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REFINEMENTS OF RESTRAINT SYSTEM DESIGN -
A PRIMARY CONTRIBUTION TO SEAT BELT EFFECTIVENESS IN SWEDEN

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ABSTRACT

The development of safety belts in Sweden from the beginning in the mid 1950s is reviewed. Both the history of regulations and the development of various belt designs are dealt with. It is found that the creative cooperation between Government agencies and industry as well as the continuous work to improve the belt wearing comfort have been advantageous to the effectiveness of safety belts in Sweden. The latest data on occupant fatalities in Sweden as well as recent findings from VOLVO accident studies are summarized. One of the VOLVO analyses shows that the rear seat is as dangerous as the front seat. The other report concludes that 74 % of the injuries sustained by truck occupants in accidents with commercial vehicles can be mitigated by the use of a 3-point-belt. VOLVO has therefore developed a special truck safety belt which has been introduced as standard equipment on some truck models.

SWEDEN IS THE COUNTRY which pioneered the safety belt for automobiles. Thanks to the pioneer work 25 years ago, and the continuous development work carried out since then by the industry in creative cooperation with the government agencies, Sweden has become one of the most traffic-safe countries in the world in terms of car occupant safety.

SWEDISH GOVERNMENT ACTIVITIES

THE SWEDISH STATE POWER BOARD in 1956 instructed a small team to do something to counteract the injuries in the increasing number of traffic accidents which happened to the Board vehicles. Full of enthusiasm Messrs B Odelgard and P O Weman, prime members of the team, started out by analyzing thoroughly the problem of restraining the occupants. I would like to give credit to their pioneer work, which became the base for the seat belt development work during the following years (1).

In 1957 Odelgard/Weman decided upon a 2-point belt for upper torso restraint. The first design suggested that the belt should be worn across the chest and below both arms of the wearer. They gave priority to the simplicity of a single belt rather than the full harness of the aircraft pilot type. For comfort reasons, particularly for the convenience of the female wearer, this design, however, was soon modified. The outer anchor point on the car body was

positioned above shoulder level and the inboard point was lowered. The very simple 2-point diagonal belt (Fig 1) was the resultant design, which then became the most common car safety belt in Sweden and Europe until the mid sixties.

In the spring of 1958 at Jordbro, Sweden, the first full-scale barrier tests were carried out to test the restraint performance of the 2-point diagonal belt as well as a few other belt designs of harness type, which had shown up on the market in the meantime. At the Jordbro-tests the AWO-dummy (a rather sophisticated anthropometric dummy in those days) was extensively used (Fig 2). AWO stands for the initials of the designers (Aldman, Weman, Odelgard).

THE FIRST SWEDISH REGULATIONS - The Swedish Dept of Transport then took action and instructed the National Swedish Road Board to issue safety belt regulations. The first Swedish regulations on safety belts and testing procedures came in April 1958 (2). They dealt with chest belts, lap belts and combined belts (harnesses). The testing procedure involved a test cart and a simple dummy. The cart carrying the bucket seat was accelerated at 0,9 g by means of a falling weight to a impact speed of 25 mph against a barrier. Stopping distance was 3 inches only. The 132-pound dummy, particularly designed for the purpose, had head, chest, pelvis and parts of legs made of wood with good anthropometrics. The dynamic test concentrated on the restraint performance, which was recorded by means of a photo by a camera with an "open" shutter for

permitted for approval.

The first officially approved belts according to the regulations came in August 1958 and included two belts of 2-point diagonal type (one was VOLVO's) and two harnesses with double shoulder straps.

In the next few years safety belts became a big issue for the motoring public in Sweden. Supported by the press, TV and by various motor organisations, - even by live-show tests (Fig 4) - the safety belt business grew rapidly.

In 1962 the National Road Board estimated that more than 60 percent of all cars in Sweden were equipped by a kind of safety belt in the front seats (3). VOLVO's initiative to make 3-point safety belts standard equipment in VOLVO cars in 1959 certainly had a promoting effect on belt installation in the after-market and also a "pushing" effect on the competitors.

Almost all safety belts sold in Sweden until the mid sixties were one of the following types:

- a. lap belt
- b. 2-point diagonal belt
- c. 3-point belt (combination lap and diagonal belt)
- d. H-belt (lap belt with 2 shoulder straps)

Official approvals could be obtained for types b, c and d only. But one was free to sell any type of belt at that time. The 2-point diagonal belt was the most common, while the 3-point belt was almost entirely installed in VOLVO cars.

THE NEXT GENERATION Swedish regulations for belts came July, 1966 (4). They required in summary, that:

the belt straps must not change position when loaded (this requirement removed in practice the Y-type of 3-point belt, see page 6)

- the 2-point diagonal belt must not be used for a seating position next to a door
- the H-harness type should be discontinued due to the unfavourable influence of the shoulder straps on the lap section and the risk of abdominal injuries
- anchor points location and arrangement will be standardized

The 1966 regulations were an adoption of a great deal of the VOLVO restraint philosophy from 1959, further dealt with on page 6.

As seen from the summary of antecedents of the Swedish Regulations given in Appendix 1 there were several revisions made during the 1970s. More important amendments were made in 1971 when the Emergency Locking Retractor (ELR) locking requirements were changed to 0,5 g for vehicle sensitivity and 2 g for webbing sensitivity. In 1974 the minimum elongation of 20 % required so far was deleted. The dynamic testing included the "long" as well as the "short" deformation travel of the sled. In 1975 only the "long" deformation dynamic test was claimed.

During the latter part of the 1970s the regulation development is characterized by the international harmonizing work. The current Swedish Regulations BOF 24-02/04-01-02 are in full practical agreement with relevant parts of R16-03 and the 77/541/EEC regulation for the Common Market (5, 6, 7).

The early Swedish regulations, including the option of a voluntary approval certification, became one important factor to promote the use of safety belts and to clear the seat belt market in Sweden. The overall positive outcome of the regulations is certainly partly thanks to the good cooperation between the government agencies and the industry. The guiding theme in the cooperation has been to promote safety belt use by promoting belts with good restraint efficiency and good wear convenience. In the first run all the poor belt designs disappeared from the market. In the second run the cooperation was the basis of a sound development, considering the obligations of both the government agencies and the industry, and mutual understanding.

SWEDISH INDUSTRIAL ACTIVITIES

Needless to say the practical output and the growing improvements within the various sections of the industry meant a valuable contribution to the safety belt acceptance in Sweden.

The one-point harness of von Döbeln (Fig 5) from the early 1950s and the full harnesses of Raddningskaren (Rescue Corps) and Astrand disappeared soon in the early 60s because they were all found to be both inconvenient in use and poor in restraint effectiveness.

Besides VOLVO, the companies KLIPPAN (former Br Ottoson), AUTOLIV, STIL-INDUSTRI, AUTOINDUSTRI, ESSEM, ought to be mentioned as major contributors to the Swedish safety belt development and its positive results. SAAB, the other Swedish car manufacturer, which tried an experimental 3-point harness for racing purposes in 1956 already has preferred to adopt the design outputs of KLIPPAN to its own engagement in safety belt design.

KLIPPAN concentrated its belt design and commercial activity in 1958 and first part of the 60s on the 2-point diagonal belt, not only in Sweden but also in Germany. In the early 60s they turned gradually over to the Y-type of the 3-point belt, a version of which they applied for patent in 1957 (Fig 6). In

1964 KLIPPAN joined the VOLVO 3-point belt philosophy. Klippan has contributed with several good belt features, e.g. the neat buckle in Fig 7 leaving the straps completely free from buckle hardware.

AUTOLIV, another creative Swedish belt manufacturer, pioneered the swiveling sleeve on the lap strap end shown in Fig 8. This simple device, which was introduced by AUTOLIV around 1965 and later was included in VOLVO's as well as SAAB's belt equipment, solved an important problem related to 2-door sedan cars. Because of the position of the lap belt outer anchor point for the 3-point belt, the front seat belt in stowed position could dangerously be a stumbling risk for the rear seat occupant at exit and entry. That problem became particularly unacceptable in conjunction with the issue of the R-14 regulations. Nowadays more advanced technical solutions of the problem have been

AUTOINDUSTRI (Nyhems Mekaniska), STILINDUSTRI and ESSEM should mainly be credited for the development and refinements of the emergency locking reel (ELR) in accordance with the Swedish regulations.

THE EMERGENCY LOCKING RETRACTOR (ELR) came into consideration in Sweden in 1950s. There was a big output of various belt designs with various quality. Many of them were not easy to use. Particularly the belt adjustment (for tightness) could be tricky and needed a great deal of skilled cooperation from the occupant for it to be manipulated. The adjustment inconvenience made that the belts were poorly adjusted quite frequently, diminishing the restraint effectiveness. Another problem was loose ends and loops of webbing when the belt was not worn. Belt straps laid often soiled on the floor and were not very inviting to put on. In a 2-door sedan the webbing loops could be a hindrance for rear seat occupants at entry and exit, which could be dangerous. A third problem appearing to the restraint occupant was that he could not easily reach some maneuver organs and knobs. Some people, finally, had the psychological discomfort of being restrained against ability to move. All these problems were motivation to see the ELR as the logical solution to all problems. Thus, the ELR was supposed to increase the belt usage drastically.

Because of the slow progress of the ISO-international standardisation on testing and approval of ELR-belts were issued in Dec 1967 (8). In fact the regulating Agency did it on strong request from the manufacturers, who had developed good performance reels in the meantime and liked to obtain the official approval. VOLVO made the retractor belt standard equipment on certain markets

THE SWEDISH ELR-REGULATIONS came to be unique for many years in one respect compared to the regulations of some other countries appearing later on. Already the 1967 Swedish regulations claimed dual locking sensitivity - both vehicle and webbing sensitivity.

The first locking requirements specified: webbing pull sensitivity 0,6 g and vehicle sensitivity 0,3 g in X- and Y-direction.

In practice the 0,6 g locking sensitivity, however, proved to be much too low. The strap locked too easily during the fastening of the belt and the public complained often. Therefore the specification was changed in 1970 into webbing sensitivity 2g and vehicle sensitivity 0,5 g.

Besides its own current regulations on safety belts (BOF 24-02-01-02, BOF 24-03-01-02) Sweden has agreed recently to the R 16/03 regulations. Sweden also accepts belt approvals based on the EEC/77/541 regulations. Both these

regulations, which are identical in practice, claim dual sensitivity: 0,5 g for the vehicle and 1,5 g for the webbing.

MUCH TIME HAS BEEN SPENT in international discussions on regulations for the automatic retractor. VOLVO has taken and takes active part in those discussions. As brought forward earlier (9) it is VOLVO's opinion that the ELR should gain - particularly in terms of reliability - from some amendments in the current regulations.

There are no regulations today on the testing of the vehicle sensitive locking function which probably reflects the reality. In most countries a "lock-up" method is used. That means that the retractor unit is accelerated to the requirement level (0,3 g - 0,7 g) with a rate of onset of about 10 g/sec. It is questioned whether the time to reach the set level in the test (40-50 ms) can satisfactorily cover the variations in reality - from the 100-200 milliseconds appearing in emergency braking to the very few milliseconds in a barrier head-on impact.

The regulation further states that the webbing should be kept against moving during the time of acceleration of the unit, i.e. that the strap is given the same acceleration in relation to the retractor as the retractor itself. In reality, emergency braking experiments show that the pull-out acceleration of the strap from the reel is substantially lower than the acceleration of the retractor unit.

It is therefore proposed that the regulations regarding the emergency locking features of the retractor should be seriously reconsidered. To some extent the specific retractor design might compensate or neutralize the shortcomings of the present regulations. The question of how many retractors have been inappropriately disapproved by the authorities, is certainly less important than the question how many retractors have been approved on compliance with the specification, although not being fully fit for the demands of the real life accident situation.

THE VOLVO SAFETY BELT INVOLVEMENTS

I dare say that the story of safety belts in Sweden is inseparably connected with the safety belt story of VOLVO. The story of VOLVO's pioneer development work of the 3-point safety belt: the continuous investigations of the field experience, the promotion of safety belt use and last but not least the indefatigable work to improve the use comfort by design refinements.

VOLVO'S AUTOMOTIVE SAFETY INVOLVEMENTS are very much related to the former president of VOLVO, Dr Gunnar Engellau, who committed himself deeply to safety matters. He joined the Company in 1956 when the growing safety belt experimental work in Sweden started. VOLVO's participation in that development work was not only supported but even promoted by Dr Engellau thanks to his personal interest and belief in safety belts.

The first resulting measures in the VOLVO car were not long wanting:

the first VOLVO safety belt of 2-point diagonal chest type came as accessory equipment in 1957, officially approved in 1958

anchor-points for the belt in the production car bodies in 1956/1957

- the diagonal 2-point belt was installed as standard equipment in front seats in sport model cars in 1958.

To gain the indispensable experience from true field accidents, VOLVO simultaneously accomplished a team for accident investigation involving any type of belt, particularly the 2-point diagonal belt. Rather soon it became evident to the VOLVO accident investigators that the 2-point diagonal belt had some shortcomings in its restraint performance, although it proved to be of rather good value in most cases. VOLVO considered those shortcomings: inefficiency against ejection and submarining, unacceptable. Consequently an improved belt was needed and the development of a new belt, the VOLVO 3-point belt, was started and enthusiastically supported by Dr Engellau. In 1959 VOLVO abandoned the 2-point diagonal belt for front seats and introduced the VOLVO 3-point belt as standard equipment for the front seats on Scandinavian market.

THE VOLVO PHILOSOPHY as to belt restraint design was pronounced already then in the following design goals:

1. The belt must be easy to use and comfortable to wear. Otherwise meaningless.
2. The belt must have good restraint efficiency when used.

The belt interaction with the occupant body should assure primary medical aspects.

Those goals were perfectly met in the original VOLVO 3-point belt design (Fig 9):

1. Ease: single-handed operation of the whole belt; both fastening and releasing the belt. One single adjustment piece for both straps.
2. Restraint efficiency: Both pelvis and upper torso are effectively restrained against forward movement and against ejection in case of door-opening. The risk of submarining is minimized.
3. Medical aspects: The belt straps engage the strongest parts of the body; the chest and the pelvis. The lap strap remains over the pelvis.

Maybe most important in the medical aspects was that the lap strap should stay over the pelvis bone (i.e. below the iliac crest) and must not slide up into the soft abdominal area, which is the consequence of submarining. To assure this important feature, the common point (the buckle point) of lap and chest straps on the inboard side was positioned low (below the occupant's hip point) and made stationary to the body structure. This also prevents the occupant from displacing the buckle inadvertently to a higher position, which he finds more comfortable at a two-hands operated buckle. Doing so, however, he can turn a good restraint into a poor and dangerous restraint. Several belt manufacturers, however, in Sweden as well as in many other countries, did not appreciate that important feature for the benefit of simplified installation and marketing reasons. Therefore the Y-formed configuration of the 3-point belt (Fig 10) (named so in opposite to the V-configuration of VOLVO) became a common 3-point belt when the 2-point belt area was over.

The alarming findings of frequent and serious abdominal injuries induced by the 3-point belt and reported by several researchers (10-12) are entirely related to the Y-type of 3-point belt, where the buckle is arranged to the inboard anchor point via an intermediate webbing strap. In the various accident

investigations at VOLVO since 1959, we have paid particular attention to abdominal injuries possibly caused by the lap strap of the VOLVO 3-point belt. I estimate that we have investigated some 50.000 accidents with VOLVO cars over the years - about half of them being belt cases. They have proven our belt philosophy of 1959 to be justified: in total no or extremely few and minor abdominal belt-induced injuries have been found (13).

Twenty years ago those belt design features mentioned were VOLVO-unique. VOLVO came to found a school in 3-point belt development during the 1960s. Today most other car manufacturers - and the regulating agencies in many countries - have adopted the VOLVO features more or less.

As far as the installation of belts as standard equipment is concerned, the safety belt legislation of Sweden is an echo of the initiatives taken by VOLVO several years before. As seen from the Antecedences of the Swedish legislations and of VOLVO's safety belts (Appendix 1 and 2) it is shown that:

- VOLVO introduced the 3-point safety belt in front seats as standard equipment in 1959 - i.e. 10 years ahead of the legal requirement in Sweden.
- VOLVO had rear seat belts available in 1964, standard equipment in 1967; they became legally required by MY 1970.
- VOLVO made the ELR belt standard equipment in front seats in 1968, or six years before those belt installation became compulsory in 1974.
- VOLVO extended the ELR belt to include the rear seat in 1971, while the Swedish legislation required it from MY 1975.

Like most safety development steps taken by VOLVO during the past years have been related to field experiences, the safety belt development in particular has been based on continuous and comprehensive studies of field accidents from the very beginning in 1958. For that purpose VOLVO established Traffic Accident Groups for both cars and trucks. The results of these studies have been frequently reported publicly (14-16). The Volvo findings have been widely appreciated and referred to. The comprehensive report in 1967 (17), was given substantial attention in the rulemaking on safety belts in the USA and Australia.

Very early the field experience proved that the basic design of the VOLVO 3-point belt was right. It proved to offer high restraint efficiency without any major physiological problems to the occupant. Understanding the importance of the comfort in fastening and in wearing the belt, VOLVO has emphasized the development to that matter. Items like the buckle, the adjustment device and the retractor have been subjected to steady refinements.

THE FIRST BUCKLE of the VOLVO 3-point belt in 1959 was quite different to common seat belt buckles (Fig 11). It was a flat "one-piece" device with a pistol handle for single hand operation. It anchored the strap intersection to the floor between the seats. Soon it was substituted by a buckle of a similar lock but even better and smoother function. The next buckle generation had the "heavy" buckle part stationary and a light tongue with a handle on the strap. The first version was lever-operated. It was, however, later changed to have push-button release. Finally the push-button buckle was integrated in the tunnel cover (Fig 12). A courtesy light was further included for convenience at night driving. This buckle has been much appreciated.

THE FIRST ADJUSTMENT DEVICE of the 3-point belt was integrated in the lower anchor point at the B-pillar and was, I must agree, not too easy to adjust. Therefore handier adjustment devices were needed until the adjustment problem was definitely solved with the introduction of the Emergency Locking Retractor (ELR).

THE FIRST ELR was not perfect. The dual sensitive locking features of the ELR caused some practical problems in the beginning but were then refined step by step for better wearing comfort as was the overall installation. (Fig 13 shows the "status" in 1968.) An important comfort factor of the retractor is the shoulder strap tension. It must be low enough not to cause an irritating load on the shoulder at long trips but strong enough to distinctly retract the belt to a neat, stowed position when the belt is not in use. In recent improvements of the ELR, a comfortable compromise of those somewhat contradicting requirements has been satisfactorily accomplished.

Another belt comfort feature is the adjustable position of the B-post anchor point. It is known that the small occupant finds the shoulder strap inconvenient when too close to his neck. While this problem is not a true safety matter (18) it still is a comfort matter, which should be recognized and taken care of. VOLVO made such an adjustment device available in 1972 (Fig 14). The device, which is easily fitted on the B-post in the ordinary anchor thread, permits the anchor point for the belt to be lowered 90 mm in five intervals. Unfortunately, the regulations R14 and ADR5B are too rigid, as to the anchor points position, to formally exclude the device in practice as standard equipment. A change of the regulations is, however, under discussion.

EFFECT OF DESIGN ON BELT USE

As said before the VOLVO safety belt development gives priority to COMFORT and aims to turn a possible negative and neglecting attitude of the occupant into a positive attitude. And this comfort line has meant much to the overall effectiveness of the VOLVO belt installation and to increased belt use. In VOLVO's follow up studies, the use-effect of almost each measure has been evaluated, e.g. the ELR increased the belt use by 24 %, while the "fasten seat belt" reminder gave an positive effect of more than 60 %.

Various studies in Sweden show that the belt use frequency in VOLVO cars has been 10 % to 35 % higher than in the Swedish average car (18).

NHTSA survey in 1978 of 84.000 observed motorists in USA shows that 44,6 % of the VOLVO drivers observed used their belts. By comparison only 18,5 % of all motorists in cars with safety belts had them fastened (19).

Another proof of the success of the VOLVO comfort line is the fact that just prior to the compulsory Swedish belt use law, effective January 1, 1975, the VOLUNTARY BELT USAGE in VOLVO's recent models was as high as 70 %. (The use law then raised it to 95 % in 1975.)

As to the safety belt use in Sweden, in general no recent studies beyond the report in 1979 (18) have been carried out. There is no reason, however, to believe that the status of 1979 (Fig 15) with about 80 % usage in the average car and about 90 % usage in VOLVO cars should have changed substantially.

SAFETY BELT EFFECTIVENESS

THE EFFECTIVENESS OF THE 3-POINT BELT has been extensively reported by VOLVO at several occasions (14 - 17). In summary the injury-reducing effect of

front seats belt has "stabilized" at an average of about 24 % for minor and moderate injuries (AIS 1-2) and at about 68 % for severe to fatal injuries (AIS 3-6).

In 1972 VOLVO made a special analysis of child safety and found that the adult belt used by children (younger than 15 years) gave an injury frequency reduction of 44 % and turned the injury seriousness from fatal to moderate (20).

REAR SEAT SAFETY BELT

As dealt with on several occasions (9, 18) the REAR SEAT SITUATION has become one of the primary restraint concerns and problems. In a joint study by the Swedish Road Safety Office (TSV) and VOLVO the injury-reducing effect of the rear seat belt has been recently evaluated (21).

Many people think that the rear seat in a car is the safer seat and therefore some people prefer to sit in the rear seat unrestrained rather than be restrained in the front seat. That opinion has been supported by some traffic accident reports which show a lower injury frequency in the rear seat than in the front seat. It is contradicted now in the evaluation mentioned.

THE VOLVO-TSV STUDY is based on some 2000 rather severe traffic accidents with VOLVO cars involving rear seats occupants. The risk of injury is highly depending on the occupant age (13). The age distribution varies greatly between the seating positions. Thus it was found that 40 % of the rear seat occupant were children while only 4 % of those in the front seat were children. The analyses in the VOLVO-TSV study considered those parameters and compared the injury frequency for the adult occupant in the front and in the rear seat, and for the children separately, belted and unbelted. The study concludes that the reducing effect on injury frequency was 28 % for adults and 52 % for children in the rear seat or about the same as in the front seats (24 %).

The result summary also shows that the rear seat belt reduces primarily the head injuries for both adults and children. On adults they are decreased by 41 % (from 17 % to 10 %). For children the head injury frequency was drastically cut from 17 % to 3 %.

Thus, the belts in the rear seats are as needed and motivated as the belts in the front seats.

As a consequence of the VOLVO-TSV findings and the fact that the rear seat belt usage is only about 5 % on average in Sweden, the Road Safety Office is considering a suggestion to the government to extend the compulsory use law to include the rear seat belt also.

For the time being the only countries in Europe requiring the installation of rear seat belts are: Sweden, Germany, France, and Switzerland.

EFFECT OF THE SWEDISH BELT USE LAW

Encouragingly good effect of the Swedish belt use law of 1975 was reported in Tokyo 1979 based on both official Swedish as well as VOLVO investigation data (18). In summary, the official law effect analysis, based on accident material including 1978, showed some 12 % reduction in car occupant fatalities. VOLVO's calculations of the law effect showed an decrease of 45 % of severe to fatal injuries (AIS 3-6) for drivers and as high as 67 % for front seat passengers.

The study of Afzelius et al (22) from 1980, reports a statistically signi-

ficant ($p < 0,05$) reduction of maxillofacial fractures due to seat belt use law.

The positive safety belt effect thus previously reported seems to be confirmed in 1979 and 1980 official Swedish accident data. The preliminary number of fatally injured car occupants for 1980 (433 occupants) is about 11 % lower than the corresponding number of 1979 (485). And the preliminary number said for 1980 is some 17 % lower than the mean figure (523) for the years 1975-1979.

THE OCCUPANT FATALITY RATE (OFR) (i.e. the number of car occupants killed divided by 100.000 vehicles in use) is a kind of measure of the vehicle safety status (Fig 16). In 1979 OFR was 19 for Sweden in total (all cars) and about 9 for the VOLVO cars. The final 1980 figures are not yet available.

SAFETY BELTS IN TRUCKS

The question of automotive safety belts is normally entirely related to cars. None or little attention is paid to the safety of the occupant of trucks and commercial vehicles.

To evaluate the potential value of safety belts for truck occupants VOLVO, however, has studied truck accidents continuously over the past ten years. One of VOLVO's recent reports on truck safety (23) shows that 66 % of injuries sustained by truck occupants is minor (AIS 1), 18 % is moderate (AIS 2). About 5 % of the injuries were fatal, according to the study, which involved trucks heavier than 3,5 tons in various accident situations.

74 % of occupant injuries was estimated to be mitigated by the 3-point safety belt if worn. Consequently VOLVO introduced 3-point belts in its biggest trucks F10 and F12 as standard equipment on the Scandinavian market in mid 1980.

It was found, however, that the ordinary car ELR 3-point belt was impractical due to the "heavy" movements of the driver's seat in the truck. Therefore a modified 3-point belt was developed for the truck purpose, comprising two special ELR-units, one for each shoulder strap och lap strap (Fig 17 and 18).

FUTURE FORECAST

The future development of the belt restraint in Sweden will certainly include one or more anchor points for the belt arranged in the seat, primarily because it means so much for the comfort. Among other advantages it eliminates in practice the problem earlier mentioned of the upper anchor position related to the small occupant.

For reasons not motivated by the accident field experience, but related to compliance with various regulations, the future also might involve auxiliary devices like e.g. pre-loader, and "web lock"-ELR or devices to lock the ingoing strap to the reel.

The need of such devices will also be greater as the cars get smaller and if the current 30 mph test speed is increased.

The future of car occupant restraint in Sweden will probably not include legally required passive restraints. The passive restraint - air bag or passive belt - is not believed to become generally marketed either.

The confidence of the Swedish agencies and of the industry in the current 3-point belt has grown solid during the years. Confidence in the belt restraint effectiveness in terms of decreasing numbers of fatally and seriously injured

car occupants. The Swedish motoring public has shown its full cooperation in the high belt usage - not only due to respect for the law but also due to its edified confidence in the indisputable value of the safety belt.

Therefore it is fair to suppose that the future years' safety belt in Sweden will be the "same" belt, refined to be even easier to use and wear. Special emphasis will be on measures to increase the belt use in the rear seats.

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23. "Personskadeolyckor i Volvo Lastbilar, Rapport 3", by Kjell Högström, Lennart Svensson, Volvo Lastvagnar AB, maj 1980

THE MAIN ANTECEDENCES OF SWEDISH REGULATIONS OF SAFETY BELT

- 1958 First regulations on safety belts and option of approval of belts based on dynamic tests
- 1966 Revised regulations on safety belts exclude the 2-point diagonal belt at seat next to a door and the Y-type of 3-point belt
- 1967 Regulations on ELR-belts and testing procedures. Option of approval
- 1969 MY 3-point safety belt of approved type is legally required in the front seats
- 1970 MY Approved safety belts is legally required in the rear seats
- 1971 Revised regulations on ELR locking requirements
- 1974 MY ELR-belt is legally required in the front seats
- 1974/75 Revised regulations on webbing elongation and test method
Long deformation travel of sled in dynamic test is included
- 1975 MY ELR-belt is legally required in the rear seats
- 1975 Jan 1 Use of safety belts in the front seats is compulsory, if belt is available. Main exemptions are children (younger than 15 years of age), cab drivers and people with medical handicaps
- 1980 BOF 24-02/04-01-01, current Swedish regulations on safety belts Agreement on R16/03

VOLVO SAFETY BELT ANTECEDENCES

- 1956 2-point diagonal belt marketed as accessory equipment
- 1957 Anchor points in body for 2-point belt in front seats
- 1958 1st approval of 2-point diagonal belt
2-point diagonal belt standard equipment in "sport"-models
Anchor points in body for 2-point belts, rear seats
- 1959 Volvo 3-point belts introduced as standard equipment in front seats,
Scandinavian market
- 1961/62 Improved, handier adjustment hardware
Improved buckle and buckle connector
- 1963 Volvo 3-point belts introduced as standard equipment in front seats,
USA
- 1966 Improved, more comfortable buckle (lever operated)
- 1967 Seat Belts standard equipment in rear seats, certain markets
- 1968 ELR-belt in front seats standard equipment in Scandinavian market
- 1969 Safety belts in all rear seats in all markets
Comfort improvement of buckle handling
- 1970 Improved ELR for comfort
- 1971 ELR-belts in rear seats, all markets
- 1972 "Fasten seat belt" - reminder introduced
Adjustable B-post anchor point available
Improved buckle for comfort (push-button)
Child seat available
- 1973 Modified buckle and ELR for comfort
Courtesy light for buckle operation

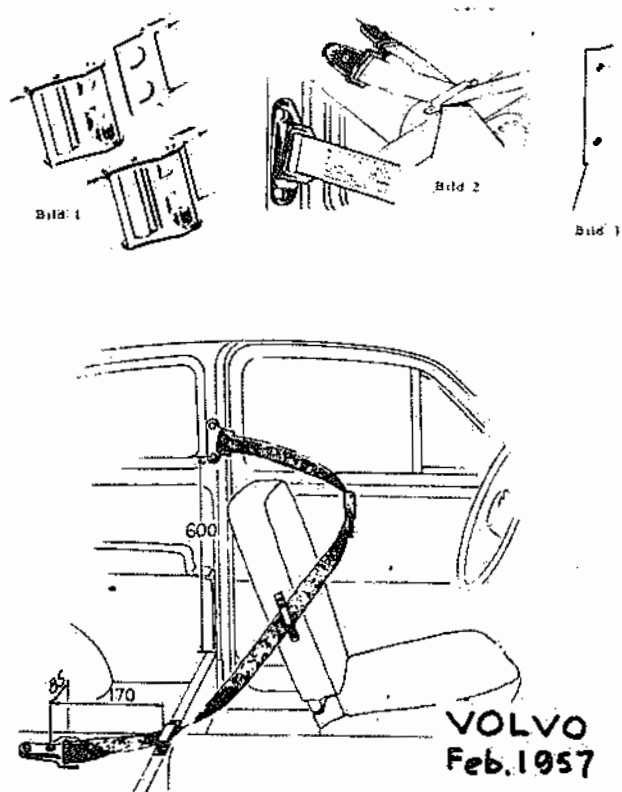


Fig. 1 - VOLVO's 2-point diagonal belt



Fig. 2 - Swedish AWO-dummy, 1958

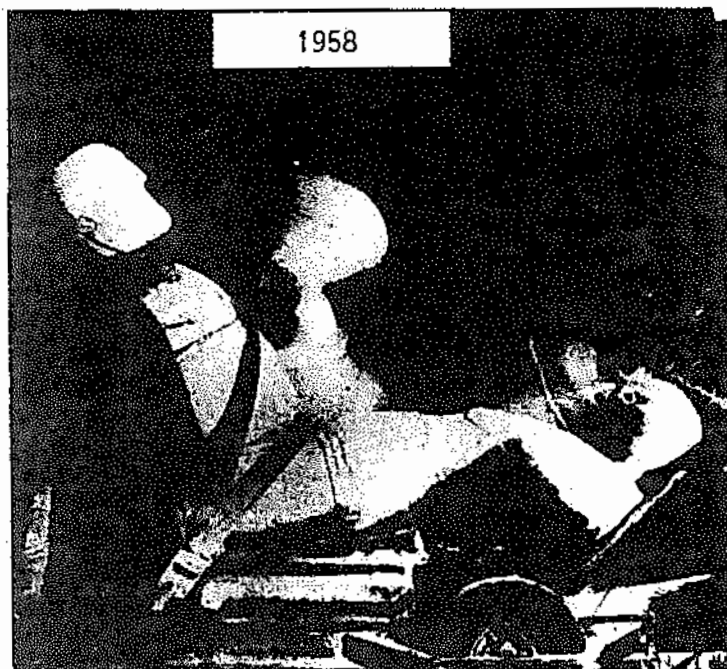


Fig. 3 - Dynamic testing of 3-point belt



Fig. 4 - Live-show of safety belt test

von Döbeln
1952

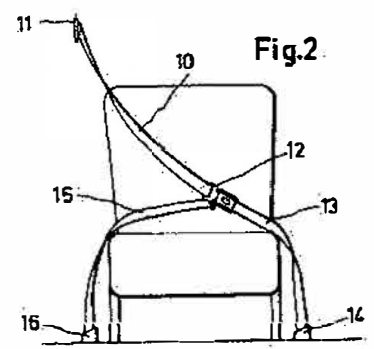
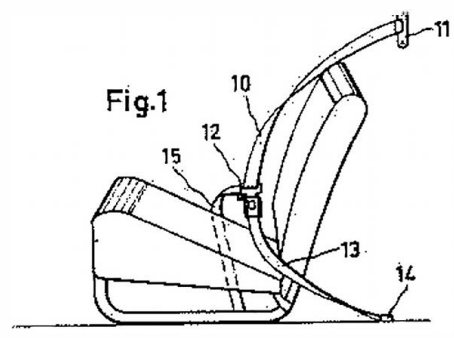
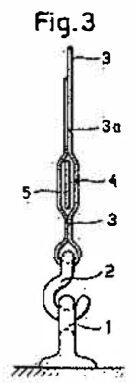
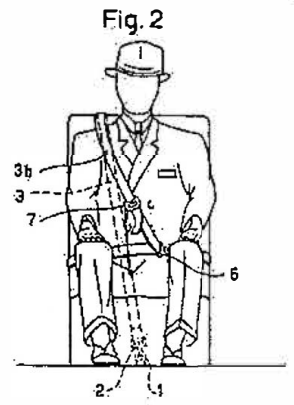
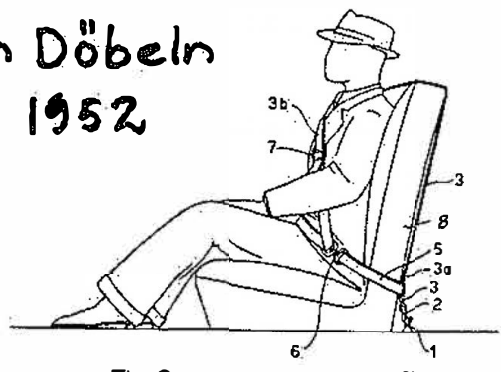


Fig. 6 - Ottoson's 3-point harness, 1957

Fig. 5 - Von Döbeln's safety harness, 1952

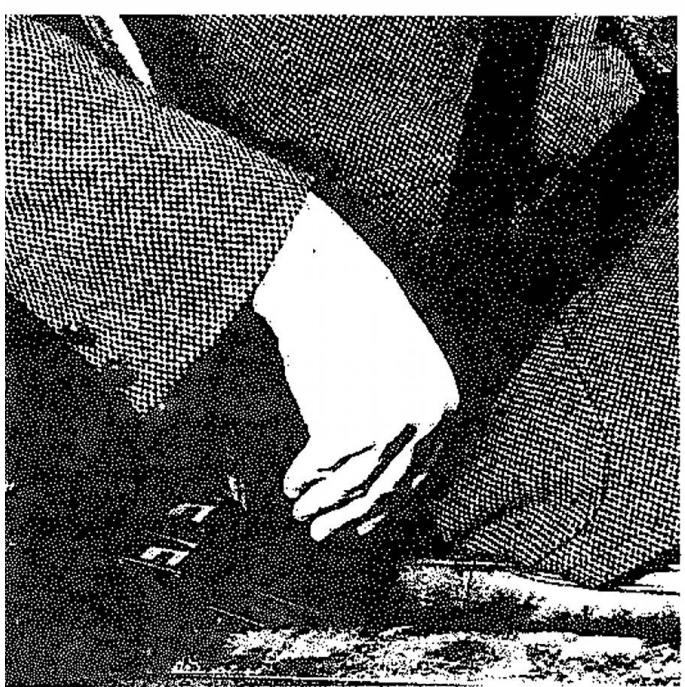


Fig. 7 - SAAB installation of KLIPPAN's buckle (Courtesy of SAAB)

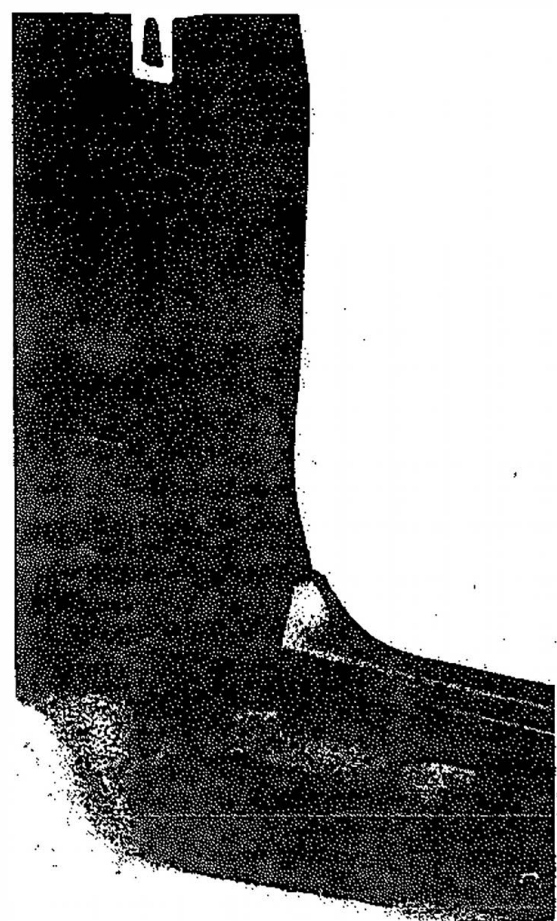


Fig. 8 - Strap "transfer" in 2-door sedan to clear entry/exit



Fig. 9 - VOLVO's original 3-point installation (3-point V-type) 1959



Fig. 10 - 3-point belt of Y-type

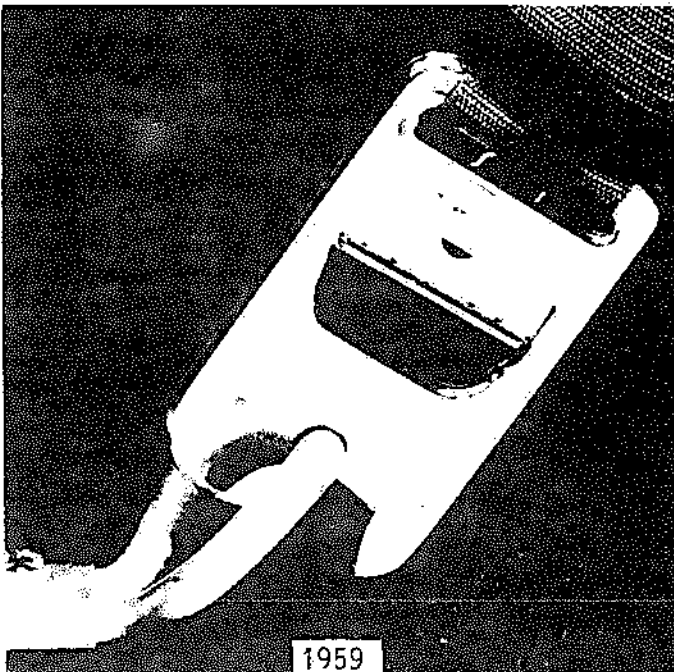


Fig. 11 - VOLVO safety belt buckle.

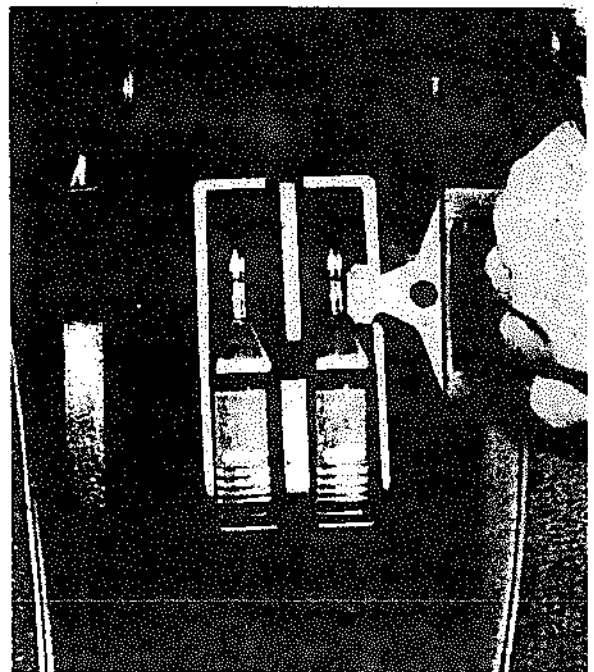
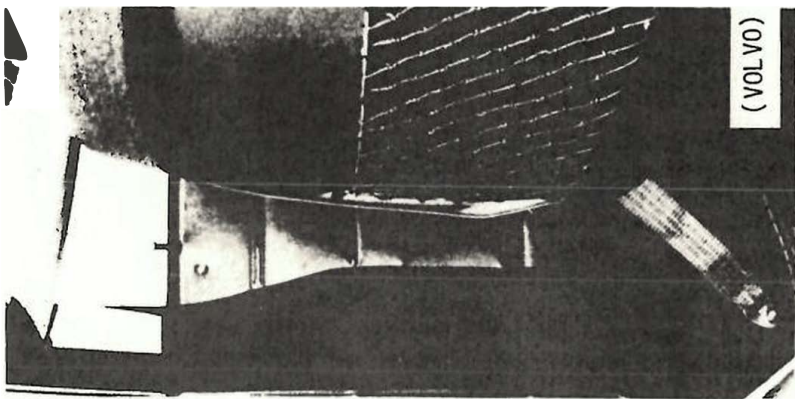


Fig. 12 - Late model of VOLVO safety buckle



(VOLVO)

Fig. 13 - ELR-belt installation in 1968

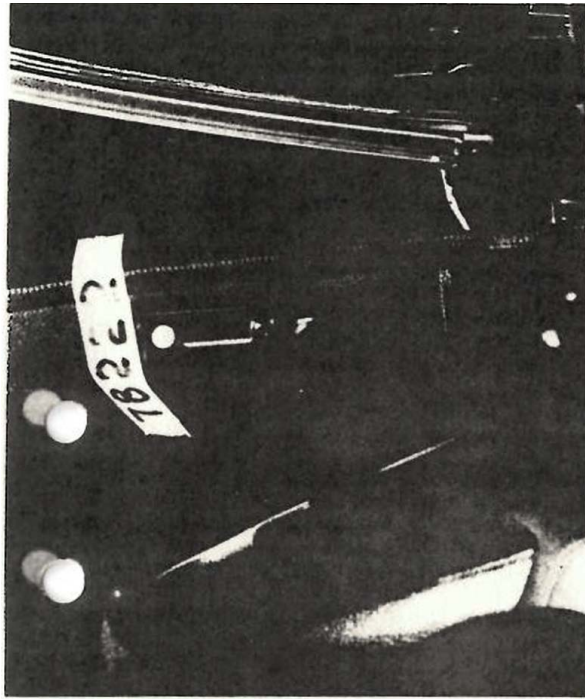


Fig. 14 - Adjustable B-post anchor point

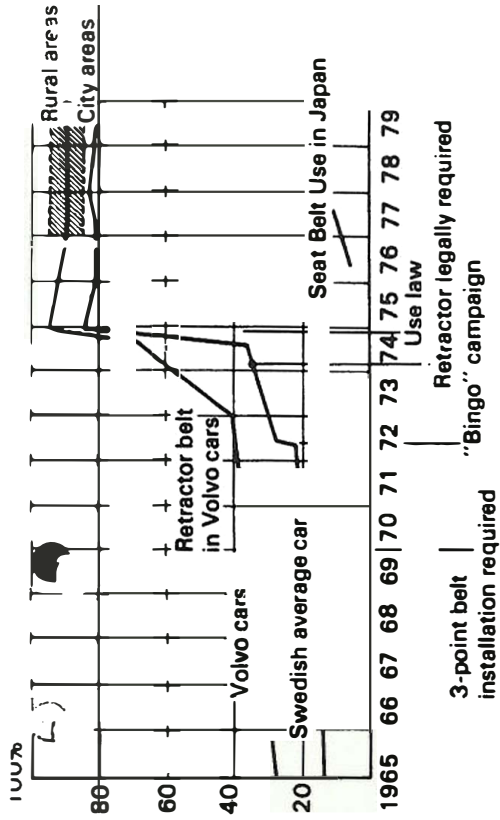


Fig. 15 - Seat belt use in Sweden 1965 - 1979

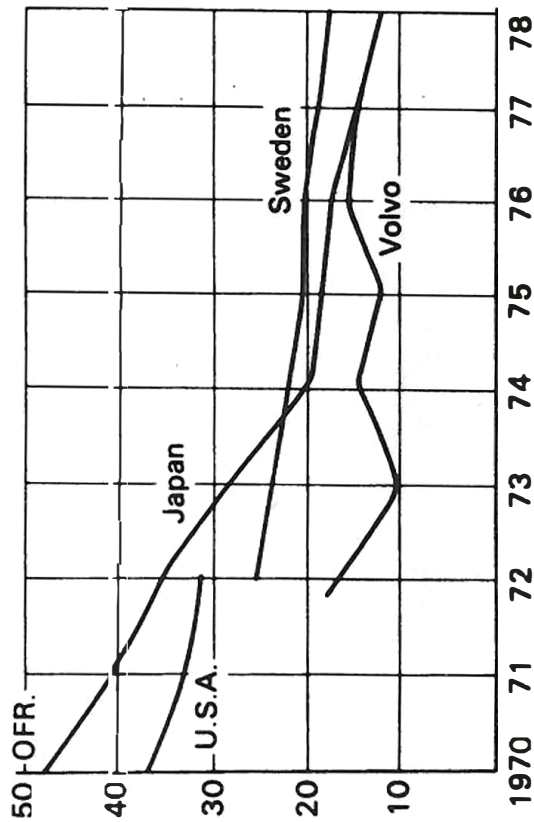


Fig. 16 - Occupant fatality rate in Sweden and Japan

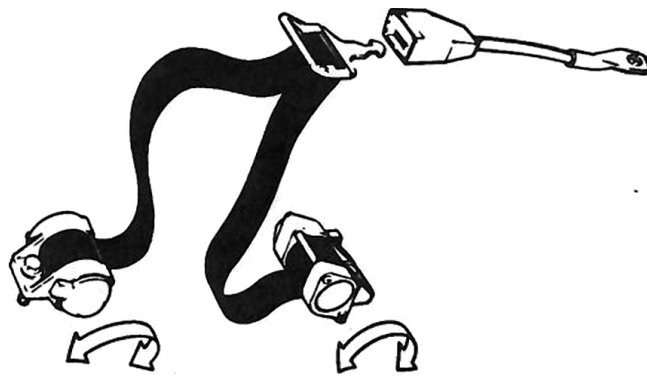


Fig. 17 - 3-point belt (VOLVO) for trucks

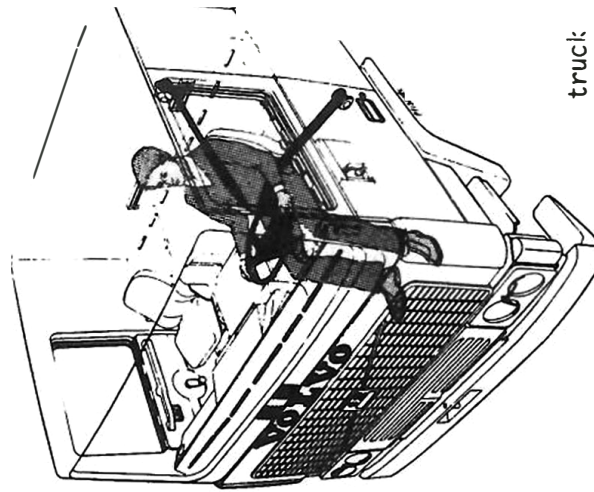


Fig. 18 - Belt installation truck