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Small Agricultural Tractor ROPS - New Operator Protective Zone

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ABSTRACT

The Equipment Manufacturers Institute (EMI) sponsored a literature search conducted by Triodyne, Inc. which attempted to identify all *Operator Protective Zones* ever utilized in the world. This effort was intended to determine whether published information existed to define a more compact Operator Protective Zone than those of current SAE (ASAE) standards for possible utilization in developing a new standard for a more compact design of Rollover Protective Structures (ROPS) for small agricultural tractors. The research has led Triodyne to conclude that the Operator Protective Zones upon which the current SAE (ASAE) ROPS standards are based are the only substantiated zones available for possible application to small agricultural tractors.

BACKGROUND

For years, there had been differences between the ROPS performance standards of North America and the rest of the world. The ROPS and ROPS test criteria were developed independently in North America and Europe. Significant differences existed in the performance evaluation procedure as a result. The areas of energy determination, tractor mass (ballasted vs. unballasted), load application points and operator protective volume (clearance zone) being the most noteworthy differences.

With the development of SAE J2194 (ASAE S519), these differences in performance evaluation were resolved. This development process took approximately ten years to complete. There were significant technical debates over what procedures should be utilized in this new standard. Finally, all issues were resolved and this new standard was issued. It is technically compatible with ISO 3463 and 5700.

It was recognized that the clearance zone of SAE J2194 (ASAE S519) was higher than the zone from SAE J1194 (ASAE S383). This is particularly true for tractors which do not utilize a suspension system for their seats. With small agricultural tractors, suspension systems are seldom utilized and because of the typical operational environment for these tractors, this increased zone height was not acceptable. Therefore, SAE J1194 (ASAE S383) remains to deal with specialized applications.

The goal is to make all U.S. ROPS performance standards acceptable on a worldwide basis along with the ROPS acceptable for market application. This literature search was initiated to determine if other operator protective zones existed and, if so, whether they might be applied to the small agricultural tractor. The size of the operator protective zone is a significant technical issue outstanding in the development of a small agricultural tractor ROPS.

INTRODUCTION

Existing Society of Automotive Engineers (SAE) standards specify their applicability to Rollover Protective Structures (ROPS) for large agricultural tractors as defined in SAE J1150:

> "*Agricultural Tractor* - A traction machine designed and advertised primarily to supply power to agricultural implements and farmstead equipment. An agricultural tractor propels itself and provides a force in the direction of travel to enable attached soil engaging and other agricultural implements to perform their intended function."

Attempts to develop ROPS for small tractors based on present guidelines result in structures that are often incompatible with the overhead clearance restrictions and width restrictions.

An extensive literature review was undertaken in an effort to discover currently recognized Operator Protective Volumes used in conjunction with ROPS in many industries and throughout the industrialized world.

Once the operator protective volumes were identified, efforts were then concentrated on learning why and how each protective volume was chosen. This search was conducted to document rationale that may be interpreted in terms of Small Agricultural Tractor requirements.

COMPUTERIZED DATABASES SEARCHED

Much of the published technical literature is organized into databases which can be searched remotely with a keyword computer; however, exceptions do exist which are pertinent to this assignment. Technical databases do not normally include bodies of information which are not considered to be "scholarly." For example, the National Hot Rod Association is a source of potentially useful information in a study focusing on rollover protection since the racing vehicles governed by the NHRA are required to be equipped with this safety device. This body of literature, however, is not available in database form.

The databases which have been searched in the course of this project include:

1. Volkswagen Kraft fahrzeugtechnik;
2. Agricola (1970 to present);
3. Agribusiness USA (1985 to present);
4. Compendex Plus (1970 to present);
5. Dissertation Abstracts (1861 to present);
6. GPO Monthly Catalog (1976 to present);
7. Hazardline (1977 to present);
8. IHS Vendor Information (current);
9. CRIS U.S. Department of Agriculture (1984 to present);
10. Industry and International Standards (current);
11. Inspec (1969 to present);
12. Military and Federal Specifications and Standards (current);
13. NIOSHTIC (19th century to present);
14. SAE Global Mobility (1971 to present); and
15. Standards and Specifications (1950 to present).

THE HISTORY AND CURRENT STATUS OF OPERATOR PROTECTIVE VOLUMES

For the purpose of this report, the Operator Protective Volumes described below constitute volumes which establish deflection limits for Roll Over Protective Structures (ROPS) or Falling Object Protective Structures (FOPS) during structural evaluation. The protective volume must also not be intruded by a plane on which the vehicle is operating when it is oriented into any overturned attitude (Figure 1). The testing methods and loading limitations, whether static or dynamic, that constitute the energy levels to which the ROPS or FOPS is subjected can be found in the cited references although the testing methods and energy absorption requirements are beyond the scope of this paper.

1. The earliest protective volume recognized by an American consensus group can be found in the Society of Automotive Engineers (SAE) standard, SAE J320,

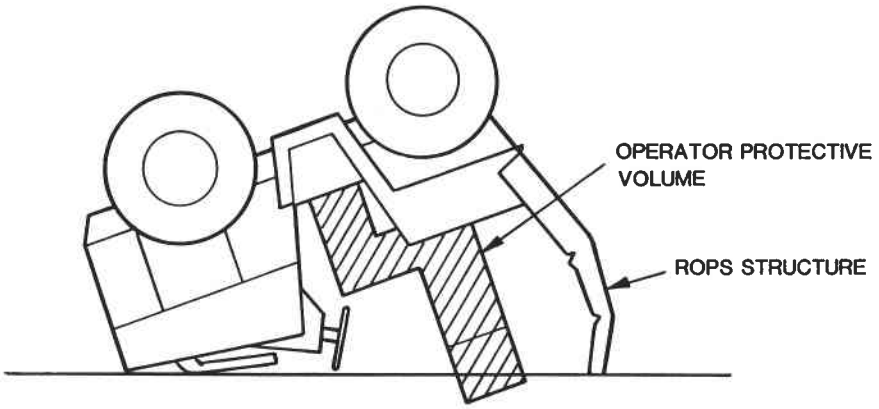


FIGURE 1: INTRUSION OF GROUND PLANE INTO OPERATOR PROTECTIVE VOLUME

Minimum Performance Criteria for Roll-Over Protective System for Rubber-Tired, Self-Propelled Scrapers.[1] This standard was approved in November, 1967 by the Construction and Industrial Machinery Technical Committee. The scraper was the only type of industrial machine for which the use of the "Critical Zone" illustrated in Figure 2 was used. Unlike the protective volumes which would be recognized in the future, the geometry of this early Critical Zone was not specified in its own individual SAE standard. By July, 1969, however, the Critical Zone would be completely redefined.

2. In July, 1969, the "Critical Zone" was adopted as a recommended practice by the Construction and Industrial Machinery Technical Committee and was large enough to accommodate a 95 percentile man dressed in arctic clothing. The standard, *Critical Zone-Characteristics and Dimensions for Operators of Construction and Industrial Machinery*, SAE J397,[2] described this volume (Figure 3a).

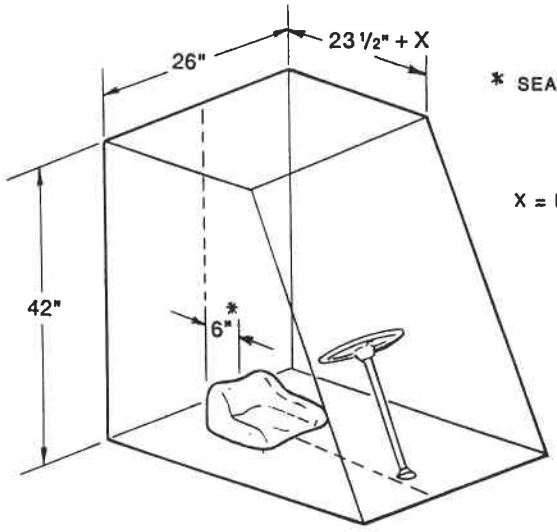
   By July, 1969, SAE J320 for scrapers had been revised to SAE J320a[3] in order to incorporate the newly revised Critical Zone. Additional types of construction and Industrial machinery also began to recognize the Critical Zone. SAE J320a was soon revised again in January, 1972, and renamed *Minimum Performance Criteria for Roll-Over Protective Structures for Prime Movers*, SAE J320b,[4] so that water wagons, bottom dump wagons, side dump wagons, rear dump wagons and towed fifth wheel attachments were included, in addition to scrapers. Front-end loaders and dozers recognized the Critical Zone in SAE J394[5] approved in July, 1969; crawler tractors and loaders in SAE J395[6] approved in July, 1969; motor graders in SAE J396[7] approved in July, 1969; and dump trucks in SAE J1011[8] approved in April, 1973. Although revisions were made to J394 in March, 1972; to J395 in January, 1972; and to J396 in March, 1972 resulting in J394a,[9] J395a,[10] and J396a,[11] respectively, the Critical Zone continued to be the recognized protective volume.

   The Critical Zone itself is made up of three individual zones which are allowed to move with respect to one another as illustrated in Figures 3b and 3c. No additional Critical Zone volume is created by the side-to-side sliding of zones A, B and C (Figure 3b). Additional Critical Zone volume is generated, however, by pivoting zones A, B, and C about imaginary hinges (Figure 3c). This additional volume also becomes part of the Critical Zone.

   When tested according to the performance criteria of SAE J320, J394, J395, J396 or J1011, the Critical Zone, in any of its accepted configurations, may not be entered by the ROPS or FOPS frame.

3. In January, 1972, the Construction and Industrial Machinery Technical Committee completely revised the Critical Zone and renamed it the "Deflection Limiting Volume" (DLV). A separate standard, *Deflection Limiting Volume for Laboratory Evaluation of Rollover Protective Structures (ROPS) and Falling Object Protective Structures (FOPS) of Construction and Industrial Vehicles*, SAE J397a[12], described this volume. The DLV represented a 95th percentile normally clothed man wearing a hard hat. If the operator does not normally wear a hard hat, the height of the upper projection of the DLV could be reduced by 50 mm (2 in).[13]

   The DLV was first recognized in the SAE recommended practice, *Performance Criteria for Rollover Protective Structures (ROPS) for Earthmoving, Construction, Logging, and Industrial Vehicles*, SAE

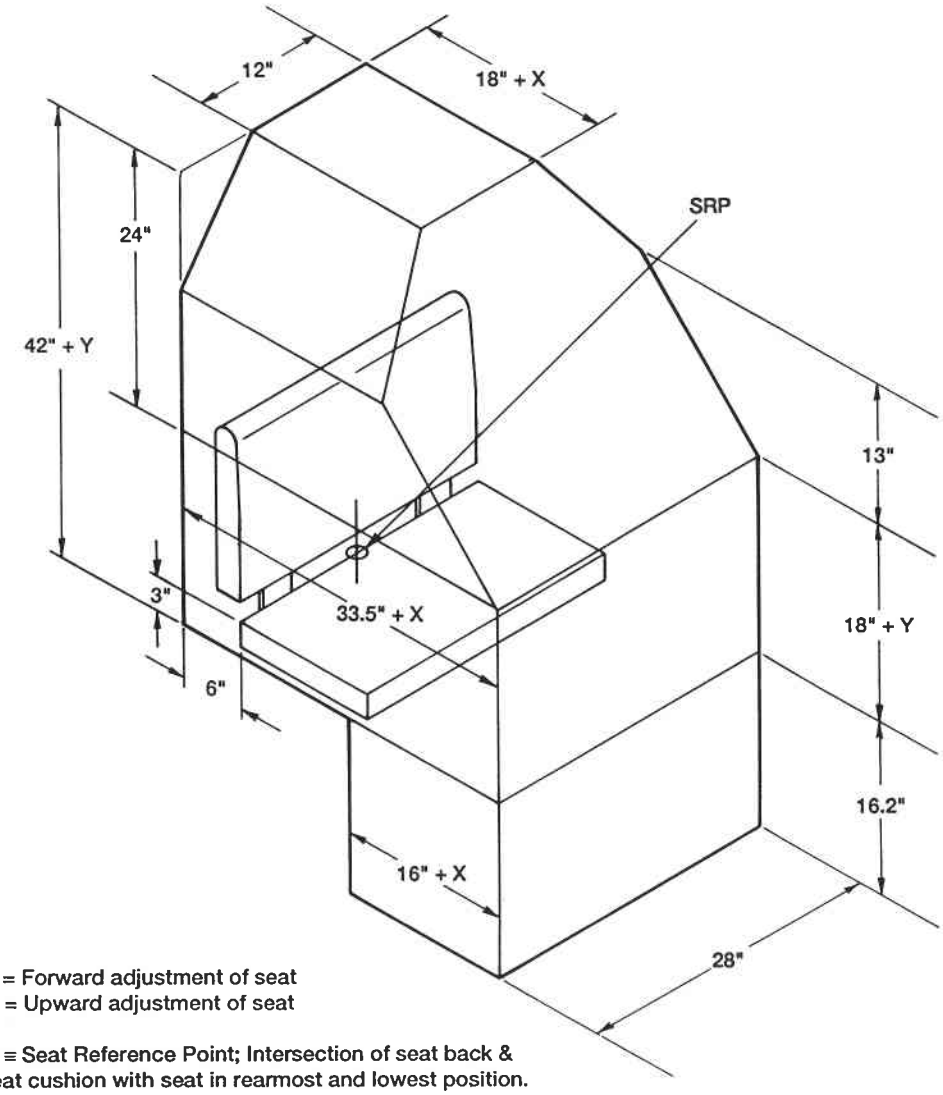


* SEAT IN REARMOST POSITION

X = FORWARD ADJUSTMENT OF SEAT

SEAT MUST BE ADJUSTED TO HIGHEST POSITION.

FIGURE 2: CRITICAL ZONE FOR SCRAPERS SAE J320, (NOV., 1967)



X = Forward adjustment of seat
Y = Upward adjustment of seat

SRP ≡ Seat Reference Point; Intersection of seat back & seat cushion with seat in rearmost and lowest position.

FIGURE 3a: CRITICAL ZONE FOR OPERATORS OF CONSTRUCTION AND INDUSTRIAL MACHINERY SAE J397 (JULY, 1969)

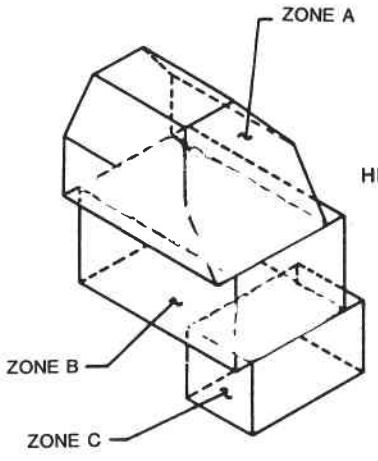


FIGURE 3b:

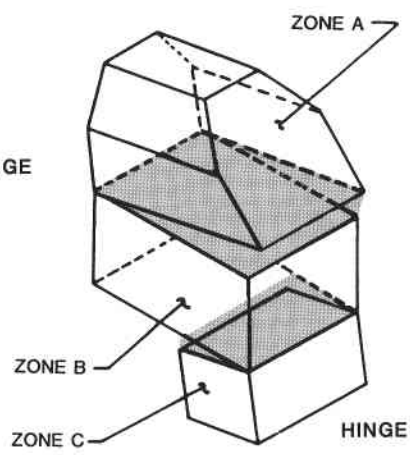


FIGURE 3c:

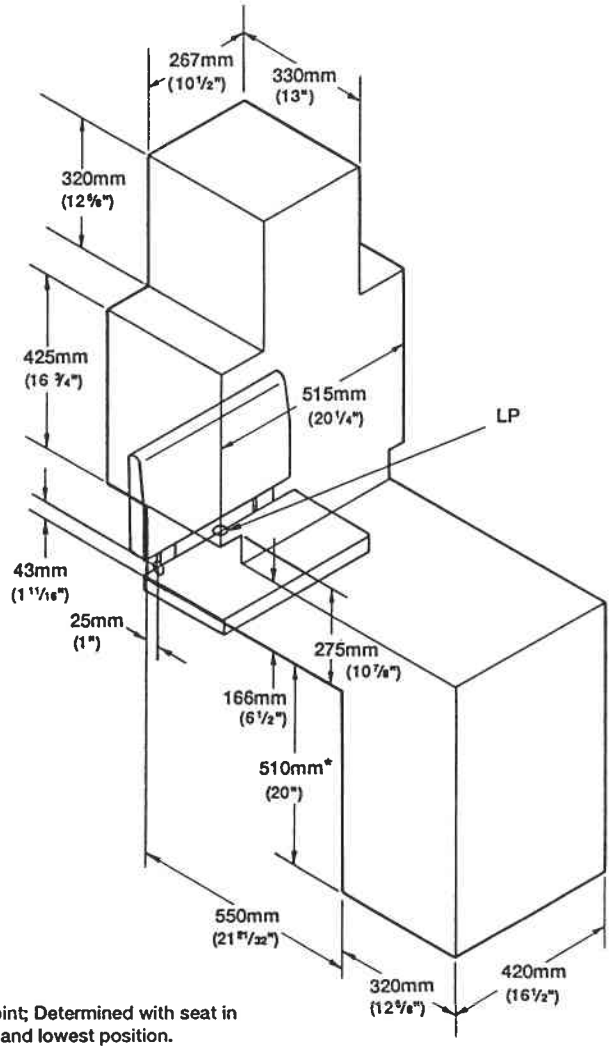
ACCEPTABLE VARIATIONS OF THE CRITICAL ZONE

J1040,[14] in April, 1974. This standard consolidated the existing similar standards governing several types of industrial and construction machinery in SAE J320, J395, J396, and J1011. Although SAE J1040 was revised in April, 1977 to SAE J1040b, *Performance Criteria for Rollover Protective Structures (ROPS) for Construction, Earthmoving, Forestry, and Mining Machines,*[15] no revisions with respect to ROPS performance were made.

In June, 1979 the Deflection Limiting Volume was revised dimensionally, although not significantly, and retitled, *Deflection Limiting Volume-ROPS/FOPS Laboratory Evaluation*, in SAE J397b[16] (Figure 4a). It remained a recommended practice as opposed to a standard. In recognition of this change to the DLV, SAE J1040b[15] was revised to SAE J1040c[17] in April, 1979.

The Deflection Limiting Volume became standardized in April, 1988 after revision by the Off-Road Machinery Technical Committee. Although the title remained unchanged, the new standard was assigned the number carried by the earlier Critical Zone, SAE J397.[18] A significant change took place, however, when the standard was adopted in April, 1988. Prior to that time, it was not required that the included volume of a four, or more, vertical member ROPS-FOPS entirely envelop the DLV.[19] In addition, forward rotation of the upper portion of the DLV 15° became allowable (Figure 4b) in recognition of the fact that the human body is not rigid, particularly in a rollover.[20] If the upper body rotation would lead to interference with any machine component or control, a lesser allowable rotation would then be imposed. Furthermore, clearance problems on small rollers and compactors led to an allowance for narrowing the recommended 920mm (36.2 in) (side-to-side) width of the space envelope to 750mm (29.5 in). The "Space Envelope" is defined in SAE J154a, *Operator Enclosures Human Factor Design Considerations.*[21] The DLV, however, remained unchanged.

SAE J1040 was also completely revised in April, 1988 and retitled, *Performance Criteria for Rollover Protective Structures (ROPS) for Construction, Earthmoving, Forestry, and Mining Machines.*[22] The DLV defined in SAE J397 of April, 1988, was



LP ≡ Locating Point; Determined with seat in rearmost and lowest position.

* Variable Dimension; Need not extend below floor plate.

FIGURE 4a: DEFLECTION LIMITING VOLUME OF A LARGE MALE WEARING REGULAR CLOTHING

SAE J397a (JAN., 1972) ISO 3164 (1979)
SAE J397b (JUN., 1979) CSA B352-M1980 (1980)

recognized for use in the design of ROPS for machinery such as crawler tractors and loaders, graders, wheel loaders, wheel tractors, dozer equipped wheel tractors, wheel log skidders, skid steer loaders, backhoe loaders, wheel industrial tractors, semi-mounted scrapers, water wagons, articulated steer dumpers, bottom dump wagons, side dump wagons, rear dump wagons, towed fifth wheel attachments, rollers, compactors, and rigid frame dumpers with full mounted bodies.

The identical DLV is recognized by the International Organization for Standardization (ISO) in ISO 3164-1979.[23]

The Canadian Standards Association (CSA) in their standard CSA B352 M1980,[24] recognized the volume illustrated in Figure 4a as a "Reference Volume." The Reference Volume establishes deflection limits for ROPS on construction, earthmoving, forestry, industrial and mining machinery. The Reference Volume is not used in the design of ROPS for agricultural tractors.

4. The first protective volume intended specifically for use in the design of ROPS for agricultural tractors was defined by the American Society of Agricultural Engineers and the Society of Automotive Engineers in 1977. This volume was given the name "Clearance Zone" in ASAE

S383[25] (March, 1977) and in SAE J1194[26] (June, 1977), *Roll-Over Protective Structures (ROPS) for Wheeled Agricultural Tractors*, and is illustrated in Figure 5.

The Canadians, in 1980, recognized the identical protective volume and named it the "Clearance Volume" in Canadian standard CSA B352-M1980.[24] In 1983, the American Society of Agricultural Engineers reconfirmed this "Clearance Zone" for ROPS on agricultural tractors in ASAE S383.1.[27]

The Clearance Zone illustrated in Figure 5 is shown with a 610mm (24-inch) wide base and a width at the top of 102mm (4 inches). As a point of clarification, the Clearance Zone is required to maintain a 610mm (24-inch) width both at the top and bottom. The zone may deflect to the left or right, however, depending upon the direction of force application, such that neither the ROPS frame nor the plane of the ground come within 51mm (2 inches) of the vertical plane which intersects the seat reference point. Therefore, Figure 5 is intended to illustrate that portion of the Clearance Zone which should not be invaded during a structural evaluation.

5. A "Survival Zone" for operators of vineyard tractors and narrow-wheeled tractors was recognized by France in 1979 in the draft French Standard, Pr U 02-047.[28] The French define the Survival Zone in the same way that the Society of Automotive Engineers in the United States defines the Deflection Limiting Volume. That is, neither the ROPS structure nor the plane of the ground may enter the protective volume. The Survival Zone (Figure 6a) is used on tractors having rollbar type ROPS mounted in front of the operator's seat.

   An identical protective volume was recognized by the Council of the European Communities in 1987 in directive (87/402/EEC)[29] and called the "Zone of Clearance." Similar to the French application, the European Council recognized the Zone of Clearance for use on narrow-track wheeled agricultural and forestry tractors with front-mounted rollbars. Such tractors were defined to have a ground clearance of 600mm (23 5/8 in) or less, a mass of 600kg (1323 lbs) to 3000kg (6615 lbs), and the width of one axle of 1500 mm (59 1/16 in) or less. In the event the

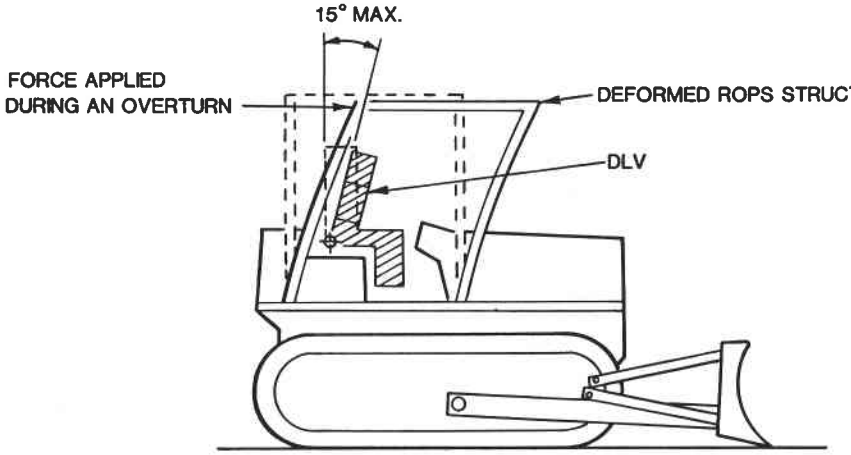
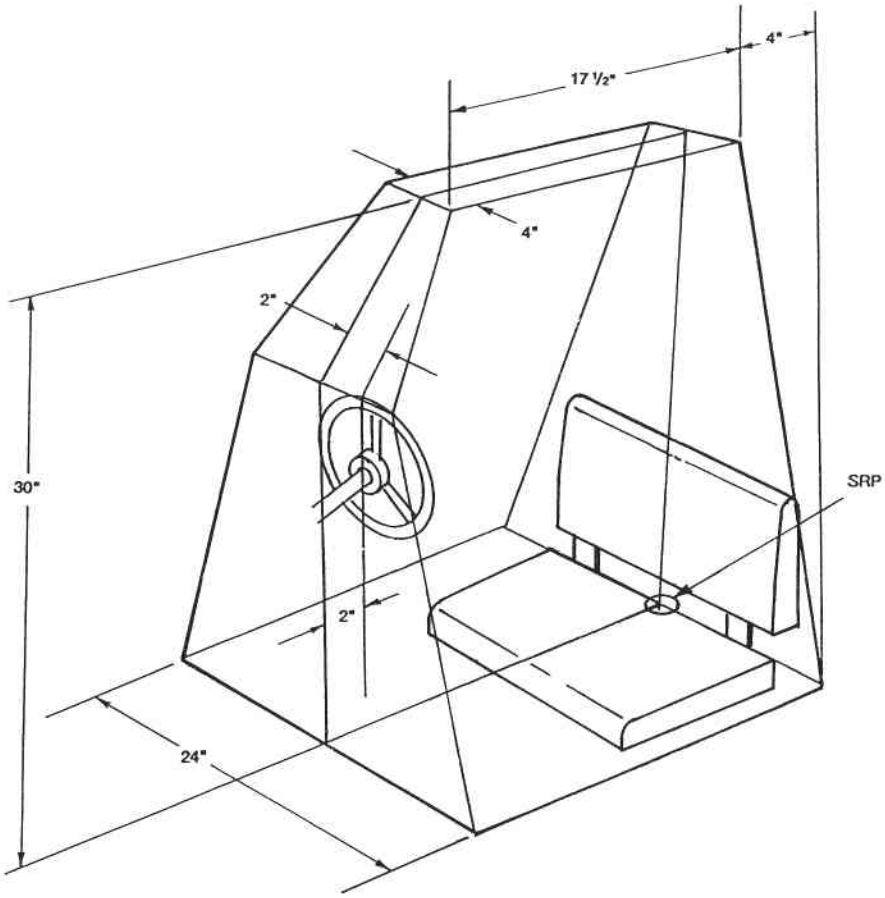


FIGURE 4b: ALLOWABLE 15° ROTATION OF DLV ON A CRAWLER TRACTOR



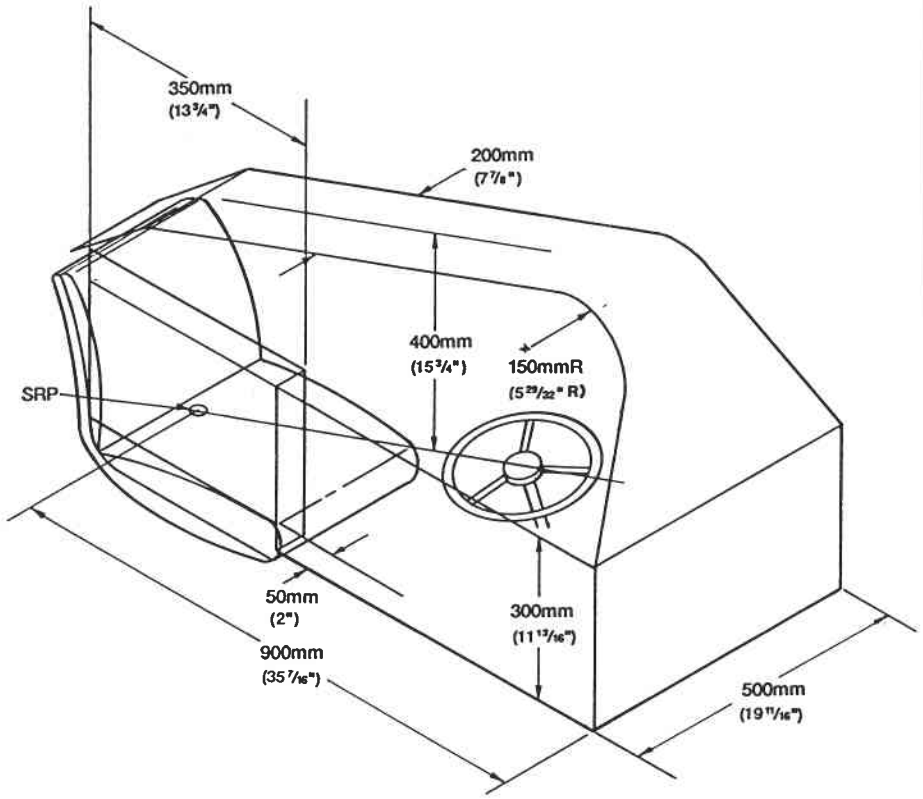
SRP ≡ Seat Reference Point; Determined with seat in rearmost and highest position.

FIGURE 5: CLEARANCE ZONE FOR AGRICULTURAL TRACTORS OF 20 HORSEPOWER OR GREATER
ASAE S383 (MAR. ,1977) SAE J1194 (JUN., 1977)
CSA B352-M1980 (1980) SAE J1194 (JUL., 1983) ASAE S383.1 (DEC., 1983)

tractor is fitted with a rigid section, a housing, or other hard fixture placed behind the driver's seat, the fixture must also be regarded as a protection point which plays an important role in the event of a side or rear overturn. For this reason, the fixture must be sufficiently rigid and firmly attached to the rear of the tractor to withstand a test which, as of the date of the standard, was undefined. However, the height of the rear structure above the seat reference point must be 500mm (19 11/16 in) or less (Figure 6b).

6. The Canadians, in 1980, defined a protective volume for one-of-a-kind or special machinery for agriculture, construction, earthmoving, forestry, industrial or mining use including industrial tractors. This "Design Space" is defined by the Canadian Standards Association standard CSA B352-M1980[24] as the minimum design volume describing the space occupied by a seated operator which establishes the minimum size ROPS (Figure 7).

7. The protective volume illustrated in Figure 8a was first proposed in SAE technical paper No. 730761[30] in 1973. It represented a revision of an existing protective volume which imposed "unexpected and unnecessary difficulties on cab designers." The British adopted the volume in 1973 in their standard BS4063, *Specifications for Requirements and Testing of Protective Cabs and Frames for Agricultural Wheeled Tractors,*[31] and named it the "Zone of Clearance." By 1981, the International Organization for Standardization Technical Committee ISO/TC 23 in standard ISO 5700 and ISO 3463 also adopted this protective volume. In 1984, the second editions of ISO 5700[32] and ISO 3463[33] were approved, and in 1989, a third edition of ISO 3463[34] was approved. The distinction between these standards is that ISO 5700 covers static testing of the ROPS, and ISO 3463 covers dynamic testing of the R0PS. However, the protective volume defined in each standard is identical. The volume was given the name "Clearance Zone" by the ISO and was prescribed for use on agricultural and forestry wheeled tractors having a mass of 800kg (1764 lbs) to 15,000kg (33,075 lbs) or greater since a standard for tractors of mass greater than 15,000kg had not yet been approved. The minimum track width of the



SRP ≡ Seat Reference Point; Intersection of seat back & seat cushion in rearmost and highest position.

FIGURE 6a: ZONE OF CLEARANCE FOR OPERATORS OF VINEYARD AND NARROW-WHEELED TRACTORS FRANCE PR U 02-047 (1979)

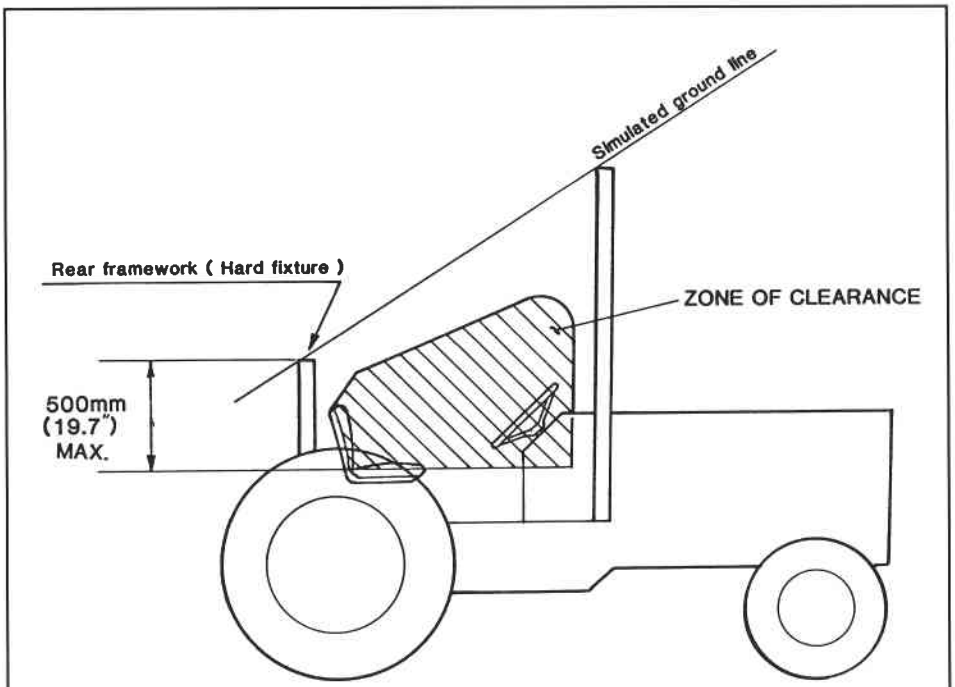
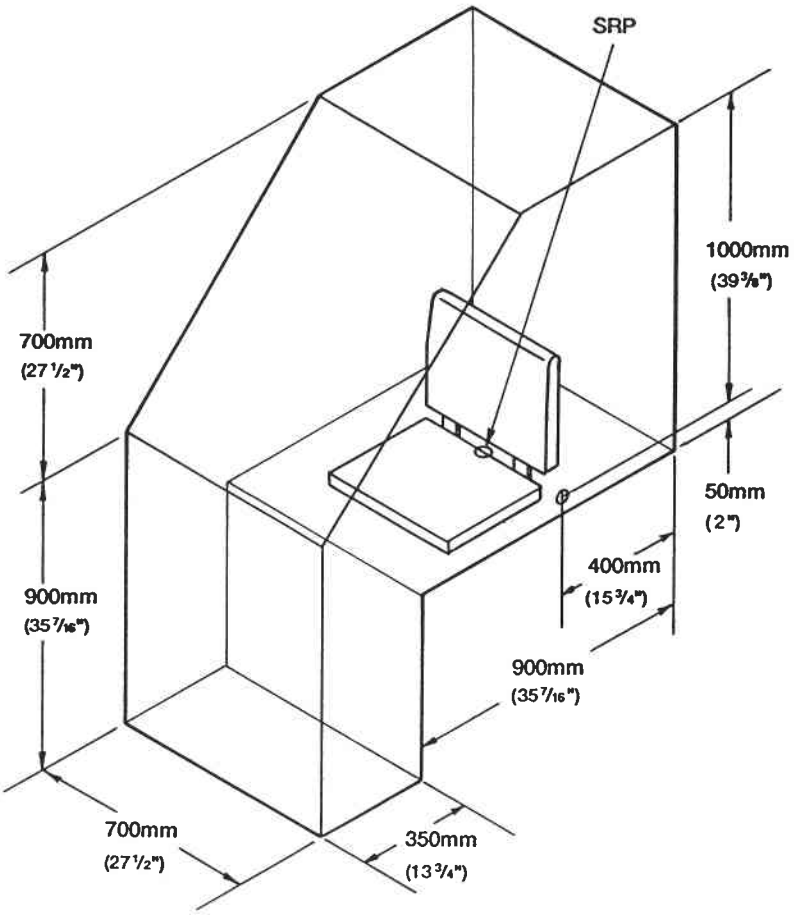


FIGURE 6b: TRACTOR WITH FRONT-MOUNTED ROLLBAR AND REAR-MOUNTED FIXTURE EUROPEAN (87/402/EEC) (1987) EUROPEAN (86/298/EEC) (1986)



SRP ≡ Seat Reference Point;
Seat in highest and rearmost position.

FIGURE 7: DESIGN SPACE FOR ONE-OF-A-KIND MACHINES OR WHEN OTHER PROTECTIVE VOLUMES CANNOT BE ATTAINED CSA B352-M1980 (1980)

rear wheels was generally greater than 1150mm (45 1/4 in). Lawn mower tractors, vineyard tractors, low profile tractors used in buildings with limited overhead clearance, orchard tractors, stilt tractors and certain forestry machines are specifically excluded from the application of ISO 5700.

An almost identical "Zone of Clearance" was adopted by the Council of the European Communities on May 26, 1986 in standard 86/298/EEC. The region to the immediate right and left of the operator's seat was made narrower in the European Council's description of the Zone of Clearance (Figure 8b) making it similar to the lower rear portion of the zone described in section (3) above for front-mounted rollover protection. This Zone of Clearance is specifically intended for application on rear-mounted rollover protection structures of narrow-track wheeled agricultural and forestry tractors. These tractors are defined as having a ground clearance of 600mm (23 5/8 in) or less, a mass of 600kg (1323 lbs) or greater, and a tread width for both axles of 1150mm (45 1/4 in) or less.

The Society of Automotive Engineers approved the Clearance Zone shown in Figure 8a in December, 1987 in standard SAE J2194[35] for wheeled agricultural tractors. Just like the ISO standard, the SAE does not demand that the mounting location of the ROPS frame be either forward or behind the operator's seat.

The Clearance Zone illustrated in Figure 8a is shown as having a width of 500mm (19 11/16 in) at the bottom and a width of 200mm (7-7/8 in) at the top. As a point of clarification, the Clearance Zone is required to maintain a 500mm (19 11/16 in) width both at the top and bottom in any structural evaluation. However, the zone may deflect to the left or right, depending upon the direction of a side force application, such that neither the ROPS structure nor the plane of the ground comes within 100mm (3 15/16 in) of the vertical plane which intersects the seat reference point (Figure 8c). Therefore, Figure 8a is intended to illustrate that portion of the Clearance Zone which may never be invaded during structural evaluation.

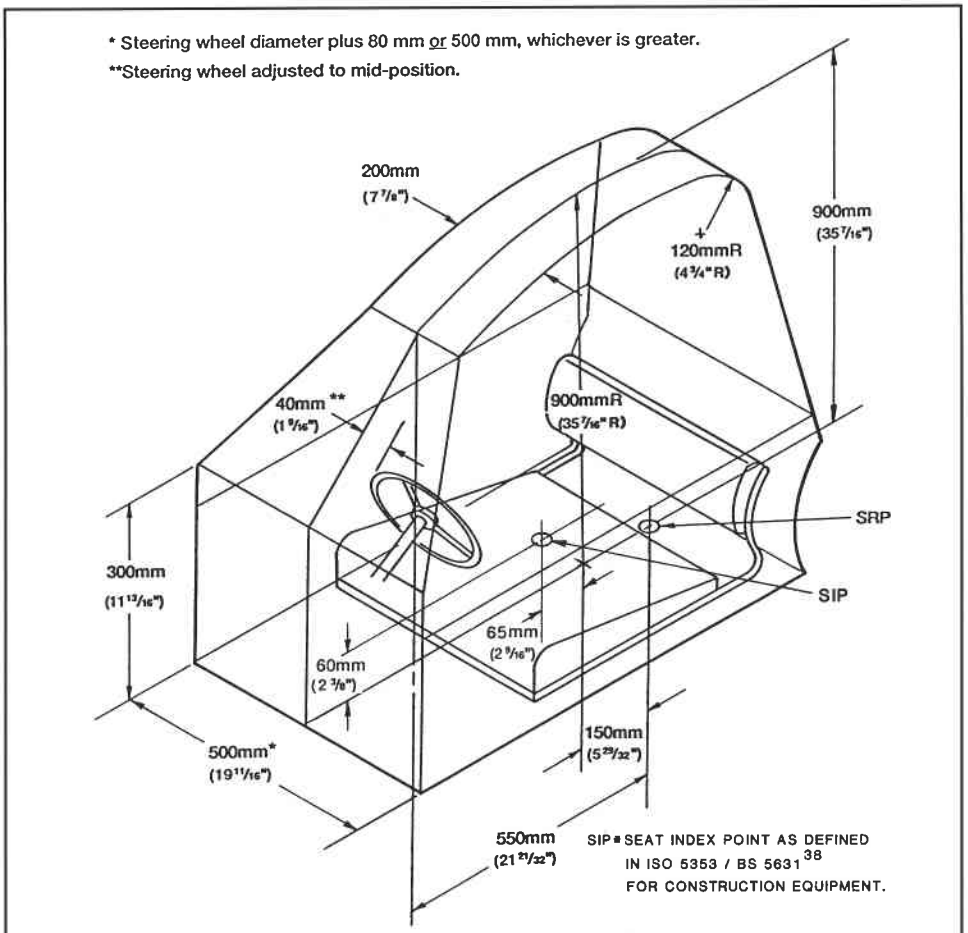
The reader should note that in a rationale statement associated with the adoption of SAE J2194 in December, 1987, a statement is made that "Small AG tractors present a unique ROPS problem which requires additional study."[36]

THE HISTORY OF ROPS DEFLECTION LIMITS FOR AGRICULTURAL TRACTORS IN AMERICA

The Tractor Technical Committee of the Society of Automotive Engineers and the American Society of Agricultural Engineers first defined performance requirements for ROPS for agricultural tractors in August, 1967. The ASAE published these performance requirements as ASAE R306[38](and R306.1[39] in December, 1967), *Protective Frame Performance Requirements*. Performance requirements for the ROPS stated that when deflected, the minimum allowable dimension from the inside of the frame upright to the vertical centerline of the tractor seat was 51mm (2 inches), from the bottom of the frame cross member to the top of the seat cushion was 762mm (30 inches), from the center line front of the seat back rest to the center crossbar was not less than 0 inches nor more than 305mm (12 inches), and the minimum horizontal distance between uprights was 610mm (24 inches) (Figure 9). SAE J333, *Operator Protection for Agricultural and Light Industrial Tractors*[40] and SAE J334, *Protective Frame Performance Requirements*[41] recognized identical performance criteria for ROPS.

The above recommendations were approved for the first time as a standard in February, 1970 by the American Society of Agricultural Engineers in ASAE S306.2, *Protective Frames-Test Procedures and Performance Requirements.*[42]

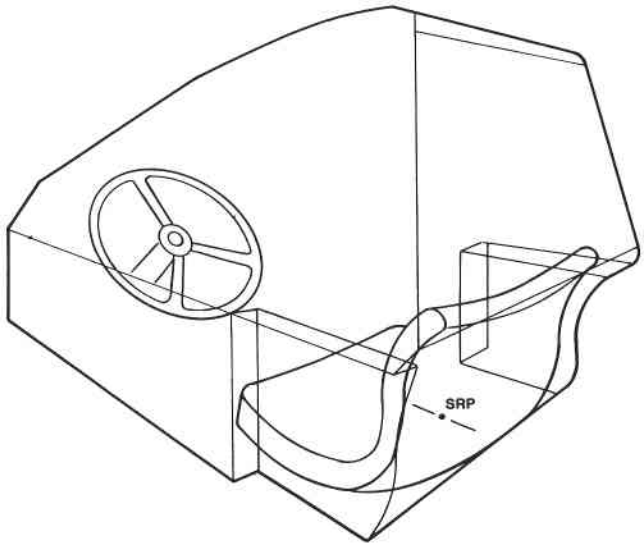
In January, 1974, the Society of Automotive Engineers revised SAE J333 to SAE J333b, *Operator Protection for Wheel-Type Agri-*



SRP ≡ Seat Reference Point; Intersection of seat back & seat cushion in rearmost and highest position.

FIGURE 8a: CLEARANCE ZONE FOR AGRICULTURAL AND FORESTRY WHEELED TRACTORS OF 20 HORSEPOWER OR GREATER

BS 4063 (1973) ISO 3463 (1981) ISO 5700 (1981)
ISO 3463 (E) (1984) ISO 5700 (1984) SAE J2194 (DEC. ,1987)
ISO 3463 (1989)



SRP ≡ Seat Reference Point; Intersection of seat back & seat cushion in rearmost and highest position.

FIGURE 8b: ZONE OF CLEARANCE WITH NARROW REGION AT OPERATORS 'S SEAT
EUROPEAN (86 / 298 / EEC) (1986)

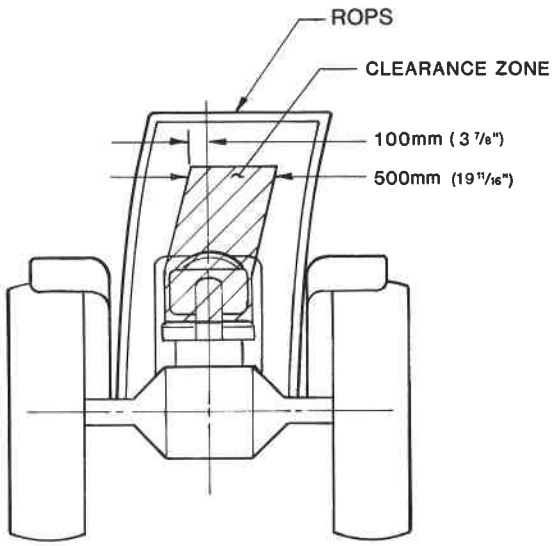


FIGURE 8c: DEFLECTED ROPS AND CLEARANCE ZONE AFTER LEFT SIDE OVERTURN

ISO 5700 (1984) ISO 3463E (1984)
SAE J2194 (DEC. , 1987) ISO 3463 (1989)

cultural Tractors,[43] before approving it as a standard. The significant revision was that an agricultural tractor was classified for the first time as a vehicle of more than 20 horsepower. Shortly thereafter, in February, 1974, SAE J334 was revised to SAE J334b, *Protective Frame for Agricultural Tractors-Test Procedures and Performance Requirements,*[44] and approved as a standard. In addition to the deflection limits already prescribed, a Seat Reference Point (SRP) was defined. The dimension from the newly defined SRP to the rear of the deflected ROPS cross member was prescribed as 102mm (4 inches) or less (Figure 10). It was this SAE standard from which the requirements of the United States Department of Labor Occupational Safety and Health Administration (OSHA) for ROPS on agricultural tractors was borrowed and published in 29 CFR 1928.52(c)(1) and 29 CFR 1928.52(e)(1)(i).[45] The regulation required employers to provide ROPS and a seat belt on all wheeled agricultural tractors greater than 20 horsepower and manufactured after October 25, 1976, with three exceptions:

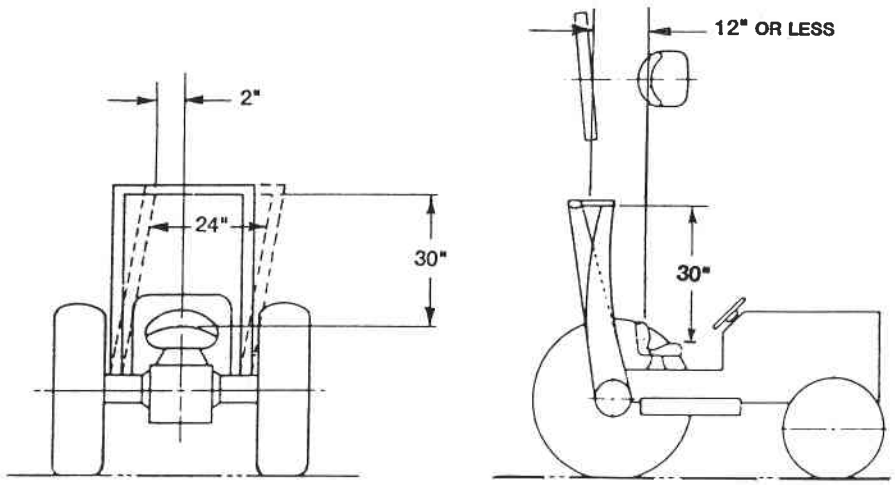
1. "Low Profile" tractors while they are used in orchards, vineyards or hop yards when the vertical clearance requirements would substantially interfere with normal operations, and while their use is incidental to the work performed therein.

2. "Low Profile" tractors while used inside a farm building or greenhouse in which the vertical clearance is insufficient to allow a ROPS equipped tractor to operate, and while their use is incidental to the work performed therein.

3. Tractors while used with mounted equipment which is incompatible with ROPS (e.g., cornpickers, cotton strippers, vegetable pickers and fruit harvesters).

OSHA specifically stated that older tractors were not required to be retrofitted with ROPS because, in many cases, the frames of older tractors would be unable to withstand the loads imposed upon a ROPS. A custom built ROPS for each older tractor was judged to be an unacceptable economic burden (29 CFR 1928(11)(3)(d)).[45]

OSHA prescribed additional dimensions for both the undamaged ROPS frame and the deflected frame (Figure 11). With these dimensions in addition to those illustrated in Figures 9 and 10, the "Clearance Zone" described earlier in this report (Figure 5) had fully evolved. However, the Clearance Zone would not become formally standardized until March, 1977 in ASAE S383[25] and June, 1977 in SAE J1194.[26]



NOTE: NOT TO SCALE

FIGURE 9: ROPS DEFLECTION LIMITS FOR AGRICULTURAL TRACTORS

ASAE R306 (AUG. ,1967) ASAE R306.1 (DEC. ,1967)
SAE J333 (APR. ,1968) SAE J334 (APR. ,1968)

SAE J1194[46] was reapproved without change in July, 1983 and remains in effect today. In December, 1987, SAE J2194[39] was approved in order to be in harmony with international standards. The Clearance Zone illustrated in Figure 8a had been long recognized by various European and international standards including OECD and ISO. Regardless of whether a rollbar-type

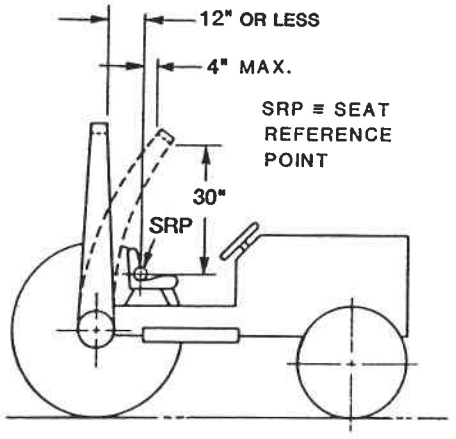


FIGURE 10: ROPS DEFLECTION LIMITS FOR AGRICULTURAL TRACTORS

SAE J333b (JAN. ,1974)
SAE J334b (FEB. ,1974)
CFR 1928.52 (OCT. ,1976)

ROPS or a full cab enclosure type ROPS was used, the performance of the ROPS was judged by its ability to protect the Clearance Zone illustrated in Figure 12.

Today, two acceptable Clearance Zones coexist in America for large agricultural tractors. These protective volumes are illustrated in Figure 5 and Figure 8a.

ROPS AND FOPS IN OTHER INDUSTRIES

In this section, several types of machines which have a ROPS-FOPS frame or overhead guard are examined in order to identify differences with the performance requirements and/or differences in performance philosophy with the ROPS-FOPS frames already examined.

1. *Skid Steer Loaders* - A recommended practice for the design of skid steer loaders was first approved in June, 1985 in SAE J1388, *Personnel Protection-Skid Steer Loader.*[47] This class of machines is required, by the Society of Automotive Engineers, to be equipped with a full ROPS enclosure cab. In addition, the use of skid steer loaders has shown that the operator can be subjected to small objects and debris entering the operator's compartment. Therefore, the ROPS is required to be equipped with side screens which can be removed in order to accommodate ingress and egress from the cab. The operator cab is designed to the size requirements stated in SAE J154, *Operator Enclosures (Cabs)-Human Factor Design Considerations*, with the exception that the inside cab width may be reduced to 600mm (23.6 inches) instead of the recommended 914mm (36 inches). SAE J154 recognizes that particular types of equipment may necessitate use of a "space envelope" smaller than the minimum indicated by this recommended practice.[48] (Note that a "space envelope" is not the same as an "operator protective volume.") The ROPS is required to meet the performance criteria of SAE J1040[14] which uses the Deflection Limiting Volume shown in Figure 4a as the recognized protective volume. The operator cab structure is also required to meet the performance criteria for FOPS specified in SAE J1043.

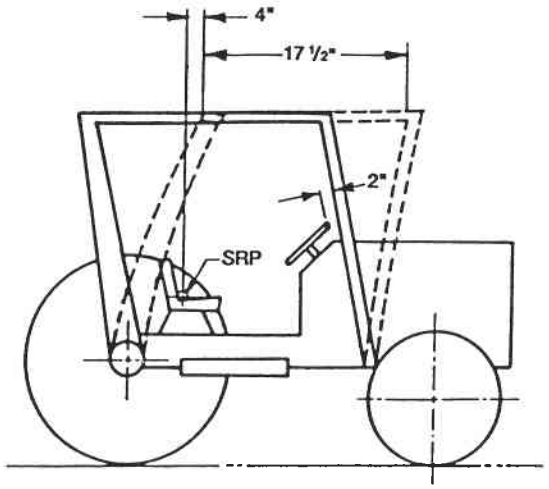


FIGURE 11: ROPS DEFLECTION LIMITS FOR AGRICULTURAL TRACTORS

CFR 1928.52 (OCT. ,1976) ASAE S383 (MAR. ,1977)
SAE J1194 (JUN. ,1977) SAE J1194 (JUL. ,1983)
ASAE S383.1 (DEC. ,1983)

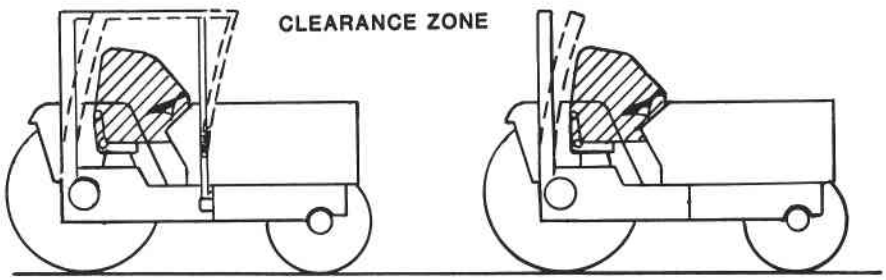


FIGURE 12: FULL CAB ENCLOSURE AND ROLLBAR TYPE ROPS DEFORMED AFTER REAR IMPACT SAE J2194 (DEC., 1987)

2. *General Purpose Industrial Machines* - A recommended practice was approved by the Construction and Industrial Machinery Technical Committee in September, 1973 and later made a standard in September, 1987 by the Off-Road Machinery Technical Committee. This standard, SAE J1043, *Minimum Performance Criteria for Falling Object Protective Structure (FOPS) for Industrial Machines,*[49] applies to general purpose industrial machines equipped with ROPS. In other words, the standard addresses itself to the ability of a ROPS to resist falling objects, not rollover. ROPS on general purpose industrial machines must protect the operator against falling objects such as bricks and concrete blocks dropped from heights of not more than 9.1m (30 feet) above the ground. The Deflection Limiting Volume shown in Figure 3a is the operator protective volume recognized in the performance of the ROPS enclosure. Therefore, the top of the enclosure must completely cover and overlap the vertical projection of the DLV. The portions of SAE J1040[14] which apply to falling object resistance must also be met.

3. *Excavators* - In February, 1988, a recommended practice was approved by the Off-Road Technical Committee in SAE J1356, *Performance Criteria for Falling Object Guards for Excavators.*[50] This recommended practice addressed itself to the performance of the required top and front screens placed onto a ROPS rather than to the performance of the ROPS itself. The Deflection Limiting Volume shown in Figure 4a defined the deflection limits for the two screens when they were subjected to the prescribed falling object tests.

4. *Forestry Equipment* - In April, 1980, a recommended practice was approved by the Off-Road Technical Committee in SAE J1084, *Operator Protective Structure Performance Criteria for Certain Forestry Equipment.*[51] Tree harvesting machinery such as skidders, grapple skidders and crawlers were included within the scope of the standard. Just as with excavators, this recommended practice addressed itself to the performance of the required screens placed onto a ROPS frame rather than to the performance of the ROPS itself. The Deflection Limiting Volume shown in Figure 4a defined the deflection limits for the screens when they were subjected to the prescribed loading.

5. *Low Lift and High Lift Trucks* - This type of equipment, otherwise known as a forklift truck, is not required to be equipped with ROPS but is required, by the applicable safety standard, to be fitted with an overhead guard. Although an overhead guard is intended to protect the truck operator from the hazard of falling objects, it is not the same as a FOPS. The lift truck industry prescribes different performance testing for overhead guards than the Society of Automotive Engineers prescribes for FOPS.

   In defining the deflection limit of the overhead guard, no operator protective volume is recognized. In the case of a sit-down rider truck, the overhead guard is allowed to deflect to a distance of 254mm (10 inches) above the top edge of the steering wheel. In the case of a stand-up rider truck, the overhead guard is allowed to deflect to a distance of 1626mm (64 inches) above the platform where the operator stands (Figure 13). These requirements can be found in ASME/ANSI B56.1-1988, *Safety Standard for Low Lift and High Lift Trucks.*[52]

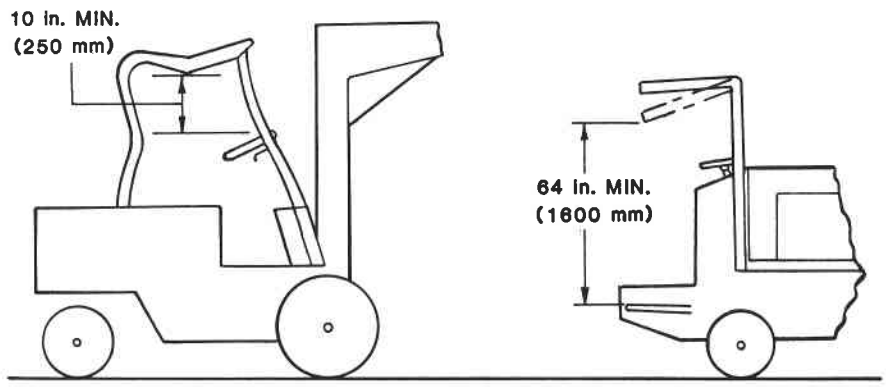


FIGURE 13: DEFLECTION LIMIT FOR OVERHEAD GUARD ON SIT-UP RIDER FORK LIFT TRUCKS
ASME/ANSI B56.1 (AUG., 1988)

6. *Rough Terrain Fork Lift Trucks* - Similar to low lift and high lift trucks, rough terrain forklifts are not required to be equipped with ROPS, but are required, by the applicable safety standard, to be fitted with an overhead guard, as well as an operator compartment. The compartment strength is acceptable if, after testing, there is no protrusion or deflection into the Deflection Limiting Volume illustrated in Figure 4a. Unlike any other performance criteria, however, the DLV is allowed to move within the confines of the operator's compartment. The overhead guard is not allowed to deflect within 254mm (10 inches) of the top of the steering wheel, similar to the requirement imposed on ordinary forklift trucks. These requirements can be found in ANSI B56.6-1978, *Safety Standard for Powered Industrial Trucks-Rough Terrain Fork Lift Trucks.*[53]

7. *United States Auto Club* - As of January 1,1979, all auto racing classifications of the United States Auto Club (USAC)[54] were required to equip the racing vehicle with either a rollbar or a roll cage. The height of the rollbar is required to "be adequate to protect the driver's head in the event of a rollover." The height and installation of the rollbar is subject to the approval of the USAC Technical Committee.

   Roll cages, on the other hand, are required to extend a minimum of 51mm (2 inches) above the driver's helmet when he is seated in an upright position. However, there is a recommendation that the roll cage extend 102mm (4 inches) above the driver's helmet. The normal "height" of the roll cage is 914mm (36 inches) measured on a line equivalent to the driver's spine when seated in the car.

   The roll cage is not permitted to encroach upon an imaginary cylinder extending upward from the cockpit opening. This imaginary cylinder appears to be a similar concept to an operator protective volume. However, the imaginary cylinder is a volume which must not be invaded by the roll cage when it is initially constructed whereas an operator protective volume must not be invaded after an overturn occurs. The diameter of the imaginary cylinder 510mm (20 inches) is defined only for the USAC Sprint Car classification, however. Construction details are illustrated in Figure 14.

8. *Sports Car Club of America* - Roll bars became mandatory safety equipment according to the racing rules of the Sports Car Club of America (SCCA) in 1957. However, construction specifications for the roll bars did not appear until 1970 when it was then required that the roll bar extend 76mm (3 inches) above the apex of the driver's helmet.[55] There has been no reference found relating roll bar performance to an operator protective volume.

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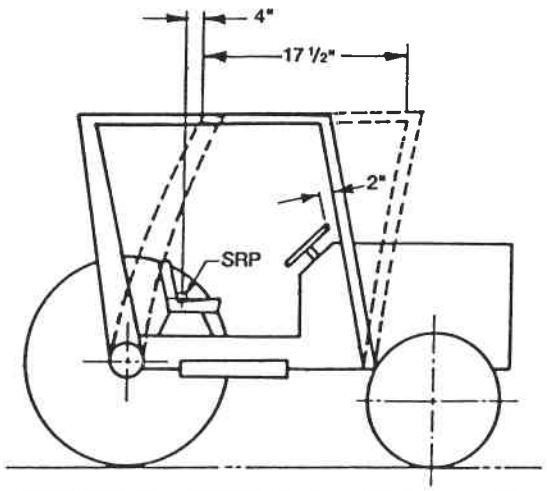
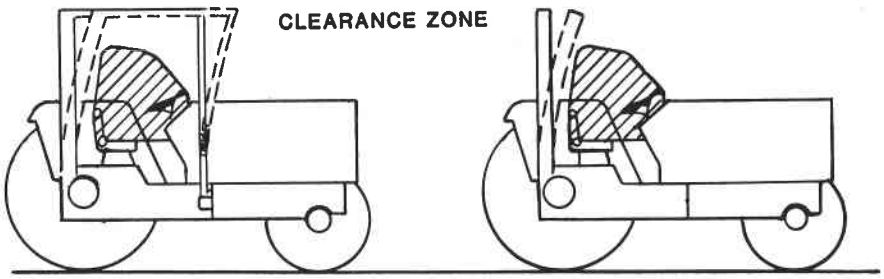


FIGURE 11: ROPS DEFLECTION LIMITS FOR AGRICULTURAL TRACTORS

CFR 1928.52 (OCT. ,1976) ASAE S383 (MAR. ,1977)
SAE J1194 (JUN. ,1977) SAE J1194 (JUL. ,1983)
ASAE S383.1 (DEC. ,1983)



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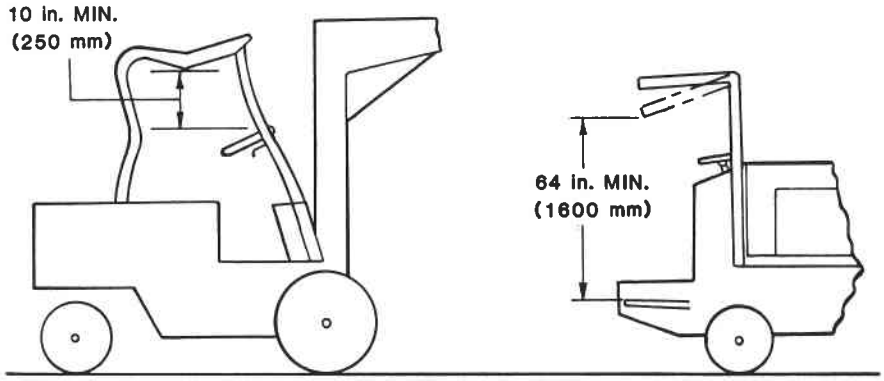

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7. *United States Auto Club* - As of January 1,1979, all auto racing classifications of the United States Auto Club (USAC)[54] were required to equip the racing vehicle with either a rollbar or a roll cage. The height of the rollbar is required to "be adequate to protect the driver's head in the event of a rollover." The height and installation of the rollbar is subject to the approval of the USAC Technical Committee.

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9. *National Association for Stock Car Auto Racing* - Roll cages (bars) became man-

datory safety equipment according to the racing rules of the National Association for Stock Car Auto Racing (NASCAR) as of January 1, 1980. The roll cage members to the left and above the driver's head are required to be padded with foam rubber. The roll cages required in both Trans-Am and NASCAR vehicles have proven to be highly effective in severe roll-overs as well as in side impact accidents.[55] Construction details are illustrated in Figure 15. Note the extensive side protection and that the shape of the roll cage is customized to the particular model of automobile. The roll cage must be of welded construction and also be welded to the vehicle frame in such a way that the vehicle frame and the roll cage are a single assembly. Tubular steel members also provide protection for the engine compartment.

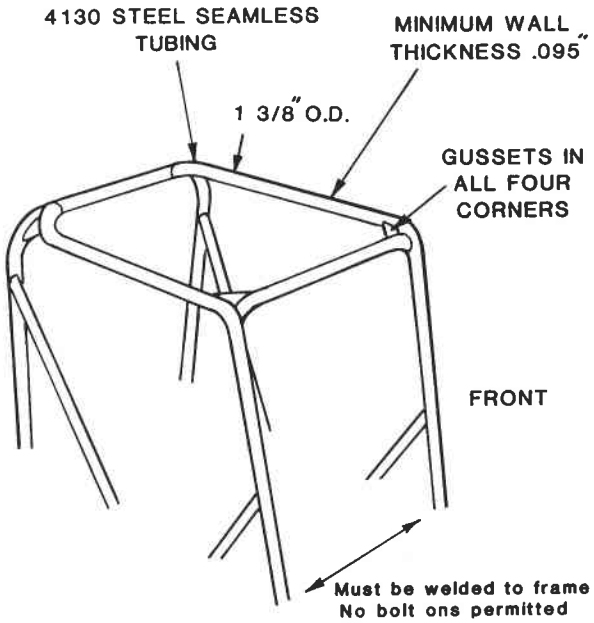

Figure 14 : USAC Sprint Car Roll Cage

There is no reference in the NASCAR rule book[56,57] relative to an operator protective volume. However, SAE paper 700660,[55] written in 1970, comments that the successful roll cage experiences of NASCAR have established "the necessity of preserving the integrity of the occupant space." At the same time, this paper recognizes that a proper roll cage cannot protect the occupant in all situations: "End-over-end roll-overs are more violent and may result in injury despite proper restraint equipment and roll-over protection."

The auto racing world is concerned with its own dilema of safety versus performance. Difficulties have been encountered in installing roll bars in monocoque and space frame types of cars. Material strengths have also been reduced in favor of weight savings. As a result, roll bar failures increased during 1968 (six) and 1969 (nine) in formula and sports racing cars over the four previous years

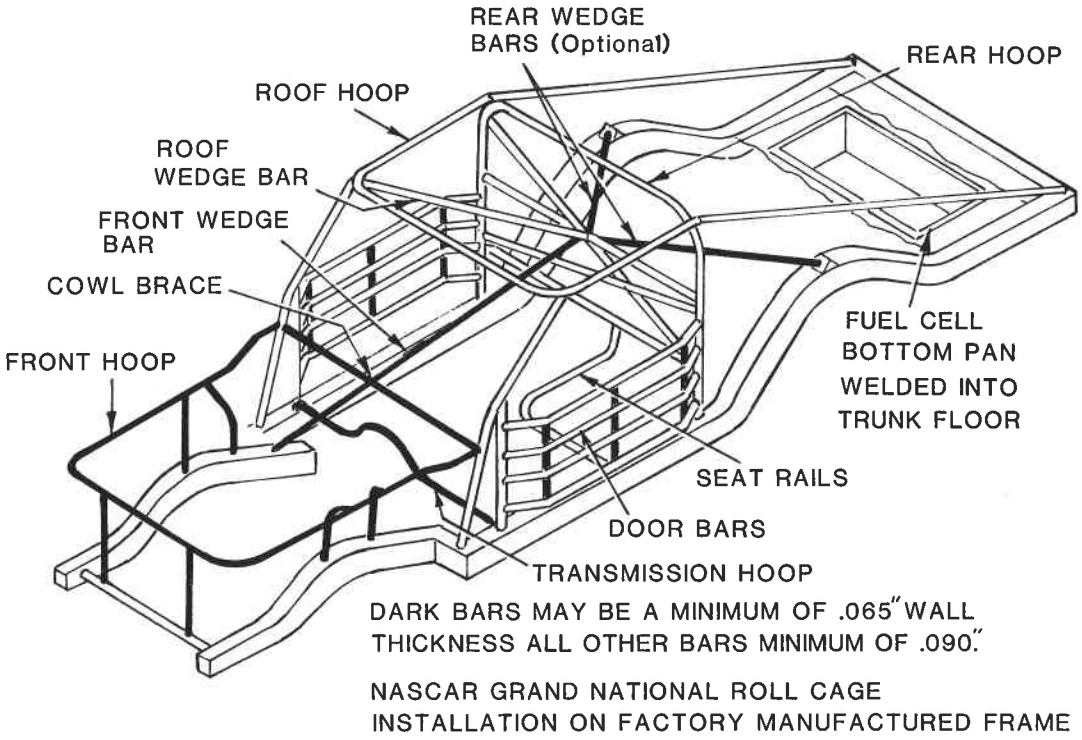

Figure 15 : NASCAR Grand National Stock Car Roll Cage

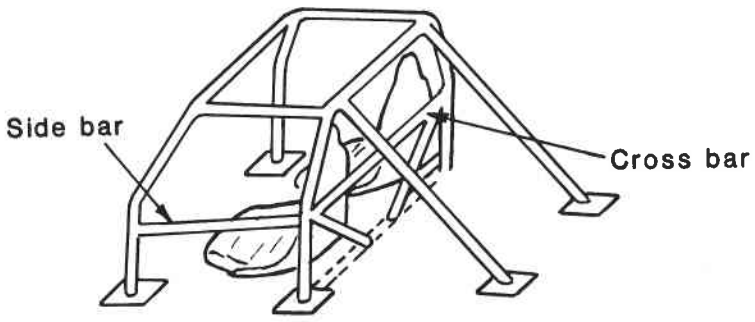

Figure 16a : 1986 NHRA Roll Cage

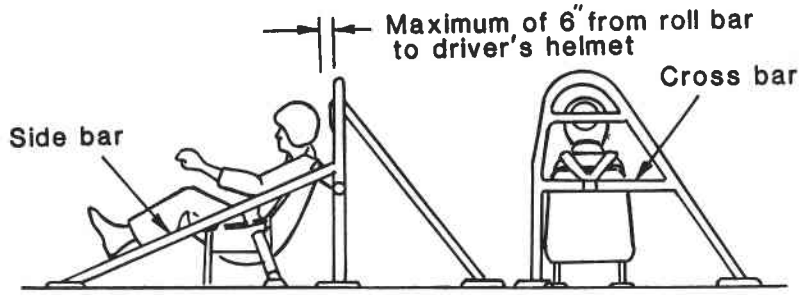

Figure 16b : 1986 NHRA Roll Bar

when two, three or four failures per year were recorded. "Injury is usually associated with roll bar failure because the occupant space is compromised."[55]

10. *National Hot Rod Association* - All drag racing vehicles governed by the competition rules of the National Hot Rod Association (NHRA)[58] are required to be equipped with roll bars or roll cages. There is no reference in the NHRA rule book relative to an operator protective volume. Unlike other forms of racing, however, the roll over protection systems are more likely to be customized to an individual driver's physical size.

    Roll bars must come within 152mm (6 inches) of the rear or side of the driver's head and extend at least 76mm (3 inches) above the driver's helmet. The width dimension limits range from the width of the driver's shoulders to within 25mm (1 inch) of the driver's door.

    A roll cage must extend at least 76mm (3 inches) in front of the driver's helmet.

    Both roll bars and cages are required to be padded anywhere the driver's head or body may make contact with it. A cross bar is required behind the driver's seat, no more than 102mm (4 inches) below the driver's shoulders, to serve as a seat bracing support and as the shoulder harness attachment point. A side bar is also required to the driver's left side and is positioned midway between the shoulder and elbow. Construction details are illustrated in Figures 16a and 16b.

DEVELOPMENT OF A NEW OPERATOR PROTECTIVE VOLUME

Exceptions to the aforementioned ROPS protective volumes and overhead guard deflection limits can be found in industries beyond construction and agriculture. Indeed, the history and evolution of operator protective volumes has shown a trend toward size reduction in order to accommodate the space available for operators on construction equipment in particular. Therefore, volumetric restrictions of the space available for an operator has comprised the rationale for deviating from the otherwise standard minimum "operator enclosure".

Even though our research has not revealed a specific exception to the use of a prescribed operator protective volume, examination of the evolution of protective volumes reveals that the size of the volume has decreased over the years.

In our opinion, additional design criteria and rationale for the development of a smaller operator protective volume should include:

1. In the event of a rollover, a space should remain such that a 99.5 percentile clothed operator would not be crushed or distorted in an unnatural way that would give rise to serious injuries. The operator should also be able to naturally move into that remaining space. This concept alone, however, does not address injuries due to impact from overturning.

2. Data from actual overturns must support the effectiveness of the protective volume selected.

3. The internal space defined by the simultaneous superposition of existing operator protective volumes can be utilized in defining a new protective volume for small agricultural tractors providing the performance criteria of each volume under consideration is satisfied. Note, however, that a common reference point first needs to be established before superposition of volumes can occur. Tractor seats of varying designs have different Seat Reference Points (SRP's), and the various protective volumes described in this report have differently defined seat locating points and seat reference points.

    There are many possible combinations of superimposed operator protective volumes. One such combination is illustrated in Figure 17. The superposition method alone does not validate the safety or effectiveness of the new volume, however.

4. The protective volume defined by the superposition method may be decreased if pure distortion without a volumetric change results and if the remaining volume is consistent with the criteria of (1) above. In other words, by allowing pure distortion without volumetric change, the re-

sulting superposition volume may be further decreased. By combining the criteria of (1) and (3) above, the smallest protective volume would result. However, the effectiveness of the resulting volume must be substantiated by ergonomic evaluation.

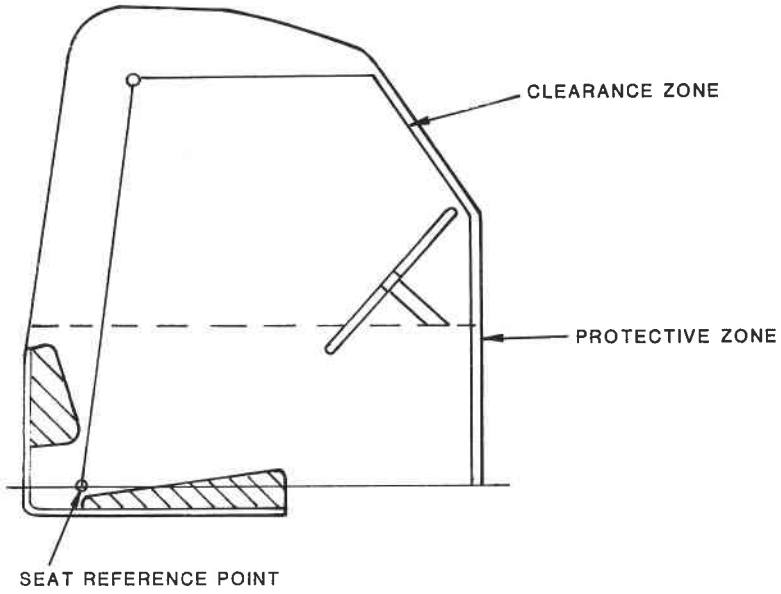

FIGURE 17: SUPERPOSITION OF CLEARANCE ZONE (FIG. 5) AND PROTECTIVE ZONE (FIG. 8a)

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3. "Minimum Performance Criteria for Roll-Over Protective Structure for Rubber - Tired, Self-Propelled Scrapers," *SAE J320a*. Report of the SAE Construction and Industrial Machinery Technical Committee, approved November 1967 and last revised July 1969; editorial change July 1970.
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15. "Performance Criteria for Rollover Protective Structures (ROPS) for Construction, Earthmoving, Forestry, and Mining Machines," *SAE J1040b*. Report of the SAE Construction and Industrial Machinery Technical Committee, approved April 1974 and last revised April 1977. (This document incorporates material formerly published as SAE J320, J394, J395, J396, and J1011). (The significant difference between this document and J1040a is in Section 6.2 and Fig. 7) Rationale Statement available.

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What Is a Defect?

The definition of a defective product in a state may be found in the case law of that state. In our Safety Briefs, we explore leading product liability case law for one or more states. Triodyne Inc. relies on the trial bar for selection of the cases cited.

Nebraska

In *Nerud v. Haybuster Manufacturing. Inc.*, 215 Neb. 604, 340 N.W. 2d 369 (1983), a buyer brought action against the seller and manufacturer of two hay stacking machines. The hay stackers were designed to be pulled behind a tractor to collect previously cut hay and then to compact the hay into five to six-ton stacks. While the operator was correctly using the machines, a conveyor shaft component overheated, causing the hay to ignite and both stackers were destroyed by fire.

The court begins by saying that in products liability litigation, there are two separate concepts with regard to a defective product. The first is labeled a *manufacturing defect.* This defect is one in which the product differs from the specifications and plan of the manufacturer. The second type of defect is characterized as a *design defect.* This is one in which the product meets the specifications of the manufacturer but the product nonetheless poses an unreasonable risk of danger. The court cited the Restatement Second of Torts dealing with design defect at Section 398. It states:

> "A manufacturer of a chattel made under a plan of design which makes it dangerous for the uses for which it is manufactured is subject to liability to others whom you should expect to use the chattel or to be endangered by its probable use for physical harm caused by his failure to exercise a reasonable care in the adoption of a safe plan or design." *Id.* at 374.

In Haybuster, the buyer sued the manufacturer under both negligence and strict liability series. The court stated that under the negligence theory, the questions of whether a design is defective refines itself into an inquiry aimed at determining whether the machines involved presented unreasonable risks of danger *and* whether Haybuster failed to exercise reasonable care in adopting its design. Under a strict liability theory, the buyer merely needs to show that the product poses an unreasonable risk of danger. There is no focus on the manufacture itself.

Proceeding under the strict liability theory, this case quotes the Restatement Second of Torts Section 402A. Its relevant part provides,

> "(1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or to his property . . ."

In addition the Supreme Court of Nebraska in *Hancock v. Paccar, Inc.*, 204 Neb. 468, 283 N.W.2d 25 (1979), adopted the definition of "unreasonably dangerous" to mean that,

> "the product has a propensity for causing physical harm beyond that which would be contemplated by the ordinary user or consumer who purchases it, with the ordinary knowledge common to the foreseeable class of users as to its characteristics." *Id.* at 375.

The court in *Haybuster* goes on to say they have not had the opportunity to define the term "defective condition." Here they reach the conclusion that a review of the cases in various jurisdictions has led them to the conclusion that a plaintiff "in order to prove that a particular product is defective in its design, must show that there was some practical way in which the product could have been made safer." This requirement has since been overruled. *Id.* at 375.

Absent this showing, a recovery under strict liability cannot be successful. In this particular case, the court found that *Nerud* failed to show that the hay stackers were defective and could not recover under **strict** liability theory.

Rahmig v. Mosley Machinery Company, Inc., 226 Neb. 423, 412 N.W.2d 56 (1987).

The Rahmig case discusses the user-contemplation test in determining a manufacturer's strict liability in tort. Rahmig involved an action brought by a worker for personal injury against the manufacturer of a guillotine scrap metal shear for damages caused while he was cleaning the shear. The shear can crush two metal car frames simultaneously, as well as large automotive components. When the chute filled up with scrap metal, Rahmig let the motor run, got out of the control tower and started taking the sheared metal out of the chute, manually removing most of it while working close to the machine. Without any warning, the upper blade suddenly descended and amputated three of Rahmig's fingers.

This case discusses the user contemplation test which was adopted in *Kohler v. Ford Motor Company*, 187 Neb. 428, 191 N.W. 2d 601 (1971). The user contemplation test is adopted from the Restatement Second of Tort at Section 402A and states that in order for a plaintiff to recover against a defendant based on a strict liability in tort, he must prove by a preponderance of the evidence that:

> "1. The defendant placed the product in question on the market for use, and the defendant knew, or in the exercise of reasonable care should have known, that the product would be used without inspection for defects . . .;
> 2. The product was in a defective condition at the time it was placed on the market and left the defendant's possession;
> 3. The plaintiff was unaware of the claimed defect;
> 4. The claimed defect was the proximate cause or a proximately contributing cause of any injury to the plaintiff occurring while the product was being used in the way and for the general purpose for which it was designed and intended;
> 5. The defect, if it existed, made the product unreasonably dangerous and unsafe for its intended use;
> 6. The plaintiff sustained damages as the direct and proximate result of the claimed defect . . ." (Citation Omitted) *Id.* at 68.

Perhaps the most important part of the *Rahmig* case is that they overruled that part of *Haybuster* that had required the worker to prove that there was some practical way in which the product could have been made safer. Here the worker was not required to prove that there was some practical way in which the product could have been made safer. This court says that it requires a plaintiff to prove the feasibility or practical alternative but safer product in a negligent design case would invite unfair prejudicial evidence of post accident matters which are excludable under Nebraska Rules of

Evidence 407. They go on to say that the reason and policy of Rule 407 would be frustrated, if not totally annihilated; therefore, to that extent the court overruled that section of *Haybuster* insofar as feasibility or reasonably alternative design must be proved by the plaintiff to prevail in a cause of action for negligence design in a products liability case.

Cases selected and text written by Melinda G. Hess of the College of St. Mary and the Melinda G. Hess Law Office, 1901 S. 72nd St., Omaha, NB 68124 (402) 399-2418.

New Mexico

New Mexico has adopted Restatement (Second) of Torts, § 402A. providing for the strict liability of manufacturers for the harm caused by unreasonably dangerous products. *Stang v. Hertz*, 83 N.M. 730,497 P.2d 732 (1972). The New Mexico appellate courts have placed heavy reliance upon the Comments to § 402A, as well.

The elements required to establish a claim under § 402A are as follows:

1. the product was defective;
2. the product was defective when it left the hands of defendant;
3. the product was substantially unchanged when it reached the user or consumer;
4. because of the defect the product was unreasonably dangerous to the user or consumer;
5. the consumer was injured or was damaged;
6. the defective condition of the product was the proximate cause of the injury or damage.

See *Tenney v. Seven-Up Co.*, 92 N.M. 158,159,584 P.2d 205,206 (Ct. App. 1978). The duties imposed by strict liability make the manufacturers liable to a broad range of individuals, including users of the product, lessees, and bystanders. S.C.R.A. 1986 U.J.I. Civ. 13-1402. The defenses to product liability in New Mexico include independent intervening cause (which must not have been reasonably foreseeable), unforeseeable alteration or misuse, obviousness of the danger, and negligence of the plaintiff or some third parties. New Mexico has adopted pure comparative negligence, and allows comparison of both negligent and strict liability causes for apportionment of liability. *Marchese v. Warner Communications. Inc.*, 100 N.M. 313,670 P.2d 113 (Ct. App. 1983).

A "defect" may arise from design, manufacturing, or packaging flaws, or from the warnings or directions which accompany the product. A manufacturer will be liable for harm caused by a product that Is unreasonably dangerous due to its condition or manner in which it is used, if that use is reasonably foreseeable. S.C.R.A. 1986 U.J.I. Civ. 13-1402, -1403, -1406. if a product is unreasonably dangerous, it is necessarily defective. An unreasonable risk of injury is a risk which a reasonably prudent person having no knowledge of the risk would find unacceptable. S.C.R.A. 1986 U.J.I. Civ. 13-1407. The concept of "defective condition unreasonably dangerous" is further explained in § 402A comments g and i. The reasonableness of the acts or omissions of the plaintiff is not considered in determining whether a product is "defective." *Rudisaile v. Hawk Aviation, Inc.*, 92 N.M. 575, 577, 592 P.2d 175, 177 (1979).

Given the fact that the concept of "defect" is determined by whether a product is "unreasonably dangerous," "defect" is an elastic term, and ultimately it is left up to the jury to apply the term to the cases and products before them. Although the law of New Mexico gives a manufacturer little guidance on what constitutes a "defect," it allows a manufacturer to introduce a wide range of evidence in opposition to the argument that its product is "defective." The matters which can be introduced Into evidence concerning a "defect" includes industry custom, standards promulgated by either the government or trade associations, products of competitors, and the state of the art.

The doctrine of strict liability does not make the manufacturer an absolute insurer. *Tenney v. Seven-Up Co.*, 92 N.M. 158,584 P.2d 205 (Ct. App.), *cert. denied*, 92 N.M. 180,585 P.2d 324 (1978). In this case, Mrs. Tenney purchased some bottles of 7-Up, took them home and refrigerated them. Two days later, Mrs. Tenney opened a bottle and poured a portion for herself and her four-month old son. While feeding the baby, she noticed what appeared to be worms in the bottom of the bottle. Upon analysis of the bottle contents, it was found that it was not worms in the bottle, but "blood vessels of unknown origin," which were found to be harmless. She failed to prove the product was unreasonably dangerous, notwithstanding her reaction of stomach cramps and anxiety over her child's drinking 7-Up from the bottle containing the blood vessels.

When the product is not dangerous to the extent beyond what would be contemplated by the ordinary consumer who purchases it, with the ordinary knowledge common to the community as to its characteristics, there is no strict liability. *Standhardt v. Flintkote Co.*, 84 N.M. 796,508 P.2d 1283 (1973). While foreseeability of the danger is ordinarily a question for the jury, it may be decided as a matter of law where the use to which the product was put was so unintended and unforeseeable that the case should be taken from the jury. The concept of strict products liability does not mean the product must be accident proof, or that the supplier will be responsible for every harm caused thereby. For example, in *Van de Valde v. Volvo of America Corp.*, 106 N.M 457,744 P.2d 930 (Ct. App. 1987), the courts dismissed the claim of person who was injured when he attempted to use a spare tire tie-down strap to secure objects on his automobile's roof luggage rack. The Court of Appeals held that such use was not to be reasonably expected by the manufacturer.

The care to be exercised by manufacturers in New Mexico is best illustrated by *First National Bank of Albuquerque v. Nor-Am Agricultural Products. Inc.*, 88 N.M. 74,537 P.2d 882 (Ct. App. 1975). In that case, the defendant manufacturer, Morton International, produced a mercury seed disinfectant which it sold to a local mill. The local mill applied the disinfectant to its grain and allowed thc waste-treated grain to collect in the mill. A mill employee gave the waste-treated grain to a patron, who fed the grain to his hog. When his family ate the hog, his four childrens' nervous systems were seriously and permanently injured by mercury poisoning. An action was brought against Morton and the mill under § 402A for failure to warn.

The court ruled that where a manufacturer has reason to anticipate danger from a particular use of his product, an adequate warning may have to be given to avoid strict liability under § 402A. Morton admitted that the misuse was foreseeable, that it knew about the chain-poisoning effect, and that it had a duty to warn about the foreseeable misuse. Morton had marked the seed disinfectant with warnings that it was poisonous, possibly fatal, and should not be in-

haled, swallowed, breathed, or absorbed through the skin. The user was instructed, "Handle carefully." Under the heading "ANTIDOTE," users were instructed to immediately induce vomiting if the disinfectant were ingested. The warnings were partially printed in red, using different sized fonts and capitals. The warnings were on the package sent to Golden West, but was not given to the patron.

Morton contended that, given its warning, it had a right to rely on the local mill to use ordinary care to prevent the misuse of treated grain. The Court of Appeals disagreed because, while the mill employees knew that the disinfectant was "poison," they did not know of the chain-poisoning effect, the potential seriousness of the injuries, the lack of antidote for long-term poisoning or the extreme potency of the disinfectant.

Morton argued that its warning was adequate. The Court of Appeals held that a warning must designate specifically all of the dangers that may cause serious injury, and the extent or seriousness of the potential harm. A general warning that the product is dangerous, or a simple directive ("Do not use . . .") is insufficient. Implicit in the duty to warn is the duty to warn with a degree of intensity that would cause a reasonable man to exercise for his own safety the caution commensurate with the potential danger. A product sold without such a warning is in a "defective condition unreasonably dangerous."

Plaintiffs argued that (1) "may be fatal" was insufficient, (2) "toxic" was too vague, (3) the antidote statement indicated that a simple antidote could counteract the poison, and (4) there was no warning that small quantities of treated grain could be lethal. There were also allegations that the physical aspects of the warning–conspicuousness, prominence, relative size of print–were inadequate to alert the reasonably prudent person. Because adequacy of a warning is a question of fact for the jury, the Court of Appeals held that the plaintiffs' allegations were sufficient to require a jury trial, and so it reversed the summary judgment that had been granted by the district court, and remanded the case for trial. The defendant settled the case without trial.

A brief look at the New Mexico appellate opinions reveals a wide range of actions in which defendants have been held liable under § 402A:

1. Failure to give accurate and updated information to physicians concerning potential side effects of a medicine or potential failure of a prosthesis;
2. Design of an automobile;
3. Blowout of a tire;
4. Airplane leased to decedent/plaintiff without oil in engines;
5. Explosion of a compressor tank;
6. Failure of a volleyball standard, which severely injured plaintiff's foot; and
7. Defective design of a combine, so that a worker was injured while clearing out a spot where the harvest was "bunched up."

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