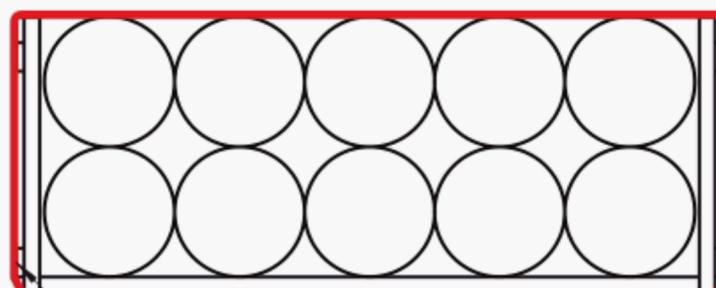
SUITABLE

NOTE: (a), (b), (c) and (d)—TOP VIEW

FIGURE 3.1 EXAMPLES OF BELLY WRAPPED CYLINDER LOAD ARRANGEMENTS

3.2.2 Strap across the frame uprights arrangement

The arrangement shown in Figures 3.2 and 3.3 are for LP Gas cylinders in an enclosure. It is possible in this situation that cylinders will have no clamping force applied to them and could possibly be propelled upwards.



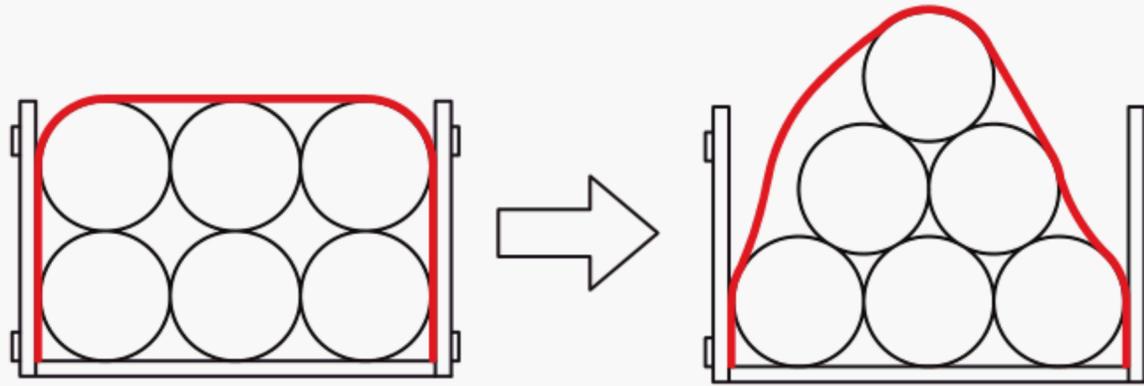
Strap restrained by vertical member

NOT SUITABLE

Cylinder may not have enough clamping force applied to them and be propelled upwards

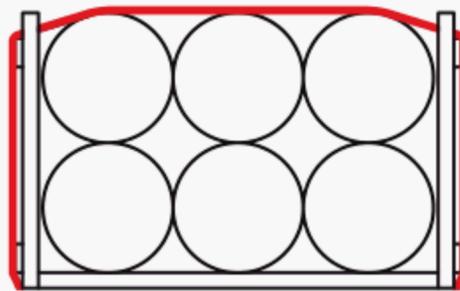
TOP VIEW

FIGURE 3.2 STRAP ACROSS THE FRAME UPRIGHTS ARRANGEMENT



(a) NOT SUITABLE; straps not restrained by vertical member (attached inside the side gates)

(b) Possible rearrangement with loss of cylinders



(c) Strap restrained by vertical member

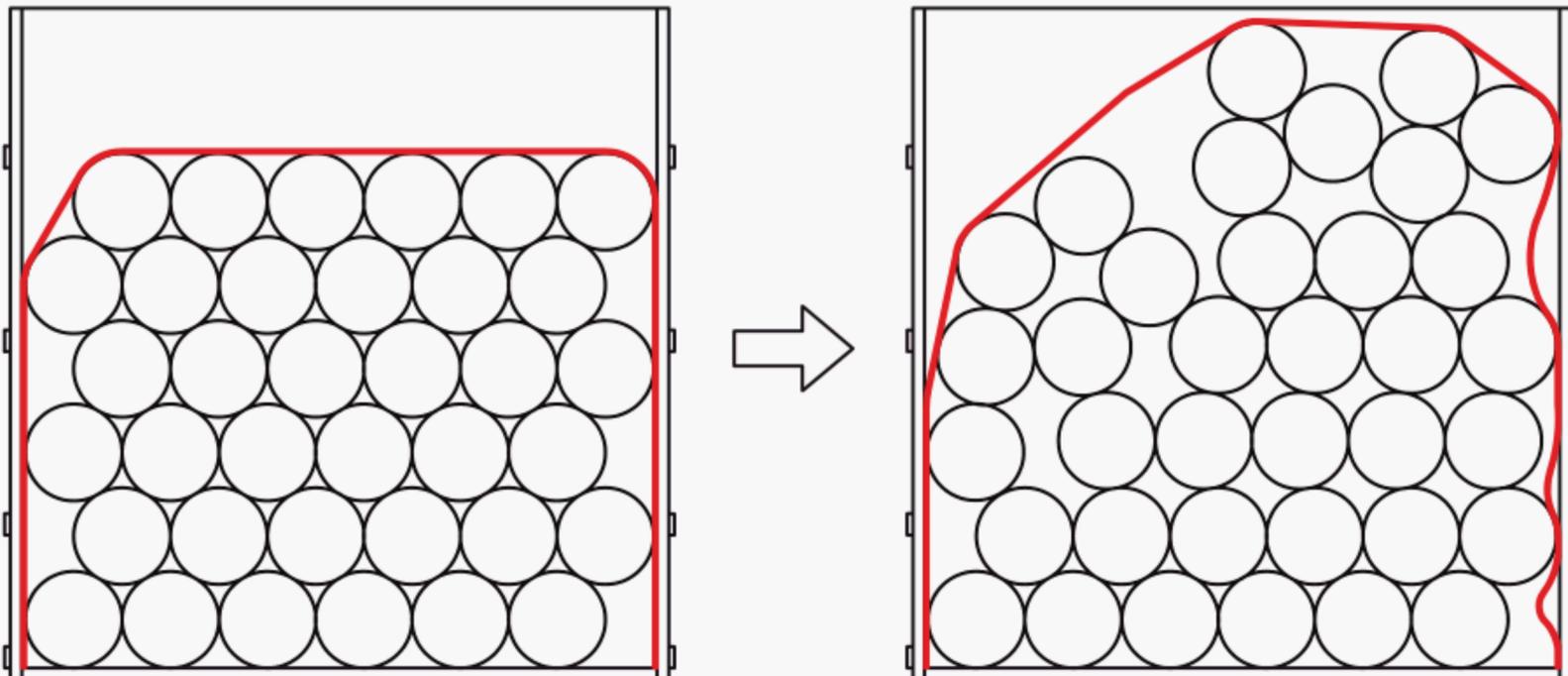
SUITABLE

NOTE: (a), (b) and (c)—TOP VIEW

FIGURE 3.3 SIX CYLINDER ARRANGEMENT

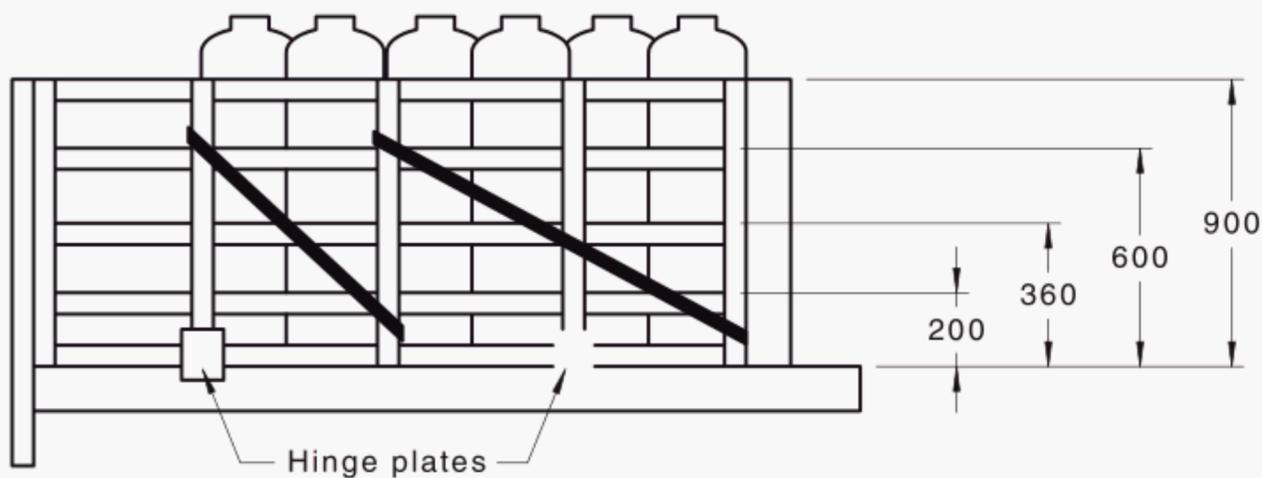
3.2.3 Large number of cylinders

Whenever cylinders are loaded in a rectilinear fashion as shown in Figure 3.4(a), they are likely to rearrange in transit if subjected to forces exceeding 0.36g. The arrangement in Figure 3.4(a) can theoretically rearrange to that shown in Figure 3.4(b) and the strap will lose all tension.



(a) NOT SUITABLE

(b) Possible rearrangement with loss of cylinders



(c) Strapping arrangement and example of cross member spacing

NOTE: (a) = TOP VIEW, (b) = TOP VIEW, (c) = SIDE VIEW

DIMENSIONS IN MILLIMETRES

FIGURE 3.4 LARGE CYLINDER LOADS

3.3 LEISURE CYLINDER CAGES AND STILLAGES

3.3.1 Effect of friction factor on number of webbing restraints

The largest stillages may weigh up to 277 kg and contain up to 44 nominal 9 kg cylinders. Tables 3.1 and 3.2 indicate the number of 50 mm webbing restraints required per row of stillages to satisfy the requirements of the NTC *Load Restraint Guide* for each stillage configuration and for three friction levels, as follows:

- (a) Galvanized steel on a new steel tray—0.2.
- (b) Steel on timber—0.4.
- (c) Steel on rubber—0.6.

(d) Steel on timber or rubber conveyor belting—0.4.

Figure 3.5 illustrates the typical arrangement of straps. Figure 3.6 illustrates blocked and unblocked loads.

Table 3.1 shows a significant advantage in ensuring that the friction factor is at least 0.4.

TABLE 3.1

MINIMUM NUMBER OF WEBBING STRAPS REQUIRED FOR EFFECTIVE STILLAGE RESTRAINT ON VARIOUS SURFACES 300 kg STRAP TENSION

Stillages		Number of webbing straps for blocked load			Number of webbing straps for unblocked load		
		Surface type					
Stillage mass kg	Number	Steel on steel	Steel on timber or conveyor belting	Steel on rubber	Steel on steel	Steel on timber or conveyor belting	Steel on rubber
250	1	1	1	1	2	2 (Note 5)	2 (Note 5)
	2	2	1	1	3	2 (Note 5)	2 (Note 5)
	4	3	2	2	6	2	2
500	1	2	1	1	3	2 (Note 5)	2 (Note 5)
	2	3	1	1	6	2	2 (Note 5)
	4	6	2	2	11	2	2
1000	1	3	1	1	6	2	2 (Note 5)
	2	6	1	1	12	4	2
	4	11	2	2	21	8	3

NOTES:

- 1 Typical lashing tensions for a 50 mm webbing strap are 300 kg with the ratchet handle tensioning up and 600 kg with the ratchet handle tensioning down.
- 2 1 stillage assumed loaded in centre of tray in longitudinal direction, 2 stillages loaded side by side, 4 stillages loaded; 2 high and 2 side by side.
- 3 Typical stillage dimensions used for calculating angles and lashing angle factor are 1200 mm high and 700 mm wide.
- 4 The front blocked and 0.6 friction factor case is limited by the 0.2g vertically up load case.
- 5 For load stability, two webbing straps should be considered as a minimum for double stacking; a single webbing strap is adequate for single stacked cages when the load is blocked.
- 6 Conservative full stillage gross weights for 9 kg cylinders are 12 cylinders 250 kg, 24 cylinders 500 kg and 48 cylinders 1000 kg.

TABLE 3.2

MINIMUM NUMBER OF WEBBING STRAPS REQUIRED FOR EFFECTIVE STILLAGE RESTRAINT ON VARIOUS SURFACES 600 kg STRAP TENSION

Stillages		Number of webbing straps for blocked load			Number of webbing straps for unblocked load		
		Surface type					
Stillage mass kg	Number	Steel on steel	Steel on timber or conveyor or belting	Steel on rubber	Steel on steel	Steel on timber or conveyor or belting	Steel on rubber
250	1	1	1	1	2 (Note 5)	2 (Note 5)	2 (Note 5)
	2	2	1	1	2	2 (Note 5)	2 (Note 5)
	4	2	2	2	3	2	2
500	1	2	1	1	2	2 (Note 5)	2 (Note 5)
	2	2	1	1	3	2	2 (Note 5)
	4	3	2	2	6	2	2
1000	1	2	1	1	3	2 (Note 5)	2 (Note 5)
	2	3	1	1	6	2	2 (Note 5)
	4	6	2	2	11	4	2

NOTES:

- 1 Typical lashing tensions for a 50 mm webbing strap are 300 kg with the ratchet handle tensioning up and 600 kg with the ratchet handle tensioning down.
- 2 1 stillage assumed loaded in centre of tray in longitudinal direction, 2 stillages loaded side by side, 4 stillages loaded; 2 high and 2 side by side.
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