SAFETY REAR UNDERRIDE GUARDS WITH AN OPTIONAL REVERSE IMPACT BRAKING SYSTEM

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ABSTRACT

This paper describes the Safe-T-Bar and Sens-N-Stop, two products aimed at reducing personal injury and damage resulting from rear impacts.

The **Safe-T-Bar** is a rear underride protection guard. It can be fitted to all vehicle types, including straight trucks and semi-trailers, up to the maximum gross vehicle weight.

There are two versions of the guard, one incorporating rubber springs, the other friction plates. Collision damage to light vehicles occurring at average speeds is radically reduced or in some instances entirely eliminated.

Both versions of the Safe-T-Bar have been laboratory tested. The rubber spring version meets EEC Directives e11-011 and e11-013. The friction plate version fully complies with the United States Federal Motor Vehicle Safety Standards FMVSS 223 and FMVSS 224.

Sens-N-Stop is an automatic impact-sensing and brake-activating system for reversing vehicles for use in conjunction with the rubber spring version of the Safe-T-Bar. Immediately the beam comes into contact with an obstruction the vehicle brakes are applied.

INTRODUCTION

Hope Technical Developments Ltd specialise in the development and manufacture of safety equipment for the road transport industry. In addition to the Safe-T-Bar and Sens-N-Stop, our products include the widely acclaimed Hope Anti Jack-Knife Device and the Scrutineer trailer test unit.

This paper is intended for general information only and does not form part of any contract with Hope Technical Developments Ltd or their agents.

The views expressed at then end of the paper are intended as a contribution to the on-going debate surrounding rear impact guards.

SAFE-T-BAR

Development History

The rubber spring version of Safe-T-Bar was first introduced in the UK and Europe in 1981. It gained EEC Type Approval in 1984, thus making it acceptable for use in all EEC Member States.

Major UK fleet operators, including the Royal Mail and the Ministry of Defence, are currently using the guard.

The design of this version of the guard has remained generally the same over the years, although modifications have been made and continue to be made in line with company product improvement policy.

Recently a new version of the Safe-T-Bar was introduced specifically to meet the needs of the USA market. This design uses friction plates to absorb energy. It has recently been tested in the United States at MGA Research Corporation according to the Laboratory Test Procedure for Federal Motor Vehicle Safety Standards 223 and 224. It exceeds the requirements of these Standards.

General Design Characteristics – Rubber Spring Version

Figure 1 shows the general arrangement of the rubber spring version of the Safe-T-Bar.

The beam is welded or bolted to the two arms. Within each arm there are two rubber springs and a simple cam mechanism. The arms are attached, via hinge pins, to mounting channels. The mounting channels are welded or bolted, via the use of brackets, to the vehicle or trailer chassis, or to a suitable mounting provided by the vehicle or trailer manufacturer. Beams and arms of various lengths are used to accommodate different vehicle types.

The larger of the springs provides progressive, low-speed impact absorption as illustrated in Figure 2. A very small force, depending on the beam and arm lengths but generally less than 0.5 kgf, is all that is required to

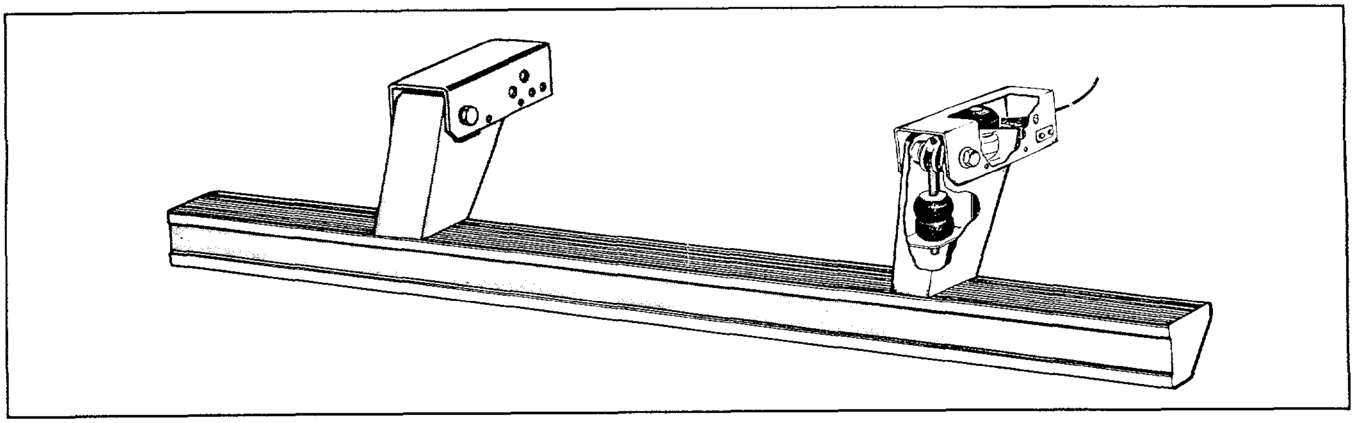

Figure 1: General arrangement – rubber spring version.

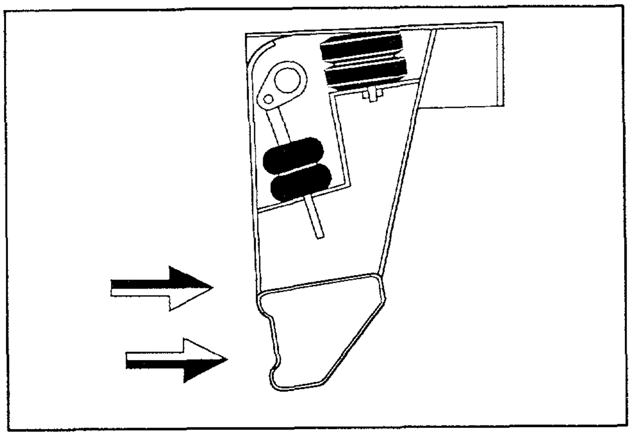

Figure 2: Low speed impact absorption.

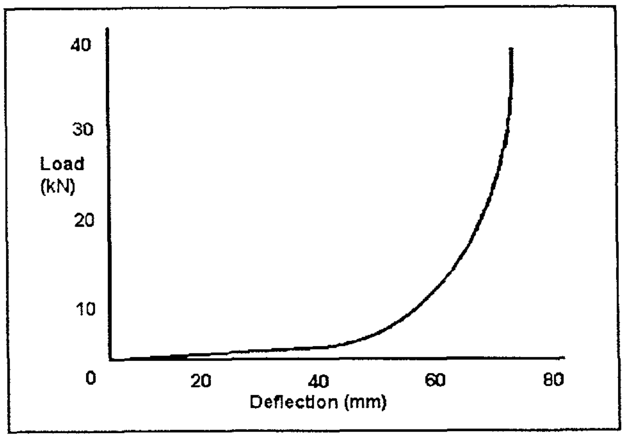

Figure 3: Spring load/deflection.

cause initial movement of the beam. Full radial movement of the arm, and full compression of the rubber spring, is reached after a vehicle movement of approximately 3" (75mm). The total force required to cause this movement is approximately 30kN (3 tonne). Figure 3 shows the load deflection curve for the spring.

When the vehicle is moving forward, the hinge action of the arms enable the beam to automatically lift, as illustrated in Figure 4, whenever an obstacle or raised obstruction such as a ramp is encountered. The lead angle on the beam aids this action. When the obstacle has been cleared, the beam drops down into its normal operating position.

At the full extent of the upward arm movement, the smaller rubber spring acts as a cushion and, when compressed, it provides an impetus to reset the beam.

Alternatively, the beam can be locked in the raised position, a feature which is particularly useful if access to ancillary equipment fitted at the rear of the vehicle is required, or if the vehicle is being used off the road in rough terrain, such as on construction sites.

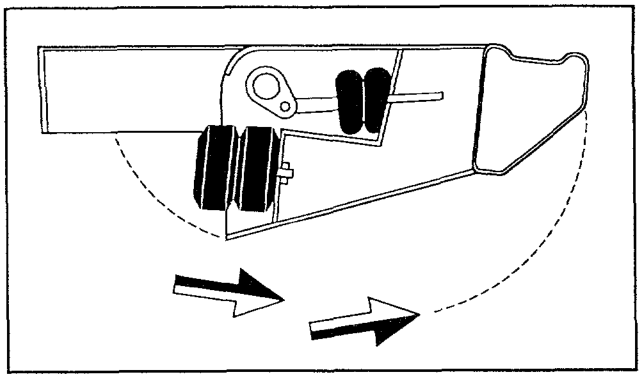

Figure 4: Automatic beam lift.

The Safe-T-Bar is fitted with a full-length, red, reflective strip and plastic endcaps. The overall design is 'non-aggressive' and generally enhances the appearance of a vehicle. It is quiet in operation and the life expectancy of the rubber springs exceed the expected life of the vehicle.

General Design Characteristics – Friction plate version

Figure 5 shows the general arrangement of the friction plate version of the Safe-T-Bar.

The assembly consists of the beam and two sub-assemblies, one right-hand and one left-hand. The sub-assemblies incorporate the power absorption feature and the means of attaching the complete assembly to the vehicle.

Each sub-assembly includes two quadrant plates, and a mounting bracket. The two quadrant plates, separated by three steel spacers, are bolted in a fixed position to the chassis rails or to a suitable location provided by the vehicle or trailer manufacturer. The mounting bracket is sandwiched between the two quadrant plates. At the fulcrum, the surfaces of the quadrant plates and the mounting brackets are separated by two nylon spacers. At the outer radius, the surfaces are separated by two friction pads. A second set of friction pads is sandwiched between the outer surface of the quadrant plates and two clamping plates. When the beam is under load, the mounting bracket swivels downward in relation to the quadrant plates.

The beam is clamped to the mounting bracket by means of a clamp plate inside the beam. To complete the assembly, the Safe-T-Bar is fitted with plastic end caps and a full-length, red, reflective strip.

On impact, energy is initially absorbed by the friction pads. Further loading results in the quadrant arms swinging downwards until they 'bottom', this occurring after a horizontal movement of 5 inches. Within this movement, when the pressure on the friction pads is correctly set using the torque values provided by the manufacturer, the guard will withstand a force in excess of 40000 lbs and absorb 13000 Joules of energy.

If an impact on the guard is off-centre, the swing of the quadrant plates will differ, thus producing a 'snowplough' effect whereby the impacting vehicle is deflected, thus reducing the possibility of a more serious underride.

The expected life of the friction pads exceeds the expected life of the vehicle.

Application

Both types of Safe-T-Bar can be fitted to all vehicle types, including rigid vehicles (trucks) and semi-trailers, up to 38 tonnes gross vehicle weight, with a channel, 'I' beam or box chassis. Because of the hinge action of the

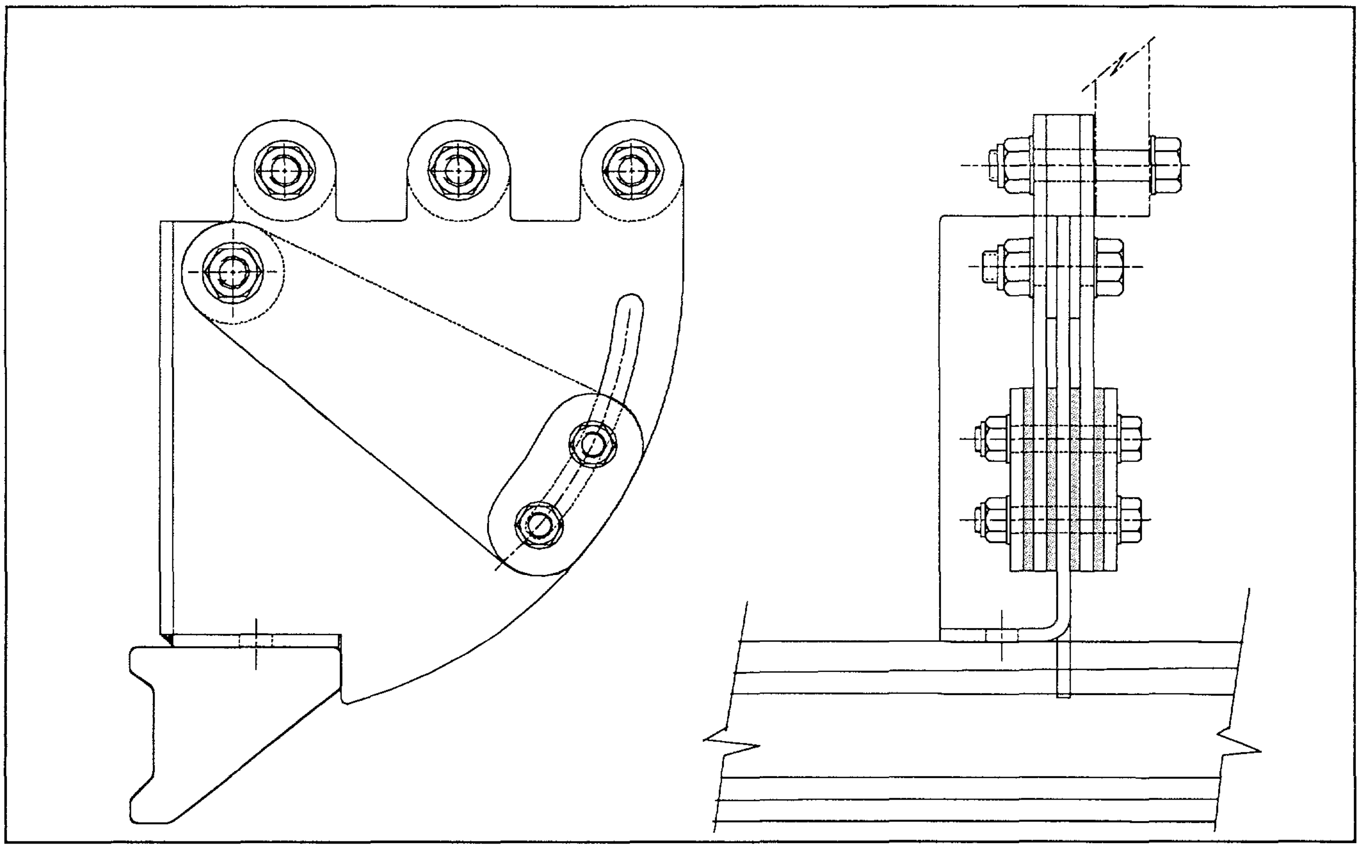

Figure 5: General arrangement – friction plate version.

Safe-T-Bars, the chassis members must be parallel to each other and in horizontal alignment.

Fitting options include incorporation in the initial vehicle design and manufacturing cycle, or retrofitting. Guards for retrofitting are supplied in kit form. To retrofit a rubber spring version of the Safe-T-Bar requires basic fitting and welding skills, basic fitting skills only are required to fit the friction plate version. To fit either type takes 1 to 2 hours.

Weight

The weights of Safe-T-Bar assemblies vary according to the length of the beam or either the size of the arms or the quadrant plates and mounting bracket, depending on the version. The maximum and minimum weights are given in the table below.

Table 1.
Safe-T-Bar Weight

Beam length (max/min)	Assembly weight (max/min)	
	Rubber spring version	Friction plate version
(81.5" – 94.5") (2070 – 2400 mm	99 – 112 lb (44.9 - 51.0 kg)	100 – 120lb (45.4 – 54.5lb)

Beam Design

A cross-sectional view of the beam is shown in Figure 6.

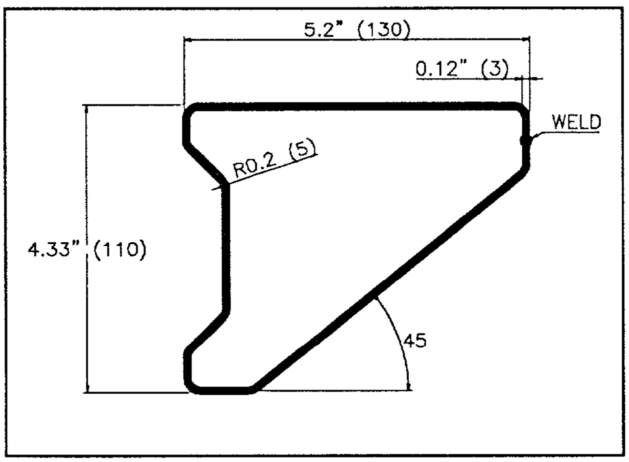

Figure 6: Beam cross-section

FMVSS 223 states that the cross-sectional height of an underride beam must not be less than 100 mm. The Safe-T-Bar beam exceeds this dimension by 10mm.

The beam is of box construction with a single, induction-welded butt joint. The top face of the beam can be used as a step. A 45° leading edge angle reduces airflow turbulence. A rear-facing recess strengthens the beam and also provides a convenient mounting for the full-length reflective strip and the product conformance label.

Test Overview

Both types of Safe-T-Bar have been laboratory tested and they comply with the requirements of FMVSS 223 and FMVSS 224. An overview of the results for the friction plate version is given below.

A Safe-T-Bar suitable for fitting to a vehicle of 20 tonne gross vehicle weight and above was subjected to the guard strength and energy absorption tests as defined in FMVSS 223. The guard was mounted on a rigid test fixture.

The test requires forces to be progressively applied as follows: 5000N at test position P1, 500N at test position P2 and 100000N at test position P3. For reference, the test positions are shown in Figure 7.

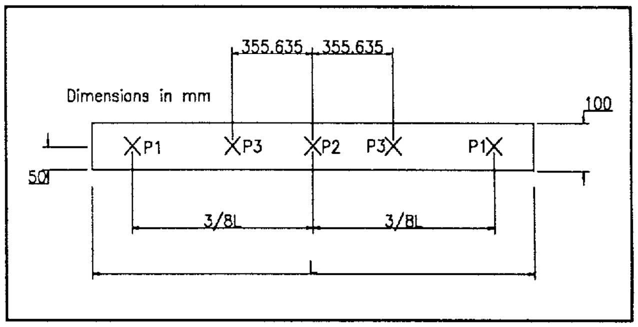

Figure 7: Test positions.

Force/displacement graphs were plotted for each test. Energy absorption rates were then calculated by determining the area below the force vs displacement curves using the Trapezoid Rule.

An example of a graph produced for a test carried out at P3 is shown in Figure 8.

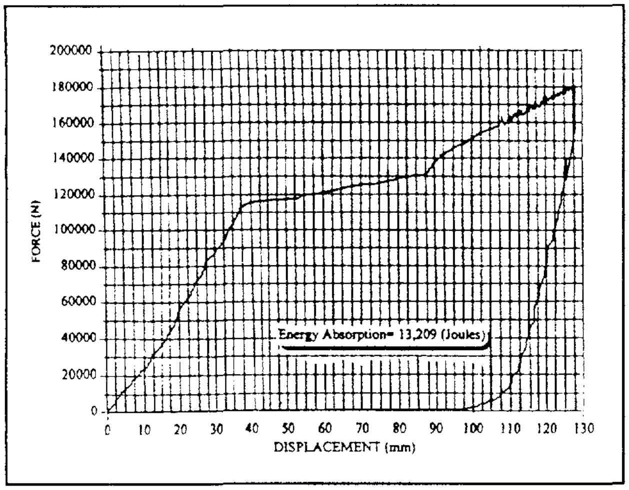

Figure 8. Example force/displacement graph.

A summary of the resulting data from tests carried out at P1, P2 and P3 is given in Tables 2 and 3.

Table 2.
Guard Strength Tests Results

Test No.	Test Location	Maximum Load	Maximum Displacement
1	P1	12,274 lbs (55 kN)	2.03 ins (52 mm)
2	P2	14,774 lbs (66 kN)	0.74 ins (19 mm)
3	P3	40,628 lbs (181 kN)	5.04 ins (128 mm)

Table 3.
Energy Absorption Test Results

Test No.	Test Position	Energy Absorption
1	P1	50,688 in-lbs (5,727 Joules)
2	P2	45,100 in-lbs (5,096 Joules)
3	P3	116,893 in-lbs (13,209 Joules)

Positioning

FMVSS requires the beam to be mounted as close to the rear of the vehicle as is practical. It must not be inboard of the vehicle rear extremity by a distance in excess of 305 mm. It must extend outward to within 100mm of the vehicle sides and the lower edge of the beam must not be more than 560mm from ground level.

To ensure each Safe-T-Bar fitted meets these requirements, various sized beams, arms or quadrant plates (depending on the version) and mounting brackets are available. To ensure the correct fittings are shipped, customers are asked to complete the Vehicle Specification form shown in Figure 9.

Production Conformance

To ensure the quality of its products, Hope Technical Developments Ltd has adopted a Quality Management System that conforms to ISO 9002:1994.

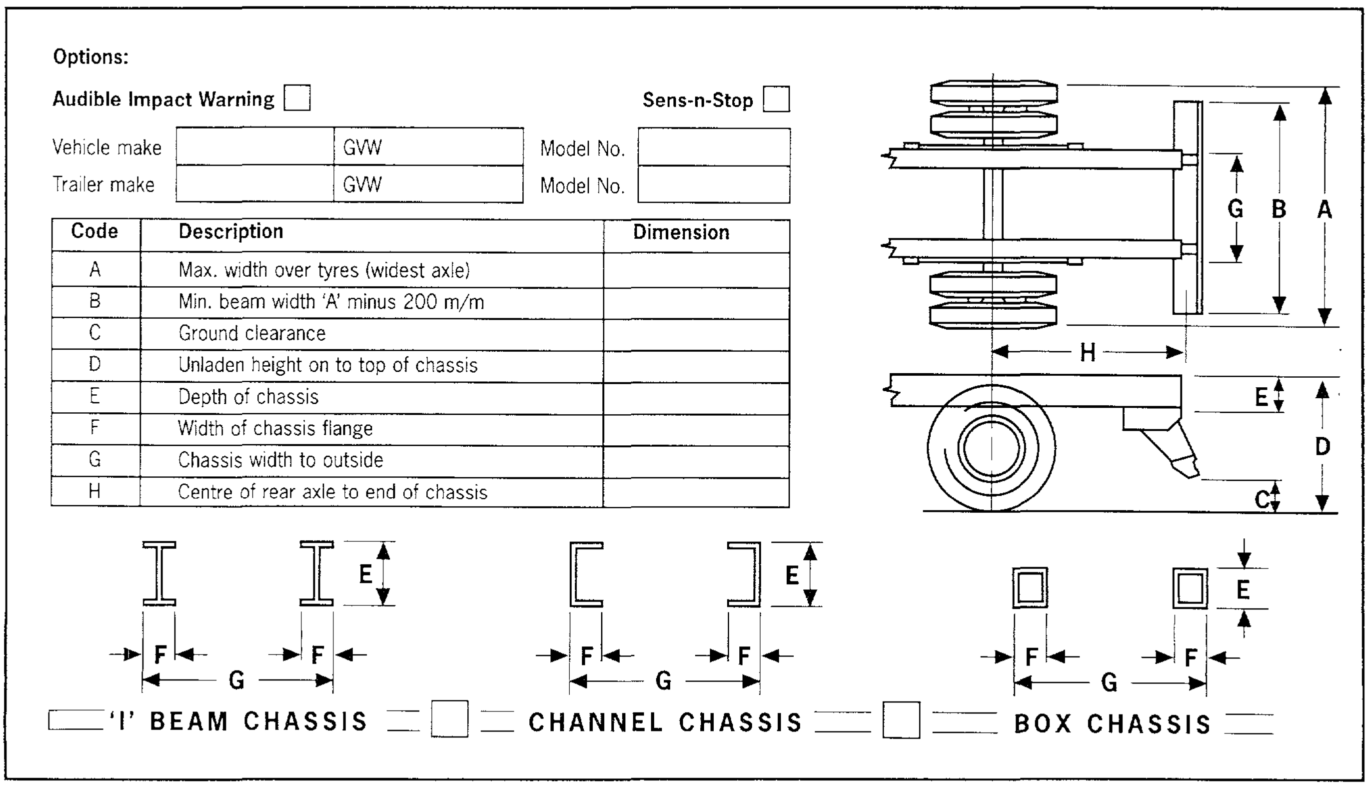

Figure 9: Positioning data.

SENS-N-STOP

Development History

Sens-N-Stop is an automatic impact sensing and brake activating system for reversing vehicles for use in conjunction with the Safe-T-Bar. It is available as an optional extra.

Sens-N-Stop was developed to combat the problem of personal injury and damage to vehicles and property caused by vehicles reversing in areas where the driver's vision is restricted. A classic example of this type of situation is the reversing of large tankers on gas station forecourts.

The system was introduced in 1988 and, like the Safe-T-Bar, is currently being used by many major UK fleet operators.

UK Reversing Accident Statistics

According to an article recently published in a UK trade journal, prior to the introduction of alarms nearly 300 persons were killed or seriously injured by reversing vehicles per week. Since their introduction there has been a 41% reduction in fatalities. However, accidents involving reversing vehicles continues to be a major safety problem as is evident by the following statistics which were also included in the article:

- 17% of transport accidents investigated by the in 1995 involved reversing vehicles (UK Health and Safety Executive)
- Reversing of commercial vehicles accounts for one UK insurance claim in every six (Association of British Insurers)
- Reversing accidents comprise the largest category of all (non-car) claims (Municipal Mutual Insurance Ltd)

Figures published by the UK government confirm the seriousness of the problem; there were 4533 reversing accidents in the UK in 1995. (1).

Recent reports in the UK trade press have stated that nearly 25% of deaths involving vehicles at work are caused by reversing, with small trucks posing the greater hazard because they are more of them, they often reverse in crowded public locations, and are legally driven by unqualified and inexperienced people.

The above figures derive from a UK vehicle population of approximately 10 million. In countries where the vehicle population exceeds the UK vehicle population, as in the USA for example, the corresponding figures will almost certainly be proportionally higher. But even these figures do not portray the full extent of the problem which can only be placed in context if the relative short time spent in reversing is taken into consideration.

If a driver is obliged to reverse without having at his disposal some form of reverse warning system then he may do so negligently. Not only may the driver and the vehicle operator be held to be negligent, they may also be liable to criminal prosecution. A recent prosecution in a UK court resulted in a building company being fined a six-figure sum when an employee was crushed against a wall by a vehicle not fitted with a reverse-in-safety system.

Reversing Warning Devices

The most widely used warning device is the audible siren, but the effectiveness of this type of device depends on people other than the vehicle driver taking evasive action. The siren may not be audible to people with a hearing impairment whilst others, such as elderly, blind or physically handicapped people, may not be capable of moving out of the way. Audio devices are not effective with regard to inert objects. There can also be problems with environmental noise pollution if vehicles are constantly in use close to dwellings, particularly at night.

Other devices include the use of electronic voice warnings, microwave sensors, radar, and camera systems, some of which depend on visibility and may also require in-cab monitoring by the driver.

By comparison, the Sens-N-Stop system is a low-cost, all-weather, light-independent system that is silent in operation and requires no additional driver involvement other than that generally associated with vehicle reversing.

General Arrangement

Figure 10 illustrates the general arrangement of the Sens-N-Stop system. Note that if Sens-N-Stop is fitted, it is essential that the Safe-T-Bar is fitted as close to the vehicle extremity as possible. The sequence of operation is as follows:

1. Reverse gear is selected - ***the system is functional only when reverse gear has been selected.***
2. As the vehicle reverses, any slight beam movement (12-15 mm) is detected by the sender unit which is mounted within one of the Safe-T-Bar arms. A force of just 0.25 kgf is sufficient to cause this movement.

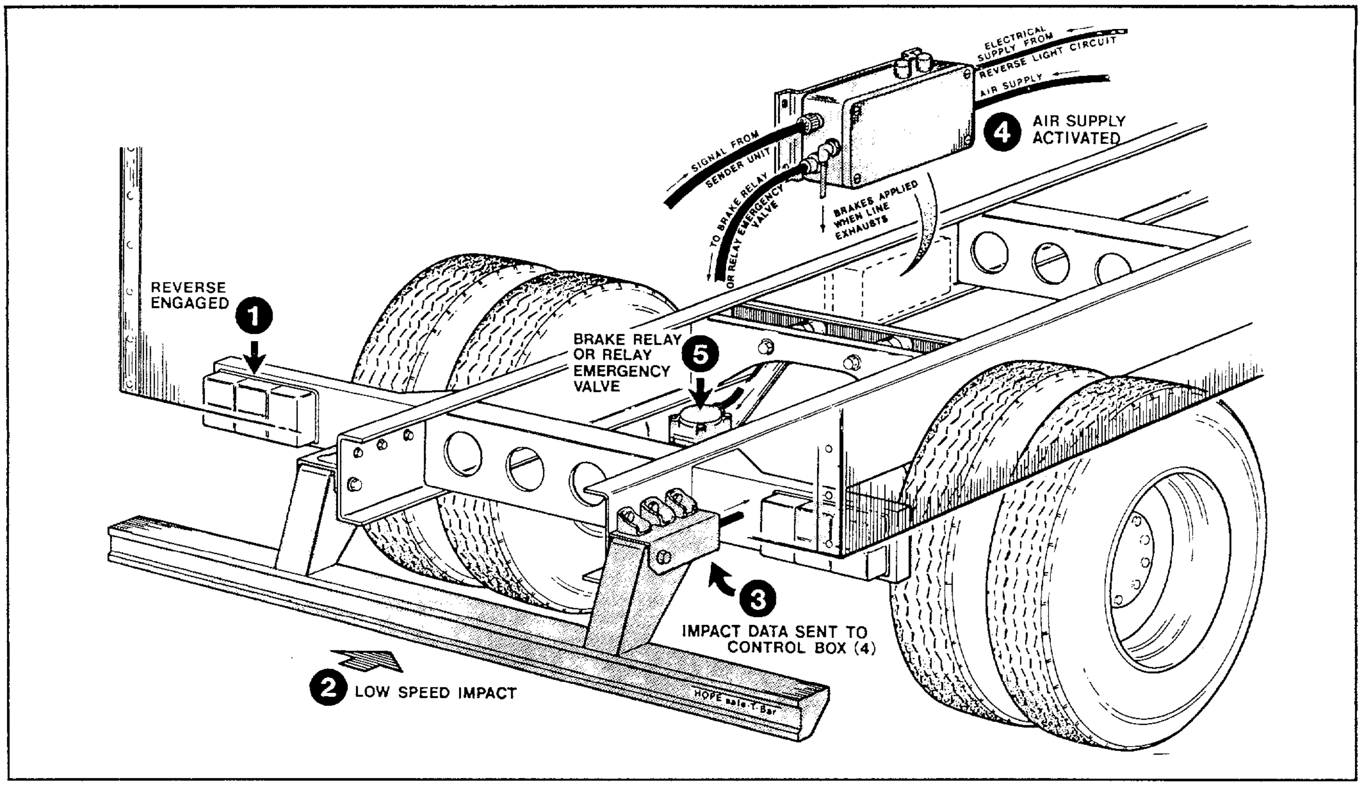

Figure 10: Sens-N-Stop general arrangement.

3. The sender unit sends a signal, by interrupting an electrical circuit, to a control box mounted on the vehicle chassis.
4. A pressure sensitive switch (signal receiver) activates the diaphragm solenoid valve.
5. Air is released from the brake relay emergency valve (trailers) or hand brake relay valve (rigid vehicles) and the brakes are automatically applied.

The brake line installation method is UK Ministry of Transport approved. Basic electrical and mechanical fitting skills only are required to fit the system and the task takes approximately one hour.

CONCLUSION

Both Safe-T-Bar and Sens-N-Stop have been widely accepted in Europe as being worthy contributions to the on-going problem of road and vehicle operating safety, the former with regard to vehicle underride and the latter with regard to reducing personal injury and damage caused to both vehicles and property caused by low-speed reversing impacts. However, the effectiveness of these and similar devices depends on other factors other than the inherent design characteristics. Therefore, I make the following observations:

- All fitted underride guards should be subjected to periodic inspection that ensures they comply ***in all respects*** to current legislation.
- Underride guards should not be permitted to be fitted unless they have official type approval and are labelled accordingly. This would eliminate the possibility of a sub-standard design being fitted particularly when changes are made to the original bodywork of the vehicle.
- Since fleet operators are ever conscious of payloads, consideration should be given to excluding the weight of underride guards, and possibly other safety equipment, from the gross vehicle weight. The initial excess weight would be rapidly balanced out by the weight of the fuel consumed early in any journey.
- Rigid vehicles should not be excluded from having underride guards fitted. Some vehicle designs present underride possibilities equally as dangerous as those associated with trailers.
- The fitting of underride guards to trucks is as important as fitting seat belts and air bags, or the inclusion of crumple zones and impact guards, to private motor cars. It needs to be given a much higher priority in vehicle design.

REFERENCES

1. *Road Accidents Great Britain: 1995 The Casualty Report.* The Department of Transport, UK

2. H Kemp and A Wilkins *A Study of Fatal accidents To Assess The Performance of Side Guards and Rear Guards on Heavy Goods Vehicles.* A report prepared on behalf of Transport and Road Research Laboratory, UK