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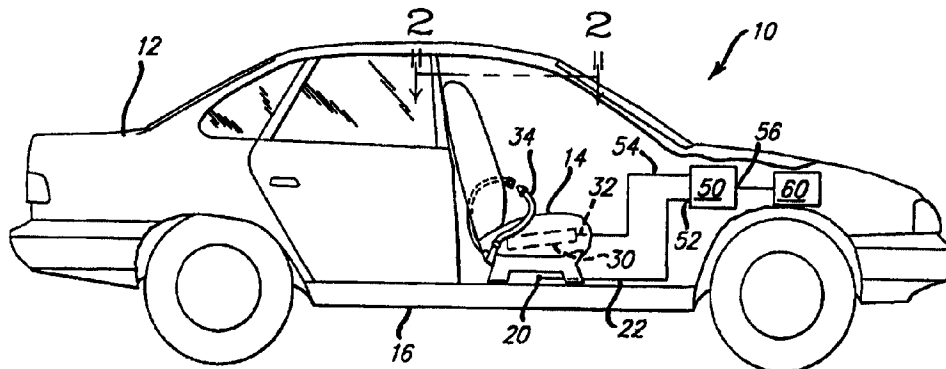
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(54) **SYSTEME DE PREDICTION DE LA TENSION D'UNE CEINTURE DE SECURITE COMPRENANT UN ACCELEROMETRE MONTE SUR LE CADRE DU SIEGE ET UN DETECTEUR DE MASSE**
(54) **SEAT BELT TENSION PREDICTION SYSTEM USING AN ACCELEROMETER MOUNTED TO THE SEAT FRAME AND A WEIGHT SENSOR**

(57) Un système et un procédé de prédiction de la tension d'une ceinture de sécurité comprennent un accéléromètre (20) dont un signal de sortie réagit à une accélération verticale du véhicule, un détecteur de masse (30) dont un signal de sortie réagit à la force exercée par une masse située sur le siège, et un processeur (50) qui calcule la tension de la ceinture de sécurité. Le processeur est pourvu d'une pluralité d'entrées qui sont couplées de manière opérationnelle aux sorties de l'accéléromètre et du détecteur de masse. Une programmation appropriée

(57) A vehicle seat belt tension prediction system and method comprises an accelerometer (20) having an output signal responsive to vertical acceleration of the vehicle, a seat weight sensor (30) having an output signal responsive to the force exerted by a mass resting on the seat, and a processor means (50) for calculating seat belt tension. The processor is provided with a plurality of inputs operatively coupled to the accelerometer output and seat weight sensor output. Suitable programming is provided to instruct the processor (50) to calculate the

est prévue pour donner ordre au processeur (50) de calculer la masse moyenne située sur le siège du véhicule et prédire la force qui devrait s'exercer sur le siège pour un niveau mesuré d'accélération verticale supposant une tension de ceinture nulle. Le processeur (50) compare ensuite la force réelle mesurée par le détecteur de masse (30) du siège à la force prédite pour déterminer la tension de la ceinture de sécurité, ceci éliminant le matériel complexe se trouvant en contact physique avec le système de ceinture de sécurité.
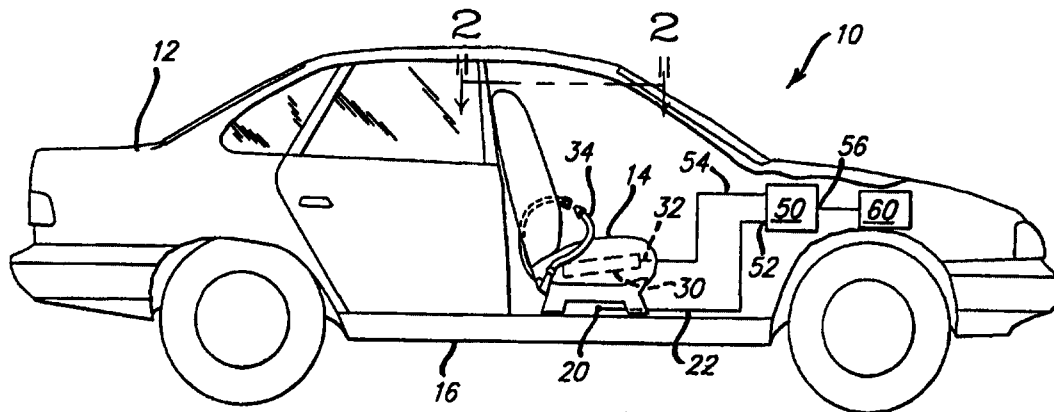
average mass resting on the vehicle seat and predict the force that should be exerted on the seat for a measured level of vertical acceleration assuming zero belt tension. The processor (50) then compares the actual force measured by the seat weight sensor (30) with the predicted force to determine seat belt tension thereby obviating the necessity of complex hardware in physical contact with the seat belt system.

PCT

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(54) Title: SEAT BELT TENSION PREDICTION SYSTEM USING AN ACCELEROMETER MOUNTED TO THE SEAT FRAME AND A WEIGHT SENSOR

(57) Abstract

A vehicle seat belt tension prediction system and method comprises an accelerometer (20) having an output signal responsive to vertical acceleration of the vehicle, a seat weight sensor (30) having an output signal responsive to the force exerted by a mass resting on the seat, and a processor means (50) for calculating seat belt tension. The processor is provided with a plurality of inputs operatively coupled to the accelerometer output and seat weight sensor output. Suitable programming is provided to instruct the processor (50) to calculate the average mass resting on the vehicle seat and predict the force that should be exerted on the seat for a measured level of vertical acceleration assuming zero belt tension. The processor (50) then compares the actual force measured by the seat weight sensor (30) with the predicted force to determine seat belt tension thereby obviating the necessity of complex hardware in physical contact with the seat belt system.

SEAT BELT TENSION PREDICTION SYSTEM USING AN ACCELEROMETER MOUNTED TO THE SEAT FRAME AND A WEIGHT SENSOR

CROSS REFERENCE TO RELATED APPLICATIONS

The instant application claims the benefit of copending U.S.

5   Provisional Application Serial No. 60/046,233, filed May 12, 1997.

Co-pending U.S. Application Serial No. 08/993,701 entitled "Seat Weight Sensor Having Fluid Filled Bladder", filed on December 18, 1997, claiming benefit of U.S. Provisional Application Serial No. 60/032,380 filed on December 19, 1996, and assigned to the assignee

10   of the instant invention discloses a hydrostatic weight sensor comprising a fluid filled bladder and a pressure sensor for sensing the weight of an occupant in a vehicle seat for controlling a safety restraint system. U.S. Application Serial No. 08/993,701 also discloses a load distributor for distributing loads across the load bearing surface of the

15   hydrostatic weight sensor. U.S. Application Serial No. 08/993,701 and U.S. Provisional Application Serial No. 60/032,380 are incorporated herein by reference.

Co-pending U.S. Application Serial No. 09/003,672 entitled "Automotive Seat Weight Sensing System", filed on January 7, 1997,

20   claiming benefit of U.S. Provisional Application Serial No. 60/034,018 filed on January 8, 1997, and assigned to the assignee of the instant invention discloses a seat weight sensing system comprising a plurality of hydrostatic weight sensors each of which is in accordance with U.S. Application Serial No. 08/993,701. U.S. Application Serial No.

25   09/003,672 and U.S. Provisional Application Serial No. 60/034,018 are incorporated herein by reference.

Co-pending U.S. Application Serial No. 09/003,870 entitled "Vehicle Seat Sensor Having Self-Maintaining Air Bladder", filed on January 7, 1997, claiming benefit of U.S. Provisional Application Serial

30   No. 60/035,343 filed on January 16, 1997, and assigned to the
      assignee of the instant invention discloses an apparatus for
      automatically maintaining the supply of sensing fluid in a hydrostatic
      weight sensor. U.S. Application Serial No. 09/003,870 and U.S.
      Provisional Application Serial No. 60/035,343 are incorporated herein by
35   reference.
            Co-pending U.S. Application Serial No. 09/003,868 entitled "Seat
      Weight Sensor with Means for Distributing Loads", filed on January 7,
      1997, claiming benefit of U.S. Provisional Application Serial No.
      60/058,084 filed on September 4, 1997, and assigned to the assignee
40   of the instant invention discloses a load distributor for distributing
      sensed load across the load bearing surface of a hydrostatic weight
      sensor. U.S. Application Serial No. 09/003,868 and U.S. Provisional
      Application Serial No. 60/058,084 are incorporated herein by reference.
            Co-pending U.S. Application Serial No. 09/003,673 entitled "Seat
45   Weight Sensor Having Self-Regulating Fluid Filled Bladder", filed on
      January 7, 1997, claiming benefit of U.S. Provisional Application Serial
      No. 60/058,119 filed on September 4, 1997, and assigned to the
      assignee of the instant invention discloses a hydrostatic weight sensor
      having a means for automatically regulating the amount of sensing fluid
50   therein. U.S. Application Serial No. 09/003,673 and U.S. Provisional
      Application Serial No. 60/058,119 are incorporated herein by reference.
            Co-pending U.S. Application Serial No. 09/003,746 entitled "Seat
      Weight Sensor Using Fluid Filled Tubing", filed on January 7, 1997,
      claiming benefit of U.S. Provisional Application Serial No. 60/065,986
55   filed on November 14, 1997, and assigned to the assignee of the instant
      invention discloses a hydrostatic weight sensor incorporating a fluid
      filled tube. U.S. Application Serial No. 09/003,746 and U.S. Provisional
      Application Serial No. 60/065,986 are incorporated herein by reference.
            Co-pending U.S. Application Serial No. 09/003,744 entitled "Low
60   Profile Hydraulic Seat Weight Sensor", filed on January 7, 1997,
      claiming benefit of U.S. Provisional Application Serial No. 60/065,832

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filed on November 14, 1997, and assigned to the assignee of the instant

invention discloses a hydrostatic weight sensor constructed from plates

or sheets of semi-rigid material and filled with a liquid, grease, Bingham

65   fluid or thixotropic material. U.S. Application Serial No. 09/003,744

and U.S. Provisional Application Serial No. 60/065,832 are incorporated

herein by reference.

TECHNICAL ART

The instant invention relates generally to automotive passenger

5   restraint systems and more specifically to a system and method for

predicting seatbelt tension in a vehicle utilizing a seat weight sensor and

an accelerometer.

BACKGROUND OF THE INVENTION

Automotive manufacturers and the National Highway

5   Transportation Safety Association are investigating methods to disable

vehicle air bags in situations where they may cause more harm than

good. Typically, airbags have been developed to deploy with enough

force to restrain a 175 lb. adult in a high velocity crash. Deployment of

the same air bags when children are seat occupants may cause serious

10   injury due to the force generated upon inflation of the bag.

As a result, seat weight sensors and systems are being developed

in an attempt to determine when the passenger seat occupant is a child.

Such systems should identify when the occupant is small, or even

15   when a child is in a rear facing infant seat, a forward facing child seat

or a booster seat. Occupant weight measurement when a child seat is

present is further complicated by the downward force applied to the

child seat by the tension of a seat belt. When a child seat is strapped

tightly, the seat belt forces the child seat into the vehicle seat and can

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20   often artificially increase the measured weight, which may lead to air
bag deployment when children or infants are present in the seat.

A variety of methods have been used for seat belt tension
measurement. Copending U.S. Provisional Application Serial No.
25   60/067,071 entitled "Villari Effect Seat Belt Tension Sensor", and
copending U.S. Provisional Application Serial No. 60/070,319 entitled
"Compressive Villari Effect Seatbelt Tension Sensor", both assigned to
the assignee of the instant invention, disclose two seat belt tension
measurement systems utilizing sensors that operate on the principle
30   known as the Villari effect. The Villari effect refers to the tendency of
certain materials with magnetostrictive properties to inhibit or enhance
the strength of an electromagnetic field within the material when the
material is being subjected to compression or tensile stress. By
measuring the field strength in magnetostrictive material placed in line
35   with a seat belt mechanism, for example in a seat belt latch or a seat
belt retractor, the relative tension in the belt may be calculated.

Furthermore, belt deflection techniques which guide a seat belt
through a mechanical system that forces the belt out of a straight line
40   when there is low tension have been used. Under high tension the seat
belt forces the displacement of a mechanical deflector. This force may
then be sensed utilizing an electromechanical switch. Tension
measurement mechanisms have also been incorporated in the buckle of
the seat belt. In one embodiment, a sliding buckle is biased back with a
45   spring. When the belt is under heavy tension, the buckle pulls forward
to control a switch that provides feedback to a vehicle processor.

The aforementioned seat belt tension measurement methods suffer
from a number of disadvantages. Initially, a great number of additional
50   parts are required for seat belt retractors or buckle configurations. This
adds complexity (and therefore cost) to vehicle assembly and provides

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for considerable difficulty in retrofitting existing vehicles. Additionally,
several of the aforementioned tension systems provide only a threshold
level of tension detection.

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The present invention may be used to detect whether the seat belt
is under high tension thereby denoting that an infant seat is present.
Furthermore, significant tension in the belt can be predicted without
resorting to the complex instrumentation required to measure actual belt

60   tension. Known belt tension measurement systems that directly contact the
seat belt require additional hardware and sensors that increase component count
and vehicle assembly complexity.

SUMMARY OF THE INVENTION

The instant invention overcomes the aforementioned problems by
5   providing a seat belt tension prediction system employing an
accelerometer and a seat weight sensor to accurately determine the
tension in a vehicle seat belt and thereby discriminate between the
presence of a tightly belted child seat or other object and an adult
occupant.

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The instant invention measures the "bounce", or vertical
acceleration, experienced by a weight on a seat weight measurement
means by monitoring an accelerometer that is rigidly mounted to the
vehicle seat. The bounce can be thought of as the temporary

15   acceleration of the weight on the seat caused by the vehicle traversing
bumps or holes in the road. This road-induced bounce causes
oscillations in the force acting upon the seat that may be measured by a
seat weight sensor.

20   A "free" or unbelted mass positioned on a vehicle seat will bounce
up and down on the seat and may, for example, completely lose contact

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with the seat in extreme cases. The weight sensor would correspondingly interpret this extreme case as a "spike" of zero force acting on the seat. Usually, however, the output signal produced by the

25 weight sensor will oscillate with a small amplitude that is dependent upon the total mass acting upon the seat and the amplitude of the road-induced vehicle bounce. When the force acting downwardly on the seat is increased due to the tension in a tight seat belt, the amplitude of oscillation of an output signal produced by the weight sensor will be

30 reduced because a component of the force caused by the tension in the seatbelt is constant. Accordingly, a seatbelt tension may be calculated by determining the vertical acceleration of the vehicle and the variation in force exerted on the seat as measured by the seat weight sensor.

35   A conventional accelerometer provides an electrical signal proportional to the vertical acceleration that the seat, and therefore the mass in the seat, experiences. When actual vertical acceleration is compared to the oscillating output signal produced by the weight sensor, a measure of the force on the seat attributable to the tension in

40 the seat belt may be calculated. The road-induced vertical acceleration acting on the vehicle is used to predict the amount of force exerted downwardly on the seat given that no seat belt tension is present.

     A conventional microprocessor is adapted to accept output signals

45 from the accelerometer and the seat weight sensor. The accelerometer output is responsive to the amount of vertical acceleration caused by road bounce acting on the vehicle seat and the weight sensor output is responsive to the amount of force exerted downwardly on the vehicle seat.

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     A normalized measurement of seatbelt tension may be calculated by the processor by first calculating an average mass on the seat using the weight sensor output. The expected variation in force is then

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calculated by multiplying the aforementioned average mass on the seat

55 by the actual acceleration as measured by the accelerometer over a
predetermined time period. A normalized seatbelt tension may then be
calculated by dividing the variation in force as measured by the seat
weight sensor over a predetermined time period by the expected or
calculated variation in force over the aforementioned period.

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The resultant scalar tension measure will approximate unity for
unbelted or loosely belted occupant situations where the mass acting on
the seat is free to travel vertically. Accordingly, the normalized tension
scalar will decrease when extremely high belt tension is present thereby

65 forcing the mass onto the seat.

Alternatively, the processor may calculate an expected force
exerted on the seat due to road-induced vehicle bounce at discrete time
intervals, assuming that no belt tension exists, and compare the results

70 with the measured force exerted on the seat at the each discrete point
in time. The ratio between the measured force and the calculated or
expected force exerted on the seat provides an indication of belt
tension.

75   Known seat weight sensors may comprise one or more pads
employing force sensitive resistive (FSR) elements disposed within the
seat to provide a weight measurement. These arrangements are
typically used as weight threshold systems that are used in conjunction
with a processor to disable a passenger air bag when the seat is empty.

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Conventional load cells attached to the seat mounting posts have
also been used in research applications. The use of load cells as weight
measurement means in the instant invention requires that the seatbelts
or passenger restraints are not mounted directly to the vehicle seat

85 because a load cell system that weighs the entire seat and its contents

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including the seatbelts and their mounting points will not be responsive
to the force applied to the seat by the tension in the seatbelt.

90   Mechanisms employing string actuated potentiometers to measure
downward seat displacement have also been utilized as weight
measurement means. In these mechanisms, a weight resting upon a
seat pad causes the pad to sag or curve downwardly, thereby displacing
a string that is positioned across the bottom of the seat pad. One end
of the string is connected to a potentiometer shaft that is rotated when
95   the string is displaced. The rotation of the potentiometer shaft causes
the resistance at the potentiometer output to change. A processor is
adapted to measure the changing resistance at the potentiometer
output, thereby providing a signal proportional to string displacement,
and therefore, the force caused by a mass present on the seat.
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        Copending U.S. Application Serial No. 08/993,701 further
discloses a weight sensor employing a gas filled bladder disposed within
the seat pad to calculate seat weight. When a load is applied to the
seat a differential pressure sensor operatively coupled to the bladder
105   generates a signal that is responsive to the pressure on the fluid within
the bladder and therefore indicative of the force acting upon the seat. A
signal processor having an input operatively coupled to the pressure
sensor then calculates the force exerted on the seat as well as the mass
present.
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        By determining the amount of mass present in a vehicle seat and
the amount of tension present in a passenger restraint belt, corrective
action may be taken to further protect a vehicle occupant by adapting
other restraint system components, such as the air bag control system.
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        The ability to sense the tension present in a seat belt may be used
in conjunction with a seat weight sensor to determine the presence of

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an occupant in a vehicle seat and the relative size of the occupant. This
information may be used either to deactivate seatbelt pretensioners,
120   and/or modify the inflation profile of an air bag.

Furthermore, by sensing the amount of tension present in the seat
belt, the deployment of an airbag may be inhibited in the presence of
infant seats or in situations where occupants are small so as to reduce
125   their risk of injury from the inflating air bag. Therefore, a system that
can reliably predict the amount of tension present in a seat belt may be
used to great advantage in vehicle safety systems.

One significant advantage of the instant invention is that it does
130   not require numerous ancillary components that are in direct contact
with the seat belt system. The present invention can predict whether
there is significant tension in the seat belt without directly measuring
seat belt tension.

135   Therefore, one object of the instant invention is to provide a seat
belt tension measurement system that does not require a mechanism in
direct contact with the seat belt or its associated assembly.

Another object of the instant invention is to use road-induced
140   vertical acceleration exerted on every vehicle as a forcing function for a
seat weight sensor signal. The oscillation of an accelerometer signal
compared with the oscillation of a weight sensor signal at discrete time
intervals provides the data required to calculate seat belt tension.

145   A yet further object of the present invention is to provide a seat
belt tension prediction system that requires minimal additional
components beyond a seat weight measurement means and the
attendant processor adapted to receive and process various vehicle
instrumentation signals. The instant invention requires only an

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150   accelerometer or equivalent acceleration sensing device and a
conventional microprocessor or equivalent processing means in
conjunction with a seat weight sensor to accurately calculate seat belt
tension.

155   A yet further object of the instant invention is to provide a seat
belt tension prediction system that is useful in determining the presence
of an infant seat in a vehicle. The present invention measures the
component of force acting on a vehicle seat that is attributable to
tension in the seat belt as well as the component of force attributable to
160   the presence of a mass on the seat, thereby providing a means to
predict whether the occupant is an adult or a child.

The instant invention will be more fully understood after reading
the following detailed description of the preferred embodiment with
165   reference to the accompanying drawings. While this description will
illustrate the application of the instant invention in an automotive safety
restraint system, it will be readily understood by one of ordinary skill in
the art that the instant invention may also be utilized in other tension
measurement systems.
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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatical view of a preferred embodiment of the instant
invention.

5   Fig. 2 is a diagrammatical view of an alternative seat weight sensor arrangement
taken along the line 2-2 of Fig. 1.

Fig. 3 is a diagrammatical view of an alternative embodiment of the instant
invention.

Fig. 4 is a diagrammatical view of an alternative embodiment of the instant
10   invention.

Fig. 5 is a view of the instant invention taken along the line 5-5 of Fig. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to Fig. 1, a seat belt tension prediction **system and
method 10** for a **vehicle 12** having a **seat 14** is comprised of an
5   **accelerometer 20** and a seat **weight sensor 30**. The **accelerometer 20** is
provided with an **output signal 22** that is responsive to the amount of
vertical acceleration acting upon the **vehicle 12** and, therefore, on the
vehicle **seat 14**. The **accelerometer 20** must be rigidly secured to a
vehicle **structural member 16** that experiences the same vertical
10   acceleration that the vehicle **seat 14** is subjected to when traversing
variations in terrain. In a preferred embodiment of the instant invention
the resolution of the **accelerometer 20** is greater than .005 g to provide
sufficient sensitivity to small variations in vertical acceleration.

15   The seat **weight sensor 30** is provided with an **output signal 32**
that is responsive to the amount of force exerted downwardly on the
vehicle **seat 14**. Accordingly, the seat weight sensor **output signal 32**
will also be responsive to additional force upon the vehicle **seat 14**
exerted by tension in a **seat belt 34**. The **output signal 32** from the
20   **weight sensor 30** must have an update period small enough to allow the
weight sensor 30 to sense oscillations in force on the **seat 14** caused by
the vehicle's vertical acceleration. In a preferred embodiment of the
instant invention the update period of the weight sensor **output signal
32** is less than 25 milliseconds. Additionally, the weight sensor **output
25   signal 32** may be AC coupled to filter low frequency signal oscillations
that normally occur as a result of occupant movement, thus ignoring
those oscillations that are not produced by road-induced vertical
acceleration.

30   Furthermore, a **processor 50** is provided, having a first **input 52**
operatively coupled to the **accelerometer output signal 22** and a second

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input **54** operatively coupled to the seat **weight sensor output signal 32.**
The **processor 50** is further operatively coupled to a vehicle **airbag**
control system 60 whereby the **processor 50** may provide an **output**

35 **signal 56,** or a plurality thereof, to the **airbag control system 60** to
inhibit deployment of an airbag and/or to modify its inflation profile.

The **processor 50** may comprise an analog or digital
microprocessor or any equivalent thereof. Although the preferred

40 embodiment of the instant invention utilizes a conventional digital
microprocessor, it is readily understood by one having ordinary skill in
the art that alternative means such as relay logic circuitry, analog
processors, analog to digital converters and TTL logic circuitry may be
employed as processor means to practice the instant invention.

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In an alternative embodiment of the instant invention shown in
FIG. 2, seat **weight sensor 40** comprises a plurality of **force sensitive**
resistive elements 42 disposed within the vehicle **seat 14** for measuring
force. The **force sensitive resistive elements 42** provide as an **output**

50 **signal 44** a variable electrical resistance responsive to the amount of
force acting on the **elements 42,** that may be operatively coupled to the
input 54 of **processor 50.** The variable resistance **output signal 44** is
generally inversely proportional to the amount of force acting on the
seat 14.

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Referring to Fig. 3 and as disclosed in U.S. Application Serial No.
08/993,701, a **hydrostatic seat weight sensor 70** as incorporated in an
alternative embodiment of the instant invention, comprises a gas filled
bladder 72 mounted within the vehicle **seat 14** and a **differential**

60 **pressure sensor 74** operatively coupled to the **bladder 72** for measuring
the difference in pressure between the **bladder 72** and the atmosphere.
The **differential pressure sensor 74** provides a **pressure sensor output 76**
that is responsive to the force exerted downwardly on the **seat 14.** The

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differential **pressure sensor output 76** is operatively coupled to **input 54**

65   of **processor 50** thereby providing an indication of the force acting

downwardly on the **seat 14.**

As shown in FIG. 4, an alternative seat weight sensor comprises a

plurality of **load cells 80** disposed between the vehicle **seat 14** and the

70   vehicle **structure 16** such that the entire weight of the **seat 14** rests

upon the **load cells 80.** The **load cells 80** are provided with an **output**

82 that is responsive to the amount of force acting upon the **seat 14.**

When utilizing **load cells 80** as a weight sensors, it is critical that the

seat belt 34 is mounted to the **vehicle 12** such that **load cell 80** is

75   responsive to the force upon the **seat 14** generated by tension present

in the **seat belt 34.** For example, Figs. 4 and 5 provide illustrations of a

seat belt 34 configuration wherein the **load cells 80** are responsive to

both the tension applied by the **seat belt 34** and the force resulting from

a mass resting on the **seat 14.**

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In operation, and in accordance with the preferred embodiment of

the instant invention, the **accelerometer 20** measures the vertical

acceleration of the **seat 14** and provides an **output signal 22** to the

processor 50. A normalized seatbelt tension measure is then calculated

85   by the **processor 50** to detect high belt tension and thereby determine

the presence of a child seat.

The **processor 50** is programmed to calculate an average mass of

an object resting on the seat by dividing the **output 32** of the **weight**

90   **sensor 30** by the earth's gravitational constant, g. This calculation may

be performed at a predetermined time during the operation of the **vehicle**

12, or preferentially, performed continuously by assuming that the

vertical acceleration of the **vehicle 12** and the belt tension are negligible,

and averaging the resultant successive mass calculations.

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A predicted variation in force exerted on the **seat 14** is calculated in the **processor 50** by multiplying the aforementioned average mass by the measured variation in vertical acceleration as provided by the **accelerometer 20** over a predetermined time period. The variation in
100 vertical acceleration over time may be determined by integrating the absolute value of the difference between the **accelerometer output 22** and the earth's gravitational constant g over the aforementioned time period.

105   The variation, or fluctuation of the actual force exerted on the **seat 14** is then determined by integrating the absolute value of the difference between the seat weight sensor **output 32** and the average force exerted on the **seat 14**. The normalized tension measurement is then calculated by dividing the variation in actual force exerted on the
110 seat over the same time period as measured by the **weight sensor 30**, by the predicted variation in force exerted on the **seat 14**. The time period over which the predicted force variation is calculated must be sufficient to allow road induced bounce to impart vertical acceleration to the **vehicle 12**. In a preferred embodiment of the instant invention the
115 time period used to calculate the normalized belt tension is .5 seconds.

In an alternative embodiment of the instant invention the **processor 50** calculates the force exerted downwardly on the **seat 14** at discrete time intervals utilizing the vertical acceleration measurement
120 provided by the **accelerometer 20**, and assuming that no **seat belt 34** tension is present in the system, and then compares the resultant predicted force with the actual measured force at each discrete point in time to calculate belt tension. As an example, the predicted force acting on the **seat 14** may be calculated by programming the **processor**
125 **50** to perform the following algorithm:

F = **M(g-A)** + **BT**, where

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F is the force acting downwardly onto the seat **14**,

M is the mass of the object on the seat **14**,

130   g is the gravitational acceleration exerted on the mass **M** by the earth,

A is the vertical acceleration of the vehicle **12**, excluding the earth's

gravity, and

BT is the vertical component of the tension present in the belt **34**.

135   The vertical acceleration **A** of the **vehicle 12** fluctuates around

zero and thus causes variations in the force **F** acting on the **seat 14**.

The belt tension **BT** approximates a constant value that is near zero for

most occupant seating situations except for the presence of tightly

belted child seats. The belt tension **BT** is generally a small value

140   because belt tension greater than a few pounds of force has been found

to be uncomfortable for most vehicle occupants thereby making it

unlikely that an occupant is present when there is significant tension in

the **seat belt 34**.

145   As previously disclosed, the **output signal 32** of the **weight sensor**

30 is divided by the earth's gravitational constant g by **processor 50** to

calculate the average mass **M** present in the **vehicle seat 14**. The

processor 50 then calculates a predicted force acting downwardly on

the **seat 14** at discrete time intervals using the aforementioned average

150   mass, with the assumption that the belt tension **BT** is zero. Still

assuming zero belt tension **BT**, the **processor 50** then compares the

actual value of the force **F** as measured at each discrete point in time by

the **weight sensor 30** with the calculated or predicted force. The

difference between the predicted and actual values of force **F** provides

155   an indication of the tension present in the belt **BT**.

In an alternative method for predicting belt tension **BT**, the

processor 50 monitors the weight sensor **output signal 32** at discrete

time intervals and measures the amplitude of the oscillations of the

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160   **output signal 32** at each discrete point in time. The **processor 50** further monitors the **accelerometer output signal 22** at the corresponding discrete time intervals and calculates the amplitudes of the oscillations of the **accelerometer output signal 22**. The resultant accelerometer amplitude measurements are then sequentially multiplied

165   by the average mass **M** present in the **vehicle seat 14** to calculate the predicted force acting on the **seat 14** at each discrete point in time. The ratio of the actual force acting on the seat 14 to the calculated force at each time interval thereby provides a measure of seat belt tension.

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A tightly belted mass present in the vehicle **seat 14** will produce a reduced ratio of actual force to predicted force as compared to the ratio calculated when a "free" mass is positioned in the vehicle **seat 14**. Therefore, the smaller the ratio between actual force as indicated by the

175   **weight sensor 30** to predicted force as calculated using the average mass **M** and the **accelerometer output signal 22**, the greater the belt tension **BT**, and the higher the probability that an infant seat is tightly belted down onto the vehicle **seat 14**. The **processor 50** may be provided with a look-up table whereby **seat belt 34** tension may be

180   determined given a specific calculated tension ratio.

Accordingly, and as shown in Fig. 1, where the **processor 50** calculates a level of tension in the **seat belt 34** in excess of a predetermined maximum, the **processor 50** will generate an **output 56**

185   operatively coupled to an **air bag control system 60** to inhibit deployment of the air bag. Alternatively, where the **processor 50** calculates a level of tension in the **seat belt 34** below the predetermined maximum and the seat **weight sensor 30** indicates that the occupant's weight is below a predetermined minimum, the **processor 50** will provide

190   an **output 56** to the **air bag control system 60** to reduce the inflation profile thereof according to the measured weight of the occupant.

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While specific embodiments of the instant invention have been
described in detail, those with ordinary skill in the art will appreciate
195   that various modifications and alternatives to those details could be
developed in light of the overall teachings of the disclosure.
Accordingly, the particular arrangements disclosed are meant to be
illustrative only and not limiting as to the scope of the invention, which
is to be given the full breadth of the appended claims and any and all
200   equivalents thereof.

I claim:

1.   A system for measuring seat belt tension in a vehicle having an airbag control system and a seat, comprising:

5   a.)   an accelerometer rigidly secured to said vehicle in proximity to the seat thereof, said accelerometer having an output signal responsive to the vertical acceleration of said vehicle;

           b.)   a seat weight sensor having an output signal responsive to the force exerted by a mass on said seat; and

10   c.)   a computer processor having first and second inputs, the first input being operatively coupled to the output signal of said accelerometer and the second input being operatively coupled to the output signal of said seat weight sensor, wherein said processor calculates tension in said seat belt

15   by comparing the output signal of said seat weight sensor at discrete time intervals with predicted fluctuations in the force exerted on the seat caused by vertical acceleration acting upon the mass, assuming no seatbelt tension.

2.   The system of claim 1 wherein said seat weight sensor comprises a hydrostatic seat weight sensor disposed within the seat.

3.   The system of claim 1 wherein said seat weight sensor comprises a plurality of load cells adapted to be responsive to the force exerted on the seat by said seat belt.

4.   The system of claim 1 wherein said seat weight sensor comprises a plurality of force sensitive resistive elements disposed within the seat.

5.   The system of claim 1 wherein said computer processor further comprises an output operatively coupled to said air bag control system for inhibiting the operation thereof upon the calculation of high seat belt tension.

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6.   The system of claim 2 wherein said computer processor further comprises an output operatively coupled to said air bag control system for inhibiting the operation thereof upon the calculation of high seat belt tension.

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7.   The system of claim 3 wherein said computer processor further comprises an output operatively coupled to said air bag control system for inhibiting the operation thereof upon the calculation of high seat belt tension.

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8.   The system of claim 4 wherein said computer processor further comprises an output operatively coupled to said air bag control system for inhibiting the operation thereof upon the calculation of high seat belt tension.

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9.   A method for predicting seatbelt tension in a vehicle having a
seat, an accelerometer rigidly secured to said vehicle in proximity to the
seat, said accelerometer having an output signal responsive to the
vertical acceleration of said vehicle, a seat weight sensor having an
5   output signal responsive to the force exerted by a mass acting on the
seat, and a processor having a first input operatively coupled to the
output signal of said accelerometer and a second input operatively
coupled to the output signal of said weight sensor comprising:

    a.)   measuring the actual variation in force due to vertical
10   acceleration exerted on the seat over a predetermined time
           period;

    b.)   calculating the average mass on the seat;

    c.)   calculating the predicted variation in force due to vertical
           acceleration exerted on the seat by multiplying the average
15   mass on the seat by the variation in vertical acceleration
           over the predetermined time period; and

    d.)   dividing the actual variation in force by the predicted
           variation in force whereby the quotient represents
           normalized seatbelt tension.

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10.   A method for predicting seatbelt tension in a vehicle having a
seat, an accelerometer rigidly secured to said vehicle in proximity to the
seat, said accelerometer having an output signal responsive to the
vertical acceleration of said vehicle, a seat weight sensor having an
5   output signal responsive to the force exerted by a mass on the seat, and
a processor having a first input operatively coupled to the output signal
of said accelerometer and a second input operatively coupled to the
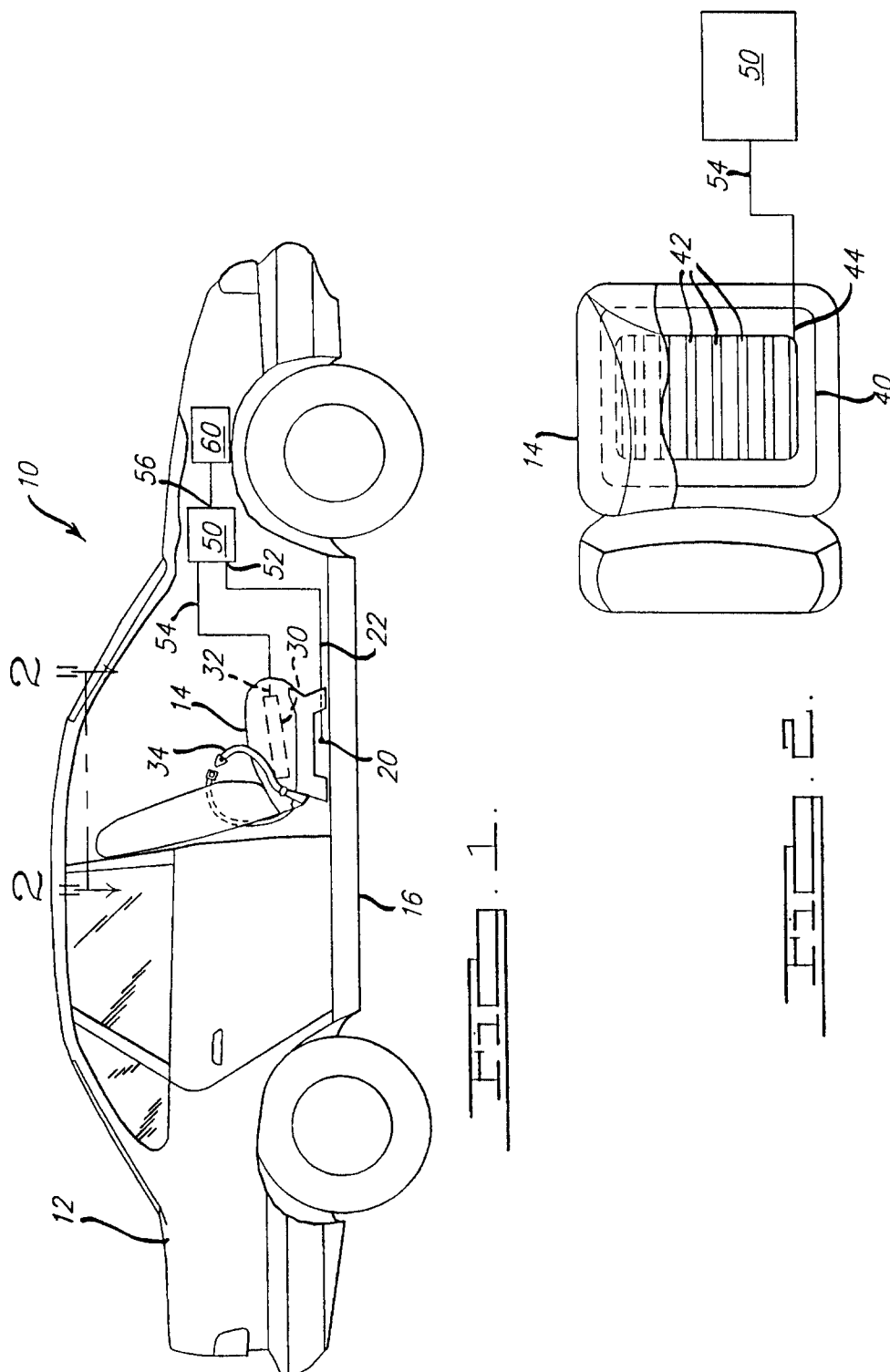output signal of said weight sensor comprising:

    a.)   measuring the force due to vertical acceleration exerted on
10   the seat at discrete time intervals;

    b.)   calculating the average mass on the seat;

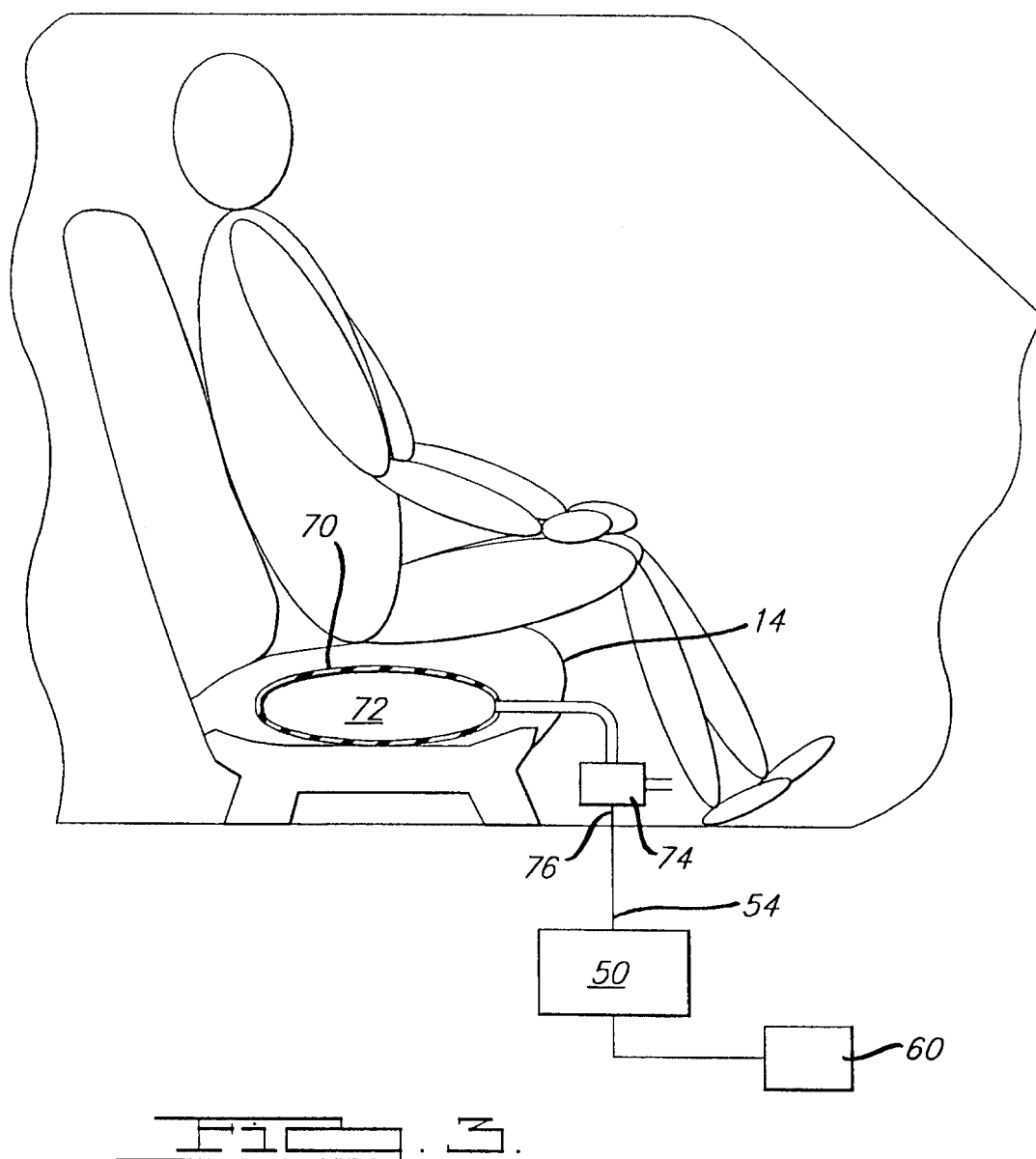   c.)   calculating at discrete time intervals a predicted force acting

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on the seat due to vertical acceleration, assuming the
tension in said seat belt is zero; and

15   d.)   calculating at discrete time intervals the difference between
                    the measured force exerted on the seat and the predicted
                    force whereby the difference is indicative of seat belt
                    tension.

11.   A method for predicting seatbelt tension in a vehicle having a
seat, an accelerometer rigidly secured to said vehicle in proximity to the
seat, said accelerometer having an output signal responsive to the
vertical acceleration of said vehicle, a seat weight sensor having an

5   output signal responsive to the force exerted by a mass on the seat, and
a processor having a first input operatively coupled to the output signal
of said accelerometer and a second input operatively coupled to the
output signal of said weight sensor comprising:

            a.)   measuring the force due to vertical acceleration exerted on

10   the seat at discrete time intervals;

            b.)   calculating the average mass on the seat;

            c.)   measuring the vertical acceleration acting on said vehicle at
                    discrete time intervals;

            d.)   calculating at discrete time intervals a predicted force

15   exerted on the seat by multiplying the vertical acceleration
                    at each time interval by the average mass, assuming the
                    tension in said seat belt is zero; and

            e.)   calculating at discrete time intervals the ratio between the
                    measured force exerted on the seat and the predicted force

20   exerted on the seat whereby the ratio is indicative of seat
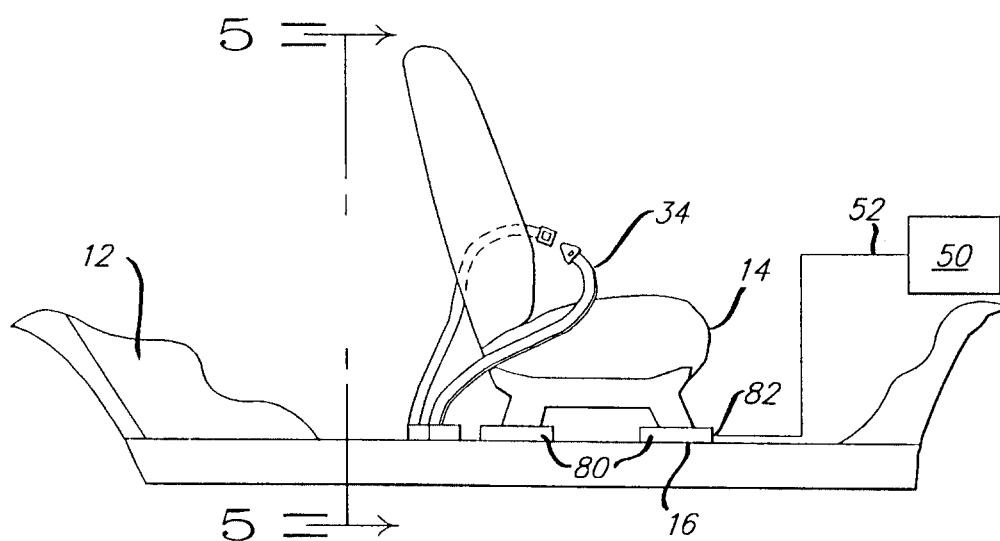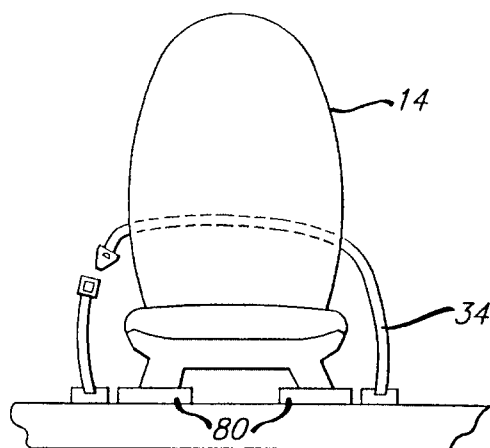   belt tension.

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FIG. 1.

FIG. 2.

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FIG. 3.

FIG. 4.

FIG. 5.