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Evaluation of the safety volume to protect the driver during rollover of small agricultural vehicles

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Fifties:
the ROPS solution for the tractors

Since 1930 tractors have been considered at risk of rollover. Moberg in Sweden proposed to protect the driver introducing a ROPS on the tractor so as to provide a survival volume for the operator during the rollover accident.

ROPS were not expected to prevent all deaths but they were conceived to minimise the rollover effects in the normal operation of the vehicle.

Rolling Over Protective Structures

ROPS

Directive 2006/42/EC

Self-propelled machinery with a ride-on driver

Current days

The manufacturer has to minimise the rollover risks fitting a ROPS which has to provide and guarantee a survival volume for the operator during the overturning.

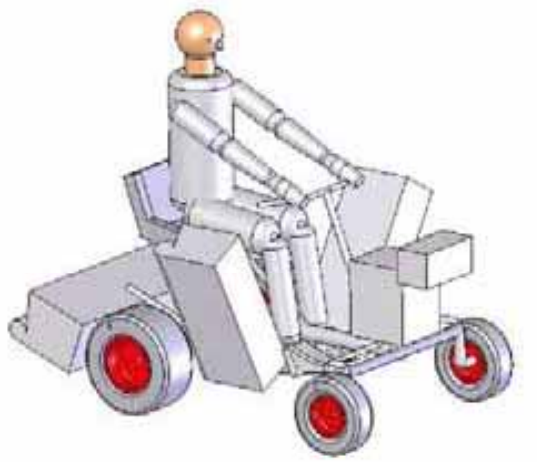
When the manufacturer provides a ROPS on the machine evidence of the ROPS strength performance has to be given.

Lack of dedicated ROPS procedures for agricultural machines

- Performing appropriate tests
- Using a computer simulation modelling

The first approach is the best consolidated but it has a crucial issue: the lack of dedicated standardised procedures for the specific types of agricultural machinery.

Small vehicles



Small machines are normally widespread in narrow areas where a standard tractor is not allowed to work due to its dimension.

These machines, as the majority of the vehicles, are recognised as potentially subject to a risk of rollover during normal operation.

The fitment of a ROPS is considered as the main approach for the operator protection.

Small vehicles

The manufacturers for designing suitable ROPS do not have ROPS performance criteria to use as reference.

An acceptable approach seems to evaluate if standards from other field of application could be adopted as basis criteria.

Two aspects:

- **survival volume**
- **strength tests**

Objective of the study

To identify a suitable survival volume for small multi-task agricultural vehicles on the basis of the main volumes consolidated in the existing ROPS standards.

This subject had a great interest because it appeared extremely difficult in small vehicles to guarantee the already defined safety volumes due to their dimensions, mass and features.

Small vehicles tested

Compact dumper with a loading platform

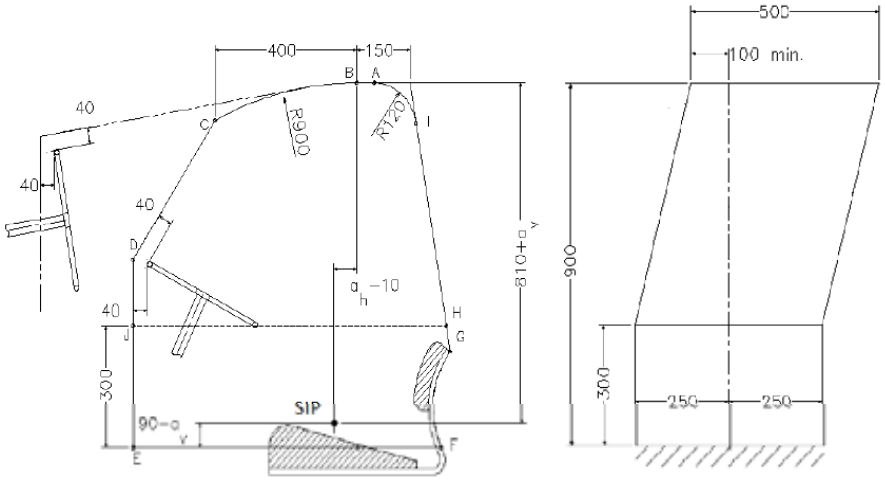
Multi-task vehicle

Driver seated in a cantilever position

Machine 1	Machine 2
-Gasoline Engine: Bicylindrical. Power 15 kW -Overall dimensions: 1660 x 700 x 1070 mm - Unladen mass: 560 kg - Loaded mass: 600 kg	-Diesel Engine 4 cylinders. Power 28 kW -Overall dimensions: 1800 x 740 x 1550 mm - Unladen mass: 880 kg -Loaded mass: 800 kg Reversible drive seat with automatic reverse

Survival volumes

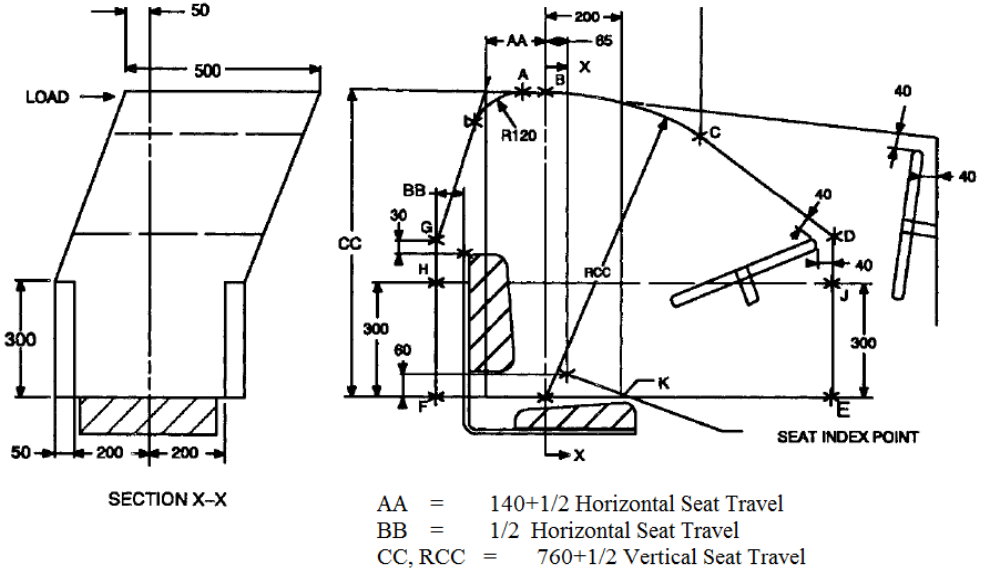
Clearance zone defined in the OECD ROPS Codes for wheeled tractors



a_h - Half of the horizontal seat adjustment
a_v - Half of the vertical seat adjustment

Survival volumes

Clearance zone defined in the ANSI/ASAE S478 standard for compact utility tractors

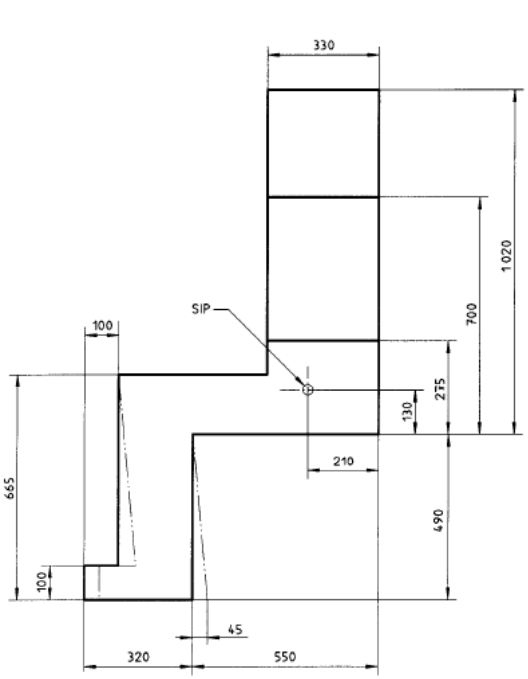


AA = 140+1/2 Horizontal Seat Travel
BB = 1/2 Horizontal Seat Travel
CC, RCC = 760+1/2 Vertical Seat Travel

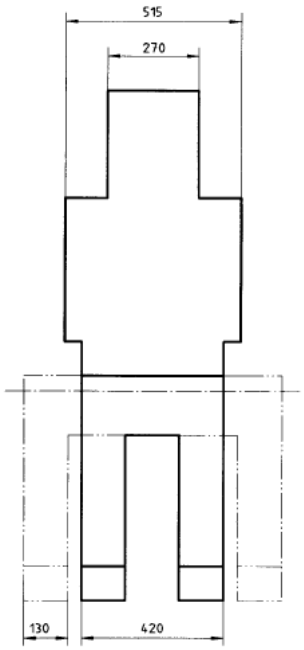
Height and width reduced in respect to the previous zone probably for the different dimension and mass of the compact tractors

Survival volumes

Deflection Limiting Volume DLV defined in the ROPS standard ISO 3164:1995 (Earth moving machinery)



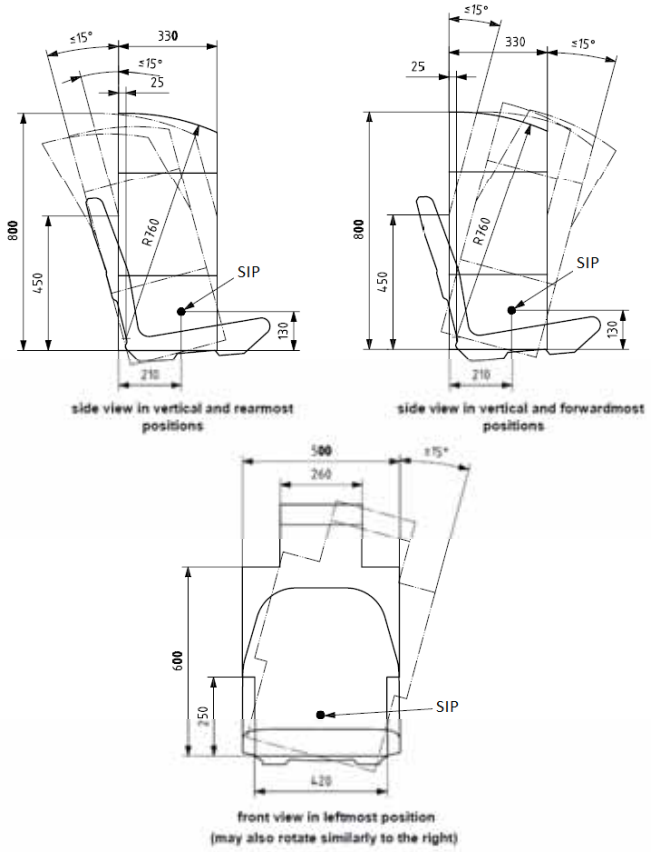
side view



front view

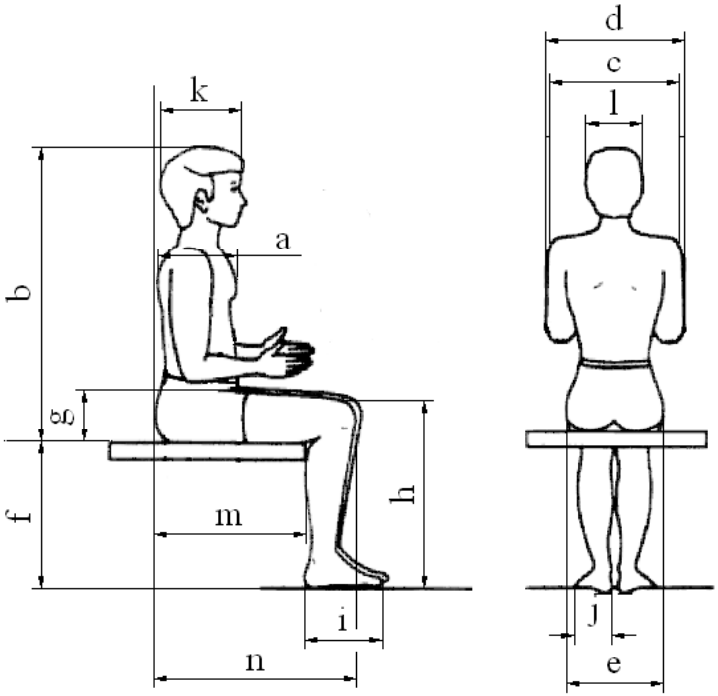
Survival volumes

Deflection Limiting Volume DLV defined in the ROPS standard ISO 21299:2009 (Powered ride-on turf care equipment)



Main anthropometric measurement of a male human body

The measures were defined to design ergonomic work place ISO 7250:2008

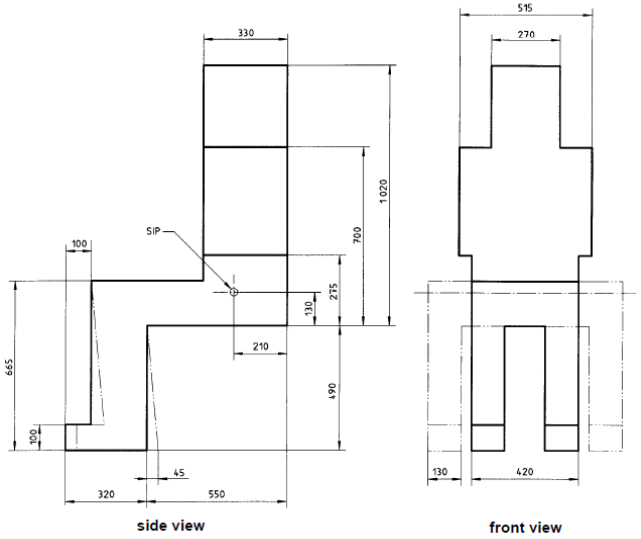


Ref.	Description	Italy		German		Max
		P50	P95	P50	P95	
	Body mass (weight), kg	75	93	79	100	100
	Stature (body eight)	1714	1834	1750	1855	1855
a	Chest depth, standing	214	255	-	-	255
b	**Sitting height (erect)**	882	946	910	965	965
c	Shoulder (bideltoid) breadth	459	500	480	525	525
d	Elbow-to-elbow breadth	499	571	480	555	571
e	Hip breadth, sitting	343	397	375	420	420
f	Lower leg lenght (popliteal height)	460	511	450	490	511
g	Thigh clearance	138	160	150	180	180
h	Knee height	530	582	535	585	585
i	Foot length	261	282	265	285	285
j	Foot breadth	99	110	101	111	111
k	Head length	191	203	195	205	205
l	Head breadth	153	164	155	165	165
m	Buttock-popliteal length (seat depth)	480	529	495	540	540
n	Buttock-knee length	-	-	610	655	655

All measurements are in mm unless specified otherwise

DLV

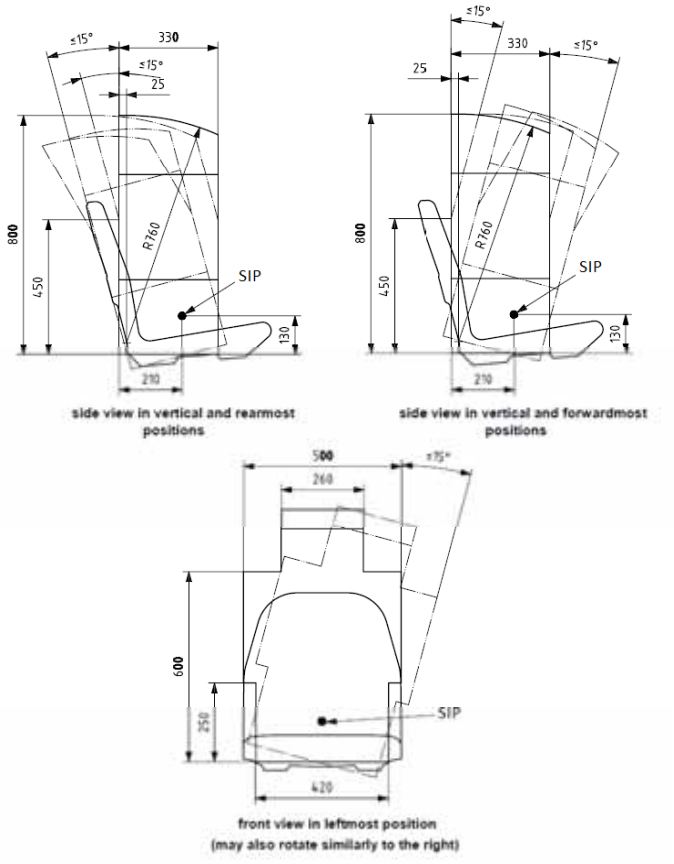
Earth moving machinery



The wide dimension of the DLV consolidated in the international ROPS procedures for tracklying tractors and earth moving machinery, appeared not achievable in the two small machines because of their masses and sizes. Moreover to fit on the small machines a ROPS allowing such DLV would potentially affect the position of the centre of gravity and the stability increasing the risk of rollover.

DLV

Powered ride-on turf care equipment

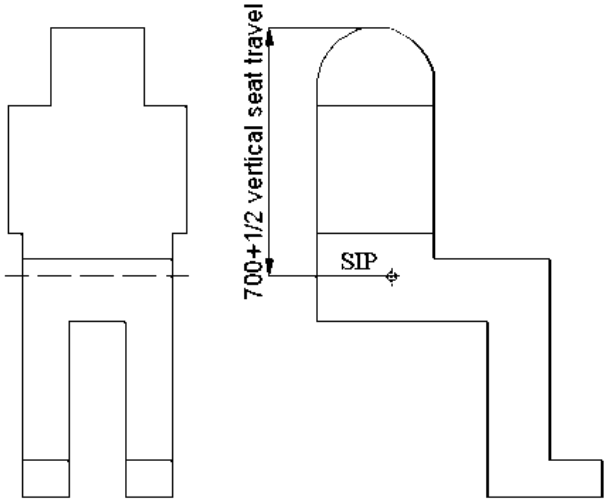


The DLV showed dimensions more suited to the small vehicles, but it was considered not acceptable to protect the driver in the specific driving position on the tested vehicles.

The height of this survival volume, appears not corresponding to the averaged dimension of a human body seated and it does not provide protection to the legs of the operator.

The safeguard of the legs was deemed a compulsory requirement due to the specific position of the operator on the cantilever seat in both machines.

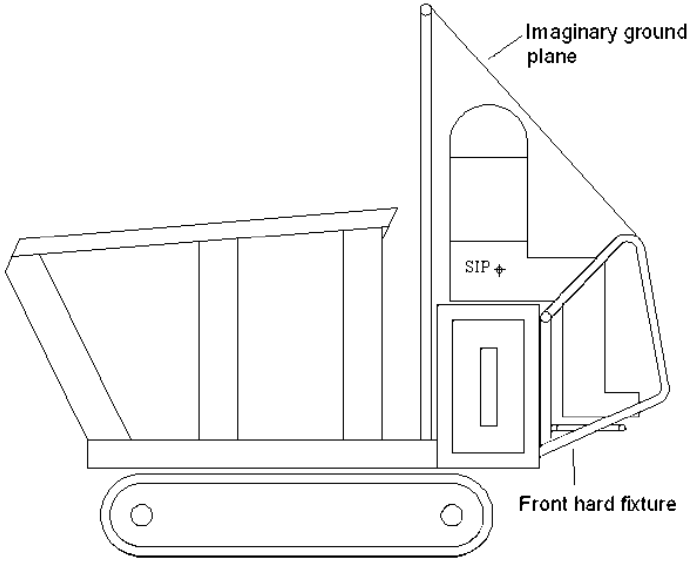
Results



The new volume was conceived as derived from the DLV adapted by the main dimensions of a male seated human body so as to match the characteristics of the small vehicles.

The height of the clearance zone defined for the compact utility tractors corresponding to 700 mm plus half vertical seat travel from the SIP was verified to be approximately in line with the dimension reported in the anthropometric measurement of a human body of 75 kg mass and was used as reference for the new volume.

Results



In the specific case of the two vehicles, in order to provide protection to the legs of the seated operator, a hard fixture had to be added in the design of the machine, as well represented by the simulated ground plane to show the position of the volume in respect to the ground in the event of a rollover.

Conclusions

The ad-hoc volume hypothesized was a compromise between the operator protection and the maintenance of the normal operation of the machines.

To define an ad-hoc protected area could give a valuable contribute to the operator protection enhancing the fitment of a ROPS to significantly reduce the risk of injury.

Moreover to limit the rollover to only a tip-over could be a valuable additional approach.

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