Bulletin No. 7 Part B

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National Code of Practice

Design Parameters Necessary for Compliance with ADR 59/00 Omnibus Rollover Strength.

-Part B

THIS CODE OF PRACTICE EXTENDS PART A OF THE CODE BY PROVIDING A MORE COMPLEX SET OF PROCEDURES FOR THE CONSTRUCTION OF A LARGER RANGE OF BUS STRUCTURES DEEMED TO COMPLY WITH AUSTRALIAN DESIGN RULE 59/00 "OMNIBUS ROLLOVER STRENGHT".

The Vehicle Standards Bulletin provides information for those associated with the design, manufacture, sale, maintenance or repairs of motor vehicles and trailers.
The series is a major channel for communication from the Vehicle Safety Standards Branch in the case of matters relating to new vehicles, and from the Australian Transport Advisory Council and its committees in the case of vehicles in service.
The series:

- Gives advance notice of matters of concern;
- Sets out codes and other standards which supplement the ADRs and AIRs; and
- Provides advice concerning vehicle design, safety and operation.

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NATIONAL CODE OF PRACTICE

DESIGN PARAMETERS NECESSARY FOR COMPLIANCE WITH ADR59/00 OMNIBUS ROLLOVER STRENGTH

Part B

ADR 59/00 ROLLOVER CODE OF PRACTICE - PART B

Contents

1 SCOPE AND GENERAL

1.1 Scope

This Part ‘B’ of the Code of Practice shall be read in conjunction with Part ‘A'. It is necessary to be conversant with the requirements of Part ‘A’ before reading Part ‘B’

Part ‘B’ of the Code is a general design method, applicable to a wide range of vehicle chassis and body configurations, for the application of the roll cage construction and hoop profile given in Part ‘A’. An additional hoop profile has been provided and is designated profile ‘B’ with that of Part ‘A’ designated as profile ‘A’.

This part of the Code of Practice details the extent to which the Part 'A' requirements may be varied. It provides means for the substitution of alternative joint designs in the hoop construction provided they meet specified test requirements.

The definitions and requirements of Part 'A' shall be complied with unless expressly modified in this Part 'B of the Code of Practice.

1.2 Definition

The definitions given below are additional to those of Part 'A' and are applicable to this code and associated documents only.

Floor Height - The height from the ground to the finished floor under the passengers' seats at tare mass.

Approved manner - An alternative procedure to that specified in the code and approved by the Administrator of Vehicle Standards as complying with the code requirements.

Hoop with Mitred Roof Bow. A hoop with a mitred connection between pillar and roof bow is illustrated in Fig 1.02.1(b). The hoop must fit within either profile ‘A’ or ‘B’ *envelope*- refer Appendix C Figure C-3.

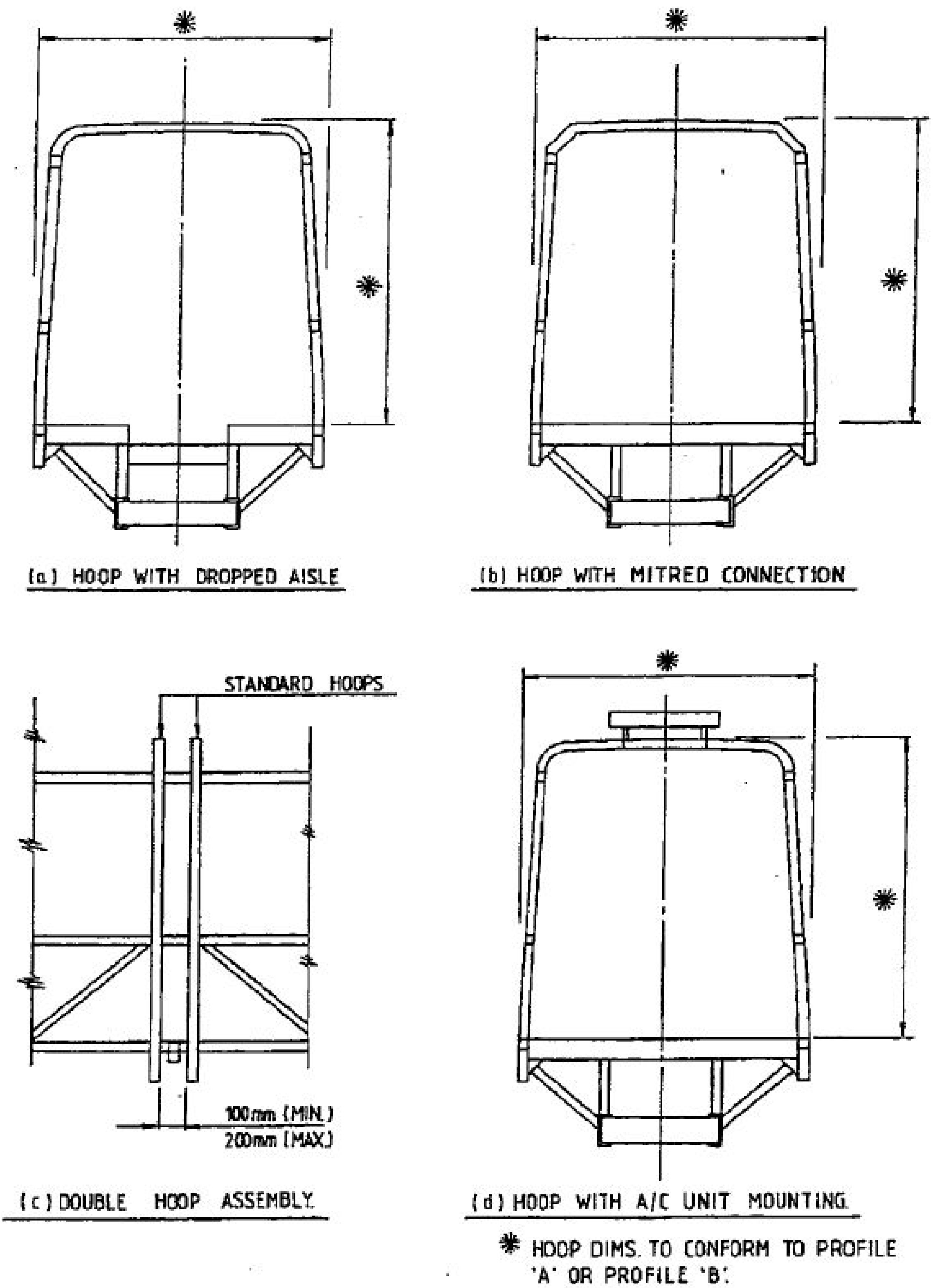
Double Hoop Assembly. This is an assembly consisting of two standard hoops of either profile

'A" or ‘B’, whose centre to centre spacing is between 150to 250 mm joined only at the sill, waist and cant ran positions by sections of those nominated members. Such an assembly is Illustrated in F19 1.02.1(c).

Hoop with Dropped Aisle. The access aisle may be set at a level lower than the seat floor to which the hoop is attached, in which case the supporting floor structure shall meet the requirements of section 3. The Hoop shall comply with either profile 'A" or ·a• as illustrated in Fig 1.02.1(a).

Hoop with Air Conditioning Unit [A/C Unit]. Two or more standard hoops of either profile ‘A' or

‘B’ may be used to provide a mounting for the evaporator unit of an air conditioning system providing the roll cage meets the requirements of section 3.00. Such an installation is illustrated in Fig 1.02.1(d).



TYPICAL HOOP CONFIGURATIONS

FIG. 1.02-1

2 GENERAL DESIGN REQUIREMENTS.

2.1 Part B - General Design Method.

The method specified under this Part 'B' of the Code is limited to the use of the roll cage structure specified in Parts 'A' and 'B' of this code to a range of single deck vehicles of the heavy omnibus category ME with tare mass ranging from 5.00 to 14.00 tonne.

The design method involves the determination of the code ron over design energy [Ec], and the selection of the required number of hoops and their dispos ion to meet this energy requirement.

Limitations imposed by the use of standard hoop profile member cross section, connections and materials are as documented in Part 'A' and Part 'B' of this Code.

The records of implementation of all these requirements shall be validated in writing and by signature of the "designer".

3 ROLL CAGE DESIGN - GENERAL METHOD.

3.1 General.

This design method is applicable to two and three axle omnibuses with maximum distance between the front and the rear most axle of 8.0m, overall length of 12.2m and of either ladder frame or space frame chassis construction.

The requirements of Part 'A' section 5.01 and 5.02 are replaced by this Part 'B' section 3.00.

3.2 Roll Cage Requirements.

3.2.1 Passenger Compartment Cross Section.

The roD over impact absorption capacity of the roll cage is directly related to geometric configuration, and hence the cross sectional profile of the roll cage is constrained within specific limits.

The cross sectional profile of the roll cage is limited to that provided by profile 'A' or 'B'·of appendix c of Part 'B'.

3.2.2 Roll Cage

The roll cage shall extend for at least the full length of the passenger compartment and shall be an assembly of components complying with the code and assembled as illustrated in Fig 1.02.1 of Part 'A'. It shall incorporate the required number of hoops conforming to either profile 'A' and/or 'B' and meeting the energy disposition requirements stipulated in this part of the code.

The cant rail member shall extend over the length of the passenger compartment of the roll cage and be at a constant height above the ground over for this length. The cant rails shall lie within the same horizontal plane and be parallel to each other in that plane.

Floor bearers supporting hoops or bearer stub pillars may be varied from the size nominated in Pan "A' provided that the proposed assembly passes, (i) the requirements of the hoop-bearer connection tests under section 4.02.1 and (ii) the full hoop tests under section 4.03.3 or 4.03.4 as applicable.

Roll cages with dropped aisles will be accepted provided that they *comply* with the requirements of this section and the stepped floor construction is shown to have adequate stillness by

passing the full hoop test requirements of sections 4.03.3 or 4.03.4.

Roll cages with air conditioning units (A/c unit] mounted to the roof and supported by standard hoops shall meet the following requirements:-

(i) The rollover energy due to the A/c unit is applied as described in Appendix E.

(ii) The roll cage energy balance requirements are maintained.

(iii) The A/c unit shall be of such width that at the moment of roll over impact it is not closer than 200mm from the ground surface. Refer Fig 3.03.2.

Roll cages using "double hoops" shall be supported by floor construction having sufficient strength and stiffness to carry the loads from the double hoop. Floor construction design acceptable under the code may take one of the following forms:

(i) Each hoop assembly Is connected to a floor bearer meeting the code requirements. **OR** .

(ii) The floor construction design shall be shown to have adequate stiffness by passing the full hoop test requirements of sections 4.03.3 or 4.03.4.

3.2.3 Hoop Numbers and Spacing.

Typical arrangements of roll cages are illustrated in Fig D-1 through D-4 of appendix D for a range of bus configurations.

The number of hoops required for any specific vehicle is dependent upon:-

Vehicle Tare Mass

Centre of Mass location

Floor Height

Overall Passenger Compartment length or overall Vehicle length

Air conditioning Unit

Determine the minimum number of hoops.as described in section 3.04 according to the vehicle roll over design energy [Ec]. The number of hoops so determined shall be not less than that required by the passenger compartment length and the maximum hoop spacing limits.

The hoops shall be spaced throughout the length of the roll cage with the centre to centre spacing of the hoops being a maximum of 1800mm.

The pillars adjacent to a door opening shall be either Front hoop, Rear hoop, Standard hoop or bearer stub pillar extended to the cant rail as illustrated in Fig D-1of appendix D.

A curtailed hoop shall not be used adjacent to any opening that extends below waist rail level. The floor bearers shall be spaced throughout the length of the bus to suit the standard hoop or bearer stub pillar spacings and at a maximum centre to centre distance of 1800mm.

The distribution of hoops forward and rearward of the CoM of the vehicle shall meet the requirements of section 3.04.

For member size and construction requirements refer to Part ‘A’ of the Code of Practice.

3.3 Roll Over Design Energy.

3.3.1 Location of Centre of Mass (CoM).

The centre of mass of the vehicle is to be located in the horizontal and vertical planes, from the centre line of the front axle assembly as illustrated in Fig 3.03.1

FIGURE 3.03.1 LOCATION OF CoM.

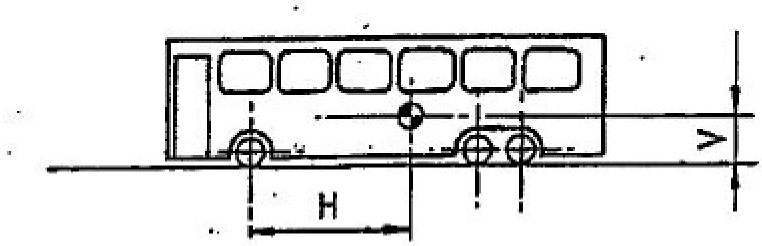


FIGURE 3.03.1 LOCATION OF CoM.

A recommended method for the determination of these values is set out in Appendix A

3.3.2 Roll Over Design Energy.

The roll over design energy [Ec) is given by the following equation:-

Ec = 0.62 M*g*H (kJ)

Where M is the tare mass of the vehicle in tonnes

g is 9.8M/s2

H is fall height of the CoM in metres (m)

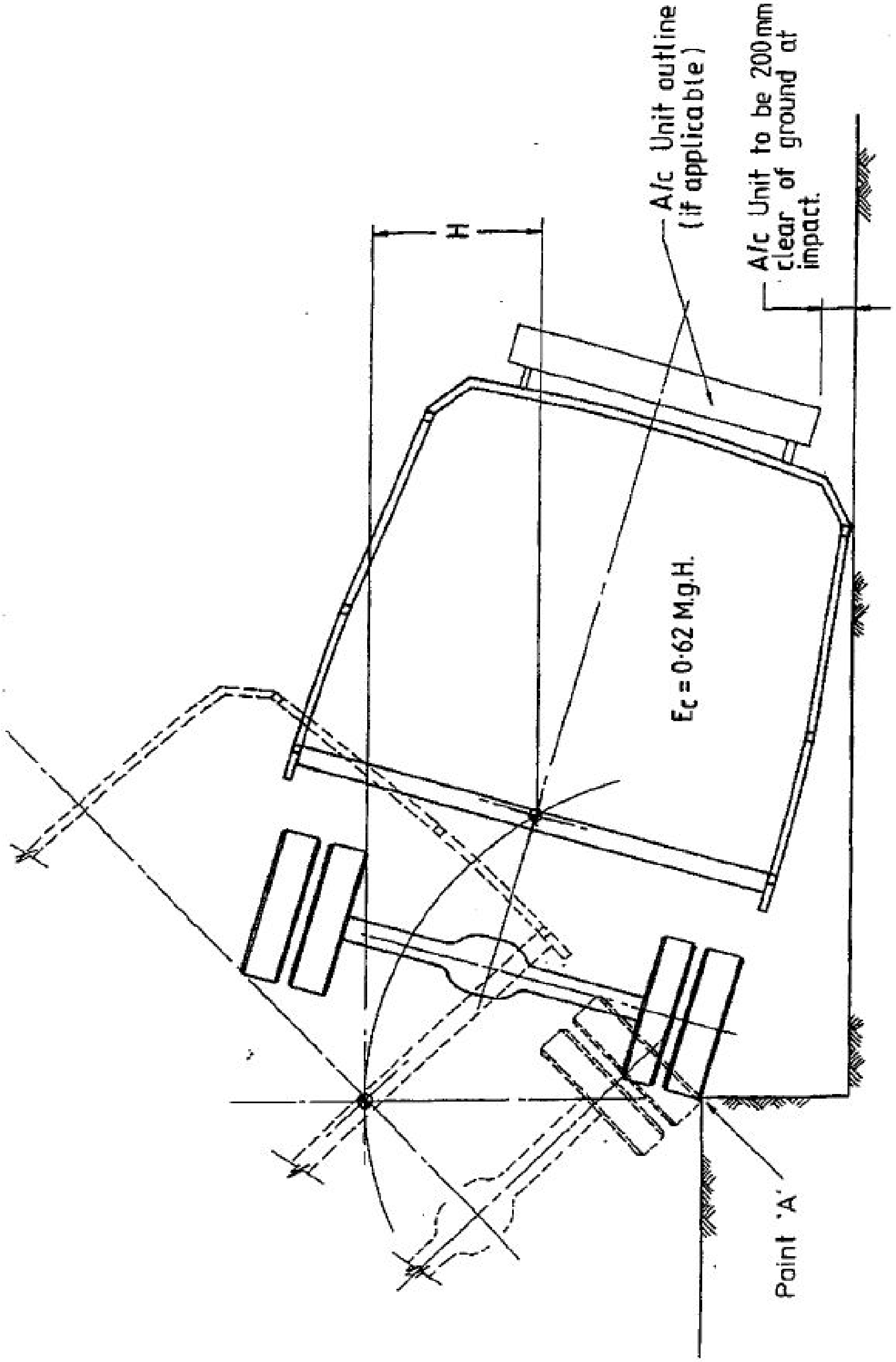
The CoM fall height is the distance from the maximum height position the CoM reaches during vehicle body rotation to the position at Impact of the *body* section with the ground.

The talof the CoM (H) *may* be determined graphically as follows:

The fall height diagram is constructed by rotating the vehicle about a contact point (A} on the rear 1yre, which is located 800mm above the ground level, until some portion of the cant rail or roof bow contacts the ground level as illustrated in Figure 3.03.2.

In creating this diagram the suspension system is assumed to be rigidly fixed and the movement of the body section is assumed to be pure rotation about point ‘B’.

Alternatively, the value of the roll over design energy [Ec] may be determined from graphs in Appendix B for vehicles using the curved roof bow configuration allowed under the hoop profile dimensions, without having to determine H.



VEHICLE ROLL OVER C o M PLOT

FIG. 3·03·2

3.4 Roll Cage Design.

3.4.1 Hoop Energy Selection.

The hoop energy absorption capacity is dependent upon both the hoop profile, hoop construction and overall cage construction. Hoop energy is influenced by the collapse mechanism of the total roll cage structure as well as the local collapse mechanism of its individual components. Hence, the energy values quoted are restricted to the materials and construction form specified in Parts ‘A’ and ‘B’ of this Code.

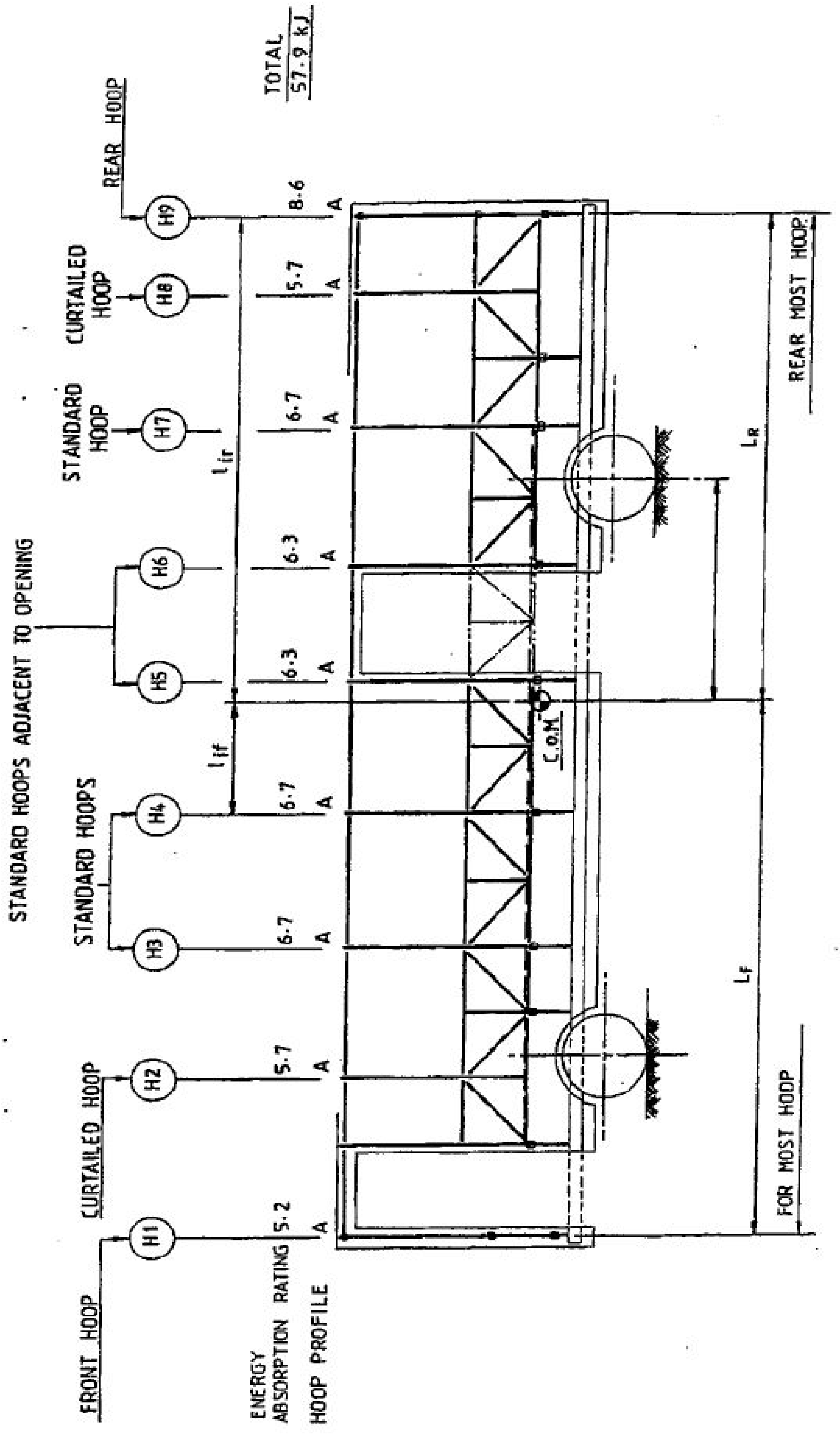
HOOP ENERGY ABSORPTION RATINGS • Units kJ

	Profile ‘A’ & ‘B’
Standard Hoop	6.7
Standard Hoop Adjacent to opening	6.3
Standard Double Hoop	12.2
Curtailed Hoop	5.7
Front Hoop	5.2
Lowered Front Hoop	2.8
Rear Hoop	8.6

The energy values given are for the maximum allowable deflection of hoop; i.e. the hoop touches residual space template at the quoted values.

The total energy absorption capacity of the number and type of hoops selected shall be greater than the calculated roll over energy Ec. If an A/c Unit is mounted to *any* two or more standard hoops then the energy absorption capacity of those hoops shall be determined in accordance with Appendix ‘E’. These values for the nominated hoops shall be used in all subsequent calculations required by sections 3.04.2 & 3.04.3.

Prepare a line diagram of the bus, similar to Figure 3.042 showing the type, energy absorption rating and the location of each hoop about the CoM.



TYPICAL ROLL CAGE DESIGN VERIFICATION DIAGRAM

FIG. 3·04·2

3.4.2 Total Hoop Energy

Having determined the roll over design energy [Ec] and selected the type and distribution of hoops throughout the vehicle body, carry out the following checks:-

(i) Sum the energy ratings of all hoops.
This total shall be greater than the roll over design energy Ec.

$$\sum_{1}^{(n+p)} Ei > Ec$$

(ii) Sum the energy ratings of all hoops forward of the centre of mass. This total shall be greater than 40% of Ec.

$$\sum_{1}^{n} Ei > 0.40\, Ec$$

(iii) Sum the energy values of all hoops rearward of the CoM. This total shall be greater than 50% of Ec.

$$\sum_{1}^{P} Ei > 0.5\, Ec$$

where Ei is the energy rating of i^{th} hoop

n is the number of hoops forward of CoM

P is the number of hoops rearward of CoM

If all of the preceding checks are complied with proceed to section 3.04.3

If some of the checks fail reconsider hoop numbers, types and distribution and repeat checks until all are complied with.

3.4.3 Energy Distribution Check.

Using the bus line diagram showing the type, disposition of hoops and the location of hoops about the CoM, carry out the following energy stiffness balance check

$EMf = \sum_1^n Eif * Lif$ - **Energy Moment forward of CoM**

$EMr = \sum_1^P Eir * Lir$ - **Energy Moment rearward of CoM**

$$0.90 \leq \frac{EMf}{EMr} =< 1.10$$

Check the distribution of energy stiffness using the following weighted mean distance.

$$Xf = \frac{\sum_1^n Eif * Lif - \textbf{Energy Moment forward of CoM}}{\sum_1^n Eif - \textbf{Total energy forward of CoM}}$$

Xf=>0.4*Lf

$$Xr = \frac{\sum_1^P Eir * Lir - \textbf{Energy moment rearward of CoM}}{\sum_1^P Eir - \boldsymbol{Total\ Energy\ rearward\ of\ CoM}}$$

Xr => 0.4*Lr

where

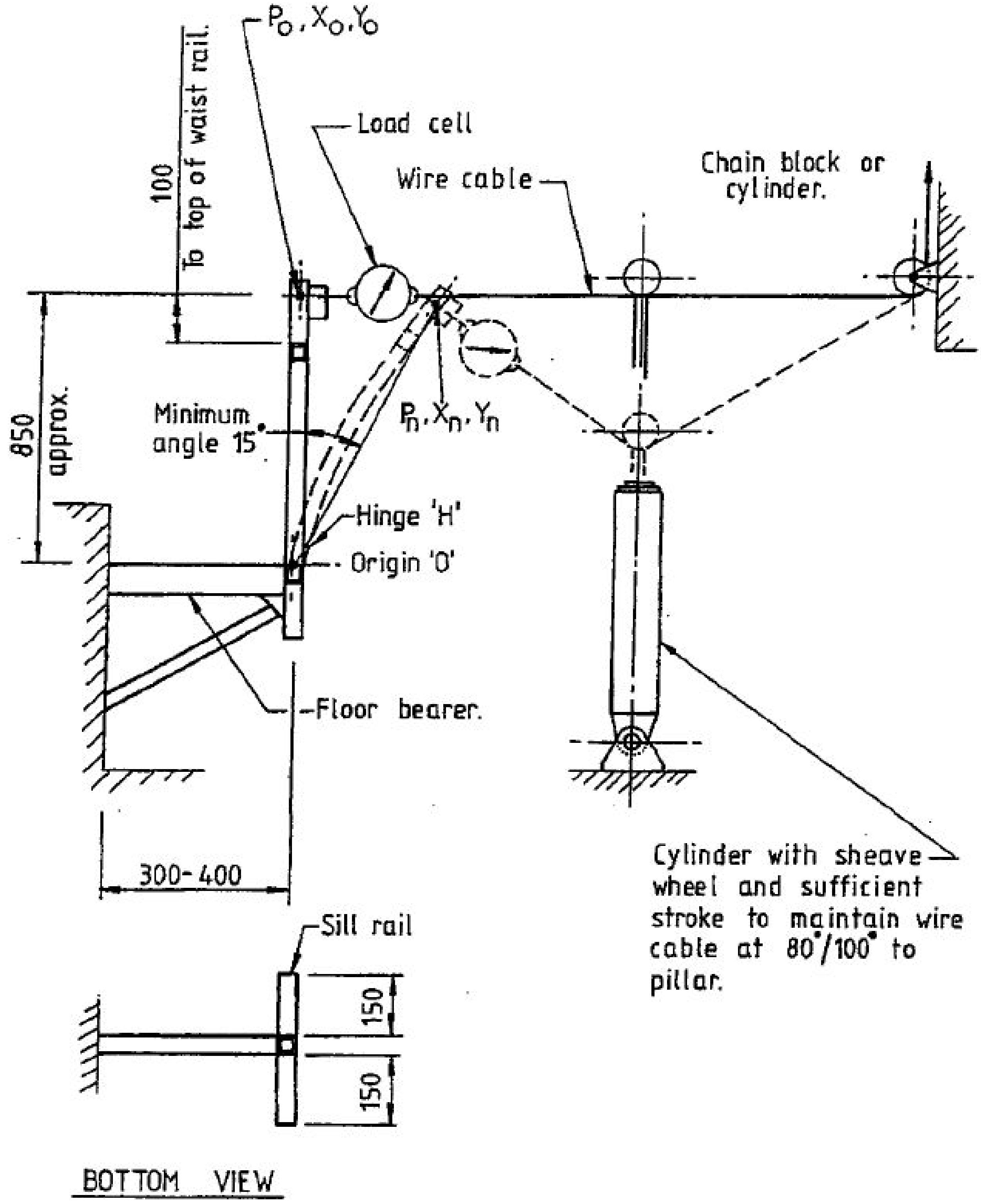
Eif - is the declared amount of energy that can be absorbed by the i^{th} roll cage hoop forward of the CoM.

Eir - Is the declared amount of energy that can be absorbed by the ith roll cage hoop rearward of the CoM.

Lif - is the distance from the CoM to the ith rollcage hoop forward of the CoM. Ur - Is the distance from the CoM to the I th roll cage hoop rearward of the CoM. U - is the cfistance from the foremost roll cage hoop to the CoM.

Lr - is the distance from the rearmost roll cage hoop to the CoM.

The selected roll cage design may be considered as meeting the Code requirements if all of the preceding checks are satisfied.



HOOP-BEAR JOINT TEST

FIG. 4·02·1 (a)

4 CONSTRUCTION VARIATION – VALIDATION PROCEDURES

4.1 General

Provision is made in the paragraphs that follow for testing and Validation of joint constructions that vary from those defined in Part 'A'. When a varied joint construction is used, a static test shall also be carried out on a full hoop as described in section 4.03 except for a varied hoop butt joint (section 4.02.2).

There is no provision in the Code for static testing validation of variations in the member sizes, which are stipulated in Part 'A', other than the composite sill to waist rail section of a hoop or bearer stub pillar, discussed in paragraph 4.02.1 below.

Manufacturers are advised that the validation tests described below may be used as weld acceptance tests for quality assurance purposes if the requirements of Part ‘A’ are complied with.

Manufacturers’ attention is drawn also to the need for their ensuring that the modified joint designs are such that could be reasonably expected to ensure adequate protection in the long term.

4.2 Component .Joint Procedures

This section describes the test and validation procedures for varied joints, the readings that are to be recorded and the derivation of moment v rotation curves where required.

In their simplest form these tests can be made using:

A suitable puling device which can be a chain block.

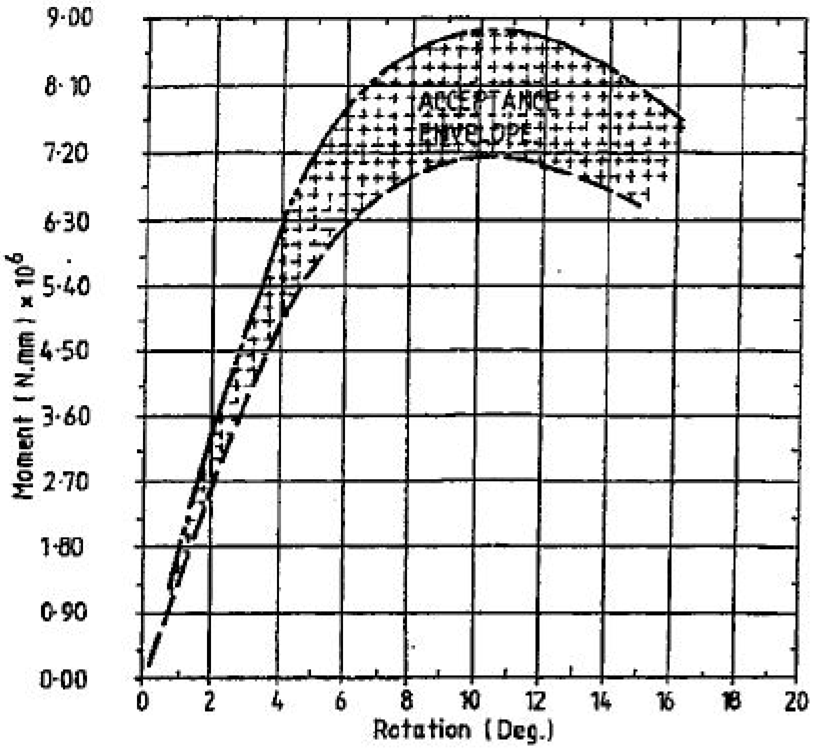
Hydraulic cylinder for adjusting the angle of pull to the member being tested.

A load cell which may be an analogue crane scale.

Shadow board for recording the position of points to be measured.

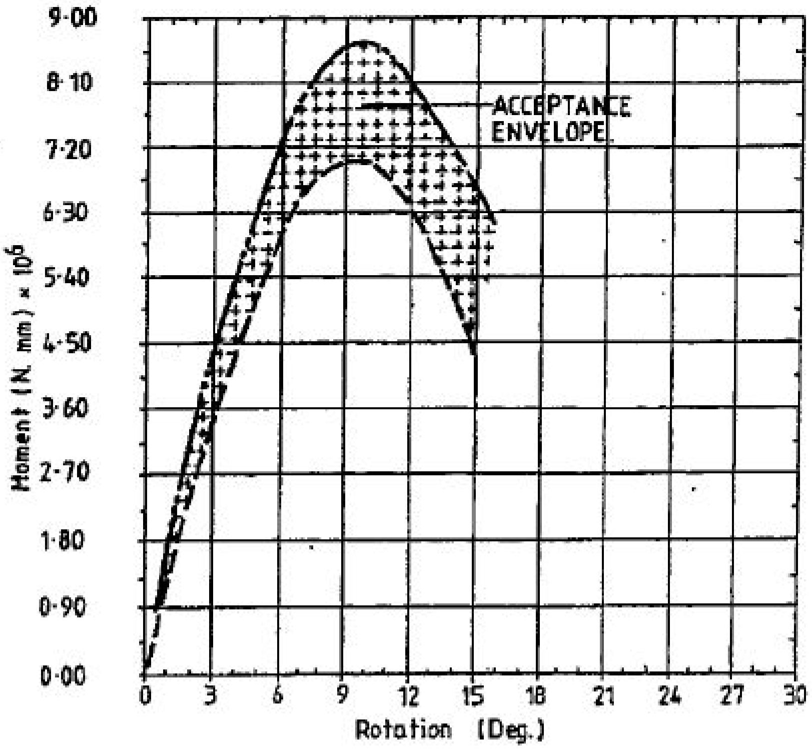
Refer to Fig 4.02.t (a} *tor* an acceptable arrangement.

Manufacturers may use other suitable equipment in an approved manner to achieve the intention of the validation requirements.



HOOP - BEARER JOINT PERFORMANCE — CLOSING.

FIG. 4 · 02 · 1 (b)



HOOP - BEARER JOINT PERFORMANCE — OPENING.

FIG 4 · 02 · 1 (c)

4.2.1 Hoop-Bearer Joint Performance Requirement

a) Mount a bearer section as shown in Fig 4.02.1 (a).
Note 150mm lengths of sill rail shall be welded to the hoop.

b) Test in both opening and closing modes by puling at an angle of 90°to 100° to the member being pulled.

c) Before starting the test,record co-ordinates for:
Pull point ‘P’ – Px, Py
Origin ‘O’ – Ox, Oy

d) During test record a minimum of 8 observations for:·
Px, Py, Ox, Oy; Load
Observe when a hinge H occurs and from then to end of test record also:
Hx, Hy

e) Test is complete when the angle between Po, Ho, and Pn is approximately 150° if a hinge occurs at H
OR
Po, Oo and Pn is approximately 15° if no hinge occurs.

f) Calculate for each position, the moment (Nm)
about O until a hinge occurs
about H after a hinge occurs

g) Calculate for each position, the angle of rotation as described in (e).

h) Plot the points on a copy of Figure 4.02.1(b) & (c).

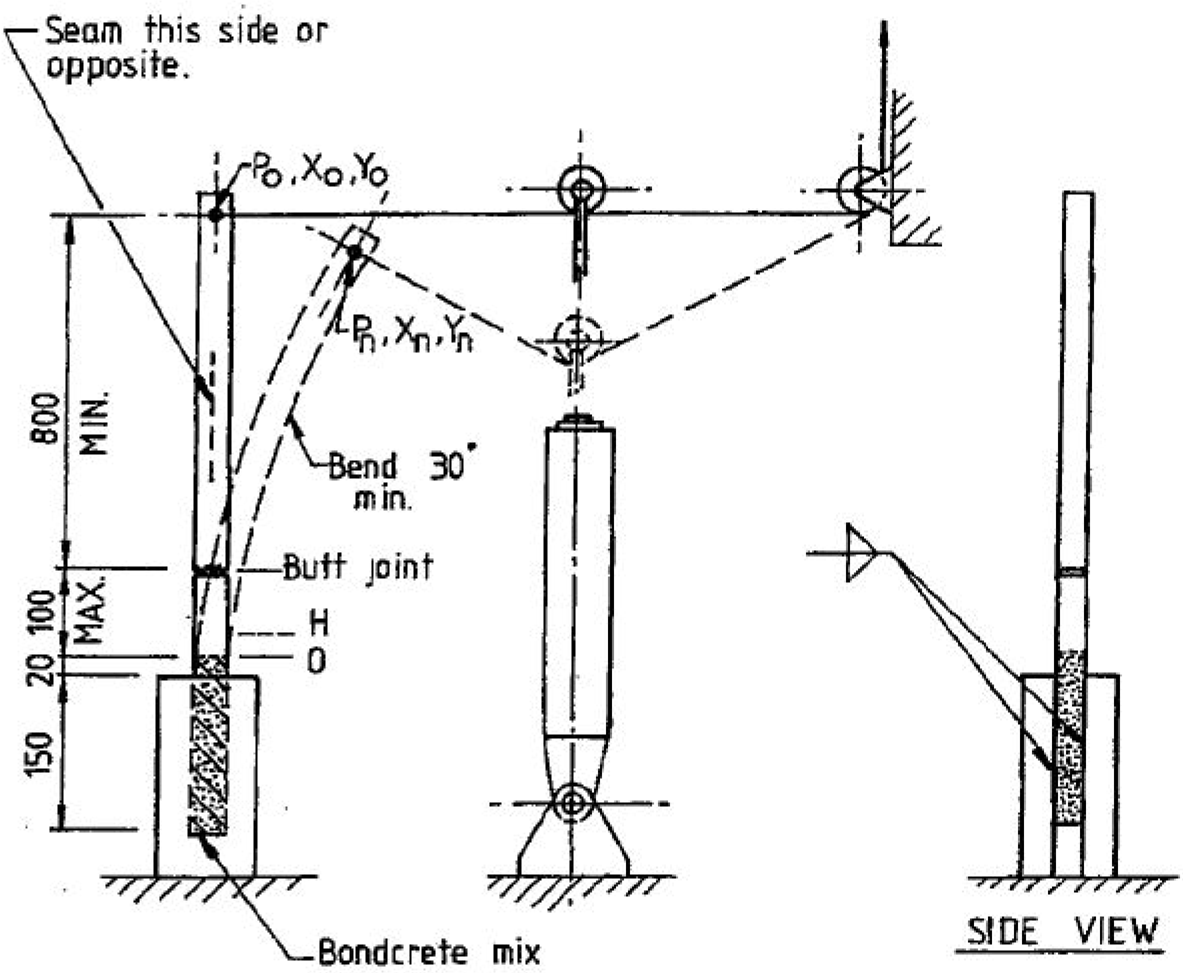
Two tests - opening and closing - are required.

For acceptance as being equivalent to the Code joint performance the resulting moment v

rotation curve shall lie within the acceptance envelope shown in F"IQ.4.02.1(b) & (c).

Note:

The code construction for this joint cals for a 40x40x2.3 RHS section to be inserted in the hoop pillar from its base below the floor and sUI rail to under side of the waist rail.Other methods of reinforcing this hoop pillar section will be considered satisfactory provided the preceding performance tests and full hoop tests of section 4.03 are complied with.



HOOP BUTT JOINT TEST

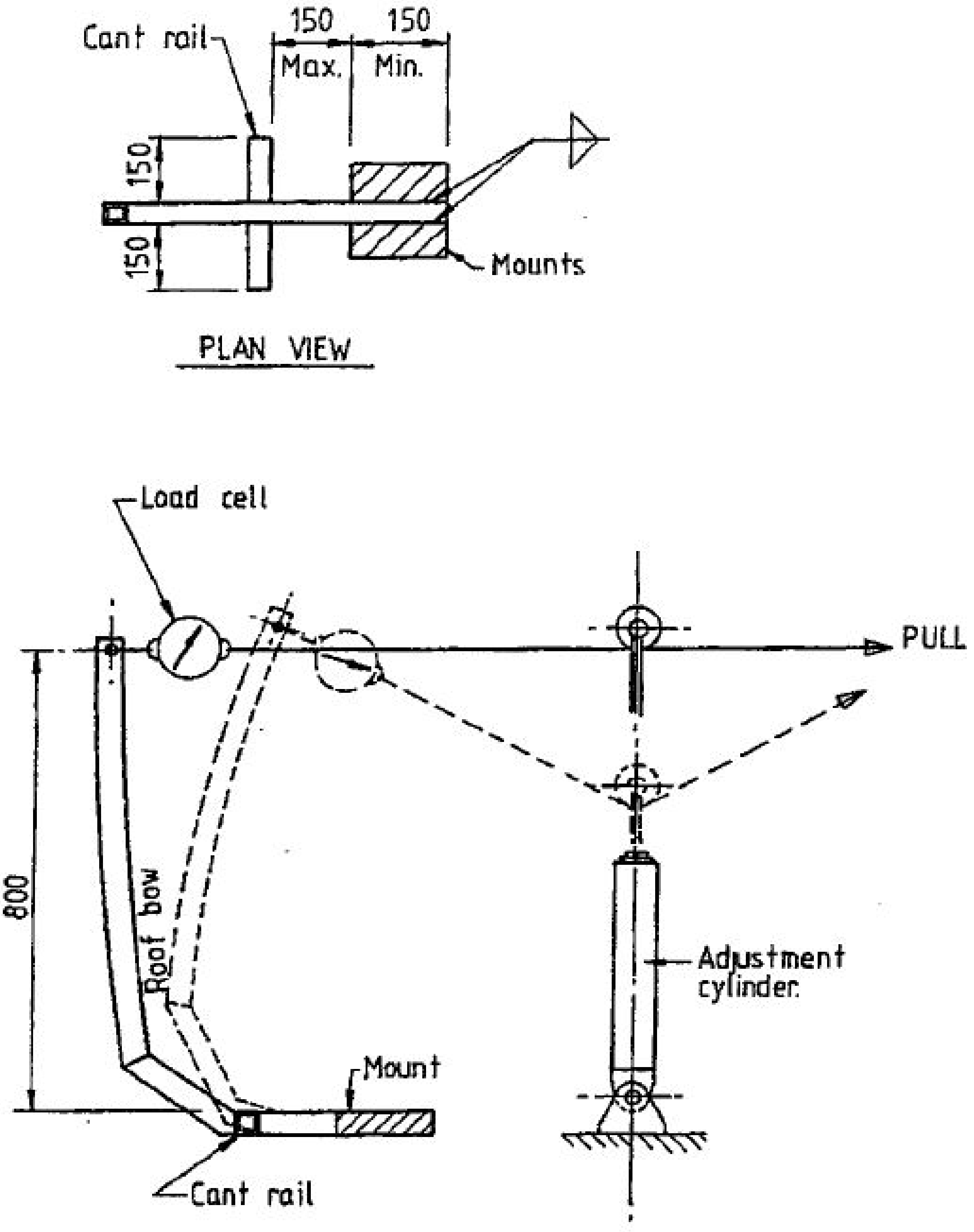
FIG. 4.02.2

4.2.2 Hoop - Butt Joint Performance Requirement

For this test, prepare the test piece by filling the lower part of the pillar section with a sand cement mix incorporating a fast setting agent such as Bondcrete, as indicated in figure 4.02.2.

a) Mount a section of pilar incorporating the butt joint as shown in figure 4.02.2.
b) Test in a similar manner to that shown in section 4.02.1 but in this case no measurements are needed.
c) Pull the test piece through a minimum angle or 30° or until a definite plastic hinge occurs in the pillar material.

For acceptance there shall be no weld failure. This shall be confirmed by magnetic particle examination; if acceptable, no full hoop test is required for this joint.



HOOP ROOF BOW TO PILLAR JOINT TEST

FIG. 4-02-3 (a)

4.2.3 Hoop Roof Bow - Pillar Joint Performance Requirement

For a joint construction that differs from that shown in the Code Pan •A'. such as illustrated in

Fig 4.02.3 (a) a total of four tests are required namely:

- An opening test and a closing test for joint sample mounted via the hoop pillar as shown in Fig4.02.3 (a).
- An opening test and a closing test for joint sample mounted via the hoop roof bow In a similar manner but with the pillar leg being 800mm long instead of the hoop leg.

The procedure outlined in paragraph (a) to (h) is to be followed for each of the four tests.

a) Mount a pillar section in a suitable fixture as shown in Figure 4.02.3(a). 150mm long sections of cant rail shall be welded to the hoop pillar in the appropriate position.

b) Test In both opening and closing modes by pulling at an angle of 900 to 1000 to the member being pulled.

c) Before starting each test, record co-ordinates for:-
Pull point "P" - Px, Py
Origin “O” - Ox, Oy

d) During each test record a minimum of B observations for:-
Px, Py; Ox, Oy; Load
Observe when a hinge H occurs and from then to end of test record also:-
Hx,Hy

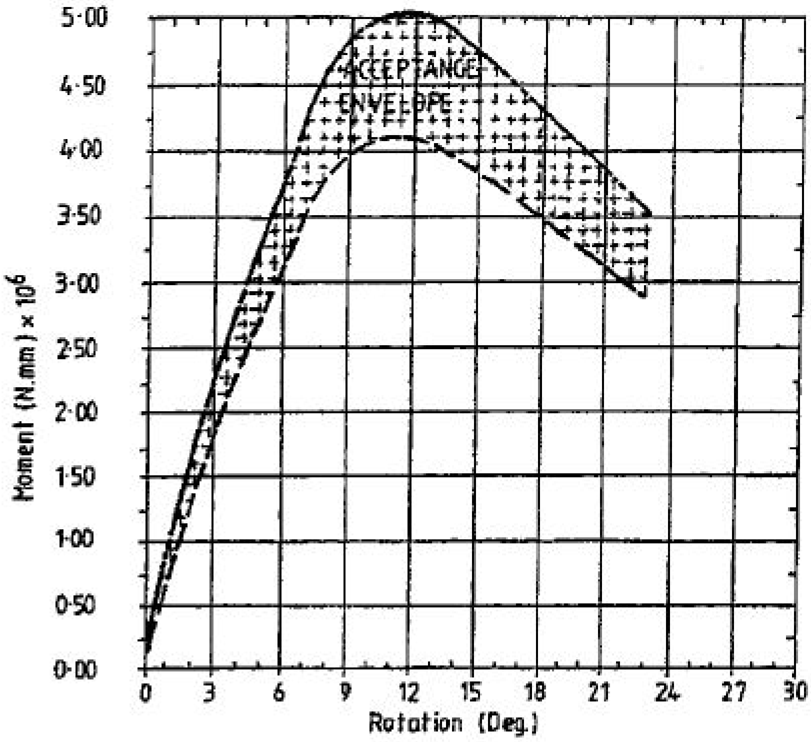
e) A test is complete when the angle between Po,Ho, and Pn is approximately 210 if a hinge occurs at H
OR
Po, Oo and Pn is approximately 21° if no hinge occurs.

f) Calculate for each position, the moment (Nm)
about O until a hinge occurs
about H after a hinge occurs.

g) Calculate for each position, the angle of rotation as described in (e).

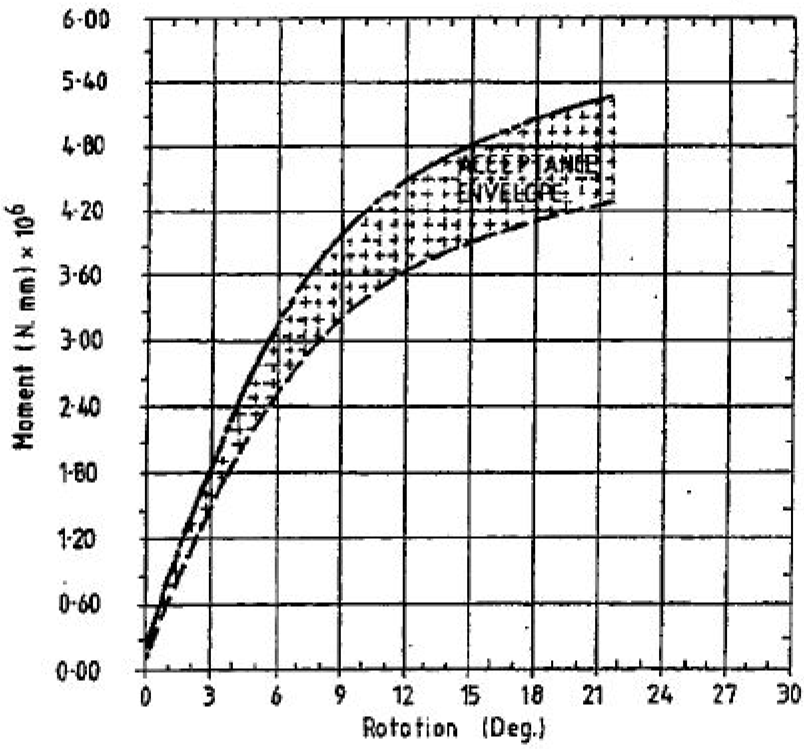
h) Plot the points on a copy of Figure 4.02.3(b) & (c).

For acceptance as being equivalent to the Code joint performance the resulting moment v rotation curves shall lie within the acceptance envelope shown in Fig. 4.02.3(b) & (c).



ROOF BOW - PILLAR PERFORMANCE - CLOSING.

FIG. 4- 02·3 (b)



ROOF BOW--PILLAR PERFORMANCE - OPENING.

FIG. 4·02·3 (c)

4.3 Full Hoop Testing

4.3.1 General

A full hoop test is required to verify the load deflection characteristics of a hoop with modified joints against the code performance data. Further the test is required to establish that the hoop collapse mechanism is similar to the code hoop; this requirement is designed to guard against the introduction of a significantly different collapse mode (for example due to excessive joint stiffness)} with the consequence of affecting the energy absorption capacity of the code hoop types shown in section 3.04.1.

The full hoop test may also be used to validate alternative floor bearer construction and hence the rotational stiffness of the hoop floor bearer construction is of significance.

The static testing of full hoops of either Profile 'A• or 'B' shall only be carried out on the satisfactory completion of joint validation tests as set out in section 4.02.

4.3.2 Testing Procedures

The following is general guide and is not intended as a fully detailed test procedure to produce the required performance graphs.

In their simplest form these tests can be made using:

A suitable pulling device which can be a chain block.

A load cell which may be an analogue crane scale.

A shadow board for recording the position of points to be measured.

A residual space template. ·

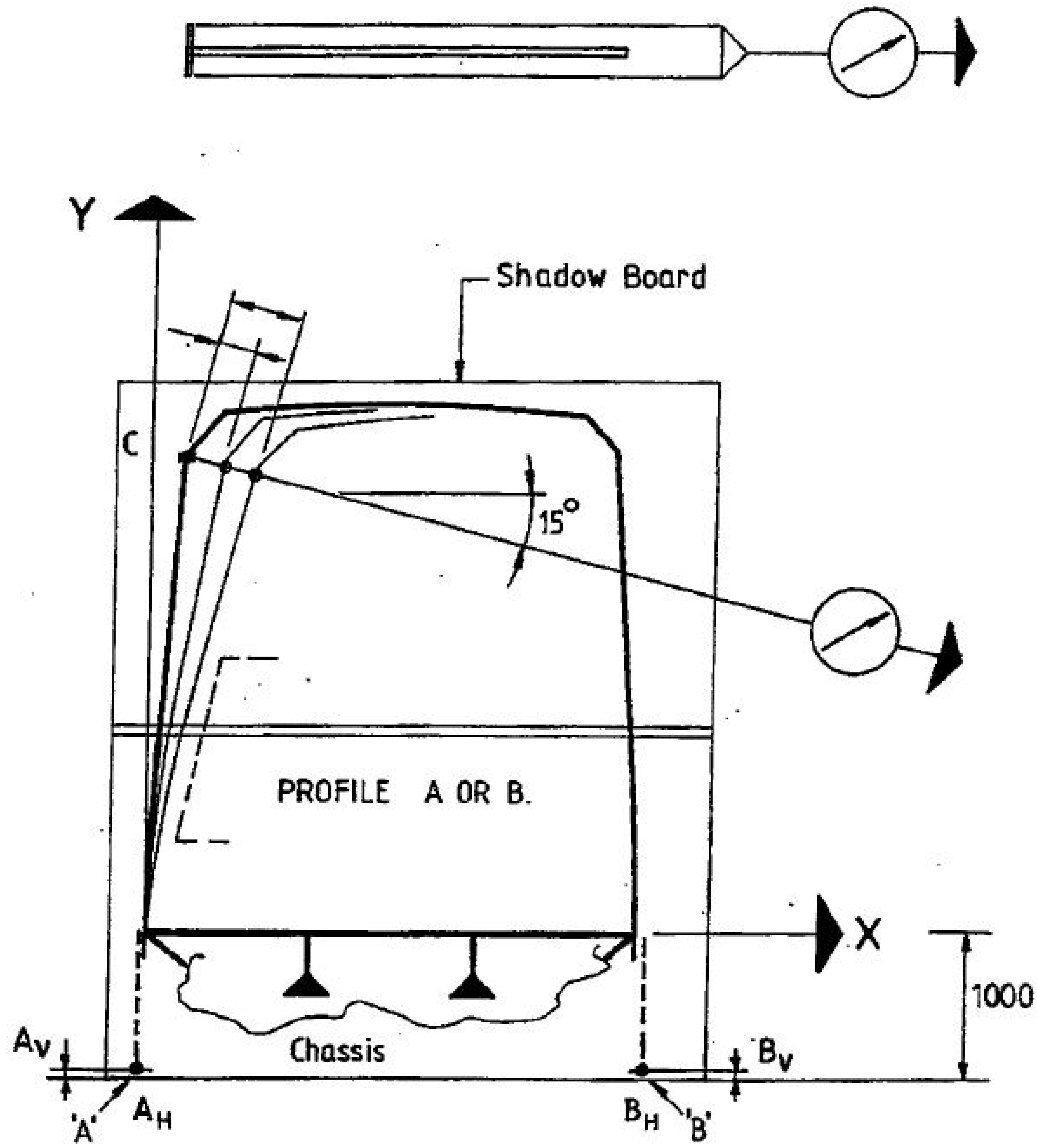
The hoop is to be built as a complete unit including floor bearer and chassis structure as illustrated in Fig. 4.03.2.One hundred and fifty millimetre lengths of sill, waist, cant rails shall be welded to the hoop in the appropriate positions.

The hoop and chassis structure shall be mounted to a rigid base frame at the chassis points with top of the floor bearer 1OOOmm above the ground as illustrated.

The hoop shall be stabilised laterally by horizontal guide bars; one at the waist rail level and the other at the cant ran level on each side. The hoop shall not be restrained otherwise.

The load shall be applied at the cant rail - point C in Fig 4.03.2 at an angle of 15° to the horizontal. A loading shoe that spreads the applied load across the full width of the hoop and up to 25mm either side of the cant rail shall be used. Load bars or rope shall run from the load shoe either side of the hoop and connect to the load measuring device as illustrated in Fig 4.03.2.

A straight bar shall be attached to each side of the hoop below the top sur1ace of the bearer with the other end stopping 50mm above the ground surface. These points are noted as positions A & B in Fig 4.03.2.This is used to assess the rotational stiffness of the floor bearer construction which must lie within prescribed limits.



FULL HOOP TEST - ASSEMBLY

FIG. 4.03.2

4.3.3 Hoop Profile ‘A’ Performance Requirement

The proposed hoop shall be validated by carrying out the tests using the equipment outlined in 4.03.2 and the following procedures or in an approved manner.

Carry out the following:

a) Apply a load to produce a 25mm deflection at the cant rail in the direction of the applied load.
b) Record the load and coordinates of point ‘C’
c) Check the clearance with the residual space template.
d) Check the movement of points ‘A' & ‘B’ in both vertical and horizontal planes from their original positions record these as AH, AV; BH,BV.

Repeat steps (a) to (d) with 50mm increments of cant rail movement until the total cant rail movement is 610mm or contact with the residual space template is reached.

The horizontal and vertical movement of point "A'& 'B' shall not exceed the following:

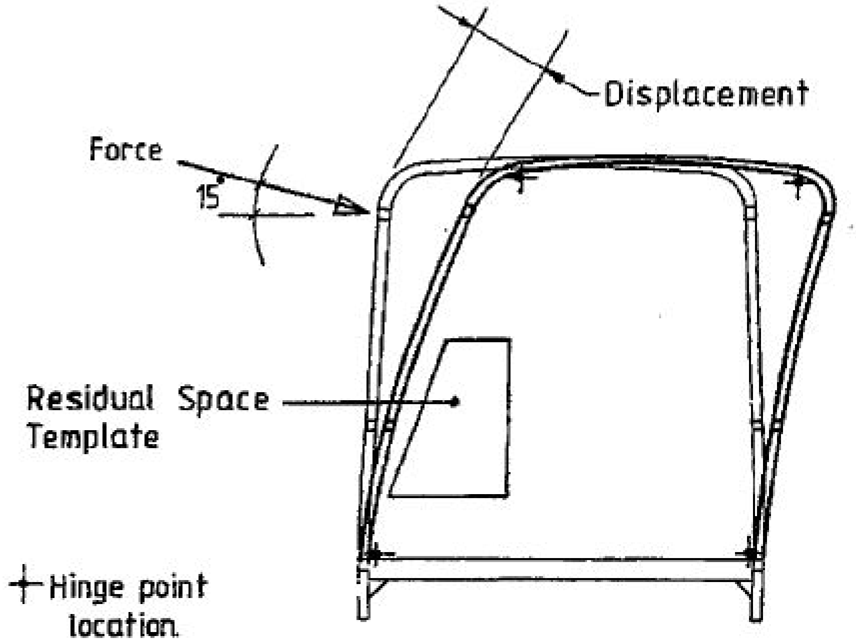
Horizontal displacement - 50mm

Vertical displacement - 15mm

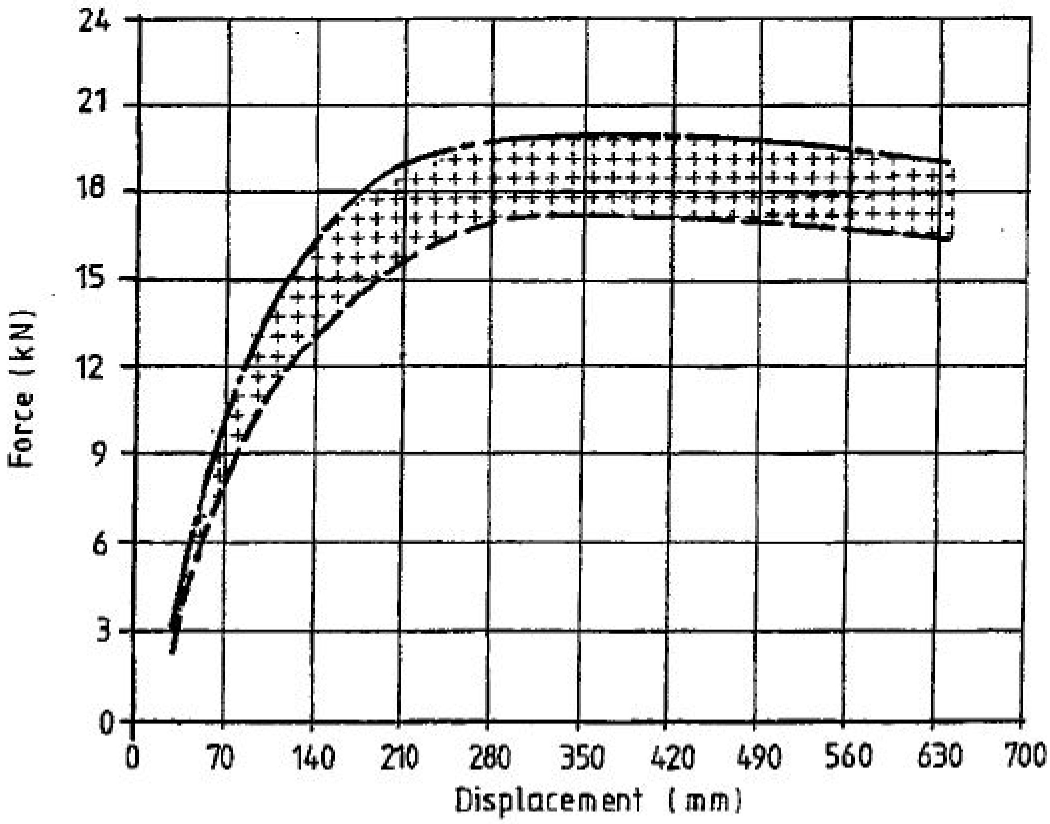
Should these be exceed then the floor bearer structure is too flexible for acceptable hoop performance and shall be strengthened and the test repeated.

From the force and displacement readings of the test procedure the load v deflection values shall be derived and plotted for point ‘C’ on figure 4.03.3.

For acceptance as being equivalent to the Code hoop performance the resulting load - deflection curve shall lie within the envelope shown in Fig. 4.03.3, the collapse shape shall be as illustrated and the residual space shall not be encroached.



STANDARD HOOP — DEFLECTION COLLAPSE MECHANISM.



HOOP PROFILE 'A' - PERFORMANCE ENVELOPE

FIG. 4-03-3

4.3.4 Hoop Profile 'B' Performance Requirement

The proposed hoop shall be validated by carrying out the tests using the equipment outlined in 4.03.2 and the following procedures or in an approved manner.

Carry out the following:

a) Apply a load to produce a 25mm deflection at the cant rail in the direction of the applied load.
b) Record the load and coordinates of point 'C'
c) Check the clearance with the residual space template.
d) Check the movement of points 'A' & 'B' in both vertical and horizontal planes from their original positions record these as AH, AV; BH, BV.

Repeat steps (a) to (d) with 50mm increments of cant rail movement until the total cant rail movement is 440mm or contact with the residual space template is reached.

The horizontal and vertical movement of point 'A'& 'B' shall not exceed the following:

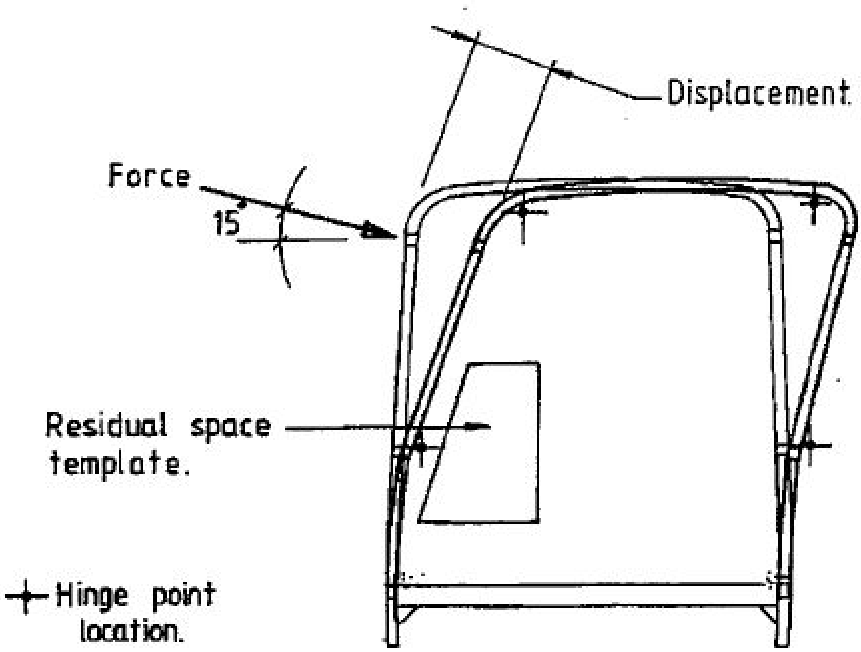
Horizontal displacement - 50mm

Vertical displacement - 15mm

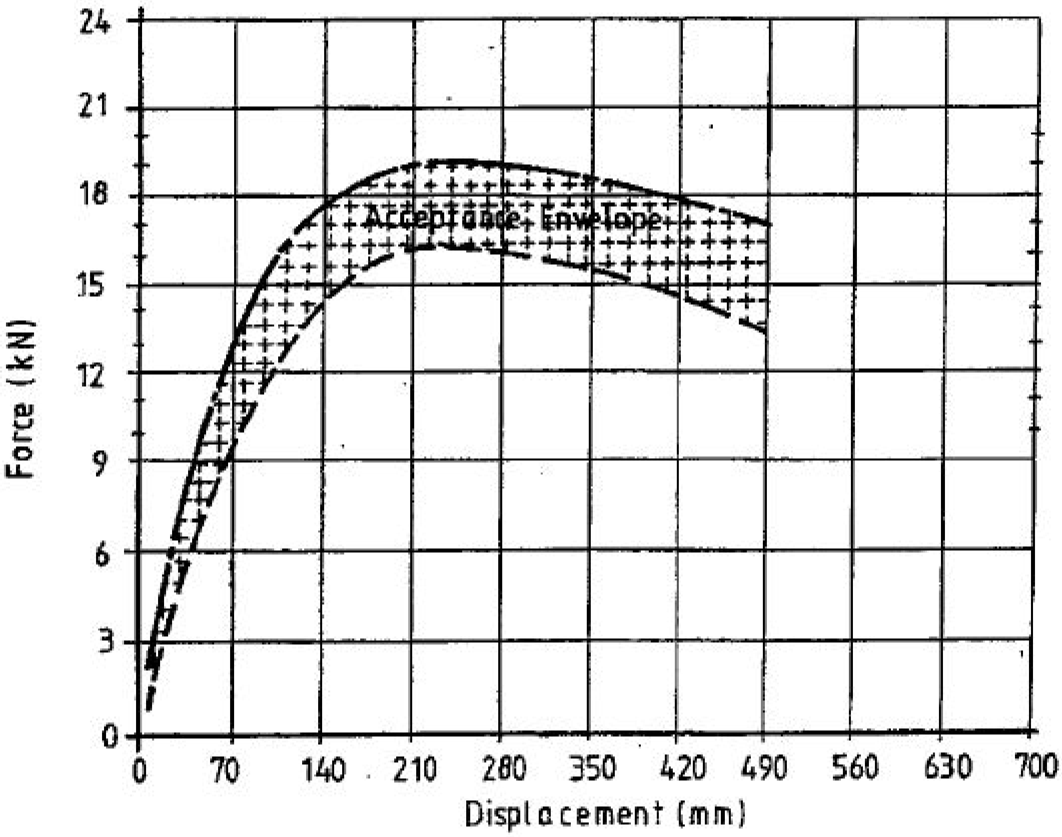
Should these be exceed then the floor bearer structure is too flexible for acceptable hoop performance and shall be strengthened and the test repeated.

From the force and displacement readings of the test procedure the load v deflection values shall be derived and plotted for point 'C' on figure 4.03.3.

For acceptance as being equivalent to the Code hoop performance the resulting load - deflection curve shall lie within the envelope shown in Fig. 4.03.3, the collapse shape shall be as illustrated and the residual space shall not be encroached.



STANDARD HOOP — DEFLECTION COLLAPSE MECHANISM



HOOP PROFILE 'B' – PERFORMANCE ENVELOPE.

FIG. 4·03·4

APPENDIX A

CENTRE OF MASS DETERMINATION PROCEDURE

1 Horizontal Location of CoM.

Weigh bridge the vehicle and record the front and rear axle weights. Retain the weigh bridge dockets for quality assurance documentation.

Measure the wheelbase [WB) with the wheels in the straight ahead position.

In a two axle vehicle:

[WB] = distance from the centre of front wheel to the centre of the rear wheel.

In a three axle vehicle:

[WB] depends on the configuration of the rear axle group.

[WB] = distance from the centre of front wheel to centre of the nearest rear wheel plus:

one third the distance between the rear wheels when the leading rear axle has four wheel and a trailing two wheel axle.

or

two third the distance between the rear wheels when the leading rear axle has two wheels and a trailing four wheel axle.

Calculate the horizontal location of the CoM - XO - as Illustrated in Fig A.1

$$X0 = \frac{RAxWB}{[FA + RA]}$$

Where

FA - is the Front Axle Load

RA - is the Rear Axle Assembly Load

WB - is the Wheel Base

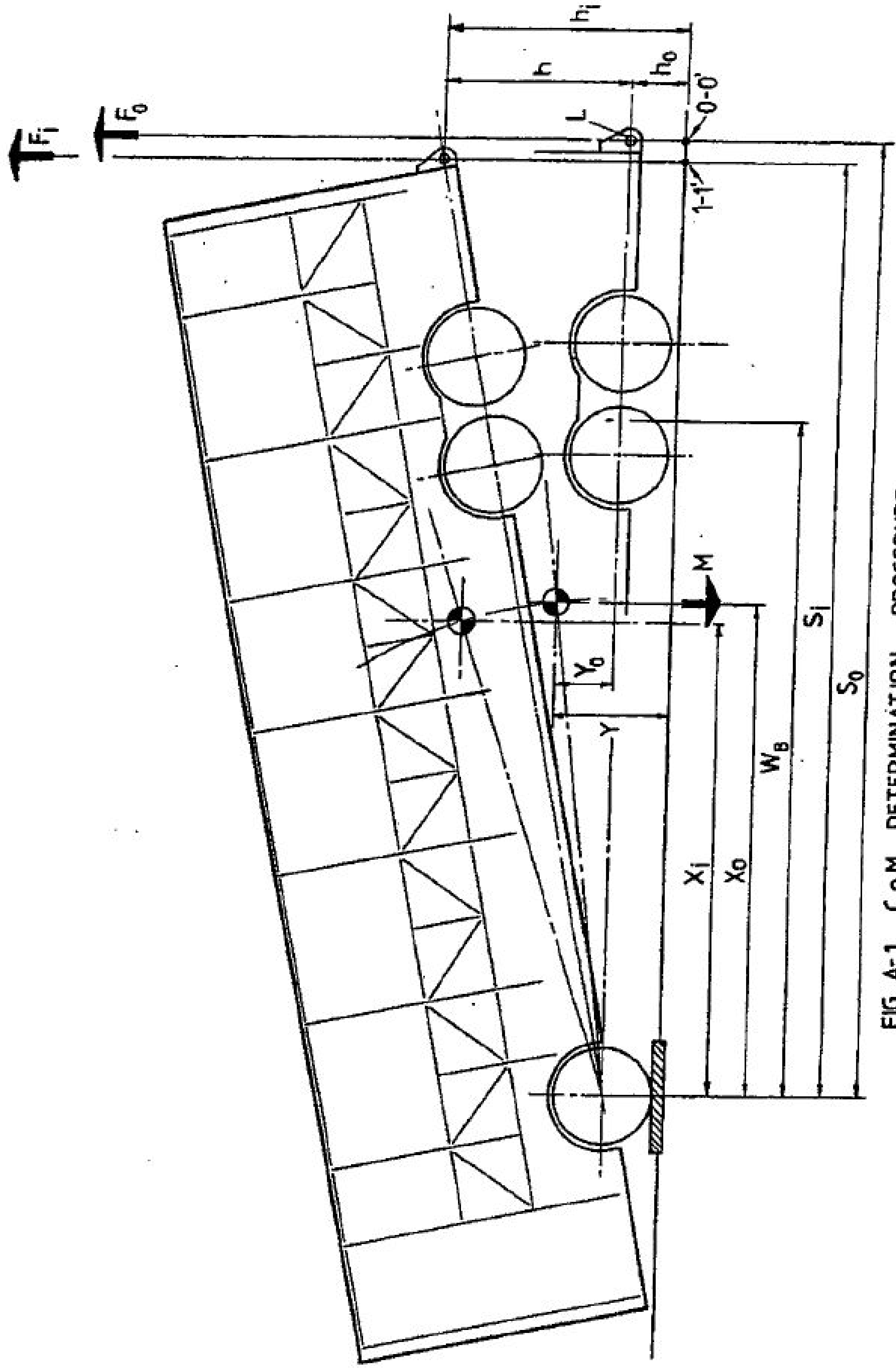


FIG. A-1 CoM DETERMINATION PROCEDURE

2 Check Crane Equipment & Mass Distribution

Connect the crane to a suitable lifting point (L) at the rear of the vehicle. The point L shall be at the same height from the ground as the wheel centres.

To record the lifted load, the crane lifting equipment shall have a load measuring device with a load display accurate to within 5kg.The use of a load cell with digital read out located at operator level is strongly recommended.

Secure the rear axle assemblies to prevent them dropping and secure the front axle to prevent its spring from depressing when the vehicle is lifted.

Measure the distance S0 - the distance from the front axle to the crane lifting point (L), refer Fig A.01. Using a plumb bob, from point (L), mark a line (O-O) on the ground parallel to the rear axles; the distance from this line to the front axle is S0.

Lift the vehicle until the rear tyres are 10mm clear of the ground.

Read the load measuring device.

Compare the reading F0 with the following calculated value:

$$F0 = \frac{[FA + RA] * X0}{S0}$$

If the reading F0 is greater than 1% of the calculated value F0 then repeat step A.02 to this point.

If the error still occurs repeat step A.01.

Lower the vehicle to the ground before proceeding with A.03

3 Vertical location of CoM

In carrying out the following instructions refer to Fig A.01

A.03.1 Step 1

Measure 'h0' - the vertical distance from the ground {line O-O) to the centre of the lift point (L)i.e.the centre of axles.

Raise the vehicle through a minimum of 500 mm.

Using the plumb bob from lift point (L), mark a line 1-1 parallel to line 0-0.

Read the load measuring device (Fi).

Measure "Si -• the distance from the front axle to line 1·1.

Measure "hi' - the distance from the ground to the centre of lift point (L).

Make the following check calculations

Calculate ‘S’·

$$S = \sqrt{}\{[hi - h0]^2 + Si^2)$$

The value of ‘S’ shall lie within 2% of S0

ie. 0.98*S0 < S < 1.02 * S0

If this relationship is correct proceed to the next step otherwise repeat section A.03.1.

A.03.2 Step 2

Calculate the vertical CoM localion from the following:

h = hi – ho

$$Xi = \frac{Fi * Si}{[FA + RA]}$$

$$Y0 = \frac{X0 * Si - Xi * S0}{h}$$

A.03.3 Step 3

Repeat steps A.03.1 to A.03.3 for two more height increments each of 1000mm and calculate the ‘YO' value.

Calculate the mean of the three Y0 values. If the calculated values for Y0 lie within 10% of this mean, adopt the mean value. If not repeat step 2 & 3.

For the purpose of the code use the mean value of Y0 in -

Y= YO + hO

Where ‘Y’ is the vertical distance from the ground to the CoM as required by the Code.

APPENDIX B

ROLL OVER DESIGN ENERGY CURVES FOR HOOP PROFILE 'A" & 'B"

1 GENERAL

The curves in figures B-1 & B·2 are produced for the Code Hoop Profiles 'A' & 'B' using curved roof bow construction as specified on drawing VSB 7.02 of Pan A of the Code.

The curves give the value of factor Kc for use in the following equation:

Ec=M * Kc

Where M - the tare mass of the vehicle in tonnes

Kc - factor from figure B-1 or B-2

Ec - the Code Rollover Energy in kilo Joules

2 Profile 'A' - Figure B·1

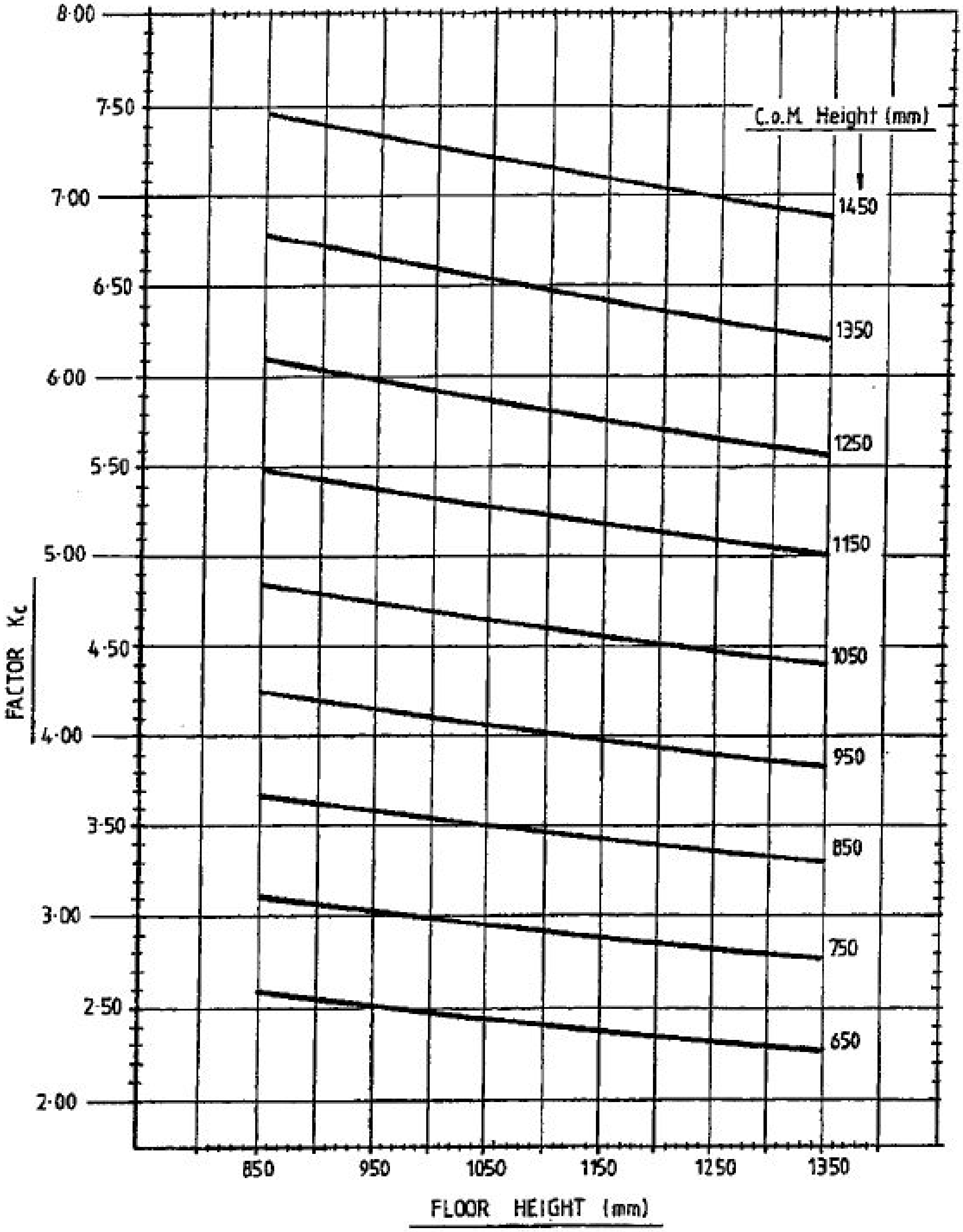
The figure is used in the following manner.

Enter the diagram at the desired floor height and move vertically upwards until the centre of mass height (CoM height) value is reached. Move horizontally to the vertical scale on the left and read off the value of factor Kc.

Use this value of Kc in the equation in 8.01 above to determine the code rol over energy as required under section 3.03.2.

The centre of mass height (CoM height) used in the diagram is that determined in accordance with section 3.03.1.

For CoM heights other than those plotted, linear interpolation between adjacent curves is permitted. For example tor a CoM height of 1100mm with a floor height of 1250mm; move up the 1250mm floor height ordinate until the 1050 CoM height curve is reached. Now locate the point midway between the 1050 & 1150 curves this is the 1100 CoM height for the 1250mm floor height. Now move horizontally to the left and read off the value of Kc which is 4.8.



CODE FACTOR 'Kc'—HOOP PROFILE 'A'

FIG. B-1

3 Profile 'B' - Figure B·2

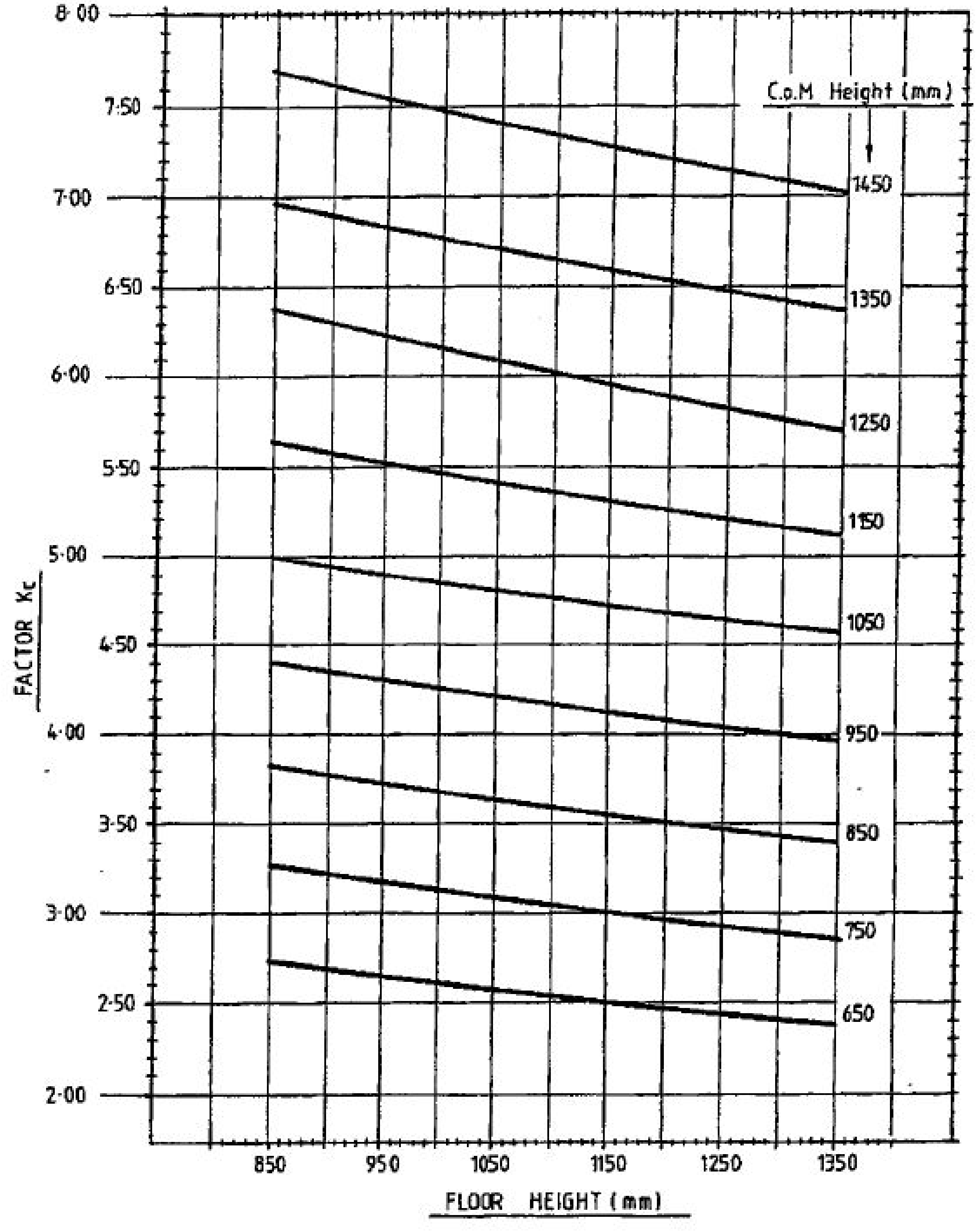
The figure is used in the following manner.

Enter the diagram at the desired floor height and move vertically upwards until the centre of mass height (CoM height) value is reached. Move horizontally to the vertical scale on the left and read off the value of factor Kc.

Use this value of Kc in the equation in B.01 above to determine the code roll over *energy* as required under section 3.03.2.

The centre of mass height (CoM height) used in the diagram is that determined in accordancewith section 3.03.1.

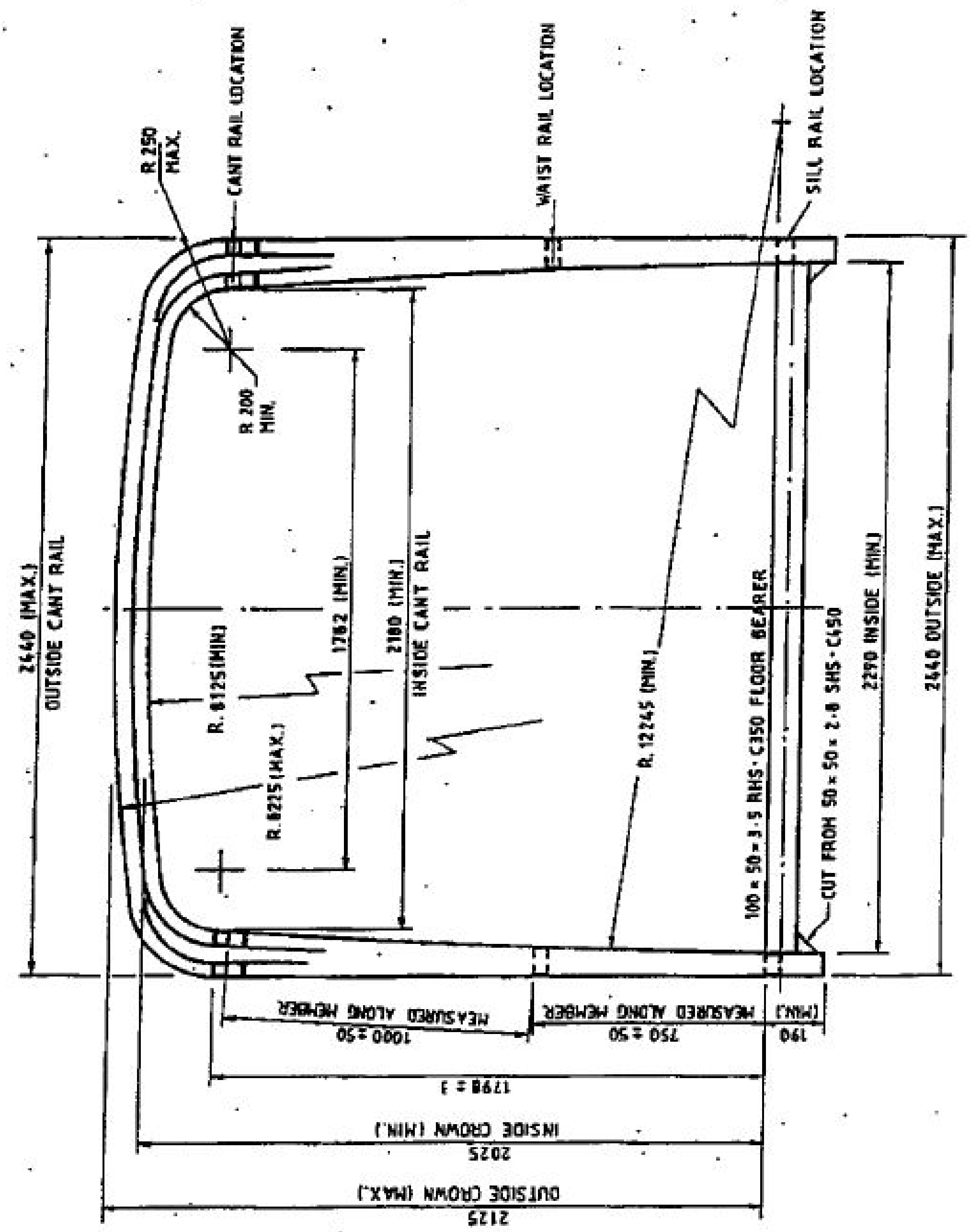
For CoM heights other than those plotted, linear interpolation between adjacent curves is permitted. For example for a CoM height of 1100mm with a floor height of 1250mm; move up the 1250mm floor height ordinate until the 1050 CoM height curve is reached. Now locate the point midway between the 1050 & 1150 curves this Is the 1100 CoM height for the 1250mm floor height. Now move horizontally to the felt and read off the value of Kc which is 4.95.



CODE FACTOR 'K_C' — HOOP PROFILE 'B'

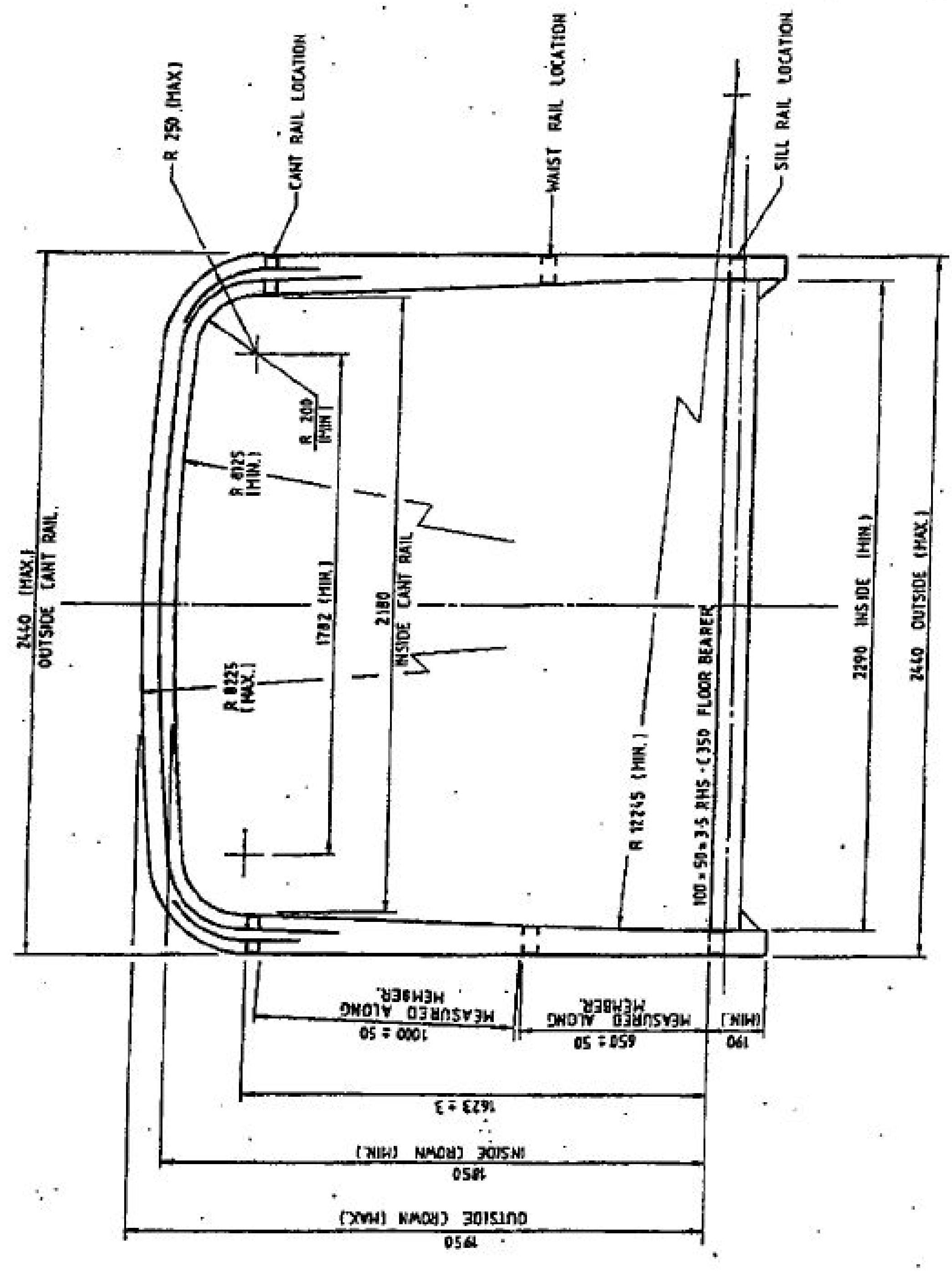
FIG. B-2

APPENDIX C



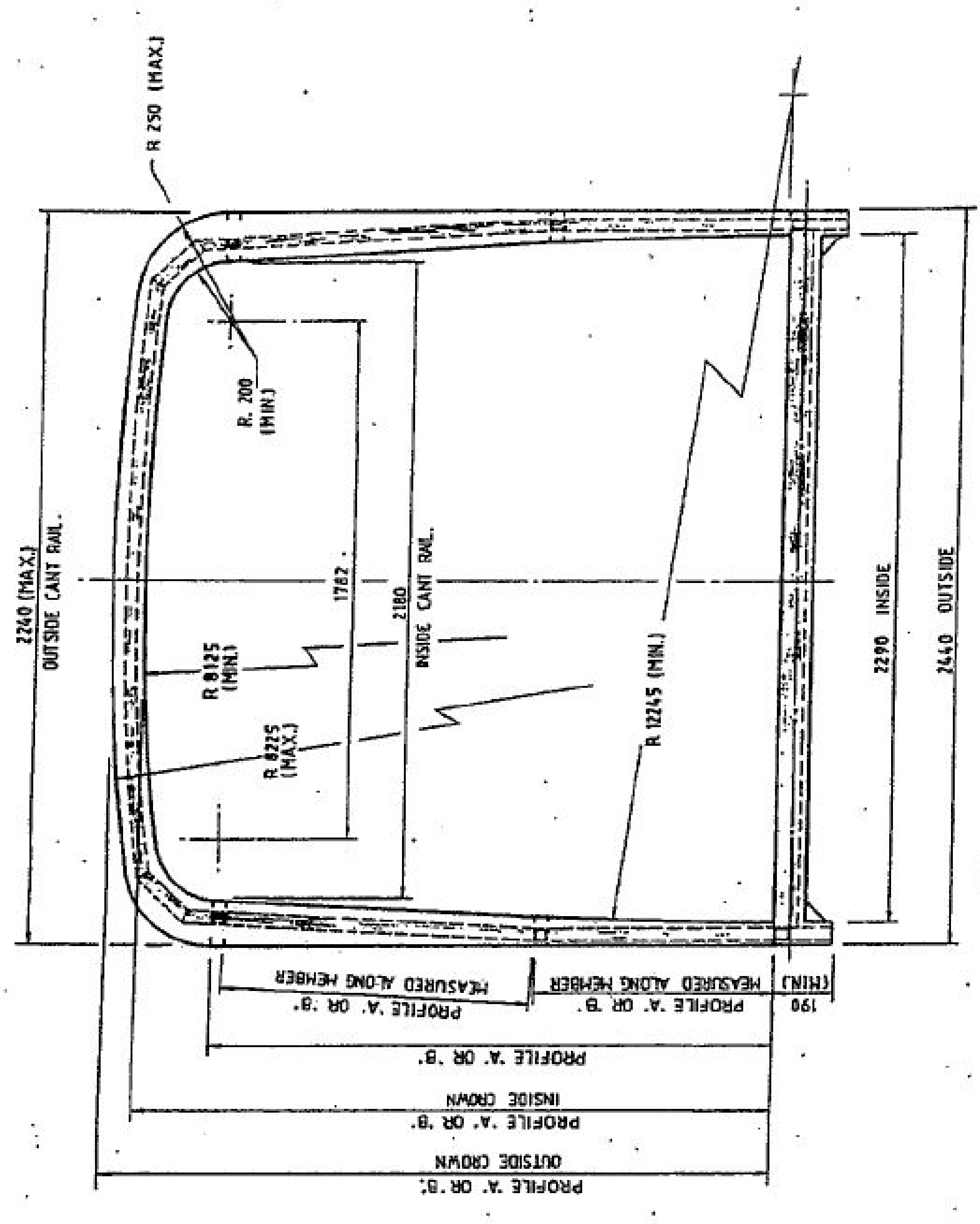
ALLOWABLE ROLL CAGE CROSS SECTION ENVELOPE - PROFILE 'A'

FIG. C-1



ALLOWABLE ROLL CAGE CROSS SECTION ENVELOPE - PROFILE 'B'

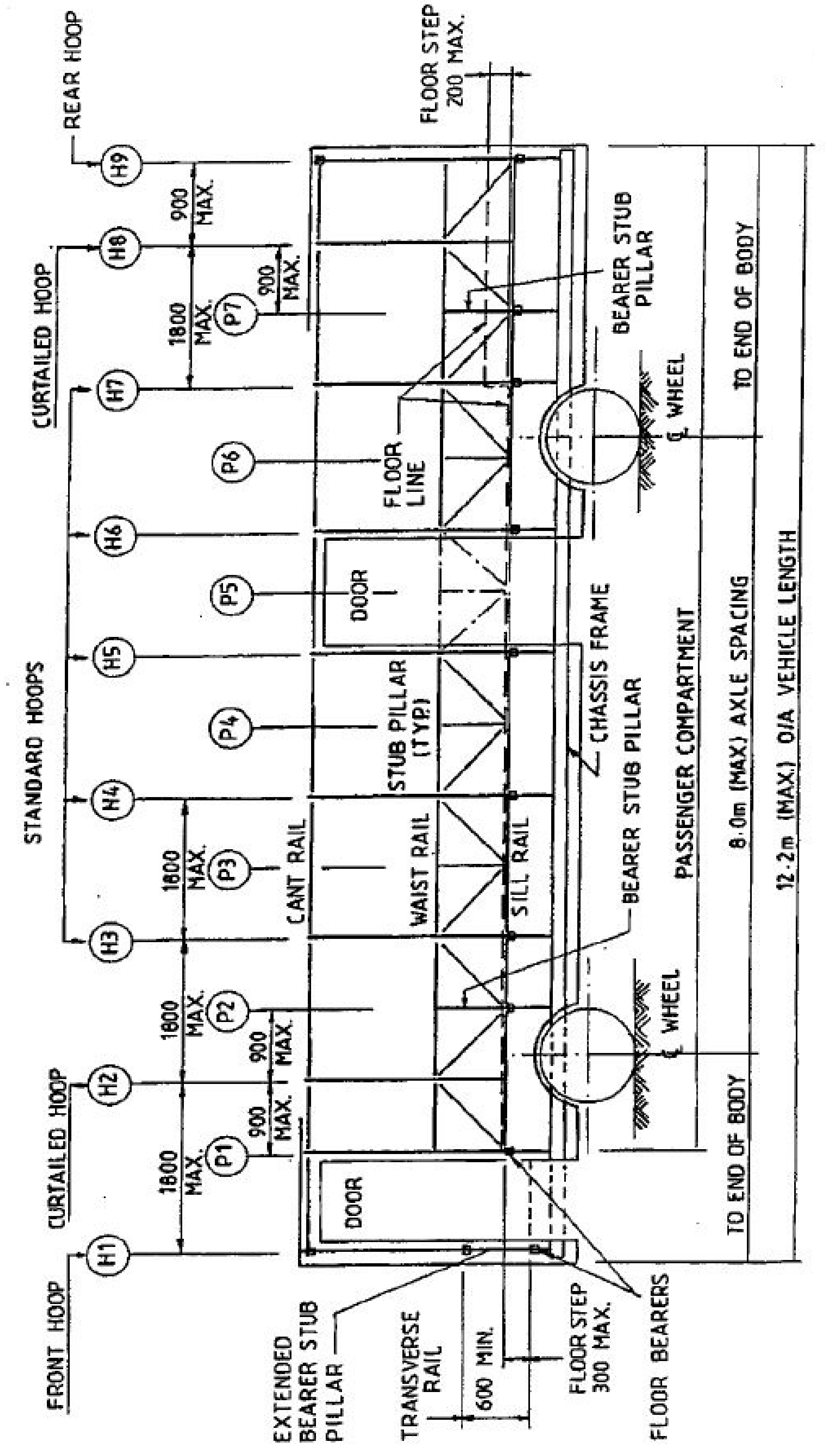
FIG. C-2



TYPICAL ROLL CAGE CROSS SECTION ENVELOPE WITH MITRED CANT RAIL HOOP

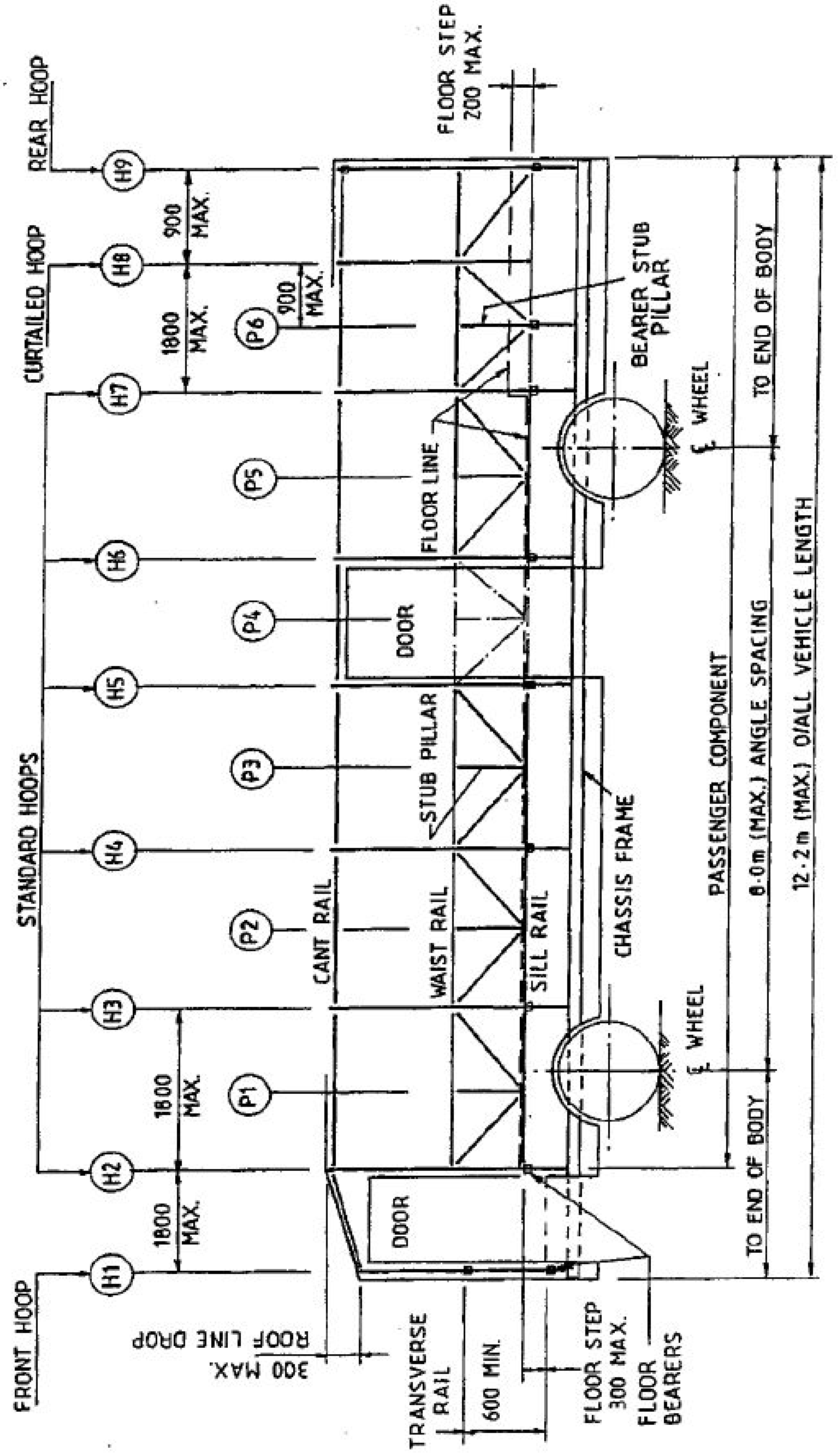
FIG. C-3

APPENDIX D



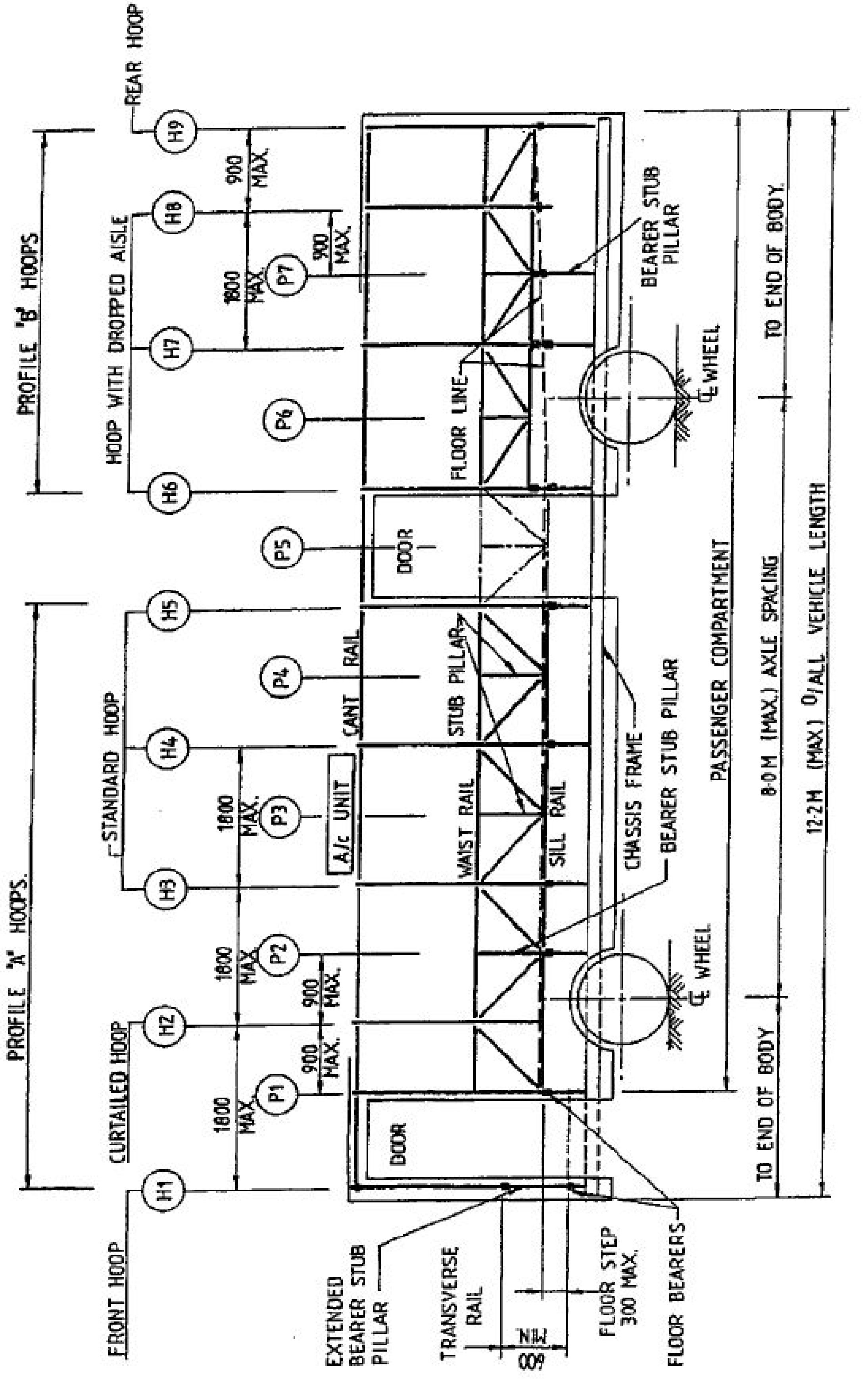
TYPICAL ROLL CAGE SETOUT FOR STANDARD BUS USING HOOPS OF EITHER PROFILE 'A' OR 'B'.

FIG. D-1

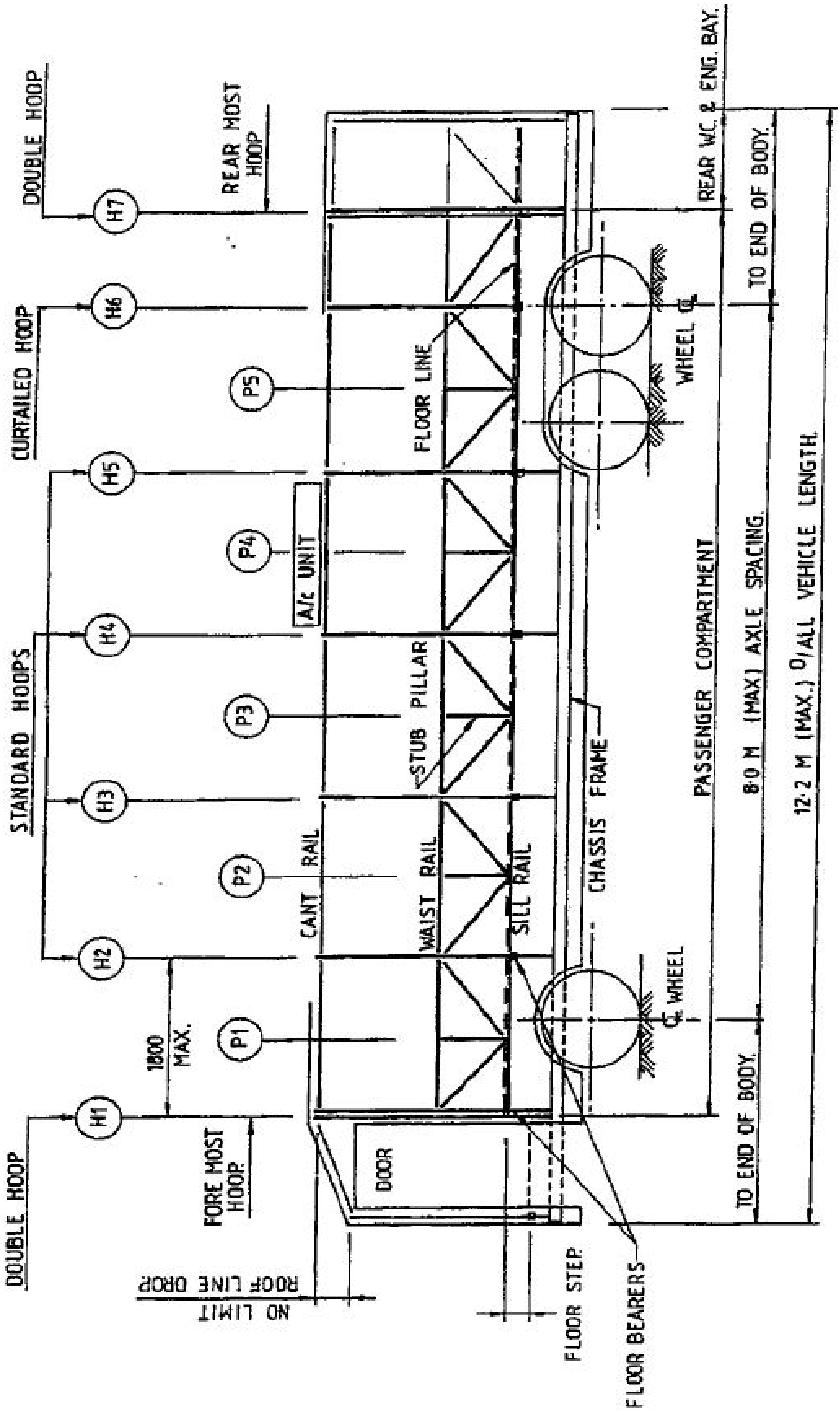


TYPICAL ROLL CAGE SETOUT FOR LOWERED ROOF LINE BUS USING HOOPS OF EITHER PROFILE 'A' OR 'B'.

FIG. D-2



TYPICAL ROLL CAGE SETOUT FOR BUS WITH REAR AISLE FLOOR.
& ROOF MOUNTED A/c UNIT.
FIG. D-3



TYPICAL ROLL CAGE SETOUT FOR COACH WITH LOWERED ROOFLINE.

FIG. D-4

APPENDIX E

Air Conditioning Unit

The effect, during roll over impact, of an air conditioning unit mounted to the roof of the bus roll cage has been examined.

The mounting methods allowed for in the CRASHD analysis may be summarised as follows:-

Model A This corresponds to an A/c unit that has little flexural strength and is rubber mounted to the roof bows.

Model B This corresponds to a rigid *Ale* unit and a mounting which has been flexibly mounted directly onto the roof bow.

The performance of both type 'A' and 'B' profiles have been considered and the following requirements are applicable to both profiles.

The following limitations are imposed on the equipment and equipment mounting procedures:-

(i) The air conditioning unit shall have a total mass inclusive of ducts, cowlings, framework, pipe/hose connections etc of not more than 250kg.

(ii) The centre of mass of the complete unit shall be at a height of not greater than 125mm above the top surface of the roof bows.

(iii) The unit shall be mounted to the roll cage structure by attachment to at least two hoops which may be by way of the roof stringers. Only one of the supporting hoops may be a curtailed hoop.

(iv) The method of mounting shall place the centre of mass of the unit on the longitudinal_centre line - z axis - of the roll cage. Further for a support method using:

a) Two hoops. The CoM of the unit shall be located within the centre 10% of the hoop spacing.

b) Three hoops. The CoM of the unit shall lie within 5% of the hoop spacing on either side of the centre hoop.

(v) The frame work supporting the unit shall be torsionally and flexurally stiff with the deflection of the framework limited to 1/500th of the hoop spacing under a loading of the unit mass times 2.5g.

For example for a 250 kg A/c unit the loading required is:

250kg x 2.5 x 9.8 = 6.13kN

This requirement shall be met with the load applied both vertically upwards (+Y axis) and downwards (-Y axis).

(vi) If mounted directly to the hoops the connections shall be by either two or three brackets attached to the hoop at approximately the quarter and centre points of the hoop bow. The attachment brackets shall be welded to the hoop in the direction of the hoop span and NOT ACROSS the width of the hoop. The brackets SHALL NOT be attached to the hoop by bolting or riveting.

(vii) If mounted to the hoops by way of roof stringers then these shall be spaced at approximately the quarter and centre points of the hoop bow.

If all the foregoing requirements are satisfied then the unit assembly meets the Code criteria.

The method of accommodating the effect of the A/c unit on the roll cage is by down rating the 'Hoop Energy Absorption Rating' given in Section 3.04.1. for the supporting hoops.

For an A/c unit supported by two hoops, the energy absorption rating for each supporting hoop shall be reduced by 0.75kJ

For an A/c unit supported by three hoops the energy absorption rating for the central hoop shall be reduced by 0.9kJ and by 0.30kJ for each of the other two hoops.

APPENDIX F

SCHEDULE OF CODE DOCUMENTS