United States Patent [15] **3,688,063**
Bell [45] **Aug. 29, 1972**

[54] **CRASH SENSING SWITCH**

[72] Inventor: **Lon E. Bell,** Altadena, Calif.
[73] Assignee: **Technar Incorporated,** Pasadena, Calif.

[22] Filed: **Feb. 22, 1971**
[21] Appl. No.: **117,560**

[52] **U.S. Cl.** ....**200/61.53,** 200/153 R
[51] **Int. Cl.** **H01h 35/14**
[58] **Field of Search**....200/52 PB, 61.45 R, 61.45 M, 200/61.53, 153 R

[56] **References Cited**

UNITED STATES PATENTS

3,452,175	6/1969	Wilkes	200/61.45 R
3,488,098	1/1970	Sobczak	308/6
3,567,881	3/1971	Duimstrd	200/61.53

Primary Examiner—Robert K. Schaefer
Assistant Examiner—M. Ginsburg
Attorney—Christie, Parker & Hale

[57] **ABSTRACT**

There is described a crash switch which can sense acceleration forces that operate for some period of time such that the product of acceleration and time exceeds some predetermined level before the switch is actuated. The switch utilizes rollers supported by a band wrapped around the rollers, in which movement of the rollers along the band actuates switch contacts to signal movement of the rollers over a predetermined distance. In one modification, change in the center of gravity of the rollers is used to shift the direction of maximum sensitivity to the accelerating force. A single calibration adjustment, by shifting the initial position of the rollers, controls both the level of acceleration force required to move the rollers and the acceleration-time product level required to trigger the switch to the nominal design levels.

20 Claims, 12 Drawing Figures

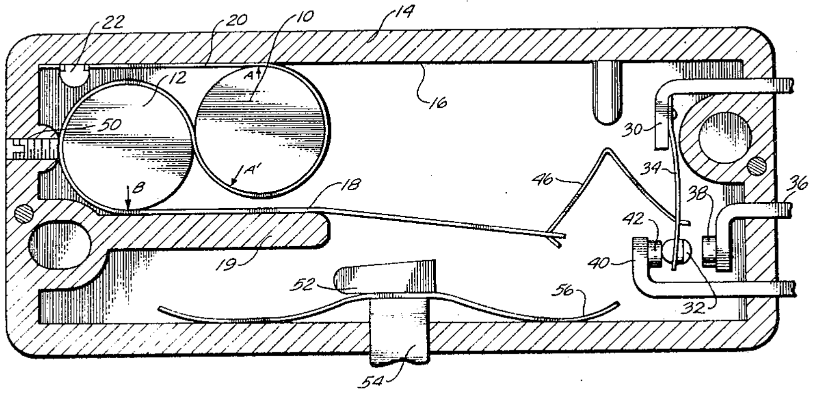


FIG_1A

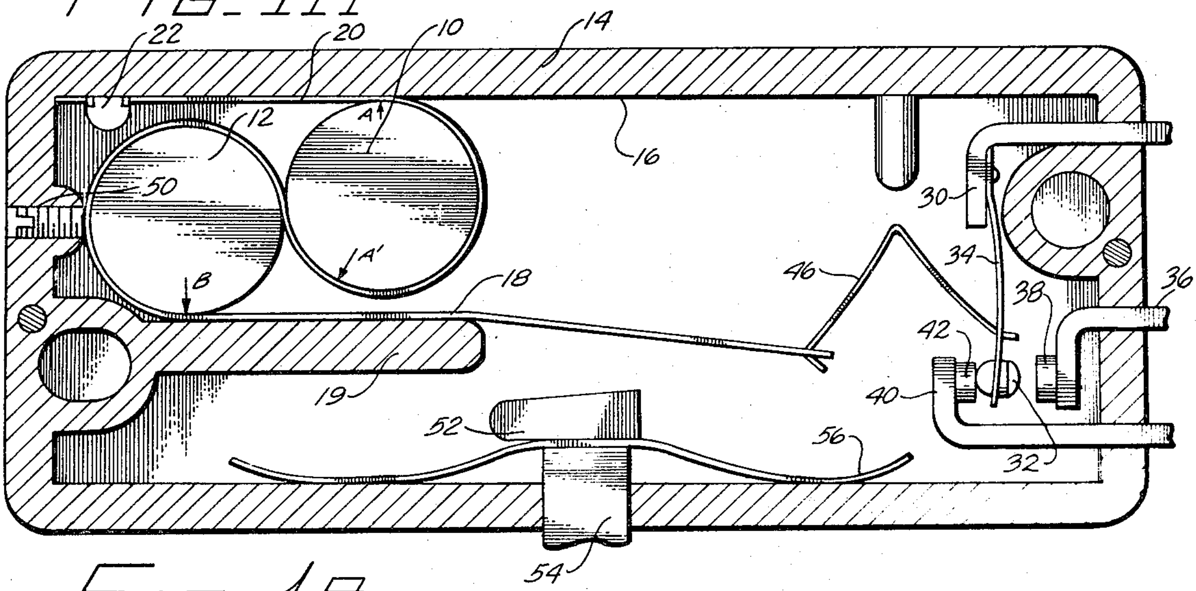


FIG_1B

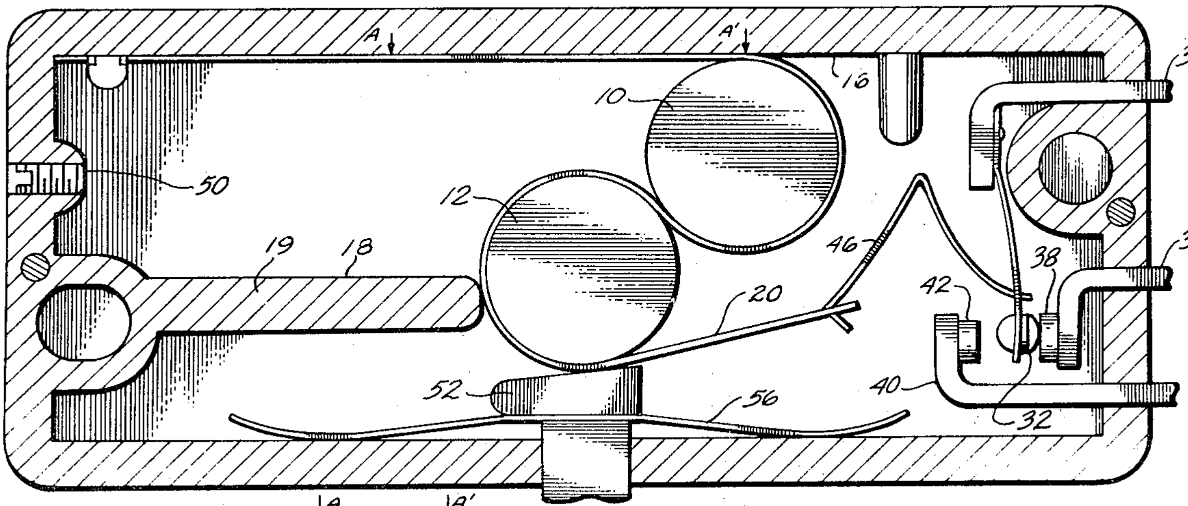


FIG_2

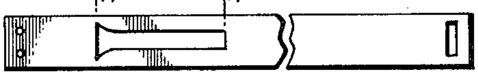


FIG_3

FIG_4

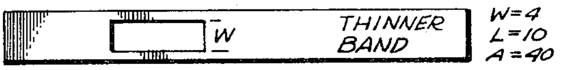
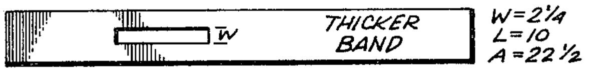
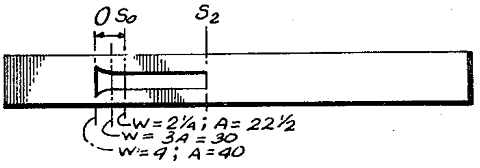


FIG_5



INVENTOR.
LON E. BELL

FIG_6



BY

Christie, Parker & Hale
ATTORNEYS

FIG_7A

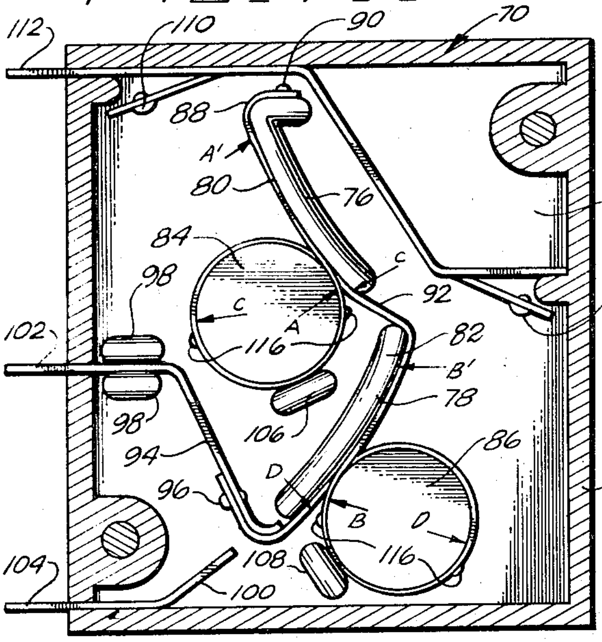


FIG_7B

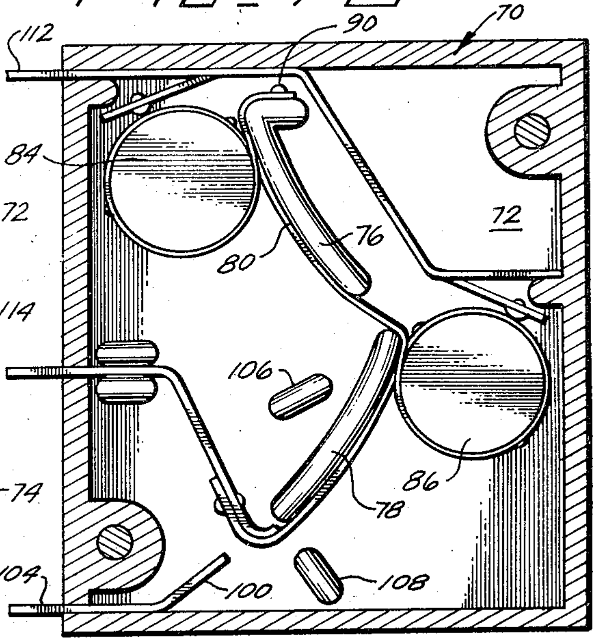


FIG_8

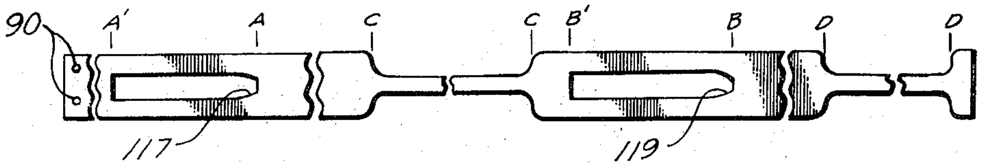


FIG_9

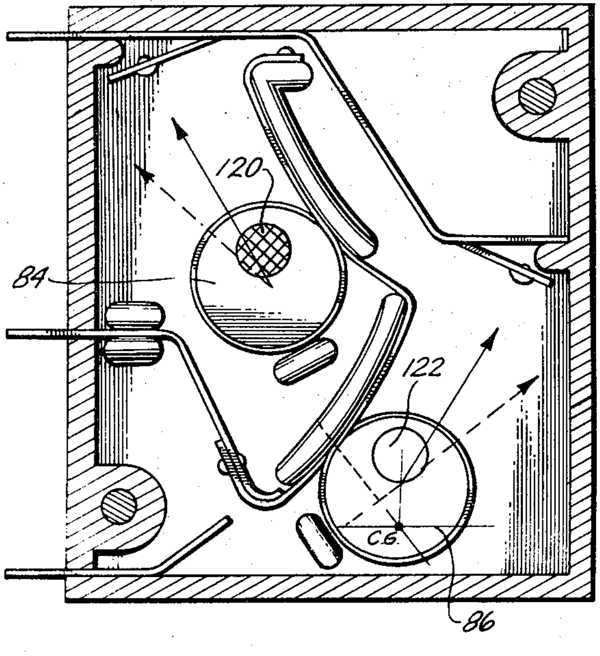
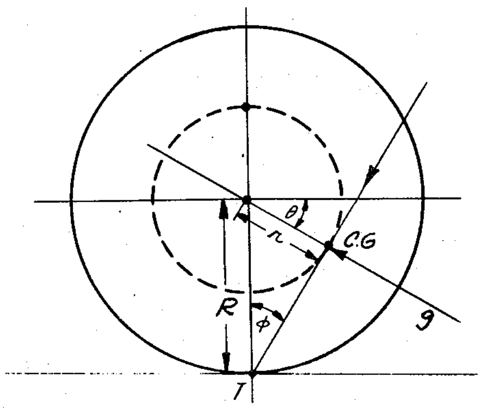


FIG_10



CRASH SENSING SWITCH

FIELD OF THE INVENTION

This invention relates to acceleration responsive switching devices, and more particularly, is concerned with a switching device which is triggered in response to an acceleration force supplied for a predetermined period of time.

BACKGROUND OF THE INVENTION

With the increased emphasis on safety devices for automobiles there has developed a need for a switching device which responds to crash situations. For example, the use of air bags which inflate rapidly to protect the occupants of the automobile in a crash situation has been proposed. Various devices have heretofore been proposed for sensing the conditions under which the triggering device should be actuated. Conventional accelerometer devices have been proposed which respond to acceleration forces above a predetermined level. However, rather high acceleration forces may be experienced through vibrations and other transient conditions which do not involve a crash situation of the automobile. Therefore conventional accelerometer sensing devices are not satisfactory unless combined with some type of timing device which determines that the high acceleration is coupled with some net change in velocity, i.e., the product of the acceleration and time must exceed some predetermined level. Another problem has been to provide sensing which is responsive to acceleration forces over a broad angular range. Conventional accelerometers are sensitive only to the component of acceleration force along a single axis. Where the acceleration is applied at some angle to this axis, the active force on the accelerometer then drops off as the cosine of the angle, which means if the acceleration is at 90° to the axis, the component of force acting along the axis of the accelerometer drops off to zero.

SUMMARY OF THE PRESENT INVENTION

The present invention is directed to an acceleration sensing device particularly suited for use as a crash switch which responds to both a particular acceleration level as well as a particular velocity level to actuate a switch. A single calibration adjustment adjusts both the acceleration level and the velocity level of the device. In one form of the invention, acceleration is sensed along two different axes. The angle of maximum sensitivity is made adjustable by changing the center of gravity of the rollers.

SHORT DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention reference should be made to the accompanying drawings wherein:

FIGS. 1A and 1B show a sectional view of one form of a crash sensing switch of the present invention;

FIG. 2 is a plan view of the flexible band used in the crash sensing switch of FIG. 1A and 1B;

FIGS. 3, 4, 5 and 6 are used in explaining the calibration technique of the present invention;

FIGS. 7A and 7B show an alternative crash switch design according to the present invention which has a broad angle of response;

FIG. 8 is a plan view of the flexible band used in the device of FIGS. 7A and 7B;

FIG. 9 is a modified form of the crash sensing switch of FIGS. 7A and 7B; and

FIG. 10 is a diagram useful in understanding the switch design of FIG. 9.

DETAILED DESCRIPTION

Referring to FIG. 1 in detail, there is shown a crash switch incorporating a regular rolamite device such as described in Research Report SC–RR–67–656, published by the National Bureau of Standards, entitled "Rolamite: A New Mechanical Design Concept" by D. F. Wilkes. The crash switch comprises a pair of cylindrical rollers **10** and **12** positioned within a molded housing **14**. The molded housing provides two flat parallel surfaces **16** and **18** which are spaced apart a distance slightly greater than the diameter of the rollers. The surface **18** is provided by a shelf **19** integrally molded as part of the housing.

The rollers are supported between the two parallel surfaces by a flexible spring band **20** made of beryllium-copper or other suitable flat spring material. The band is anchored to the housing **14** at the left-hand end of the upper parallel surface **16** by means of studs **22**. The band extends around the roller **10** and then around the roller **12** and back along the lower parallel surface **18**. The other end of the band extends beyond the end of the shelf **19** in the housing and terminates adjacent a two-pole switch mounted within the housing. The switch comprises an upper lug **30** which supports a movable contact **32** positioned on the end of a cantilever spring **34** attached to the lug **30**. The lug provides an electrical terminal by extending through the wall of the housing to provide an external connection. Similarly a lug **36** supports one fixed contact **38** while a lug **40** supports a second fixed contact **42** on either side of the movable contact **32**. The lugs **36** and **40** extend through and are supported by the housing **14** to provide external electrical connections to the fixed contacts of the switch. The band **20** is linked to the movable contact **32** by a spring element **46**, which preferably is in the form of an inverted V with one end hooking through a hole in the end of the band and the other end hooking through a hole in the cantilever spring **34**. The cantilever spring **34** and spring element **46** combine to maintain tension on the band sufficient to hold the roller **10** firmly against the upper surface **16**. The band **20**, in a manner hereinafter described in detail, as a result of this tension produces a net force on the rollers urging them to the left, as viewed in the drawing.

The rollers are shown in FIG. 1A in the normal position in which the roller 12 and the surrounding band **20** are against an adjustable stop provided by a screw **50** extending through the wall of the housing. This screw provides a means of calibrating the device in the manner described below. The switch has contacts **32** and **42** closed. FIG. 1B shows the condition of the rollers as they are moved to the right relative to the housing to a position where the roller **12** drops off the end of the shelf **19**. In this position, the roller **12** forces the band downwardly against a spring-loaded re-set member indicated generally at **52**. The re-set member **52** includes a re-set button **54** which projects through the wall of the housing **14**. A spring member **56** mounted on the re-set member **52** engages the inside of the housing and urges the re-set member **52** in a direction toward the rollers. The strength of the spring **56** is not sufficiently strong to overcome the downward force of the roller **12** when it drops off the edge of the shelf **19**. However, by pressing on the re-set button **54** on the outside of the housing **14**, the re-set member **52** engages the band **20** and roller **12**, forcing the roller **12** upwardly back onto the shelf **19**, permitting the rollers to return to the position illustrated in FIG. **1**A.

It will be noted in FIG. **1**B that when the roller **12** drops off the end of the shelf **19**, it permits the end of the band **20** to move to the right. This permits the contact **32** to move to the right over against the fixed contact **38**. Thus two switching conditions are provided. In the initial condition of the crash switch, the rollers are in the position shown in FIG. **1**A and an electrical circuit is completed through contacts **32** and **42**. When an acceleration force is applied to the housing **14**, moving the housing to the left as viewed in the figures, the inertia of the rollers causes them to remain relatively fixed. As the housing moves to the left, the rollers reach the point where the roller **12** drops off the end of the shelf **19** into the position shown in FIG. **1**B. This is a stable latched position in which the electrical circuit is completed through contacts **32** and **38**. The switch remains in this condition until it is re-set by depressing the re-set button **54**.

The band **20** is designed to produce a net force on the rollers **10** and **12** tending to move the rollers against the adjustable screw **50**. This force is produced by the band **20** under tension by providing a cutout in the band in the manner shown in FIG. **2**. It is a well known property of the rolamite that a net force is produced by the band by the difference in the spring stiffness at the point where the band leaves the roller **10** and the point where the band leaves the roller **12**. One way of reducing the stiffness of the spring band is to reduce its effective width by providing a cutout in the band. The cutout, as shown in FIG. **2**, must extend for a sufficient distance along the length of the band so that the tangent point between the upper roller **10** and the band, as indicated at A in FIG. **1**A and at A′ in FIG. **1**B, is always at a cutout portion of the band. The length of the cutout of course must not extend to the tangent point B between the roller **12** and the lower surface **18**. By making the slot of constant width over its length, a constant force is applied to the rollers regardless of the position of the rollers along the guide surfaces **16** and **18**. It will be apparent that the acceleration force applied to the housing **14** must exceed the force produced by the spring tension of the band **20** before the rollers will move away from the adjusting screw **50**. Thus by properly selecting the spring modulus of the material, the thickness of the material, and the effective width of the band at points A and B, the crash switch can be made to respond to any desired level of acceleration of the housing **14**. This level is referred to as the *g*-level of the switch.

One of the significant features of the switch device of FIG. **1** for use as a crash sensing switch is that not only must the acceleration of the housing exceed some predetermined *g*-level before the rollers will begin to move, but this acceleration must be sustained for a sufficient length of time for the rollers to move from their

initial position against the adjusting screw **50** to the point where the roller **12** drops off the end of the shelf **19** so as to actuate the switch. By controlling the distance that the rollers have to move, the device must experience a certain change in velocity before the switch is actuated. This level, referred to as the acceleration-time product level or $g{\cdot}t$ level, is therefore a function of the difference in the stiffness of the band at point A and point B and the distance the rollers must move in going from point A to point A′. Since the difference in stiffness at tangent points A and B is provided by a cutout in the band extending from point A to point A′, the *g*-level is determined by the difference in width of the band at point A and point B, i.e., the *g*-level is proportional to the width of the cutout. The $g{\cdot}t$ level of the switch is therefore proportional to the area of the cutout, i.e., the width w times length L.

In building units of FIGS. **1**A and **1**B, *w* and L can be very accurately controlled. However, for a given width and length of cutout, the thinner the band the lower the *g*-level and therefore the $g{\cdot}t$ level of the device. Likewise, the thicker the band the greater is the *g*-level and therefore the $g{\cdot}t$ level of the device. Not only changes in thickness of the band but changes in the modulus of elasticity of the band affect the *g*-level and the $g{\cdot}t$ level of the device. Since the effective stiffness of the band may vary due to normal manufacturing tolerances, some means must be provided to correct for such variations so that the switch unit can be accurately calibrated to the nominal *g*-level and $g{\cdot}t$ level.

Consider a normal band as shown in FIG. **3** having a stiffness factor of **1** with a cutout of $w = 3$ and $L = 10$, giving an area $A = 30$. If this band were replaced by a thinner band having a stiffness factor equal to three-fourths of the normal band, to obtain the same *g*-level and $g{\cdot}t$ level, the width of the cutout could be increased to $w = 4$ and an area $A = 40$, as shown in FIG. **4**. On the other hand, if a thick band is used having a stiffness factor of four-thirds of the normal band, the width of the cutout should be narrowed to $w = 2\ ½$ and an area $A = 22\ ½$ to get the same *g*-level and $g{\cdot}t$ level.

According to the present invention, rather than using bands having different size cutouts depending upon the relative stiffness of the band, a calibration arrangement is provided by which merely changing the effective value of the length L it is possible to control both the *g*-level and the $g{\cdot}t$ level so as to compensate for variations in the stiffness of the band. Suppose, for example, it is found that the stiffness factor of band materials tends to vary anywhere over the limits from the factor three-quarters to a factor of four-thirds. A *g*-level and $g{\cdot}t$ level corresponding to a nominal stiffness factor of **1** can then be achieved by providing a cutout as shown in FIG. **6** which includes a uniform cutout width W_o from s_o to s_2 and then is tapered outwardly to some maximum width at 0. Assume the initial position *s* of the roller can be adjusted between the limits of 0 to s_o. By making the portion of the cutout from s_o to s_2 with a uniform width of $W = 2\ ¼$ giving an area equal $22\ ½$, it will be seen that the desired *g*-level and $g{\cdot}t$ level will be achieved for a band having a stiffness factor of four-thirds normal stiffness by positioning the roller at the initial position corresponding to s_o. For a normal band having a stiffness factor of **1**, the initial tangent point A of the roller (See FIG. **1**A) of the roller is moved along the length of the tapered section to a point having a width W = 3, giving the desired *g*-level. By designing the shape of the tapered section such that the resulting area of the cutout to the right of the initial tangent point of the roller is equal to **30**, the correct g.t level is also achieved. For a band having a stiffness factor of three-quarters, the roller is positioned at 0 in FIG. **6**, where the cutout width is W = 4 and the cutout area is arranged to equal **40**. This provides the proper *g*-level and *g·t* level for a band having a stiffness factor of three-quarters. Thus by providing the proper shape of tapered cutout, the device can be calibrated to achieve both the correct *g*-level and the correct *g·t* level by a single adjustment of the initial position of the rollers along the band. This adjustment of the initial position is provided by the adjusting screw **50**.

The above description illustrates that it is possible to provide simultaneous calibration of both the *g*-level and the *g·t* level of the switch.

In the more generalized solution, the force F produced by the band for a given difference in the effective width Δ*w* of the band at the two tangent points is given by the expression

$$F=\frac{Et^3}{gd^2}\Delta w=k\Delta w \qquad (1)$$

where E is the plate modulus of the band material, *t* is the band thickness, and *d* is the diameter of the rollers. By effective width is meant the total width of material. Thus the effective width Δ W of the band is reduced by a cut-out or by indenting the margins of the band. The acceleration g_o required to move the rollers is selected for the particular application. This is the *g*-level of the crash unit. Selecting the minimum thickness within the tolerance range of the band, Δw_o for the point s_o can be established from the above relation, using Newton's Second Law

$$g(s)=F/W \qquad 2$$

where *W* is the weight of the two rollers.

The *g·t* level for an initial setting of the roller tangent point at s_o is

$$G_0=\int_{s_0}^{s_2} g(s)\,ds \qquad (3)$$

The solution of equation (3) for a rectangular cutout is

$$G_o=g_o(s_2-s_o) \qquad 4$$

The shape of the curve and therefore the change in Δ*w* as a function s in the calibration region ($s \leq s_o$) is determined from the expression

$$g(s)=g_0 e\frac{G_0}{g_0}(s_0-s) \qquad (5)$$

Combining equations (1), (2) and (5) gives

$$\Delta w(s)=\frac{g_0}{Wk}\cdot e\frac{g_0}{G_0}(s_0-s) \qquad (6)$$

in the region ($s \leq s_o$). If the region *s* to s_2 is a rectangle, equation (6) combined with equation (4) becomes

$$\Delta w(s)=\frac{g_0}{Wk}e\frac{s_0-s}{s_2-s_0}=\Delta w_0 e\frac{s_0-s}{s_2-s_0} \qquad (7)$$

It will be noted that the difference in width Δ*w* at the two tangent points as a function of (*s*) can be achieved not only by a cutout, as shown in the drawings, but also by varying the width of the band in the region of either tangent point. The cutout is preferred because it provides a uniform margin along the length of the band. The necessity of calibration of the switch can be seen from equation (1) which shows that the *g*-level is proportional to t^3. Thus small variations in band thickness due to ordinary manufacturing tolerances can very materially affect the *g*-level.

While the switch unit of FIGS. **1**A and **1**B provides a highly sensitive switch for sensing accelerations which exceed a particular *g*-level and are of sufficient duration to exceed a particular *g·t* level, the device only responds to the component of acceleration of the device which is in a direction parallel to the direction in which the rollers move. As the angle of acceleration deviates from this direction, this component of acceleration drops off as the cosine of the angle. In other words the sensitivity of the device drops off according to the cosine function as the direction in which the accelerating force applied to the device changes relative to the longitudinal axis of the device. A force normal to the direction of roller movement has no effect. It is frequently desirable, however, to provide a crash sensing device which is sensitive to accelerations over a broad range of angles relative to the position of the device. A device providing an extended angular range of sensitivity is shown in FIGS. **7**A and **7**B. FIG. **7**A shows the device in its initial condition and FIG. **7**B shows the same device with the switch triggered by exposing the device to a particular *g·t* level. The device of FIG. **7**A includes a housing indicated generally at **70**. The housing is molded in plastic, for example, and has a back wall **72** and outer side walls **74** extending on four sides. Within the housing are a pair of integrally molded guide members **76** and **78** providing flat, smooth, slightly convex guide surfaces **80** and **82**, respectively.

A pair of rollers **84** and **86** are held in rolling relationship to the guides **76** and **78**, respectively, by a single band **88**. The band is anchored at one end by a pin **90** to the guide member **76**. The band extends in a loop around the roller **84** and then passes through a gap **92** between the adjacent ends of the guide member **76** and **78** onto the guide surface **82**. The band passes over the guide surface **82** and forms a loop around the roller **86**. The band **88** then passes from the end of the guide member **78** to a mounting bracket **94** in the form of a stiff cantilever spring. The band **88** passes around the outer end of the supporting bracket **94** and is pinned to the bracket **94** by a rivet **96** or other suitable holding means. The bracket **94** is securely supported to the housing **70** by a pair of lugs **98** which clamp the bracket **94**. The cantilever spring effect of the bracket **94** places the band **88** under tension. If the band **88** should break, the bracket **94** springs over against a contact **100**. The bracket **94** and the contact **100** extend outside of the housing to provide a pair of electrical terminals **102** and **104**. Thus it will be seen that failure of the band causes an electrical path to be completed between the terminals **102** and **104**, which path can be used to indicate failure at some remote point of the device due to breakage of the band.

The shape of the band is shown in FIG. **8**. The band includes an end portion where pins **90** anchor the band to the guide member **76**. The band is provided with a cutout region extending from A' to A. The length of this cutout region is slightly in excess of the maximum distance of the travel of the roller **84** along the surface **80**. The band is provided with a reduced cross section from C to C, which is narrow enough to pass through the cutout region A–A′ so that the band can be looped around the roller. The distance A′–A in FIG. **8** corresponds to the circumference of the roller **84**. Similarly the band is provided with a second cutout region B′–B and a second reduced cross-sectional region D—D, which is narrow enough to pass through the cutout region B′–B. Again the distance B′–B along the band, as shown in FIG. **8**, corresponds to the circumference of the roller **86**.

Because of the difference in width of material of the band at the tangent point A for the roller **84** and tangent point B for the roller **86**, a net force is provided on each of the rollers **84** and **86** urging the rollers against stops **106** and **108** respectively. An acceleration force parallel to the guiding surface **80** which exceeds the force produced by the band **88** is required to move the roller **84** away from the stop **106**. If such a force is applied to the housing **70** and it continues for a sufficient period of time, the inertia of the roller **84** will cause the housing to move relative to the roller. As a result, the roller moves along the extent of the guide **76** in a direction away from the stop **106** until it comes in contact with an electrical contact member **110**. The contact member **110**, in the form of a cantilever spring, is electrically connected to an external terminal **112**. Thus movement of the roller **84** against the contact **110** completes an electrical path between the terminals **102** and **112**.

Similarly a force accelerating the housing **70** parallel to the guide surface **82** which exceeds the force on the roller **86** produced by the band **88**, causes the roller **86** to move along the guide surface **82**. If this force continues for a sufficient length of time, the roller will move over into contact with a contact member **114**. The contact member **114** is also in the form of a cantilever spring which is electrically connected to the external terminal **112**. Thus movement of the roller **86** against the contact **114** completes an electrical circuit between the terminals **102** and **112**. Position of the rollers **84** and **86** when they are moved against the contacts **110** and **114** is illustrated in FIG. **7B**.

Since the crash switch is normally mounted so that the force of gravity is perpendicular to the plane of the paper as the device is viewed in FIGS. 7A and 7B, it is necessary to support the rollers **84** and **86** against movement due to the force of gravity. This is accomplished by securing the band **88** directly to the rollers **84** and **86** by pins, as indicated at **116**. While two pins for each roller have been shown in the figure, it will be understood that the band can be cemented, brazed, or otherwise secured to the roller within the arc between the two pin positions shown. Within this arc, the band always remains in contact with the roller over the full distance of movement of the roller between the stop and the contact member. Thus the rollers are supported by the band, the tension in the band being sufficient to suspend the rollers and to hold the band in contact with the guide surfaces **80** and **82**.

It should also be noted that the calibration technique described above is applicable to the arrangement of FIGS. 7A and 7B by providing the cutout regions with the proper shape and making the positions of the stop members **106** and **108** adjustable from outside of the housing. Thus by shifting the initial position of the rollers **84** and **86**, the device can be calibrated to the nominal g-level and $g{\cdot}t$ level. One way of providing the correct variation in band width is shown in FIG. **8** at **117** and **119**.

In the arrangement of FIGS. 7A and 7B, the direction of maximum sensitivity for the roller **84** is in a direction substantially parallel to the guide surface **80**. The direction of sensitivity of the roller **86** is in a direction substantially parallel to the guide surface **82**. By providing the two rollers which are sensitive to accelerations along two different angles, a crash sensing device is achieved having a much wider range of angular sensitivity than the device of FIG. **1**.

While the device of FIG. **7** has two angles of maximum sensitivity, these angles are fixed by the relative angular positions of the guide members **76** and **78** in the housing. It is frequently desirable to be able to modify these angles without completely redesigning the housing. A simple and effective way to shift the angles of sensitivity of the unit of FIG. **7** is shown in FIG. **9**. The unit of FIG. **9** is basically identical to that described above in connection with FIGS. 7A and 7B. In the arrangement of FIG. **9**, the rollers **84** and **86** have holes drilled in the rollers, as indicated at **120** and **122**, respectively. The holes are drilled off center so as to shift the center of gravity c.g. off the axis of revolution of the rollers. The effect of shifting the center of gravity is to shift the angle of maximum sensitivity of each of the rollers to any acceleration forces applied to the housing **70**. The effect of shifting the center of gravity relative to the axis of revolution of the roller can best be understood by reference to FIG. **10**. If the center of gravity is assumed to be at the center of revolution of the roller, it will be seen that the direction of maximum sensitivity of the roller to an accelerating force is in a direction parallel to the surface on which the roller is moving. Since the roller is held against the surface by the looping band, any direction of force on the center of the roller which has a component perpendicular to the plane on which the roller is moving has no effect on the acceleration of the roller. However, if the center of gravity is shifted from the center of the roller, the center of gravity moves in a circular path as the roller moves. It will be seen that the direction of maximum sensitivity to an external force is always in a direction perpendicular to the line extending between the tangent point of the roller to the guide surface and the point at which the center of gravity is located. Thus the larger the distance between the center of gravity and the center of rotation of the roller, the greater the angle of the direction of maximum sensitivity can be shifted. From FIG. **10** it will be seen that by changing the angular position θ of the center of gravity relative to the path of the center of the roller, as well as changing the distance at which the center of gravity is shifted from the center of the roller, the angle of maximum sensitivity to an external accelerating force can be controlled. The greatest value for θ is achieved if the center of gravity is positioned at the tangent point of a line tangent to the circular path of the center of gravity of the roller and passing through the point of contact of the roller and the band, as shown in FIG. **10**.

What is claimed is:

1. A crash switch comprising a housing having an in-

terior chamber, the chamber having first and second parallel guide surfaces, said second surface terminating at one end at an intermediate point within the chamber, a pair of cylindrical rollers, the diameters of the rollers being less than the normal distance between the first and second surfaces but greater than half said normal distance, a flexible spring band anchored at one end to the housing adjacent one end of the first surface, the band passing around a portion of each of the rollers in a substantially S-shaped path between the two surfaces, the other end of the band extending beyond said one end of the second surface such that movement of the rollers along the band extends from between the two parallel surfaces to a position beyond said one end of the second surface, spring means connected between said other end of the band and the housing for imparting tension to the band, and a re-set plunger extending into the chamber adjacent said one end of the second surface, the plunger having a portion movable toward and into engagement with the band for urging the band in a direction toward the first surface when the position of the rollers is beyond said one end of the second surface.

2. Apparatus as defined in claim 1 wherein said spring means includes a movable switch contact, and at least one fixed contact mounted within the housing, the movable contact being urged into and out of contact with said fixed contact by movement of the associated end of the band.

3. Apparatus as defined in claim 1 wherein the band includes a modified portion along its length to produce a net force on the rollers in a direction toward the end of the band anchored to the housing.

4. Apparatus as defined in claim 3 wherein the modified portion changes the effective width of the band along its length, the width of material of the band at the tangent point between the roller and band adjacent the first surface is less than the width of the band at the tangent point between the roller and band adjacent the second surface.

5. Apparatus as defined in claim 4 wherein the modified portion constitutes a cut-out strip along the center of the band.

6. Apparatus as defined in claim 4 wherein the difference in width at the two tangent points varies as the position of the rollers in a direction parallel to said guide surfaces is shifted.

7. Apparatus as defined in claim 6 further including adjustable stop means for adjusting the initial position of the rollers over a range of positions to change the difference in width of the two tangent points for the initial position of the rollers.

8. Apparatus as defined in claim 7 wherein the difference in width of the band at the two tangent points over said range of adjustable initial position varies exponentially.

9. Apparatus as defined in claim 8 wherein said width varies exponentially according to the relationship

$$\Delta w(s)=\frac{g_o}{Wk}e^{\frac{g_o}{G_o}(s_o-s)}$$

where g_o is the nominal design g-level of the switch, s_o-s is the distance from the adjustable initial position s of the tangent point and the tangent point s_o of maximum adjustment, k is a constant determined by the physical properties of the band and roller means, W is the weight of the rollers, and

$$G_o=\int_{s_o}^{s_2} g(s)\,ds$$

where s_2-s_o is the minimum distance of the movement of the tangent point along the band for the nominal design $g{\cdot}t$ level of the switch.

10. Apparatus as defined in claim 8 wherein said width varies exponentially over the adjustable range of the initial position of the tangent points according to the relationship

$$\Delta w(s)=w_o e^{\frac{s_o-s}{s_2-s_o}}$$

where w_o is the width over the length s_2-s_o of the band, s_2-s_o is the minimum distance of roller movement from the initial position.

11. An omnidirectional crash sensor comprising: a housing, means within the housing defining first and second surfaces, a pair of rollers, a spring band looping completely around each of the rollers and along the two surfaces, means for holding the band under tension, each roller being positioned to move along a respective one of said surfaces, the band having two cutouts extending partially around the respective rollers to provide a net force on each roller urging the roller in one direction along the associated surface and against an associated stop, a pair of contact means mounted in the housing and actuated by movement of the respective rollers along said surfaces a predetermined distance from said stops.

12. Apparatus as defined in claim 11 wherein the first and second surfaces are positioned at a substantial angle to each other.

13. Apparatus as defined in claim 11 wherein said first and second surfaces are slightly convex in the direction of movement of the rollers along the surfaces.

14. Apparatus as defined in claim 11 wherein the center of gravity of at least one of the rollers is displaced from the axis of revolution of the roller.

15. Apparatus as defined in claim 11 comprising a spring member anchored to the housing and secured to the band to exert a tension force on the band, and an electrical contact mounted in the housing adjacent to but spaced from the spring member, the spring member being positioned to engage the contact to complete an electrical current path in the absence of the restraining action of the band.

16. Apparatus comprising means defining a convexly curved surface, a cylindrical roller, a band of spring material extending in a closed loop around the roller, and means secured to opposite ends of the band for holding the band under tension against the curved surface, the band having a slot extending along a portion of its length and reduced width along a portion of its length, the reduced width portion passing through the slot to form the closed loop extending around the roller, the band having a different spring stiffness in the slotted portion and the reduced width portion to provide a net force on the roller urging the roller in one direction along the curved surface.

17. The apparatus of claim 16 further including electrical contact means positioned adjacent the curved surface, the contact means being actuated by movement of the roller to make and break an electrical current path.

18. Apparatus as defined in claim 17 wherein the

center of gravity of the roller is displaced from the axis of revolution of the roller.

19. A switch device for sensing acceleration forces comprising housing means having a pair of spaced apart parallel guide surfaces, a flexible spring band, a pair of rollers each having a diameter less than the spacing normally positioned between said guide surfaces but greater than half said spacing, the band being secured to the housing means at a first end against one guide surface and extending in an S-shaped path around the two rollers into contact with the other guide surface, said other guide surface terminating in a ledge, a second end of the band extending beyond said ledge, switch means including a movable contact and at least one fixed contact, said switch means also including spring means urging the movable contact into engagement with the fixed contact, and tension spring means operatively connecting said second end of the band to the movable contact for applying tension to the band, the tension spring means being sufficiently strong to pull the movable contact away from the fixed contact thereby opening the switch means when both rollers are between the guide surfaces, the rollers being movable in rolling contact with the band to a position beyond the ledge in which the band is no longer in contact with said other guide surface, permitting one of the rollers to be moved away from the one guide surface by the tension in the band, the movement of the one roller reducing the tension in said tension spring means and permitting the movable contact to move against the fixed contact thereby closing the switch means.

20 Apparatus of claim **19** further including reset means movably supported by the housing means, the reset means being positioned to engage the band adjacent the ledge, the reset means when actuated urging the band toward said one guide surface to reposition the rollers between the guide surfaces.

* * * * *