OECD Standard Codes for the Official Testing of Agriculture and Forestry Tractors

SUB-WORKING GROUP (SWG) ON FOLDABLE ROPS

OECD Headquarters, Paris, France
29-30 May 2013

This document was prepared by France (Convenor), Italy (Bologna), Italy (Milan), Italy (Torino), Turkey, Germany and the OECD Coordinating Centre and was discussed at the Technical Working Group Meeting held on 29-30 May, Paris, France.

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<th>Country/Institution</th>
</tr>
</thead>
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</tbody>
</table>

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1 ROLLOVER PROTECTIVE STRUCTURES

1.1 Definition

There are four types of rollover protective structures: cab, frame, fixed or foldable rear roll-bar, fixed or foldable front roll-bar.

These four types of protective structure are designed to meet the same objective: to protect the driver in case of a rollover. OECD codes for testing of protective structures give the following definition:

*Roll-over protective structure (safety cab or frame), means the structure on a tractor the essential purpose of which is to avoid or limit risks to the driver resulting from roll-over of the tractor during normal use.*

*The roll-over protective structure is characterized by the provision of space for a clearance zone large enough to protect the driver when seated either inside the envelope of the structure or within a space bounded by a series of straight lines from the outer edges of the structure to any part of the tractor that might come into contact with flat ground and that is capable of supporting the tractor in that position if the tractor overturns.*

In the case of a tractor with a protective structure of the front or rear roll-bar type, the outer edges of the roll-bar delimit the space required to protect of the clearance zone of the driver.

![Figure 1: Clearance zone – Tractor with a front roll-bar](image)
One of the barriers to increase installation of ROPS has been the complaint that ROPS interfere with using tractors in low clearance situations, such as low buildings, orchards or greenhouses. The manufacturers of tractors and ROPS have responded to this concern by manufacturing fold-down type ROPS.

A foldable ROPS gives additional clearance when needed and when low clearance is not required it must be in the upright and locked position.

1.2 Special case of foldable ROPS

1.2.1 Tractors concerned

According to the types of tractors introduced by the European Directive on type-approval of agricultural tractors (Directive 2003/37/EC), tractors of types T1 (standard tractors) and of type T2 (narrow tractors) can be equipped with foldable Roll-bar.

<table>
<thead>
<tr>
<th>Rear roll-bar</th>
<th>Front roll-bar¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2²</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Types of tractors

These tractors have significant differences in terms of performance, design and use. It could be necessary to take this diversity into account in the risk analysis and requirements to be defined.

¹ Unladen mass less than 3000 kg
² Track width of not more than 1 150 mm.
1.2.2 How they are addressed in the regulation

1.2.2.1 Type-approval of agricultural or forestry tractors

For standard tractors, during the ROPS test a second longitudinal load test is required in some conditions.

3.4.5 Second longitudinal loading
3.4.5.1 A second longitudinal loading shall be applied to tractors fitted with a folding (e.g. two posts) or tiltable (e.g. non-two posts) protective structure, if one or more of the following conditions exists:

- Temporary folding for special operating conditions;
- Structures designed to tilt for service, unless the tilt mechanism is independent from the structural integrity of the roll-over protective structure.

3.4.5.2 For folding protective structures, if the first longitudinal loading was applied in the folding direction then a second longitudinal loading is not required.

The aim of this second longitudinal loading is to verify the strength the locking system of the foldable ROPS. Remark: for narrow track tractors in any case two longitudinal loadings (front and rear) shall be carried out.

Except this there is nothing else dealing with the safety of foldable ROPS in the current regulation (directive 2003/37).

The reliability of the locking system or even the basic safety rules such as the use of captive pins, or minimum warnings labels on the roll-bar are not at all taken into account.

Typically, manufacturers provide a minimum of information in the operator manual and affix a warning symbol on the roll-bar.

<table>
<thead>
<tr>
<th>.....</th>
<th>This tractor is equipped with a foldable Roll-Over Protective Structure (ROPS). The ROPS should be kept in the “up” or extended position with lynch pins and locking pins, except when it is necessary to fold it for low clearance operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>.....</td>
<td>Abstract of an operator manual.</td>
</tr>
</tbody>
</table>

Conclusion:

Easiness of use: Nothing
Durability of locking system: Nothing
Ergonomics: Nothing

We just know that the roll-bar properly locked and with the original locking mechanism in a good repair, protects the driver in case of rollover.

1.2.2.2 Tractors in use

Employers have obligations to protect the health and safety of workers.
For example in the French employment code the use of tractors with foldable ROPS is tackle as follows:

........
the lowering of the protective structure should only be used for operations that require it and then measures must be taken to prevent the risk of rollover of the tractor, such as restriction of use, speed or fitting-out of work areas.
........

The first requirement relates to the lowering of the protective structure that should be used only for the operations required it.

The second one is about measures that must be taken to reduce the probability of a rollover when the roll bar is lowered. These measures deal essentially with work organization and fitting-out of work areas, but could be also technical solutions for tractors such as automatic speed limit when the roll bar is lowered.

1.2.3 Use of tractors with foldable ROPS

Tractors with foldable ROPS are very common in certain types of farms, a survey of 60 farmers in the south-east of France shows that there are even more than 40% of the total tractors.

They are currently necessary in situations when the roll-bar is its upright position will not allow free movement of the tractor.

This is the case for example in orchards application without damaging crops.

Figure 3 : orchards application

These tractors are also used in greenhouses or in mixed farming operations type to access the inside of old farm buildings.
In 2002, an enquiry was done by Irstea among 57 buyers of standards tractors (45-70 kW) with foldable rear roll-bar.

These tractors were primarily used by individual farmers on mixed farming farm type. The foldable ROPS was in 70% of cases the main criterion of choice.

More than 80% of the buyers need to access to old buildings, relatively low (old stables, barns, tunnels ...) and use the tractor in orchards.

Users were perfectly aware of the risks and, for some, spontaneously mentioned the three main risks.

- Rollover with the roll-bar not in place,
- Failure or incorrect installation of the locking system,
- Injuries when handling the roll-bar.

Despite the user regulation and warnings or labels on the tractors, due to the difficulty of the operation or neglect, when low clearance is not required the ROPS is not always in the upright and locked position.

In 2004 an enquiry was done by French agricultural social insurance among 57 farm managers and 57 dealers located in orchard, vineyard and vegetable-growing farms areas.

Results of this enquiry showed that 2/3 of the tractors are narrow tractors and 1/2 of the ROPS on narrow tractors are foldable.

Foldable ROPS were appreciated (57%) in that it allows working in low clearance situation (greenhouses, orchards, in the nearby foliage and trees), the other advantage is its versatility. On the other
hand 30% considered that its implementation is difficult because of its weight, its lack of maneuverability, the locking system quite impractical ... This explains why 36% of respondents said that the main disadvantage of this type of ROPS is to be very often folded and no longer fulfill a protection in the event of a rollover.

To the question "When the roll-bar was folded down position, why the drivers do not erect it (reasons other than the negligence or lack of time), "users responded with synonymous of negligence at 27% (forgetting, lazy ...) and also 27% for reasons of painfulness to erect the roll-bar; this painfulness is related to the design of the roll-bar: his weight, the system locking system.

Another technical reason given with 17% of the responses is that the roll-bar must be lowered to work in orchards and that the time spent on the road is negligible. The last reason is that they feel that the risk of rollover is low or does not exist on their farms.

Although neglect and poor understanding of risk are also certainly to take into account the difficulty of the operation and the loss of time are real.

In addition, this can itself generate other risks. This is the case for standard tractors the upper part of the roll-bar which is relatively heavy and must be operated from the seat in a very uncomfortable position. There is therefore a risk of pinching, binding and shear but also higher risk of muscle injury or back pain.

The theoretical weight of a sample of rear and front roll-bars was calculated together with the theoretical maximum torque needed to put them in the up-right position.

Results are presented in the Annex.

An experiment on one tractor showed that, due to friction, misalignment of axis, etc the real torque was 35 higher than the theoretical one.
1.2.4  Locking system

Users mentioned the risks of failure or incorrect installation of the locking system and also the fact that sometimes the locking system is quite impractical.

The correct fitting of pins needs sometime the use of a hammer.

This fact is the main raison for users to claim about foldable ROPS on some forum.

The bad design of the locking system gives rise to "home made" modifications to allow easy use of the foldable ROPS.

Example of home made modifications on a front foldable roll-bar in order to "facilitate" the handling and the locking :
- cutting of the top part of the mounting.
- changing pins by smaller ones

1.2.5  Accidents

A folded down roll-Bar increases dramatically the severity of the risk in case of overturning.
An analysis of a list of fatal overturns in France and Spain with narrow tractors and foldable two-post frame not in upright position showed that roughly half of the fatal overturns occurs on the way to the field (far from a low clearance situation).

Abstracts of these lists of accident have been presented during the 2009 Test Engineers’ Conference in Korea (see room document TEC15/7).

The US FACE program (Fatality Assessment and Control Evaluation) of the National Institute for Occupational Safety and Health (NIOSH), conducts in-depth studies of two rollover fatal accidents with ROPS folded down.

<table>
<thead>
<tr>
<th>FACE Program</th>
<th>Case No.</th>
<th>Report Date</th>
<th>SUBJECT:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa</td>
<td>3IA72</td>
<td>17 June 2005</td>
<td>Overturn of a Tractor with ROPS Folded Down Kills Operator</td>
</tr>
<tr>
<td>Washington</td>
<td>10WA07201</td>
<td>April 2, 2012</td>
<td>Orchard Tractor Operator Dies When Tractor Rolls Over</td>
</tr>
</tbody>
</table>

A simple search on the net with few keywords in some European languages reveals too many cases of fatal rollovers. And for many of them the photos show obviously that low clearance was not needed.
2 SOLUTIONS ALREADY IMPLEMENTED BY MANUFACTURERS

2.1 Solutions that apply on the driver (Prevention, education, training, information…)

Employers, advisors, social insurances and public authorities are aware for a long time of dangers of the use of foldable roll-bars. And campaigns to inform or to train drivers are regularly implemented.

Other ways than labels to warn the driver directly on tractor during his daily work could be foreseen. One of the recommendations issued from the FACE program (Case n° 3IA72) would be perfectly complementary to the implementation of mechanical solutions on the roll-bar in order to facilitate its handling.

**Recommendation #4 Tractor and ROPS manufacturers should consider means which alert operators who are initiating operations with a tractor with ROPS folded or telescoped down.**

**Discussion:** Cars have visual and audible signals reminding the driver and the passengers if front seat occupants are not wearing their seatbelts. These warnings offer an instant reminder to buckle up, and likely contribute to higher seatbelt usage rates. A similar warning signal for the fold-down ROPS could indicate that the ROPS should be returned to the upright position before operating the tractor.

As fold-down ROPS become more common, there is a danger that many will be operated with the ROPS down, making overturn protection ineffective. All efforts should be made to ensure that operators realize the danger from using the tractor with the ROPS down.

2.2 Solutions that apply on the tractor and promote the replacement of the foldable roll-bar by something else (Compact ROPS, anchor mechanism…)

Among solutions that are devised to replace foldable ROPS must be mentioned CROPS (Compact ROPS) and Anchor Mechanism.

The research on Anchor Mechanism driven by Hassan Silleli from the Faculty of Agriculture of the Ankara University (Turkey) aims to design and develop an automatically deployable anchor mechanism to prevent continuous rolling in case of an overturn. The design will allow reduction of the ROPS height and increase the clearance zone.

The CROPS (Compact ROPS) promoted by the INAIL (Italy) is a non foldable ROPS for narrow-track wheeled tractors which provides rollover protection all the time and is able to eliminate the risks related to foreseeable misuse of the traditional foldable ROPS.

2.3 Solutions that apply on the foldable roll-bar it-self (deployment of the roll-bar with more or less assistance, more or less speed)

This is performances and requirements related to this third kind of solutions that are addressed in this document. According type of solutions that could be implemented and risks for the user these solutions could be classified in three levels.
2.3.1 Level one: Voluntary deployment of the roll-bar by the operator with or without the assistance of energy (hydraulic, electric…).

The operator decides when he wants to erect or fold down the roll bar. Numerous solutions belong to this level and have various features.

- Purely mechanical solutions handles, springs, ...
- Solutions using hydraulic or electric power,
- Automatic locking system or not,
- Implemented from the driven position or not.

2.3.2 Level two: Automatic deployment of the roll-bar in situations of potentially significant risk of overturning (important slope for example). The deployment is done gently.

The system decides when the roll-bar shall be erect on the base information issued from sensor(s) that identify a risky situation. The deployment is done gently, smoothly allowing time to the operator to make decisions (stopping the tractor, reducing the speed, fastening of the seat belt...)

2.3.3 Level three: Automatic deployment of the roll-bar in case of rollover (high speed deployment).

The system decides when the roll-bar shall be erect on the base information issued from sensor(s) that identify the beginning of a rollover. The deployment is done at very high speed.

3 REQUIREMENTS

3.1 Hypothesis

The current test methods (OECD codes or directives) allow checking of performances of a foldable roll-bar properly locked in the upright position without any need of updating.

According to first exchanges during EEC meeting the regulation will not focus on solutions but will set requirements en terms of safety and ergonomics. This will be up to manufacturers to choose the best solution to fit requirements.

Firstly all the risks and corresponding requirements will be addressed. In a second step those that can lead to tests or checking to be included in the codes will be identified and developed.

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3 This is a working document on potential technical safety requirements for foldable ROPS. OECD does not recommend the use of any particular mechanism to deploy a foldable ROPS, but rather focus on the minimum safety requirements that any foldable ROPS should satisfy in order to obtain an OECD approval number. Given that some risks and technical safety requirements cannot be fully checked during the ROPS testing, the technical requirements included in this document should be considered as initial proposals made by the experts of the Sub-Working Group on Foldable ROPS.
3.2 Risks versus requirements

3.2.1 Durability of automatic locking system:

Object: Mechanical locking systems that lock the roll-bar in its upright position without any action of the operator (roll-bar raised manually or with the help of energy)

References: no references identified

Proposals:

a. Carry out the ROPS test after a number of cycles of locking and unlocking.
b. Indicator to inform about the operator about any dysfunction.

3.2.2 Easiness of use of manual locking system

Object: Usability and easiness of use of manual locking/unlocking systems

References: ISO 15077 - Tractors and self-propelled machinery for agriculture — Operator controls — Actuating forces, displacement, location and method of operation

Proposals:

a. Set requirements in terms of maximums forces and shapes of pins
b. Use of captive pins

3.2.3 Safety during manual handling of the roll-bar

Object: Requirements to insure that the foldable roll-bar could be handling from a safe place, with an appropriate force and without risks for hands.

References: ISO 4254-1 and directive 2009/144/EC annex 2

Proposals:

a. Make reference to ISO 4254-1 paragraph 4.9 front roll-bar and also to paragraph 4.8 for rear roll-bar in order to address those who cannot be handled from the ground.
b. Update directive 2009/144/EC annex 2 to address explicitly risks of pinching or sharing hands during manual handling of foldable ROPS

3.2.4 Use of energy to assist the rising of the roll-bar

Existing potential relevant test methods or requirements that could be used with or without updating.
Object: The energy that is use to assist (fully or not) the raising of the roll-bar shall not create additional risks.

Reference: Directive 2009/144/EC annex 2

Proposal: Make reference to requirements already set in directive 2009/144/EC for the use of hydraulic

3.2.5 Use of controls to raise the roll-bar

Object: Installation, operation and identification of any controls used for operating foldable ROPS.

Reference: Directive 86/415/EEC

Proposals:

a. Update directive 86/415/EEC to address explicitly controls for foldable ROPS.

3.2.6 Performance of self-deployable ROPS

Object: Performance requirements of any automatically deployable protective structure (design and testing requirements).

References: ASAE ANSI/ASABE S599 - Standardized Deployment Performance of an Automatic Deployable ROPS for Agricultural and Turf & Landscape Equipment

Proposals:

a. Analyze this standard dedicated to the AutoRops system and if relevant make reference

3.2.7 Functional safety of self-deployable ROPS

Object: Requirements for documentation, fault strategy and verification with respect to the safety aspects of electronic systems.

References: Regulation n° 13 annex 18 (Special requirements to be applied to the safety aspects of complex electronic vehicle control systems) and regulation n° 79 annex 6 (Special requirements to be applied to the safety aspects of complex electronic vehicle control systems)

Proposals:

a. Set requirements to be applied to safety aspects using as example those set for braking and/or steering.

3.2.8 Other risk during the deployment of a self-deployable ROPS
Object: Risks for the operator during the deployment under normal conditions of a self-deployable ROPS

References: no references identified

Proposals:

a. no proposals already set

3.3 Summary of requirements and possibility to include them in the OECD ROPS codes

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Category of solution</th>
<th>OCDE ROPS code</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability of automatic locking system:</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Easiness of use of manual locking system:</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Safety during manual handling of the roll-bar</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Use of energy to assist the raising of the roll-bar:</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Use of controls to raise the roll-bar:</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Performances of self-deployable ROPS</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
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<tr>
<td>Functional safety of self-deployable ROPS</td>
<td>NO</td>
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<td>YES</td>
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<tr>
<td>Risks during deployment of self-deployable ROPS</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>
Front roll-bar

Torque (N.m)

1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67
Rear roll-bar

Torque ( N.m )

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57