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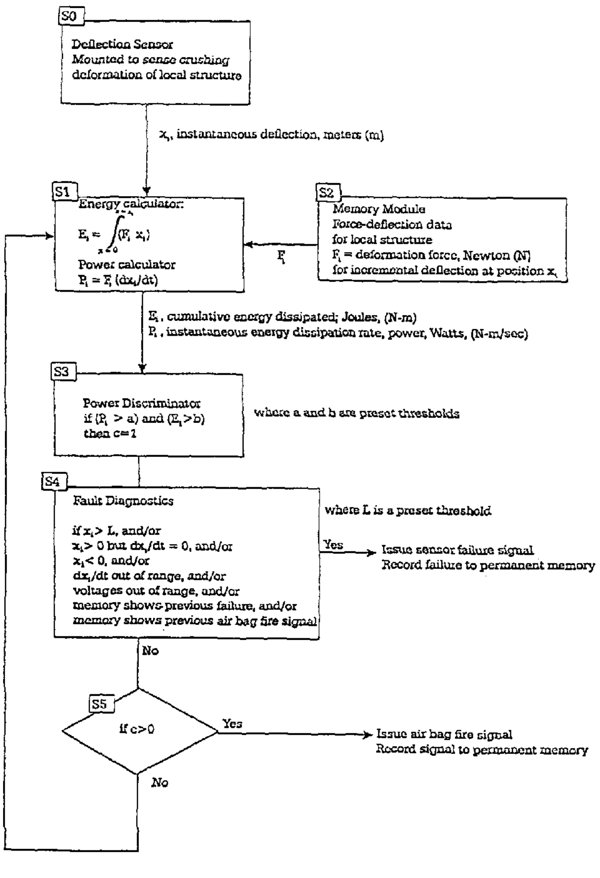
(54) Title: MECHANICAL SENSING ARRANGEMENT AND CRASH ENERGY SENSOR

Single Point Crush Energy Sensor



(57) Abstract: One development described herein relates to a mechanical sensing arrangement, particularly suitable for use in crash detector devices, which converts mechanical motion to a reduced scale compatible with the signal characteristics of a low-grade commercial sensor. Another development described relates to a sensing system which determines optimum deployment conditions for automotive or vehicle safety systems, such as air bags, in the event of a collision or impact.

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MECHANICAL SENSING ARRANGEMENT AND CRASH ENERGY SENSOR

FIELD OF THE INVENTION

One development described herein relates to a mechanical sensing arrangement, particularly suitable for use in crash detector devices, which converts mechanical motion to a reduced scale compatible with the signal characteristics of a low-grade commercial sensor. Another development described relates to a sensing system which determines optimum deployment conditions for automotive or vehicle safety systems, such as air bags, in the event of a collision or impact.

BACKGROUND OF THE INVENTION

With respect to the energy sensor development, sensors are known in the art for their use in detecting structural deformation during an automotive or vehicle impact with objects such as another vehicle or a pole, etc. Examples of references which discuss various particular features of sensor structure and their use are described below.

A typical application of sensor technology is described in US Patent 5,419,407, Meyer, et al., which teaches a deformation sensor, namely a pressure sensitive foil which determines the rate of structural deformation upon an impact and triggers an air bag should the deformation rate exceed a predetermined threshold value.

The above application is similarly taught in US Patent 5,435,409, Meyer, et al., which discloses a dual deformation sensing element having outer and inner sensor planes and incorporates a force sensing resistor. Predetermined threshold values determine the triggering of a safety device such as an air bag should these threshold values be exceeded.

US Patent 6,095,553, Chou, et al., teaches a side impact sensor which incorporates accelerometer elements for comparing the force of a first and a second sensing from an impact. These elements can also be compared to a "safety" sensor which considers additional force information.

US Patent 6,144,790, Bledin, Anthony, G., discloses an optical fiber impact sensor which detects deflection properties (not location specific) from thermal, direct force or pressure. External perturbation of light properties will trip a relay, sound a buzzer, or the like.

An electrical contact sensor is taught in US Patent 5,680,909, Lofy, John, D., where an inflator for an air bag is actuated upon the surface of one of the electrical contacts being crushed during impact. A "safety" sensor is contemplated in this reference but is not described.

A crush box is disclosed in US Patent 5,547,216, Iwata, et al., as having a pressure sensor for detecting both the velocity and severity of the structural deformation from an impact. These values are then compared to predetermined threshold values and a vehicle safety device will, in turn, be deployed upon the appropriate characteristics being detected.

Other references include, US Patent 5,392,024, Kiuchi, et al., which teaches the use of two or more conditions, e.g. two impact sensing events within a predetermined time frame as a means of deployment. Moreover, the applicant of the present invention, in US Patent 5,917,180, Reimer, et al., discloses an optical scattering geometry sensor which includes a compressible carrier medium, a source and receiving wave, and a signal to be transferred to a pressure indicator. Also, CA Patent 2,254,538, Reimer, et al., discloses this same sensor for use in the crush zone of a vehicle.

In addition to the above references, publications such as "Crush Zone Intrusion Sensor", a promotional handout from January, 2001, a CZi presentation dated September 15, 2001, and the "GM-CZi Test Data Review" of September, 2001 discuss the sensing technology and the use of the technology in vehicle collisions or impacts.

Turning to the sensing arrangement, commercial sensors, such as reflective sensors, which detect the range of a reflective surface are generally manufactured in large quantities at very low cost. The range within which a sensor of this type may detect the proximity of the reflective surface is generally a few millimeters for low-end commercial devices. Typically, the response characteristics are non-linear meaning that a low signal condition exists where the distance between the sensor and the reflective surface is more or less than the optimum for maximum signal strength.

An example of art that discloses a mechanical sensing mechanism is US Patent 5,917,180, Reimer, et al. This patent describes an integrating cavity sensor that incorporates a light emitter and light detector positioned in close proximity and uses mechanical deformation of the integrating cavity to sense deflection. Deflection sensing is possible whereby an isotropic scattering medium surrounding the light source and detector act as an integrating cavity. It is a property of the medium that compression of the whole body results in proportional compression of the localized region that is the integrating cavity which in turn changes the optical density of the medium proportionate to the deflection of the medium. Due to this proportionality, this sensor can be configured to sense deflection on an arbitrary distance scale by simply changing the dimension of the scattering medium. In the above reference, the medium is an elastomeric foam which provides the proportional compression.

The purpose of the present invention is therefore to provide an mechanical sensing arrangement for use in applications such as crash detector sensors, and other like uses.

In automotive crash sensing a number of devices are used or suggested for the detection of compression or deflection of the 'crush zone' or 'crumple zone' of the car. These devices include contact switches, fiber optic deflection sensors, Kinotex™ deflection sensors, air pressure sensors, etc. In these sensing devices it is desirable to match the deflection range of the sensor to a scale that matches the physical deformation scale of the crushing.

SUMMARY OF THE INVENTION

In one development of the present invention, one embodiment provides for an air bag actuation system comprising at least one deflection sensor adapted to be mounted at a deflection point of a primary energy absorbing location of a vehicle, the deflection sensor generating an output signal with sensed deflection data, reference data means having stored force deflection data, calculator program means receiving reference data from the reference data means and receiving the output signal having sensed deflection data, the calculator program means generating cumulative energy dissipated values (E) and instantaneous energy dissipation values (P) from the reference data and the deflection data, calculator program means generating an output signal containing E and P values to a comparative program means, comparative program means for receiving an output signal from the calculator program means the comparative program means comparing received E and P values to predetermined threshold values and generating an output deployment signal upon exceedence of predetermined threshold values, and air bag actuation means to actuate at least one air bag upon receiving the output signal from the comparative program means.

Preferably the calculator program means is adapted to calculate velocity (V) to generate a velocity signal which outputs a deployment signal upon exceedence of preset velocity threshold values.

Another embodiment of the above development of the present invention includes fault detection program means adapted to detect failures in the system, the output deployment signal being received by the fault detection program means, the fault detection program means generating an output actuation signal to permit actuation of an air bag actuation means upon no fault being detected in the system.

In a further embodiment of the above, the fault detection program means includes predetermined threshold values whereby an actuation signal is generated when threshold values are exceeded.

Another further embodiment of the above provides for the system including at least two deflection sensors.

Desirably, the comparative program means comprises a primary discriminator having primary count means, the comparative program means receiving P values for each sensor, the primary count means recording exceedence of the predetermined threshold P values for each sensor whereby when the primary count means records at least two counts of exceedence of predetermined threshold values, the comparative program generates an output deployment signal, and the at least two deflection sensors are adapted to sense at least one of spatial resolution, temporal resolution, and deformation measurement at said primary energy absorbing location of the vehicle.

It is also preferable the said system is adapted to sense crush zone deformation energy dissipation and energy dissipation rates during an automotive impact and, the system is adapted to analyse energy dissipation rates, amounts and patterns.

It is further desirable, the system further includes a secondary discriminator adapted to evaluate aggregate energy dissipation rates from the deflection sensors and compare said aggregate energy dissipation rates to a predetermined threshold value, the secondary discriminator having count means, recording exceedence of any predetermined threshold value, the secondary discriminator receiving the output deployment signal from the comparative program means, generating an output deployment signal upon receiving the output deployment signal from the comparative program means and, upon the second count means recording exceedence of the predetermined threshold value, to actuate an air bag actuation means, and the system further includes a tertiary discriminator adapted to discriminate collision events by pattern analysis and an intrusion signature, the tertiary discriminator having count means, the at least two deflection sensors having energy and energy dissipation output signals, the intrusion signature combining instantaneous energy dissipation rates and time-history of a deflection and energy and energy dissipation output signals from the deflection sensors of an array, the intrusion signature having a deployment or a non-deployment output signal, the tertiary discriminator identifying the deployment and non-deployment signal output and increasing the count means of said tertiary discriminator by a count of one when the deployment output signal is detected.

Desirably the predetermined threshold value is set at a value exceeding power dissipation rates during low energy events requiring air bag deployment.

Moreover, it is preferred in the above embodiment, the system further has an event classifier having predetermined event data, the event classifier identifying an event type by comparing an aggregate time-history deflection and an energy dissipation pattern to the predetermined event data.

Preferably, the system includes a Kinotex™ deflection sensor.

In another embodiment of the development there is provided a system comprising: one or more deflection sensors positioned in a structure at >n= key deflection points, where 'n' is a number from one to a hundred, the deflection points representing primary energy absorbing points in the structure for sensing event information including deflection and deflection velocity data; look-up data table means providing force-deflection curves for the points; an algorithm employing the deflection and deflection velocity data combined with the force deflection curves to calculate total energy absorbed and instantaneous energy dissipation rates, where absorption is equal to dissipation, for each deflection sensor; wherein a calculated total of energy is adapted to have offset-energy constants for the points, the algorithm being adapted to discriminate events exceeding a predetermined threshold value and calculate cumulative energy and aggregate energy dissipation rates for the deflection sensor, the algorithm identifying a type of crash event from classification of multi-point time-history, where multi-point time-history are deflection, velocity and energy values and an intrusion signature by pattern analysis; and, a logic sequence having an air bag deployment signal capable of being generated by combining energy dissipation rates, cumulative energy, aggregate energy dissipation rates and event type from intrusion signature, the logic sequence adapted to operate the system during failure of one or more of the deflection sensors and discriminate severe crash events.

Further, it is another embodiment of the development, to provide a safety system comprising: first logic means having a predetermined threshold value, the first logic means adapted to generate an output signal of deflection characteristics detectable during a crash event, second logic means generating an output signal determined during a crash event having force-deformation values to a third logic means, third logic means receiving the first logic means output and the second logic means output and calculating impact severity during a crash event and output a third logic means signal to a fourth logic means, fourth logic means having a primary discriminator, the primary discriminator having count means adaptably increasing by a count of one for each instance the predetermined threshold value is exceeded and outputting a signal to a fifth logic means to deploy a safety device when the count is at least two, fifth logic means adapted to determine a fault in the system, the fifth logic means rendering the system inoperable when a fault is determined in the system, the fifth logic means outputting a signal to a sixth logic means to deploy a safety device when a system fault is not detected; and, sixth logic means for measuring said signal from the fifth logic means and for generating a deployment signal to a safety device when an output signal from said fifth logic means is received.

Preferably, in the above embodiment, the deflection characteristics include deformation energy dissipation, energy dissipation rates, instantaneous energy dissipation rates, time-history of deflection energy and energy dissipation signals during an automotive impact.

It is further preferable the deflection characteristics are detectable by deflection sensors positioned at one or more energy absorbing points in a vehicle structure.

It is desirable in the above embodiment impact severity is determined by comparing an energy dissipation rate P^n, wherein 'n' is a numerical value between one and a hundred, for each of the deflection sensors to a predetermined threshold a^n for each of the deflection sensors, the counter increasing a count for each incident where the energy dissipation rate exceeds the predetermined threshold value, the fourth logic means further includes a secondary discriminator for evaluating energy dissipation rates by obtaining aggregate signal output rates from the first logic means and comparing the output rates to the predetermined threshold value, the secondary discriminator having count means for detecting threshold value exceedence, the count means increasing count for each incidence where the aggregate signal output rates exceeds the predetermined threshold value, the count means adapted to combine a single count from the count means of the primary discriminator with a count from the count means of the secondary discriminator to output a deployment signal to the safety device, and the fourth logic means further includes a tertiary discriminator, the tertiary discriminator providing fine event discrimination by pattern analysis, the pattern analysis comparing intrusion signatures accessed from the second logic means to an intrusion signature pattern of an event, the intrusion signature combining instantaneous energy dissipation rates and time-history of deflection, energy and energy dissipation signals from a sensor, the tertiary discriminator identifying a deployment or non-deployment signature for the event and increasing a count means by a value associated with the intrusion signature.

In another embodiment of the above development, there is provided a method for actuation of a safety device system including the steps of: sending an output signal having deflection characteristics sensed from a primary energy absorbing location of a vehicle to a first program means, referencing force deflection data for output to the first program means, comparing the deflection characteristics and referencing force deflection data, generating an output signal from first program means having calculated total energy absorbed and instantaneous energy dissipation rates at the primary energy absorbing location to a second program means, calculating cumulative energy and aggregate energy dissipation rates, generating an output signal to actuate a safety device when a predetermined threshold value is exceeded, comparing the second program means output signal to the referencing force deflection data to determine a type of event, generating an output signal to actuate the air bag safety system once the event type is identified as an event to deploy a safety device, and actuating a safety device system determined by the type of event.

In another development the present invention also, provides for a crash deflection sensing device suitable for use in a crush zone of an automobile, and in which there is provided the improvement wherein the sensing device includes mechanical actuation means in combination with a reflective sensor and reflective means operatively associated with the sensor, the sensor and reflective means being mounted in spaced-apart relationship, the mechanical means being adapted to effect relative movement between the sensor and reflective means whereby the mechanical means upon effecting relative movement between the sensor and reflective means permits displacement of one relative to the other to provide a reduced scale compatible with signal characteristics of the sensor.

Further, the mechanical actuation means can comprise a pair of pivotably connected levers, one of the reflective sensor or reflective means being mounted by the levers whereby the levers when pivotably reduced in height are effective to reduce the distance between the reflective sensor and reflective means.

In another further embodiment of another development, the mechanical means comprises a pair of spaced-apart spring means, the spring means mounting one of the reflective sensor or reflective means whereby the spring means when compressed is effective to reduce the distance between the reflective sensor and reflective means.

It is also further desirable in certain embodiments that the mechanical means comprises a pair of compressible spaced-apart elastomeric supports, the elastomeric supports mounting one of the reflective sensor or reflective means whereby the elastomeric supports when compressed are effective to reduce the distance between the reflective sensor and the reflective means.

It is preferable the calculator program means is adapted to calculate velocity (V) to generate a velocity signal which outputs a deployment signal upon exceedence of preset velocity threshold values.

Another embodiment of another aspect above, provides for a crash deflection sensing device, for use in a crush zone of an automobile, comprising: a reflective sensor; a reflective panel; movable actuating means mounting the reflective sensor and reflective panel in opposed, space-apart, relationship of movement toward and away from each other; actuation of the actuating means effecting relative movement between the reflective sensor and the reflective panel to provide a reduced scale movement compatible with signal characteristics of the reflective sensor.

It is desirable the moveable actuating means comprises opposed space-apart actuating members, one of the reflective sensor and reflective panel mounted between the actuating members and the other mounted on one of said actuating members.

Preferably, one of the reflective sensor and reflective panel is mounted closer to the one of the actuating member than the other.

It is also preferable the actuating means further comprises a pair of levers extending between the actuating members, the levers pivotably connected at a pivot point, the pivot point closer to the one of the actuating members, the one of the reflective sensor and reflective panel mounted at the pivot point; and the actuating means further comprises a compressible elastomeric support extending between the actuating members, the one of the reflective sensor and reflective panel mounted on the support and positioned closer to one of the actuating members than the other of the actuating members.

Desirably, the actuating means comprises a pair of compressible, spaced-apart, elastomeric supports, extending between the actuating members, one of the reflective sensor and reflective panel mounted on the supports.

Moreover, it is also preferable the actuating means comprises at least one compression spring member extending between the actuating members, the one of the reflective sensor and reflective panel mounted on the spring, and positioned closer to one of the actuating members than the other of the actuating members.

Further, the actuating means comprises a pair of spaced-apart compression springs extending between the actuating members, one of the reflective sensor and reflective panel connected to said springs.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus generally described the invention, reference will now be made to the accompanying drawings illustrating preferred embodiments in which:

Figure 1 shows an embodiment of one development of the present invention as a flow chart diagram showing a single point crush energy sensor;

Figure 1a shows a further embodiment of the above single point crush energy sensor;

Figure 2 shows another embodiment of one development of the present invention as a flow chart diagram showing a multi-point crush energy sensor;

Figure 2a shows another further embodiment of the above multi-point crush energy sensor;

Figure 3a shows an embodiment of another development of the present invention as a schematic view of a mechanical arrangement for use;

Figure 3b shows another embodiment of another development of the present invention as a schematic illustrating the use of the mechanical lever arrangement of Figure 3a in a reflective sensor arrangement;

Figure 4a shows an alternate arrangement of another development as a schematic view of a spring mediated mechanical arrangement;

Figure 4b shows an alternate arrangement of another development as a schematic view of a spring mediated mechanical arrangement in use; and

Figure 5a is a further embodiment of another development of the present invention showing a schematic view of an elastomer mediated mechanical arrangement; and

Figure 5b is a further embodiment of another development of the present invention showing a schematic view of an elastomer mediated arrangement in use.

DETAILED DESCRIPTION OF THE DRAWINGS

With reference to the sensor development, and in the sensor arrangement, shown in the accompanying drawings, it will be understood that the certain preferred embodiments and alternatives may be readily made without departing from the concept of the present invention.

Turning to Figure 1, a single-point crush energy sensor incorporated into a vehicle safety restraint system is illustrated.

There are a series of modules for performing logic functions to determine the severity of a collision or impact event.

<u>Module S0, Deflection Sensor</u>

The primary module includes data capture of collision event characteristics. At least a single deflection sensor is located at a crush energy dissipation point in the vehicle's structure and senses deformation characteristics such as spatial resolution in the order of 1mm, temporal resolution at 100 microseconds/sample and deformation measurements ranging from 10mm to 100mm.

The sensor can be any conventionally known type of deflection sensor and, for example, a Kinotex device as described in US patent 5,917,180 and in Canadian patent application 2,254,538 has been used herein.

The placement of the deflection sensor is dependent on the type of impact the vehicle is to encounter. For example, the sensing of a side-crash would be optimally monitored by the deflection of the door reinforcing bar as the primary intrusion resisting element in the door. Alternatively, a deflection sensor may be located behind the support bracket, a location that deflects with a known resistance.

Another possible placement for the sensor is located directly behind the outer door skin. In this location the crush resistance is low but crush information can be indicated very early in the crash event.

Another option might be to place the sensor on the inner door frame, offset from the outer portions of the door. In this location crush information would be provided later in the event when deflection characteristics exceed or are about to exceed a critical threshold.

When a frontal collision is to be sensed, the ideal deflection sensor location would be a collapsible energy absorbing structure located between the bumper and the frame of the car, crash box or it's equivalent. It is designed to deform and absorb energy during medium speed collisions. Its crushing resistance is precisely engineered.

<u>Module S1, Energy Calculator</u>

Once the primary module senses deflection, the velocity and energy of the deflection is calculated in the secondary module for producing output. An instantaneous deflection reading (x_i) from the deflection sensor (S0) simultaneously calculated with accessed data from memory produces the value for:

1. cumulative energy dissipated, E_i; and,
2. instantaneous energy dissipation rate, P_i

E_i is calculated by integration of the force data F_x over the deflection distance X_i.

In cases where there is some energy dissipated before the deflection sensor is engaged, an offset energy E_o is added. For example, a vehicle door may crumple with a defined resistance rising from zero to 10 kN at 50 mm deflection. The resistance may plateau at 10 kN for the next 50 mm deflection. If the sensor is located so as to sense deflection from 50 mm to 100 mm and if the instantaneous deflection value is 80 mm, then E_i = integral of $F_x x_i$ from 50 mm to 80 mm plus E_o where E_o is the integral from 0 mm to 50mm. The value of E_o may be stored in the look-up table.

P_i is calculated as force F_x times instantaneous velocity dx_i/dt. For example, at a deflection rate dx_i/dt = 10 meters/second and for incremental deformation resistance F_x = 10 kN resistance, the energy dissipation rate would be 10 meters/sec x 10,000 N =100,000 N-m.sec^{-1} (100 kilowatts).

As used herein, these units are known units and include:

1. Force: Newton, or pounds-force;
2. Deflection: meters or feet;
3. Time: seconds;
4. Energy: Newton-meters (N-m) or foot-pounds (ft-lbs); and
5. Power (instantaneous energy dissipation rate): Newton-meters/second (N-m.sec.$^{-1}$) or Watts, ft-lb/sec.

<u>Module S2, Memory Module</u>

Since force deformation relationships for certain vehicles and associated data are known, these values can be stored in memory. Module S2 provides recall for similar deformation events tested for the vehicle for comparison by a further module. For example, door reinforcing bars are typically designed to provide deflection resistance in the order of 10,000 Newton, e.g. USLAC Engineering Report.

Module S3, Power and Velocity Discriminator

Module S3 functions to assess crash severity by comparing the instantaneous velocity V_i to a preset velocity threshold q and the instantaneous energy dissipation rate, P_i, to a preset energy threshold a_x determined from module S2. Since deformation is a progressive action, the value of a_x can change during the event based on the severity of deformation depending on known structural factors.

For example high energy dissipation rates early in a crash event may not be diagnostic of a severe event, in the first 50 mm of deflection most vehicle doors do not present much intrusion resistance. A small mass of a few 10 of kilograms impacting the door at high velocity (> 10 m/sec) may intrude rapidly with high energy dissipation rates but will not progress very far into the structure because of its low kinetic energy as compared to a larger (> 1000 Kg) mass.

The value of a_x may be set as either a function of intrusion distance or cumulative crush energy dissipation.

Cumulative energy dissipated, E, is an index of cumulative damage. In the example above, it may not be desirable to actuate an air bag early during an event even though the instantaneous energy dissipation rate, P, is high. Therefore the threshold, b, may be set to a predetermined value that requires a given level of accumulated damage before a firing decision could be made on the basis of a high P value. This discrimination threshold may be contingent on the combined P and E values or it may be absolute.

Module S4, Fault Diagnostics

A Fault Diagnostic module, module S4, functions to search for and identify system errors and device failures. For example, should the sensor become unserviceable due to damage from a previous event, the module identifies the error and signals the Initiation Module that a fault has occurred and an unwanted initiation of the system is avoided.

A situation probable from a high energy crash involves the deformation sensor exceeding a predefined range L. The system is prevented from reporting under conditions where there may be physical damage to the sensor, e.g. if crushing continues after the dynamic range of the sensor is exceeded.

Further, the system detects any latent sensor deformation or damage. If deformation (x_i) is greater than zero but the deformation rate (dx_i/dt) is zero, the device becomes unserviceable. For example, the sensor may permanently deflect due to previous damage to the structure and this module includes latency so that the system will not disqualify itself from service during a crash event.

If the deformation signal is negative the sensor becomes unserviceable. This traps for sensor error due to loss of power or electronic damage. Further, if the rate of change (dx_i/dt) is abnormal the sensor becomes unserviceable. This traps for unforeseeable damage conditions.

If the electronic system voltages do not correspond to predefined startup/shutdown and operating conditions the system will become unserviceable. This traps for electronic failure and power failure.

Moreover, if the system has previously detected a failure condition or has issued an air bag deployment signal it becomes unserviceable. This prevents the reuse of the system without qualified servicing.

Module S5, Initiation Module

The Initiation Module (S5) accepts data from the Fault Diagnostic module (S4) which can initiate a deployment signal to a safety device if no system error or failure is detected. The Initiation Module operates for one deployment cycle only and further deployment is reneged for safety purposes.

In the above described embodiments, the single-point device may not incorporate the full range of decision logic described above since some of these functions would be allocated to the central computer and the decision logic may be different.

It should be noted that subsequent logical functions that may be executed by a central safety system are not described herein. Only functions that would be executed in the single-point device are described.

In another embodiment of the development, shown in Figure 2, an array of deflection sensors are used in the system. Figure 2 illustrates a multi-point crush energy sensor that incorporates its own central processor and uses the full logical sequence described above to arrive at a deployment decision.

Module AO^1, AO^2, AO^n, Deflection Sensor Array

The primary module AO^1 is accompanied by AO^n modules where the number of modules are factored by "K". The system includes an array of deflection sensors located at specified crash energy dissipation points in the vehicle structure. In a manner similar to that of the primary module of Figure1, modules AO^1 to AO^n capture data characteristics sensed from a collision or impact event. The locations of the sensors are determined based on a selected set of criteria with the added consideration of redundancy and pattern apprehension.

Any commonly known type of deflection sensor can be used to identify deflection characteristics of an event. For example, three deflection sensors arrayed at the center and ends of a vehicle door reinforcing bar provides both sensing redundancy and event pattern information for discrimination between an intrusion at the front or rear of the door.

Once an event is detected, characteristic data of the event are distributed from each sensor in the array to a secondary module for energy calculation based on each sensor.

<u>Module A4, Fault Diagnostics</u>

This module identifies system errors and device failures. This module can, for an array of sensors, disqualify individual sensors without disqualifying the function of the whole array.

For instance, if the deformation of any sensor (n) exceeds a predefined range or; threshold L^n, the sensor is identified by the system as unserviceable. This prevents the system from using a sensor signal under conditions where physical damage to the sensor may be occurring. The A4 module will record a sensor failure and will disqualify itself from service within 10 seconds after recording a sensor failure. The system will not disqualify itself immediately because sensor damage is probable during a severe collision event and the sensor may be required to continue functioning during the event to detect secondary collisions, etc.

If a reported deformation value is greater than zero but the deformation rate is zero, the system identifies the sensor as unserviceable averting a failure due to latent sensor deformation or damage to the sensors. However, the system will not disqualify itself from service during a crash.

In the instance of power damage, the deformation signal is negative and the sensor is identified by the system as being unserviceable. This traps for loss of power damage.

For any unforeseen damage to the sensor, the sensor will be identified by the system as unusable if the rate of change is abnormal.

The above-noted failures will not stop the system from operating with the remaining serviceable sensors if the fault(s) occurred within, e.g. the previous 10 seconds. This condition allows the system to continue functioning during a damage event but stops the system from functioning after a damage event.

The system is also configured to become unserviceable if the electronic system voltages do not correspond to the predefined startup/shutdown and operating conditions but correspond to a power failure and/or an electronic failure.

Further, if the system has previously detected a failure condition or has issued a deployment signal it becomes unserviceable preventing the system from being reused without qualified servicing.

If the system does not detect a fault the module will not output a fault signal and the system configures the safety device being dispatched in accordance with the primary, secondary and tertiary discriminators.

An array configuration for the system requires data characteristics to be transmitted from at least more than one sensor to evaluate qualifying factors for the deployment signal to the initiation module.

Module A1, Energy Calculator

This secondary module, receives an instantaneous deflection position reading (x_i) of each sensor 1 to n which in turn accesses data from the memory module (A2). Thus, as shown in the drawings, cumulative and instantaneous energy dissipation rates for each sensor is calculated and a signal is generated containing (E_i) and (P_i) values which is transmitted to the A3 Module.

Module A2, Memory Module

The memory module (A2) is similar in function to the memory module in Figure 1 (Module S2). However, additional data values for storing pattern recognition and redundancy enable signature events to be determined and appropriate signals generated for actuation of different safety devices.

Module A3, Primary Exceedence Threshold Discriminator

Module A3, is the Primary Exceedence Threshold Discriminator receiving the output signal from A1 and functions to compare instantaneous energy dissipation rates P^n of each sensor to a pre-determined threshold value a^n for each sensor. For each sensor exceeding its threshold value, the discriminator increments a counter which is tallied. If the value exceeds one count, which is transmitted to the logic module A5, as described later, the module A5 will fire. No single sensor will result in deployment of a safety device. Thresholds can be set at values which exceed power dissipation rates of low energy events that do not warrant safety device deployment.

Module A6, Secondary Threshold Discriminator

A Secondary Threshold Discriminator evaluates aggregate energy dissipation rates relative to all of the sensors of modules AO^1 and AO^n and compares the summation of these rates to a set threshold.

Any exceedence in the threshold will result in a counter being incremented. Should the tally include a single increment from the primary discriminator (A3), the two signals combine to meet the criteria for generating an output signal which signals an initiation module to deploy a safety device, such as an air bag. This module will not signal safety deployment by itself.

The value of using energy values rather than deformation rates is that energy values can be added in physically meaningful way relating directly to crash severity. This property is particularly valuable when comparing the effects of intrusion by different sized objects.

For example, a side collision with a large barrier, such as a wall, causes intrusion dispersed across a vehicle. Thus, the intrusion rates may not be large at any given point but, the aggregate energy dissipation will be large and deployment conditions detectable.

Module A7, Tertiary Discrminator

A third discriminator, module A7, identifies an "intrusion signature" through pattern analysis by comparing the emerging pattern identified by the sensors and the patterns stored in the memory module A2.

Some crash events that may warrant air bag deployment may not be as energetic as some that do not warrant deployment. For example, this may be the case for intermediate velocity side collisions with a tree "pole crash" which may be lethal in comparison with a bicycle collision that may not be severe because of the low mass of the bicycle. The Primary and Secondary discriminators will not be able to distinguish between these two events until it is too late to deploy an air bag. Other sensor types currently in use such as an air pressure pulse sensor may not be capable of distinguishing these events.

Module A7 is capable fo fine event discrimination through the use of pattern analysis, an examination of the 'intrusion signature'. The 'intrusion signature' is a combination of the instantaneous values plus the time history of the deflection, energy and energy dissipation signals from the array of sensors. Module A7 views the pattern and compares the emerging patterns to known events from the memory module A2. Module A7 will look for specified deployment and/or non-deployment signatures and will increment the counter if it identifies a specified intrusion signature.

Module A5, Initiating Module

The Initiating Module is calibrated to receive deployment signals from the fault diagnostic module, the primary, secondary and tertiary modules sequentially. Conditions for deployment can be met e.g. a count of two or more.

The three discriminators operate in sequence and in such a way that either, e.g. the Primary Discriminator can create a deployment condition if two of the deflection points show threshold exceedence and two of the three discriminators can create a deployment condition by each separately detecting a condition warranting deployment. The decision heirarchy and thresholds are such that all disccriminators may respond to severe events ensuring robust decisions.

The system is permanently disqualified from service once a "fire" decision has been made.

Module A8, Reset Module

A Reset Module can be used in the system which will enable summation values identified in the discriminator modules to return to a zero value should deployment conditions be determined unnecessary during the course of an event.

The logic functions as described for each module of various embodiments may be associated with a dedicated processor, for example, a microprocessor or the like. The processor may form part of the safety system or alternatively form separate components of the vehicle.

It is understood that a safety precaution of the present invention includes deactivation of the system once a deployment signal is transmitted and the system may not be recycled for re-use. It is also understood that the system described above would include a conventional clock.

Referring to Figure 3a and the other development described herein, the mechanical arrangement of the present invention, otherwise described in greater detail hereinafter with reference to Figure 3b, is illustrated. In the arrangement, a device of the present invention is contained within a pair of opposed members 12, one or both which are capable of actuating the mechanical arrangement described hereinafter. Thus, at least one of the members 12 function as a pressure actuating point for the mechanical sensor arrangement described herein.

Turning to Figure 1a and 2a, a velocity discriminator can be included in the system.

Module A9, Velocity Discriminator

This module sets counter C to zero if no sensed intrusion velocity exceed set threshold, for example, 5 meters per second. In this event, Module A5 will not send an airbag deployment signal even if the other discriminator modules have detected a deployment condition.

As can be seen from Figure 1a, optionally, the primary discriminator can include the velocity discrimination function. In this configuration counter reset would not occur during the instance of velocity exceeding the preset threshold, the velocity data is signaled to module S5.

A first movable pivotable lever 1 made of suitable material, operates in conjunction with a second movable pivotable lever 2. Levers 1 and 2 are pivotably connected by means of a pivot 3 at a suitable point, generally beyond a mid-point. By virtue of being pivotable, each of levers 1 and 2 may rotate about the pivot point 3 whereby their respective ends designated 4 and 5 can be displaced outwardly relative to each other.

In Figure 3a, the normal, or static, position of the arms 1 and 2 is illustrated wherein such arms have a total height indicated by the arrow h. At this point, the total pivot height indicated by arrow line d under a static condition is shown, confined within the area of the opposed members 12.

Turning now to Figure 3b, the mechanical arrangement of Figure 3a is shown in simplified schematic form; the system of the present invention includes a reflective panel 8 fixedly secured to or about the pivot point 3 of the mechanical arrangement. In addition, a reflective sensor 9 is located in a fixed relationship to at least one pressure actuating member 12, as indicated by arrows 15, normal to the planes of the members 12. Upon pressure being exerted to at least one actuating member 12, lever arms 1 and 2 will pivot about pivot point 3 whereby the height indicated by arrow h will be reduced and correspondingly the pivot height d will likewise be reduced as arms 1 and 2 are subjected to an opposed movement . The height d will be reduced less than the height h. Thus, relative to the reflective source, into compatibility with the signal characteristics of the sensor.

Aspheric lenses, to improve the sensitivity, can be included, for example as in the HEDS-1300 device. Such lenses image the active areas of the emitter and detector to a single spot, on the reflective panel, and which defines the resolution.

Referring now to Figures 4a and 4b, an alternate embodiment of another development is disclosed, in which the device is within an ambient air medium between spaced-apart members 12. In Figures 4a, 4b and others, similar reference numerals designate similar components - e.g. 8 designates a reflective panel, 9 reflective sensor, etc.

In Figure 4a, a pair of spaced-apart coil or similar spring members 10 are mounted between (and preferably fixedly secured to) members 12. The reflective panel 8 is attached to the springs 10 such that under normal conditions, the reflective sensor 9 is spaced from the reflective panel 8 by a distance of d, with a distance h being the width between the members 12 under non-compressed conditions.

Upon deflection exerted by either one or both of members 12, as shown in Figure 4b, the springs will compress to give a modified or shorter distance d' between the reflective panel 8 and the reflective sensor 9 as the distance h' is reduced. It will be seen from Figures 4a, 4b, 5a and 5b that, compared to Figure 3a and 3b, a pivot is not required but the same effect is achieved. In Figures 4a and 4b, a spring with a uniform spring constant will compress uniformly and therefore a point fixed at an arbitrary distance along the spring will always remain in the same proportionate position along the spring. The spring can be any suitable spring such as a coil spring but other equivalents can obviously be employed in place of a coil spring. For example, a single large annular spring can be used, with the reflective panel 8 mounted within the spring. One such example of a single large annular spring is known as a bellows spring.

Referring to Figures 5a and 5b, another embodiment in which the mechanical principle is employed is illustrated wherein the mechanical means comprises an elastomer in the form of a pair of spaced-apart elastomeric members 11 positioned between members 12. The reflective panel 8 is mounted on the members 11. In this embodiment, the elastomeric members can be any suitable polymer having the properties desired relative to compressibility of the elastomer. For example, an isotropic elastomer will deform with the same proportionality. Suitable polymers include either non-foamed or foamed elastomers. In the case of a foamed polymer (or an equivalent non-foamed polymer) a foam column will support a reflective target at a desired distance from the reflective sensor and regardless of the height of the column the deflection will always be proportionately scaled at the target. Thus, as illustrated in Figure 5, the reflective panel may be mounted by suitable means or molded into the foam columns 11. Again, in a modification, a single tubular elastomeric member can be used, with the reflective panels mounted within the tube. Venting of the space within the tube may be necessary.

The use of a bellows spring, or a single tubular elastomeric member provides the advantage that the reflective panel 8 and the reflective sensor 9 can be mounted in a enclosed space with consequent protection.

The use of an opto-mechanical system such as those described in Figures 3a, 3b, 4a, 4b, 5a and 5b of the present application utilizes an arbitrary range of motion for optimal opto-electronic response characteristics of a reflective target and at an optimal distance from a reflective sensor thus, regardless of the height of the column, the deflection is always proportionately scaled at the target.

Thus, an important difference of this aspect of the present invention over the prior art is that in this aspect, the reflective sensor is not looking at or into a medium that is being compressed. Rather, the reflective sensor sees a reflective target supported by the mechanical arrangement and thus, is effective to provide a simple and reliable crash sensor device.

This aspect of the present invention provides a mechanical arrangement which has the desirable characteristics of utilizing components which are relatively inexpensive and readily available, thus lending the utilization of the invention to many uses such as automotive crash sensors, in which application, for practical purposes the working range of a crash deflection sensor must be matched to the scale of the crushing event.

Those skilled in the art to which the invention pertains understand the invention has been described by way of a detailed description of preferred embodiments and departures from and variations to this arrangement may be made without departing from the spirit and scope of the invention, as the same is set out and characterized in the accompanying claims.

CLAIMS:

1. An air bag actuation system comprising:

- at least one deflection sensor adapted to be mounted at a deflection point of a primary energy absorbing location of a vehicle, said deflection sensor generating an output signal with sensed deflection data and reference data means having stored force deflection data

- calculator program means receiving reference data from said reference data means and receiving said output signal having sensed deflection data, said calculator program means generating cumulative energy dissipated values (E) and instantaneous energy dissipation values (P) from said reference data and said deflection data, and said calculator program means generating an output signal containing E and P values to a comparative program means

- comparative program means for receiving said output signal from said calculator program means

- said comparative program means comparing received E and P values to predetermined threshold values, said comparative program means generating an output deployment signal upon exceedence of predetermined threshold values, and

- air bag actuation means to actuate at least one air bag upon receiving said output signal from said comparative program means.

2. The system of claim 1, wherein said calculator program means is adapted to calculate velocity (V) to generate a velocity signal which outputs a deployment signal upon exceedence of preset velocity threshold values.

3. The system of claim 1, including fault detection program means adapted to detect failures in said system, said output deployment signal being received by said fault detection program means, said fault detection program means generating an output actuation signal to permit actuation of said air bag actuation means upon no fault being detected in said system.

4. A system according to claim 3, wherein said fault detection program means includes predetermined threshold values whereby said actuation signal is generated when threshold values are exceeded.

5. The system as described in claim 3 wherein said system includes at least two deflection sensors.

6. The system as described in claim 5, wherein said comparative program means comprises a primary discriminator having primary count means, said comparative program means receiving P values for each sensor, said primary count means recording exceedence of said predetermined threshold P values for each sensor whereby when said primary count means records at least two counts of exceedence of predetermined threshold values, said comparative program generates an output deployment signal.

7. The system as described in claim 4, wherein said system is adapted to sense crush zone deformation energy dissipation and energy dissipation rates during an automotive impact.

8. The system as described in claim 4, wherein said system is adapted to analyse energy dissipation rates, amounts and patterns.

9. The system as described in claim 5, wherein said at least two deflection sensors are adapted to sense at least one of spatial resolution, temporal resolution, and deformation measurement at said primary energy absorbing location of said vehicle.

10. The system as described in claim 6, wherein said system further includes a secondary discriminator adapted to evaluate aggregate energy dissipation rates from said deflection sensors and compare said aggregate energy dissipation rates to a predetermined threshold value, said secondary discriminator having

count means, said count means of said secondary discriminator recording exceedence of any predetermined threshold value, said secondary discriminator receiving said output deployment signal from said comparative program means, said secondary discriminator generating an output deployment signal upon receiving said output deployment signal from said comparative program means and upon said second count means recording exceedence of said predetermined threshold value to actuate said air bag actuation means.

11. The system as described in claim 6, wherein said system further includes a tertiary discriminator adapted to discriminate collision events by pattern analysis and an intrusion signature, said tertiary discriminator having count means, said at least two deflection sensors having energy and energy dissipation output signals, said intrusion signature combining said instantaneous energy dissipation rates and time-history of a deflection and said energy and energy dissipation output signals from said deflection sensors of said array, said intrusion signature having a deployment or a non-deployment output signal, said tertiary discriminator identifying said deployment and said non-deployment signal output and increasing said count means of said tertiary discriminator by a count of one when said deployment output signal is detected.

12. The system as described in claim 11, wherein said predetermined threshold value is set at a value exceeding power dissipation rates during low energy events requiring air bag deployment.

13. The system as described in claim 11, wherein said system further having an event classifier having predetermined event data, said event classifier identifying an event type by comparing an aggregate time-history deflection and an energy dissipation pattern to said predetermined event data.

14. A system as described in claim 1, wherein said system includes a Kinotex™ deflection sensor.

15. A system comprising:

- one or more deflection sensors positioned in a structure at >n= key deflection points, where 'n' is a number from one to a hundred, said deflection points representing primary energy absorbing points in said structure for sensing event information including deflection and deflection velocity data;
- look-up data table means providing force-deflection curves for said points;
- an algorithm employing said deflection and said deflection velocity data combined with said force deflection curves to calculate total energy absorbed and instantaneous energy dissipation rates, where absorption is equal to dissipation, for each deflection sensor;
- wherein a calculated total of said energy is adapted to have offset-energy constants for said points, said algorithm being adapted to discriminate events exceeding a predetermined threshold value and calculate cumulative energy and aggregate energy dissipation rates for said deflection sensor, said algorithm identifying a type of crash event from classification of multi-point time-history, where said multi-point time-history are deflection, velocity and energy values and an intrusion signature by pattern analysis; and,
- a logic sequence having an air bag deployment signal capable of being generated by combining said energy dissipation rates, said cumulative energy, said aggregate energy dissipation rates and said event type from said intrusion signature, said logic sequence adapted to operate said system during failure of one or more of said deflection sensors and discriminate severe crash events.

16. A vehicle safety system comprising:

- first logic means having a predetermined threshold value, said first logic means adapted to generate an output signal of deflection characteristics detectable during a crash event,
- second logic means generating an output signal determined during a crash event having force-deformation values to a third logic means,
- third logic means receiving said first logic means output and said second logic

means output and calculating impact severity during a crash event and output a third logic means signal to a fourth logic means,

- fourth logic means having a primary discriminator, said primary discriminator having count means adaptably increasing by a count of one for each instance said predetermined threshold value is exceeded and outputting a signal to a fifth logic means to deploy a safety device when said count is at least two,

- fifth logic means adapted to determine a fault in said system, said fifth logic means rendering said system inoperable when a fault is determined in said system, said fifth logic means outputting a signal to a sixth logic means to deploy said safety device when a system fault is not detected, and

- sixth logic means for measuring said signal from said fifth logic means and for generating a deployment signal to a safety device when an output signal from said fifth logic means is received.

17. The system as described in claim 16, wherein said deflection characteristics including deformation energy dissipation, energy dissipation rates, instantaneous energy dissipation rates, time-history of deflection energy and energy dissipation signals during an automotive impact.

18. The system as described in claim 17, wherein said deflection characteristics are detectable by deflection sensors, said sensors being positioned at one or more energy absorbing points in a vehicle structure.

19. The system as described in claim 18, wherein impact severity is determined by comparing an energy dissipation rate P^n, wherein 'n' is a numerical value between one and a hundred, for each of said deflection sensors to a predetermined threshold a^n for each of said deflection sensors, said counter increasing a count for each incident where said energy dissipation rate exceeds said predetermined threshold value.

20. The system as described in claim 19, wherein said system further includes a

seventh logic means for resetting said counter when velocity values are less than preset velocity threshold values.

21. The system as described in claim 16, wherein said fourth logic means further includes a secondary discriminator for evaluating said energy dissipation rates by obtaining aggregate signal output rates from said first logic means and comparing said output rates to said predetermined threshold value, said secondary discriminator having count means for detecting threshold value exceedence, said count means increasing count for each incidence where said aggregate signal output rates exceeds said predetermined threshold value, said count means adapted to combine a single count from the count means of said primary discriminator with a count from the count means of said secondary discriminator to output a deployment signal to said safety device.

22. The system as described in claim 21 wherein said fourth logic means further includes a tertiary discriminator, said tertiary discriminator providing fine event discrimination by pattern analysis, said pattern analysis comparing said intrusion signatures accessed from said second logic means to an intrusion signature pattern of an event, said intrusion signature combining said instantaneous energy dissipation rates and said time-history of deflection, said energy and said energy dissipation signals from a sensor, said tertiary discriminator identifying a deployment or non-deployment signature for said event and increasing said count means by a value associated with said intrusion signature.

23. A method for actuation of a safety device system including the steps of:
- sending an output signal having deflection characteristics sensed from a primary energy absorbing location of a vehicle to a first program means,
- referencing force deflection data for output to said first program means,
- comparing said deflection characteristics and said referencing force deflection data,
- generating an output signal from said first program means having calculated

total energy absorbed and instantaneous energy dissipation rates at said primary energy absorbing location to a second program means,

- calculating cumulative energy and aggregate energy dissipation rates
- generating an output signal to actuate a safety device when a predetermined threshold value is exceeded,
- comparing said second program means output signal to said referencing force deflection data to determine a type of event,
- generating an output signal to actuate said air bag safety system once said event type is identified as an event to deploy a safety device, and
- actuating a safety device system determined by said type of event.

24. In a crash deflection sensing device suitable for use in a crush zone of an automobile, the improvement wherein said sensing device includes mechanical actuation means in combination with a reflective sensor and reflective means operatively associated with said sensor , said sensor and said reflective means being mounted in spaced-apart relationship, said mechanical means being adapted to effect relative movement between said sensor and said reflective means whereby said mechanical means upon effecting relative movement between said sensor and said reflective means permits displacement of one relative to the other to provide a reduced scale compatible with signal characteristics of said sensor.

25. A device according to claim 24, wherein said mechanical actuation means comprises a pair of pivotably connected levers, one of said reflective sensor or reflective means being mounted by said levers whereby said levers when pivotably reduced in height are effective to reduce the distance between said reflective sensor and said reflective means.

26. A device according to claim 24, wherein said mechanical means comprises a pair of spaced-apart spring means, said spring means mounting one of said reflective sensor or reflective means whereby said spring means when

compressed is effective to reduce the distance between said reflective sensor and said reflective means.

27. A device according to claim 24, wherein said mechanical means comprises a pair of compressible spaced-apart elastomeric supports, said elastomeric supports mounting one of said reflective sensor or reflective means whereby said elastomeric supports when compressed are effective to reduce the distance between said reflective sensor and said reflective means.

28. A crash deflection sensing device, for use in a crush zone of an automobile, comprising:

a reflective sensor;

reflective panel; and

movable actuating means mounting said reflective sensor and reflective panel in opposed, space-apart, relationship of movement toward and away from each other;

actuation of said actuating means effecting relative movement between said reflective sensor and said reflective panel to provide a reduced scale movement compatible with signal characteristics of said reflective sensor.

29. A device as claimed in claim 28, said moveable actuating means comprising opposed space-apart actuating members, one of said reflective sensor and reflective panel mounted between said actuating members and the other mounted on one of said actuating members.

30. A device as described in claim 29, said one of said reflective sensor and reflective panel mounted closer to said one of said actuating member than the other of said actuating member.

31. A device as claimed in claim 29, said actuating means further comprising a pair of levers extending between said actuating members, said levers pivotably

connected at a pivot point, said pivot point closer to said one of said actuating members, said one of said reflective sensor and reflective panel mounted at said pivot point.

32. A device as claimed in claim 29, said actuating means comprising at least one compression spring member extending between said actuating members, said one of said reflective sensor and reflective panel mounted on said spring, and positioned closer to said one of said actuating members than the other of said actuating members.

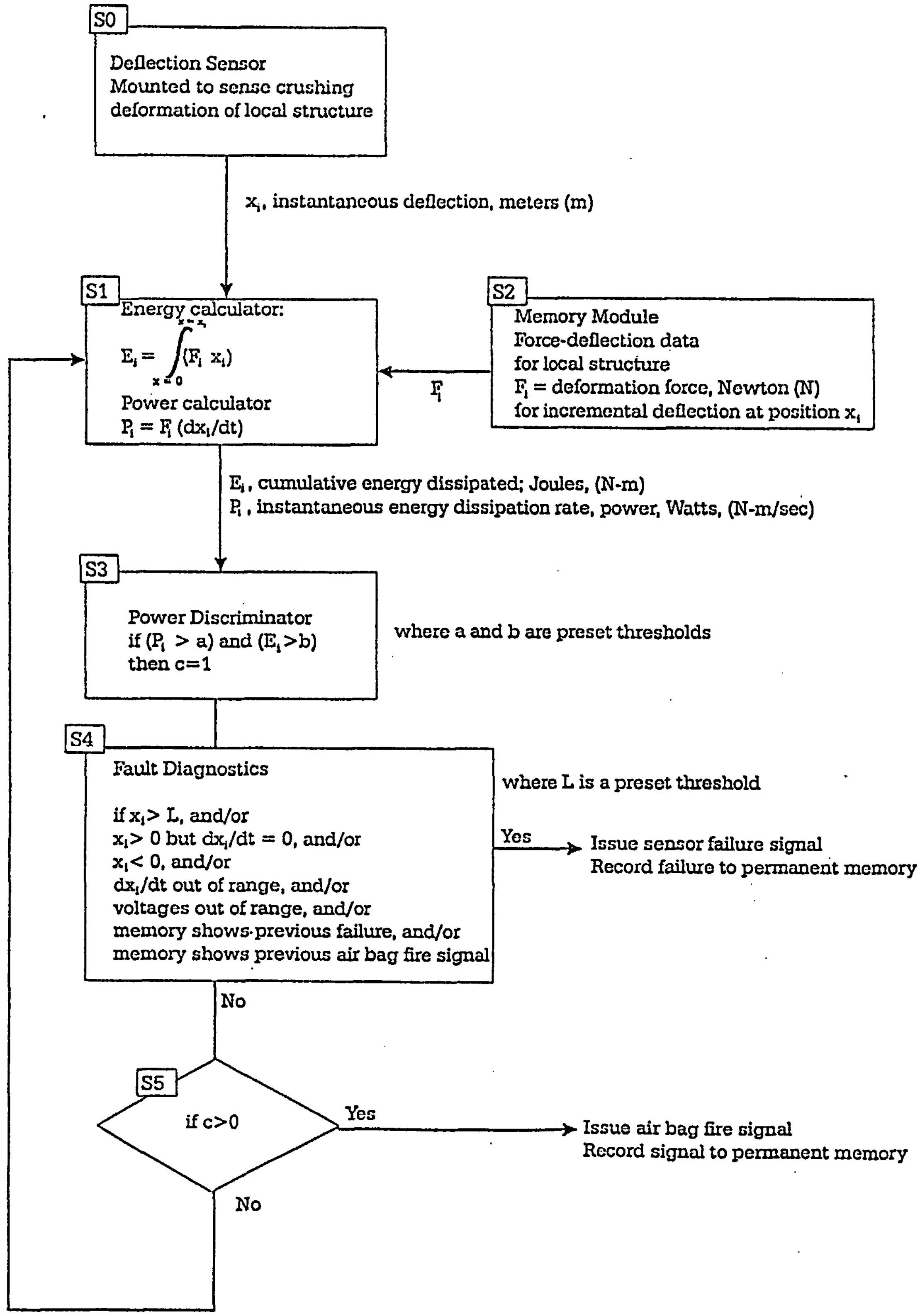
33. A device as claimed in claim 29, said actuating means comprising a pair of spaced-apart compression springs extending between said actuating members, said one of said reflective sensor and reflective panel connected to said springs.

34. A device as claimed in claim 29, said actuating means further comprising a compressible elastomeric support extending between said actuating members, said one of said reflective sensor and reflective panel mounted on said support and positioned closer to said one of said actuating members than the other of said actuating members.

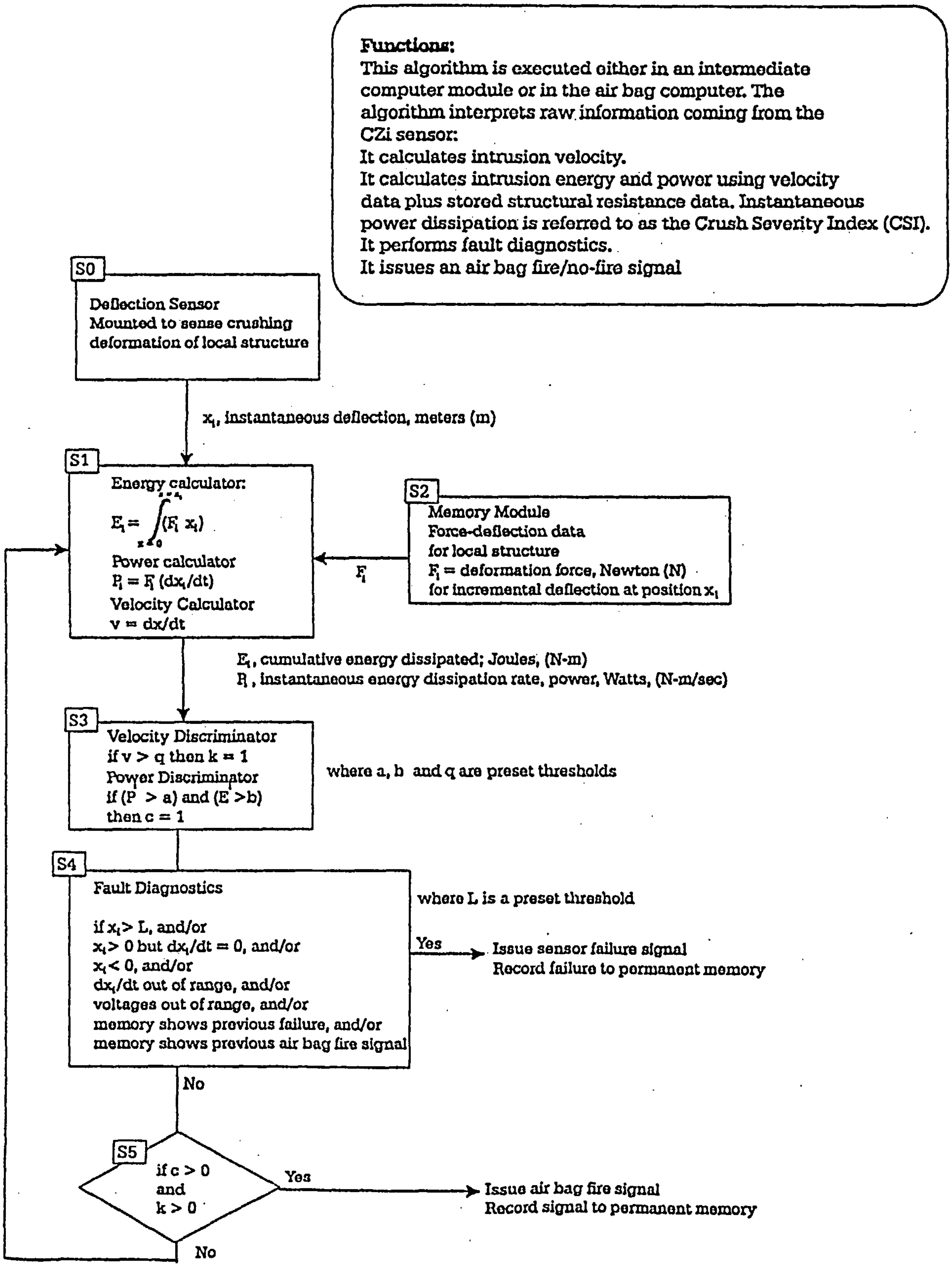
35. A device as claimed in claim 34, said elastomeric supports, spaced-apart, extending between said actuating members, said one of said reflective sensor and reflective panel mounted on said supports.

36. A device as claimed in claim 28, said reflective panel mounted between said actuating member and said reflective sensor mounted on said one of said actuating members.

Figure 1: Single Point Crush Energy Sensor

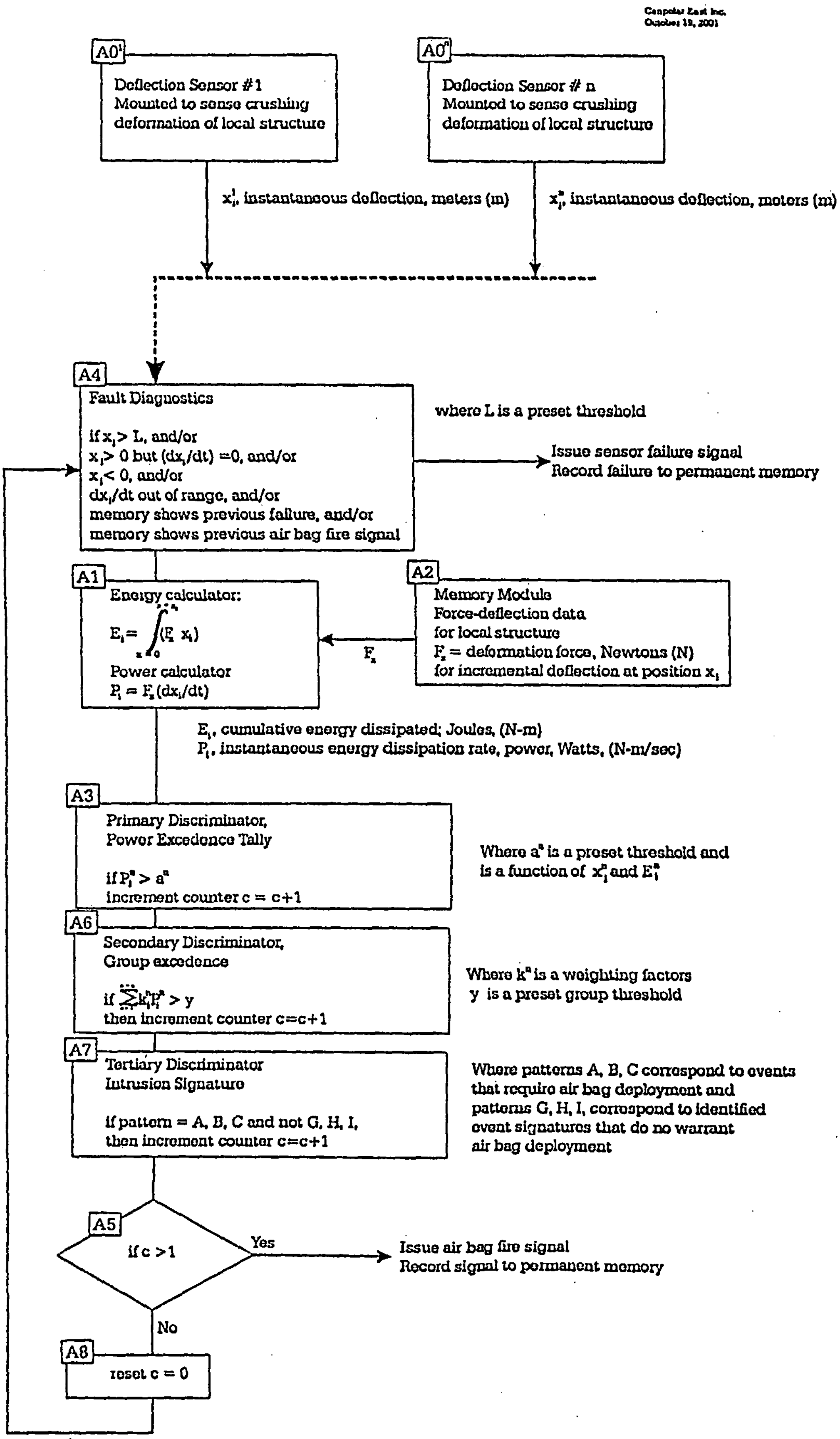


1a. **Algorithms, single CZi Sensor**

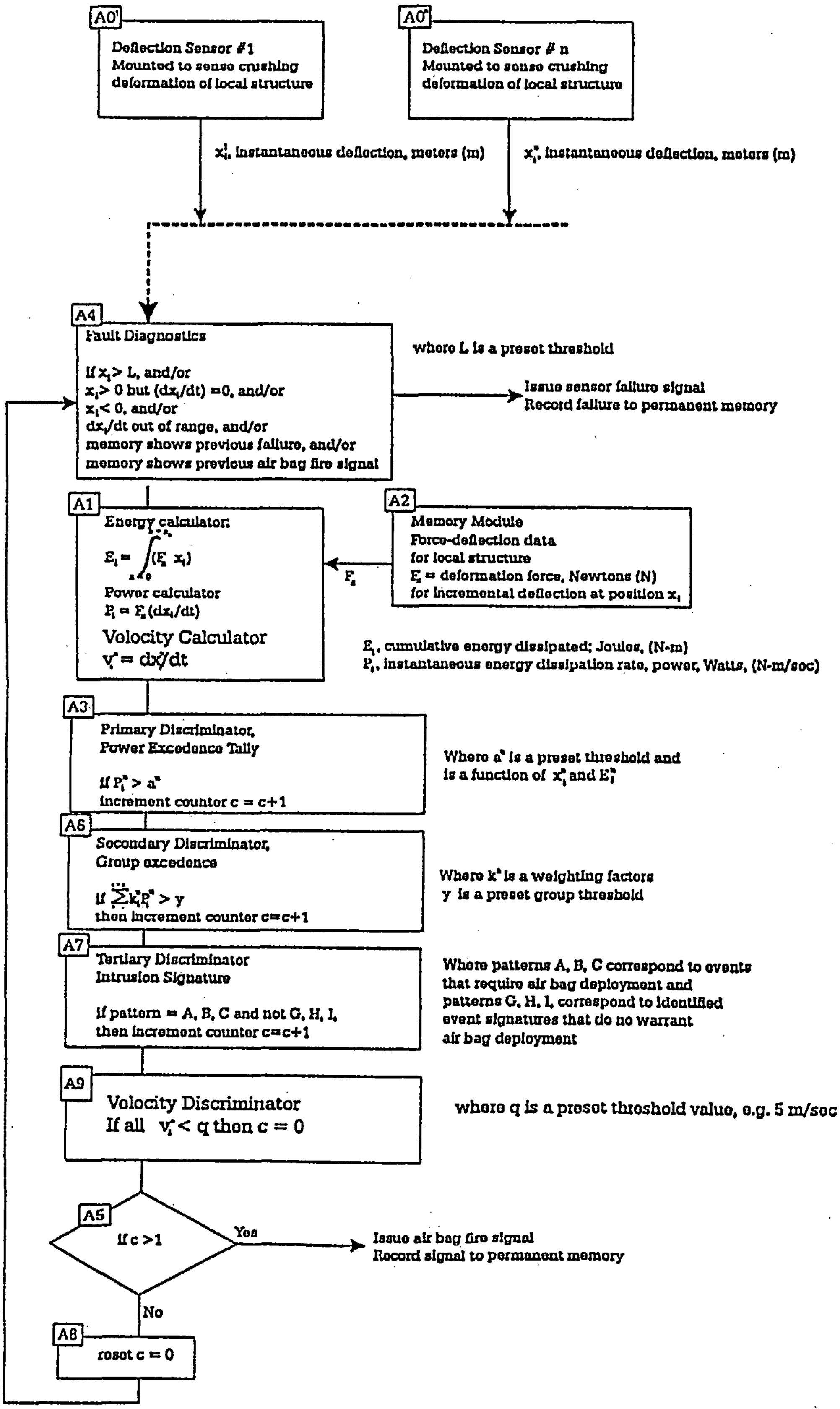


3/7

Figure 2: Multi-Point Crush Energy Sensor



2a. **Algorithms, multiple CZi Sensor Array**



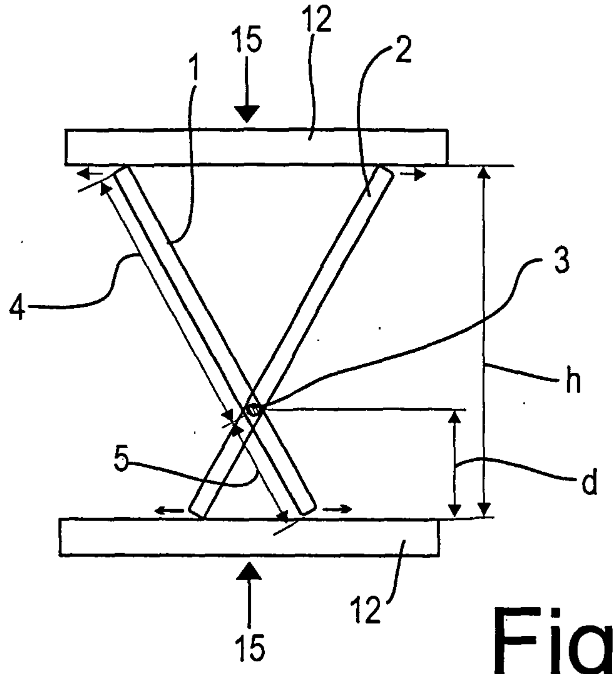


Fig. 3a

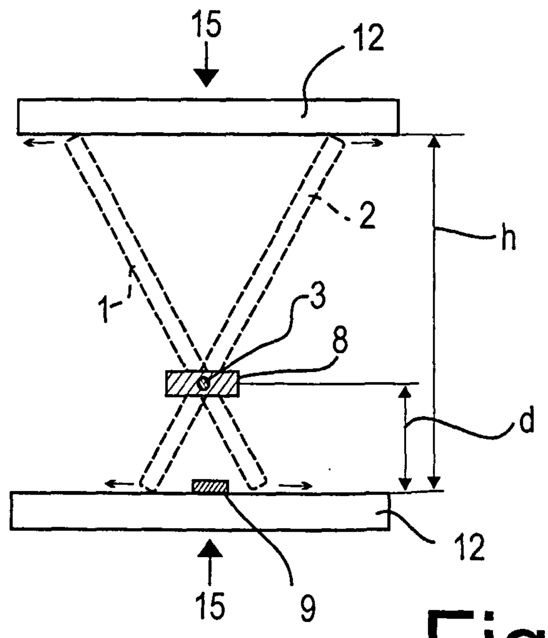


Fig. 3b

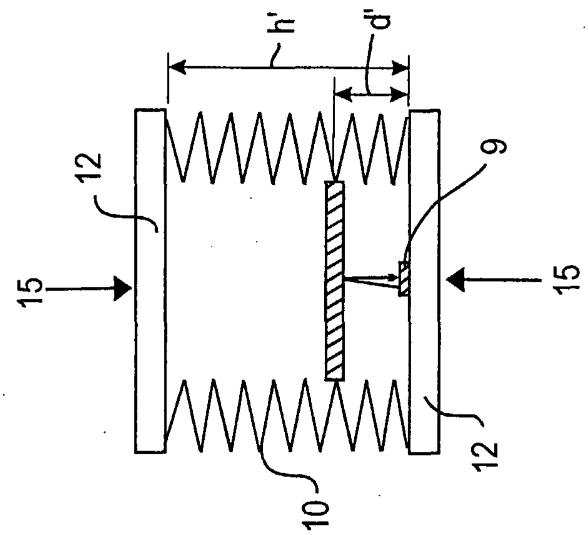


Fig. 4b

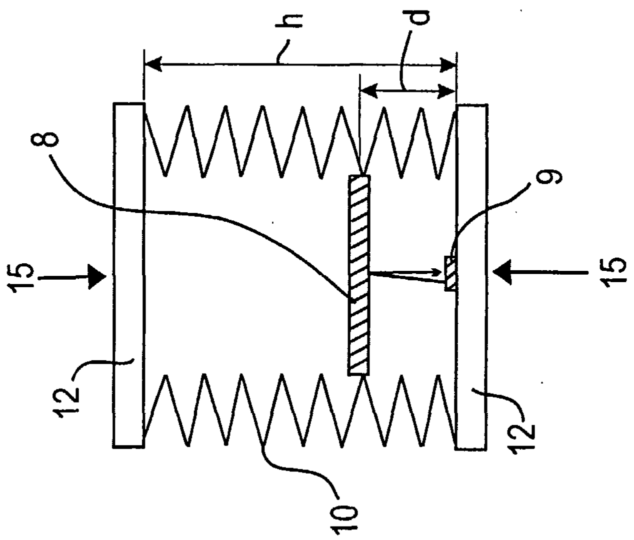


Fig. 4a

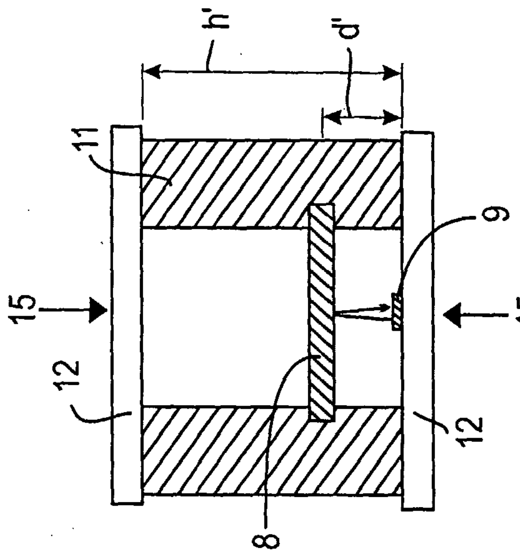


Fig. 5b

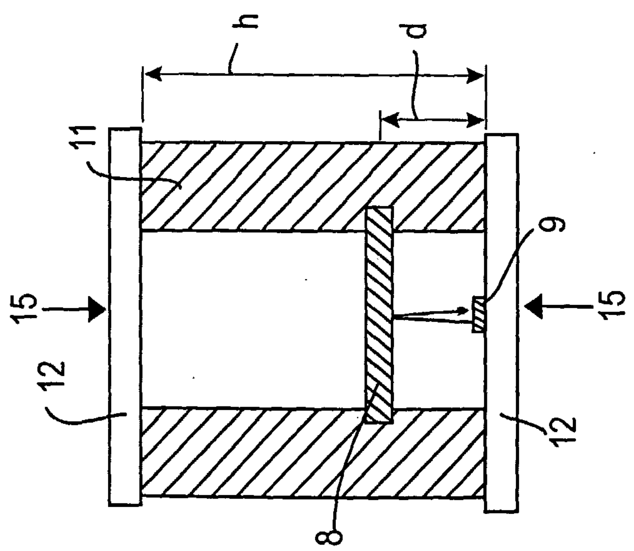


Fig. 5a