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Preliminary Design of Passive Tilting System for Amcoach

Volume 2. Preliminary Design for Amcoach Tilting Modification

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16. Abstract

A preliminary design of the tilting truck for AMCOACH is presented to achieve speed-up in cerves without increasing lateral acceleration of carbody, to maintain good ride quality and shorten operation time. The passive tilting system is adopted on the basis of successful experiences of Japanese National Railways (JNR) 381-series tilting trains. This report presents a description of truck and truck components, modification of carbody, truck performance, ride quality, stress analysis, performance simulation of vehicle running through curves and operation time reduction by the modified tilting Amcoach train between New York and Washington.

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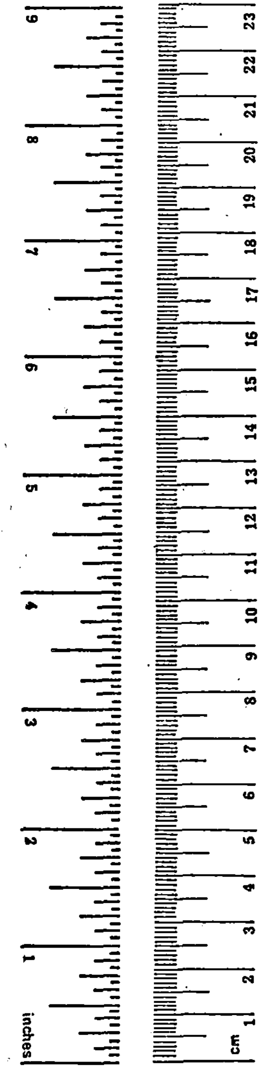
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

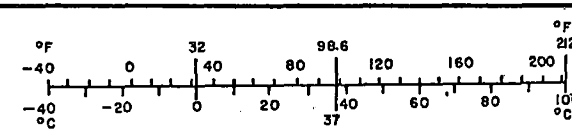
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

This is a report of preliminary design of a passive tilting truck retrofitting for AMCOACH.

The tilting truck is designed in order to achieve speed-up in curves without increasing lateral acceleration of carbody, to maintain good ride quality and to shorten operation time.

In designing the truck, the passive tilting system is adopted on the basis of successful experiences of Japanese National Railways (JNR) 381 series tilting trains.

This report presents description of the truck, modification of the carbody, truck performance, stress analysis and performance of the vehicle running through curves.

2. GENERAL DESCRIPTION OF TRUCK

The truck is a four-wheel truck incorporated with such devices as cylindrical journal box guide, body mount type air spring, roller type passive tilting mechanism, disc brake and unit type tread brake.

The truck wheelbase is 2500 mm (98.4")

The maximum tilting angle is 6 degrees.

The features of the truck are as follows.

1) Light weight unsprung part by adoption of hollow axles.

2) Dry type (without oil) cylindrical journal box guide for easier maintenance and better running performance.

3) Roller type passive tilting system for high speed performance in curves.

4) Diaphragm type secondary air spring with good lateral ride quality.

5) Truck frame and bolster of steel plate fabricated construction.

The truck is shown in Figure 2.1.

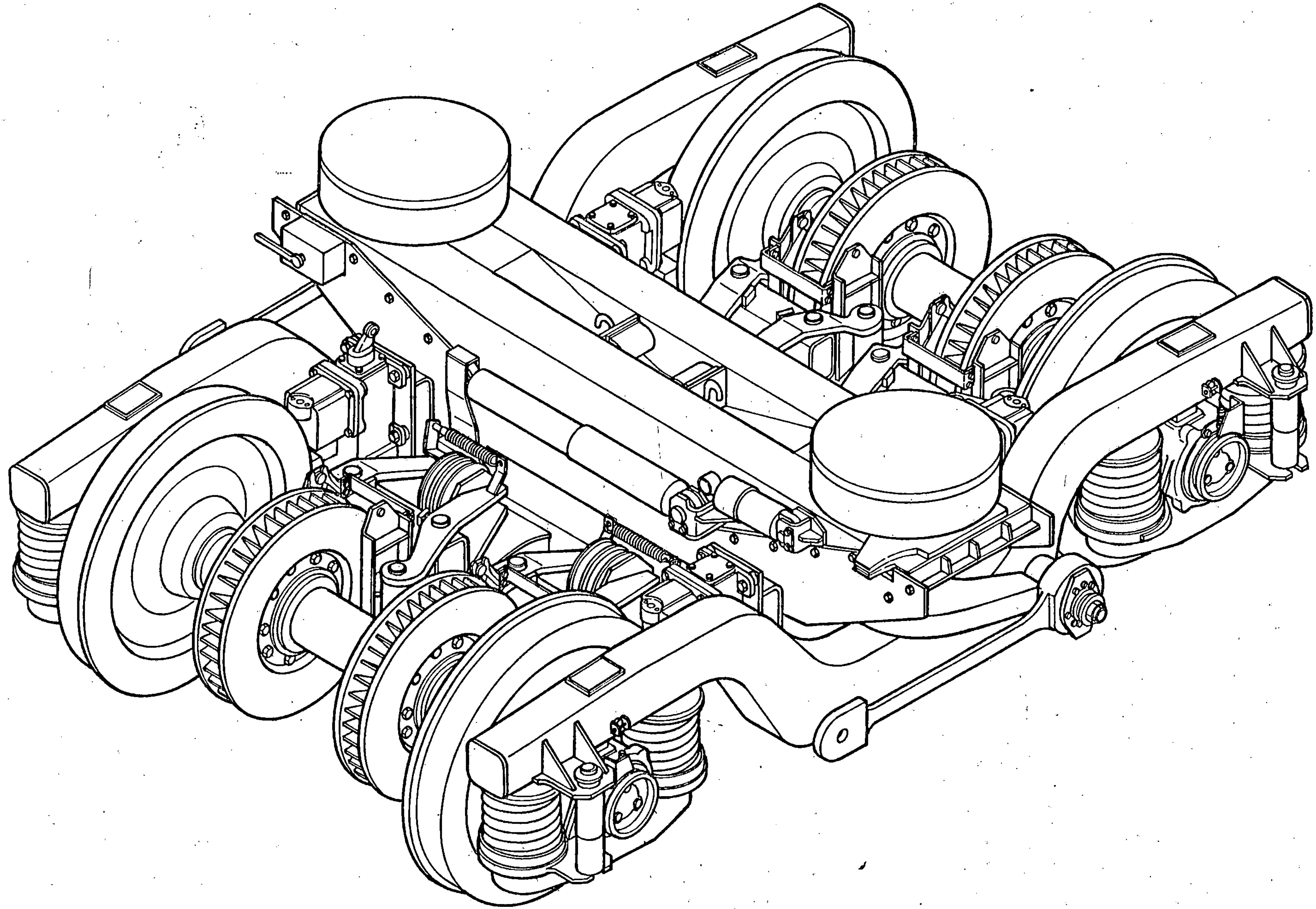


Figure 2.1 General View of Tilting Truck

2.1 PRINCIPAL DIMENSIONS

- Track gauge ..... 1435 mm (4'-8½")
- Wheelbase ..... 2500 mm (98.4")
- Wheel Diameter ..... 914 mm (36")
- Maximum tilting angle ..... 6 degrees
- Height of tilting center from top of rail ... 2700 mm (106.3")
- Maximum operation speed ..... 193 Km/h (120 m p h)

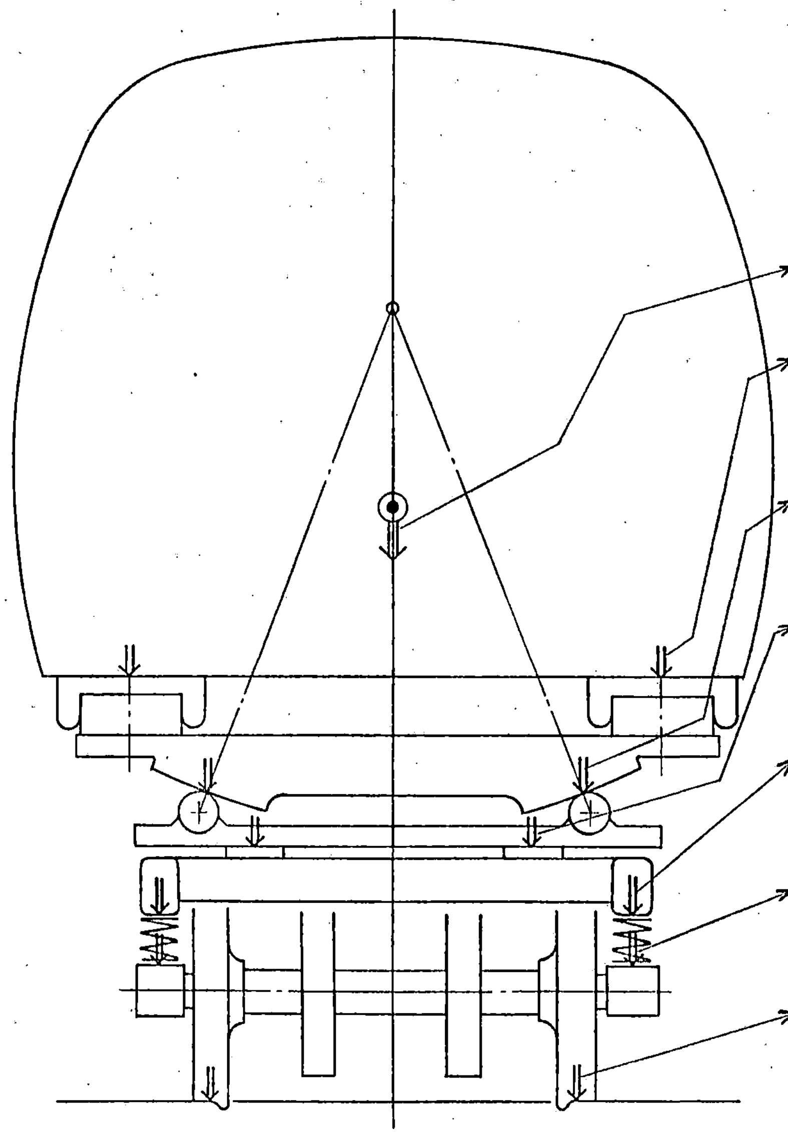
The distance between tilting center and center of gravity of carbody is 800 mm. (Cf. Section 7.8)

2.2 WEIGHT AND LOAD CONDITIONS

Empty car weight and loads are as follows.

° Empty car weight	49880 Kg (109966 lbs.)
° Normal load	5667 Kg (12494 lbs.)
(water	(315 Kg (694 lbs.)
59 passengers)	90.7 Kg (200 lbs.)x59 = 5352 Kg (11800 lbs.))
° Maximum load	7935 Kg (17494 lbs.)
(water	(315 Kg (694 lbs.)
84 passengers)	90.7 Kg (200 lbs.)x84 = 7620 Kg (16800 lbs.))

Car weight and load conditions are shown in Figure 2.2.



	TARE CONDITION	NORMAL CONDITION	MAX. CONDITION
WEIGHT OF CAR BODY WITH PASSENGERS AND WATER	35,040^{kg}	40,707^{kg}	42,975^{kg}
LOAD ON AIR SPRING	36,620^{kg}/car 8,905^{kg}/set	41,287^{kg}/car 10,322^{kg}/set	43,555^{kg}/car 10,889^{kg}/set
LOAD ON ROLLER	36,820^{kg}/car 9,205^{kg}/set	42,487^{kg}/car 10,622^{kg}/set	44,755^{kg}/car 11,189^{kg}/set
LOAD ON SIDE BEARER	37,860^{kg}/car 9,465^{kg}/set	43,527^{kg}/car 10,882^{kg}/set	45,795^{kg}/car 11,449^{kg}/set
LOAD ON PRIMARY SPRING	42,160^{kg}/car 2,635^{kg}/set	47,827^{kg}/car 2,989^{kg}/set	50,095^{kg}/car 3,131^{kg}/set
LOAD ON JOURNAL BEARING	42,680^{kg}/car 5,335^{kg}/set	48,347^{kg}/car 6,044^{kg}/set	50,615^{kg}/car 6,327^{kg}/set
LOAD ON RAIL	49,880^{kg}/car 6,235^{kg}/wheel	55,547^{kg}/car 6,943^{kg}/wheel	57,815^{kg}/car 7,227^{kg}/wheel

Figure 2.2 Car Weight and Load Conditions

3. TRUCK COMPONENTS

3.1 WHEELS AND AXLE

Wheels and axle are shown in Figure 3.1.

3.1.1 WHEEL

The wheel is 914 mm (36") diameter, a solid rolled type and has 1/40 tapered tread.

The material is in accordance with A.A.R. Specifications M-107, class B.

The wheel profile is in accordance with High Toughness (HT) wheel, H-36, (Cf. Section 6.2)

3.1.2 AXLE

The axle is a hollow type to reduce unsprung weight of truck, maintaining high fatigue strength.

The material is in accordance with AlSl 5150, quenched, tempered and subcritically quenched.

Two brake discs are mounted on the axle.

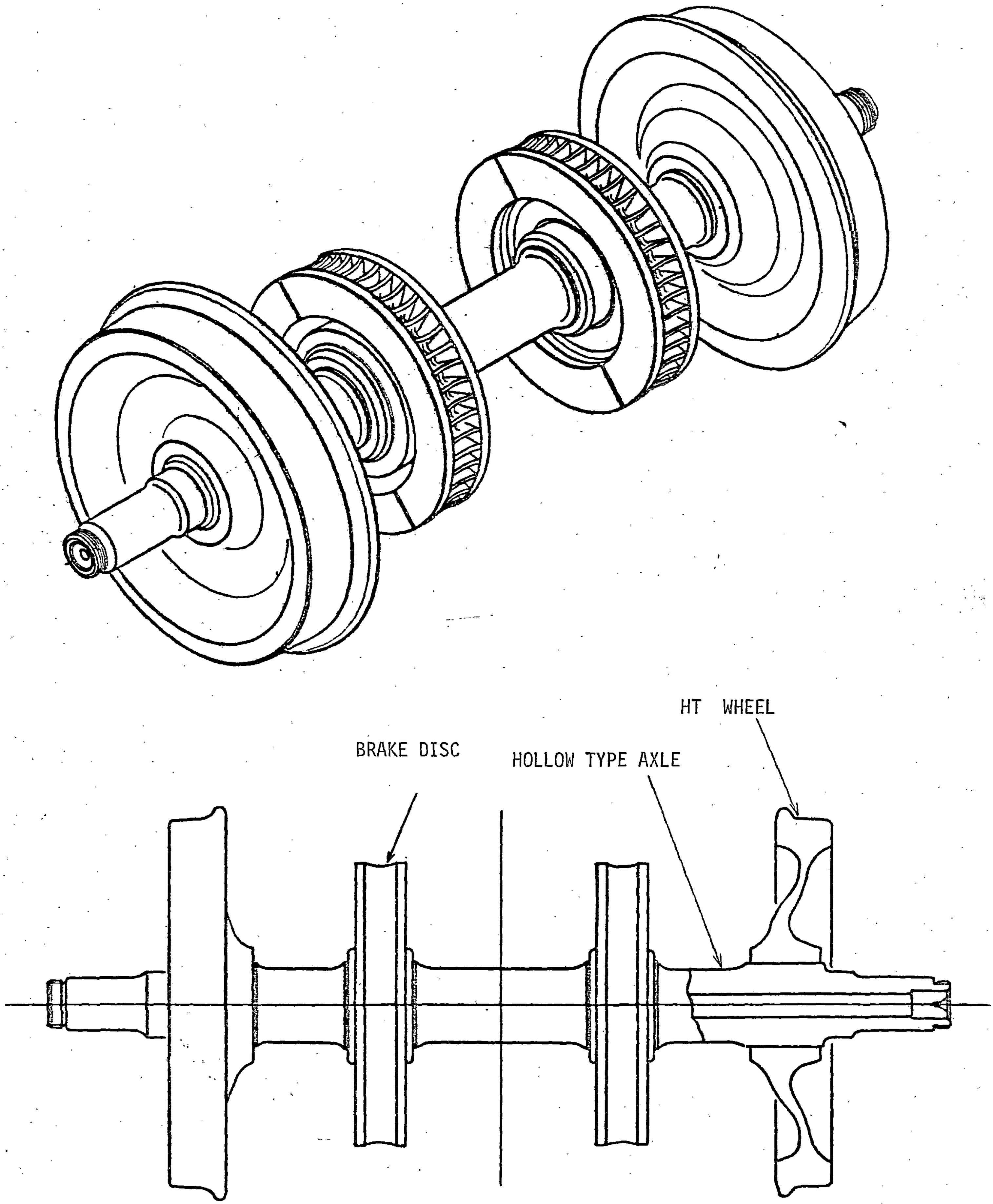


Figure 3.1 Wheels and Axle

3.2 JOURNAL BOX ASSEMBLY

The journal box assembly consists of a RCT type journal bearing, a journal box housing, a front cover, a rear cover and an end cap. Thrust load is taken by the front cover and the rear cover. The journal box assembly is shown in Figure 3.2.

3.2.1 JOURNAL BEARING

The journal bearing is a RCT type bearing (130mm x 250mm). Grease lubricant is supplied to the center of the bearing through the under nipple of the journal box housing.

3.2.2 JOURNAL BOXE

The journal boxe is of cast steel. The end cap has a gear for wheel-slide detection.

3.3 JOURNAL BOX SUPPORTING DEVICE

The journal box is supported by dry type cylindrical journal box guide system.
The sliding surface between inner and outer cylinder is provided with anti-friction resin wear plate.
In this journal box guide, wear can be reduced to minimum degree because of cylindrical sliding surface, and good performance can be maintained from overhaul to overhaul.
The cylindrical resilient rubber between inner and outer cylinder provides proper longitudinal and lateral stiffness to prevent hunting motion.
The journal box supporting device is shown in Figure 3.3.

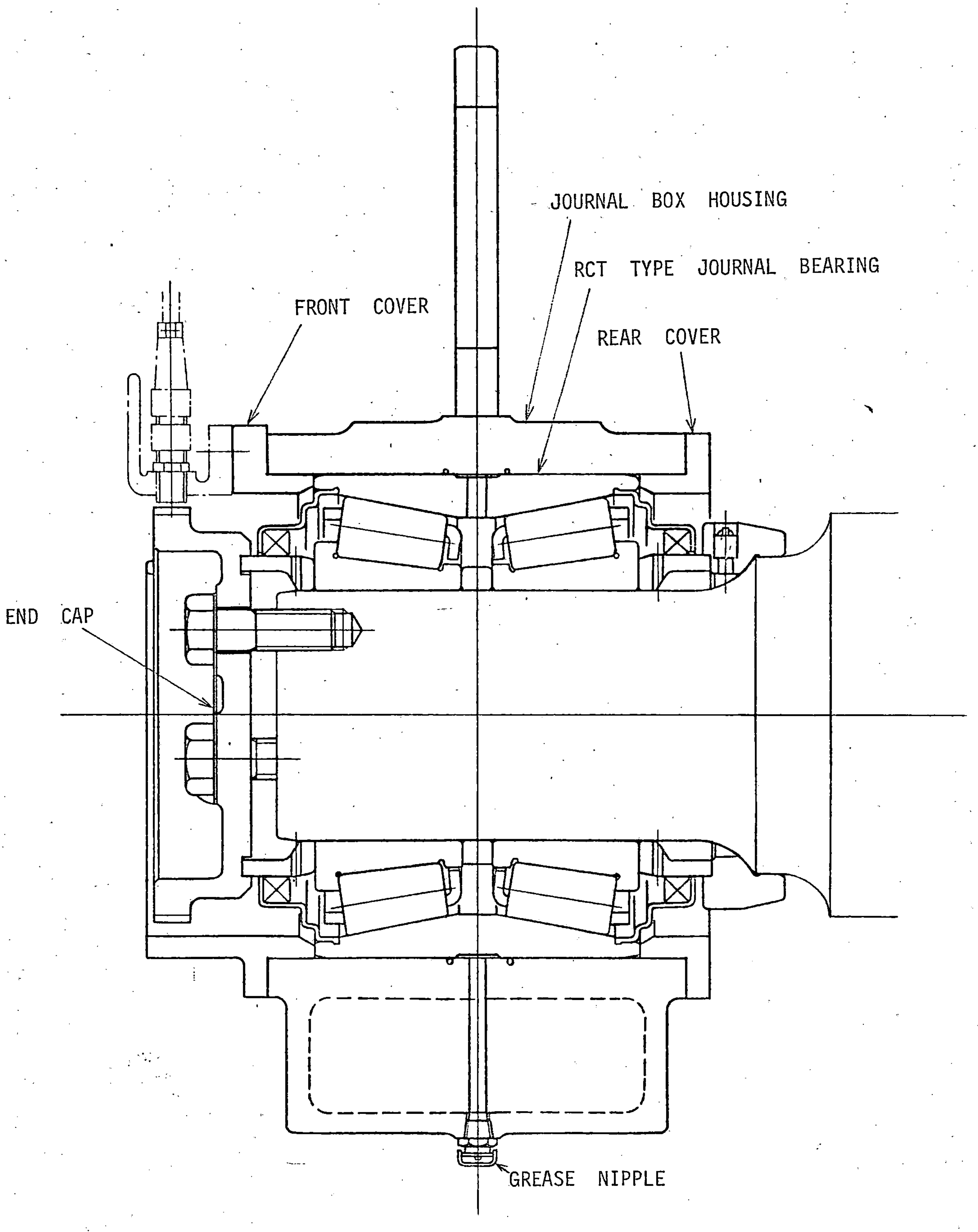


Figure 3.2 Journal Box Assembly

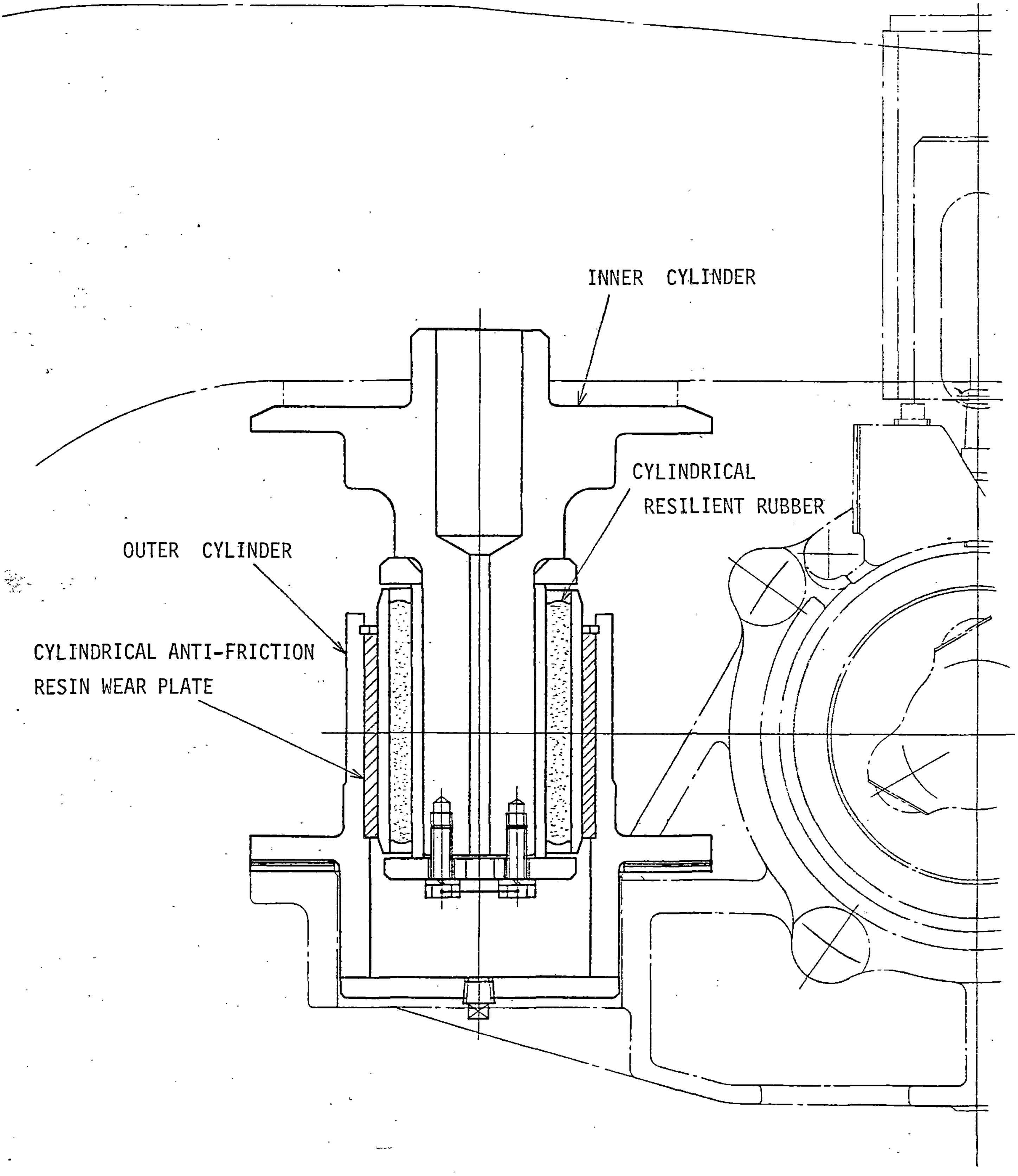


Figure 3.3 Journal Box Supporting Device

3.4 SUSPENSION SYSTEM

The principal components of the primary and the secondary suspension systems are shown in Figure 3.4.

3.4.1 PRIMARY SUSPENSION SYSTEM

The primary suspension system consists of coil springs, cylindrical resilient rubbers and a vertical damper.

The elements of the primary suspension system are shown in Figure 3.4.1.

3.4.1.1 PRIMARY SPRING

The primary spring is a helical coil with rubber coating, so called, "Eligo".

The features of the rubber coating are as follows.

1) Seal of the sliding surface of journal box guide to keep off a dust and snow.
2) Insulation of vibration in high frequency band.
3) Prevention from rust of the helical steel spring.
4) Damping effect.

The coil spring bears 80 percent of the primary spring load and the rubber takes 20 percent load.

Principal dimensions of coil springs are shown in Table 3.4.1.1 (A).
Principal dimensions of "Eligo" springs are shown in Table 3.4.1.1 (B).
Load-deflection diagram is shown in Figure 3.4.1.1.

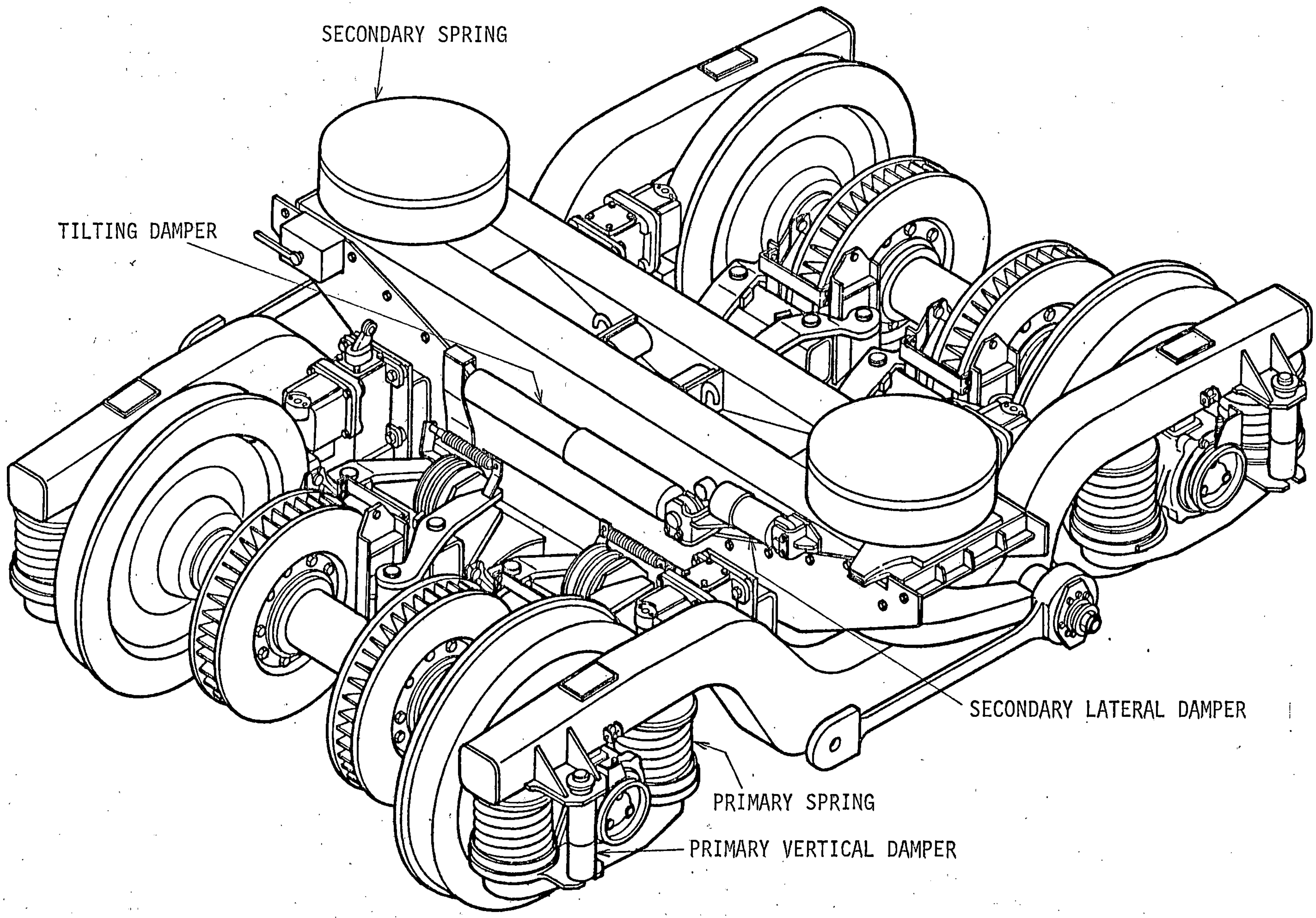


Figure 3.4 Suspension System

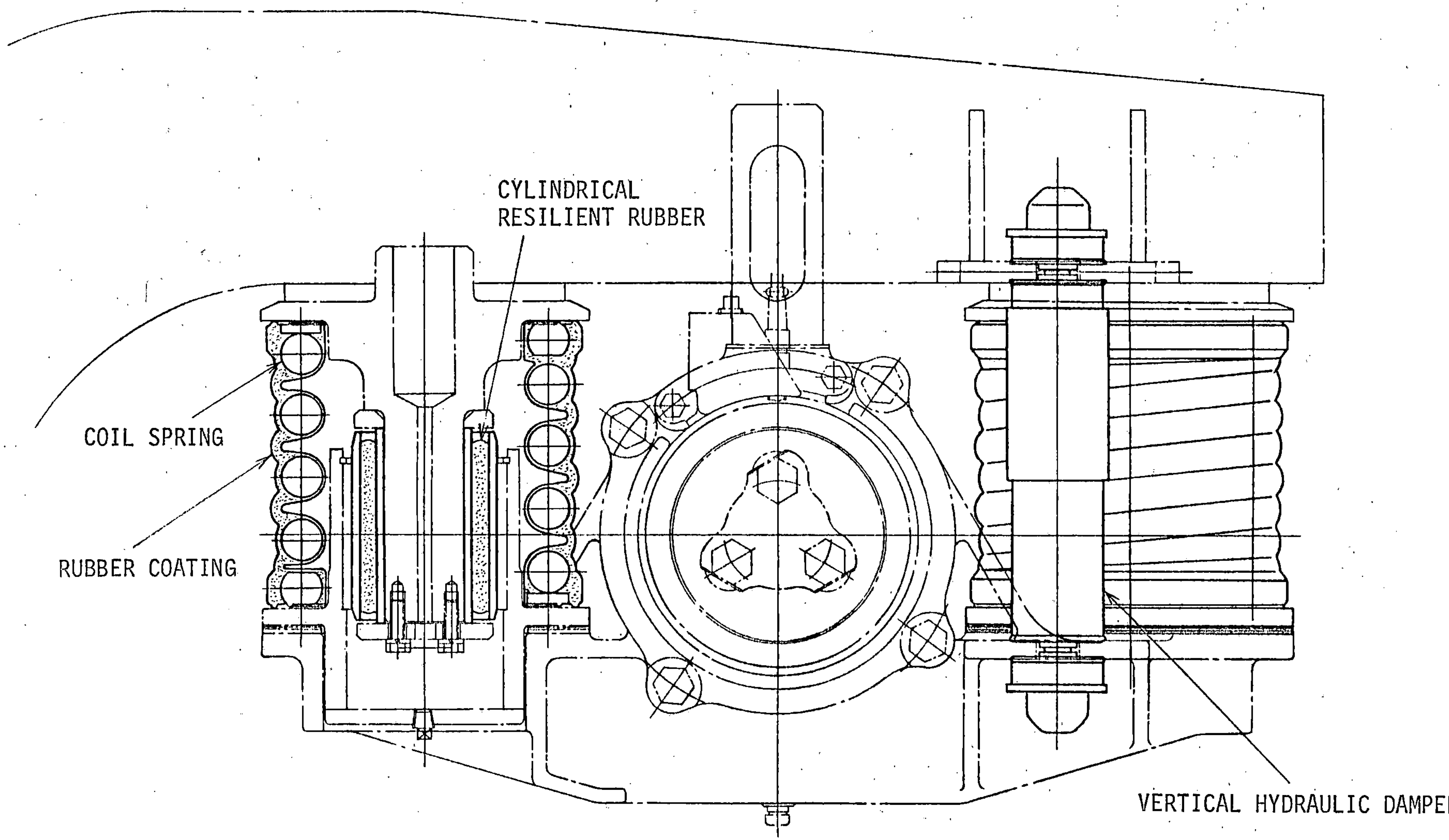


Figure 3.4.1 Primary Suspension System

Table 3.4.1.1 (A) Principal Dimensions of Coil Spring

DESCRIPTION	DESIGN VALUE
Coil diameter	34$^{DIA.}$ mm
mean diameter of coil	203$^{DIA.}$ mm
number of total turns	5.5
number of active turns	3.5
spring constant	42 Kg/mm
stress modification factor	1,253
free height	280 mm
solid height	170 mm

Table 3.4.1.1 (B) Principal Dimensions of Eligo

DESCRIPTION	DESIGN VALUE
outer diameter	246$^{DIA.}$ mm
inner diameter	164$^{DIA.}$ mm
spring constant (tare)	54 Kg/mm
maximum outer diameter (at maximum load)	280$^{DIA.}$ mm

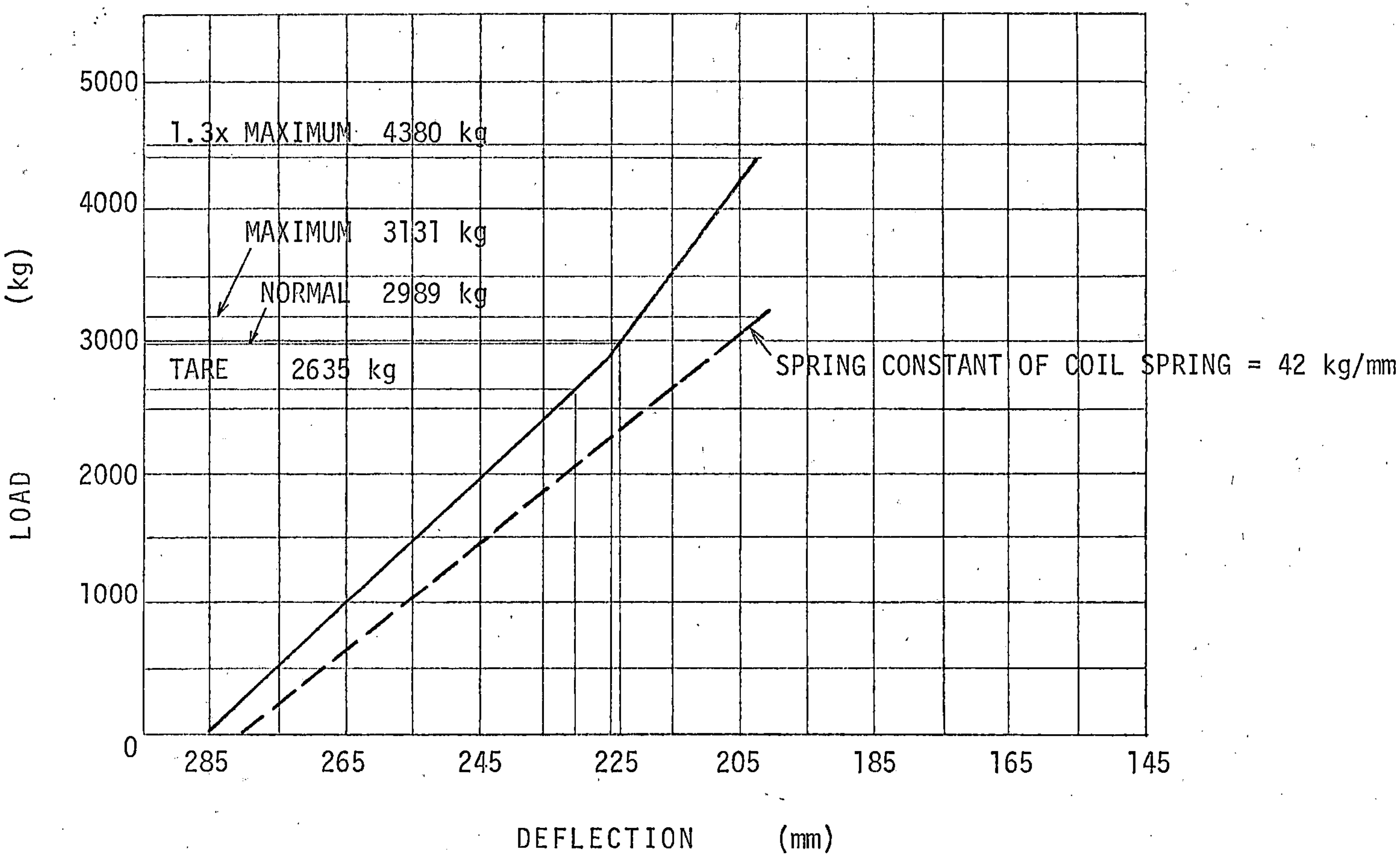


Figure 3.4.1.1 Load-Deflection Diagram of Primary Spring

3.4.1.2 PRIMARY VERTICAL DAMPER

The vertical hydraulic damper is provided on each journal box in order to reduce vertical shock.

The damping force of the vertical damper is as follows.

The damper acts only in the direction of extension.

Table 3.4.1.2 Damping Force of Vertical Damper

piston velocity	damping force
5 cm/sec.	200 Kg
10 cm/sec.	400 Kg

3.4.2 SECONDARY SUSPENSION SYSTEM

The secondary suspension system is a body mounted type air spring.

The elements of secondary suspension system are shown in Figure 3.4.

3.4.2.1 SECONDARY SPRING

The secondary spring is a diaphragm type air spring with adequately stable lateral stiffness.

Principal dimensions of the air spring are shown in Table 3.4.2.1.

The frequency characteristics of the spring constant and the damping coefficient of the air spring are shown in Figure 3.4.2.1 (B).

A differential pressure valve is provided to keep the pressure balance of the two air springs on both sides of a truck.

The air spring is shown in Figure 3.4.2.1 (A).

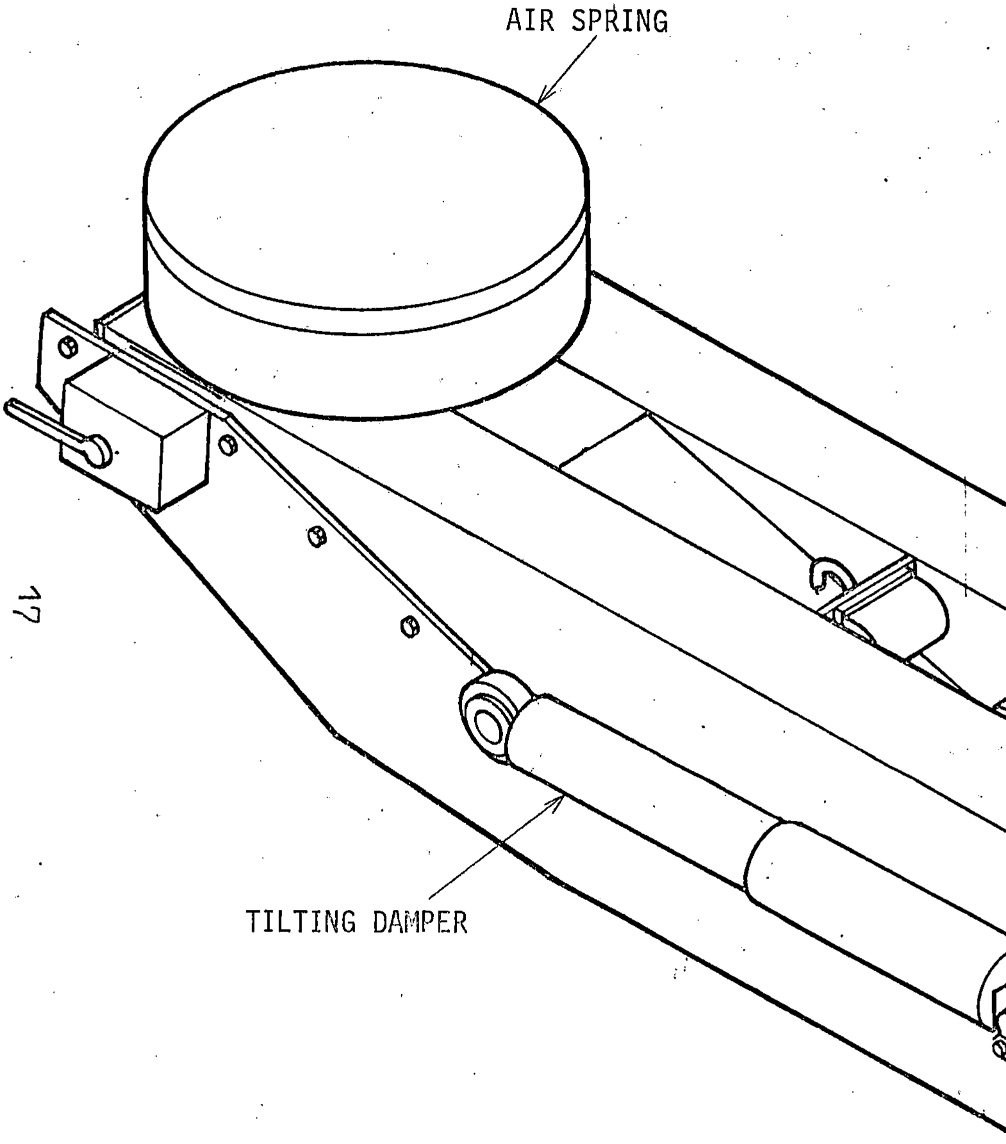
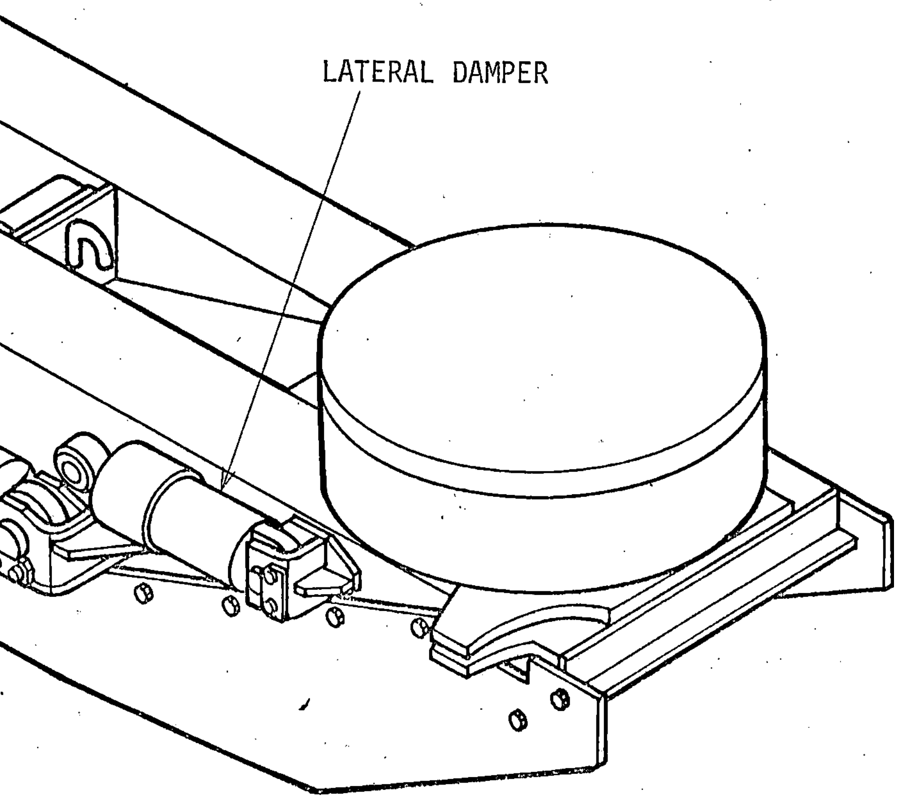
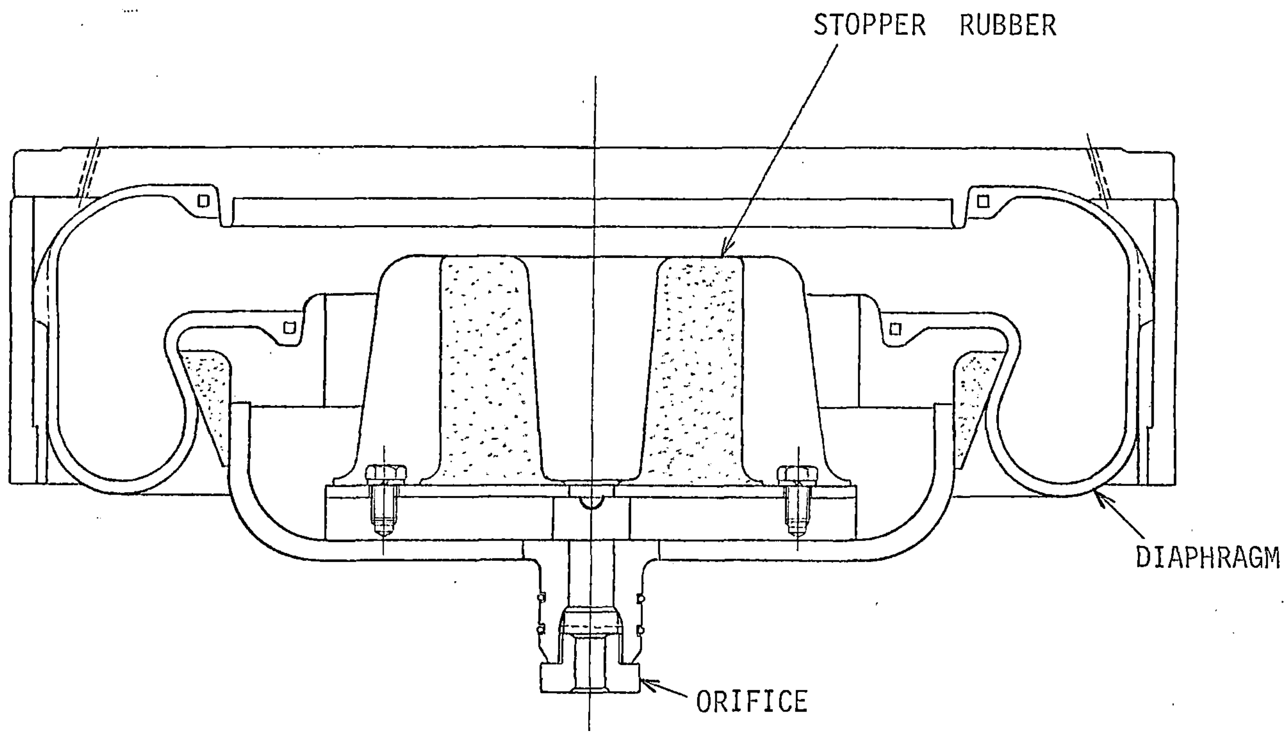


Figure 3.4.2 Secondary Suspension system


LATERAL DAMPER



3.4.2.1 (A) Cross Section of Air Spring

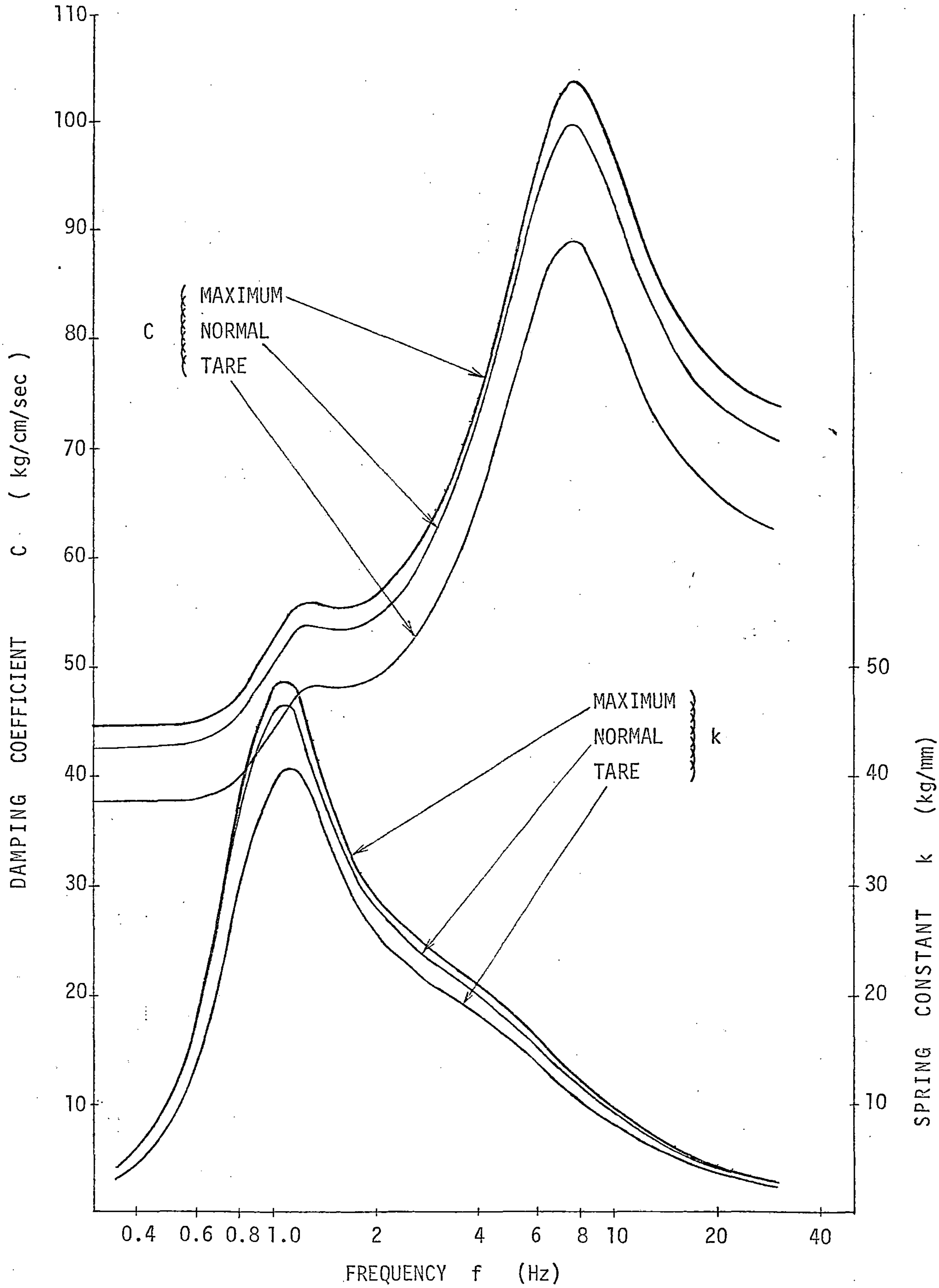


Figure 3.4.2.1 (B) Frequency Characteristics of Spring Constant and Damping Coefficient of Air Spring

Table 3.4.2.1 Principal Dimensions of Air Spring

DESCRIPTION	DESIGN VALUE
effective diameter	500 DIA. mm
height (with air supplied)	216 mm
volume of diaphragm	20.7 ℓ
volume of auxiliary reservoir	50 ℓ
static vertical spring constant (tare)	26.0 Kg/mm
static lateral spring constant (tare)	29.6 Kg/mm

3.4.2.2 SECONDARY LATERAL DAMPER

Two lateral hydraulic dampers are provided between the upper bolster of a turck and the underframe of the carbody in order to improve lateral vibration.

The damping coefficient of the lateral damper is 50 Kg/cm/sec.

3.4.2.3 TILTING DAMPER

A tilting hydraulic damper is provided between the upper bolster and the transom of a truck frame in order to accomplish smooth tilting motion.

The damping coefficient of a tilting damper is 10 Kg/cm/sec.

Refer to Section 7.9 for the influence of damping coefficient of the tilting damper.

3.5 TRUCK FRAME

The truck frame is "H" shape steel plate welded-construction and consists of two side frames and a transom.

The material of the steel plate is in accordance with SMA50B, Japanese Industrial Standard (JIS) G 3114 with a tensile strength of 50 Kg/mm^2.

3.6 SIDE BEARER

Two side bearears with anti-friction resin plates are placed between the transom and the lower bolster of a truck to support vertical load of the carbody and provide suitable rotational resistance of the truck for the purpose of preventing hunting motion.

3.7 TRUCK BOLSTER

A truck bolster, which actually conducts tilting motion, is placed on the two side bearers of a truck frame and supports the carbody by means of the two air springs on both sides.

The truck bolster consists of the upper swing bolster (tilting part), the lower bolster (non-tilting part) and the roller device between them.

The components of the truck bolster are shown in Figure 3.7.

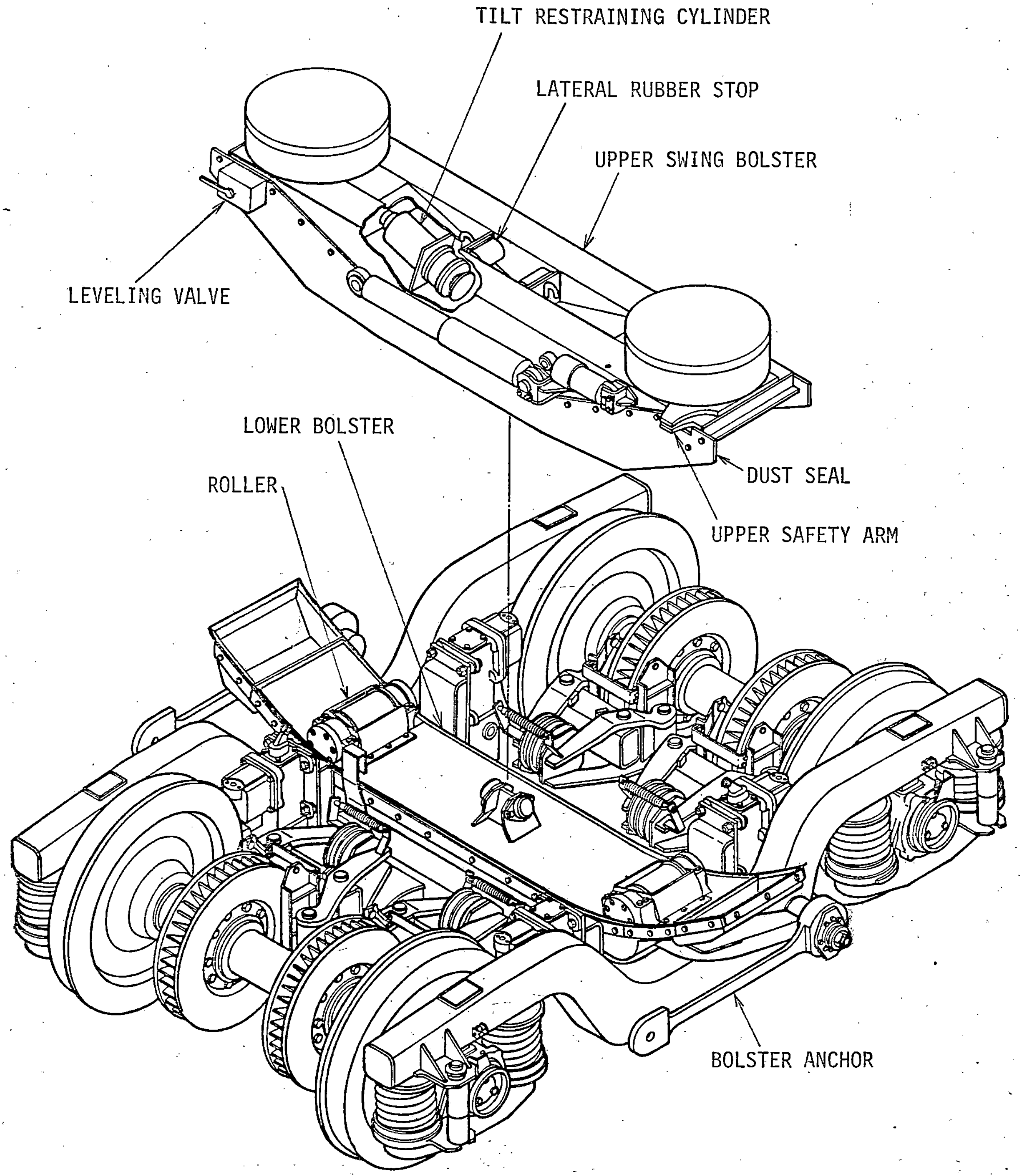


Figure 3.7 Components of Truck Bolster

3 7.1 LOWER BOLSTER

The lower bolster is steel plate welded-construction and placed on the two side bearers of the truck frame.

A center pin is provided at the bottom of the lower bolster to allow the truck rotation.

Two rollers are installed on both sides of the upper side of the lower bolster.

Two rubber stops for restraint of tilting motion are equipped at the center of the upper side.

Two bolster anchors are connected at both ends of the lower bolster.

The elements of the lower bolster are shown in Figure 3.7.1.

3.7.2 ROLLER DEVICE

The roller device is installed between the lower bolster and the upper swing bolster.

The roller device consists of the roller supported by needle roller bearings on the upper side of the lower bolster, and a roller guide plate equipped at the bottom of the upper swing bolster.

Tilting motion is conducted by means of the lateral displacement of the roller guide plates on the rollers.

The flanges at both ends of the roller are fitted in the grooves of the roller guide plate to secure relative positioning of the roller and roller guide plate in the longitudinal direction.

The surface of the roller and that of the roller guide plate are treated with the carburizing.

The elements of the roller device are shown in Figure 3.7.2.

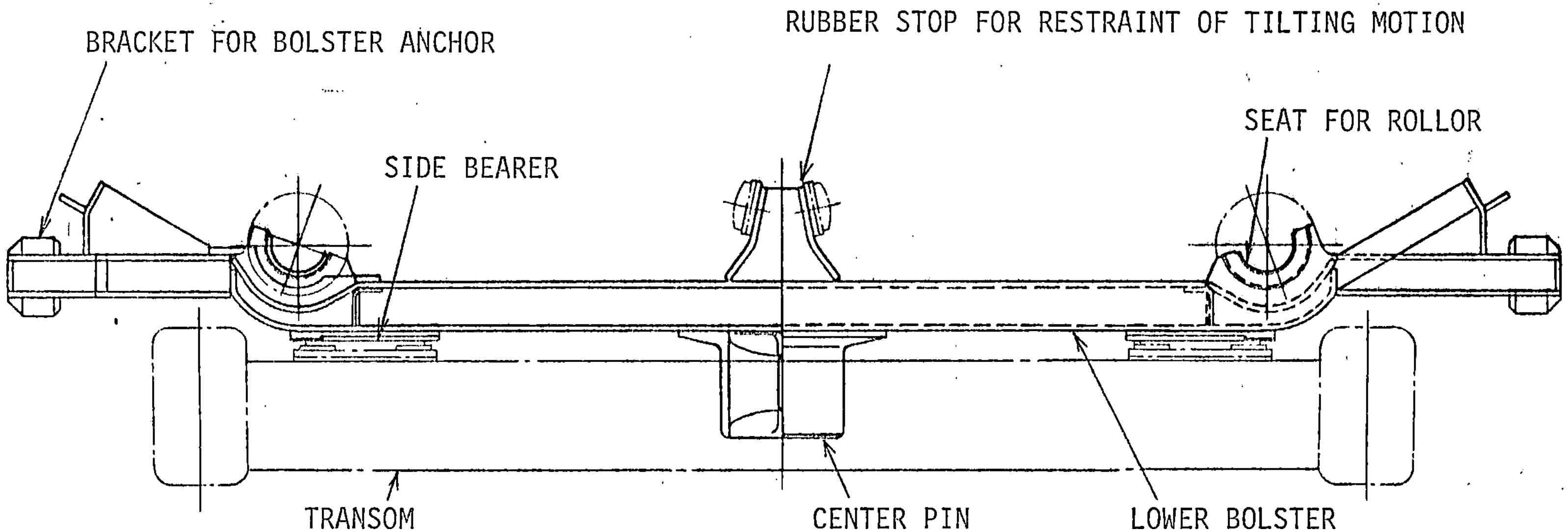
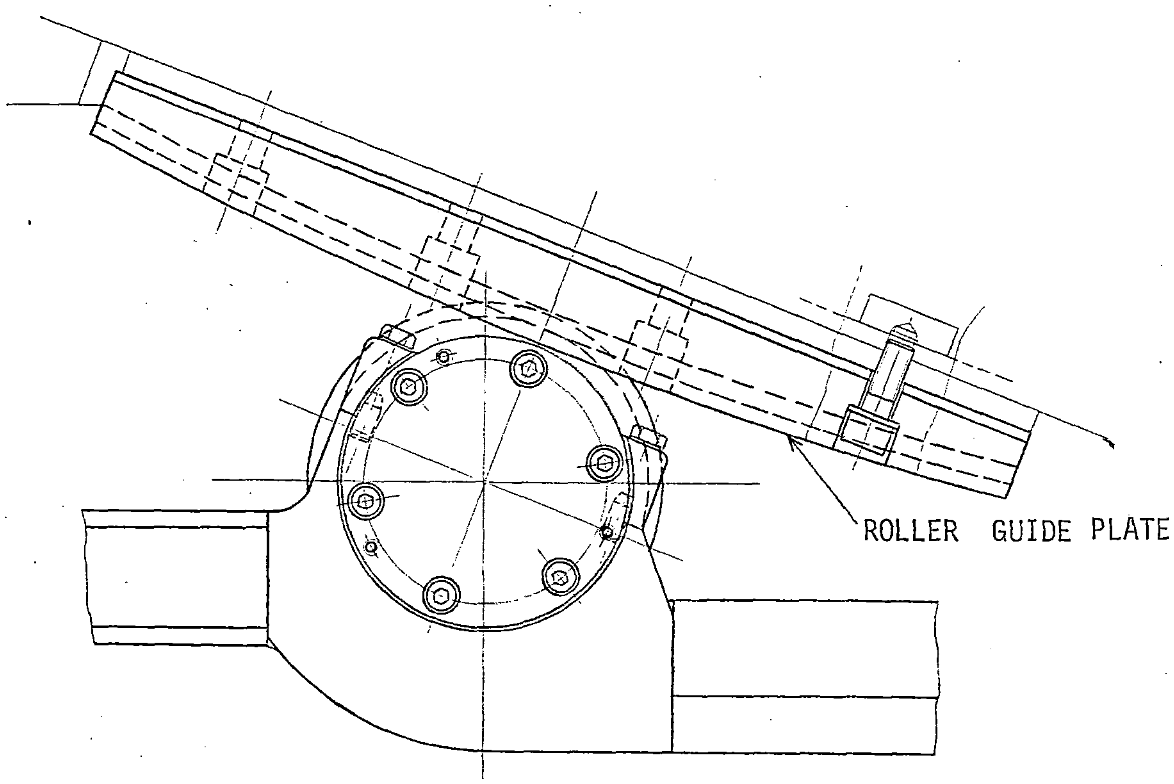


Figure 3.7.1 Elements of Lower Bolster



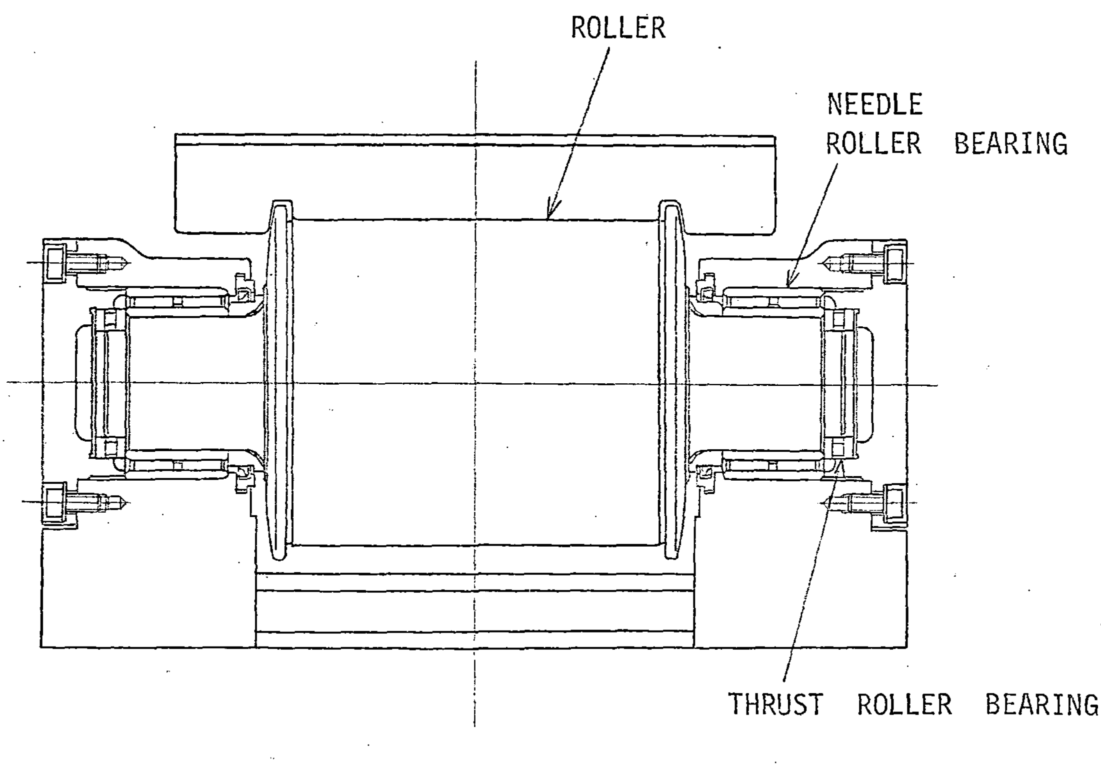


Figure 3.7.2 Elements of Roller Device

3.7.3 UPPER SWING BOLSTER

The upper swing bolster is steel plate welded-construction and consists of two beams which are used as the auxiliary reservoir for the air springs.

The air springs are placed on the upper both sides of the upper swing bolster and support the carbody.

The roller guide plates are equipped at the lower both side of the upper swing bolster and roll on the rollers of the lower bolster.

Two restraining cylinders are provided between the two beams.

Other equipments, lateral rubber stops, leveling valves, a differential pressure valve, upper safety arms, two lateral dampers and a tilting damper are provided.

The elements of the upper swing bolster are shown in Figure 3.7.3.

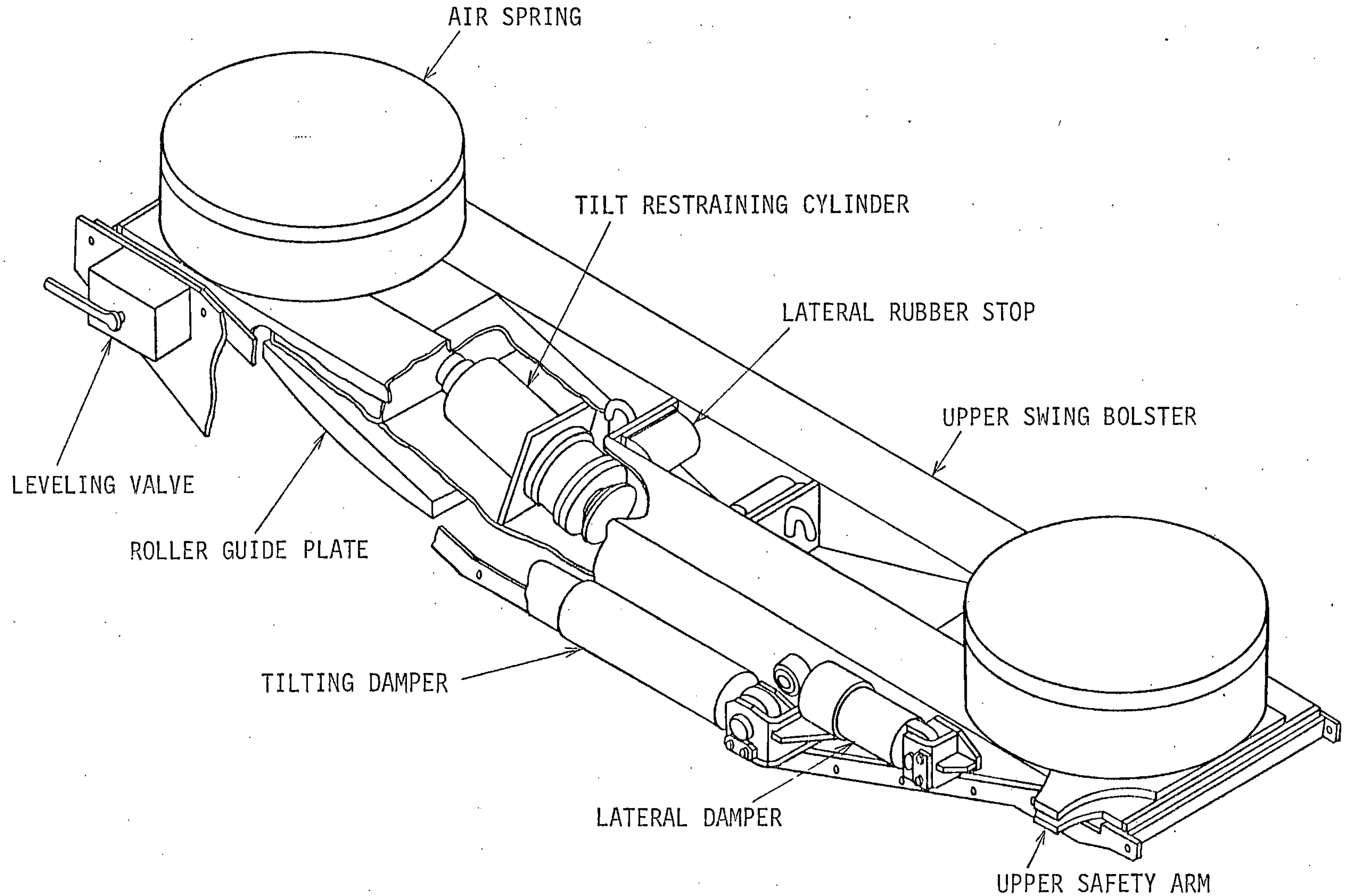


Figure 3.7.3 Elements of Upper Swing Bolster

3.7.4 TILT RESTRAINING SYSTEM

The tilting motion is controlled by the restraint air cylinders in order to prevent excessive inclination of the carbody under following conditions.

1) When the train stops at stations.

2) When the train passes switches at low speed.

3) When the train stops in curves.

In case of the above conditions, the pistons of the cylinders stroke and touch the rubber stops provided at the center of the lower bolster, and thus the tilting motion is restrained.
The distance between the piston and the rubber stops is equivalent to the maximum tilting angle of 6 degrees.
Also, the tilting angle can be adjusted by inserting adjusting plates between the rubber stop and the bracket of the lower bolster.
The tilt restraining system is automatically operated by means of train speed detection and besides is able to be manually operated.
The tilt restraining system is shown in Figure 3.7.4 (A).
The circuit diagram of the tilt restraining system is shown in Figure 3.7.4 (B).

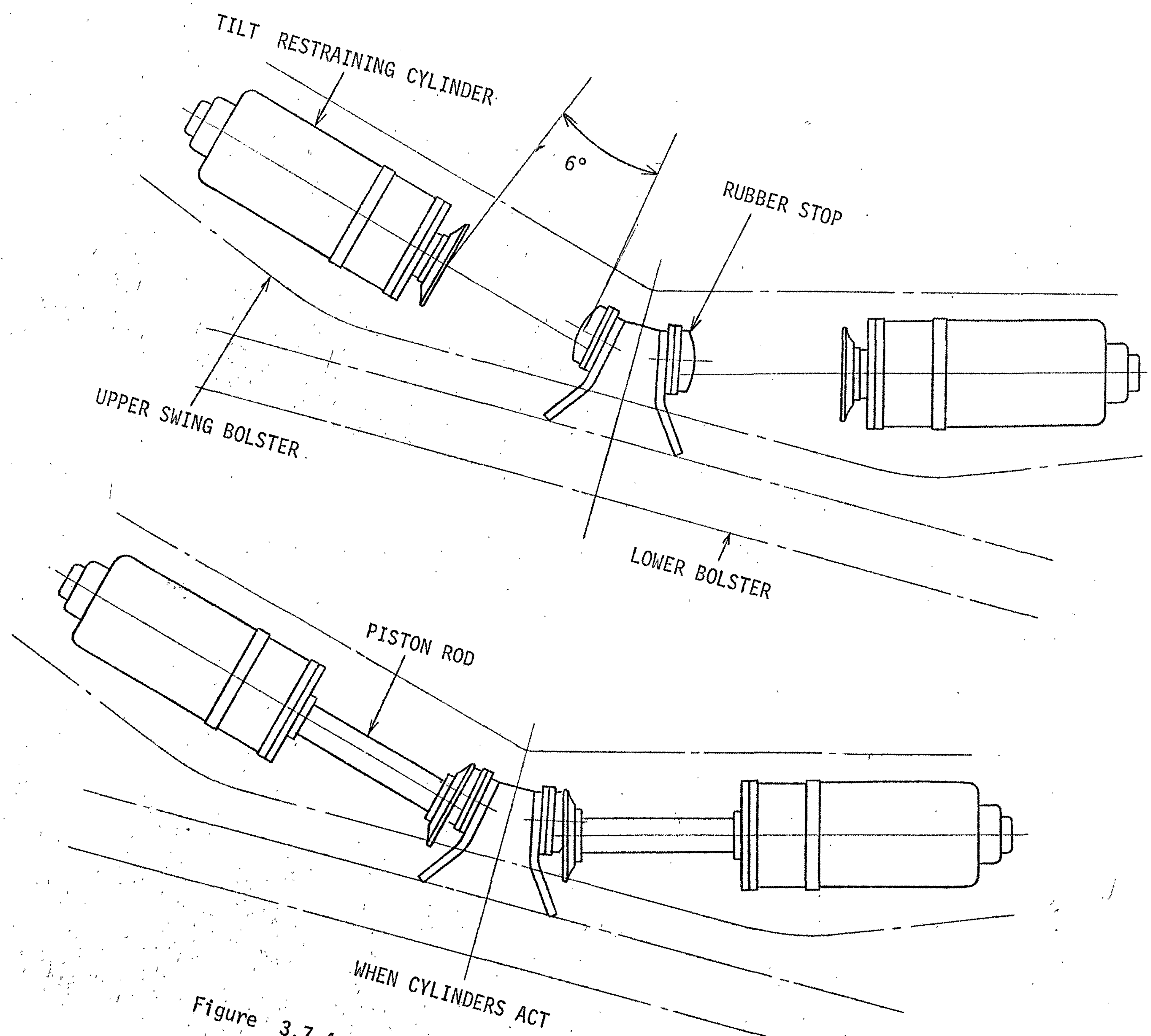


Figure 3.7.4 (A) Tilt Restraining System

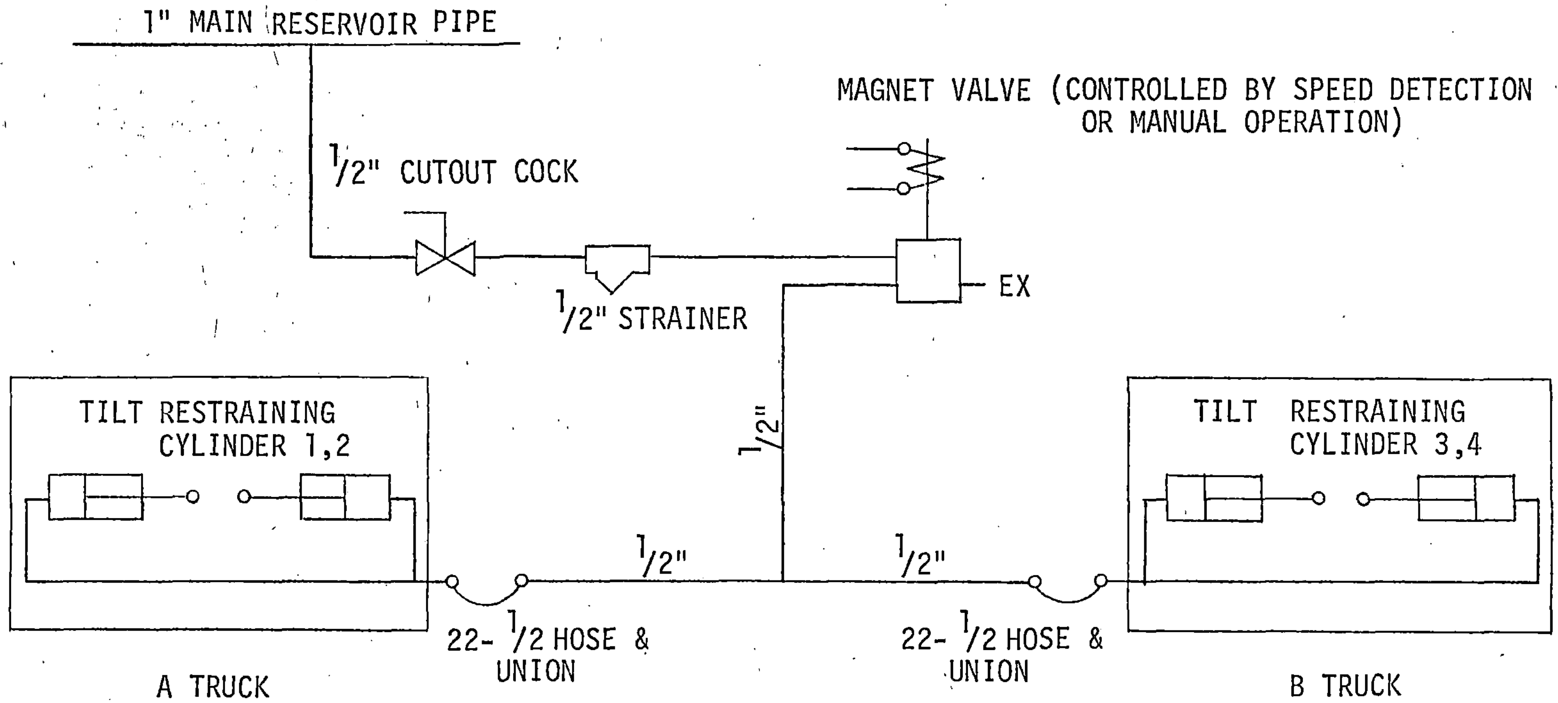


Figure 3.7.4 (B) Circuit Diagram of Tilt Restraining System

3.7.5 LATERAL RUBBER STOP

Two lateral rubber stops are equipped on the upper swing bolster for the purpose of limiting lateral movement between the carbody and the upper swing bolster.

3.7.6 CARBODY LEVELING SYSTEM

Leveling valve for the air spring is provided to keep constant floor height against the load variation.

3.7.7 UPPER SAFETY ARM

Upper safety arm is provided to restrain excessive inflation of the air springs when high pressure air is abnormally supplied.

3.7.8 DUST SEAL DEVICE

Dust seal is provided between the lower bolster and the upper swing bolster to protect the roller device from dust and snow.
The dust seal can keep the performance regardless of lateral movement of the upper swing bolster by tilting.
The dust seal device is shown in Figure 3.7.8.

3.7.9 BOLSTER ANCHOR

Bolster anchor connects the carbody with the lower bolster and transmits tractive and braking force.
Spherical joints are provided to allow the lateral motion of the carbody by tilting.
Rubber bush is provided to give adequate longitudinal stiffness between the carbody and the truck.
The bolster anchor is shown in Figure 3.7.9.

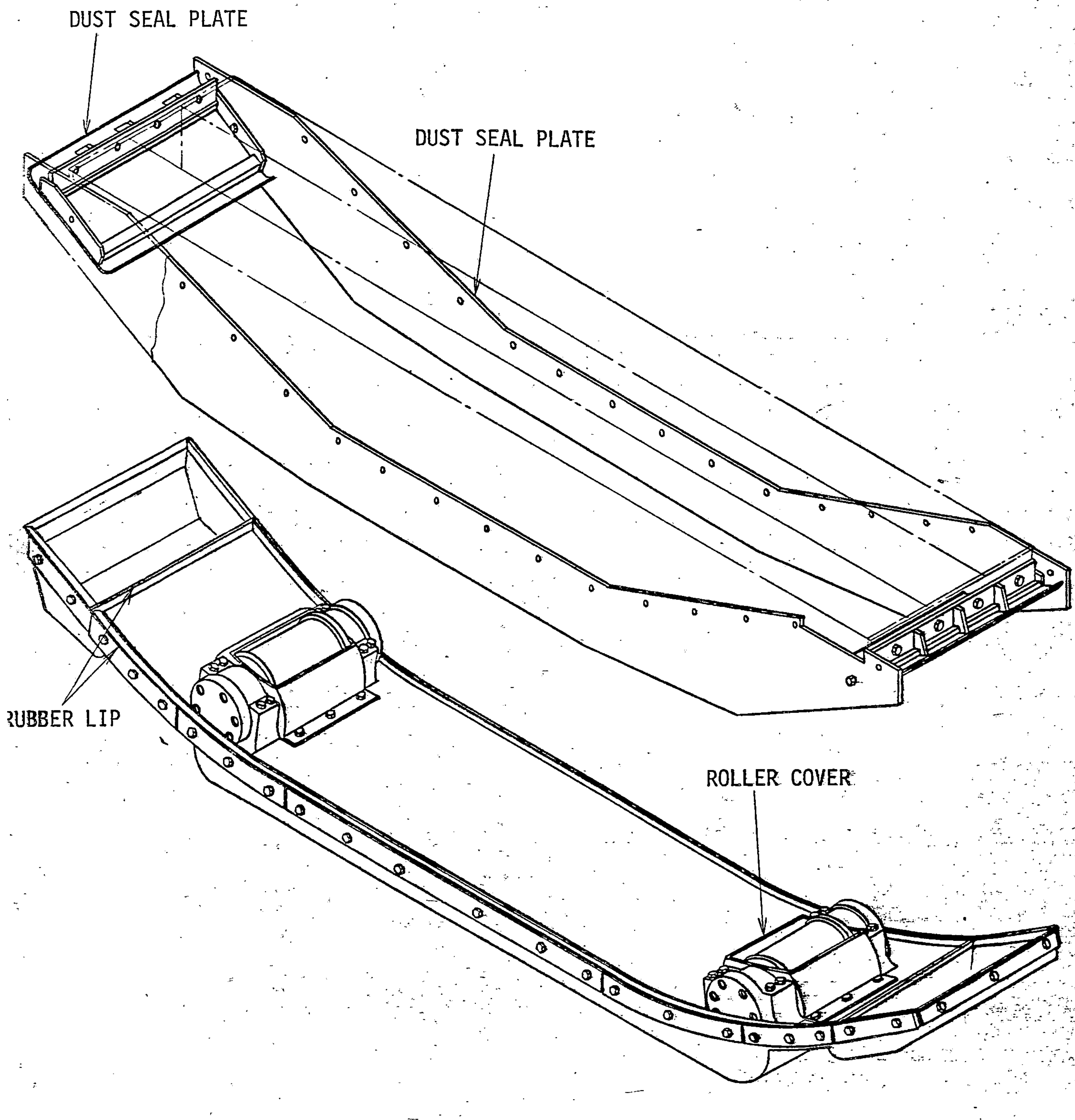


Figure 3.7.8 Dust Seal Device

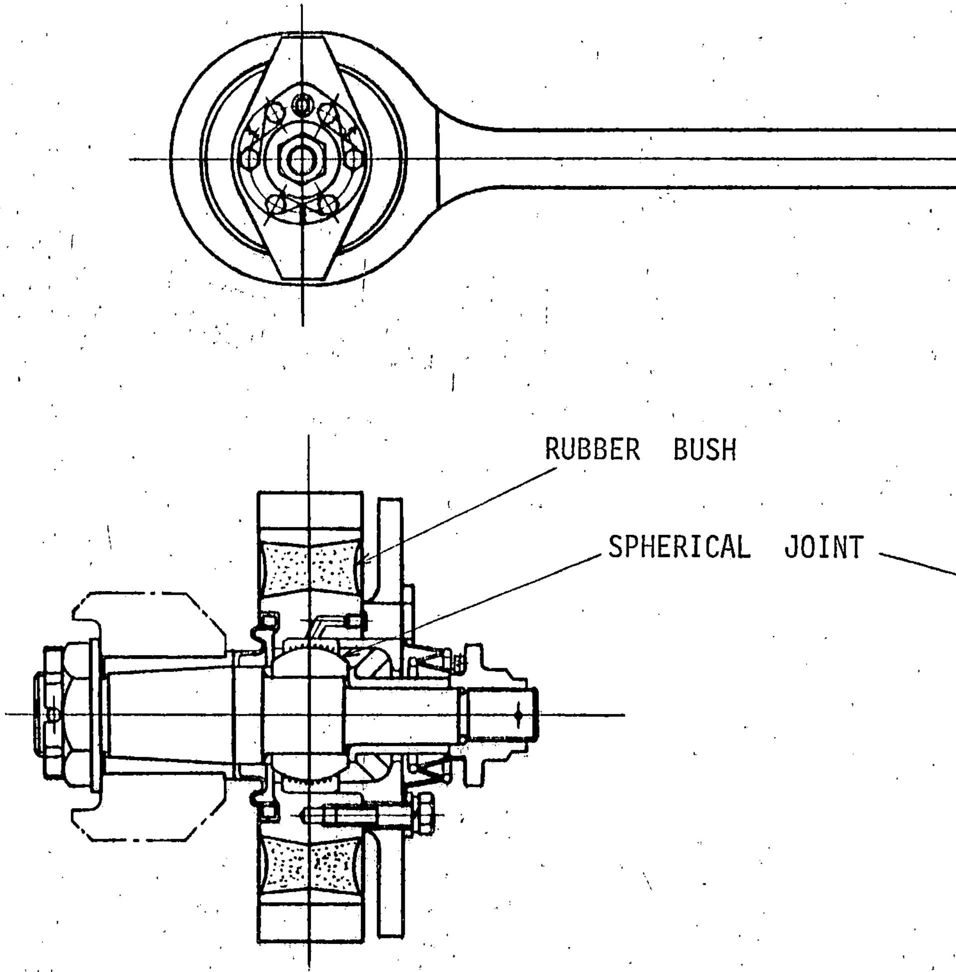
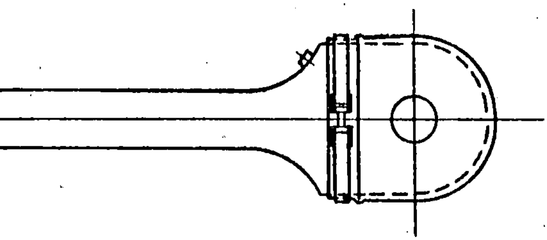
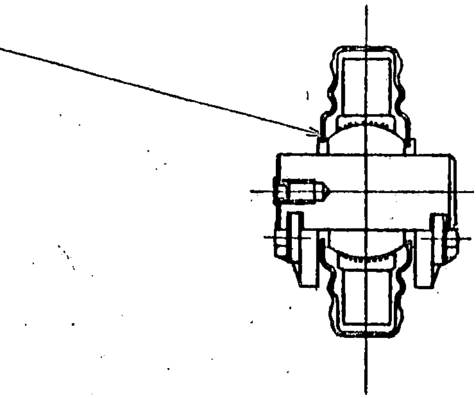


Figure 3.7.9 Bolster Anchor





3.8 BRAKE SYSTEM

The brake system is composed of disc brake, unit tread brake and hand brake.

The disc brake system shares 60 percent of total brake force and the unit tread brake system takes 40 percent.

It is generally desirable to keep tread brake force at minimum possible rate to protect wheel treads from damages, so that the truck can maintain good running quality.

However, comparatively large tread brake force is preferable in terms of maintaining good adhesion between wheels and rails.

Therefore it is difficult to determine most adequate share of tread brake force since adhesion largely depends on the track conditions and climates.

Therefore, it is desirable to observe running state of the vehicle and to adjust the share between disc brake force and tread brake force, which can be achieved by changing brake cylinder pressure and so on.

The brake system is operated by the pneumatic air.

The air brake system is shown in Figure 3.8.

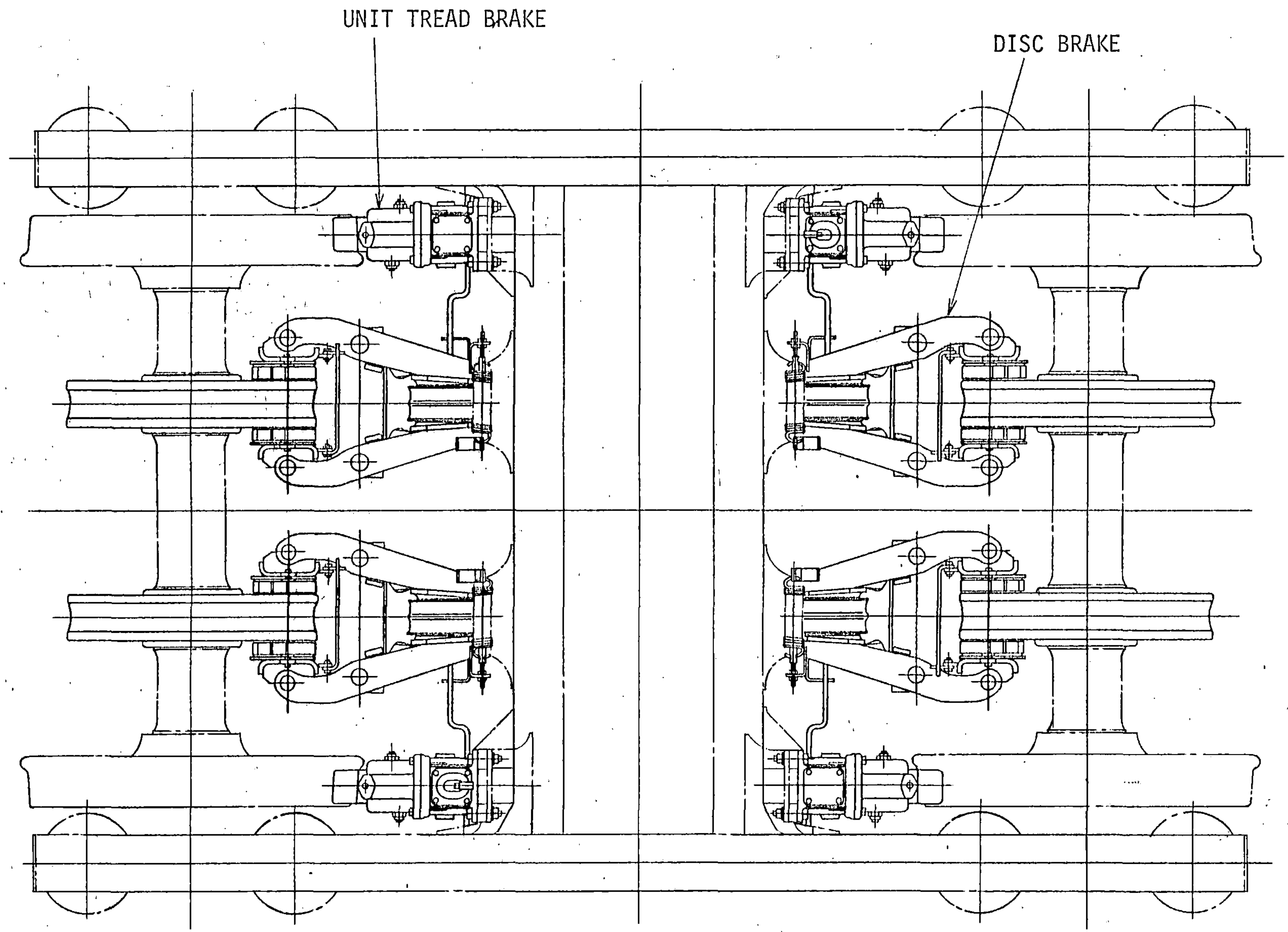


Figure 3.8 Air Brake System

3.8.1 DISC BRAKE SYSTEM

The disc brake system consists of diaphragm type rubber brake cylinders, brake levers, brake heads, brake linings and brake discs mounted on an axle.

The disc brake rigging is supported by the brackets installed on the transom of the truck frame.

The brake cylinder is 200 mm (7.874") in diameter.

The brake cylinder stroke covers the necessary movement of the brake levers up to the maximum wear of brake linings without adjustment.

The lever ratio per disc is 2.5.

The brake lining is of resin composition.

The brake disc is 700 mm (27.559") in diameter and two-piece construction.

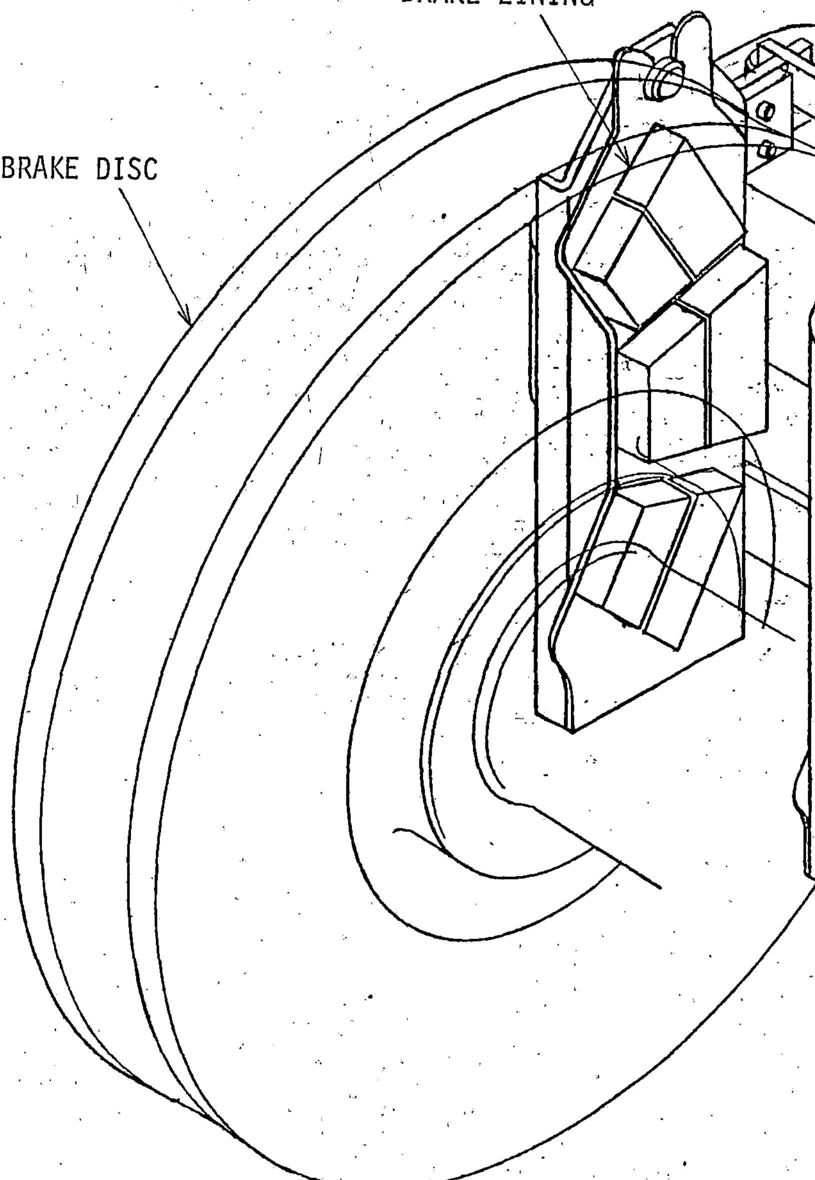
The brake discs are bolted to the brake disc seats fitted on the axle.

The two separate pieces of a disc are jointed by knock pins.

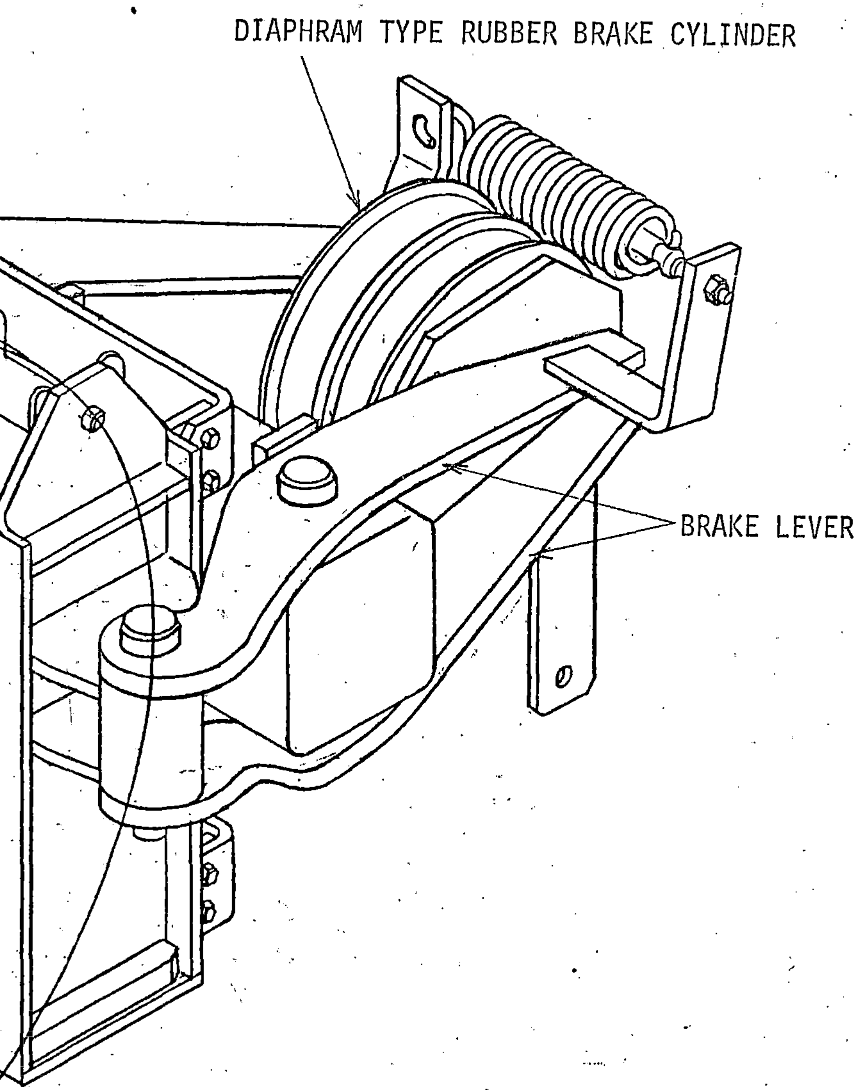
This rigid attachment of the brake disc is superior to flexible attachment against thermal expansion in terms of strength for running vibration.

Therefore, it is desirable to mount rigidly the brake disc on the axle in the line where the track conditions are not so good.

The disc brake system and the brake disc are shown in Figure 3.8.1 (A) and Figure 3.8.1 (B), respectively.



Figure



3.8.1(A) Disc Brake System

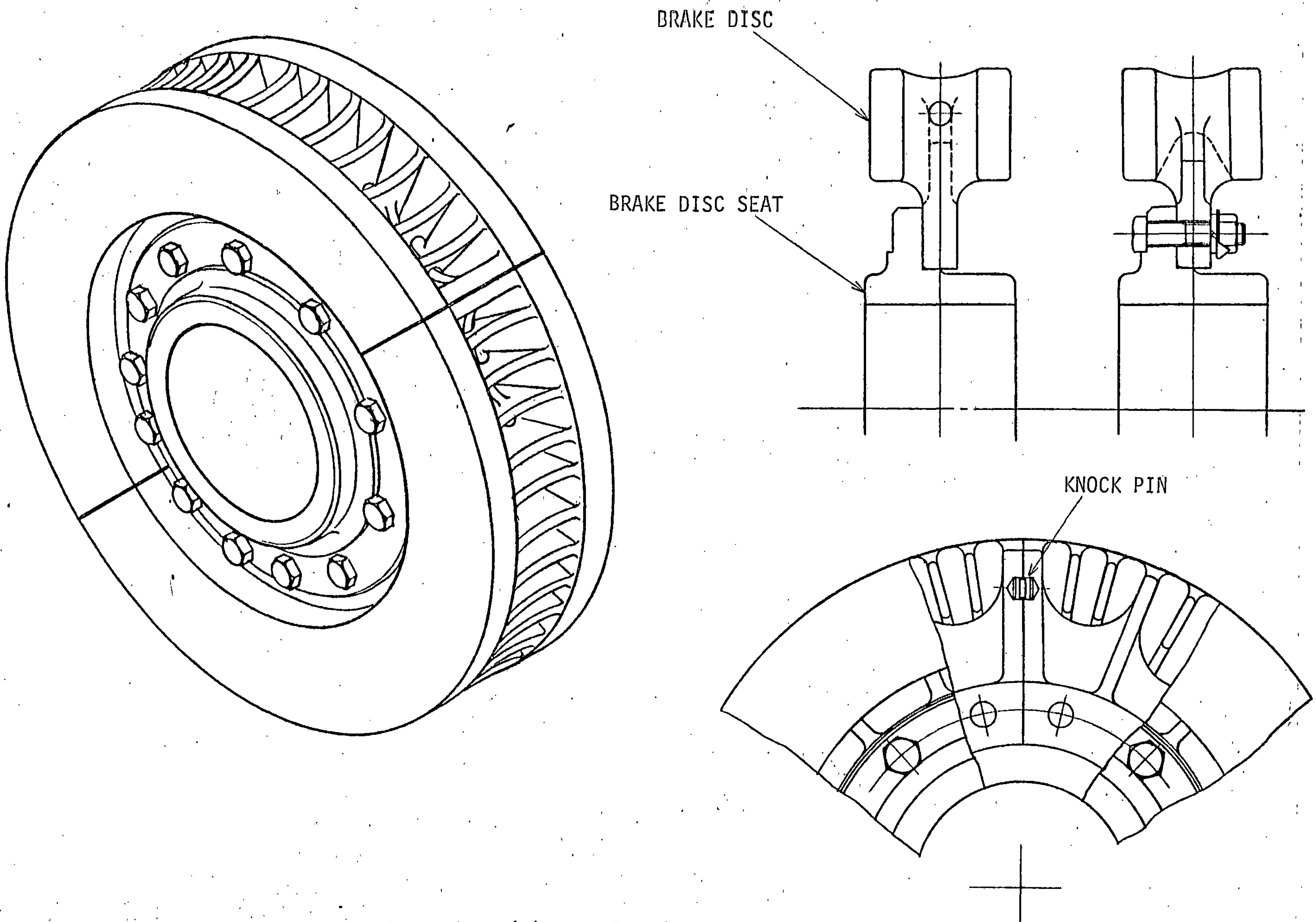


Figure 3.8.1 (B) Brake Disc

3.8.2 UNIT TREAD BRAKE SYSTEM

The unit type tread brake system is composed of a brake cylinder, a brake shoe, a brake head, brake levers and a built-in slack adjuster.

The tread brake units are mounted on the transom of the truck frame.

The brake cylinder is 127 mm (5") in diameter.

The built-in slack adjuster automatically compensates for the brake shoe wear and the wheel tread wear.

The lever ratio per unit is 4.

The brake shoe is of resin composition (or of sintered metal).

Mechanical hand brake is connected with the top lever.

The cross section of the tread brake unit is shown in Figure 3.8.2.

3.8.3 HAND BRAKE

Hand brake is furnished on the two tread brake units of one truck per car.

Flexible cables are connected with the hand brake levers of the unit tread brake.

The hand brake system is shown in Figure 3.8.3.

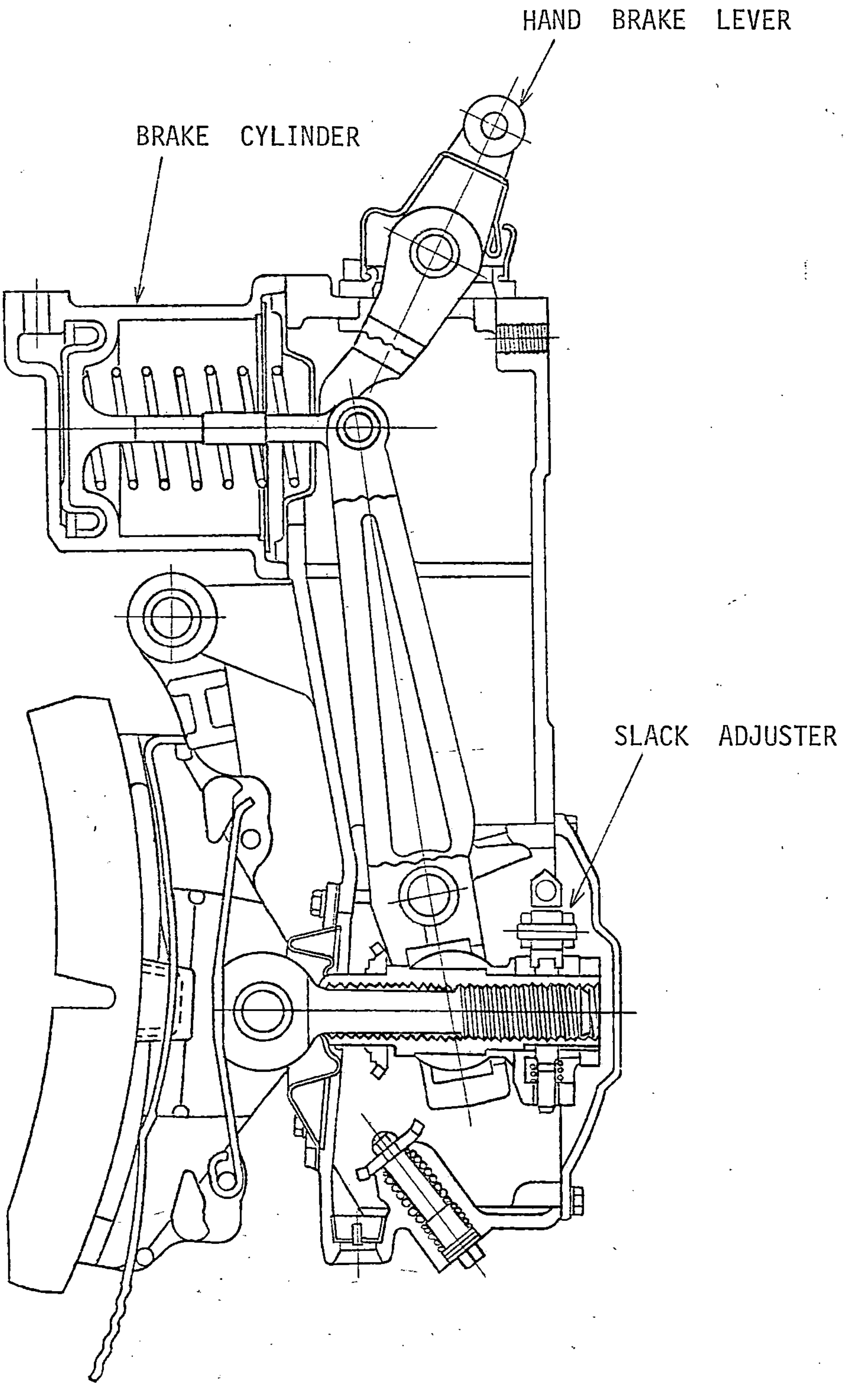


Figure 3.8.2 Cross Section of Tread Brake Unit

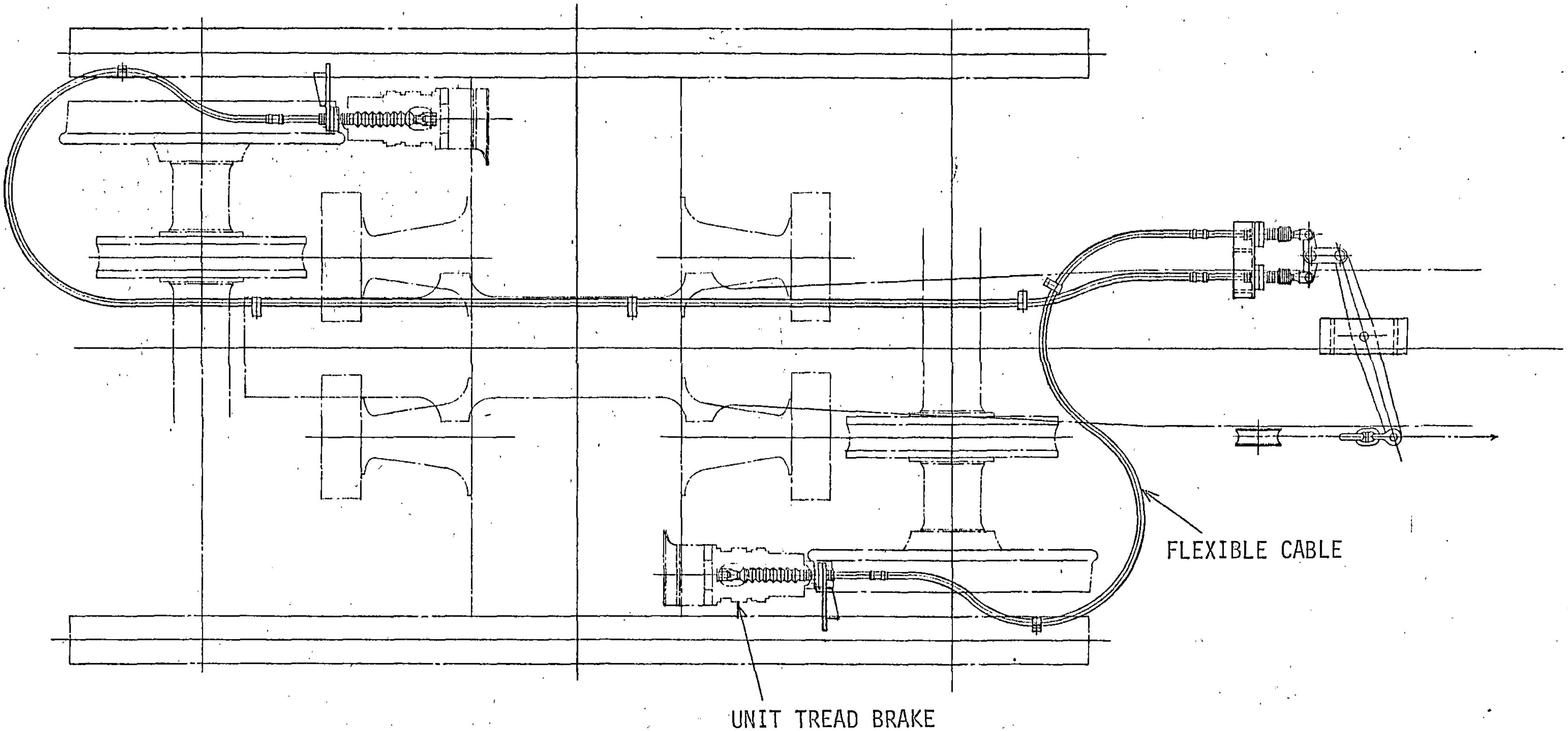


Figure 3.8.3 Hand Brake System

3.9 WHEEL SLIDE PROTECTION SYSTEM

Wheel slide protection system is provided to prevent flat-spotting and other damages to the wheel treads by braking by means of the wheel-slide detection device.

The magnetic pick-up housing is attached to the front cover of journal box.

The magnetic pick-up is used in conjunction with gear of journal box end cap to detect the wheel slide.

The magnetic pick-up is provided to each axle.

The wheel-slide detection device is shown in Figure 3.9.

4. MODIFICATION OF CARBODY

When the tilting truck is incorporated in AMCOACH, the following parts of the carbody are to be modified.

1) Seat for air spring.
2) Brackets for bolster anchors, secondary lateral dampers, lateral rubber stops and upper safety hooks.
3) Piping for air springs, brake cylinders and tilt restraining cylinders.
4) Coupler for tilting vehicle.

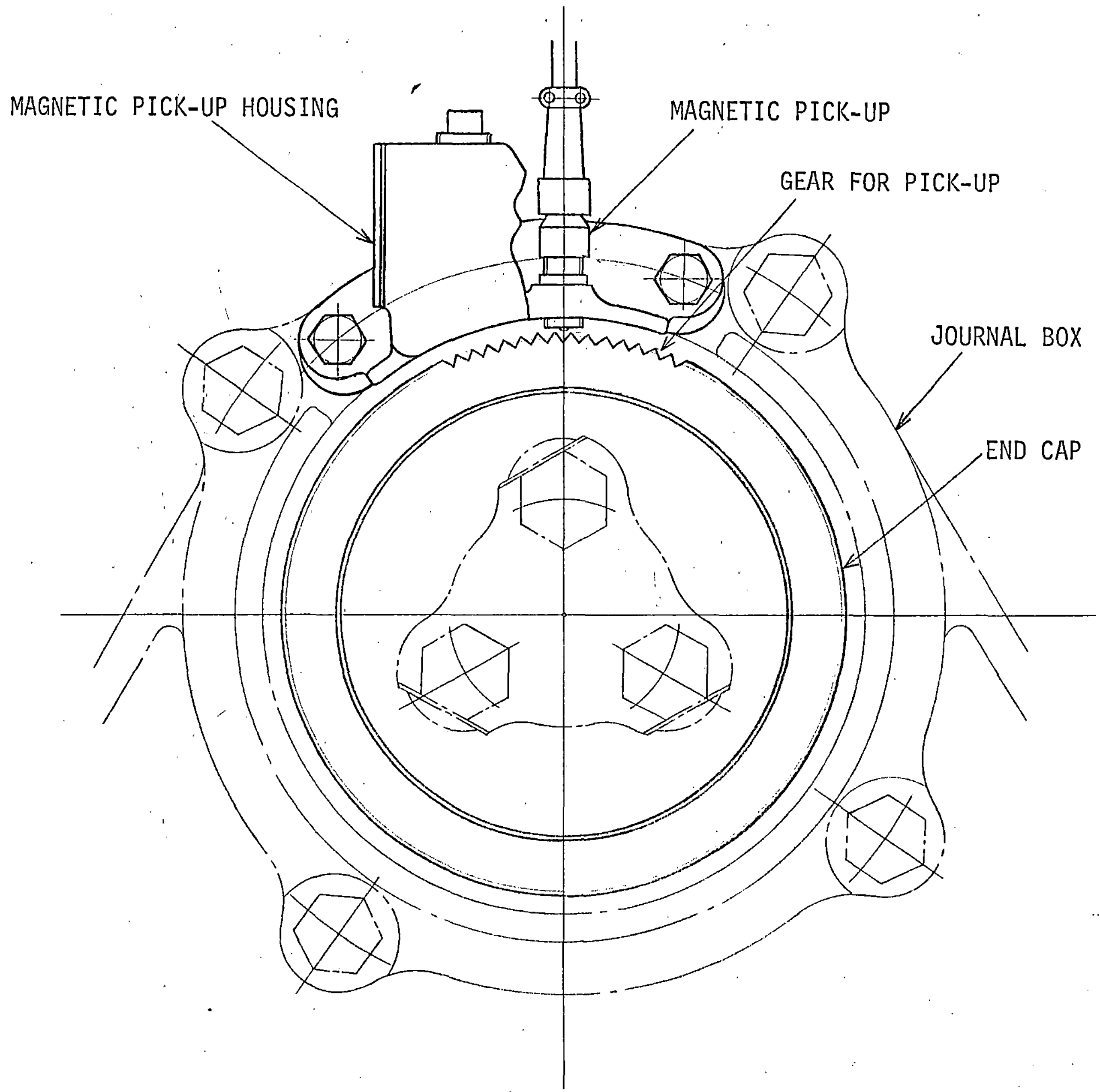


Figure 3.9 Wheel-Slide Detection Device

5. TRUCK PERFORMANCE

The following analyses of the truck performance have been done in terms of running safety and ride quality.

5.1 RUNNING SAFETY ANALYSES

The following analyses have been conducted with respect to running safety.

1) Stability Against Overturn - calculation of overturn of the tilting vehicle toward the outside of the lines on the condition that the vehicle is running on the curved track and the wind pressure works on the side of the carbody.
2) Wheel Load Equalization - calculation of wheel load variation when one wheel of the truck is lifted while other wheels remain on level rail.
3) Derailment Safety - calculation of lateral force on the wheels when the vehicle is running on the curved track.
4) Hunting Stability - investigation that the critical hunting speed is higher than the maximum operation speed.

5.1.1 STABILITY AGAINST OVERTURN

The criteria for stability against overturn are shown in terms of the wheel load reduction ratio:

$$C_r = \frac{\Delta P}{P} \times 100 \quad (\%)$$

where, ΔP : wheel load reduction

P : normal wheel load

The safety limit of Cr is 80 experientially.

Model is shown in Figure 5.1.1 (A).

The forces on the vehicle are as follows.

1) Excessive centrifugal force

The excessive centrifugal force acts on the center of gravity of the carbody when the vehicle is passing through curve at high speed.

The excessive centrifugal force F_B is given by the following formula.

$$F_B = W_B \left(\frac{V^2}{127R} - \frac{C}{G} \right)$$

where, W_B : weight of carbody

V : velocity of vehicle

R : radius of curve

C : superelevation

G : track gauge

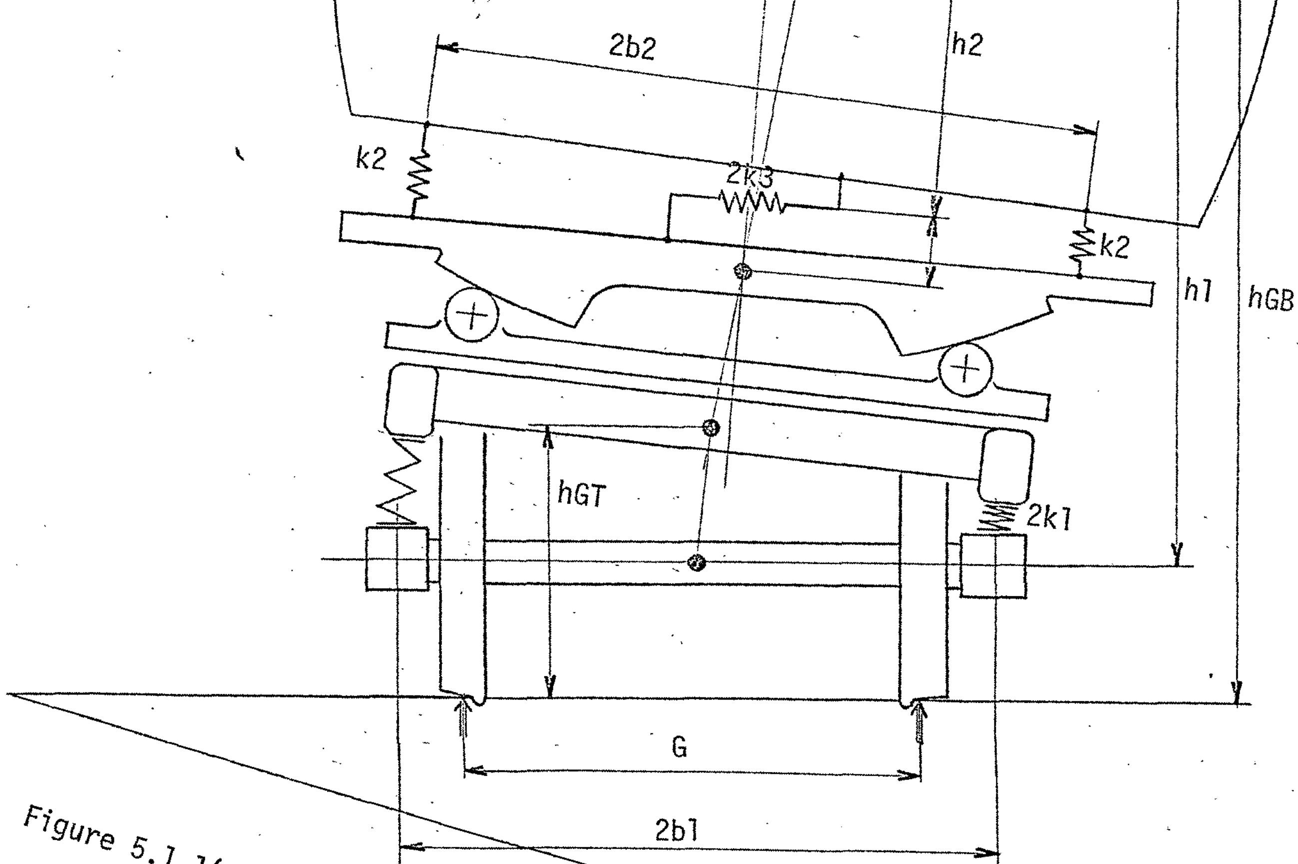
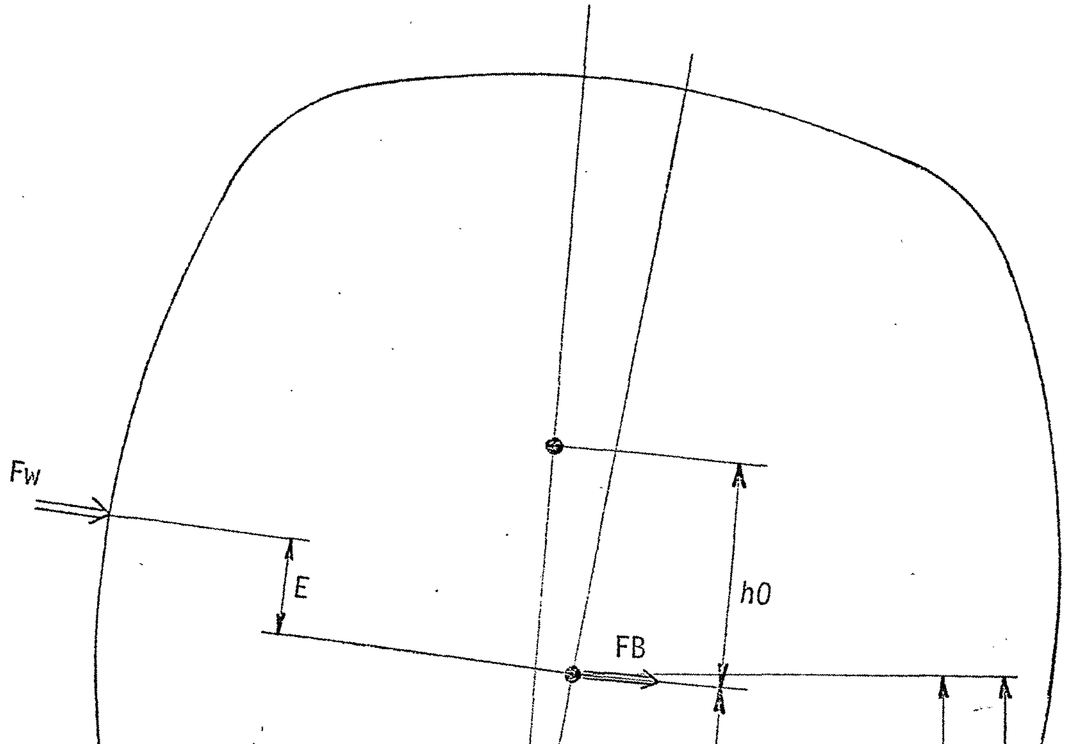


Figure 5.1.1(A) Model of Stability Against Overturn



Fw
E
h0
FB

2) Wind force

The wind force Fw is given by the following formula.

$$Fw = Cd \cdot \frac{1}{2} \cdot \rho \cdot S^2 \cdot A$$

where, Cd : drag coefficient

ρ : specific gravity of air

S : speed of wind

A : side area of carbody

3) Vibration of carbody

The wheel load reduction occurred by the vibration of carbody is given by the following formula.

$$\Delta P3 = \frac{(hGB + CyW_B)\ W_B\ a\ y}{2G}$$

where, GB : height of center of gravity of carbody

C_y : peculiar value of suspension system

a y : lateral acceleration of carbody

The static wheel load reductions by the excessive centrifugal force and wind are indicated ΔP_1 and ΔP_2 respectively.
On the other hand, ΔP_3 is a dynamic wheel load reduction.
Total wheel load reduction ΔP is ;

$$\Delta P = \Delta P_1 + \Delta P_2 + \Delta P_3$$

The calculation data are shown in Table 5.1.1 (A).
The data of curve radius, superelevation, velocity of vehicle and wind speed are shown in Table 5.1.1 (B).

Table 5.1.1(A) Calculation Data of Stability Against Overturn

SYMBOL	DESCRIPTION	DESIGN VALUE
W_B	weight of carbody (tare) /truck	17520 Kg
W_T	sprung weight of truck / truck	3270 Kg
$2b_1$	distance between primary springs	1960 mm
$2b_2$	distance between secondary springs	2120 mm
k_1	vertical spring constant of primary spring / wheel	108 Kg/mm
k_2	vertical spring constant of secondary spring / set	40 Kg/mm
k_3	lateral spring constant of secondary spring / set	35 Kg/mm
h_o	distance between tilting center and center of gravity of carbody	800 mm
h_1	distance between center of gravity of carbody and axle center	1443 mm
h_2	distance between secondary spring center and center of gravity of carbody	863 mm
h_{GB}	height of center of gravity of carbody from top of rail	1900 mm
h_{GT}	height of center of gravity of truck frame	557 mm
G	track gauge	1435 mm
Cd	drag coefficient	0.9
ρ	specific gravity of air	0.125
A	side area of carbody	23 m^2
E	distance between center of gravity of carbody and center of wind force	436 mm
θ	maximum tilting angle	6°

Table 5.1.1(B) Calculation Data R,C,V and S - Stability against Overturn

Curve radius R (m)	Superelevation C (m)		Velocity of vehicle V (Km/h)		Wind speed S (m/sec.)		
200	57	111	40 ~ 90	40 ~ 90	10	20	30
300	57	105	60 ~ 110	60 ~ 110	〃	〃	〃
400	80	152	80 ~ 130	80 ~ 130	〃	〃	〃
500	60	127	80 ~ 130	80 ~ 140	〃	〃	〃
600	70	147	100 ~ 150	120 ~ 160	〃	〃	〃
700	70	152	120 ~ 160	120 ~ 170	〃	〃	〃
800	57	152	120 ~ 170	140 ~ 190	〃	〃	〃
900	50	152	120 ~ 180	140 ~ 200	〃	〃	〃
1000	50	150	140 ~ 190	160 ~ 210	〃	〃	〃
1100	60	152	140 ~ 200	160 ~ 220	〃	〃	〃
1200	57	152	140 ~ 200	160 ~ 220	〃	〃	〃
1300	57	152	160 ~ 210	180 ~ 240	〃	〃	〃
1400	50	152	160 ~ 220	180 ~ 240	〃	〃	〃
1500	50	152	160 ~ 230	200 ~ 260	〃	〃	〃
1600	47	152	180 ~ 230	200 ~ 260	〃	〃	〃
1700	47	152	180 ~ 240	200 ~ 270	〃	〃	〃
1750	50	146	180 ~ 240	220 ~ 270	〃	〃	〃
1800	57	146	200 ~ 250	220 ~ 280	〃	〃	〃
2000	40	149	200 ~ 250	220 ~ 290	10	20	30

The results are shown in Figure 5.1.1 (B) and Figure 5.1.1 (C).
Figure 5.1.1 (B) shows the relation among velocity of vehicle, wheel load reduction ratio and wind speed.
Figure 5.1.1 (C) shows the relation among superelevation, safety limit velocity and radius of curve.
The safety limit velocities are the values when the wheel load reduction ratio comes to be 80 percent.
The safety limit velocities under the wind speed of 20 m/sec. condition are shown in Table 7.6 as V4.
The velocities running through curves are set at the lower value of either V2 or V4 after comparison.

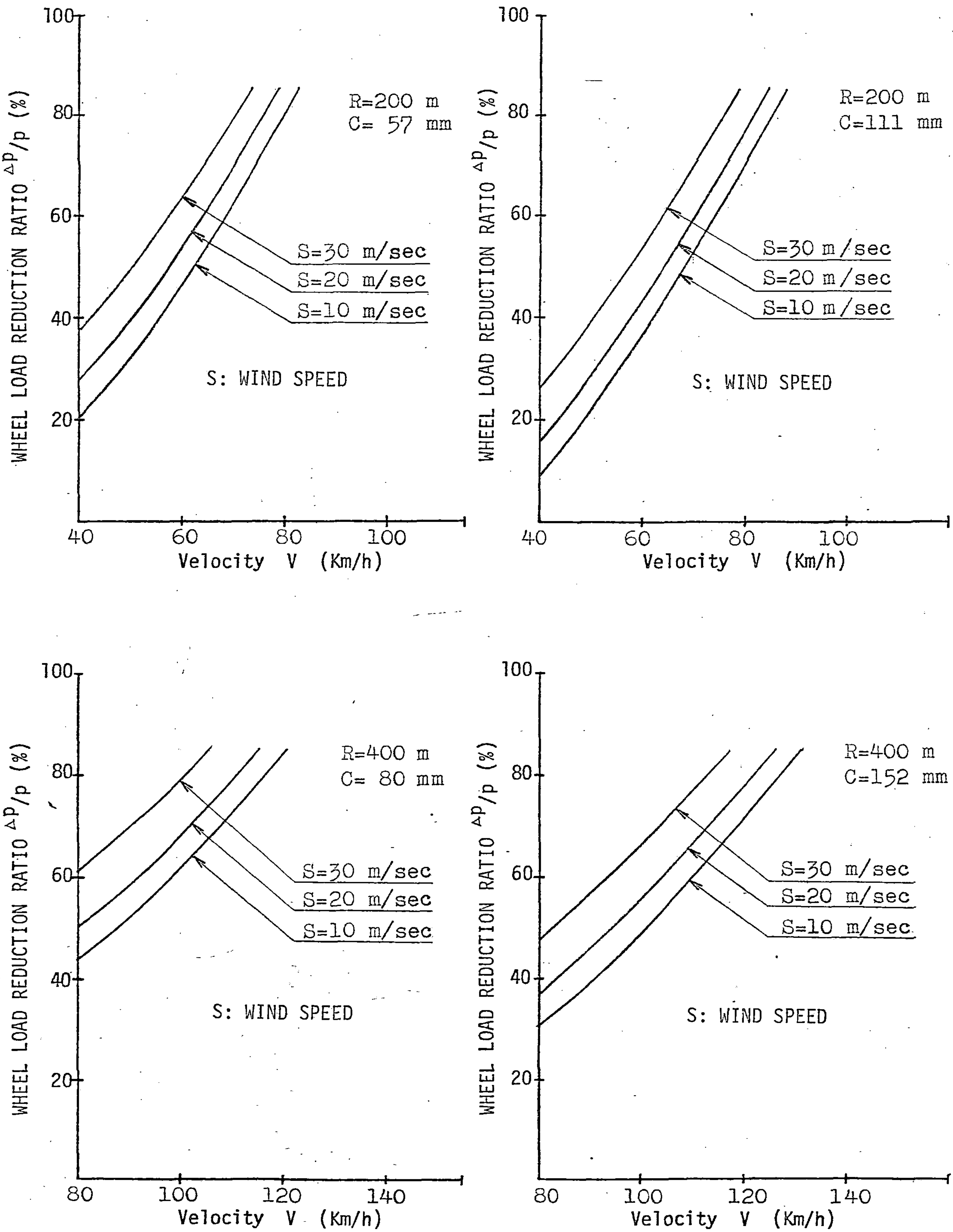
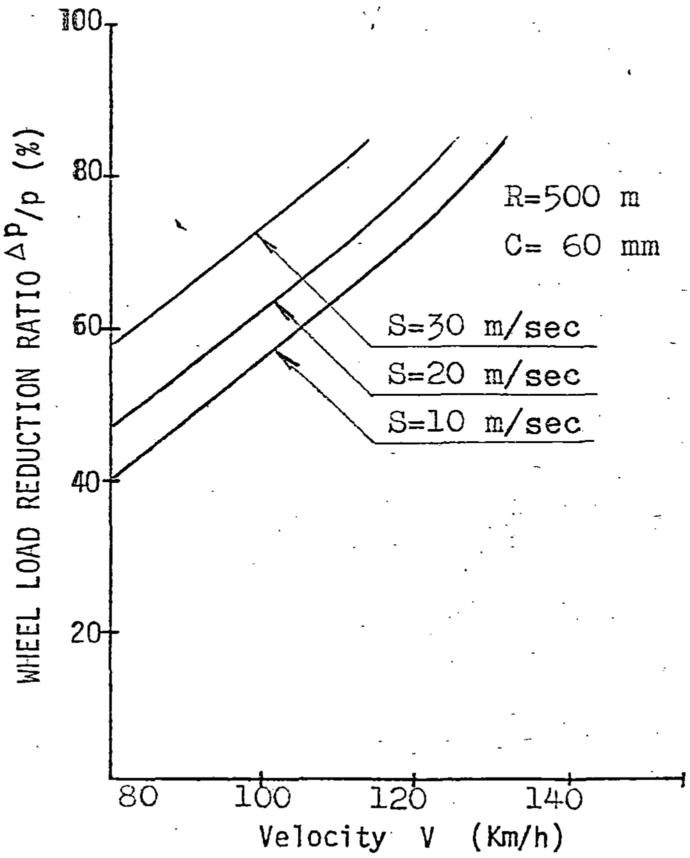
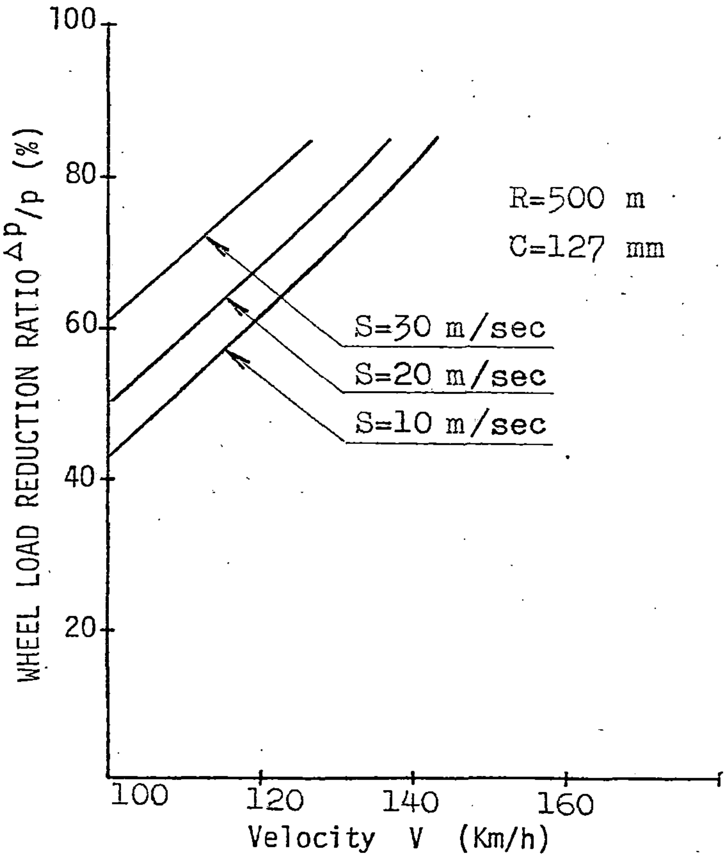
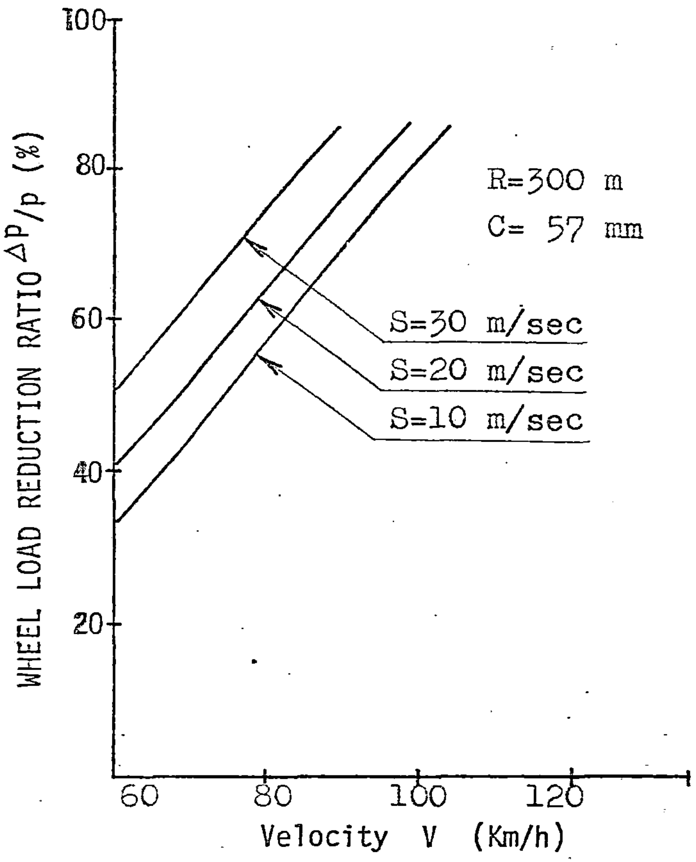
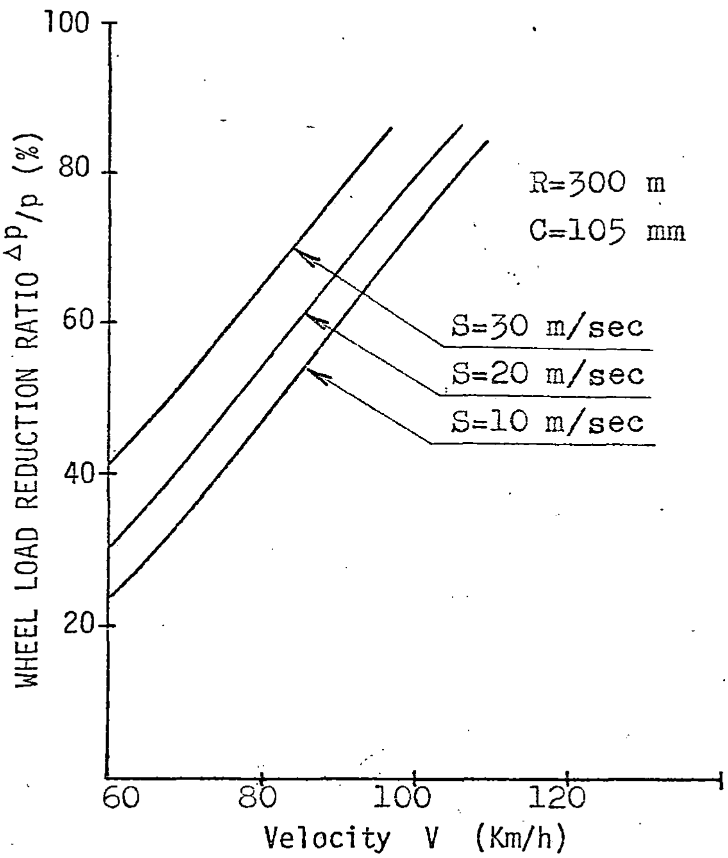


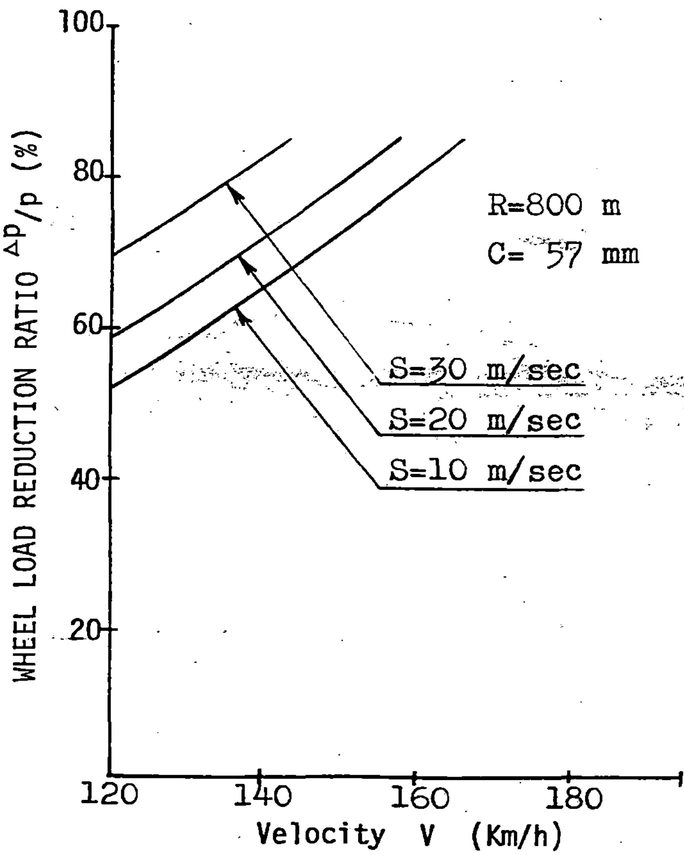
Figure 5.1.1 (B) Wheel Load Reduction - Stability against Overturn


WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
80
100
120
140
Velocity V (Km/h)
R=500 m
C= 60 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec

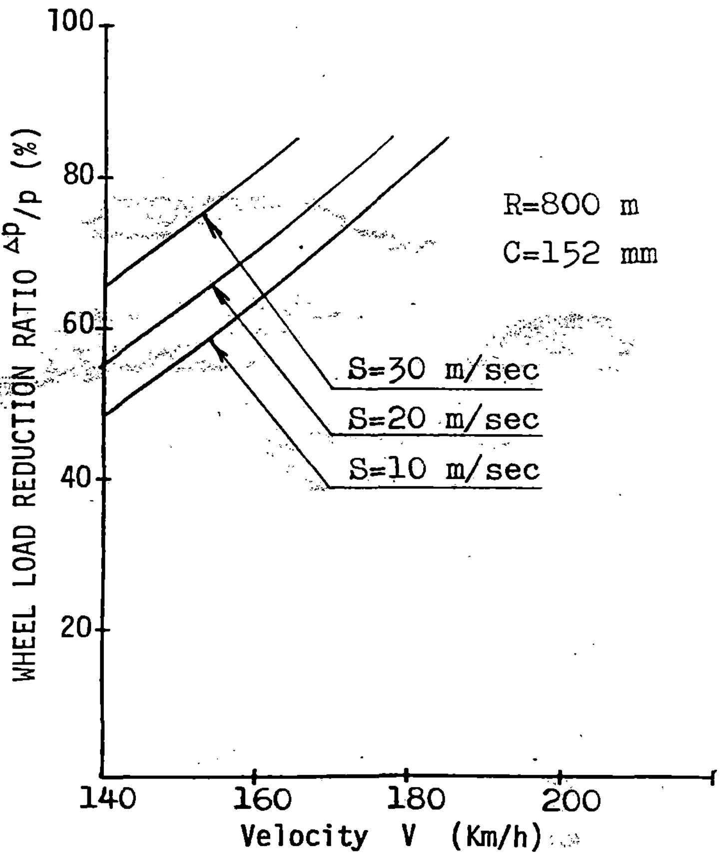

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
100
120
140
160
Velocity V (Km/h)
R=500 m
C=127 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec


WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
R=300 m
C= 57 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
60
80
100
120
Velocity V (Km/h)

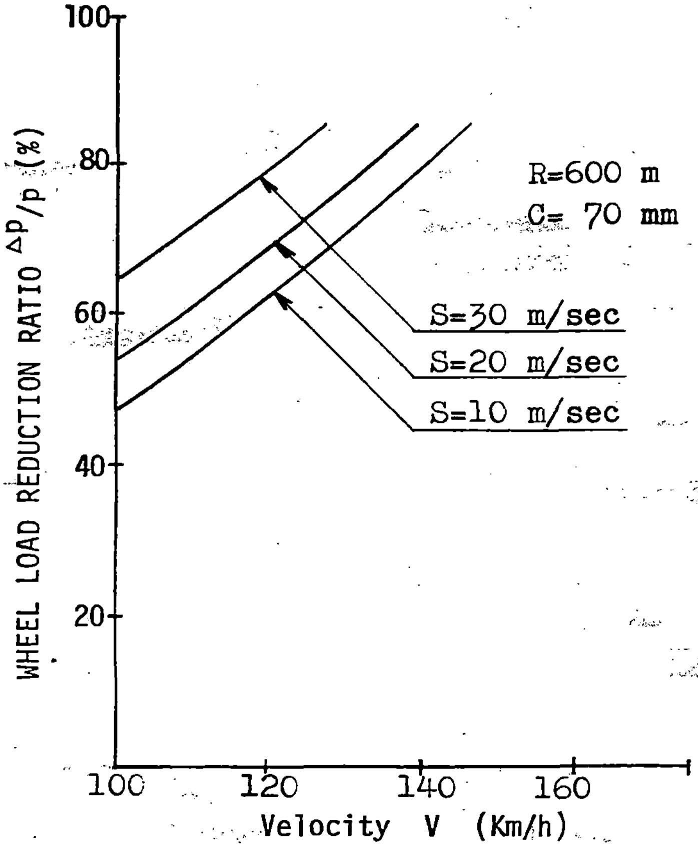

WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
R=300 m
C=105 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
60
80
100
120
Velocity V (Km/h)

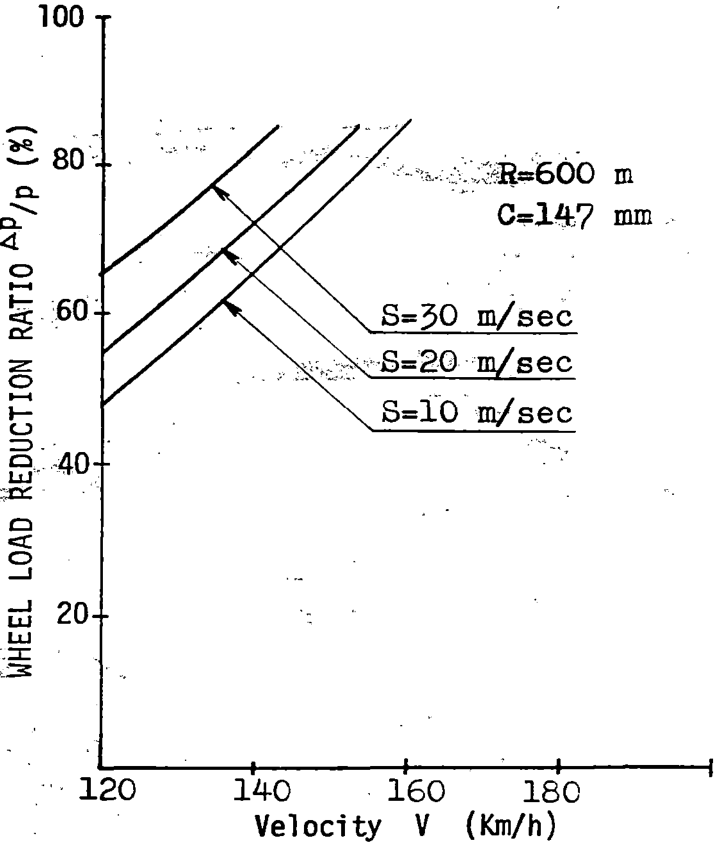


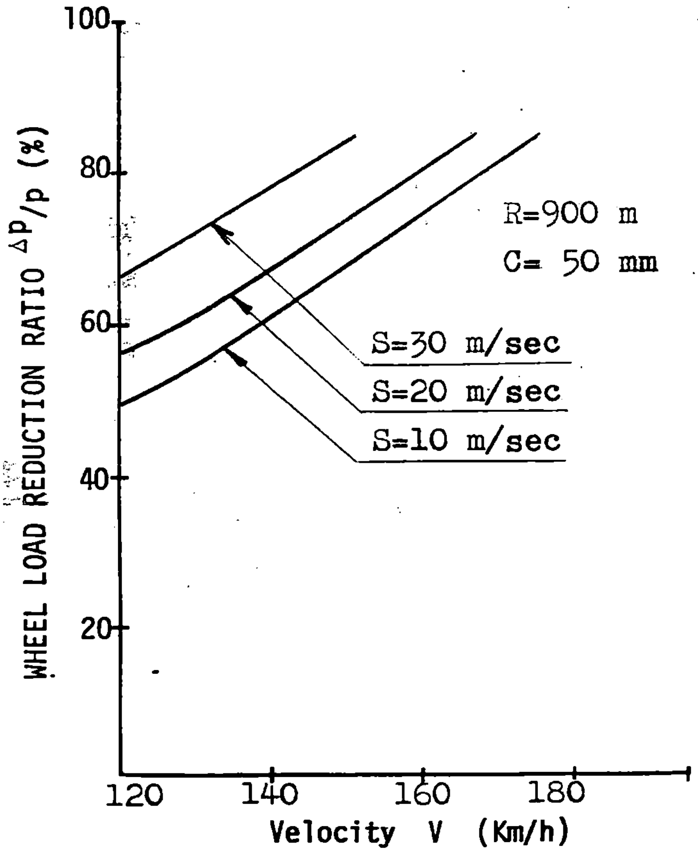
WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
120
140
160
180
Velocity V (Km/h)
R=800 m
C= 57 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec



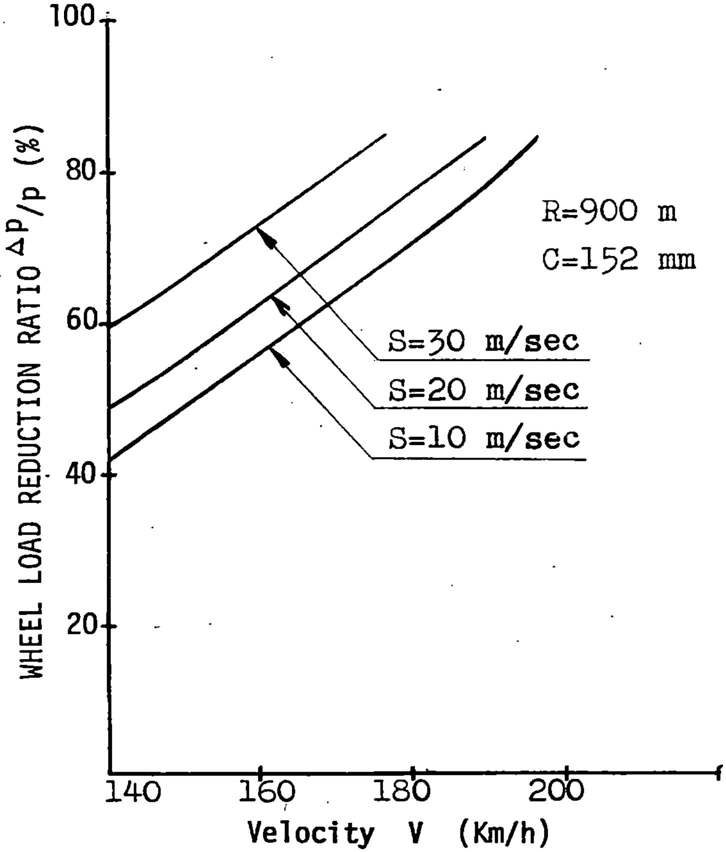
WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
140
160
180
200
Velocity V (Km/h)
R=800 m
C=152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec


WHEEL LOAD REDUCTION RATIO $^{\Delta P}/_{p}$ (%)
100
80
60
40
20
100
120
140
160
Velocity V (Km/h)
R=600 m
C= 70 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec

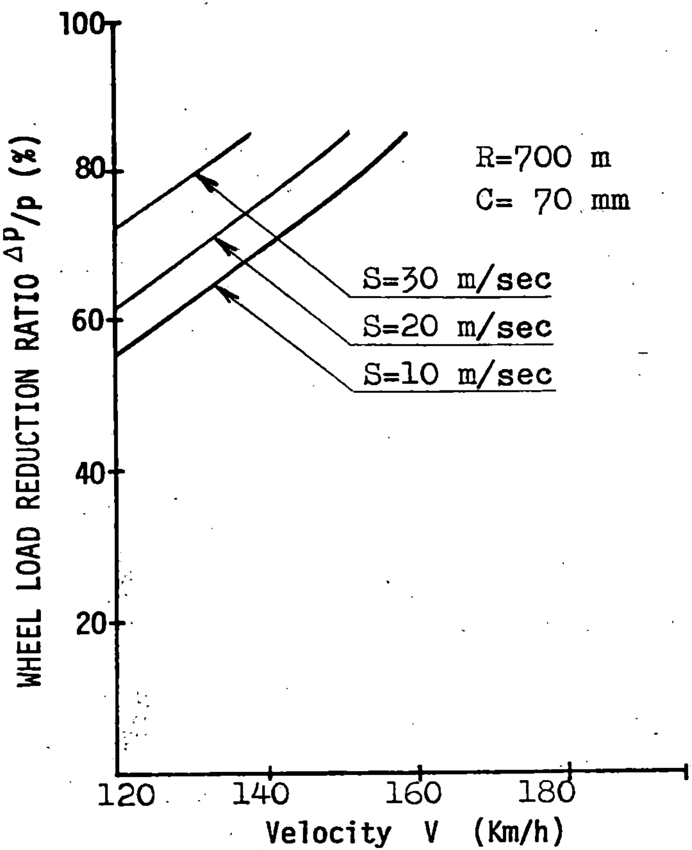

WHEEL LOAD REDUCTION RATIO $^{\Delta P}/_{p}$ (%)
100
80
60
40
20
120
140
160
180
Velocity V (Km/h)
R=600 m
C=147 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec



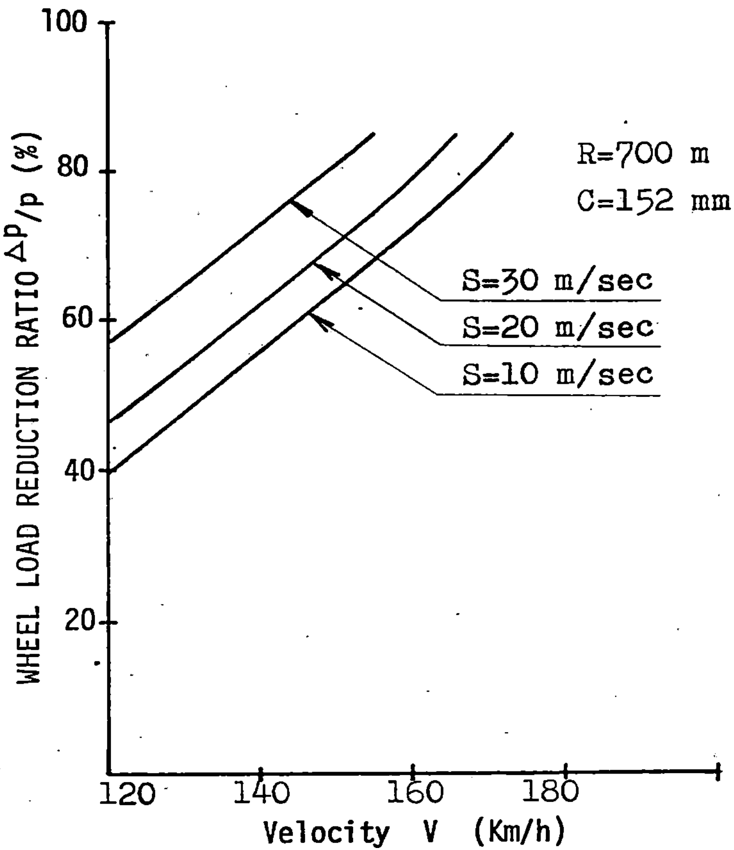
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
120
140
160
180
Velocity V (Km/h)
R=900 m
C= 50 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec



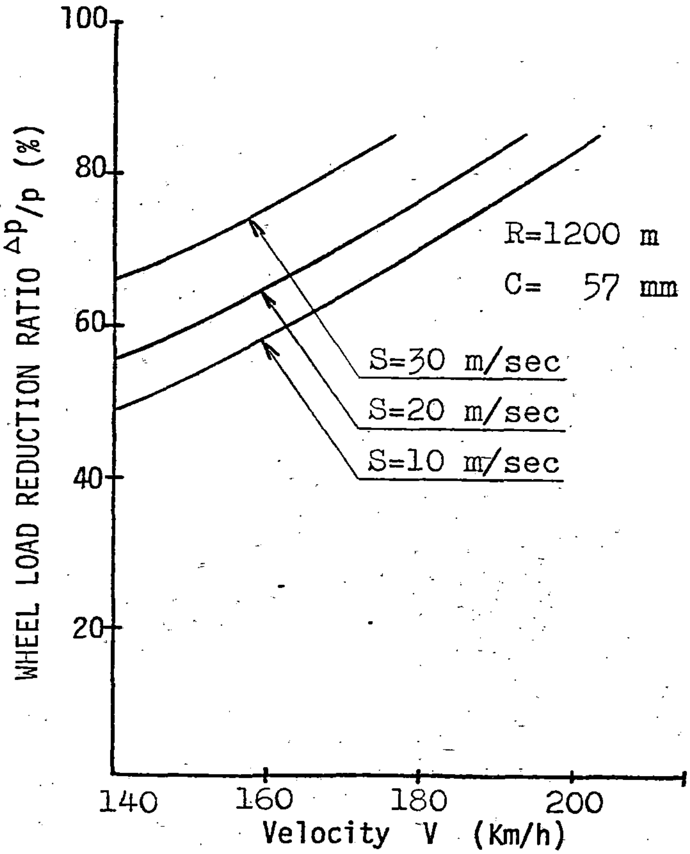
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
140
160
180
200
Velocity V (Km/h)
R=900 m
C=152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec

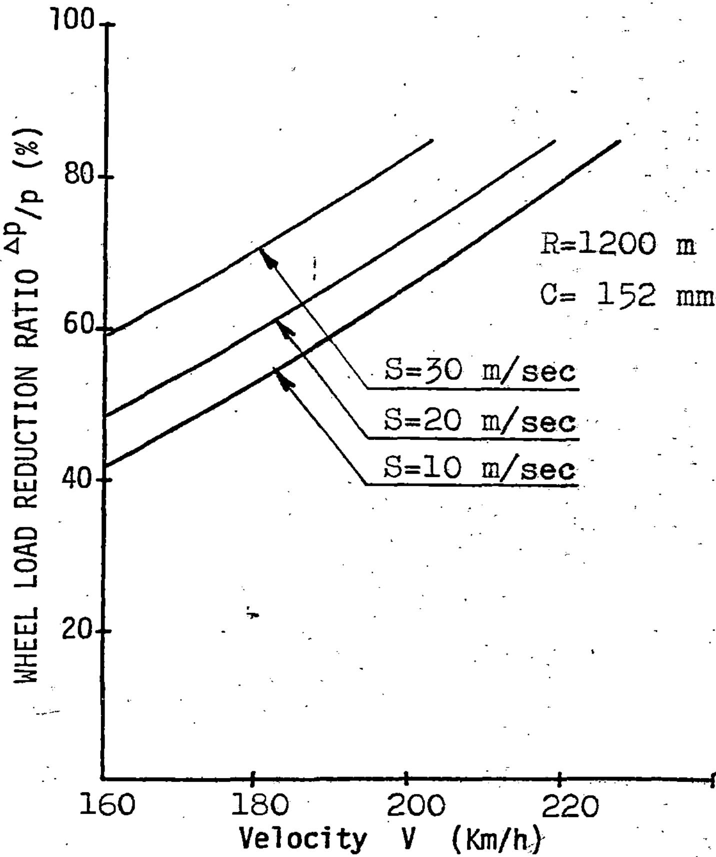


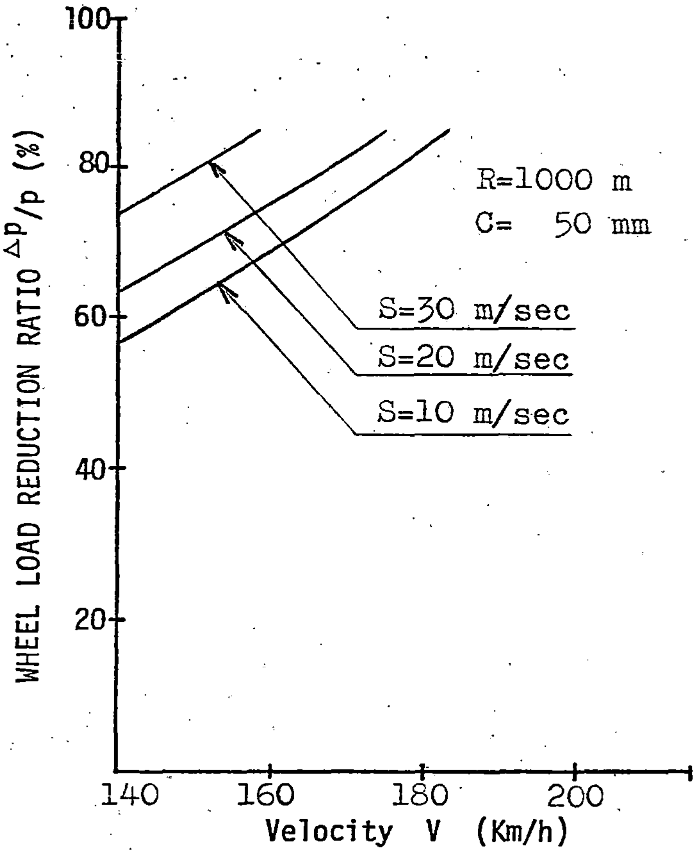
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
R=700 m
C= 70 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
120
140
160
180
Velocity V (Km/h)

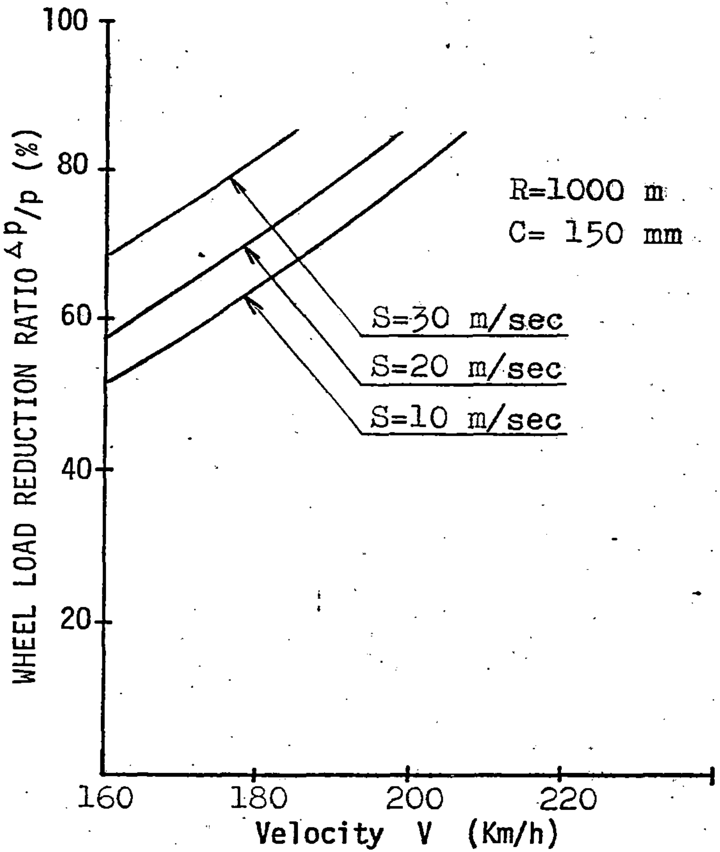


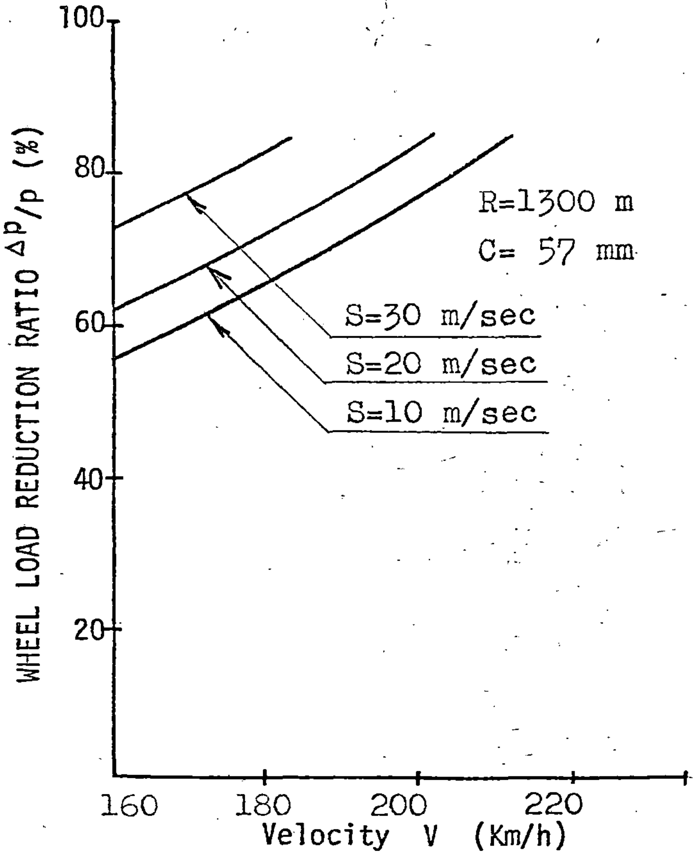
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
R=700 m
C=152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
120
140
160
180
Velocity V (Km/h)

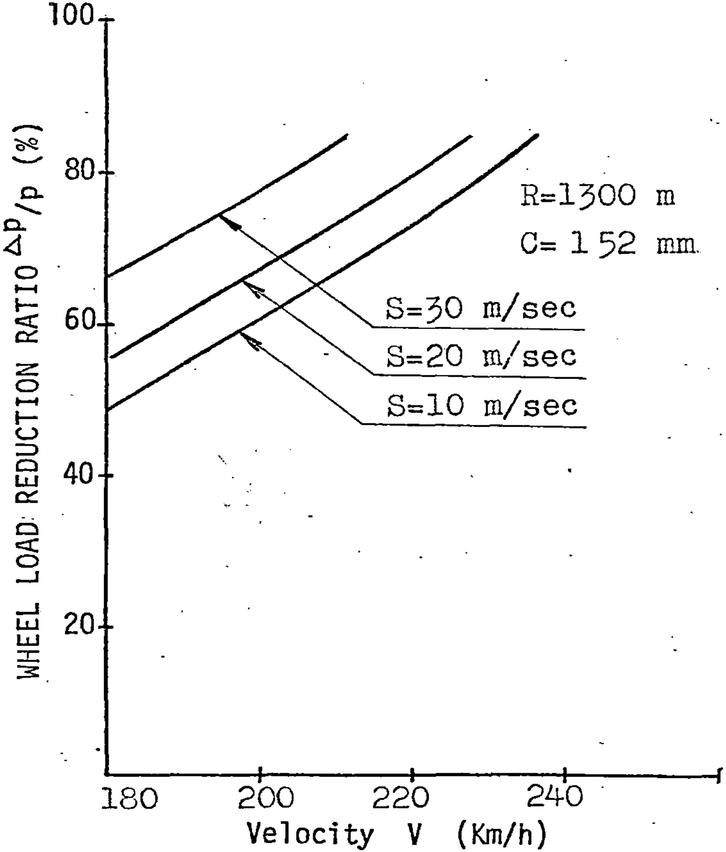

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1200 m
C= 57 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
140
160
180
200
Velocity V (Km/h)

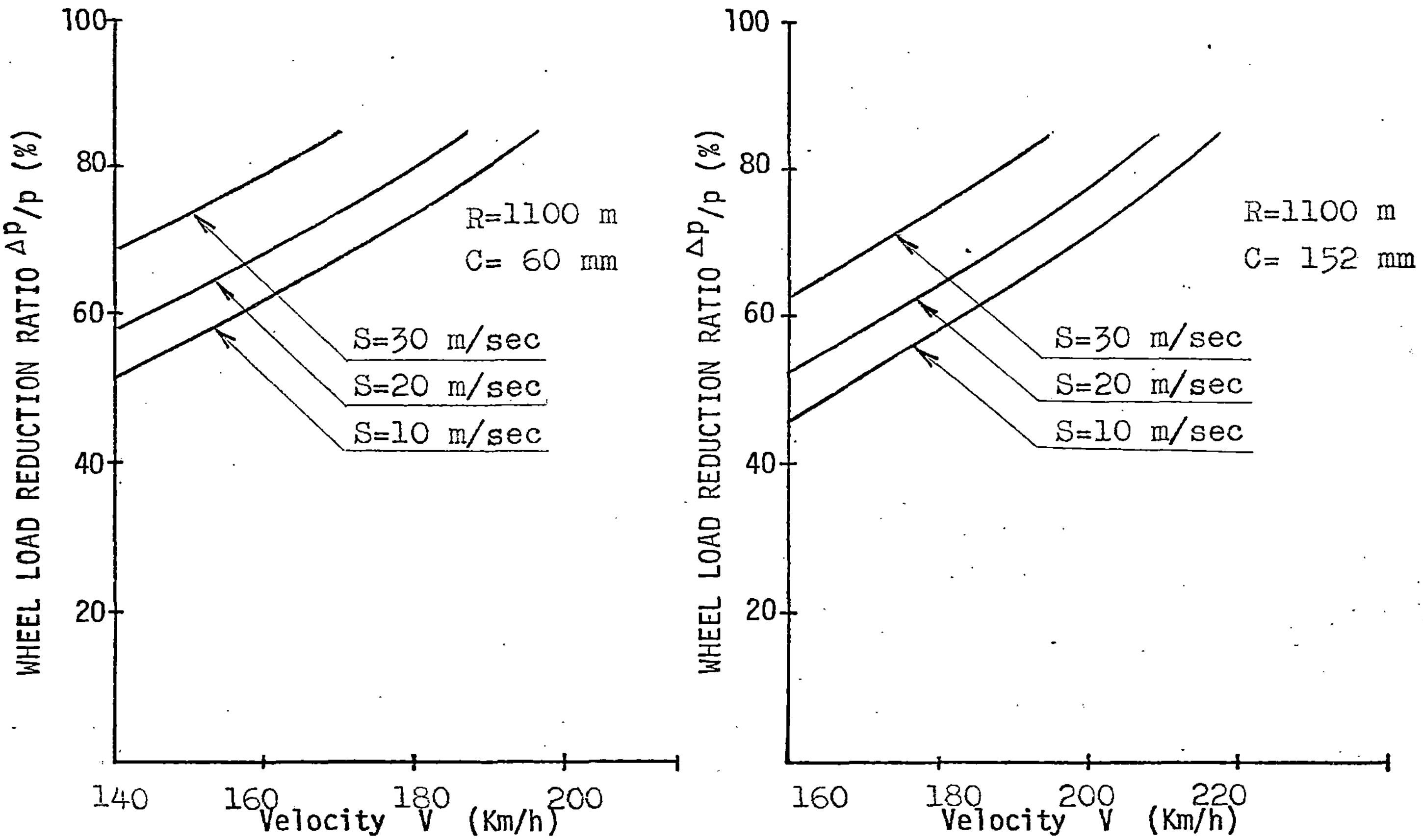

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1200 m
C= 152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
160
180
200
220
Velocity V (Km/h)

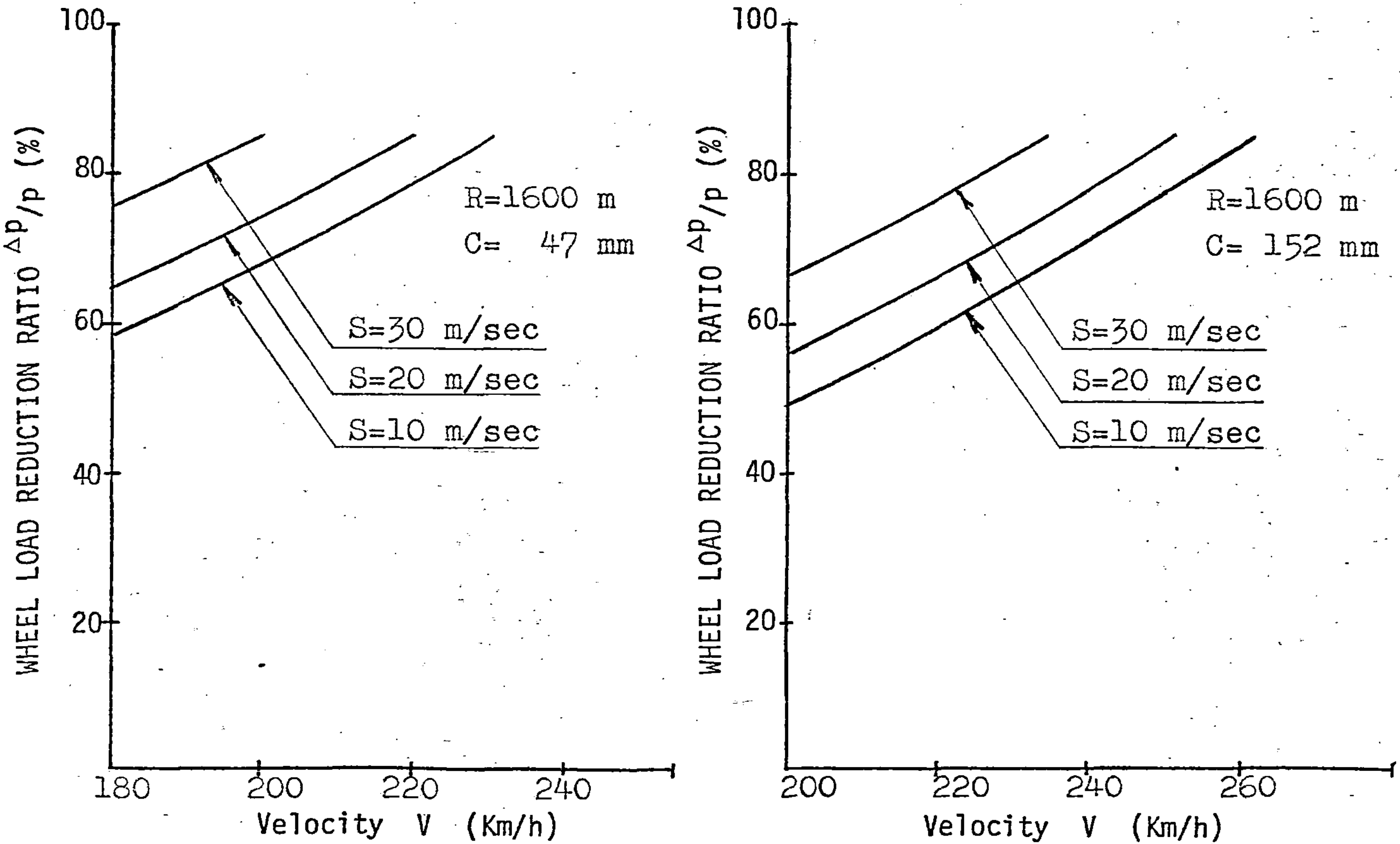

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1000 m
C= 50 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
140
160
180
200
Velocity V (Km/h)

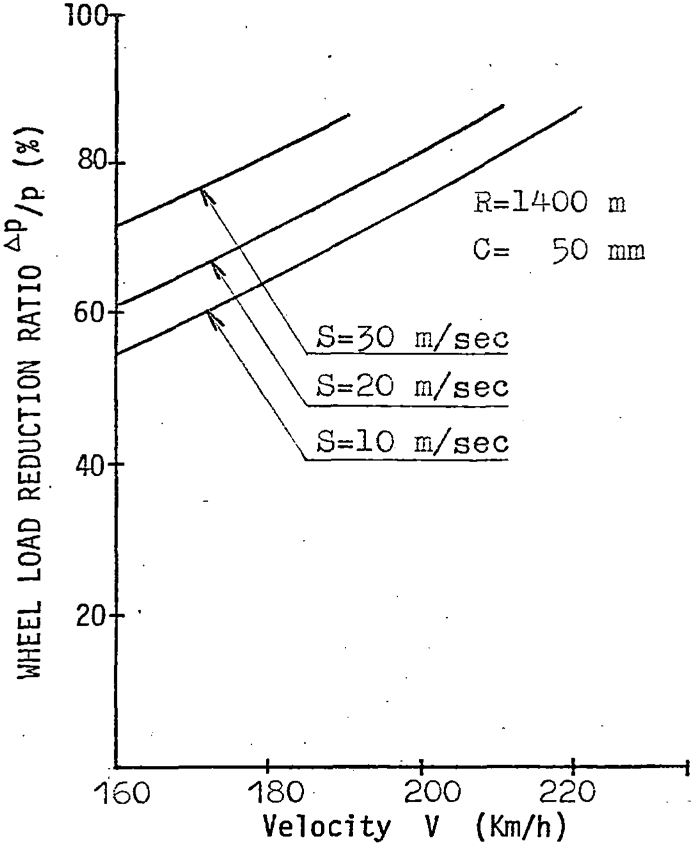

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1000 m
C= 150 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
160
180
200
220
Velocity V (Km/h)

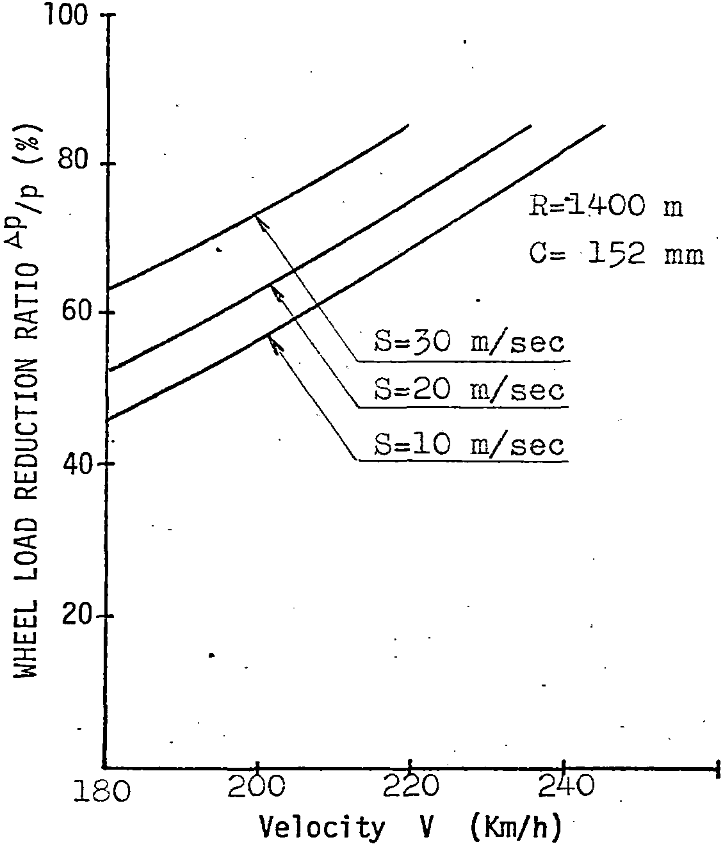

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1300 m
C= 57 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
160
180
200
220
Velocity V (Km/h)

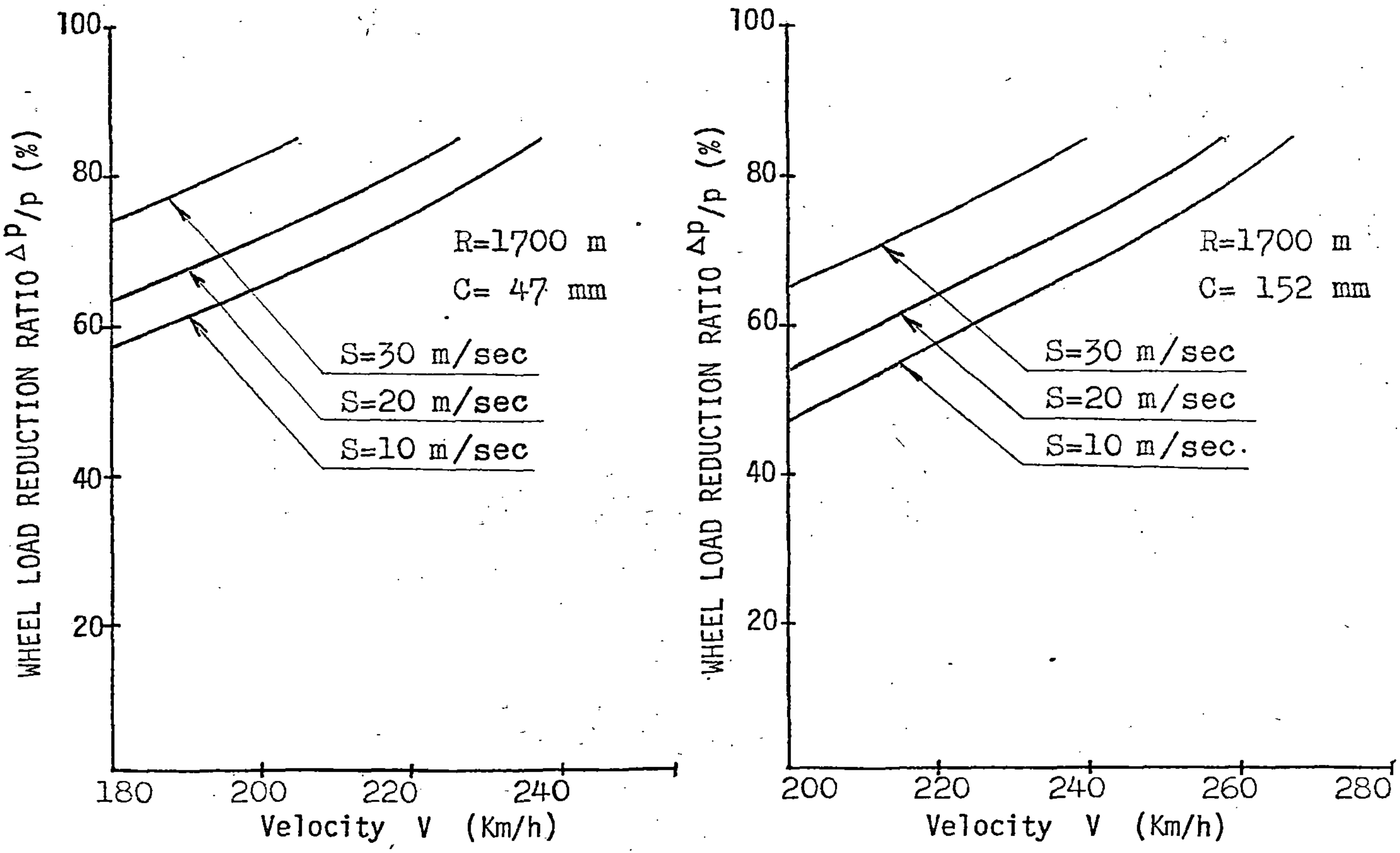

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1300 m
C= 1 52 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
180
200
220
240
Velocity V (Km/h)


WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
R=1100 m
C= 60 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
140
160
180
200
Velocity V (Km/h)
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
R=1100 m
C= 152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
160
180
200
220
Velocity V (Km/h)

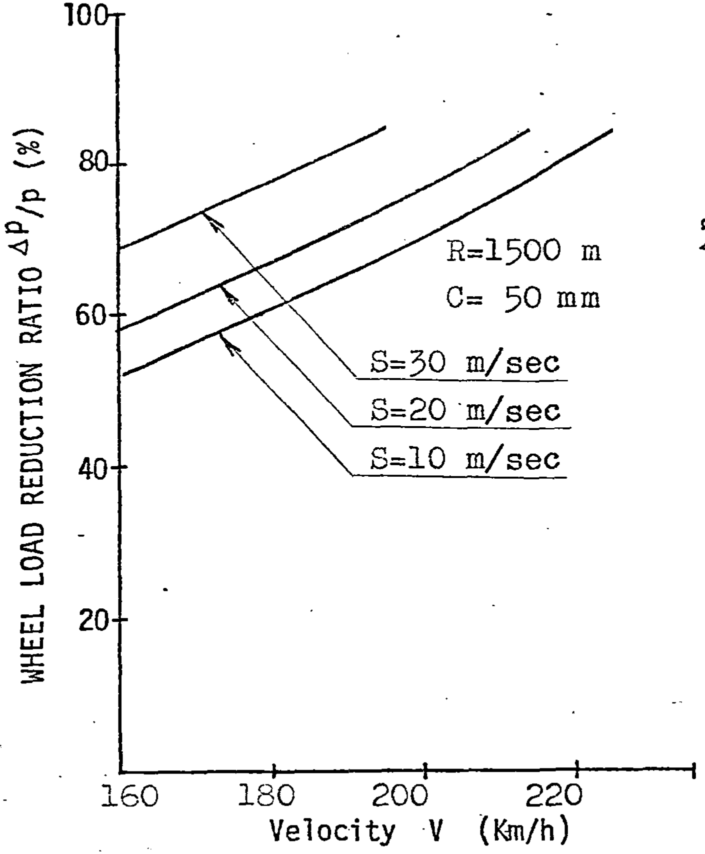

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
180
200
220
240
Velocity V (Km/h)
R=1600 m
C= 47 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
200
220
240
260
Velocity V (Km/h)
R=1600 m
C= 152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec


WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1400 m
C= 50 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
160
180
200
220
Velocity V (Km/h)

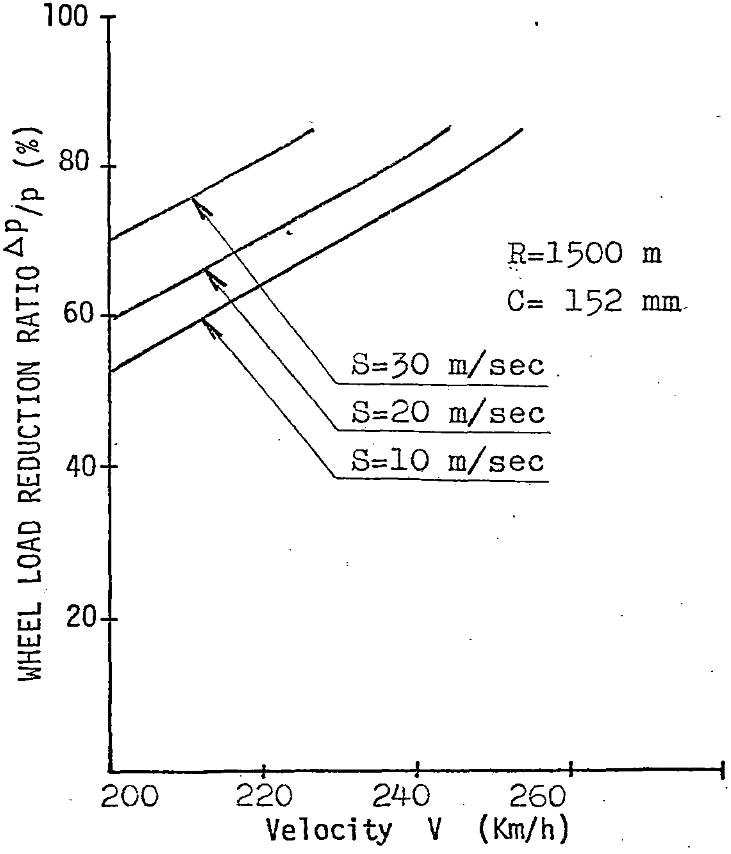

WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
R=1400 m
C= 152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
180
200
220
240
Velocity V (Km/h)



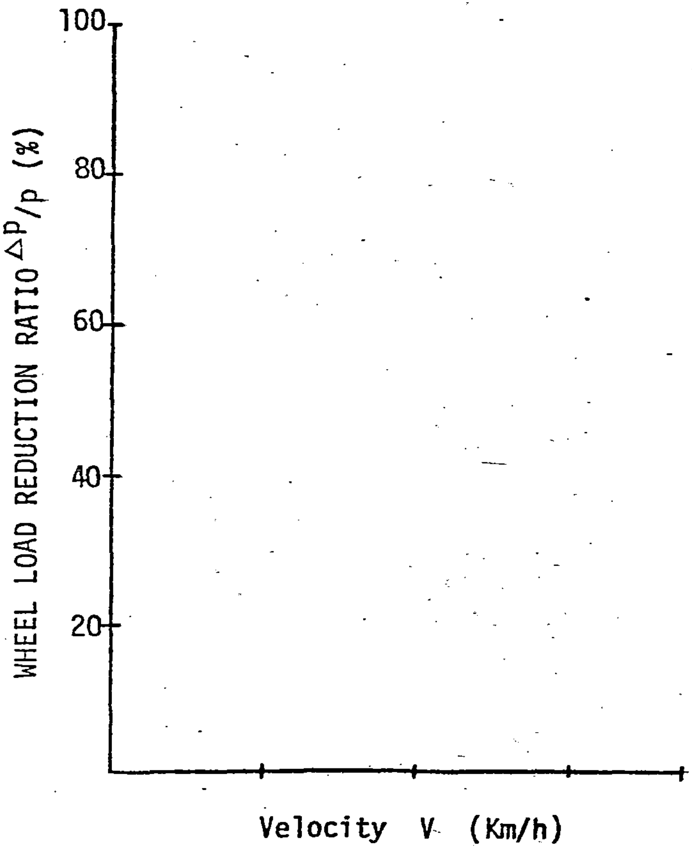
WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
180
200
220
240
Velocity V (Km/h)
R=1700 m
C= 47 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec
WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
200
220
240
260
280
Velocity V (Km/h)
R=1700 m
C= 152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec.



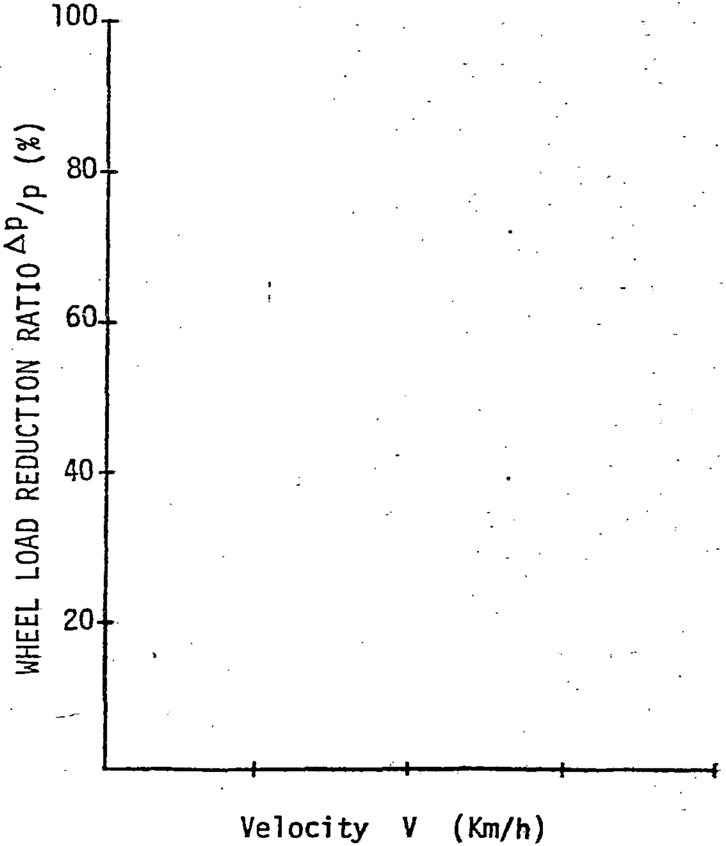
WHEEL LOAD REDUCTION RATIO $\Delta P/p$ (%)
100
80
60
40
20
160
180
200
220
Velocity V (Km/h)
R=1500 m
C= 50 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec



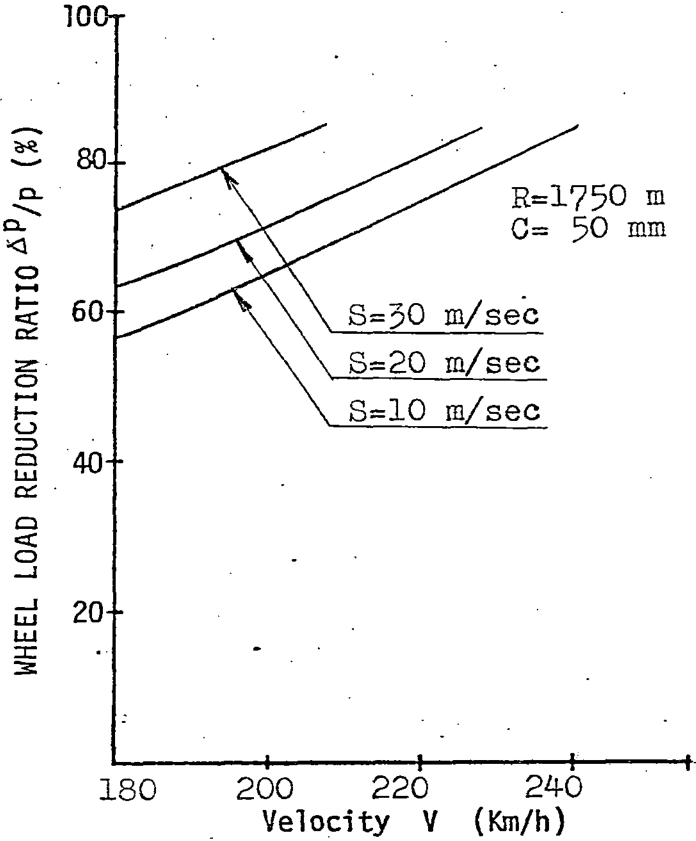
WHEEL LOAD REDUCTION RATIO $\Delta P/p$ (%)
100
80
60
40
20
200
220
240
260
Velocity V (Km/h)
R=1500 m
C= 152 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec

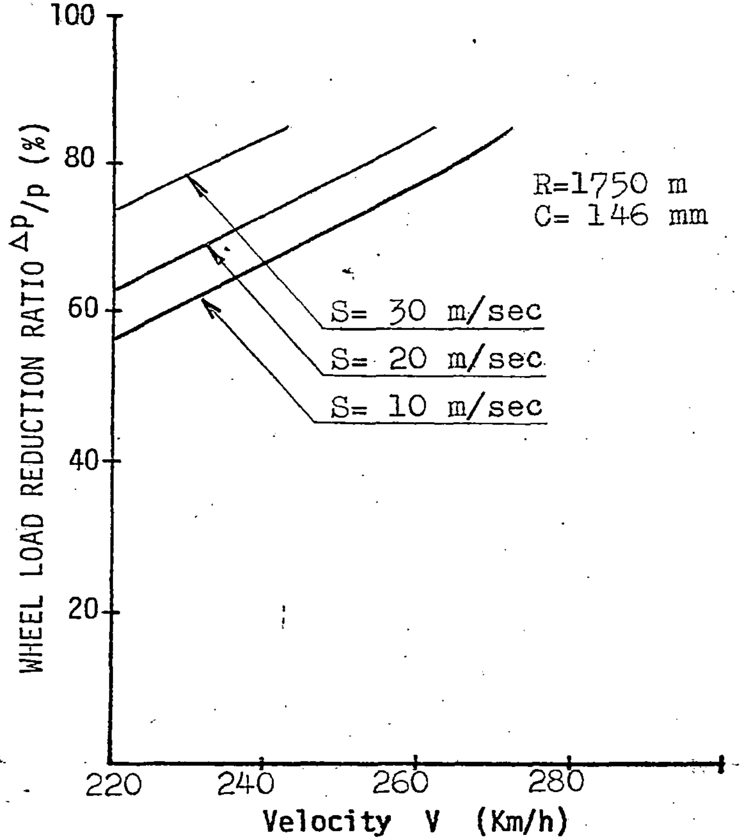


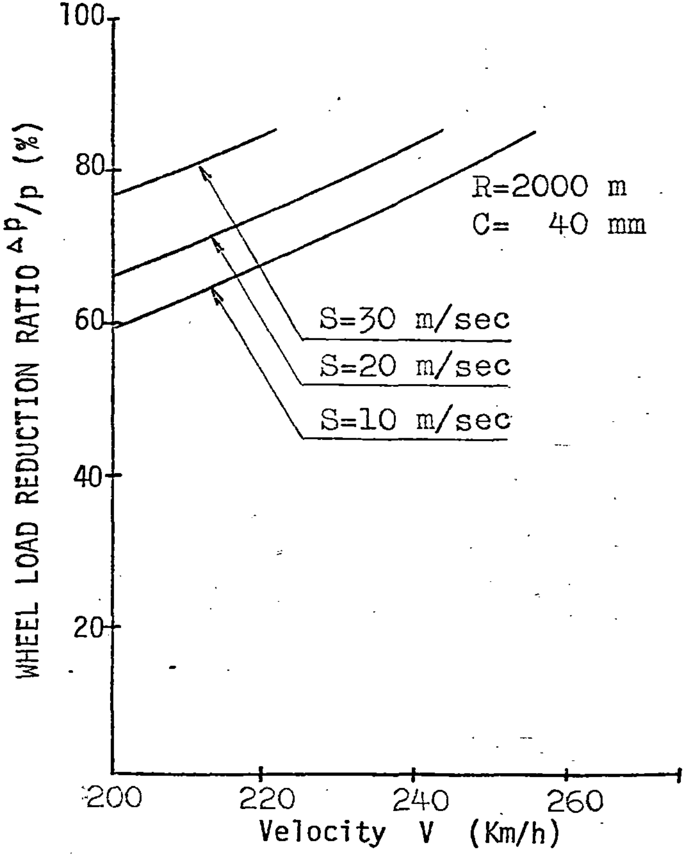
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
Velocity V (Km/h)

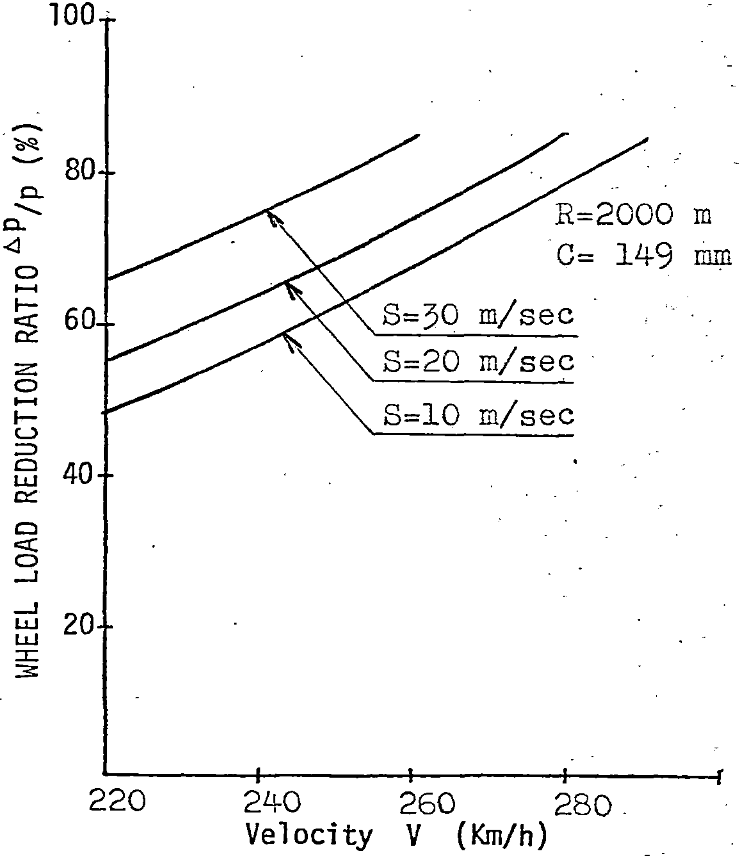


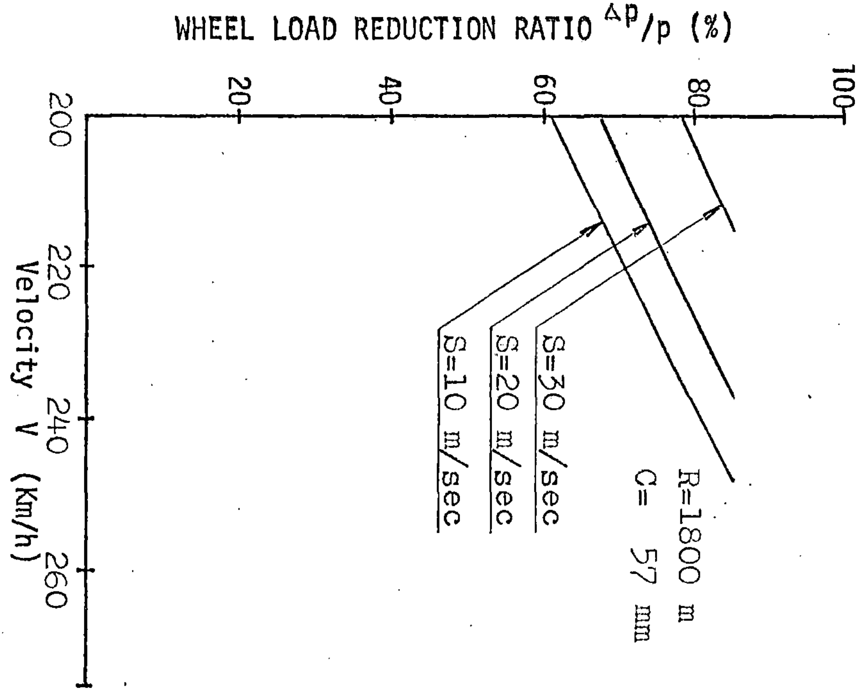
WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
Velocity V (Km/h)

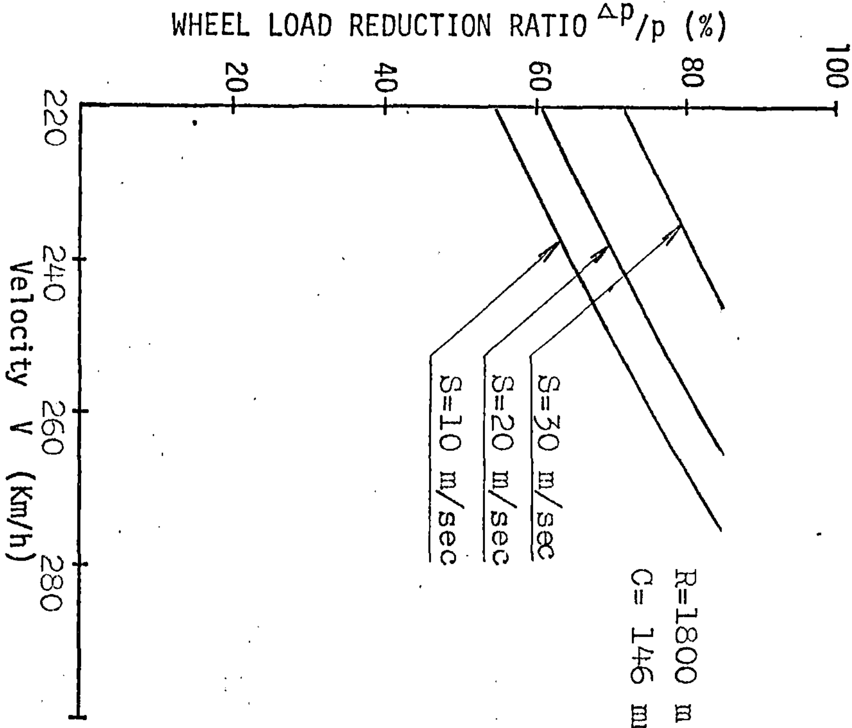

WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
180
200
220
240
Velocity V (Km/h)
R=1750 m
C= 50 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec


WHEEL LOAD REDUCTION RATIO ΔP/p (%)
100
80
60
40
20
220
240
260
280
Velocity V (Km/h)
R=1750 m
C= 146 mm
S= 30 m/sec
S= 20 m/sec
S= 10 m/sec


WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
200
220
240
260
Velocity V (Km/h)
R=2000 m
C= 40 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec


WHEEL LOAD REDUCTION RATIO Δp/p (%)
100
80
60
40
20
220
240
260
280
Velocity V (Km/h)
R=2000 m
C= 149 mm
S=30 m/sec
S=20 m/sec
S=10 m/sec


WHEEL LOAD REDUCTION RATIO Δp/p (%)
20
40
60
80
100
200
220
240
260
Velocity V (Km/h)
S=30 m/sec
S=20 m/sec
S=10 m/sec
R=1800 m
C= 57 mm


WHEEL LOAD REDUCTION RATIO Δp/p (%)
20
40
60
80
100
220
240
260
280
Velocity V (Km/h)
S=30 m/sec
S=20 m/sec
S=10 m/sec
R=1800 m
C= 146 mm

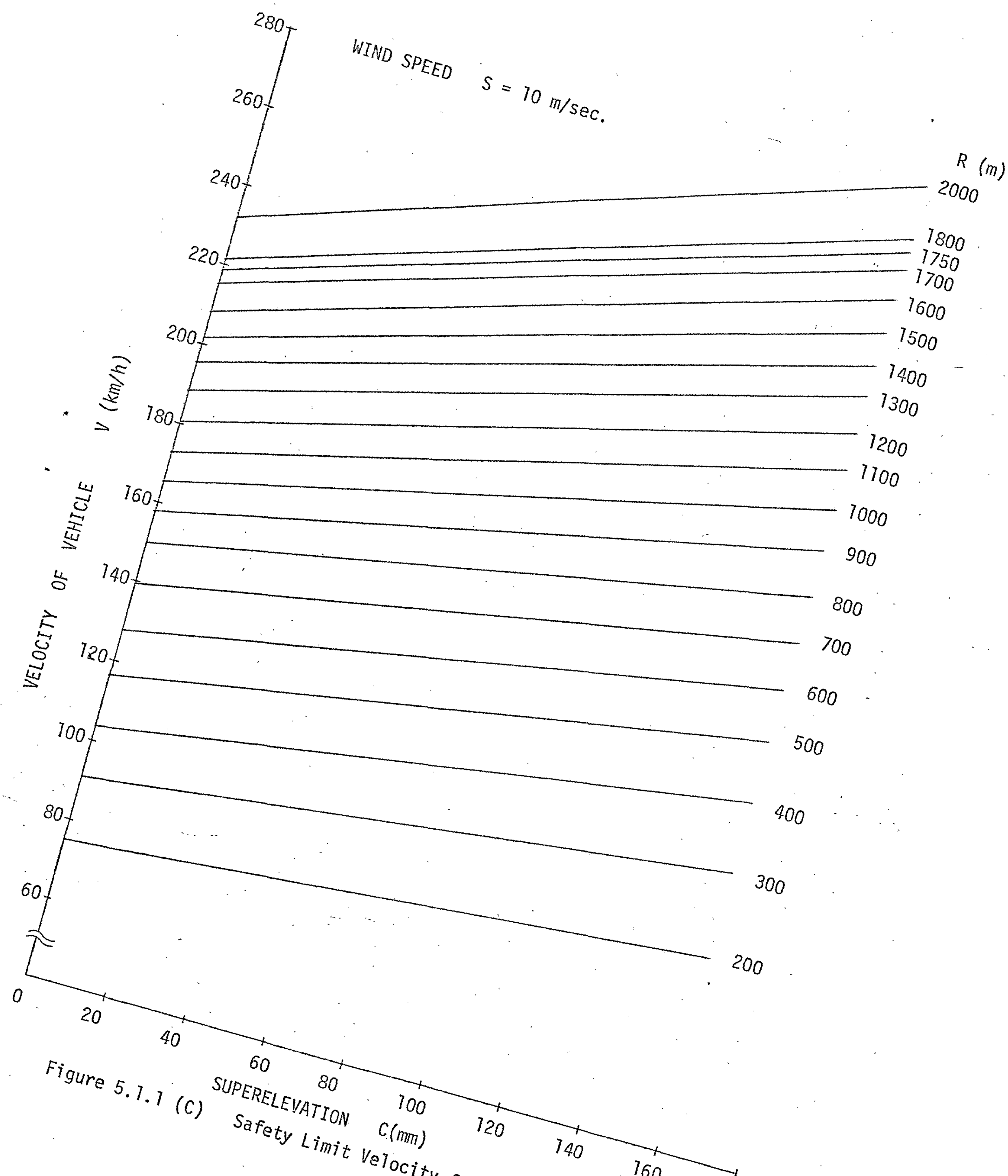


Figure 5.1.1 (C) Safety Limit Velocity for Overturn

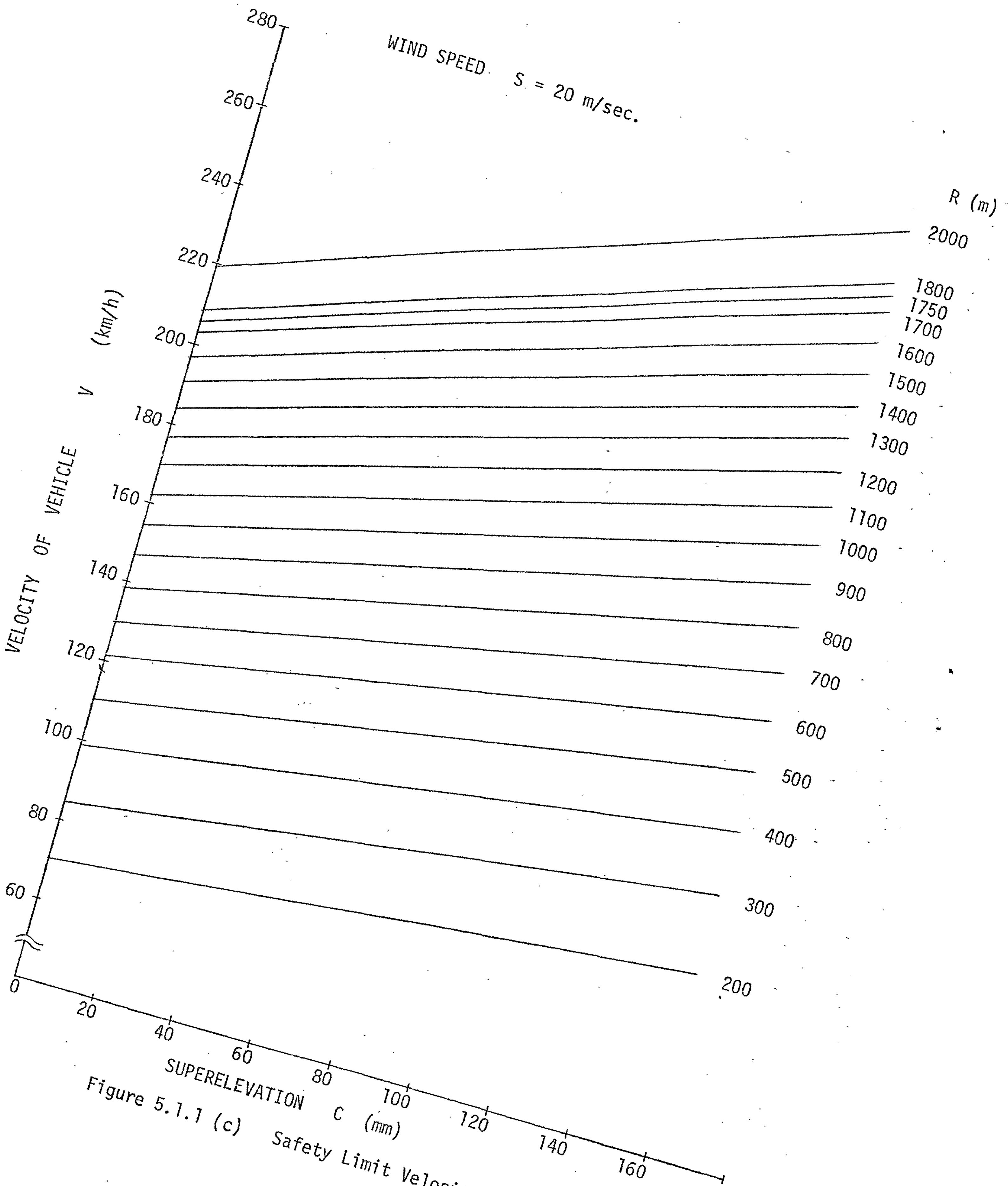


Figure 5.1.1 (c) Safety Limit Velocity for Overturn

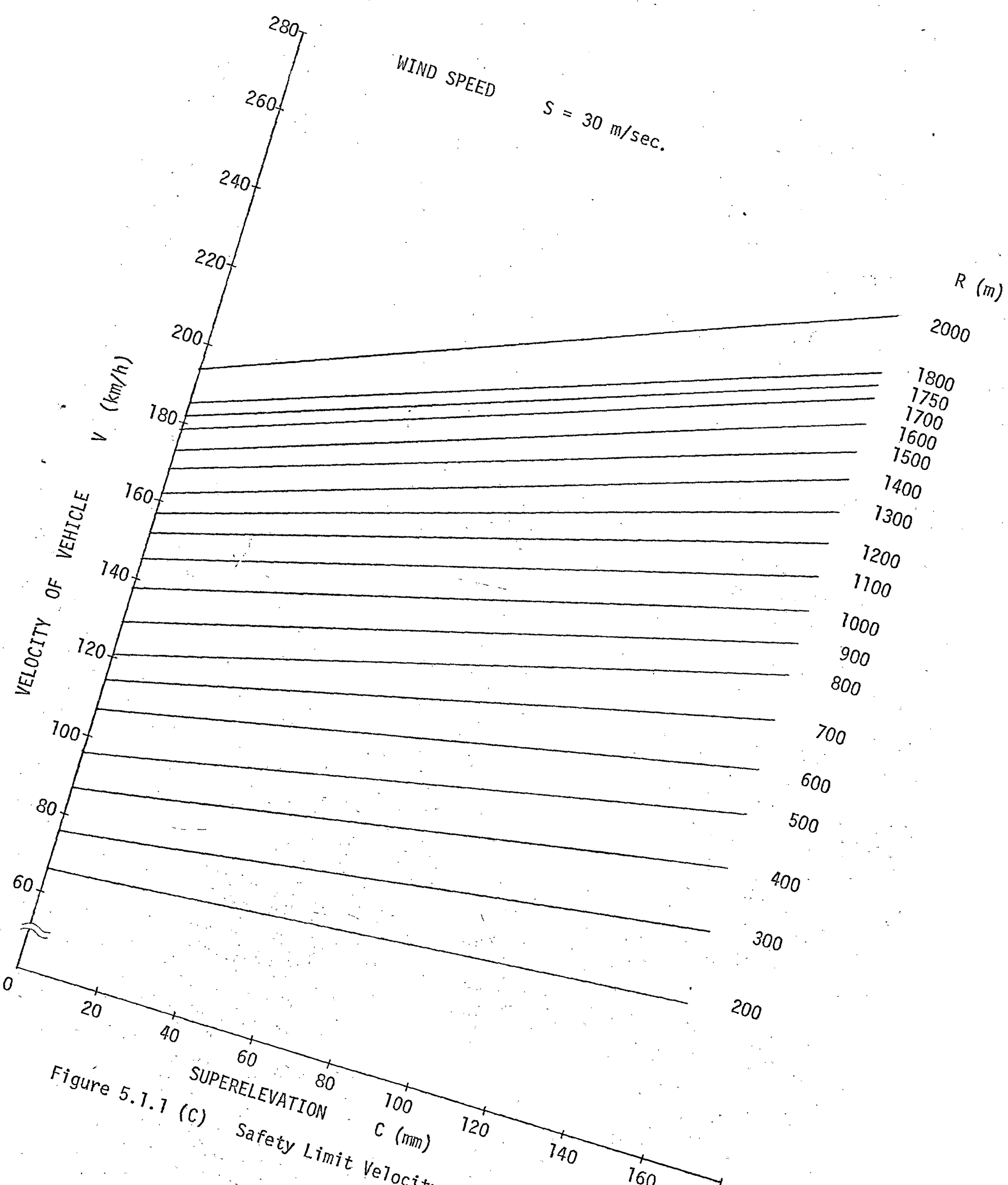


Figure 5.1.1 (C) Safety Limit Velocity for Overturn

5.1.2 WHEEL LOAD REDUCTION

The analysis is made to estimate the wheel load reduction and the torsional displacement of truck frame by means of "Finite Element Method".

1) Load conditions

Tare weight of car	....	49,880 Kg
Car body weight	....	35,040 Kg
Truck weight (2 sets)	....	14,840 Kg
where, sprung weight of one truck	....	3,560 Kg
unsprung weight of one truck	..	3,860 Kg
Wheel load under tare condition	....	6,235 Kg
Initial displacement at wheel "A"	....	1" (25.4 mm)

2) Calculation procedure

a. The trucks and car body are modeled as Rahmen structure combined with primary and secondary springs and the displacements of each member and wheel load are calculated.

b. Geometrical moment of inertia and polar twisting moment of inertia of area for truck and carbody member are shown in Table 5.1.2 (A).

c. The complete car model used for this calculation is shown in Figure 5.1.2 (A).

3) Calculation results-

a. The displacements of car under tare load and 1" up at wheel "A" conditions are shown in Figure (A) by dotted line.

b. The wheel loads and wheel load variation of car are shown in Table 5.1.2 (B) and Figure 5.1.2 (B).

Table 5.1.2 (A) Moment/Polar Twisting Moment of Inertia

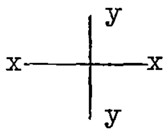
MEMBER	MOMENT/POLAR TWISTING MOMENT OF INERTIA
WHEEL 	$I_{x,y} = 3.0 \times 10^8\ mm^4$ $J = 3.0 \times 10^8\ mm^4$
AXLE	$I_{x,y} = 1.5 \times 10^7\ mm^4$ $J = 2.8 \times 10^7\ mm^4$
SIDE FRAME	$I_x = 8.54 \times 10^7\ mm^4$ $I_y = 3.93 \times 10^7\ mm^4$ $J = 8.62 \times 10^7\ mm^4$
TRANSOM	$I_x = 1.42 \times 10^8\ mm^4$ $I_y = 1.16 \times 10^9\ mm^4$ $J = 3.75 \times 10^8\ mm^4$
TRUCK BOLSTER	$I_x = 9.66 \times 10^7\ mm^4$ $I_y = 2.65 \times 10^8\ mm^4$ $J = 2.35 \times 10^8\ mm^4$
CAR BODY BOLSTER	$I_{x,y} = 3.0 \times 10^8\ mm^4$ $J = 3.0 \times 10^8\ mm^4$
CAR BODY UNDER FRAME	$I_x = 1.26 \times 10^9\ mm^4$ $I_y = 4.35 \times 10^{10}\ mm^4$ $J = 3.14 \times 10^{11}\ mm^4$
CAR BODY SIDE FRAME	$I_{x,y} = 3.0 \times 10^2\ mm^4$ $J = 0\ mm^4$

Table 5.1.2 (B) Wheel Load Variation of Complete Car

WHEEL NUMBER / WHEEL LOAD		No.1 TRUCK				No.2 TRUCK			
		A	B	C	D	E	F	G	H
WHEEL LOAD UNDER STATIC LOAD	KG	6235	6235	6235	6235	6235	6235	6235	6235
UNDER STATIC LOAD PLUS 1" UP AT WHEEL "A"	KG	7337	5133	5315	7155	6135	6335	6153	6317
WHEEL LOAD VARIATION	KG	+1102	-1102	-920	+920	-100	+100	-82	+82
WHEEL LOAD VARIATION RATIO	%	+17.7	-17.7	-14.8	+14.8	-1.6	+1.6	-1.3	+1.3

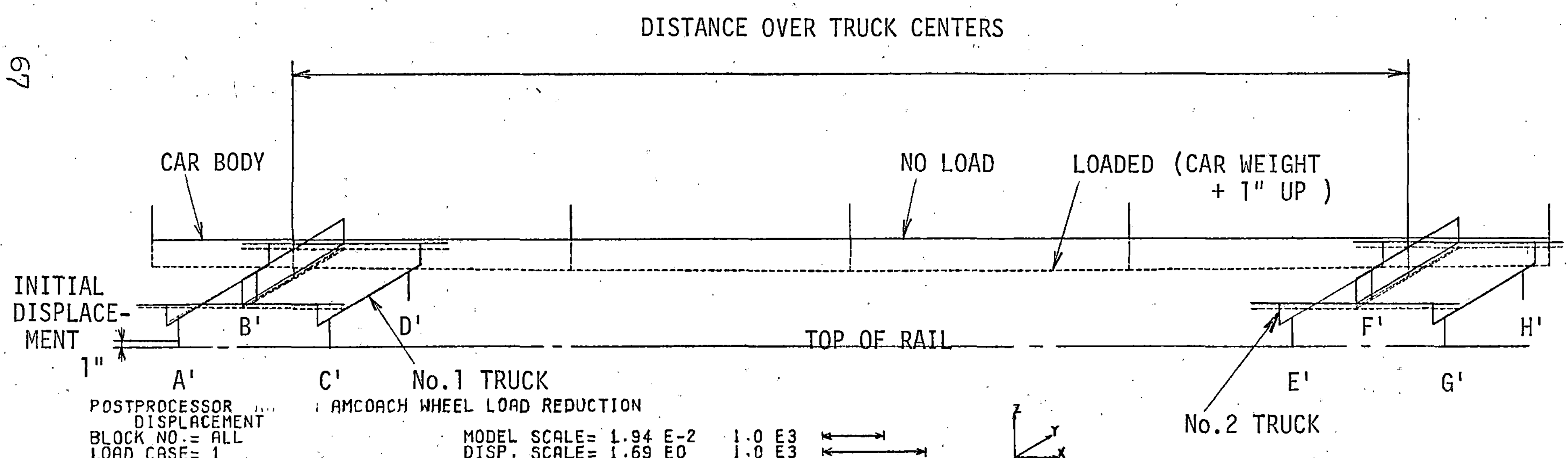


Figure 5.1.2 (A) Displacement of Complete Car

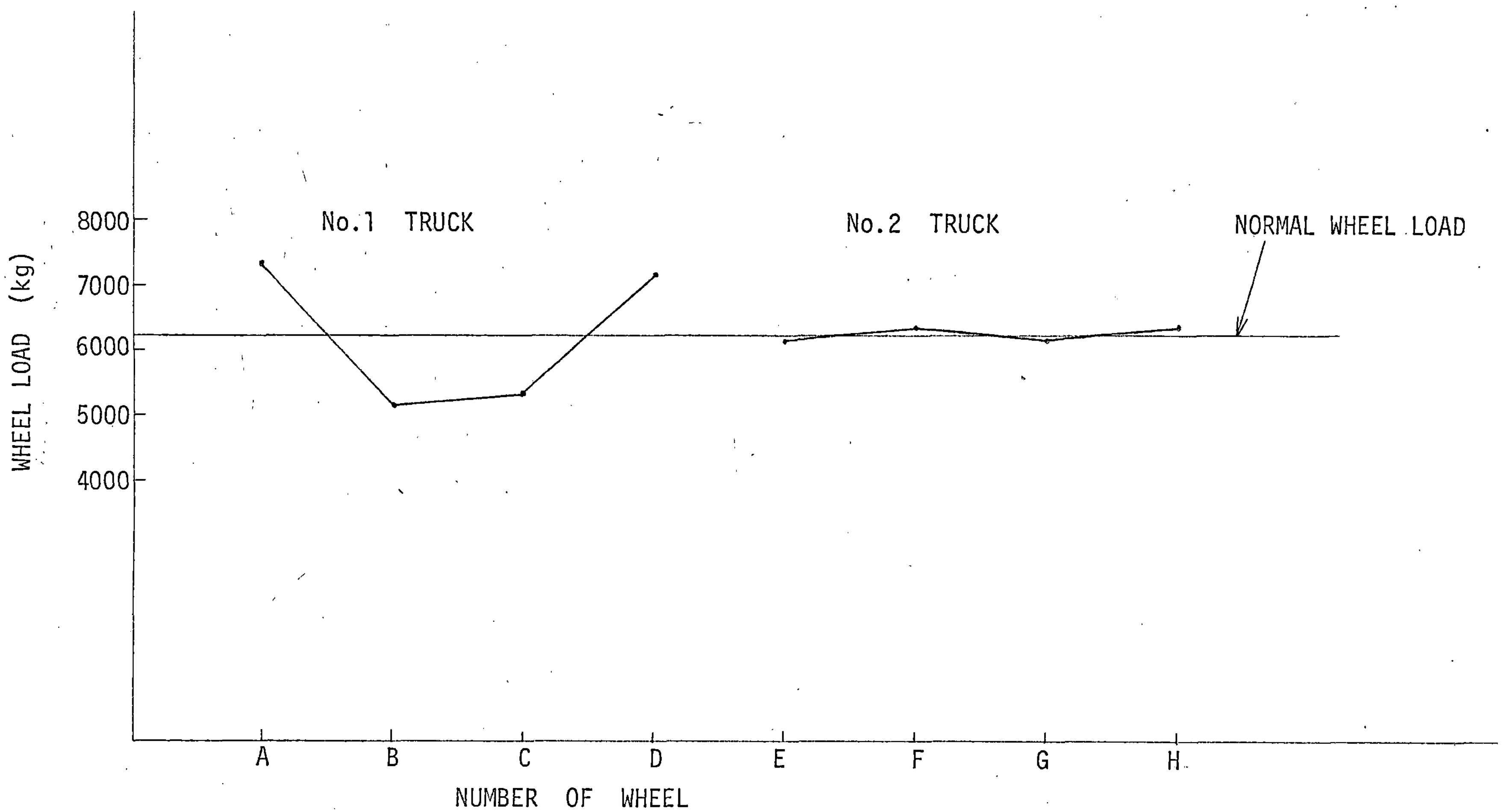


Figure 5.1.2 (B) Wheel Load Variation

5.1.3 DERAILMENT SAFETY

The safety against derailment is determined by the derailment factor Q/P.

where, Q : lateral force on rail caused by wheel

P : wheel load

Generally, the safety limit of derailment factor is taken 0.8.

Model is shown in Figure 5.1.3 (A).

Wheel-rail interaction forces are shown in Figure 5.1.3 (B)

The calculation formulate are as follows.

(1) Wheel load (static)

$$P_o = \frac{mg}{4}\left\{\left(1 + \frac{V^2}{gR}\alpha\right) + \frac{hG}{a}\left(\frac{V^2}{gR} - \alpha\right)\right\} \quad \text{... outer wheel}$$

$$P_i = \frac{mg}{4}\left\{\left(1 + \frac{V^2}{gR}\alpha\right) - \frac{hG}{a}\left(\frac{V^2}{gR} - \alpha\right)\right\} \quad \text{... inner wheel}$$

Wheel load (dynamic)

$$P_o' = P_o + \frac{mBg}{4}\left[aH\left\{\frac{hGB}{a}\left(1 + \frac{i_{xB}^2}{hGB\,\ell N}\right) + \frac{g}{afH^2}\right\} - aV\right] \cdot\cdot \text{outer wheel}$$

$$P_i' = P_i + \frac{mBg}{4}\left[-aH\left\{\frac{hGB}{a}\left(1 + \frac{i_{xB}^2}{hGB\,\ell N}\right) + \frac{g}{afH^2}\right\} - aV\right] \cdot\cdot \text{inner wheel}$$

where, aH : lateral acceleration of carbody

aV : vertical acceleration of carbody

Combinations of aH and aV are considered for dynamic wheel load.

1) aH positive, av positive

2) aH positive, av negative

3) aH negative, av positive

4) aH negative, av negative

(2) Flange force

$$F_1 = \mu\ (P_o + P_i)\left\{\cos\xi 1 + \frac{a}{2b}(\sin\xi 1 + \sin\xi 2)\right\} + \frac{P_T}{2}\ \cdots$$

outer wheel of first axle

$$F_2 = \mu\ (P_o + P_i)\left\{\cos\xi 2 + \frac{a}{2b}(\sin\xi 1 + \sin\xi 2)\right\} + \frac{P_T}{2}\ \cdots$$

inner wheel of second axle

where, P_T : lateral force on truck center

$$P_T = mg\left(\frac{V^2}{gR} - \alpha\right) + mBg \cdot aH$$

(3) Lateral force on rail (static)

$Q_{1o} = F_1 - \mu P_o \cos\xi 1$ ... outer wheel of first axle

$Q_{1i} = \mu P_i \cos\xi 1$ .... inner wheel of first axle

$Q_{2o} = \mu P_o \cos\xi 2$ .... outer wheel of second axle

$Q_{2i} = -F_2 + \mu P_i \cos\xi 2$ .. inner wheel of second axle

Lateral force on rail (dynamic)

$Q'_{1o} = F_1 - \mu P'_o \cos\xi 1$ ... outer wheel of first axle

$Q'_{1i} = -\mu P_i \cos\xi 1$ .... inner wheel of first axle

$Q'_{2o} = \mu P_o \cos\xi 2$ .... outer wheel of second axle

$Q'_{2i} = -F_2 + \mu P_i \cos\xi 2$ .... inner wheel of second axle

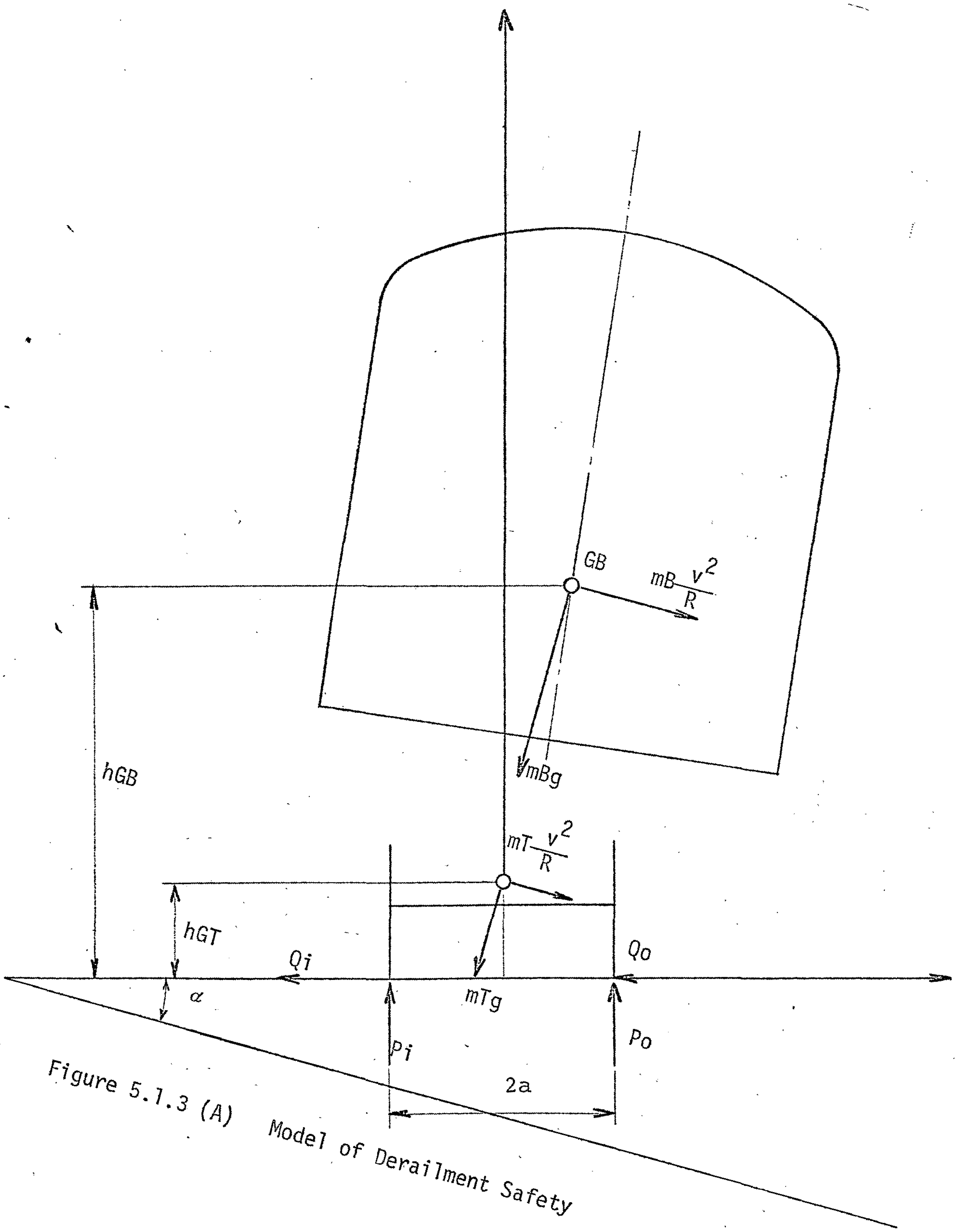


Figure 5.1.3 (A) Model of Derailment Safety

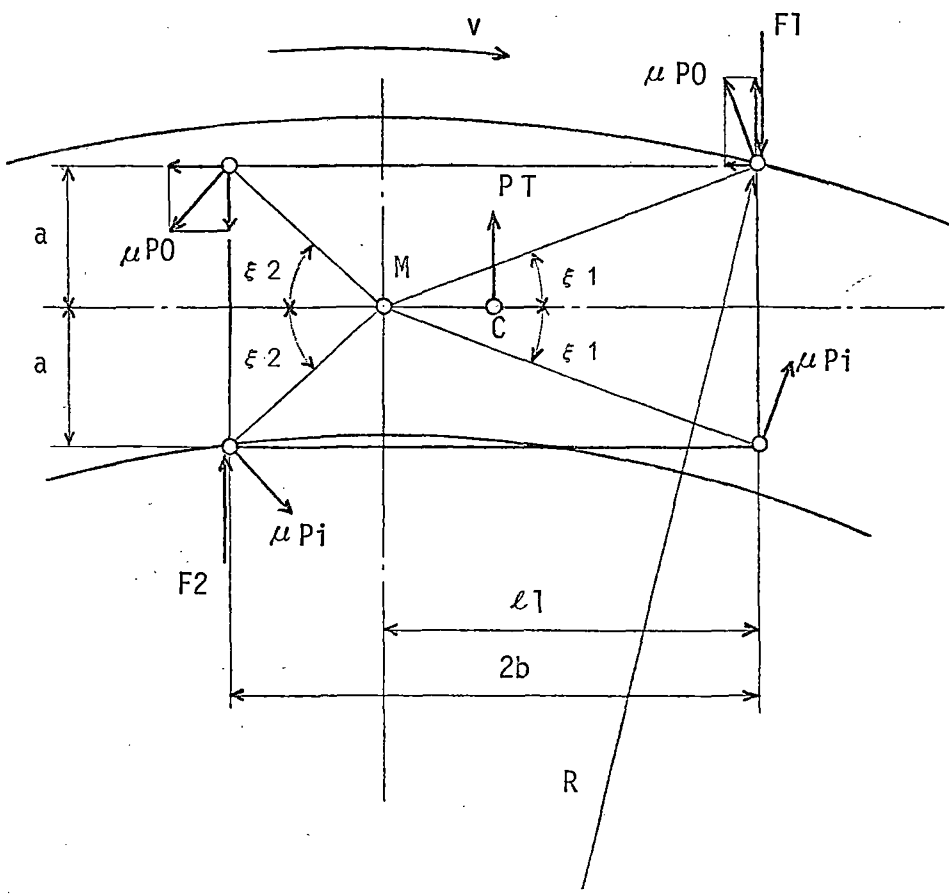


Figure 5.1.3 (B) Wheel-Rail Interaction Forces

The calculation data are shown in Table 5.1.3 (A).

The data of curve radius, superelevation, velocity of vehicle and coefficient of friction between wheel and rail are shown in Table 5.1.3 (B).

The calculation results of Q, P and Q/P are shown in Table 5.1.3 (C).

The relation between R and Q/P is shown in Figure 5.1.3. (C).

Table 5.1.3(A) Calculation Data of Derailment Safety.

SYMBOL	DESCRIPTION	DESIGN VALUE
mg	weight of car (maximum) / truck	28908 Kg
mBg	weight of carbody (maximum) / truck	21488 Kg
hG	effective center of gravity height of car (from top of rail)	2015 mm
hGB	center of gravity height of carbody (from top of rail)	1900 mm
2a	track gauge	1435 mm
2b	wheelbase	2500 mm
aH	lateral acceleration of carbody	0.1 g
aV	vertical acceleration of carbody	0.1 g

Table 5.1.3 (B) Calculation Data of R,C,V and μ

Curve radius R (m)	Superelevation C (mm)	Velocity of vehicle V (Km/h)	Coefficient of friction between wheel and rail μ
200	77	73	0.25
	111	77	
400	115	109	0.20
	152	115	
600	117	134	0.16
	147	140	
800	127	157	0.12
	152	163	
1000	92	167	0.11
	150	181	
1200	95	183	0.10
	130	193	
1400	80	193	0.10
	117		
1600	47	193	0.10
	115		
1750	50	193	0.10
	108		

Where, $V^2 = 127\ R\ \left(ag + \frac{C}{2\ a} + \theta\right)$

ag : lateral acceleration ag = 0.05 (g)

θ : maximum tilting angle θ = 0.1047 (rad)

Table 5.1.3 (C) Calculation Results of Q,P and $^{Q}/_{P}$

R (m)	C (mm)	V (km/h)	Q (kg) STATIC	Q (kg) DYNAMIC	P (kg) STATIC	P (kg) DYNAMIC	Q/P STATIC	Q/P DYNAMIC
200	77	73	Q10 5253	3928	Po 10477	7276	Q10/Po 0.50	0.54
			Q20 182	126			Q20/Po 0.02	0.02
			Q1i -993	-1503	Pi 4139	6266	Q1i/Pi 0.24	0.24
			Q2i 72	-187			Q2i/Pi 0.02	0.03
	111	77	5260	3948	10525	7324	0.50	0.54
			183	127			0.20	0.02
			-1005	-1515	4190	6317	0.24	0.24
			73	-197			0.02	0.03
400	115	109	7608	5683	10482	7282	0.73	0.78
			-1690	-1174			0.16	0.16
			-791	-1187	4242	6369	0.19	0.19
			-684	-1027			0.16	0.16
	152	115	7658	5732	10560	7359	0.73	0.78
			-1702	-1186			0.16	0.16
			-800	-1197	4293	6419	0.19	0.19
			-692	-1035			0.16	0.16
600	117	134	7380	5403	10493	7292	0.70	0.74
			-1606	-1116			0.15	0.15
			-671	-1007	4238	6365	0.16	0.16
			-649	-974			0.15	0.15
	147	140	7420	5444	10558	7358	0.70	0.74
			-1616	-1126			0.15	0.15
			-677	-1013	4276	6403	0.16	0.16
			-654	-980			0.15	0.15

R (m)	C (mm)	V (km/h)	Q (kg)		P (kg)		Q/P	
			STATIC	DYNAMIC	STATIC	DYNAMIC	STATIC	DYNAMIC
800	127	157	6698	8339	10510	12636	0.64	0.70
			-1236	-1486			0.12	0.12
			-507	-130	4255	1054	0.12	0.12
			-500	-124			0.12	0.12
	152	163	6753	8394	10585	12711	0.64	0.66
			-1245	-1495			0.12	0.12
			-509	-127	4270	1069	0.12	0.12
			-502	-126			0.12	0.12
1000	92	167	6545	8227	10484	12611	0.62	0.65
			-1140	-1372			0.11	0.11
			-457	-106	4173	972	0.11	0.11
			-454	-106			0.11	0.11
	150	181	6521	8203	10536	12662	0.62	0.65
			-1146	-1377			0.11	0.11
			-472	-121	4308	1107	0.11	0.11
			-469	-120			0.11	0.11
1200	95	183	6314	8037	10448	12575	0.60	0.64
			-1037	-1248			0.10	0.10
			-420	-101	4216	1015	0.10	0.10
			-419	-101			0.10	0.10
	130	193	6338	8061	10509	12635	0.60	0.64
			-1043	-1254			0.10	0.10
			-425	-106	4265	1064	0.10	0.10
			-423	-106			0.10	0.10

R (m)	C (mm)	V (kg/h)	Q (kg)		P (kg)		Q/P	
			STATIC	DYNAMIC	STATIC	DYNAMIC	STATIC	DYNAMIC
1400	80	193	6317	8040	10432	12558	0.61	0.64
			-1038	-1250			0.10	0.10
			-418	-99	4191	990	0.10	0.10
			-417	-99			0.10	0.10
	117	193	5363	7358	9947	12074	0.57	0.61
			-990	-1201			0.10	0.10
			-474	-155	4753	1553	0.10	0.10
			-473	-154			0.10	0.10
1600	47	193	6221	7944	10326	12452	0.60	0.64
			-1029	-1241			0.10	0.10
			-421	-101	4215	1014	0.10	0.10
			-420	-101			0.10	0.10
	115	193	4966	6689	9427	11553	0.53	0.58
			-939	-1151			0.10	0.10
			-523	-203	5239	2039	0.10	0.10
			-522	-203			0.10	0.10
1750	50	193	5744	7466	9963	12090	0.58	0.62
			-993	-1205			0.10	0.10
			-457	-137	4575	1374	0.10	0.10
			-456	-137			0.10	0.10
	108	193	4672	6394	9192	11319	0.51	0.56
			-916	-1128			0.10	0.10
			-543	-224	5444	2243	0.10	0.10
			-543	-224			0.10	0.10

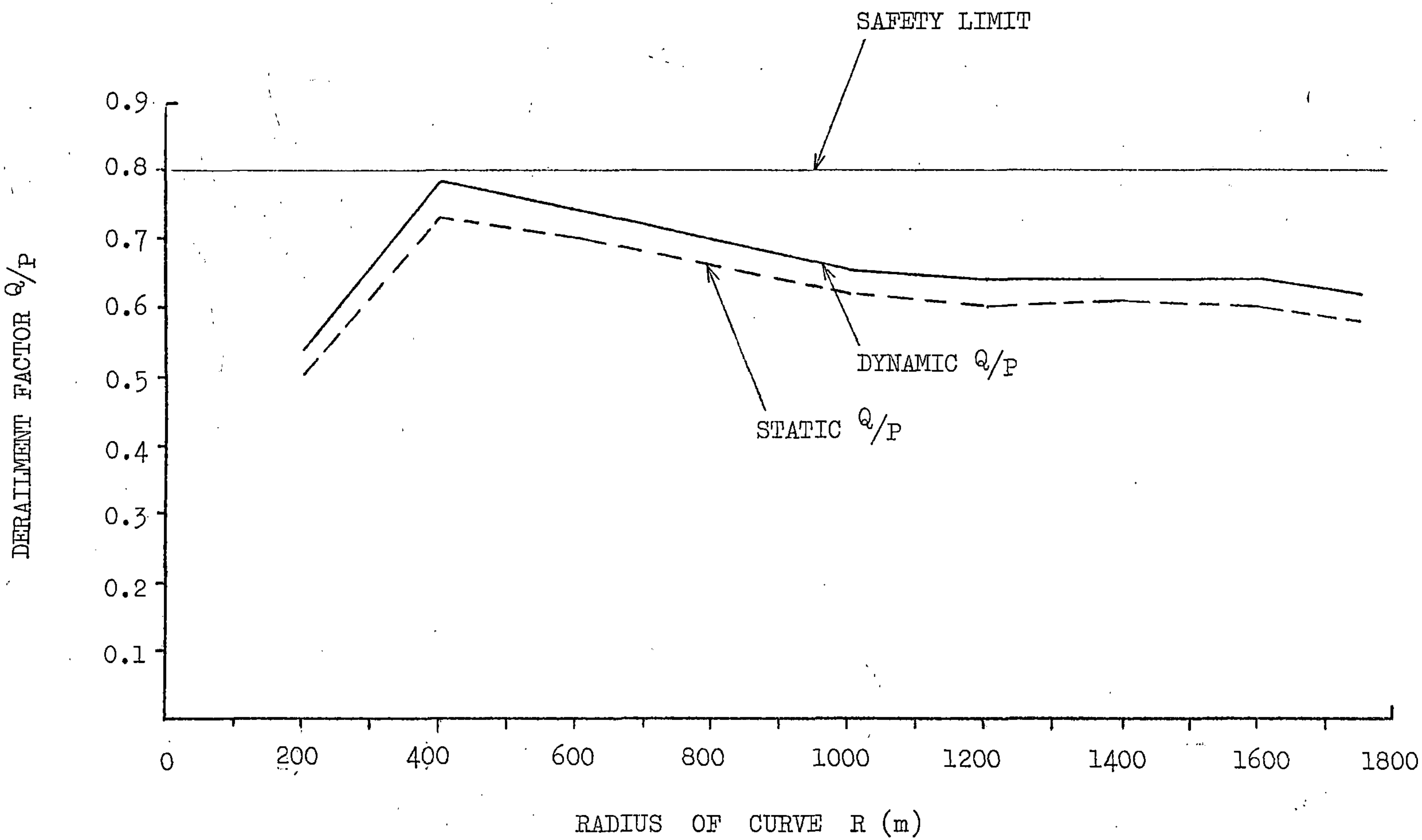


Figure 5.1.3 (C) Relation between R and Q/P

5.1.4 HUNTING STABILITY

The hunting stability is analyzed in this section.

Model is shown in Figure 5.1.4 (A).

The calculation data are shown in Table 5.1.4 (A).

For this analysis, the following assumption are taken.

1) Adhesion coefficient between wheel and rail is assumed to be the following formula.

$$\mu = \frac{27.2}{V + 85}$$

where, μ : adhesion coefficient

V : vehicle speed

2) Creep coefficient, defining interaction forces between wheel and rail, is calculated by the method of Cain as follows.

$$= 465\sqrt{D \cdot x W}$$

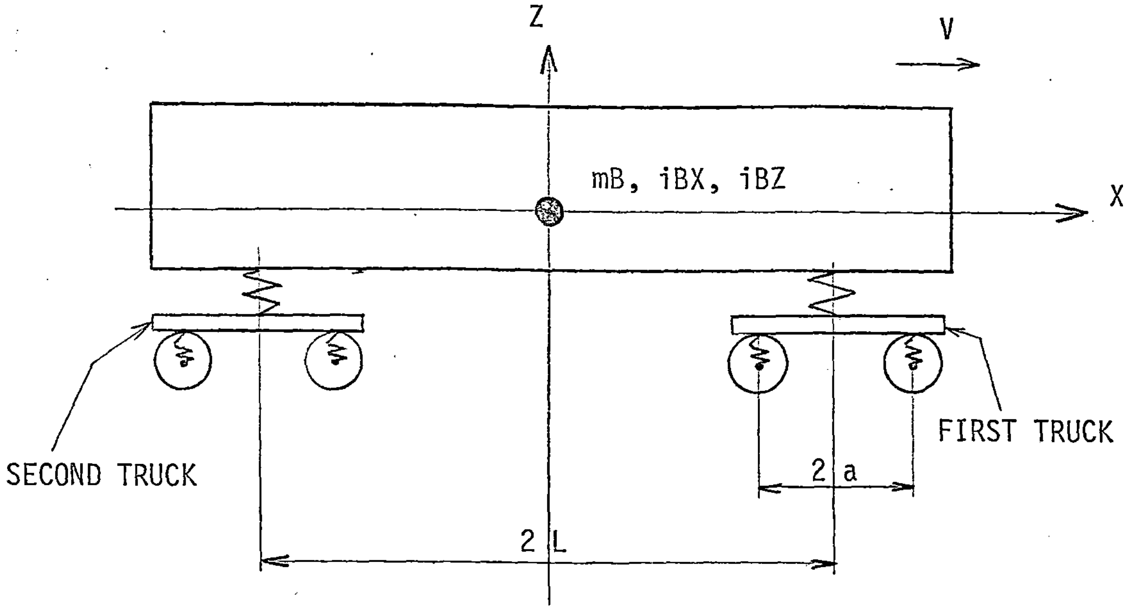
where, : creep coefficient

D : wheel diameter

W : axle load

3) Initial condition is assumed that at time $t = 0$, lateral displacements of two wheel sets and center of gravity of truck frame of second truck are 10 mm, and other initial displacements and velocities are nought.

Hunting motion is controlled mainly by taper of wheel tread, recondary yawing resistance and running speed.



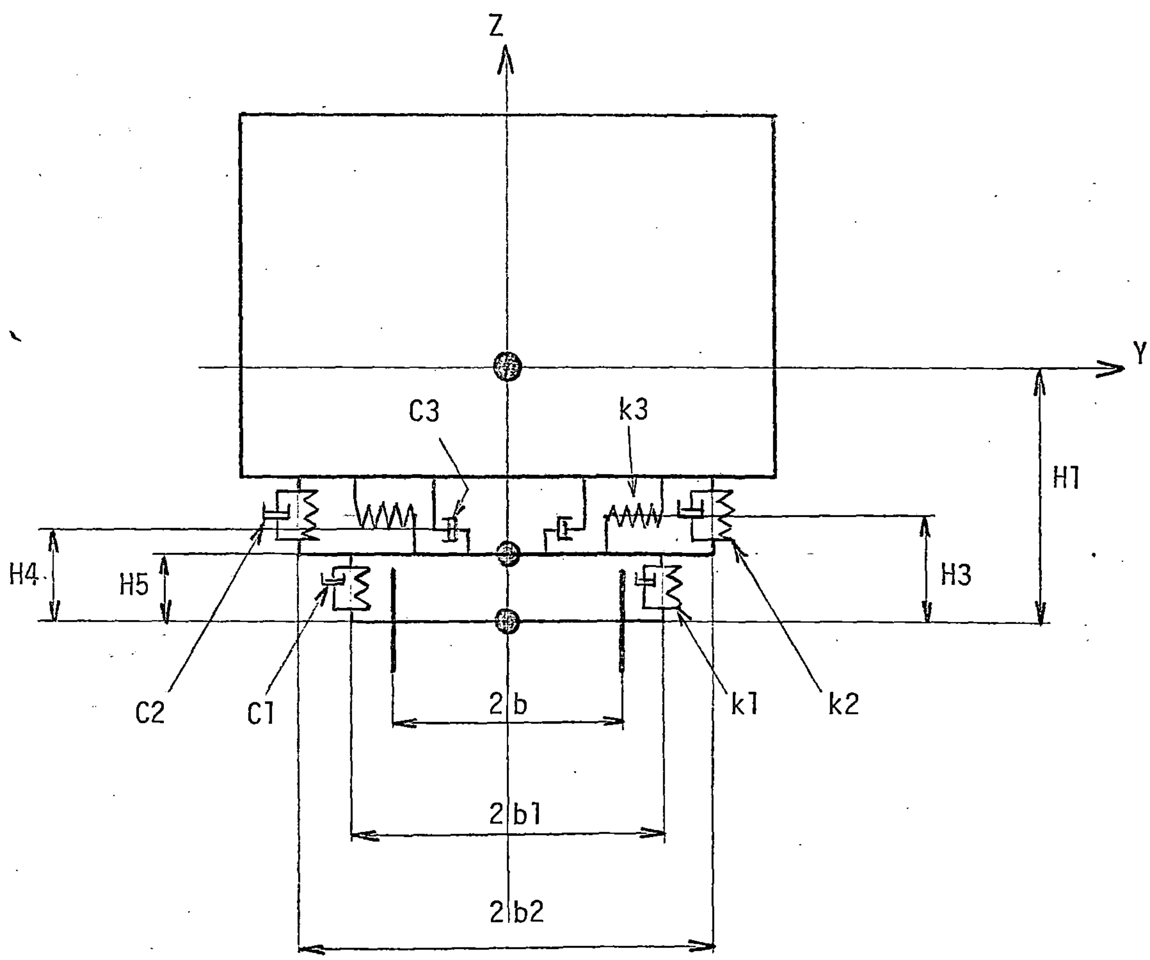


Figure 5.1.4 (A) Model of Hunting Stability

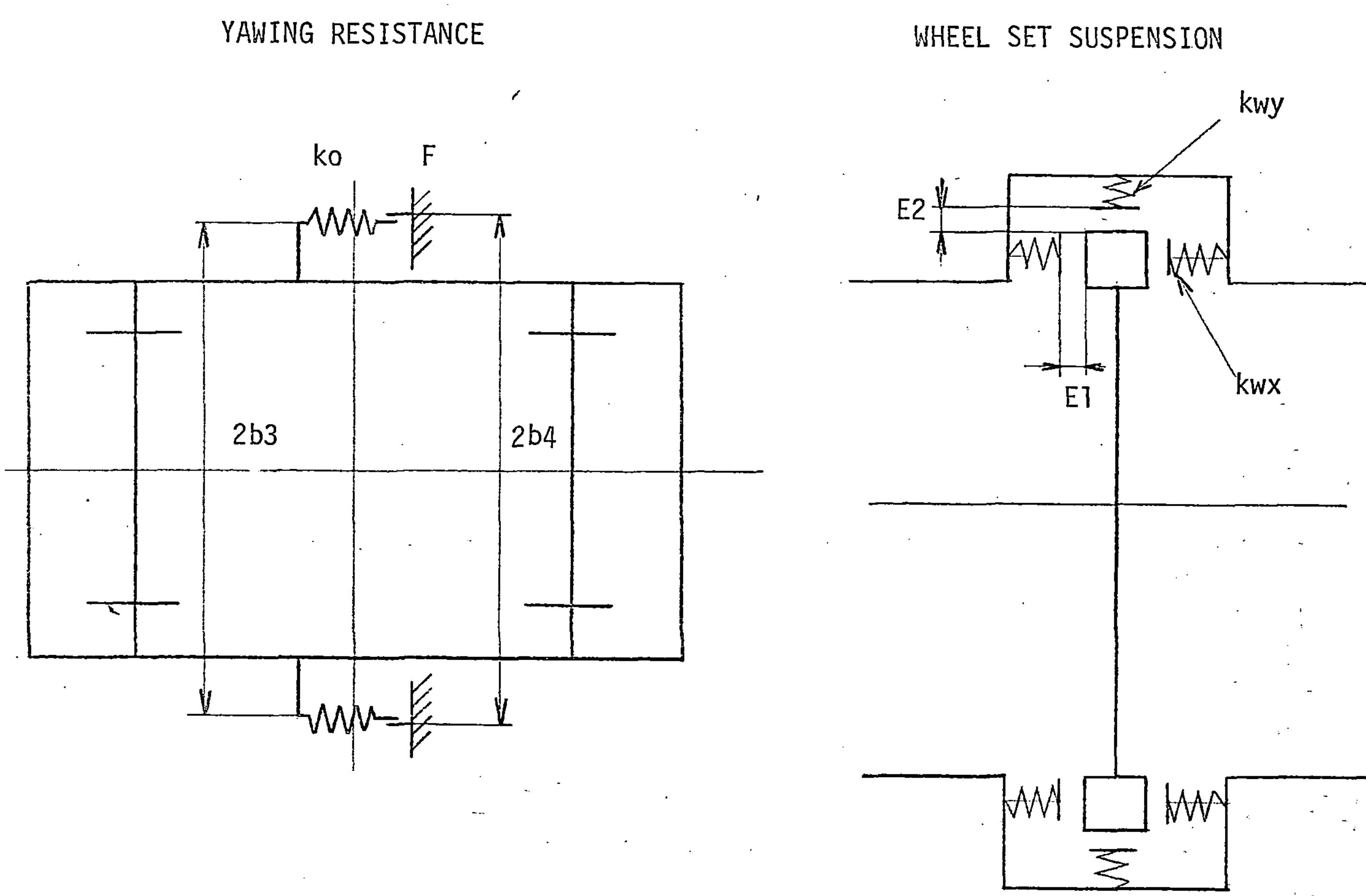


Figure 5.1.4 (A) Model of Hunting Stability

Calculations are made for the following three cases.

The data of taper of wheel tread, coefficient of friction of said bearer and vehicle speed are shown in Table 5.1.4 (B).

a) Case 1 - under the condition of design value.

b) Case 2 - under the critical condition of convergent vibration.

c) Case 3 - under the critical condition of divergent vibration.

Calculation results are shown in Figure 5.1.4 (B) $\sim$ (D), and the symbols in these figures are shown in Table 5.1.4 (C).

Table 5.1.4(A) Calculation Data of Hunting Stability

SYMBOL	DESCRIPTION	DESIGN VALUE
$mB \cdot g$	weight of carbody (normal) / car	40708 Kg
iBz	gyration radius of yawing of mB	7.569 m
iBx	gyration radius of rolling of mB	1.016 m
$mT \cdot g$	sprung weight of truck / truck	3270 Kg
iTZ	gyration radius of yawing of mT	1.0 m
iTX	gyration radius of rolling of mT	0.5 m
$mW \cdot g$	weight of wheels and axle / axle	1400 Kg
iWZ	gyration radius of yawing of m_W	0.75 m
k_{WY}	lateral spring constant of primary spring / axle	1680 Kg/mm
k_{WX}	longitudinal spring constant of primary spring / half axle	4500 Kg/mm

Table 5.1.4(A) Calculation Data of Hunting Stability (Cont'd)

SYMBOL	DESCRIPTION	DESIGN VALUE
k_0	longitudinal stiffness of bolster anchor / half truck	500 Kg/mm
k_1	vertical spring constant of primary spring / axle	216 Kg/mm
k_2	vertical spring constant of secondary spring / set	45 Kg/mm
k_2'	lateral spring constant of secondary spring / set	35 Kg/mm
kr	lateral spring constant of track / one side of track	2700 Kg/mm
C_1	damping coefficient of primary damper / axle	40 Kg/cm/sec.
C_2	damping coefficient of secondary spring / set	50 Kg/cm/sec.
C_2'	damping coefficient of secondary lateral damper / half truck	70 Kg/cm/sec.
2a	wheelbase	2.5 m
2b	lateral distance between contact points of rail and wheel	1.48 m
$2b_1$	distance between primary springs	1.96 m
$2b_2$	distance between secondary springs	2.12 m
$2b_3$	distance between bolster anchors	2.7 m
$2b_4$	distance between side bearers	1.4 m
2L	distance over truck centers	18.14 m
H_1	distance between center of gravity of carbody and axle center	1.443 m

Table 5.1.4(A) Calculation Data of Hunting Stability (Cont'd)

SYMBOL	DESCRIPTION	DESIGN VALUE
H_3	distance between secondary spring center and axle center	0.545 m
H_4	distance between secondary lateral damper and axle center	0.39 m
H_5	distance between center of gravity of truck frame and axle center	0.1 m
E_1	longitudinal clearance between primary spring and axle	0.0 m
E_2	lateral clearance between primary spring and axle	0.0 m
Er	clearance between wheel flange and rail	0.015 m
r	wheel radius	0.457 m
γ	taper of wheel tread	1/40
P	wheel load / wheel	6943 Kg

Table 5.1.4(B) Calculation Data of Hunting Stability

CASE	TAPER OF WHEEL TREAD γ	COEFFICIENT OF FRICTION OF SIDE BEARER μ	VEHICLE SPEED V
1	1/40	0.13	193 Km/h (120 m p h)
2	1/10	0.09	260 Km/h (161 m p h)
3	1/10	0.09	270 Km/h (168 m p h)

Table 5.1.4 (C) Calculation Symbols of Hunting Stability

SYMBOL	DESCRIPTION	UNIT
M1	Yawing resistance of first truck	kg·m
M2	Yawing resistance of second truck	kg·m
y_B	Lateral displacement of center of gravity of carbody	mm
ψB	Yawing angle of carbody	rad
ϕB	Rolling angle of carbody	rad
y_{T1}	Lateral displacement, center of gravity of first truck frame	mm
y_{T2}	Lateral displacement, center of gravity of second truck frame	mm
$\psi T1$	Yawing angle of first truck frame	rad
$\psi T2$	Yawing angle of second truck frame	rad
y_{W1}	Lateral displacement of first axle	mm
y_{W3}	Lateral displacement of third axle	mm

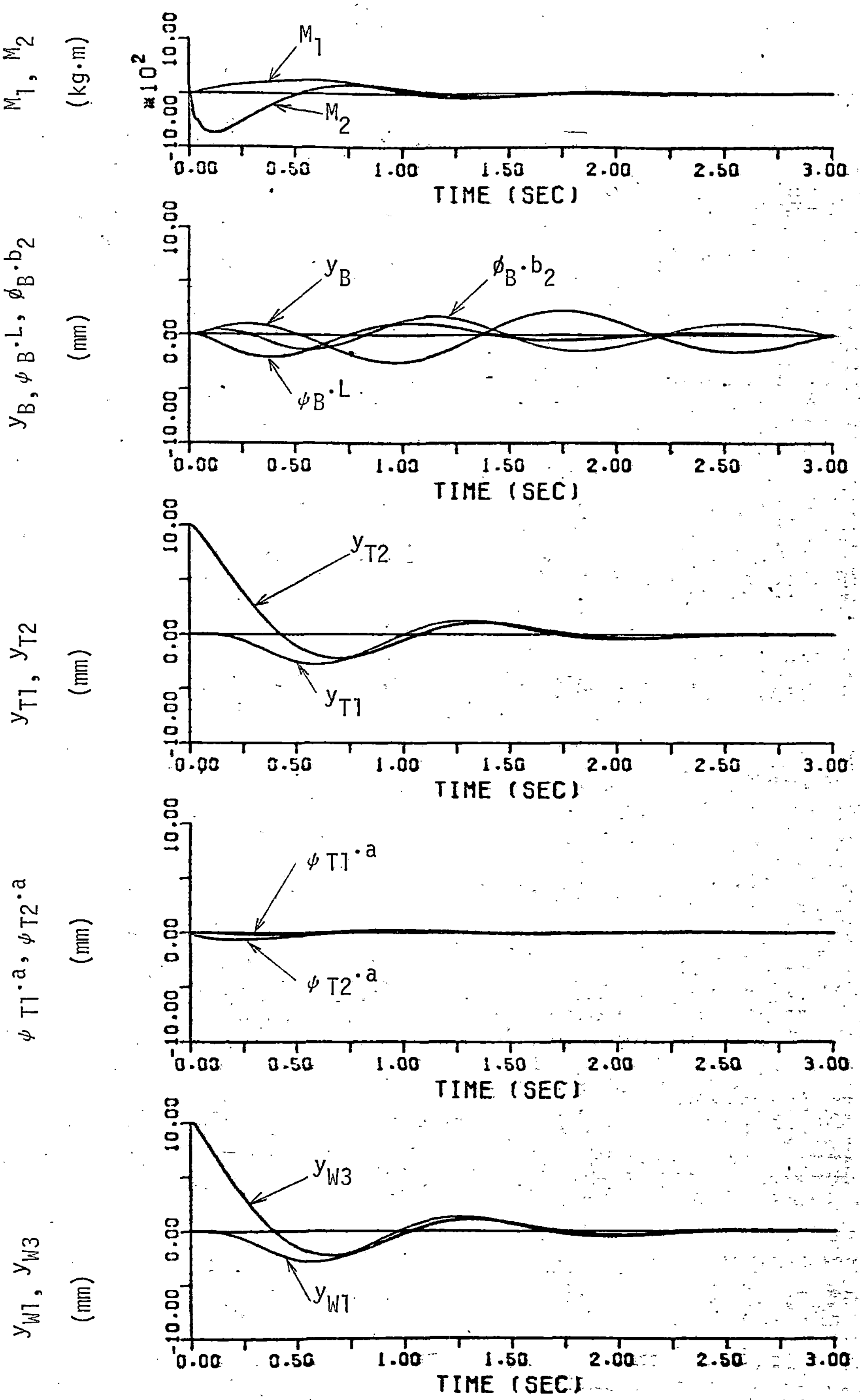


Figure 5.1.4 (B) Hunting Stability (Case 1)

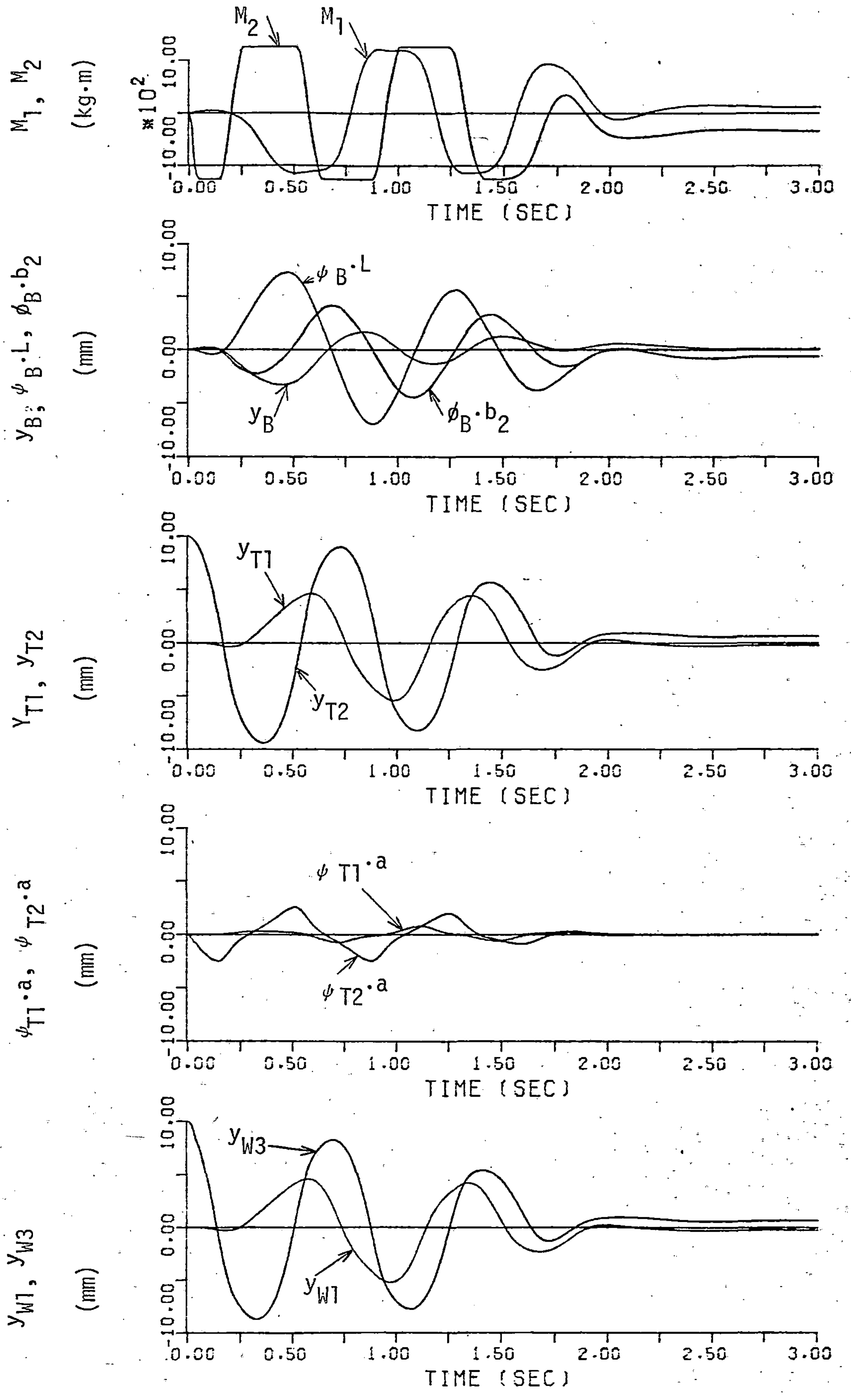


Figure 5.1.4 (C) Hunting Stability (Case 2)

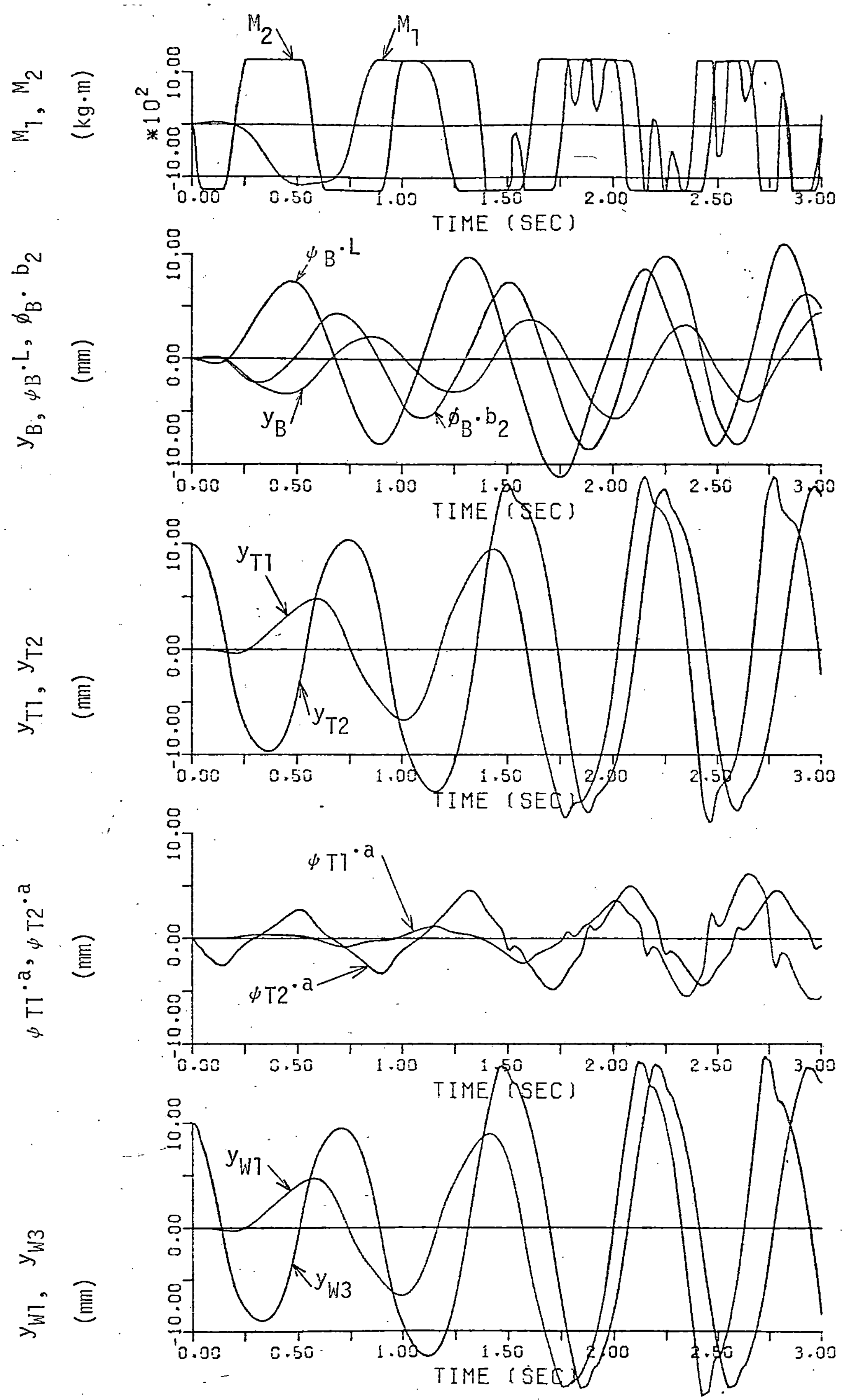


Figure 5.1.4 (D) Hunting Stability (Case 3)

5.2 RIDE QUALITY ANALYSES

The analyses of ride quality are done to determine the suitable values of suspension parameters so that the vehicles possess the good ride quality.

The frequency responses of vertical, lateral and longitudinal vibration are conducted.

5.2.1 VERTICAL VIBRATION

Model is shown in Figure 5.2.1 (A).

The calculation data are shown in Table 5.2.1.

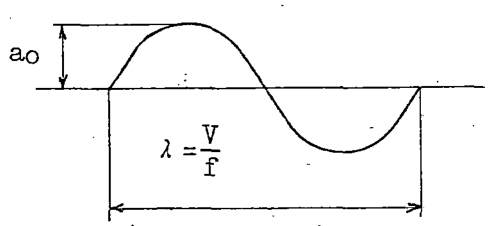
Vertical track irregularity is assumed to be the following formula.

$$a_0 = a_s \times \frac{V}{3.6\,f} \quad (\text{mm})$$

where, a_s : irregularity of longitudinal level surface

V : velocity of vehicle

f : frequency



The frequency response of vertical vibration is shown in Figure 5.2.1 (B).

The ride quality is judged by JNR ride index.

JNR ride index is classified into the following;

ride index < 1 : very good

$1 \leqq$ ride index $\leqq 1.5$: good

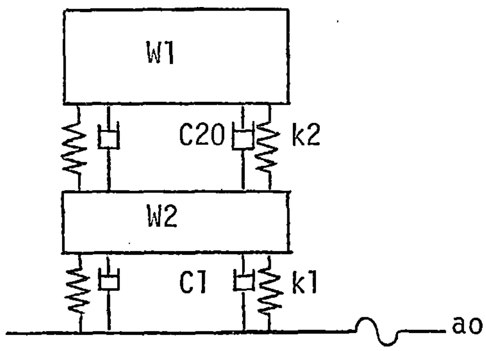


Figure 5.2.1(A) Model of Vertical Vibration

Table 5.2.1 Calculation Data of Vertical Vibration

SYMBOL	DESCRIPTION	DESIGN VALUE
W1	Weight of carbody (normal)/truck	20354 kg
W2	Sprung weight of truck/truck	3270 kg
k1	Vertical spring constant of primary spring/axle	216 kg/mm
C1	Damping coefficient of primary damper/axle	40 kg/cm/sec.
C20	Damping coefficient of secondary damper/set	0 kg/cm/sec.
Characteristic of Air Spring		
D	Effective diameter	500 mm
VB	Inner volume of air spring	20.7
VT	Volume of auxiliary reservoir	50
P	Working pressure	5.34 kg/cm^2
d	Orifice diameter	15 mm
V	Velocity of vehicle	193 km/h
as	Irregularity of longitudinal level surface	0.3 mm/m

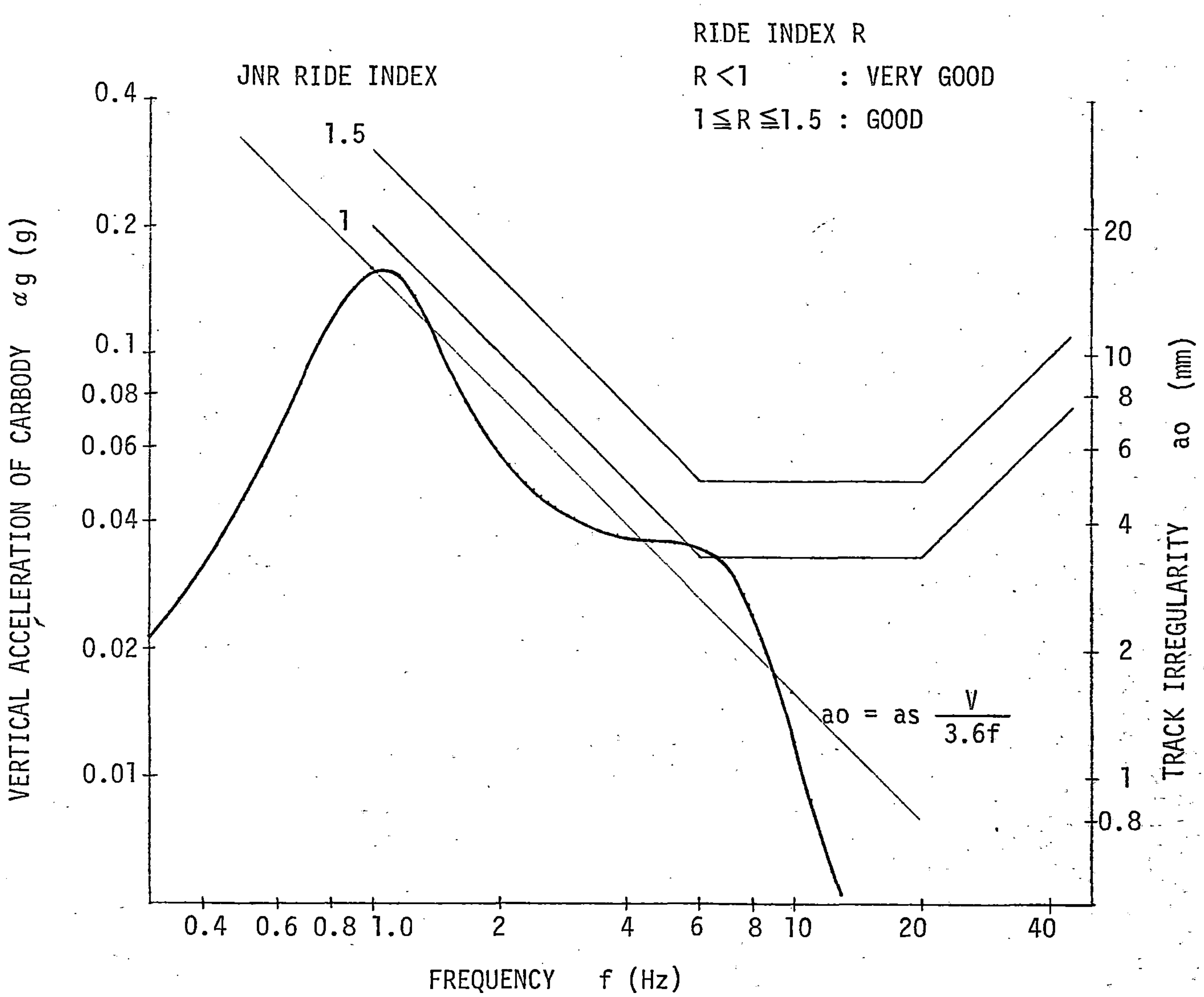


Figure 5.2.1 (B) Frequency Response of Vertical Vibration

5.2.2 LATERAL VIBRATION

This analysis is a steady-state response of lateral vibration. The transient response of lateral vibration is described in Section 7.

Model is shown in Figure 5.2.2 (A).

The calculation data are shown in Table 5.2.2.

Track irregularity (irregularity of alignment) is assumed to be the next formula.

$$a_o = 2.7 \left(\frac{V}{3.6f} \right)^{0.5} \quad : f \leqq 1 \quad \text{Hz}$$

$$a_o = 0.012 \left(\frac{V}{3.6f} \right)^{1.9} \quad : f \geqq 1 \quad \text{Hz}$$

where, V : velocity of vehicle

f : frequency

The frequency response of lateral vibration is shown in Figure 5.2.2 (B).

Table 5.2.2 Calculation Data of Lateral Vibration

SYMBOL	DESCRIPTION	DESIGN VALUE
W0	weight of carbody (normal) / truck	20354 Kg
W1	weight of bolster device / truck	620 Kg
W2	weight of truck frame / truck	2650 Kg
i0	radius of gyration of carbody	1.016 m
i1	radius of gyration of bolster device	0.6 m
i2	radius of gyration of truck frame	0.5 m
k1	vertical spring constant of secondary spring / set	45 Kg/mm
k2	lateral spring constant of secondary spring / truck	70 Kg/mm
k3	vertical spring constant of primary spring / axle	216 Kg/mm

SYMBOL	DESCRPITION	DESIGN VALUE
C1	damping coefficient of secondary spring / set	50 Kg/Cm/sec.
C2	damping coefficient of tilting damper / truck	10 Kg/Cm/sec.
C3	damping coefficient of primary damper / axle	40 Kg/Cm/sec.
C4	damping coefficient of secondary lateral damper / truck	140 Kg/Cm/sec.
2b1	distance between secondary spring	2120 mm
2b2	distance between primary springs	1960 mm
2d	distance between primary dampers	2300 mm
$\ell 0$	distance between tilting center and center of gravity of carbody	800 mm
$\ell 1$	distance between tilting center and center of gravity of bolster device	1950 mm
$\ell 2$	distance between tilting center and center of tilting damper	2000 mm
$\ell 3$	radius of tilting motion	2250 mm
h1	distance between axle center and center of gravity of bolster device	295 mm
h2	distance between axle center and center of gravity of truck frame	100 mm
e	distance between center of secondary spring and center of gravity of bolster device	250 mm

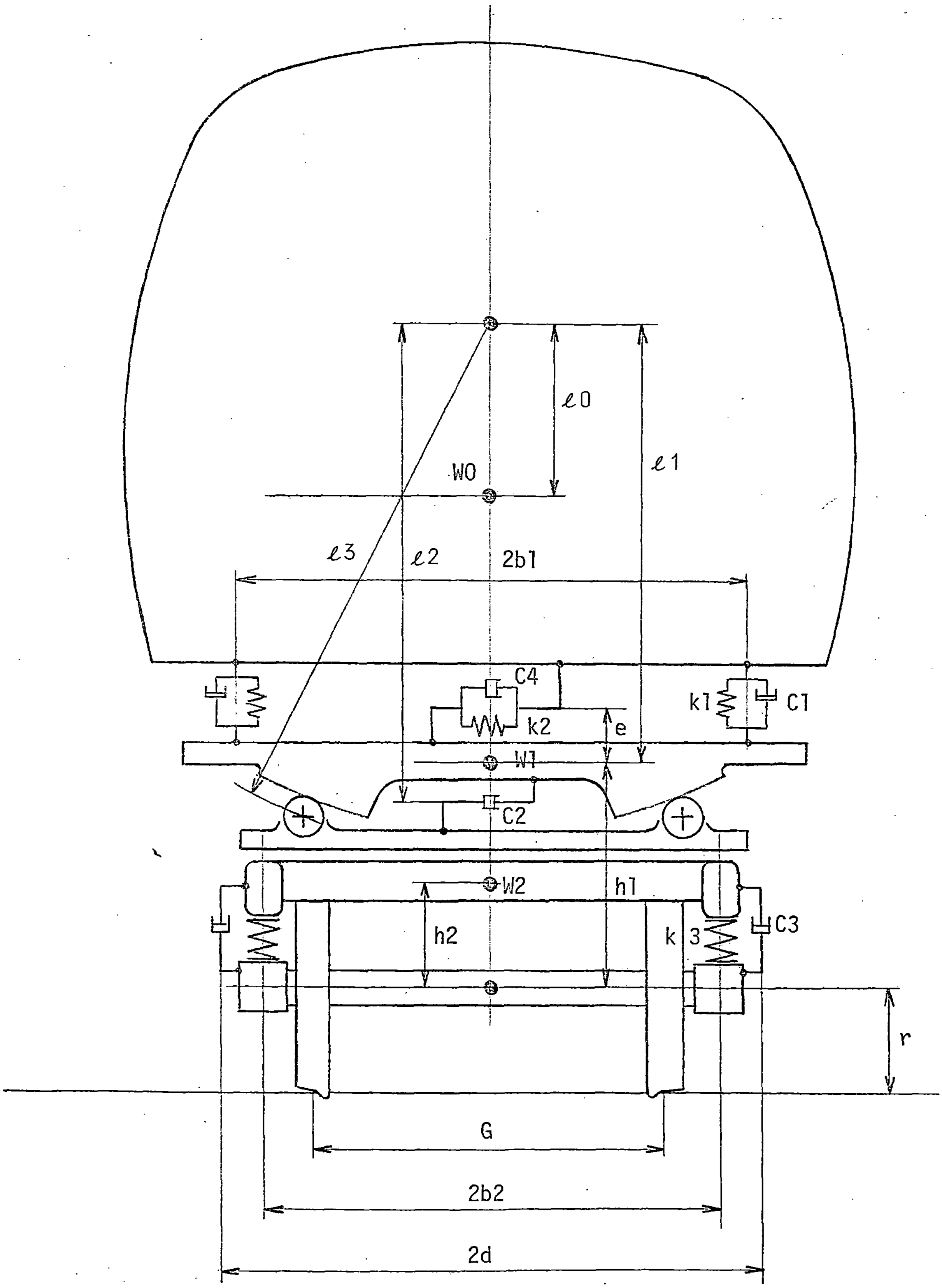


Figure 5.2.2 (A) Model of Lateral Vibration

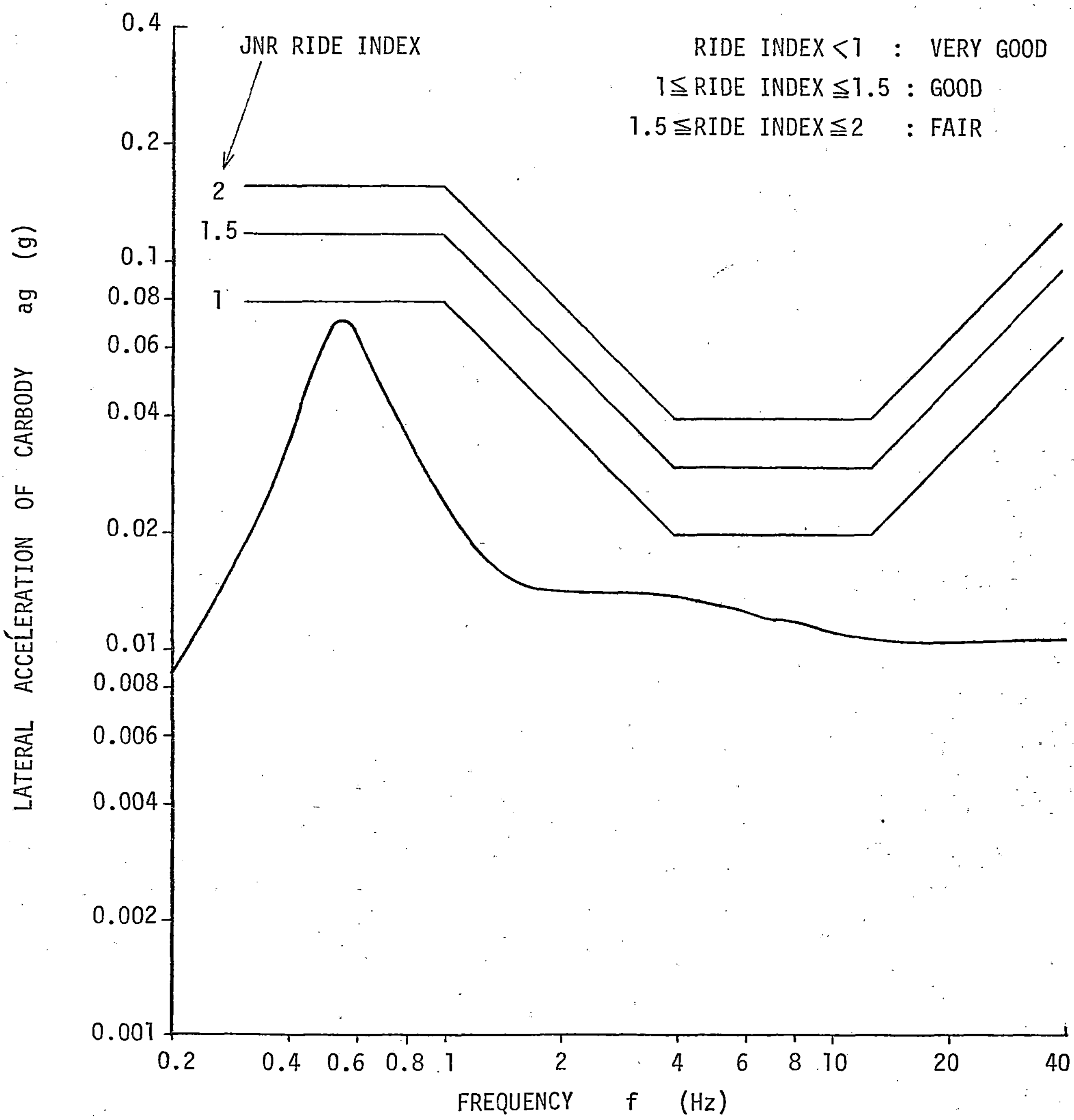


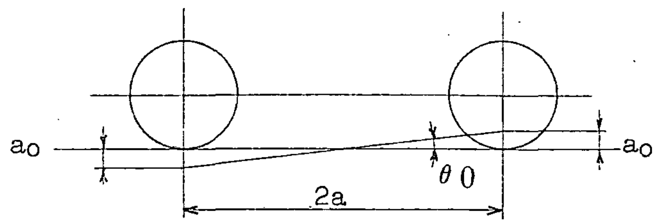
Figure 5.2.2 (B) Frequency Response of Lateral Vibration

5.2.3 LONGITUDINAL VIBRATION

Model is shown in Figure 5.2.3 (A).

The calculation data are shown in Table 5.2.3

Assumption of track irregularity

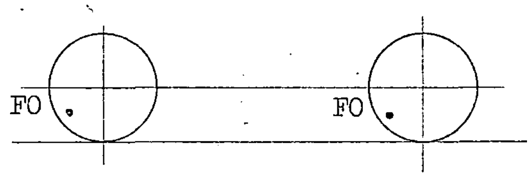


a_o = 1 mm

2a ; wheelbase

$$\theta_o = \frac{2a_o}{2a} \quad \text{(rad)}$$

unbalance mass of wheels and axle



FO = 0.05 Kg·m

Above track irregularity and unbalance mass act on vehicle at same time as the force which cause the longitudinal vibration. The frequency response of longitudinal vibration is shown in Figure 5.2.3 (B).

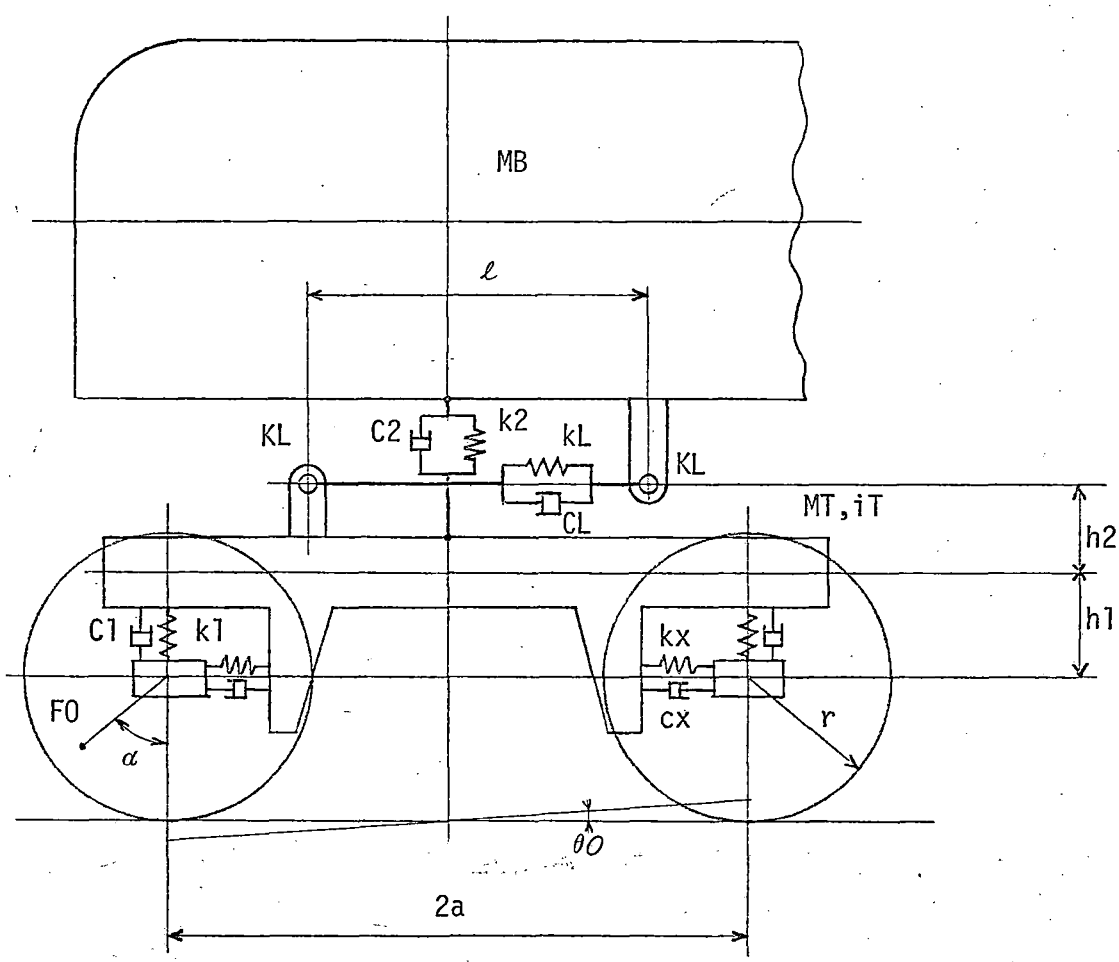


Figure 5.2.3(A) Model of Longitudinal Vibration

Table 5.2.3 Calculation Data of Longitudinal Vibration

SYMBOL	DESCRIPTION	DESIGN VALUE
MB.g	weight of carbody (normal) / truck	20354 Kg
MT.g	sprung weight of truck / truck	3270 Kg
MW.g	unsprung weight of truck / axle	1930 Kg
iT	radius of gyration of truck frame	1.0 m
iW	radius of gyration of wheels and axle	0.3 m
kx	longitudinal stiffness of primary spring / axle	9000 Kg/mm
k1	spring constant of primary spring / axle	216 Kg/mm
k2	spring constant of secondary spring / set	45 Kg/mm
kL	longitudinal stiffness of bolster anchor / truck	1000 Kg/mm
KL	torsional stiffness of bolster anchor / truck	55000 Kg·Cm/rad
Cx	damping coefficient of primary spring / axle	15 Kg/Cm/sec.
C1	damping coefficient of primary damper / axle	40 Kg/Cm/sec.
C2	damping coefficient of secondary spring / set	50 Kg/Cm/sec.
CL	longitudinal damping coefficient of bolster anchor / truck	80 Kg/Cm/sec.
2a	wheelbase	2500 mm
r	radius of wheel	457 mm
ℓ	length of bolster anchor	1000 mm
h1	distance between axle center and center of gravity of truck frame	100 mm
h2	distance between center of bolster anchor and center of gravity of truck frame	-10 mm
α	phase difference of unbalance mass between first axle and second axle	0°

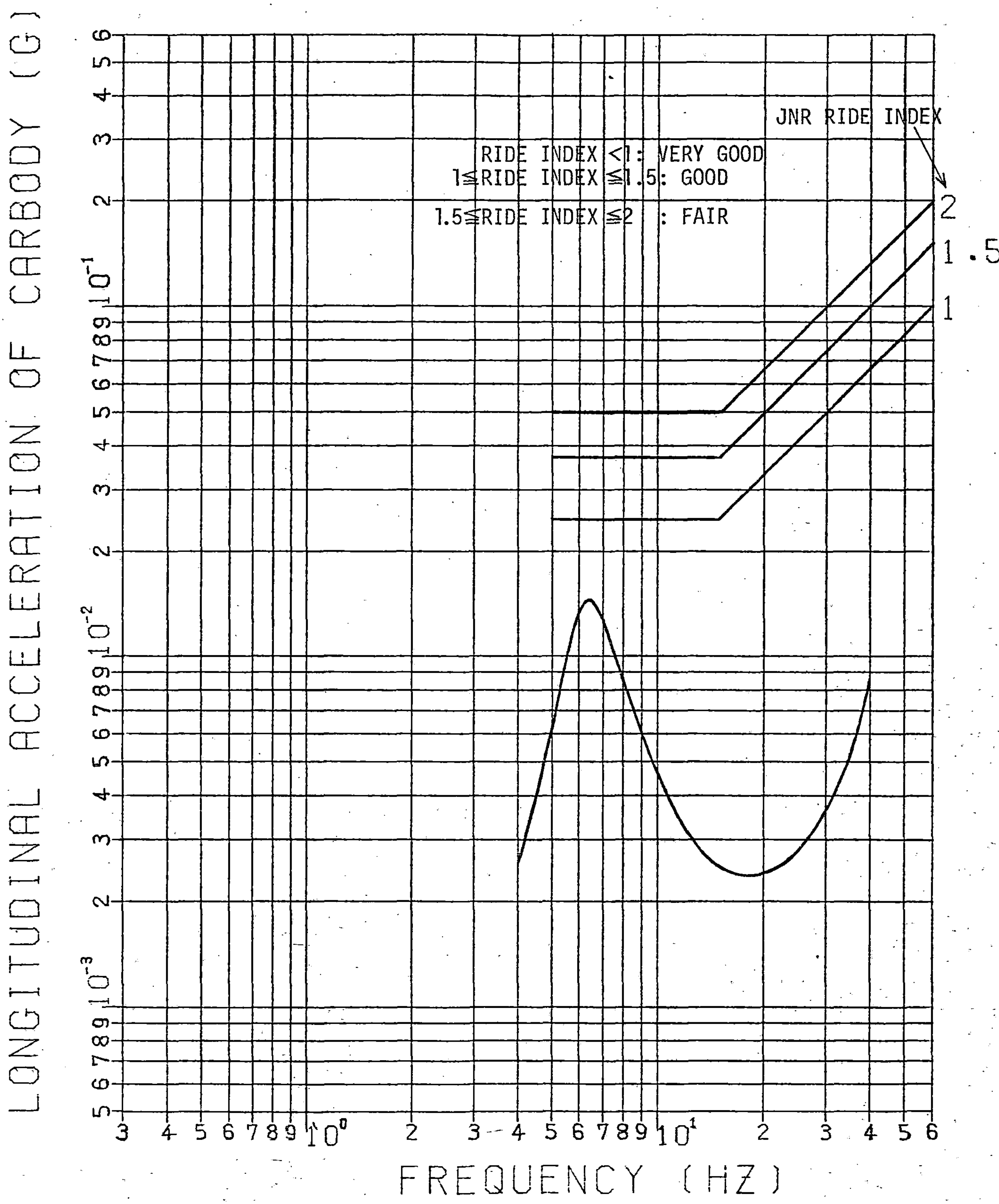


Figure 5.2.3 (B) Frequency Response of Longitudinal Vibration

5.3 LIFE CALCULATION OF JOURNAL BEARING

The life of the journal bearing is calculated as follows.

The calculation data are shown in Table 5.3 (A).

Table 5.3 (A) Calculation Data of Journal Bearing

SYMBOL	DESCRIPTION	DESIGN VALUE
W_r	normal load / box	6044 Kg
W_f	maximum load / box	6327 Kg
C	bearing load rating	99000 Kg
V	maximum speed of vehicle	193 Km/h
D_W	mean wheel diameter	874 mm

The journal bearing is 130 x 250 RCT type.

Assuming that the radial load factor is 1.5 and the thrust load with the dynamic augment 50% is applied during 3% of total running distance and no thrust load for the remaining.

The calculation procedure is as follows.

Axle load

$$W_1 = 2W$$

where, W : bearing static load

Dynamic radial load

$$F_r = 1.5\ W$$

Thrust load

$$F_a = 0.5\ W_1/2$$

Equivalent radial load

$$P = X \cdot Fr + Y \cdot Fa$$

where, x : radial factor x = 0.67

Y : thrust factor Y = 3.8

Mean effective load

$$P_m = (0.97F^{10/3} + 0.03P^{10/3})^{3/10}$$

Life total number of revolutions

$$L_n = (C/P_m)^{10/3} \times 10^6 \text{ (rev.)}$$

Life expectancy in kilometers

$$L_s = \pi \cdot D_W \cdot L_n \times 10^6 \text{ (Km)}$$

The calculation results are shown in Table 5.3 (B).

Table 5.3 (B) Calculation Results of Journal Bearing

	LOAD CONDITION	
	NORMAL LOAD	MAXIMUM LOAD
W	6044 Kg	6327 Kg
Wl	12088 Kg	12654 Kg
Fr	9066 Kg	9490 Kg
Fa	3022 Kg	3164 Kg
P	17558 Kg	18382 Kg
Pm	9674 Kg	10127 Kg
Ln	2327×10^6 rev.	1988×10^6 rev.
Ls	6.39×10^6 Km	5.49×10^6 Km

5.4 CALCULATION OF SPRING

5.4.1 PRIMARY SPRING

The deflection of primary spring and stress of coil spring are shown in Table 5.4.1.

The material of coil spring is in accordance with SUP9A, JIS G 4801 and the maximum permissible stress is 75 Kg/mm^2.

The stress is calculated by the following formula.

$$\tau = K \frac{8DP}{\pi d^3}$$

where, P : spring load

D : mean diameter of coil

d : coil diameter

K : Wahl's stress modification factor

Table 5.4.1 Deflection and Stress of Primary Spring

	LOAD (Kg)			DEFLECTION	HEIGHT	COIL SPRING
	TOTAL	COIL SPRING	RUBBER	(mm)	(mm)	STRESS (Kg/mm^2)
FREE	0	0	0	0	280	0
TARE	2635	2108	527	50.2	229.8	34.8
NORMAL	2989	2989	598	56.9	223.1	39.4
MAXIMUM	3131	2505	626	59.6	220.4	41.3
MAX.x1.3	4380	3234	1146	77.0	203.0	53.3

5.4.2 SECONDARY SPRING

Working pressure, vertical and lateral spring constant of air spring are shown in Table 5.4.2.

Table 5.4.2 Calculation Results of Secondary Spring

	LOAD (Kg)	WORKING PRESSURE (Kg/cm^2)	VERTICAL SPRING CONSTANT (Kg/mm)		LATERAL SPRING CONSTANT (Kg/mm)	
			STATIC	DYNAMIC	STATIC	DYNAMIC
TARE	8905	4.43	26.0	38.4	29.6	31.1
NORMAL	10322	5.13	29.2	43.2	32.8	34.3
MAXIMUM	10899	5.41	30.5	45.1	34.0	35.5

5.5 BRAKE CALCULATION

In this section, the braking distance is calculated.

The calculation data are shown in Table 5.5 (A).

The calculation results are shown in Table 5.5 (B).

The brake distance and deceleration are calculated by the following formulate.

1) Actual brake distance

$$S_{V_1 - V_2} = \frac{\left\{1 + \frac{n \ \alpha W_0}{W}\right\} \times 3.9368}{\frac{F_B + R}{W} - i} \times (V_1^2 - V_2^2) \quad \text{m}$$

where, α ; Augment by inertia of wheel and axle ; 0.06 (6%)

W ; Weight of car/train (tare) ; 299.28 ton

(maximum) ; 346.89 ton

W_0 ; Weight of car/car (tare) ; 49.88 ton

F_B; Braking force/train ; $F_B = n \cdot F$ kg. $F = 4Pf$

R ; Running resistance

$$R = (1.32+0.0164V)\ W + \left\{0.082+0.0078(n-1)\right\} V^2 \ \text{kg.}$$

n ; Car numbers/train ; 6 Cars

i ; Grade resistance

V_1 , V_2 ; Velocity of vehicle ; $V = (V_1 + V_2)/2$

2) Idle running distance

$$S_0 = \frac{V\ max}{3.6} \cdot t \quad \text{m}$$

where, V max ; Initial velocity at braking ; 193 km/h

t ; Idle time ; 1.5 sec.

3) Total brake distance

$$S = S_{V_1 - V_2} + S_0 \quad \text{m}$$

4) Mean deceleration

$$\beta = \frac{V^2 max}{7.2\ S}$$

Table 5.5 (A) Calculation Data of Brake Calculation

DESCRIPTION		AMCOACH	NEW DESIGN CAR	
Weight of Car (tare)		47040 kg	49880 kg	
Weight of passengers	normal	5352 kg	5352 kg	
	maximum	7620 kg	7620 kg	
Weight of Car (with water)	normal	47355 kg	50195 kg	
	maximum	54975 kg	57815 kg	
Brake system		DISC BRAKE	DISC BRAKE	TREAD BRAKE
Lever ratio γ / set		2.3	2.5	4
Brake cylinder numbers / car		8	8	8
Brake cylinder diameter D		204 mm	200 mm	127 mm
Brake cylinder pressure P_b	service	4.78 kg/cm^2	3.19 kg/cm^2	2.37 kg/cm^2
	emergency	5.98 kg/cm^2	3.99 kg/cm^2	2.96 kg/cm^2
mean wheel radius R		437 mm	437 mm	
friction radius of brake lining r		279 mm	293 mm	
Brake cylinder force $P = \frac{\pi}{4} D^2 P_b \times \frac{1}{100}$	service	1547 kg	1002 kg	300 kg
	emergency	1936 kg	1253 kg	375 kg
Pressing force on brake lining/axle $P = \eta \cdot P_A \cdot \gamma \cdot n, \eta = 0.95$	service	6711 kg	4760 kg	2280 kg
	emergency	8411 kg	5952 kg	2850 kg
Pressing force at tread $Pt = P \times \frac{r}{R}$	service	4285 kg	3191 kg	
	emergency	5370 kg	4251 kg	
Brake force sharing ratio ε		100 %	60 %	40 %
mean coefficient of friction of brake lining and brake shoe f		0.35	0.3	0.28

Table 5.5 (B) Brake Distance and Deceleration

		AMCOACH		NEW DESIGN CAR	
Car numbers/train		6		6	
Grade resistance 0/1000		0		0	
Initial velocity at braking (km/h)		193		193	
Lode condition		tare	maximum	tare	maximum
Actual brake distance (m)	service	1179.5	1353.8	1169.1	1339.9
	emergency	848.6	1089.5	942.1	1080.4
Idle running distance (m) (idle time 1.5 sec.)		80.4		80.4	
Total brake distance S (m)	service	1259.9	1434.2	1249.5	1420.3
	emergency	1029.0	1169.9	1022.5	1160.8
Mean deceleration β (km/h/sec)	service	4.39	3.82	4.42	3.86
	emergency	5.45	4.75	5.49	4.79

5.6 CLEARANCE DIAGRAM

The clearance diagrams are shown in Figure 5.6 (A), (B). Figure 5.6 (A) shows the static condition of the vehicle on the level tangent track for static clearance line.

Figure 5.7 (B) shows the dynamic condition of the vehicle on the tangent track having 6" superelevation for dynamic clearance line.

In Figure 5.7 (B), two conditions of the tilting vehicle are as follows.

1) Running condition

   Maximum tilting motion (tilting angle of 6 degrees) including maximum lateral movement of the carbody (20 mm) is conducted.

2) Stop on the tangent track having 6" superelevation.

   In this case, tilt restraint system operates.

   Accordingly, the vehicle inclines by deflection and lateral movement of suspension (by superelevation) just as the conventional vehicle.

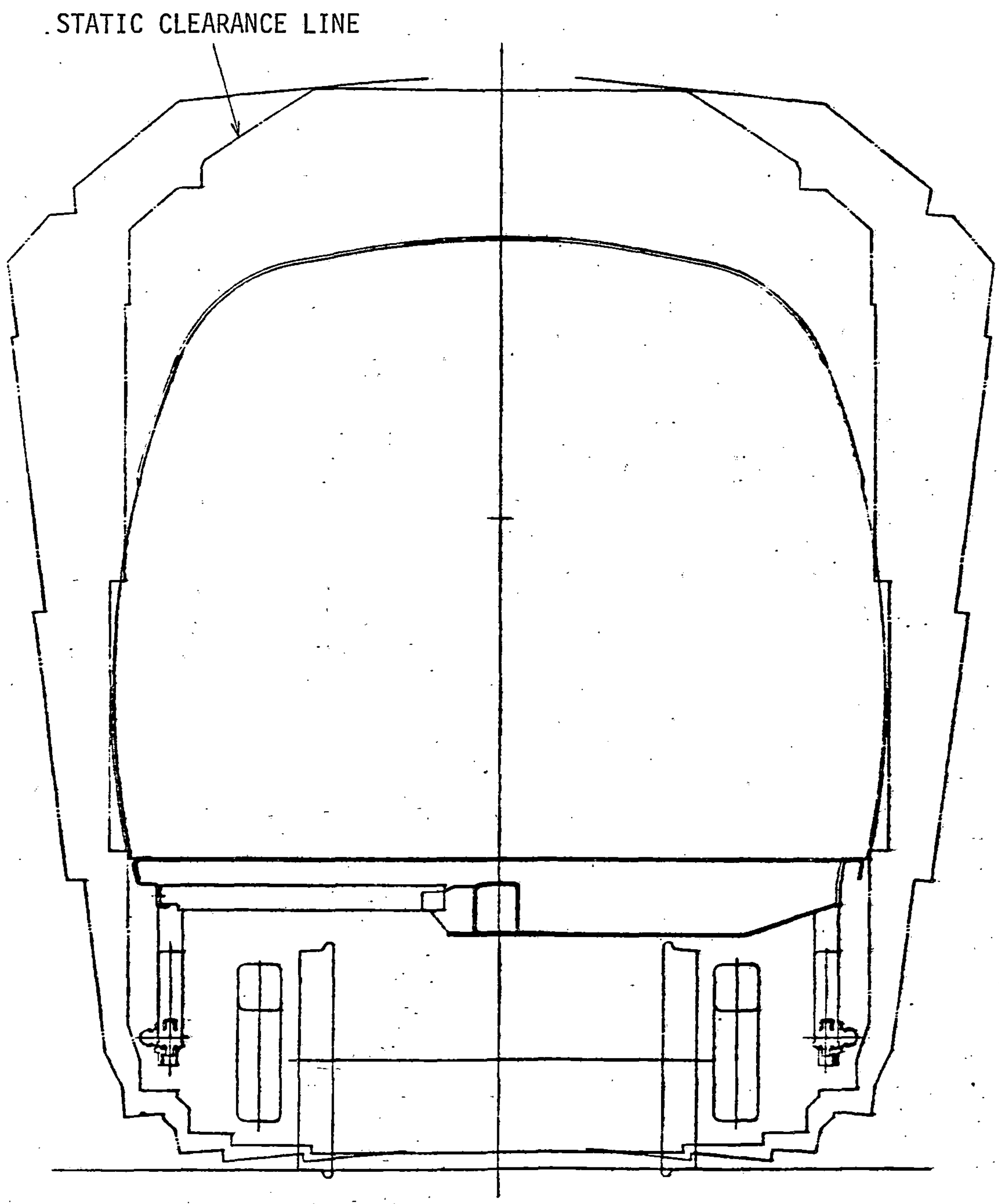


Figure 5.6 (A) Static Clearance Diagram

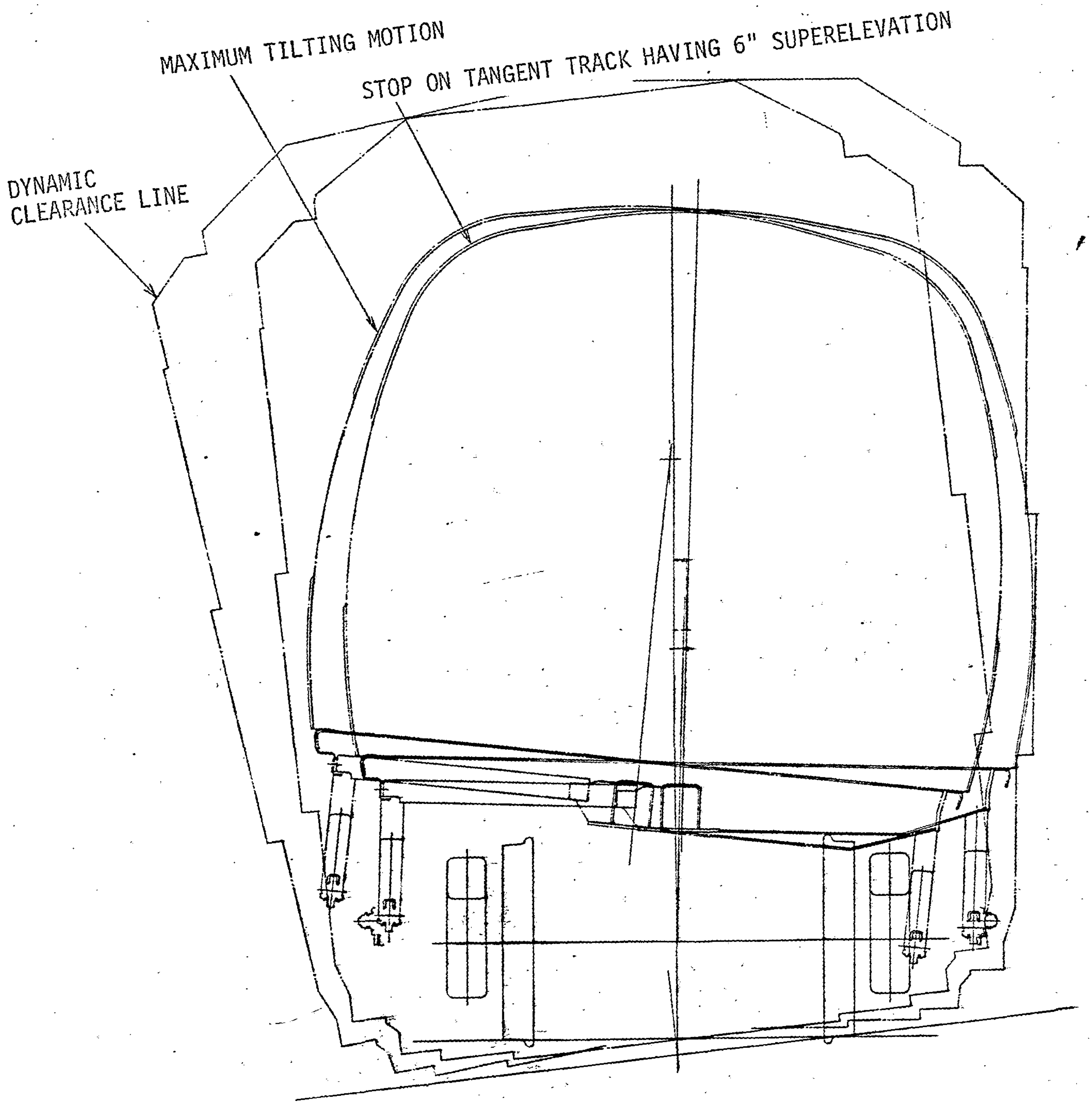


Figure 5.6 (B) Dynamic Clearance Diagram

6. STRESS ANALYSES

The following stress analyses for the components of truck are conducted with respect to the strength.

1)	Axle	-	calculation of strength of axle under static and dynamic load conditions.
2)	HT wheel	-	results of strength tests
3)	Truck frame	-	calculation of stress of truck frame by means of "FEM" under static and dynamic load conditions.
4)	Roller	-	calculation of surface stress on roller under static and dynamic load conditions.
5)	Upper swing bolster	-	calculation of stress of upper swing bolster under static and dynamic load conditions.
6)	Brake disc	-	calculation of thermal stress of brage disc by means of "FEM" under thermal load conditions.

6.1 AXLE

The calculation of strength of axle is made by the process as follows.

1) Load acting on axle (Cf. Figure 6.1(A), 6.1(B) and table 6.1(A).)

Maximum speed of car is 193Km/h.

WO : vertical load on journal (including the additional load caused by vertical acceleration of 0.6g)

$$WO = \frac{WA}{2} \times 1.6 = 0.8\ WA$$

where, WA : maximum load on axle (13100 kg)

P : horizontal load (caused by the acceleration of lateral movement 0.4g)

$$P = 0.4\ WA$$

QO : vertical load on journal by P

$$QO = \frac{Ph}{j}$$

RO : vertical load on wheel tread by P

$$RO = \frac{P(h + r)}{g}$$

Vertical load on axle by braking reaction, So, is obtained as follows.

T : maximum tangential force on tread

$$T = 2 \times \mu \times WO = 0.64\ WA$$

where, μ : coefficient of friction between tread and rail (0.4)

Td : vertical force on brake disc

$$Td = \frac{r}{rd} \times \frac{T}{2} = 0.32\ WA \times \frac{r}{rd}$$

$$\therefore\ SO = \frac{L - Ld}{L} \times Td = 0.64\ WA \times \frac{r}{L}$$

2) Perpendicular force acting on axle

The value obtained is to be combined respectively at each position. In this way, the resultant perpendicular force is obtained as summarized Figure 6.1 (A) and Table 6.1 (B).

Table 6.1 (B) Combined Perpendicular Force

FORCE / POINT	BY VERTICAL LOAD	BY HORIZONTAL LOAD	BY BRAKING REACTION	COMBINED LOAD
F0	WO = 0.8 WA	Qo	-S0 + Td	Wo+Q-So+Td
F1	-WO = -0.8 WA	-RO	SO	-Wo -RO+SO
F2			-Td	-Td

3) Bending moment acting on axle

Using the resultant perpendicular force obtained in paragraph 2), respective bending moment which acts on each point of axle is obtained. For instance, MA and MII, which are the bending moments at the points of A and II, are as follows;

$$MA = F_0 \cdot \ell a$$

$$MII = F_0 \cdot (a + \ell 1) + F_1 \cdot y + P \cdot r$$

4) Calculation of torsional moment

Mt ; maximum torsional moment acting on axle

$$Mt = T \cdot r$$

5) Stress of axle at each point

Stress of axle at each point can be calculated by the following formula.

$$\sigma b = \frac{Mb}{Zb} \quad , \quad \tau = \frac{Mt}{Zt}$$

where ; σb : bending stress

τ : torsional stress

Mb : bending moment (calculated by par. 3))

Mt : torsional moment (calculated by par. 4))

Zb : modulus of section for bending

Zt : modulus of section for twisting

6) Fatigue limit of axle

The following values are adopted for fatigue limit of bending, σwb and elastic limit of twisting, τe respectively.

Fatigue limit : σwb Kg/cm^2

AXLE MATERIAL	PRESS-FITTED PORTION	PLAIN PORTION	CHANGING PORTION OF SECTIONAL AREA
AISI 5150	1100	1550	{fatigue limit of plain portion} $\times \frac{1}{Bk}$

where, B_k : coefficient of notch

The coefficient of notch is obtained as shown below according to relation $^{ds}/_{d\ell}$ and $\rho/_{ds}$. (Cf. Figure 6.k (C))

POINT	ds/d	ρ/ds	Bk
A	0.81	0.19	1.14
B	0.76	0.09	1.28
C	0.90	0.53	1.07
D	0.88	0.53	1.08
E	0.88	0.53	1.08

Elastic limit of twisting : $\tau e = 2040\ Kg/cm^2$

7) Calculation of safety factor

The safety factor, n, is calculated by the following formula.

$$n = \frac{1}{\left(\frac{\sigma b}{\sigma wb}\right)^2 + \left(\frac{\tau}{\tau e}\right)^2}$$

Results of the calculation are shown in Table 6.1 (C).

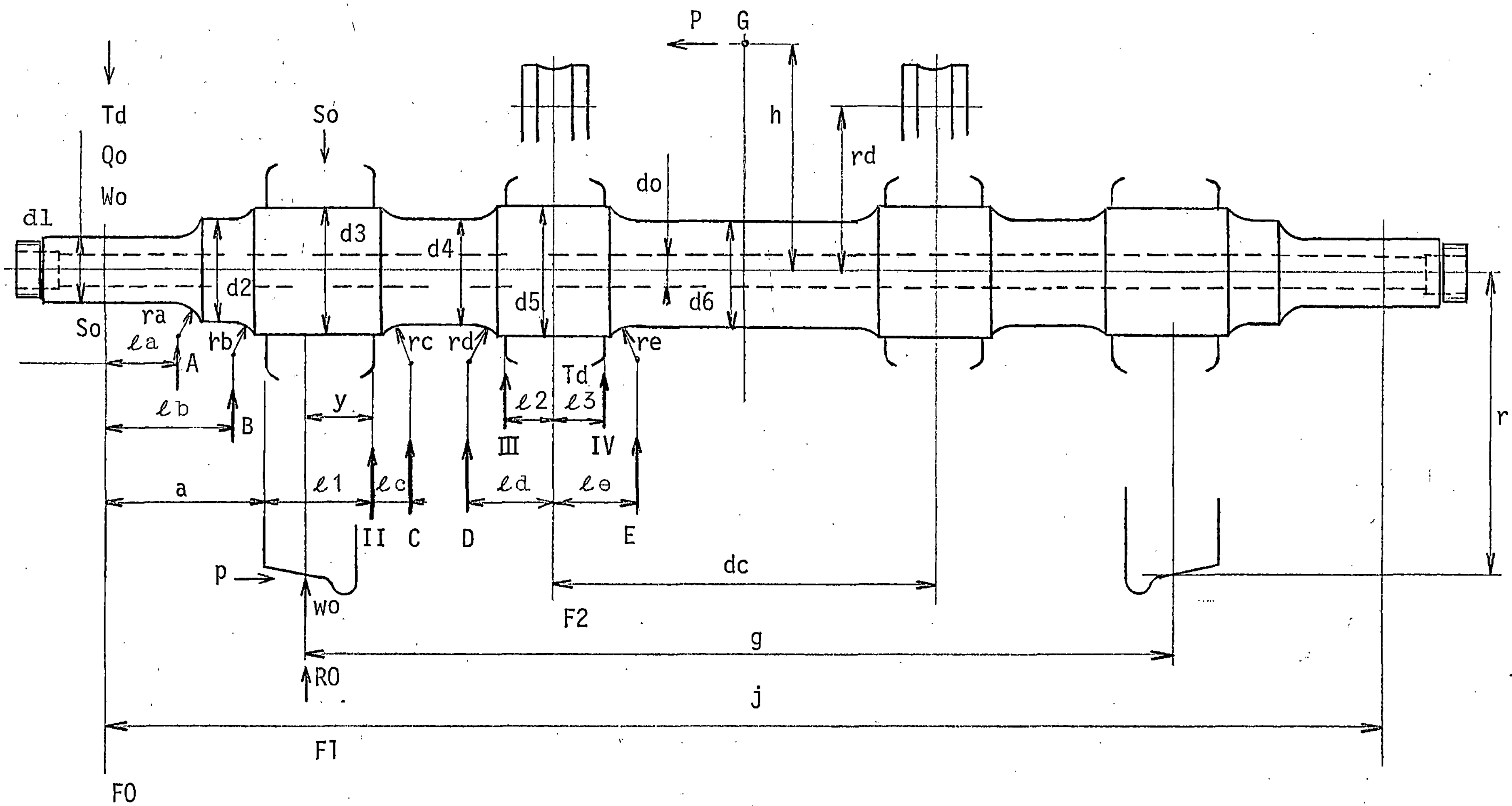


Figure 6.1 (A) Symbols and Load - Axle Stress Analysis

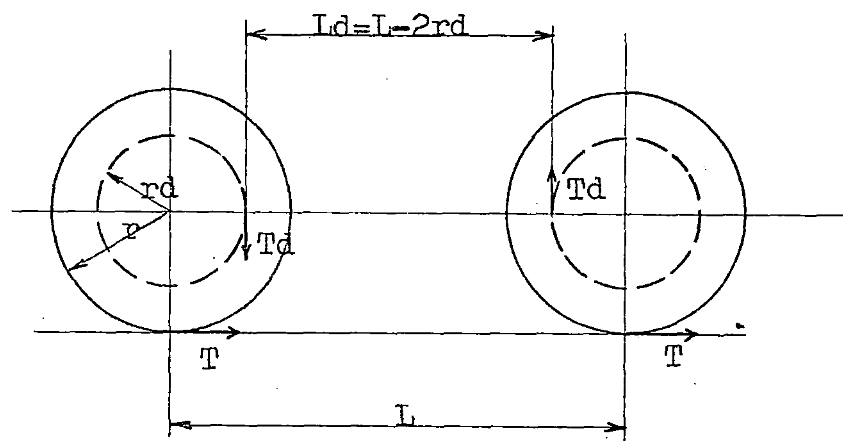


Figure 6.1 (B) Wheels Arrangement and Braking Reaction

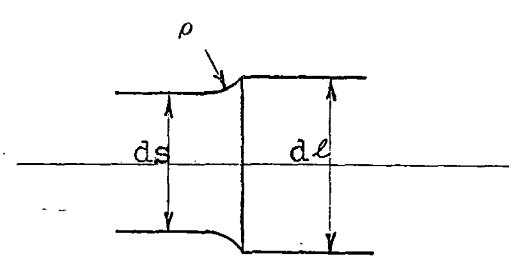


Figure 6.1 (C) Changing Portion of Sectional Area

Table 6.1(A) Legend and Values of Symbol in Fig. 6.1(A) and Fig.6.1(B).

SYMBOL	DESCRIPTION	DESIGN VALUE
h	height from center of axle to center of gravity of car	1077 mm
r	wheel radius (new)	457 mm
j	distance between journal centers	1960 mm
g	distance between wheel tread centers	1496.6 mm
$\ell 1$	width of wheel hub	177.8 mm
a	distance between center of journal and outer side of wheel hub	189.7 mm
y	distance between tread center of wheel and inner side of wheel hub	135.8 mm
rd	radius of friction surface of brake disc	293 mm
L	distance of wheel centers	2500 mm
Ld	distance between brake force points of brake discs	1942 mm
dc	distance between brake disc centers	600 mm
$\ell 2$	distance between brake disc center and outer side of brake disc	80 mm
$\ell 3$	distance between brake disc center and inner side of brake disc	80 mm

SYMBOL	DESCRIPTION	DESIGN VALUE
ℓa	distance between center of journal and point A	89.1 mm
ℓb	distance between center of journal and point B	167.5 mm
ℓc	distance between points II and C	50.6 mm
ℓd	distance between center of the brake disc and point D	130.9 mm
ℓe	distance between center of brake disc and point E	130.9 mm
d_1	diameter of journal seat	130 mm
d_2	diameter between journal seat and wheel seat	160 mm
d_3	diameter of wheel seat	210 mm
d_4	diameter between wheel seat and brake disc seat	190 mm
d_5	diameter of brake disc seat	215 mm
d_6	diameter of axle center	190 mm
d_o	diameter of hollow of axle	60 mm
ra	curvature radius at point A	25 mm
rb	curvature radius at point B	15 mm
rc	curvature radius at point C	100 mm
rd	curvature radius at point D	100 mm
re	curvature radius at point E	100 mm

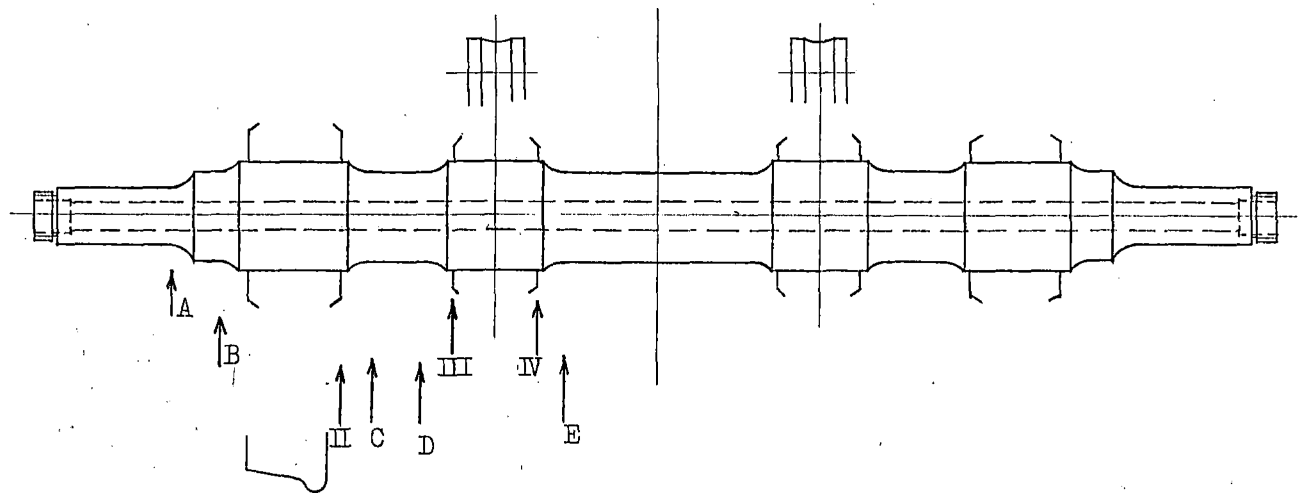


Table 6.1 (C) Stress and Safety Factor of Axle

Section	Maximum Bending Moment M Kg-cm	Dia. D cm	Modulus of Section for Bending Zb cm³	Bending Stress σb Kg/cm²	Twisting Moment Mt Kg-cm	Modulus of Section for Twisting Zt cm³	Twisting Stress τ Kg/cm²	Fatigue Limit of Bending σwb Kg/cm²	Elastic Limit of Twisting τe Kg/cm²	Safety Factor n
A	167x10³	13.0	205.9	811				1100		1.36
B	314x "	16.0	394.2	797				1100		1.38
II	733x "	21.0	903.1	812	192x10³	1806.3	106	1100	2040	1.35
C	755x "	19.0	666.7	1132	"	1333.4	144	1550	"	1.36
D	813x "	19.0	666.7	1219	"	1333.4	144	1550	"	1.27
III	834x "	21.5	969.8	860	"	1939.6	99	1100	"	1.28
IV	849x "	21.5	969.8	875				1100		1.26
E	837x "	19.0	666.7	1255				1550		1.24

6.2 HT WHEEL

1) Introduction

The wheel fracture results when the resistance of the material against fracture is overpowered by the stress applied to the crack.
Therefore, there are two ways to obtain the higher fracture resistance of the wheel. One is the improvement of the profile to reduce the applied stress, and the other is the improvement of the material to increase the toughness.

Profile → Stress Distribution → Stress Intensity Factor = K

Material → Resistance against Fracture → Fracture Toughness = KIC

K > KIC ⇒ FRACTURE

2) Improvement of Profile

When the wheel is abnormally heated by the severe braking on the tread and is cooled subsequently, it causes the harmful tensile residual stress in the rim.
However, this residual stress can be minimized by the improvement of the plate profile. Stress distributions of conventional and HT wheel are shown in Figure 6.2 (A).

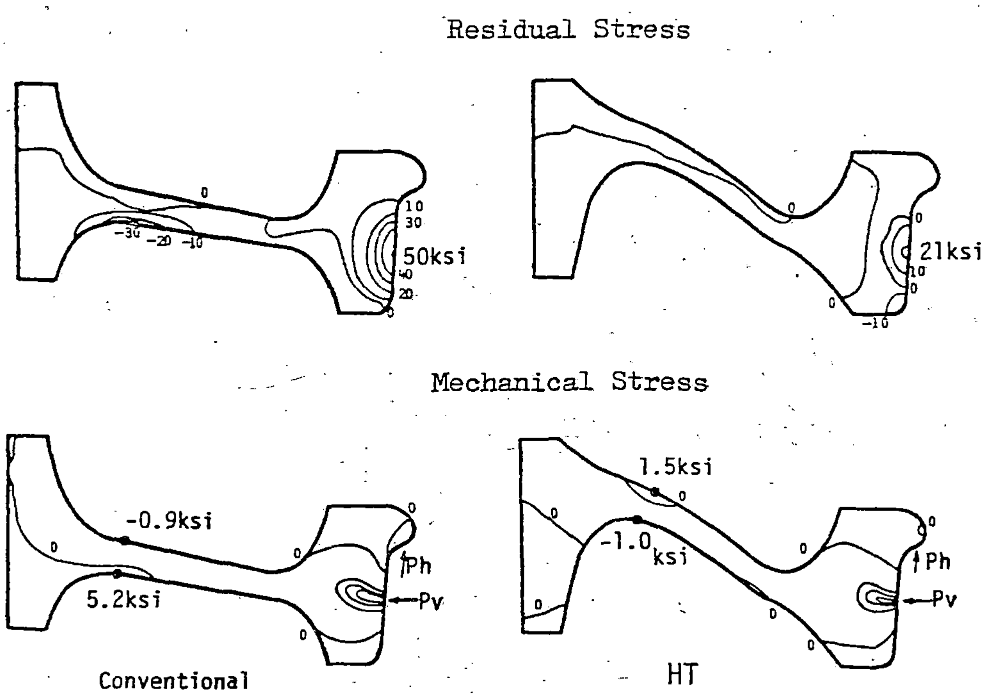


Figure 6.2 (A). Stress Distribution

3) Improvement of Material

There are three stages in a wheel fracture process, that is, the crack initiation, the crack propagation and subsequent brittle fracture.

Therefore, in order to obtain the excellent performance against the fracture, it is necessary to have superior characteristics on all these stages.

Fracture toughness is shown in Figure 6.2 (B).

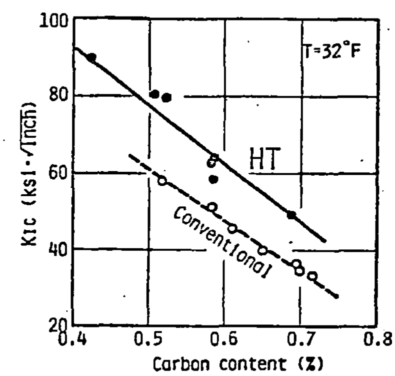


Figure 6.2 (B) Fracture Toughness

4) Braking Test

In order to evaluate the total performance of HT-WHEEL, several braking tests have been carried out using working model of various kinds of wheels.

Figure 6.2 (C) shows evidently that HT-WHEEL has excellent performance against the initiation and propagation of cracks. Moreover it is to be noted that no brittle fracture resulted with HT-WHEEL due to its superior plate profile and HT material.

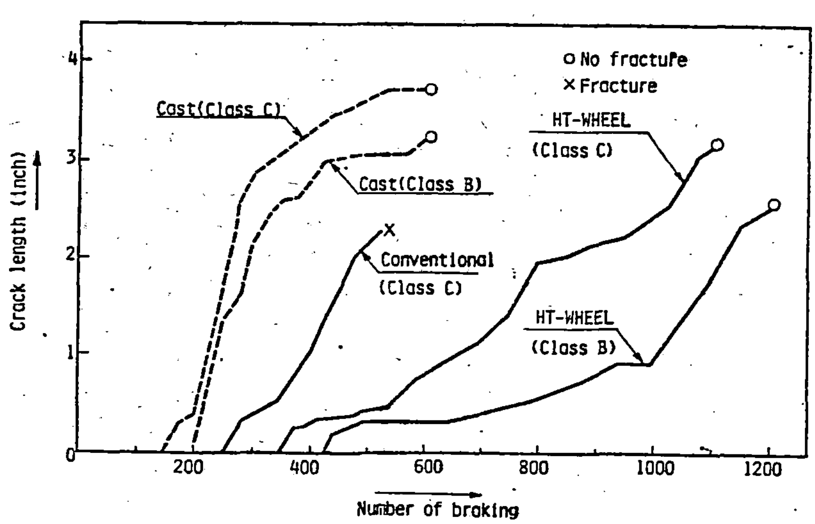
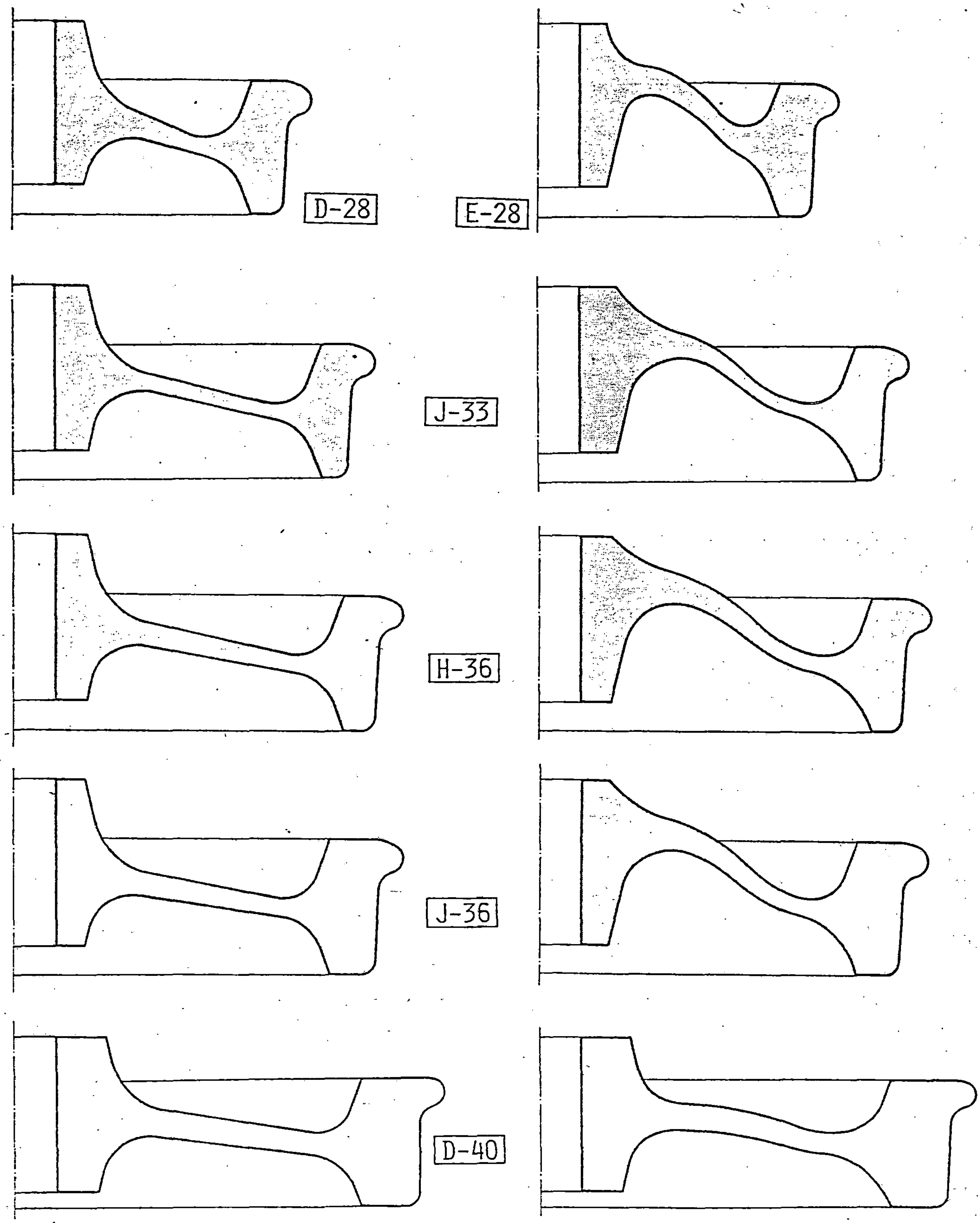


Figure 6.2 (C) Results of Braking Tests

WHEEL PROFILE

CONVENTIONAL HT-WHEEL



6.3 TRUCK FRAME

Stress analysis of truck frame is done by means of "Finite Element Method", NASTRAN (NASA Structual Analysis Program).

The truck frame is modeled by the plate elements (QUAD and TRIA element).

Model is shown in Figure 6.3 (A).

The partitioning and Element Numbers of each side are shown in Figure 6.3 (B) ~ (E).

The load conditions are as follows.

1) Vertical load on side bearer

P : maximum side bearer load 11449 Kg

2) Lateral force on journal box guide

$Q = 0.3 \times P_A/4 = 1084$ Kg

where, P_A : maximum axle load 14442 Kg

3) Longitudinal force on journal box guide

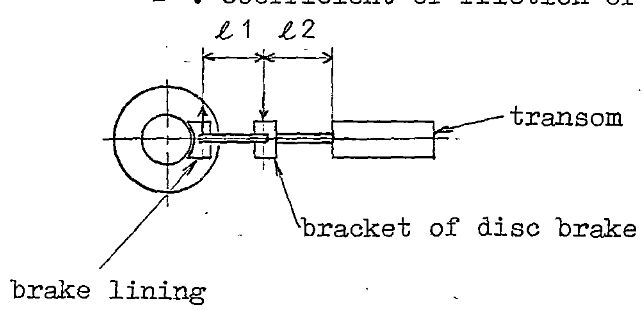
$F_L = 0.3 \times P_A/4 = 1084$ Kg

4) Braking force (disc brake) on bracket of disc brake

$F_{B1} = f \cdot Pb \cdot \ell 1/\ell 2 = 420$ Kg

where, Pb : pressing force on lining/disc (at emergency)

f : coefficient of friction of brake lining

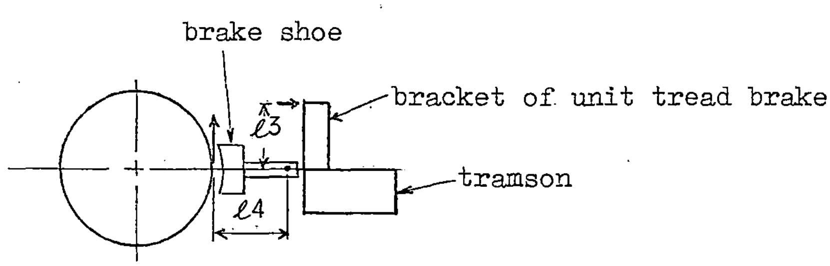


5) Braking force (tread brake) on bracket of tread brake

$F_{B2} = f \cdot Pb \cdot \ell 3/\ell 4 = 400$ Kg

where, Pb ; pressing force on brake shoe/unit (at emergency)

f ; coefficient of friction of brake shoe



The thickness of main members of truck frame is 12 mm.

Load and constraint conditions for each force are shown in Figure 6.3 (F) ~ (J).

The constraints are all Single - Point Constraints.

The example of output is shown in Table 6.3 (A).

The values of stress are shown in Table 6.3 (B).

The symbols in Table 6.3 (B) are as follows.

σ_V : stress by vertical load

σ_H : dynamic stress by lateral load

σ_L : dynamic stress by longitudinal load

σ_{BD} : dynamic stress by braking force (disc brake)

σ_{BT} : dynamic stress by braking force (tread brake)

σ_D : combined dynamic stress

where, σ_D is calculated by the following formula.

$$\sigma_D = \sqrt{(0.3 x \sigma_V)^2 + \sigma_H^2 + \sigma_L^2 + \sigma_{B1}^2 + \sigma_{B2}^2}$$

static stress $\sigma_S = \sigma_V$

The high stresses are plotted in Endurance Limit Diagram and shown in Figure 6.3 (K), (L).

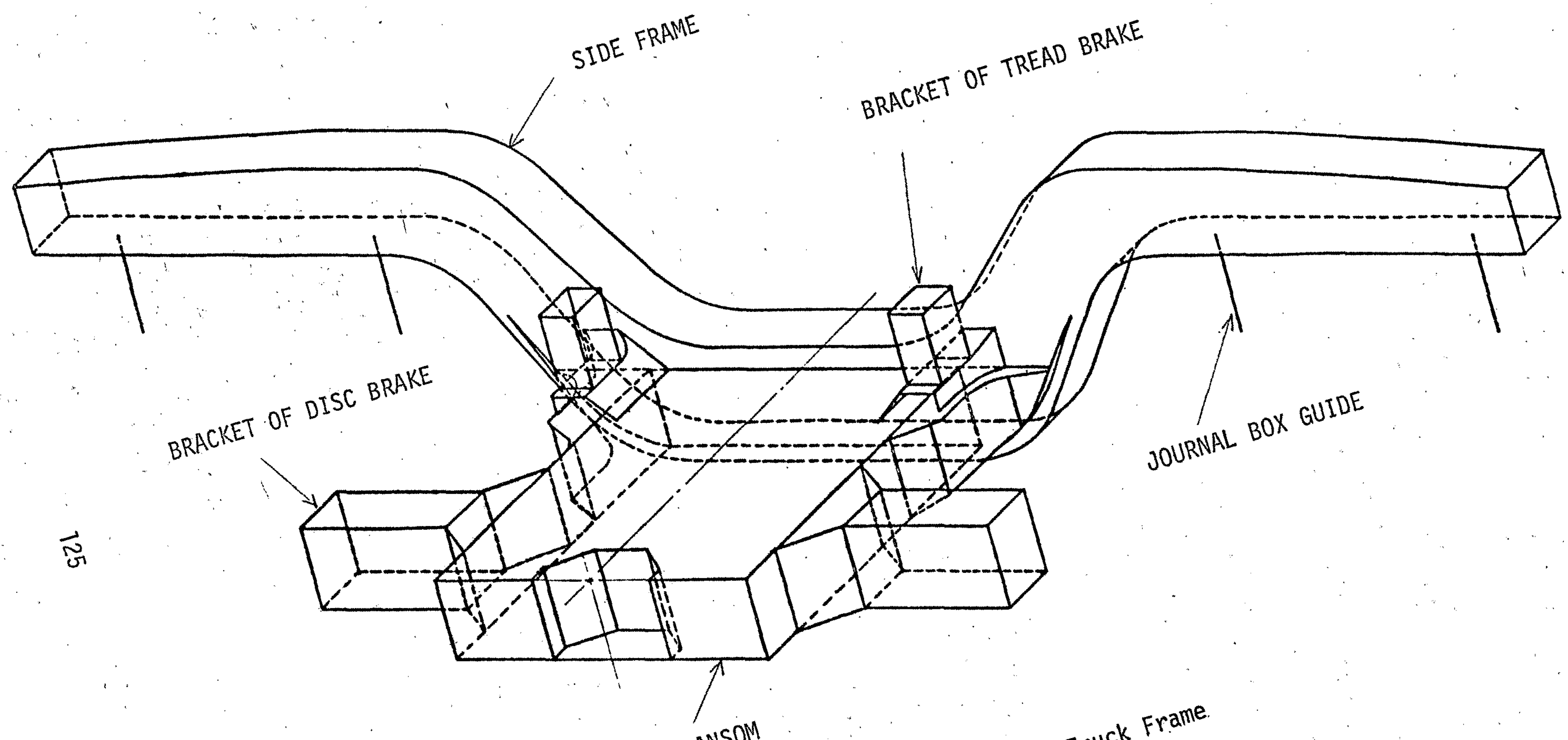


Figure 6.3 (A) Model of Stress Analysis of Truck Frame

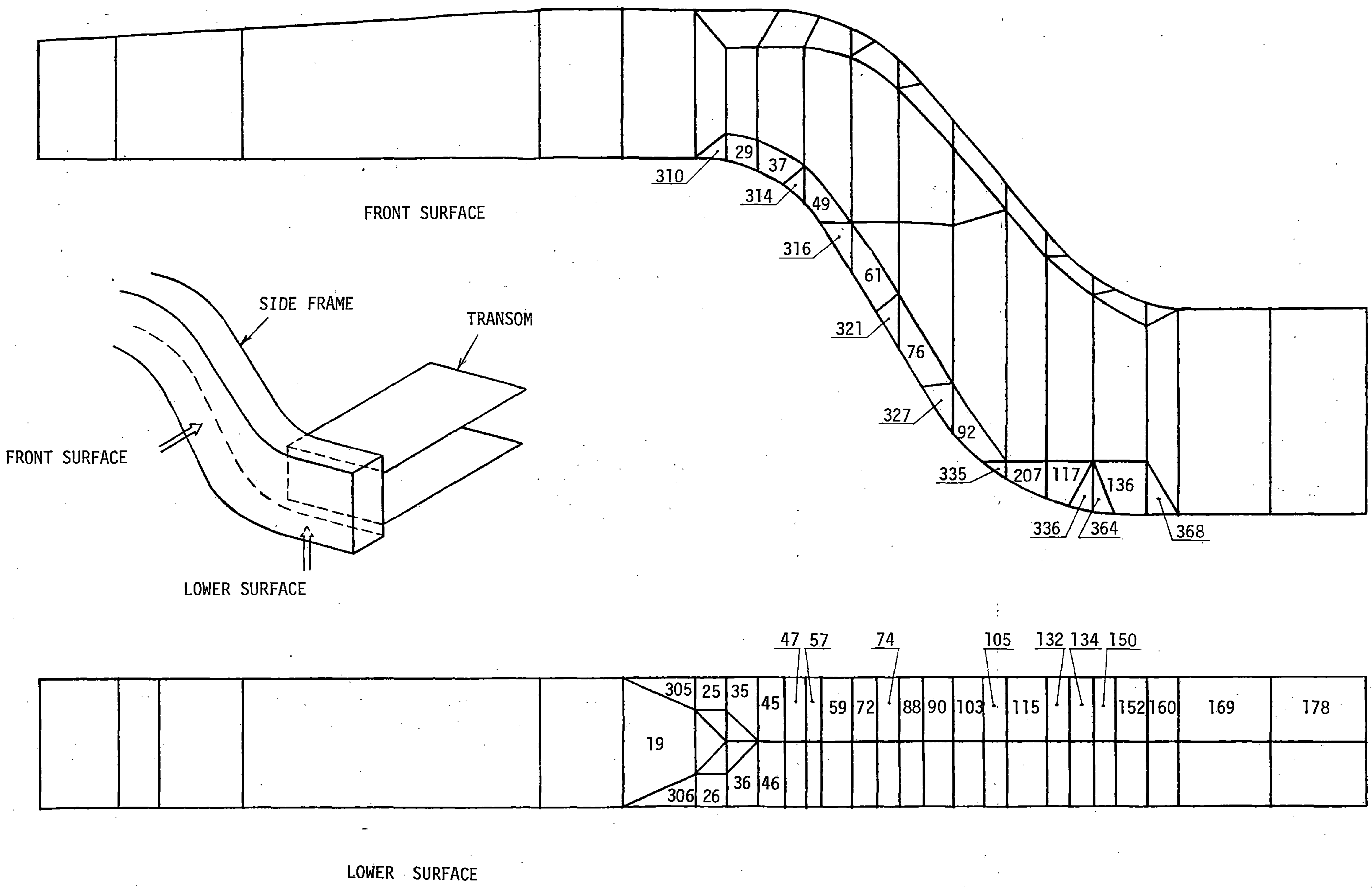


Figure 6.3 (B) Partitioning and Element Numbers (Side Frame 1)

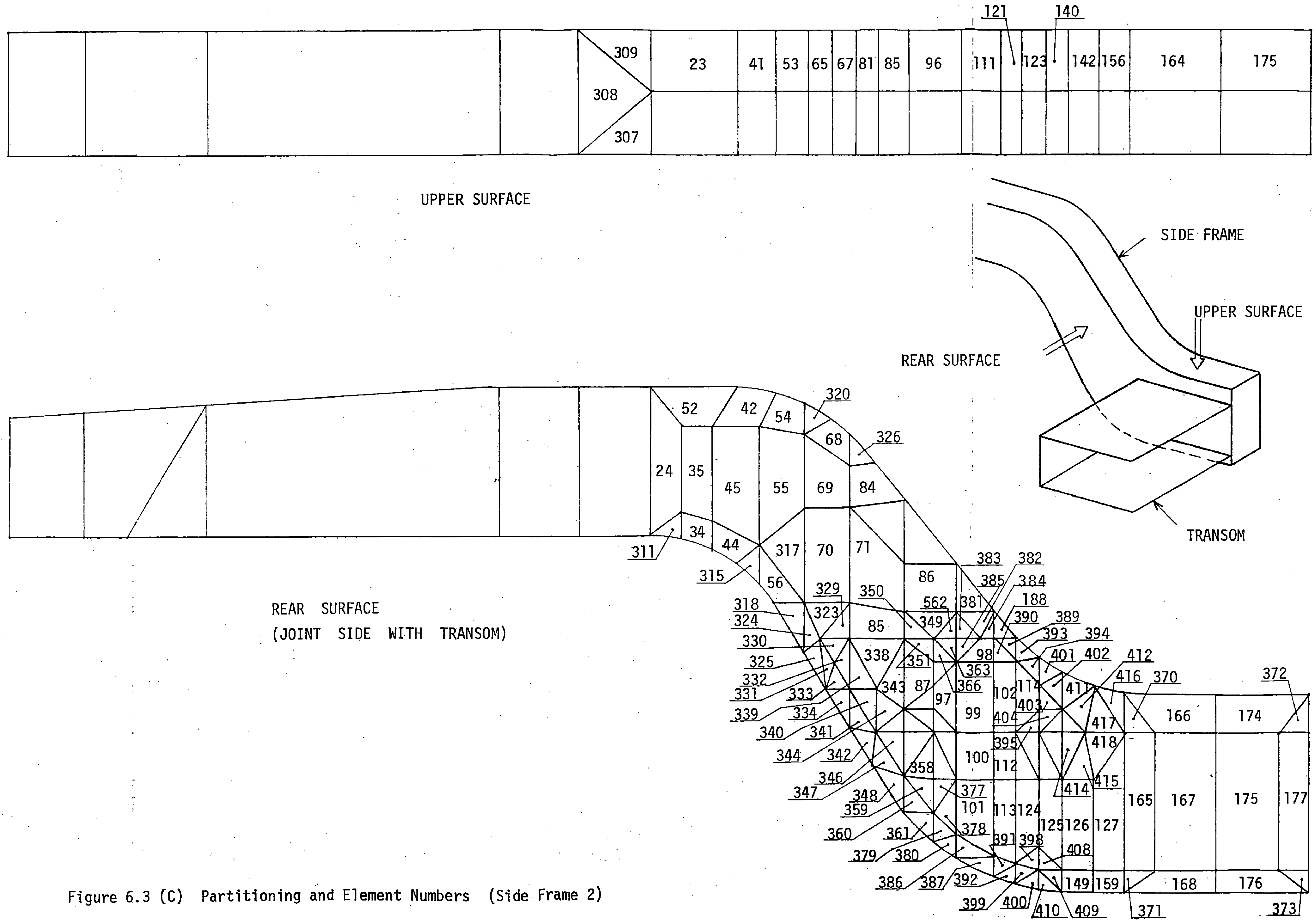


Figure 6.3 (C) Partitioning and Element Numbers (Side Frame 2)

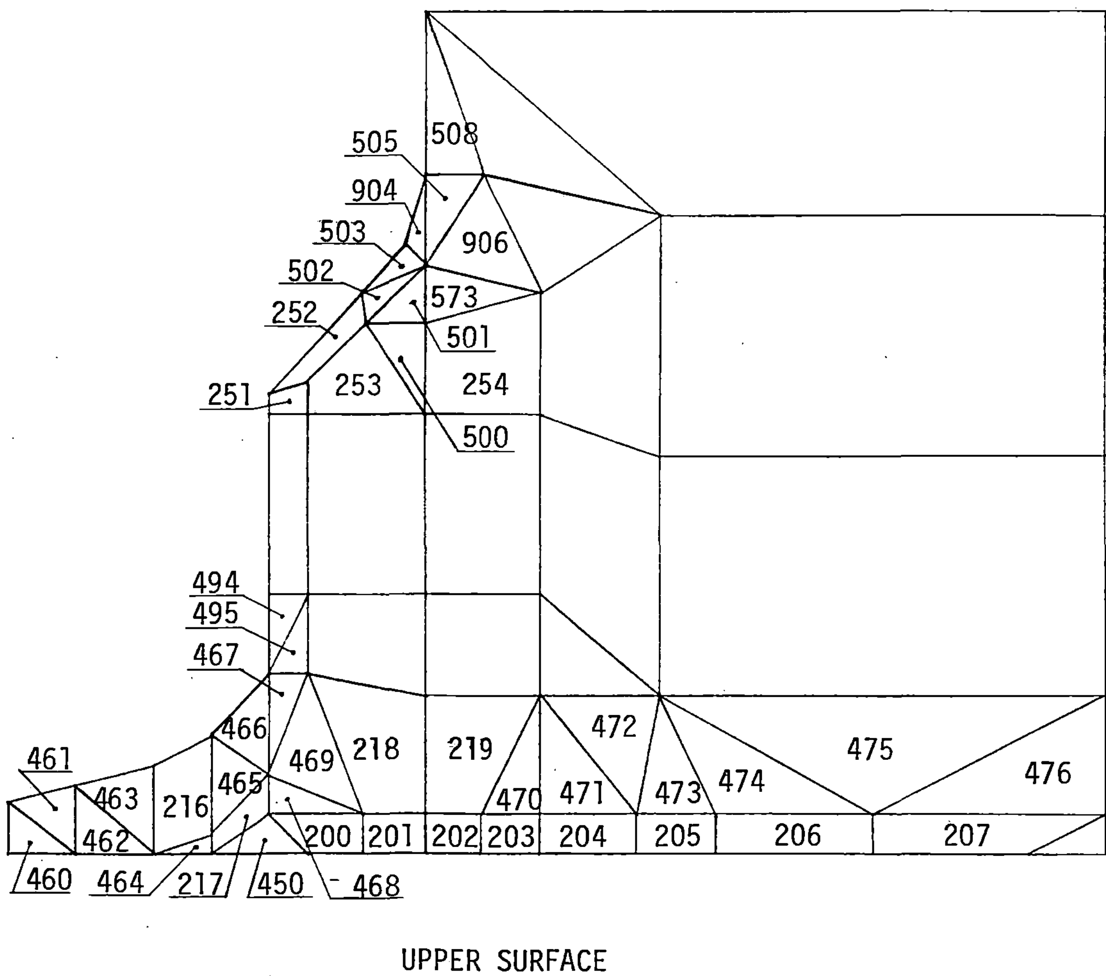
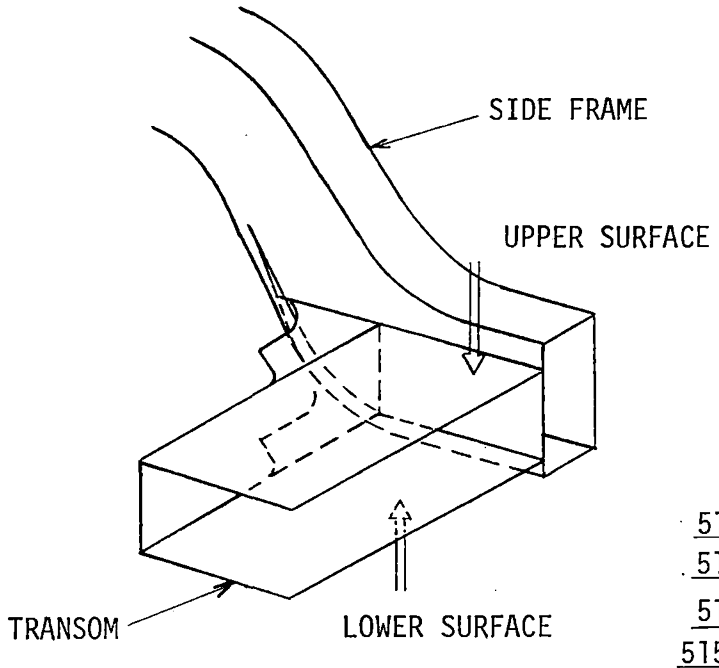
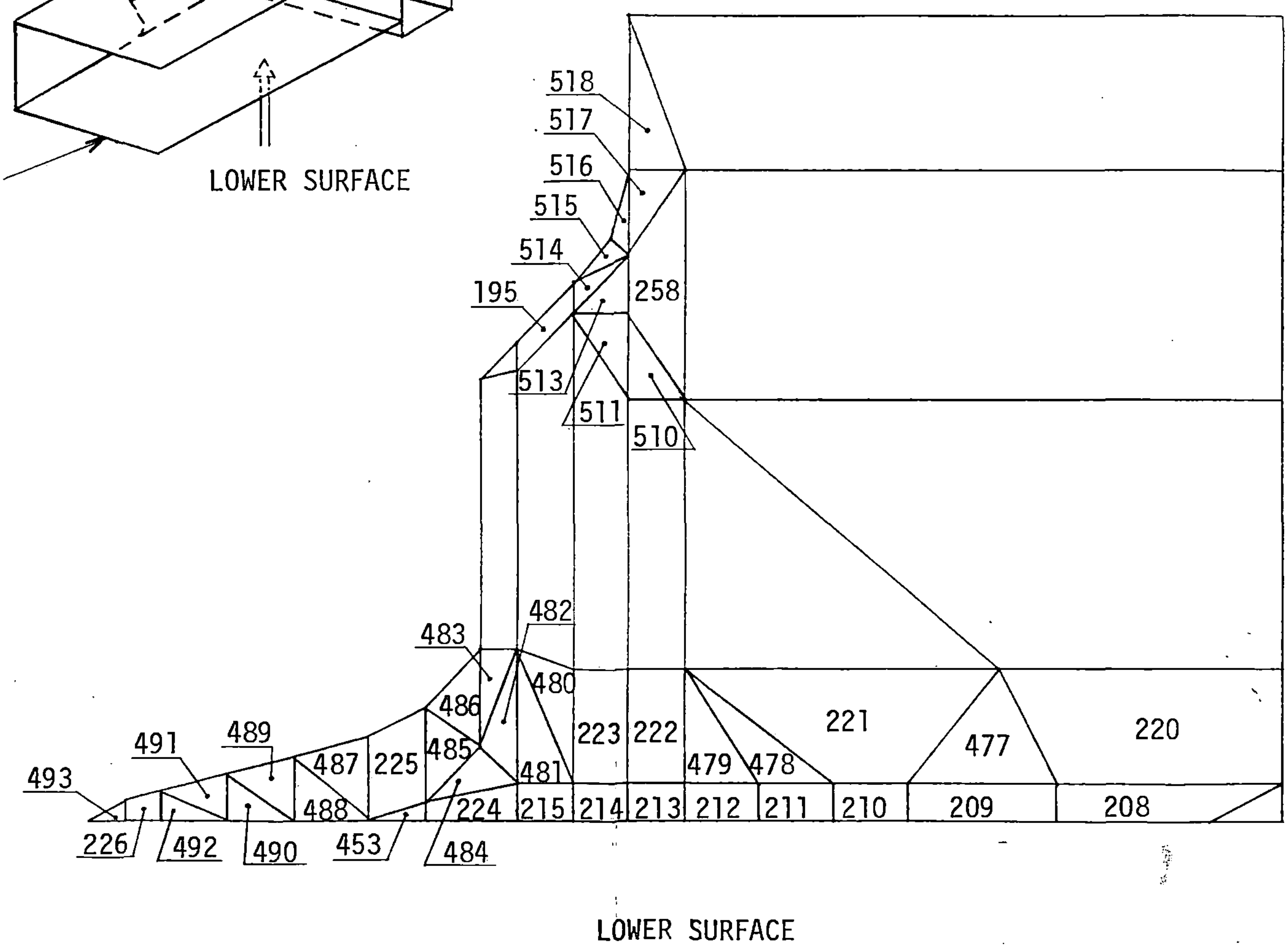


Figure 6.3 (D) Partitioning and Element Numbers (Transom 1)


SIDE FRAME
UPPER SURFACE
TRANSOM
LOWER SURFACE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LOWER SURFACE

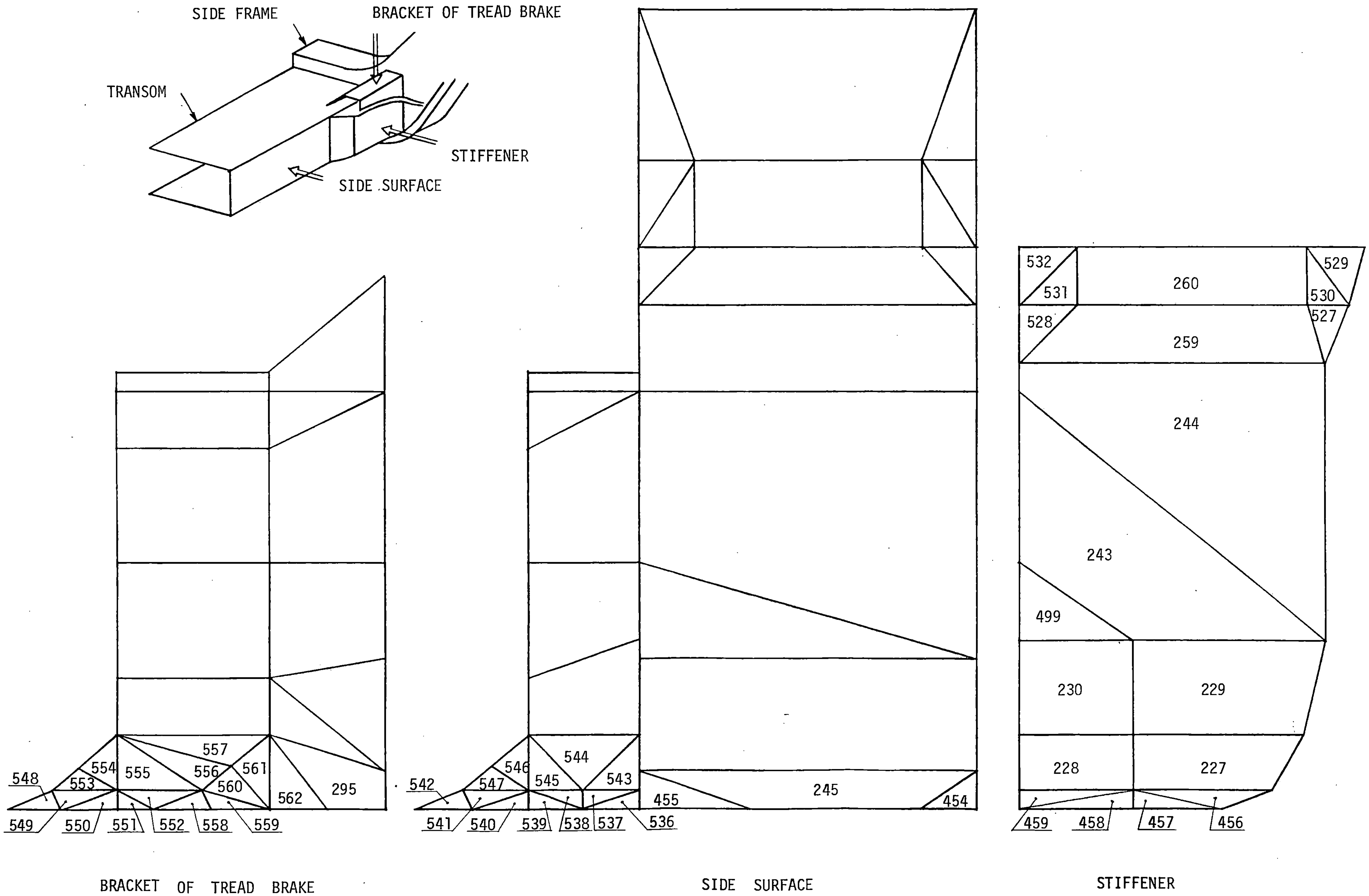

Figure 6.3 (E) Partitiong and Element Numbers (Transom 2)

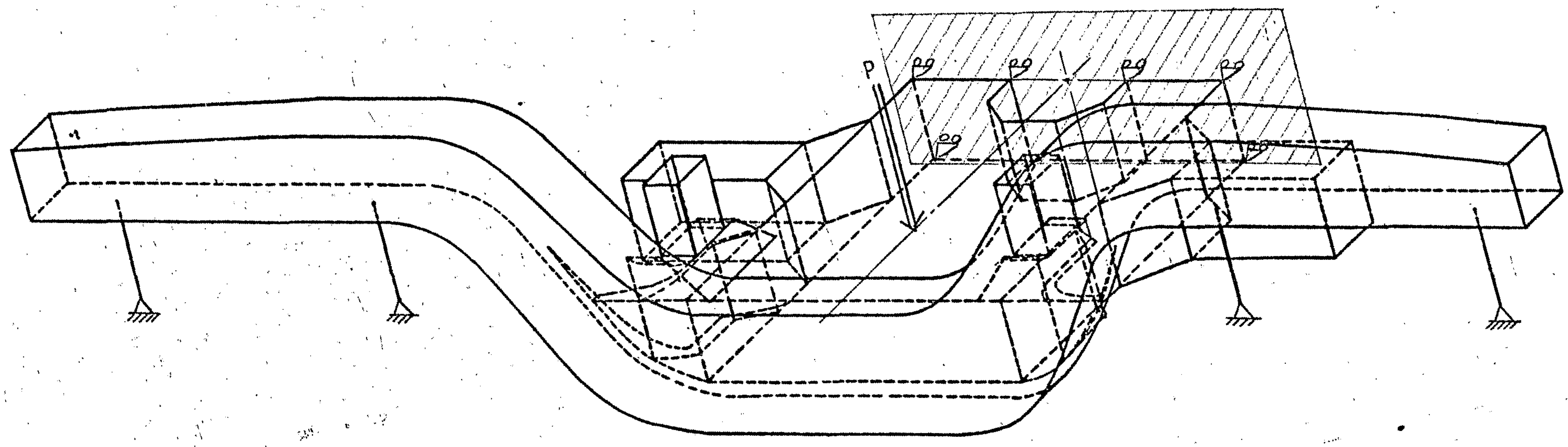

Figure 6.3 (F) Load and Constraints (Vertical Load)

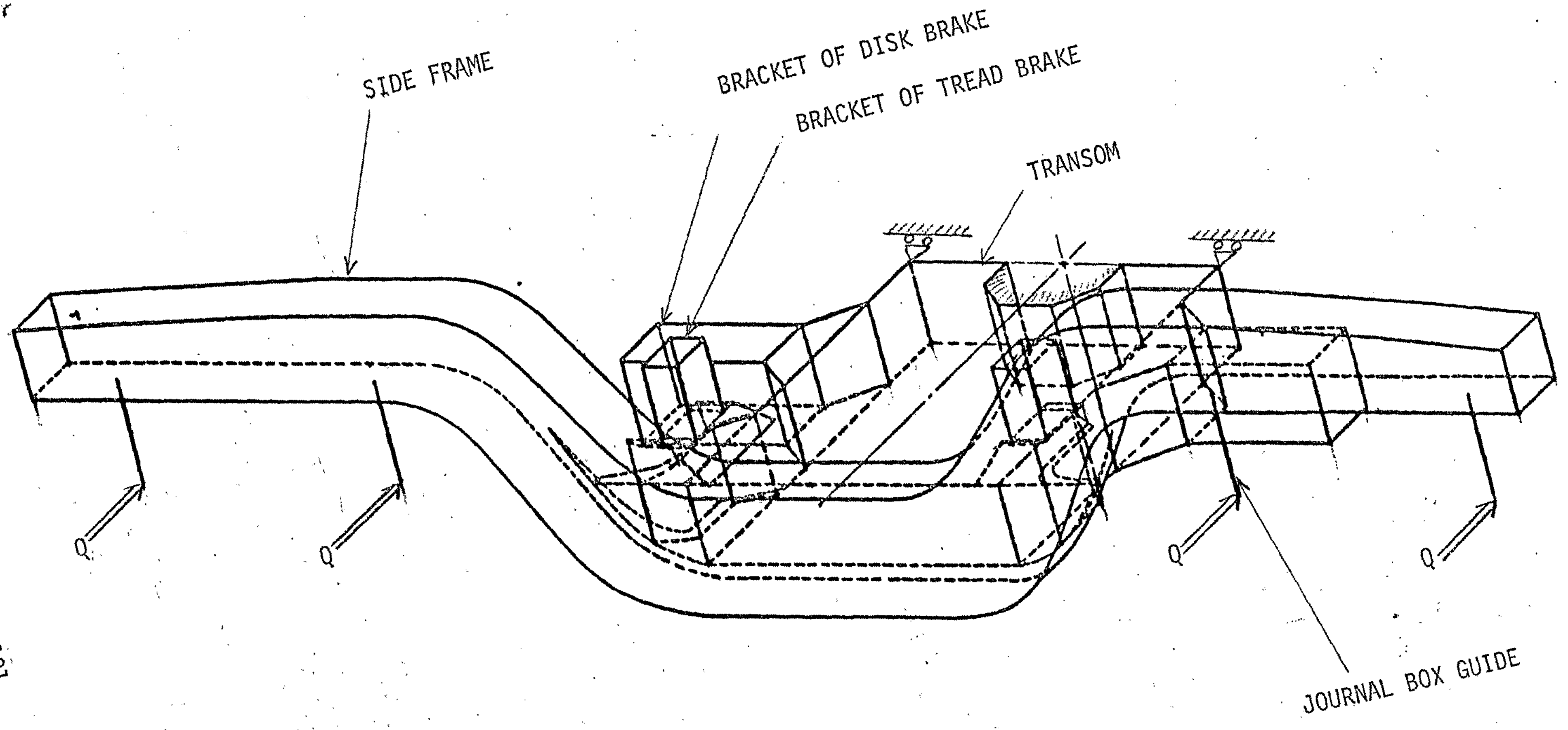

Figure 6.3 (G) Load and Constraints (Lateral Force)

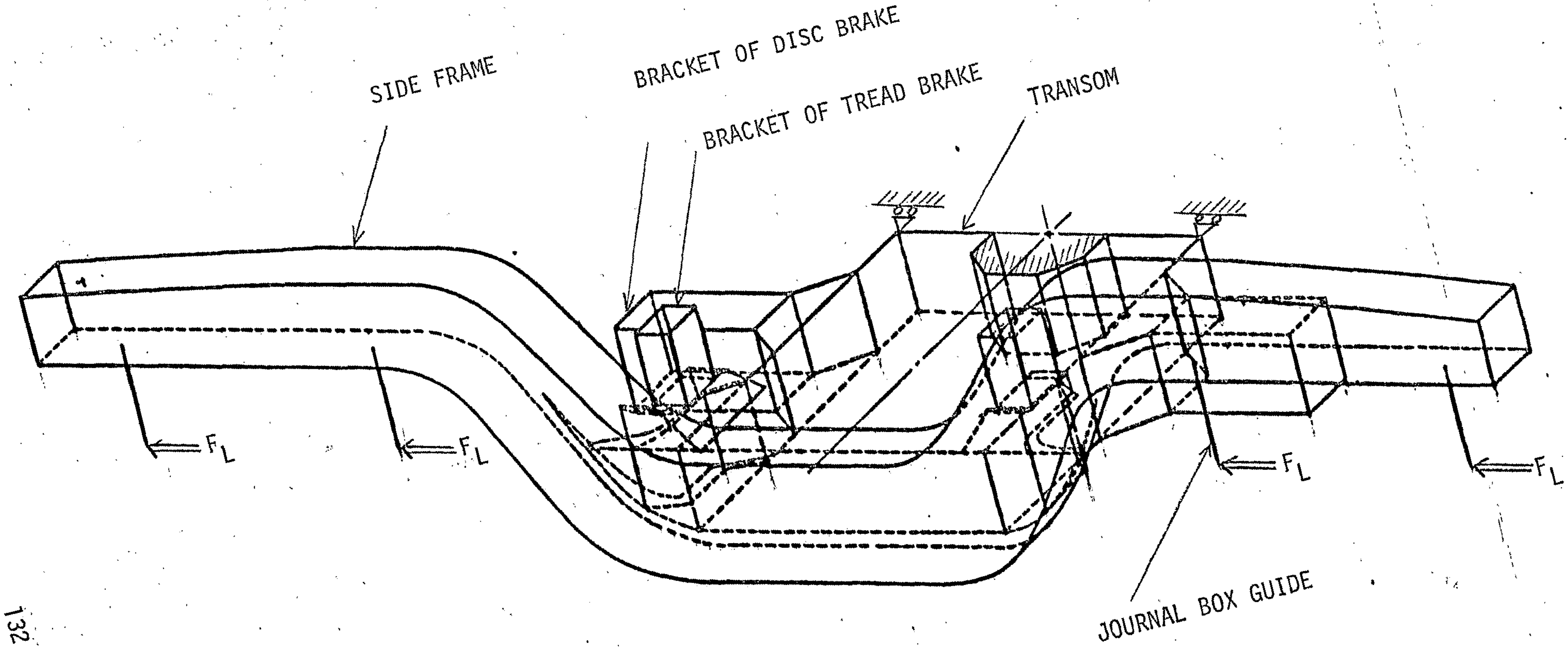

Figure 6.3 (H) Load and Constraints (Longitudinal Force)

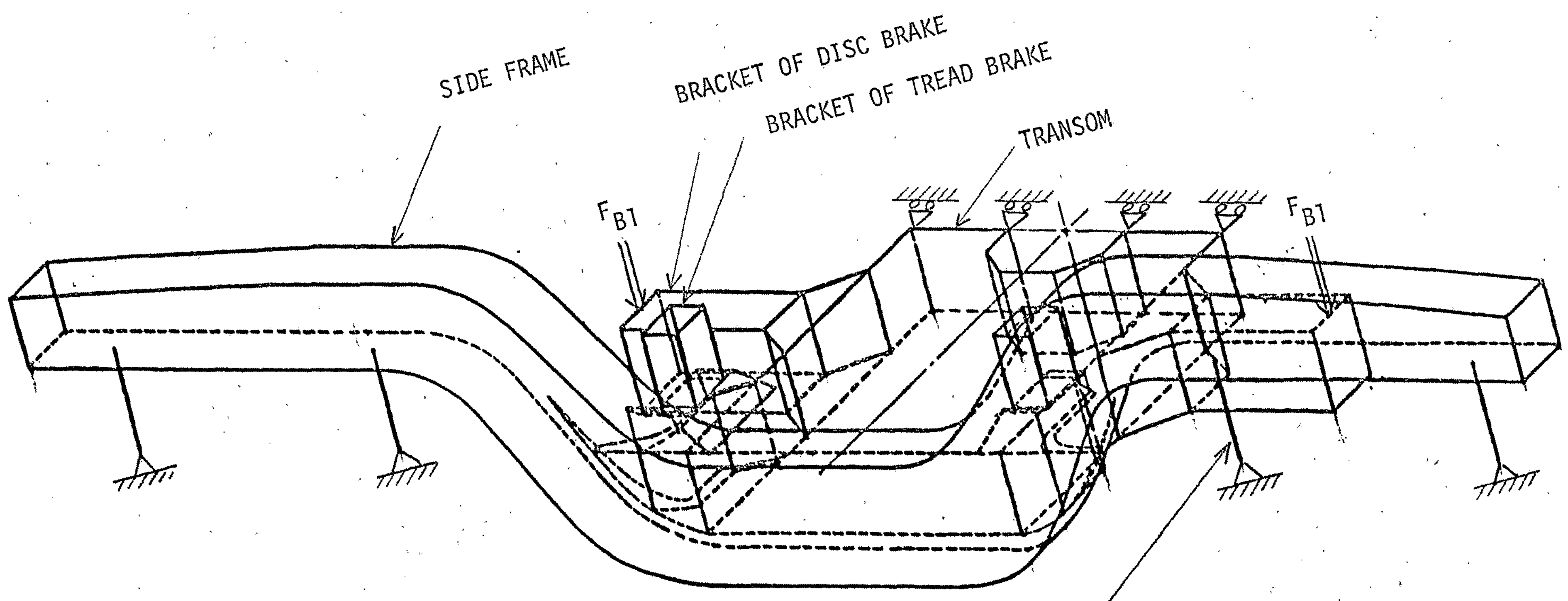

Figure 6.3 (I) Load and Constraints (Disc Brake Braking Force)

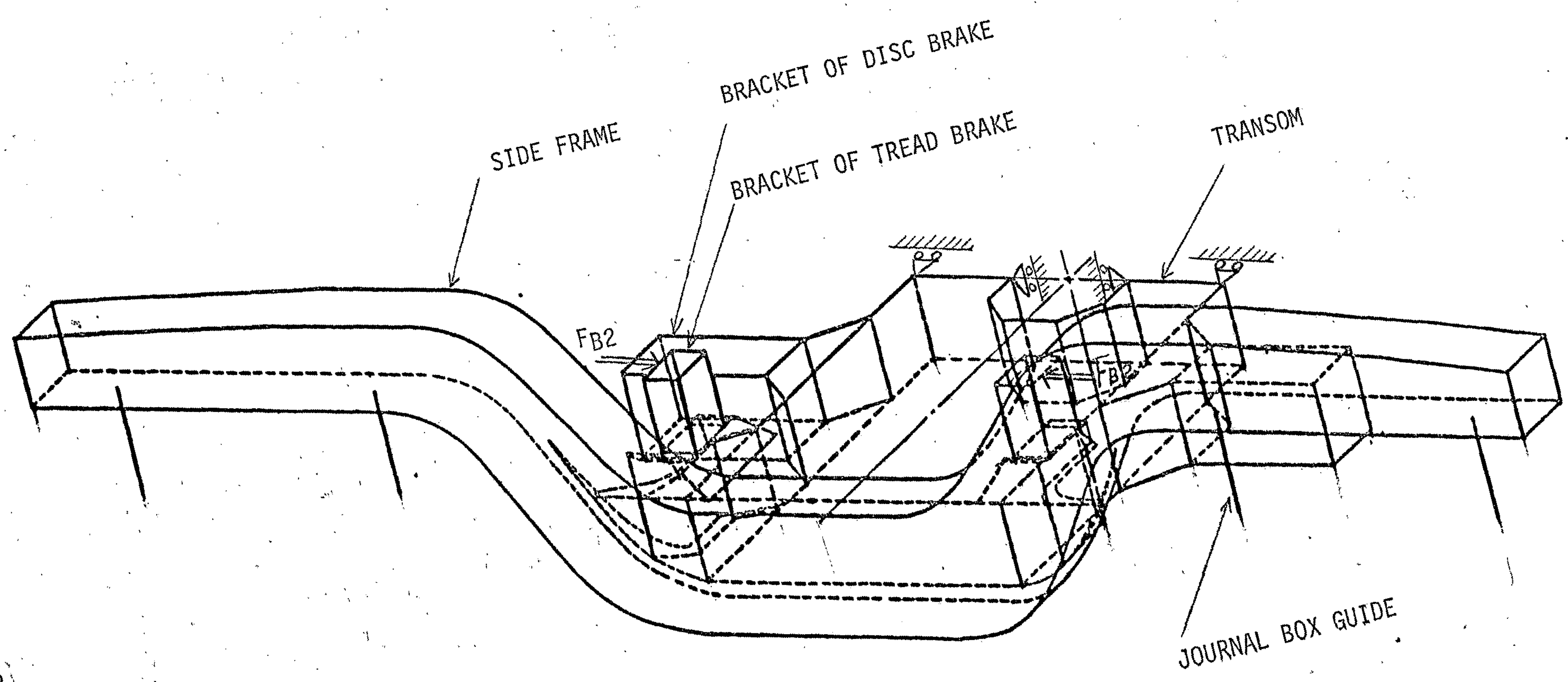

Figure 6.3 (J) Load and Constraints (Tread Brake Braking Force)

AMCOACH TILT TRUCK Table 6.3 (B) Example of Output SUBCASE 1

S T R E S S E S I N Q U A D R I L A T E R A L E L E M E N T S (Q U A D 4)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
1	-6.000000E+00	-2.050970E-03	1.428880E-03	1.900380E-01	45.2623	1.897349E-01	-1.903570E-01	1.900460E-01
	6.000000E+00	-2.406405E-02	-6.478272E-03	6.014260E-02	49.1589	4.551080E-02	-7.605308E-02	6.078196E-02
2	-6.000000E+00	-1.345602E-02	9.638679E-02	-1.055655E-01	-58.7430	1.604630E-01	-7.753229E-02	1.189976E-01
	6.000000E+00	3.621772E-02	2.584572E-01	-6.198803E-02	-75.4225	2.745778E-01	2.009708E-02	1.272404E-01
3	-6.000000E+00	7.543180E-03	1.115385E-02	1.040547E-01	45.4970	1.134189E-01	-9.472185E-02	1.040704E-01
	6.000000E+00	-1.169253E-02	1.252151E-02	8.695489E-02	48.9633	8.820820E-02	-8.737922E-02	8.779371E-02
4	-6.000000E+00	1.854612E-02	-1.087769E-02	-1.113364E-01	-41.2363	1.161384E-01	-1.084700E-01	1.123042E-01
	6.000000E+00	-2.563098E-02	-1.762837E-01	-6.522852E-02	-20.4454	-1.313847E-03	-2.006008E-01	9.964347E-02
5	-6.000000E+00	-9.874146E-03	-4.493692E-02	-1.432620E-01	-41.5116	1.169251E-01	-1.717362E-01	1.443306E-01
	6.000000E+00	1.149864E-02	3.410711E-02	-4.742267E-02	-51.7038	7.155418E-02	-2.594849E-02	4.875136E-02
6	-6.000000E+00	-1.549743E-01	3.582093E-01	2.509261E-01	67.8198	4.605092E-01	-2.572742E-01	3.588917E-01
	6.000000E+00	-1.328954E-01	5.757654E-01	2.623602E-01	71.7411	6.623238E-01	-2.194538E-01	4.408888E-01
7	-6.000000E+00	7.416457E-02	-4.396646E-02	1.487877E-01	34.1740	1.751819E-01	-1.449837E-01	1.600828E-01
	6.000000E+00	6.175146E-02	-4.762677E-02	1.404185E-01	34.3602	1.577549E-01	-1.436302E-01	1.506926E-01
8	-6.000000E+00	1.779211E-01	-6.668746E-03	4.114438E-03	1.2763	1.780127E-01	-6.760411E-03	9.238654E-02
	6.000000E+00	1.612663E-01	-2.104674E-01	1.339672E-02	2.0613	1.617485E-01	-2.109495E-01	1.863490E-01
9	-6.000000E+00	3.994275E-01	8.497052E-03	6.934247E-01	37.1288	9.244097E-01	-5.164851E-01	7.204474E-01
	6.000000E+00	4.966931E-01	3.065213E-01	7.462267E-01	41.3692	1.153867E+00	-3.506531E-01	7.522603E-01
10	-6.000000E+00	8.588215E-01	1.977349E-02	1.939721E-01	12.4070	9.014940E-01	-2.289898E-02	4.621965E-01
	6.000000E+00	8.319234E-01	-1.971746E-02	2.167748E-01	13.4898	8.839256E-01	-7.171953E-02	4.778225E-01
11	-6.000000E+00	5.128206E-01	2.480192E-01	-3.075381E-01	-33.3536	7.152477E-01	4.559214E-02	3.348278E-01
	6.000000E+00	4.229518E-01	-1.964233E-02	-2.602028E-01	-24.8098	5.432363E-01	-1.399267E-01	3.415815E-01
12	-6.000000E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6.000000E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	-6.000000E+00	8.074285E-01	-8.478314E-02	1.010853E+00	33.0937	1.466236E+00	-7.435911E-01	1.104914E+00
	6.000000E+00	9.384369E-01	3.155723E-01	1.079845E+00	36.9561	1.750862E+00	-4.968536E-01	1.123857E+00
14	-6.000000E+00	1.543646E+00	6.017330E-02	2.577580E-01	9.5813	1.587156E+00	1.666322E-02	7.852468E-01
	6.000000E+00	2.006543E+00	1.226957E-01	2.995436E-01	8.8207	2.053026E+00	7.621330E-02	9.884065E-01
15	-6.000000E+00	9.545264E-01	1.764033E-01	-6.804029E-01	-30.1193	1.349248E+00	-2.183188E-01	7.837837E-01
	6.000000E+00	8.737158E-01	-1.446008E-01	-6.327304E-01	-25.5882	1.176708E+00	-4.475939E-01	8.121514E-01
16	-1.350000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.350000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	-6.000000E+00	7.056825E-01	-1.686330E+00	5.258790E-01	11.8674	8.161905E-01	-1.796838E+00	1.306514E+00
	6.000000E+00	8.803388E-01	-1.165241E+00	6.304564E-01	15.8250	1.059037E+00	-1.343940E+00	1.201488E+00
18	-6.000000E+00	9.718654E-01	-1.548657E+00	-1.309764E-01	-2.9667	9.786532E-01	-1.555446E+00	1.267049E+00
	6.000000E+00	7.450182E-01	-2.006883E+00	-1.886344E-02	-0.3927	7.451475E-01	-2.007011E+00	1.376080E+00
19	-1.350000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.350000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	-5.000000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.000000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	-6.000000E+00	1.329191E+00	-2.061909E+00	-1.848630E+00	-23.7366	2.142092E+00	-2.874809E+00	2.508451E+00
	6.000000E+00	1.743972E+00	-1.500971E+00	-1.361734E+00	-20.0033	2.239693E+00	-1.996691E+00	2.118192E+00
22	-6.000000E+00	1.614101E+00	8.287088E-01	-1.185448E-01	-8.3988	1.631604E+00	8.112060E-01	4.101993E-01
	6.000000E+00	1.072457E+00	-8.795145E-01	1.168427E-01	3.4134	1.079426E+00	-8.864837E-01	9.829552E-01
23	-6.000000E+00	1.364385E+00	-4.998069E-01	8.769910E-01	21.6276	1.712099E+00	-8.475220E-01	1.279811E+00
	6.000000E+00	1.792581E+00	3.498415E-01	6.757327E-01	21.5645	2.059639E+00	8.278364E-02	9.884277E-01
24	-6.000000E+00	1.686046E+00	-2.082764E+00	2.164658E+00	24.4797	2.671610E+00	-3.068329E+00	2.869969E+00
	6.000000E+00	1.367275E+00	-2.522746E+00	2.740279E+00	27.3167	2.782651E+00	-3.938122E+00	3.360387E+00
25	-1.050000E+01	5.848776E+00	1.828688E+00	-2.264531E-01	-3.2139	5.861492E+00	1.815971E+00	2.022759E+00
	1.050000E+01	-4.192699E+00	-1.512313E+00	1.283708E-01	87.2643	-1.506179E+00	-4.198833E+00	1.346327E+00

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AMCOACH TILT TRUCK SUBCASE 1

S T R E S S E S I N Q U A D R I L A T E R A L E L E M E N T S (Q U A D 4)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
26	-1.350000E+01	6.061338E-03	-2.058247E-02	1.072907E-02	19.4235	9.844583E-03	-2.436572E-02	1.710515E-02
	1.350000E+01	-2.094986E-02	-2.933347E-02	-1.664150E-02	-37.9310	-7.980354E-03	-4.230298E-02	1.716131E-02
27	-1.350000E+01	1.731452E-02	1.692815E-02	-1.013299E-02	-44.4539	2.725617E-02	6.986506E-03	1.013483E-02
	1.350000E+01	-9.371333E-03	9.261627E-03	4.073497E-03	78.1917	1.011325E-02	-1.022295E-02	1.016810E-02
28	-1.050000E+01	1.222329E+00	6.090490E+00	9.227388E-01	79.6194	6.259522E+00	1.053297E+00	2.603112E+00
	1.050000E+01	-7.970059E-01	-2.416387E+00	5.183797E-01	16.3141	-6.452827E-01	-2.568110E+00	9.614139E-01
29	-6.000000E+00	1.003963E+00	-1.015489E+00	-1.957271E+00	-31.3557	2.196612E+00	-2.208138E+00	2.202374E+00
	6.000000E+00	2.666641E+00	7.854030E-01	-1.536890E+00	-29.2661	3.527909E+00	-7.586467E-02	1.801887E+00
30	-6.000000E+00	5.785261E-01	-1.912119E-01	-1.477526E+00	-37.7000	1.720486E+00	-1.333172E+00	1.526829E+00
	6.000000E+00	1.323576E+00	2.607664E-01	-1.455052E+00	-34.9686	2.341225E+00	-7.568828E-01	1.549054E+00
31	-6.000000E+00	-9.764615E-01	1.058083E+00	5.683534E-01	75.4039	1.206086E+00	-1.124465E+00	1.165276E+00
	6.000000E+00	-1.015329E+00	1.027350E+00	5.117836E-01	76.6925	1.148402E+00	-1.136380E+00	1.142391E+00
32	-6.000000E+00	1.078533E+00	-2.009436E+00	1.488063E+00	21.9717	1.678895E+00	-2.609797E+00	2.144346E+00
	6.000000E+00	1.739425E+00	-4.212617E-01	1.176683E+00	23.7221	2.256494E+00	-9.383306E-01	1.597412E+00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.580770E+00	2.204369E+00

REAR SIDE

FRONT SIDE

Table 6.3 (A) Calculation Stress

Front Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
29	-2.2	-2.3	+1.5	-0.1	0	2.8
37	+2.9	+2.6	+1.4	-0.1	0	3.1
49	+2.2	+2.4	+0.7	+0.1	-0.1	2.6
61	+1.5	+3.2	+0.6	+0.1	0	3.3
76	-0.6	+3.0	+0.4	+0.1	0	3.0
92	-0.8	+2.2	-0.2	+0.1	0	2.2
107	-0.6	+1.8	+0.4	+0.1	0	1.9
117	-0.4	+1.7	+0.3	+0.1	0	1.7
136	+0.5	+1.1	+0.2	+0.1	0	1.1
310	-4.2	+2.5	+1.9	-0.1	0	3.4
314	+3.1	+2.8	+1.4	-0.1	0	3.3
316	+2.0	+2.3	-0.6	+0.1	-0.1	2.5
321	+1.1	+3.2	+0.5	+0.1	0	3.3
327	-0.8	+2.8	-0.3	+0.1	0	2.8
335	-0.7	+3.2	-0.3	-0.1	-0.1	3.2
356	-0.4	+1.7	+0.2	+0.1	0	1.7
364	+0.5	+1.7	+0.2	+0.1	0	1.7
368	+1.3	+1.0	+0.2	+0.1	+0.1	1.1

Front Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
29	+3.5	+5.2	+1.2	-0.1	0	5.4
37	+3.1	+5.2	+1.4	-0.1	0	5.5
49	+1.9	+3.8	+0.8	-0.1	+0.1	3.9
61	+1.6	-2.6	+0.9	-0.1	0	2.8
76	+0.9	-2.4	+0.6	-0.1	0	2.5
92	+0.8	-2.2	+0.4	+0.1	0	2.3
107	+0.5	-1.7	+0.5	+0.2	+0.1	1.8
117	+0.4	-1.5	+0.4	+0.2	+0.1	1.7
136	+0.6	-1.0	+0.3	+0.1	+0.1	1.1
310	+3.3	+4.8	+1.7	-0.1	0	5.2
314	+3.3	+5.4	+1.4	-0.1	0	5.7
316	+1.9	+3.2	+0.9	-0.1	0	3.4
321	+1.1	-2.2	+0.8	-0.1	0	2.4
327	+0.7	-2.0	+0.5	+0.1	0	2.1
335	+0.9	-2.1	+0.4	+0.2	+0.1	2.2
356	+0.5	-1.4	+0.3	+0.2	+0.1	1.5
364	+0.5	-1.6	+0.3	+0.2	+0.1	1.6
368	+0.7	-1.1	+0.1	+0.2	+0.1	1.1

Rear Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
24	-3.1	-1.3	+0.9	+0.2	0	1.8
32	-2.6	-1.7	+0.8	+0.2	0	2.0
33	+2.8	-1.4	+0.9	+0.2	0	1.9
34	+4.1	+2.1	+1.7	+0.2	0	3.0
42	-1.8	-1.6	-0.7	-0.1	0	1.8
43	+2.8	-1.9	+0.8	+0.2	0	2.2
44	+4.5	-2.6	+1.6	+0.3	0	3.4
54	-1.8	-1.6	-0.5	-0.1	0	1.8
55	+2.4	-1.4	+0.5	+0.1	0	1.7
56	+5.5	-3.7	+1.4	+0.2	0	4.3
68	-1.4	-1.2	-0.5	+0.1	0	1.4
69	+1.4	-1.4	+0.4	+0.1	0	1.5
70	+3.4	-2.8	+0.7	+0.2	0	3.1
71	+3.7	-2.3	+0.4	+0.1	0	2.6
84	+1.4	-1.9	-0.4	+0.1	0	2.0
85	+3.5	+3.4	+0.6	+0.1	0	3.6
86	+2.6	+1.8	-0.3	+0.1	0	2.0
87	+2.7	+3.8	-0.3	+0.1	0	4.0
97	+2.6	+3.6	-0.3	+0.1	0	3.7
98	+3.7	+5.1	+0.5	-0.2	+0.1	5.2
99	+3.0	+2.5	+0.4	-0.1	0	2.7
100	+2.3	+1.7	+0.2	+0.1	-0.2	1.8
101	-1.5	+1.9	+0.2	+0.2	+0.1	2.0
102	+3.6	+1.6	+0.4	-0.1	-0.1	2.0
112	+2.8	+0.6	+0.3	+0.1	-0.2	1.1
113	+1.8	+0.9	+0.2	+0.2	+0.1	1.1
114	+4.4	-1.7	+0.5	-0.1	-0.1	2.2
124	+1.9	-0.5	+0.2	+0.1	+0.1	0.8
125	+2.3	+0.6	+0.2	+0.1	-0.1	0.9
126	+3.2	-1.1	+0.1	+0.1	+0.1	1.5
127	+3.8	-1.2	-0.1	+0.1	0	1.7
149	-3.7	-4.1	-0.4	+0.1	+0.1	4.3

Rear Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm^2)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
24	-3.9	-2.8	+0.4	+0.2	0	3.1
32	+2.3	+1.2	-1.0	+0.2	0	1.7
33	+2.7	-2.7	+0.3	+0.2	0	2.8
34	-2.6	-5.1	+0.9	+0.2	0	5.2
42	+3.0	+1.4	-1.1	+0.1	0	2.0
43	+2.4	-2.3	+0.3	+0.2	0	2.4
44	+2.9	-4.7	+1.0	+0.3	0	4.9
54	+2.2	+1.3	-0.9	+0.1	0	1.7
55	+2.1	-1.4	-0.5	+0.2	0	1.6
56	+3.2	-3.0	+0.5	+0.3	+0.1	3.2
68	+1.8	+1.2	-0.7	-0.1	0	1.5
69	+1.7	-1.5	-0.5	+0.1	0	1.7
70	+2.8	-1.9	-0.4	+0.2	0	2.1
71	+3.9	-3.6	+0.5	+0.1	0	3.8
84	+2.1	-2.4	-0.4	-0.1	0	2.5
85	+3.9	-3.3	+0.6	+0.2	0	3.6
86	+3.5	-4.3	+0.6	-0.1	+0.1	4.5
87	+4.4	-6.2	+0.8	+0.1	-0.1	6.4
97	+2.0	-2.7	+0.3	+0.1	0	2.8
98	+2.6	-3.6	+0.4	+0.1	+0.1	3.7
99	+2.1	-1.5	+0.3	+0.1	0	1.7
100	+2.3	-0.8	+0.2	+0.1	+0.2	1.1
101	+2.3	-0.4	-0.3	+0.1	-0.1	0.9
102	+2.6	-0.8	+0.4	-0.1	+0.1	1.2
112	+2.8	-0.4	+0.2	-0.1	+0.1	1.0
113	+2.6	+0.5	-0.2	+0.1	-0.1	1.0
114	+3.0	-1.3	+0.5	-0.1	-0.1	1.7
124	+1.6	+0.5	0	+0.1	-0.1	0.7
125	+2.5	-0.2	+0.2	+0.1	+0.1	0.8
126	+4.3	+0.7	+0.2	+0.1	-0.1	1.5
127	+4.8	+0.8	+0.2	+0.1	-0.1	1.7
149	+4.1	+3.9	-0.1	+0.1	+0.1	4.1

Rear Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
159	-3.0	-3.5	-0.4	+0.1	+0.1	3.6
165	+4.3	-1.2	-0.2	0	0	1.8
166	+3.2	+2.1	+0.7	-0.1	-0.1	2.4
167	+4.3	-1.4	-0.4	0	0	1.9
168	+2.5	-2.7	-0.4	+0.1	+0.1	2.8
174	-5.2	+2.1	+0.6	0	-0.1	2.7
175	+4.3	-1.5	-0.5	0	0	2.0
176	+7.1	-2.5	-0.7	+0.1	+0.1	3.4
177	+2.9	-1.4	-0.5	0	0	1.7
311	-4.2	-2.5	+2.0	-0.3	0	3.5
315	+5.1	-3.2	+1.7	+0.2	0	3.9
317	+3.7	-3.9	+1.4	+0.2	0	4.3
318	+5.0	-3.7	+1.1	+0.2	0	4.1
320	-1.2	-1.2	-0.5	+0.1	0	1.4
323	+4.6	-4.5	+1.1	+0.2	0	4.8
324	+4.9	-6.6	+1.0	+0.2	0	6.8
326	-1.1	-0.9	-0.6	+0.1	0	1.1
328	+3.9	-5.4	+0.8	+0.2	0	5.6
329	+4.0	-4.0	+0.8	+0.2	0	4.3
330	+3.8	-3.9	+0.9	+0.2	0	4.2
331	+4.2	-7.0	+0.8	+0.2	0	7.2
332	+3.5	-3.5	+0.7	+0.2	0	3.7
333	+3.8	-6.6	+0.6	+0.2	0	6.7
334	+3.8	-6.7	+0.6	+0.2	0	6.8
337	+2.3	-1.4	-0.5	+0.1	0	1.6
338	+3.3	+2.7	+0.6	+0.1	0	2.9
339	+2.9	+2.7	+0.5	+0.2	0	2.9
340	+2.9	+2.6	+0.4	+0.2	0	2.8
341	+2.8	-2.8	+0.3	+0.2	0	2.9
342	+2.5	-4.3	+0.5	+0.2	0	4.4
343	+2.6	+3.4	-0.3	+0.1	0	3.5
344	+2.5	+3.7	-0.3	+0.2	0	3.8

Rear Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
159	+3.2	+3.4	+0.2	+0.1	+0.1	3.5
165	+4.8	+0.9	+0.3	0	-0.1	1.7
166	-3.1	-1.8	-0.3	-0.1	-0.1	2.1
167	+5.0	+1.4	+0.4	0	0	2.1
168	+4.4	+2.5	+0.2	+0.1	+0.1	2.8
174	+5.0	-1.7	-0.5	0	-0.1	2.3
175	+5.5	+1.6	+0.6	0	0	2.4
176	-4.5	+2.4	+0.8	+0.1	+0.1	2.9
177	+5.0	+1.5	+0.7	0	0	2.2
311	-5.6	-4.7	+1.6	-0.3	0	5.2
315	+4.0	-4.9	+1.2	+0.3	0	5.2
317	+3.0	-3.2	+1.0	+0.2	0	3.5
318	+3.1	+2.6	-0.6	+0.3	0	2.8
320	+1.9	+1.3	-1.0	+0.1	0	1.7
323	+3.9	-2.3	+0.8	+0.3	0	2.7
324	+3.3	+4.2	-0.4	+0.3	0	4.3
326	+1.8	-1.1	-0.7	-0.1	0	1.4
328	+2.4	+4.0	-0.5	+0.3	0	4.1
329	+3.1	-1.2	-0.5	+0.2	0	1.6
330	+3.4	-1.5	+0.4	+0.3	0	1.9
331	+3.2	+5.0	-0.5	+0.3	0	5.1
332	+3.1	-1.7	-0.4	+0.2	0	2.0
333	+2.9	+5.1	-0.5	+0.2	0	5.2
334	+2.7	+5.2	-0.5	+0.3	0	5.3
337	+2.6	-2.6	-0.4	-0.1	+0.1	2.7
338	+3.8	-3.2	+0.5	+0.2	0	3.4
339	+3.2	-2.4	-0.4	+0.2	0	2.6
340	+3.1	-2.7	-0.3	+0.2	0	2.8
341	+3.2	+3.6	-0.4	+0.3	+0.1	3.8
342	+2.9	-2.2	-0.2	+0.2	-0.1	2.4
343	+3.6	-4.8	+0.4	+0.2	-0.1	5.0
344	+3.6	-4.4	+0.4	+0.2	-0.1	4.6

Rear Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
345	+2.6	+3.4	-0.3	+0.2	0	3.5
346	+2.0	+2.4	-0.2	+0.2	0	2.5
347	+2.1	-1.1	-0.3	+0.2	0	1.3
348	-2.0	-1.5	+0.4	-0.2	0	1.7
349	+3.2	+5.3	+0.3	-0.1	+0.1	5.4
350	+2.9	+5.5	-0.4	+0.1	+0.1	5.6
351	+2.7	+5.3	+0.3	-0.1	+0.1	5.4
352	+2.9	+3.8	-0.4	+0.1	-0.1	3.9
353	+2.9	+3.5	-0.3	+0.1	+0.1	3.6
354	+2.9	+3.5	-0.3	+0.2	0	3.6
355	+2.3	+2.5	-0.2	+0.2	0	2.6
358	+2.2	+2.6	-0.2	+0.2	0	2.7
359	+1.8	+2.3	+0.4	+0.2	+0.1	2.4
360	-2.4	+0.5	+0.3	-0.1	0	0.9
361	-3.7	+1.2	+0.8	-0.2	0	1.8
362	+2.8	+5.4	+0.4	-0.1	+0.1	5.5
363	+2.4	+5.1	+0.3	-0.1	+0.1	5.2
366	+2.5	+5.5	-0.3	-0.1	+0.1	5.6
367	+2.7	+4.0	-0.3	+0.1	0	4.1
370	+4.5	+1.5	+0.7	-0.1	-0.1	2.1
371	-2.9	-3.1	-0.4	+0.1	+0.1	3.2
372	-7.5	+1.8	+0.8	0	-0.1	3.0
373	+11.3	-2.7	-1.2	+0.1	0	4.5
374	+2.4	+4.1	-0.4	+0.1	-0.1	4.2
375	+1.9	+3.2	-0.2	+0.1	-0.1	3.3
376	+1.9	+2.8	-0.2	+0.1	-0.1	2.9
377	+1.5	+2.5	+0.2	+0.1	-0.1	2.6
378	-1.3	+3.4	+0.2	+0.2	-0.1	3.4
379	-3.5	+2.0	+0.6	+0.1	-0.1	2.3
380	-3.2	-1.4	+0.4	+0.1	-0.1	1.7
381	+3.3	-1.8	-0.4	-0.1	+0.1	2.1
382	+3.4	+3.3	+0.4	-0.1	+0.1	3.5

Rear Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
345	+2.9	-4.7	+0.3	+0.2	-0.1	4.8
346	+2.6	-3.9	-0.3	+0.2	0	4.0
347	+2.7	+2.4	-0.3	+0.2	0	2.6
348	+2.8	+1.6	-0.3	+0.3	0	1.9
349	+5.1	-6.7	+0.7	+0.2	-0.1	6.9
350	+5.3	-7.7	+0.9	+0.1	0	7.9
351	+5.1	-7.8	+0.9	+0.2	-0.1	8.0
352	+2.9	-5.0	+0.5	+0.1	-0.1	5.1
353	+2.8	-4.8	+0.5	+0.1	-0.1	4.9
354	+2.7	-3.7	+0.3	+0.1	-0.1	3.8
355	+2.5	-2.8	-0.3	+0.2	0	2.9
358	+2.3	-2.7	-0.2	+0.2	+0.1	2.8
359	+2.5	-2.6	-0.3	+0.2	-0.1	2.7
360	+3.3	-1.7	-0.5	+0.2	0	2.0
361	+3.5	-2.0	-0.6	+0.2	+0.1	2.3
362	+4.7	-5.7	+0.6	+0.2	-0.1	5.9
363	+3.3	-5.0	+0.6	+0.1	0	5.1
366	+3.1	-4.9	+0.6	+0.1	-0.1	5.0
367	+2.5	-4.4	+0.6	-0.1	0	4.5
370	-2.8	-1.4	-0.3	+0.1	+0.1	1.7
371	+3.0	+3.1	+0.2	+0.1	+0.1	3.2
372	+8.0	-1.5	-0.3	0	-0.1	2.8
373	-8.4	+2.4	+0.9	+0.1	+0.1	3.6
374	+1.5	-1.3	+0.2	+0.1	0	1.4
375	+1.6	-1.2	+0.3	+0.1	+0.1	1.3
376	+1.8	-1.8	-0.2	+0.1	+0.1	1.9
377	+2.0	-1.8	-0.3	+0.1	-0.1	1.9
378	+2.1	-0.4	-0.4	+0.1	-0.1	0.9
379	+3.4	-0.7	-0.6	+0.2	+0.1	1.4
380	+3.5	+0.9	-0.5	+0.2	+0.2	1.5
381	+3.9	-3.3	+0.5	-0.1	+0.1	3.5
382	+3.9	-4.5	+0.5	+0.1	+0.1	4.7

Rear Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
383	+3.4	+5.2	+0.5	-0.1	+0.1	5.3
384	+5.0	+3.2	+0.6	-0.2	+0.1	3.6
385	+3.0	+4.9	+0.5	-0.1	+0.1	5.0
386	-3.4	+1.4	+0.4	+0.2	-0.1	1.8
387	-3.9	-2.6	+0.4	+0.2	-0.1	2.9
388	+4.9	+2.1	+0.5	-0.2	-0.2	2.6
389	+4.9	+4.1	+0.5	-0.2	-0.1	4.4
390	+4.2	+4.8	+0.5	-0.2	-0.1	5.0
391	-3.8	-2.8	+0.4	+0.2	-0.1	3.1
392	-4.1	-4.1	+0.3	+0.1	-0.1	4.3
393	+6.4	+3.9	+0.6	-0.3	-0.2	4.4
394	+5.4	+3.6	+0.6	-0.3	-0.2	4.0
395	+3.8	+0.5	+0.5	-0.1	-0.1	1.3
396	+3.1	-0.4	+0.3	-0.1	-0.2	1.1
397	+3.0	+0.5	+0.2	+0.1	-0.1	1.1
398	-2.7	-1.7	+0.3	+0.2	+0.1	1.9
399	-4.2	-4.0	+0.5	+0.2	+0.1	4.2
400	-3.9	-4.6	+0.4	+0.1	+0.1	4.8
401	+5.8	+3.1	+0.6	-0.2	-0.2	3.6
402	+4.8	+1.9	+0.5	-0.2	-0.2	2.4
403	+4.6	-1.9	+0.5	-0.2	+0.1	2.4
404	+4.2	-2.0	+0.5	-0.2	+0.1	2.4
405	+4.4	-1.3	+0.5	-0.1	-0.1	1.9
406	+3.7	-0.7	+0.3	-0.1	-0.1	1.3
407	+4.0	+0.5	+0.2	0	-0.1	1.3
408	-3.1	-1.7	+0.5	+0.2	+0.1	2.0
409	-3.7	-4.1	+0.7	+0.1	+0.1	4.3
410	-4.3	-4.7	+0.5	+0.1	+0.1	4.9
411	+5.6	-2.4	+0.6	-0.2	-0.2	3.0
412	+4.9	-1.5	+0.6	-0.1	-0.2	2.2
413	+4.7	-1.4	+0.6	-0.1	-0.1	2.1
414	+4.1	-0.8	+0.4	-0.1	+0.1	1.5

Rear Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σV	σH	σL	σBD	σBT	σD
383	+4.2	-4.6	-0.4	+0.2	-0.1	4.8
384	+3.9	-5.3	+0.5	+0.1	+0.2	5.5
385	+2.7	-3.8	+0.4	+0.1	0	3.9
386	+3.0	+1.1	-0.5	+0.1	+0.2	1.5
387	+3.9	+2.1	-0.5	+0.1	+0.1	2.5
388	+4.3	-4.1	+0.6	+0.1	+0.1	4.3
389	+3.1	-4.0	+0.6	+0.2	+0.2	4.2
390	+3.4	-2.0	+0.5	+0.1	+0.1	2.3
391	+3.7	+2.4	-0.4	+0.1	+0.1	2.7
392	+4.0	+3.6	-0.4	+0.1	+0.1	3.8
393	+4.1	-3.9	+0.5	+0.2	+0.1	4.1
394	-2.7	-3.1	+0.4	+0.2	+0.2	3.2
395	+2.7	+0.5	+0.5	0	-0.1	1.1
396	+2.9	-0.4	+0.3	-0.1	-0.2	1.0
397	+2.8	+0.33	+0.2	+0.1	-0.1	0.9
398	+2.9	+1.1	-0.3	+0.1	-0.1	1.4
399	+4.0	+3.6	-0.4	+0.1	+0.1	3.8
400	+4.5	+4.0	-0.4	+0.1	+0.1	4.2
401	+4.9	-2.4	+0.6	-0.2	-0.2	2.9
402	+2.3	-1.9	+0.3	+0.1	-0.2	2.0
403	+2.5	-1.0	+0.4	+0.1	-0.2	1.3
404	+3.0	+0.8	+0.4	-0.1	-0.1	1.3
405	+2.8	+0.9	+0.3	0	-0.1	1.3
406	+3.5	-0.8	+0.4	-0.1	-0.2	1.4
407	+3.5	-0.9	+0.2	0	+0.1	1.4
408	+4.1	+0.9	-0.3	+0.1	+0.1	1.6
409	+4.1	+3.8	-0.3	+0.1	+0.1	4.0
410	+4.7	+4.1	-0.3	+0.1	+0.1	4.3
411	+4.6	-1.9	+0.6	-0.2	-0.2	2.4
412	+3.3	-1.1	+0.3	-0.1	-0.2	1.5
413	+3.3	+1.1	+0.3	-0.1	-0.1	1.5
414	+4.0	-1.0	+0.4	-0.1	-0.2	1.6

Rear Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
415	+4.0	-0.2	+0.3	+0.1	+0.1	1.3
416	+5.2	+1.6	+0.7	-0.2	-0.2	2.4
417	+5.2	+1.3	+0.7	-0.2	-0.1	2.2
418	+4.8	-0.8	+0.4	-0.1	-0.1	1.7

Rear Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
415	+4.7	-0.6	+0.3	-0.1	-0.2	1.6
416	+4.2	-3.4	+0.4	-0.2	-0.2	3.7
417	+3.3	-2.2	+0.2	+0.1	-0.1	2.4
418	+5.5	-1.7	+0.3	-0.1	-0.2	2.4

Upper Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
23	+1.7	-1.6	-0.9	+0.1	0	1.9
41	+1.3	-1.0	-0.7	+0.1	0	1.3
53	+1.0	-1.0	-0.6	+0.1	0	1.2
65	+0.9	-1.0	-0.5	+0.1	0	1.2
67	+0.9	-0.8	-0.6	+0.1	0	1.0
81	+0.9	-0.6	-0.5	+0.1	0	0.8
83	+1.3	-0.7	-0.4	+0.1	0	0.9
96	+1.9	-0.7	-0.2	+0.1	0	0.9
111	+2.3	-2.1	-0.2	+0.1	0	2.2
121	+1.5	-3.0	-0.2	+0.2	0	3.0
123	-1.9	-2.3	-0.3	+0.2	0	2.4
140	+1.7	+2.5	-0.2	+0.2	0	2.6
142	+2.1	+3.7	+0.2	+0.1	-0.1	3.8
156	+2.1	+4.5	+0.3	+0.1	-0.1	4.6
164	+2.2	+4.6	+0.4	-0.1	-0.1	4.7
173	+3.2	+4.5	+0.8	-0.1	-0.1	4.7
307	+2.6	+1.9	-0.8	+0.1	0	2.2
308	+2.0	+1.0	-0.7	+0.1	0	1.4
309	+2.7	-1.9	-0.9	+0.2	0	2.3

Upper Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
23	+2.1	+1.7	-0.7	+0.1	0	1.9
41	+1.2	+1.0	+0.5	-0.1	0	1.2
53	+0.9	+1.1	+0.5	-0.1	0	1.2
65	+0.8	+1.0	+0.5	-0.1	0	1.1
67	+0.7	+0.9	+0.5	-0.1	0	1.1
81	+1.0	+1.0	-0.3	-0.1	0	1.1
83	+1.4	-1.3	-0.4	-0.1	0	1.4
96	+1.8	+1.5	-0.2	-0.1	0	1.6
111	+2.5	+1.8	+0.2	-0.1	+0.1	2.0
121	+1.5	+1.3	+0.3	-0.1	+0.1	1.4
123	+1.7	-1.9	+0.5	-0.2	+0.1	2.0
140	+3.6	-2.5	+0.4	-0.1	-0.1	2.8
142	+3.0	-3.0	+0.4	-0.1	-0.1	3.2
156	+2.2	-3.6	+0.4	-0.1	-0.1	3.7
164	-2.1	-3.6	-0.3	-0.1	-0.1	3.7
173	-3.7	-3.9	-0.7	-0.1	-0.1	4.1
307	+2.5	-1.9	-0.9	+0.1	0	2.2
308	+2.5	-0.2	-1.0	+0.2	0	1.3
309	+3.3	+1.9	-0.8	+0.3	0	2.3

Lower Surface of Side Frame (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
19	0	+0.6	-2.3	0	0	2.4
25	+5.9	+1.5	+1.1	-0.1	0	2.6
28	+6.3	-1.5	+1.0	-0.1	0	2.6
35	+1.2	-1.6	+0.6	0	0	1.7
36	+1.7	+1.7	-0.8	-0.1	0	1.9
45	-1.1	-1.3	-0.7	+0.1	0	1.5
46	-2.0	+1.4	-0.9	-0.1	0	1.7
47	-1.5	-1.2	-0.6	+0.1	0	1.4
57	-1.5	-1.4	-0.5	+0.1	0	1.6
59	+2.0	-1.6	-0.3	+0.1	0	1.7
72	+2.3	-2.9	+0.3	+0.1	0	3.0
74	+2.9	-4.7	+0.3	+0.2	0	4.8
88	+2.5	-5.4	+0.2	+0.2	0	5.5
90	+2.3	-4.6	0	+0.1	0	4.7
103	+2.0	-3.9	-0.2	+0.1	0	4.0
105	+1.7	-3.5	-0.4	+0.1	+0.1	3.6
115	+1.6	-2.5	-0.4	+0.1	+0.1	2.6
132	+1.8	-1.6	-0.5	+0.1	+0.1	1.8
134	+2.0	-1.0	-0.5	-0.1	+0.1	1.3
150	+2.3	-0.7	-0.5	+0.1	+0.1	1.1
152	+2.1	-0.6	-0.4	+0.1	+0.1	1.0
160	+2.0	-0.6	+0.3	+0.1	+0.1	0.9
169	+2.1	-0.7	+0.5	+0.1	+0.1	1.1
178	+3.7	-0.6	+0.8	+0.1	+0.1	1.5
302	+7.1	-1.5	-1.5	+0.1	0	3.0
303	+6.8	+1.6	-1.1	+0.1	0	2.8
304	+6.7	-1.5	-1.3	+0.1	0	2.8
305	0	+1.7	-2.1	+0.1	0	2.7
306	0	-1.6	-2.2	-0.1	0	2.7
312	+1.8	+1.4	-1.3	0	0	2.0
313	+1.9	-1.3	-1.4	+0.1	0	2.0

Lower Surface of Side Frame (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
19	0	+0.8	+3.7	-0.2	0	3.8
25	-4.2	-3.2	+1.3	-0.1	0	3.7
28	-2.6	+3.2	+1.4	-0.1	0	3.6
35	+3.4	-2.9	+1.4	-0.1	0	3.4
36	+3.5	+3.0	+1.4	-0.1	0	3.5
45	+4.7	-2.5	+1.1	+0.1	0	3.1
46	+4.1	+2.4	+1.1	-0.1	0	3.0
47	+4.7	-2.3	+0.9	+0.2	0	2.9
57	+3.9	-1.7	+0.8	+0.2	0	2.2
59	+2.5	+2.2	+0.4	+0.2	0	2.4
72	+1.7	+2.6	+0.1	+0.2	0	2.7
74	+2.2	+3.7	-0.1	+0.2	0	3.8
88	+1.6	+4.7	-0.2	+0.2	0	4.7
90	+1.1	+3.9	-0.2	+0.2	0	4.0
103	-0.8	+2.8	-0.1	+0.1	0	2.8
105	-0.8	+2.2	+0.2	+0.1	0	2.2
115	-0.8	+1.7	+0.1	+0.1	0	1.7
132	-0.9	+1.3	+0.2	+0.1	+0.1	1.3
134	-1.0	+1.3	+0.2	+0.1	+0.1	1.4
150	-1.4	+1.0	+0.2	+0.1	+0.1	1.1
152	+1.2	+0.9	+0.1	+0.1	+0.1	1.0
160	+2.0	+0.9	-0.1	+0.1	+0.1	1.1
169	+3.1	+0.8	-0.2	+0.1	+0.1	1.2
178	+5.0	+0.7	-0.4	+0.1	+0.1	1.7
302	-4.0	-0.4	+1.3	-0.1	0	1.8
303	-3.6	-2.0	+1.4	-0.1	0	2.7
304	-2.7	+2.1	+1.3	-0.2	0	2.6
305	0	-3.5	+4.0	-0.3	0	5.3
306	0	+3.5	+4.0	-0.1	0	5.3
312	+1.7	-1.2	+1.1	-0.1	0	1.7
313	+1.5	+1.0	+1.1	-0.1	0	1.6

Upper Surface of Transom (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
200	+0.7	-1.6	+0.3	0	-0.1	1.6
201	+1.1	-1.8	+0.4	0	-0.1	1.9
202	+0.3	-0.6	+0.3	-0.1	-0.2	0.7
203	-0.2	-0.8	+0.5	-0.1	-0.3	1.0
204	+2.5	-2.0	-1.9	-0.1	-0.2	2.9
205	+3.9	-2.8	+1.8	-0.1	-0.2	4.0
206	+3.7	-2.5	-1.6	-0.1	-0.1	3.2
207	-11.9	-1.8	-2.1	-0.1	-0.1	4.5
216	+1.1	-7.3	+0.5	-0.1	0	7.3
217	+0.7	-1.0	+0.2	-0.1	-0.2	1.0
218	+0.7	-2.1	+0.4	-0.1	-0.2	2.1
219	-0.2	-1.0	+0.4	-0.1	+0.2	1.0
251	+1.1	+0.7	-0.7	+0.1	+0.4	1.0
252	+0.8	-0.9	-0.5	-0.1	+0.3	1.1
253	-0.2	-0.9	+0.2	-0.1	0	0.9
254	-1.2	-0.8	-0.5	-0.1	-0.1	1.0
450	+0.7	-2.1	+0.2	0	+0.2	2.1
460	+1.7	-8.4	+0.4	-0.1	0	8.4
461	+1.4	-9.0	+0.5	-0.1	0	9.0
462	+1.3	-2.2	+0.4	0	0	2.3
463	+1.7	-10.4	+0.7	-0.1	+0.1	10.4
464	+0.8	+2.5	+0.1	0	+0.1	2.5
465	+0.5	-1.7	+0.2	-0.1	-0.1	1.7
466	+0.7	-7.8	+0.5	-0.2	-0.2	7.8
467	+0.7	-2.4	+0.2	-0.1	+0.3	2.4
468	+0.6	-2.4	+0.2	-0.1	-0.2	2.4
469	+0.6	-3.8	+0.4	-0.1	-0.3	3.8
470	-0.6	-0.7	+0.4	-0.1	+0.3	0.8
471	-0.5	-0.6	-0.6	-0.1	+0.1	0.9
472	-1.0	-1.0	-0.6	-0.1	+0.1	1.2
473	+1.5	-1.4	-0.8	-0.1	-0.1	1.7

Upper Surface of Transom (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
200	+1.2	+1.4	+0.3	-0.1	-0.2	1.5
201	+0.9	-1.5	+0.2	-0.1	-0.1	1.5
202	+0.9	-0.8	+0.3	-0.1	+0.1	0.9
203	+1.0	-0.7	0	+0.1	+0.2	0.8
204	-0.9	+2.7	+1.7	-0.1	+0.2	3.2
205	-2.4	+3.7	+1.4	+0.1	+0.2	4.0
206	-2.0	+3.5	+1.3	0	+0.1	3.8
207	+10.9	+2.7	+1.9	0	+0.1	4.6
216	+0.8	-7.2	+0.5	-0.1	-0.1	7.2
217	+1.5	-2.5	+0.5	-0.1	+0.2	2.6
218	+0.5	-1.6	+0.4	-0.1	+0.1	1.7
219	+0.6	-1.3	+0.3	-0.1	-0.1	1.3
251	-1.4	-1.4	+0.8	-0.1	-0.4	1.7
252	-0.7	-1.2	+0.3	-0.1	-0.2	1.3
253	-0.5	-1.2	-0.4	-0.1	-0.1	1.3
254	+0.5	-1.2	-0.5	-0.1	-0.1	1.3
450	+1.2	-1.0	+0.3	0	-0.1	1.1
460	+2.3	-8.7	+0.6	-0.1	-0.1	8.7
461	+1.3	-8.2	+0.4	-0.1	-0.1	8.2
462	+0.8	-1.5	+0.3	0	-0.1	1.5
463	+1.2	-9.4	+0.5	-0.1	-0.1	9.4
464	+0.7	+3.0	+0.2	+0.1	-0.1	3.0
465	+0.7	-2.8	+0.3	-0.1	0	2.8
466	+0.9	-9.2	+0.6	-0.2	+0.1	9.2
467	+0.8	-2.3	+0.2	-0.1	-0.1	2.3
468	+1.1	-2.5	+0.4	-0.1	+0.3	2.6
469	+1.1	-3.9	+0.6	-0.1	+0.1	4.0
470	+0.8	-1.1	+0.3	-0.1	-0.2	1.2
471	+1.8	-1.5	+0.8	-0.1	-0.2	1.8
472	+1.4	-1.8	+0.8	-0.1	-0.2	2.0
473	+0.8	+1.5	+0.8	-0.1	-0.1	1.7

Upper Surface of Transom (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
474	-1.2	-1.1	-0.7	-0.1	-0.1	1.4
475	+1.8	-1.3	-0.9	0	-0.1	1.7
476	+9.5	-1.5	-0.9	-0.1	-0.1	3.3
494	-0.7	-2.7	-0.1	-0.1	+0.2	2.7
495	-0.7	-3.9	-0.1	0	-0.3	3.9
500	-0.5	-1.1	-0.5	-0.1	-0.1	1.2
501	-0.6	-1.3	+0.5	-0.2	-0.2	1.4
502	-0.9	-1.3	+0.5	-0.2	-0.3	1.4
503	-0.8	-2.1	-0.3	-0.3	-0.2	2.2
504	-0.6	-1.7	-0.8	-0.3	-0.1	1.9
505	-1.7	-1.8	-0.8	-0.4	-0.2	2.1
506	-2.1	-1.8	-0.9	-0.4	-0.2	2.1
508	-1.5	-1.1	-1.7	-0.3	-0.2	2.1
573	-1.7	-1.1	-0.4	-0.2	-0.2	1.3

Upper Surface of Transom (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
474	+1.5	+1.7	+0.7	-0.1	-0.1	1.9
475	-0.7	+2.2	+0.7	0	0	2.3
476	-9.3	+2.1	+1.0	0	-0.1	3.6
494	-0.2	-2.9	0	-0.1	-0.2	2.9
495	+0.7	-3.6	+0.2	-0.1	-0.1	3.6
500	-0.6	-1.2	-0.6	-0.1	-0.1	1.4
501	+0.6	-1.2	-0.7	-0.2	+0.2	1.4
502	+0.5	-1.2	-0.3	-0.2	+0.2	1.3
503	-0.6	-2.0	-0.3	-0.3	-0.2	2.1
504	+0.2	-1.8	-1.0	-0.3	-0.1	2.1
505	+1.2	-1.5	-1.2	-0.3	+0.2	2.0
506	+0.8	-1.7	-1.3	-0.3	+0.1	2.2
508	+1.2	-1.6	-1.7	-0.4	+0.1	2.4
573	+0.9	-1.2	-0.9	-0.2	+0.1	1.5

Lower Surface of Transom (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
193	0	+0.5	-0.7	+0.2	+0.1	0.9
208	+10.8	-1.0	+1.1	+0.1	0	3.6
209	-5.1	-1.5	+0.8	+0.1	+0.1	2.3
210	-4.0	-1.7	+1.2	+0.1	+0.1	2.4
211	-3.0	-1.5	+1.6	+0.1	0	2.4
212	-2.0	-1.1	+0.5	+0.2	+0.1	1.4
213	-2.1	-1.4	+0.4	+0.2	+0.1	1.6
214	-2.5	-0.9	+0.3	+0.2	+0.1	1.2
215	-3.2	-1.1	+0.5	+0.2	-0.1	1.6
220	-5.4	-0.9	+0.4	+0.1	0	1.9
221	+2.0	-0.8	+0.5	+0.1	0	1.1
222	+2.8	+0.5	-0.3	+0.1	-0.1	1.0
223	+2.6	-0.6	-0.3	+0.1	-0.1	1.0
224	-3.2	+1.0	+0.6	+0.2	-0.1	1.5
225	+2.3	-4.4	-0.7	+0.2	-0.1	4.5
226	+2.6	-1.9	+0.1	+0.2	0	2.1
258	+2.3	+0.3	-0.6	-0.3	+0.1	1.0
453	-3.7	+2.5	+0.9	+0.1	-0.2	2.9
477	+1.8	-1.0	+0.5	+0.1	0	1.2
478	+1.6	-0.7	+0.8	+0.1	0	1.2
479	+1.9	-0.7	+0.4	+0.1	+0.1	1.0
480	+2.5	-0.6	-0.4	+0.2	+0.2	1.1
481	+2.0	-0.5	-0.2	+0.2	+0.1	0.8
482	+2.8	-1.9	-0.6	+0.1	+0.1	2.2
483	+1.1	-1.0	-0.4	0	+0.1	1.1
484	+2.6	-2.1	-0.4	-0.1	+0.1	2.3
485	+1.7	+1.5	+0.3	+0.1	+0.1	1.6
486	+2.4	-5.1	-1.1	-0.1	+0.1	5.3
487	+1.7	+3.4	+0.3	+0.2	-0.1	3.5
488	+2.2	+2.8	-0.3	+0.2	0	2.9
489	+1.7	-1.9	+0.1	+0.2	0	2.0

Lower Surface of Transom (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
193	0	+0.5	-0.8	+0.2	+0.1	1.0
208	-7.3	+1.1	-1.2	+0.1	+0.1	2.7
209	+5.1	+1.6	-1.2	+0.1	+0.1	2.5
210	+3.0	+1.5	-1.7	+0.1	+0.1	2.4
211	+3.5	+1.6	-2.0	+0.1	+0.1	2.8
212	+3.1	+2.0	-0.2	-0.1	-0.1	2.2
213	+3.7	+2.4	-0.6	-0.2	+0.1	2.7
214	+4.9	+2.2	-0.7	-0.1	+0.1	2.7
215	+4.8	+0.9	-0.8	-0.2	+0.1	1.9
220	+4.8	+1.0	+0.3	+0.1	+0.1	1.8
221	+2.0	+1.0	-0.4	+0.1	+0.1	1.2
222	+1.4	+0.5	-0.2	+0.2	+0.1	0.7
223	+1.9	-0.6	-0.4	+0.1	+0.1	0.9
224	+4.8	-1.9	-1.0	+0.2	+0.1	2.6
225	+2.7	-4.0	-0.9	+0.1	0	4.2
226	+2.6	-1.3	0	+0.2	0	1.5
258	-1.6	-0.4	-0.8	+0.3	+0.1	1.1
453	+5.8	-6.0	-1.4	+0.1	+0.2	6.4
477	+3.4	+1.2	-0.3	+0.1	+0.1	1.6
478	+2.7	+1.1	-0.5	+0.1	+0.1	1.5
479	+2.4	+1.0	-0.4	+0.1	+0.1	1.3
480	+1.4	-0.7	-0.3	-0.1	-0.1	0.9
481	+2.8	-0.7	-0.7	-0.1	-0.1	1.3
482	+2.5	-3.0	-1.0	+0.2	-0.1	3.3
483	+1.7	-2.5	-0.8	+0.1	-0.1	2.7
484	+2.1	-2.0	-0.7	+0.2	-0.1	2.2
485	+2.2	-2.8	-0.7	+0.2	-0.1	3.0
486	+2.5	-5.9	-1.3	+0.2	-0.1	6.1
487	+3.2	-6.4	-0.7	+0.2	+0.1	6.5
488	+2.7	-2.6	-0.5	+0.2	+0.1	2.8
489	+2.6	-5.6	-0.3	+0.2	0	5.7

Lower Surface of Transom (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
490	+1.8	+4.0	-0.4	+0.2	0	4.1
491	+2.8	-4.7	+0.2	+0.2	0	4.8
492	+2.7	-1.4	0	+0.2	0	1.6
493	+3.1	-1.3	+0.2	+0.2	0	1.6
510	+2.8	+0.5	-0.4	+0.2	-0.1	1.1
511	+0.9	+0.4	-0.6	+0.2	0	0.8
513	+0.8	+0.1	-0.5	+0.2	-0.1	0.6
514	+0.6	-0.1	-0.7	+0.2	0	0.8
515	+0.9	-0.2	-1.1	+0.3	+0.1	1.2
516	+0.8	+0.2	-0.8	+0.3	0	0.9
517	+1.7	+0.2	-0.7	+0.3	0	0.9
518	+1.4	+0.1	-0.5	+0.3	0	0.7

Lower Surface of Transom (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
490	+2.2	+1.6	-0.4	+0.2	0	1.8
491	+2.5	-5.2	+0.1	+0.2	0	5.3
492	+2.3	-1.3	0	+0.2	0	1.5
493	+2.9	-1.2	+0.2	+0.2	0	1.5
510	-1.8	-0.5	-0.4	+0.2	+0.1	0.9
511	-1.0	+0.4	-1.3	+0.2	+0.2	1.4
513	-0.8	+0.3	-1.2	+0.2	+0.2	1.3
514	+0.4	-0.3	-1.3	+0.2	+0.2	1.4
515	+0.6	-0.3	-1.5	+0.3	+0.1	1.6
516	-0.4	+0.1	-1.2	+0.3	+0.1	1.2
517	-1.1	+0.2	-0.6	+0.3	-0.1	0.8
518	-0.9	+0.3	-0.7	+0.4	0	0.9

Side Surface of Transom (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
245	-0.5	-0.9	-0.3	-0.1	+0.1	1.0
454	+0.4	-1.0	-0.4	-0.2	-0.1	1.1
455	+0.9	+0.5	-0.4	+0.1	+0.2	0.7
536	+1.8	+2.3	-0.3	+0.1	+0.1	2.4
537	-1.8	-1.0	-0.8	-0.2	+0.2	1.4
538	-1.9	+1.1	-0.3	+0.1	-0.2	1.3
539	-1.7	+2.6	-0.5	+0.1	+0.1	2.7
540	+1.8	+3.6	-0.3	+0.2	-0.1	3.7
541	+2.1	+2.5	+0.2	+0.2	-0.1	2.6
542	+1.2	+5.0	-0.5	0	+0.1	5.0
543	+0.9	-1.0	+0.2	+0.1	+0.2	1.1
544	-1.5	-1.4	-0.2	+0.1	-0.2	1.5
545	+1.5	+1.7	-0.2	+0.1	-0.2	1.8
546	-3.1	-1.4	-0.4	+0.1	-0.1	1.7
547	-1.3	-2.0	-0.5	0	-0.1	2.1

Side Surface of Transom (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
245	+0.7	+0.5	+0.2	-0.1	0	0.6
454	+2.1	+1.6	-0.5	-0.1	0	1.8
455	+0.9	+0.9	+0.3	-0.1	-0.1	1.0
536	+0.9	-1.6	-0.2	+0.1	-0.1	1.6
537	+1.0	-2.4	+0.6	+0.3	-0.1	2.5
538	-1.0	-2.7	+0.3	+0.1	-0.1	2.7
539	+1.4	-4.2	+0.3	+0.1	+0.1	4.2
540	+1.0	-4.4	-0.4	-0.1	-0.1	4.4
541	+1.1	-5.9	-0.5	-0.1	-0.1	5.9
542	+3.0	-7.1	+0.6	+0.2	-0.1	7.2
543	-0.8	-3.0	-0.4	-0.1	-0.2	3.0
544	-1.6	-3.3	+0.3	+0.1	+0.3	3.3
545	-1.3	-3.7	+0.3	+0.1	+0.3	3.7
546	-5.4	-4.2	+0.3	+0.2	-0.2	4.5
547	-2.1	-4.4	+0.5	+0.2	+0.1	4.5

Side Frame • Transom Stiffener (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
227	+1.0	+0.6	-0.3	+0.1	-0.2	0.7
228	-0.6	+1.4	-0.2	+0.1	-0.2	1.4
229	+0.6	+0.4	-0.2	+0.1	+0.1	0.5
230	-0.6	+0.6	+0.2	+0.1	-0.1	0.7
243	+0.2	-0.8	+0.1	-0.1	+0.1	0.8
244	+0.6	-0.6	-0.4	+0.1	+0.1	0.7
259	+0.7	-0.5	-0.7	+0.1	+0.2	0.9
260	-0.6	-0.2	+0.4	+0.1	-0.1	0.5
456	+1.2	+1.1	+0.2	-0.1	+0.1	1.2
457	-1.3	+1.0	-0.2	+0.1	+0.1	1.1
458	+0.9	+1.6	+0.1	+0.2	-0.1	1.6
459	+1.1	+2.1	+0.2	+0.2	-0.1	2.1
499	+0.5	-0.9	-0.2	-0.2	-0.2	1.0
527	+0.9	+0.3	-1.1	+0.2	+0.3	1.2
528	-0.7	-1.3	-0.6	-0.2	-0.2	1.5
529	+1.0	-0.2	-0.7	+0.2	+0.1	0.8
530	+0.6	+0.2	-0.6	+0.1	+0.2	0.7
531	-0.7	-0.4	+0.6	-0.1	-0.2	0.8
532	-1.1	-1.2	+0.8	-0.2	-0.3	1.5

Side Frame · Transom Stiffener (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
227	+1.3	-2.0	-0.4	+0.1	-0.1	2.1
228	+0.5	-2.7	+0.4	-0.1	+0.2	2.7
229	+0.6	-1.6	-0.5	-0.1	-0.1	1.7
230	+0.4	-1.5	-0.3	+0.1	+0.2	1.5
243	+0.3	-0.3	-0.5	+0.1	+0.1	0.6
244	+0.7	-0.5	-0.6	+0.1	+0.2	0.8
259	-0.8	-0.2	+0.6	+0.1	+0.2	0.7
260	+0.8	-0.4	-0.6	-0.1	-0.1	0.8
456	+2.3	-3.0	-0.4	+0.1	+0.1	3.1
457	+0.9	-1.8	-0.4	+0.1	+0.1	1.9
458	+0.8	-2.2	-0.6	0	+0.1	2.3
459	+1.1	-2.6	-0.6	-0.2	+0.1	2.7
499	-0.4	-0.5	-0.3	+0.2	+0.3	0.6
527	-0.6	+0.1	+0.7	+0.2	-0.2	0.8
528	+0.8	-0.7	+0.5	-0.2	+0.2	0.9
529	+0.5	-0.2	-1.3	+0.3	+0.2	1.4
530	+1.1	+0.1	-0.7	+0.2	+0.2	0.8
531	-0.8	-0.8	-0.5	-0.2	-0.1	1.0
532	-0.9	-1.7	-0.4	-0.3	-0.2	1.8

Transom Bracket of Tread Brake (front side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
295	+1.9	-1.1	+0.3	-0.1	-0.3	1.3
548	+1.5	+3.1	+0.3	-0.1	+0.1	3.1
549	+2.2	+2.4	+0.8	-0.1	+0.1	2.6
550	+2.3	+2.9	+0.7	-0.2	+0.1	3.1
551	+2.9	+3.0	+0.5	-0.2	+0.1	3.2
552	+2.7	+1.9	-0.3	-0.1	+0.1	2.1
553	+2.3	-1.6	-0.2	-0.1	+0.1	1.8
554	+1.0	-0.9	-0.2	-0.1	+0.1	1.0
555	+2.5	-1.5	+0.6	-0.1	-0.1	1.8
556	+2.1	-2.2	+0.4	0	+0.2	2.3
557	+1.4	-2.7	+0.4	0	+0.2	2.8
558	+3.4	-3.2	+0.4	-0.1	+0.3	3.4
559	+4.8	+5.4	+0.5	-0.2	-0.1	5.6
560	+3.0	-1.6	+0.4	-0.1	+0.3	1.9
561	+2.3	-2.8	+0.4	-0.1	-0.2	2.9
562	+3.8	-1.0	+0.5	-0.1	-0.3	1.6

Transom Bracket of Tread Brake (rear side)

ELEMENT NUMBER	STRESS (kg/mm²)					
	σ_V	σ_H	σ_L	σ_{BD}	σ_{BT}	σ_D
295	+2.5	+2.2	+0.1	+0.1	-0.3	2.3
548	+3.4	-6.4	+0.6	+0.2	-0.2	6.5
549	+1.2	-4.6	-0.4	+0.2	-0.1	4.6
550	+1.5	-5.4	-0.3	+0.2	-0.2	5.4
551	-1.4	-5.7	-0.3	+0.3	-0.2	5.7
552	+2.6	-7.3	+0.7	+0.3	+0.3	7.4
553	+1.0	-4.8	+0.6	+0.2	-0.2	4.9
554	-3.2	-5.0	+0.5	+0.2	-0.3	5.1
555	-2.9	-3.9	-0.5	+0.2	-0.4	4.0
556	-1.9	-3.5	+0.4	+0.2	+0.4	3.6
557	-2.0	-3.0	+0.4	+0.2	+0.4	3.1
558	-4.7	-8.8	+0.4	+0.5	+0.5	8.9
559	+3.5	-1.4	+0.4	+0.2	-0.1	1.8
560	+2.8	-3.0	+0.5	+0.2	+0.3	3.2
561	-2.1	-2.0	+0.4	+0.2	+0.5	2.1
562	+3.0	+1.3	+0.4	+0.2	+0.3	1.6

ENDURANCE LIMIT DIAGRAM

SMA 50B

Tensile Stress 50-62 kg/mm

Min. Yield stress 37 kg/mm

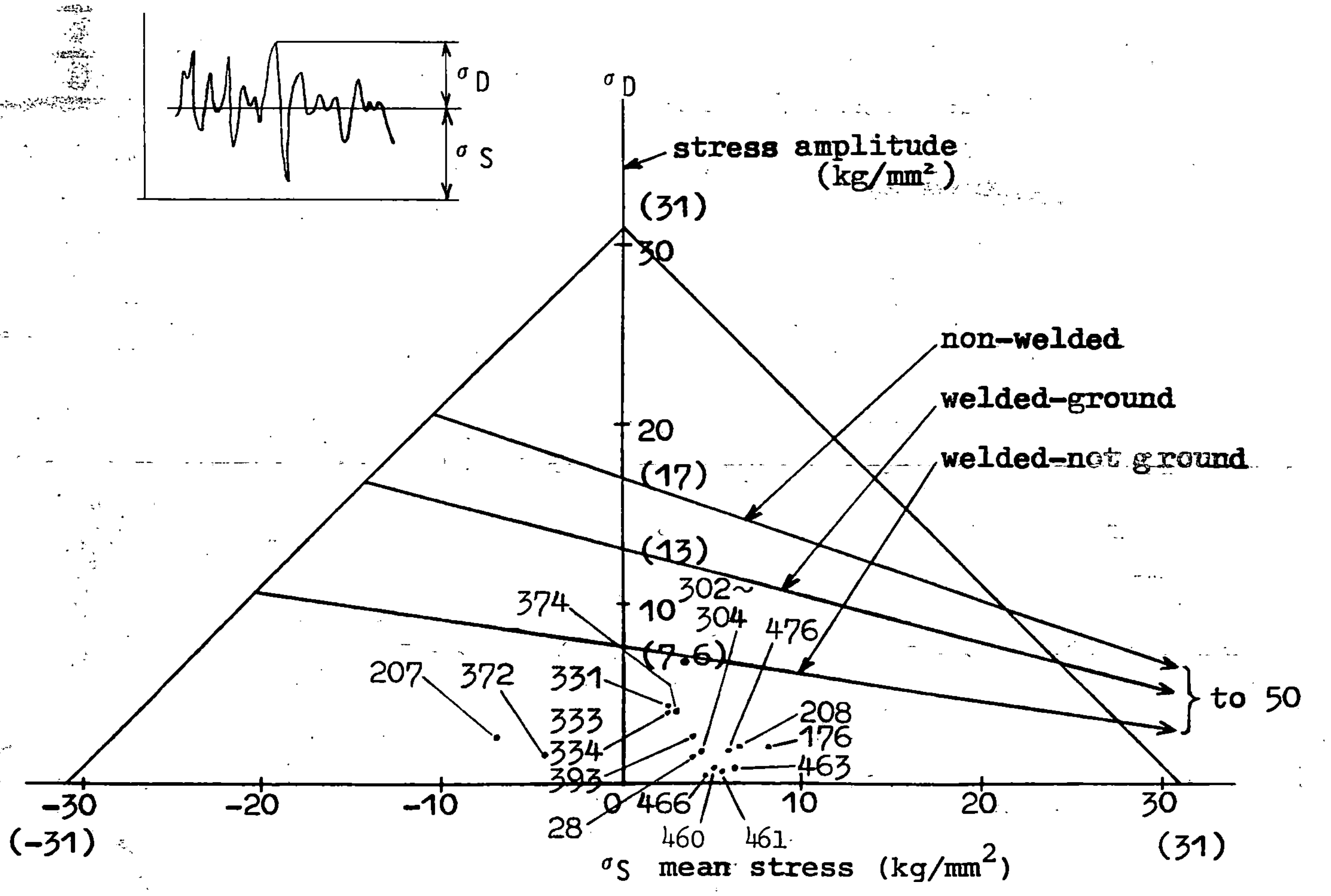


Figure 6.3 (K) Endurance Limit Diagram

Truck Frame (Front Side)

ENDURANCE LIMIT DIAGRAM

SMA 50B

Tensile Stress	50-62 kg/mm
Min. Yield stress	37 kg/mm

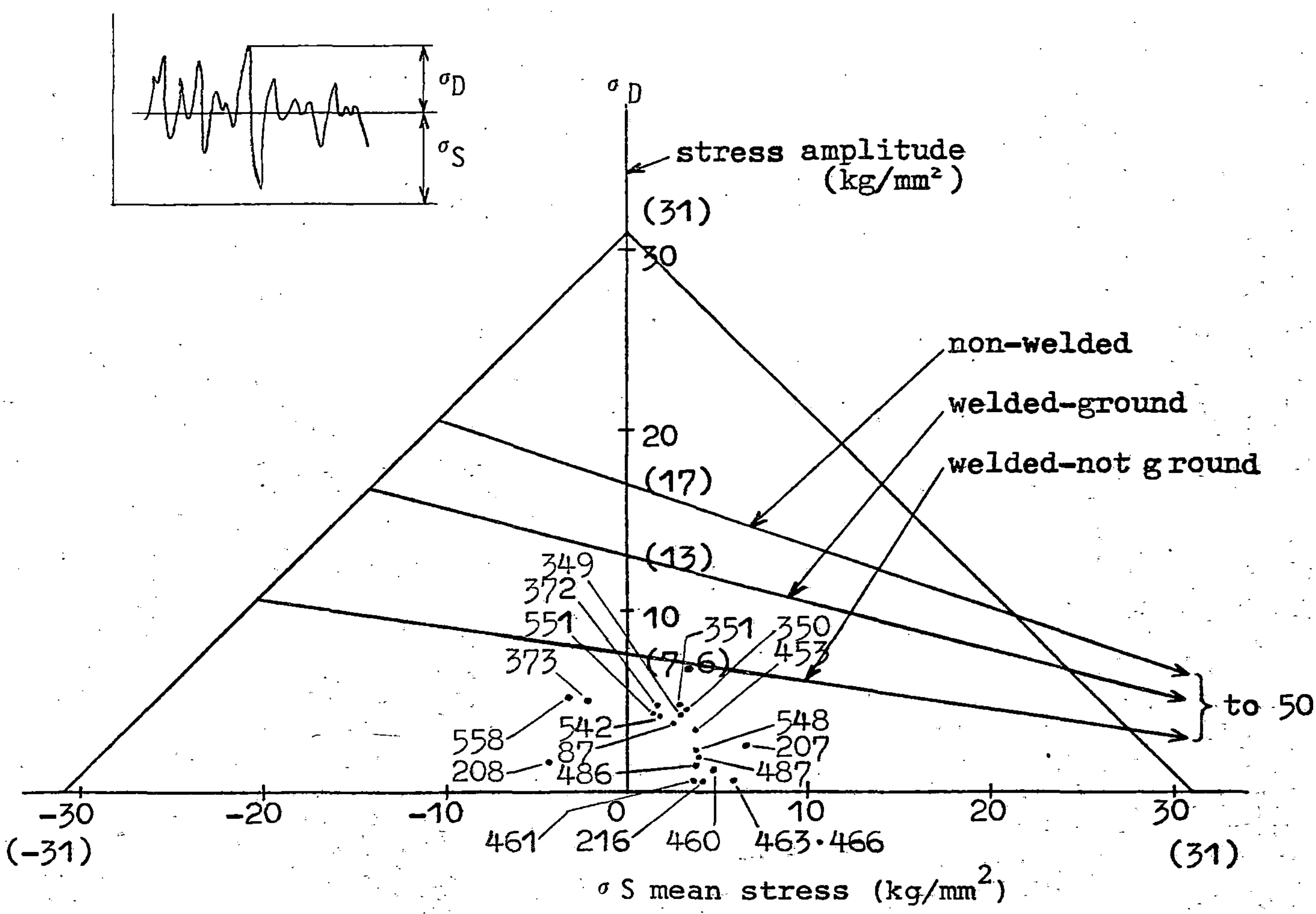


Figure 6.3 (L) **Endurance Limit Diagram**

Truck Frame (Rear Side)

6.4 ROLLER

Stress analysis of tilting roller is made as follows.

Analysis model is shown in Figure 6.4 (A).

1) Lateral force at center of gravity is calculated as follows. (Cf. Figure 6.4(A))

   Dynamic lateral force Qo caused by lateral acceleration of carbody is obtained by the following formula.

   $$Q_o = \alpha \cdot W = 4{,}298 \text{ Kg.}$$

   where, W : carbody load at center of gravity under max. condition load (21,488 Kg)

   α : lateral acceleration of carbody (0.2g)

   When tilting angle is over 6° , tilting movement is limited by rubber stop.

   So lateral force P under max. tilting movement is obtained by the following formula.

   $$P = W \cdot \tan\theta = 2{,}258 \text{ Kg}$$

   where, θ : tilting angle (6°)

   After tilting movement is limited by rubber stop total lateral force Q is obtained as follows.

   $$Q = Q_o - P = 2{,}040 \text{ Kg}$$

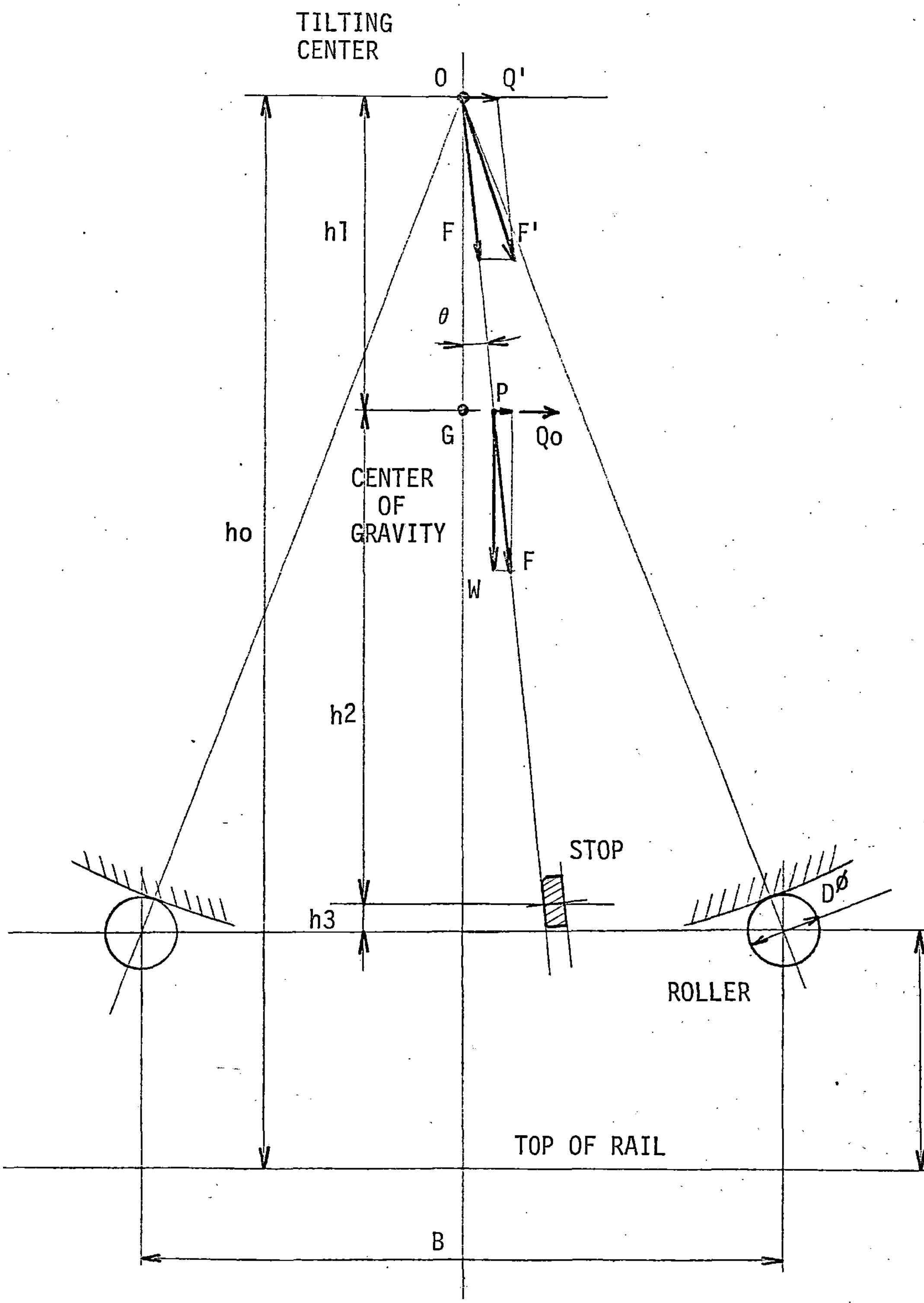


Figure 6.4 (A) Model of Tilting Movement of Roller

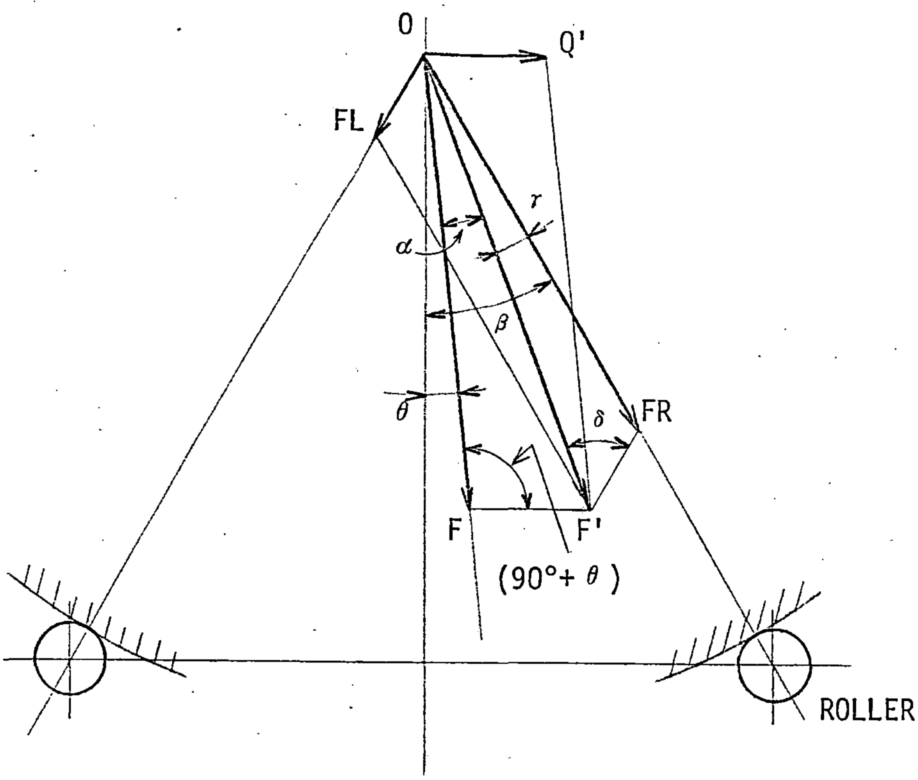


Figure 6.4 (B) Model of Force Vector

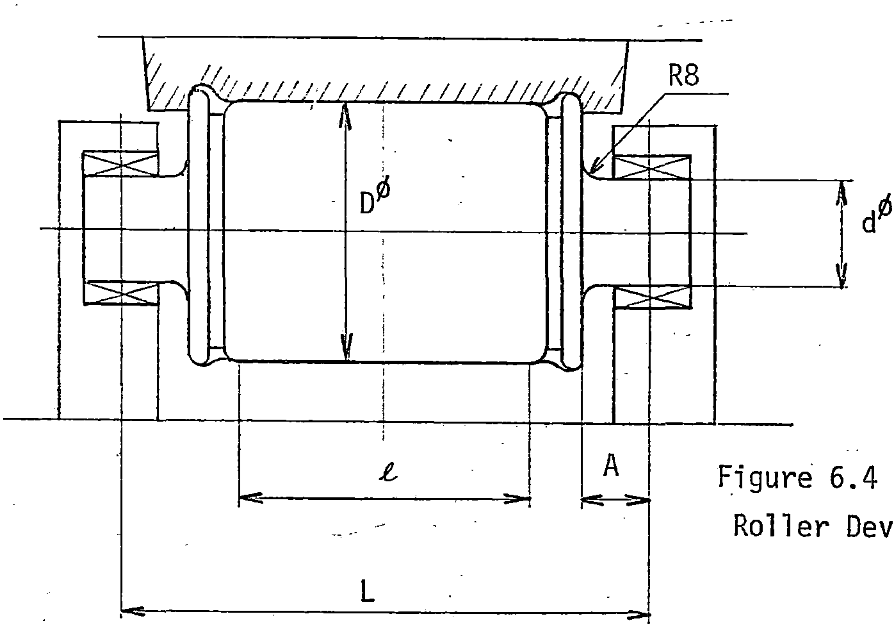
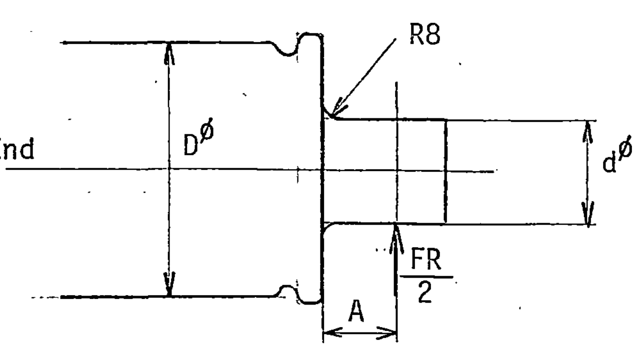


Figure 6.4 (C)
Roller Device

Figure 6.4 (D)
Enlarged Drawing of Roller End



2) Forces at tilting center are calculated as follows.

(Cf. Fig. 6.4(A) and 6.4(B).)

$$Q' = \frac{Q \cdot h_2}{h_o - h_3 - h_4} = 1{,}240 \text{ Kg}$$

$$F = \frac{W}{\cos\theta} = 21{,}606 \text{ Kg}$$

where, Q' : lateral force

F : centrifugal force

h_o: height of tilting center from top of rail

h_2: distance between center of gravity and center of stop

h_3: distance between centers of stop and roller

h_4: height of roller center from top of rail

The resultant force F' composed of forces Q' and F is obtained by the following formula.

$$F' = \left\{ F^2 + Q'^2 - 2 \cdot F \cdot Q' \cdot \cos(90° + \theta) \right\}^{1/2} = 21{,}771 \text{ Kg}$$

Angles for force vectors are obtained by the following formula.

$$\alpha = \sin^{-1} \frac{Q' \sin(90° + \theta)}{F'} = 3.247°$$

$$\beta = \tan^{-1} \frac{B/2}{h_o - h_4} = 21.093°$$

$$\gamma = \beta - \theta - \alpha = 11.8451°$$

$$\delta = \beta + \theta + \alpha = 30.3395°$$

where, α : angle between force vectors F and F'

β : angle between tilting center and force vector F_R

γ : angle between force vectors F' and F_R

δ : angle between force vectors F' and F_L

The resultant force F' is divided into two components of force, F_R and F_L.

Two components of force are obtained by the following formula.

$$\frac{F'}{\sin(180° - \gamma - \delta)} = \frac{F_R}{\sin \delta} = \frac{F_L}{\sin \gamma}$$

$$\therefore \; F_R = F' \times \frac{\sin \delta}{\sin(180° - \gamma - \delta)} = 16{,}376 \text{ Kg}$$

$$\therefore \; F_L = F' \times \frac{\sin \gamma}{\sin(180° - \gamma - \delta)} = 6{,}655 \text{ Kg}$$

3) Surface stress on roller, so called as Hertz stress, is calculated by the following formula. (Cf. Figure 6.4(A), (C))

$$P_{max} = 0.591 \sqrt{\frac{F_R}{\ell} \cdot \left(\frac{E_1 \cdot E_2}{E_1 + E_2}\right)\left(\frac{R_1 + R_2}{R_1 \cdot R_2}\right)} = 61.8 \text{ Kg/mm}^2$$

where, $P_{max.}$: allowable maximum surface stress

E_1 : modulus of elasticity of roller guide plate (2.1×10^4 Kg/mm^2)

E_2 : modulus of elasticity of roller (2.1×10^4 Kg/mm^2)

R_1 : radius of curvature of roller guide plate $\left\{ \sqrt{\left(\frac{B}{2}\right)^2 + (h_o - h_4)^2} - \frac{D}{2} = 2166 \text{ mm} \right\}$

B, center distance of rollers (1620 mm)

D, roller diameter (170Ø mm)

R_2 : radius of roller $\left(\frac{D}{2} = 85 \text{ mm}\right)$

ℓ : effective width of roller (192 mm)

Allowable maximum surface stress are shown below.

material of contacting members	experimental values of allowable max. stress
Steel (H_B400) - steel (H_B400)	$P_{max.} < 106$ Kg/mm^2
Steel (H_B500) - steel (H_B500)	$P_{max.} < 134$ Kg/mm^2

where, H_B : Brinell hardness

Material of both roller and roller guide plate is in accordance with JIS G 4103, SNCM420. Contacting surfaces of these material are treated with carburizing harden to provided hardness of H_B500 and over.

4) Bending stress at roller end is calculated by the following formula. (Cf. Figure 6.4(D))

$$M = \frac{F_R}{2} \times A = 372554 \quad \text{Kg.mm}$$

$$Z_b = \frac{\pi d^3}{32} = 33657 \text{ mm}^3$$

$$\sigma_b = \frac{M}{Z} = 11.1 \text{ Kg/mm}^2$$

where, M : bending moment (Kg-mm)

A : distance between roller end and supporting point (45.5 mm)

Z : modulus of section for bending (mm^3)

d : diameter of roller shaft (70ϕ mm)

σ_b : bending stress (Kg/mm^2)

Maximum bending stress (by stress concentration) is obtained as follows.

$$\sigma_{b,max} = K \cdot \sigma_b = 15.8 \text{ Kg/mm}^2$$

where, K : factor of stress concentration (1.42)

The material JIS G 4103, SNCM420 with heat treatment of Quenched and Tempered has tensile strength of 100 Kg/mm^2 and over.

6.5 UPPER SWING BOLSTER

Stress analysis of upper swing bolster is made as follows.

Analysis model is shown in Figure 6.5.

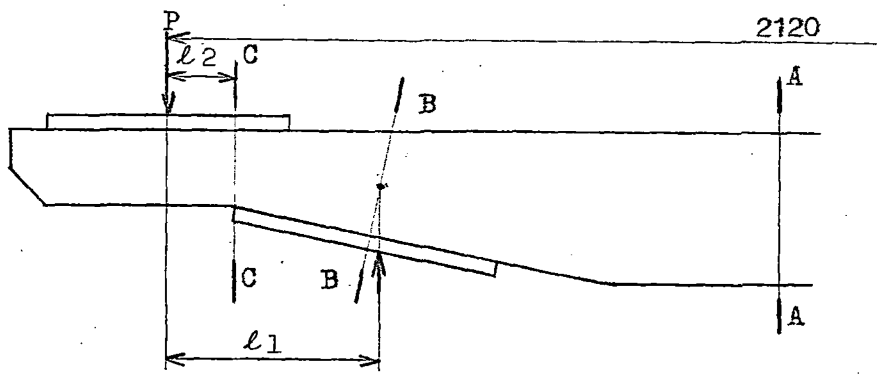


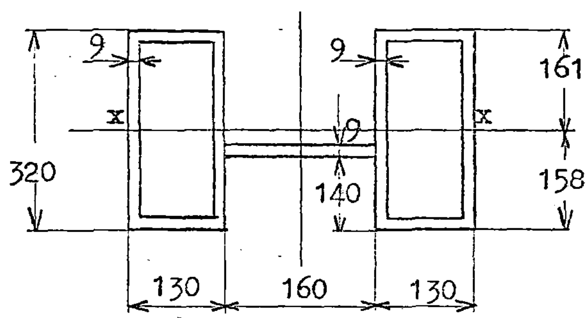
Figure 6.5 Stress Analysis Model of Upper Swing Bolster

1) Vertical load P

P : maximum air spring load 10889 Kg

2) Calculation of Stress

a) Section A - A



$I_X = 1.93 \times 10^8$ mm^4

$Z_{XL} = 1.22 \times 10^6$ mm^3

$Z_{XU} = 1.19 \times 10^6$ mm^3

where, I_X ; geometrical moment of inertia

Z_{XL} ; modulus of section for bending (lower section)

Z_{XU} ; modulus of section for bending (upper section)

$MA = P \times \ell 1 = 10889 \times 325 = 3.54 \times 10^6$ Kg.mm

$\sigma AL = MA/ZXL = 2.90$ Kg/mm2

$\sigma AU = MA/ZXU = 2.97$ Kg/mm2

$\sigma VL = 0.3 \sigma AL = 0.87$ Kg/mm^2

$\sigma VU = 0.3 \sigma AU = 0.89$ Kg/mm2

where, M : moment by load P at section A - A

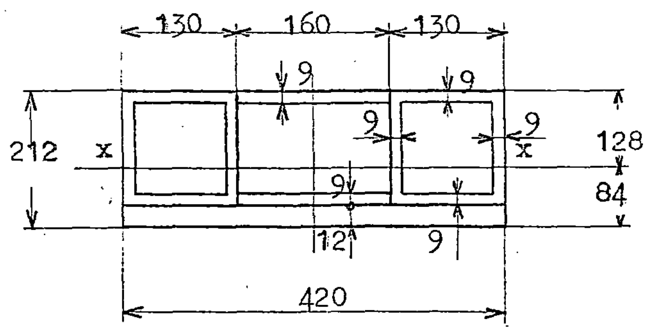
σ AL : **static** bending stress (lower section)

σ AU : static bending stress (upper section)

σ VL : dynamic bending stress (lower section)

σ VU : dynamic bending stress (upper section)

b) Section B - B



$I_x = 1.28 \times 10^8$ mm^4

$Z_{XL} = 1.53 \times 10^6$ mm^3

$Z_{XU} = 9.96 \times 10^5$ mm^3

$MB = P \times \ell 1 = 10889 \times 325 = 3.54 \times 10^6$ Kg.mm

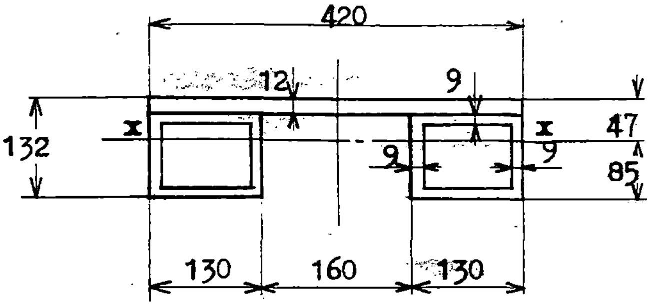
$\sigma BL = MB/ZXL = 2.31$ Kg/mm2

$\sigma BU = MB/ZXU = 3.55$ Kg/mm2

$\sigma VL = 0.3 \sigma BL = 0.69$ Kg/mm2

$\sigma VU = 0.3 \sigma BU = 1.07$ Kg/mm^2

c) Section C - C



$I_x = 3.14 \times 10^7 \ mm^4$

$Z_{XL} = 3.70 \times 10^5 \ mm^3$

$Z_{XU} = 6.65 \times 10^5 \ mm^3$

$MC = P \times \ell 2 = 10889 \times 40 = 4.36 \times 10^5 \ Kg.mm$

$\sigma_{CL} = MC/Z_{XL} = 1.18 \ Kg/mm^2$

$\sigma_{CU} = MC/Z_{XU} = 0.66 \ Kg/mm^2$

$\sigma_{VL} = 0.3 \sigma_{CL} = 0.35 \ Kg/mm^2$

$\sigma_{VU} = 0.3 \sigma_{CU} = 0.20 \ Kg/mm^2$

The stresses are plotted in Endurance Limit Diagram and shown in Figure 6.5.

ENDURANCE LIMIT DIAGRAM

SMA 50B

Tensile Stress	50-62 kg/mm
Min. Yield stress	37 kg/mm

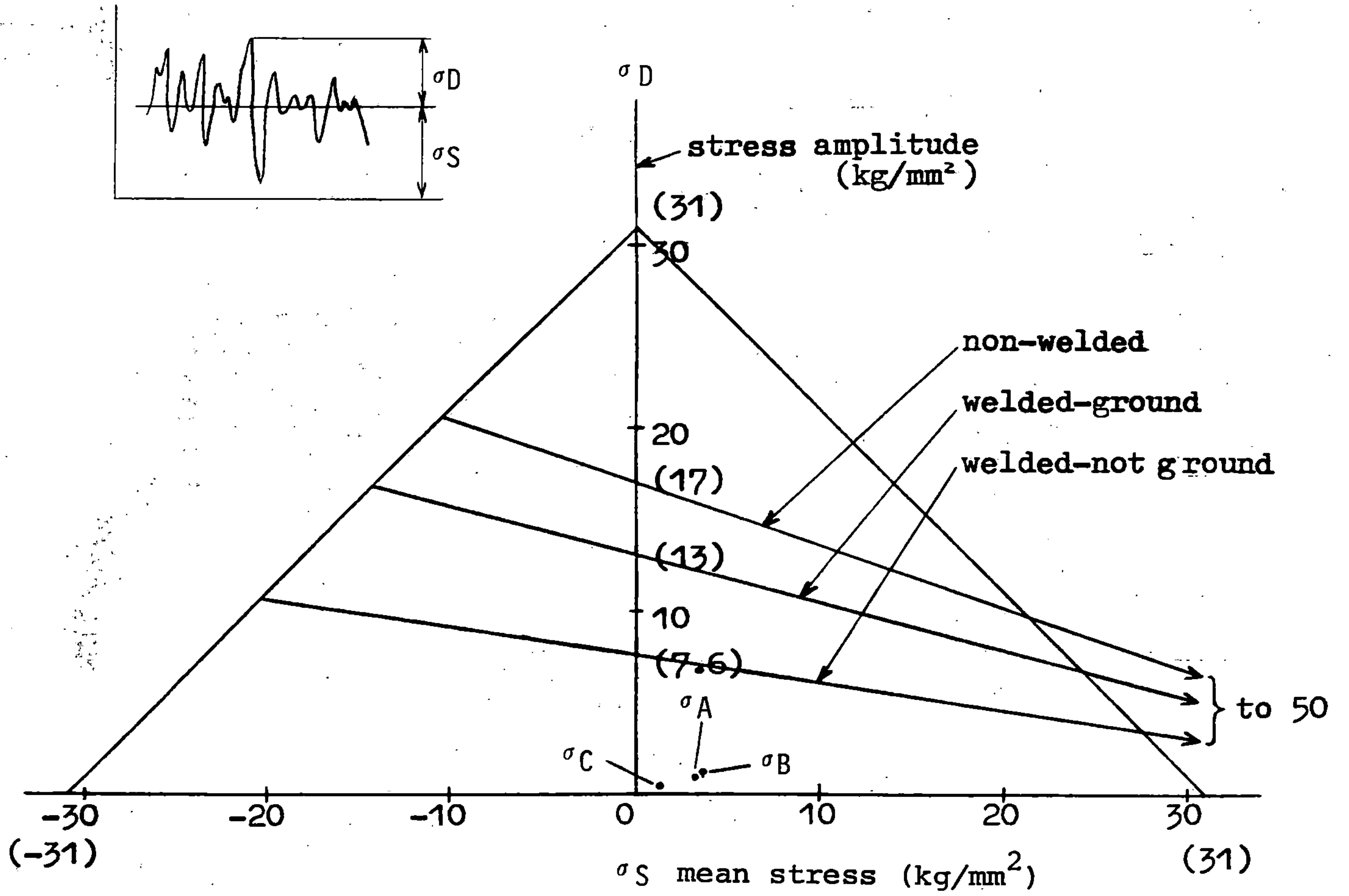


Figure 6.5 **Endurance Limit Diagram**

Upper Swing Bolster

6.6 BRAKE DISC

Stress analysis (by thermal load) of brake disc is done by means of "Finite Element Method", NASTRAN.

The plate elements (QUAD and TRIA element) are used.

Model is shown in Figure 6.6 (A).

The thermal load is calculated by the following formula.

1) Heat quantity absorption of brake disc

$$Q = \frac{1}{2} \times \frac{W}{g} \times \left(\frac{V}{3.6}\right)^2 \times \frac{1}{426.9} \times \varepsilon \quad \text{(Kcal/disc)}$$

where, W : maximum wheel load

V : initial velocity of vehicle at braking

ε : brake force share ratio

2) Temperature rise of outer disc plate

$$T = \frac{Q}{C \cdot Wd}$$

where, Wd : weight of outer disc plate

C : specific heat of brake disc

The calculation values are as follows.

$W = 7227$ Kg, $V = 193$ Km/h, $\varepsilon = 0.6$

$Wd = 113$ Kg, $C = 0.13$ Kcal/kg °C

$T = 103$ °C

The thicknesses of each plate are as follows.

t1 (outer disc plate) = 35 mm

t2 (rib 5) = 25 mm

t3 (center plate) = 22 mm

t4 (rib 1 ~ rib 4) = 20 mm

t5 (rib 41, rib 42) = 10 mm

This thermal load (T = 103°C) is applied at each grid point of outer disc plate.

The temperatures of remaining grid of brake disc are 20°C.

The partitioning, constraints and calculation stresses are shown in Figure 6.6 (B) ~ (G).

Material of brake disc is cast iron.

Allowable maximum stess for endurance limit is 25 Kg/mm^2 (± 12.5 Kg/mm^2).

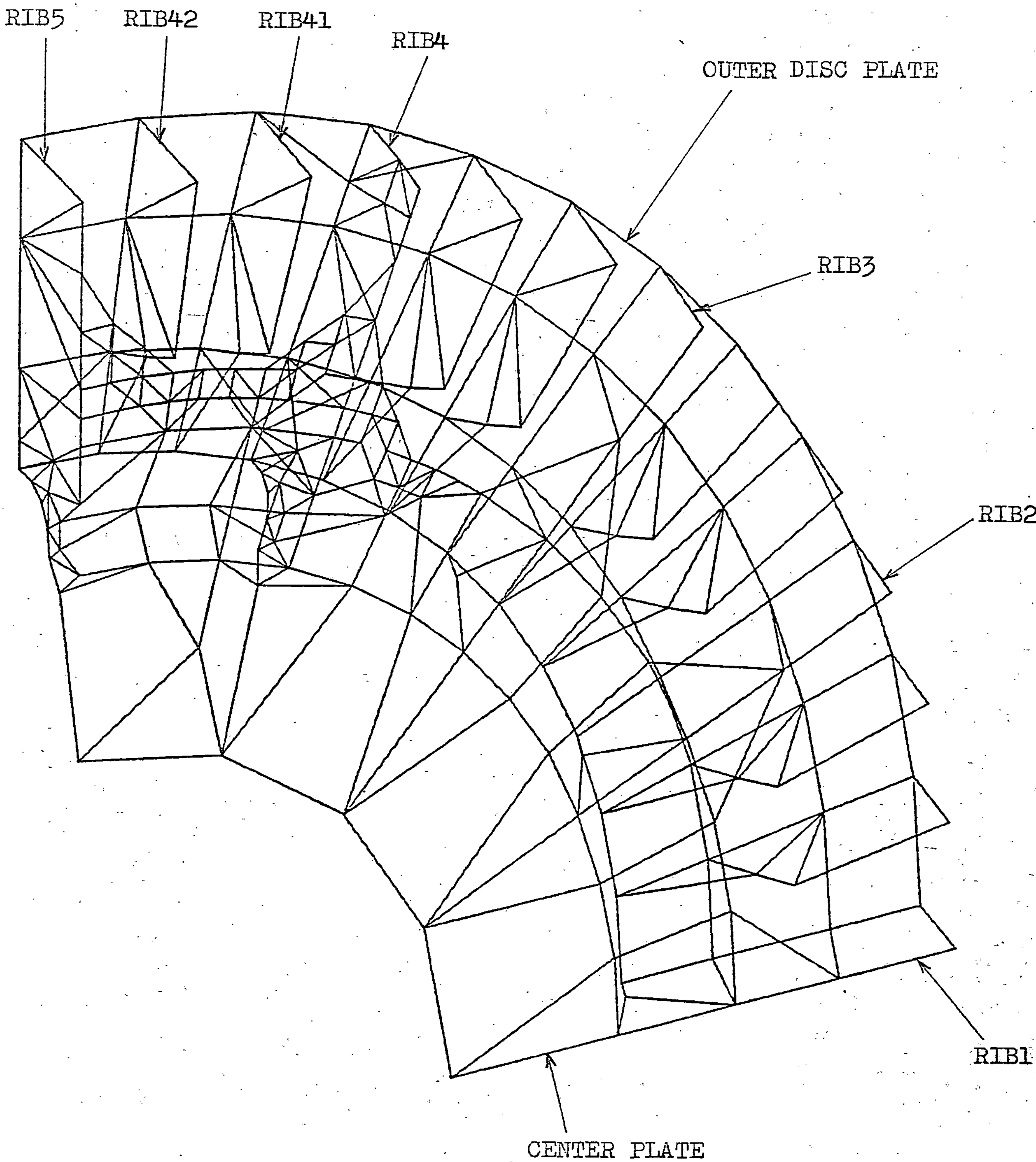


Figure 6. 6 (A) Model of Stress Analysis of Brake Disc

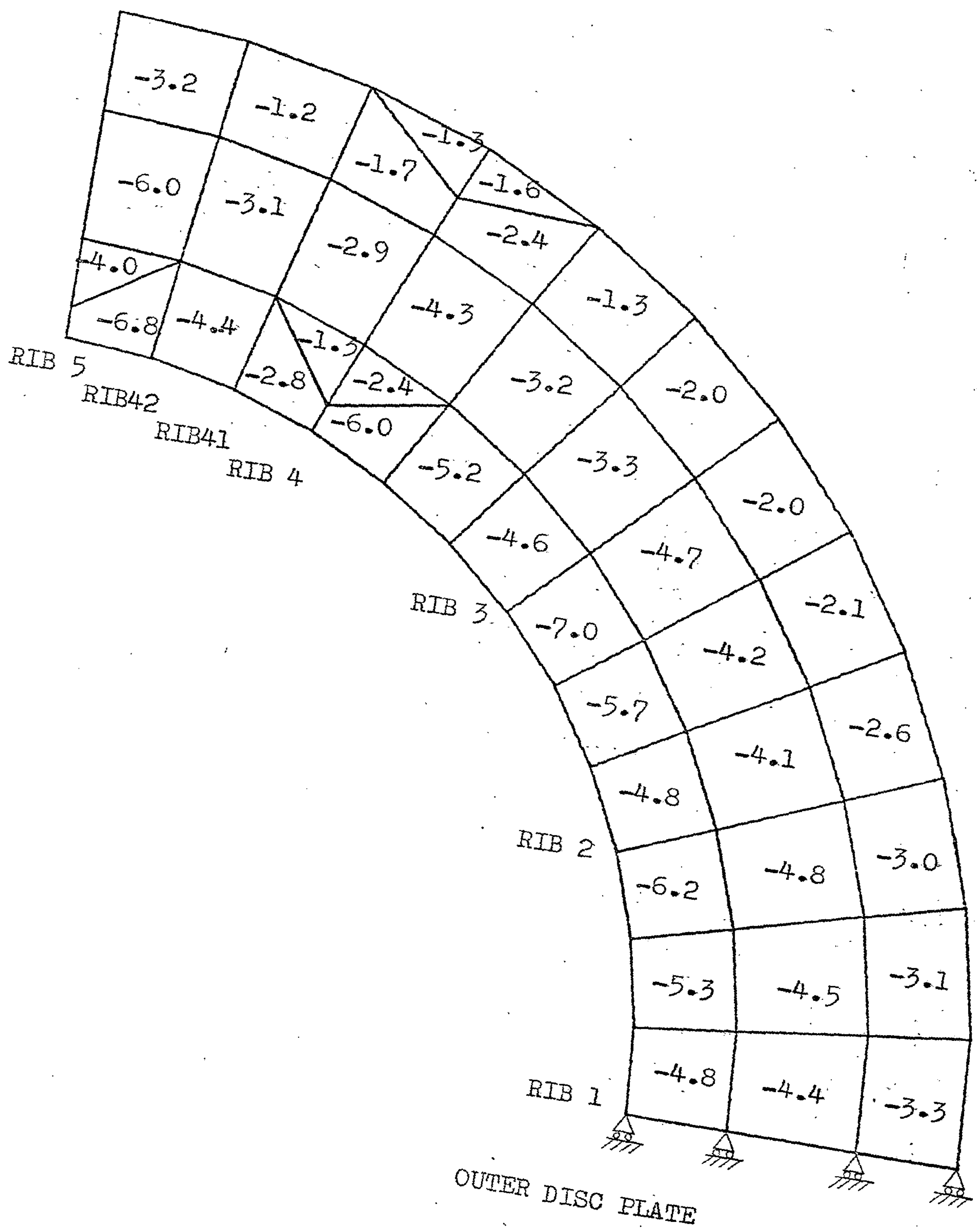


Figure 6.6 (B) Stress of Brake Disc (front side)

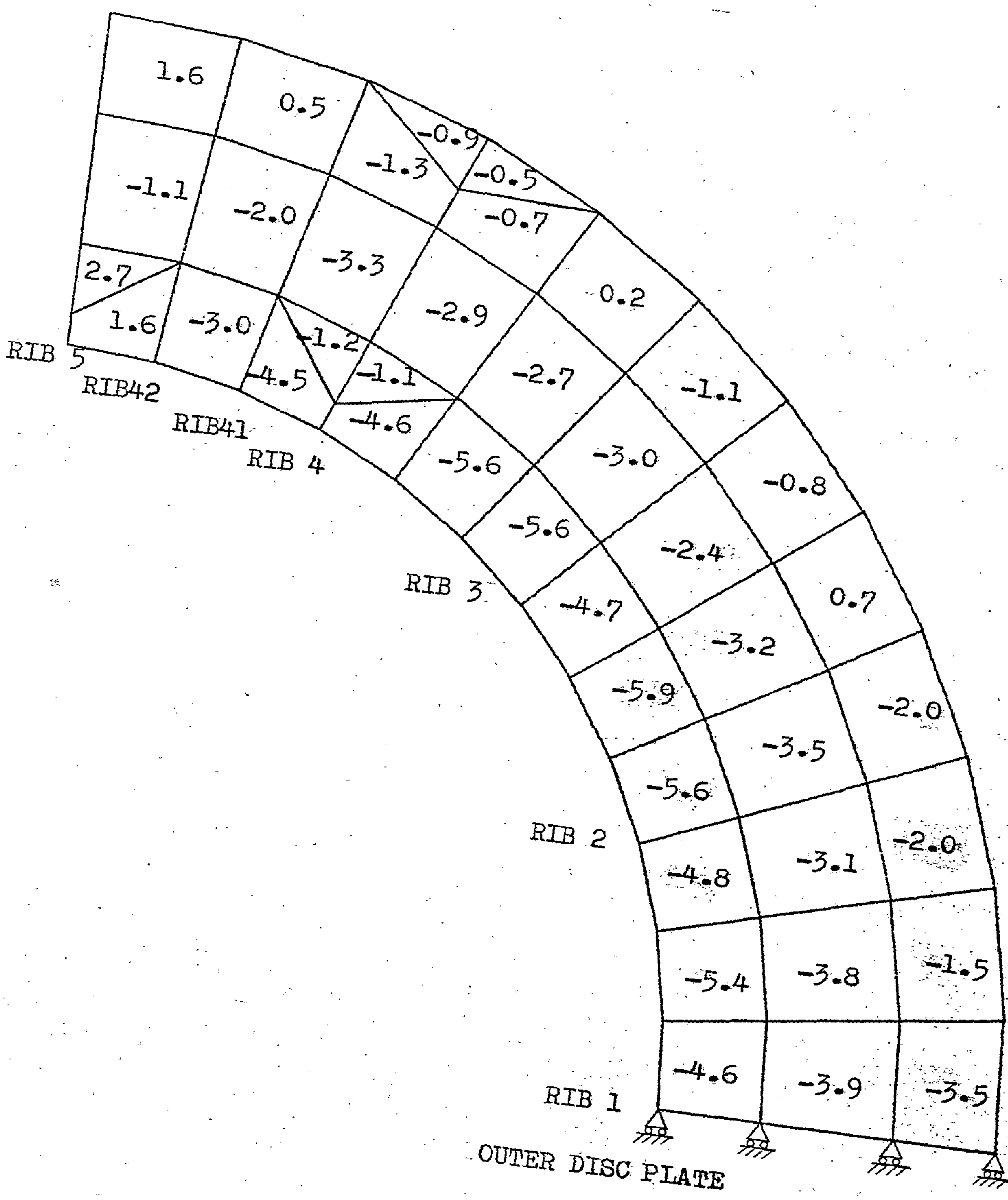


Figure 6.6 (C) Stress of Brake Disc (rear side)

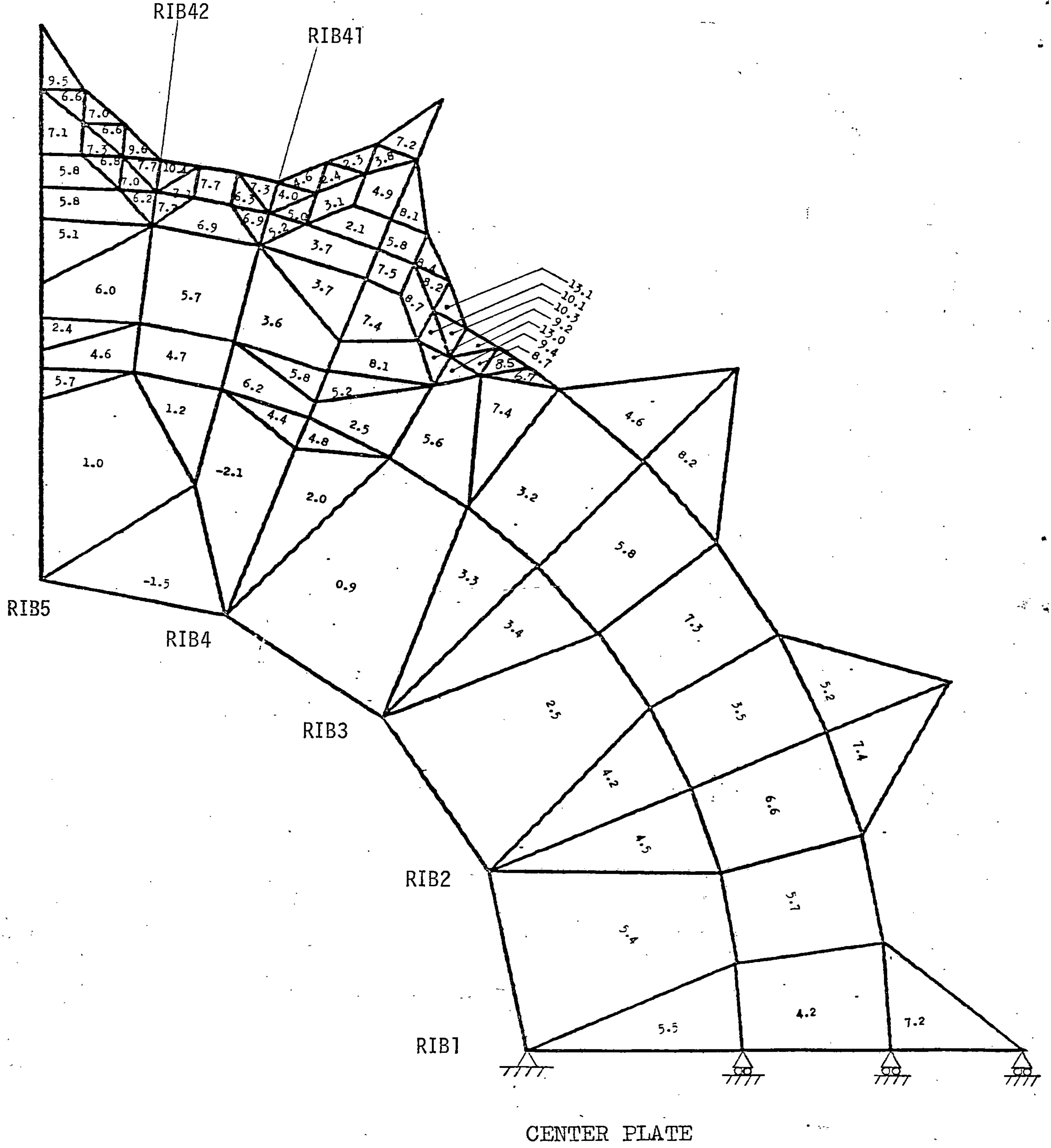


Figure 6.6 (D) Stress of Brake Disc (front side)

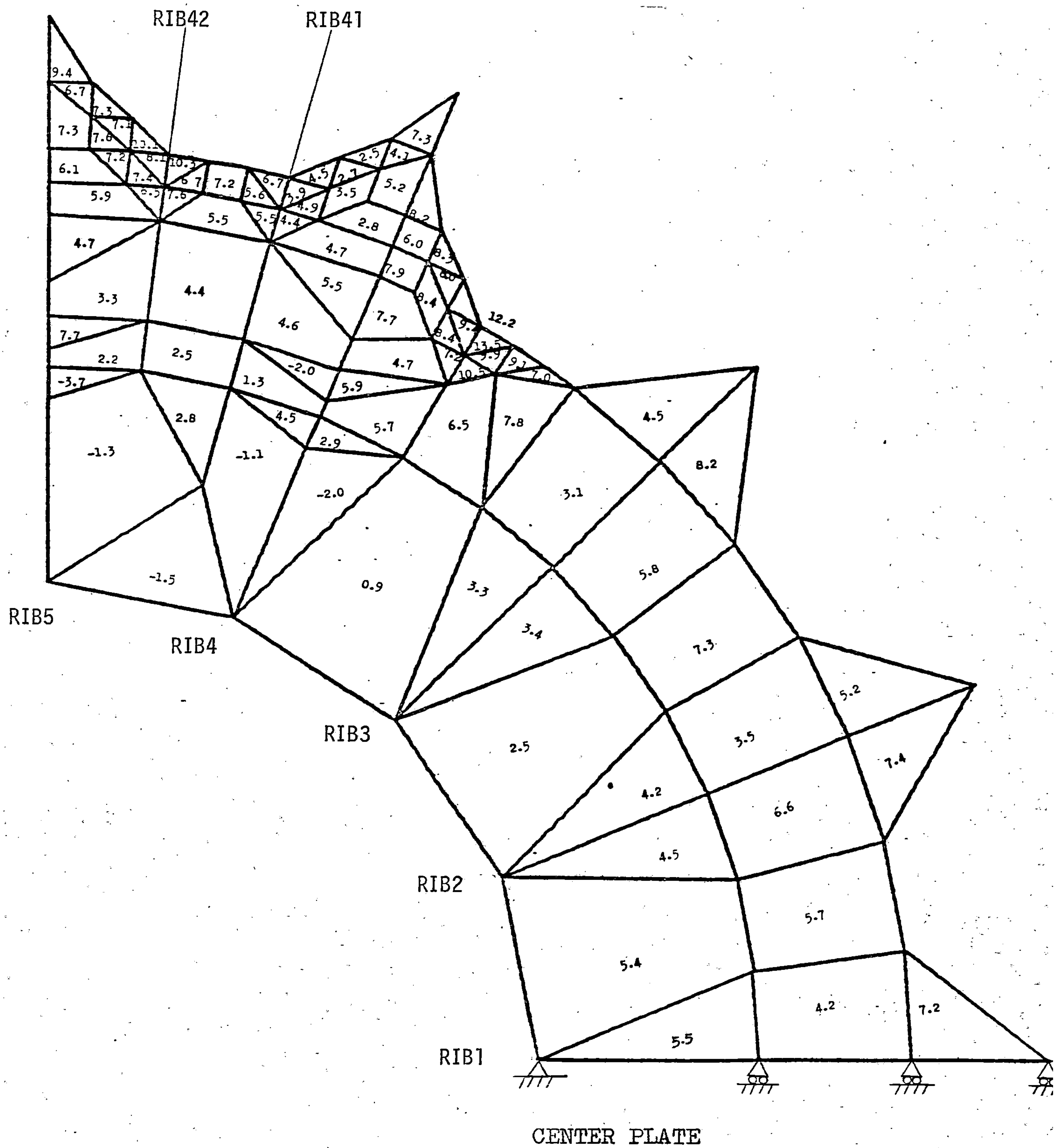


Figure 6.6 (E) Stress of Brake Disc (rear side)

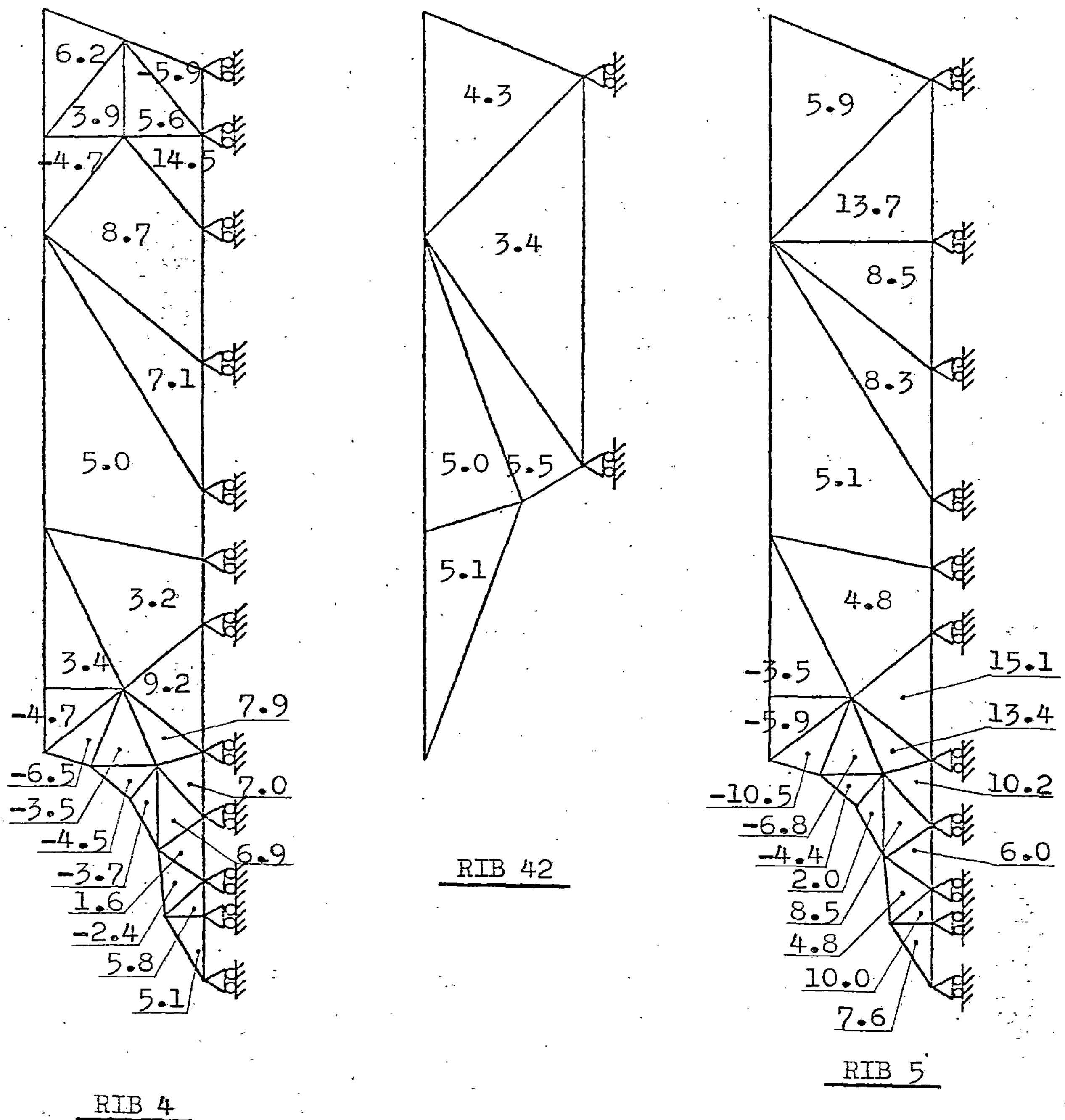


Figure 6.6 (F) Stress of Brake Disc (front side)

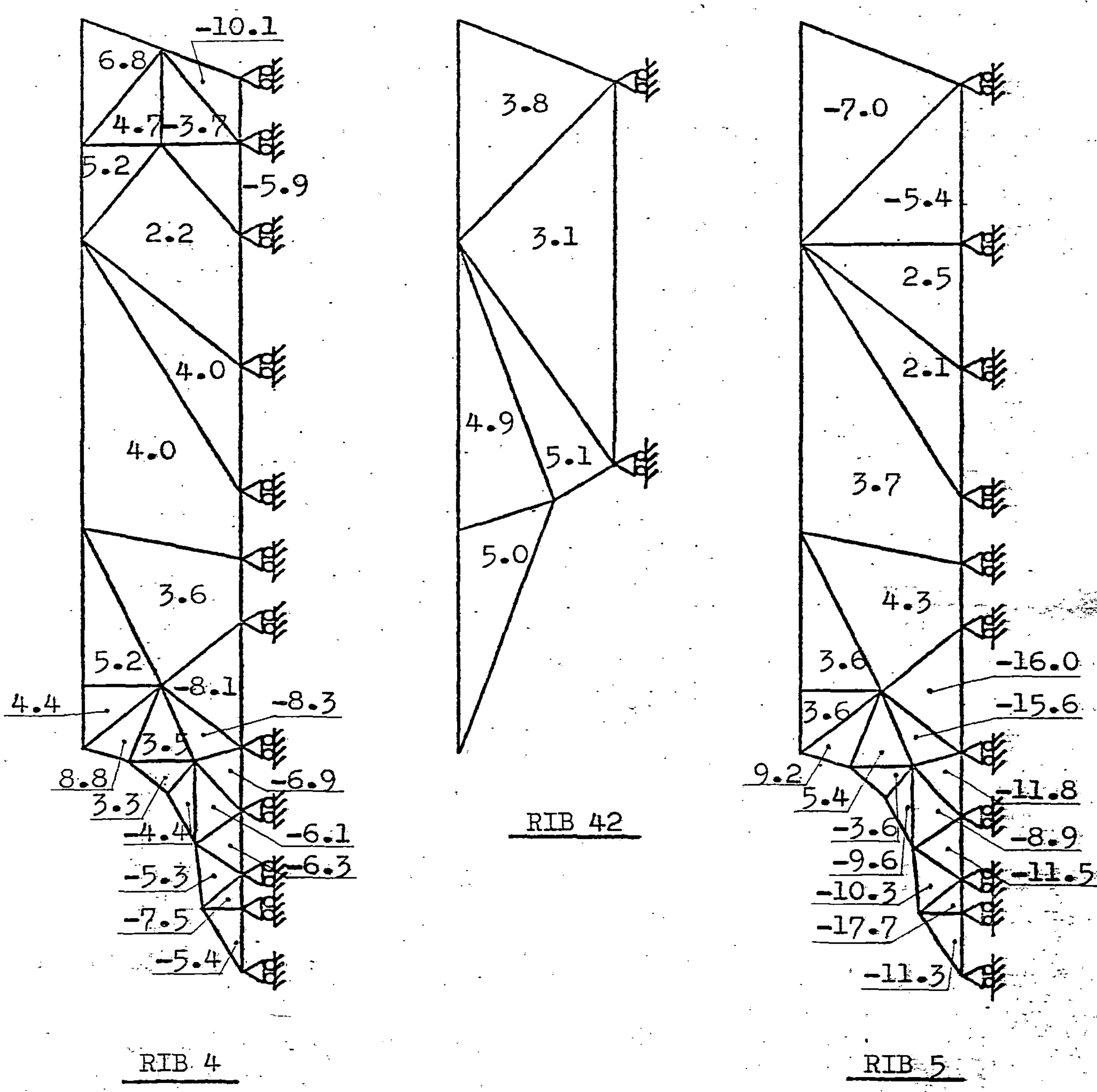


Figure 6.6 (G) Stress of Brake Disc (rear side)

7. PERFORMANCE OF VEHICLE RUNNING THROUGH CURVES

Transient response analysis of tilting vehicle running through curves is described in this section.

This section presents the following descriptions.

1) Data of existing track.
2) Relation between maximum lateral acceleration of carbody and transition curve length.
3) Maximum permissible velocity of vehicle at each curve.
4) Operation time.
5) Influence of tilting length.
6) Influence of damping coefficient of tilting damper.
7) Transient response diagram

7.1 MODEL

The model of tilting vehicle for transient response is shown in Figure 7.1

7.2 CALCULATION DATA OF VEHICLE

The calculation data of tilting vehicle for transient response are shown in Table 7.2

7.3 CALCULATION DATA OF TRACK CONDITIONS AND RUNNING SPEED

The calculation data of track conditions and running speed for transient response are shown in Table 7.3

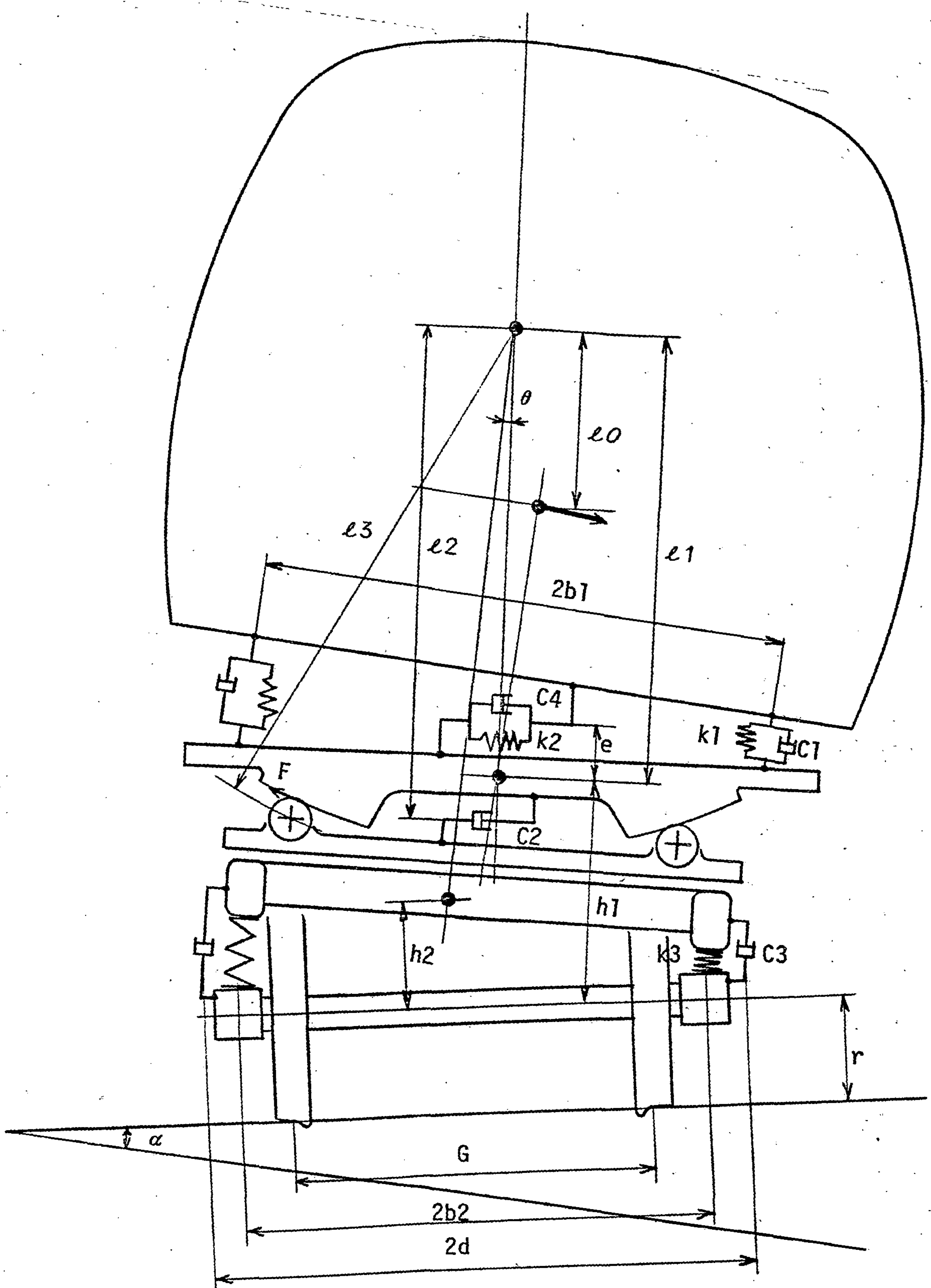


Figure 7.1 Model of Tilting Vehicle for Transient Response

Table 7.2 Calculation Data of Tilting Vehicle for Transient Response

SYMBOL	DESCRIPTION	DESIGN VALUE
W_0	weight of carbody (normal) / truck	20354 Kg
W_1	weight of bolster device / truck	620 Kg
W_2	weight of truck frame / truck	2650 Kg
i_0	radius of gyration of carbody	1.016 m
i_1	radius of gyration of bolster device	0.6 m
i_2	radius of gyration of truck frame	0.5 m
k_1	vertical spring constant of secondary spring / set	45 Kg/mm
k_2	lateral spring constant of secondary spring / truck	70 Kg/mm
k_3	vertical spring constant of primary spring / axle	216 Kg/mm
C_1	damping coefficient of secondary spring / set	50 Kg/cm/sec.
C_2	damping coefficient of tilting damper / truck	10 Kg/cm/sec.
C_3	damping coefficient of primary damper / axle	40 Kg/cm/sec.
C_4	damping coefficient of secondary lateral damper / truck	140 Kg/cm/sec.
$2b_1$	distance between secondary springs	2120 mm
$2b_2$	distance between primary springs	1960 mm
$2d$	distance between primary dampers	2300 mm
ℓ_0	distance between tilting center and center of gravity of carbody	800 mm
ℓ_1	distance between tilting center and center of gravity of bolster device	1950 mm
ℓ_2	distance between tilting center and center of tilting damper	2000 mm

Table 7.2 Calculation Data of Tilting Vehicle for Transient Response (Cont'd)

SYMBOL	DESCRIPTION	DESIGN VALUE
ℓ_3	radius of tilting motion	2250 mm
h_1	distance between axle center and center of gravity of bolster device	295 mm
h_2	distance between axle center and center of gravity of truck frame	100 mm
e	distance between center of secondary spring and center of gravity of bolster device	250 mm
r	radius of wheel	457 mm
F	frictional force on roller	70 Kg
G	track gauge	1435 mm
α	angle of superelevation	——

Table 7.3 Calculation Data of Track Conditions and Running Speed for Transient Response

RADIUS OF CURVE	SUPERELEVATION			LENGTH OF TRANSITION CURVE				RUNNING SPEED		
R (m)	C (mm)			LS (m)				V. (Km/h)		
200	57	77	111	50	70	100	160	60	70	80
300	57	63	105	40	60	100	160	70	80	90
400	80	115	152	40	80	150	200	90	100	115
500	60	82	127	40	60	90	120	100	110	125
600	70	117	147	40	70	100	150	110	125	140
700	70	98	152	60	100	140	180	125	140	155
800	57	127	152	30	70	120	180	130	145	160
900	50	105	152	60	90	120	170	140	155	170
1000	50	92	150	30	80	120	160	140	160	180
1100	60	101	152	30	80	150	200	155	170	190
1200	57	95	152	50	90	130	200	160	180	200
1300	57	110	152	50	90	150	200	160	180	200
1400	50	117	152	50	80	120	160	160	180	200
1500	50	88	152	50	80	150	210	160	180	200
1600	47	115	152	30	80	150	200	160	180	200
1700	47	89	152	30	80	150	200	160	180	200
1750	50	108	146	30	70	110	160	160	180	200
1800	57	92	146	50	90	140	200		170	200
2000	40	73	149	40	80	120	180		170	200

7.4 DATA OF EXISTING TRACK

Kilopost location, curve No., radius of curve, superelevation and length of transition curve are shown in Table 7.4

The numbers of superelevation and length of transition curve for each curve are shown in Figure 7.4

Mark O in figure shows the value of calculation data of C and LS.

CONDITIONS OF TRACK
(BOSTON - NEW YORK)

Table 7.4 Data of Existing Track

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
368.77-368.46	1	219	76.2	-	-
-367.66	4	373	19.1	-	-
-366.40	5	426	38.1	-	-
-366.37	6	184	127	-	-
-365.87					
-365.63	7	1806	12.7	-	-
-362.81	9	1278	108	-	-
-362.2	10	1177	108	-	-
349.96-349.64					
-349.47					
-347.87					
-346.64	16	1733	108	116	126
-344.1					
-337.2	17-21	1744	108	107	107
-333.21					
-332.23	22	1750	120.7	132	128
-330.33					
-329.73	23	1750	120.7	130	122
-312.98					
-311.52	24	1115	143	152	152
-306.59					
-305.87	25	579	98.6	102	37
-305.39					
-303.94	27	474	124	139	139
-303.46					
	29	3492	25.4	30	30
-303.17	31	1644	57.2	30	30
-300.53	32	975	92.2	91	91
-300.26	35	866	92.2	95	104
-299.79	36	1037	76.5	128	78
299.79-298.31	37	418	114.3	122	79
-297.83					
-297.50					

CONDITION OF TRACK
(BOSTON - NEW YORK)

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
297.5-297.39	40	355	82.6	-	-
297.39-295.4	41	533	108	81	73
-294.25	43	572	98.6	73	103
-292.85	45	432	108	140	178
-292.16	46	359	139.7	105	105
-292.42	47	1000	146.1	152	152
-289.89	48	1838	92.1	101	101
-289.62	49	1822	92.1	92	92
-280.64					
280.64-279.47	50	1140	133.4	152	152
	51	1397	123.8	126	126
-275.85	52	1330	139.7	111	157
-274.19	53	1822	92.1	92	92
-258.21					
-256.81	58	1746	139.7	-	152
-251.82					
251.82-249.33	61	888	149.2	152	152
-247.20					
-245.45	62	1167	101.6	141	144
-244.18	63	787	146.1	165	152
-242.34	64	998	123.8	126	126
-240.56					
-238.90	65	1096	127	141	92
-236.78	66	902	142.9	151	143
-233.94					
233.94-233.30	67	698	142.9	152	152
-231.63	68	895	117.5	118	117
-229.63					
-228.76	69	1048	101.6	114	114
-227.94	70	759	152.4	152	152
-226.59	71	847	127	128	128
-223.79	72	880	120.7	127	156

CONDITION OF TRACK
(BOSTON - NEW YORK)

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
223.79-222.66	73	851	127	131	131
-222.28	74	1219	60.3	122	122
-219.90					
-218.42	75	456	111.1	112	90
-217.72	76	625	101.6	101	101
	77	598	142.9	141	141
	78	698	139.7	152	152
217.72-213.36	79	475	152.4	108	-
-212.27	81	470	127	-	-
-209.12	82	1037	101.6	-	-
-208.79	84	657	123.8	136	129
-207.86	85	562	127	95	109
-207.25	86	1180	76.2	88	88
-205.45					
-203.61	87	1746	50.8	46	61
-202.29	88	486	152.4	122	122
-201.89	89	743	59.7	128	128
-201.0	90	389	127	149	149
-199.97	91	612	72.5	-	82
-199.4	92	421	146.1	120	43
-198.08	93	289	63.5	162	99
198.08-197.75	94	183	76.2	58	60
-197.23					
-196.7	95	244	57.2	59	50
-196.33	96	829	50.8	45	59
-193.11	98	3227	19.1	73	69
-191.29	99	3131	98.4	115	109
-190.62	100	554	127	115	127
-190.06	101	817	127	102	101
-189.48	102	582	120.7	120	97
-188.12	103	592	123.8	152	97
-188.71	104	785	120.7	102	97
-186.11	105	969	111.1	223	106

CONDITION OF TRACK
(BOSTON - NEW YORK)

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
183.53-183.34	106	900	146.1	167	143
-181.65	107	866	127	112	126
	108	714	82.6	102	93
-180.94	109	581	117.5	96	113
-180.24	110	545	130.2	135	127
	111	848	130.2	135	137
-176.21	112	874	123.8	117	93
-175.57	113	858	127	129	133
172.91-171.58	115	863	127	94	107
-170.76	116	498	79.4	80	68
167.16-166.82	118	812	139.7	124	142
164.51-164.20	120	683	98.4	80	105
163.98-160.25	121	920	114.3	152	153
	122	831	133.4	-	87
-157.60	123	1496	69.9	70	85
-155.46	124	1795	57.2	66	55
-154.62	125	1182	95.3	79	141
-152.69					
-151.69	126	706	152.4	137	168
-149.44	127	939	111.1	101	96
-147.49					
-146.46	128	1887	88.9	90	110
-146.06	129	6984	0	-	-
-145.92	130	4762	12.7	-	-
-140.88	133	1570	108.2	80	80
140.8-140.27	134	732	152.4	150	181
138.27-137.78	137	848	152.4	121	121
-132.30	138	1749	71.9	72	72
-131.66	140	1219	65.8	99	49
-130.87	141	446	125.9	94	94
	142	574	77.2	57	142
-128.47	144	594	136.9	108	133

CONDITION OF TRACK
(BOSTON - NEW YORK)

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
126.56-125.92	145	762	99.1	74	125
-125.13	146	559	136.9	57	132
125.13	147	1323	92.5	96	92
-122.23	148	602	105.4	55	99
118.51	149	380	86.9	65	84
	150	419	81.8	61	80
	151	474	78.2	58	80
-117.81	152	945	40.9	30	30
116.49-116.33					
116.33-115.89	153	788	19.1	-	-
-114.33	154	534	57.2	-	-
-112.64	155	1475	57.2	-	-
-111.85	156	911	114.3	-	-
-102.57	161	927	95.3	-	-
-100.57	162	1080	108	-	-
-99.80	163	1871	69.9	-	-
-97.82	164	1435	88.9	-	-
-97.44	165	4762	12.7	-	-
-96.02	168	927	127	-	-
-93.94	169	5238	12.7	-	-
-92.77	170	1069	139.7	-	-
92.77 -90.98					
90.98 -89.99	171	355	152.4	-	-
-89.13	172	582	63.5	-	-
-87.85	173	389	152.4	-	-
-85.29					
-84.48	175	743	127	-	-
-80.03					
-79.11	178	806	114.3	-	-
-75.71	180	1204	114.3	-	-
-73.32	181	1541	82.6	-	-
-67.36					

CONDITION OF TRACK
(BOSTON - NEW YORK)

KILOPOST LOCATION	CURVE	RADIUS OF CRUVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
67.36--66.88	185	893	133.4	-	-
-66.11	186	429	76.2	-	-
-64.89	187	852	127	-	-
-63.34	188	873	139.7	-	-
-60.65					
60.65 -	191	1069	108	-	-
-59.32	192	788	152.4	-	-
-55.78	193	852	139.7	-	-
55.36 -54.19	194	845	146.1	-	-
-53.25	195	961	133.4	-	-
-52.05	196	873	127	-	-
-50.87	197	1190	101.6	-	-
-48.72					
-47.73	199	895	108	-	-
-47.09	200	903	127	-	-
-43.01	203	873	127	-	-
-42.49	204	873	139.7	-	-
-42.10	205	733	133.4	-	-
-41.17	206	569	114.3	-	-
-39.05	207	888	127	-	-
-38.77	208	602	139.7	-	-
-35.68	209	873	133.4	-	-
-34.75	210	961	114.3	-	-
-34.23	211	1475	82.3	-	-
-28.3					
28.3 -26.74	213	1048	101.6	-	-
26.74 -	214	651	76.2	-	-
-26.22	215	398	57.2	-	--
29.95 -28.65	216	1230	57.2	46	46
-25.48					

CONDITION OF TRACK
(BOSTON - NEW YORK)

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
25.48 -	218	699	111	83	83
-24.93	219	536	82.6	62	62
24.93 -	220	554	69.9	77	58
-24.34	221	721	79.4	65	71
-20.78					
20.78 -19.16	222	2238	44.5	113	92
-18.05	224	690	146.1	115	115
-17.39	225	569	60.3	60	60
-16.73	226	577	85.7	30	65
-15.60	228	889	95.3	71	71
-13.93	229	1529	60.3	221	47
-13.45	230	409	79.4	58	58
-11.27	232	553	63.5	48	48
- 8.81					
8.81 -	234	496	82.6	60	60
- 8.04	235	471	57.2	43	77
- 7.09					
7.09 - 0.48	236	2328	25.4	-	-
0.48 - 0					

CONDITION OF TRACK
(NEW YORK - WASHINGTON)

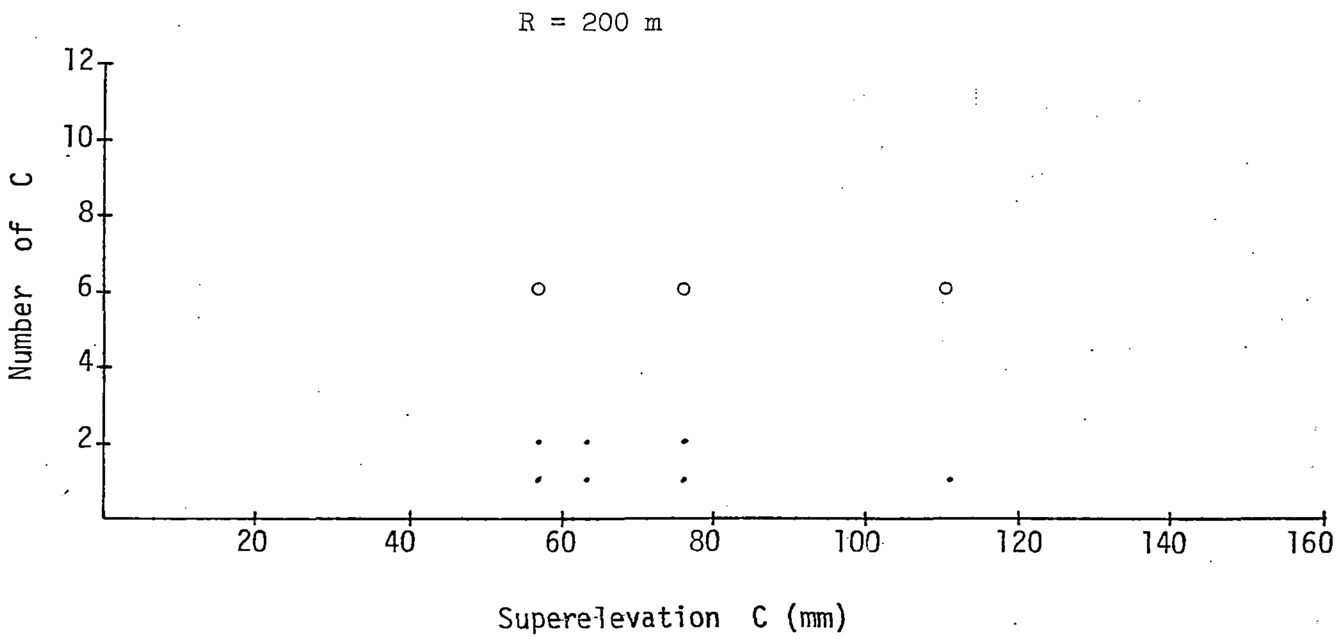
KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
0.00 - 1.15					
- 4.48					
4.84 - 5.93	240	919	76.2	57	57
12.52 - 12.92	243	551	101.6	76	76
- 13.46					
- 13.51					
- 14.48					
- 15.04	248	1732	34.9	36	25
- 17.15	249	1757	69.9	-	-
- 22.44	252	883	104.8	78	91
- 23.81	253	1397	79.4	38	41
- 32.74					
- 33.61	259	3457	82.6	82	-
- 35.07	261	2439	111.1	111	111
- 35.62	262	1343	117.5	117	117
- 37.32					
- 37.94					
- 38.69	265	3871	133.5	111	111
- 39.71	266	1143	146.1	126	134
- 42.31	267	1448	117.5	128	157
- 43.04	268	884	152.4	169	178
- 43.89	269	1145	152.4	178	194
- 44.71	270	2084	108	161	161
- 90.34					
- 90.77					
- 91.47					
-119.95					
-120.96	291	1089	152.4	123	120
-130.02					
-130.99	297	959	50.8	155	61
-131.74	298	437	152.4	129	82
-134.28					

CONDITIONS OF TRACK
(NEW YORK - WASHINGTON)

KILOPOST LOCATION (Km)	CURVE NO.	RADIUS OF CURVE R(m)	SUPER-ELEVATION C(mm)	LENGTH OF TRANSITION CURVE LS1(m)	LS2(m)
134.28-136.34	299	683	149.2	112	85
-136.92					
-137.00					
-137.68	302	836	57.2	80	50
-140.19	303	344	104.8	36	36
-144.16					
-145.18					
3.00- 3.41	304	425	88.9	-	-
- 4.68	306	695	66.7	91	91
- 4.95	307	1397	108	112	80
- 8.52	308	1650	47.6	36	61
- 11.1	309	1743	54	40	40
- 11.81	311	1746	50.8	38	38
- 14.99					
- 17.95	312	1646	152.4	183	174
- 28.72					
- 32.08	319	1713	139.7	152	152
- 35.09					
- 36.73	323	2183	114.3	126	126
- 38.45	324	1134	146.1	152	122
- 41.97					
41.97-	327	579	28.6	122	61
- 43.12	328	438	31.8	32	97
- 44.44					
- 48.22					
- 49.07					
- 95.57					
- 97.82					
-103.82					
-105.42	351	1744	130.2	132	132
-115.71					
-116.65					

CONDITIONS OF TRACK
(NEW YORK - WASHINGTON)

KILOPOST LOCATION	CURVE	RADIUS OF CURVE	SUPER-ELEVATION	LENGTH OF TRANSITION CURVE	
(Km)	NO.	R(m)	C(mm)	LS1(m)	LS2(m)
116.65-125.16					
-126.29	357	1485	152.4	245	152
-127.91					
-139.14					
-142.45	361	2590	104.8	-	156
-147.65	371	1397	50.8	58	58
-148.89	372	1035	66.7	30	30
-150.84	373	872	76.2	76	76
-151.4	374	430	108	99	80
-153.12					
-153.98					
-154.62					
154.62-	375	388	123.8	170	198
	376	355	69.9	-	-
-157.85	380	466	57.2	-	-
-158.82	381	457	127	99	116
158.82-	382	884	152.4	122	122
-161.04	383	1352	88.9	91	91
-202.23					
-215.61					
-216.73					
-217.22	415	556	74.9	38	80
-218.82					



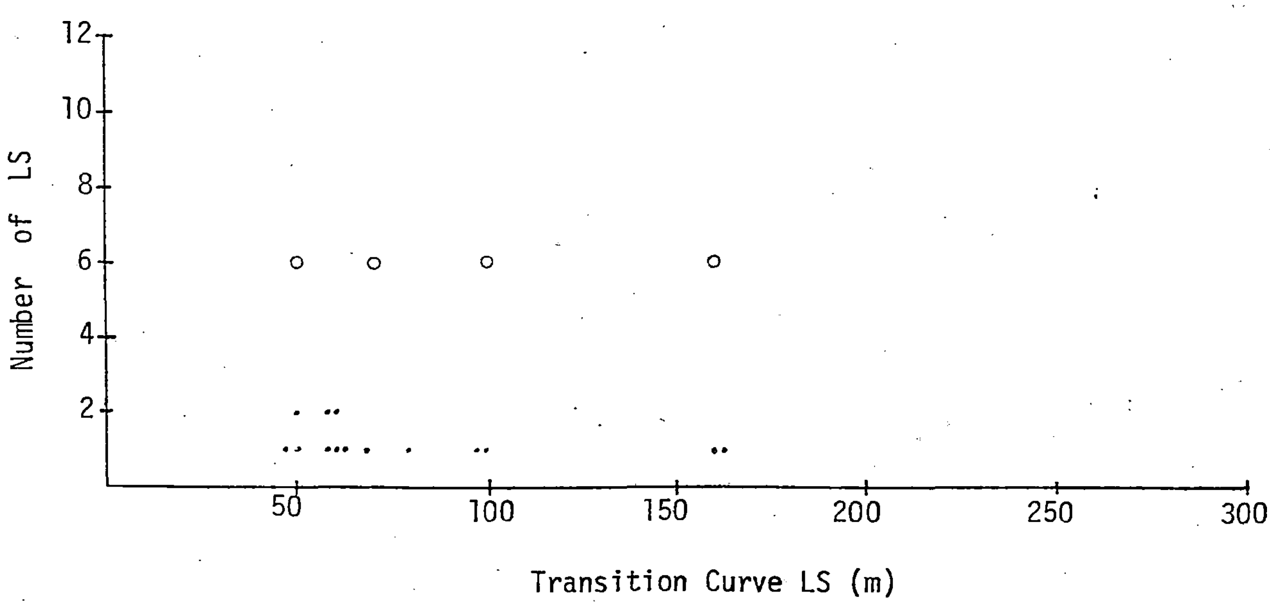
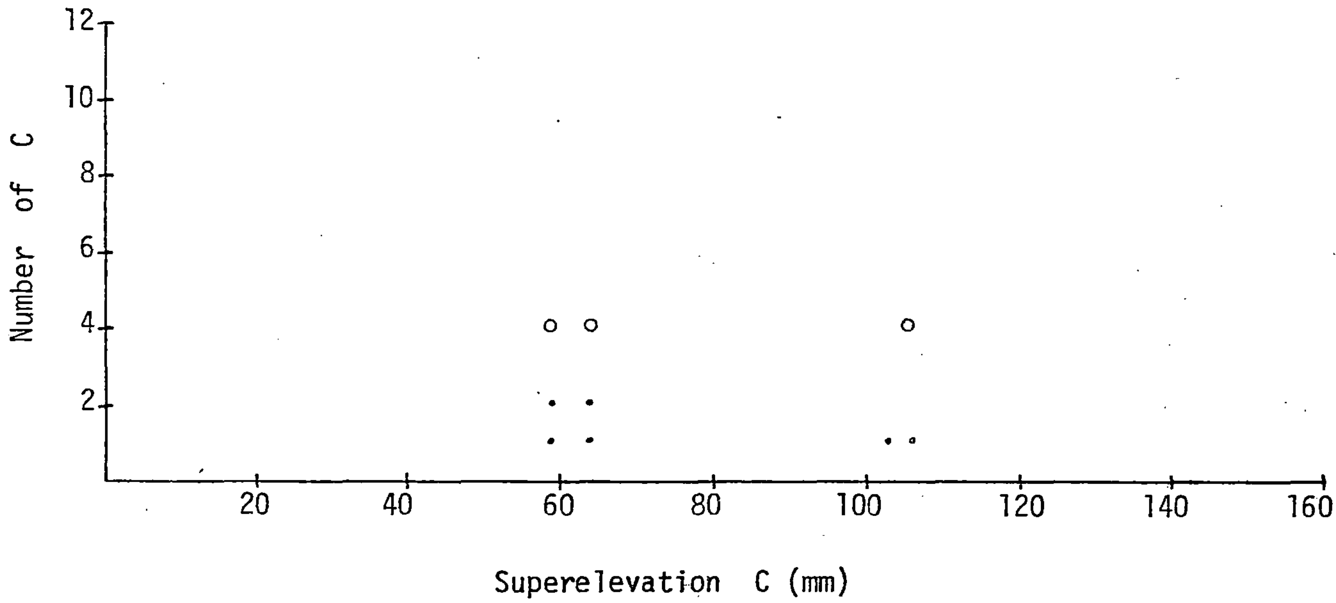
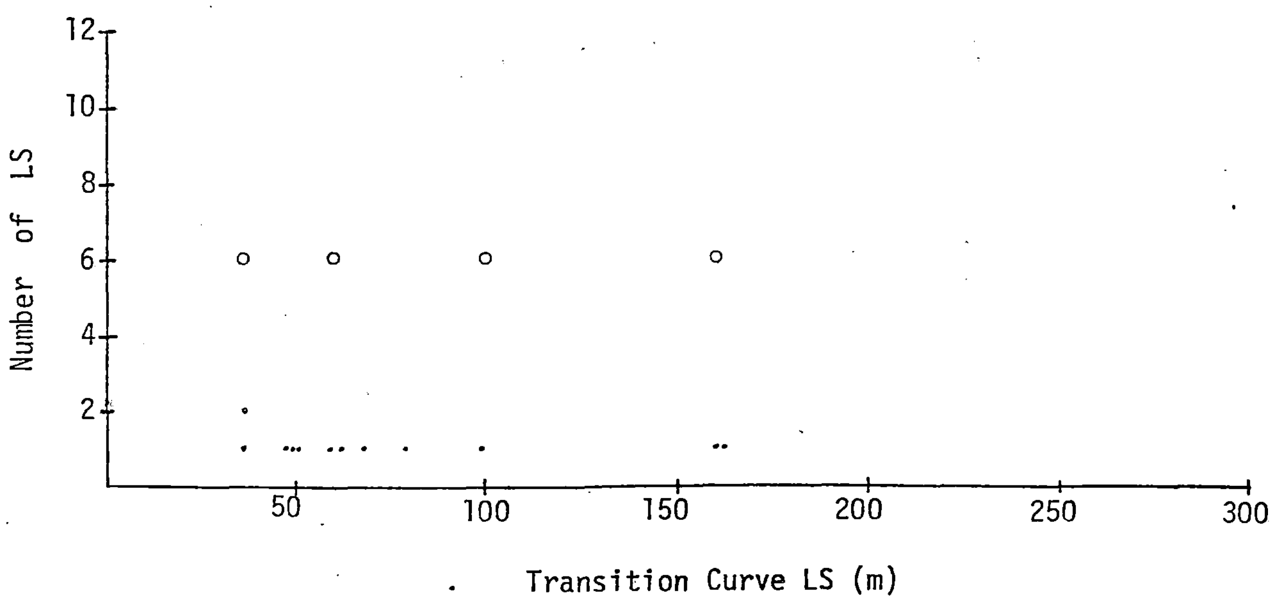


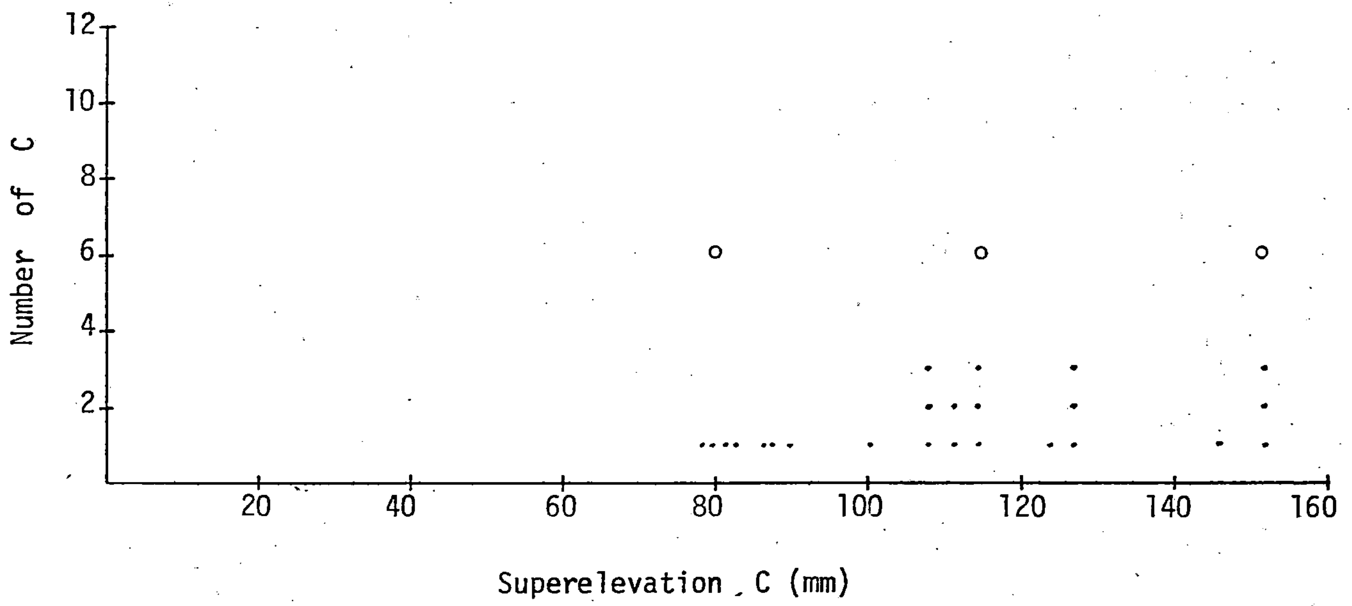
Figure 7.4 Data of Existing Track

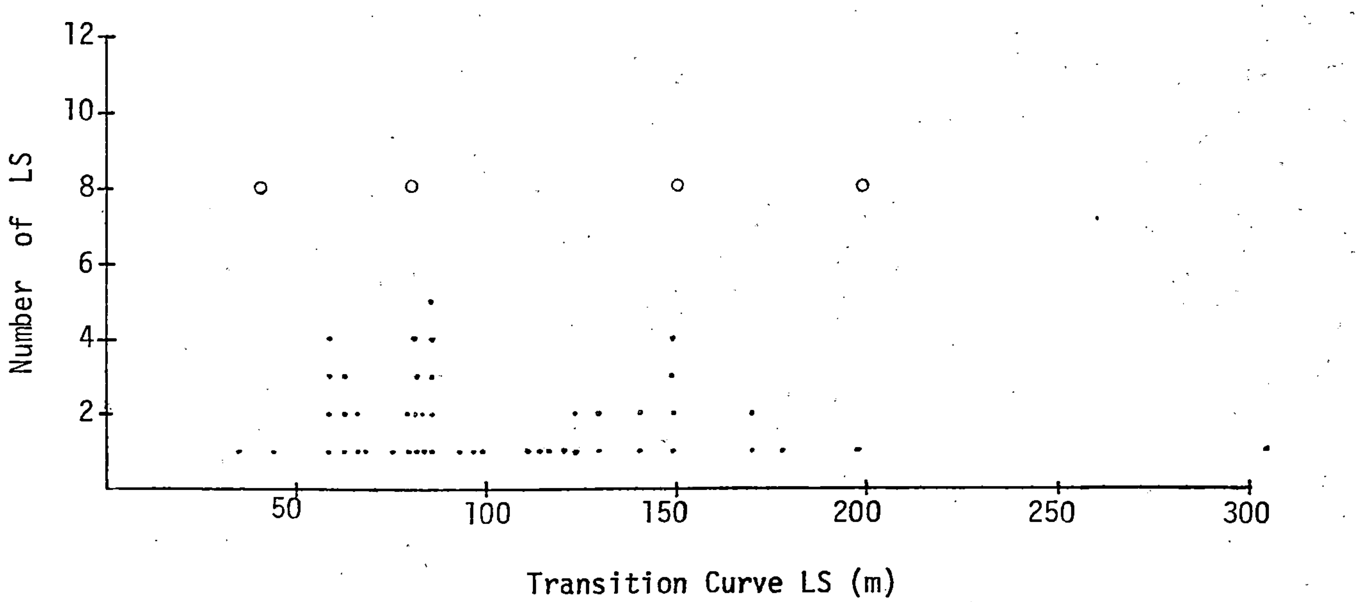
R = 300 m


Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)

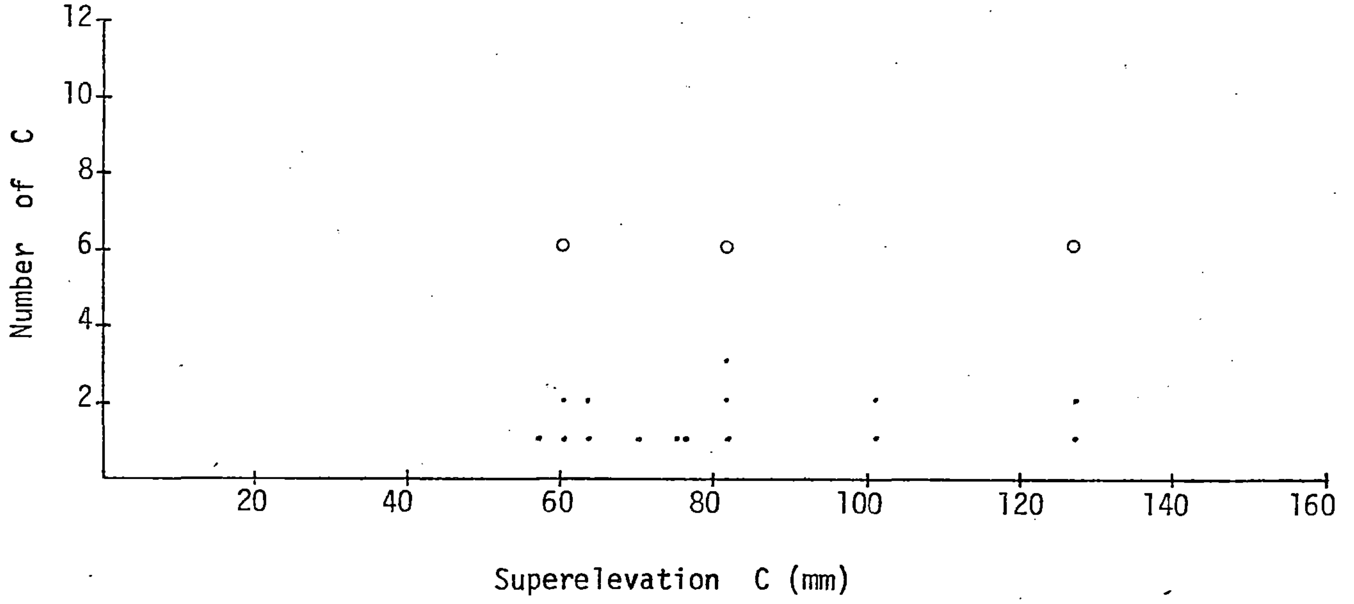

Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

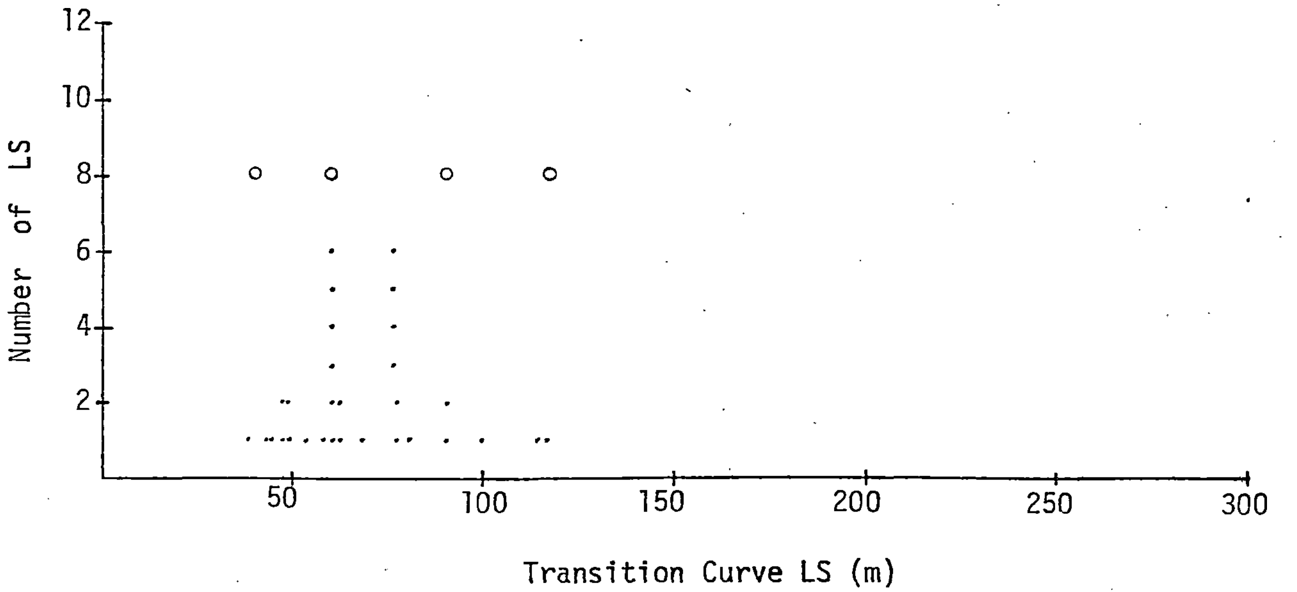
R = 400 m

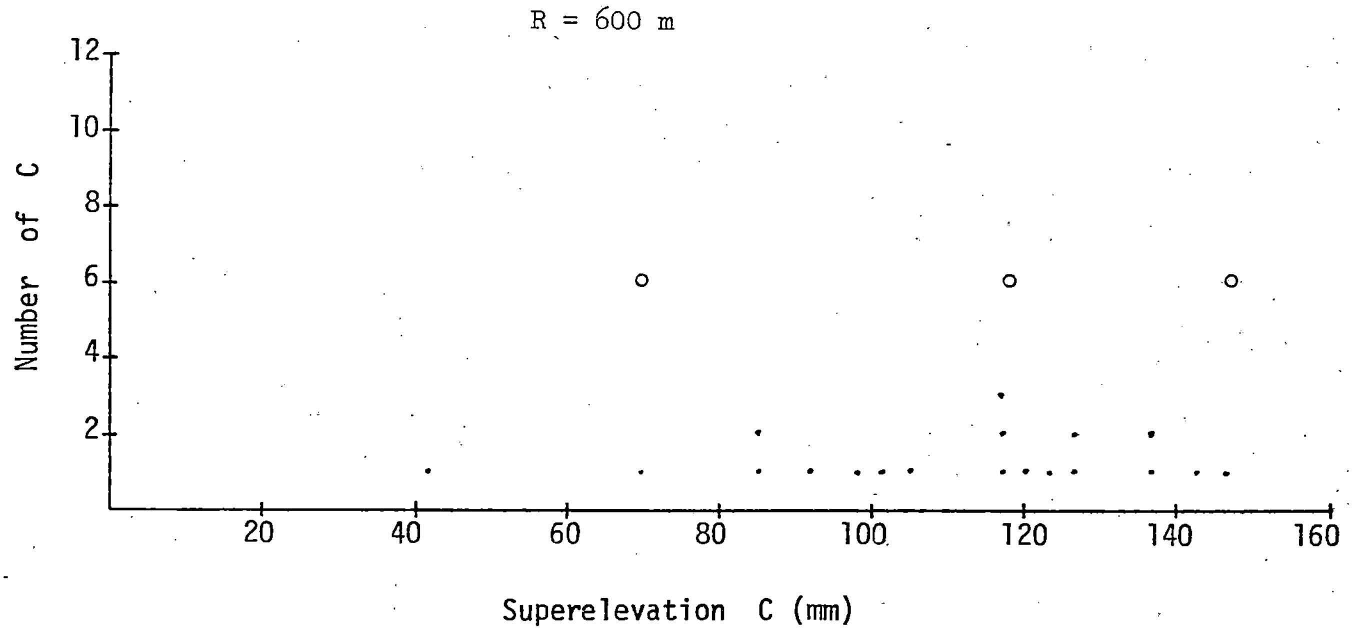

12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation , C (mm)

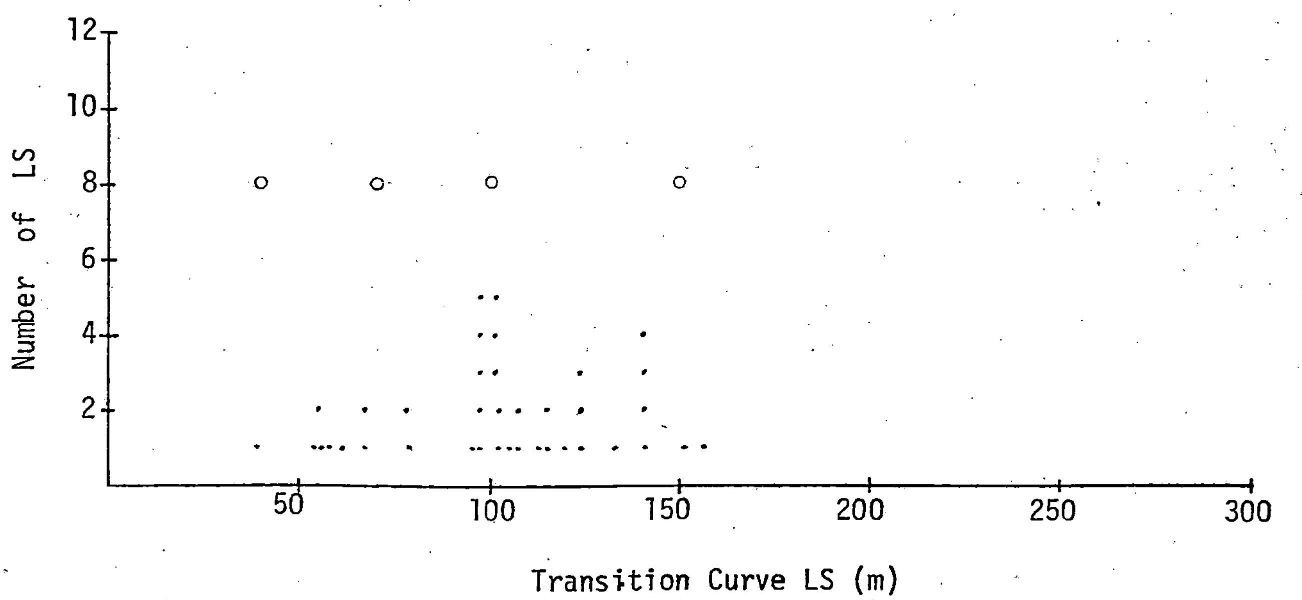

12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)

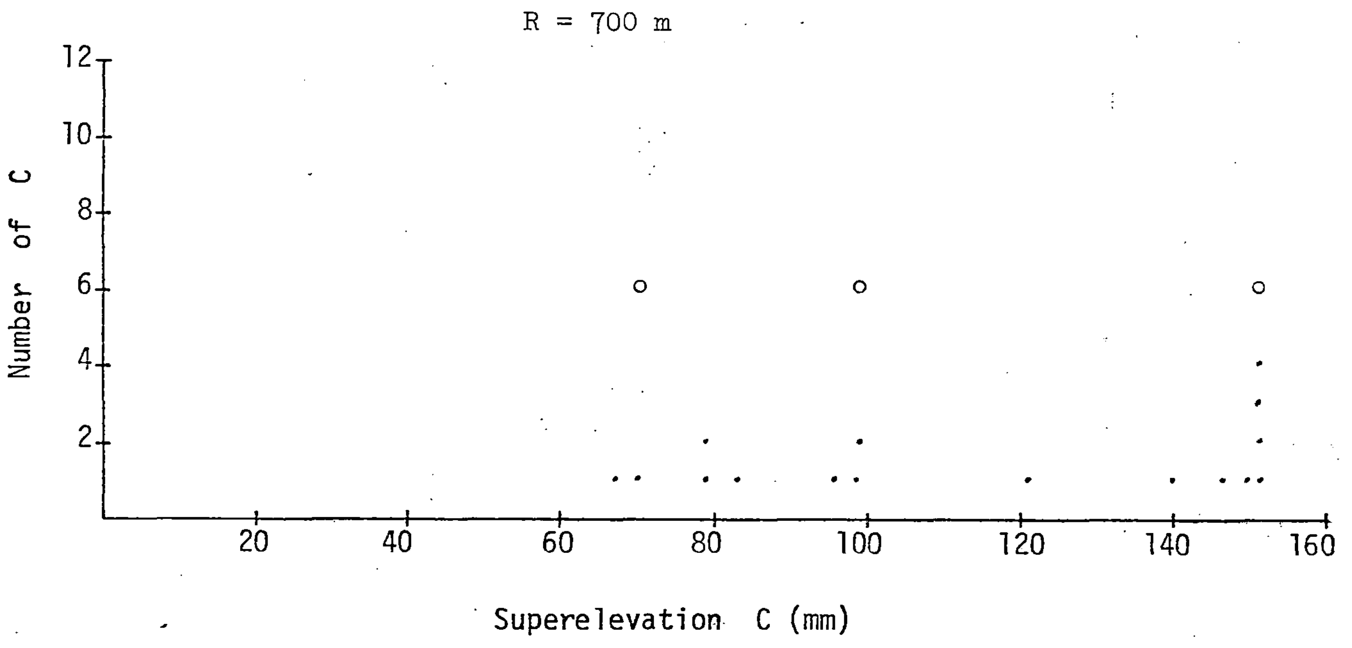
R = 500 m


12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)

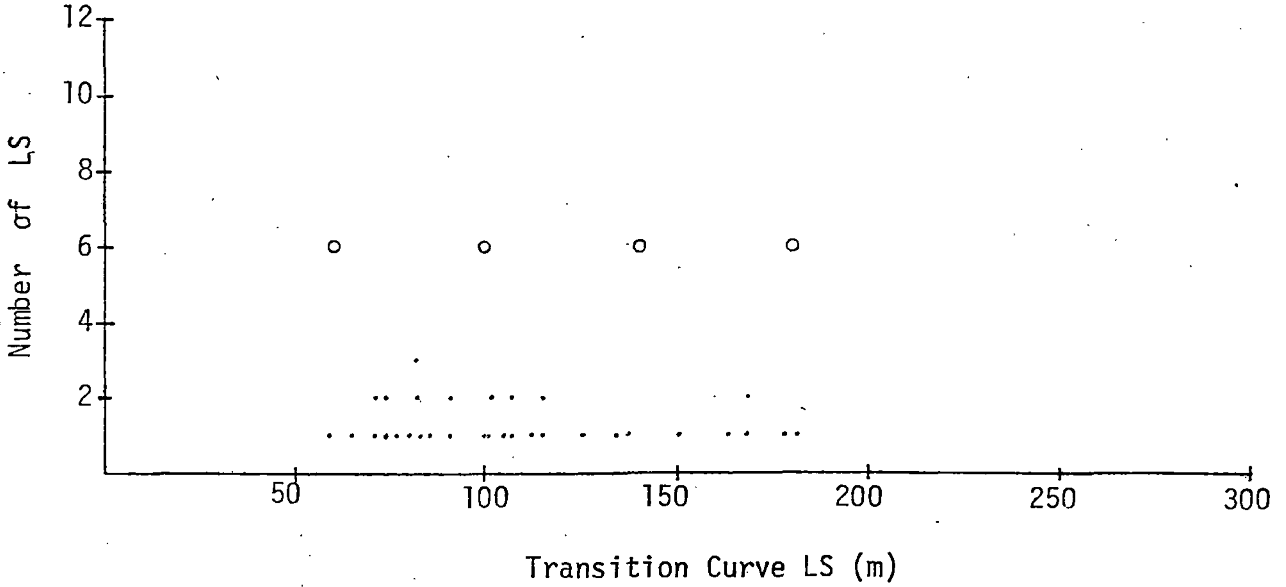

12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)


R = 600 m
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)


Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

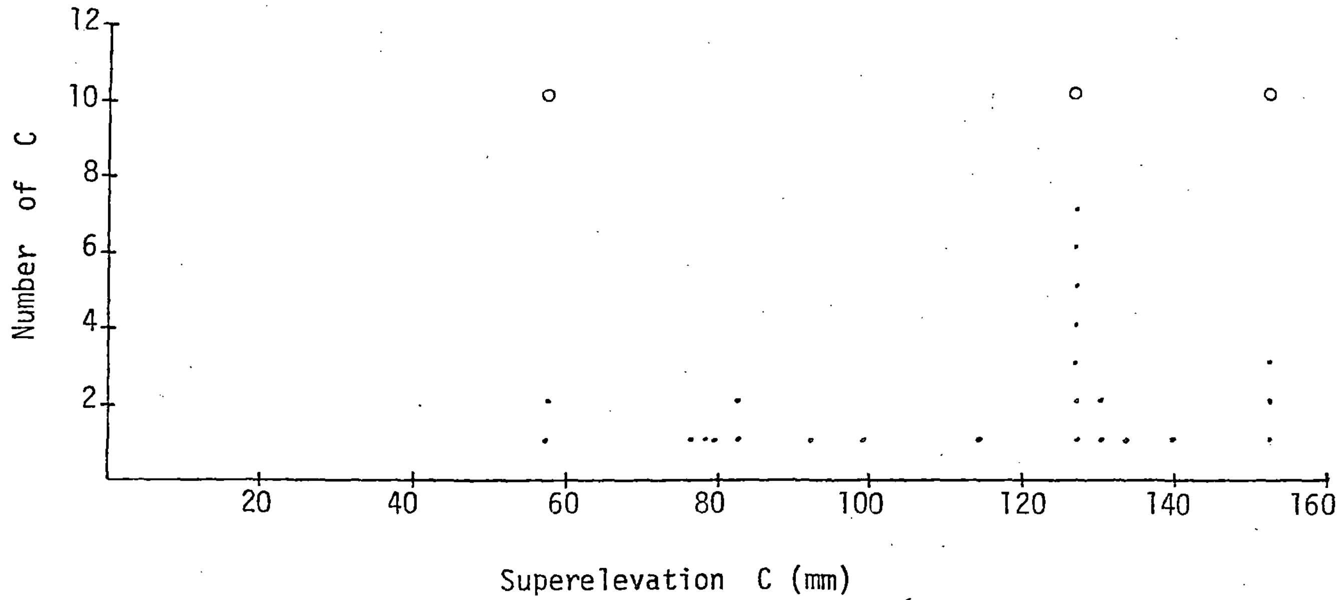


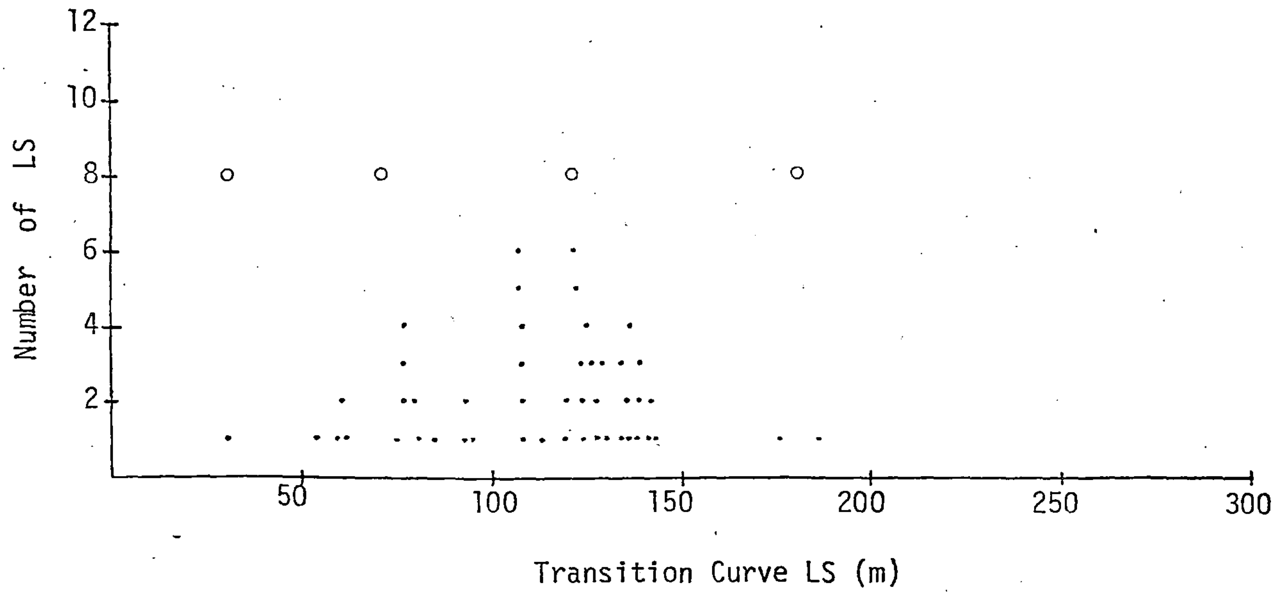
R = 700 m
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)

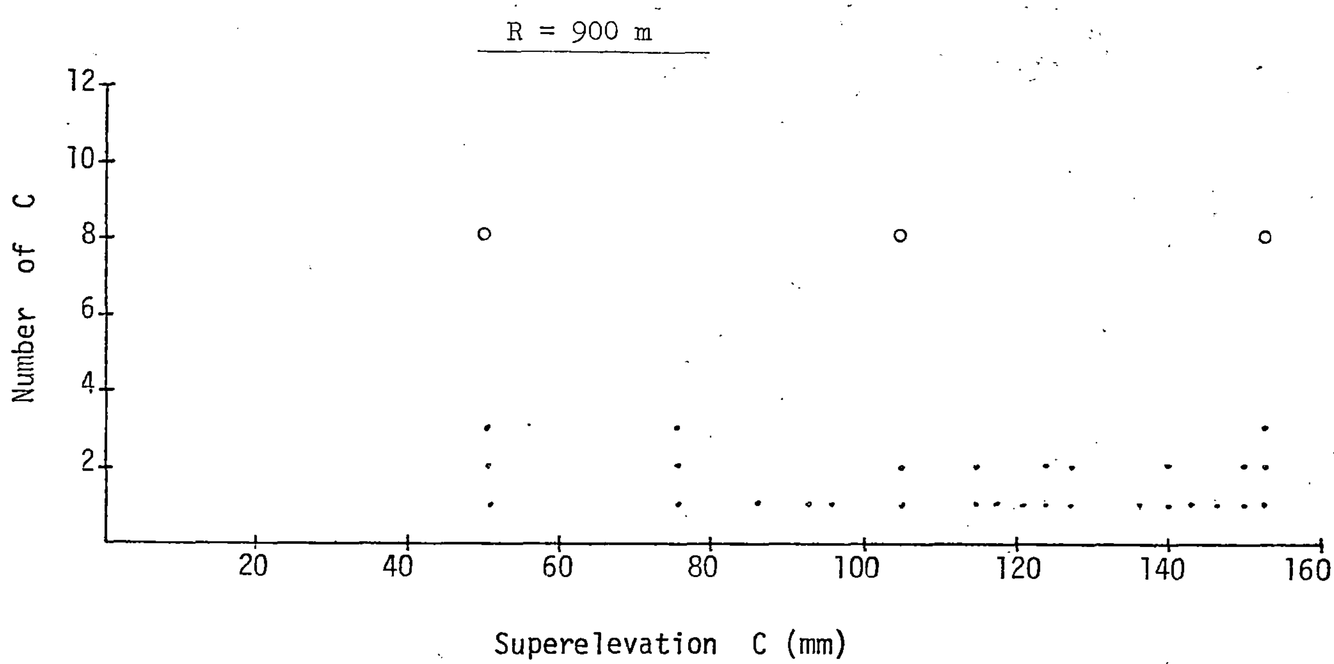


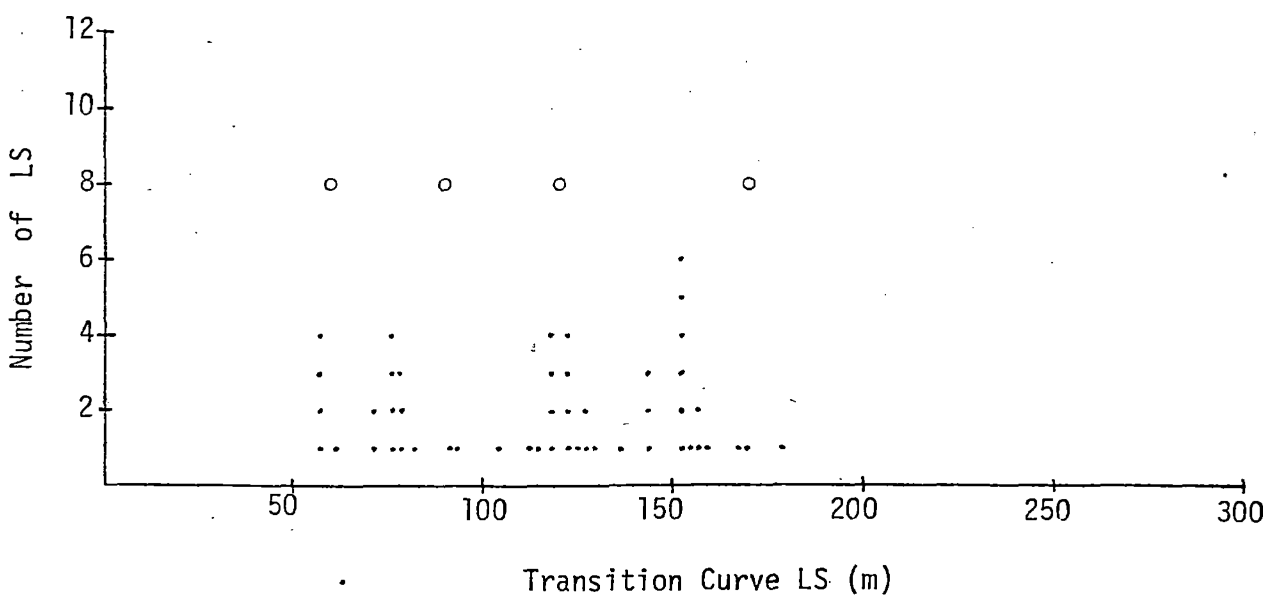
Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

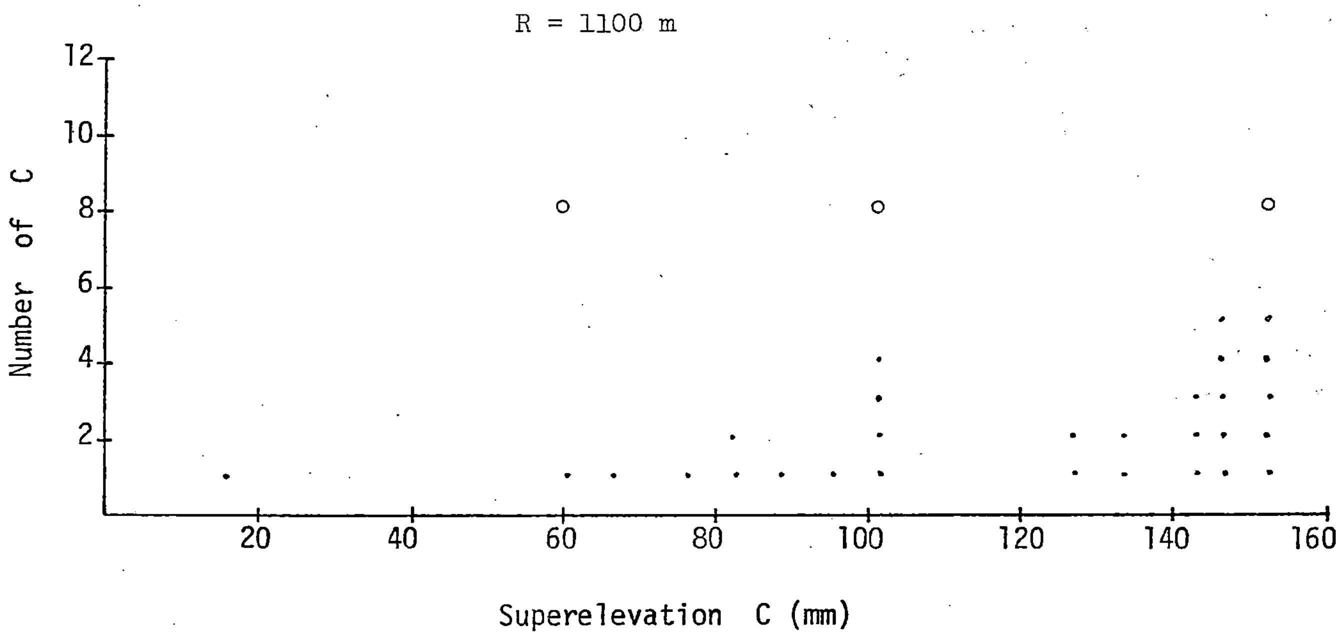
R = 800 m


12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)

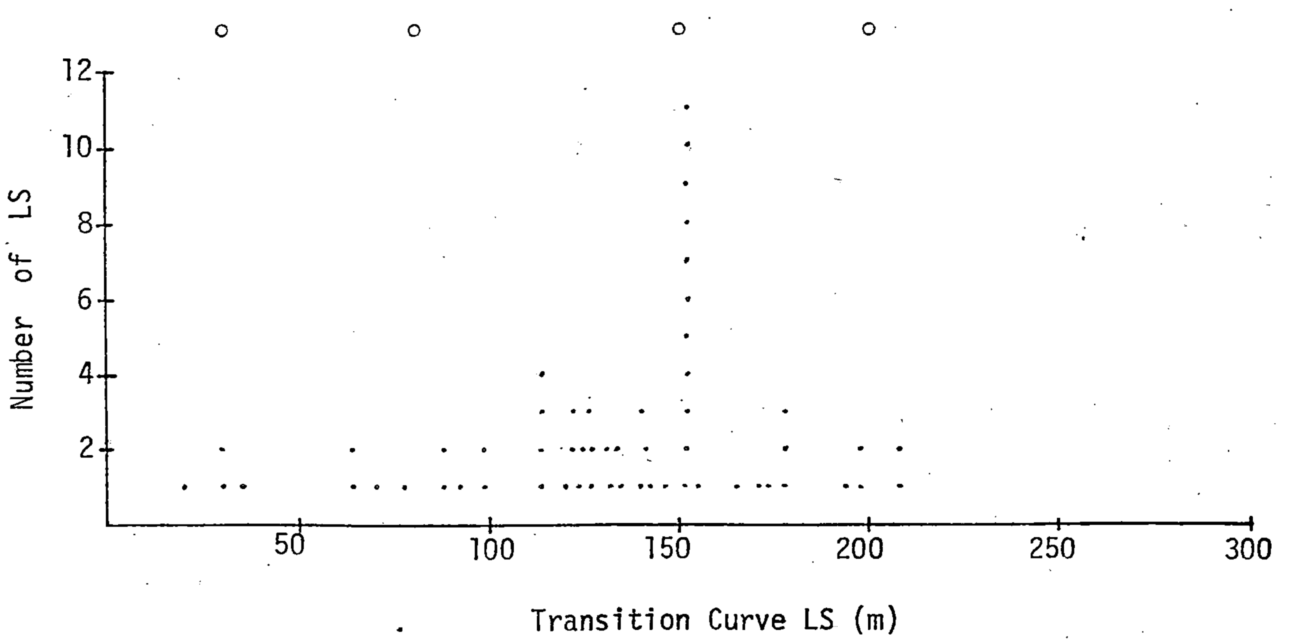

12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)


R = 900 m
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)

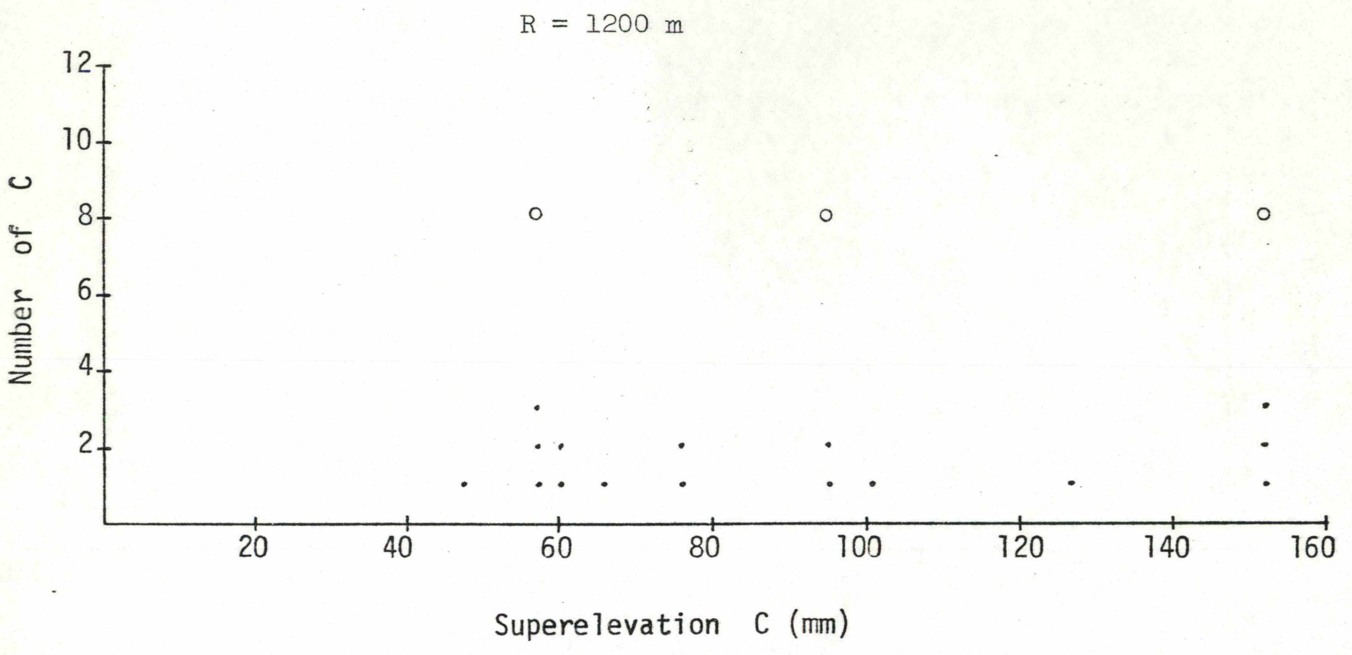

Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

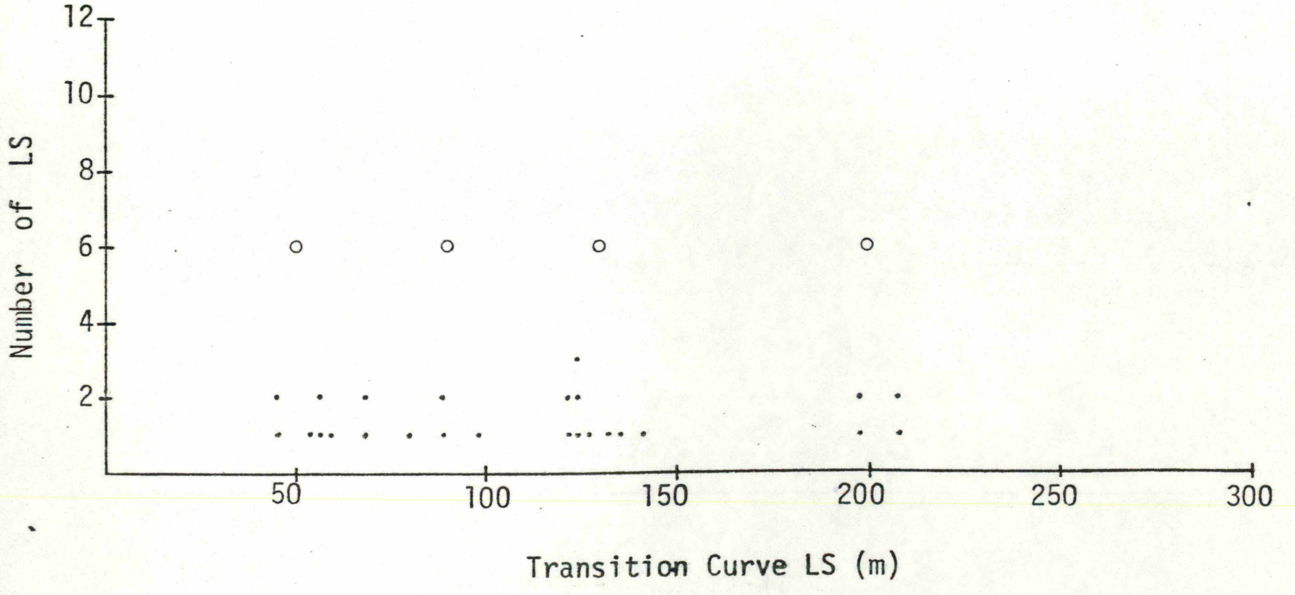


R = 1100 m
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)

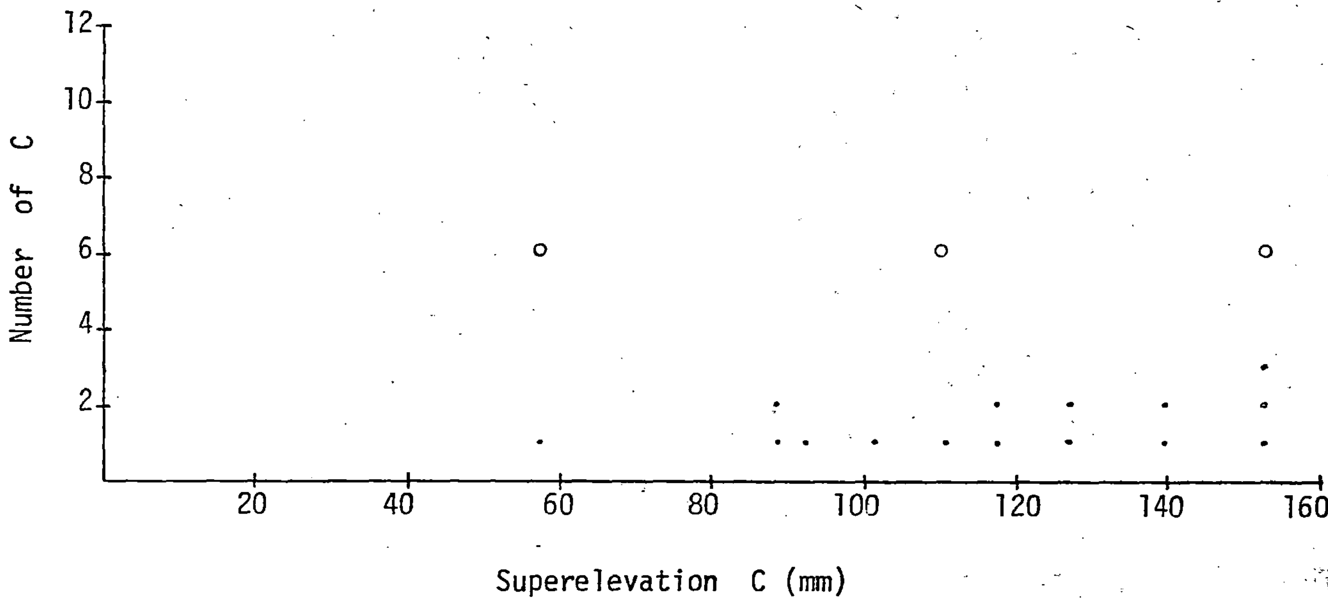


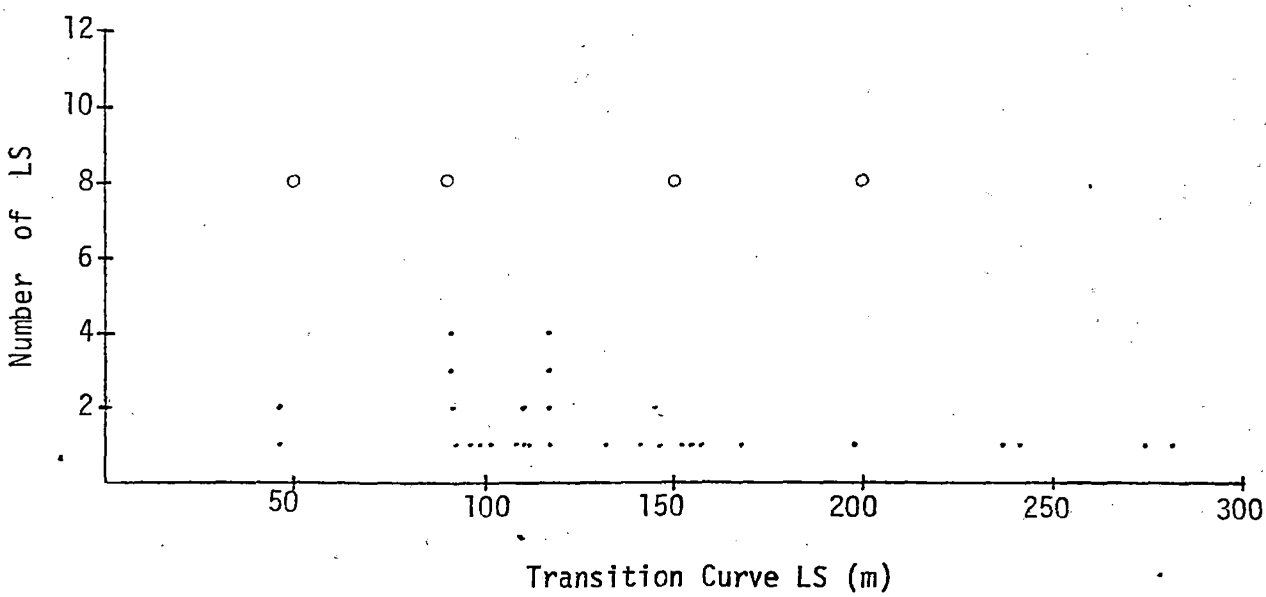
Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)


R = 1200 m
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)

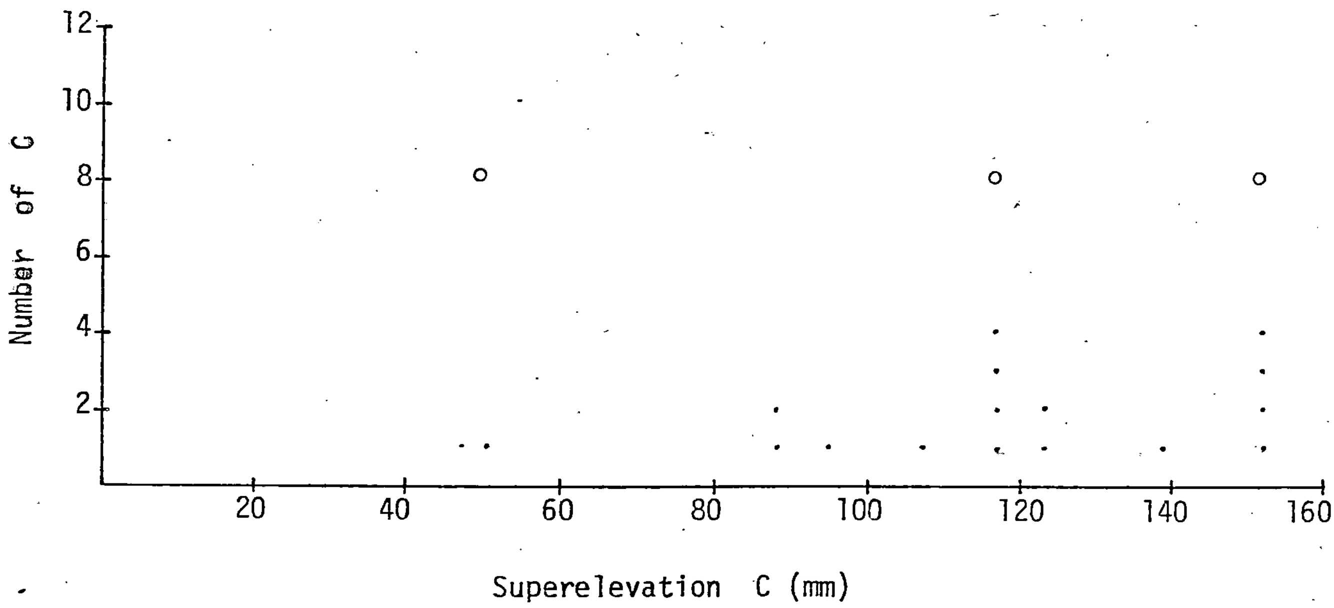

Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

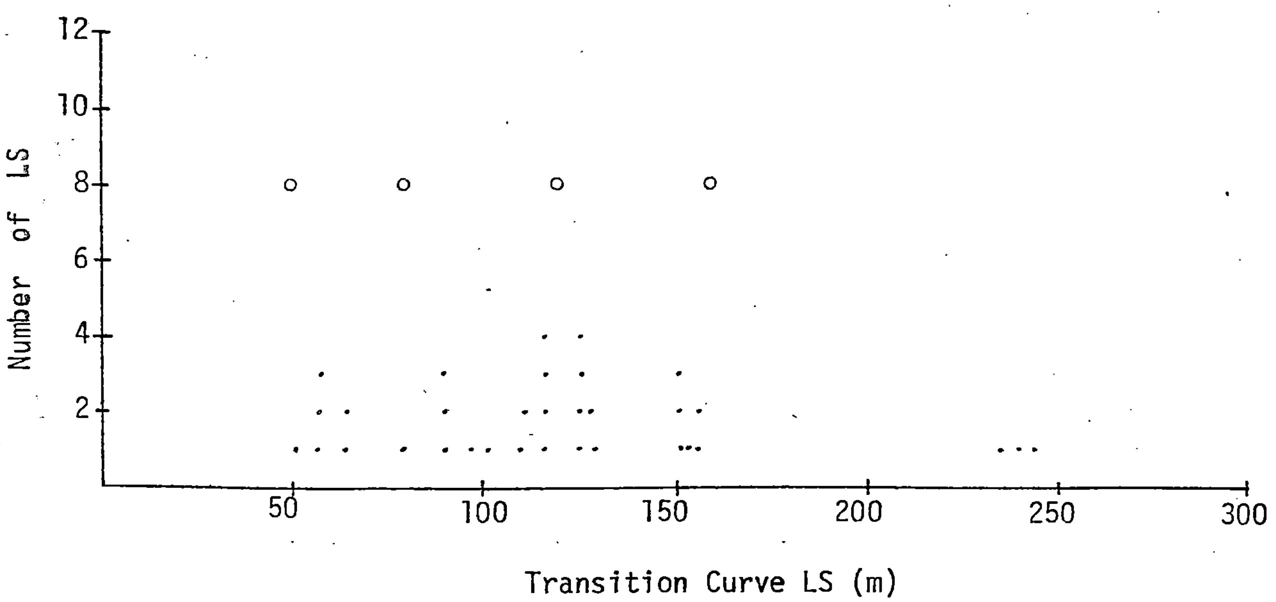
R = 1300 m


12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)

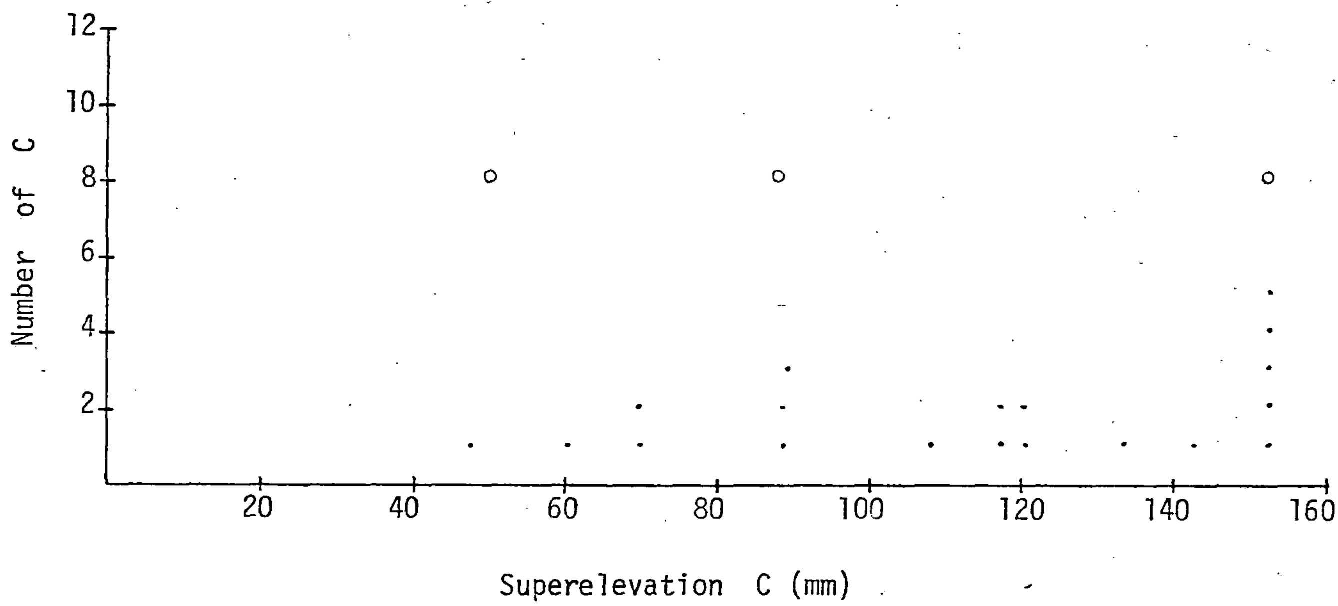

12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)

R = 1400 m

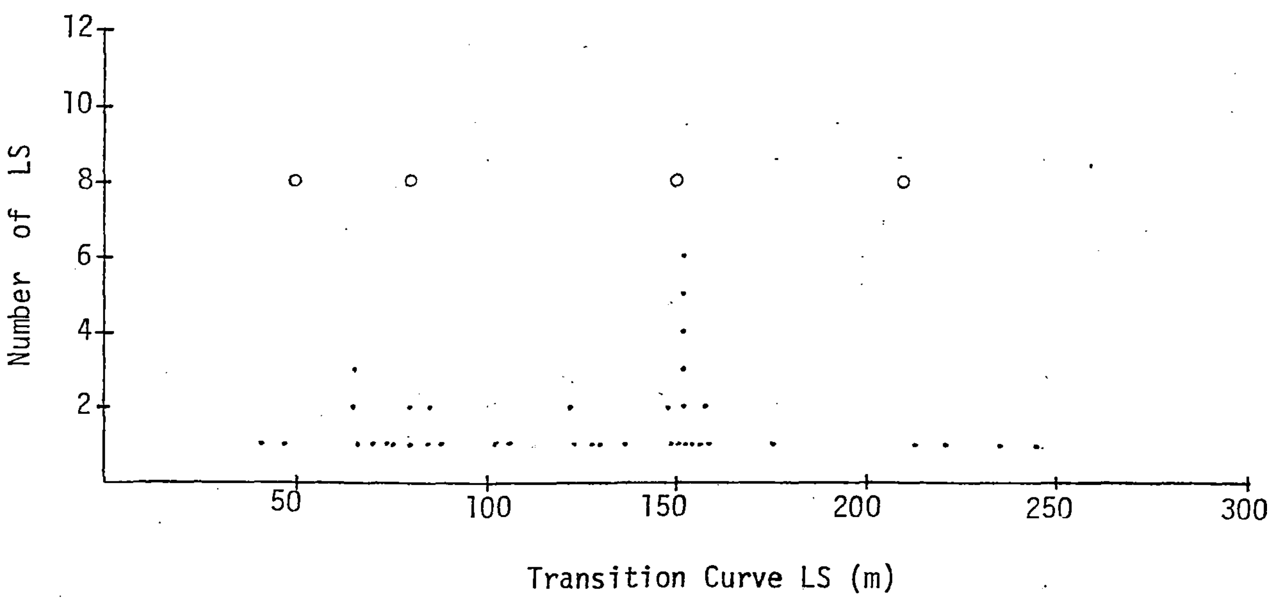

12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)


12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)

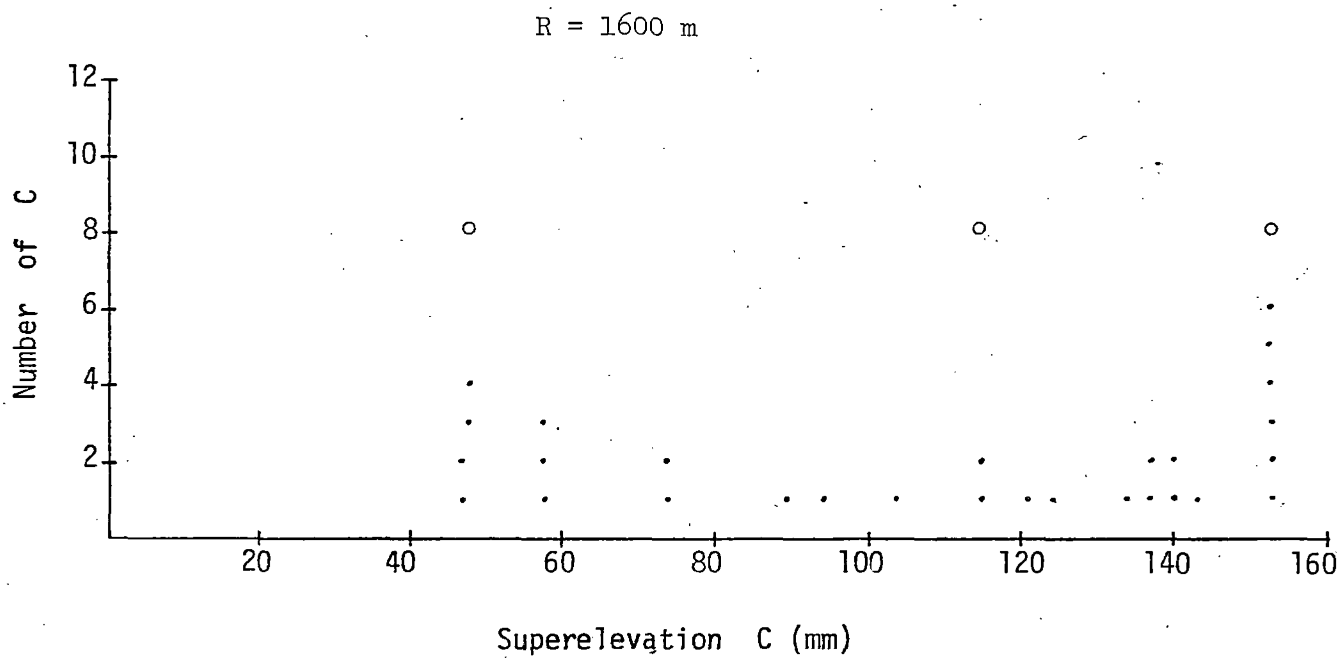
R = 1500 m

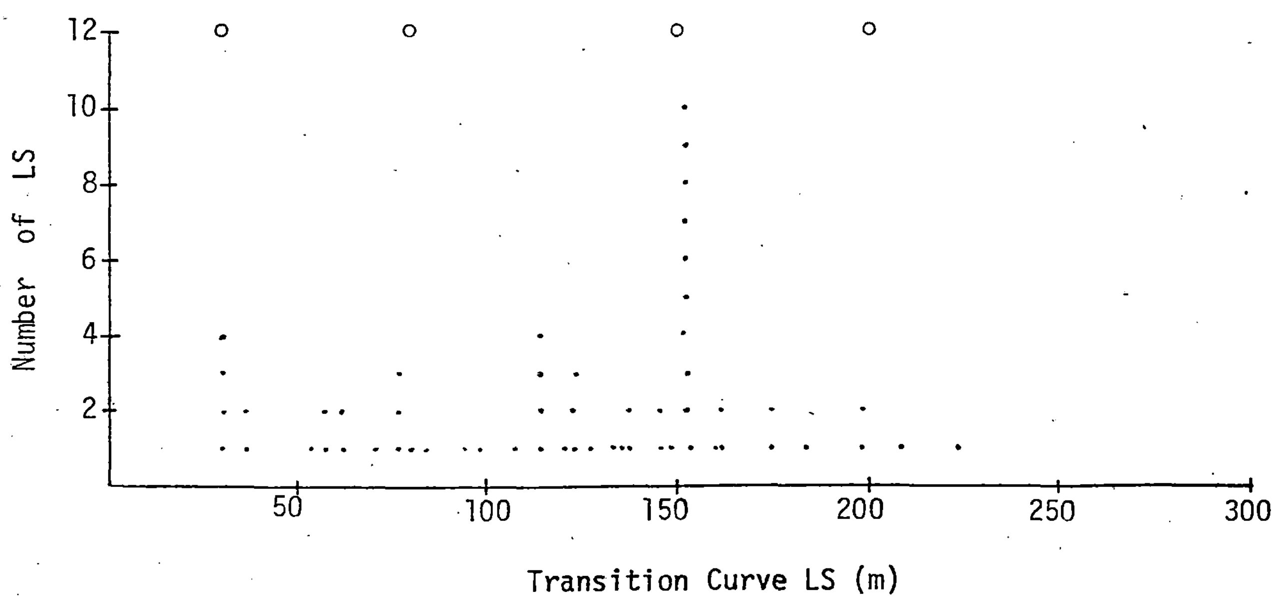


Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)

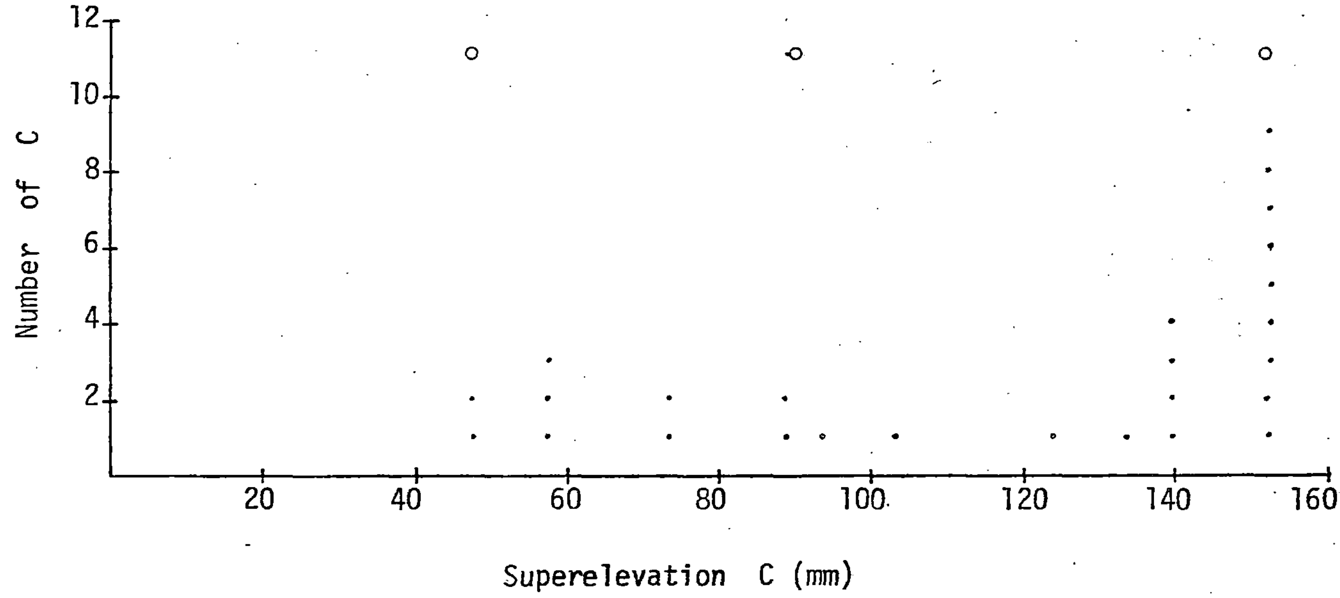


Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

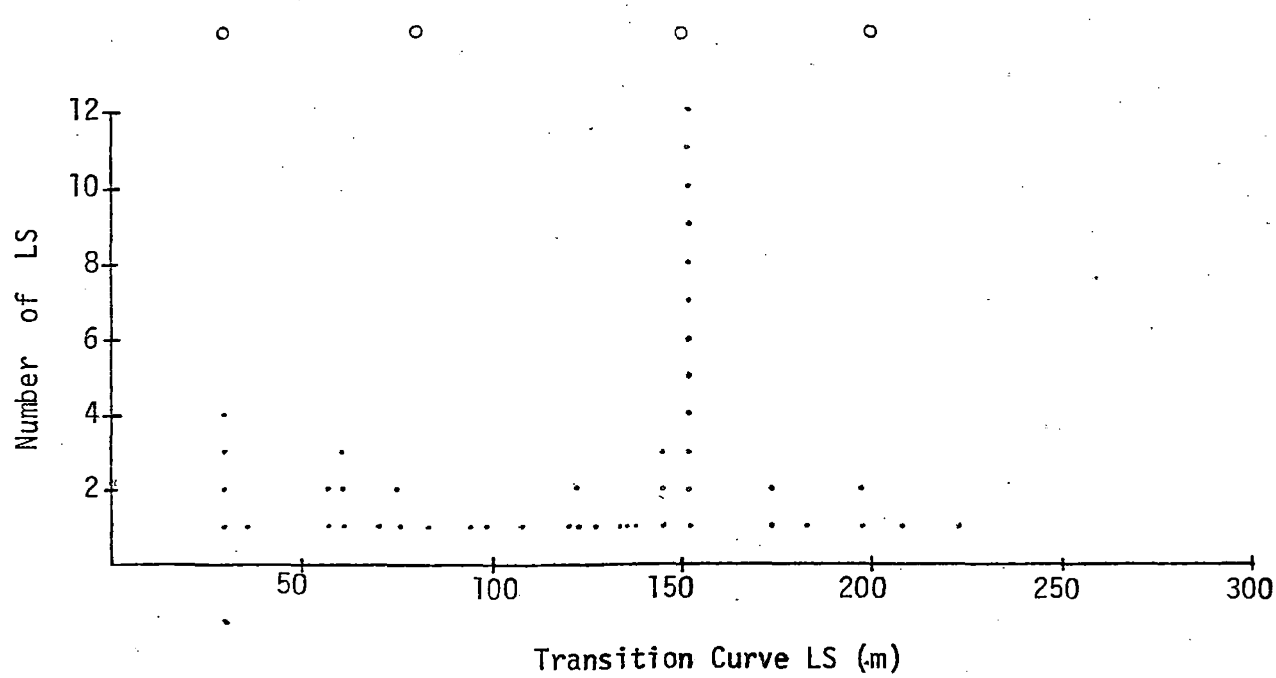

R = 1600 m
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)


Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

R = 1700 m

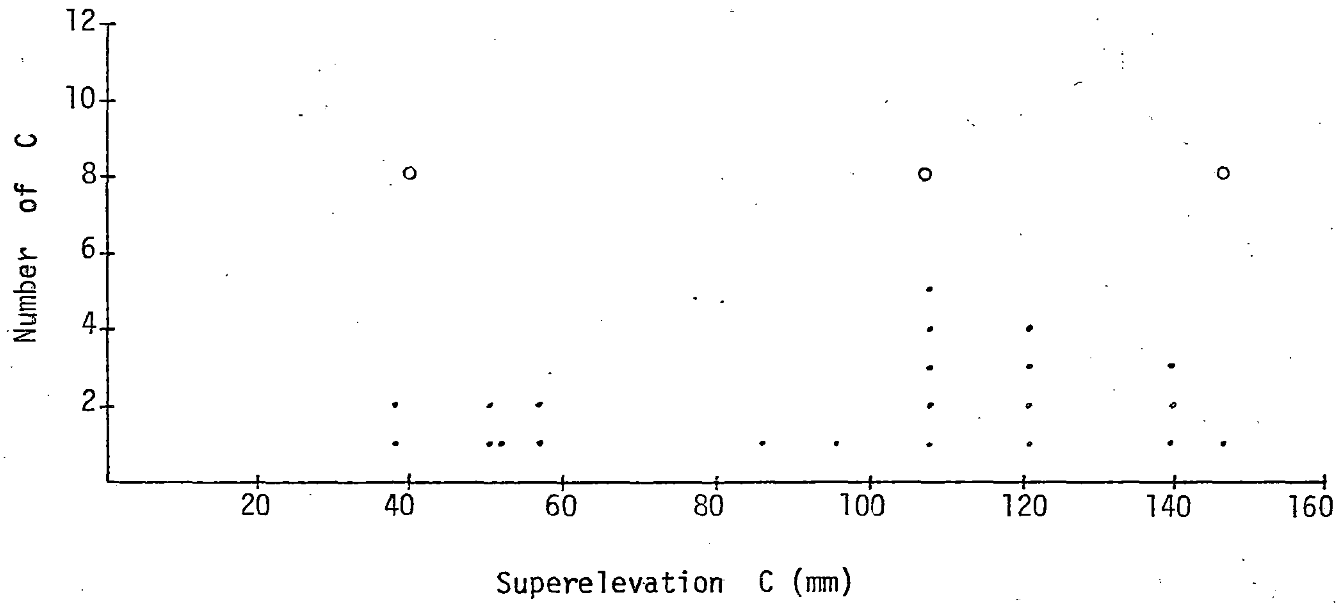


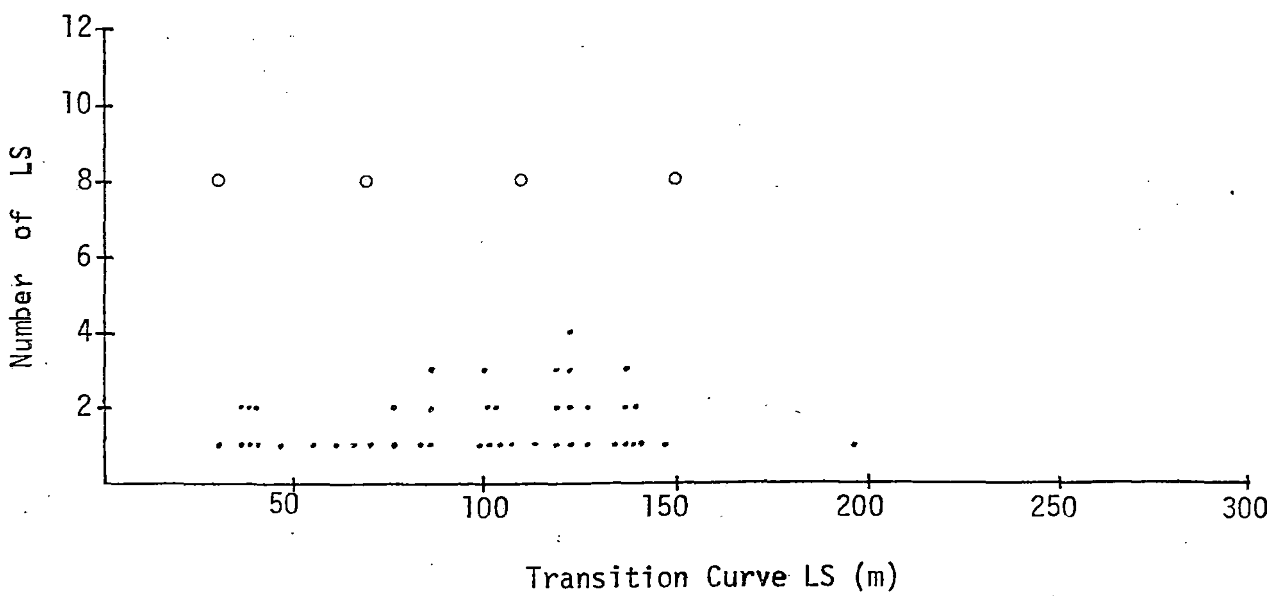
Number of C
12
10
8
6
4
2
20
40
60
80
100
120
140
160
Superelevation C (mm)



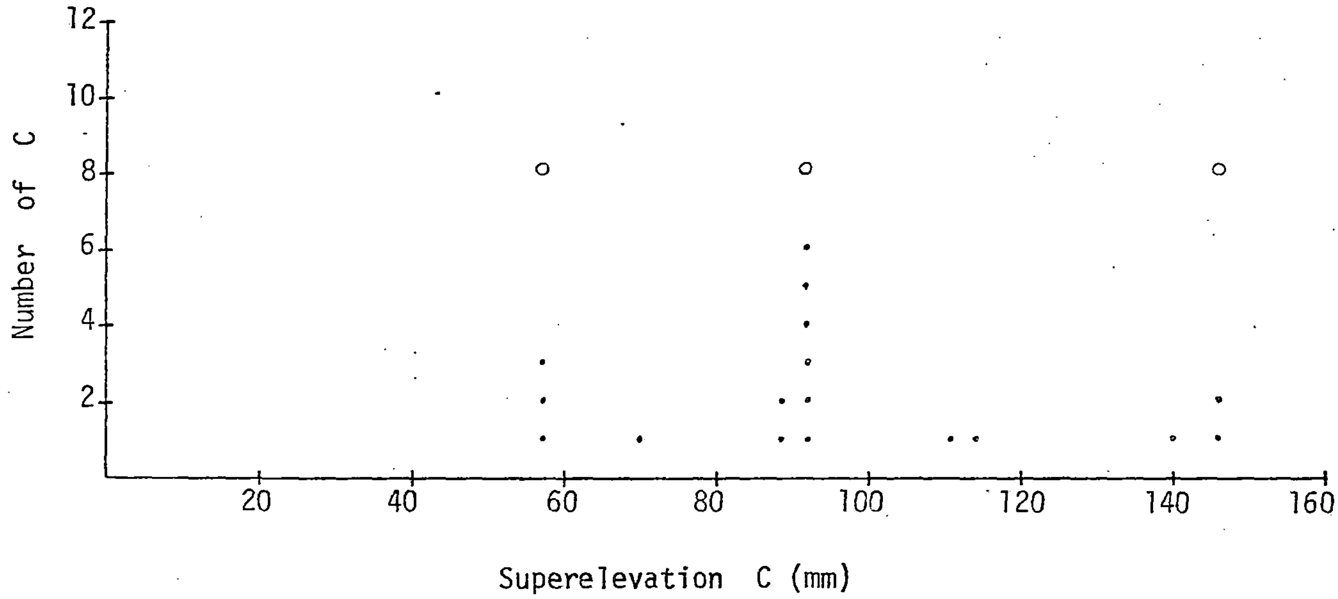
Number of LS
12
10
8
6
4
2
50
100
150
200
250
300
Transition Curve LS (m)

R = 1750 m

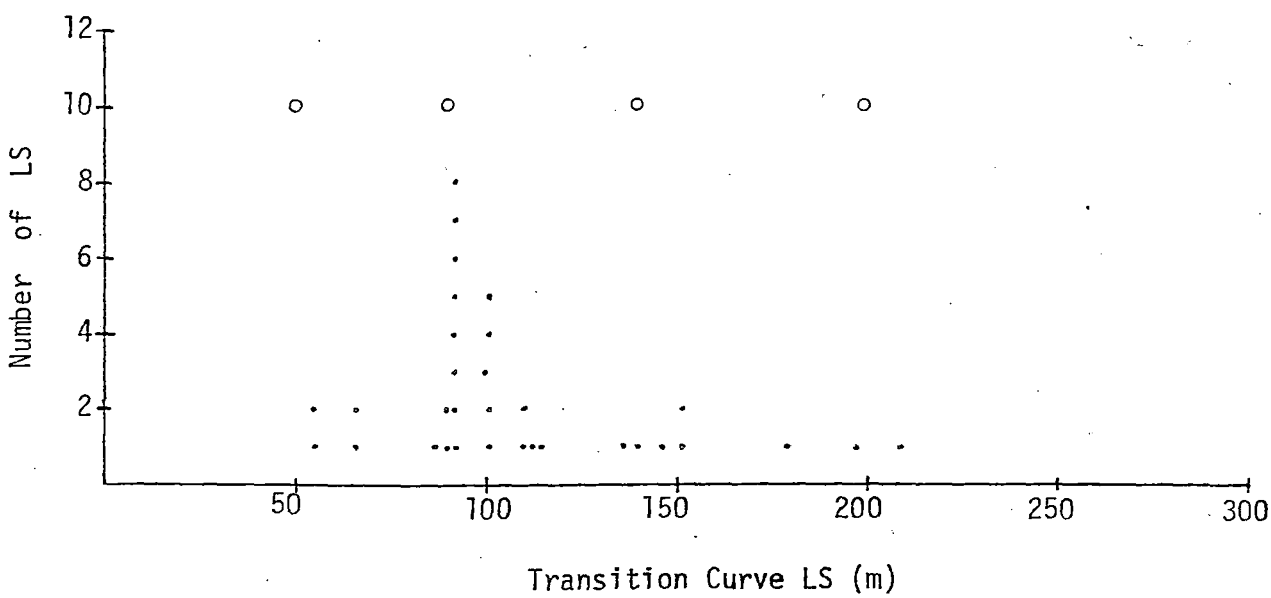

12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)


12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)

R = 1800 m

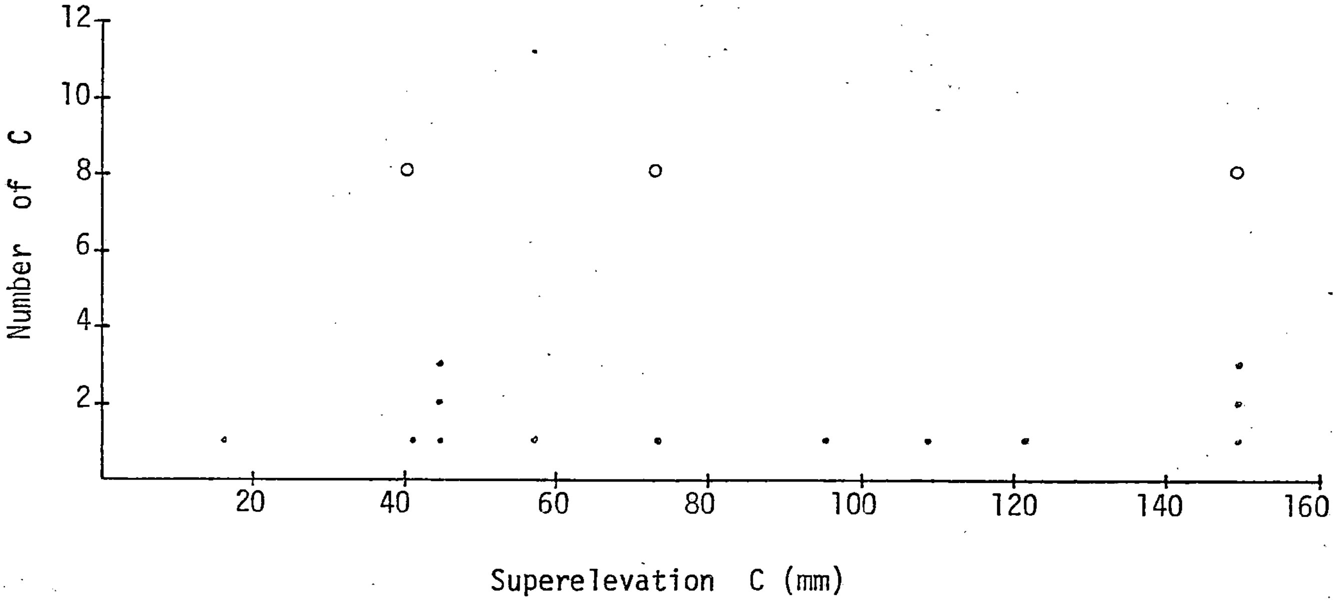


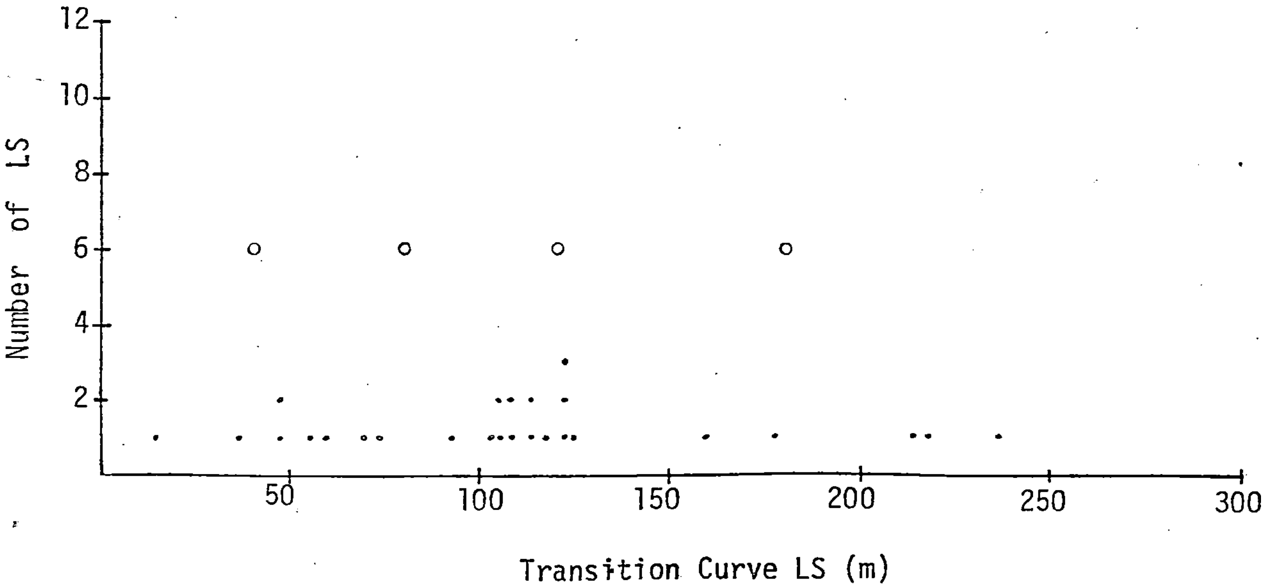
12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)



12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)

R = 2000 m


12
10
8
6
4
2
Number of C
20
40
60
80
100
120
140
160
Superelevation C (mm)


12
10
8
6
4
2
Number of LS
50
100
150
200
250
300
Transition Curve LS (m)

7.5 RELATION BETWEEN MAXIMUM LATERAL ACCELERATION OF CARBODY AND TRANSITION CURVE LENGTH

The relations between maximum lateral acceleration of carbody in transition curve and length of transition curve are shown in Figure 7.5

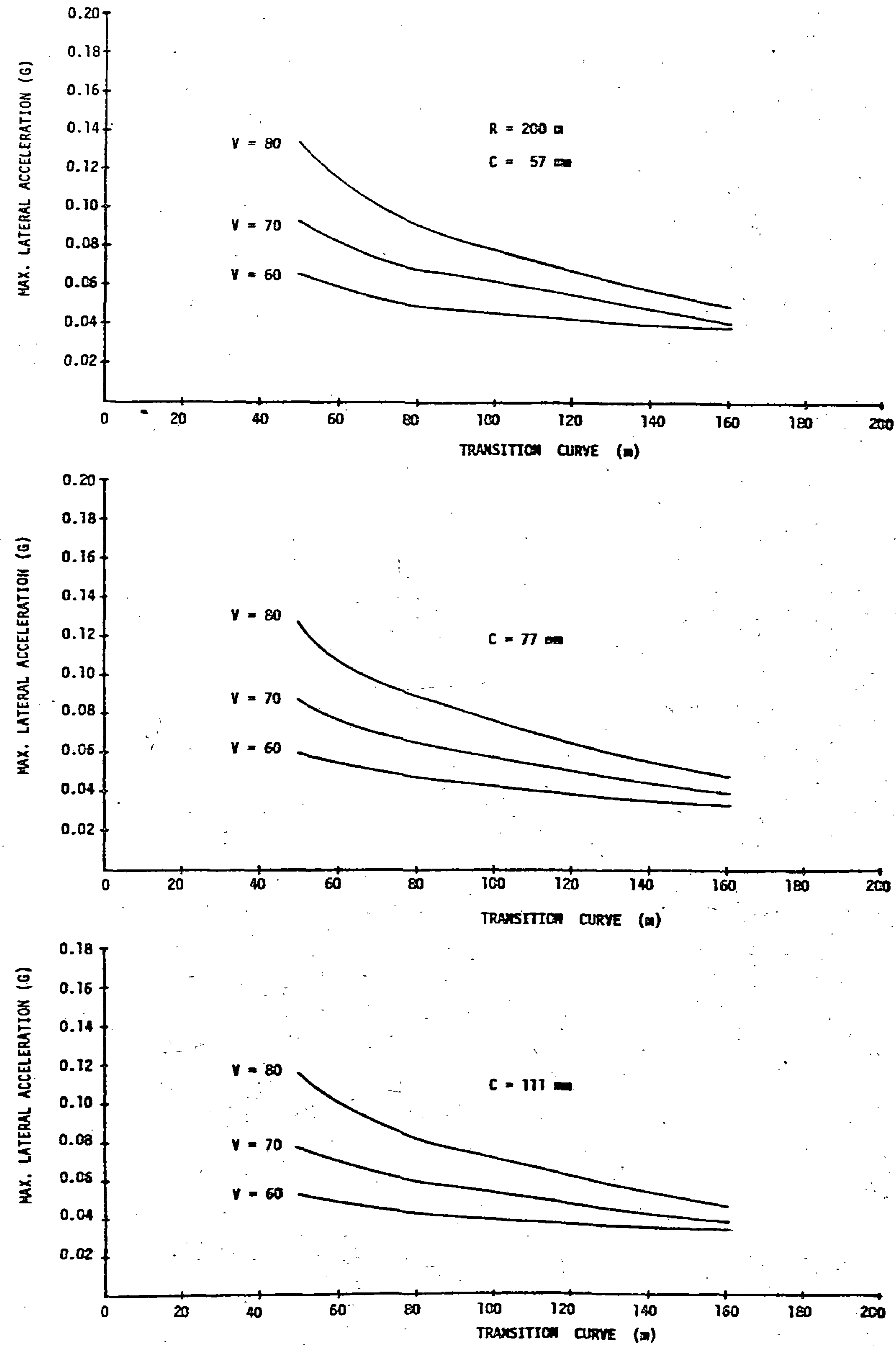
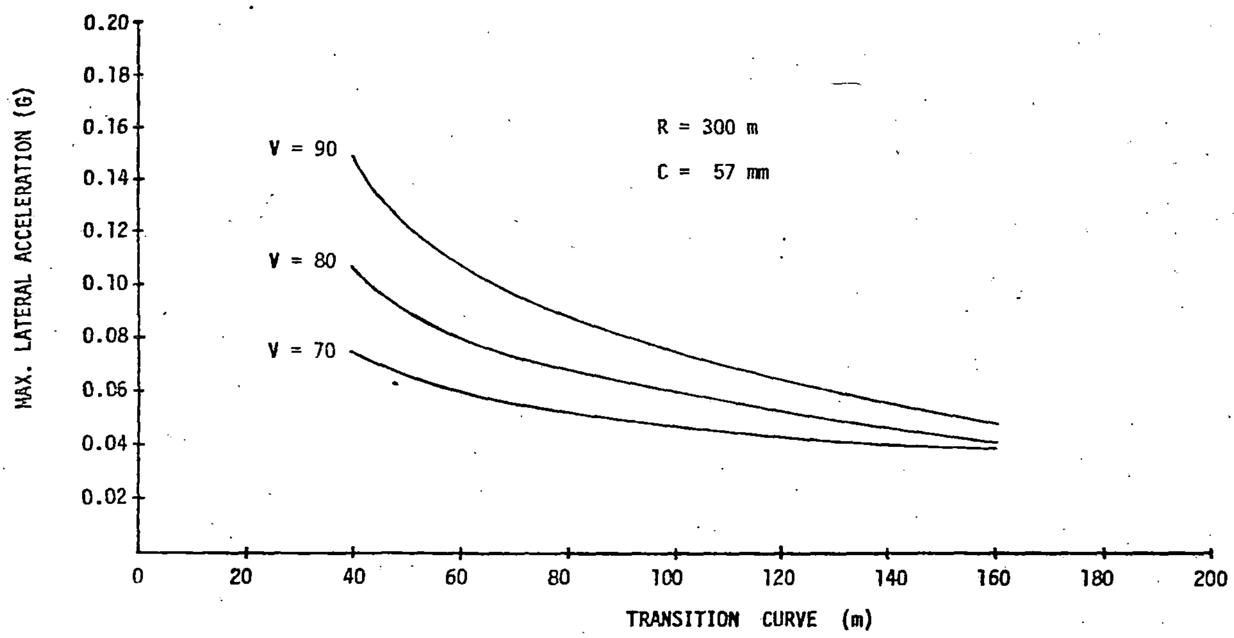
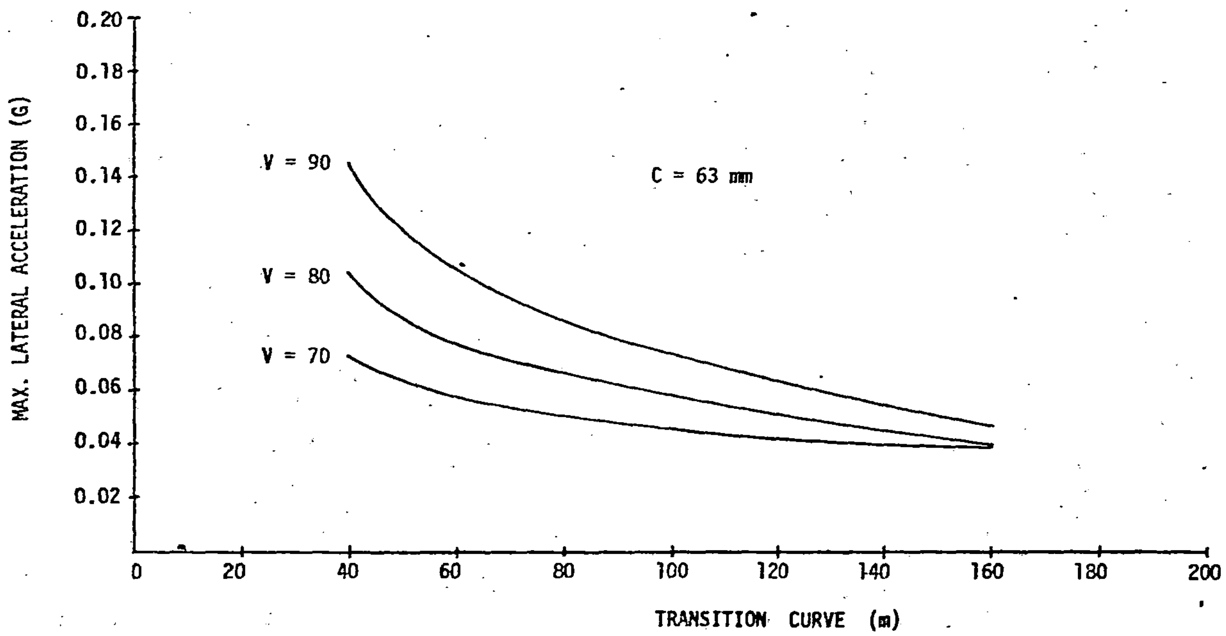
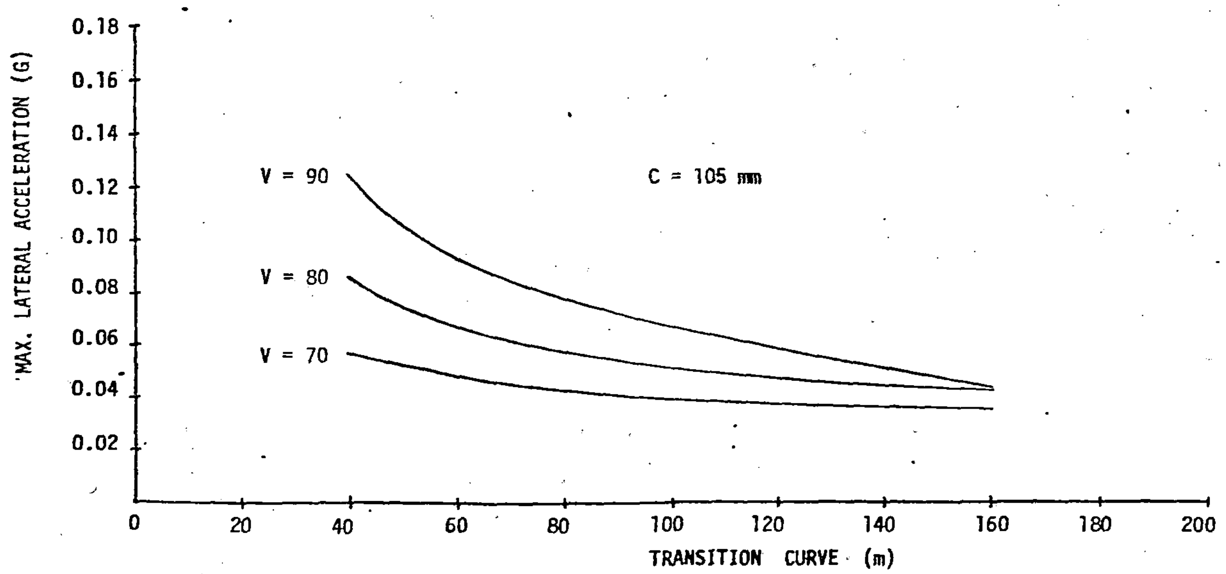
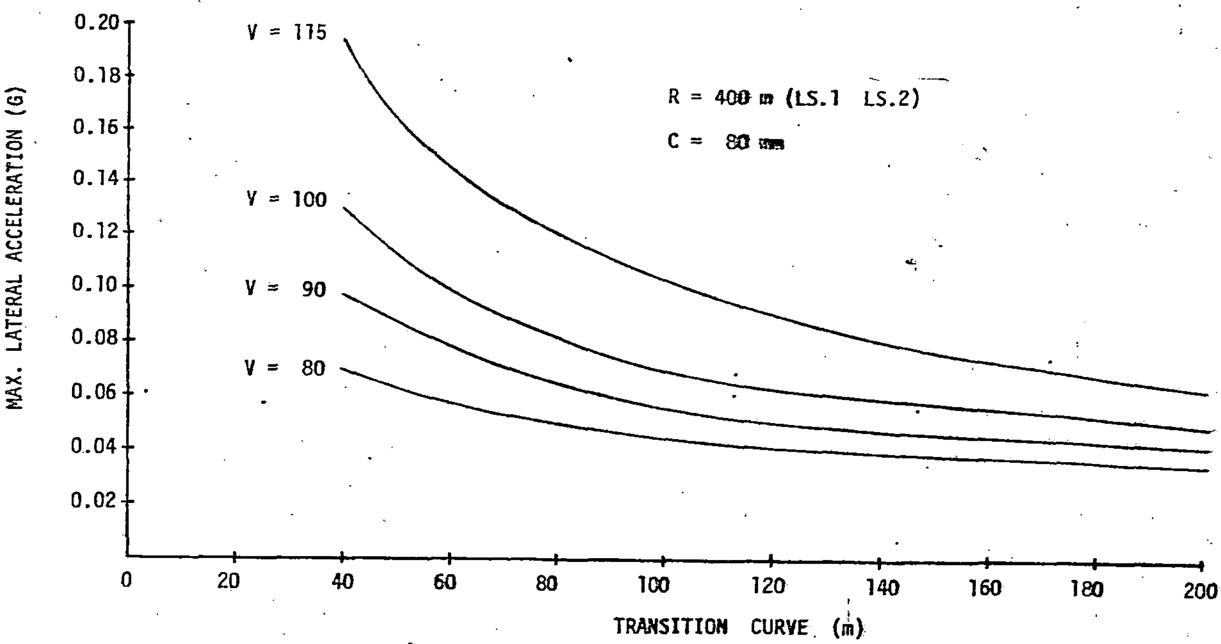


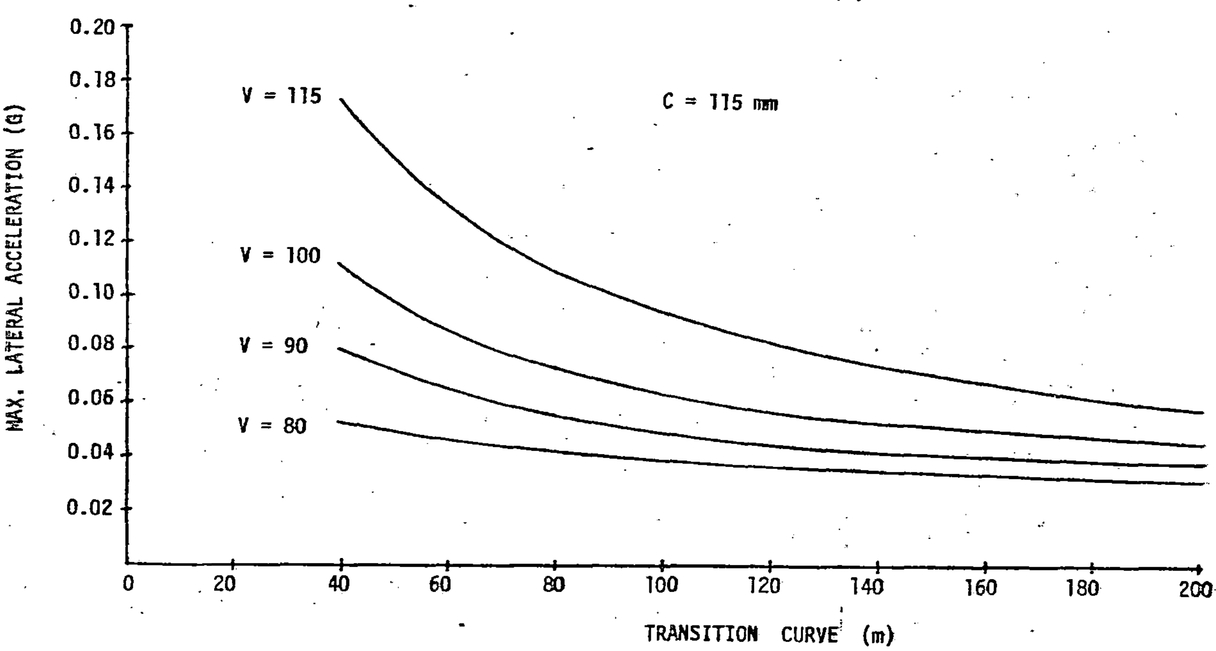
Figure 7.5 Relation between Max. Lateral Acceleration and Length of Transition Curve

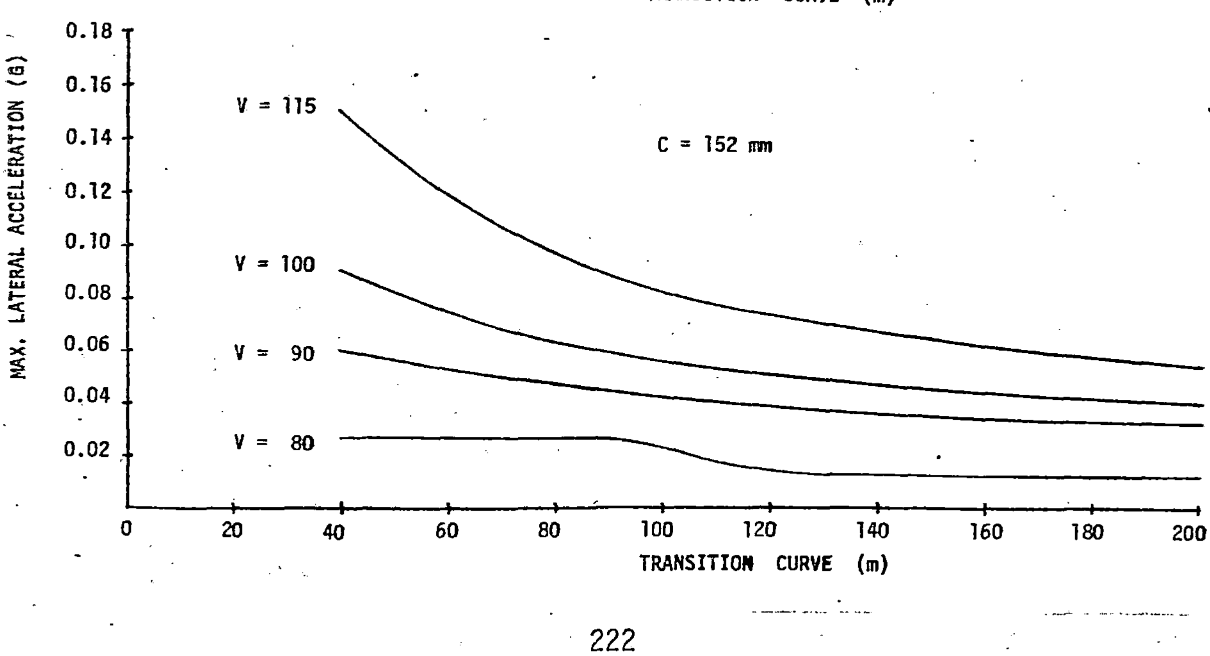

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 90
V = 80
V = 70
R = 300 m
C = 57 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

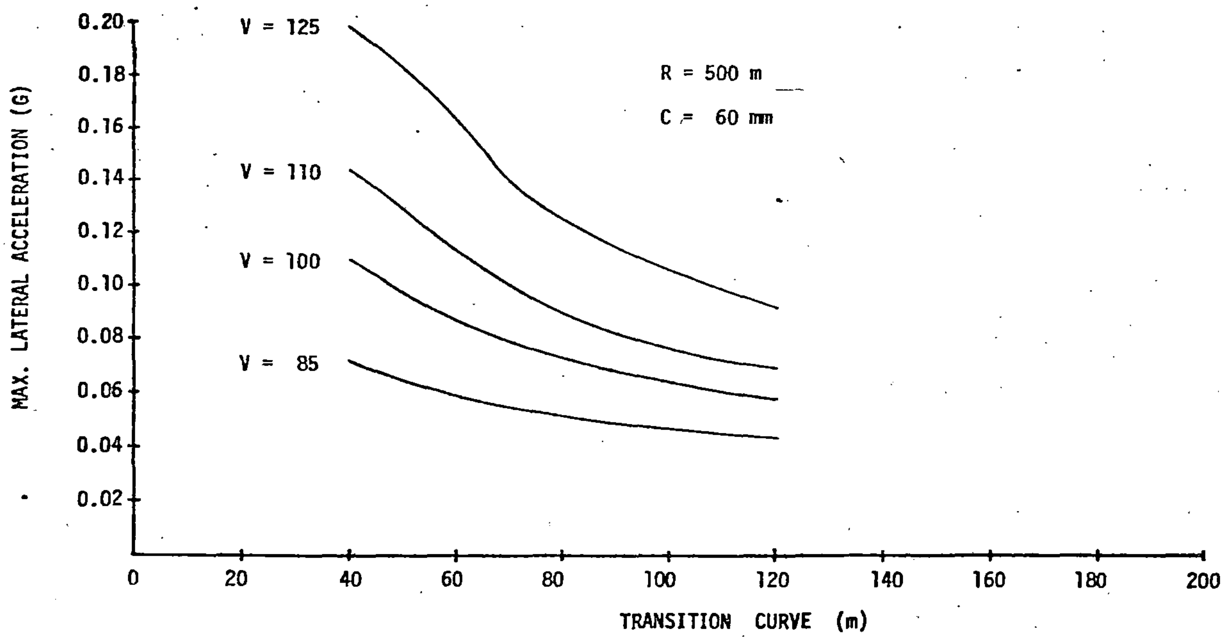

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 90
V = 80
V = 70
C = 63 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

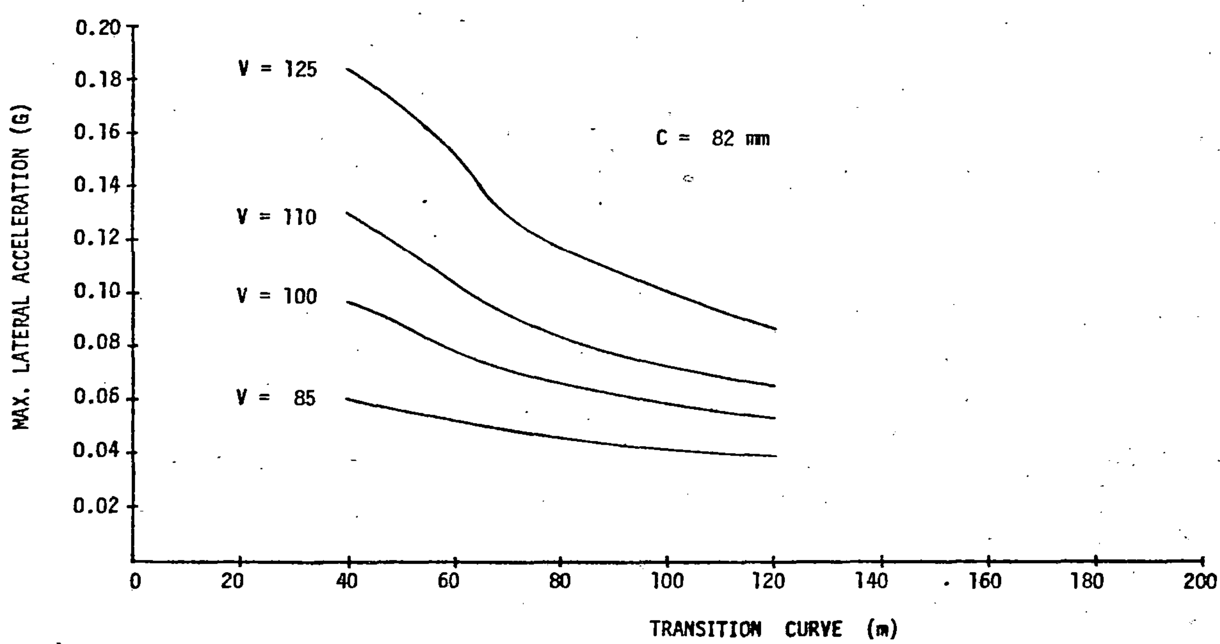

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 90
V = 80
V = 70
C = 105 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

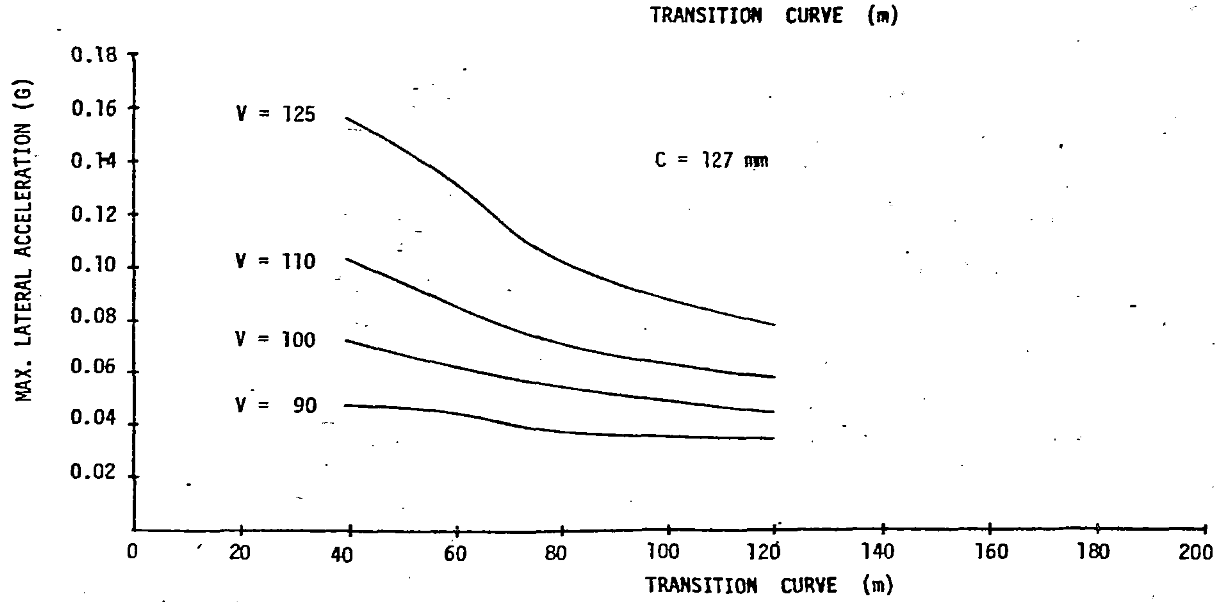

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 115
V = 100
V = 90
V = 80
R = 400 m (LS.1 LS.2)
C = 80 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

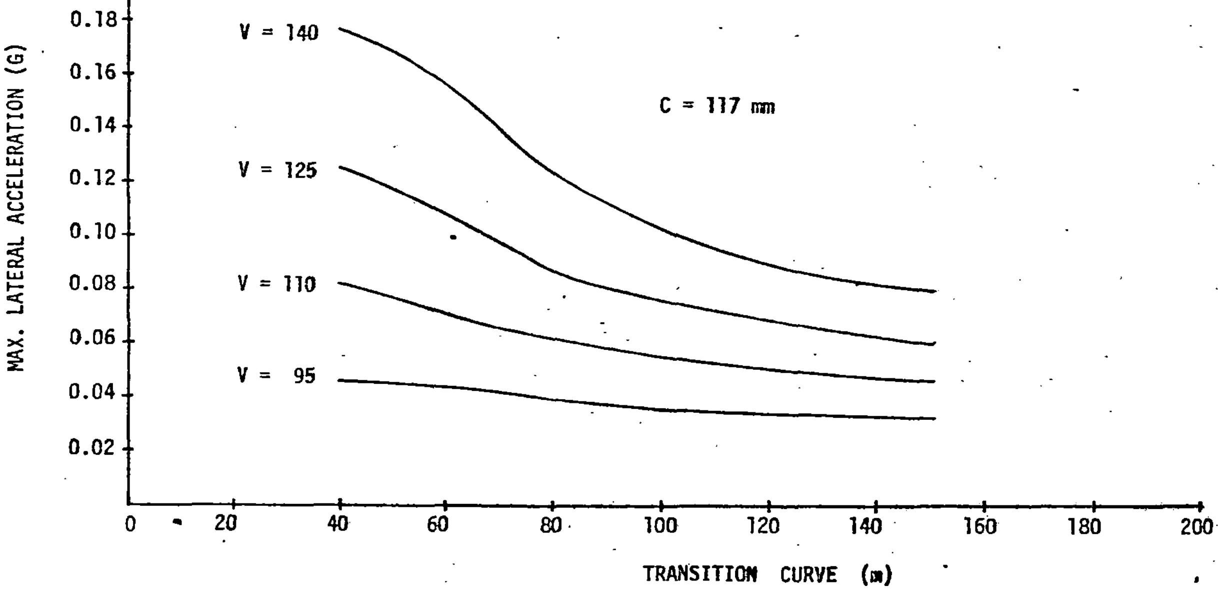

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 115
V = 100
V = 90
V = 80
C = 115 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

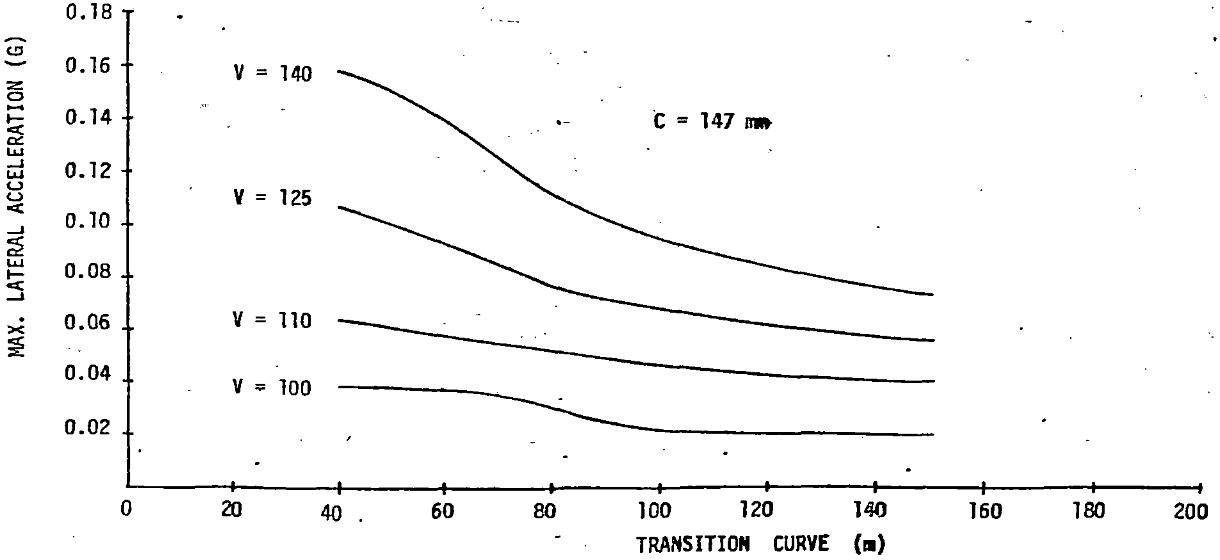

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 115
V = 100
V = 90
V = 80
C = 152 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

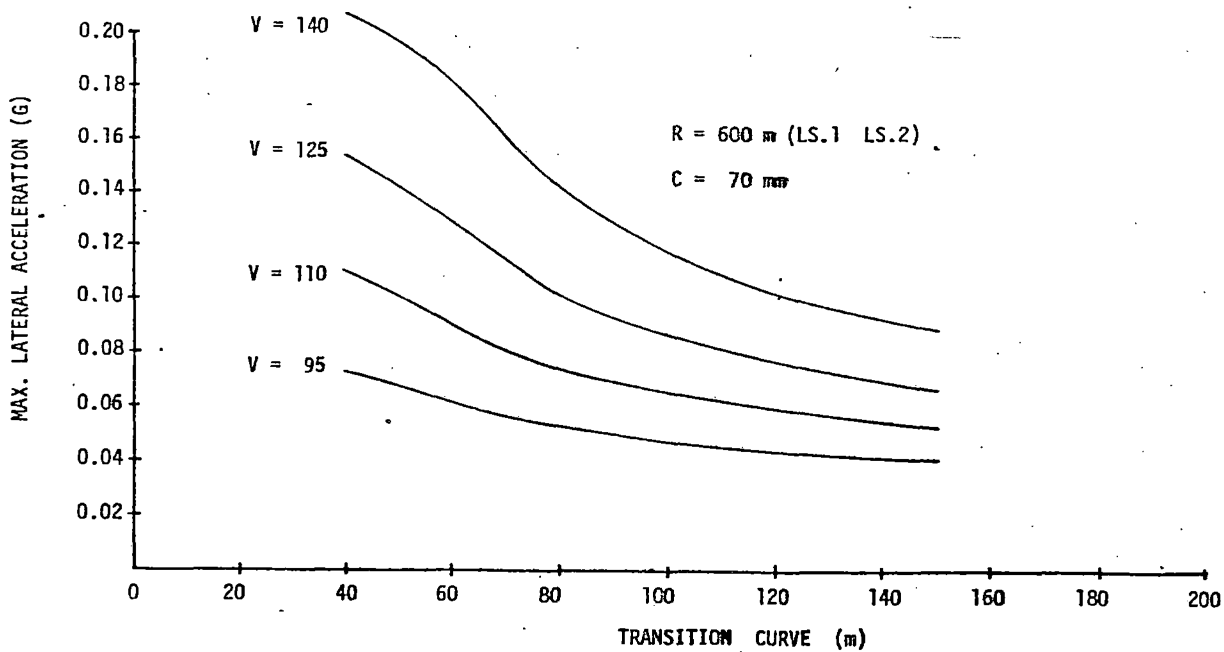

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 125
V = 110
V = 100
V = 85
R = 500 m
C = 60 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

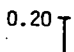

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 125
V = 110
V = 100
V = 85
C = 82 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

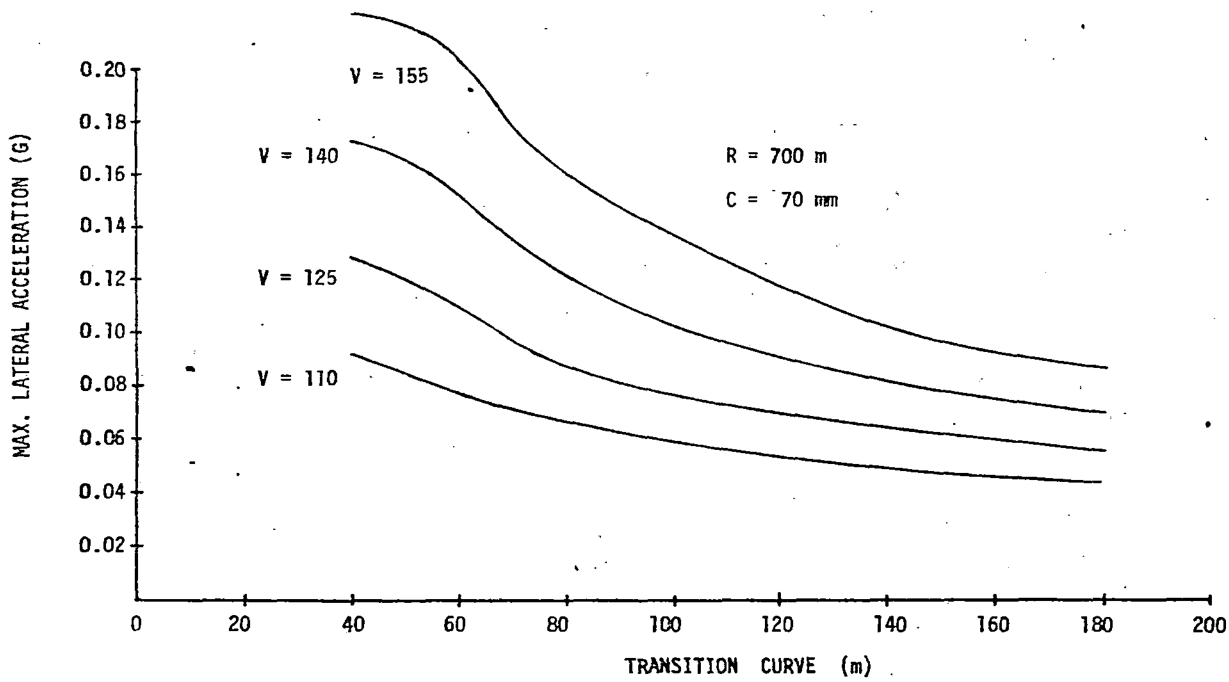

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 125
V = 110
V = 100
V = 90
C = 127 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 140
V = 125
V = 110
V = 95
C = 117 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

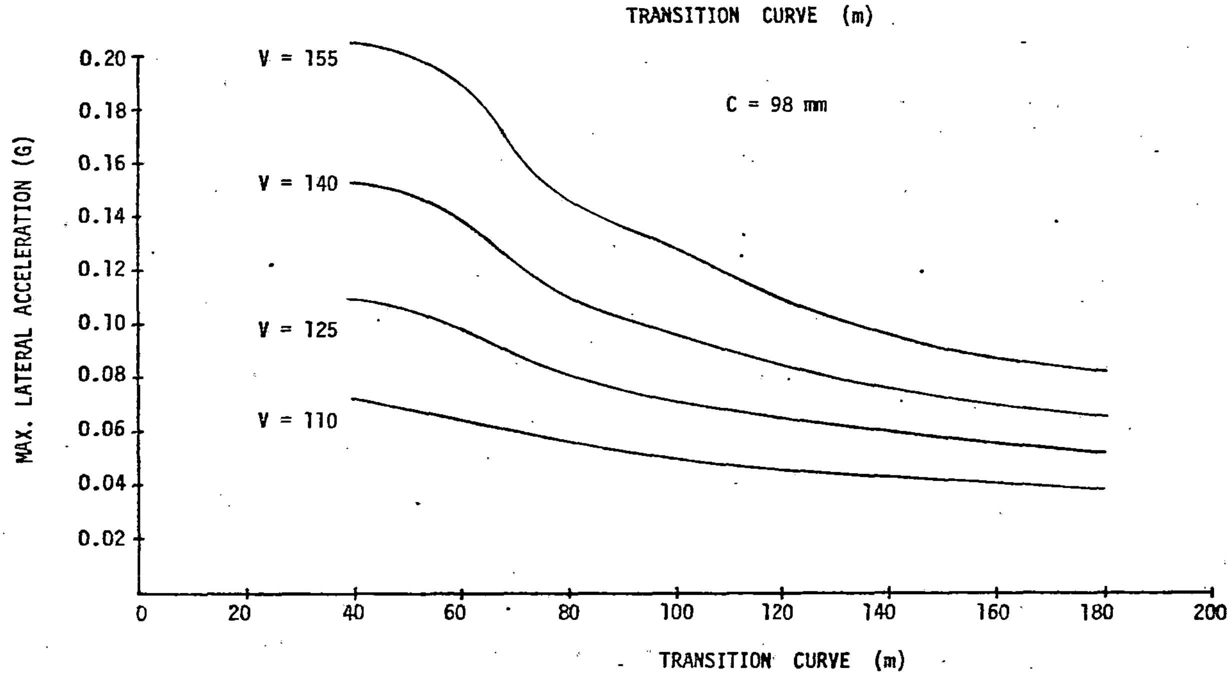

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 140
V = 125
V = 110
V = 100
C = 147 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 140
V = 125
V = 110
V = 95
R = 600 m (LS.1 LS.2)
C = 70 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

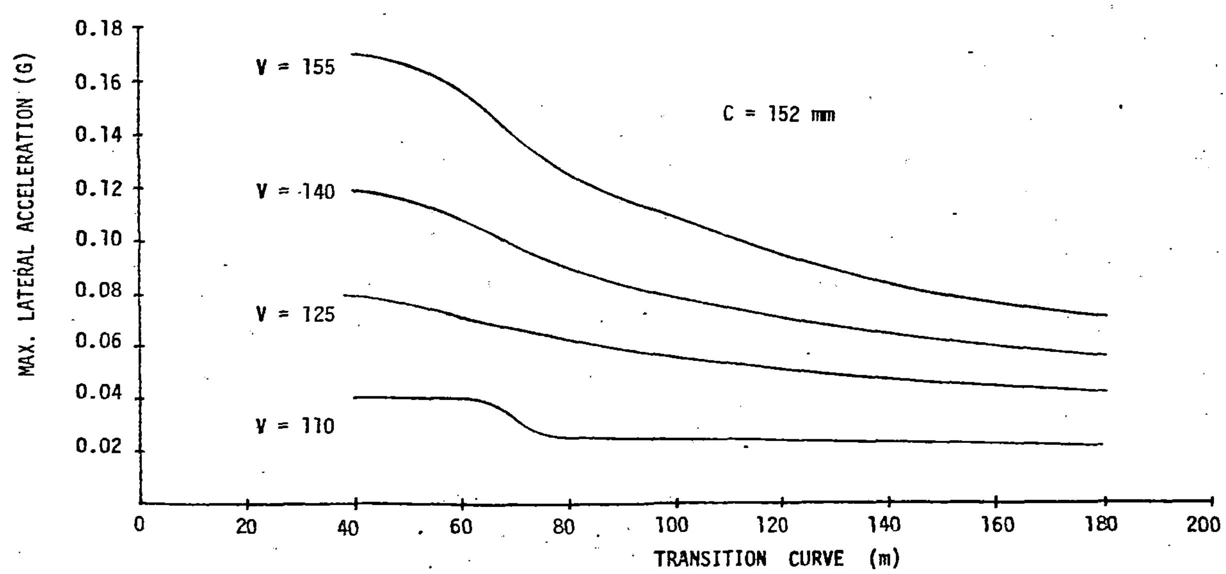

0.20



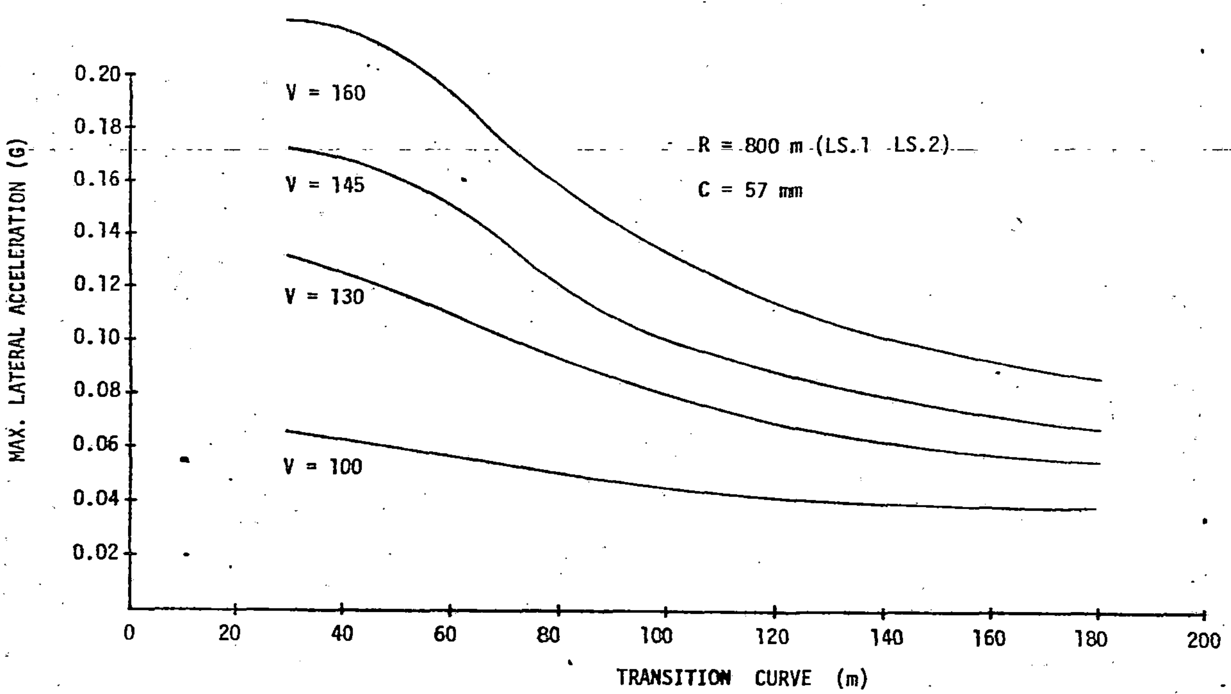
MAX. LATERAL ACCELERATION (G)
V = 155
V = 140
V = 125
V = 110
R = 700 m
C = 70 mm
TRANSITION CURVE (m)

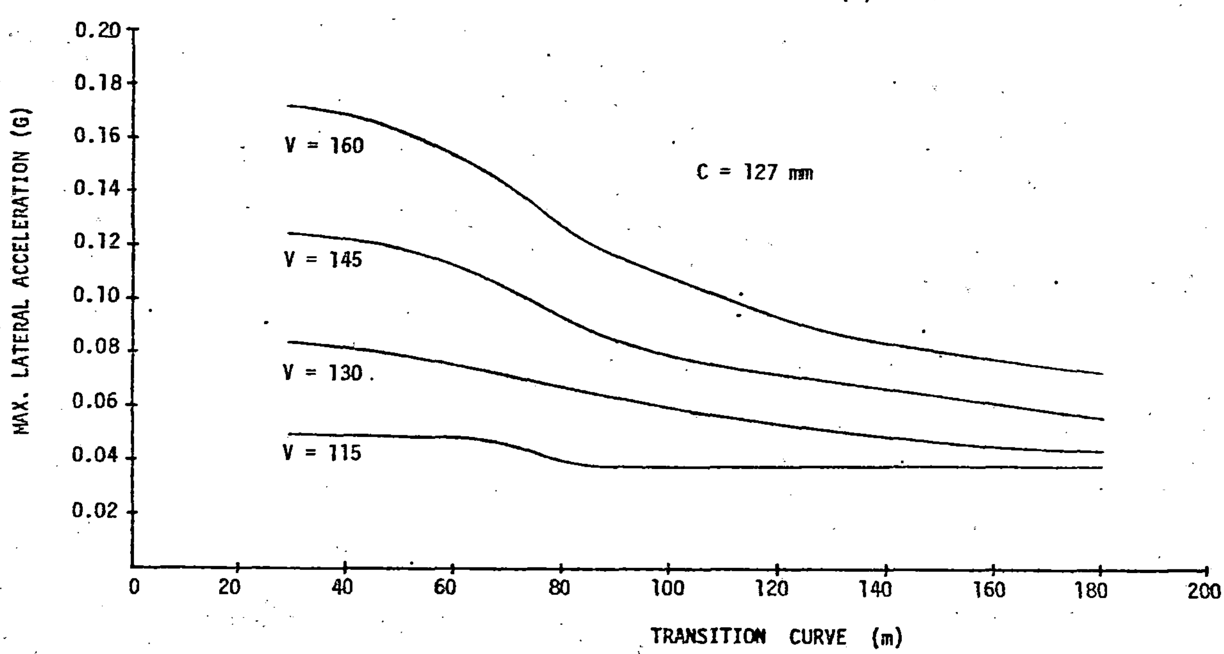


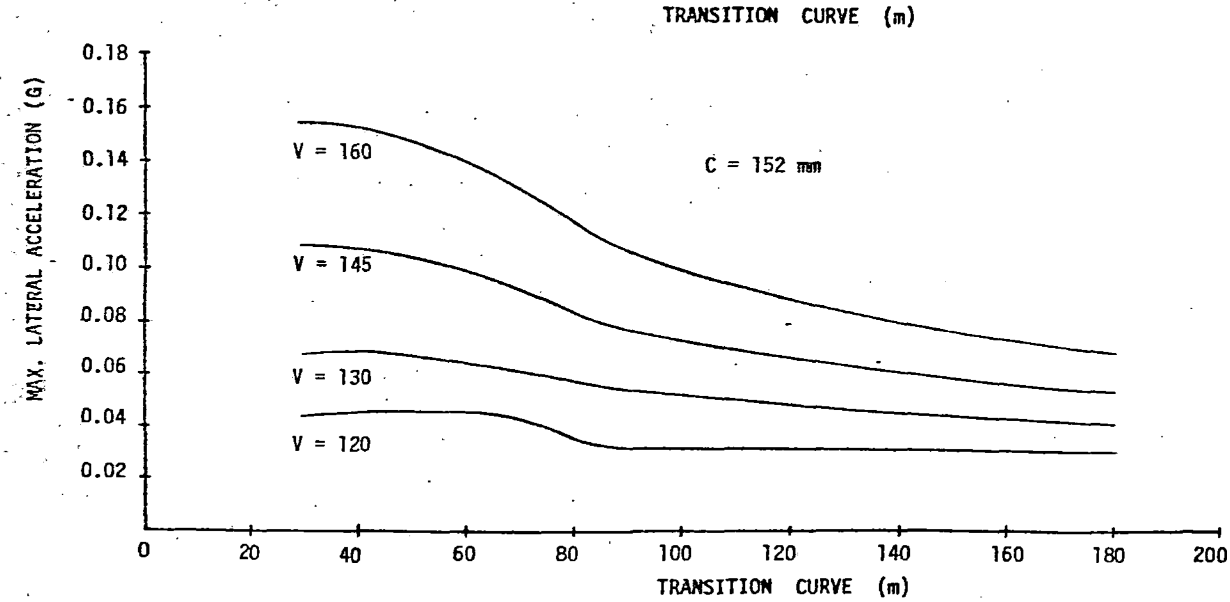
MAX. LATERAL ACCELERATION (G)
V = 155
V = 140
V = 125
V = 110
C = 98 mm
TRANSITION CURVE (m)

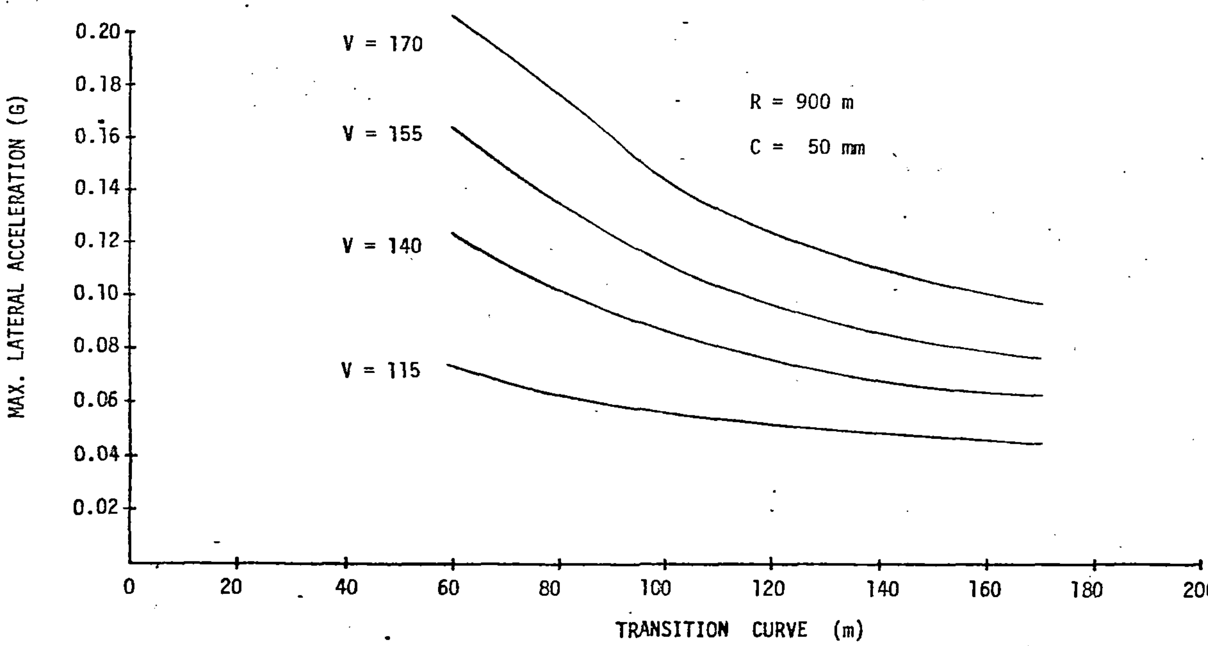


MAX. LATERAL ACCELERATION (G)
V = 155
V = 140
V = 125
V = 110
C = 152 mm
TRANSITION CURVE (m)

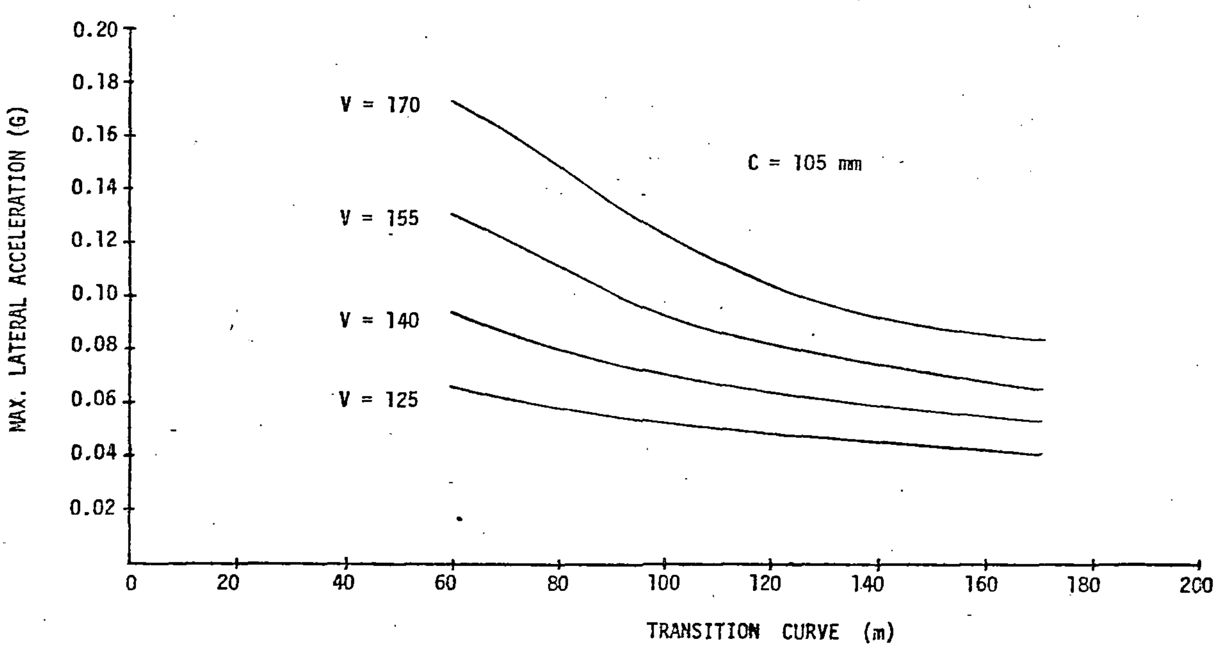

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 160
V = 145
V = 130
V = 100
R = 800 m (LS.1 LS.2)
C = 57 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 160
V = 145
V = 130
V = 115
C = 127 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

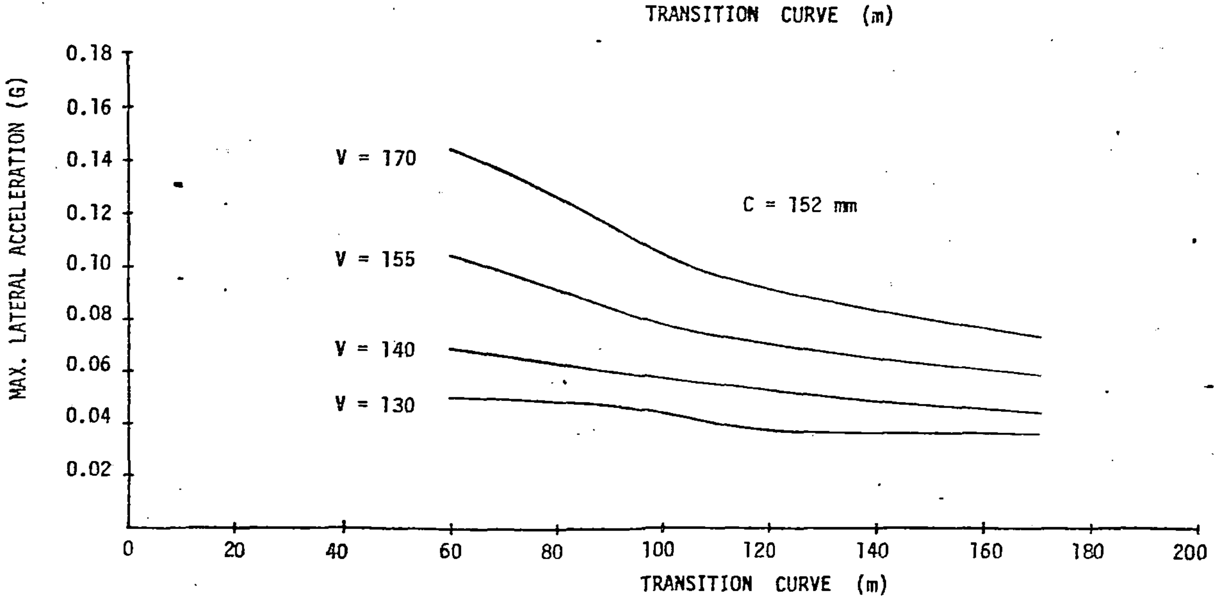

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 160
V = 145
V = 130
V = 120
C = 152 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)



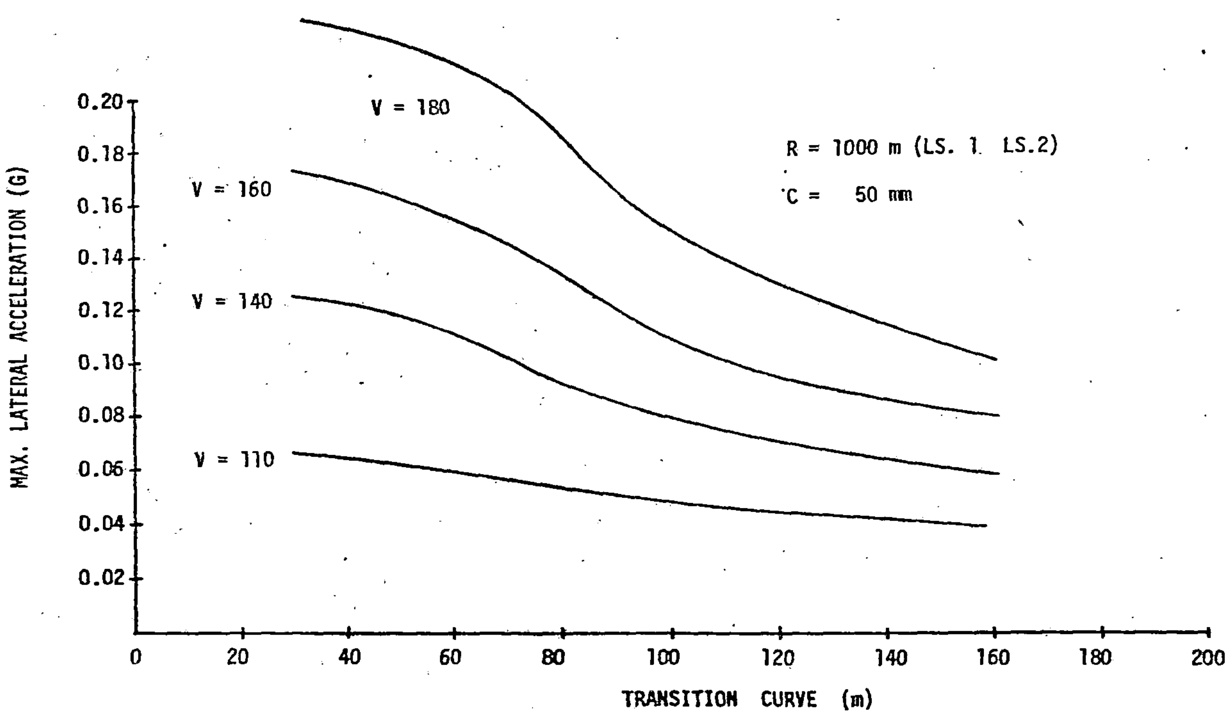
MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 170
V = 155
V = 140
V = 115
R = 900 m
C = 50 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

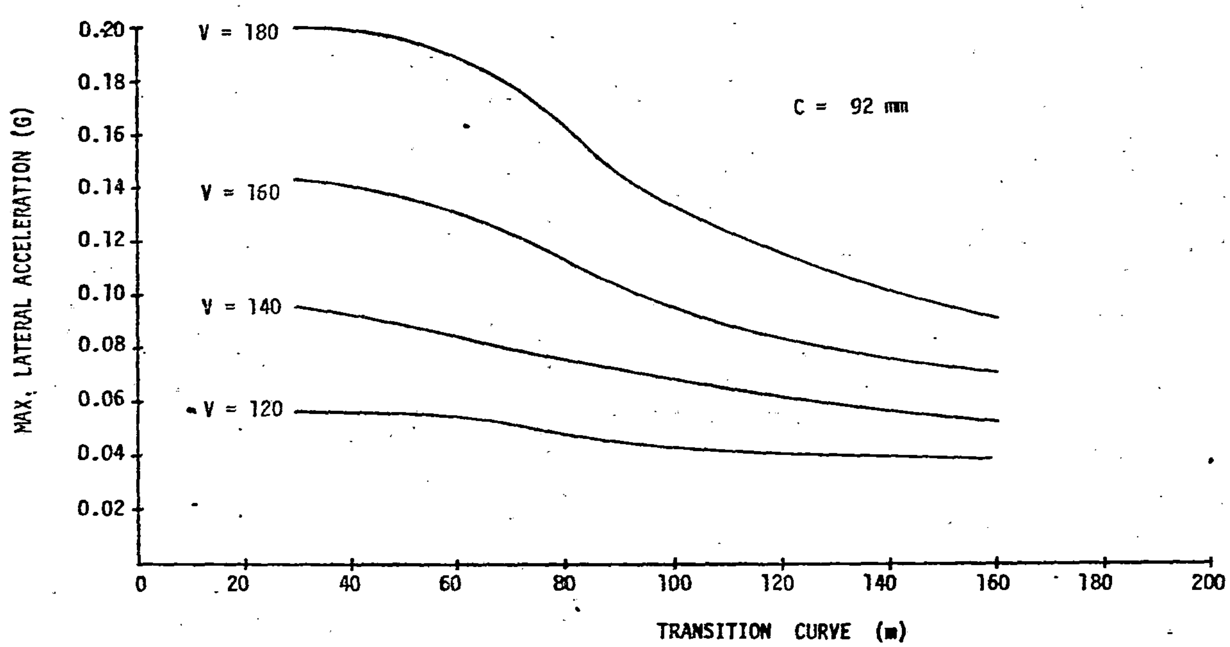


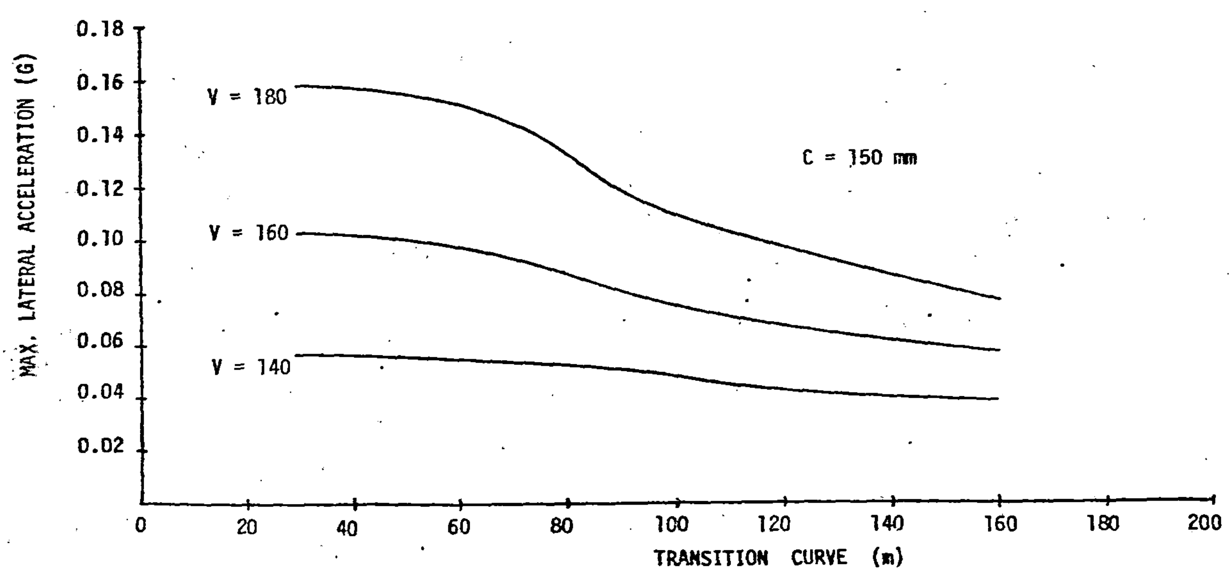
MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 170
V = 155
V = 140
V = 125
C = 105 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

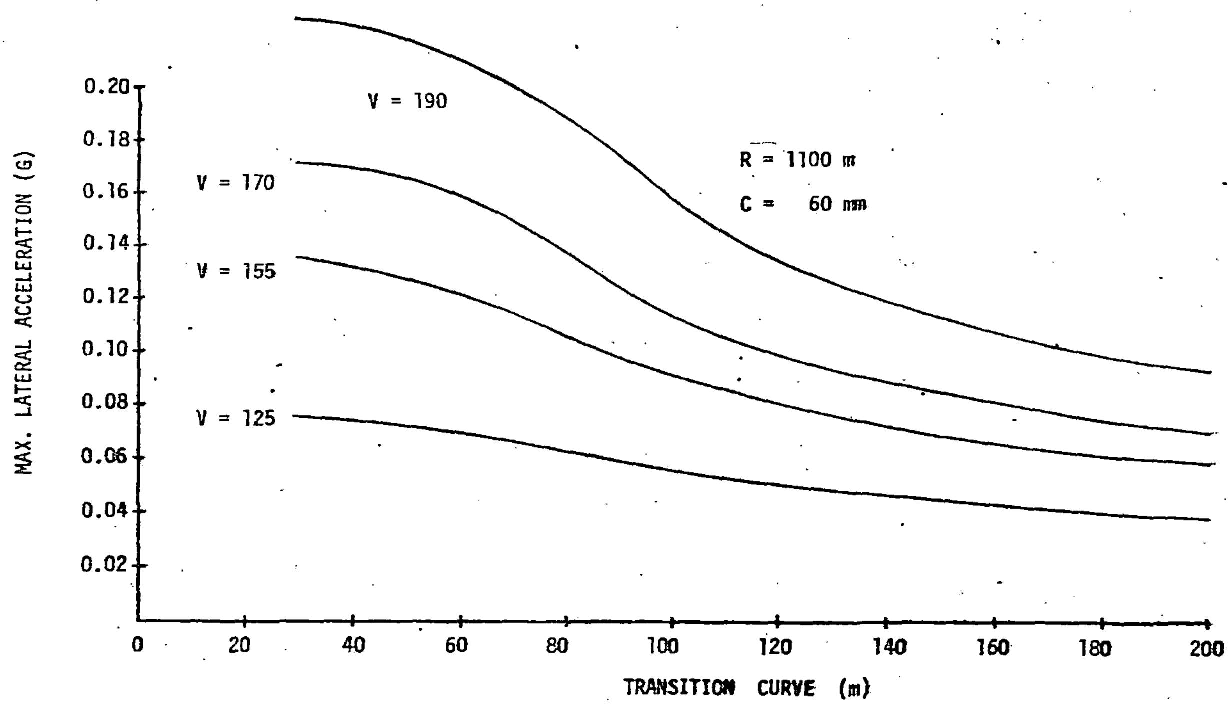


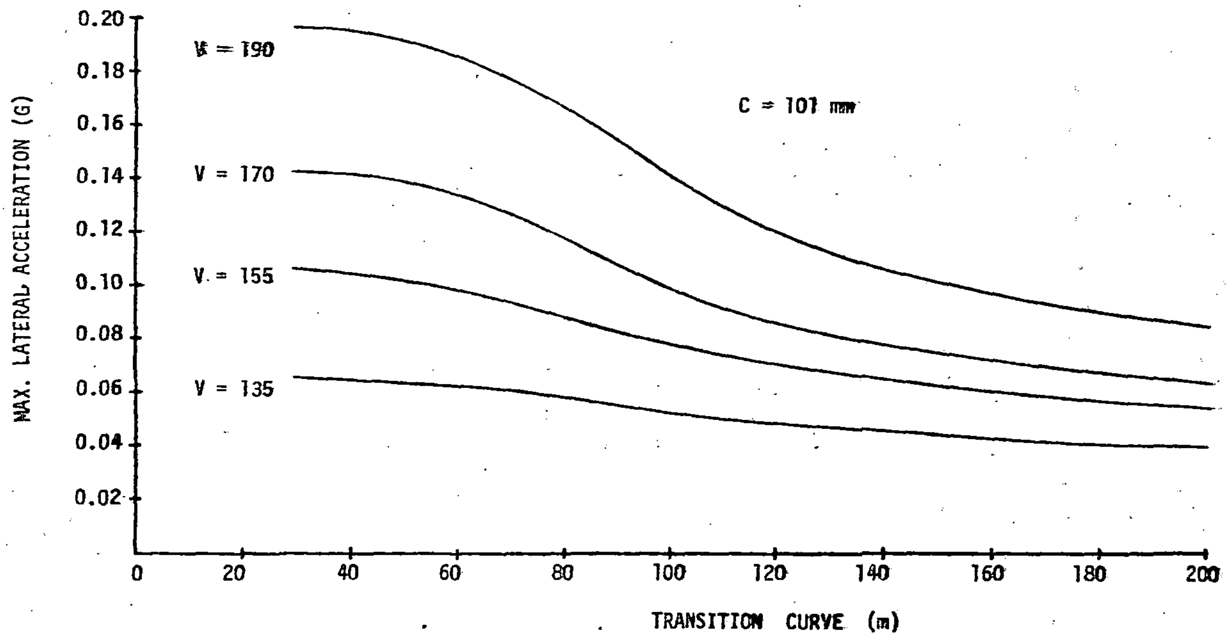
MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 170
V = 155
V = 140
V = 130
C = 152 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

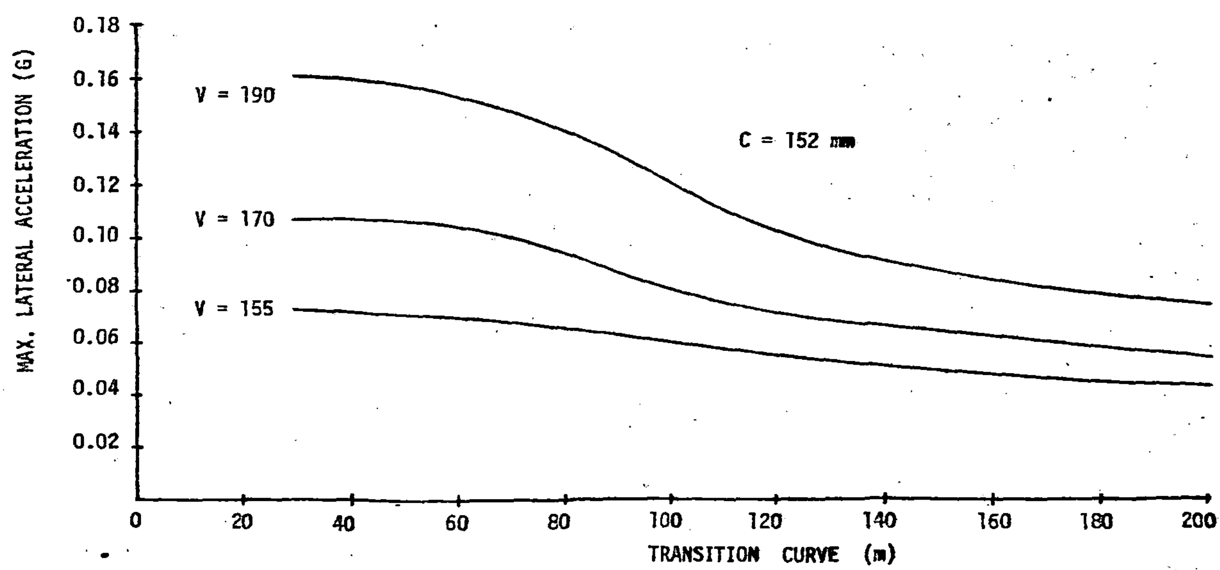

MAX. LATERAL ACCELERATION (G)
V = 180
V = 160
V = 140
V = 110
R = 1000 m (LS. 1 LS.2)
C = 50 mm
TRANSITION CURVE (m)

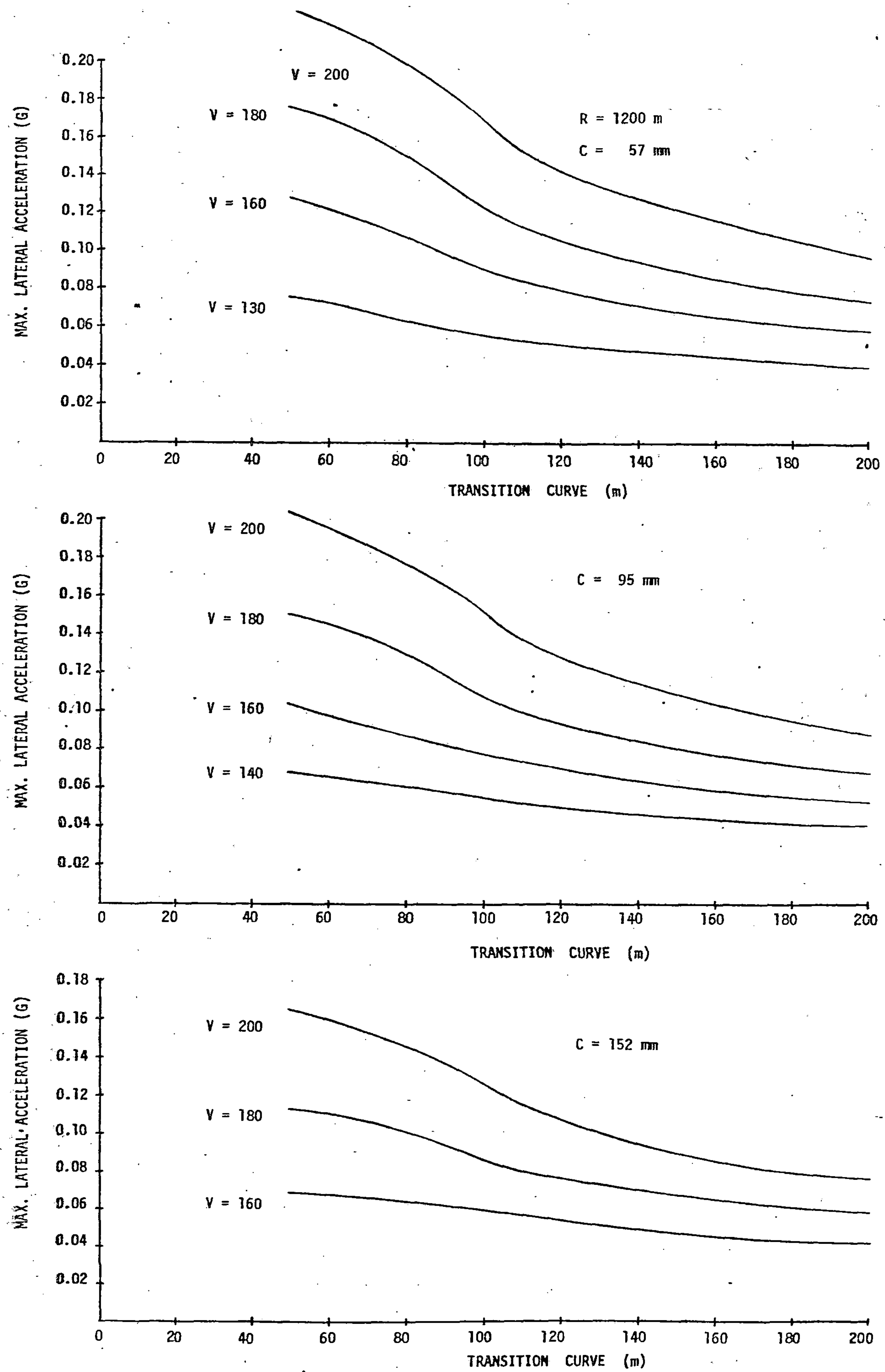

MAX. LATERAL ACCELERATION (G)
V = 180
V = 160
V = 140
V = 120
C = 92 mm
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
V = 180
V = 160
V = 140
C = 150 mm
TRANSITION CURVE (m)

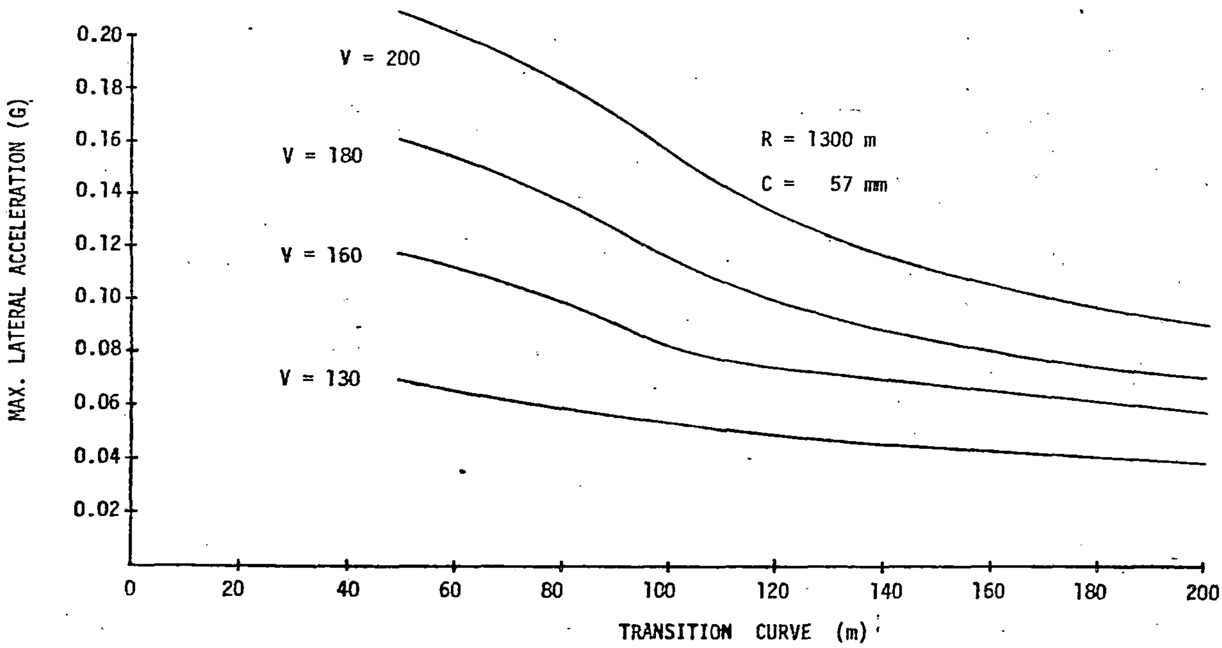

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 190
V = 170
V = 155
V = 125
R = 1100 m
C = 60 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

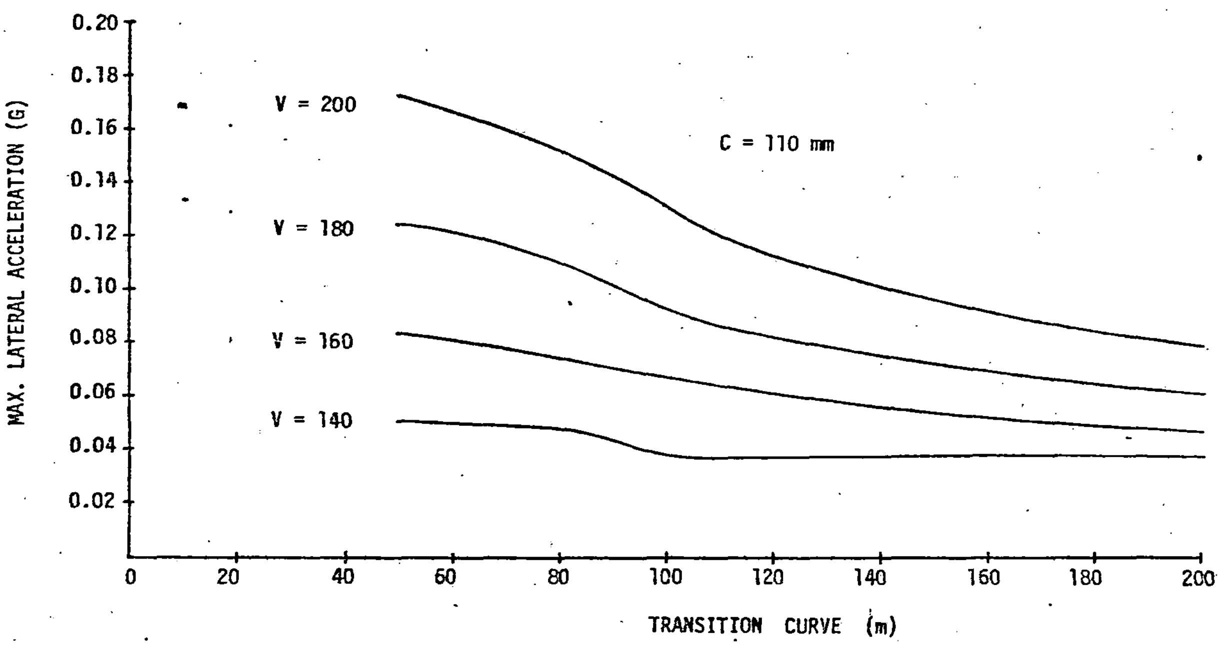

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 190
V = 170
V = 155
V = 135
C = 101 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

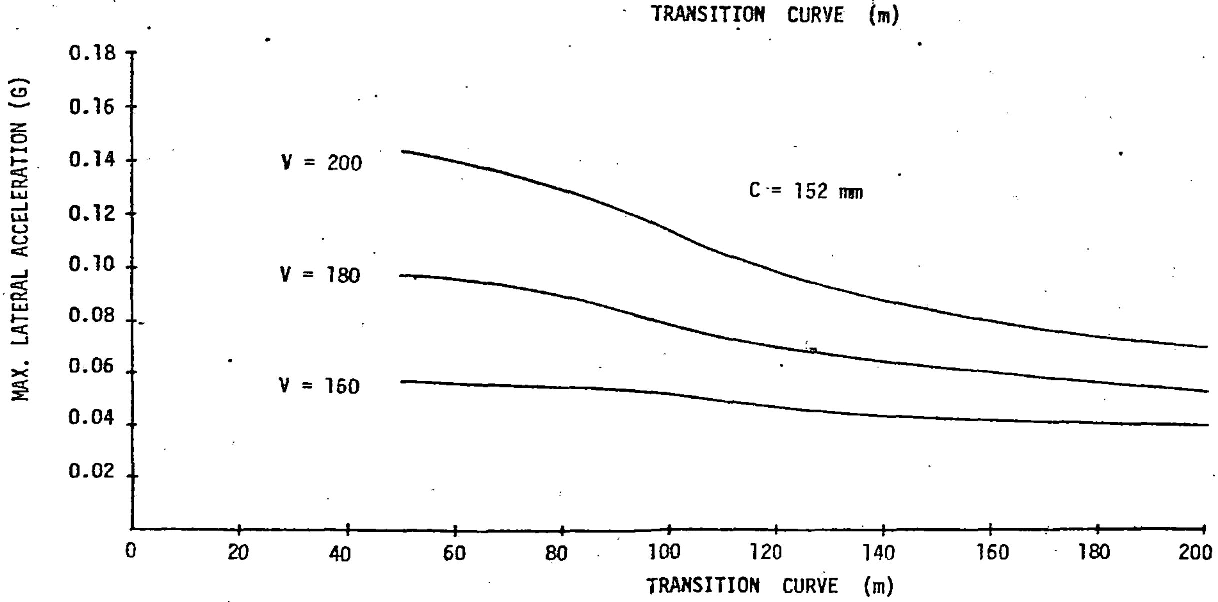

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 190
V = 170
V = 155
C = 152 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

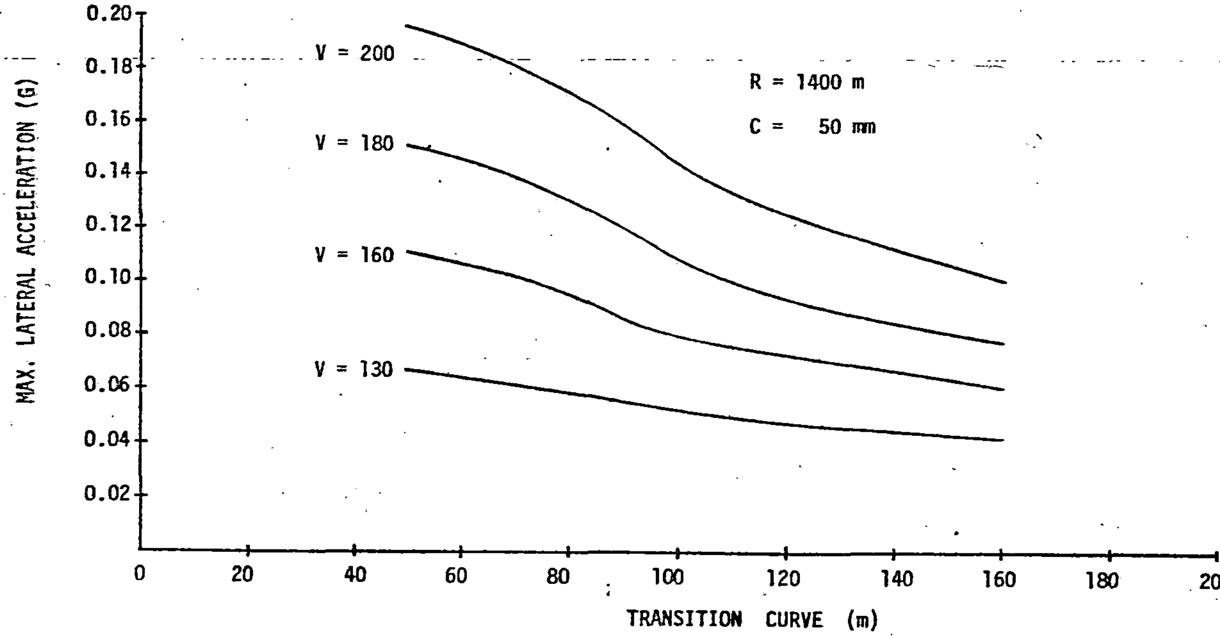


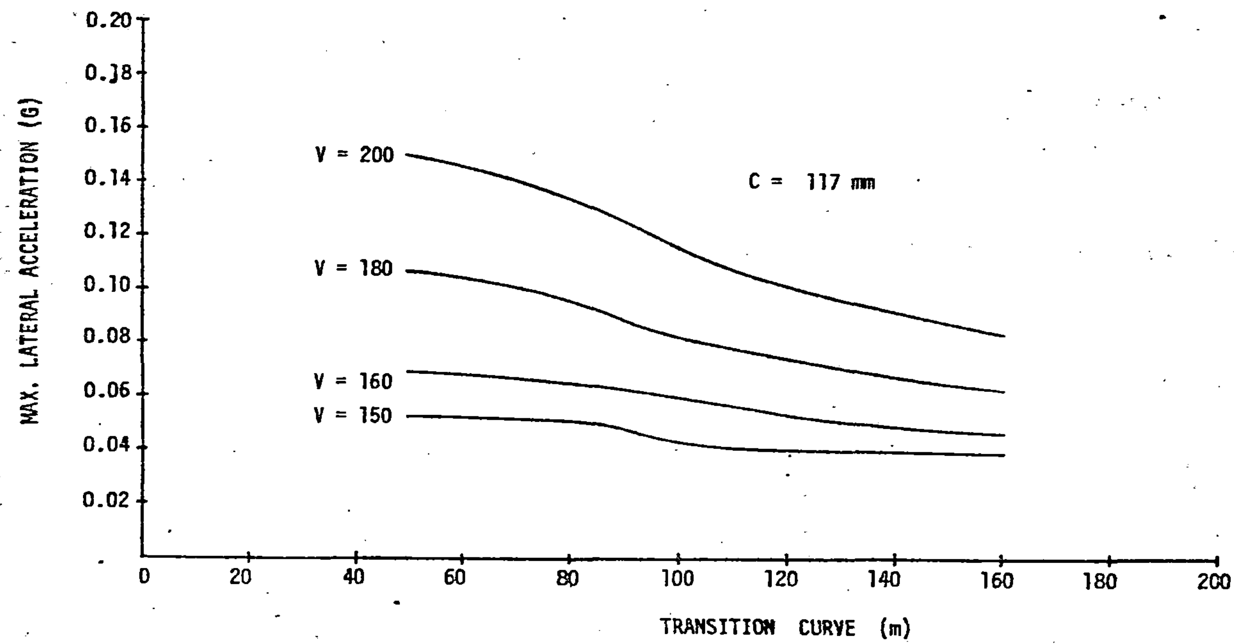
MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
V = 130
R = 1200 m
C = 57 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)
MAX. LATERAL ACCELERATION (G)
V = 200
V = 180
V = 160
V = 140
C = 95 mm
TRANSITION CURVE (m)
MAX. LATERAL ACCELERATION (G)
V = 200
V = 180
V = 160
C = 152 mm
TRANSITION CURVE (m)

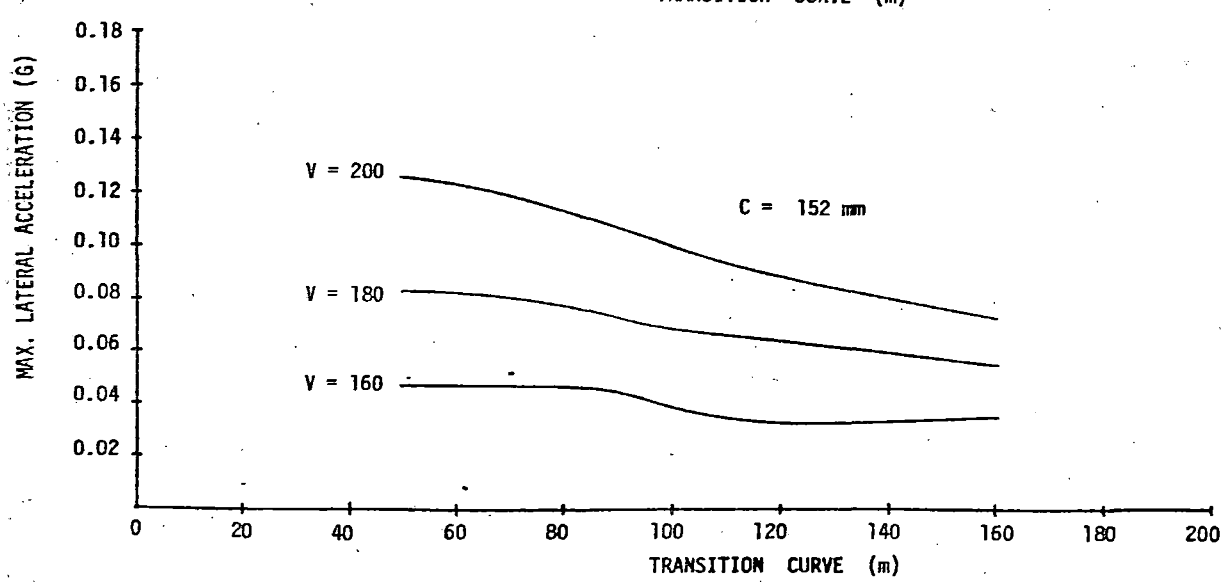

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
V = 130
R = 1300 m
C = 57 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

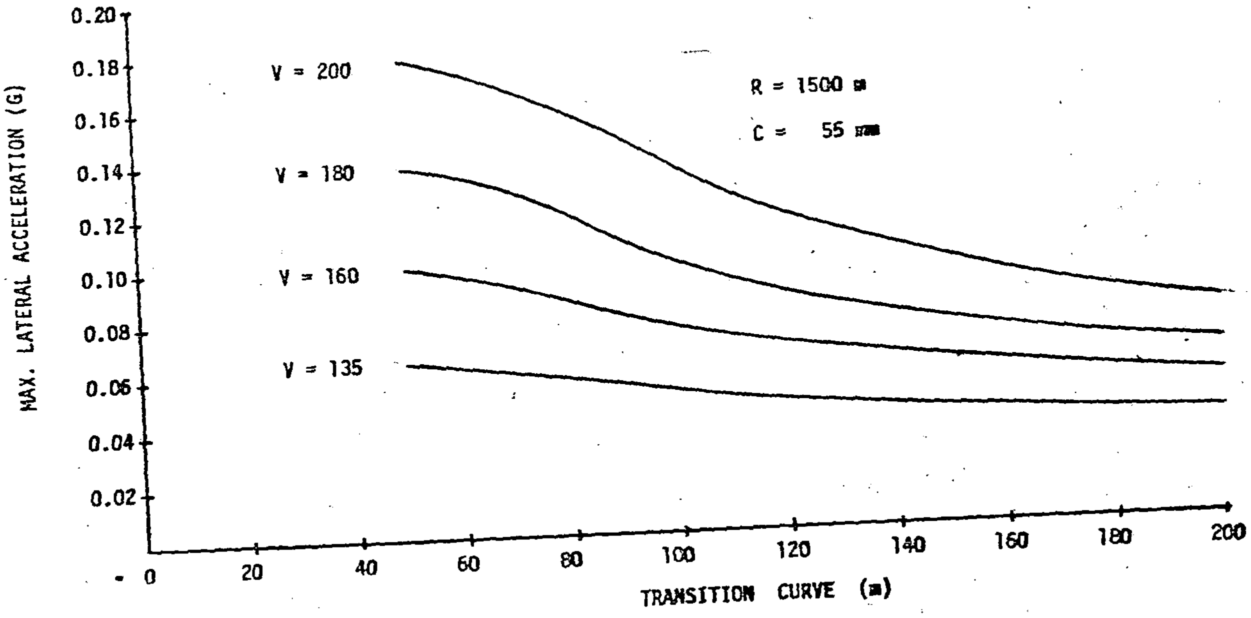

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
V = 140
C = 110 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

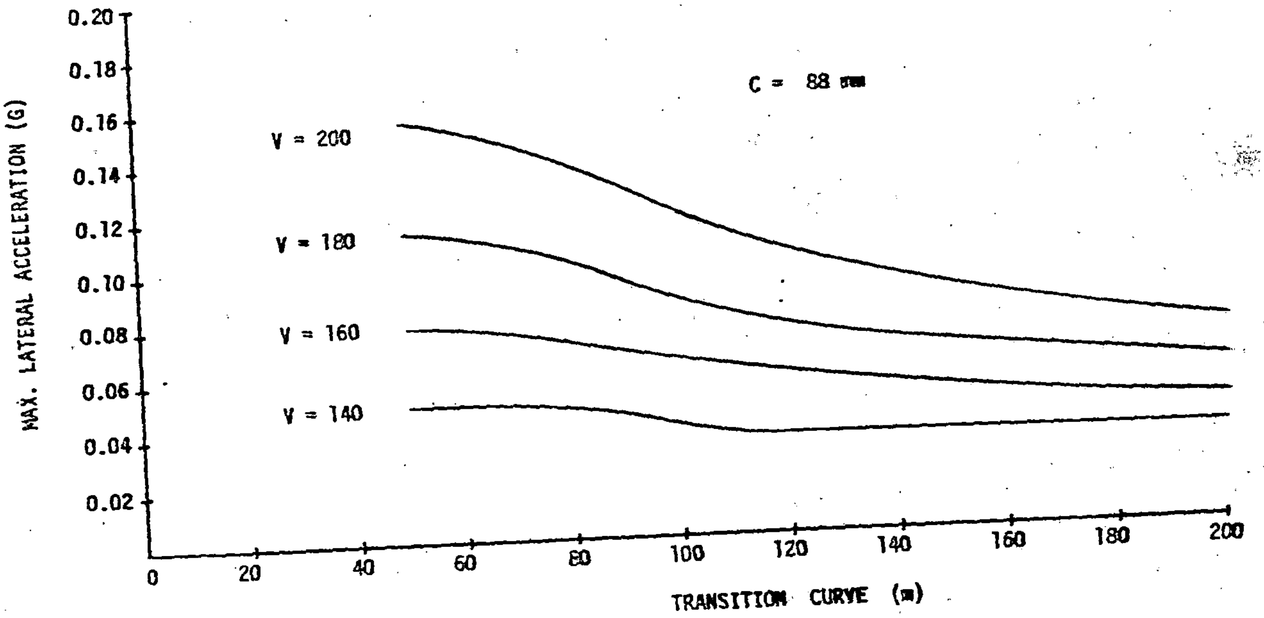

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
C = 152 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

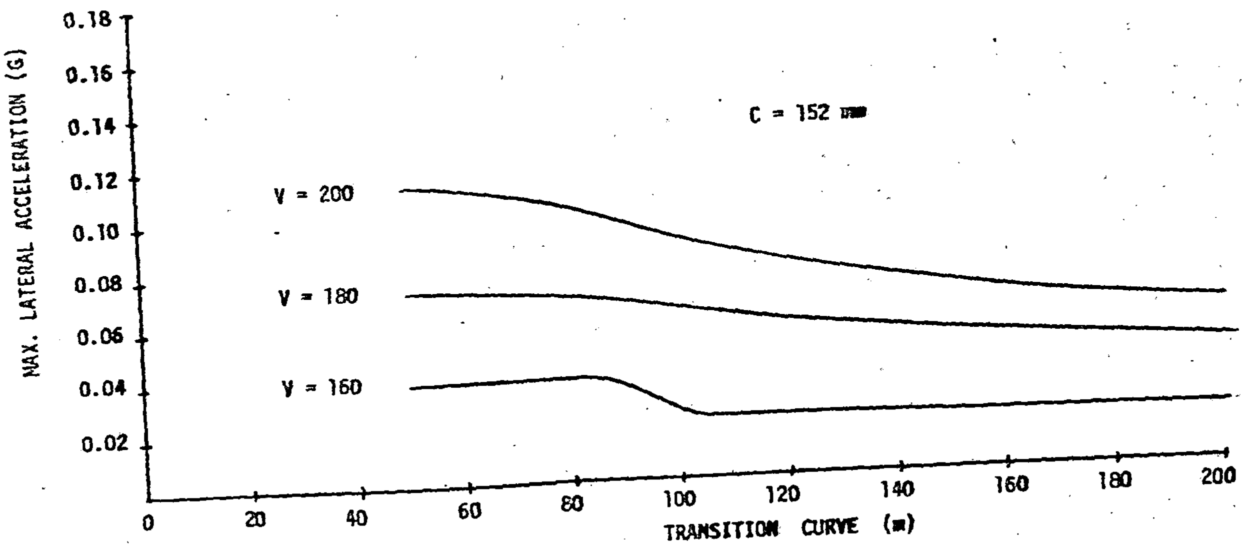

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
V = 130
R = 1400 m
C = 50 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

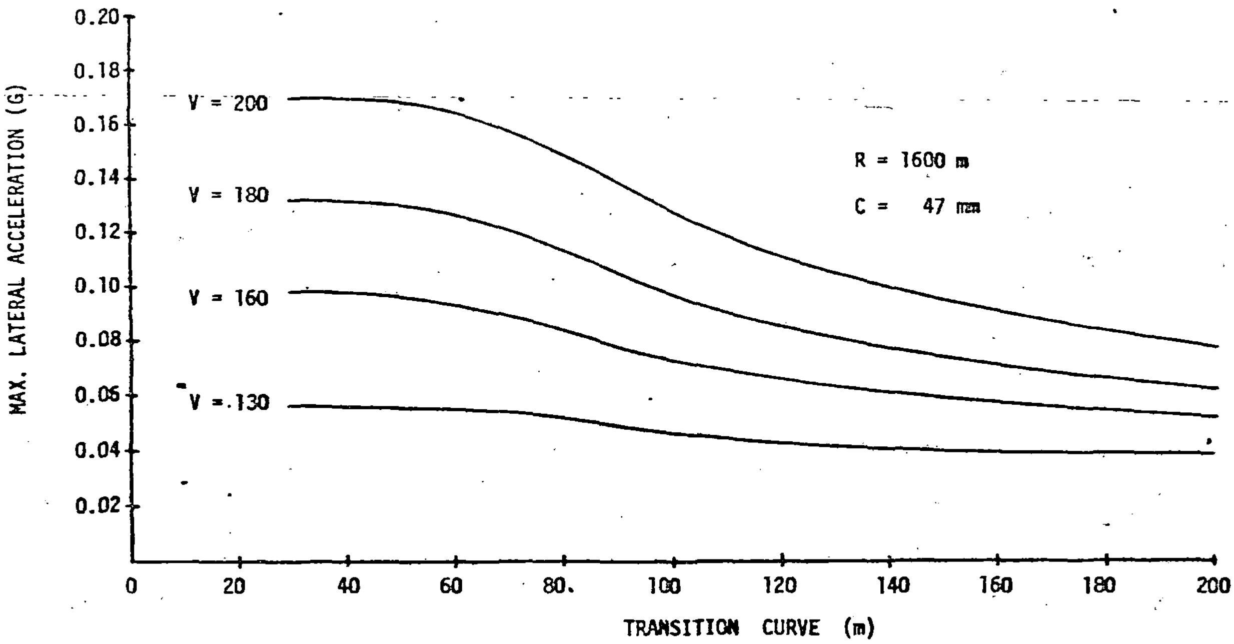

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
V = 150
C = 117 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

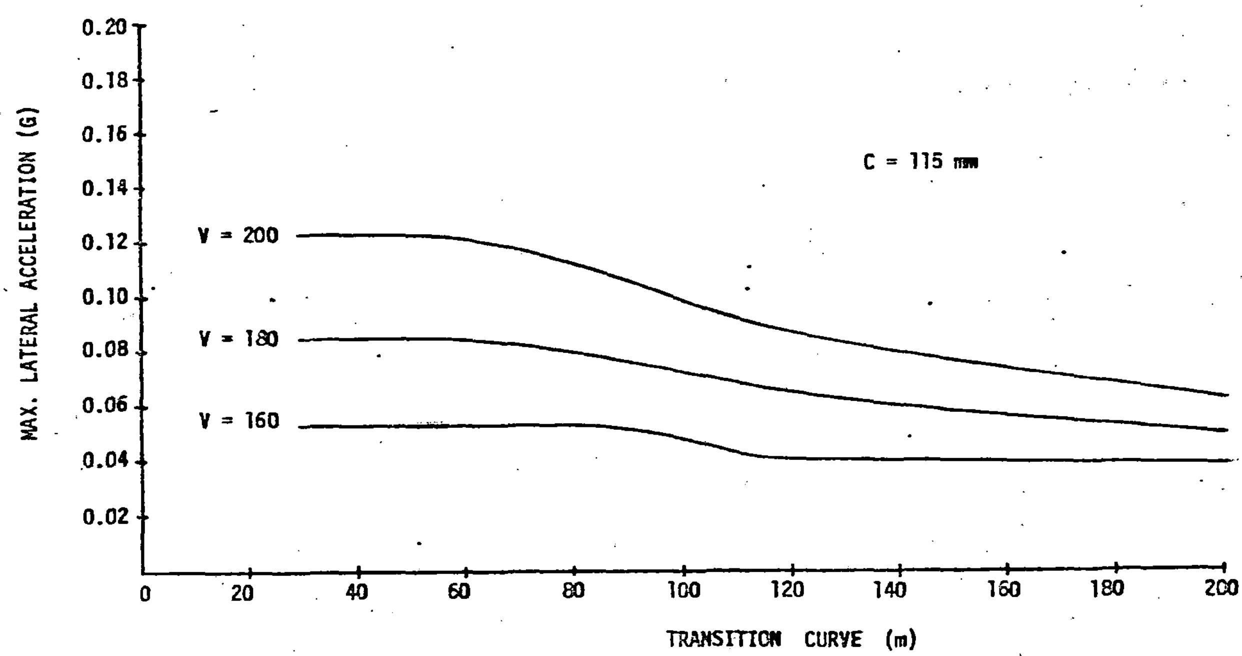

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
C = 152 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

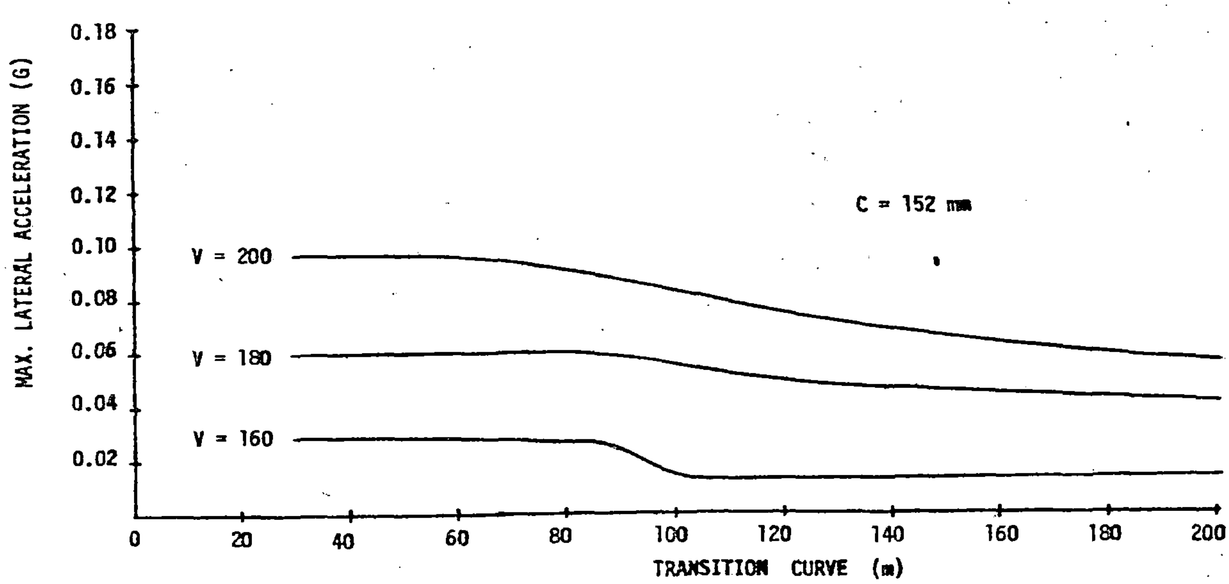

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 180
V = 160
V = 135
R = 1500 m
C = 55 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

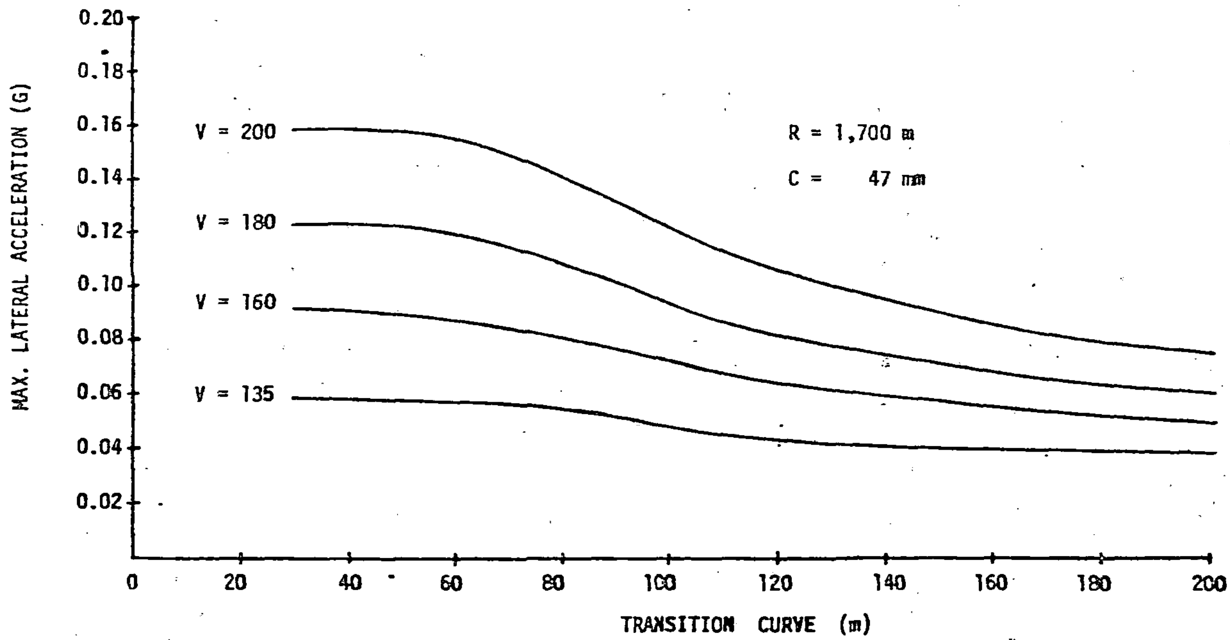

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
C = 88 mm
V = 200
V = 180
V = 160
V = 140
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

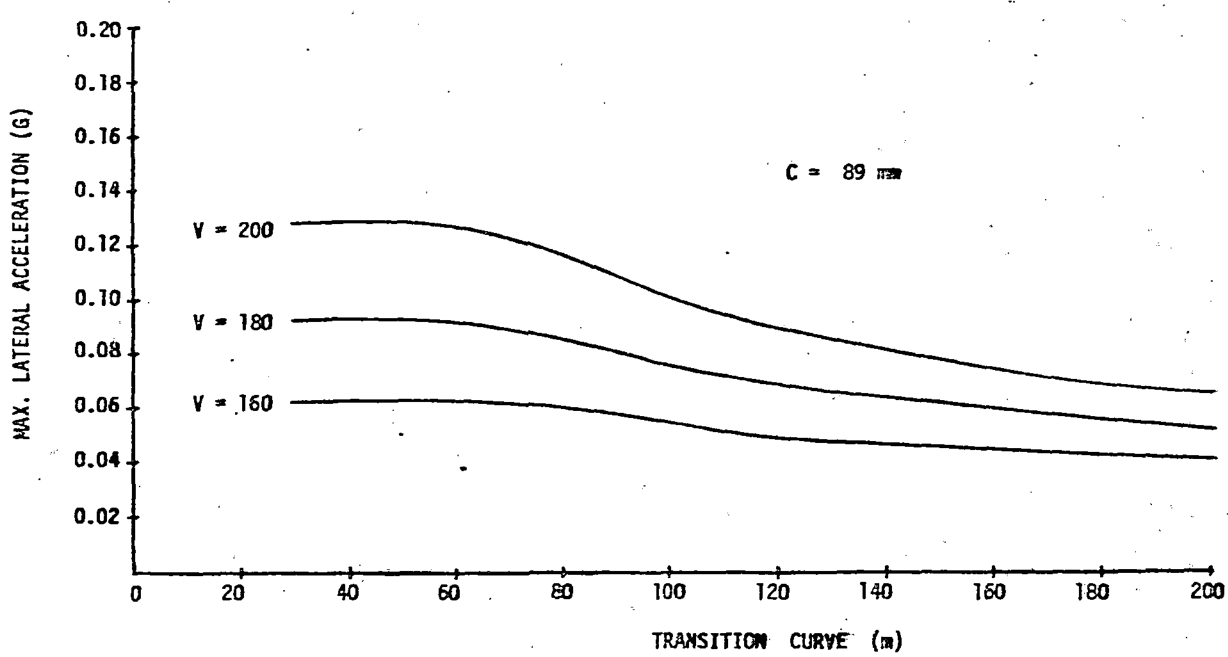

MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
C = 152 mm
V = 200
V = 180
V = 160
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)

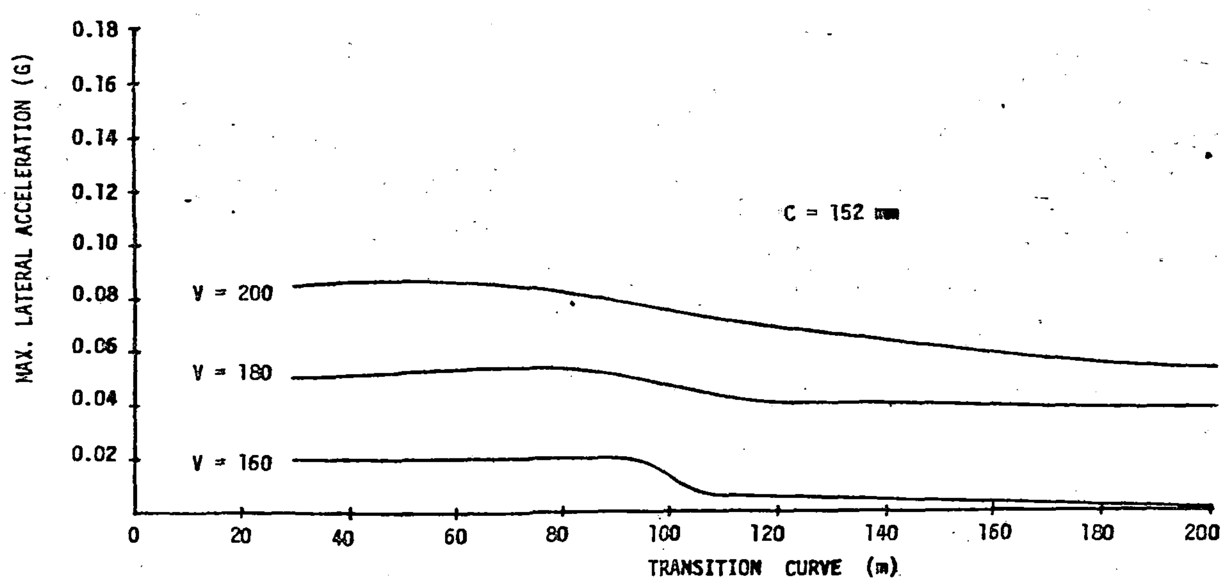

MAX. LATERAL ACCELERATION (G)
V = 200
V = 180
V = 160
V = 130
R = 1600 m
C = 47 mm
TRANSITION CURVE (m)

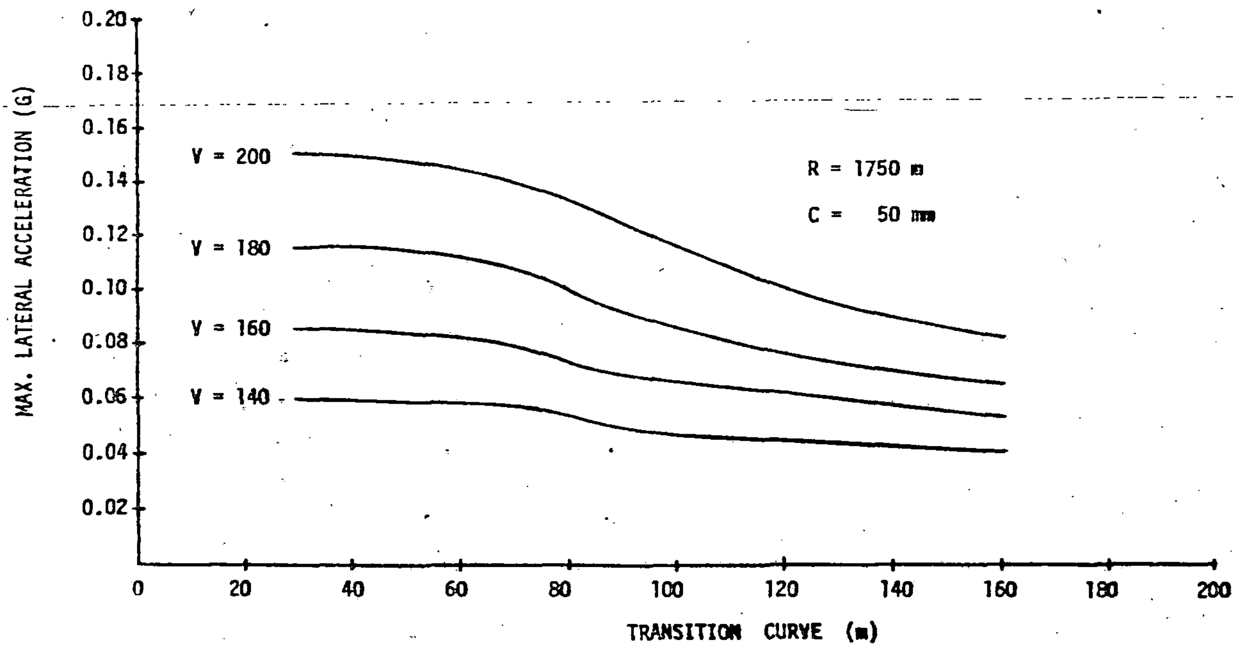

MAX. LATERAL ACCELERATION (G)
V = 200
V = 180
V = 160
C = 115 mm
TRANSITION CURVE (m)

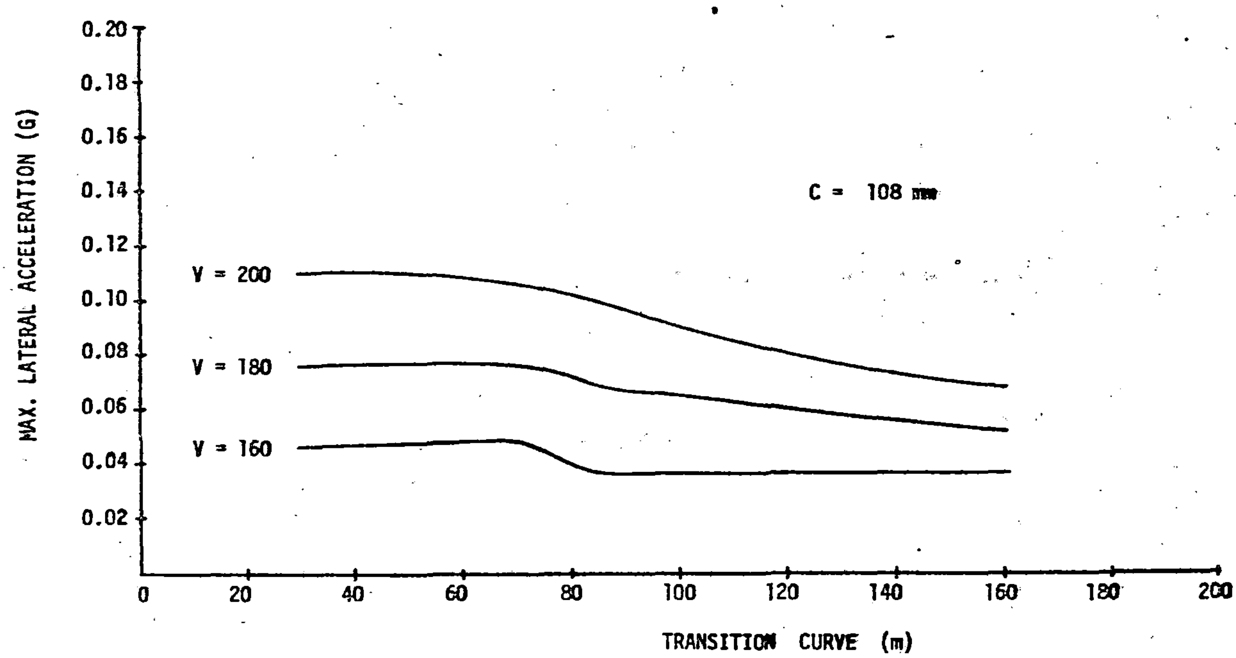

MAX. LATERAL ACCELERATION (G)
V = 200
V = 180
V = 160
C = 152 mm
TRANSITION CURVE (m)

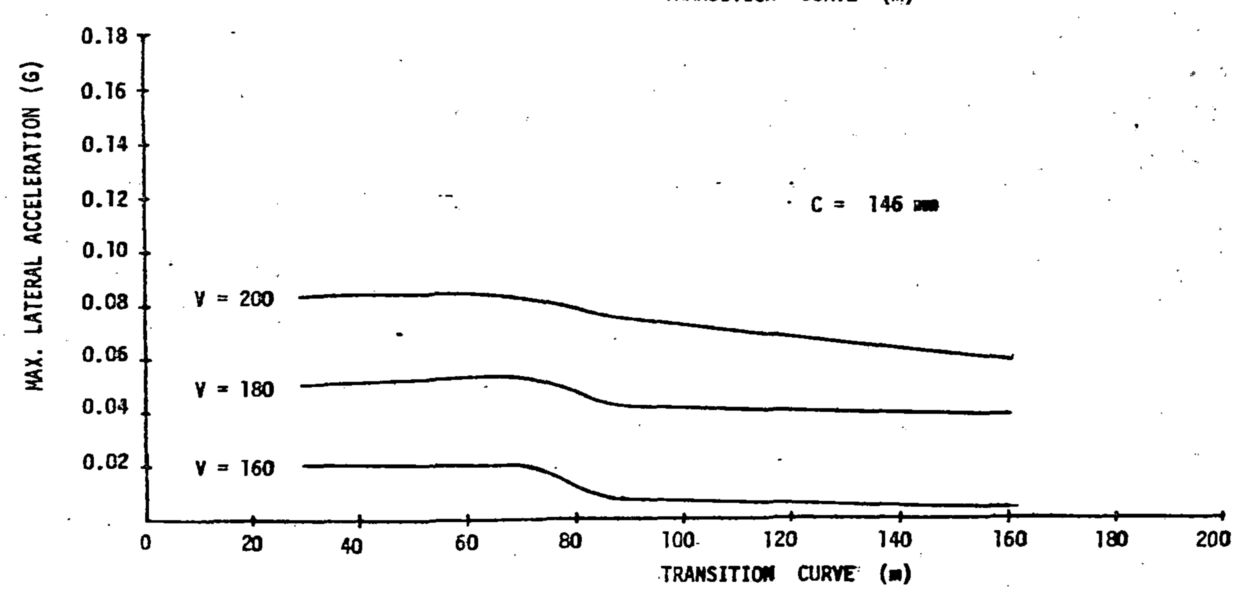

MAX. LATERAL ACCELERATION (G)
TRANSITION CURVE (m)
V = 200
V = 180
V = 160
V = 135
R = 1,700 m
C = 47 mm

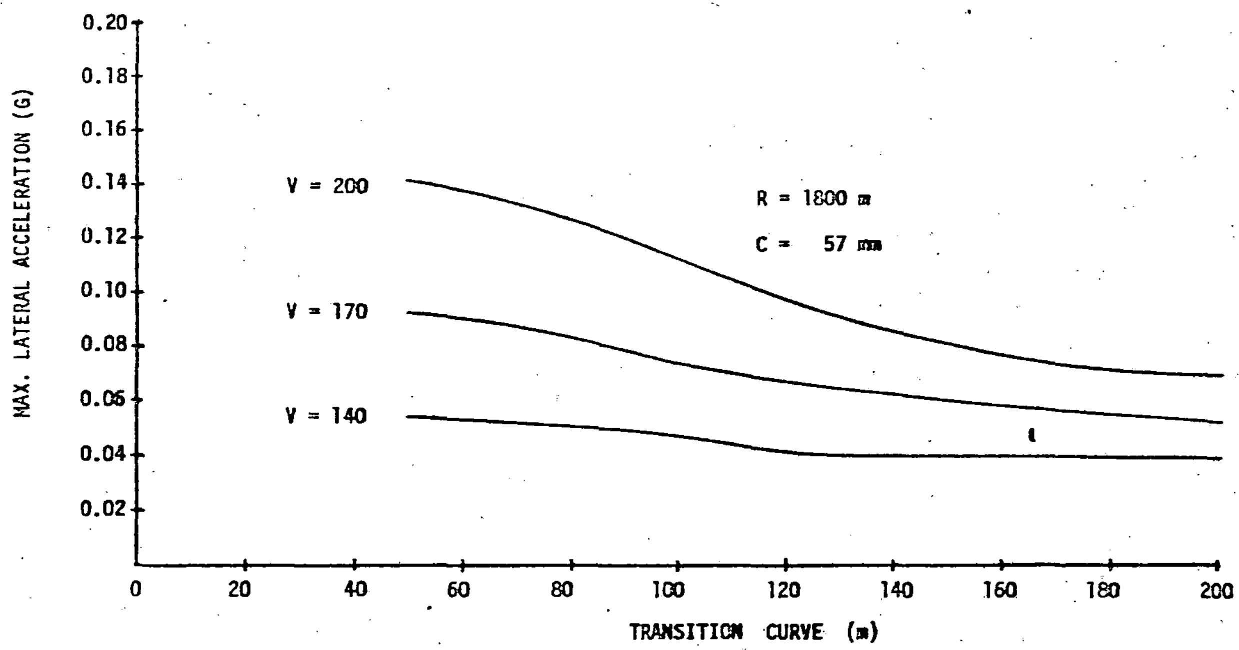

MAX. LATERAL ACCELERATION (G)
TRANSITION CURVE (m)
V = 200
V = 180
V = 160
C = 89 mm

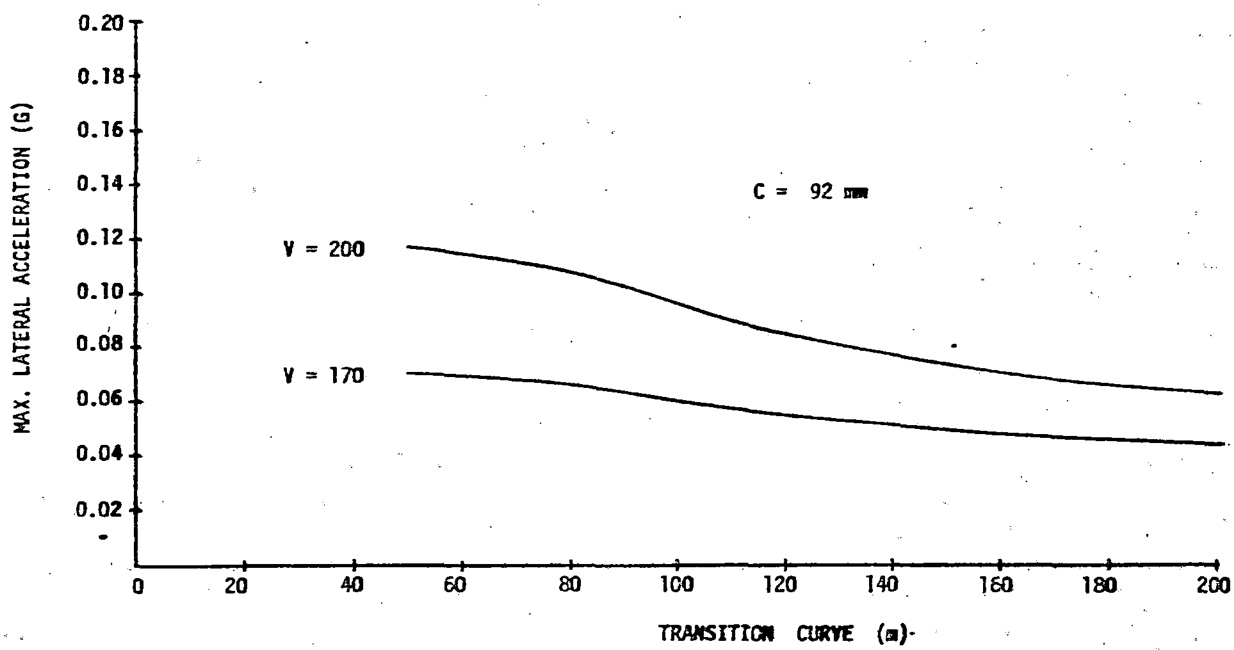

MAX. LATERAL ACCELERATION (G)
TRANSITION CURVE (m)
V = 200
V = 180
V = 160
C = 152 mm

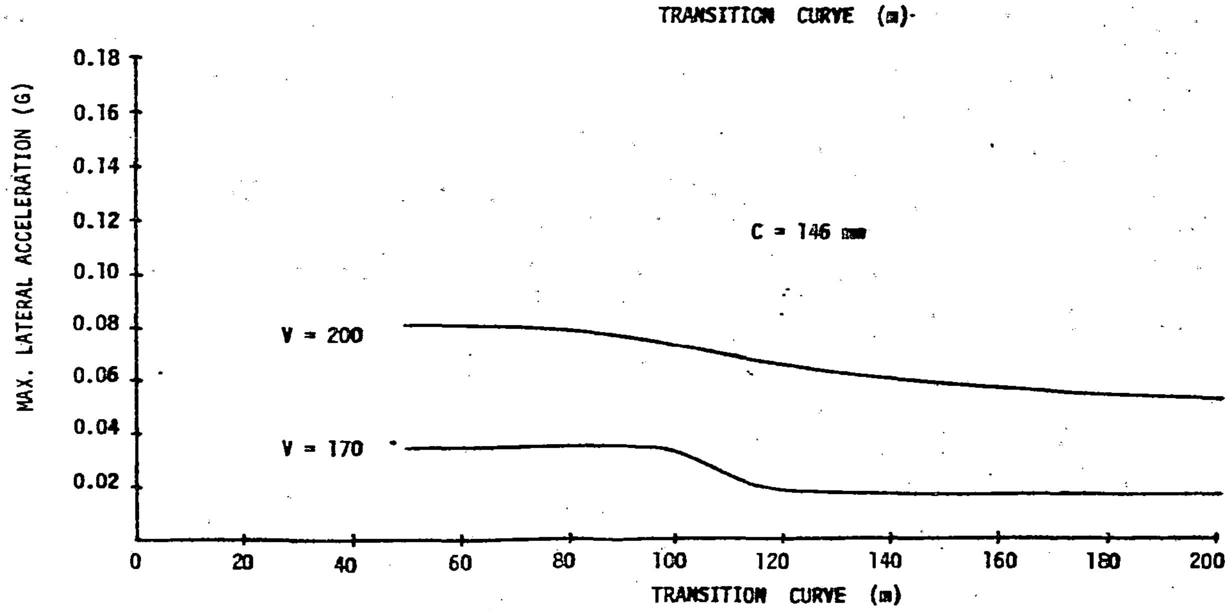

MAX. LATERAL ACCELERATION (G)
V = 200
V = 180
V = 160
V = 140
R = 1750 m
C = 50 mm
TRANSITION CURVE (m)

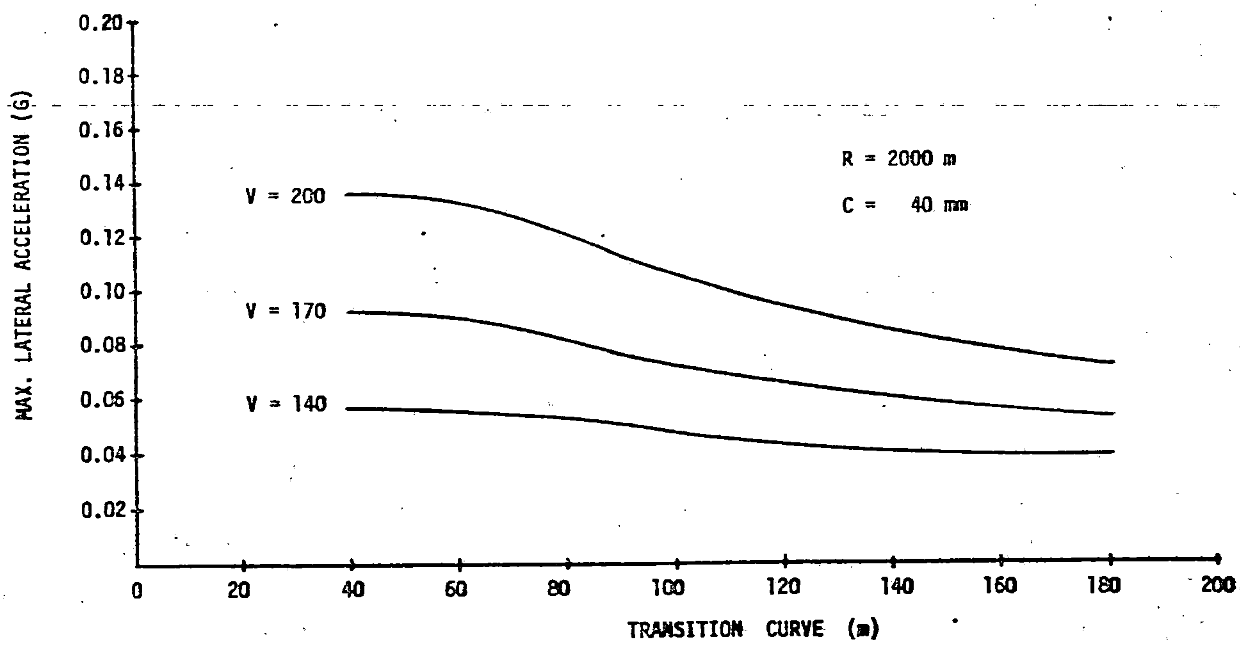

MAX. LATERAL ACCELERATION (G)
C = 108 mm
V = 200
V = 180
V = 160
TRANSITION CURVE (m)

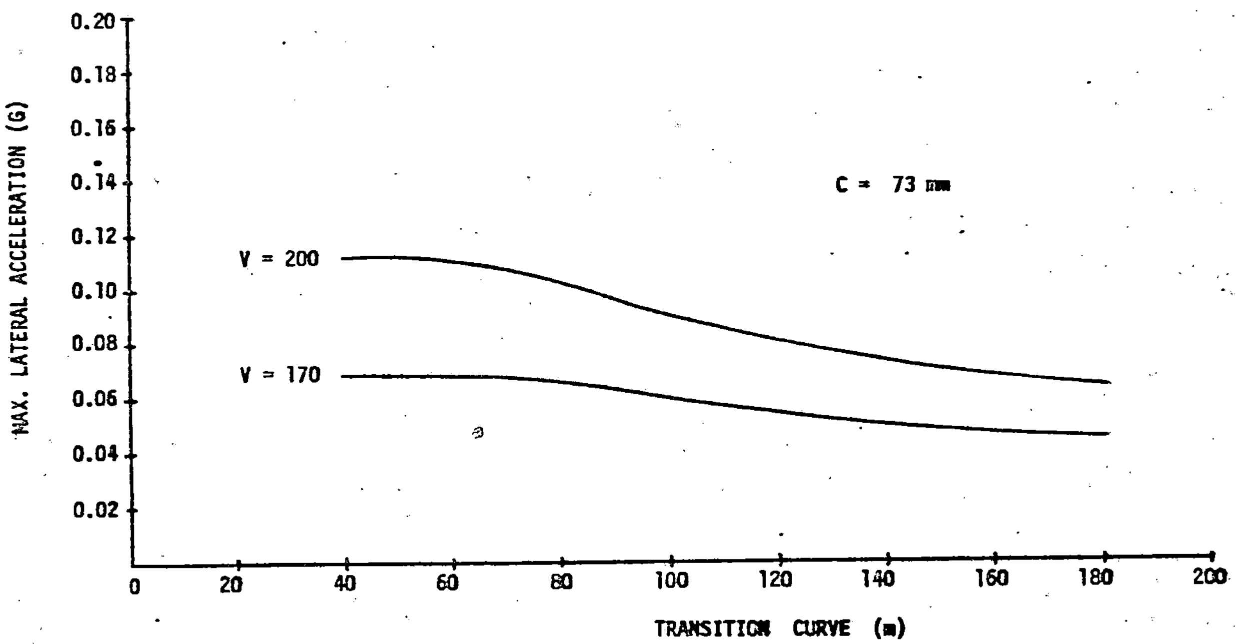

MAX. LATERAL ACCELERATION (G)
C = 146 mm
V = 200
V = 180
V = 160
TRANSITION CURVE (m)

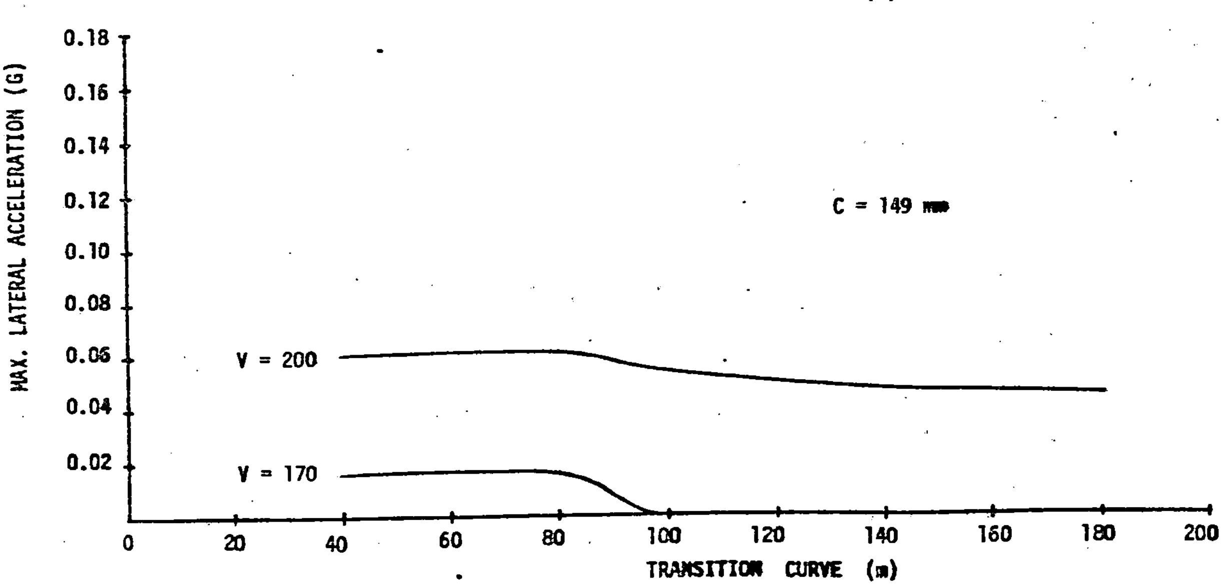

MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 170
V = 140
R = 1800 m
C = 57 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 170
C = 92 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
V = 200
V = 170
C = 146 mm
0
20
40
60
80
100
120
140
160
180
200
TRANSITION CURVE (m)


MAX. LATERAL ACCELERATION (G)
TRANSITION CURVE (m)
V = 200
V = 170
V = 140
R = 2000 m
C = 40 mm


MAX. LATERAL ACCELERATION (G)
TRANSITION CURVE (m)
V = 200
V = 170
C = 73 mm


MAX. LATERAL ACCELERATION (G)
TRANSITION CURVE (m)
V = 200
V = 170
C = 149 mm

7.6 MAXIMUM PERMISSIBLE VELOCITY OF VEHICLE AT EACH CURVE

The maximum permissible velocities of vehicle at each curve are shown in Table 7.6.

The symbols in Table are as follows.

V1 ; velocity of vehicle when uncompensated lateral static acceleration (by means of tilting mechanism with maximum tilting angle 6°) is 0.05g in circular curve.

V1 is calculated by the following formula.

$$V1^2 = 127R\ (ag + \frac{C}{G} + \theta)$$

where, R ; radius of curve

ag ; lateral acceleration   ag = 0.05 g

C ; superelevation

G ; track gauge

θ ; maximum tilting angle $\theta = 6°$ (0.1047 rad)

V2 ; velocity of vehicle (maximum lateral acceleration of carbody occurred in transition curve is 0.08 g)

V2 is decided by reading from ag - LS diagram (Section 7.5).

V3 ; velocity of vehicle (maximum lateral acceleration of carbody occurred in transition curve is 0.05 g)

V3 is decided by reading from ag - LS diagram (Section 7.5).

V4 ; safety limit velocity for overturn (wind speed S=20 m/sec.) (Cf. Section 5.1.2)

V2 is considered as the maximum permissible velocity of vehicle at each curve in terms of ride comfort in transition curves.

Table 7.6 MAXIMUM PERMISSIBLE VELOCITY FOR EACH CURVE (BOSTON - NEW YORK)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g 1 (g)	a_g 2 (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
1	219	-	-	76	-	-	76	76	81
4	373	-	-	89	-	-	89	89	98
5	426	-	-	99	-	-	99	99	108
6	184	-	-	75	-	-	75	75	80
7	1806	-	-	193	-	-	193	193	217
9	1278	-	-	193	-	-	193	193	198
10	1177	-	-	185	-	-	185	185	197
16	1733	116	126	193	0.072	0.070	193	170	239
17-21	1744	107	107	193	0.075	0.075	193	155	240
22	1750	132	128	193	0.062	0.063	193	177	245
23	1750	130	122	193	0.062	0.065	193	177	245
24	1115	152	152	190	0.087	0.087	184	155	201
25	579	102	37	128	0.088	0.158	103	93	136
27	474	139	139	120	0.069	0.069	120	105	127
29	3492	30	30	193	-	-	193	193	-
31	1644	30	30	193	0.157	0.157	154	134	217
32	975	91	91	165	0.117	0.117	143	126	175
35	866	95	104	155	0.105	0.099	140	117	165
36	1037	128	78	166	0.090	0.132	139	118	177
37	418	122	79	112	0.074	0.099	104	88	118

Cd/G : Maximum acceleration by cant deficiency in circular curve

Cd : Cant deficiency

G : Gauge

a_g : Maximum lateral acceleration of carbody in transition curve

S : Wind speed

(BOSTON - NEW YORK)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g1 (g)	a_g2 (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
40	355	-	-	98	-	-	98	98	104
41	533	81	73	125	0.102	0.110	111	94	132
43	572	73	103	127	0.111	0.087	113	95	136
45	432	140	178	112	0.068	0.056	112	99	119
46	359	105	105	107	0.078	0.078	107	90	113
47	1000	152	152	180	0.082	0.082	177	149	191
48	1838	101	101	193	0.085	0.085	187	162	241
49	1822	92	92	193	0.090	0.090	185	162	240
50	1140	152	152	189	0.088	0.088	184	154	200
51	1397	126	126	193	0.089	0.089	188	161	219
52	1330	111	157	193	0.092	0.074	184	160	218
53	1822	92	92	193	-	-	193	193	239
58	1746	-	152	193	-	0.052	193	189	250
61	888	152	152	171	0.080	0.080	171	142	181
62	1167	141	144	183	0.090	0.088	175	142	194
63	787	165	152	160	0.074	0.077	160	136	169
64	998	126	126	175	0.094	0.094	166	138	185
65	1096	141	92	184	0.090	0.126	161	138	195
66	902	151	143	171	0.084	0.085	167	140	181
67	698	152	152	150	0.075	0.075	150	128	159
68	895	118	117	164	0.093	0.094	155	128	174
69	1038	114	114	173	0.101	0.101	159	132	183
70	759	152	152	159	0.079	0.079	159	135	167
71	847	128	128	162	0.088	0.088	157	131	171
72	880	127	156	163	0.086	0.076	157	131	173
73	851	131	131	162	0.085	0.085	157	132	172
74	1219	122	122	175	0.095	0.095	162	133	187
75	456	112	90	116	0.080	0.091	111	92	123
76	625	101	101	134	0.092	0.092	127	105	143
77	598	141	141	139	0.076	0.076	139	118	147
78	698	152	152	149	0.073	0.073	149	127	158
79	475	108	-	125	0.084	-	123	102	132

(BOSTON - MEW YORK)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g1 (g)	a_g2 (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
81	470	-	-	120	-	-	120	120	128
82	1037	-	-	172	-	-	172	172	183
84	657	136	129	142	0.078	0.081	142	117	150
85	562	95	109	132	0.098	0.091	124	105	139
86	1180	88	88	176	0.125	0.125	150	127	188
87	1746	46	61	193	0.133	0.128	156	135	222
88	486	122	122	127	0.079	0.079	127	107	134
89	743	128	128	136	0.077	0.077	136	111	148
90	389	149	149	110	0.061	0.061	110	100	116
91	612	-	82	126	-	0.098	115	95	136
92	471	120	43	117	0.069	0.122	102	92	131
93	289	162	99	85	0.044	0.069	85	72	91
94	183	58	60	69	-	-	69	69	75
95	244	59	50	78	0.095	0.108	70	59	85
96	829	45	59	142	0.155	0.142	110	95	152
98	3227	72	69	193	-	-	193	193	-
99	3131	115	109	193	-	-	193	193	-
100	554	115	127	131	0.089	0.085	130	109	138
101	817	102	101	159	0.124	0.125	134	125	168
102	582	120	97	133	0.081	0.095	125	106	141
103	592	152	97	135	0.071	0.095	126	107	144
104	785	102	97	154	0.100	0.104	142	120	163
105	969	223	106	169	0.059	0.104	153	129	179
106	900	167	143	171	0.072	0.081	170	145	186
107	866	112	126	164	0.098	0.089	153	129	173
108	714	102	93	139	0.094	0.101	128	106	148
109	581	96	113	132	0.095	0.084	124	104	140
110	545	135	127	130	0.074	0.076	130	109	138
111	848	135	137	163	0.085	0.084	159	133	172
112	874	117	93	164	0.095	0.113	146	125	173
113	858	129	133	163	0.087	0.085	157	132	172
115	863	94	107	163	0.111	0.100	147	124	173

(BOSTON - NEW YORK)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g 1 (g)	a_g 2 (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
116	498	80	68	115	0.098	0.109	103	85	123
118	812	124	142	161	0.088	0.080	155	131	170
120	683	80	105	139	0.114	0.095	123	103	148
121	920	152	153	165	0.079	0.079	165	136	176
122	831	-	87	162	-	0.115	144	125	171
123	1496	70	85	193	0.141	0.129	156	133	211
124	1795	66	55	193	0.124	0.128	155	100	227
125	1182	79	141	182	0.139	0.088	157	129	194
126	706	137	168	153	0.082	0.071	151	127	161
127	939	101	96	166	0.112	0.107	154	131	177
128	1887	90	110	193	0.088	0.080	185	161	242
129	6984	-	-	193	-	-	193	193	-
130	4762	-	-	193	-	-	193	193	-
133	1570	80	80	193	0.108	0.108	176	154	227
134	732	150	181	156	0.078	0.069	156	131	164
137	848	121	121	168	0.093	0.093	158	135	177
138	1749	72	72	193	0.116	0.116	169	143	229
140	1219	99	49	176	0.113	0.158	136	119	189
141	446	94	94	117	0.089	0.089	113	95	124
142	574	57	142	123	0.133	0.068	103	88	132
144	594	108	133	137	0.088	0.076	133	112	145
145	762	74	125	147	0.123	0.084	126	108	156
146	559	57	132	133	0.131	0.076	113	102	141
147	1323	96	92	192	0.125	0.130	163	139	204
148	602	55	79	132	0.141	0.108	110	96	140
149	380	65	84	102	0.102	0.084	94	76	108
150	419	61	80	106	0.112	0.093	93	80	113
151	474	58	80	106	0.104	0.083	97	80	120
152	945	30	30	148	0.164	0.164	109	94	160
153	788	-	-	130	-	-	130	130	141
154	534	-	-	115	-	-	115	115	124
155	1475	-	-	191	-	-	191	191	205

(BOSTON - NEW YORK)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g1 (g)	a_g2(g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
156	911	-	-	165	-	-	165	165	175
161	927	-	-	161	-	-	161	161	176
162	1080	-	-	178	-	-	178	178	189
163	1871	-	-	193	-	-	193	193	235
164	1435	-	-	193	-	-	193	193	212
165	4762	-	-	193	-	-	193	193	-
168	927	-	-	169	-	-	169	169	179
169	5238	-	-	193	-	-	193	193	-
170	1069	-	-	185	-	-	185	185	196
171	355	-	-	108	-	-	108	108	114
172	582	-	-	121	-	-	121	121	130
173	389	-	-	114	-	-	114	114	119
175	743	-	-	151	-	-	151	151	160
178	806	-	-	155	-	-	155	155	165
180	1204	-	-	189	-	-	189	189	201
181	1541	-	-	193	-	-	193	193	217
185	873	-	-	166	-	-	166	166	175
186	429	-	-	106	-	-	106	106	114
187	852	-	-	162	-	-	162	162	172
188	873	-	-	167	-	-	167	167	177
191	1069	-	-	177	-	-	177	177	188
192	788	-	-	162	-	-	162	162	171
193	852	-	-	165	-	-	165	165	175
194	845	-	-	166	-	-	166	166	175
195	961	-	-	174	-	-	174	174	184
196	873	-	-	164	-	-	164	164	174
197	1190	-	-	185	-	-	185	185	196
199	895	-	-	162	-	-	162	162	172
200	903	-	-	167	-	-	167	167	177
203	873	-	-	164	-	-	164	164	174
204	873	-	-	167	-	-	167	167	177
205	733	-	-	152	-	-	152	152	161

(BOSTON - NEW YORK)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g 1 (g)	a_g 2 (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
206	569	-	-	130	-	-	130	130	138
207	888	-	-	166	-	-	166	166	175
208	602	-	-	139	-	-	139	139	146
209	873	-	-	166	-	-	166	166	175
210	961	-	-	169	-	-	169	169	179
211	1475	-	-	193	-	-	193	193	213
213	1048	-	-	173	-	-	173	173	184
214	651	-	-	131	-	-	131	131	140
215	398	-	-	99	-	-	99	99	107
216	1230	46	46	174	0.160	0.160	133	116	187
218	699	83	83	144	0.113	0.113	128	110	152
219	536	62	62	120	0.123	0.123	104	87	128
220	554	77	58	120	0.103	0.130	102	85	128
221	721	65	71	137	0.128	0.120	116	101	148
222	2238	113	92	193	-	-	193	193	248
224	690	115	115	150	0.092	0.092	143	122	158
225	569	60	60	119	0.125	0.125	102	85	128
226	577	30	65	125	0.165	0.121	90	75	134
228	889	71	71	158	0.135	0.135	133	115	168
229	1529	221	47	193	0.068	0.156	150	128	210
230	409	58	58	104	0.113	0.113	91	80	112
232	553	48	48	118	0.143	0.143	95	83	127
234	496	60	60	116	0.115	0.115	101	83	124
235	471	43	77	108	0.136	0.096	87	75	116
236	2328	-	-	193	-	-	193	193	246

(NEW YORK - WASHINGTON)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	$a_g 1$ (g)	$a_g 2$ (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
240	919	57	57	156	0.150	0.150	125	109	167
243	551	76	76	126	0.107	0.107	113	95	134
248	1732	36	25	193	0.150	0.150	148	124	215
249	1757	-	-	193	-	-	193	193	228
252	883	78	91	160	0.128	0.113	136	118	170
253	1397	38	41	193	0.166	0.164	149	131	206
259	3457	82	-	193	-	-	193	193	-
261	2439	111	111	193	-	-	193	193	284
262	1343	117	117	193	0.098	0.098	180	154	213
265	3871	111	111	193	-	-	193	193	-
266	1143	126	134	193	0.100	0.096	180	153	204
267	1448	128	157	193	0.085	0.074	190	161	221
268	884	169	178	171	0.075	0.072	171	145	181
269	1145	178	194	193	0.078	0.075	193	164	206
270	2084	161	161	193	-	-	193	193	261
291	1089	123	120	190	0.101	0.103	175	149	201
297	959	155	61	152	0.074	0.144	121	105	164
298	437	129	82	120	0.073	0.098	112	96	127
299	683	112	85	150	0.092	0.113	135	119	158
302	836	80	53	144	0.115	0.150	113	96	154
303	344	36	36	100	0.154	0.154	81	71	106
304	425	-	-	108	-	-	108	108	115
306	695	91	91	133	0.097	0.097	125	98	143
307	1397	112	80	193	0.111	0.125	167	143	214
308	1650	36	61	193	0.151	0.146	150	128	214
309	1743	40	40	193	0.135	0.135	158	134	223
311	1746	38	38	193	0.139	0.139	156	132	222
312	1646	183	174	193	0.051	0.052	193	190	246
319	1713	152	152	193	0.080	0.080	193	178	248
323	2183	126	126	193	-	-	193	193	269
324	1134	152	122	192	0.087	0.102	178	151	203
327	579	122	61	113	0.073	0.119	95	75	124

(NEW YORK - WASHINGTON)

CURVE NO.	RADIUS OF CURVE	LENGTH OF EXISTING TRANSITION CURVE		VELOCITY OF VEHICLE ($\theta = 6°$)	MAXIMUM LATERAL ACCELERATION IN TRANSITION CURVE		REDUCED VELOCITY OF VEHICLE ($\theta = 6°$)		SAFETY LIMIT VELOCITY FOR OVERTURN
		ENTRANCE	EXIT	Cd/G = 0.05 g	ENTRANCE	EXIT	a_g = 0.08 g	a_g = 0.05 g	S = 20 m/sec.
	R (m)	LS1 (m)	LS2 (m)	V1 (Km/h)	a_g 1 (g)	a_g 2 (g)	V2 (Km/h)	V3 (Km/h)	V4 (Km/h)
328	438	32	97	99	0.169	0.086	78	85	108
351	1744	132	132	193	0.061	0.061	193	182	247
357	1485	245	152	193	0.047	0.063	193	177	234
361	2590	-	156	193	-	-	193	193	292
371	1397	58	58	184	0.155	0.155	116	73	198
372	1035	30	30	163	0.158	0.158	125	110	174
373	872	76	76	152	0.125	0.125	129	110	162
374	430	99	80	112	0.083	0.096	105	87	119
375	388	170	198	109	0.056	0.053	109	103	115
376	355	-	-	96	-	-	96	96	102
380	466	-	-	107	-	-	107	107	116
381	457	99	116	119	0.086	0.077	115	97	125
382	884	122	122	171	0.092	0.092	161	135	181
383	1352	91	91	193	0.134	0.134	163	139	205
415	556	38	80	121	0.130	0.524	95	83	129

7.7 OPERATION TIME

Operation time (NEWYORK - WASHINGTON) is calculated for AMCOACH incorporated with the tilting truck.

Calculation conditions are as follows.

- Train Arrangement

  AEM 7 Electric Locomotive + AMCOACH 4 cars

  AEM 7 Electric Locomotive + AMCOACH 6 cars

- Weight of Car

  AEM 7 EL ..... WM = 90.7 ton

  AMCOACH ..... WC = 57.815 ton per car (maximum load)

- Running Speed

  V2 and V3 (Cf. Section 7.6)

- Maximum Running Speed

  193 Km/h (120 mile/h)

- Station Dwell Time

Station	Dwell Time
NEWYORK	
TRENTON	1 minute
PHILADELPHIA	1 minute 30 seconds
WILMINTON	1 minute
BALTIMORE	1 minute
BELTWAY	1 minute
WASHINGTON	
Total Time	5 minutes 30 seconds

Calculation Result is shown in Table 7.7.

Run curve (AEM 7 + AMCOACH 6 cars, running speed V2) is shown in Figure 7.7.

Table 7.7 Operation Time Table

NEWYORK - WASHINGTON

Running Speed	Arrangement of Vehicles	NEWYORK - TRENTON - PHILADELPHIA - WILMINTON - BALTIMORE - BELTWAY - WASHINGTON						Total Stop Time at Stations	Total Operation Time
V2	AEM 7 + AMCOACH 4 cars	36.76 min.	24.33 min.	15.93 min.	38.87 min.	19.15 min.	9.98 min.	5.5 min.	150.51 min.
V3	AEM 7 + AMCOACH 4 cars	37.68 min.	25.13 min.	17.04 min.	39.63 min.	19.44 min.	10.03 min.	5.5 min.	154.45 min.
V2	AEM 7 + AMCOACH 6 cars	37.13 min.	24.66 min.	16.23 min.	39.24 min.	19.43 min.	10.30 min.	5.5 min.	152.49 min.
V3	AEM 7 + AMCOACH 6 cars	38.12 min.	25.5 min.	17.37 min.	40.05 min.	19.73 min.	10.35 min.	5.5 min.	156.62 min.

Maximum Running Speed : 193 Km/h (120 mile/h)

Figure 7.6 Run Curve - AMCOACH with Tilting Truck

7.8 INFLUENCE OF TILTING LENGTH

Influence of tilting length on transient response of tilting vehicle has been investigated.

Calculation data are as follows.

R : radius of curve 400 m

C : superelevation 115 mm

LS1 : length of entrance transition curve 50 m

LS2 : length of exit transition curve 120 m

V : running speed 100 Km/h

hG : center of gravity height of carbody 1900 mm

$\ell 0$: tilting length 600, 700, 800, 900, 1000 mm

Relation between tilting length and maximum lateral acceleration of carbody in transition curve is shown in Figure 7.8.

It is effective for transient response to lengthen tilting length.

However, if the tilting length is too long, lateral movement of carbody becomes large.

Therefore, maximum tilting length is taken within a limit of of clearance line.

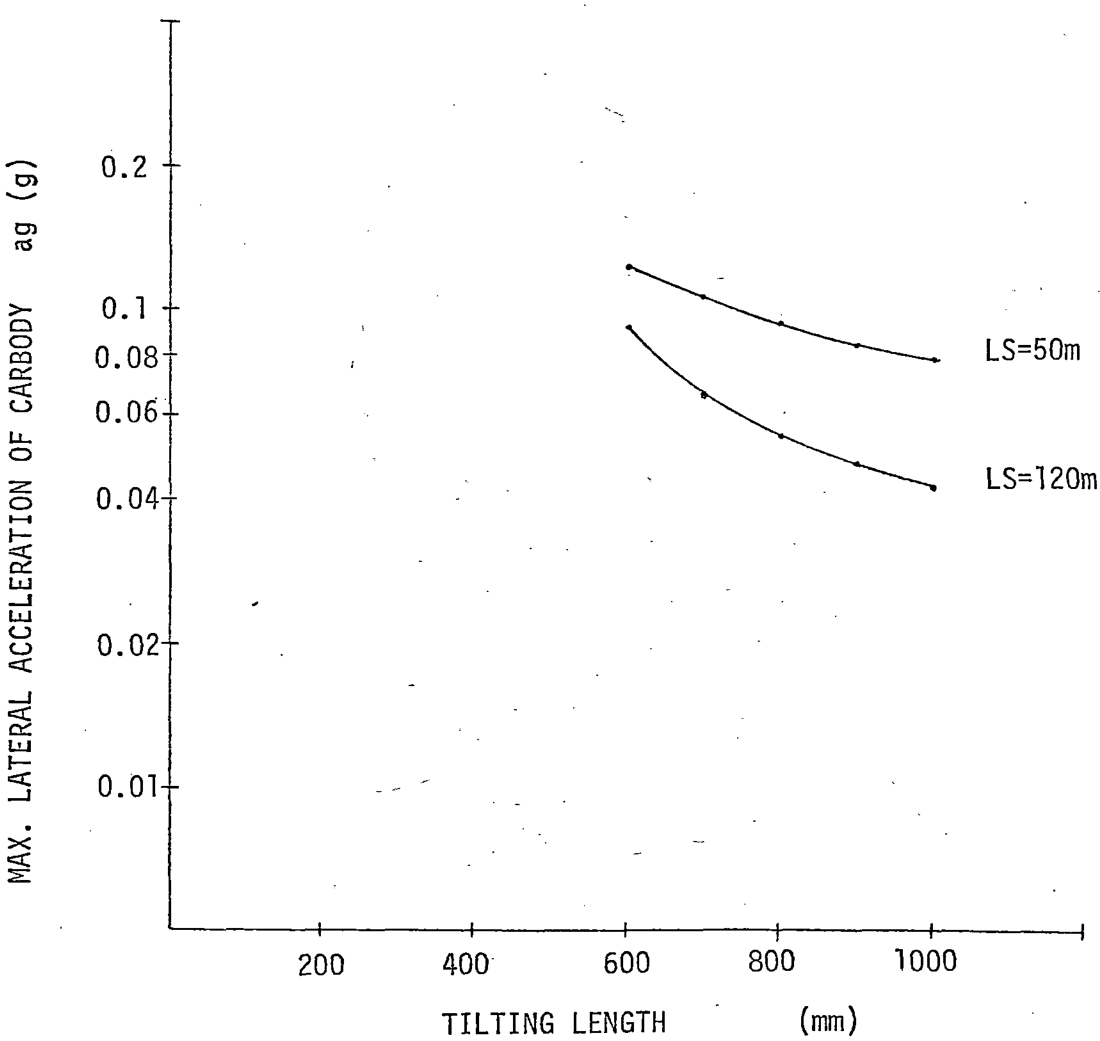


Figure 7.8 Influence of Tilting Length

7.9 INFLUENCE OF DAMPING COEFFICIENT OF TILTING DAMPER

Influence of damping coefficient of tilting damper on transient response has been examined.

Calculation data are as follows.

R	;	radius of curve 400 m
C	;	superelevation 115 mm
LS1	;	length of entrance transition curve 50 m
LS2	;	length of exit transition curve 120 m
V	;	running speed 100 Km/h
$\ell 0$	;	tilting length 800 mm
C2	;	damping coefficient of tilting damper 5, 10, 15, 20 Kg/cm/sec.

Relation between damping coefficient of tilting damper and maximum lateral acceleration of carbody in transition curve is shown Figure 7.9.

Low damping coefficient is better for transient responce.

However, if the damping coefficient is too low, the vehicle shows a over tilting motion.

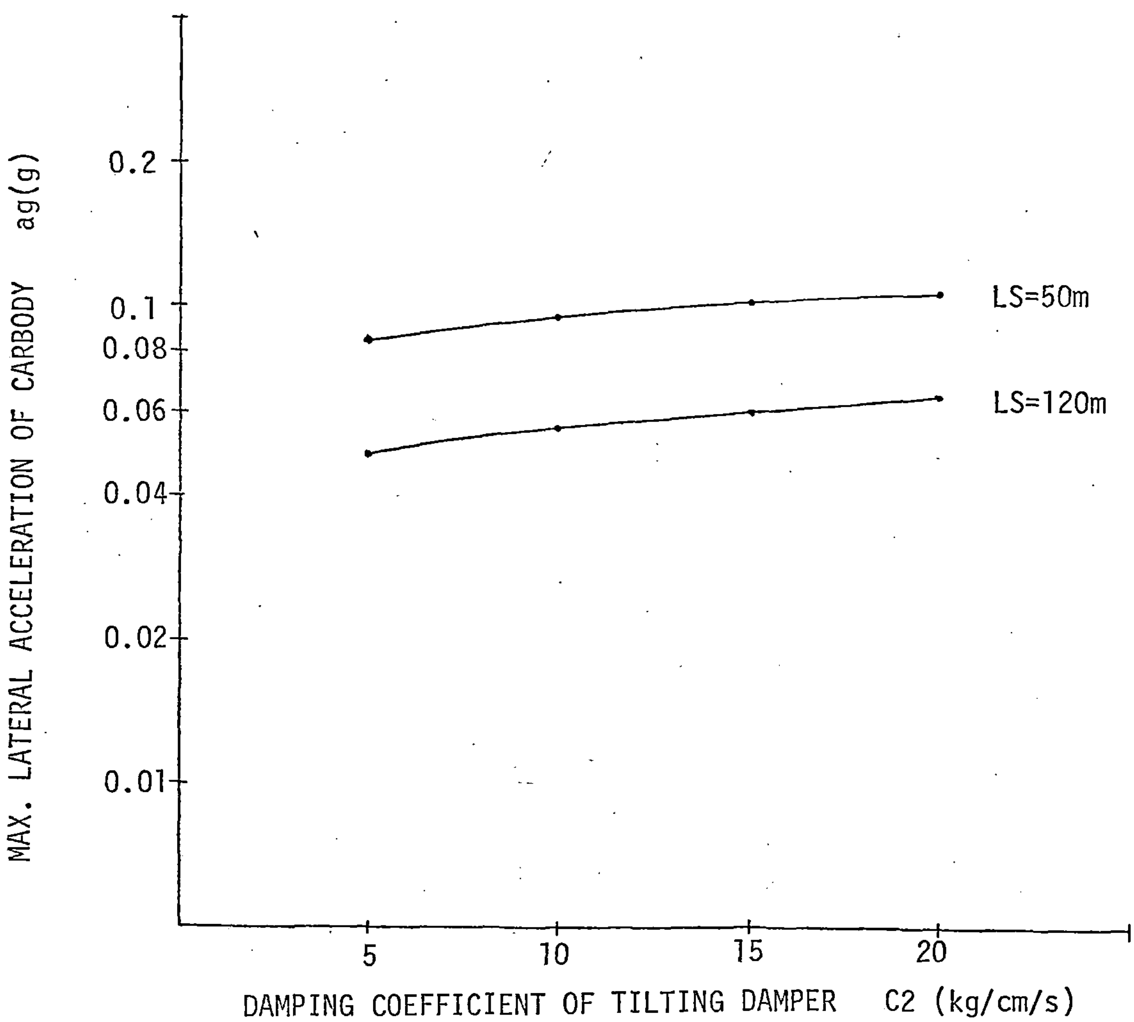
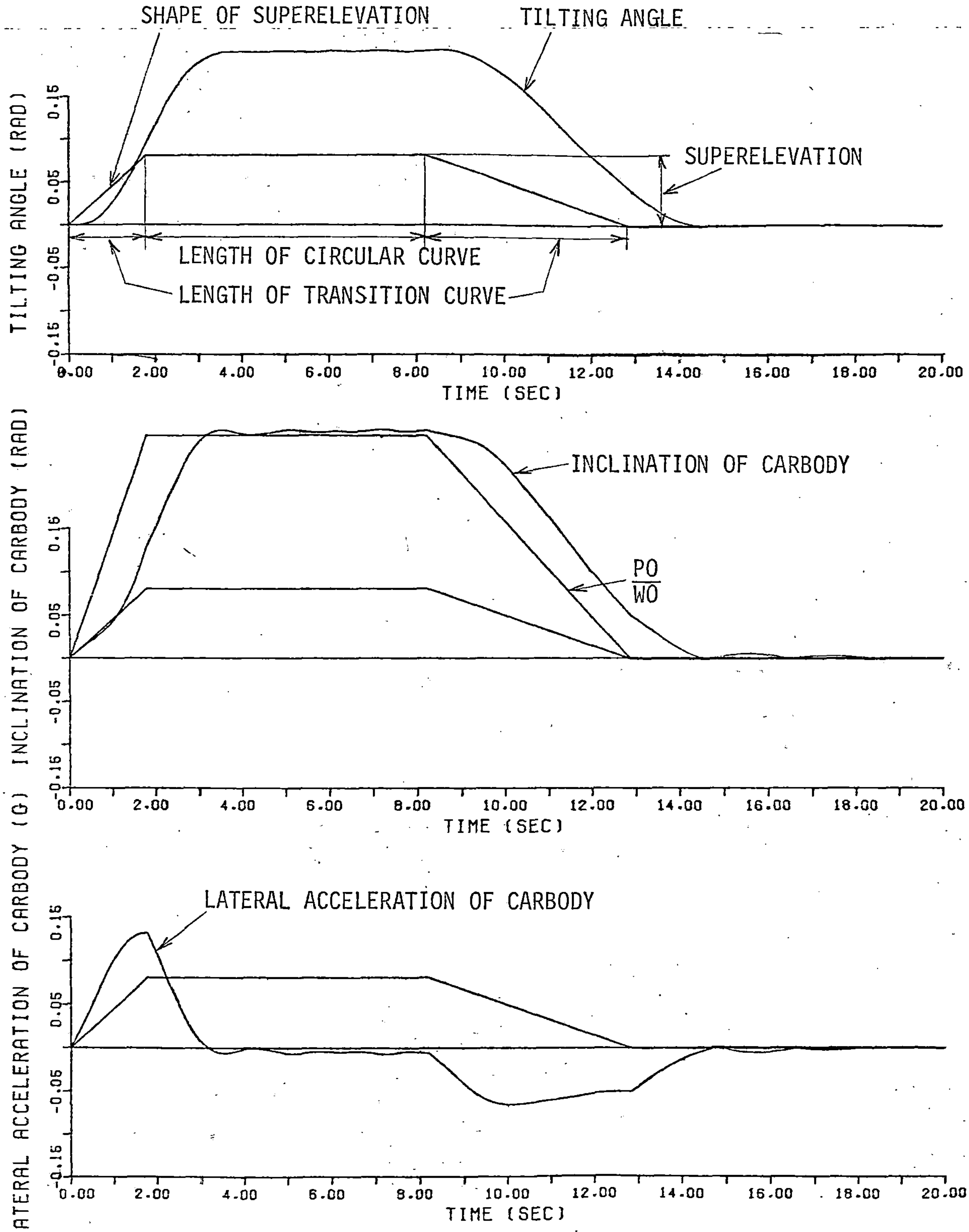


Figure 7.9 Influence of Damping Coefficient of Tilting Damper

7.10 TRANSIENT RESPONSE DIAGRAM OF TILTING VEHICLE

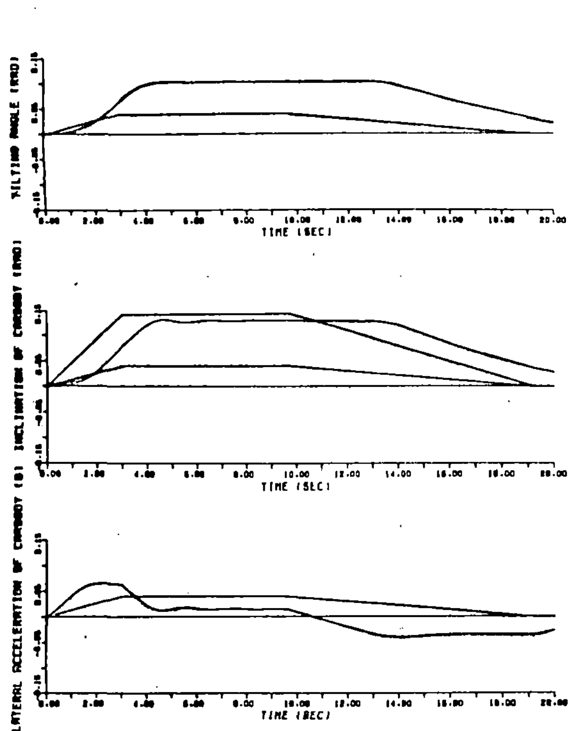
The example of output of transient response diagram is shown in Figure 7.10 (A).

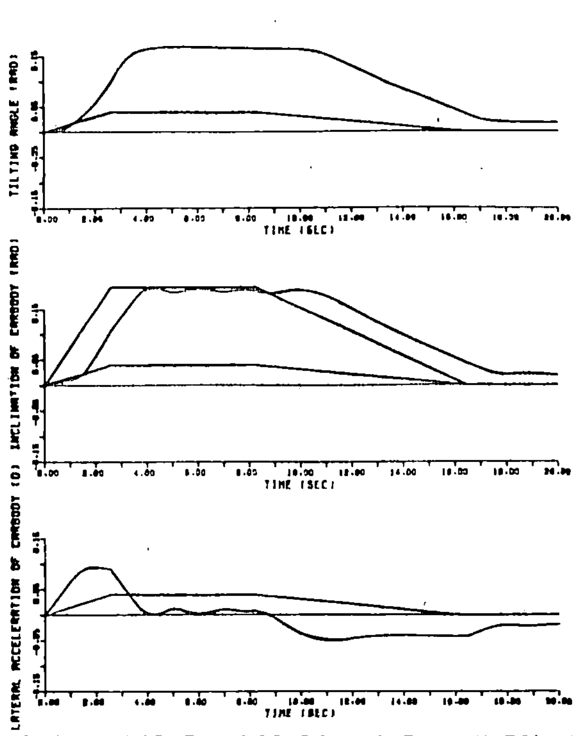
The transient response diagrams for each curve are shown in Figure 7.10 (B).

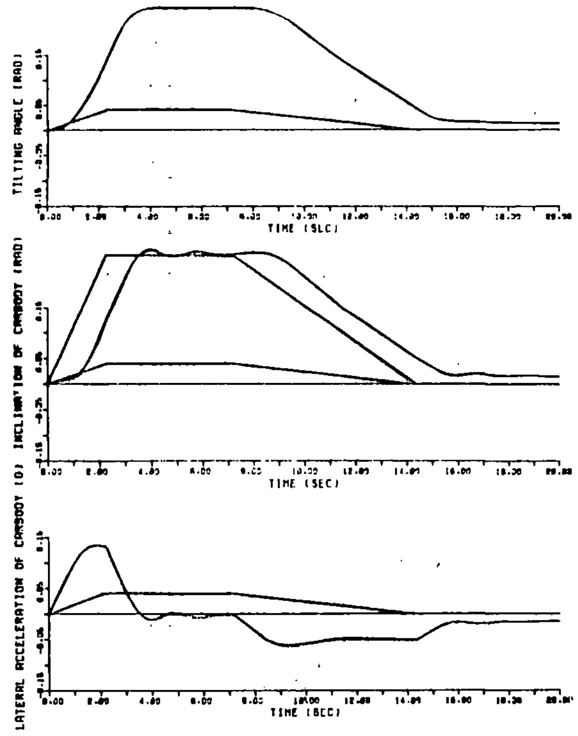


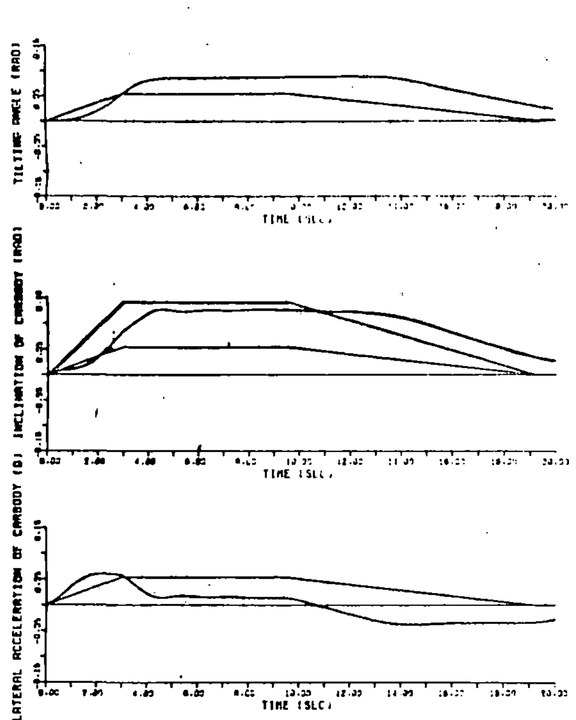
R=600m LS1=70m LS2=180m C=117mm V=140 km/h

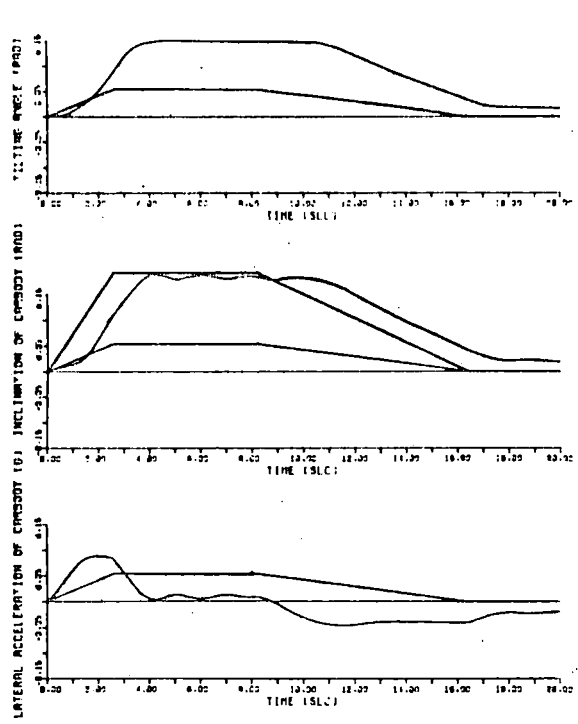
Figure 7.10 (A) Example of Output - Transient Response Diagram

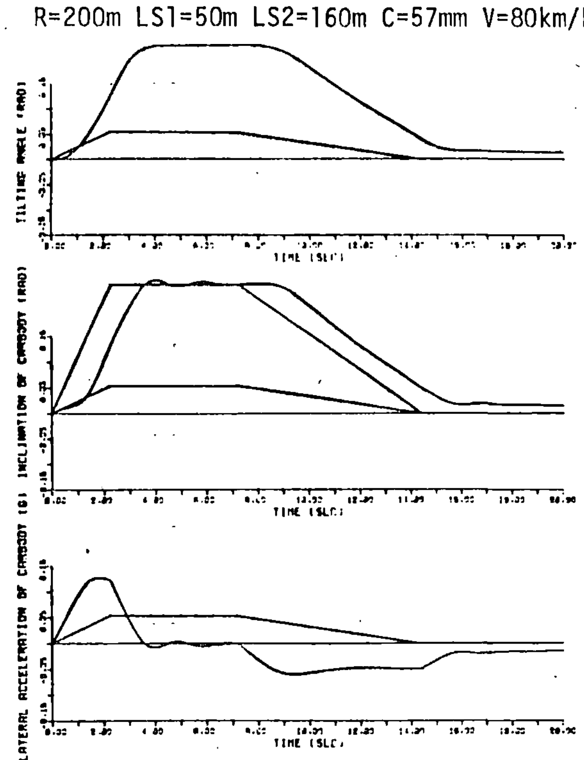

R=200m LS1=50m LS2=160m C=57mm V=60km/h

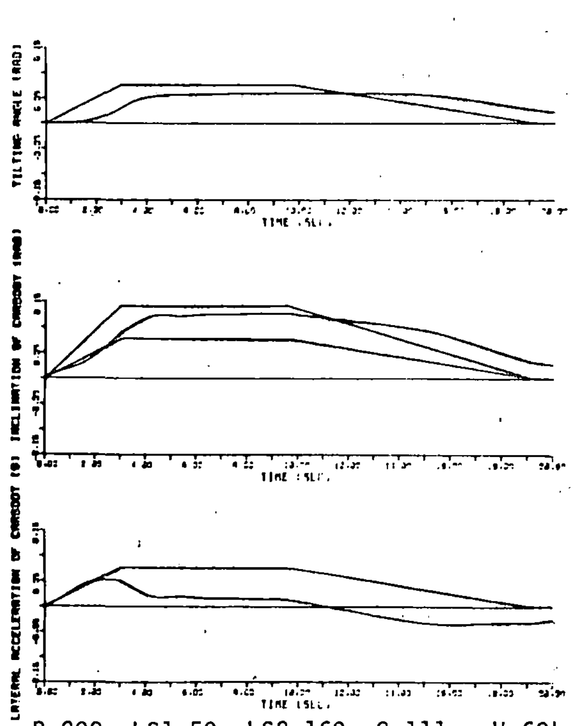

R=200m LS1=50m LS2=160m C=57mm V=70km/h

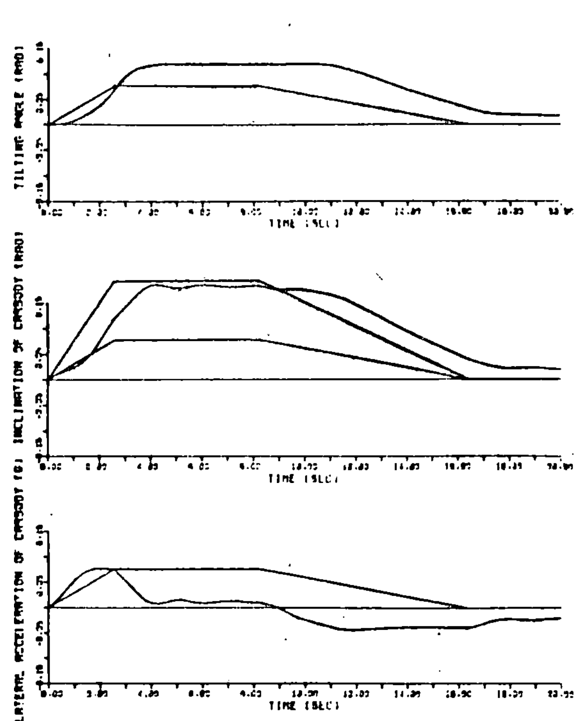

R=200m LS1=50m LS2=160m C=57mm V=80km/h


R=200m LS1=50m LS2=160m C=77mm V=60km/h


R=200m LS1=50m LS2=160m C=77mm V=70km/h


R=200m LS1=50m LS2=160m C=77mm V=80km/h


R=200m LS1=50m LS2=160m C=111mm V=60km/h


R=200m LS1=50m LS2=160m C=111mm V=70km/h

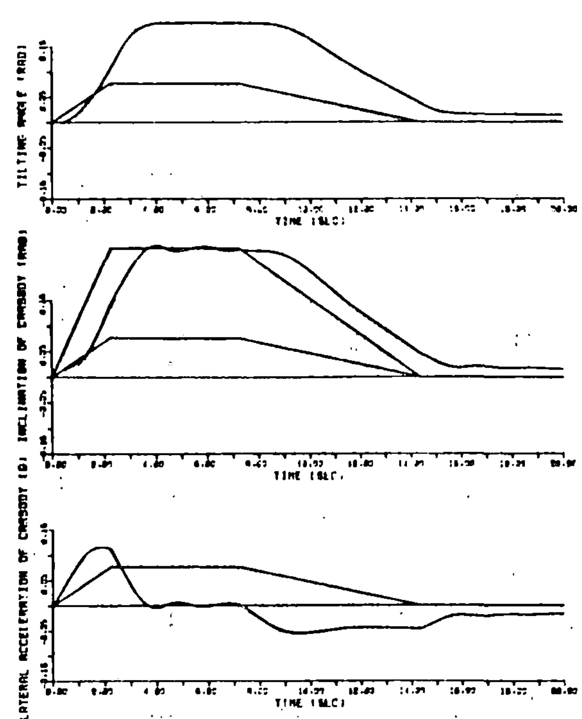
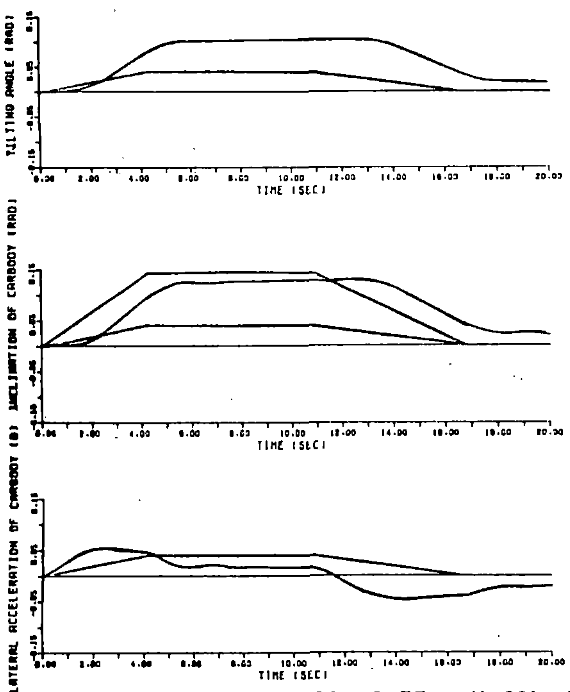
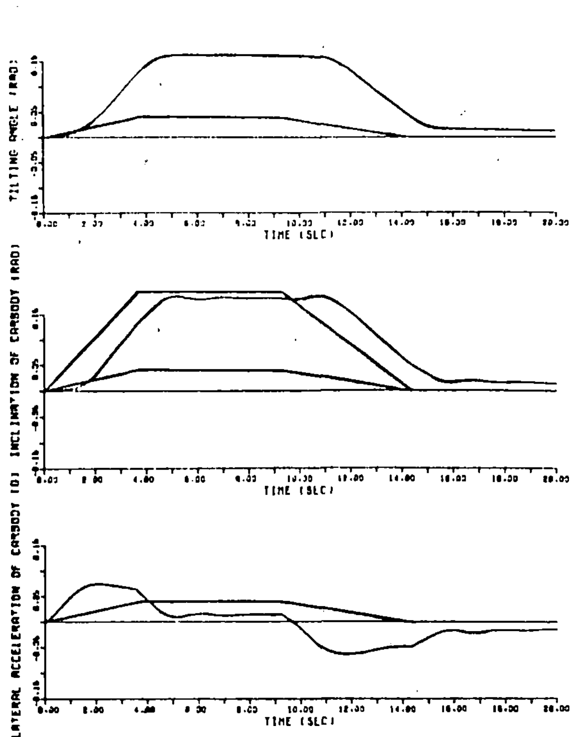

R=200m LS1=50m LS2=160m C=111mm V=80km/h

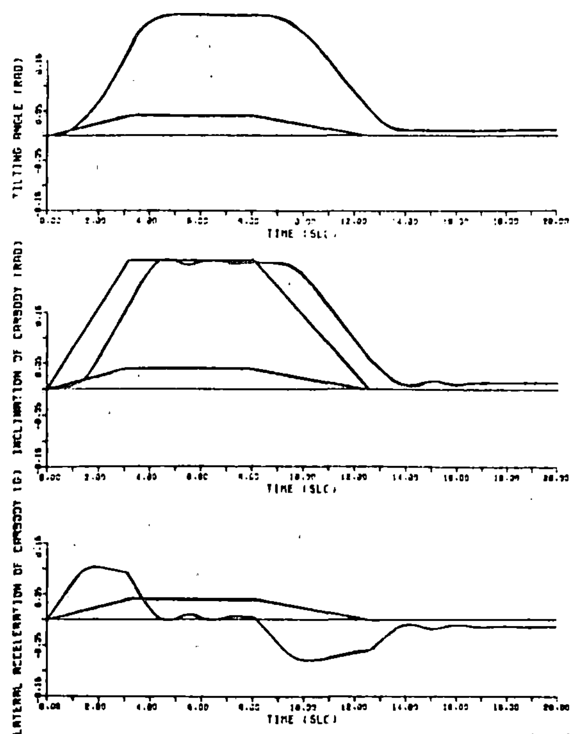
Figure 7.10 (B) Transient Response Diagram



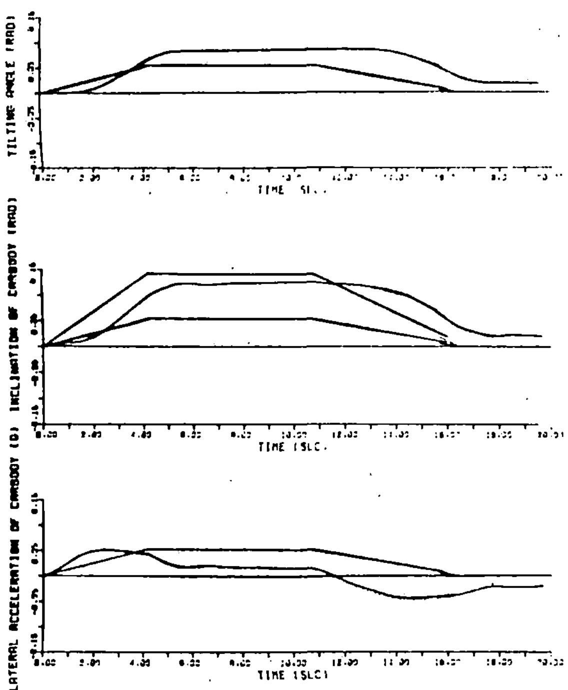
R=200m LS1=70m LS2=100m C=57mm V=60km/h



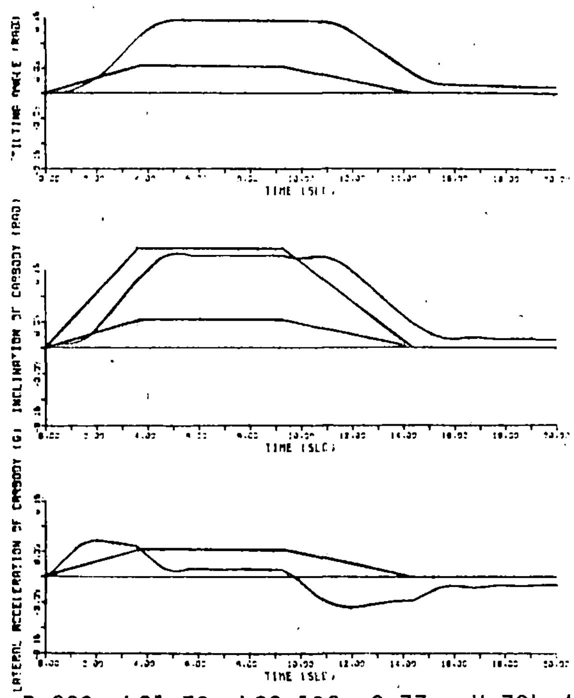
R=200m LS1=70m LS2=100m C=57mm V=70km/h



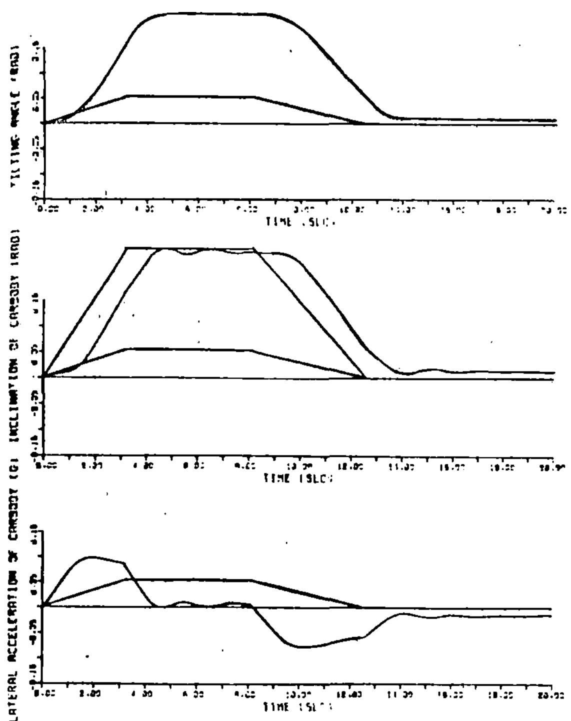
R=200m LS1=70m LS2=100m C=57mm V=80km/h



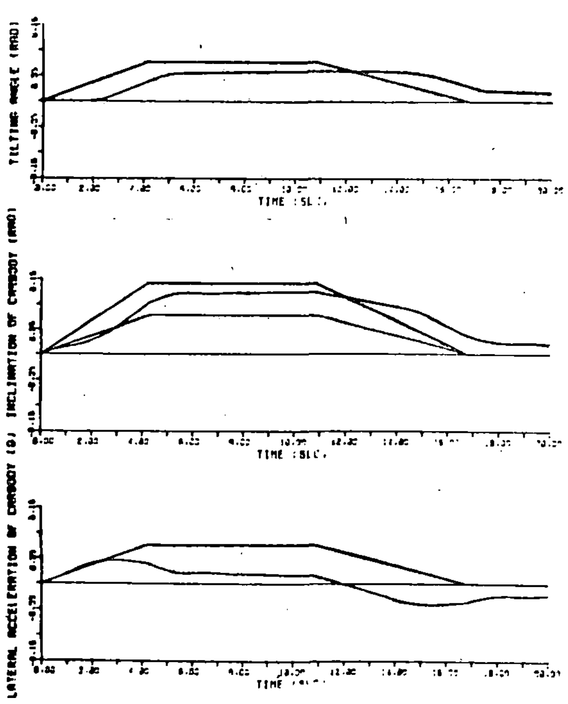
R=200m LS1=70m LS2=100m C=77mm V=60km/h



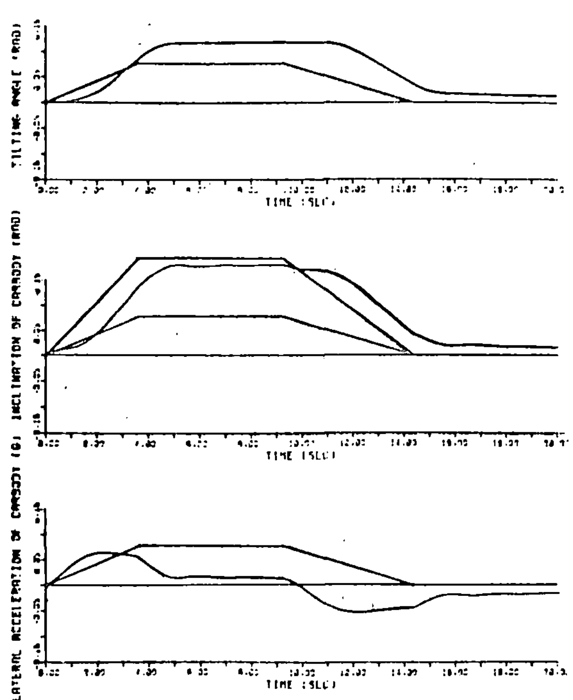
R=200m LS1=70m LS2=100m C=77mm V=70km/h



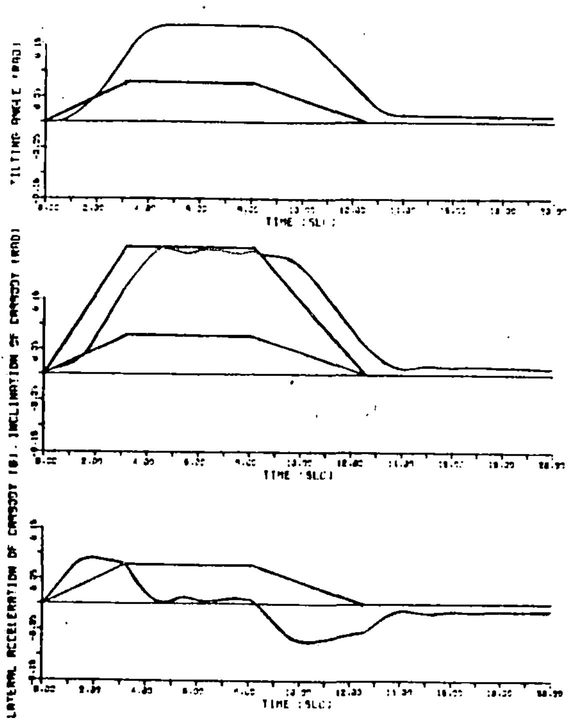
R=200m LS1=70m LS2=100m C=77mm V=80km/h



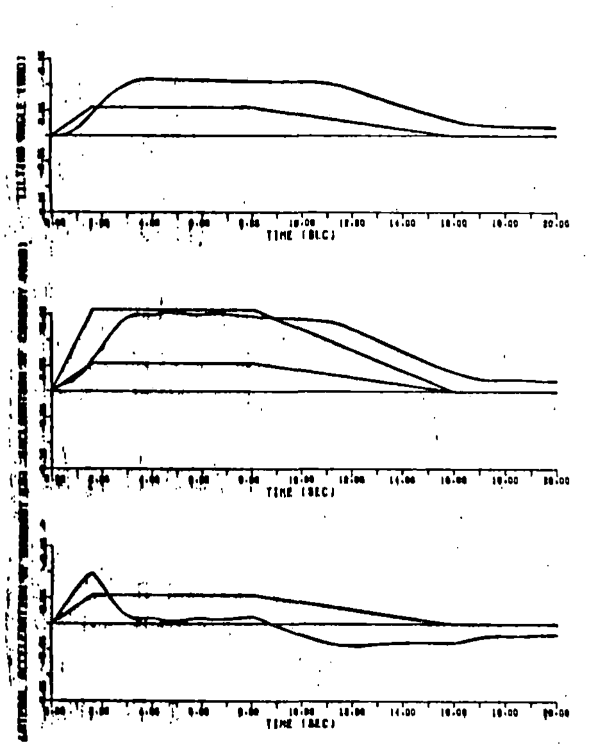
R=200m LS1=70m LS2=100m C=111mm V=60km/h



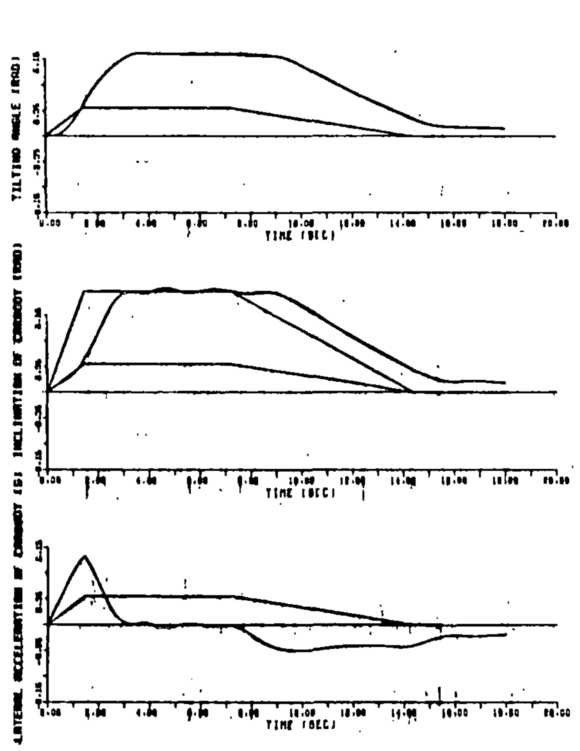
R=200m LS1=70m LS2=100m C=111mm V=70km/h



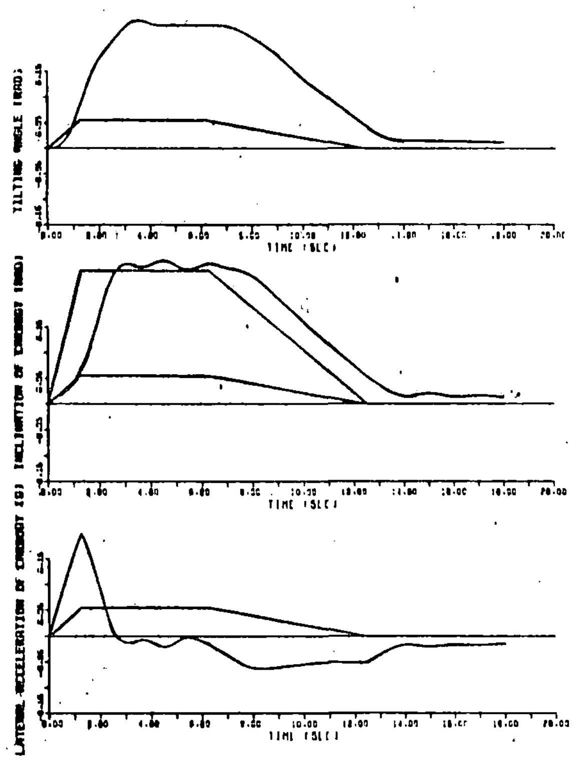
R=200m LS1=70m LS2=100m C=111mm V=80km/h



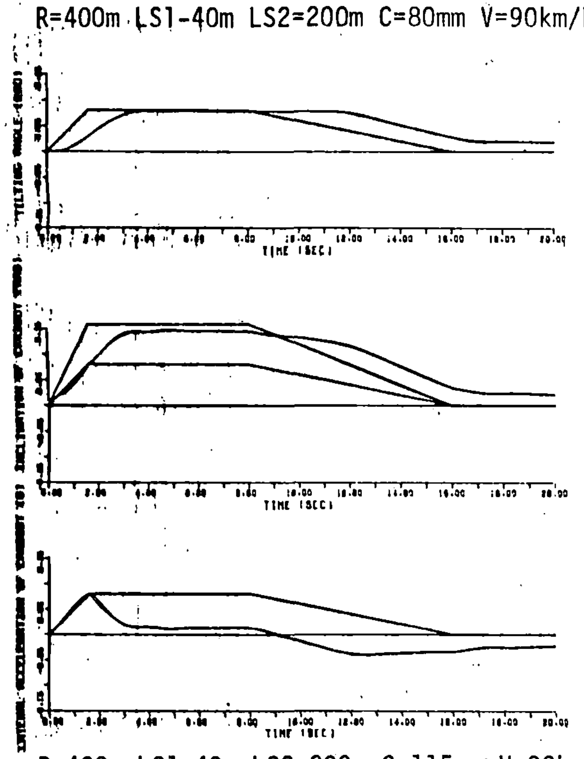
R=400m LS1-40m LS2=200m C=80mm V=90km/h



R=400m LS1=40m LS2=200m C=80mm V=100km/h



R=400m LS1=40m LS2=200m C=80m V=115km/h



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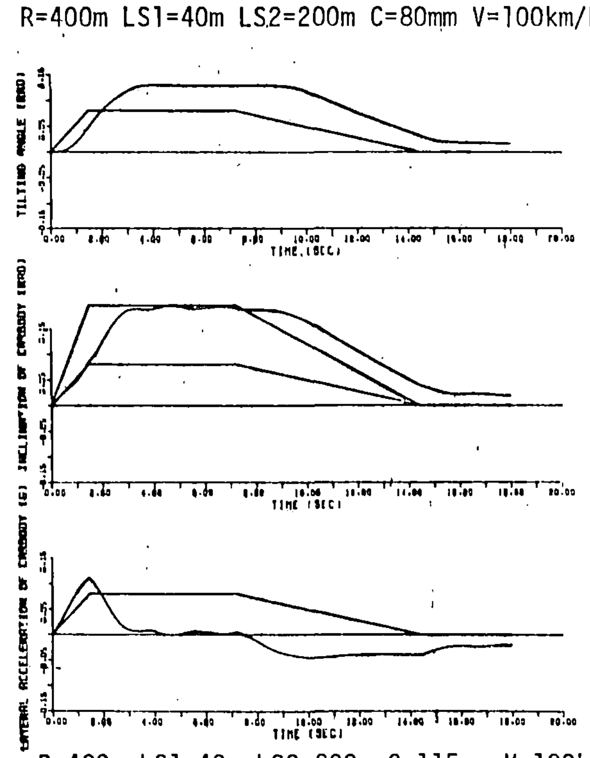

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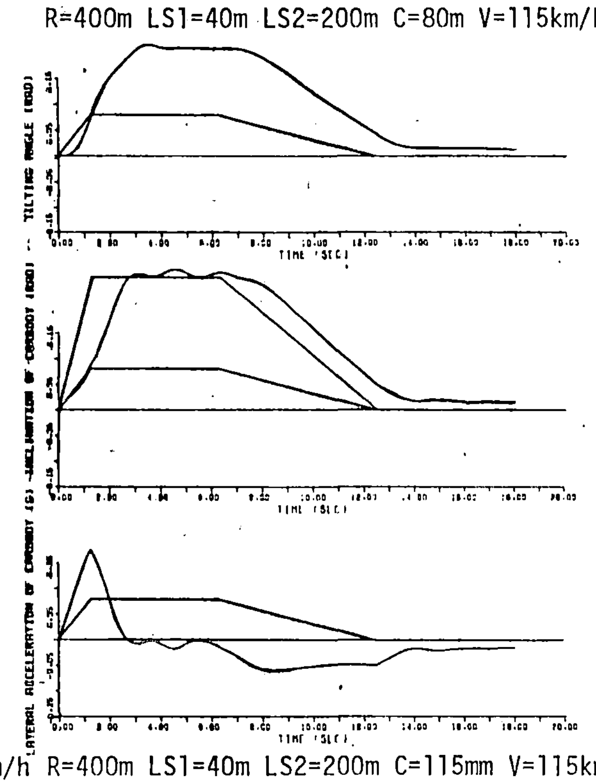

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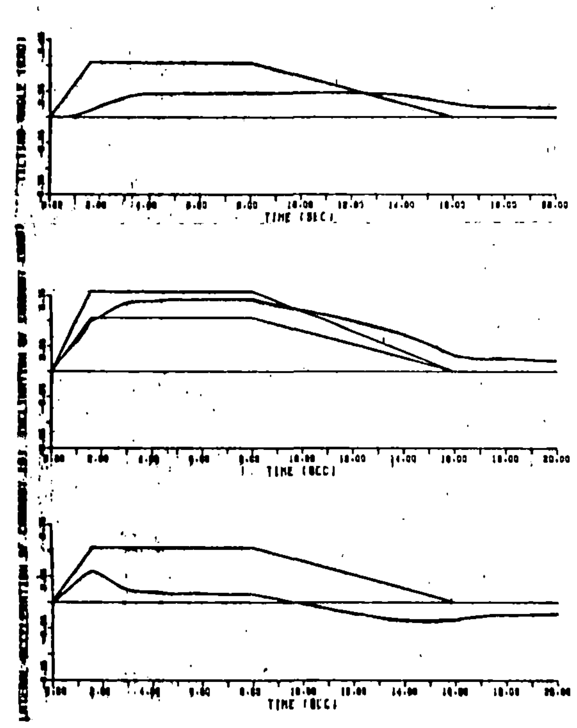
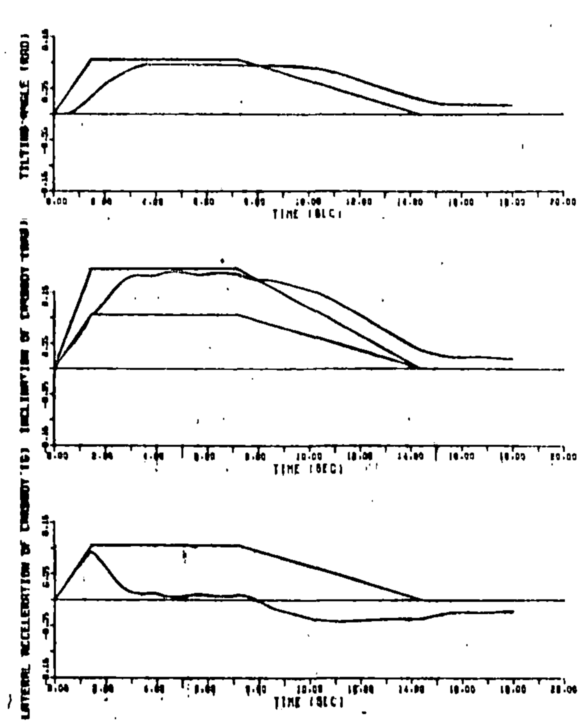


R=400m LS1=40m LS2=200m C=152mm V=90km/h



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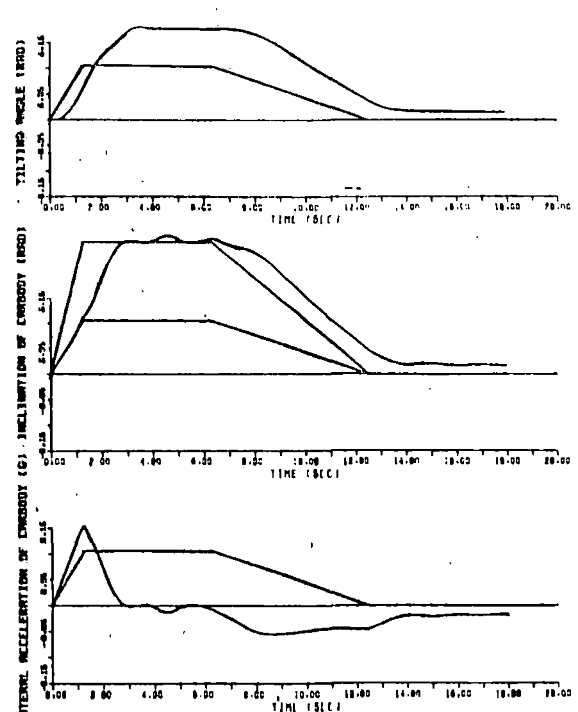

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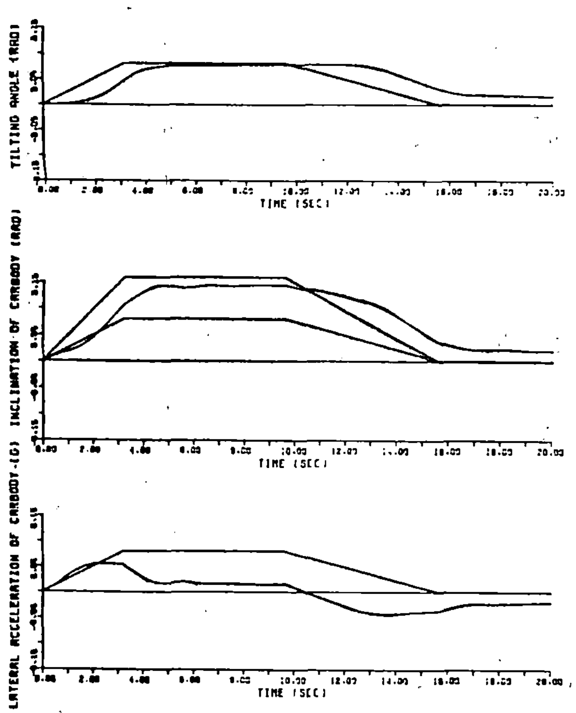

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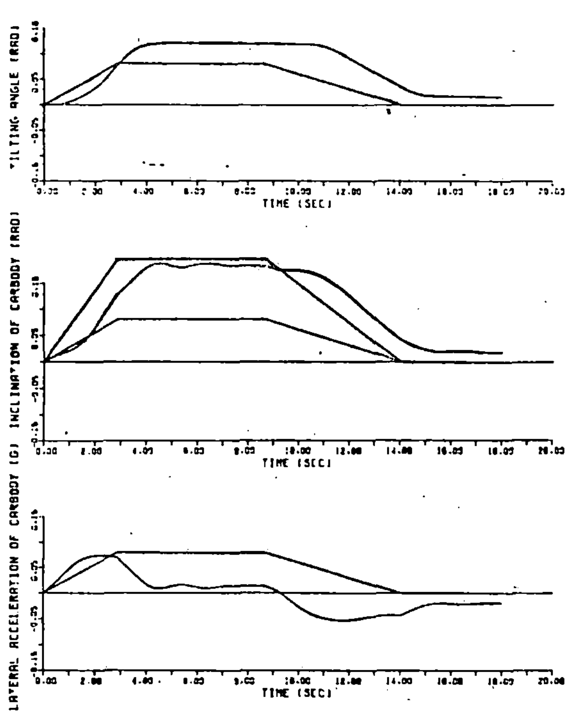

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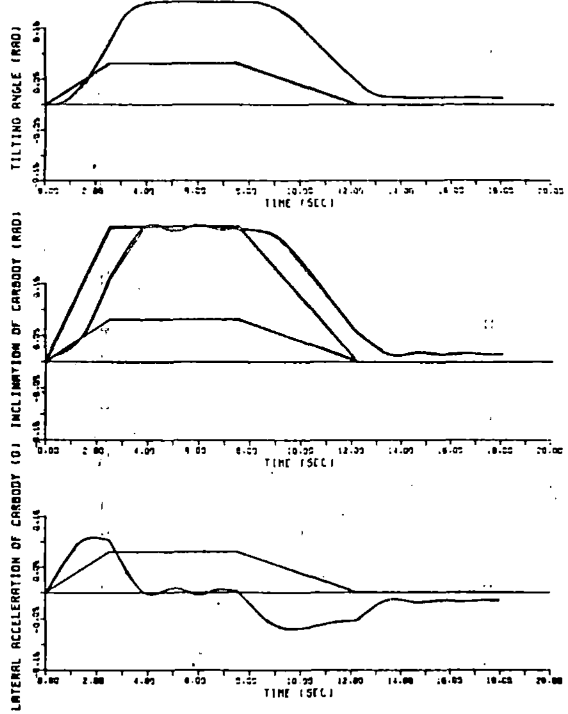

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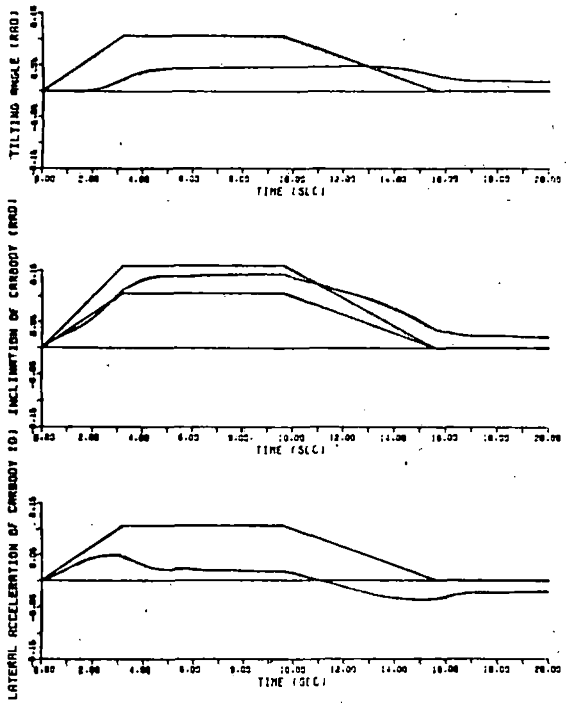

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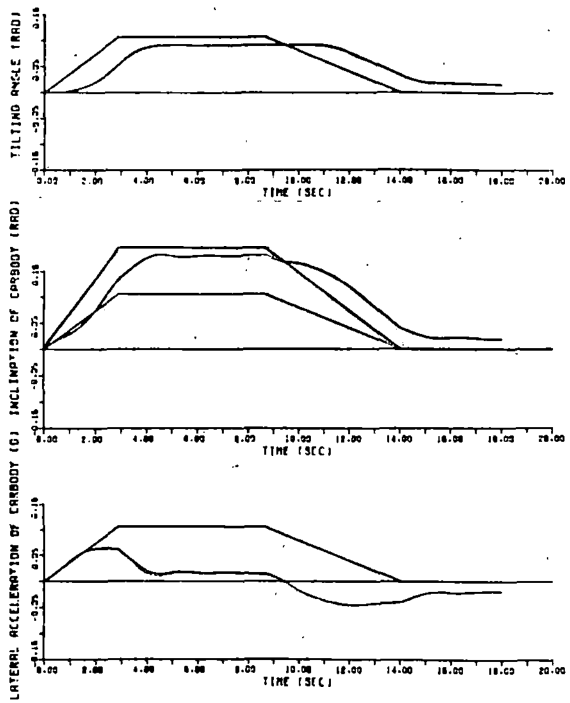

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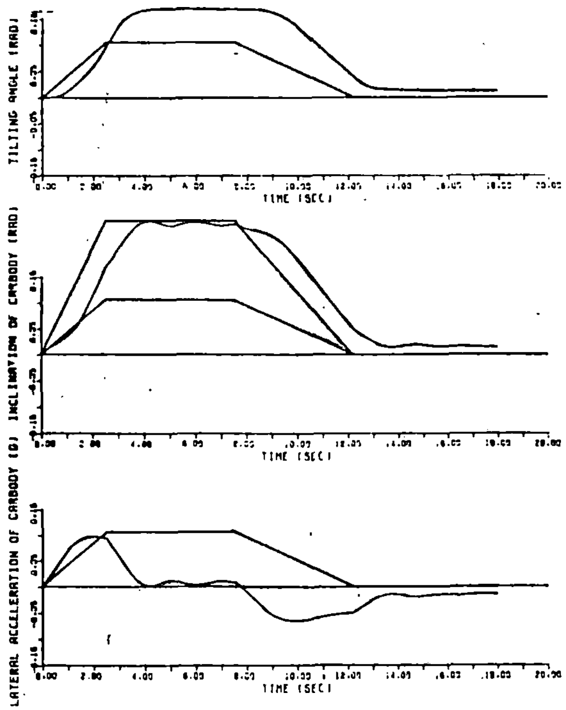

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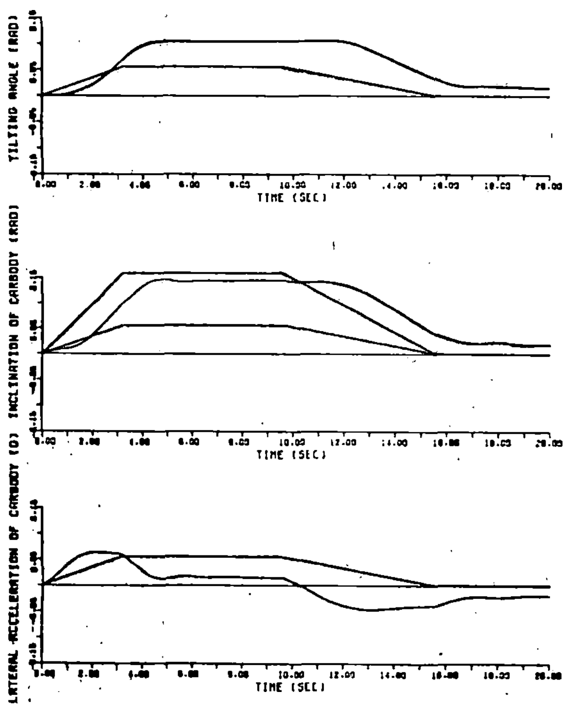

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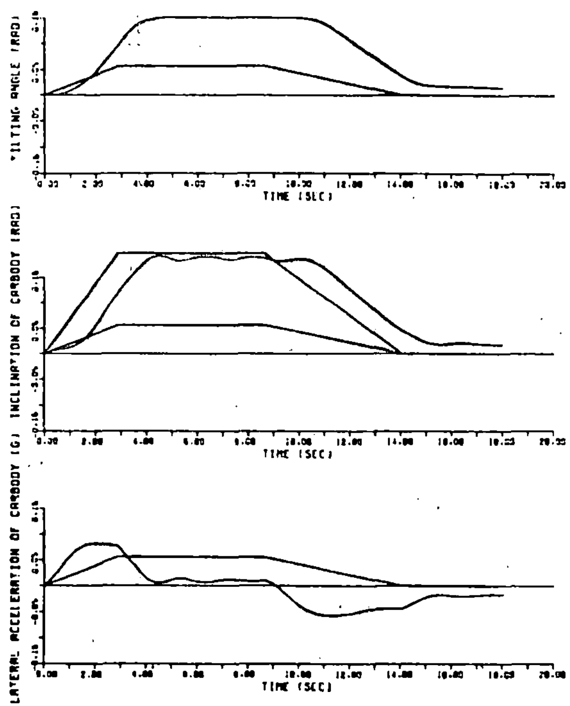

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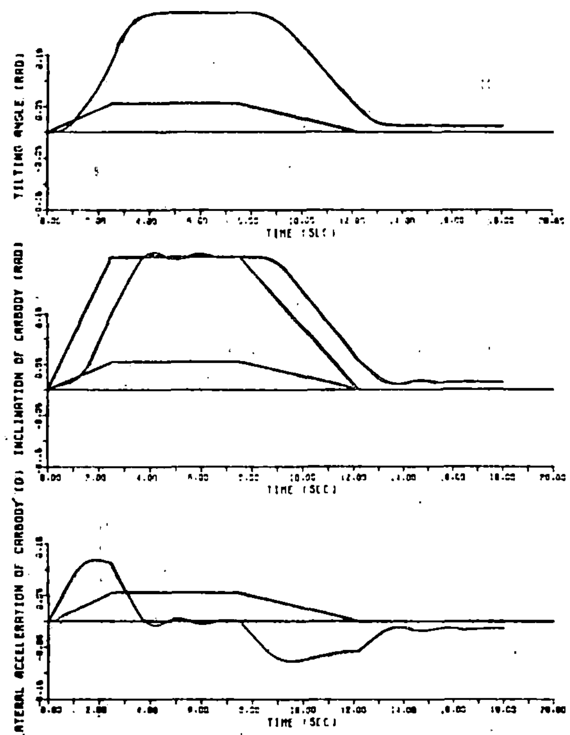

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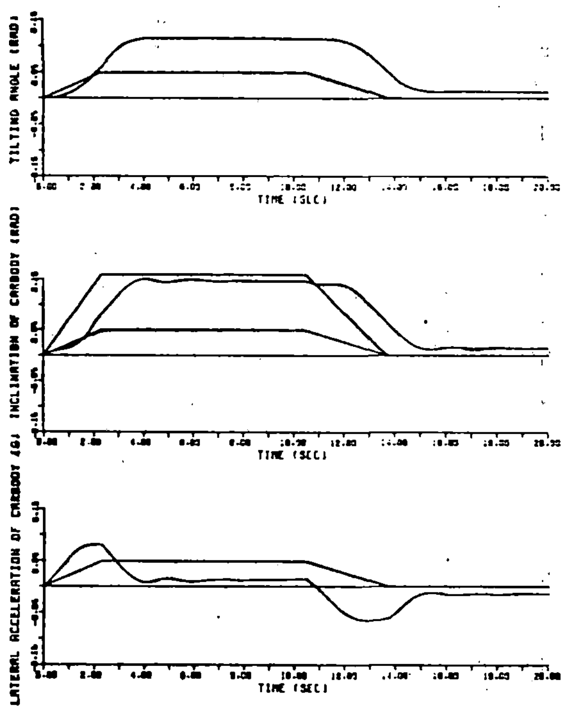
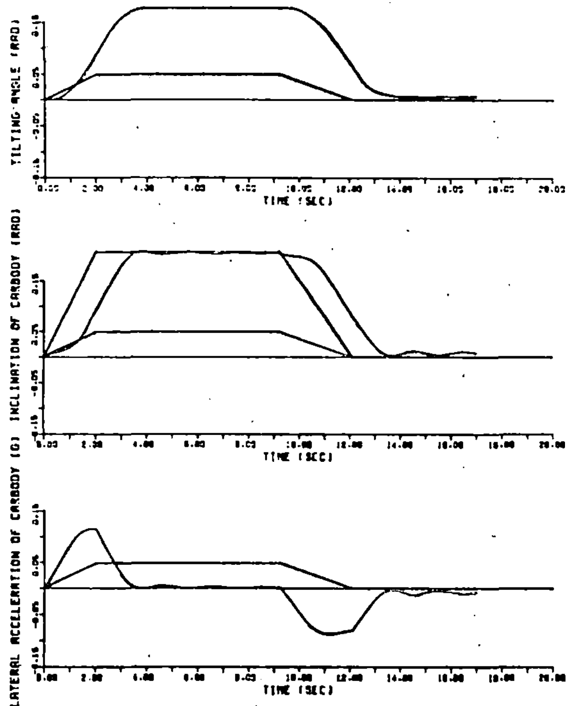


R=600m LS1=70m LS2=100m C=70mm V=110km/h



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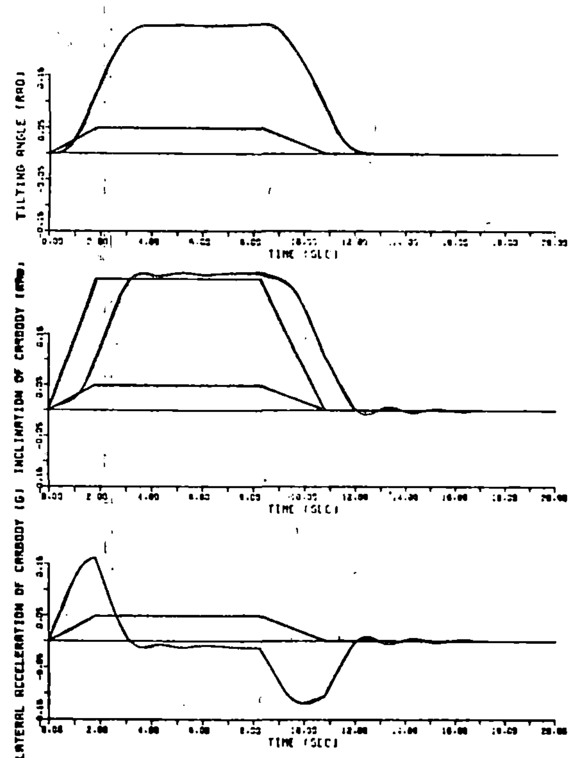

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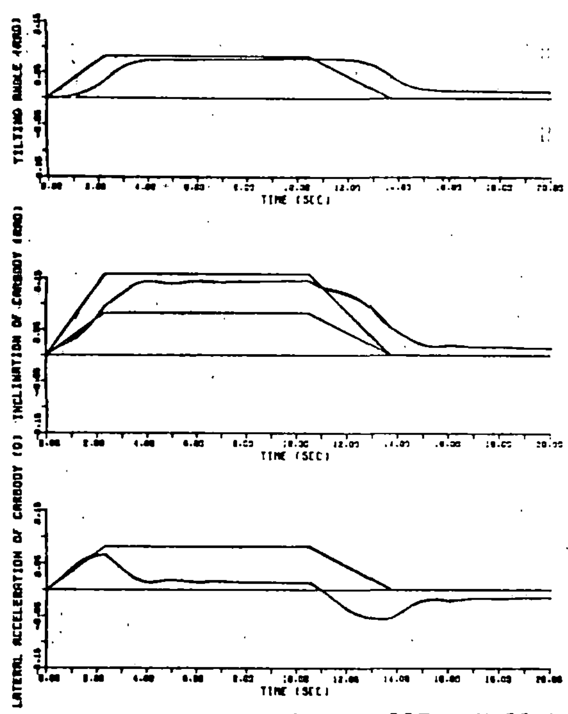
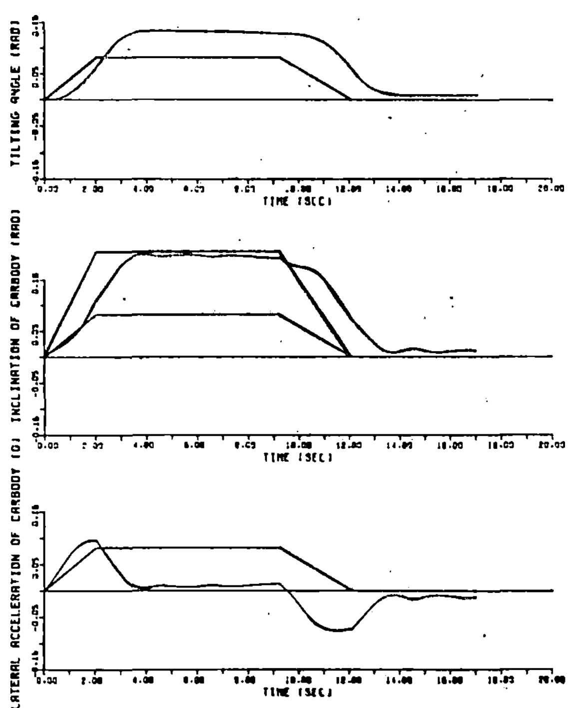


R=600m LS1=70m LS2=100m C=117mm V=110km/h



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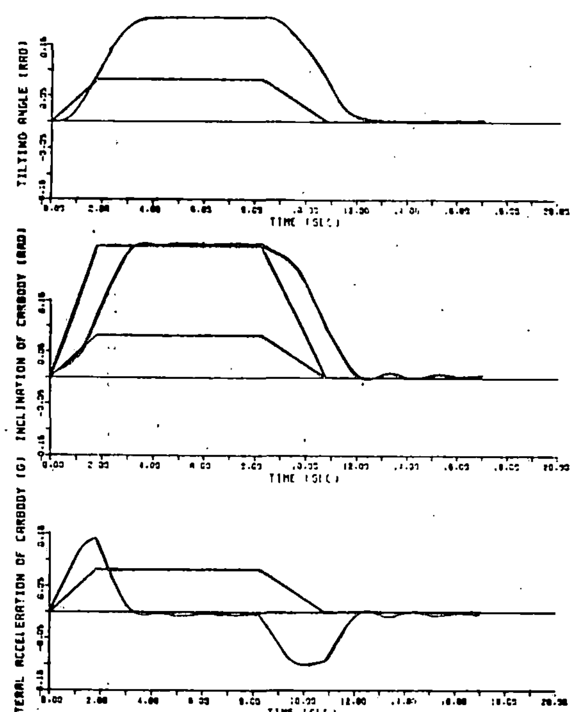

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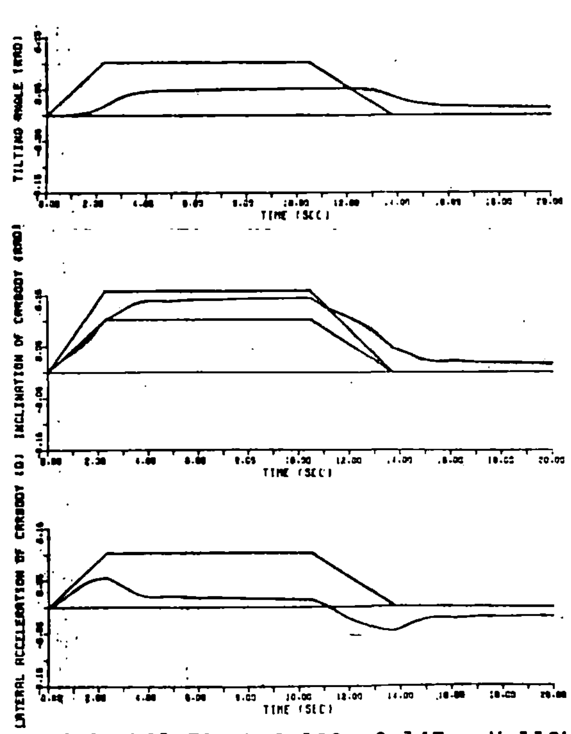
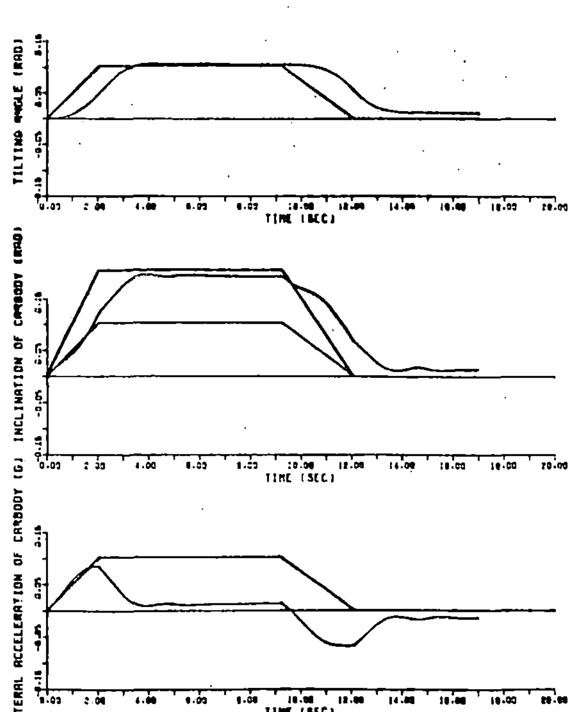


R=600m LS1=70m LS2=100m C=147mm V=110km/h



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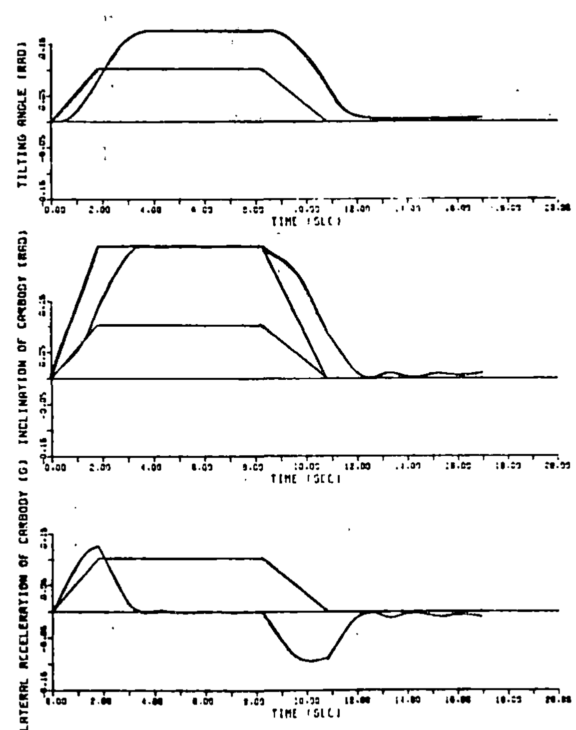

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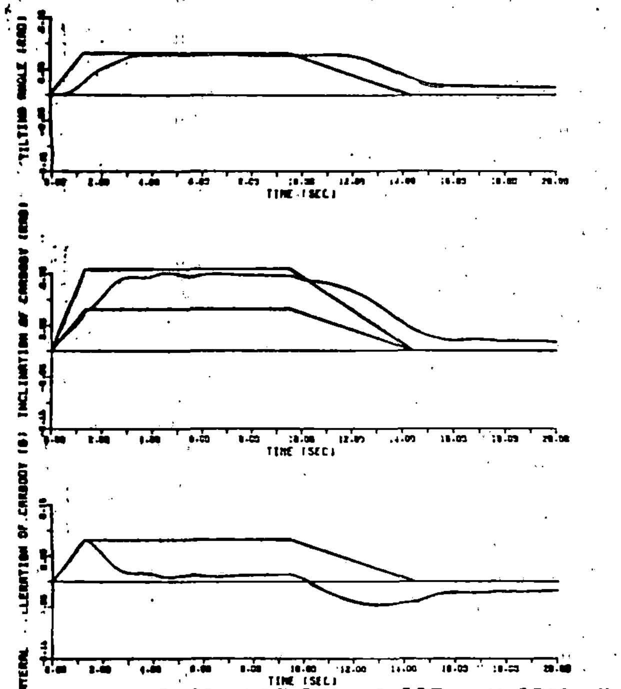
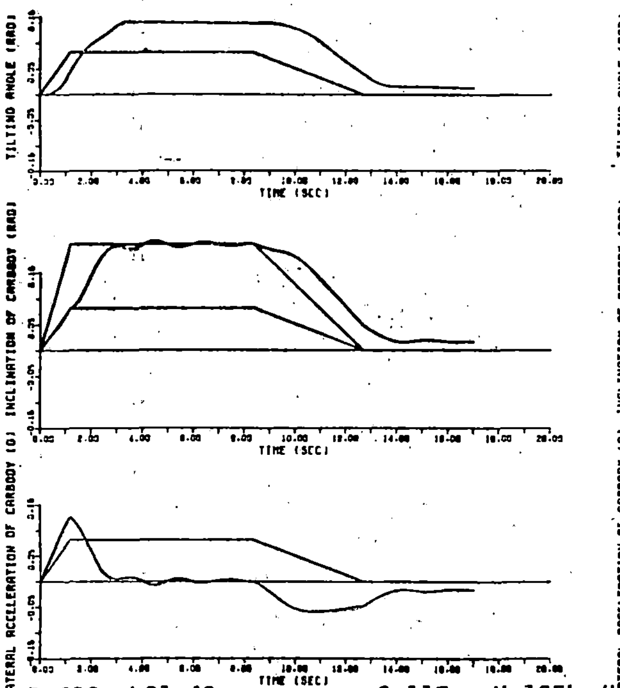


R=600m LS1=40m LS2=150m C=117mm V=110km/h



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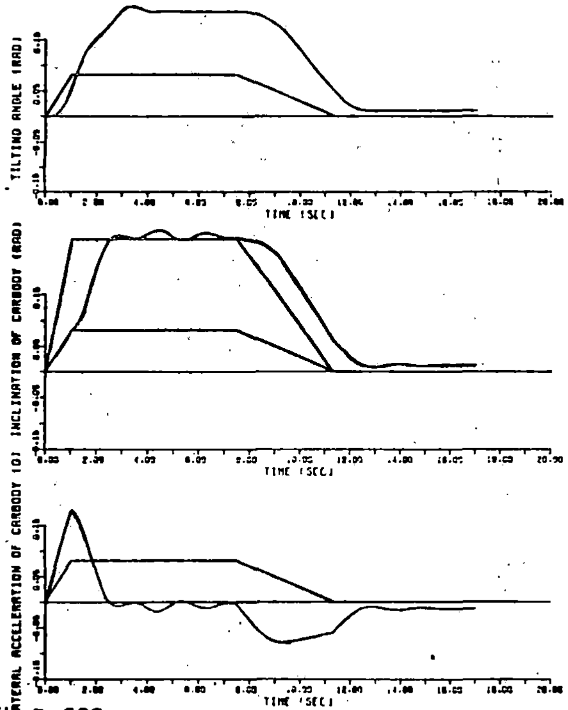

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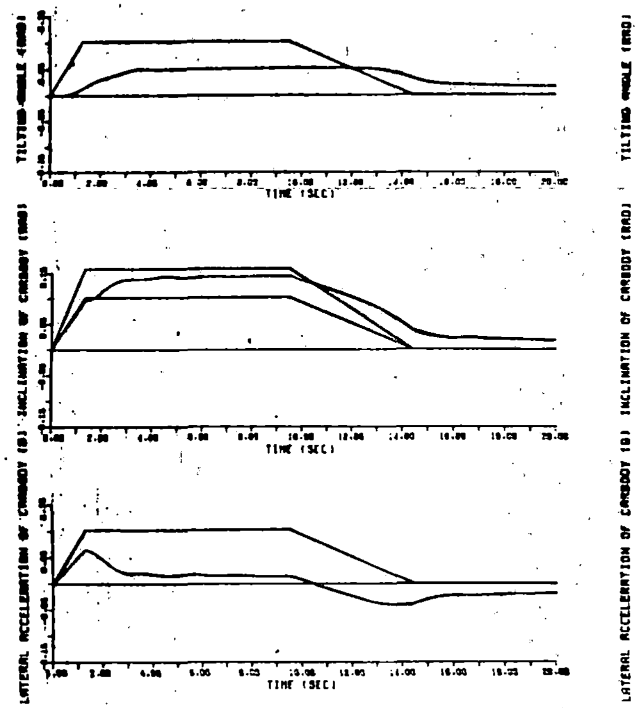

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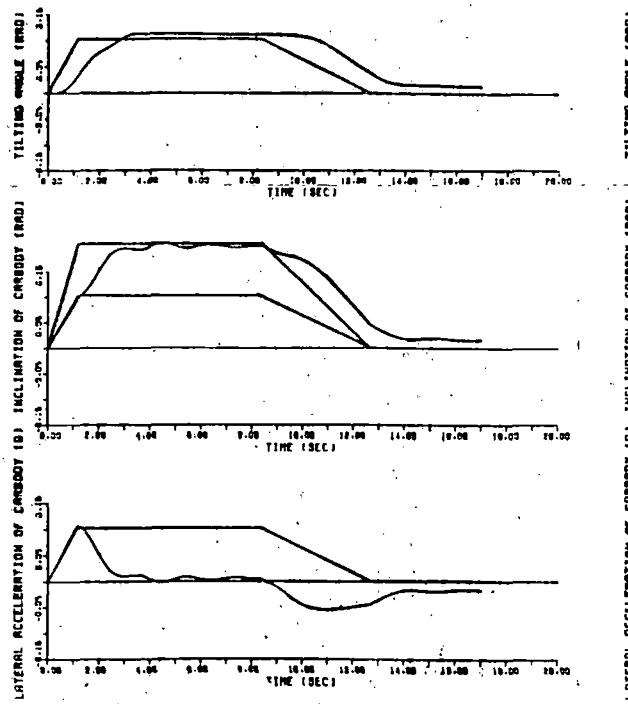

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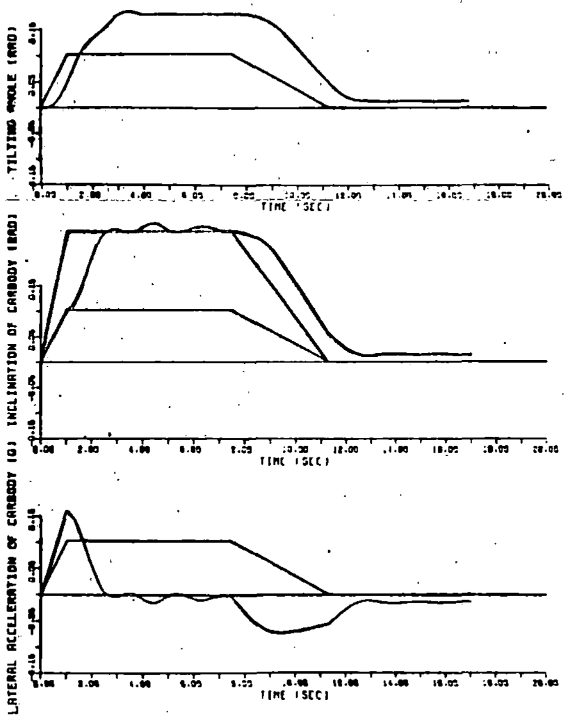

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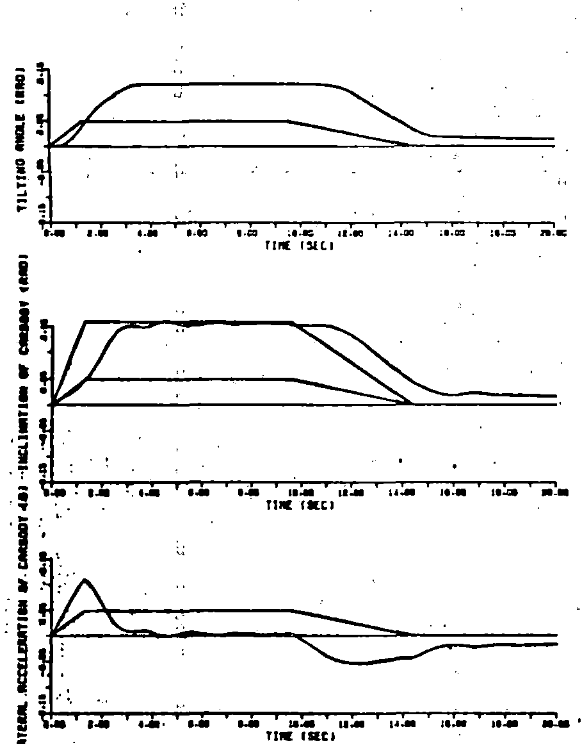

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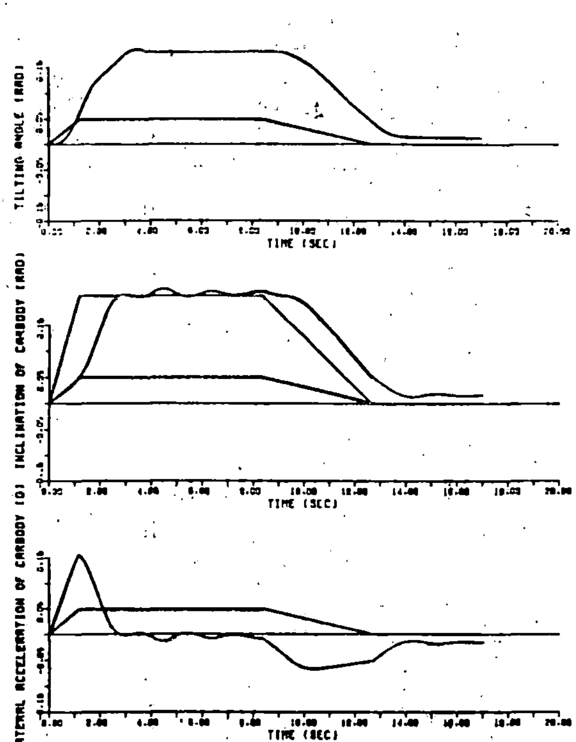

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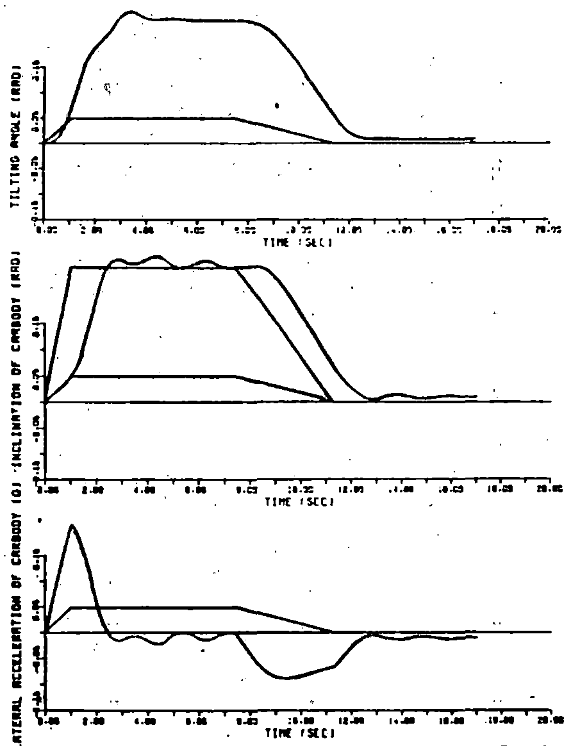

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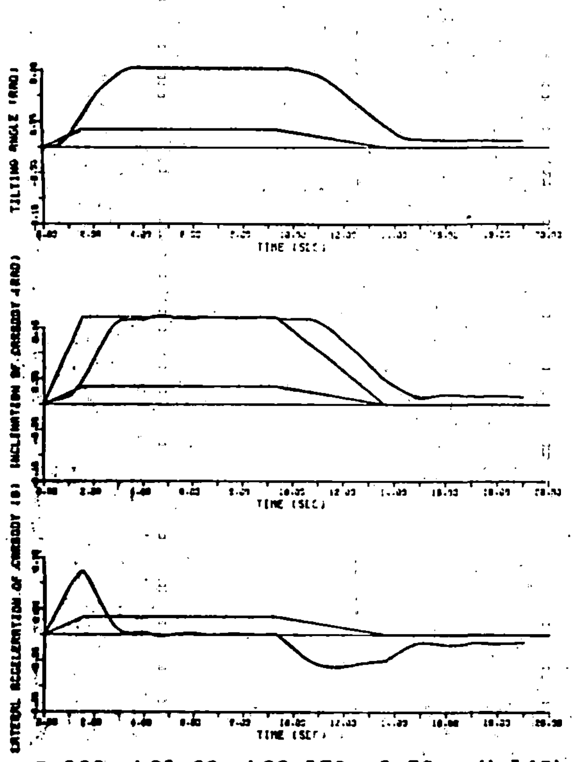

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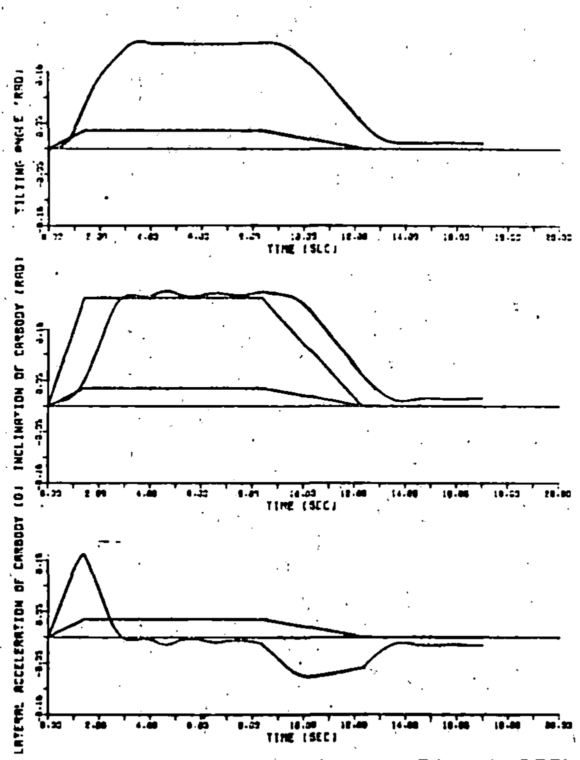

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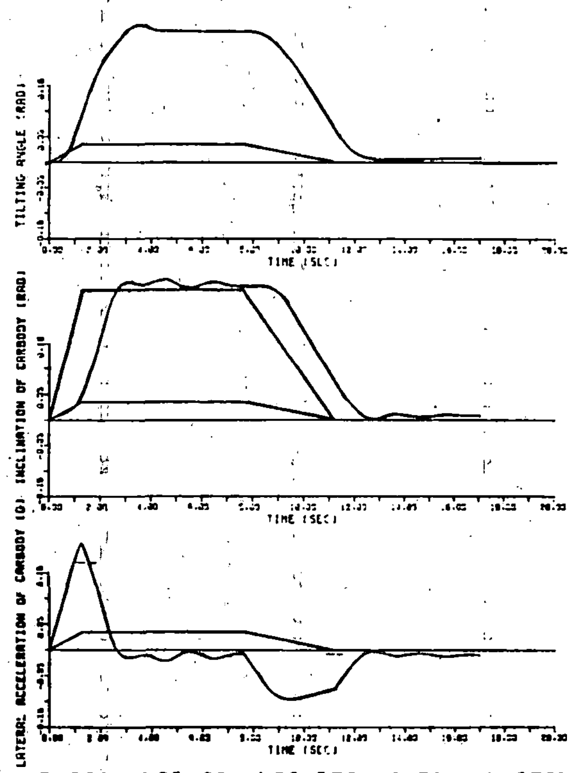

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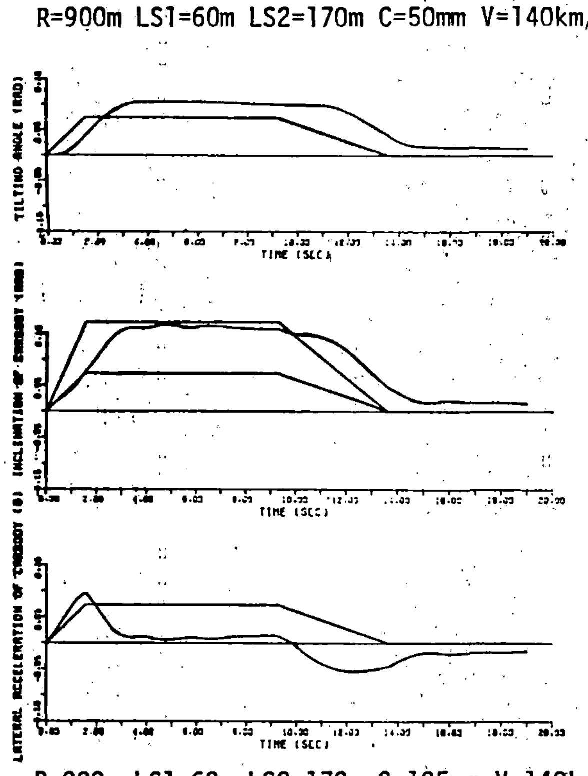

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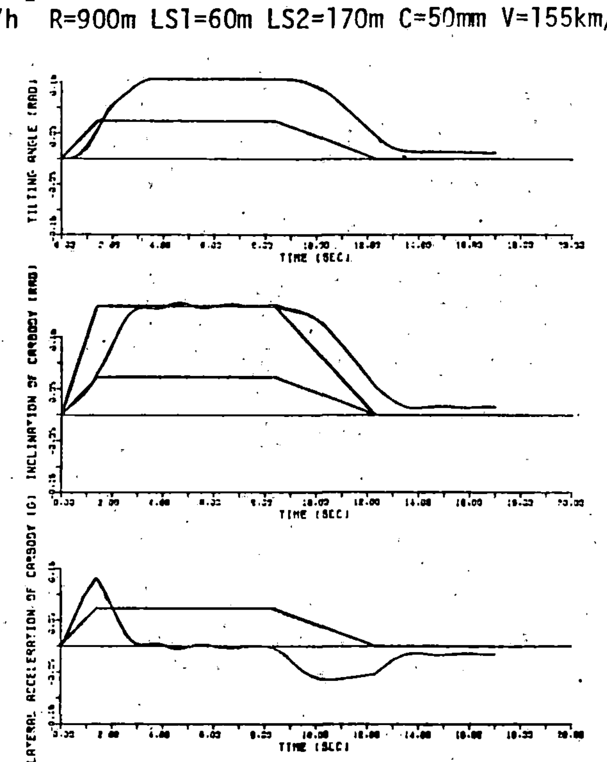

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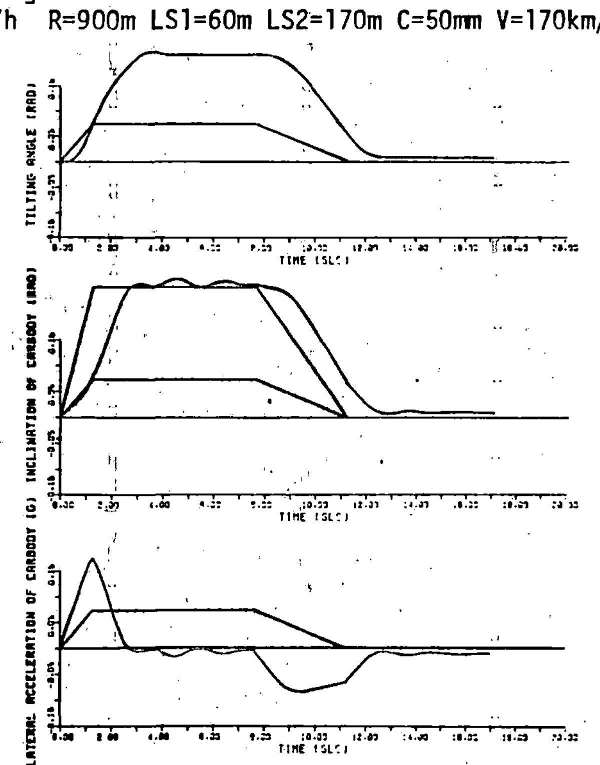

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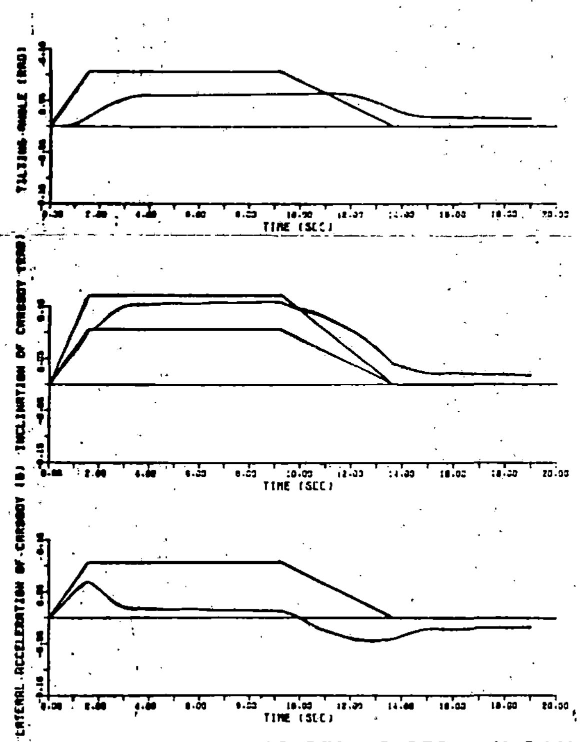

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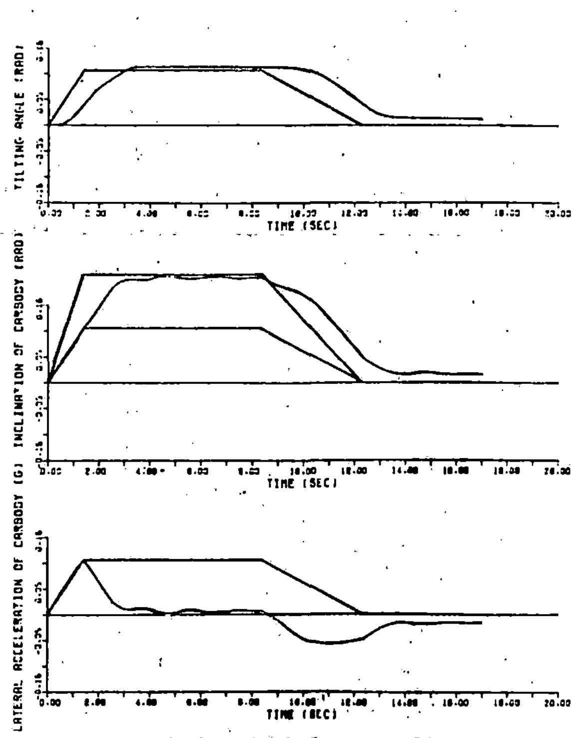

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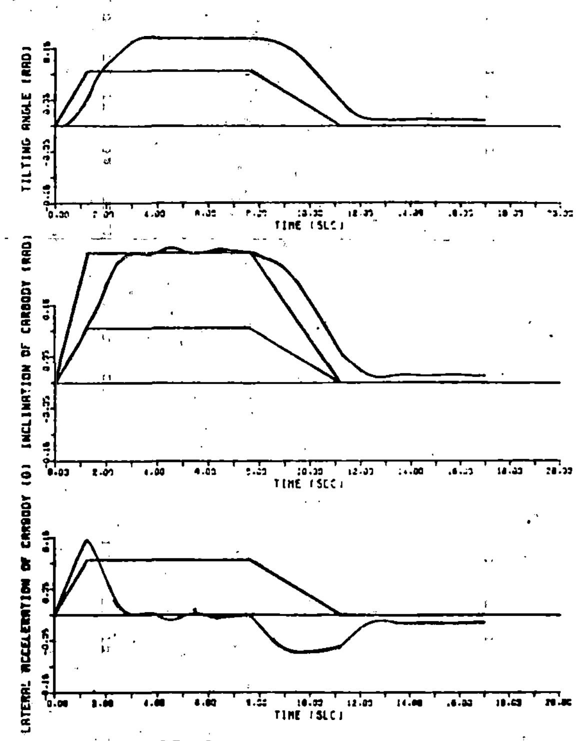

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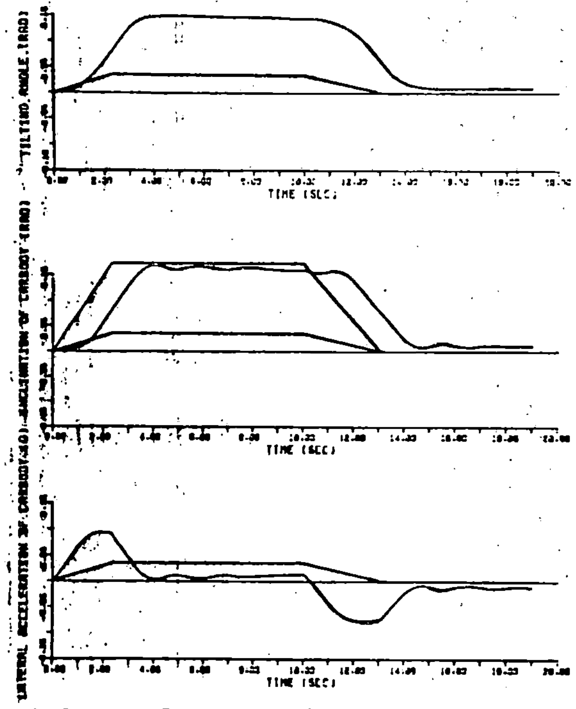

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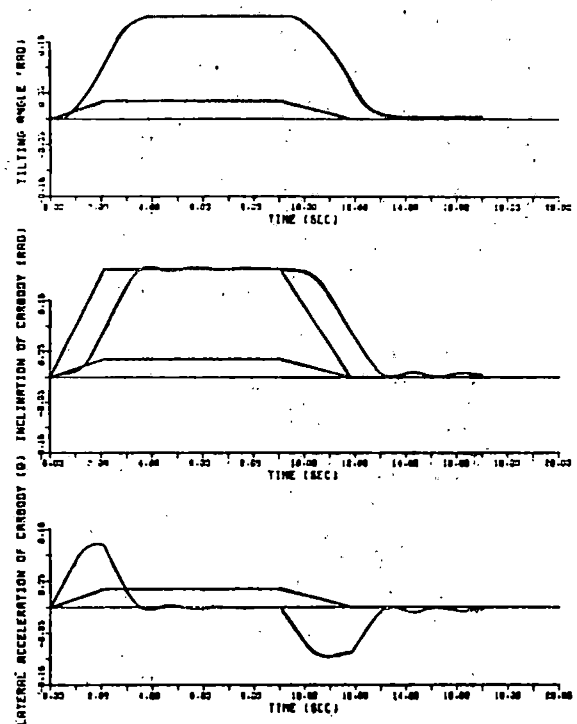

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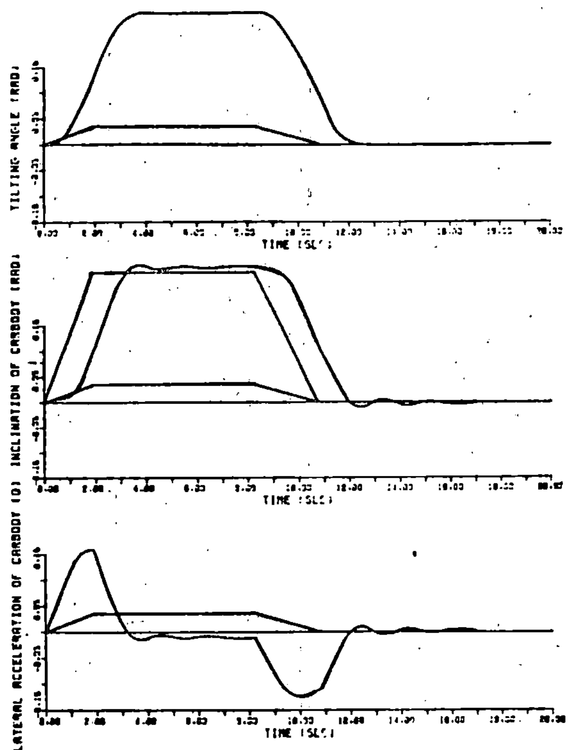

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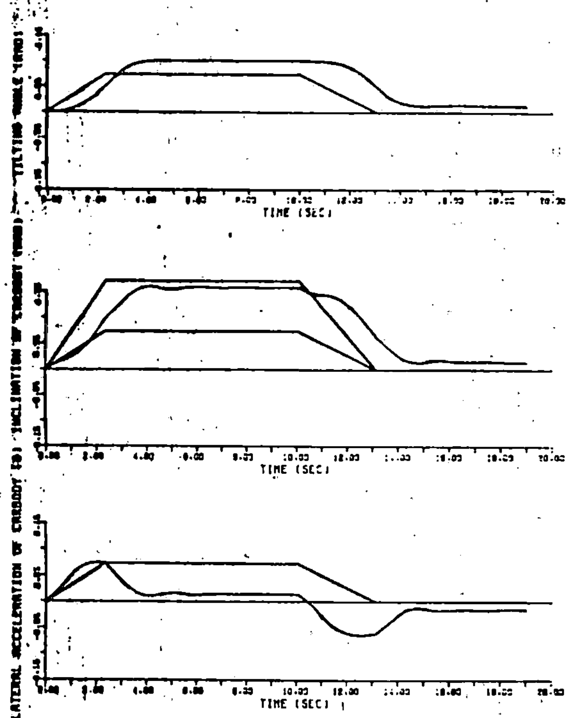

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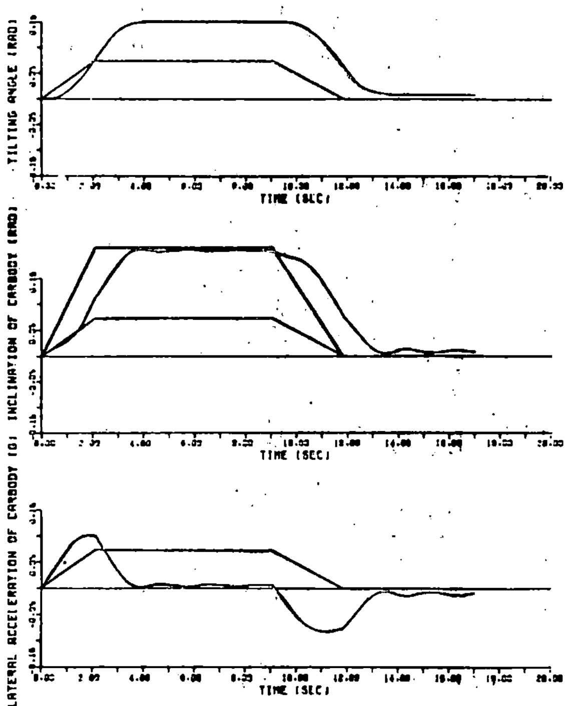

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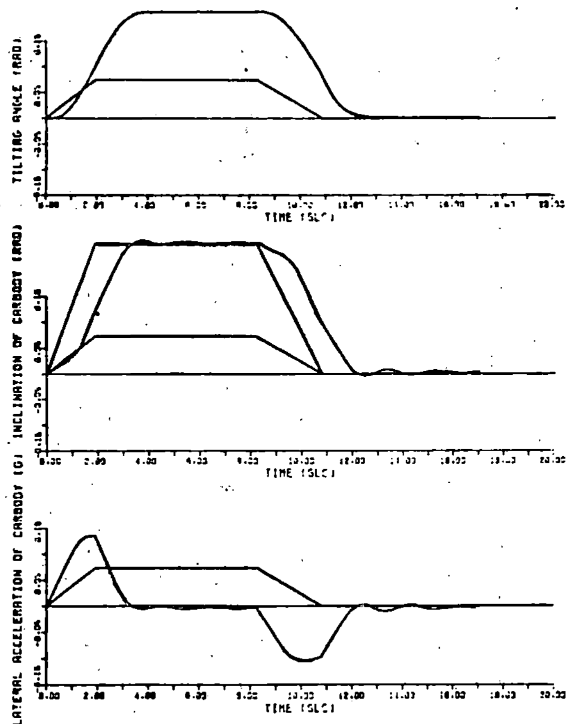

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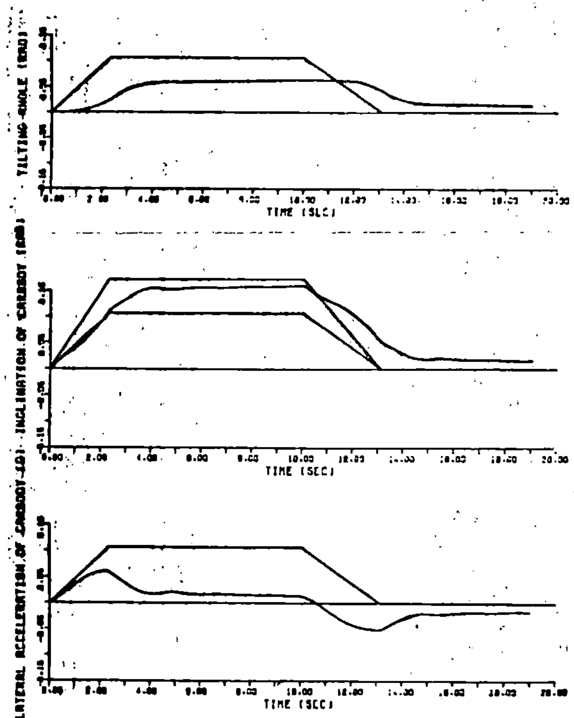

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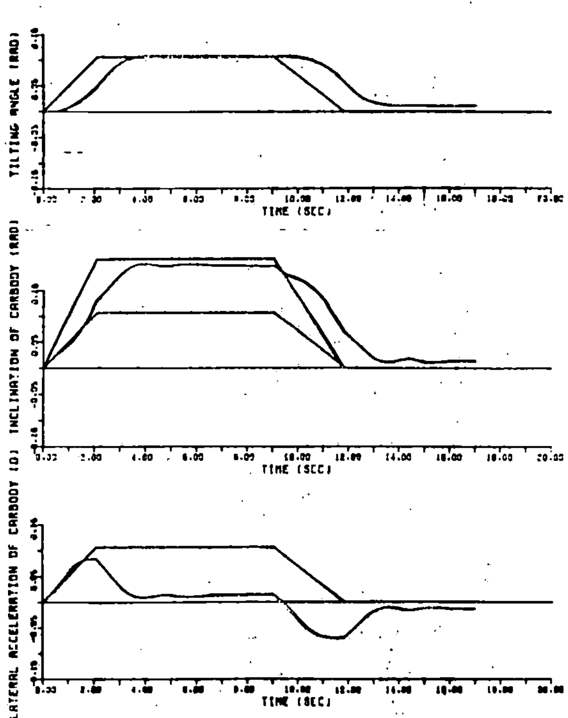

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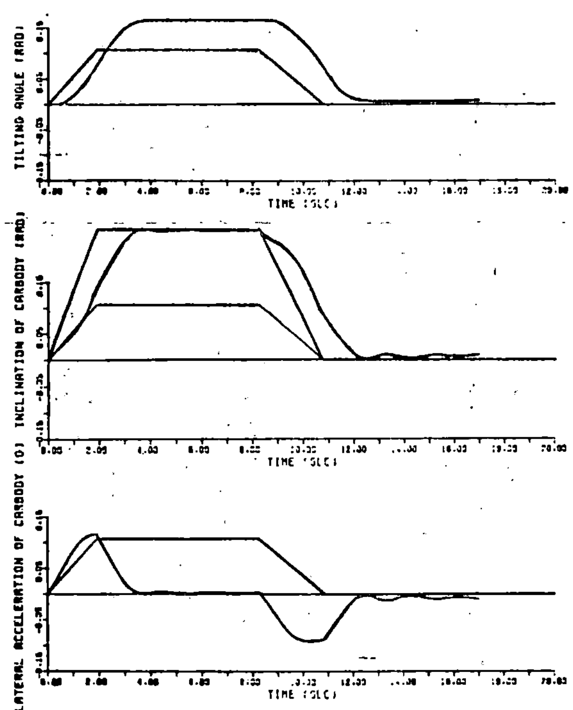

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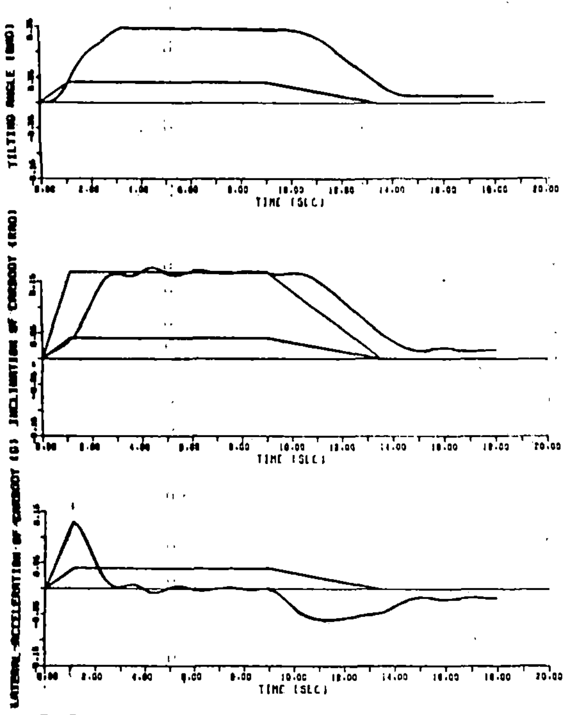

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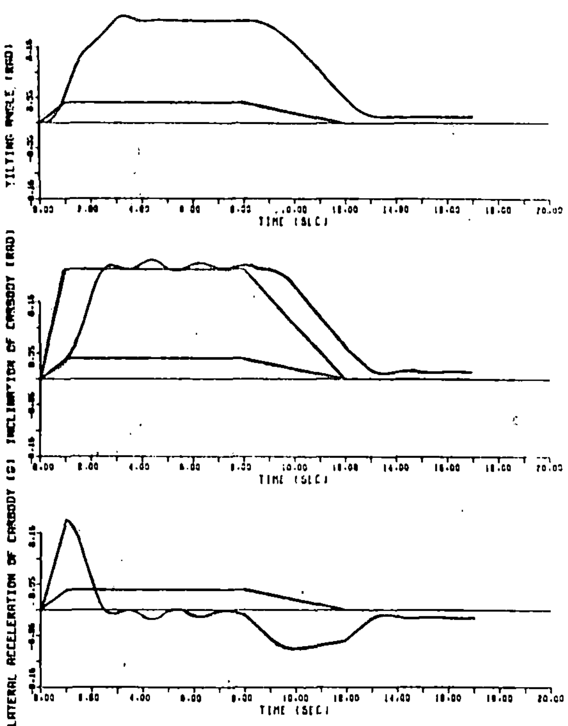

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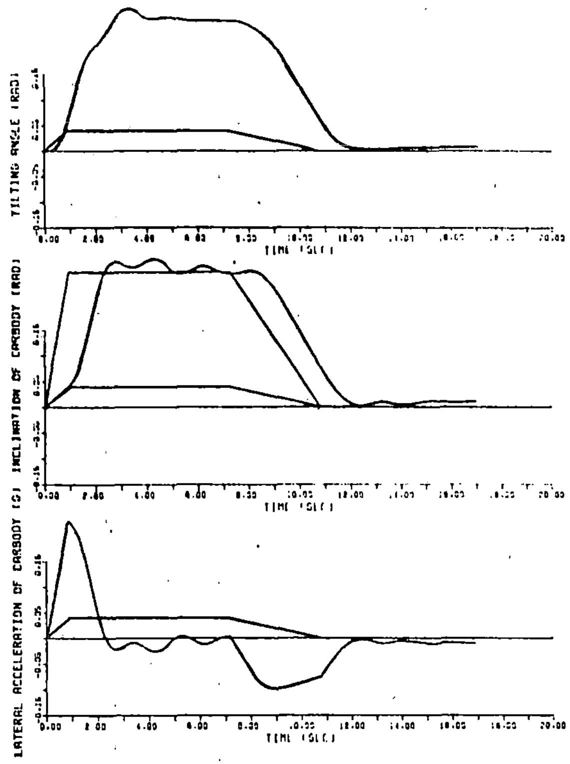

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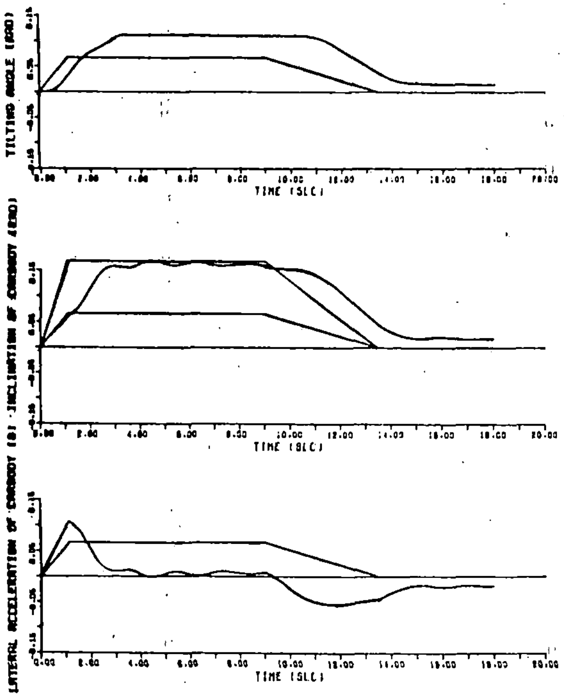

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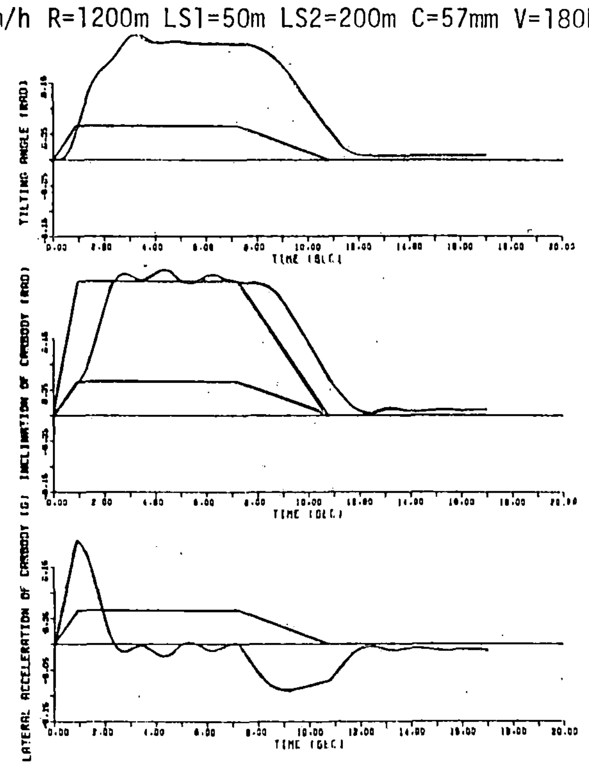

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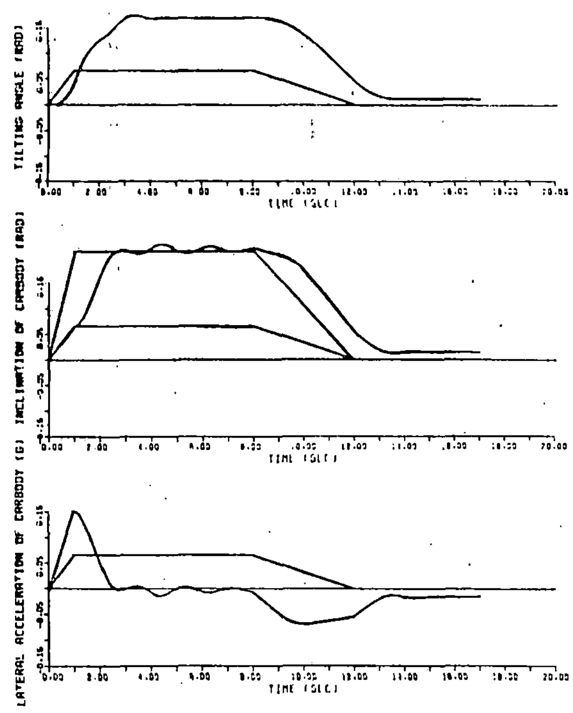

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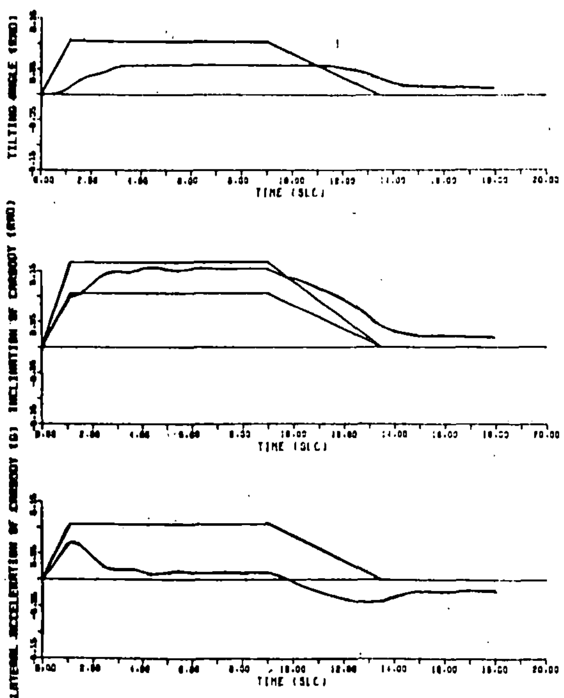

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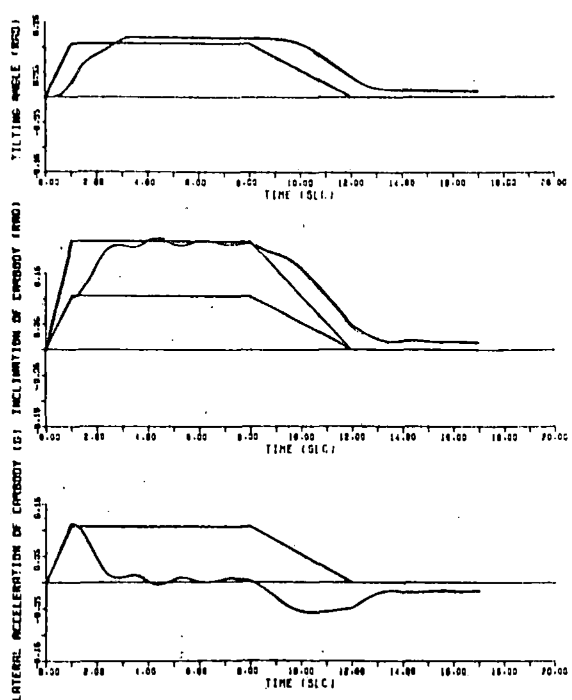

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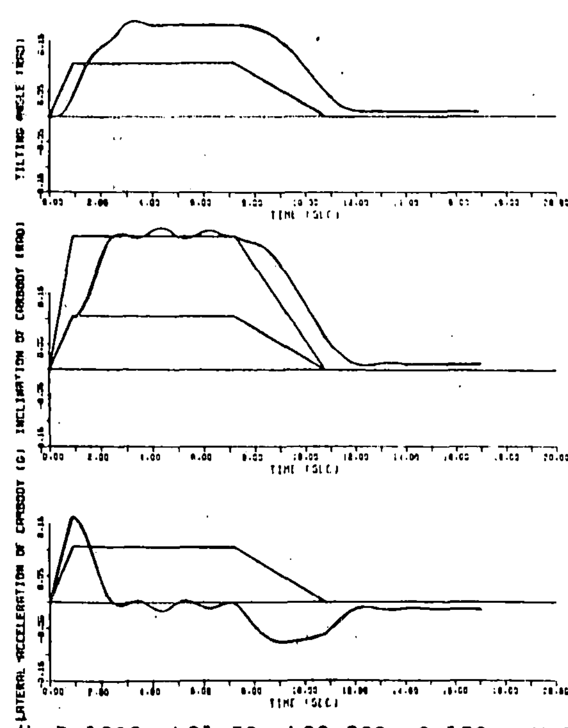

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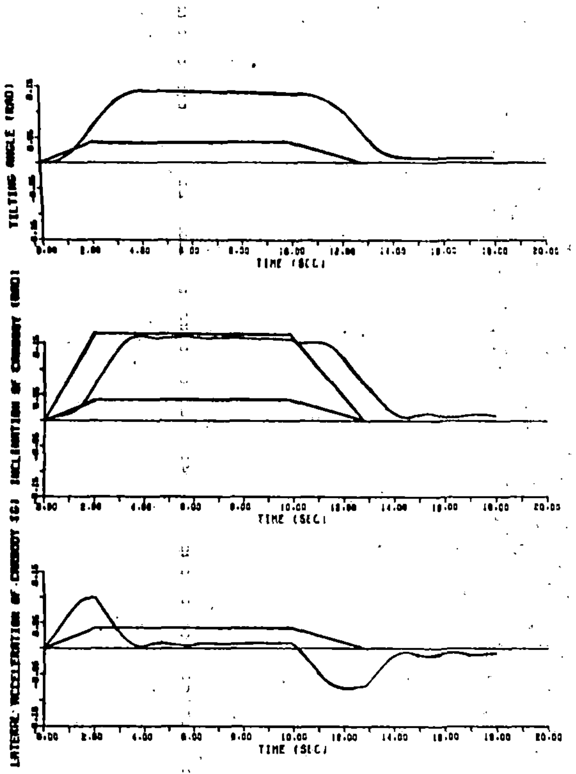

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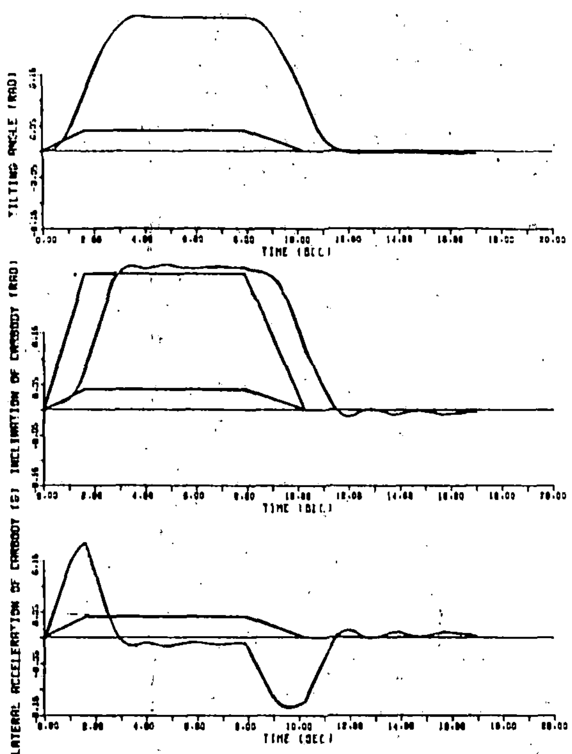

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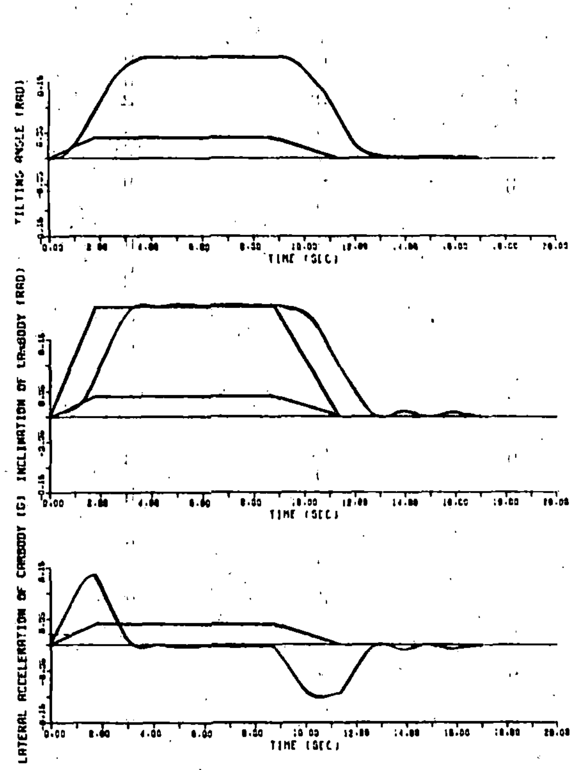

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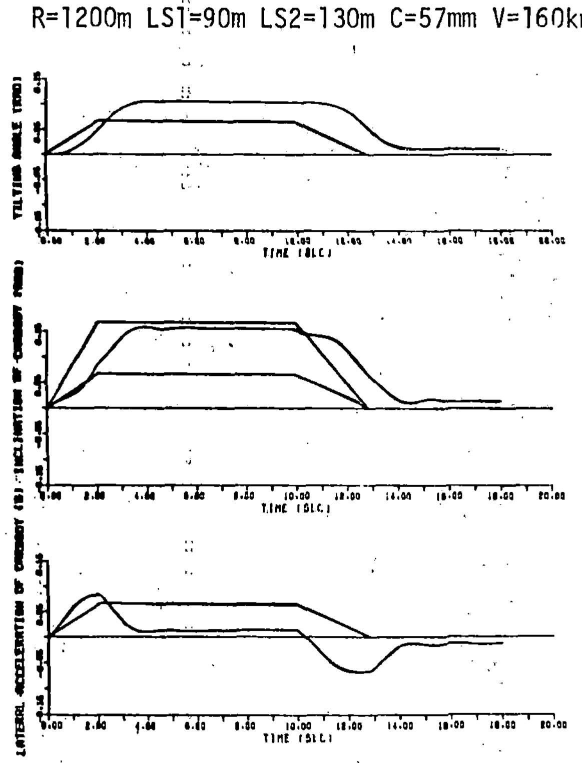

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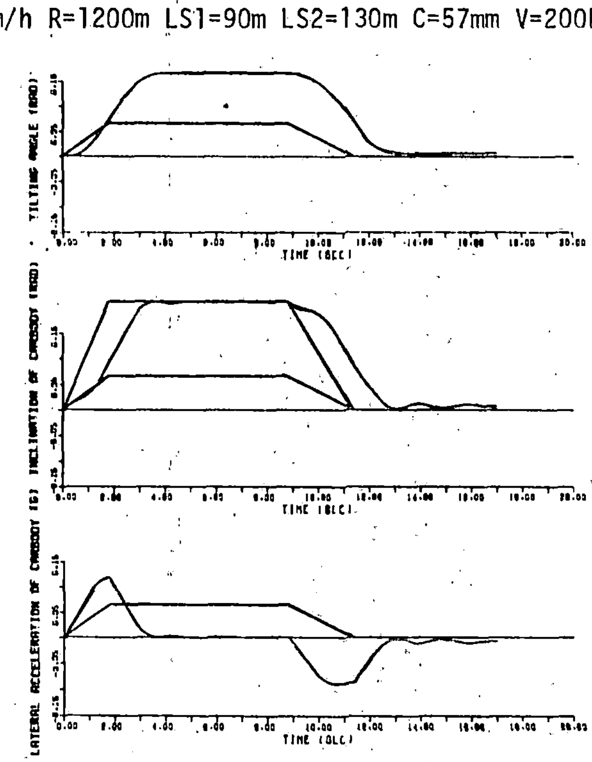

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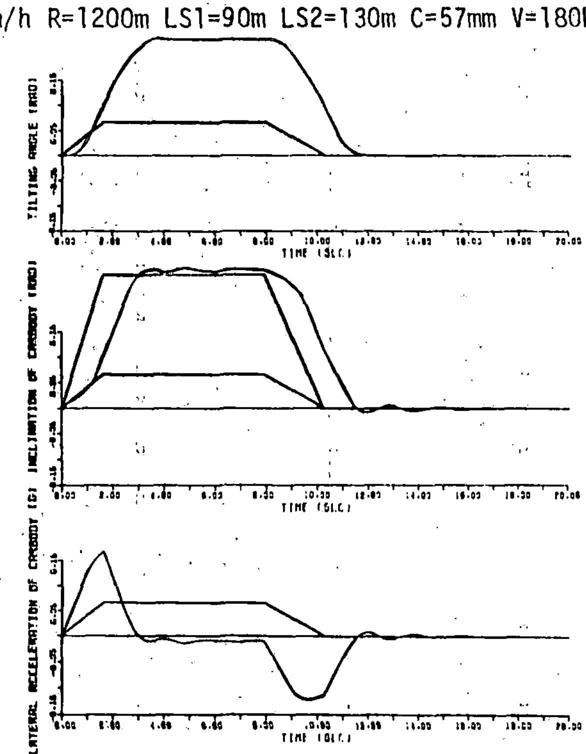

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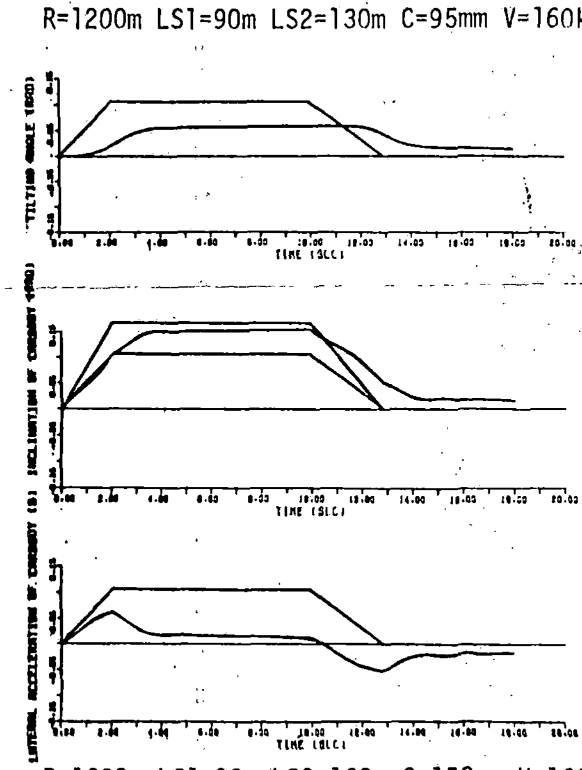

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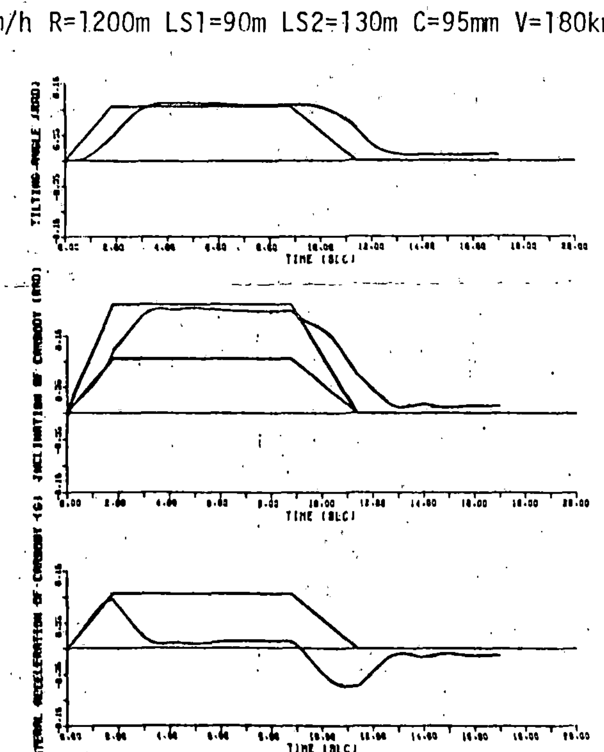

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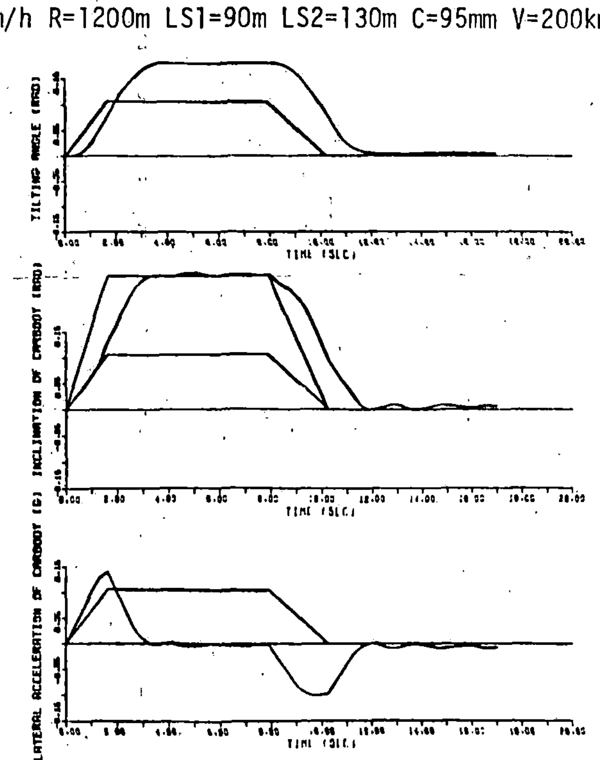

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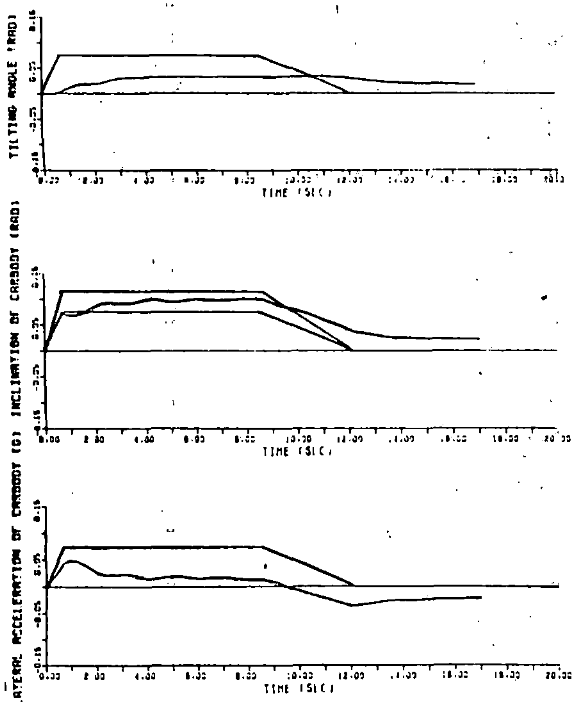

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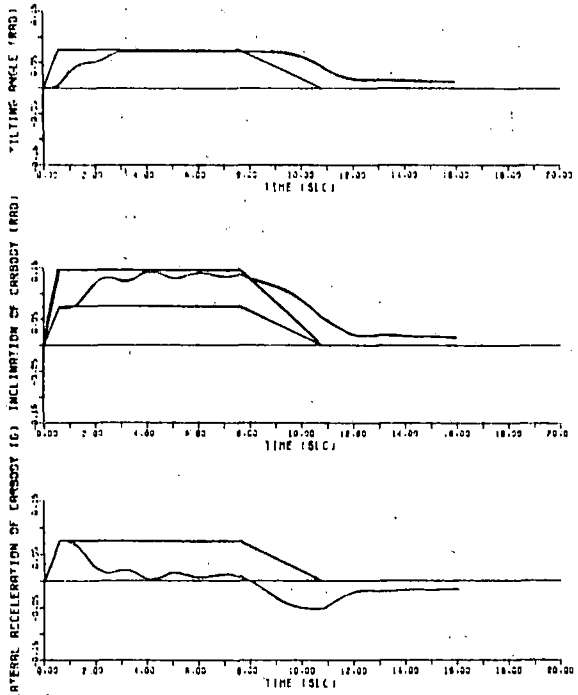

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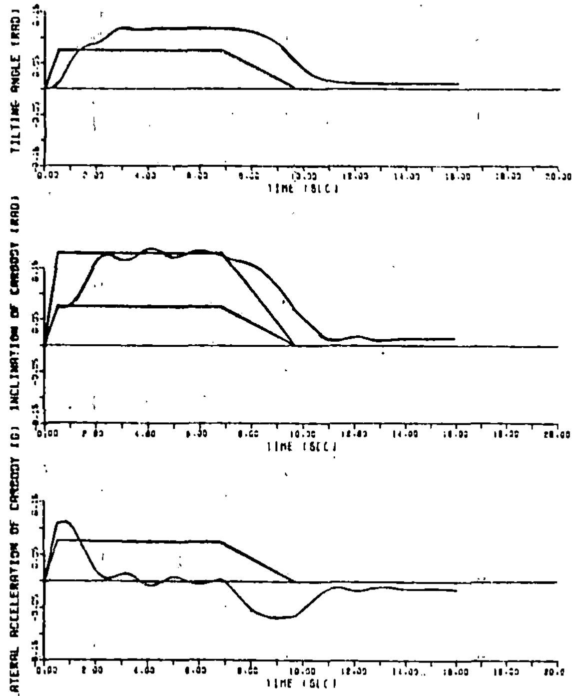

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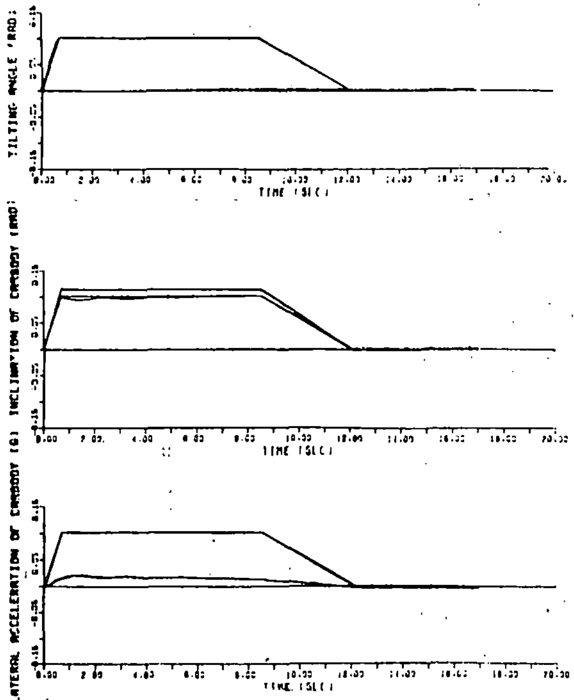

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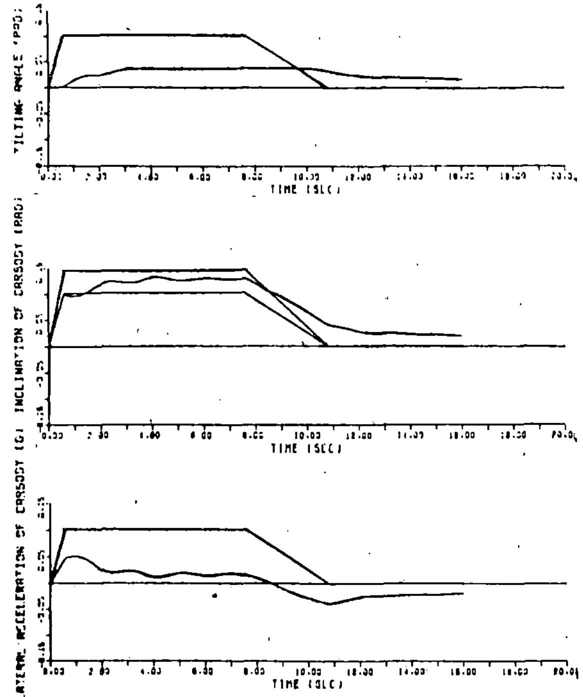

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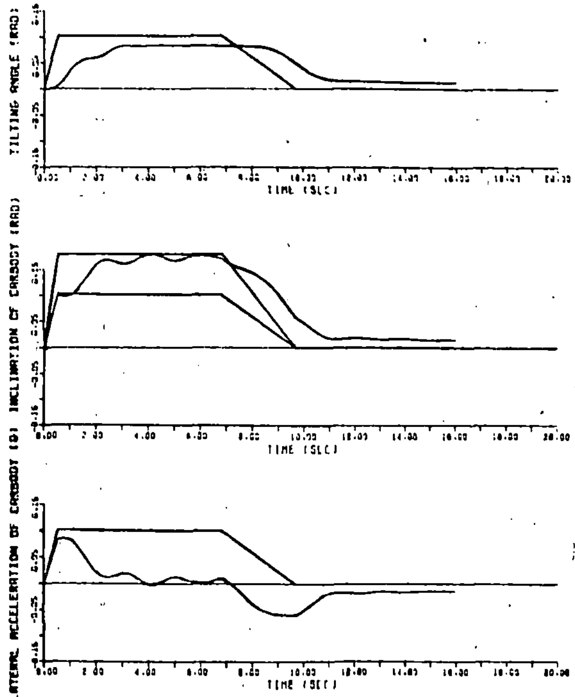

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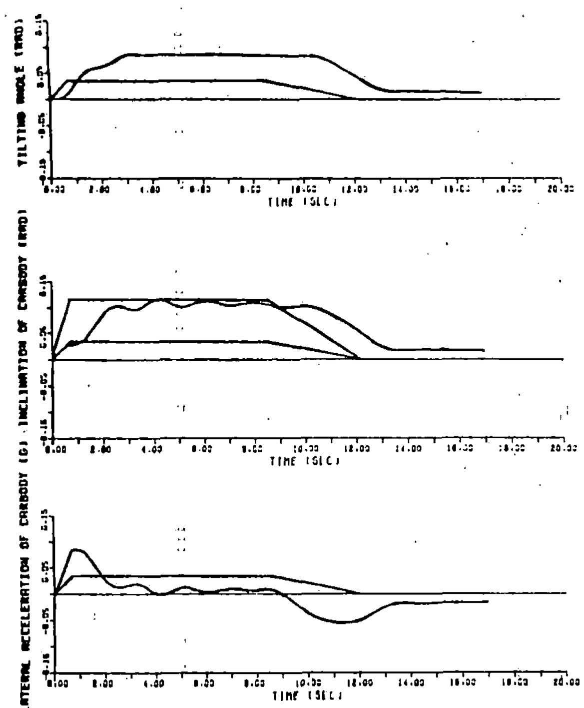

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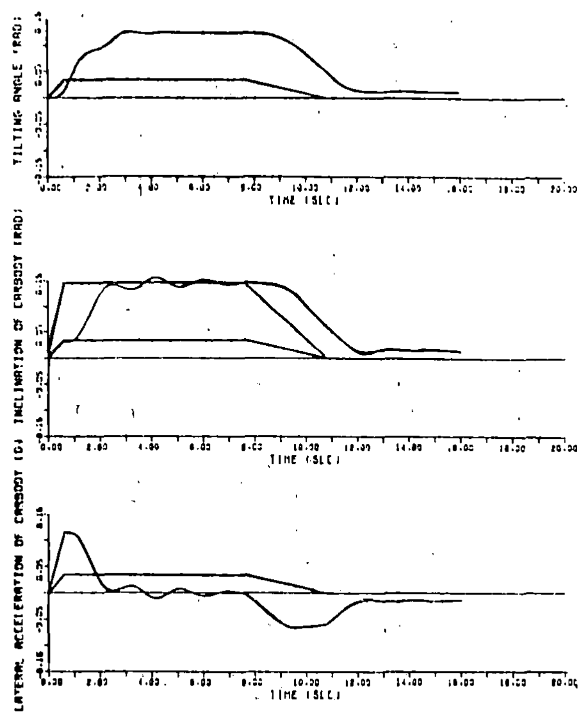

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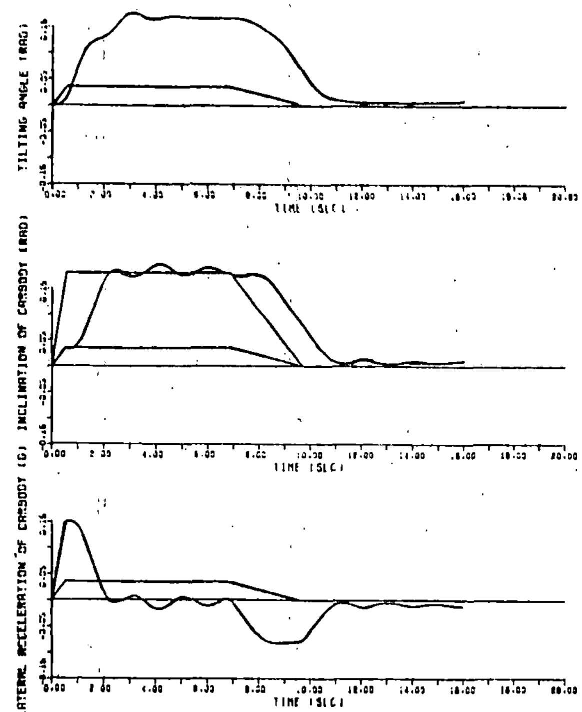

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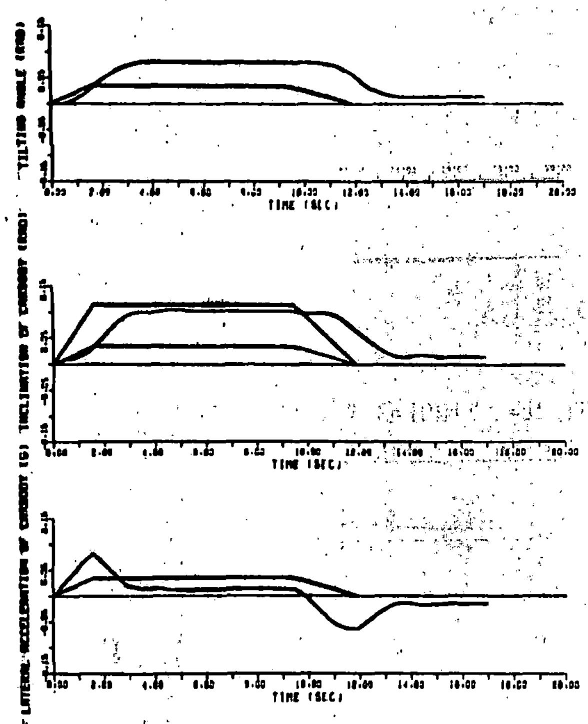

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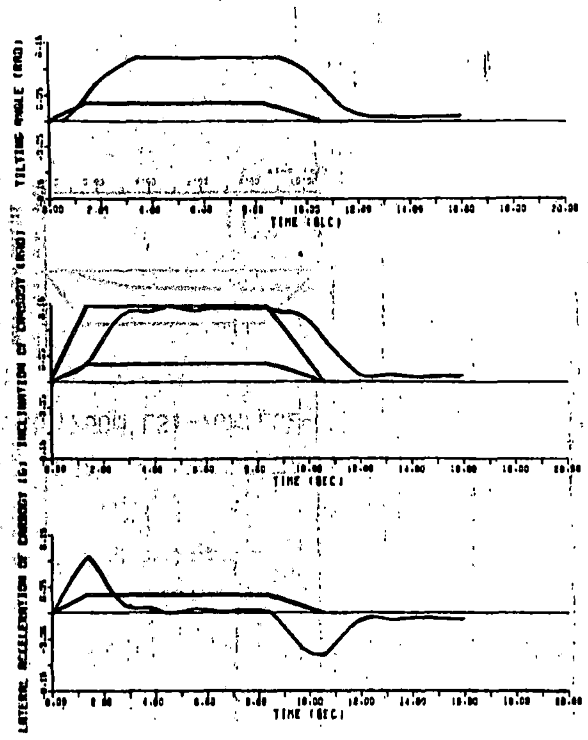

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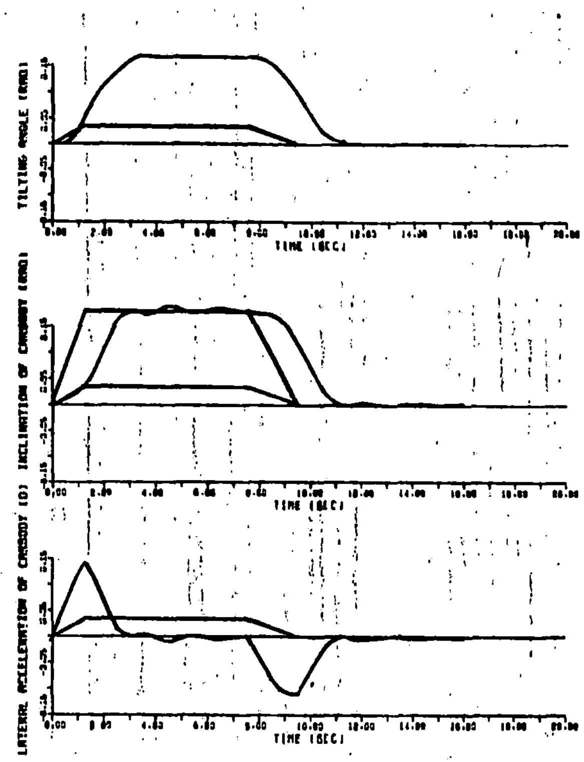

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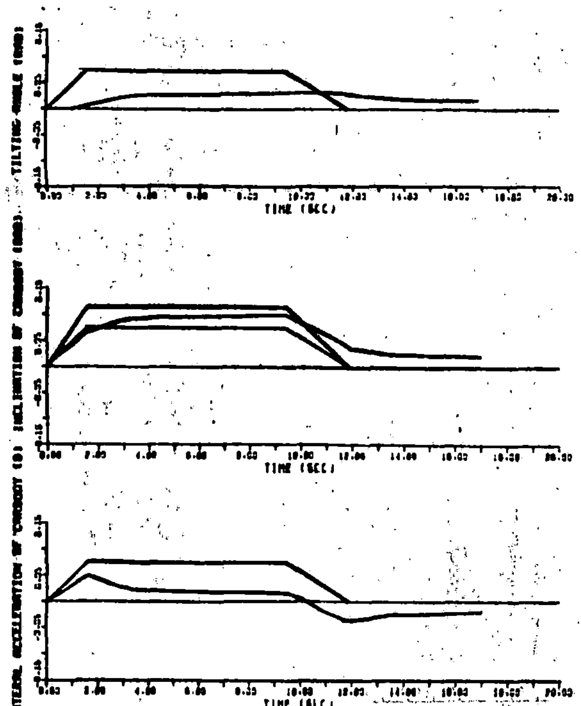

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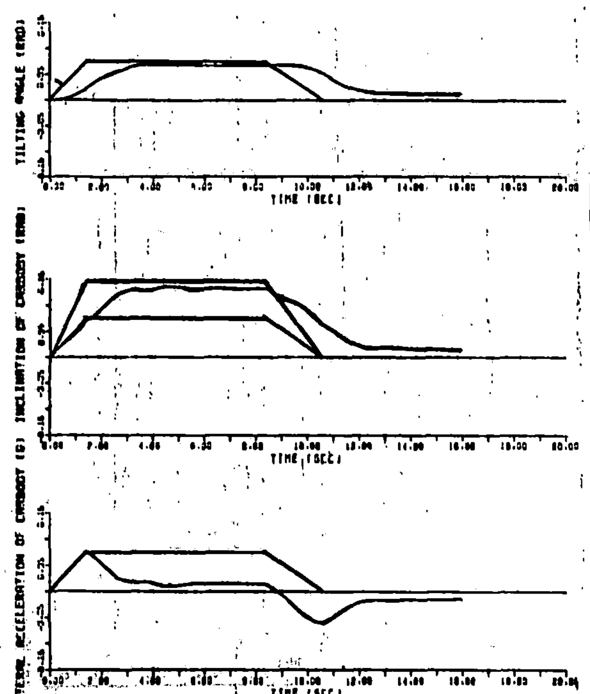

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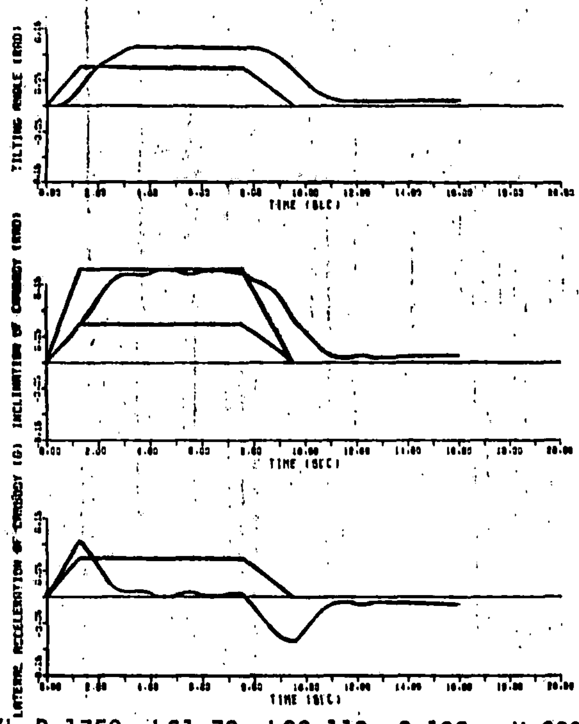

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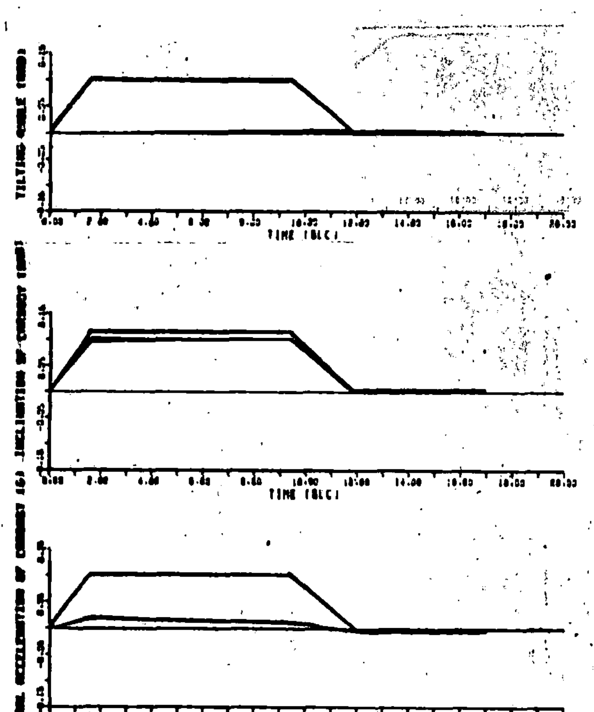

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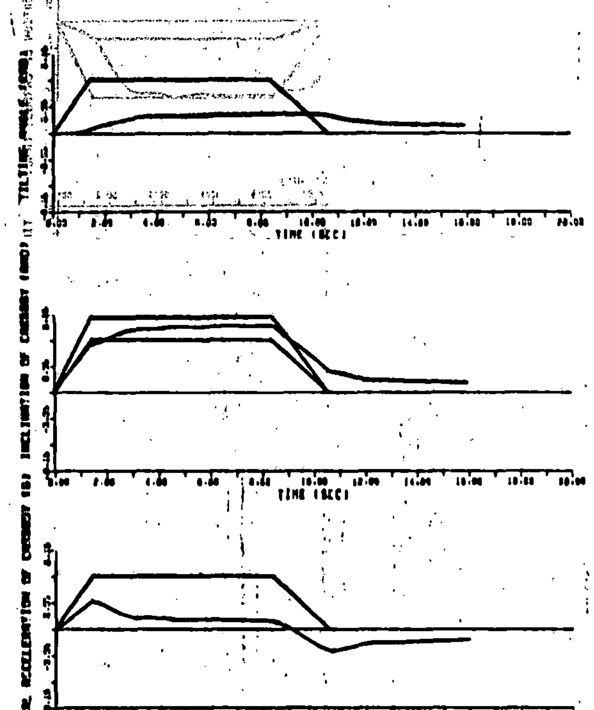

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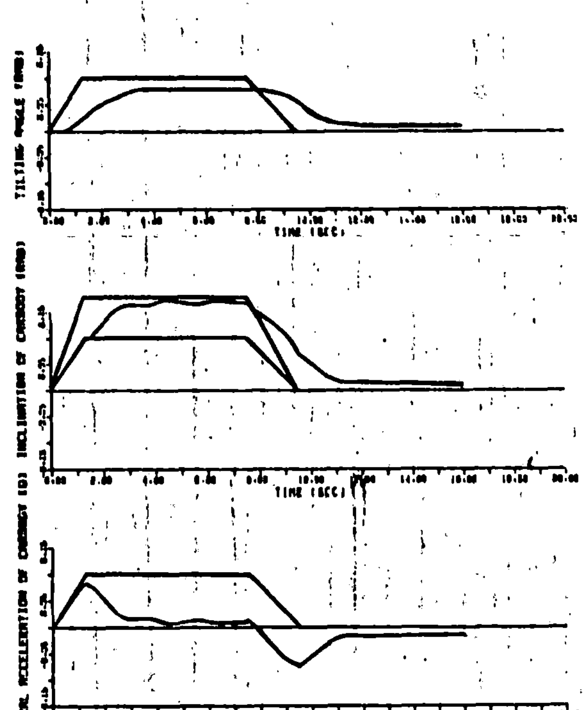

R=1750m LS1=70m LS2=110m C=146mm V=200km/h

Preliminary Design of a Passive Tilting System for Amcoach: Volume 2: Preliminary Design for Amcoach Tilting Modification, 1981
US DOT, FRA, T Shima, K Jindai, H Namba