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(54) Title: METHOD FOR CRASH TESTING A MOTOR VEHICLE

208 Test Matrix			32km/h		37km/h		40km/h		48km/h		56km/h		64km/h	
			Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay
Flat Barrier No Belt	AF5	DR			★	①	★	★	③					
		PA			★		★	★						
	AM50	DR			★	②	★	★	④					
		PA			★		★	★						
Flat Barrier Belted	AF5	DR			★	⑤	★	★	★	⑦				
		PA			★		★	★						
	AM50	DR			★	⑥	★	★	★	⑧				
		PA			★		★	★						
Angle Barrier No Belt	AM50 R30	DR					★	★	⑨					
		PA					★	★						
	AM50 L30	DR	★	⑫			★	★	⑩					
		PA					★	★						
ODB Belted	AF5	DR					★	★						
	AM50	DR					★	★						
		PA												

(57) Abstract: A method for crash testing a motor vehicle is disclosed. The method provides a crash test routine where an inflatable restraint is deployed using a single deployment pattern throughout at least one government regulation zone. This helps to prevent overlap of a transition zone and can help make the deployment of the inflatable restraint more predictable. This can increase occupant safety and simply testing.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD FOR CRASH TESTING A MOTOR VEHICLE

DESCRIPTION

1 **Technical Field**

2 This invention relates to the field of motor vehicle restraint systems, and more
3 particularly, to a method for crash testing a motor vehicle.

4 **Background Art**

5 Currently, some cars, trucks and vans provide some kind of supplemental restraint
6 system (SRS). Often, these supplemental restraint systems take the form of inflatable
7 devices or restraints. In some cases, airbags are used. The following related art
8 references provide a general background of the field.

9 Cooper (U.S. patent number 6,696,933) discloses an air bag system with a
10 biomechanical grey zone. The biomechanical grey zone is an attempt to comply with
11 recent legislative changes that require airbags to restrain women and children as well as
12 adult males. To help restrain women and children, Cooper proposes the use of a system
13 where air bags include multi-level inflators that can adjust the inflation characteristics of
14 the air bag. The biomechanical zone is defined as a region where it is acceptable to deploy
15 the air bag using either a low power inflator or a high power inflator. While the use of
16 biomechanical grey zones may help to comply with new governmental requirements, the
17 grey zones introduce uncertainty in the deployment characteristics of the air bag and this
18 makes system design and testing difficult. The Cooper reference is incorporated by
19 reference in its entirety.

20 Corrado et al. (U.S. patent number 6,249,729) teaches an occupancy sensing
21 system for an automobile. The system is used in conjunction with an airbag deployment
22 system to determine the nature, location and motion parameters of an occupant within the
23 vehicle interior. These parameters are determined by ultrasound and/or infrared sensors.
24 The system establishes criteria for airbag disablement or for modified airbag deployment
25 based on sensor information. In particular, Corrado teaches the use of a Keep Out Zone
26 (KOZ) within the vehicle interior relative to the dashboard or instrument panel. Analyzing
27 the relative location of an occupant with respect to the Keep Out Zone can be used to
28 determine whether the airbag deployment is disabled or modified.

29 Wang et al. (U.S. patent number 6,662,092) teaches a control method for
30 deploying an air bag using fuzzy logic. Wang attempts to provide a fuzzy logic deployment
31 system that is more direct than previous fuzzy logic systems and where the calibration

1 process if more user friendly. The method uses a deployment control algorithm to
2 determine whether certain stages are deployed based on certain thresholds related to
3 predicted occupant movement and crash severity.

4 There is currently a need for a way to increase the predictability of the deployment
5 of an inflatable restraint to improve occupant safety and to simplify the process of crash
6 testing the motor vehicle.

7 **Disclosure of the Invention**

8 A system and method for crash testing a motor vehicle is disclosed. The invention
9 can be used in connection with a motor vehicle. The term "motor vehicle" as used
10 throughout the specification and claims refers to any moving vehicle that is capable of
11 carrying one or more human occupants and is powered by any form of energy. The term
12 motor vehicle includes, but is not limited to cars, trucks, vans, minivans, SUV's,
13 motorcycles, scooters, boats, personal watercraft, and aircraft.

14 Generally, the related art teaches systems and methods for a single deployment
15 event and focus on correctly making a single deployment decision. In contrast, one aspect
16 of the present invention is directed to providing a novel deployment map that applies to a
17 number of different deployment scenarios and conditions. This novel map can help
18 improve the predictability of a deployment of an inflatable restraint, and this predictability
19 can help designers and engineers improve occupant safety over a wide range of different
20 collision scenarios and conditions. In another aspect, the present invention is directed to a
21 method of qualifying a motor vehicle to use the novel deployment map.

22 In another aspect, the invention provides a method of deploying an inflatable
23 restraint wherein a single deployment pattern is used throughout at least one government
24 regulation zone.

25 In another aspect, a single deployment pattern is used throughout every
26 government regulation zone.

27 In another aspect, the government regulation zone extends from 32 km/h to 40
28 km/h.

29 In another aspect, the single deployment pattern is a delayed deployment pattern.

30 In another aspect, a second government regulation zone extends from 0 km/h to 48
31 km/h.

32 In another aspect, a second deployment pattern is used throughout the second
33 government regulation zone.

34 In another aspect, a second deployment pattern is substantially similar to the single
35 deployment pattern.

1 In another aspect, the invention provides a method of deploying an inflatable
2 restraint having at least one transition zone is disposed between a first deployment pattern
3 and a second deployment pattern; wherein the transition zone includes probabilities of
4 deploying the inflatable restraint using either the first deployment pattern or the second
5 deployment pattern; and wherein a government regulation zone is separated from every
6 transition zone.

7 In another aspect, the transition zone includes a lower end and an upper end and
8 wherein the government regulation zone includes a lower end and an upper end; and
9 wherein the upper end of the transition zone is less than the lower end of the government
10 regulation zone.

11 In another aspect, the second deployment pattern is a delay deployment pattern.

12 In another aspect, first deployment pattern is a no deploy pattern.

13 In another aspect, a first crash test validates the results for an entire government
14 regulation zone.

15 In another aspect, the first crash test is conducted at a speed corresponding to an
16 upper end of the government regulation zone.

17 In another aspect, the invention provides a method of simultaneously deploying an
18 inflatable device comprising the steps of: determining that a first charge configured to
19 inflate the inflatable device; deploying the inflatable device using the first charge; providing
20 a delay; determining whether a second charge configured to inflate the inflatable device
21 should be deployed; and using the second charge in conjunction with the first charge if the
22 inflatable device should be deployed.

23 In another aspect, the second charge has less power than the first charge.

24 In another aspect, the delay is about 0 to 10 milliseconds.

25 In another aspect, the delay is about 5 milliseconds.

26 In another aspect, information from a sensor is retrieved during the delay.

27 In another aspect, an additional computation is made during the delay.

28 In another aspect, the step of determining whether a second charge configured to
29 inflate the inflatable device should be deployed, is made during the delay.

30 Other systems, methods, features and advantages of the invention will be, or will
31 become, apparent to one with skill in the art upon examination of the following figures and
32 detailed description. It is intended that all such additional systems, methods, features and
33 advantages be included within this description, be within the scope of the invention, and be
34 protected by the following claims.

1 **Brief Description of the Drawings**

2 The invention can be better understood with reference to the following drawings
3 and description. The components in the figures are not necessarily to scale, emphasis
4 instead being placed upon illustrating the principles of the invention. Moreover, in the
5 figures, like reference numerals designate corresponding parts throughout the different
6 views.

7 Figure 1 is a schematic diagram of a preferred embodiment of a method for
8 improving a crash test routine for a motor vehicle.

9 Figure 2 is a schematic diagram of a conventional firing map for an inflatable
10 restraint.

11 Figure 3 is a schematic diagram of a preferred embodiment of a firing map for an
12 inflatable restraint.

13 Figure 4 is a table of a series of crash tests when using a conventional firing map.

14 Figure 5 is a table of a series of crash tests when using a preferred embodiment of
15 a firing map.

16 Figure 6 is a flow diagram of a preferred embodiment of a method for qualifying a
17 motor vehicle for a crash test routine.

18 Figure 7 is an enlarged schematic diagram of a preferred embodiment of step 604
19 of Figure 6.

20 Figure 8 is an enlarged schematic diagram of a preferred embodiment of step 608
21 of Figure 6.

22 Figure 9 is an enlarged schematic diagram of a preferred embodiment of step 616
23 of Figure 6.

24 Figure 10 is a schematic diagram of a preferred embodiment of a No Good Zone.

25 Figure 11 is a schematic diagram of a failed crash test.

26 Figure 12 is a schematic diagram of a preferred embodiment of a crash test that
27 has been passed.

28 Figure 13 is a schematic diagram of a preferred embodiment of a motor vehicle
29 interior and a child occupant.

30 **Best Mode(s) for Carrying Out the Invention**

31 Figure 1 is a flow diagram of a preferred embodiment of a method of improving a
32 crash test regiment for a motor vehicle. The method shown in Figure 1 can include the
33 following steps. The method begins with step 102 where a new firing map is designed.
34 This new firing map helps to simplify the firing conditions of an inflatable restraint and
35 reduce occupant injury. The simplified algorithm or firing map can help make the

1 deployment conditions of the inflatable restraint more predictable and this helps to provide
2 a supplemental restraint system that is more reliable and easier to test. This predictability
3 also helps designers improve occupant safety. Another benefit of the new firing map is that
4 it can help reduce the number of vehicles required to comply with government-mandated
5 crash tests. In some cases, this reduction is substantial.

6 After the new firing map has been designed, the method can proceed to step 104
7 where a motor vehicle is qualified for using the new firing map. In step 104, the process
8 helps to identify which motor vehicles can accept the new map and can also help tune or
9 modify a motor vehicle so that it can become a motor vehicle capable of using the new
10 firing map.

11 After the motor vehicle has been qualified to use the new firing map, the motor
12 vehicle is then subjected to a simplified crash test routine in step 106. Preferably, step
13 106 includes the process of actually conducting real world crash tests with actual motor
14 vehicles and crash test dummies.

15 Figure 2 is a schematic diagram of a conventional firing map 200 for an inflatable
16 restraint. The conventional firing map 200 includes three deployment scenarios depending
17 on the type of impact. The three types of impact are a conventional flat barrier scenario
18 202, a conventional angled barrier scenario 204 and a conventional offset barrier scenario
19 206. In each of the scenarios, the conventional firing map 200 also deploys the inflatable
20 restraints differently depending on the speed of the impact. Generally, conventional firing
21 map 200 considers the speed of the impact and the type of impact to determine how or if
22 the inflatable restraint is deployed.

23 In the conventional flat barrier scenario 202, conventional firing map 200 includes
24 three different deployment options, which are related to corresponding regions in the bar
25 graph representing conventional flat barrier scenario 202. The first deployment option is a
26 no fire option and this first option occurs in region 208. A second deployment option is a
27 delay fire option, and this second option occurs in region 210. The third deployment option
28 is a simultaneous fire option that occurs in region 212.

29 Generally, inflatable restraint systems can include two charges, a low power charge
30 and a high power charge. The high power charge is generally designed to provide a low
31 energy deployment that is suitable for smaller and less massive occupants, for example, a
32 woman with physical characteristics similar to an AF5% crash test dummy. The low power
33 charge is generally used to supplement the energy of the high power charge, and when
34 these two charges are deployed simultaneously, they produce a high energy deployment
35 that is suitable for larger and more massive individuals, for example, a male with physical
36 characteristics similar to an AM50% crash test dummy.

1 A delay deployment can be conducted in many different ways. The system can
2 delay deploying the inflatable restraint in the following ways: the system can immediately
3 deploy the high power charge and delay deploying the low power charge, the system can
4 delay first and then deploy the two charges simultaneously, or the system can deploy the
5 low power charge immediately and delay deploying the high power charge. In a
6 simultaneous deployment, the system deploys both the low power charge and the high
7 power charge at the same time to inflate the restraint very quickly.

8 In some embodiments, a simultaneous deployment can include a slight delay. In
9 these embodiments, the high power charge is initially deployed, and then a slight delay is
10 provided. This delay can be used to provide the system with a little more time to decide
11 whether to deploy the second low power charge. In some cases, the system has
12 determined that the high power charge needs to be deployed. The slight delay can be
13 used to retrieve information from other sensors or perform other computations. These
14 steps can be used by the system to decide whether to also deploy the low power charge.
15 This slight delay can range from about 0 to 10 milliseconds and in an exemplary
16 embodiment, the delay is about 5 milliseconds.

17 The conventional firing map 200 includes transition zones between two adjacent
18 deployment regions. Considering conventional flat barrier 202, a first transition zone 214
19 is disposed between first region 208 and second region 210. This first transition zone 214
20 is bounded, on the low speed end, at about 13 km/h and on the high speed end at about
21 19 km/h.

22 This first transition zone 214 determines the deployment characteristics for the
23 inflatable restraint where the passenger or driver is unbelted. First transition zone 214
24 graphically represents the percentage chance between first region 208 and second region
25 210. In conventional map 200, first region 208 corresponds to a no fire condition and
26 second region 210 corresponds to a delay fire condition. Thus, first transition zone 214
27 graphically represents the percentage chance that the inflatable device will either not
28 deploy (no fire) or will deploy in a delay mode.

29 As shown in Figure 2, at the low end of first transition zone 214, the bar graph
30 representing the conventional flat barrier scenario 202 is almost completely represented by
31 first region 208. This means that there is almost a 100% chance that the deployment
32 condition associated with first conventional region 208 will occur. Since first conventional
33 region 208 represents a no fire condition, there virtually no chance that the inflatable
34 device will deploy at the low end of first transition zone 214.

35 At the opposite end of first transition zone 214, at about 19 km/h, the bar graph
36 representing first scenario 202 is almost completely represented by second region 210.

1 Since second region 210 corresponds to a delay fire condition, it is virtually assured that
2 inflatable restraint will deploy in a delay fire mode. At speeds between 13 km/h and 19
3 km/h, there is a generally linear relationship between speed and the likelihood that the
4 inflatable device will be deployed in a delay mode. Generally, as speed increases, it
5 becomes more and more likely that the inflatable restraint will be deployed in a delay
6 mode.

7 Conventional flat barrier scenario 202 also includes a second transition zone 216.
8 This second transition zone 216 extends from a low end of about 13 km/h to a high end of
9 about 26 km/h. In order to accurately show first transition zone 214, Figure 2 shows only a
10 portion of second transition zone 216, the slope of which should continue until 13 km/h.
11 This second transition zone relates to a belted occupant, either driver or passenger.
12 Second transition zone 216 provides the probability that the inflatable device will either not
13 deploy or will deploy in a delay mode. Again, like first transition zone 214, the percentage
14 chance of either a no fire condition or a delay fire condition is graphically related to ratio of
15 the first region 208 compared to the second region 210 at a given speed.

16 Conventional flat barrier scenario 202 includes a third transition zone 218. This
17 third transition zone 218 is disposed between second region 210 and third region 212 and
18 provides the percentage chance of either a delay mode deployment or a simultaneous
19 deployment.

20 Third transition region starts at about 30 km/h and extends to about 37 km/h.
21 Similar to the first and second transition regions, third transition region 218 provides a
22 percentage chance that the inflatable device will deploy in accordance with the pattern
23 associated with second region 210 or third region 212. Recall that second region 210 is
24 associated with a delay fire condition and third region 212 is associated with a
25 simultaneous fire condition. Because of these associations, third transition zone 218
26 graphically represents the percentage chance that an inflatable device will deploy in a
27 delay fire mode or a simultaneous fire mode.

28 As shown in conventional flat barrier scenario 202, the percentage chance that the
29 inflatable device will deploy in a simultaneous fire mode increases as the speed of the
30 impact increases. At about 37 km/h, it is a virtual certainty that the inflatable device will
31 deploy in a simultaneous mode and at speeds above 37 km/h, the inflatable device is
32 designed to deploy in simultaneous mode.

33 Conventional angle barrier scenario 204 includes three regions, first region 208,
34 second region 210 and third region 212 corresponding to three different deployment
35 patterns for an inflatable restraint. Conventional angle barrier scenario 204 includes a
36 fourth transition zone 220 disposed between first region 208 and second region 210.

1 Fourth transition zone 220 extends from a low end of about 13 km/h to a high end of about
2 19 km/h.

3 Fourth transition zone 220 is similar to first transition zone 214. As shown in Figure
4 2, at the low end of fourth transition zone 220, the bar graph representing the angle barrier
5 scenario 204 is almost completely represented by first conventional region 208. This
6 means that there is almost a 100% chance that the deployment condition associated with
7 first conventional region 208 will occur. Since first conventional region 208 represents a
8 no fire condition, there virtually no chance that the inflatable device will deploy at the low
9 end of fourth transition zone 220.

10 At the opposite end of fourth transition zone 220, at about 19 km/h, the bar graph
11 representing second scenario 204 is almost completely represented by second region 210.
12 Since second region 210 corresponds to a delay fire condition, it is virtually assured that
13 inflatable restraint will deploy in a delay fire mode. At speeds between 13 km/h and 19
14 km/h, there is a generally linear relationship between speed and the likelihood that the
15 inflatable device will be deployed in a delay mode. Generally, as speed increases, it
16 becomes more and more likely that the inflatable restraint will be deployed in a delay
17 mode.

18 Conventional angle barrier scenario 204 also includes a fifth transition zone 222
19 disposed between second region 210 and third region 212. This fifth transition zone 222
20 extends from a low end of about 26 km/h to a high end of about 32 km/h and provides the
21 percentage chance of either a delay mode deployment or a simultaneous deployment.

22 Fifth transition zone 222 starts at about 26 km/h and extends to about 32 km/h.
23 Similar to other transition zones, fifth transition zone 222 provides a percentage chance
24 that the inflatable restraint will deploy in accordance with the pattern associated with
25 second region 210 or third region 212. Recall that second region 210 is associated with a
26 delay fire condition and third region 212 is associated with a simultaneous fire condition.
27 Because of these associations, fifth transition zone 222 graphically represents the
28 percentage chance that an inflatable restraint will deploy in a delay fire mode or a
29 simultaneous fire mode.

30 As shown in conventional angle barrier scenario 204, the percentage chance that
31 the inflatable device will deploy in a simultaneous fire mode increases as the speed of the
32 impact increases. At about 32 km/h, it is virtual assured that the inflatable restraint will
33 deploy in a simultaneous mode and at speeds above 32 km/h, the inflatable restraint is
34 designed to deploy in simultaneous mode.

35 Conventional offset barrier scenario 206 includes two regions, first region 208 and
36 second region 210. Conventional offset barrier scenario 206 does not include a third

1 region. Sixth transition zone 224 is disposed between first region 208 and second region
2 210. Sixth transition zone 224 is larger than some other transition zones and extends from
3 about 26 km/h to about 40 km/h.

4 As shown in Figure 2, at the low end of sixth transition zone 224, the bar graph
5 representing the offset barrier scenario 206 is almost completely represented by first
6 conventional region 208. This means that there is almost a 100% chance that the
7 deployment condition associated with first conventional region 208 will occur. Since first
8 conventional region 208 represents a no fire condition, there virtually no chance that the
9 inflatable restraint will deploy at the low end of sixth transition zone 224.

10 At the opposite end of sixth transition zone 224, at about 40 km/h, the bar graph
11 representing offset barrier scenario 206 is almost completely represented by second
12 region 210. Since second region 210 corresponds to a delay fire condition, it is virtually
13 assured that inflatable restraint will deploy in a delay fire mode. At speeds between 26
14 km/h and 40 km/h, there is a generally linear relationship between speed and the likelihood
15 that the inflatable device will be deployed in a delay mode. Generally, as speed increases,
16 it becomes more and more likely that the inflatable restraint will be deployed in a delay
17 mode.

18 Government rules generally require motor vehicles to undergo crash testing at
19 certain speeds and under certain conditions. Currently, there are two government
20 regulation zones, a first regulation zone between 32 km/h to 40 km/h for unbelted
21 occupants and a second regulation zone between 0 km/h and 48 km/h for belted
22 occupants. Motor vehicles sold in the United States must be subjected to a number of
23 crash tests to establish passenger and occupant safety in these regulation zones in the
24 event of a collision.

25 While transition zones have been used in the past as a way to decide how to
26 deploy an inflatable restraint, they also introduce a number of problems. Deployments that
27 occur within transition zones are unpredictable because the transition zones only provide
28 percentage chances of two competing deployment conditions. In some cases, the
29 response of a system using conventional firing map 200 is so unpredictable that it is
30 possible for an inflatable restraint to deploy two different ways in two successive and
31 identical crash tests.

32 Because the deployment of an inflatable restraint is unpredictable in a transition
33 zone, the system must be tested at the government mandated speeds as well as at all
34 endpoints of the transition zone.

35 In order to minimize the number of crash tests, engineering reasoning is generally
36 used and a worst case scenario is tested. Using engineering reasoning, if a motor vehicle

1 passes a crash test conducted under the worst case, then it can be assumed that the
2 motor vehicle will also pass a crash test at under less severe conditions. This is one way
3 to validate the response of the system under many different possible conditions. For
4 example, if a motor vehicle passed a crash test at 40km/h, engineering reasoning dictates
5 that the same motor vehicle, identically prepared and equipped, should pass the same
6 crash test at 35 km/h. In fact, the motor vehicle should also pass the same crash test at
7 any speed between 0 and 40 km/h.

8 Referring to Figure 4, which is a table of crash tests for conventional firing map
9 200, and Figure 2, the crash tests that are required can be observed. The crash tests are
10 preferably conducted in sets, and each set preferably includes a driver and a passenger.
11 Set 1 is conducted at a speed of 37 km/h and with a flat barrier collision condition. Set 1 is
12 used to test the occupant safety of a typical female and an AF5% crash test dummy (which
13 stands for American Female 5 percentile) can be used to model the behavior of a
14 hypothetical female occupant. Set 1 is an unbelted test, meaning seat belts are not used
15 during the test.

16 Set 2 is similar to set 1 except that set 2 is used to test the occupant safety of a
17 typical male and an AM50% crash test dummy (which stands for American Male, 50
18 percentile) can be used to model the behavior of a hypothetical male. The conditions and
19 attributes of the remaining eleven sets of crash tests are self-explanatory from the table
20 shown in Figure 4.

21 Figure 3 is a schematic diagram of a preferred embodiment of firing map 300. It
22 has been discovered that with careful design of motor vehicle 100, the simultaneous fire
23 mode is not necessary to provide occupant safety and also meet government crash test
24 requirements. In other words, it is possible to use a delay fire mode to meet government
25 crash test requirements under conditions where conventional systems use a simultaneous
26 fire mode.

27 This discovery can be used to create a firing map 300 that is less complex than
28 conventional firing map 200. It is believed that this discovery will help to improve occupant
29 safety because the reduction in the complexity of the new firing map 300 compared to the
30 conventional firing map 200 can provide more predictable deployments of inflatable
31 devices. This improved predictability can, in turn, be used to better understand the
32 interplay between occupants and the inflatable restraint system at various different speeds
33 and collision conditions. This can help engineers design safer motor vehicles and
34 inflatable restraint systems. As a side benefit, this discovery also allows the locations of
35 the various transition zones to be selected to prevent overlap with one or more
36 government regulation zones.

1 Also, because a simultaneous fire mode is no longer required, this entire
2 deployment mode can be omitted from firing map 300. In the embodiment shown in Figure
3 4, firing map 300 does not include a simultaneous deployment or firing condition. Firing
4 map 300 includes just two deployment patterns, a no fire mode and a delayed deployment
5 mode.

6 Preferably, the various transition zones are carefully selected so that none of the
7 transition zones overlaps a regulation zone. In one embodiment shown in Figure 3, the
8 transition zones have been moved away or separated from the regulation zones. This
9 allows the crash test routine to be greatly simplified. Referring to Figure 5, which is a table
10 of crash tests corresponding to firing map 300 reflected in Figure 3, differences between
11 this table and the table shown in Figure 4 are readily apparent.

12 As shown in Figure 5, several crash tests are no longer needed. Set 1 is no longer
13 needed because set 3 is conducted at 40 km/h under the same conditions, namely in delay
14 mode. Note the arrows indicating that new set 3 is conducted in delay mode from the
15 previous no delay mode. As discussed earlier, if a motor vehicle passes a crash test at a
16 higher speed, then it can be assumed that the motor vehicle will pass the same crash test
17 at a lower speed. Because the new firing map 300 uses the same deployment conditions
18 at 40 km/h and 37 km/h, any motor vehicle using new firing map 300 that passes the 40
19 km/h crash test should also pass set 1 as well. For the same reasons, sets 2, 5, 6 and 12
20 are no longer required.

21 Returning to Figure 1, some embodiments include provisions 104 to determine if a
22 motor vehicle is qualified to use new firing map 300. Although many different methods can
23 be used to determine if a motor vehicle is qualified to use new firing map 300, the following
24 method is preferred. Referring to Figure 6, which is a flow diagram of a preferred
25 embodiment of a method 104 for determining if a motor vehicle is qualified to use new
26 firing map 300, this method can both determine if a motor vehicle is qualified to use new
27 firing map 300 and also help modify or "tune" the motor vehicle so it becomes qualified to
28 use new firing map 300.

29 Method 104 can include a number of different tests and a number of modifications
30 that can be made to help the motor vehicle to pass those tests. Preferably, these tests
31 and modifications are arranged sequentially within method 104 in a systematic way so that
32 a modification does not invalidate previous test results.

33 Preferably, method 104 begins with first test 602. In first test 602, the relative
34 position of a hypothetical child with respect to a No Good Zone ("NGZ") 1002 is
35 considered. In some cases, a C3Y (child, three year old) and/or C6Y (child, six year old)
36 dummy is used to model the hypothetical child. Referring to Figure 10, NGZ 1002 is a

1 zone roughly between inflatable restraint lid 1004 and windshield 1006. In some
2 embodiments, NGZ 1002 is defined using particular relative offsets and spacing from
3 various components.

4 In a preferred embodiment, NGZ 1002 is defined by one or more boundaries.
5 These boundaries are preselected or predefined distances from various objects or lines.
6 In the embodiment shown in Figure 10, inflator module 1020 includes an inflator center line
7 1022. In some embodiments, a boundary is established based on inflator center line 1022.
8 In the embodiment shown in Figure 10, inflator center line boundary 1026 is defined as a
9 boundary that is parallel and spaced from inflator center line 1022. The distance can be
10 varied, however, any distance of about 30mm to 200mm can be used. In an exemplary
11 embodiment, inflator center line boundary 1026 is disposed about 70mm away from inflator
12 center line 1020 towards or into the passenger cabin of motor vehicle 100.

13 Inflator module 1020 can also include an edge 1024. In some embodiments, a
14 boundary is established based on inflator edge 1024. In the embodiment shown in Figure
15 10, inflator edge boundary 1028 is defined as a boundary that is vertical and horizontally
16 spaced from inflator edge 1024. The distance can be varied, however, any distance of
17 about 30mm to 200mm can be used. In an exemplary embodiment, inflator edge
18 boundary 1028 is disposed about 70mm away from inflator edge 1024 towards or into the
19 passenger cabin of motor vehicle 100.

20 In some embodiments, a boundary can be established based on windshield 1006.
21 In the embodiment shown in Figure 10, windshield boundary 1030 is defined as a
22 boundary that is roughly parallel to windshield 1006. The distance between windshield
23 1006 and windshield boundary 1030 can be varied, however, any distance of about 50mm
24 to 300mm can be used. In an exemplary embodiment, windshield boundary 1030 is
25 disposed about 100mm away from windshield 1006 towards or into the passenger cabin of
26 motor vehicle 100.

27 In some embodiments, a boundary can be established based on inflator lid 1004.
28 In the embodiment shown in Figure 10, the arc or range of motion of the inflator lid is
29 indicated by 1004. A lid boundary 1032 is defined as a locus of points equally spaced from
30 arc 1004 and disposed outward or away from inflator module 1020. The distance between
31 inflator lid 1004 and lid boundary 1032 can be varied, however, any distance of about 1mm
32 to 50mm can be used. In an exemplary embodiment, lid boundary 1032 is disposed about
33 10mm away from arc 1004 towards or into the passenger cabin of motor vehicle 100.

34 One or more of these various different boundaries can be used to establish NGZ
35 1002. In an exemplary embodiment, shown in Figure 10, all of the above boundaries are

1 used. However, other embodiments may use more or less boundaries to establish NGZ
2 1002.

3 Referring to Figure 6, if the hypothetical child passenger is clear of NGZ 1002, then
4 the process moves on to step 606. However, if the hypothetical child passenger does not
5 clear NGZ 1002, then the process moves to step 604.

6 Figure 7 is an enlarged view of step 604, and one or more of the modifications
7 shown in Figure 7 can be made to help motor vehicle 100 pass first test 602. One option
8 is to modify the Instrument Panel (IP) 1008 shape. The shape of IP 1008 can be extended
9 into the passenger cabin to help prevent entry of the hypothetical child in to NGZ 1002.
10 Another option is to modify the shape of first thigh bolster or first contact point. Another
11 option is to modify the passenger seat height and/or angle. One or more of these options
12 can be used to prevent the hypothetical child occupant from entering NGZ 1002.

13 Some of these modifications can be seen in Figure 13, which is a schematic
14 diagram of a motor vehicle interior and an out of position child 1302. Motor vehicle interior
15 includes a seat 1304. The forward edge 1306 of seat 1304 generally serves as the first
16 contact point for child 1302. As shown schematically in Figure 13, the location of forward
17 edge 1306 and/or the angle of seat 1304 can be modified to help motor vehicle 100 pass
18 first test 602.

19 After these modifications are made, the process returns to first test 602 until it has
20 been confirmed that the hypothetical child does not enter NGZ 1002.

21 After this has been confirmed, the process moves on to step 606, the second test,
22 where the process determines whether or not the kinematic arc of an average male
23 passenger will strike windshield 1006. Figures 11 and 12 are schematic diagrams of
24 examples demonstrating contact with windshield 1006 and clearance of windshield 1006,
25 respectively. In some cases, an AM50% crash test dummy (which stands for American
26 Male, 50 percentile) is used in second test 606. Referring to Figure 11, crash test dummy
27 1100 is in a first position 1102 prior to the collision and is in a second position 1104 after
28 the collision. As shown in Figure 11, crash test dummy 1100 contacts windshield 1006 in
29 second position 1104. It can also be observed that the pelvis 1105 of crash test dummy
30 1100 moves from a first position 1106 to a second position 1107 as indicated by arrow
31 1112 causing an excessive pelvic stroke during the collision. Both of these incidents are
32 not desirable and would cause the design shown in Figure 11 to fail second test 606.

33 Because the motor vehicle failed second test 606, the process would move to step
34 608 where stage two modifications can be made. Figure 8 is an enlarged view of step
35 608, and from Figure 8, there are preferably three available stage two modifications that
36 can be made. The Knee Bolster (K/B) 1108 can be moved; the windshield 1106 can be

1 moved forward and away from the occupant; and finally the stiffness of knee bolster 1108
2 can be adjusted. One or more of the stage two modifications can be made, and eventually
3 the goal is to design the motor vehicle to pass second test 606.

4 Figure 12 is a preferred embodiment of an example of a motor vehicle that passes
5 second test 606. In Figure 12, crash test dummy 1200 moves from a first position 1202
6 prior to the collision to a second position 1204 after the collision. It can be observed in
7 Figure 12, that crash test dummy 1200 clears windshield 1006 and no head contact with
8 windshield 1006 occurs. It can also be observed that re-designed knee bolster 1208 helps
9 to manage the motion of pelvis 1206 to acceptable levels.

10 After motor vehicle 100 passes second test 606, the process proceeds to third test
11 610 where an Out Of Position (OPP) child passenger is tested with a delayed firing
12 inflatable restraint. In a preferred embodiment, the firing delay is about 20 to 30
13 milliseconds. Again, like other tests, a C6Y (child, six year old) dummy can be used for
14 third test 610. If motor vehicle 100 fails third test 610, then the process moves to step
15 612, where stage three modifications, including tuning the passenger side inflatable
16 restraint can be made. After the inflatable restraint has been tuned, the process returns to
17 third test 610. Preferably, this is done until motor vehicle 100 passes third test 610.

18 After motor vehicle 100 passes third test 610, the process moves on to fourth test
19 614. Fourth test 614 determines whether motor vehicle 100 can protect occupants during
20 a frontal 40 km/h collision who are not wearing their seat belts. Preferably, both a
21 hypothetical male occupant and a hypothetical female occupant are tested in fourth test
22 614. In some embodiments, an AM50% crash test dummy (which stands for American
23 Male, 50 percentile) is used to model the behavior of a hypothetical male and an AF5%
24 crash test dummy (which stands for American Female 5 percentile) is used to model the
25 behavior of a hypothetical female occupant.

26 If motor vehicle 100 fails fourth test 614, then the process moves to step 616 where
27 stage four modifications can be made. Figure 9 is an enlarged view of step 616.
28 Preferably, stage four modifications include the optional modifications of tuning the
29 steering wheel and tuning the driver's side knee bolster.

30 In some embodiments, the size, shape, and collapsing stiffness of the steering
31 wheel can be varied to help protect the occupants. Also, in some embodiments, the
32 driver's side knee bolster can be repositioned and the stiffness of the driver's side knee
33 bolster can be tuned.

34 The passenger side knee bolster 1108 (see Figures 11 and 12) can only be
35 modified by stiffening knee bolster 1108. This is because any reduction in stiffness of
36 passenger side knee bolster 1108 would invalidate the results of second test 606.

1 Preferably, the process is designed so that no modification invalidates previous test
2 results. Like other steps, the stage four modifications are preferably tuned until motor
3 vehicle 100 passes fourth test 614.

4 After motor vehicle 100 passes fourth test 614, the process proceeds to fifth test
5 618. Fifth test 618 determines whether motor vehicle 100 can protect a male occupant
6 during a frontal 48 km/h collision when the male occupant is wearing his seat belt.
7 Preferably, a hypothetical male occupant is tested in fifth test 618 and in some
8 embodiments an AM50% crash test dummy (which stands for American Male, 50
9 percentile) is used to model the behavior of a hypothetical male occupant.

10 If motor vehicle 100 fails fifth test 618, then the process moves to step 620 where
11 stage five modifications can be made. Preferably, stage five modifications do not
12 invalidate any of the test results from any of the previous tests. In one embodiment, stage
13 five modifications include tuning the seat belt.

14 In some embodiments, the position, anchor points and/or tension of the seat belt
15 can be adjusted to help protect the male occupant. Like other steps, the stage five
16 modifications are preferably tuned until motor vehicle 100 passes fifth test 618.

17 One of the goals of method 600 is to avoid making a modification or adjustment
18 during a current test that would invalidate a previous successful test result. At this point in
19 the preferred embodiment of method 600, no other major modifications are available that
20 would not invalidate previous test results and any modification could invalidate a previous
21 successful test result. Therefore, there are no major modifications available for the
22 remaining tests and the process attempts to confirm that motor vehicle 100 passes the
23 next several tests.

24 After motor vehicle 100 passes fifth test 618, the process proceeds to sixth test
25 622, seventh test 624 and eighth test 626. Sixth test 622 determines whether motor
26 vehicle 100 can adequately protect a female occupant during a frontal 48 km/h collision
27 when the female occupant is wearing her seat belt. Preferably, a hypothetical female
28 occupant is tested in sixth test 622 and in some embodiments an AF5% crash test dummy
29 (which stands for American Female 5 percentile) is used to model the behavior of a
30 hypothetical female occupant.

31 Seventh test 624 determines whether motor vehicle 100 can protect a male
32 occupant during a collision with an angled barrier at 40 km/h when the male occupant is
33 not wearing his seat belt. Preferably, a hypothetical male occupant is tested in seventh
34 test 624 and in some embodiments an AM50% crash test dummy (which stands for
35 American Male, 50 percentile) is used to model the behavior of a hypothetical male
36 occupant.

1 Eighth test 626 determines whether motor vehicle 100 can adequately protect a
2 female occupant during a collision with an offset barrier at 40 km/h when the female
3 occupant is wearing her seat belt. Preferably, a hypothetical female occupant is tested in
4 eighth test 626 and in some embodiments an AF5% crash test dummy (which stands for
5 American Female 5 percentile) is used to model the behavior of a hypothetical female
6 occupant.

7 Again, because no major modifications are available, the process determines if
8 motor vehicle 100 passes sixth test 622, seventh test 624 and eighth test 626. If motor
9 vehicle 100 passes all of those tests, then the process proceeds to step 628 where the
10 process concludes that motor vehicle 100 is qualified to use new firing map 300.

11 If motor vehicle 100 fails any one of the last three tests, then the process returns to
12 a previous stage of modification. In some embodiments, this previous stage of
13 modification can be determined by considering which modification would assist motor
14 vehicle 100 in passing the failed test. Preferably, the highest stage of modification is
15 selected with a goal of minimizing the number of tests that are invalidated. In other
16 embodiments, this previous stage of modification is predetermined and the process moves
17 to a certain predetermined modification stage if motor vehicle 100 fails any of the last three
18 tests. In a preferred embodiment, the process moves to third test 610 if motor vehicle 100
19 fails any of the last three tests.

20 Although, it is preferred that the inflatable restraint include only two deployment
21 modes, a first mode where the inflatable restraint does not deploy and a second mode
22 where the inflatable restraint is deployed with a delay, it is possible to provide
23 embodiments where a simultaneous deployment mode is used at some speed greater than
24 48 km/h. If a simultaneous deployment mode is used, it is preferred that the transition
25 zone between the simultaneous deployment mode and any adjacent mode would not
26 overlap with any regulation zone.

27 Using principles disclosed above, it is possible to provide a simplified inflatable
28 restraint system that has more predictable characteristics, improved safety and the
29 operation of which is easier to test and validate.

30 Each of the various components or features disclosed can be used alone or with
31 other components or features. Each of the components or features can be considered
32 discrete and independent building blocks. In some cases, combinations of the
33 components or features can be considered a discrete unit.

34 While various embodiments of the invention have been described, it will be
35 apparent to those of ordinary skill in the art that many more embodiments and

1 implementations are possible that are within the scope of the invention. Accordingly, the
2 invention is not to be restricted except in light of the attached claims and their equivalents.

3 **Industrial Applicability**

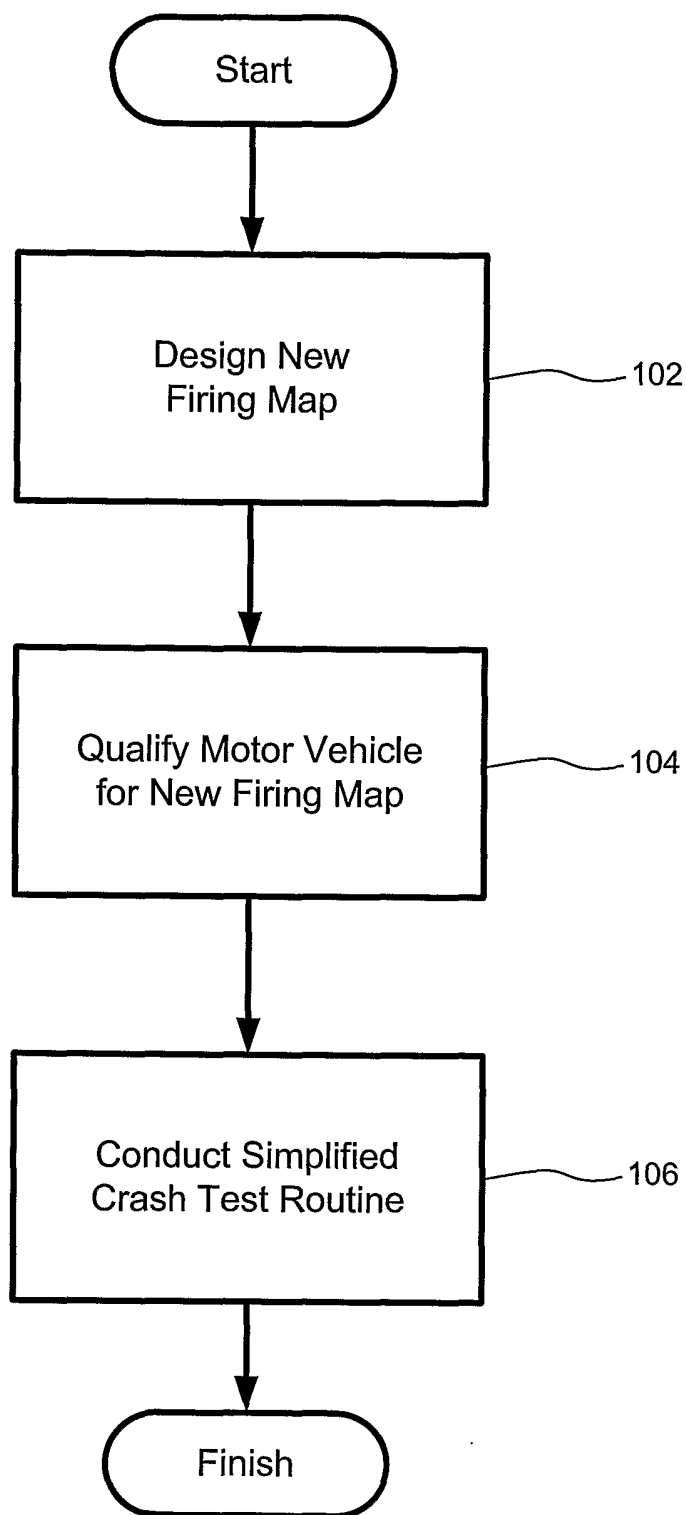
4 The present invention can be used to assist in conducting crash tests for motor
5 vehicles. In one example, the present invention can be used to design a crash test
6 regimen or crash test plan.

CLAIMS

1. A method of deploying an inflatable restraint wherein a single deployment pattern is used throughout at least one government regulation zone.
2. The method according to claim 1, wherein a single deployment pattern is used throughout every government regulation zone.
3. The method according to claim 1, wherein the government regulation zone extends from 32 km/h to 40 km/h.
4. The method according to claim 3, wherein the single deployment pattern is a delayed deployment pattern.
5. The method according to claim 1, wherein a second government regulation zone extends from 0 km/h to 48 km/h.
6. The method according to claim 5, wherein a second deployment pattern is used throughout the second government regulation zone.
7. The method according to claim 6, wherein a second deployment pattern is substantially similar to the single deployment pattern.
8. A method of deploying an inflatable restraint having at least one transition zone is disposed between a first deployment pattern and a second deployment pattern;
wherein the transition zone includes probabilities of deploying the inflatable restraint using either the first deployment pattern or the second deployment pattern; and
wherein a government regulation zone is separated from every transition zone.
9. The method according to claim 8, wherein the transition zone includes a lower end and an upper end and wherein the government regulation zone includes a lower end and an upper end; and wherein the upper end of the transition zone is less than the lower end of the government regulation zone.

- 1 . 10. The method according to claim 8, wherein the second deployment pattern is a delay
2 deployment pattern.
- 3 11. The method according to claim 8, wherein first deployment pattern is a no deploy
4 pattern.
- 5 12. A method of crash testing a motor vehicle wherein a first crash test validates the
6 results for an entire government regulation zone.
- 7 13. The method according to claim 12, wherein the first crash test is conducted at a speed
8 corresponding to an upper end of the government regulation zone.
- 9 14. A method of simultaneously deploying an inflatable device comprising the steps of:
10 determining that a first charge configured to inflate the inflatable device;
11 deploying the inflatable device using the first charge;
12 providing a delay;
13 determining whether a second charge configured to inflate the inflatable device
14 should be deployed; and
15 using the second charge in conjunction with the first charge if the inflatable device
16 should be deployed.
- 17 15. The method according to claim 14, wherein the second charge has less power than
18 the first charge.
- 19 16. The method according to claim 14, wherein the delay is about 0 to 10 milliseconds.
- 20 17. The method according to claim 14, wherein the delay is about 5 milliseconds.
- 21 18. The method according to claim 14, wherein information from a sensor is retrieved
22 during the delay.
- 23 19. The method according to claim 14, wherein an additional computation is made during
24 the delay.

- 1 20. The method according to claim 14, wherein the step of determining whether a second
- 2 charge configured to inflate the inflatable device should be deployed, is made during the
- 3 delay.

**Figure 1**

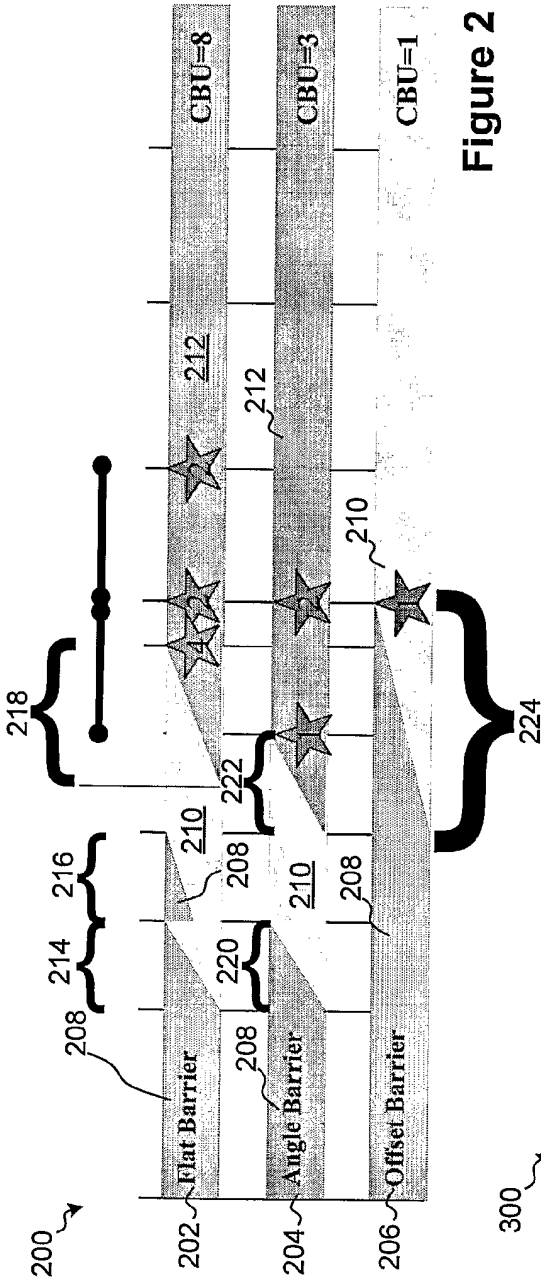


Figure 2

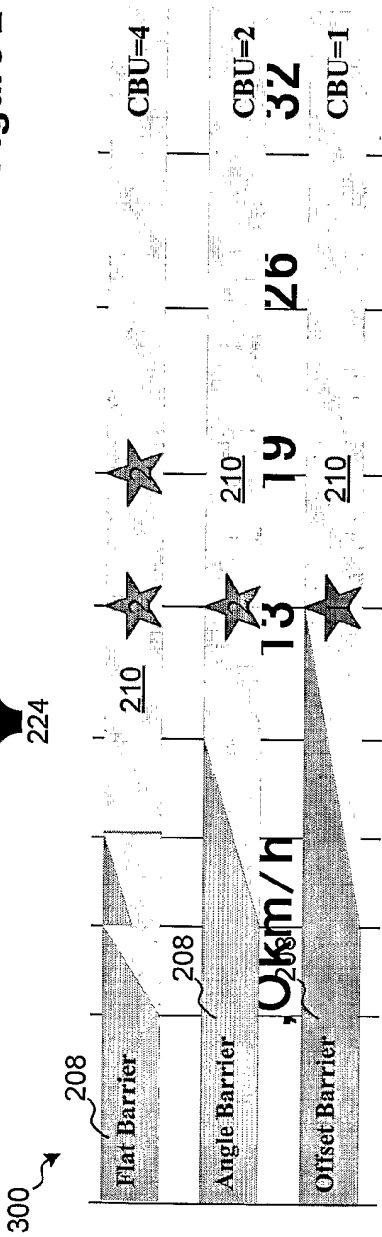


Figure 3

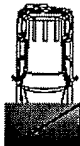
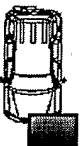
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			Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay
Flat Barrier No Belt 	AF5	DR	★	①	★	★	★	★	③	★				
	AM50	PA			★			★	④	★				
Flat Barrier Belted 	AF5	DR	★	⑤	★	★			★	⑦				
	AM50	PA	★	⑥	★	★			★	⑧				
Angle Barrier No Belt 	AM50 R30	DR					★	⑨						
	AM50 L30	PA					★	★						
ODB Belted 	AF5	DR	★	⑫	★	★	★	★	⑩	★				
	AM50	PA	★						⑪	★				
		DR												
		PA												

Figure 4

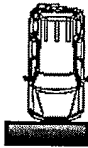
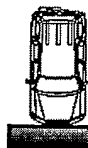
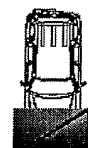
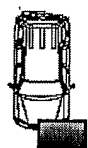
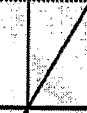
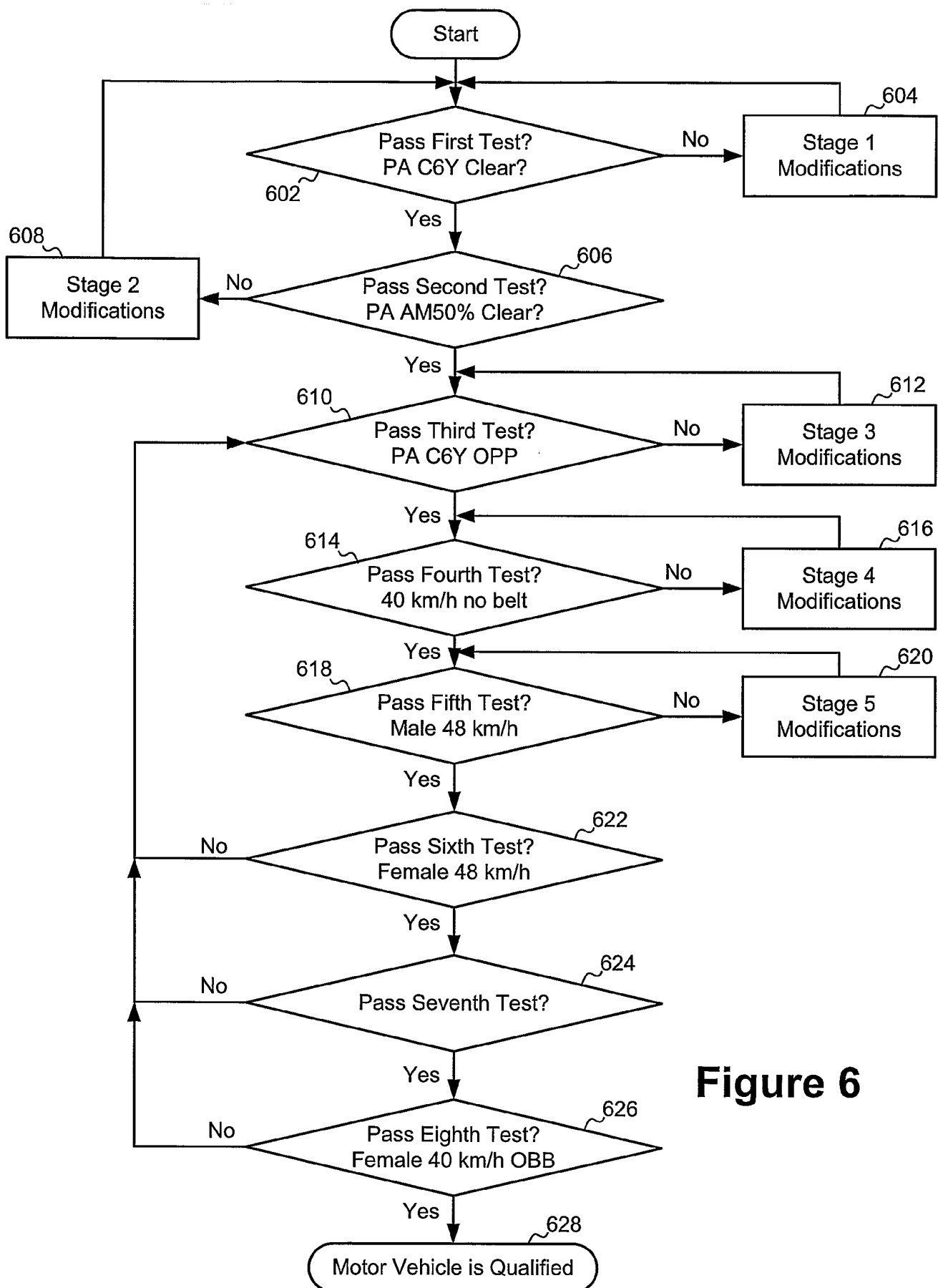
208 Test Matrix			32km/h		37km/h		40km/h		48km/h		56km/h		64km/h	
			Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay	Delay	No Delay
Flat Barrier No Belt 	AF5	DR												
Flat Barrier Belted 	AF5	DR												
Angle Barrier No Belt 	AM50 R30	DR												
ODB Belted 	AF5	DR												
	AM50	DR												
		PA												
		PA												
		PA												
		PA												

Figure 5

**Figure 6**

6/9

604

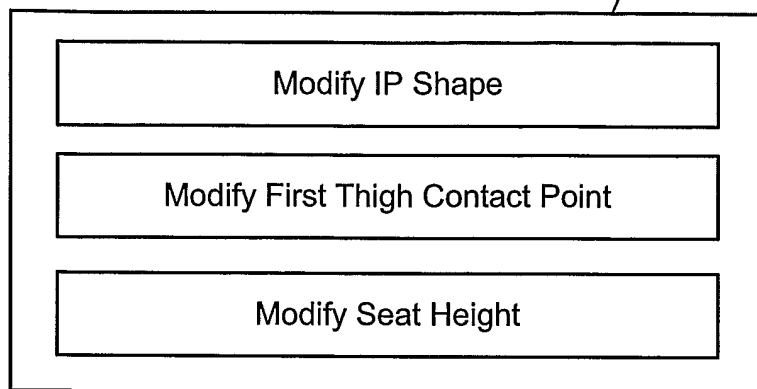


Figure 7

608

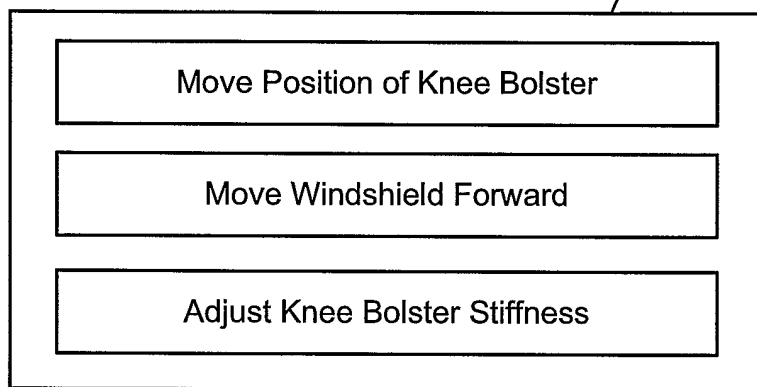


Figure 8

616

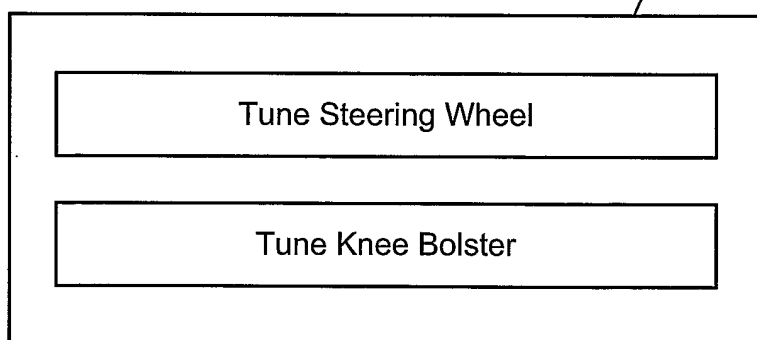


Figure 9

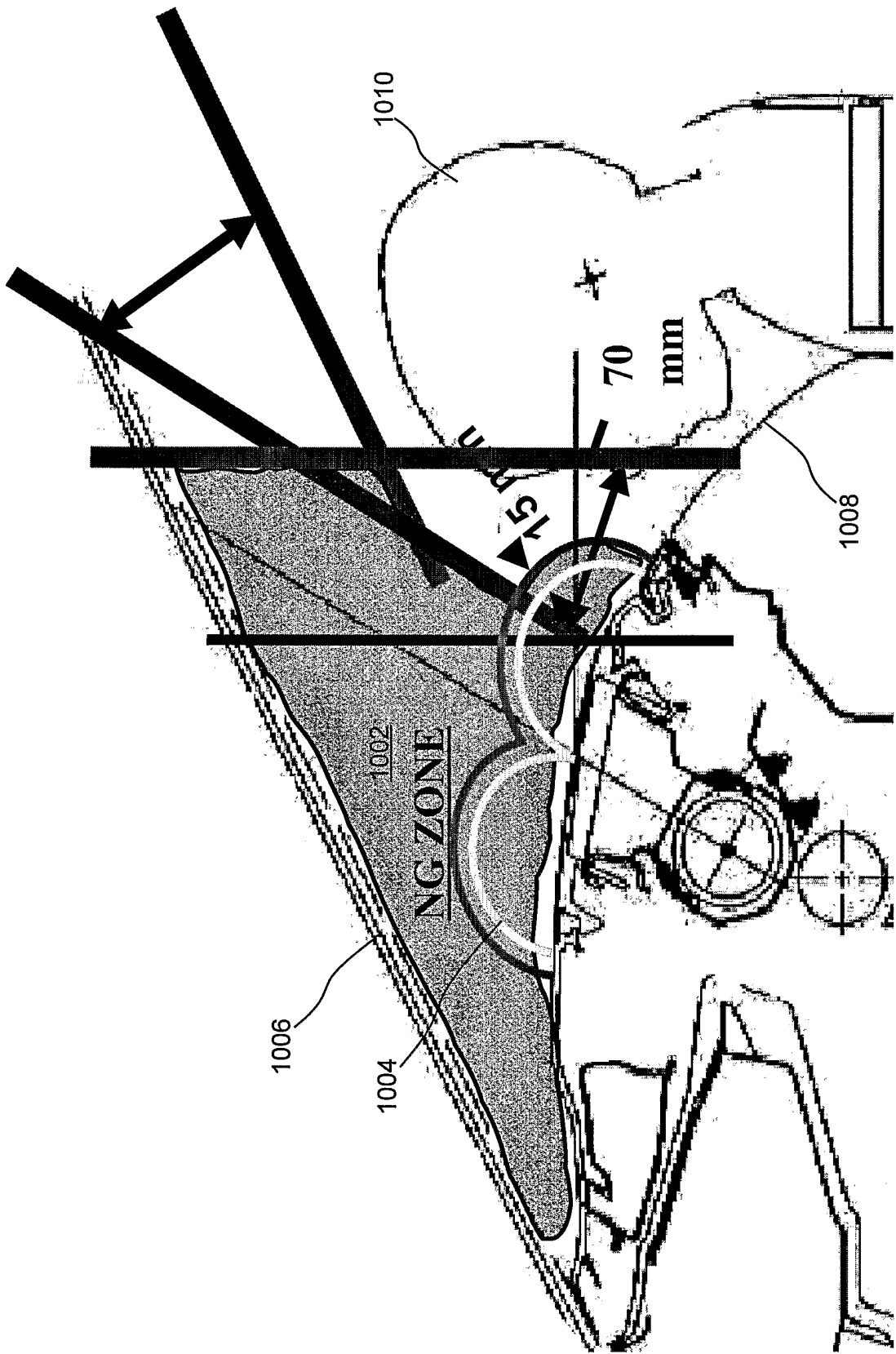


Figure 10

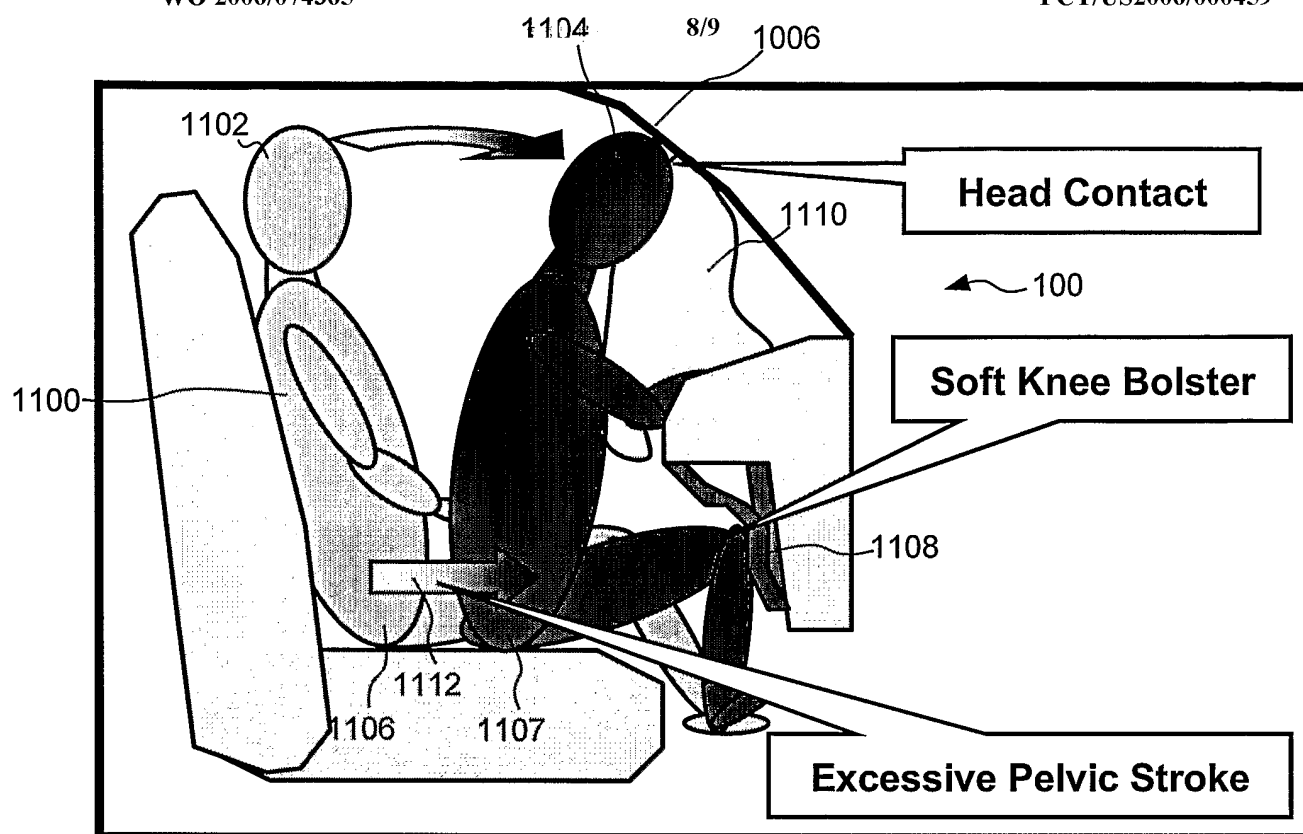


Figure 11

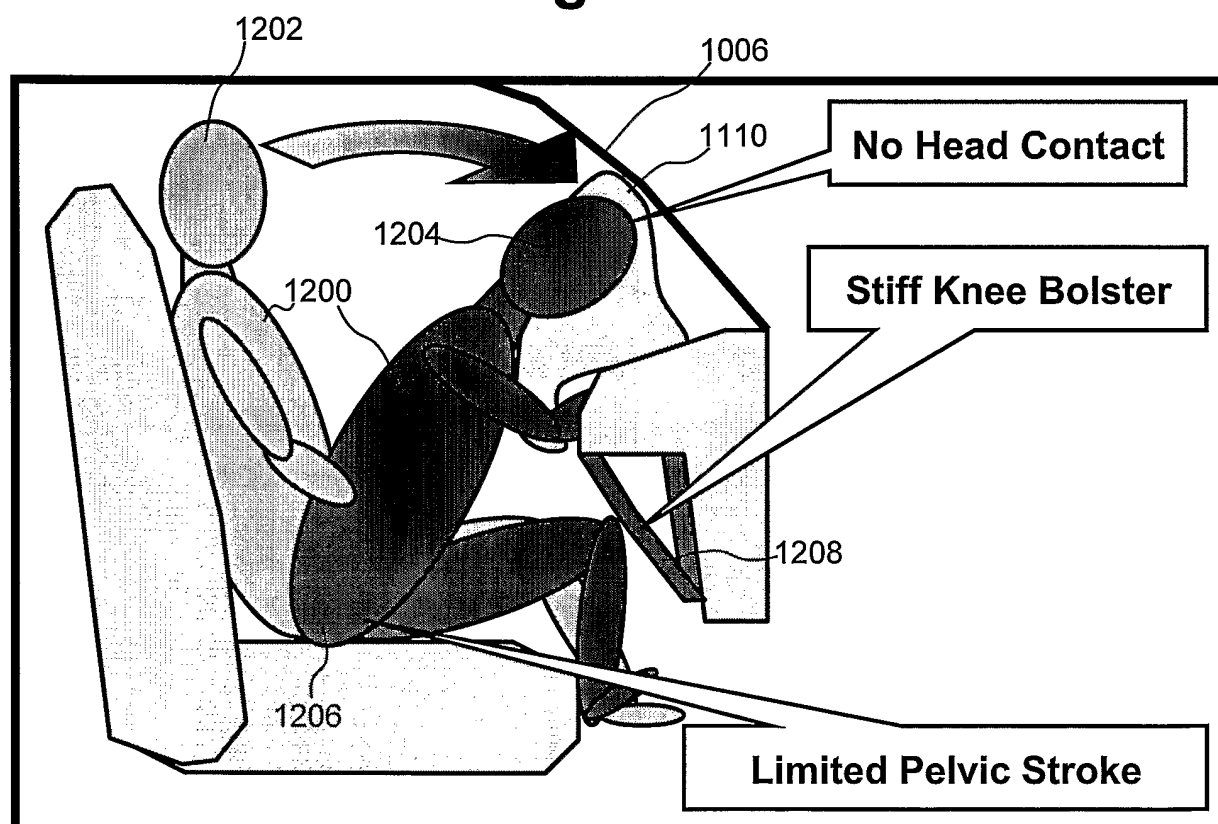


Figure 12

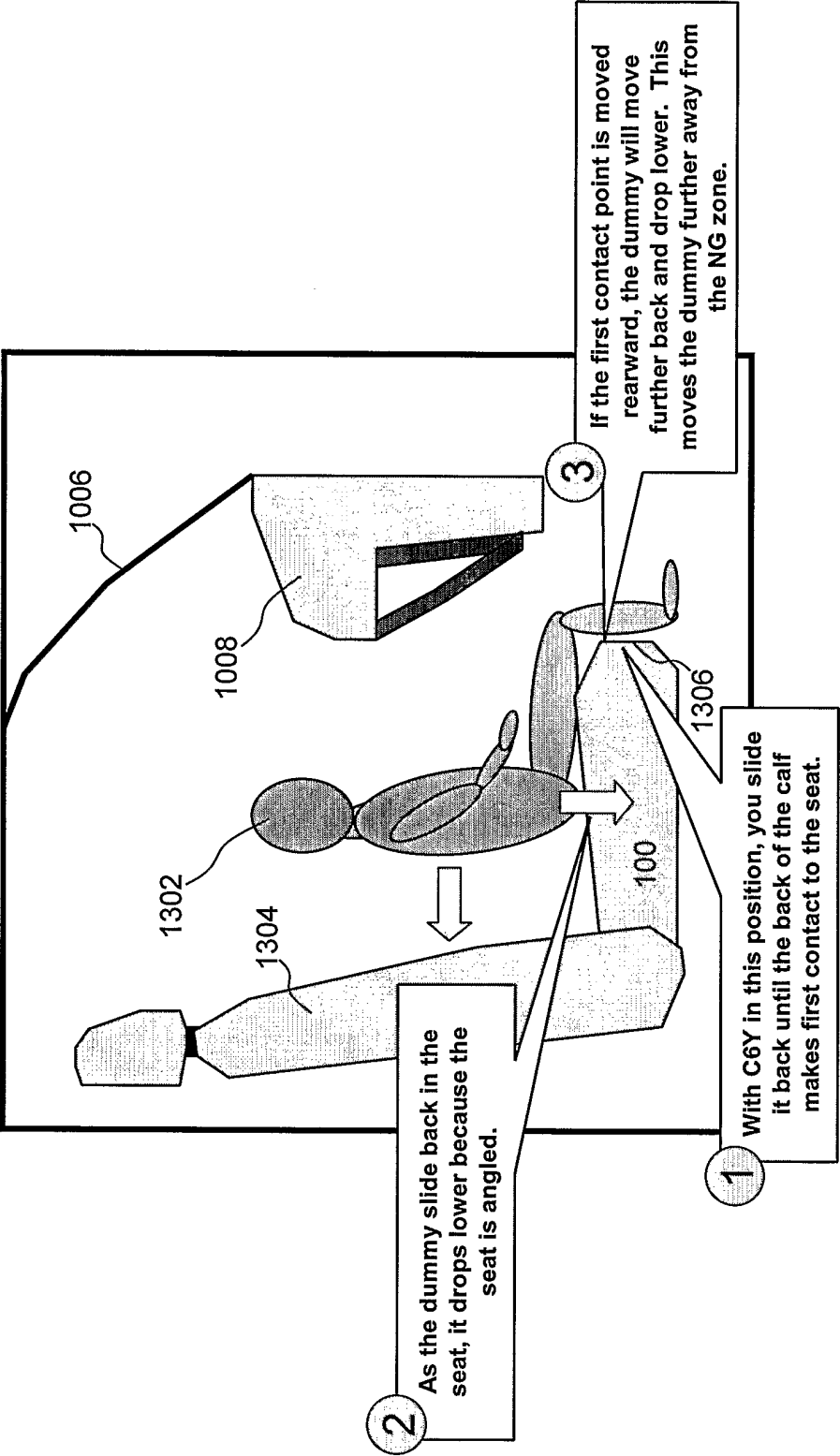


Figure 13