

sume the body of the considered person to be sitting supported by the back of seat as the movements through **collision A** are ended, as **collision B** starts.

Collision A is a rear-end collision between two cars. The car in which the woman was sitting, is at rest after being stopped because of an accident on the highway. The velocity of the cars was about 140 to 150 km/h as the situation arise and the striking car might have had the same level of velocity as the driver became aware of the situation in front of him and engaged the brakes.

A velocity around 80 - 90 km/h at the moment of striking is mentioned as a probable velocity V_{0a} . The struck car has run a good distance until this car struck the car in front, still at a significant velocity judging the deformations in front.

The weight of these two cars is assumed to be about the same: approx. 1500 Kgs.

Case A: Collision in France the summer 1987



Fig. 1.a

The visible damage of the two cars together with the long distance the Car C has been running and the deformations of the Car B and C in the following frontal collision indicates a very high velocity of the car D as it strikes car C.

Collision A:

Approximate velocity of car A at the moment the impact C-A starts: $V_{0A} = 80$ km/h. $V_{0b} = 0$.
Weight of both cars approx. Equal = 1500 Kgs.
(Packed for holiday).

Calculation done based on the strength on the deformation figures of Car type 2. The deformation lengths corresponds to the pictures of the two cars and the driver of car B's opinion.

Degree of strength about 7, i.m. high. See **Fig. B.20**.

Calculation of probable accelerating loads towards front seat passenger in car B.

Impact between cars:

Change of velocities during impact, $ef = 0,25$.

$V_u = 11,1$ m/sec = 40,0 km/h

$V_{1a} = 8,3$ m/sec = 30,0 km/h

$V_{1b} = 13,9$ m/sec = 50,0 km/h

Total length of deformation A+B at t_u : 0,91 m.

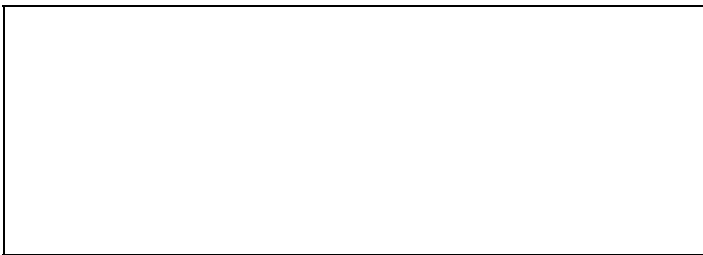
Max. Acceleration:



Fig. 1.b

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The accelerating force between car and body has to act towards the lower part of her back and as horizontal force between the seat and the body due to the friction. See **Fig.1.e**.

Because of the resistance against changes of the mass (The Inertial Law) the upper part of body will rise up as the body is accelerated forward.

Phase B:

The passenger hits the upper part of the front screen with her head and the screen is broken. Probably will the safety belt cause a reduction of the forward velocity of the body dampening the impact towards the screen. The laminated screen got a deformation where struck by head.

The screen could have been broken in the proceeding frontal collision. But, as the hitting point of the screen is posi-

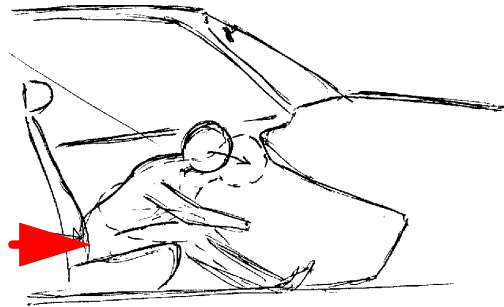


Fig. 1.e
FIG. CASE A.4

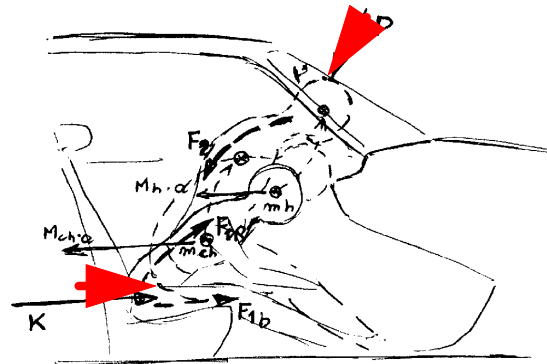


Fig. 1.F

tioned at the upper edge of the screen I find good relations between the movement of upper part of body and the forward acceleration during collision A. I will claim the breaking of the screen probably to be a result of collision A.

The car was struck slightly out of centre to the right side, giving relative movements towards right. I find the head to hit the screen slightly bent down with the face slightly turned to the right. This gives an increase of the affecting stretching loads at the left side of neck. The heeling of screen causes a force towards head giving a forward deflection of head giving additional stretching loads onto neck.

The bending of the neck region as the head is pressed down by direct affecting forces as it hits the screen cause a displacement of the head giving stretching and compression loads onto the neck region. I will not define this affection as a «Whiplash-mechanism».

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Specific deformation of seat: 0,025 m at 5 g. Coefficient of elasticity e_f estimated = 0,9.

A specific deflection of 0,01 m at 5 g corresponds to measurements carried out on seats in a Saab 9000 and of seat of the type Recaro. A specific deformation of 0,025 is significant softer. Because of the way the person was seated affecting the lower parts of the seat back, any structural deflection of seat during Phase A would be minor.

Phase A:

The body is affected by a horizontal friction force giving the body an initial velocity prior to the impact. Coefficient of friction μ , is assumed to be approx. 1,0.

Calculated acceleration values at specific velocities of B:

Distance run: 0,01 m

$V_{0b} = 1,67 \text{ m/sec} = 6,0 \text{ km/h}$ $V_{0c} = 0,27 \text{ m/sec} = 1,0 \text{ km/h}$ $a_c = 9,7 \text{ g}$

$V_{1b} = 1,60 \text{ m/sec} = 5,8 \text{ km/h}$ $V_{1c} = 2,19 \text{ m/sec} = 7,9 \text{ km/h}$

Distance run: 0,05 m

$V_{0b} = 3,79 \text{ m/sec} = 13,6 \text{ km/h}$ $V_{0c} = 0,41 \text{ m/sec} = 1,5 \text{ km/h}$ $a_c = 14,9 \text{ g}$

$V_{1b} = 3,51 \text{ m/sec} = 12,6 \text{ km/h}$ $V_{1c} = 6,79 \text{ m/sec} = 24,4 \text{ km/h}$

The effect of an increasing velocity of B:

Taking the effect of an increasing velocity of car during impact in account assuming the mean values of an impact between the car and the body that lasts as long as the car has run 0,6 m, i.m. until the V_u has been reached in the impact between the cars, these values of impact car and body gives:

$V_{0b} = 7,26 \text{ m/sec} = 26,1 \text{ km/h}$ $V_{0c} = 0,53 \text{ m/sec} = 1,9 \text{ km/h}$ $a_c = 29,7 \text{ g}$

$V_{1b} = 6,7 \text{ m/sec} = 24,1 \text{ km/h}$ $V_{1c} = 13,1 \text{ m/sec} = 47,2 \text{ km/h}$

Adding the difference in velocities of car and person on the top of maximum velocity of the car gives a velocity of body after impact B-C of:

approx. $20,29 \text{ m/sec} = 73 \text{ km/h}$.

Phase B:

Impact between body and the front screen of car.

Velocity of body = $20,0 \text{ m/sec}$ Velocity of car = $13,9 \text{ m/sec}$

The coefficient of elasticity is assumed to be low as the laminated screen become broken. e_f approx. 0,15.

Change of velocities during phase B:

$V_{0c} = 20 \text{ m/sec}$ $V_{0b} = 13,9 \text{ m/sec}$

$V_u = 14,2 \text{ m/sec}$ $V_{1b} = 14,2 \text{ m/sec}$ $V_{1c} = 13,3 \text{ m/sec}$

Assuming a total length of deformation, i.m. the deformation of screen + the deflection of head, of approximately 10 cm, the maximum acting force towards head is 23,2 kN giving a maximum acceleration of head:

$a_c = 36,3 \text{ g}$

Phase C:

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ity of car A has been estimated to approximately 104 km/h. (Stated in the prosecution against the driver of car A.)

Type of cars:

Car A: Ford Granada Sedan. Calculated as car type 2.

Persons seated: 4 youngsters. Estimated weight about 1350 kgs.

Car B: Toyota Starlet. Calculated as car type 1.

Persons seated: 4 adults. Car packed for holiday. Estimated weight about 1200 kgs.

Damage towards cars:

Source: Pictures of that particular accident in newspapers.

Car A: See deformation of car A in case 1.

Car B: Totally destroyed to the rear edge of front door. Car was thrown about 40 m ahead.

Strength of collision according to Fig. B.20: Very high, degree of strength: 10

Calculated results of impact:

Change of velocity during the impact. $ef = 0,15$

$V_u = 15,00 \text{ m/sec} = 54 \text{ km/h}$

$V_{1a} = 12,92 \text{ m/sec} = 46,5 \text{ km/h}$

$V_{1b} = 17,25 \text{ m/sec} = 62,1 \text{ km/h}$

Distance s car A: $t_0 - t_1 = 1,905 \text{ m}$ Total distance sa: 2,087 m

Time the impact A-B lasts: $T_0 - T_1: 0,087 \text{ secs}$ Total time: 0,1 secs.

Effects of engaged brakes on car A during impact calculated as the mean value of V_{0a} with and without brakes as the V_{0a} :

Mean $V_{0a} = 28,68 \text{ m/sec} = 103,2 \text{ km/h}$

$V_u = 14,77 \text{ m/sec} = 53,2 \text{ km/h}$

$V_{1a} = 12,72 \text{ m/sec} = 45,8 \text{ km/h}$

$V_{1b} = 16,99 \text{ m/sec} = 61,2 \text{ km/h}$

Total distance sa = 2,06 m

Total time impact A-B: 0,099 secs

Deformation and acceleration values of cars:

Deformation length car A: -0,55 m

Deformation length car B: -0,76 m Total length of deformation = 1,31 m

Maximum acceleration car B: 26,4 g.

Acceleration of persons seated in front seats car B:

Calculated at specific velocity of B at $0,01 \text{ m} < \delta s < 0,1 \text{ m}$

Distance run $\delta s = 0,01 \text{ m}$ (see x on the figure below)

$V_{0b} = 1,44 \text{ m/sec} = 5,2 \text{ km/h}$ $ac = 6,4 \text{ g}$

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car it gives a velocity of body after impact B-C of:

approx. 22,65 m/sec = 81,5 km/h.

Consequences of injuries towards the persons in car B:

The rear seat passengers: Died immediately.

Front seat passengers: Died after some minutes.

Ref.: Dr.med. Ingard Lerheim, The Region Hospital of Trondheim. Seminar about Neck distortions, University of Bergen, May 1991.

All four died as a result of the «Whiplash-mechanism». No other of the injuries of the persons in the rear seats could have given such a result.

The persons in front seat were not exposed to direct violence causing other type of injuries.

Case 3: Chain collision near Bergen 1987.

The driver of car B had stopped behind a large delivery van because of a car crossing the main road. Still standing car B was struck by a large van. No signs of using brakes prior to the impact. The velocity of acting car A is assumed to be 60 km/h im. the maximum allowed speed. The persons in car B, the driver and his wife in the frontal seats were completely unaware of what to come.

As a result of impact the back of the drivers seat were broken and fell down.

Car B is accelerated forward and is in the next moment striking the delivery van C in front from behind. The distance between cars was so close that these to incidents has to be considered as one with a strengthening of loads affecting the passenger.

Driver watched the traffic on left side as the impact A-B starts.

Type of cars:

Car A: A Volkswagen Transporter of type LT. Assumed weight 3500 Kgs. Considered as Car type 3, slightly strengthened.

Car B: A Saab 900 Sedan. Assumed weight 1250 Kgs. Considered as Car type 2, strength slightly reduced.

Car C: Delivery van, considered as Car type 4. Assumed weight 6000 Kgs

Specific deflection of seats calculated as 0,01 m at 5 g.

Collision A:

Strength of collision given by Fig. B.20: High, degree ab. 7,5

Change of velocities during impact:

Coefficient of elasticity estimated: $e_f = 0,25$

$V_u = 12,28 \text{ m/sec} = 44,2 \text{ km/h}$

$V_{1a} = 11,18 \text{ m/sec} = 40,3 \text{ km/h}$

$V_{1b} = 15,35 \text{ m/sec} = 55,3 \text{ km/h}$

Distance run car A during impact:

sa $T_0 - T_u = 1,20 \text{ m}$ sa $T_u - T_1 = 0,24 \text{ m}$ Total distance sa = 1,45 m

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The effect of an increasing velocity of car B:

Taking the effect of an increasing velocity of car during impact in account assuming the mean values of an impact between the car and the body that lasts as long as the car has run 0,51 m, i.m. until the V_u has been reached in the impact between the cars, these values of impact car and body gives:

$$V_{0b} = 5,80 \text{ m/sec} = 20,9 \text{ km/h} \quad a_c = 40,85 \text{ g} \quad *)$$

$$V_{1b} = 5,50 \text{ m/sec} = 19,8 \text{ km/h} \quad V_{1c} = 10,73 \text{ m/sec} = 38,6 \text{ km/h}$$

*) *If calculated with a specific deflection of seat = 0,025m: $a_c \text{ max} = 25,8 \text{ g}$*

Adding the difference in velocities of car and person on the top of maximum velocity of car it gives a velocity of body after impact B-C of:

$$\text{approx. } 20,57 \text{ m/sec} = 74,1 \text{ km/h.}$$

Collision B:

A chain, frontal collision towards car C. The «Whiplash-mechanism» due to collision A is to be considered as not ended.

Velocity of passenger about 75 km/h as the impact starts. The velocity of head is probably significant higher.

Car C was about to proceed as the impact takes place. It means there might be a slow forward movement of car C reducing the loads acting towards car B. The forward velocity of C estimated to 5 km/h.

Calculated results of impact B:

The curve of deformation considered as approximately constant. Parts of car C cuts it's way into car B. $e_f = 0,15$

$$V_{0b} = 15,35 \text{ m/sec} = 55,3 \text{ km/h}$$

$$V_{0c} = 1,38 \text{ m/sec} = 5 \text{ km/h}$$

$$V_{1b} = 2,06 \text{ m/sec} = 7,4 \text{ km/h}$$

$$V_{1c} = 4,15 \text{ m/sec} = 14,9 \text{ km/h}$$

An estimated total length of deformation of approx. 0,7 m gives a constant acceleration of car B at 11,7 g.

Mechanical damage to car B:

Collision A:

The safety zone knuckled down and given deformation making it difficult to open the front door on the left side.

Seats torn loose from fastenings. Drivers back of seat broken by the hinges. Severe damage to the rear end and the roof structures.

Collision B:

Makes deformation making damage onto the frontal parts of the engine of car B as well as deformation to cargo lift on car C at the car B is pressed underneath.

Consequences of injuries towards the persons in car B:

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Comments regarding the velocity of car A, V0a.

A velocity of that height is difficult to judge and the speed measuring devices in the car will hardly be able to show velocities below 15 to 20 km/h with any accuracy. I have done calculations of the impact using different velocities of car A ranging from 5 to 20 km/h and analysed the loads towards a person in car B at a velocity V0a at 10 km/h. Probably the velocity of car A is more than 10 km/h.

Deformation values of the cars are from the Burg Databank. Curve of deformation: linear.

Ref. report made by ing. Torstein Haug dated November 14 th. 1995.

Calculated results of the impact A-B, V0a = 10 km/h.

Maximum accelerating force: 30,0 kN. Max. acceleration of A: $-30,98 \text{ m/sec}^2 = -3,15 \text{ g}$
Max. acceleration of A: $24,48 \text{ m/sec}^2 = 2,49 \text{ g}$

Coefficient of elasticity estimated as 0,25.

Depth of deformation at tu of the cars: Car A: 0,09 m. Car B: 0,05 m

Change of velocity during the collision: Vu = 4,4 km/h. V1a = 3,0 km/h V1b = 5,5 km/h

The distance car A has moved: T0-Tu = 0,20 m Total distance = 0,23 m

The distance car B has moved: T0-Tu = 0,06 m Total distance approx. 0,09 m

The time the impact lasts: T0-Tu = 0,100 secs. Total time: 0,125 secs.

Calculated results of the acceleration of a body C inside car B:

Mass of body C: 35 kgs. Estimated mass of the upper part of a body at 60 kgs.

The person considered is of a higher mass, but compared to the mass of the car a change in the mass of the accelerated body will give only a minor influence on the loads affecting the body.

The coefficient of elasticity between the seat and the body estimated to 0,98.

The acceleration of the body takes place when the car has moved between 0,01 and 0,15 m.

Acceleration of the body:

Deflection of the seat dl = 0,01m at 5 g:

At $\delta s = 0,01 \text{ m}$: V0b = 0,55 m/sec Vu = 0,54 m/sec V1c = 1,07 m/sec ac max = 3,9 g

At $\delta s = 0,15 \text{ m}$: V0b = 1,53 m/sec Vu = 1,49 m/sec V1c = 2,95 m/sec ac max = 10,8 g

Deflection of the seat dl = 0,025m at 5 g:

At $\delta s = 0,01 \text{ m}$: V0b = 0,55 m/sec Vu = 0,54 m/sec V1c = 1,07 m/sec ac max = 2,5 g

At $\delta s = 0,15 \text{ m}$: V0b = 1,53 m/sec Vu = 1,49 m/sec V1c = 2,95 m/sec ac max = 6,8 g

The calculations give a probable acceleration of the person between 3 and 7 g at a velocity of the striking car at 10 km/h, even with a pretty soft seat structure and a mass ratio ma/mb between the cars at 0,8.

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