

# Full scale test results of the RIMOB Crash Cushion

*Description of tests and results conform standard CEN/TC 226/WG1*

R-95-16  
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**preface**

## Preface

In 1981 and 1982 SWOV has carried out final tests with the RIMOB crash cushion. In those years there were no test conditions for crash cushion available. In accordance with some of the experiences carried out in the United States, chosen is for relevant tests: central impacts, frontal off set impacts and side impacts.

In this report the 'old' tests and results are redescribed similar to standard CEN/TC 226/WG1. Owing to differences between RIMOB and CEN test conditions the given results are not directly comparable. On the other hand there is much agreement.

The RIMOB is developed for passenger car with is a mass of approximately 900 kg. An integrated buffer segment provides for well function to vehicles with a higher mass. Collisions with vehicles with a lower mass give higher values for the Acceleration Severity Index (ASI-criterium) as described in this report.

After the tests the RIMOB is applied in practice. After seven years about 170 impact attenuators have been installed on the medians and shoulders of motorways in the Netherlands. At that time an evaluation study has been carried out (Schoon, 1990). Analyzed are 38 accidents registered by police. From the accident figures it was concluded that the RIMOB functions effectively. Even though collision speeds have been found of over 100 km/h no fatal accident was registered. Of the 38 collisions six resulted in injuries, of which one or two were taken to hospital and four or five only were slight injuries.



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## 1. Testing laboratory

TNO Wegtransportmiddelen  
(TNO Road-vehicles Research Institute)  
Schoemakerstraat 97  
P. O. Box 6033  
2600 JA DELFT  
The Netherlands  
Phone: +31 (0)15 - 696900  
Fax: +31 (0)15 - 620766  
Test site location: same location as address above

## 2. Client

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P. O. Box 1031

3000 BA ROTTERDAM

Phone: +31 (0)10 - 4026200



## 3. Tests with the RIMOB

### 3.1. Name of road restraint system

Crash Cushion: RIMOB

Dutch: RIMpelbuis Obstakel Beveiliger

English: Impact attenuator equipped with crumpling tubes.

### 3.2. Testing dates

F 4, F 5	:27th May	1981
F 6, F 7	:24th June	1981
F 8, F 9	:26th August	1981
F 10	:17th November	1981
F 11, F 12	:18th November	1981
F 13	:27th January	1982

### 3.3. Description of the RIMOB

A RIMOB (see Annex 1) consists of a composition of box-like segments which are compressed in a head-on collision. Each segment is one metre long and contains aluminium tubes which are placed in axial direction. The tubes serve to be compressed in a violent head-on collision to a maximum of approximately 20% of their initial length. The RIMOB also has side protection that consists of 2 m long guide-rail-elements which are partly placed on top of each other. Because of this placement the parts can slip on top of each other when this is needed. A standard profile is used. In case of a collision with the side of a RIMOB, it functions like a regular barrier construction.

The impact which RIMOB can absorb can be programmed. The absorption can be adjusted by changing the number of segments, the number of crumpling tubes per segment, the diameter of the tubes and the thickness of the tube-walls. The RIMOB is attached to the ground at only two points. The advantages are simple foundation and easy erection. Standard barriers can be connected to RIMOB, so it can be fully integrated.

Two types of RIMOB have been tested: The RIMOB-V 270 and the RIMOB-P 110. The RIMOB-V 270 (see Annex 2) has a V-shape with a base width of 2.70 m. The RIMOB-P 110 (see Annex 3) has a parallel shape with a base width of 1.10 m. The RIMOB-P is developed for a maximum collision speed of 70 km/h.

### 3.4. Drawing of the RIMOB-types

RIMOB-V (V 270): Annex 1 and 2

RIMOB-P (P 110): Annex 3

## 4. General test data (tests F4 to F13)

### 4.1. Vehicles

Opel Kadett-B sedan cars have been used for the crash tests in all cases with exception of test F7 where a Coupé is used.

*Vehicle data:*

mass:	715 kg to 847 kg
width:	1.57 m
length:	4.11 m (coupé: 4.18 m)
wheelbase:	2.42 m
track width:	front: 1.25 m; rear: 1.28 m

*Center of gravity:*

horizontal distance (x) from front axle:	1.20 m
longitudinal distance (y) is in the center of the car	
vertical distance (z) from ground:	0.57 m

### 4.2. Dummies

In each test vehicle two 'Hybrid II'-dummies were installed. One dummy on the driver-seat and one on the passenger-seat, both wearing safety-belts. The mass of each Hybrid II dummy is 75 kg.

### 4.3. Data registration

The test vehicles were provided with triaxial acceleration meters, excluded the tests F11 and F13 (see the remark at these tests). For the positions of the acceleration meters see Annex 4.

Apart from acceleration meters, in tests F10 and F12 both dummies were equipped with triaxial acceleration meters; one in the head and the other in the chest. Also shoulder belt loads were registered with Lebow 3419 meters.

### 4.4. Total weight

In order to prevent fire, the fuel tanks were all emptied. To simulate the mass of a full tank, a weight with a mass of 40 kg was added. The weight of the electronic equipment on board is also included.

### 4.5. Weather conditions

In all cases it was dry.

## 5. Test procedure of RIMOB with results

In order to test the RIMOB-V, nine crash tests were performed. The tests were divided in 4 categories:

- Frontal: 3 tests
- Offset: 2 tests
- 15° Frontal: 1 test
- Side impact 65 km/h - 22°: 1 test
- Side impact 80 km/h - 15°: 2 tests

Most of the impact conditions have been in accordance with the CEN standard. In case of differences the extent is expressed in percents.

With the RIMOB-P one frontal test is carried out.

From each test the impact conditions and results are given. Pre test and post test situations are shown in figures. The acceleration values (horizontal, lateral and vertical) are expressed in the value of the ASI.

In the paragraphs 3.3. 'Injury assessment', the ASI values are given according to CEN standard as well as according to SWOV calculations (resp. mentioned ASI-CEN and ASI-SWOV).

*ASI-CEN*: the reference acceleration values in the CEN standard are:  $a_{hor} = 12g$ ,  $a_{lat} = 9g$  and  $a_{vert} = 10g$ . With these values the ASI criterium is '1' for belted occupants.

*ASI-SWOV*: in 1982 SWOV used the reference acceleration values  $a_{hor} = 7g$ ,  $a_{lat} = 5g$  and  $a_{vert} = 6g$ . With these values the ASI criteria is '1' for unbelted occupants and '1.6' for belted occupants.

The given time-history curves of ASI values are the ASI-SWOV values.

The ASI criterium is not fully appropriate for side impact tests. See for instance the remarks given at side impact tests F10.

The last page of each test contents pictures of the RIMOB and test vehicle after the test.

In Chapter 6 the final results are given in accordance with in the CEN standard mentioned 'Acceptance Classes'.

## 5.1. Frontal tests

### A. CEN test specifications TC 1.1.C.

Target impact speed: 100 km/h  
Target impact angle: 0°  
Target impact point: center  
Target vehicle test mass: 900 kg

### B. Test performed

Three tests are carried out: Test-numbers: F7, F11 and F13

Test impact speed: 100 km/h (0% difference)  
Test impact angle: 0° (0% difference)  
Test impact point: center

- *Test-number:*

F7	F11	F13
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- *Car:*

Opel Kadett Olympia 1500 Coupé	Opel Kadett B	Opel Kadett B
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- *Model year:*

1970	1973	1971
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- *Test mass:*

997 kg	975 kg	approx. 970 kg
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- *Test date:*

06.24.82 (mm.dd.yy)	11.18.81	01.27.82
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## C. Results TC 1.1.C.

### C.1. Data of the RIMOB

- Test-number	F7	F11	F13
- Damage to RIMOB:	compression: 5.1 m dynamic compression: 5.35 m	compression: 4.5 m dynamic compression: 4.9 m	compression: 4.1 m dynamic compression: 4.9 m
- Maximum permanent deflection (lateral):	0.1 m	0 m	0 m
- Major parts fractured or detached?:	none	none	none

### C.2. Vehicle

- Rebound:	0 m	0 m	0.7 m
- Length reduction of hood:	0.25 m	0.26 m	0.34 m
- Vehicle cockpit deformation index VCDI:	no deformation	no deformation	no deformation

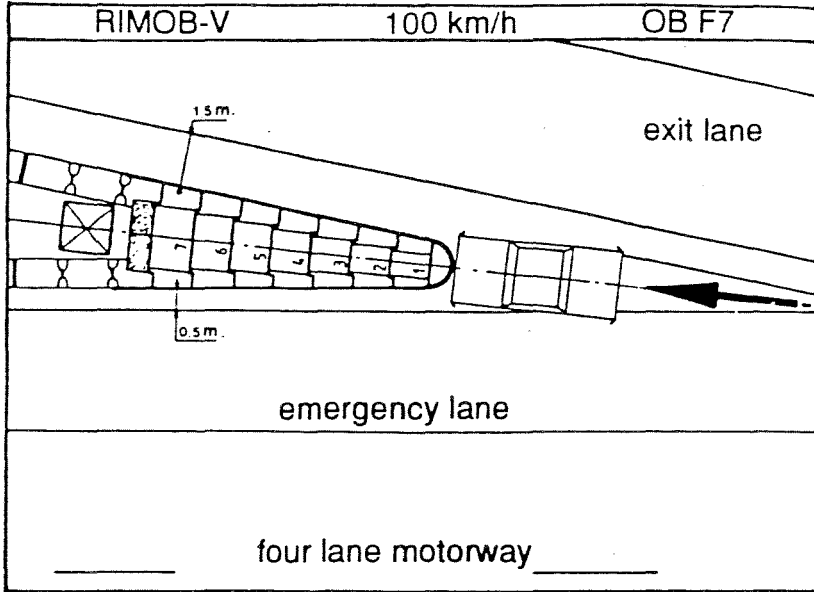
### C.3. Injury assessment

- Acceleration severity index ASI-CEN (criteria: $ASI_{max-belted} = 1,0$ )	0.87	no data *)	no data *)
- Acceleration severity index ASI-SWOV (zie graphs) (criteria: $ASI_{max-belted} = 1,6$ ; $ASI_{max-unbelted} = 1,0$ ;) )	1.5	no data *)	no data *)
- Average acceleration ( $a_{avg.} = v^2 / 2s$ ) ( $v =$ impact velocity; $s =$ dynamic compression distance):	72.1 m/s <sup>2</sup>	78.7 m/s <sup>2</sup>	78.7 m/s <sup>2</sup>

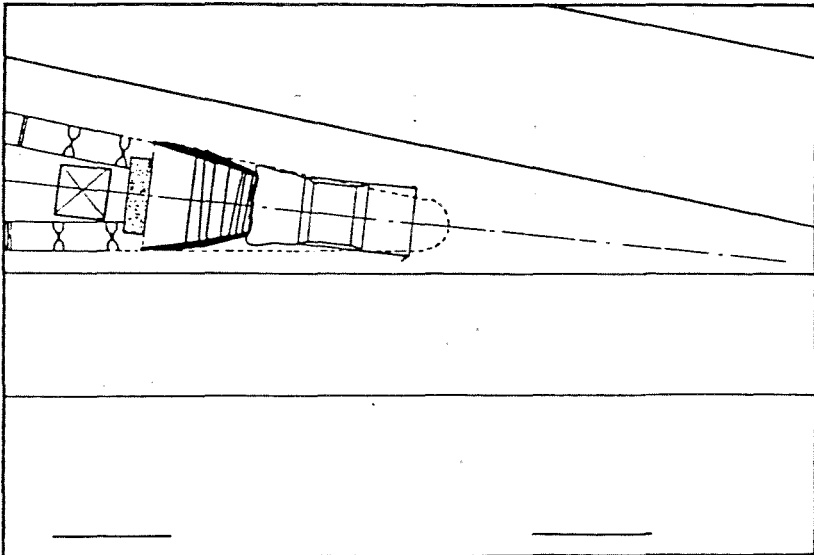
\*) Not recorded owing to minor changes in design of the RIMOB in comparison with test F7. The calculation of the 'average acceleration' (see below) shows that the level of acceleration of tests F11 and F13 is slightly higher than that of test F7.

# TEST F7

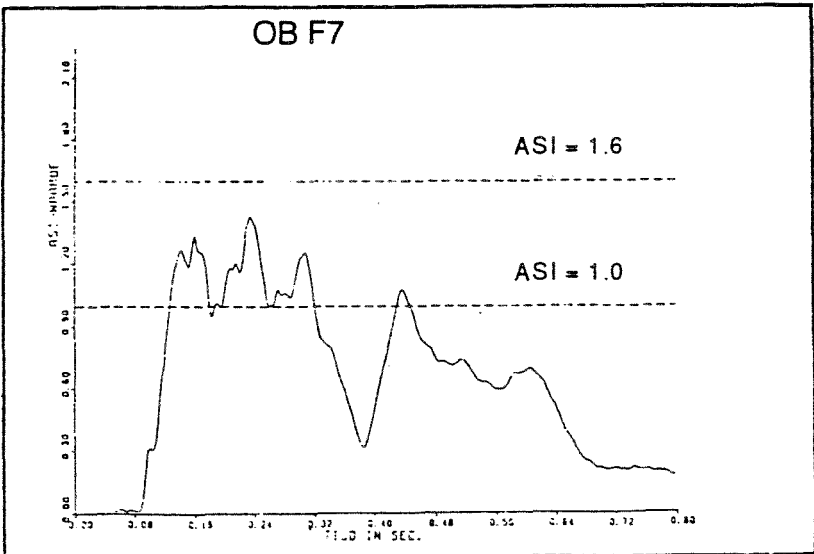
PRE TEST  
(test conditions  
projected on  
motorway situations)



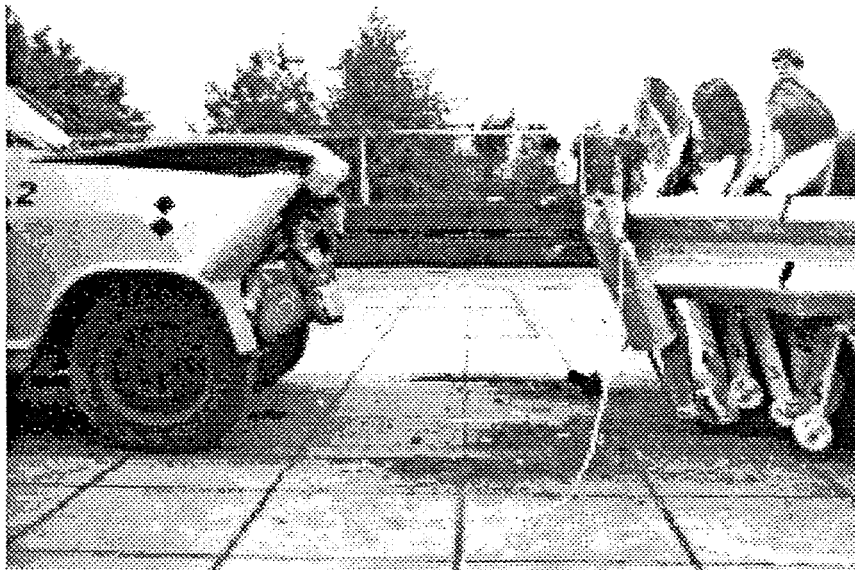
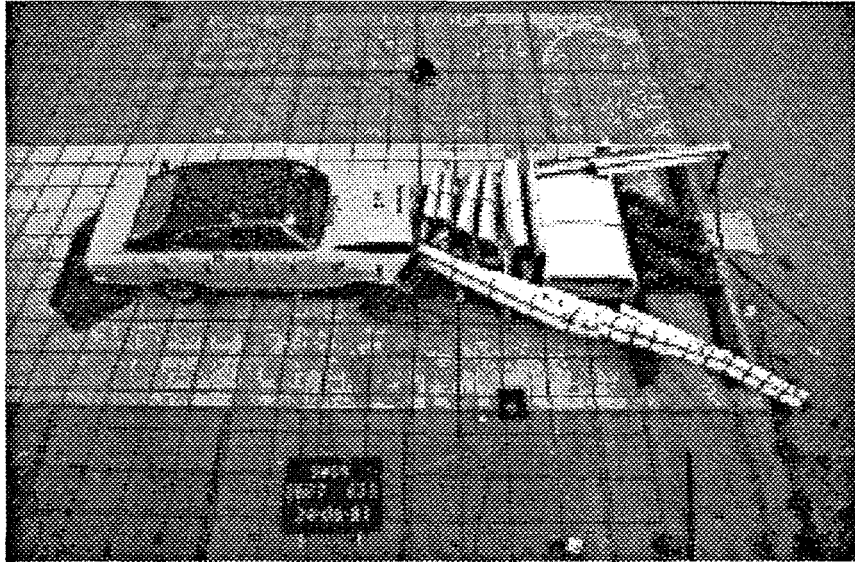
POST TEST  
SITUATION



ASI-SWOV  
(values calculated  
for the time-history)

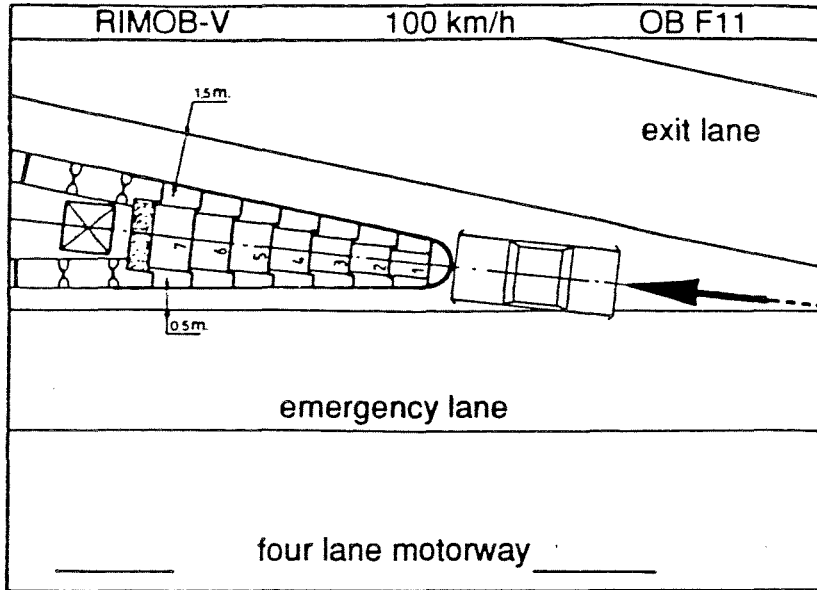


ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$

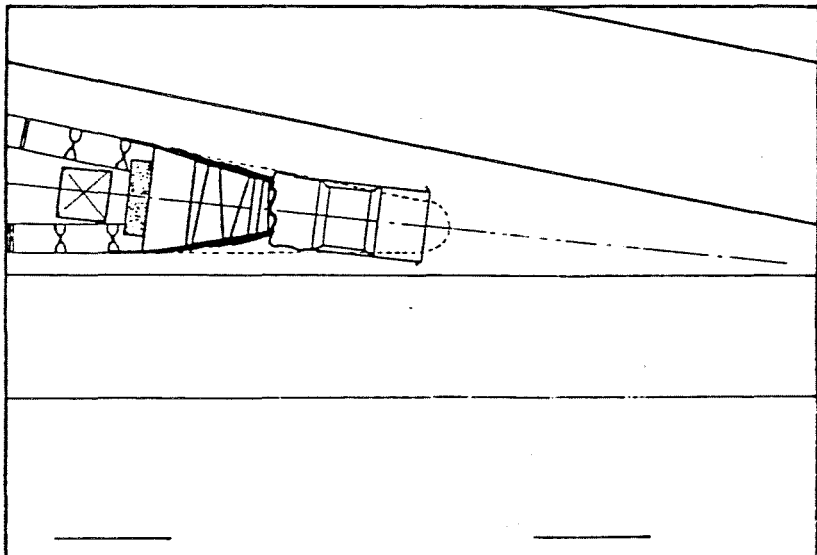


# TEST F11

PRE TEST  
(test conditions  
projected on  
motorway situations)

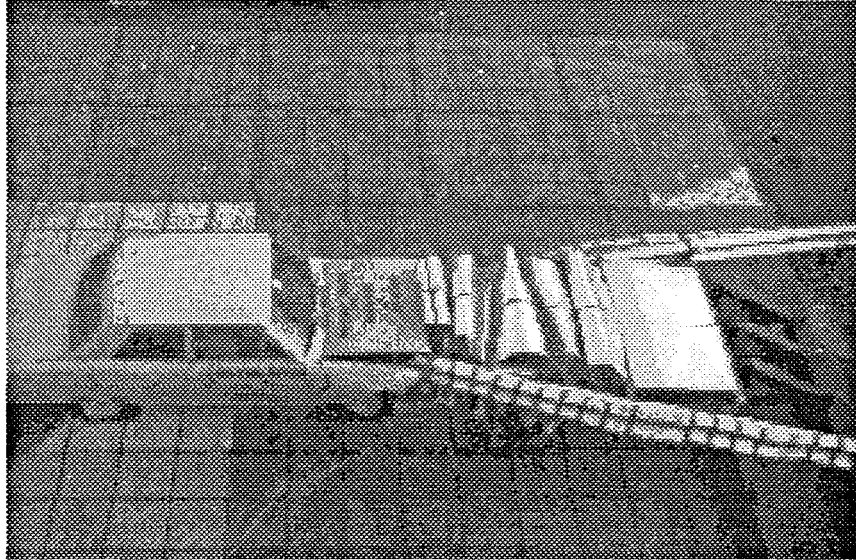


POST TEST  
SITUATION



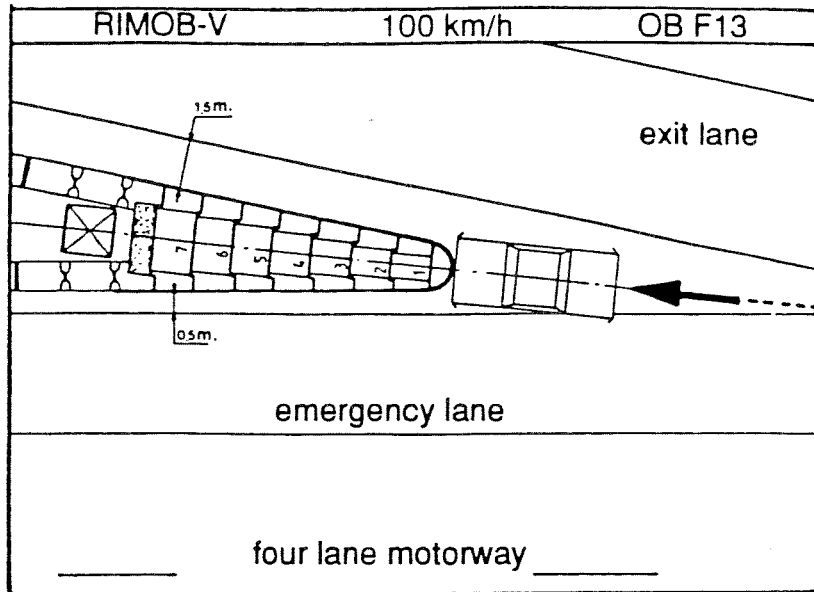
Vehicle deceleration not recorded



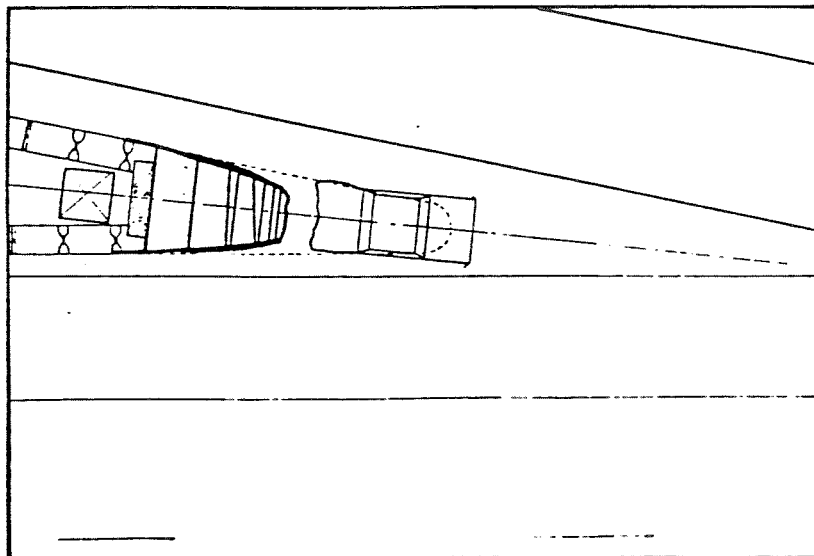


# TEST F13

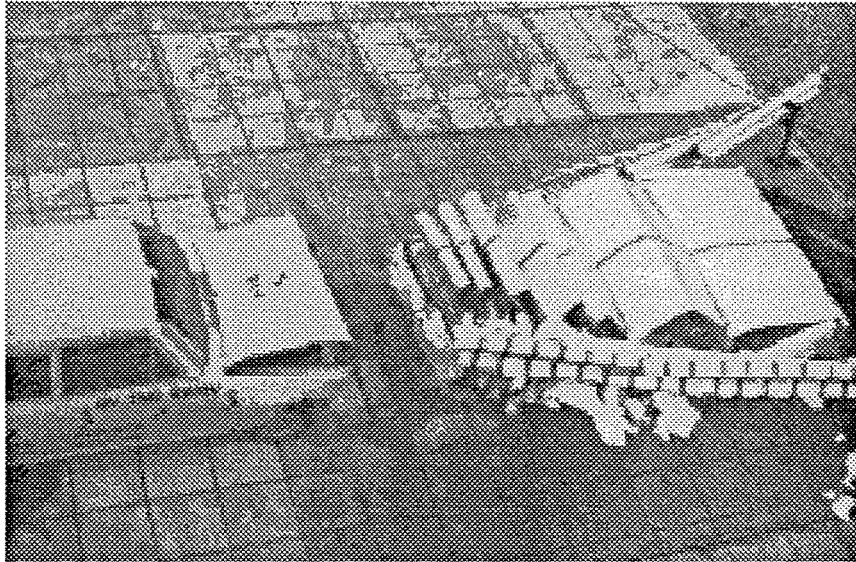
PRE TEST  
(test conditions  
projected on  
motorway situations)



POST TEST  
SITUATION



Vehicle deceleration not recorded



## 5.2. Offset tests

### D. CEN test specifications TC 2.1.B.

Target impact speed: 80 km/h  
Target impact angle: 0°  
Target impact point: center 1/4 offset  
Target vehicle test mass: 900 kg

### E. Test performed

Two tests are carried out: Test-number F8

Test impact speed: 70 km/h (12.5% difference)  
Test impact angle: 0° (0% difference)  
Test impact point: 0.5 m from the right side of the car's center

and Test-number F12

Test impact speed: 80 km/h (0% difference)  
Test impact angle: 0° (0% difference)  
Test impact point: 0.5 m from the right side of the car's center

*Test-number:*

F8

F12

*Car:*

Opel Kadett B

Opel Kadett B

*Model year:*

1969

1971

*Test mass:*

970 kg

955 kg

*Test date:*

08.26.81

11.18.81

## F. Results TC 2.1.B.

### F.1. Data of the RIMOB

Test-number:

F8

F12

Damage to RIMOB:

compression: 2.4 m

compression: 3.3 m

Maximum permanent deflection (lateral):

0.33 m

0.95 m

Major parts fractured or detached?:

none

none

### F.2. Vehicle

Rebound:

3 m

1.5 m

Length reduction of hood:

0.34 m

0.37 m

Vehicle cockpit deformation index VCDI:

RF 0 0 0 0 0 0 0

RF 0 0 1 0 0 0 0

floor intrusion of 3 cm

floor intrusion of 6 cm

### F.3. Injury assessment

Acceleration severity index ASI-CEN:

(criteria:  $ASI_{max-belted} = 1,0$ ):

0.63

0.76

Acceleration severity index ASI-SWOV (zie graphs)

(criteria:  $ASI_{max-belted} = 1,6$ ;  $ASI_{max-unbelted} = 1,0$ ;) )

1.1

1.3

HIC value:

(criteria: max = 1000)

not registered

driver: 98

passenger: 93

Maximum shoulder belt load:

(a general accepted criteria is max. 5000N)

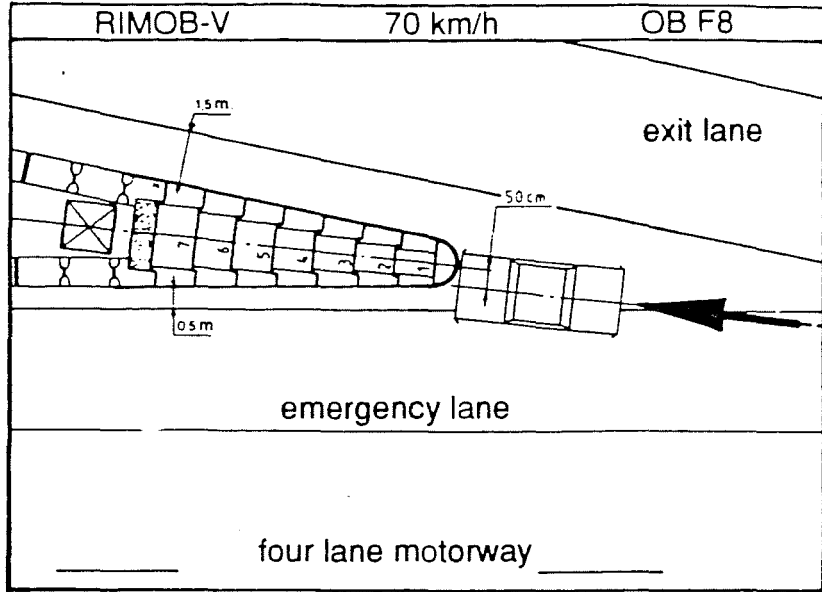
not registered

driver: 3091 N

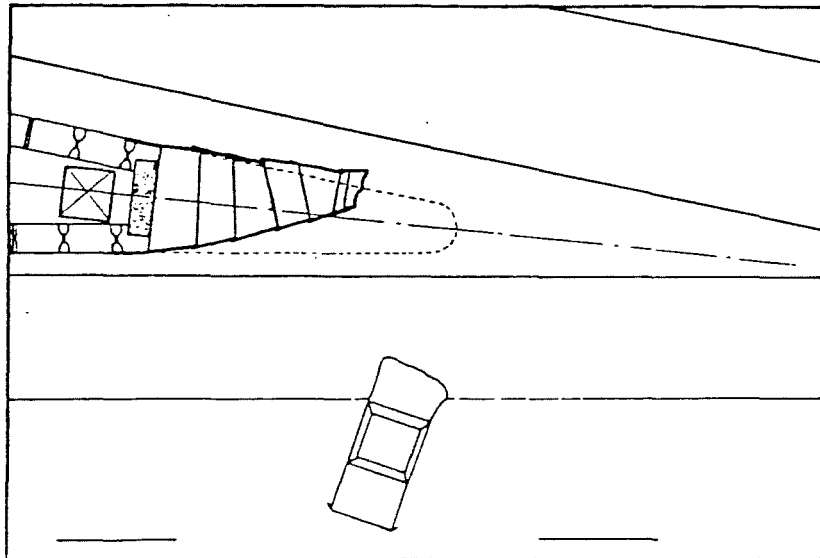
passenger: 5144 N

# TEST F8

PRE TEST  
(test conditions  
projected on  
motorway situations)

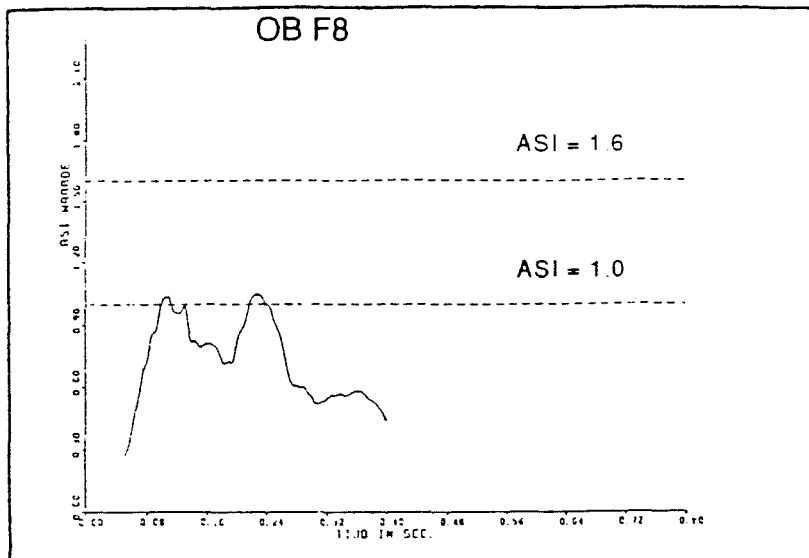


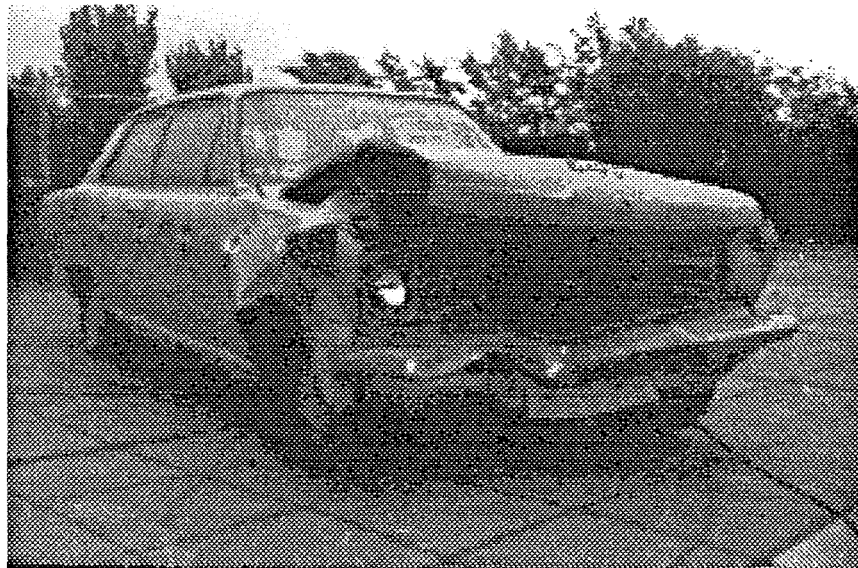
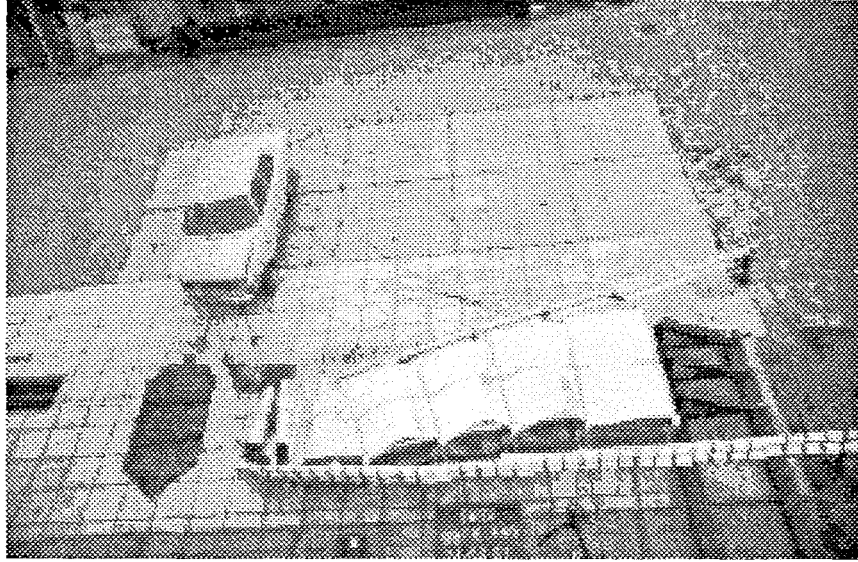
POST TEST  
SITUATION



ASI-SWOV  
(values calculated  
for the time-history)

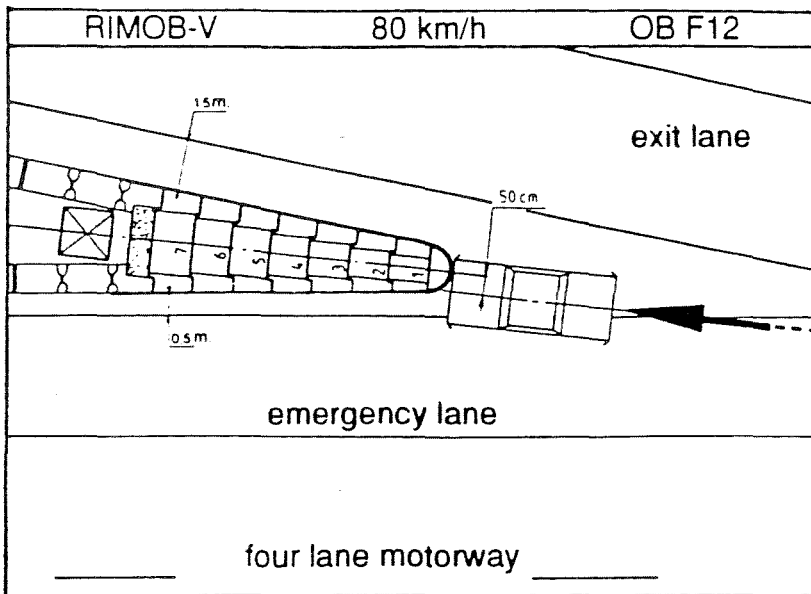
ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$



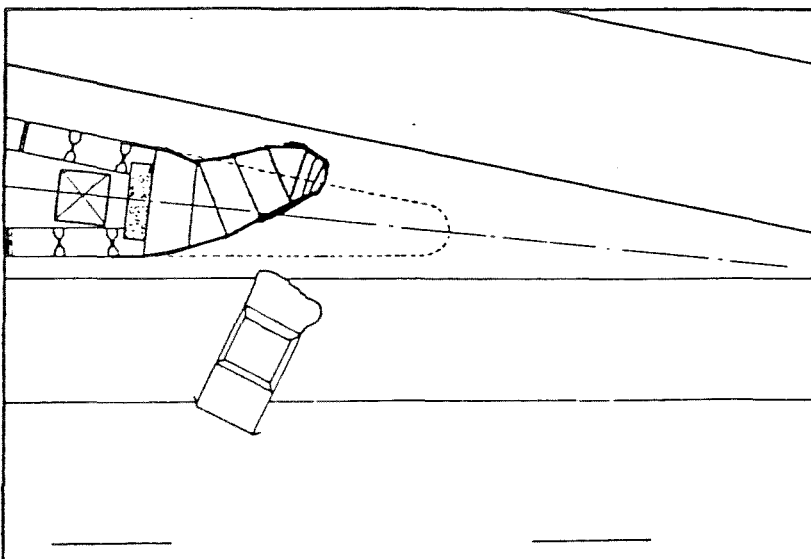


# TEST F12

PRE TEST  
(test conditions  
projected on  
motorway situations)

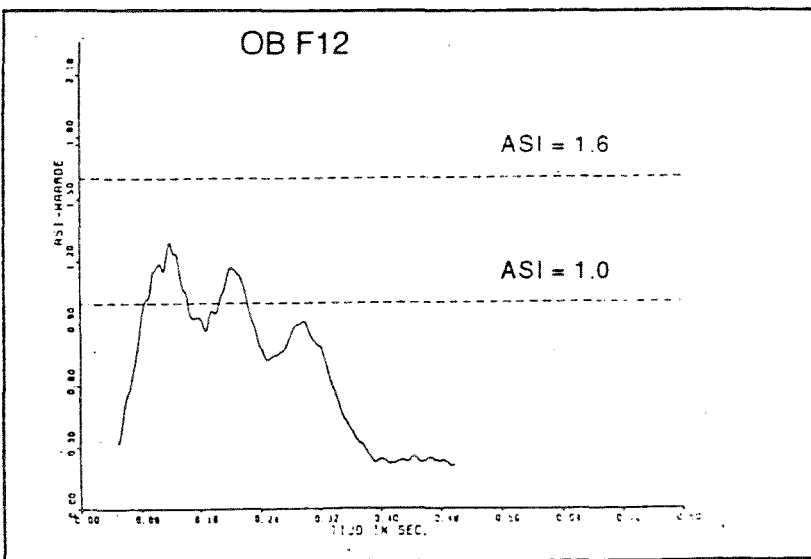


POST TEST  
SITUATION

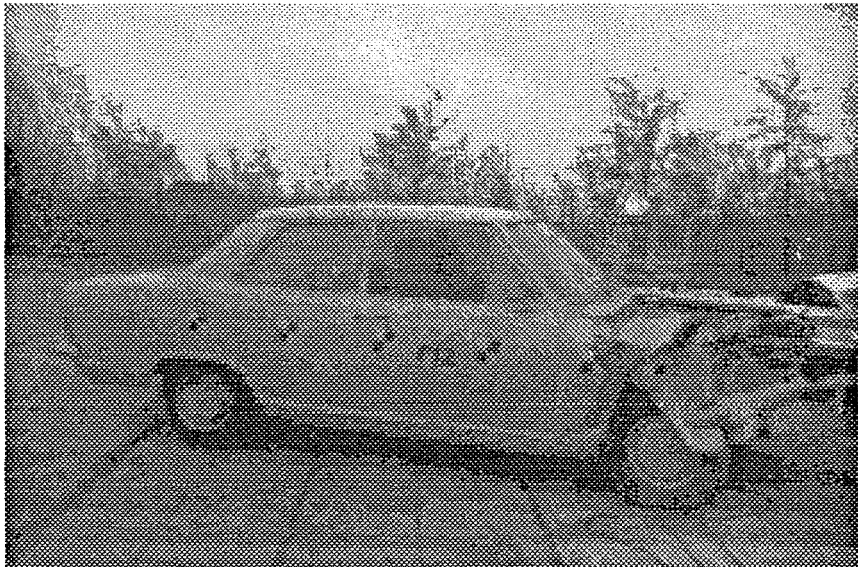
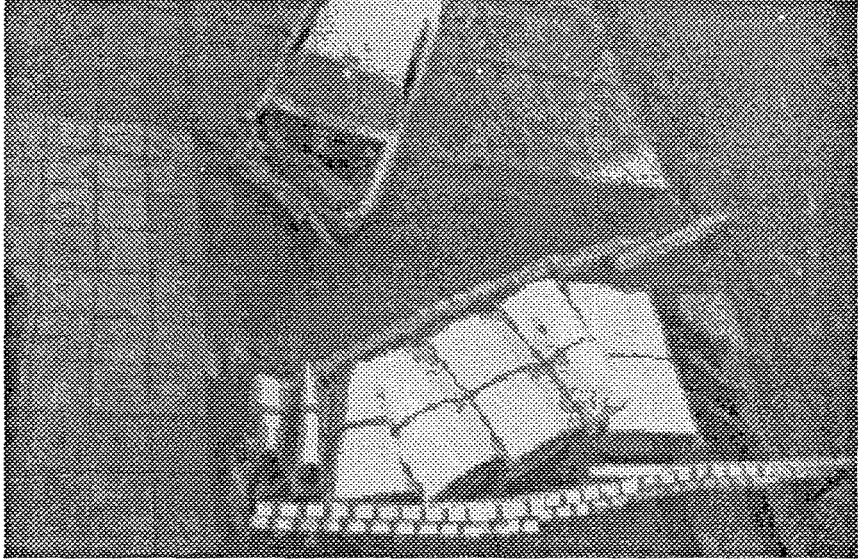


ASI-SWOV  
(values calculated  
for the time-history)

ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$







### 5.3. Frontal test

#### G. CEN test specifications TC 3.2.B.

Target impact speed: 80 km/h  
Target impact angle: 15°  
Target impact point: nose center at 15°  
Target vehicle test mass: 900 kg

#### H. Test performed

One test is carried out: Test-number: F5  
Test impact speed: 80 km/h (0% difference)  
Test impact angle: 15.2° (1.3% difference)  
Test impact point: nose center

*Test-number:*

F5

*Car:*

Opel Kadett B

*Model year:*

1970

*Test mass:*

910 kg

*Test date:*

05.27.81

## **J. Results TC 3.2.B.**

### **J.1. Data of the RIMOB**

*Test-number:*

F5

*Damage to RIMOB:*

compression: 3.2 m

*Maximum permanent deflection (lateral):*

0.81 m

*Major parts fractured or detached?:*

none

### **J.2. Vehicle**

*Rebound:*

0.42 m

*Length reduction of hood:*

0.30 m

*Vehicle cockpit deformation index VCDI:*

no deformation

### **J.3. Injury assessment**

*Acceleration severity index ASI-CEN:*

*(criteria:  $ASI_{max-belted} = 1,0$ ):*

0.88

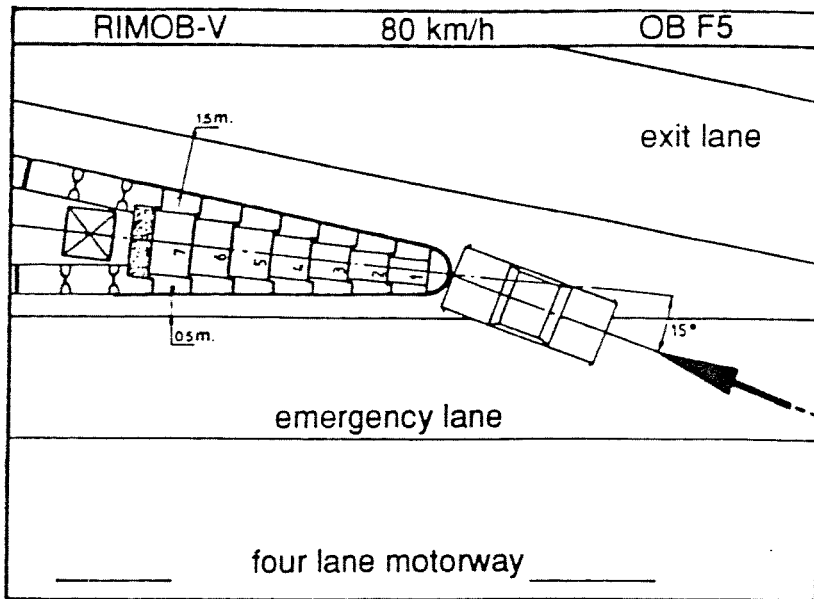
*Acceleration severity index ASI-SWOV (zie graphs)*

*(criteria:  $ASI_{max-belted} = 1,6$ ;  $ASI_{max-unbelted} = 1,0$ ):*

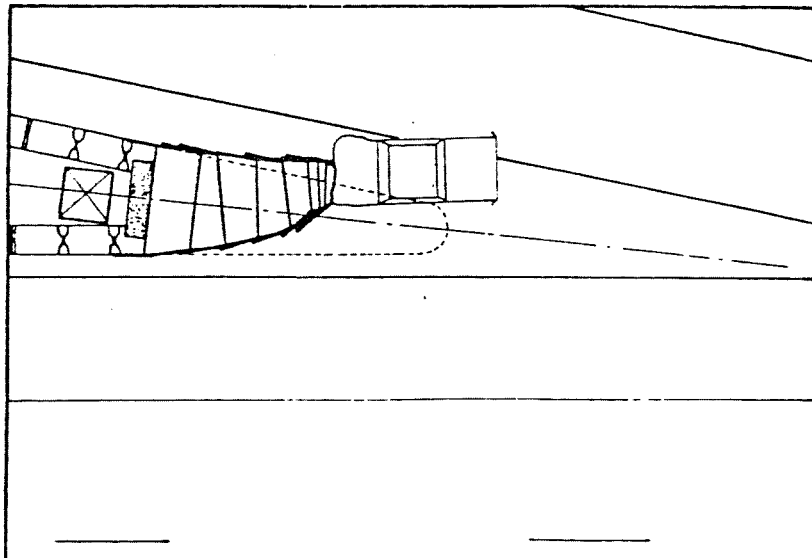
1.5

# TEST F5

PRE TEST  
(test conditions  
projected on  
motorway situations)

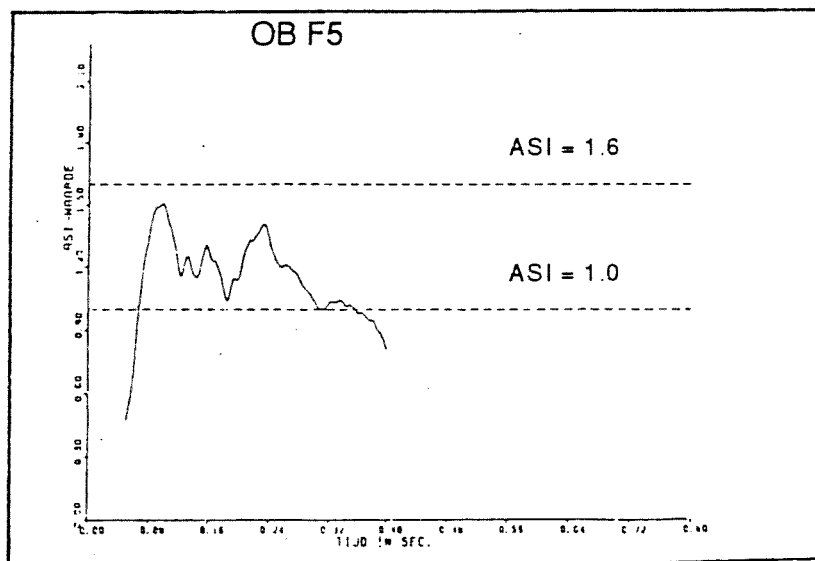


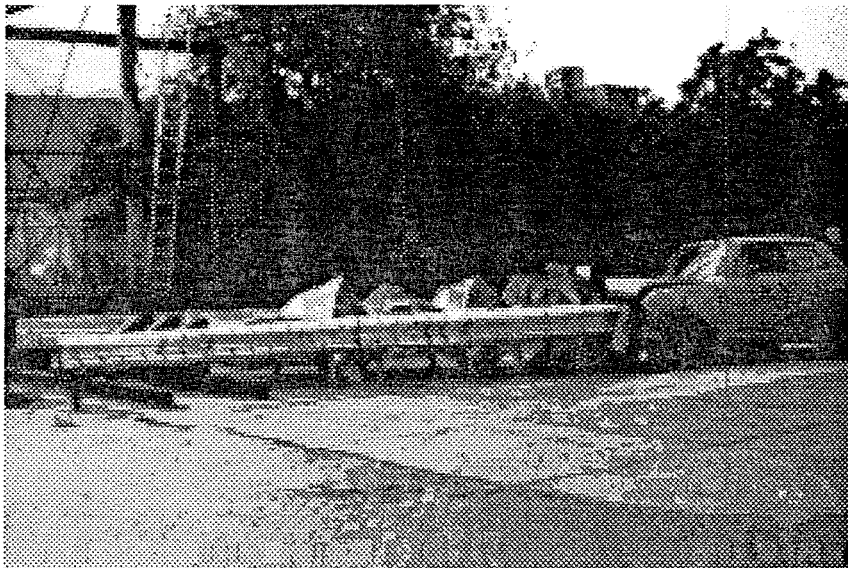
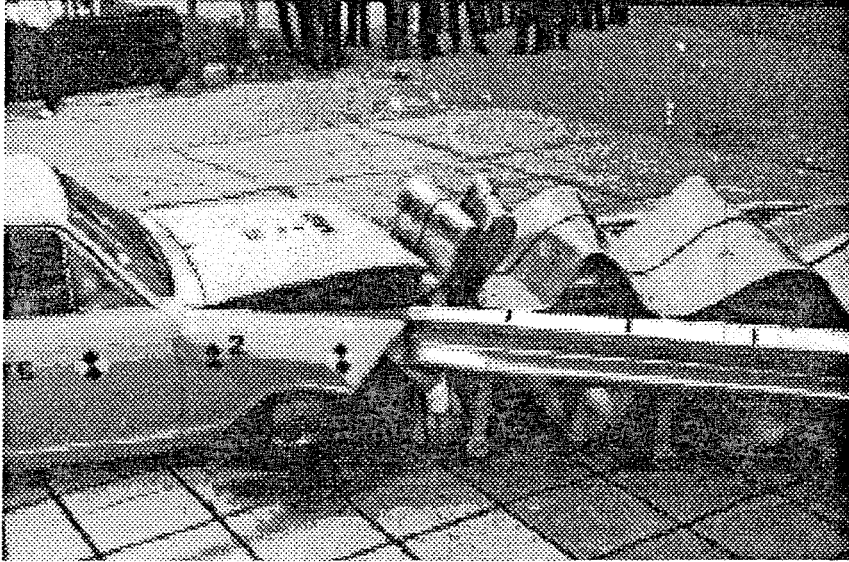
POST TEST  
SITUATION



ASI-SWOV  
(values calculated  
for the time-history)

ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$





#### 5.4. Side impact test 65 km/h, 22°

##### K. CEN test specifications TC 4.2.A.

Target impact speed: 50 km/h  
Target impact angle: 15°  
Target impact point: side impact (middle of construction)  
Target vehicle test mass: 1300 kg

##### L. Test performed

One test is carried out: Test-number: F4  
Test impact speed: 65 km/h (30% difference)  
Test impact angle: 22.4° (49.3% difference)  
Test impact point: side (near front)

*Test-number:*

F4

*Car:*

Opel Kadett B

*Model year:*

1971

*Test mass:*

910 kg

*Test date:*

05.27.81

## M. Results TC 4.2.A.

### M.1. Data of the RIMOB

*Test-number:*

F4

*Damage to RIMOB:*

One tube has been slightly deformed

*Maximum permanent deflection (lateral):*

0.10 m (departure side)

*Major parts fractured or detached?:*

none

### M.2. Vehicle

*Rebound:*

not applicable

*Exit angle:*

4° to guard rail

*Vehicle damage:*

small dents and scratches

*Vehicle cockpit deformation index VCDI:*

no deformation

### M.3. Injury assessment

*Acceleration severity index ASI:*

*(criteria:  $ASI_{max-belted} = 1,0$ )*

1.06 \*)

*Acceleration severity index ASI-SWOV (zie graphs):*

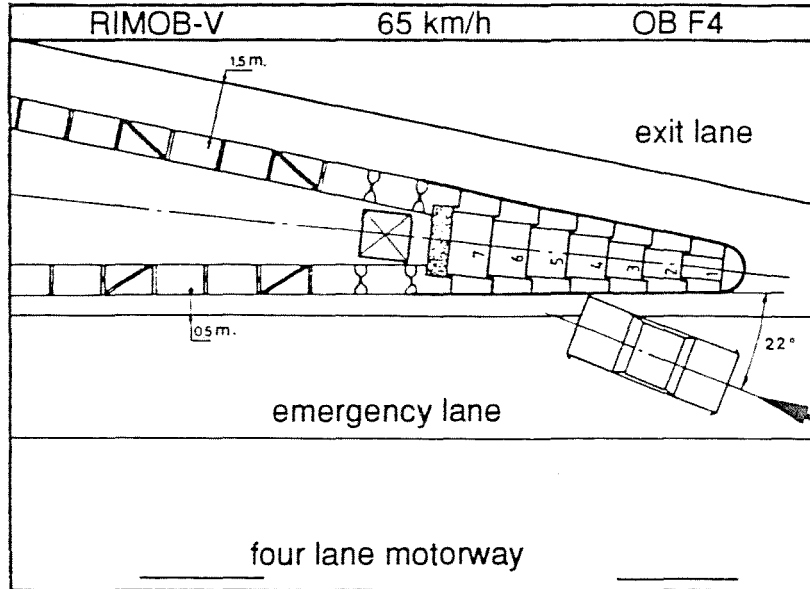
*(criteria:  $ASI_{max-belted} = 1,6$ ;  $ASI_{max-unbelted} = 1,0$ ;)*

1.8 \*)

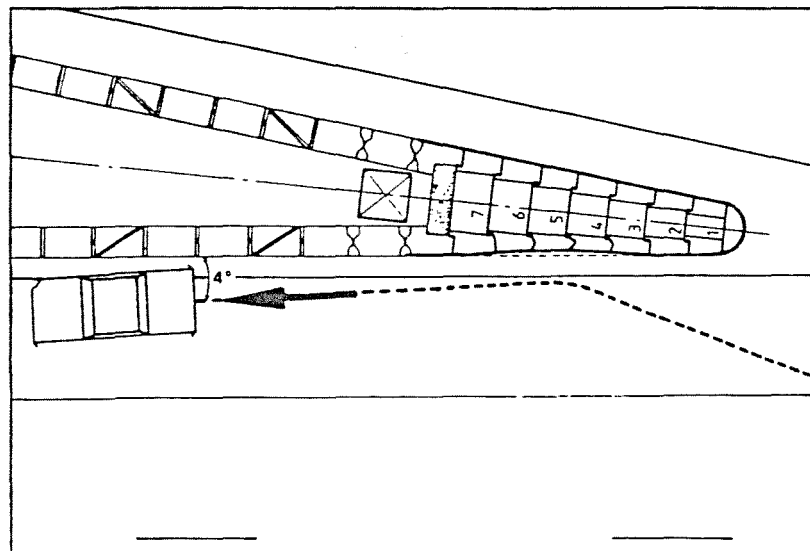
\*) ASI is not fully appropriate for side impact tests. See for instance the data of the head acceleration of the instrumented dummies at the side impact test F10. The values show a HIC-value which is far below the criteria of 1000.

# TEST F4

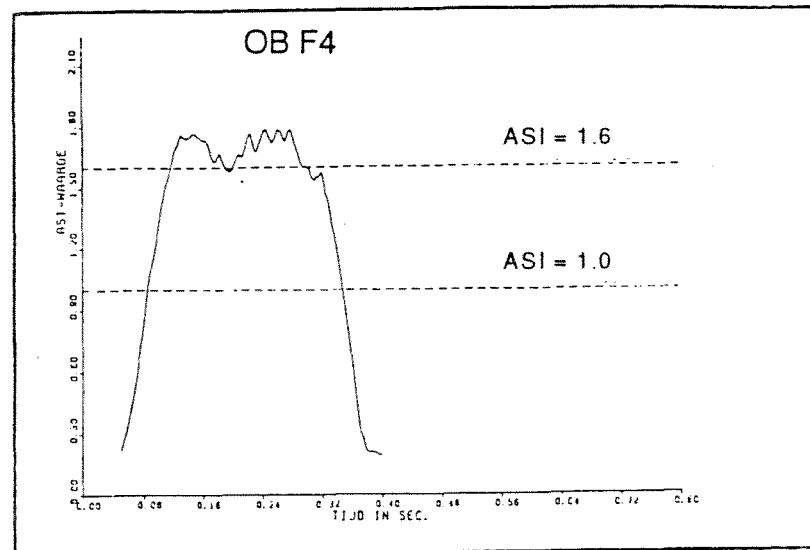
PRE TEST  
(test conditions  
projected on  
motorway situations)



POST TEST  
SITUATION

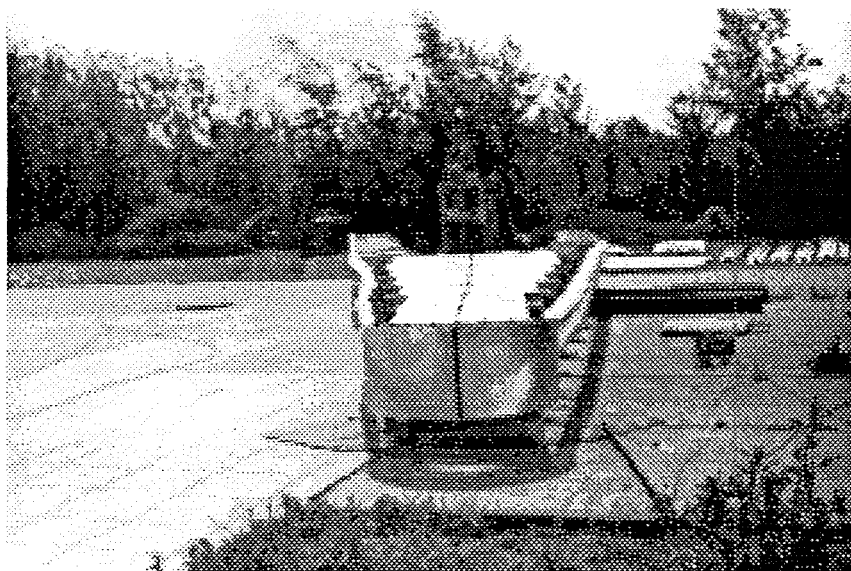
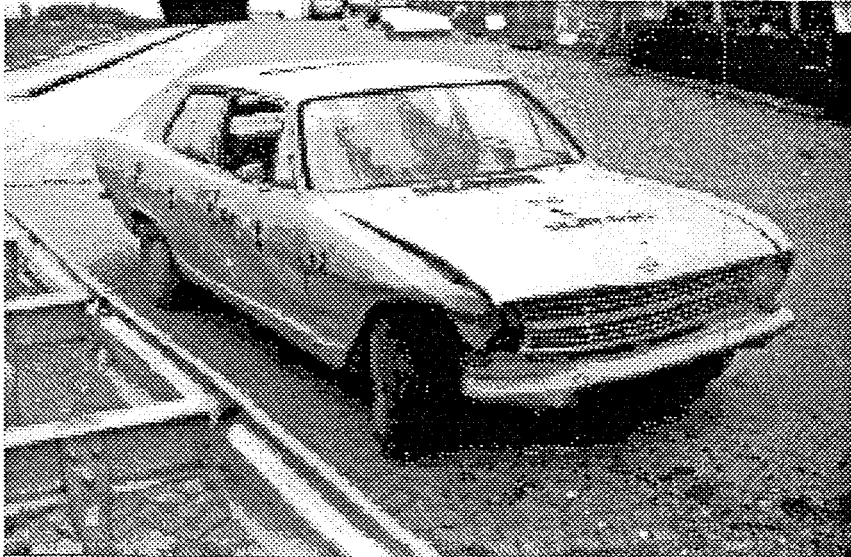


ASI-SWOV  
(values calculated  
for the time-history)



ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$





## 5.5. Side impact tests 80 km/h, 15°

### N. CEN test specifications TC 4. 2. B.

Target impact speed: 80 km/h  
Target impact angle: 15°  
Target impact point: side impact (middle of construction)  
Target vehicle test mass: 1300 kg

### O. Test performed

Two tests are carried out: Test-numbers: F6 and F10

Test impact speed: 80 km/h (0% difference)  
Test impact angle: 15° (0% difference)  
Test impact point: side (near back)

<i>Test-number</i>	F6	F10
<i>Car:</i>	Opel Kadett B	Opel Kadett B
<i>Model year:</i>	1972	1972
<i>Test mass:</i>	905 kg	965 kg
<i>Test date:</i>	06.24.81	11.17.81

## P. Results TC 4.2.B.

### P.1. Test item

*Test-number*

F6

F10

*Damage to RIMOB:*

slight

slight

*Maximum permanent deflection (lateral):*

0 m (departure side)

0.25 m (departure side)

*Major parts fractured or detached?:*

none

none

### P.2. Vehicle

*Rebound:*

not applicable

not applicable

*Exit angle:*

0° to guard rail

0° to guard rail

*Vehicle damage:*

small dents and scratches

small dents and scratches

*Vehicle cockpit deformation index VCDI:*

no deformation

no deformation

### P.3. Injury assessment

*Acceleration severity index ASI:*

*(criteria:  $ASI_{max-belted} = 1,0$ ):*

1.41 \*)

1.03 \*)

*Acceleration severity index ASI-SWOV (zie graphs)*

*(criteria:  $ASI_{max-belted} = 1,6$ ;  $ASI_{max-unbelted} = 1,0$ ;)*

2.5 \*)

1.6 \*)

*HIC:*

*(criteria: max = 1000)*

not registered

95

*Maximum shoulder belt load:*

*(a general accepted criteria is max. 5000N)*

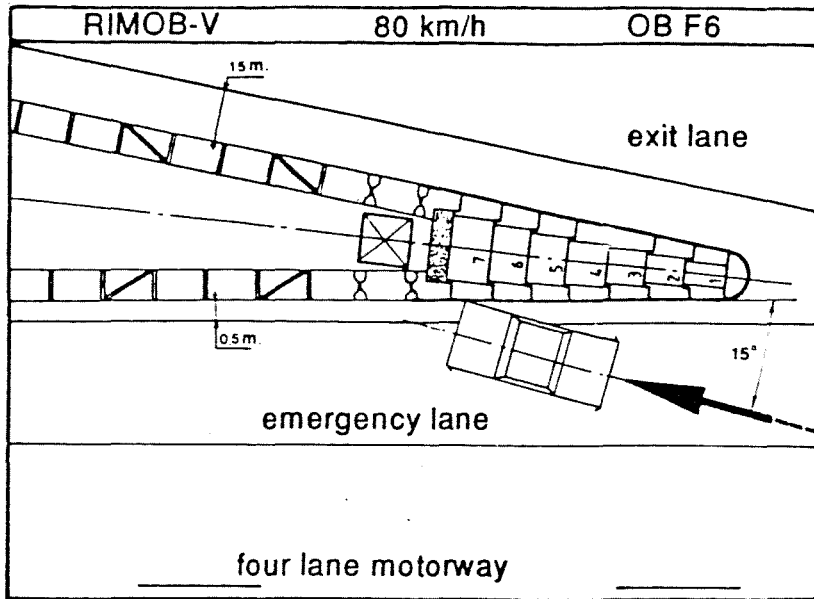
not registered

2000 N

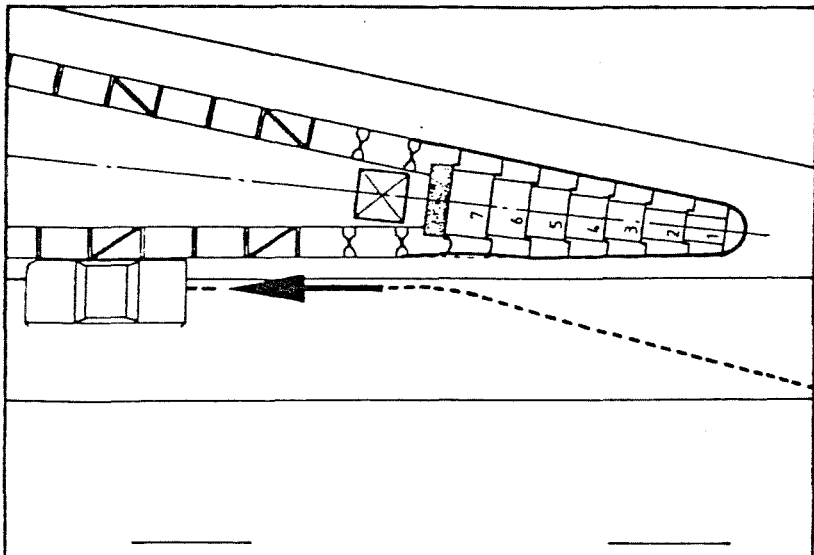
\*) ASI is not fully appropriate for side impact tests. See the results of the instrumented dummy at test F10. The values of the ASI are rather high, while the values of the head acceleration and belt load are low.

# TEST F6

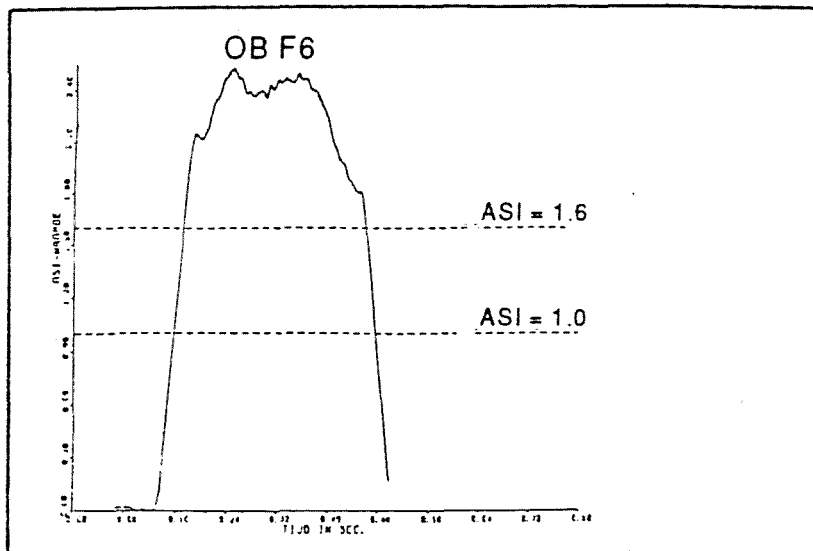
PRE TEST  
(test conditions  
projected on  
motorway situations)



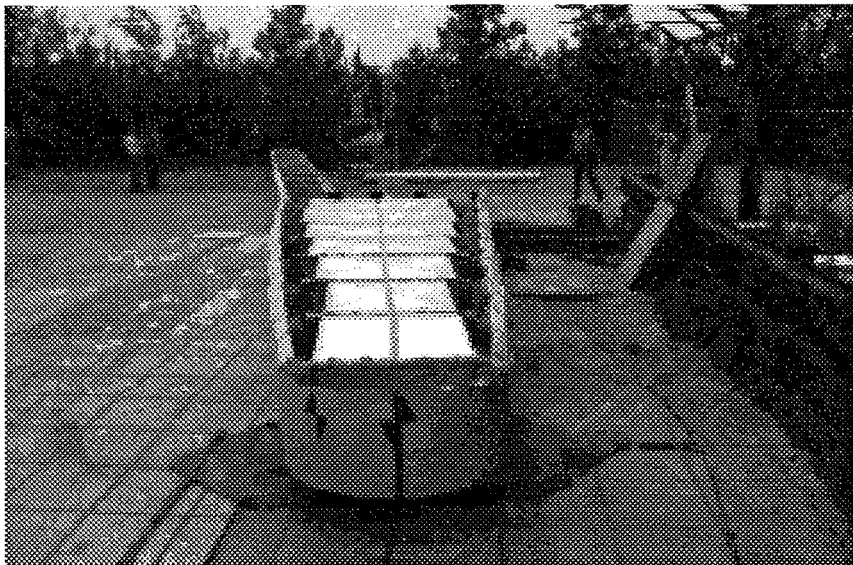
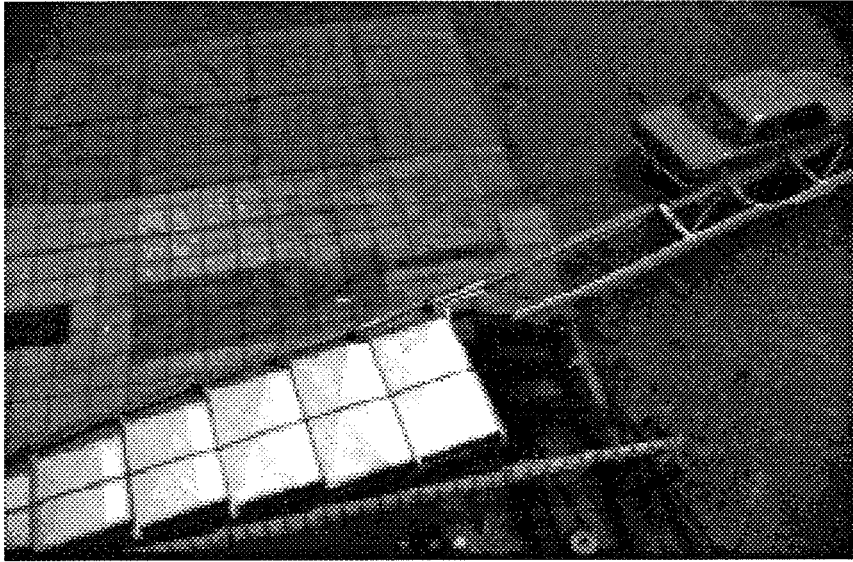
POST TEST  
SITUATION



ASI-SWOV  
(values calculated  
for the time-history)

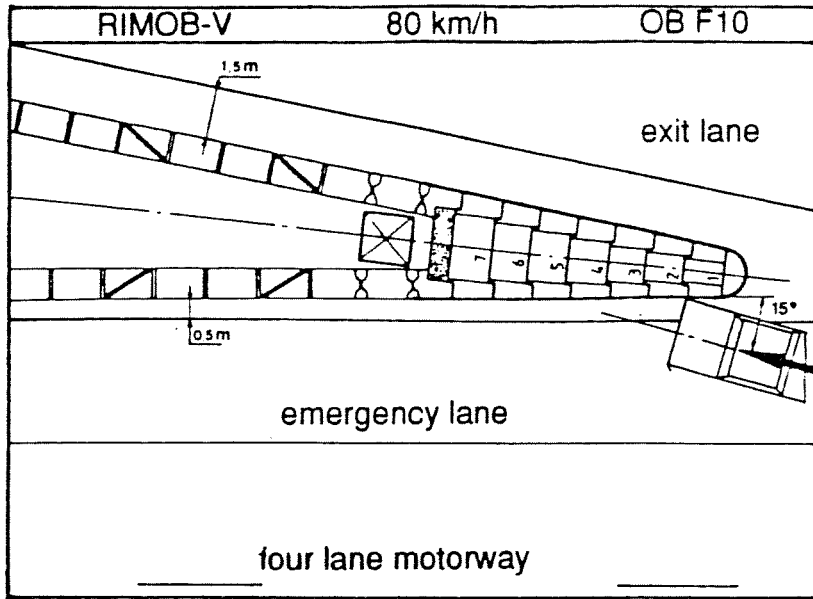


ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$

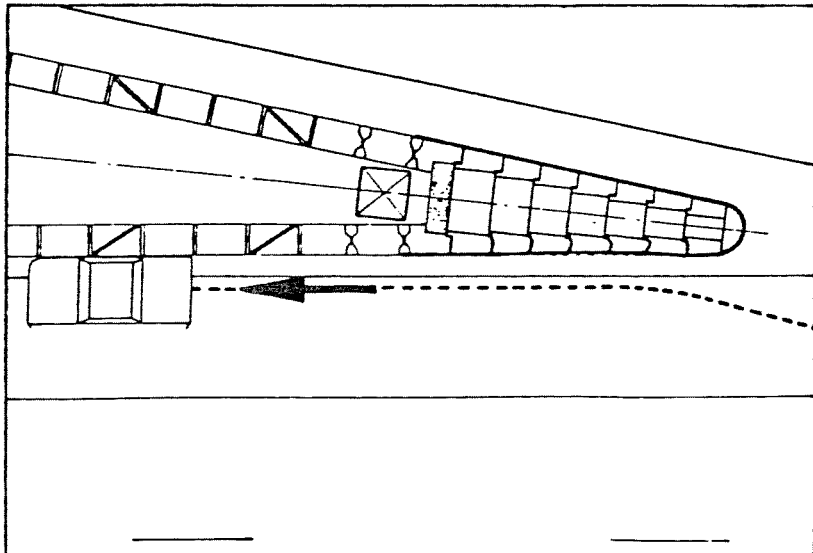


# TEST F10

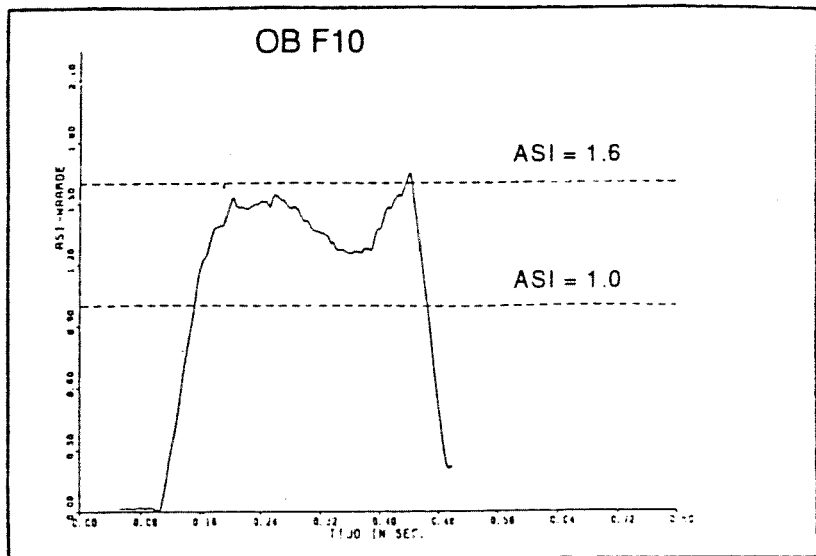
PRE TEST  
(test conditions  
projected on  
motorway situations)



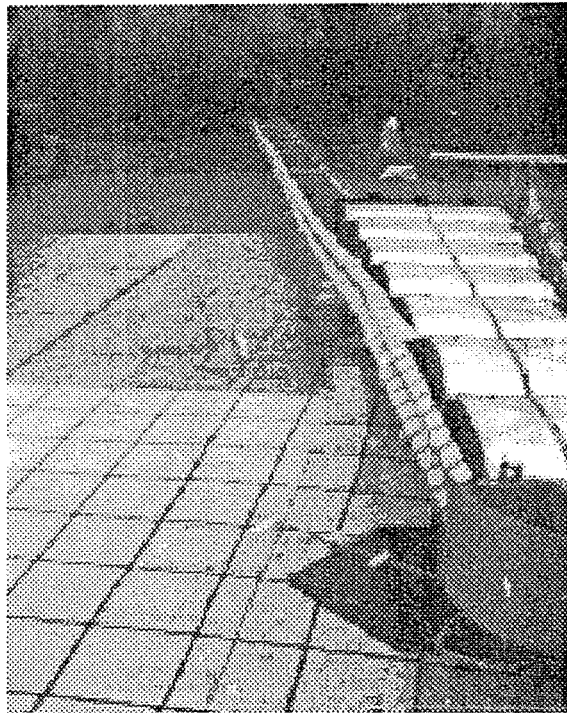
POST TEST  
SITUATION



ASI-SWOV  
(values calculated  
for the time-history)



ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$



## 5.5. RIMOB-P, frontal test

### Q. CEN test specifications TC 1. 1. B.

Not applicable: RIMOB-P is developed for a collision speed up to 70 km/h.

### R. Test performed

One test is carried out: Test-number: F9

Test impact speed: 70 km/h (12.5% difference)

Test impact angle: 0° (0% difference)

Test impact point: center

*Test-number:*

F9

*Car:*

Opel Kadett B

*Model year:*

1973

*Test mass:*

946 kg

*Test date:*

08.26.81



## S. Results TC 1. 1. B.

### S.1. Data of the RIMOB

Test-number:

F9

Damage to RIMOB:

compression: 2.9 m  
dynamic compression: 2,9 m

Maximum permanent deflection (lateral):

0 m

Major parts fractured or detached?:

none

### S.2. Vehicle

Rebound:

0.26 m

Length reduction of hood:

0.21 m

Vehicle cockpit deformation index VCDI:

no deformation

### S.3. Injury assessment

Acceleration severity index ASI:

(criteria:  $ASI_{max-belted} = 1,0$ ):

0.71

Acceleration severity index ASI-SWOV (zie graphs)

(criteria:  $ASI_{max-belted} = 1,6$ ;  $ASI_{max-unbelted} = 1,0$ ;) )

1.2

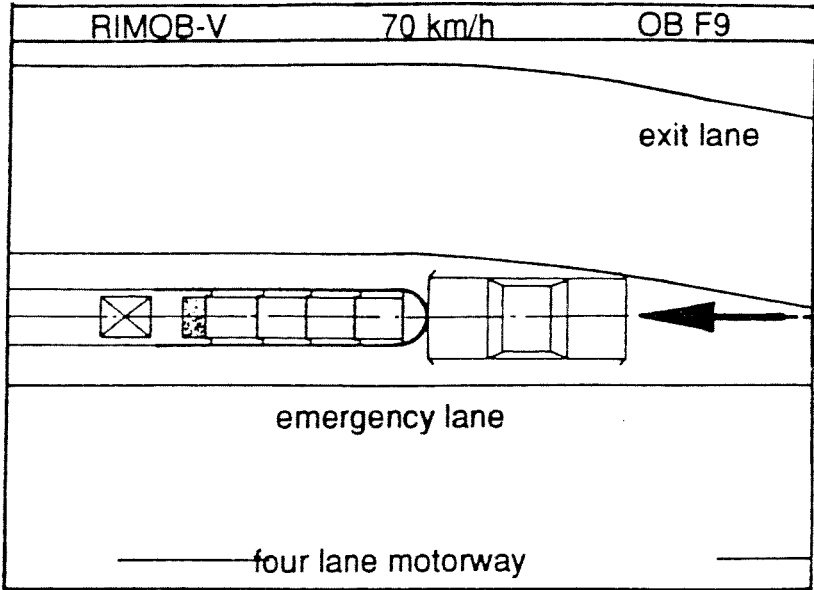
Average acceleration ( $a_{avg.} = v^2 / 2s$ )

( $v =$  impact velocity;  $s =$  dynamic compression distance):

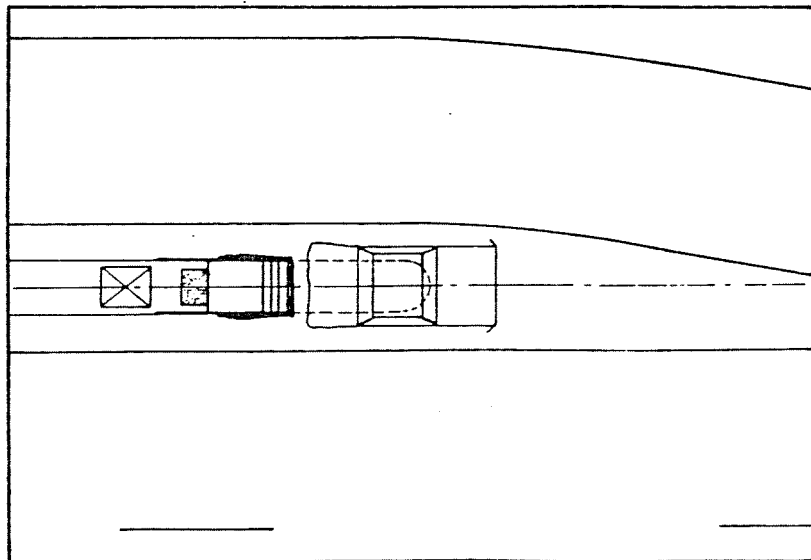
65,2 m/s<sup>2</sup>

# TEST F9

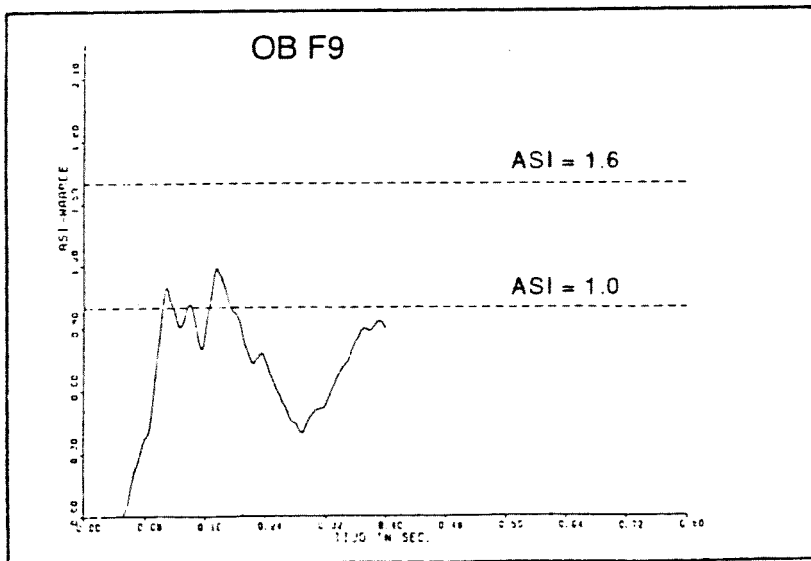
PRE TEST  
(test conditions  
projected on  
motorway situations)



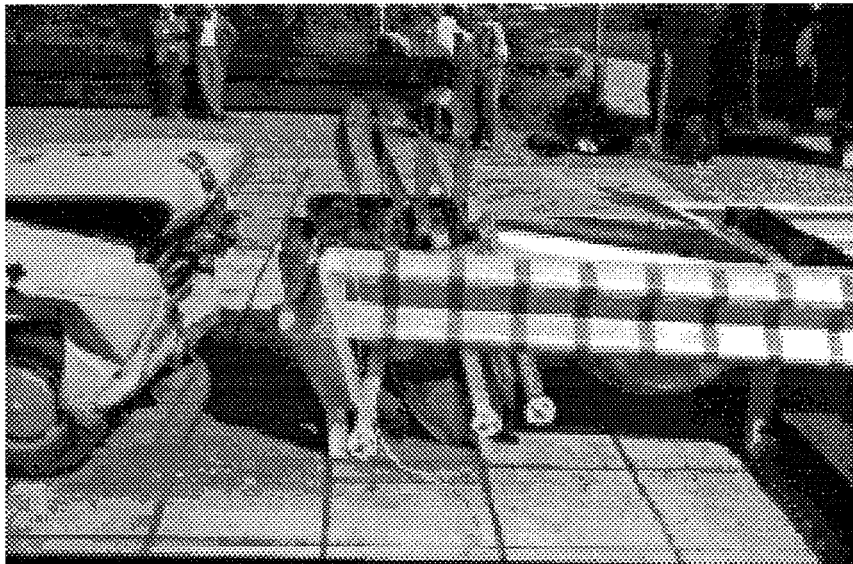
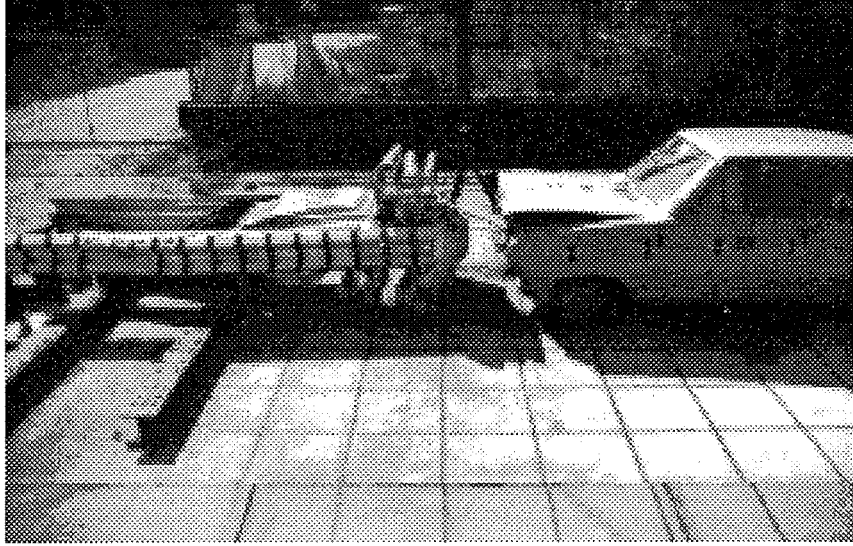
POST TEST  
SITUATION



ASI-SWOV  
(values calculated  
for the time-history)



ASI-SWOV is based on  
limit acceleration:  
 $a_x = 7g$ ;  $a_y = 5g$ ;  $a_z = 6g$



## 6. Final results

### *Crash cushion behaviour*

No elements of the crash cushion penetrate the passenger compartment of the vehicle.  
 No major parts of the crash cushion becomes totally detached.  
 Anchorages and fixings perform to the design specifications.

### *Vehicle behaviour*

The vehicle remains upright during and after the collision

### *Summary of impact test acceptance criteria*

In the next table a summary is given in the way the RIMOB meets the acceptance criteria. It is in accordance with the classes mentioned in the CEN standard.

The classes A (ASI), W1 (redirection) and D1 (deflection) represent an acceptance on the highest level. Classes B (ASI), W2 (redirection) and D2 (deflection) represent a lower level.

Tests	Acceptance Classes		
	ASI	Redirection	Deflection (deformation)
<i>Frontal test</i>			
F7	A	W1	D1
F11	-	W1	D1
F13	-	W1	D1
<i>Offset test</i>			
F8	A	W2	D1
F12	A	W1	D1
<i>15° Frontal test</i>			
F5	A	W1	D1
<i>Side impact 65 km/h</i>			
F4	B*	W1	D1
<i>Side impact 80 km/h</i>			
F6	B*	W1	D1
F10	A/B*	W1	D1
<i>RIMOB-P, frontal test</i>			
F9	A	W1	D1

\*) ASI is not fully appropriate for side impact tests. See the remarks at side impact test F10

Concluded is that the RIMOB meets fully the highest class D. With the exception of the results of one test (F8), the Rimob meets also the highest class W. Concerning the acceptance criteria for the ASI, the RIMOB meets the highest class A for the frontal tests. Concerning the side impact tests a remark is given below the table.

This leads to the final conclusion that the RIMOB V-shape is a safe construction for application as crash cushion on motorways.

## 7. General statements

The test results in this report relates only to the items tested.

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## 8. Approval of report

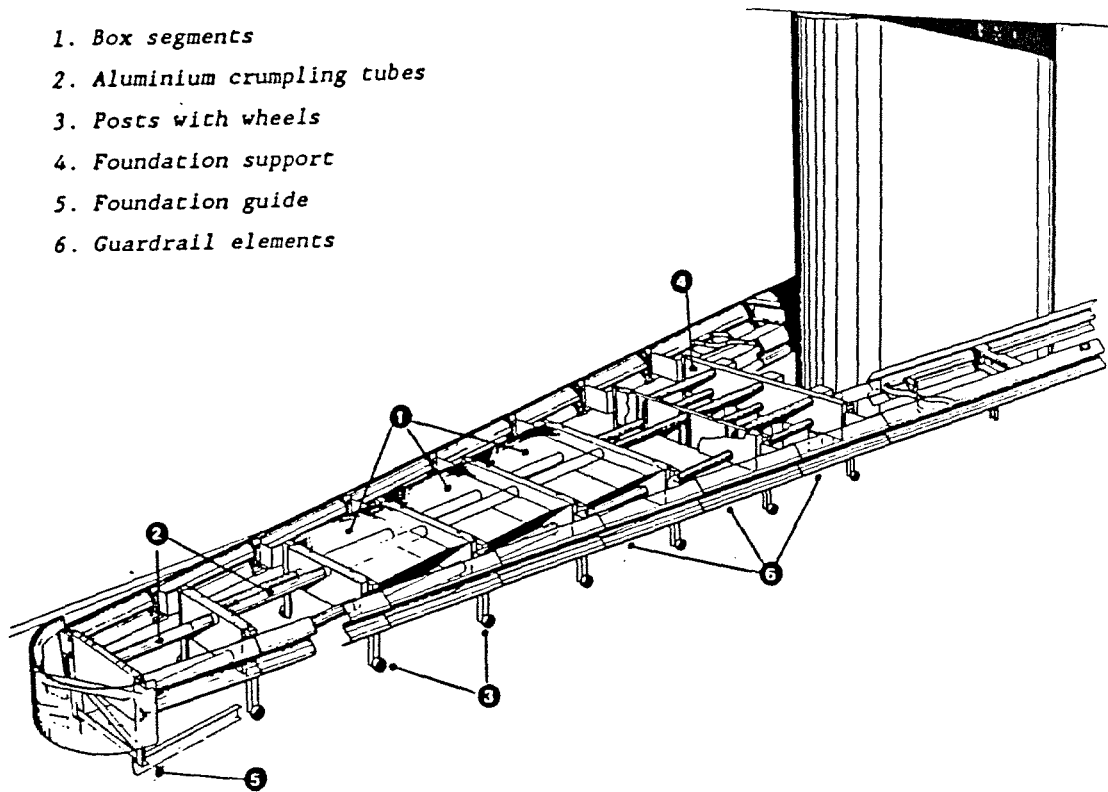
*Date:*

*Signature:*

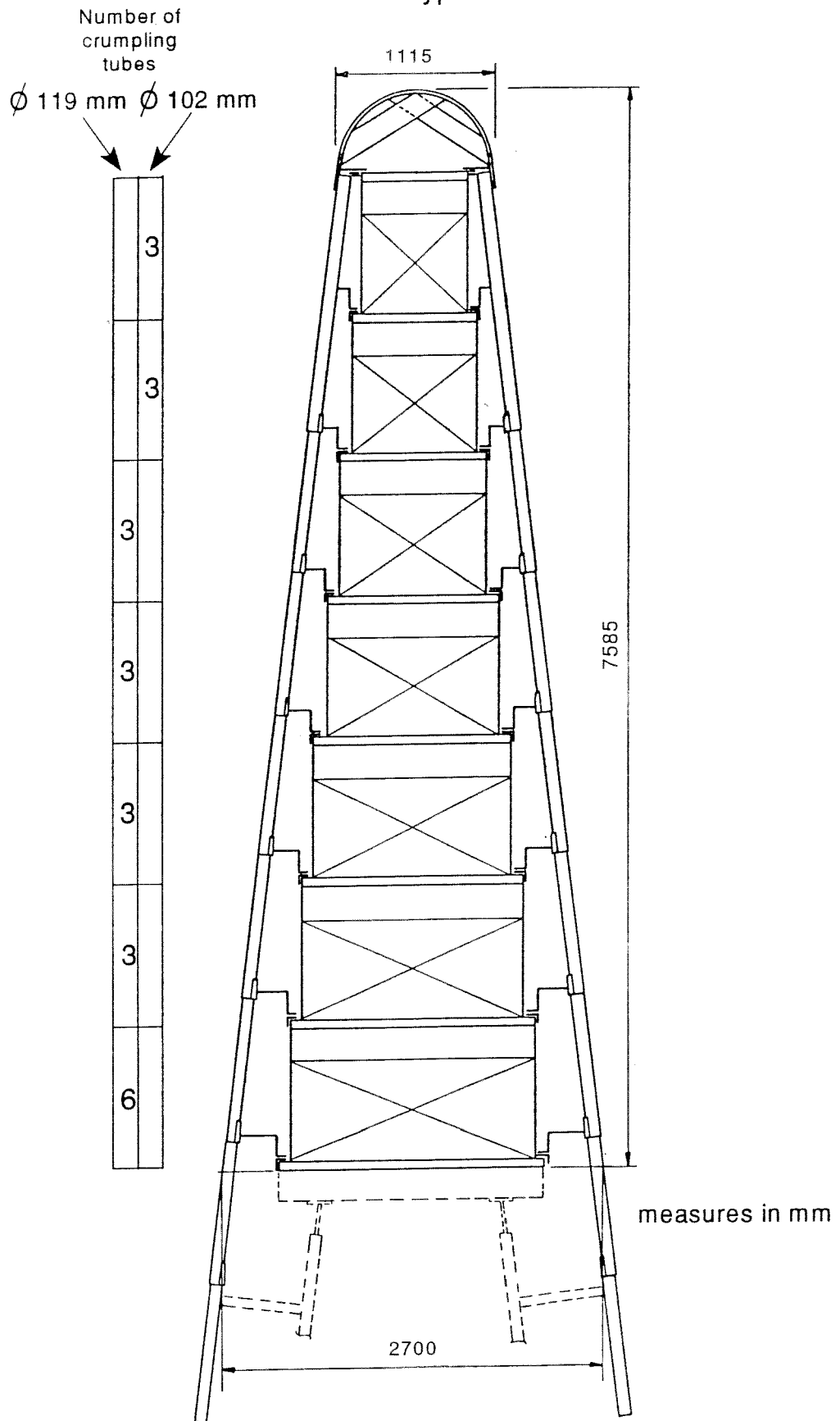
*Title:*

Open-worked drawing of RIMOB

1. Box segments
2. Aluminium crumpling tubes
3. Posts with wheels
4. Foundation support
5. Foundation guide
6. Guardrail elements

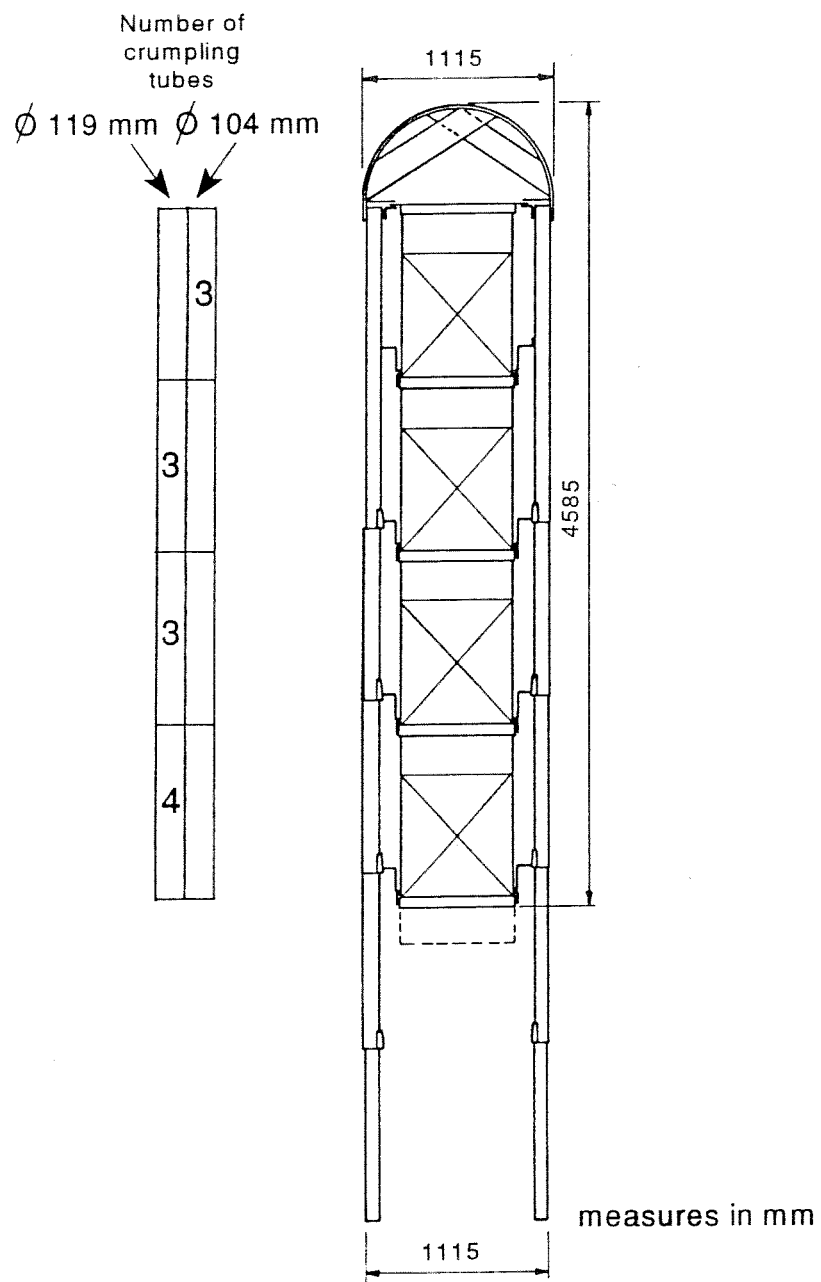


### RIMOB type V-270

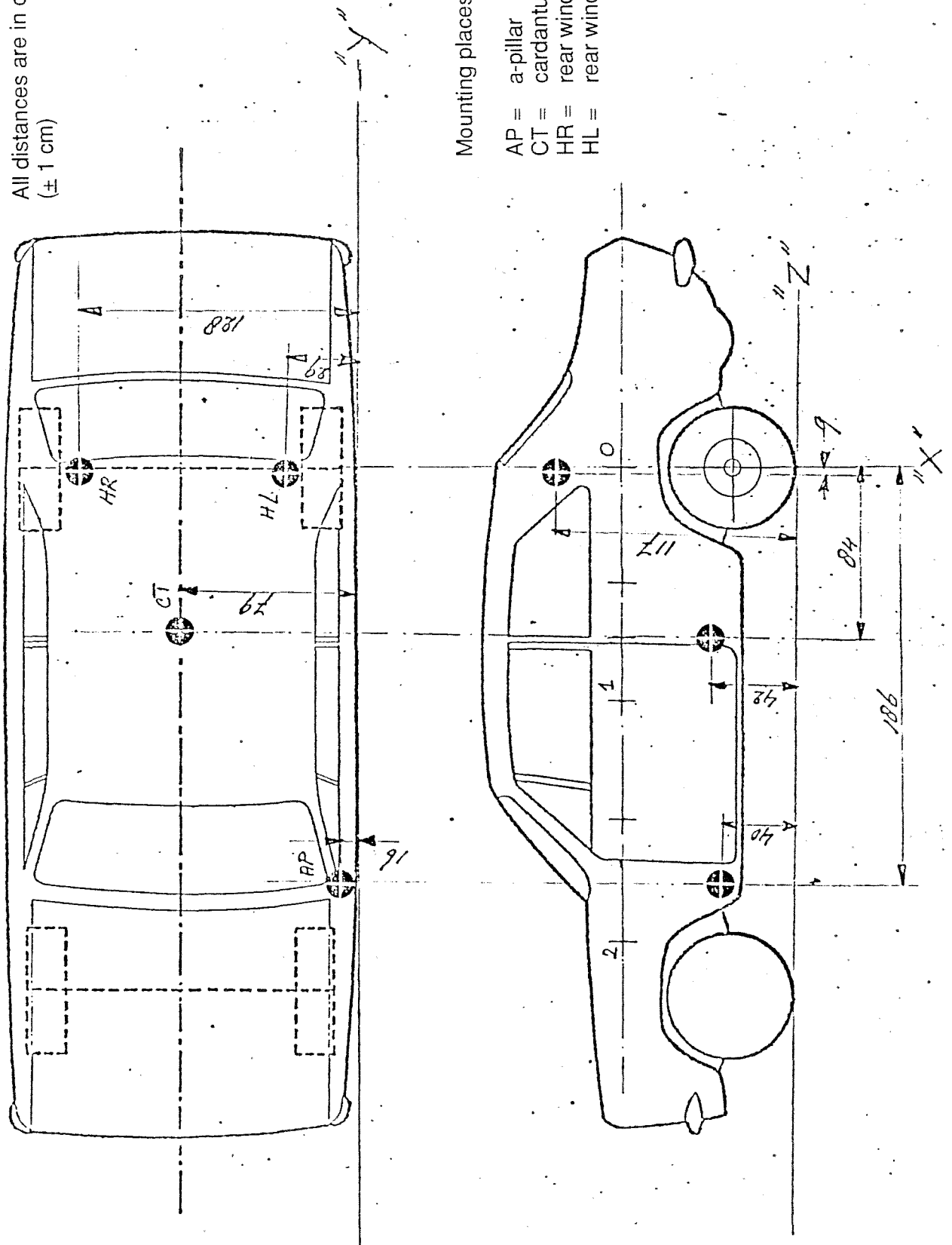




## RIMOB type P



All distances are in cm  
(± 1 cm)



Mounting places:

- AP = a-pillar
- CT = cardantunnel
- HR = rear window right
- HL = rear window left