COMPLETE ANALYSIS OF A TYPICAL CASE OF AN HEAD-ON AND OFFSET COLLISION RECONSTRUCTED WITH DUMMIES AND FRESH CADAVERS (x).

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ABSTRACT

This survey describes results and information obtained from the reconstructions of an actual accident which occured between a Renault 12 and a Chrysler 180, using dummies and, then, fresh unembalmed cadavers. All the experimental conditions and results obtained with regard to vehicles and to their occupants are given in detail, as a first stage. The problem due to the faithfulness of the reconstruction and the data gained on tolerance of impact of the human body are approached, as a second stage.

The quality of information given by an accident reconstruction greatly depends on good selection of the actual accident. This impact between an R.12 and a Chrysler 180 has a number of interesting aspects. Its offset frontal-frontal configuration is representative of many accidents which occur on the highway. Its violence places it among the most severe of actual accidents occuring on the roads as may be seen from Fig. 1 extracted from a previously published paper (1). Finally, the front passengers of the R.12 suffered noticeable injuries though they were wearing their 3-point belts correctly. The conditions were therefore present to give results which would logically be interesting with regard to human tolerance, in reconstructing the accident. Two reconstructions were therefore carried out under the true conditions of impact as defined by the IRO/Peugeot-Renault multi-disciplinary accident investigation team.

EXPERIMENTATION

Conditions of impact:

a) Actual accident - The Chrysler crossed the central part of the road and struck the Renault 12 which was coming in the opposite direction (Fig. 2). The approach speed was estimated at 100 kmh.

b) Reconstruction - This is a frontal-frontal collision offset by 300 mm on the side of the drivers. Both vehicles were travelling at 50 kmh at the moment of impact.

(x) This research was performed with the collaboration of Anatomy Laboratory of the Biomedical Research and Teaching Department (U.E.R.) of René Descartes University, Paris (Pr. DELMAS).

(1) Numbers in parentheses designate References at end of paper.

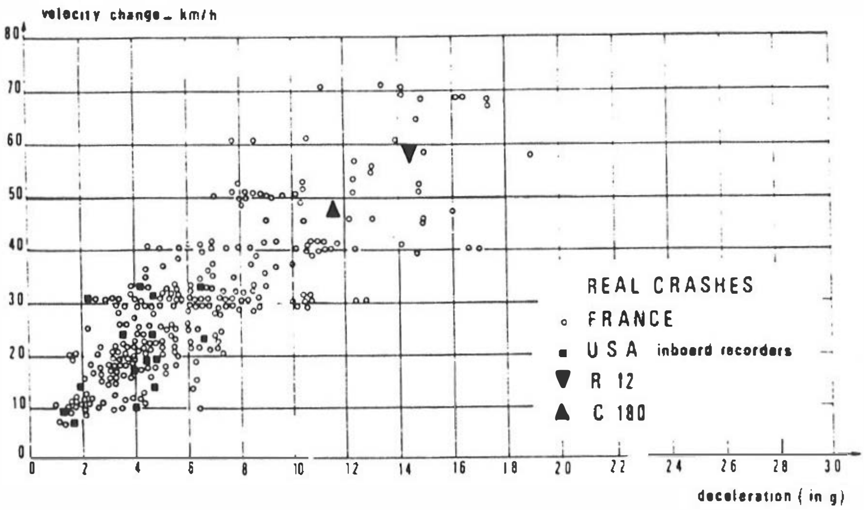


Figure 1 - Violence distribution in real frontal accidents for France.

Occupants:

The details of injuries which occured to the actual victims of the accident are given in Tables 3 to 5.

a) Renault 12 - Four occupants. The two front occupants were correctly belted whereas the rear passengers were not belted.

b) Chrysler 180 - The driver was alone in the car and was wearing the original seat belt loosely.

Measurements.

All the occupants were simulated by dummies firstly, and then by cadavers to re-create the actual conditions of impact but the rear R.12 ones were not fitted with instruments.

Accelerometers were fitted to the head, the chest and the pelvis of the dummies and cadavers. The cadavers were prepared in the same way as has been described in previous publications (2)(3). Load transducers give us information on the retention forces in the belt.

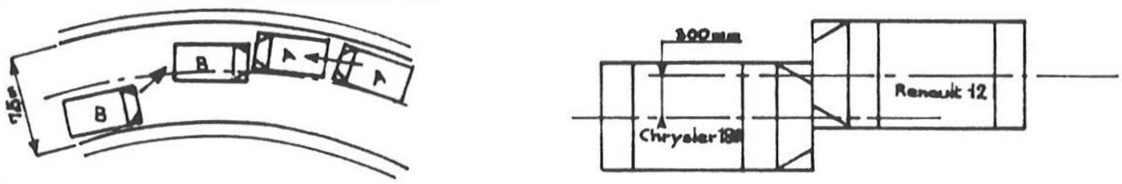
Table 1 gives anthropometric data for cadavers and real victims.

ANALYSIS OF RESULTS

Vehicles

A good equivalence may be seen as regards car deformations in the three collisions. The photographs (Fig. 3) enable to judge the accuracy of the reconstructions. Mean acceleration γ and speed variation ΔV, estimated for each car from permanent deformations (1) are very similar in the three accidents

A: Renault 12



B: Chrysler 180

Figure 2 - Sketch-plan of real accident and reconstructions.

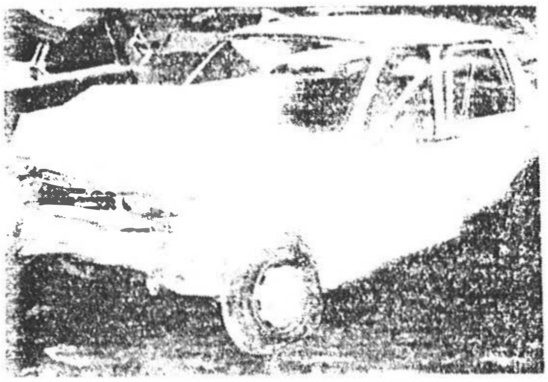
SUBJECT / parameters	RENAULT 12						CHRYSLER 180		
	DRIVER			RIGHT front passenger			DRIVER		
	real crash	hybrid II	cadaver	real crash	hybrid II	cadaver	real crash	VIP 50	cadaver
Sex/Age	M 21	M	M 29	M 25	M	M 53	M 65	M	F 69
Height	166		166	173		173	170		163
Weight	66	74,3	66	76	74,3	68	88	74,3	75
U (SAE J 963)	83	91	93	89	91	94		91	85,5
I+J (SAE J 963)	61	60	70	63	60	68		60	64
P Thigh (SAE J 963)		59,2	54,5		59,2	54		59,2	55
Thorax thickness		23	24,5		23	21		23	19
Thorax wideness		28	29		28	29		28	27
Thorax perimeter	84	96	90,5	88	96	98,5		96	88,8

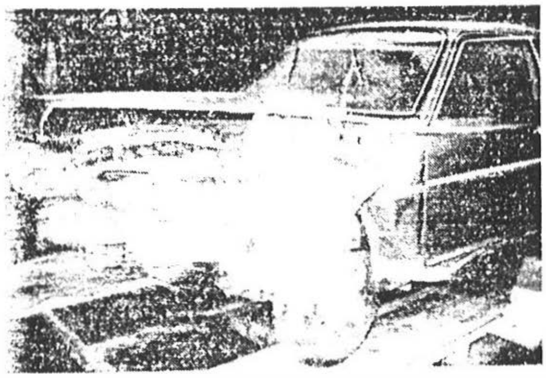
Table 1 - Selected anthropometric data.

Parameters	RENAULT 12			CHRYSLER180		
	Real	Dummies	Cadavers	Real	Dummies	Cadavers
SPEED Km/h	—	50,4	48,2	—	50,4	48,2
WEIGHT Kg	1184	1197	1180	1185	1180	1180
ΔV Km/h	57	54	53	47	46	44
γ mean g	14	13	13	12	11	11

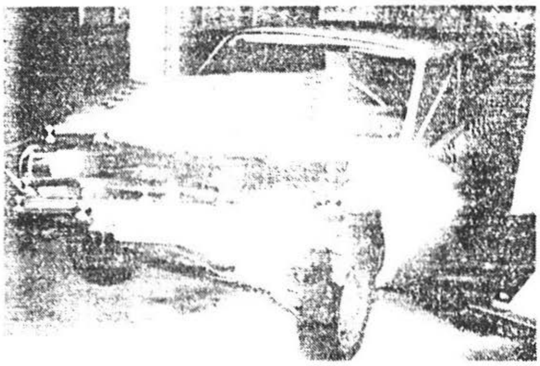
Table 2 - Severity of the impacts for the occupants

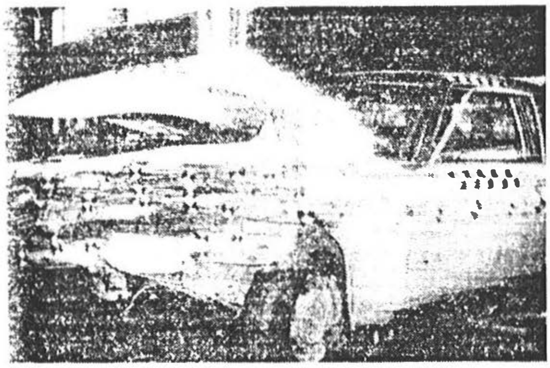
Renault 12 | Chrysler 180



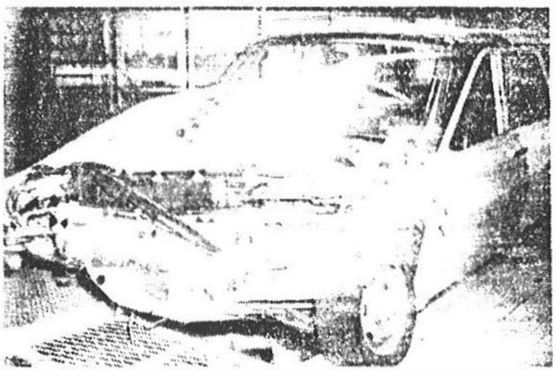


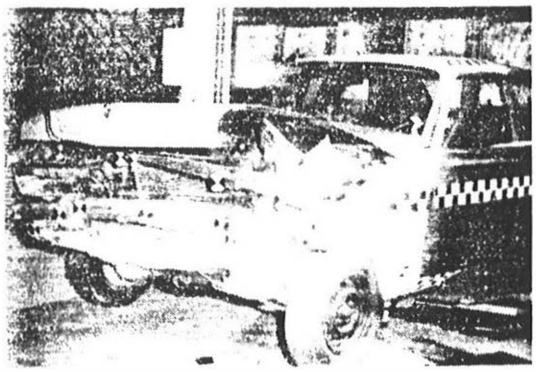
real accident





reconstruction with dummies





reconstruction with cadavers

Figure 3 - Deformations of Vehicles

(Table 2). Moreover, all the R.12 belted occupants broke the 5 strands of their belt force limiting device. One may therefore feel justified in comparing the results obtained with regard to occupants in each test.

Occupants.

We are interested in the injuries which are recorded on the victims and on the cadavers and in clarification of their probable cause. Besides, we have measurements available taken from the dummy and from the cadaver.

a) Driver of the Chrysler 180 (Table 3).

Head/Neck - The wide difference between the figures measured on the cadaver and on the dummy may be due to differences of cinematics. The impact occured on the face in the case of the dummy and the living occupant. In the case of the cadaver, the neck was impacted first; because the head rotated backwards during the launching travel before the impact, due to the flexibility of the neck.

The head then swung rapidly over the steering wheel rim. The sensor on the back of the head, which was located far from the centre of rotation, therefore measured an acceleration greater than at the centre of gravity. The severe injuries of the neck noted on the cadaver were caused by the impact against the steering wheel and to the important rotation of the head over its rim.

Thorax - The impact on the thorax seems to have been different for the three occupants. From examination of deformations of the steering wheel, the living driver seems to have incurred the most violent impact. Anthropometric differences between the three occupants and doubtful reproduction of belt slack explains this varied behaviour.

b) Driver of R.12 (Table 4).

Head/Neck - The impact of the chin on one of the spokes of the steering wheel noted during the accident could not be reproduced because the steering wheel of R.12 cars available for the reconstructions had branches of design different to those fitted to the car involved in the accident.

Two distinct peaks were noted on the acceleration graphs of the head of the cadaver and of the dummy. The first corresponds to the impact on the steering wheel and the second to the impact by the head of the rear passenger. The second impact is markedly more violent and must be the reason for the cause of loss of consciousness of the actual driver who was subjected to the same type of impact.

With regard to impacts of head against head, it may be noted that HIC measured on the dummy is greater than that measured on the cadaver. During tests of direct impact of the head on a rigid surface, using cadavers and dummies, it has already be noted that the severity indices calculated for the dummy are greater than those found on the cadaver. This might be explained by the flexibility of the human skull which is more important than those of the dummy. Cerebral injection did not succeed for this cadaver. The injuries noted on the neck of the cadaver have been caused by the impact against the steering wheel. Furthermore, calculations of linear acceleration at the centre of gravity of the head were not carried out for the direct impact of the head of the rear passenger on one of the accelerometers disturbed the measurements.

Table 3 - Results for Chrysler Driver.

	Real Victim	Cadaver	Dummy
Head/Neck			
SI/HIC........	-	8835/5835 (occiput)	1333/1145
γ max./γ3 ms g	-	281/250	90/85
Injuries	(x) nose AIS 1	(x) C1-C2 AIS 5 section of the medulla	-
Impacts	Steering wheel	steering wheel	steering wheel
Thorax			
SI	-	662	810
γ max./γ3 ms g	-	75/75	67/63
Injuries	Flail chest AIS 4	(x) 13 ribs AIS 3	-
Impacts	Steering wheel	Steering wheel	steering wheel
Pelvis			
SI	-	135	426
γ max./γ3 ms g	-	51/51	63/59
Injuries	(x) left cotyle AIS 3	No injury	-
Impacts	no	no	no
Legs			
Femur force (daN) - left .	-	-	460
- right	-	-	180
Injuries	Bruises of knees AIS 1	Bruises of knees AIS 1	-
Impacts	under dashboard	under dashboard	under dashboard

Note: (x) for fracture.

Table 4 - Results for R.12 Driver.

	Real Victim	Cadaver	Dummy
Head/Neck			
SI/HIC........	-	3526/1995 (occiput)	3383/2300
γ max./γ 3 ms g	-	216/140	377/75
Injuries	Unconsciousness 2Hrs (AIS 2)	(x) posterior arc of C 2 (AIS 3)	-
Impacts	Chin and neck on steering wheel, head of rear passenger.	Steering wheel, head of rear passenger.	Steering wheel, head of rear passenger.
Thorax			
SI	-	3441	386
γ max./γ 3 ms g	-	242/145	49/49
Shoulder load (daN)	-	860	-
Load on thorax (daN)	-	1140	-
Injuries	(x) left clavicle AIS2	(x) 9 ribs - AIS 3	-
Impacts	no	no	no
Pelvis			
SI	-	436	167
γ max./γ 3 ms g	-	65/52	55/45
Injuries	Erosions of iliac crests (AIS 1)	no	-
Impacts	no	no	no
Legs			
Femur force (daN) - Left:	-	-	320
Right:	-	-	540
Injuries	Cuts on knees AIS 1	no	-
Impacts	Under dashboard	Under dashboard	Under dashboard

Note: (x) for fracture.

Thorax - It is difficult to make use of the acceleration measurements taken at the thorax of the cadaver because the presence of the rear passenger disturbed them.

c) Right front passenger of the R.12 (Table 5)

Head and neck - The difference between the HIC values found during the two reconstructions is explained by the position on the head of the accelerometer in question and the violent rotational movement of the head caused by the lack of rigidity of the neck of the cadaver. Our failure to carry out cerebral injection prevents us having knowledge of any injuries that may have occurred to the brain.

Thorax-pelvis - The type of injuries noted at the abdomen of the passenger without any submarining indication on the pelvis allows someone to think that these injuries are due to deceleration. Such injury causation has already been noticed (2).

DISCUSSION

Selection of Accident

It was possible to carry out faithful reconstructions of this accident of which the kinematics were simple and which was well understood from the technical and medical point of view. However, the mutual contacts of the R.12 occupants makes difficult any result analysis.

Accidents should be limited to those that involve two persons at the most per vehicle. Finally, and because of the difficulties of relative simulation in the case of the driver of the Chrysler, it would be desirable to select accidents in which the conditions under which the seat belt is worn are reproducible and in which the anthropometry of the victims is not too different from that of the dummies.

Protection tolerances and criteria

Head - The failure of cerebral injection in the case of cadavers deprives us of information on cerebral tolerance. In the case of the driver of the R.12, it is interesting to note that the head impact which lead to AIS 3 injuries in the living person gave rise in the reconstructions to an HIC of 2,300 for the dummy Hybrid II and 2,000 for the cadaver. In the case of the front passenger of the actual accident, the head movement did not cause injuries, the noticed head impact being negligible. This confirms observations made on actual accidents which show that, if there is no direct impact, no cerebral injuries occur to occupants held by seat belts in a frontal collision.

Thorax - We have two passengers, in the R.12, which were subject to very high retention forces. The cadaver placed in the passenger's position had 17 rib fractures for a force at the shoulder less than that exerted on the driver who only had 9 rib fractures. Allowance must be made for their respective weights and resistances, to explain this. Application of the predicted formula established by Eppinger (4) for an "average" cadaver with respect to the force at the shoulder and its weight, indicate 16 fractures for the body placed in the passenger position with a "corrected" force on the shoulder of 800 daN and

Table 5 - Results for R.12 Front Passenger.

	Real Victim	Cadaver	Dummy
Head/Neck			
SI/HIC	-	4727/4037 (occiput)	1180/835
γmax./γ3 ms g	-	201/152	101/95
Injuries	no	no macroscopic lesion	-
Impacts	Dashboard	dashboard	dashboard
Thorax			
SI	-	1823	393
γmax./γ3 ms g	-	130/104	68/44
shoulder load (daN)	-	750	-
Load on thorax (daN)	-	870	-
Injuries	(x) 6 ribs AIS 3	(x) 17 ribs (AIS 4)	-
Impacts	no	no	no
Pelvis			
SI	-	2000	1074
γmax./γ3 ms g	-	145/139	88/60
Injuries	Desinsertion of the mesentary, devitalisation of small intestine (AIS 4)	(x) right iliac wing (AIS 2)	-
Impacts	no	no	no
Legs			
Femur force (daN) - left:	-	-	80
-right:	-	-	210
Injury.........	no	no	-
Impact	under dashboard	under dashboard	under dashboard

Note: (x) for fracture

12 fractures for the driver with a force of 936 daN. Furthermore, if these occupants are plotted on a graph with the number of fractures as a function of the force applied to the thorax expressed in units of weight, this graph being extracted from a previously published paper (2), it may be seen that the passenger remains within the range of dispersal of injuries of the cadavers used in experiments whereas the driver is outside it. (Fig. 4).

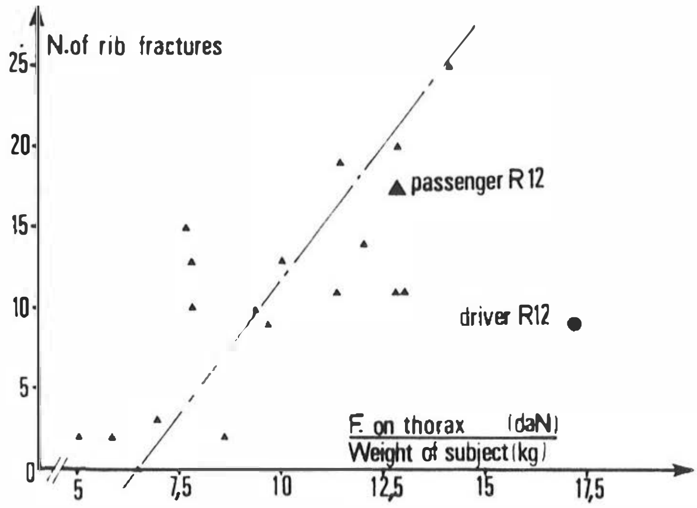


Figure 4 - Number of rib fractures sustained by the R.12 driver and the right front passenger compared to other subjects.

These differences between the results obtained for the two cadavers may be explained by the difference of bone strength in the two subjects. Mechanical tests of bone strength carried out on the ribs (Table 6), place the cadaver in the passenger's position among the average of cadavers of aged persons and the driver among young persons who have died suddenly before the skeleton has been weakened. The bone strength of the driver is this different from that of the cadaver of aged persons and is nearer to that of a living person in good health.

Table 6 - Results of tests of ribs.

		Static bending tests		Static shearing tests		Mineral salts
Subject	Age	Energy (J)	Fmax. (daN)	2 W (J)	2 Fmax. (J)	c/m
Driver R12	29	1,19	25,5	3,42	170,6	35,65
Right front passenger R12	53	0,48	17,8	3,34	115	26,5
Mean values						
11 subjects (cadavers)	54	0,73	19,8	2,47	86,8	24,65
9 subjects (unexpected deaths)	29	1,17	32,57	3,9	152	37,35

Note: c/m: weight of mineral salts/weight of rib piece (%)

These differences of bone strength thus explain the differences found in the severity of chest injuries. A thorough study of the response of the thorax in relation to the retention mechanism should enable us to give a quantitative definition of the differences and to set a figure for tolerance of the human body by means of tests carried out on cadavers of all ages. (8)

The injuries that occur to the driver-cadaver of the R.12 could be compared to those of the actual driver. It is undeniable that the body was more seriously injured than the living person who only suffered a fracture of the clavicle. It should be noted that the actual victim, ages 21, was in a physical state superior to those of the average living person, leaving aside the effect of the difference between dead and living person of equal skeleton strength.

It may be seen from this reconstitution that, in the case of a living person comparable to the occupants of the R.12, a retention force at the shoulder of 860 daN (935 daN for a weight of 75 kg) is not incompatible with injuries of degree AIS 3.

Pelvis-Lower limbs - The abdominal injuries noted on the front passenger of the R.12 seem, because of their type, to have been caused by high deceleration of the pelvis and of the abdomen. For a figure of acceleration of the pelvis of 145 g (139 g/3 ms) the cadaver placed in the same position had no abdominal injuries. It may therefore be thought that the deceleration of the pelvis, which caused the injuries noted on the living person, was very high.

With regard to the passengers of the R.12, they remain very distinctly within the tolerable limits for impacts of knees with forces which attained 540 daN measured on the Hybrid II during the reconstruction. As regards the Chrysler 180 driver, the 460 daN recorded on the dummy femur cannot be compared to the injuries of the real victim. The real victim sustained more severe knee impacts, because his seat belt worked less efficiently, as indicated by the results concerning his thorax.

CONCLUSIONS

The accurate reproduction of an actual accident has provided a comparison of results obtained from living people, from dummies, and from cadavers under very similar conditions of impact as may be seen by comparing the values for average ΔV and mean γ. Nevertheless, the success of reconstructions is not sufficient to ensure that reliable data is obtained on tolerances of the human body because of complex interactions, particularly between the occupants of the same car. It thus proves to be important to carry out severe selection of accidents in order to obtain results as precise as possible. In these reconstructions for example, the presence of rear passengers in the R.12 led to perturbations of measurements.

With regard to tolerance of the head in the case of impact, the injuries that occured to the driver of the R.12, of AIS 3 degree, should be compared with the HIC of 2300 measured on the Hybrid II dummy and an HIC of 2000 measured on the cadaver. On the other hand, the figure of 1100 measured on the VIP 50 A Dummy is comparable with an AIS 1 for the actual driver of the Chrysler. These results are compatible with a criterion of protection of the head, in the event of impact, such as HIC $\leq$ 1500, proposed in another paper (5)(6).

Knowledge of cerebral injuries which may have occured to the cadavers requires successful cerebral injection. All actions should therefore be taken so that is performed under good conditions.

The presence in the R.12 of a young cadaver with good bone strength enabled us to evaluate indirectly the difference between the tolerance of the thorax of a living person and that of bodies of old people. Though multiple rib fractures appear on cadavers of old people as a result of forces of the order of 500 daN at the shoulder(2)(4), a shoulder retention figure of about 900 daN is observed here without any injury of excessive importance (AIS 3) to the cadaver/driver of the R.12, of which the bone condition is similar to that of ordinary accident victims. This result agrees with the recent observations of accidents (7).

A precise evaluation of the tolerance of the thorax of living people necessitates the drawing up of an equivalence between the injuries noted on cadavers of all ages and those noted on the actual accident victims. This research is in progress (8) and first results are published in these same proceedings.

The injuries noted on the abdomen of the actual accident victim in the R.12 confirmed that a very high degree of deceleration of the pelvis may cause internal injury.

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