(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 July 2009 (23.07.2009)

PCT

(10) International Publication Number
WO 2009/090681 A1

(51) International Patent Classification:
*E01F 15/04* (2006.01)

(21) International Application Number:
PCT/IT2009/000009

(22) International Filing Date: 14 January 2009 (14.01.2009)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
RM2008A000022 15 January 2008 (15.01.2008) IT

(71) Applicant and
(72) Inventor: IMPERO, Pasquale [IT/IT]; Via Caudio 53, I-80013 Casalnuovo di Napoli (NA) (IT).

(74) Agent: FIAMMENGHI, Eva; c/o Fiammenghi Fiammenghi, Via Quattro Fontane 31, I-00184 Roma (IT).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

**(54) Title:** ROAD SAFETY BARRIER

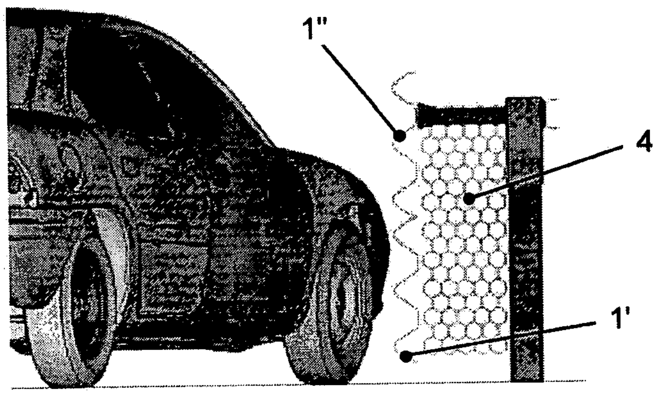


Fig. 4a

**(57) Abstract:** The invention consists of the use of hexagonal cell panels made of inelastically deformable ductile material in the field of road safety barriers and impact energy attenuators. The panels are oriented so as to be deformed in the plane of the hexagonal cells in case of impact. The deformation of the panels causes a controlled deceleration of the vehicle, which results improved with a lower ASI value than that of conventional safety barriers with regard to the UNI-EN 1317 standard.

WO 2009/090681 A1

# Description

## Road Safety Barrier

### Field of the art

The present invention generally refers to longitudinal road safety barriers, including those installed along the road borders, those set on the central traffic divider and those on the edge of a bridge; it also refers to impact energy attenuators.

### Prior art

The performance class of a road barrier is measured through the ASI index. The acceleration severity index, ASI, is a function of time, and is calculated with the following equation:

$$ASI(t) = [(a_x / a^*_x)^2 + (a_y / a^*_y)^2 + (a_z / a^*_z)^2]^{1/2},$$

where $a_x, a_y, a_z$ are the acceleration components of a point P inside the body of the vehicle close to the center of gravity, averaged over a 50 ms mobile time window, while $a^*_x, a^*_y, a^*_z$ are the limit values for the acceleration components along the vehicle axes x, y, z, respectively equal to 12g, 9g and 10g (g is the acceleration due to earth's gravity).

The maximum value reached by ASI in a collision is taken as a single measurement of the impact severity,

ASI = max [ASI(t)]. The value = 1 is deemed very safe, while the value = 1.4 is still acceptable; above this value, it is probable that there will be serious negative consequences.

A longitudinal barrier is of class A if it has an ASI <1, while it is of class B if it has an ASI <1.4. If the barrier is characterized by a value of ASI>1.4, then it can no longer be approved. The European standard of reference is UNI-EN 1317.

A first aspect of the invention regards the longitudinal safety barriers, which constitute road safety barriers for vehicles and are installed along the borders of a road or on the central traffic divider.

We will first describe the performances of the barriers of the prior art below.

*A) Longitudinal safety barriers*

The longitudinal safety barriers are classified on the basis of the containment level. The containment level is a function of the maximum kinetic energy that the barrier is capable of absorbing due to the impact of a vehicle.

The applicant's research activity was concentrated on the road barriers of type H1, H2 and H3, respectively characterized by a kinetic energy value of 126.6 kJ, 287.5 kJ and 462.1 kJ.

For the sake of brevity, in the following discussion only the data related to the barrier H3 will be reported.

The certification of a barrier provides that it is tested for a 100 km/h impact, which occurs with an angle of 20° with an automobile of 900 kg weight. For a comparison with the prior art, the impact simulations were executed by A.M.S. (applicant), using the Dodge Neon as automobile.

The safety barriers proposed by the applicant were compared with the safety barriers of the same performance level currently on the market (prior art).

*B) Longitudinal safety barrier of type H3*

The performances of the barrier H3 proposed by the applicant were compared with the lateral edge barrier H3 produced by the company Marcegaglia. The comparison is based on the calculation results of the finite element method executed by means of an explicit code, as well as on relative practical tests.

The H3 Marcegaglia safety barrier was modeled starting from the structural drawings of the same barrier which are available on-line on the Marcegaglia website.

Fig. 1 shows the FE (finite element) model of the H3 Marcegaglia barrier.

In Fig. 2, the impact dynamics are reported for the Marcegaglia barrier. As is noted from Fig. 2, the double wave spacer, in the lower part of the barrier, collapses, while the spacer related to the triple wave, in the upper part of the barrier, remains practically non-deformed (see also Fig. 3). It is too rigid and makes the impact quite harmful for the motor vehicle occupants. Indeed, it is observed in Fig. 3 that the Marcegaglia barrier has a height nearly equal to that of the car and the triple wave impacts against the car posts and window, increasing the risk of physical harm to the vehicle occupants.

From the preceding observations, one observes several disadvantages of the prior art with regard to the longitudinal road safety barriers.

In Figure 7, the time progressions of the ASI index for the Marcegaglia barrier and for the barrier of the presented invention are reported.

Figure 7 will be discussed below, in the detailed description of the present invention, but it is clear that the maximum 1.16 of the ASI for the barrier of the prior art approaches the maximum limit value 1.4 for safety barrier certification, hence also under this aspect it is seen that the prior art still has drawbacks.

Fig. 8 shows the HIC progression (defined below in the detailed description) of an accelerometer placed inside the vehicle at the position of the driver's head, so to evaluate the damage caused to the occupants in the case of the two barriers (prior art (Marcegaglia), and present invention). Also under this aspect, the prior art can be improved.

Therefore, in a first aspect thereof, the present invention intends to provide a longitudinal road safety barrier, which for a lateral impact, on the side of the barrier itself, has the following improved characteristics:

- reduced overall height of the barrier, which reduces the risk of impact of the head of the passenger against the barrier itself;
- reduced overall height of the barrier, so that the posts (of the windows) of an automobile are not affected by the impact;

- progressive deformation of the barrier during impact, so to limit the maximum value of the ASI to a much greater extent than that of the prior art;
- the car wheel remains substantially aligned in the motion direction, even after impact;
- lower weight of the barrier;
- lower maximum value of the HIC parameter (see detailed description of the invention for the exact definition of the HIC parameter), in order to make the barrier safer for the vehicle occupants.

In a second aspect thereof, the present invention regards the impact energy attenuators: the attenuator can be connected to the barrier itself or it can also exist on its own, independent of the same.

An impact energy attenuator is a device placed before an obstacle in order to dampen the violence of the impact. An impact energy attenuator is placed wherever there is a fixed obstacle, not protected by safety barrier, for example, therefore, in front of:

- non-pliable sign poles (portals) and lighting poles
- pillars of vehicle bridges, foot bridges, supports, etc.
- cusps in which two barrier sections are joined
- the beginning of metal barriers or cement barriers (New Jersey) or non-protected anti-noise walls
- work site ends
- highway tollbooth bumpers.

The object of the present invention is that of obtaining impact energy attenuators with ASI less than 1 and which are not as long as those of the prior art.

In particular, one object of the present invention is that of providing impact energy attenuators having the preceding innovative/advantageous characteristics that can both be connected to the longitudinal safety barriers and mounted on their own to protect tollbooths, art works, pillars and other objects. Then, in a second aspect thereof, the present invention in particular concerns a road barrier equipped with an impact energy attenuator according to the present invention.

The aforesaid objects are obtained, with regard to the first aspect, as indicated in the independent claim 1.

Moreover, the objects of the invention related to the second aspect are obtained by means of the characteristics contained in the dependent claims 6-15 and the independent claim 16. The two aspects of the invention are united by the use of hexagonal cell panels, wherein said panels are arranged in a manner such that the impact of the vehicle occurs against the plane defined by the hexagonal cell panels, and not orthogonally to the plane itself.

The hexagonal cell structure is made by means of a ductile metal material, having a high capacity to be inelastically deformed when the system is subjected to stresses in the hexagon plane.

Brief description of the drawings

The present invention will now be illustrated by means of the drawing set, only as a non-limiting example, wherein:

FIGURE 1a is a type H3 barrier model of the prior art (Marcegaglia company), shown in cross section, in which the vehicle is approaching the barrier with an impact angle that is provided for by the certification standards;

FIGURE 1b is the barrier model shown in Fig. 1a, seen in perspective and from its rear side;

FIGURE 2 is the impact dynamics for the barrier of Figures 1a and 1b;

FIGURE 3 is a detail of the impact at time t = 0.20 s for the barrier of Figures 1a, 1b and 2;

FIGURE 4 (a, b = section, perspective rear) is a model (possible embodiment) of a longitudinal road safety barrier according to the present invention, of H3 category, and specifically a FE (finite element) model of such barrier;

FIGURE 5 shows the dynamics of the impact for the barrier H3 of the invention, illustrated in the preceding Fig. 4;

FIGURE 6 represents a detail of the impact for the barrier of H3 type of the present invention, already shown in the preceding Figures 4 and 5;

FIGURE 7 shows the time progressions of the ASI index for the barrier of the prior art (Marcegaglia, light curve) and for the barrier of the present invention (dark curve);

FIGURE 8 shows a comparison between the parameter HIC(t) (in g units) for the barrier of the prior art (light curve) and for the barrier of the present invention ("AMS": dark curve), as a function of the collision time (in seconds);

FIGURE 9 is a plan and section view of the modular impact energy attenuator of the present invention, made by means of hexagonal cell panels, in a first embodiment thereof;

FIGURE 10 is a perspective view of inside the impact energy attenuator of a longitudinal safety barrier with strips and bars (posts), the impact energy attenuator being arranged in the head part (terminal) of the safety barrier;

FIGURE 11a is a side view of a traditional, non-redirective impact energy attenuator with "performance level 50";

FIGURE 11b is a plan view of the traditional impact energy attenuator shown in Fig. 11a;

FIGURE 12 shows an automobile which is about to hit an impact energy attenuator model of the present invention of "performance level 50";

FIGURE 13 shows the dynamic behavior (for a collision of type TC 1.1.50) in the case of the attenuator of the present invention shown in Fig. 12;

FIGURE 14 illustrates the progression of the ASI as a function of time for the TC 1.1.50 test on the impact energy attenuator of the present invention;

FIGURE 15a is a side view of the prior art reference attenuator for "performance level 80" tests for non-redirective attenuators;

FIGURE 15b is the corresponding plan view;

FIGURE 16 is an impact energy attenuator model according to the present invention, for "performance level 80" tests.

Detailed description of the present invention

The present invention will now be described in detail, making reference to several particular and non-binding embodiments thereof, so that a man skilled in the art can reproduce it if he so desires.

Those details considered as being known to the man skilled in the art will not be described/mentioned; these are thus not strictly tied to the innovative aspects of the invention.

As shown in Fig. 4a and Fig. 4b, with respect to the Marcegaglia barrier the double wave 1 was in practice substituted with a triple wave 1', whose thickness is reduced. The spacers 2, 3 were substituted with the hexagonal cell panel 4. The introduction of the hexagonal cell panel 4 and the two triple waves 1', 1" permitted reducing the overall height of the 150 mm barrier. A lower barrier reduces the risk of impact of the passenger head against the barrier itself.

In Figure 5, the impact dynamics for the barrier H3 of the invention are reported. As is known from Figures 5 and 6, the hexagonal cell panel is progressively deformed. It is also noted from Fig. 6 that the barrier of the present invention has a height such that the posts of the automobile are not affected by the impact. In addition, it is possible to observe that the right front wheel (Fig. 6) remains aligned with the direction of the motion, unlike that which occurs in the case of the Marcegaglia barrier.

In Figure 7, the time progressions are reported of the ASI index for the Marcegaglia barrier and for the barrier of the present invention.

It is observed from Fig. 7 that there is a reduction of the ASI of about 30%. This is an optimal result considering that the barrier, subject of the present invention, has a weight per linear meter that is 5 kg less than that of the Marcegaglia barrier.

In order to evaluate the damage sustained by car occupants after impact, an accelerometer was placed inside the vehicle at the position of the driver's head. The resulting acceleration was calculated and this was then averaged over a 50 ms mobile time window.

We define such parameter HIC as

$$HIC(t) = 1/\delta \int_{t}^{t+\delta} a_r(t')dt'$$

In Fig. 8, the progression of such parameter HIC is reported as a function of time, both for the present barrier and for the Marcegaglia barrier.

It is observed how the maximum value of the HIC for the barrier proposed by the applicant is reduced nearly 50% with respect to that of Marcegaglia. Thus, the barrier, subject of the present patent application, is capable of simultaneously meeting the requirements of several certification classes.

The present invention was described, with regard to its first aspect, in the case of a strip and bar barrier. Nevertheless, the present inventive concept could also be applied to other barrier types, if one wishes to protect the barrier in specific points with the hexagonal cell panels arranged in a direction substantially orthogonal to the longitudinal extension of the barrier.

With regard to the second aspect of the invention (impact energy attenuator and safety barrier equipped with impact energy attenuator), this will be described with a direct comparison with the prior art, highlighting the advantages of the present finding.

An impact energy attenuator is a device placed in front of an obstacle in order to dampen the impact violence. An impact energy attenuator is positioned wherever there is a fixed obstacle that is unprotected by a safety barrier: for example, therefore, in front of:

* non-pliable sign poles (portals) and lighting poles
* pillars of vehicle bridges, foot bridges, supports, etc.
* cusps in which two barrier sections are joined
* the beginning of metal barriers or cement barriers (New Jersey) or non-protected anti-noise walls
* work site ends
* highway tollbooth bumpers.

The applicant designed impact energy attenuators for the 50 km/h and 80 km/h speed classes, using a series of hexagonal cell panels connected with each other as element capable of absorbing the kinetic energy of the motor vehicle and transforming it into deformation energy.

In Figures 9 and 10, a drawing is reported of the elementary cell which constitutes the modular metal panel used in the impact energy attenuators of the present invention.

In the attenuator model proposed by the applicant of modular type, every module or elementary cell could be composed of four panels 11, 500 mm x 800 mm, arranged in parallel. Every module 10 could be separated from the others by means of 3 mm plates 12 (see Figs. 9 and 10).

In the tests, the directives of the UNI EN 1317-3 reference standard of 2002 were taken under consideration, borrowing, for the indications related to size and bulk of the attenuator, the TAU models of the Company Sn S.p.A. (prior art).

The finite element method calculations were executed by means of explicit, dynamic finite element commercial software.

The objective of the simulations was to obtain energy absorbers, i.e. impact energy absorbers, with ASI of less than 1 and which are not as long as those of the prior art.

The impact energy attenuator, as shown in Fig. 9, has a U-shaped portion 13 which covers the inner part of the actual attenuator (with components 10, 11, 12). The portion 13, preferably metal, is joined to the actual barrier 15 (see Fig. 10). The number 14 indicates a vehicle colliding with the impact energy attenuator.

*A) Performance level 50 tests for non-redirective impact energy attenuators (TC 1.1.50)*

The attenuator of the invention was modeled and made starting from the impact energy absorber TAU, PARALLEL 60 model of Sn S.p.A.

The height from the ground and width were maintained unchanged, while the length was diminished, which for such model was 4200/3700 mm, while in the present invention one can start from 1500 mm (2 grating packs), before preferably reaching the optimal configuration of 2000 mm. In addition, the attenuator of the present invention is connected to the road barrier 15 (Figs. 9 and 10) while the TAU model is not. Frontally, the model of the invention has a curved triple wave, (formed by the aforesaid U-shaped portion 13), the TAU model has a plastic band of fluorescent color.

The test type TC 1.1.50. of the reference standard provides for a frontal impact with a 900 kg car impacting at 50 km/h.

The attenuator, subject of the invention, that is used for such simulations has hexagonal cell panel modules arranged in series, having cells with progressively greater thickness: for example 1.2/1.2/1.5 mm.

In Fig. 12, the performance level 50 attenuator model proposed by the present invention is reported; Fig. 13 reports its dynamic behavior for an impact of type TC 1.1.50.

In Fig. 14, the progression of the ASI is reported as a function of time for the TC 1.1.50 test in the case of the attenuator of the invention. It is observed that the maximum value of ASI is equal to 0.561<1. A non-redirective attenuator of class A was thus obtained, with considerable space savings in longitudinal direction with respect to the conventional case, given the same width and height.

In the following table, the size and ASI values are compared for the attenuator of the prior art (TAU) and for that proposed by the present invention (AMS).

| Length comparison of performance level 50 attenuators | |
|---|---|
| TAU Model | AMS Model |
| L = 3700/4200 mm | L = 2000 mm |
| ASI = 1-1.4 | ASI = 0.561 |

*B) Performance level 80 tests for non-redirective impact energy attenuators*

The reference attenuator for the simulations and the tests was the redirective impact energy absorber TAU, PARALLEL 80 model of Sn S.p.A. whose scheme is reported in Fig. 15a and Fig. 15b.

For such performance level, the standard UNI EN 1317-3 provides for four different tests:

- TC 1.1.80: frontal impact in axis with 900 kg mass
- TC 2.1.80: frontal impact with misalignment of ¼ the width of the vehicle with

900 kg mass

- TC 1.2.80: frontal impact in axis with 1300 kg mass
- TC 3.2.80: frontal impact tilted 15° with 1300 kg mass.

After numerous attempts with four and then five modules 10 made with hexagonal cell panels, which gave ASI values greater than 1 for the tests TC 1.2.80 and TC 3.2.80, it was decided to use six modules, also inserting the hexagonal cell panels in the zone 13 (see Fig. 16) delimited by the curved part of the guardrail, obtaining an 3500 mm attenuator (see Fig. 16). The same structure was subsequently also tested for the test TC 1.1.50, in order to obtain a single product which can go well for both performance levels. All of the abovementioned tests gave optimal results, as seen in the tables related to the ASI reported below. Therefore, the attenuator that is the subject of the present invention fully meets the standards related to several certification classes as polyvalent attenuator.

The attenuator of the invention used for such simulations has grating packs (modules) 10, 10, ... , arranged in series, with panels 11 with hexagonal cells having progressive thickness: 1.2 in the curved part/1.4/1.5/1.6/1.7/1.8/2.0 mm.

The maximum ASI values are reported in the following table (AMS = present invention)

| Tests on 3.5 m structure, Model, 1.2 CURVED Part/1.4/1.5/1.6/1.7/1.8/2.0 | | |
|---|---|---|
| Performance level 80 tests | Model | A.S.I |
| | TC 1.1.80 | 0.747 |
| | TC 1.2.80 | 0.855 |
| | TC 2.1.80 | 0.732 |
| | TC 3.2.80 | 0.956 |
| Performance level 50 test | TC 1.1.50 | 0.607 |

(AMS = present invention)

| Attenuator length comparison and performance level 80 ASI comparison | |
|---|---|
| TAU Model | AMS Model |
| L = 6300/7000 mm | L= 3500 mm |
| 1< ASI <1.4 | 0.732 <ASI <0.956 |

In conclusion, the attenuator model proposed by the applicant for the performance level 80 has longitudinal size equal to about half that proposed by the prior art and ensures a considerably lower ASI value than that of the prior art.

## Claims

1. A longitudinal safety barrier for a traffic divider or lateral border, characterized in that it has, on its side turned towards the roadway, one or more hexagonal cell panels (4), wherein the plane of each single hexagonal cell panel (4), or plane of the hexagons of the panel cells, is substantially orthogonal to the ideal vertical plane of longitudinal extension of the barrier; said panel (4) being formed of ductile material that can be deformed in an inelastic manner, preferably metal.

2. A longitudinal safety barrier according to claim 1, characterized in that it constitutes a strip (1'; 1") and bar barrier.

3. A longitudinal safety barrier according to claim 1 or 2, comprising a plurality of said hexagonal cell panels (4) arranged equidistant from each other along the longitudinal safety barrier.

4. A longitudinal safety barrier according to claim 2 or 3 in turn dependent on claim 2, wherein the barrier comprises, for each bar, a relative hexagonal cell panel (4) which extends between the bar and a pair of triple waves (1'; 1").

5. A longitudinal safety barrier according to any one of the preceding claims, characterized in that it comprises an impact energy attenuator at a cusp thereof or at a beginning region thereof.

6. A longitudinal safety barrier according to claim 5, characterized in that said impact energy attenuator comprises one or more modules (10), each formed by a plurality of parallel flanked panels (11, 11, ...), the modules being separated from each other by plates (12), said parallel flanked panels (11, 11, 11, ...) constituting hexagonal cell panels made of inelastically deformable ductile material; wherein each ideal geometric

plane orthogonal to all the planes of the hexagons of a respective module (10) of the attenuator is also orthogonal to the ideal vertical plane of longitudinal extension of the safety barrier.

7. A longitudinal safety barrier according to claim 6, wherein the planes of the hexagons of each parallel flanked panel (11, 11, 11, ..) are substantially horizontal.

8. A longitudinal safety barrier according to claim 7, wherein said modules (10) of the attenuator are externally covered by a U-shaped portion (13), for example of triple wave form, which is preferably directly connected to the remaining part (15) of the barrier.

9. A longitudinal safety barrier according to claim 8, wherein there is an empty space inside the curved part, or vertex, of the U-shaped portion (13).

10. A longitudinal safety barrier according to claim 8, wherein, also inside the curved part, or vertex, of the U-shaped portion (13), there is a plurality of parallel flanked panels (11, 11, ...) with hexagonal cells, these too constituting a module (10).

11. A longitudinal safety barrier according to any one of the claims 6 - 10, characterized in that the packs or modules (10) of parallel flanked panels (11, 11, ...) have a progressive thickness of the material which forms the hexagonal cells, i.e. increasing from one module (10) to the adjacent one.

12. A longitudinal safety barrier according to any one of the claims 6 - 11, wherein the ASI of the impact energy attenuator is less than 1.

13. A longitudinal safety barrier according to claim 12, wherein the ASI is in the

range of about 0.6 to about 1 for performance level 80 tests, and is less than 0.6 for performance level 50 tests.

14. A longitudinal safety barrier according to any one of the claims 6 - 13, wherein the length of the attenuator does not exceed 2000 mm for a performance level 50.

15. A longitudinal safety barrier according to any one of the claims 6 - 13, wherein the length of the attenuator does not exceed 3500 mm for a performance level 80.

16. An impact energy attenuator of polyvalent type for several certification classes, adapted to protect the passengers of an automobile in case of collision against a fixed obstacle, in particular but not exclusively usable for:

- non-pliable sign poles (portals) and lighting poles
- pillars of vehicle bridges, foot bridges, supports or the like
- cusps in which two barrier sections are joined
- the beginning of metal barriers or cement barriers (New Jersey) or non-protected anti-noise walls
- work site ends
- highway tollbooth bumpers.

the impact energy attenuator being characterized in that it comprises one or more modules (10) each formed by a plurality of parallel flanked panels (11, 11, ...) and separated from each other by plates (12) arranged orthogonally to the parallel flanked panels, said parallel flanked panels (11, 11, 11, ...) constituting hexagonal cell panels made of inelastically deformable ductile material; wherein each ideal geometric plane, parallel to said plates (12) and orthogonal to all the planes of the hexagons of a respective module (10) of the attenuator, is also orthogonal to the predetermined probable direction of impact of the automobile.

17. An impact energy attenuator according to claim 16, wherein the planes of the hexagons of each parallel flanked panel (11, 11, 11, ..) are substantially horizontal.

18. An impact energy attenuator according to claim 16 or 17 wherein, starting from the module (10) of the impact energy attenuator which is first deformed in case of collision of an automobile against the impact energy attenuator, the thicknesses of the hexagonal cells of the parallel flanked panels (11, 11, 11...) progressively increase from one module (10) to the next module (10).

19. An impact energy attenuator according to any one of the preceding claims 16 - 18, wherein a U-shaped cover portion (13) is provided, preferably with triple wave configuration.

20. An impact energy attenuator according to any one of the claims 16 - 19, wherein only the curved part of the cover portion (13) is internally empty.

21. An impact energy attenuator according to any one of the claims 16 - 19, wherein also the curved part of the U-shaped cover portion (13) is internally filled with parallel flanked panels (11, 11, ...) like those of the modules (10).

22. An impact energy attenuator according to claim 18 and 21, wherein the thicknesses of the hexagonal cells progressively increase from the parallel flanked panels (11, 11, ...) inside the curved part of the cover portion (13), and from one module (10) to the next module (10).

23. An impact energy attenuator according to any one of the preceding claims 16 - 22, wherein the ASI of the attenuator is less than 1.

24. An impact energy attenuator according to claim 23, wherein the ASI is in the range of about 0.6 to about 1 for a performance level 80, and is less than 0.6 for a performance level 50.

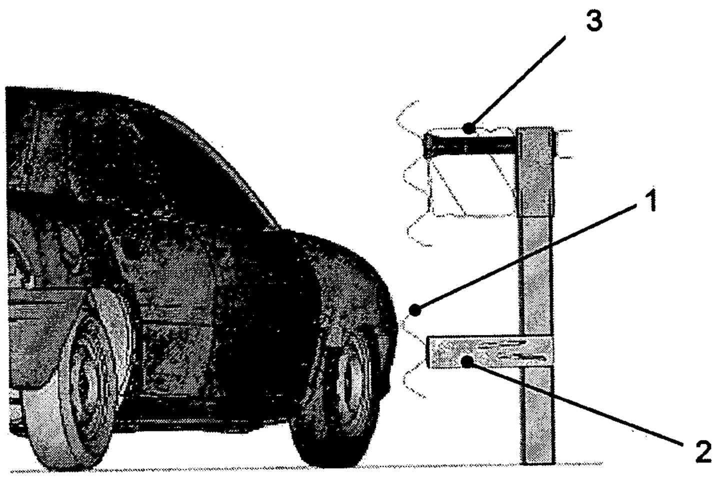


Fig. 1a

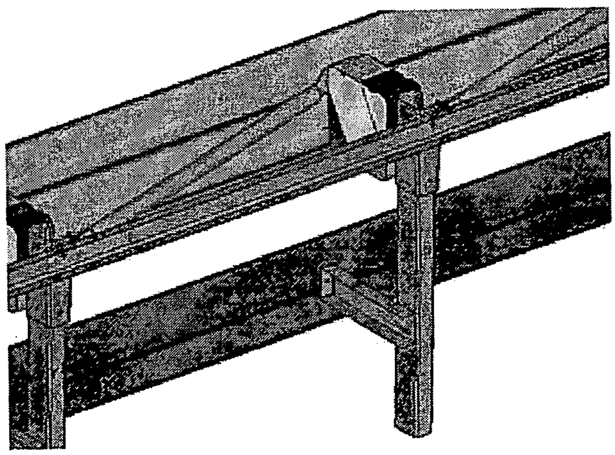

Fig. 1b

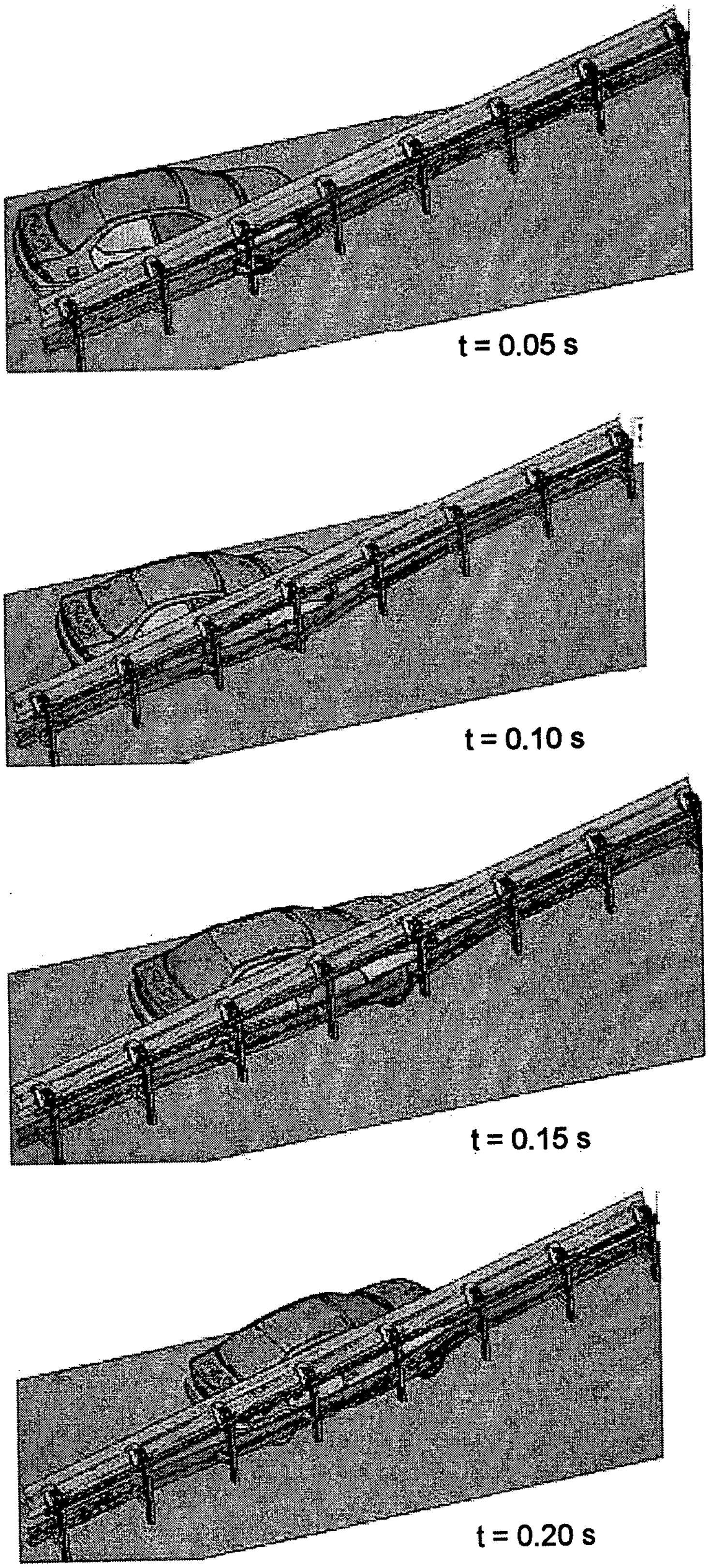


Fig. 2

HOJA DE SUSTITUCION (REGLA 26)

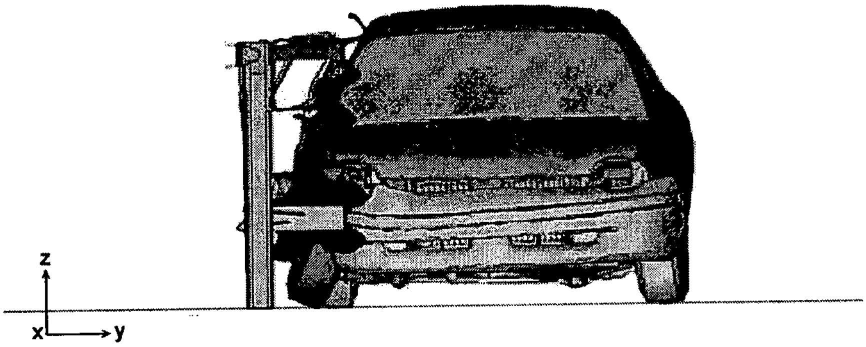


Fig. 3

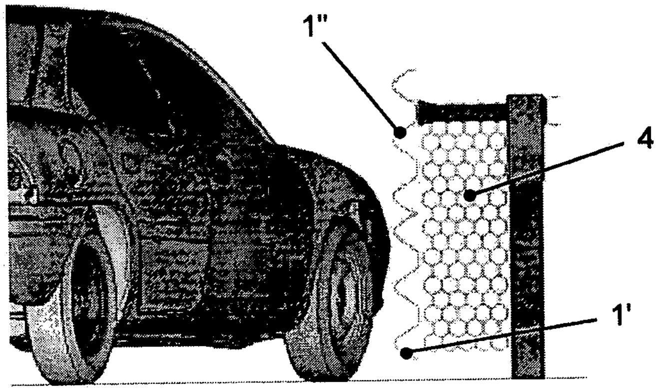


Fig. 4a

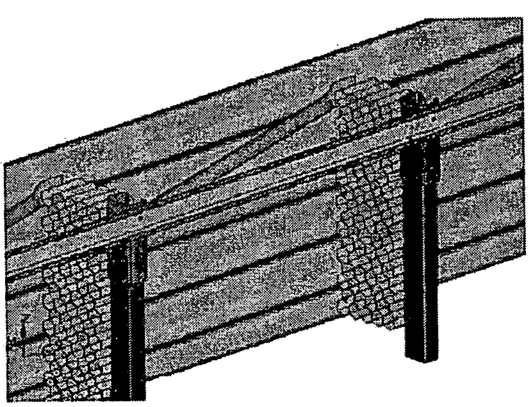

Fig. 4b

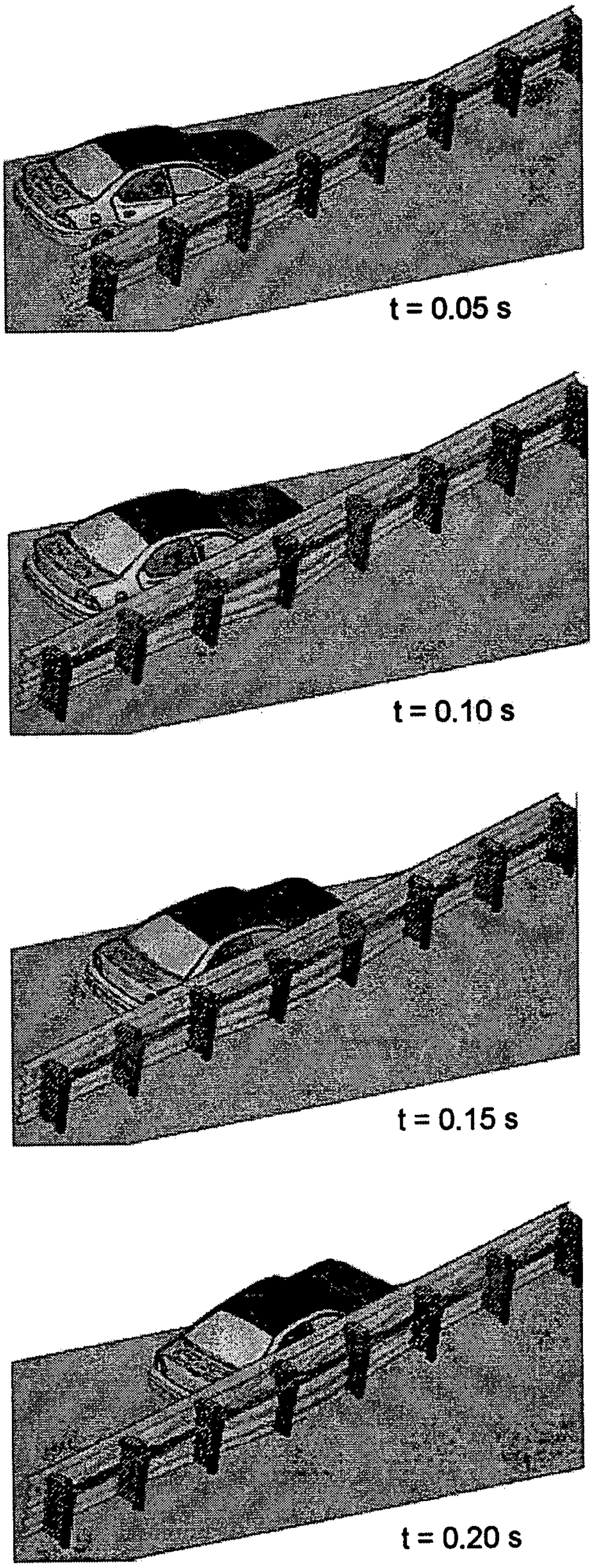


Fig. 5

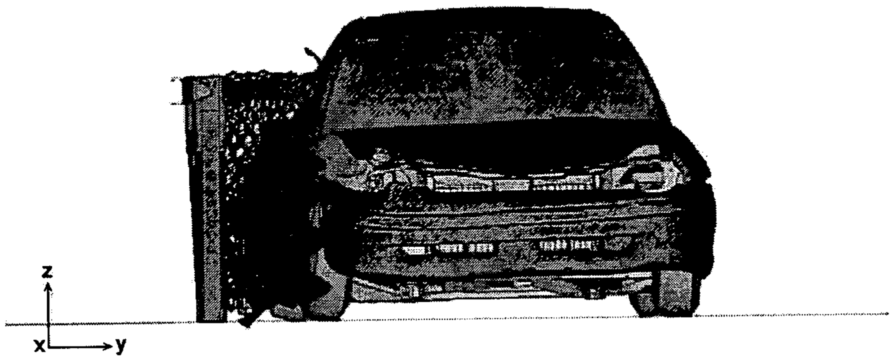


Fig. 6

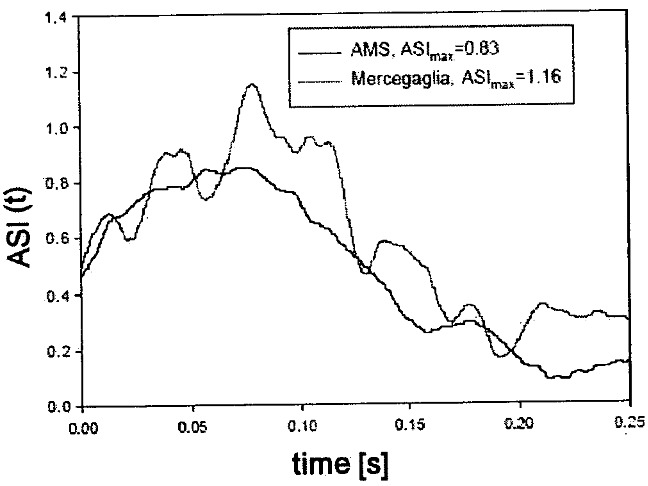


Fig. 7

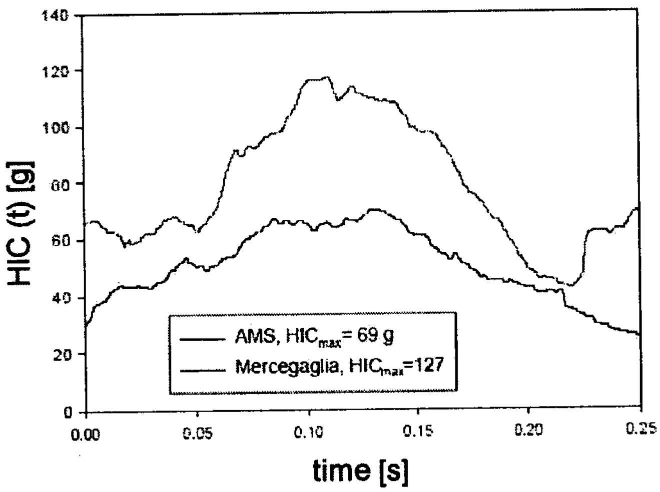


Fig. 8

HOJA DE SUSTITUCION (REGLA 26)

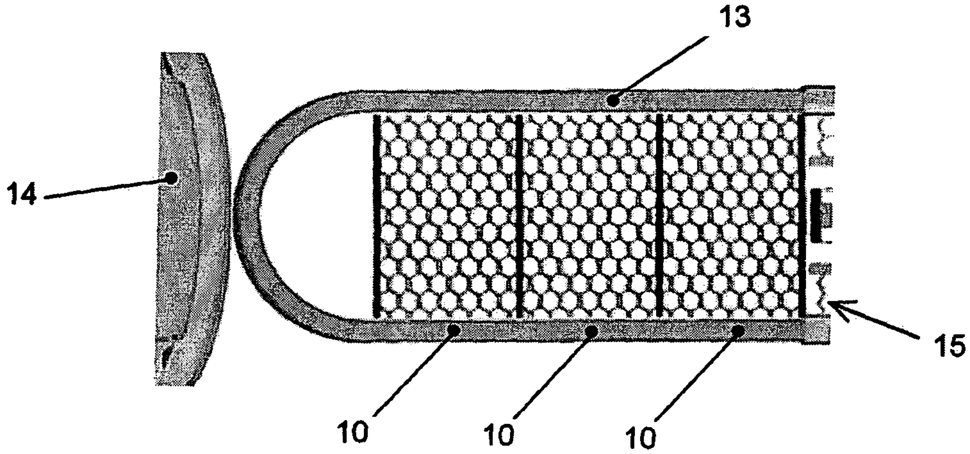


Fig. 9

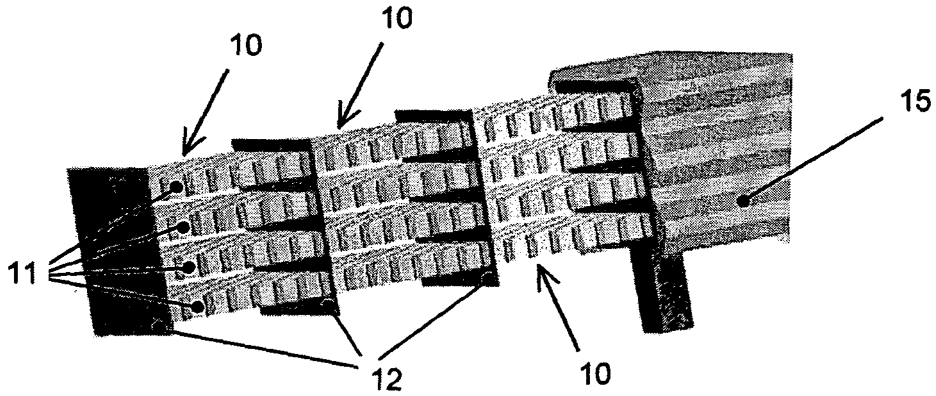


Fig. 10

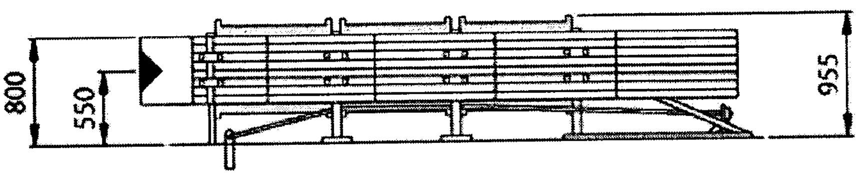


Fig. 11a

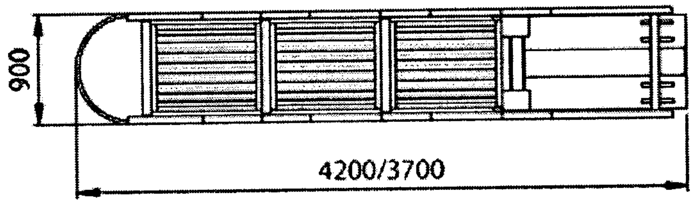


Fig. 11b

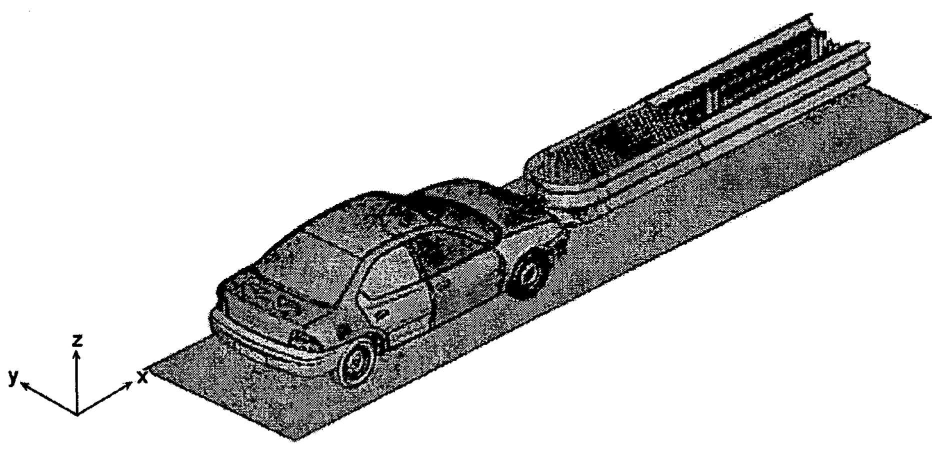


Fig. 12

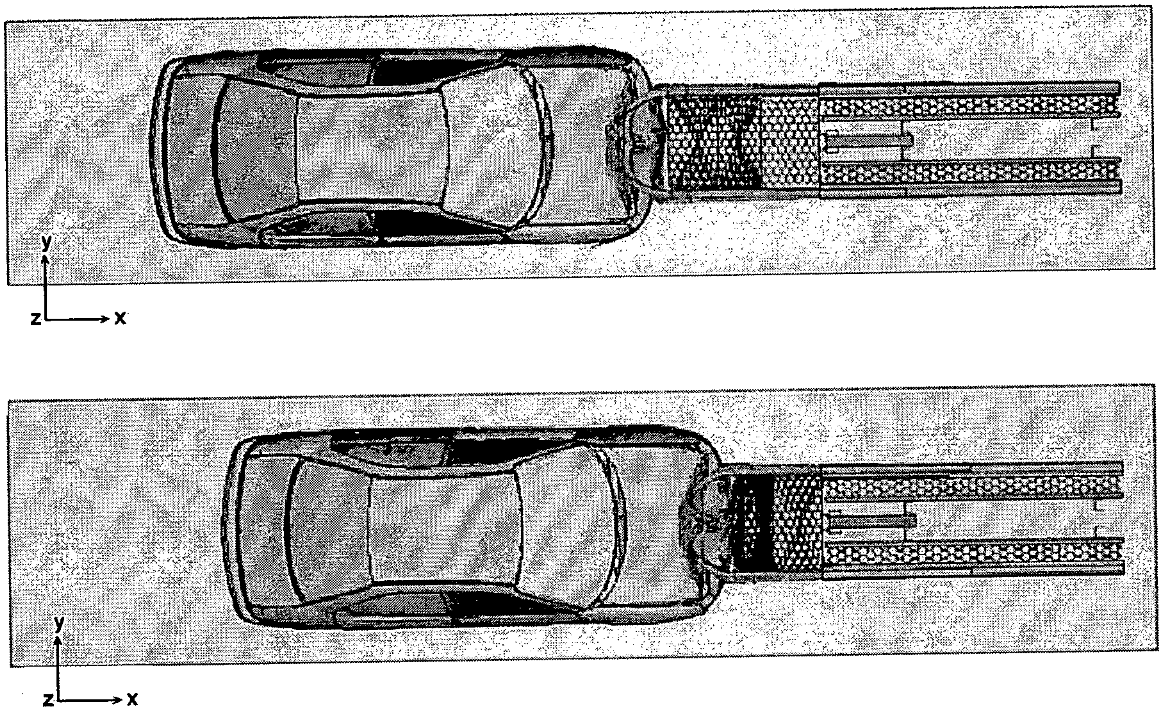
y
z
x
y
z
x

Fig. 13

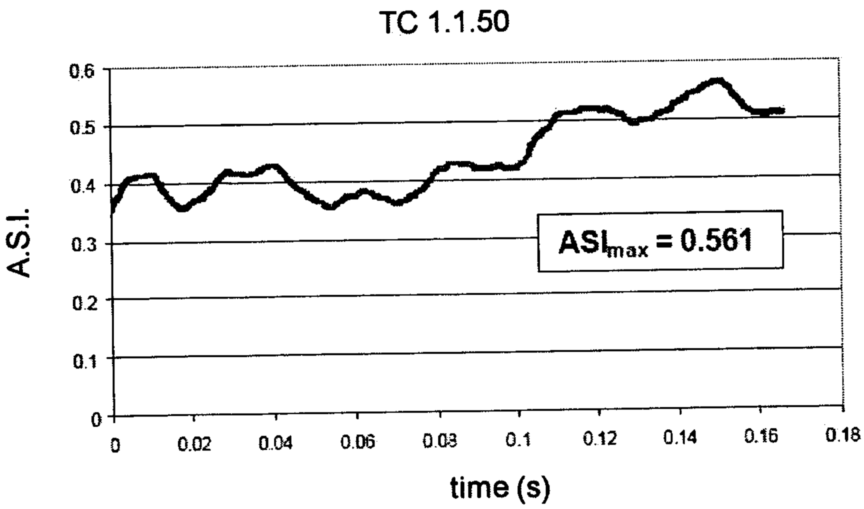
TC 1.1.50
A.S.I.
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
time (s)
ASI$_{max}$ = 0.561

Fig. 14

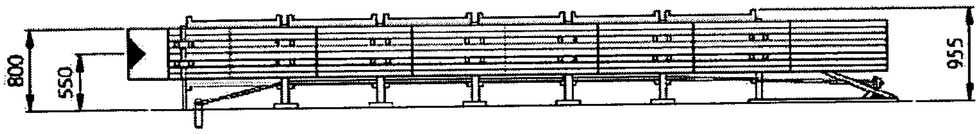


Fig. 15a

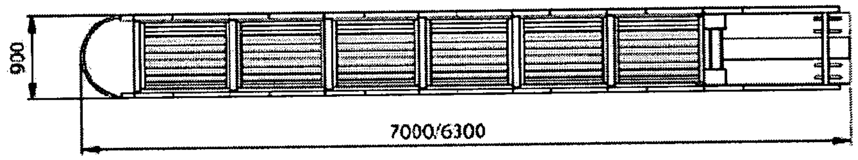


Fig. 15b

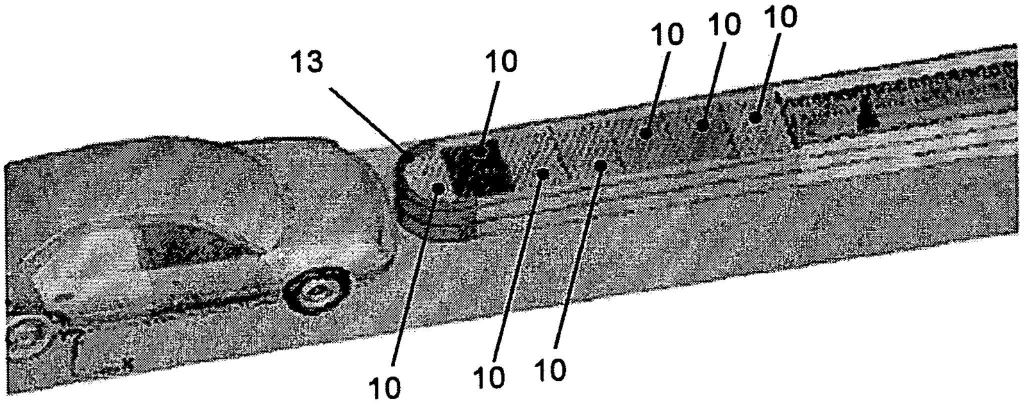


Fig. 16

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2009/000009

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. E01F15/04

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
E01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | CH 432 573 A (HOLECZ FERENC [CH]) 31 March 1967 (1967-03-31)<br>column 2, lines 39-42<br>figures 2,3,7 | 1-4,7,8, 12-15, 17,19 |
| X | GB 2 083 162 A (ENERGY ABSORPTION SYSTEM) 17 March 1982 (1982-03-17)<br>figures 6-8 | 1-9, 11-20, 22-24 |
| A | DE 41 31 937 A1 (SPIG SCHUTZPLANKEN PROD GMBH [DE]) 8 April 1993 (1993-04-08)<br>figure 1 | 7,16,17 |
| A | DE 31 06 694 A1 (URLBERGER HERMANN HANS) 9 September 1982 (1982-09-09)<br>figures 1-4 | 1,10,21 |

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 28 May 2009 | 05/06/2009 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Tran, Kim-Lien |

International application No
PCT/IT2009/000009

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| --- | --- | --- |
| A | WO 99/55970 A (BRIGANTINE S A [FR]; CARAMANOS FREDERIC [FR]) 4 November 1999 (1999-11-04) page 2, lines 12-31 | 11,18,22 |

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IT2009/000009

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| CH 432573 | A | 31-03-1967 | NONE | | | |
| GB 2083162 | A | 17-03-1982 | AR | 224435 | A1 | 30-11-1981 |
| | | | AU | 542096 | B2 | 07-02-1985 |
| | | | AU | 6762981 | A | 11-03-1982 |
| | | | BE | 887808 | A1 | 01-07-1981 |
| | | | BR | 8101769 | A | 17-08-1982 |
| | | | CA | 1161866 | A1 | 07-02-1984 |
| | | | CH | 654633 | A5 | 28-02-1986 |
| | | | DE | 3108607 | A1 | 15-04-1982 |
| | | | FR | 2489912 | A1 | 12-03-1982 |
| | | | IT | 1170808 | B | 03-06-1987 |
| | | | JP | 1025928 | B | 19-05-1989 |
| | | | JP | 1542930 | C | 15-02-1990 |
| | | | JP | 57047046 | A | 17-03-1982 |
| | | | NL | 8101065 | A | 01-04-1982 |
| | | | SE | 461924 | B | 09-04-1990 |
| | | | SE | 8101261 | A | 06-03-1982 |
| | | | US | 4352484 | A | 05-10-1982 |
| DE 4131937 | A1 | 08-04-1993 | NONE | | | |
| DE 3106694 | A1 | 09-09-1982 | NONE | | | |
| WO 9955970 | A | 04-11-1999 | NONE | | | |