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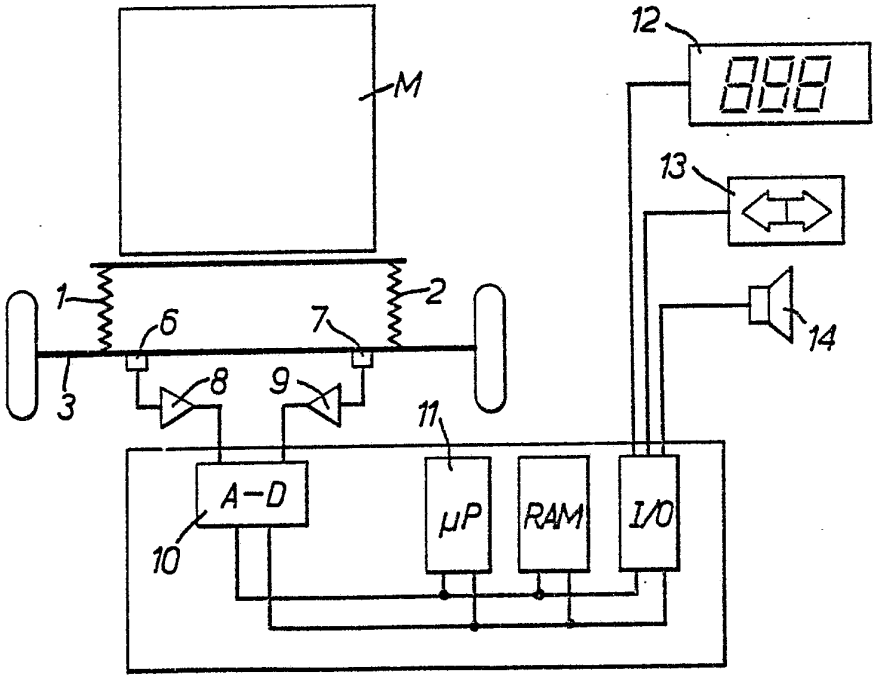

(57) Abstract

A roll-over warning system for wheeled vehicles has strain gauge transducers (6, 7) fitted to an axle (3), symmetrical with respect to the centre. Their combined signals can indicate the load, and the amount of effective lateral shift of the load, due to cornering. This can be compared with a given maximum and a warning given when the danger level is approached. The rate and acceleration of load shift can also be determined to anticipate such an approach. With the usual compliant suspension (1, 2) parameters dependent on that and the load are introduced into the calculation.

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"A Roll-Over Warning System"

This invention relates to a roll-over warning system for motor vehicles having a load carrying chassis mounted on a wheel assembly with or without an intermediate suspension system.

In such vehicles, particularly lorries and especially articulated lorries, negotiation of a bend at too great a speed can lead to rolling over. The speed at which such rolling can take place may be quite low, particularly if the bend is tight, such as on a roundabout.

There have been various proposals for giving warning about, and even preventing, a vehicle overturning. One is described in French Patent No. 2,352,692, which relies on the optical detection of the surface of a bath of mercury exceeding a given angle in relation to the transverse plane of the vehicle. Another is described in published British Specification No. 2,066,538A, which correlates vehicle speed with steering angle and, as well as operating an alarm, interferes with the vehicle controls when danger is approached. A third technique is adopted in published British Specification No. 2,088,606A, which proposes

accelerometers to measure lateral acceleration. The first two take no account of vehicle loading, which is the most important factor in determining imminent roll over, and the proposal to over-ride the driver's controls, particularly the steering, is extremely dangerous. The third system puts the accelerometers on the axle and the chassis respectively, and recognises that their movement is different as a result of a compliant suspension. One part of the system relies on external indications of the nature of the bend to be negotiated, such as roadside signs, or signal loops below the road surface, which do not exist and which are not likely to as the cost would be prohibitive. The other part compares lateral accelerations and from them determines the roll angle of the chassis. The relationship of this to the expected roll angle for the instantaneous lateral acceleration and a maximum permitted acceleration governs the actuation of an alarm. To a certain extent this takes account of the loading, but the only readings taken are of accelerations. The load has to be determined by other means, its centre of gravity worked out, and this translated into a reference signal representing the maximum permitted chassis acceleration. Also, one is working in small angles and the derivation of the actual roll angle from acceleration signals will be of uncertain accuracy in practice. This is recognised by the suggested alternative of pendulums whose angles can be measured, but the necessary damping will make their response too slow.

It would be of considerable advantage not to have to ascertain loading and centre of gravity by separate means before every trip, and to have more distinguishable and instantaneously available signals than marginally different accelerations and angles. It would also be useful to be able to anticipate a roll-over crisis at the earliest possible moment.

According to one aspect of the present invention there is provided a roll-over warning device for vehicles having a chassis mounted on a wheel assembly or assemblies, the device comprising laterally spaced means on a wheel axle for producing electrical signals representative of local loading means for combining said signals to determine the degree of shift of the effective centre of loading of the vehicle, means for comparing said shift signal with an electrical signal representative of a predetermined maximum safe shift,and means for operating a warning when the comparison indicates an approach to said maximum.

According to another aspect of the present invention there is provided a roll-over warning device for vehicles having a chassis mounted on a wheel assembly or assemblies, the device comprising laterally spaced means for determining from said signals the rate and/or acceleration of shift of the effective centre of loading, means for calculating therefrom a predicted maximum shift of centre of loading, means for comparing this predicted maximum shift of centre of loading with a predetermined

maximum safe shift, and means for operating a warning when the comparison indicates an approach to said maximum.

Generally, the chassis will be mounted by a compliant suspension on the wheel assembly or assemblies. There will then be means for combining said signals to determine total loading, and the calculating means will have an input for at least one parameter corresponding to the suspension compliance and damping for the determined load.

Preferably, the load signals producing means are strain transducers, arranged to produce signals corresponding to axle bending moments. Such transducers may be of the form described in British Patent No. 2,050,624B.

For a better understanding of the invention an embodiment will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic end view of a vehicle equipped with transducers on an axle,

Figure 2 is a block diagram of a vehicle roll-over warning device, and

Figure 3 shows characteristics obtainable from the axle transducers.

In Figure 1 a load M, which will include the chassis of the vehicle, is carried by a compliant suspension indicated by arrowed lines 1 and 2 on an axle 3 having wheels 4 and 5. Strain gauge transducers 6 and 7 are attached symmetrically to the axle either side of its centre

point. The suspension spacing is S, the transducer spacing is T,the wheel spacing is W and the height of the centre of mass of the load M above the axle is H. The suspension forces are SL and SR (L and R indicating left and right as one looks at the figure), the bending moments at the transducers are TL and TR, and the ground reaction forces on the wheels are WL and WR. A sideways force on the load, as a result of cornering for example, is F.

First, it will be demonstrated that these transducers, assuming that they each provide an output proportional to bending moments, will thereby produce signals which can indicate the roll-over tendency. Further assumptions are that the axle is symmetrical and that the mass is concentrated in the load on the suspension, with the axle weight ignored.

Bending moments at transducers 6 and 7 are:

$$TL = -SL\left(\frac{S-T}{2}\right) + WL\left(\frac{W-T}{2}\right) + WR\left(\frac{W+T}{2}\right) - SR\left(\frac{S+T}{2}\right) \quad (1)$$

$$TR = -SL\left(\frac{S+T}{2}\right) + WL\left(\frac{W+T}{2}\right) + WR\left(\frac{W-T}{2}\right) - SR\left(\frac{S-T}{2}\right) \quad (2)$$

The sum of the bending moments is (1) + (2):

$$TL+TR = W(WL+WR) - S(SL+SR) \quad (3)$$

and we may assume $Mg=SL+SR = WL+WR$ (4)

independent of F, so that the bending moment sum is, from (3) & (4):

$$TL+TR = Mg(W-S) \quad (5)$$

Thus the sum of the transducer output signals is proportional to M, (W and S being constant).

In the presence of a sideways force F, equating moments:

$$FH = (SL-SR)\frac{S}{2} = (WL-WR)\frac{W}{2} \quad (6)$$

The difference between transducer bending moments is (1)-(2)

$$TL-TR = T\left((WR-WL) - (SR-SL)\right) \quad (7)$$

substituting (6) into (7)

$$TL-TR = T\left(\frac{2FH}{S} - \frac{2FH}{W}\right)$$

$$TL-TR = 2FH\ \left(\frac{1}{S} - \frac{1}{W}\right) \quad (8)$$

Thus the difference between the transducer output signals is proportional to F.

A danger point exists when WR=O (9)

as the vehicle is then on the point of overturning. At this condition, substituting (9) and (4) into (6)

$$FH = \frac{WLW}{2} = \frac{MgW}{2} \quad (10)$$

from (10) and (8):

$$TL-TR = MgW\ T\ \left(\frac{1}{S} - \frac{1}{W}\right)$$

$$TR-TR = Mg\ \frac{T}{S}\ (W - S) \quad (11)$$

The sum of bending moments is still

$$TL+TR = Mg\ (W - S) \quad (5)$$

So that the ratio $\frac{TL-TR}{TL+TR} = \frac{T}{S}$ a constant. This will be referred to as the danger ratio.

When WR$>$O, the difference: sum ratio R will be less than T/S, and so the outputs of the transducers will be processed to ascertain continuously the value of the ratio and to generate a warning if T/S is approached.

Similar considerations give the same result when there is a sideways shift of load, or the vehicle is tilted.

Thus the approach to the danger point is determined from the ratio R between the sum and difference responses of the sensors, and the critical value of this ratio depends on the vehicle constants of spacing between the sensors, and spacing between the suspension points.

Turning to Figure 2, the outputs of the strain gauges 6 and 7 are amplified in 8 and 9, digitized in A-D converter 10 and fed to a microcomputer 11. The microcomputer processes the strain gauge signals and has outputs to energize warning indicators 12, 13, 14 as required. As evident from the drawing, these may show a numeric quantity, indicate a directional warning by an illuminated arrow and sound an audible alarm. This microcomputer may be of a type which is already used to produce axle load indication and overload warning, and will not be described in detail.

It has been shown that the vehicle will be on the verge of falling over when the difference signal from left and right sensors stands in a certain ratio (the danger ratio) to the sum signal. The difference between the actual ratio at any instant and the danger ratio is the safety margin. In a dynamic situation, however, the compliances of the suspension will allow a danger situation to occur which may not be correctable unless an appropriate manoeuvre is made. This tendency will be modified by the damping and nonlinearity of the suspension.

Advance warning can in principle be obtained by continuously calculating from the shift, rate of shift, and acceleration of shift of effective loading, the maximum shift that will occur in the absence of an appropriate manoeuvre. A warning will be issued if this maximum predicted shift exceeds the danger ratio. The calculation will require as an extra input at least one parameter corresponding to the suspension compliances and damping for the particular load. A range of such parameters may be available as constants on a look-up table and the appropriate one or ones could be manually keyed in; or they may be in memory and automatically accessed according to the load, which can be determined from the sum of the transducer outputs (see equation (5)). The degree by which the warning of roll-over will precede the event will be a function of the vehicle suspension time constants.

Consider, for example, the effect of a sudden sideways force due to entering a constant radius curve. Various responses are shown in Figure 3.

The first graph (a) indicates that, at constant speed and radius, the sideways force F likewise remains constant over time C.

The second graph (b) indicates that the difference/sum ratio R from the transducers will increase at a rate, and to an extent, dependent on the weight of the load, the suspension influencing the curves.

The rate and acceleration of load shift have

characteristics as shown in the third and fourth graphs (c) and (d), and the peaks of either or both characteristics, which are readily detectable in periods C and D some time before the ratio R approaches the danger level, can be used to calculate the final maximum ratio. Since the effect on suspension dynamic roll characteristics is substantially predictable from the total load (the sum of the sensor outputs) all the information required is available from the sensors.

It will be understood that the transducers may be fitted to one or any number of axles, and that if two or more are so equipped, any one of the transducer pairs could give a warning, independently of the others.

CLAIMS

1. A roll-over warning device for vehicles having a chassis mounted on a wheel assembly or assemblies, the device comprising laterally spaced means on a wheel axle for producing electrical signals representative of local loading means for combining said signals to determine the degree of shift of the effective centre of loading of the vehicle, means for comparing said shift signal with an electrical signal representative of a predetermined maximum safe shift, and means for operating a warning when the comparison indicates an approach to said maximum.

2. A roll-over warning device for vehicles having a chassis mounted on a wheel assembly or assemblies, the device comprising laterally spaced means on a wheel axle for producing electrical signals representative of local loading means for determining from said signals the rate and/or acceleration of shift of the effective centre of loading, means for calculating therefrom a predicted maximum shift of centre of loading, means for comparing this predicted maximum shift of centre of loading with a predetermined maximum safe shift, and means for operating a warning when the comparison indicates an approach to said maximum.

3. A device as claimed in claim 2 for a vehicle in which the chassis is mounted by means of a compliant suspension on the wheel assembly or assemblies, wherein there are means for combining said signals to determine total loading, and wherein the calculating means has an input for at least one parameter corresponding to the suspension compliance and damping for the determined load.

4. A device as claimed in claim 1, 2 or 3, wherein the load signal producing means are strain transducers.

5. A device as claimed in claim 4, wherein the strain transducers are arranged to produce signals corresponding to axle bending moments.

CLAIMS

1. A roll-over warning device for vehicles having a chassis mounted on a wheel assembly or assemblies, the device comprising laterally spaced means on a wheel axle for producing electrical signals representative of local loading means for combining said signals to determine the degree of shift of the effective centre of loading of the vehicle, means for comparing said shift signal with an electrical signal representative of a predetermined maximum safe shift, and means for operating a warning when the comparison indicates an approach to said maximum.

2. A roll-over warning device for vehicles having a chassis mounted on a wheel assembly or assemblies, the device comprising laterally spaced means on a wheel axle for producing electrical signals representative of local loading means for determining from said signals the rate and/or acceleration of shift of the effective centre of loading, means for calculating therefrom a predicted maximum shift of centre of loading, means for comparing this predicted maximum shift of centre of loading with a predetermined maximum safe shift, and means for operating a warning when the comparison indicates an approach to said maximum.

3. A device as claimed in claim 2 for a vehicle in which the chassis is mounted by means of a compliant suspension on the wheel assembly or assemblies, wherein there are means for combining said signals to determine total loading, and wherein the calculating means has an input for at least one parameter corresponding to the suspension compliance and damping for the determined load.

4. A device as claimed in claim 1, 2 or 3, wherein the load signal producing means are strain transducers.

5. A device as claimed in claim 4, wherein the strain transducers are arranged to produce signals corresponding to axle bending moments.

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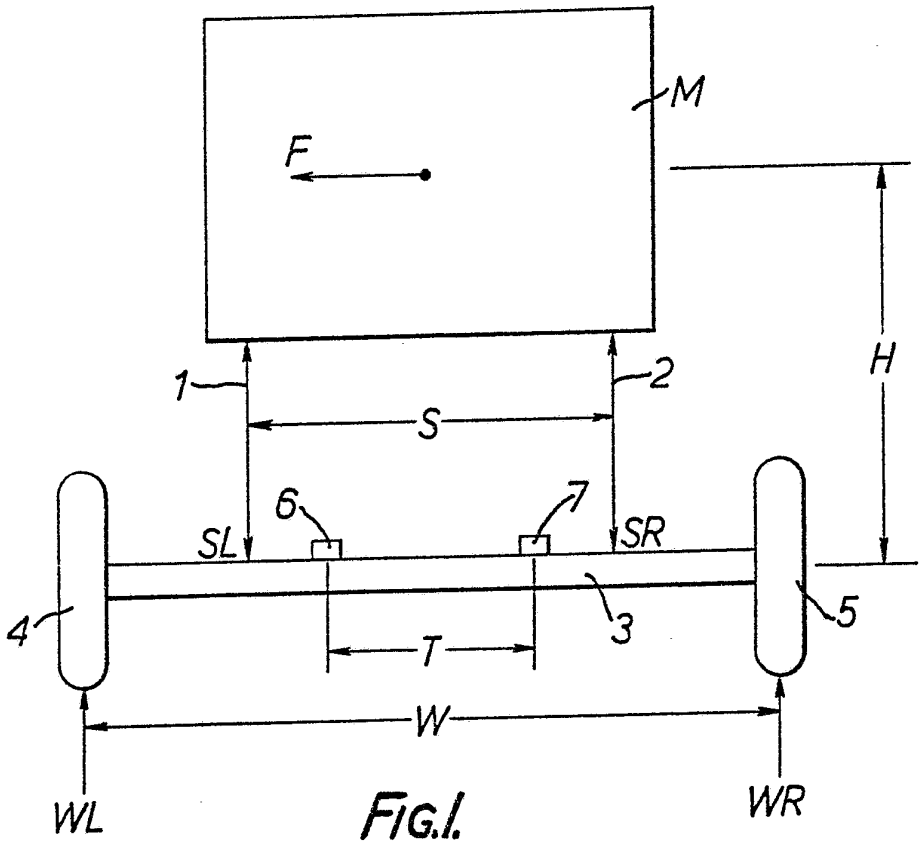

FIG.1.

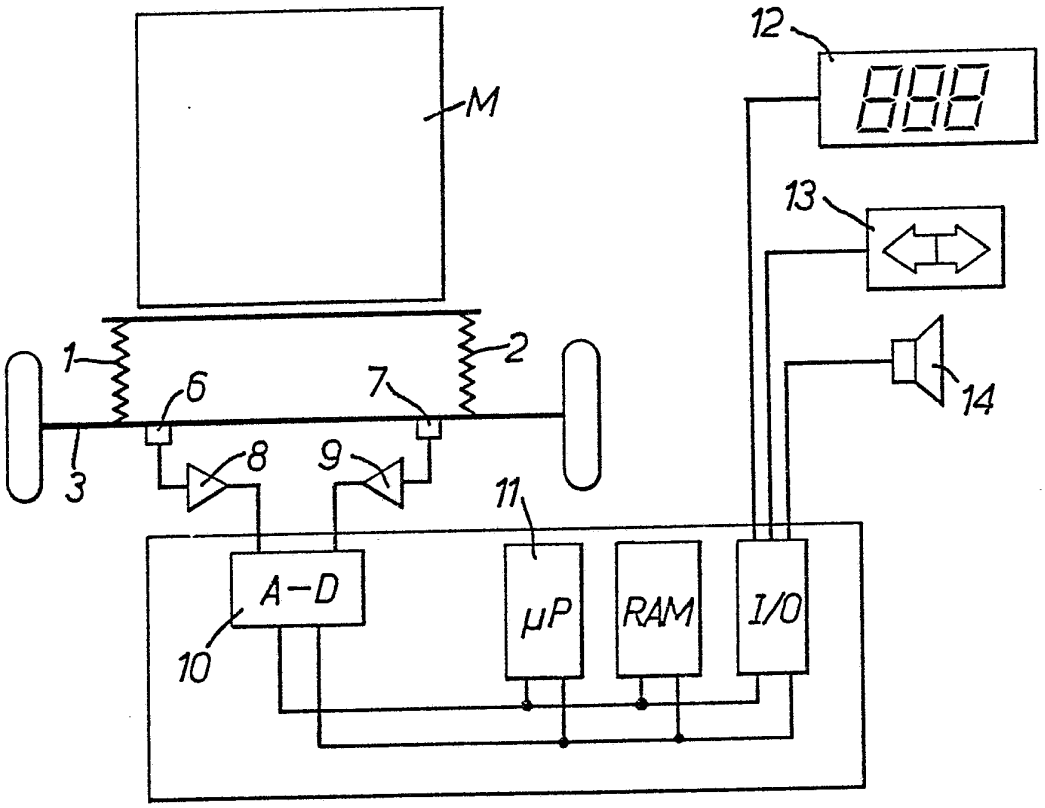

FIG.2.

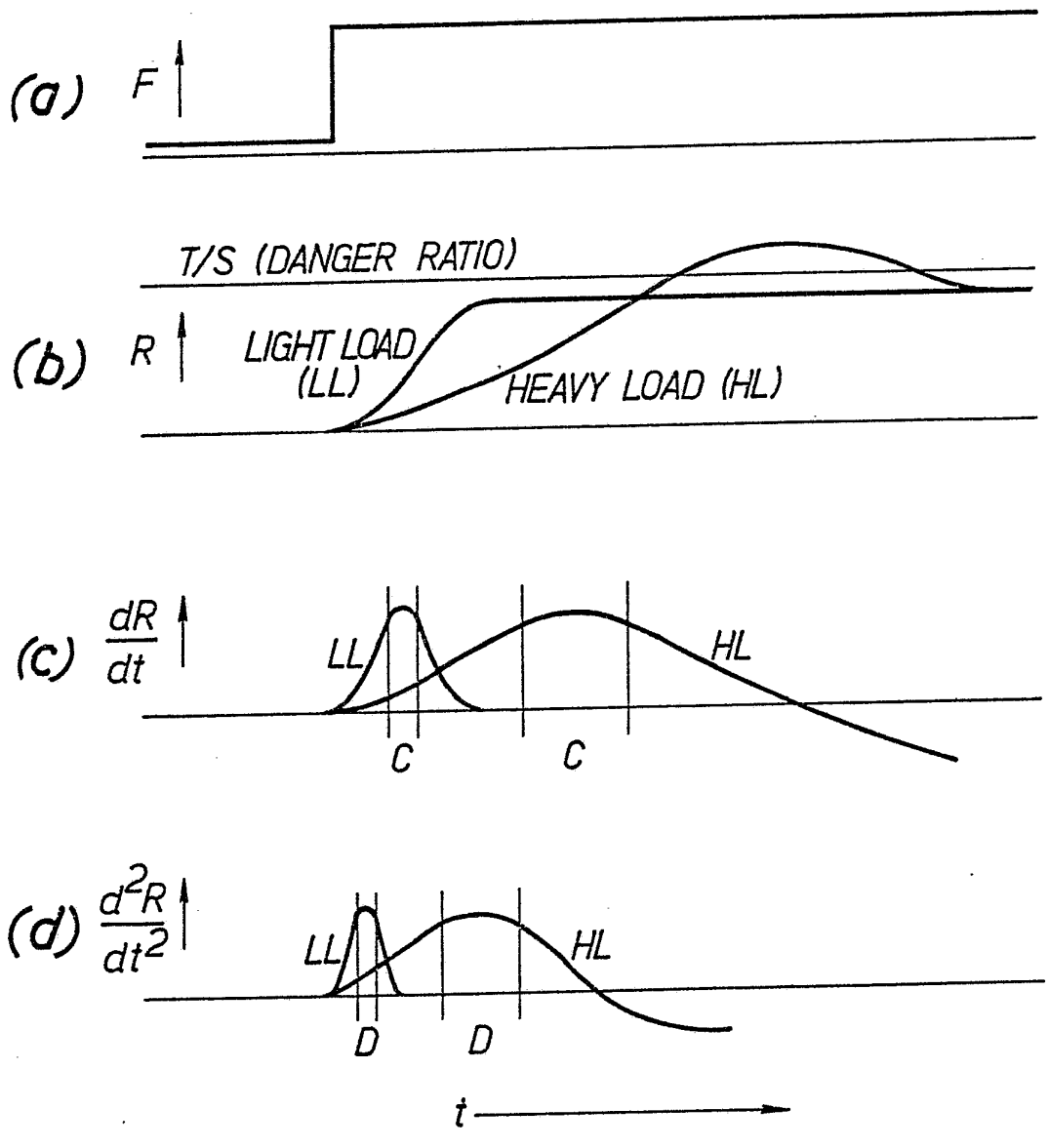

FIG.3.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 84/00050

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[3]: B 60 Q 9/00; B 62 D 49/08

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC[3]	B 60 Q 9/00; B 62 D 49/08

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	COAL AGE, vol. 86, December 1981, no. 12 (New York, US) N.P. Chironis: "How to prevent loader rollovers", pages 62-65, see figure 3	1-5
Y	GB, A, 2088606 (MOTORINDUSTRY RESEARCH ASSOCIATION) 9 June 1982 see page 1, lines 16-28; figures (cited in the application)	1,2
Y	GB, A, 2066538 (TOYO UMPANKI COMPANY LTD.) 8 July 1981 see figures 1,2 (cited in the application)	1,2
A	FR, A, 2271957 (SOCIETE-TITAN-CODER SA) 19 December 1975 see figures 4 and 5	1

* Special categories of cited documents: [15]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
17th May 1984	19 JUIN 1984
International Searching Authority [1]	Signature of Authorized Officer [20]
EUROPEAN PATENT OFFICE	G.L.M. Kruydenberg

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 84/00050 (SA 6709)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 30/05/84

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
GB-A- 2088606	09/06/82	EP-A-	0053516	09/06/82
GB-A- 2066538	08/07/81	NL-A-	8006728	16/07/81
		JP-A-	56095768	03/08/81
		DE-A-	3048856	17/09/81
		AU-A-	6557480	02/07/81
		AU-B-	521936	06/05/82
		US-A-	4386674	07/06/83
		SE-A-	8009131	28/06/81
FR-A- 2271957	19/12/75	None		