IPENZ ENGINEERS NEW ZEALAND

Practice Note 12

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Operator Protective Structures

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Image couretsy of Brian Clark.

Contents

1. Introduction

1.1 Introduction

In 2004, the Department of Labour (DoL) Occupational Safety and Health Service approached IPENZ with its concerns over some engineering design practices that purported to satisfy the requirements of its Approved Codes of Practice (ACoPs) for frames designed to protect drivers of tractors and other mobile machines.

DoL plans to revise these ACoPs, but in the meantime IPENZ encourages engineers to use the guidance in this *Practice Note* to help satisfy the ACoPs' requirements. A possible consequence is that design procedures may become more rigorous and take more time to complete. A balance must be struck between academic rigour and the commercial realities of the marketplace, so that clients will see the value in an engineered product over one that is simply welded together to look right. Engineers must use their professional judgement to decide how to use this *Practice Note* to assist them in their work.

1.2 Objective

The objective of this *Practice Note* is to clarify for engineers the processes involved in selecting, designing and verifying protective structures on self-propelled mobile mechanical plant in construction, forestry and agriculture.

1.3 Scope

This *Practice Note* is not to be used as the sole means of designing a protective structure, but as a complement to available standards and codes. Engineers should read and understand all applicable standards and codes before designing a frame.

1.4 Regulatory environment

The duties of designers of self-propelled mechanical plant or protective structures are set out in Clauses 66 and 67 of the Health and Safety in Employment Regulations 1995. These include the requirement that the designer takes all practicable steps to ensure that there is no likelihood that the plant or structure will be a cause or source of harm to any person, and to minimise as far as practicable the likelihood that the plant will be a cause or source of harm.

2. Construction and Forestry Machines

2.1 Approved Code of Practice

Early in 2008 DoL had two ACoPs for earth-moving machinery: those used in construction (citing ISO 3471) and those used in forestry (ISO 8082). These differ only in the application of the vertical load. The construction machinery standard allows the engineer to assess the best way to apply the vertical load, whereas the forestry standard applies the load across a 250 mm-wide bar above the operator. Hence a frame that complies with the forestry standard ISO 8082 also complies with ISO 3471, but not vice versa.

Currently ISO standards exist for:

- tip-over protective structures (TOPS) for excavators up to 6000 kg (ISO 12117)
- roll-over protective structures (ROPS) for excavators over 6000 kg (ISO/DIS 12117-2)
- roll-over protective structures (ROPS) on machines in construction (ISO 3471)
- roll-over protective structures (ROPS) on machines in forestry (ISO 8082)
- falling-object protective structures (FOPS) for forestry machines (ISO 8083)
- falling-object protective structures (FOPS) for construction machines (ISO 3449)
- operator protective structures (OPS), ie grills to prevent objects entering the cabin (ISO 8084)
- earth-moving machinery – hydraulic excavators – laboratory tests and performance requirements for operator protective guards (ISO 10262).

Currently there is no standard that allows protective structures to be verified by any means other than physical testing. There is also no standard for roll-over protection on excavators other than ISO 12117 – tip-over protective structures for excavators up to 6000 kg.

Due to the “one-off” nature of the New Zealand market and the need for protection on heavy excavators, DoL developed the *Approved Code of Practice for Operator Protective Structures on Self-Propelled Mobile Mechanical Plant* (ACoP). A frame locally designed and built to this code would be called a Cabin Operator Protective Structure (COPS). The four grades of structure should be used in a prioritised manner.

PRIORITY GRADES FOR PROTECTIVE STRUCTURES

If unable to attain or fit, then move from top to bottom – Grade 1 is ideal.

Grade 1 – An operator protective structure of an appropriate grade to the risk present (as defined in Appendix B) that is in full compliance with the appropriate ISO standard, including the requirement to prove performance in accordance with the specification by physical test of a prototype.

Grade 2 – A protective structure which is locally made and complies with all of the original designer's requirements for an ISO manufactured unit. These include meeting the material specifications, bolts and fittings, welds and welding procedures, surface finish, and quality assurance. Such a structure would, for example, be likely to be a copy of a plant manufacturer's standard frame. Certification would be to confirm that the specifications have been adhered to. Grade 2 structures would not be proved by testing, but would be subject to a design reviewer certifying that they comply with these requirements.

Grade 3 – A protective structure which is locally made and designed to meet the requirements of the relevant ISO standards, but which is designed on the alternative static force resistance basis allowed for in the ACoP. This structure will be then known and recorded as a Cabin Operator Protective Structure (COPS). Designers will need to have the skills and resources to model structures computationally to the extent that they can prove compliance with the relevant ISO standards on a calculated basis. This procedure could allow a structure that would otherwise be a Grade 3 to be upgraded to a Grade 2 structure, but this could only be undertaken by design organisations prepared to have their computational models, techniques and quality control reviewed by a design reviewer approved by IPENZ's structural section.

Grade 4 – A structure which is designed by an experienced professional design engineer (registered under their Act) and based on the engineer's opinion of the best practical means of providing an appropriate level of protection to an operator.

This could include structures on plant that already exist at the time the code was implemented. Typically, these structures would be the "structure of last resort" and should only be used in special circumstances. Example – a machine that violates the deflection limiting volume (DLV) when rolled onto its top may have its use limited to that of a side tip only. It is therefore still a safe structure if used within its limitations. These limitations must be labelled clearly to avoid misuse.

At present, the best option that can be provided for an excavator is ISO TOPS or Grade 3 COPS, depending on the machine mass. ISO 3164 specifies that the design actions below must give deformations that do not intrude on the DLV (see Appendix A).

2.2 Forces and Energies

ISO 3471/AS 2994 Table 1 Crawler tractors and loaders specifies the following design actions for other earth-moving machines, and the ACoP specifies them for excavator COPS:

MACHINE MASS M (kg)	LATERAL FORCE (N)	LATERAL ENERGY (J)	VERTICAL FORCE (N)	LONGITUDINAL FORCE (N)
$700<M\leq4,630$	6M	$13,000\ (M/10,000)^{1.25}$	19.61M	4.8M
$4,630<M\leq59,500$	$70,000\ (M/10,000)^{1.2}$	$13,000\ (M/10,000)^{1.25}$	19.61M	$56,000\ (M/10,000)^{1.2}$
M>59,500	10M	2.03M	19.61M	8M

The forces must be applied in the following order: lateral, then vertical onto the deflected structure, then longitudinal onto the twice deflected structure. Both ISO 3471 and AS 2294 give more detail.

For excavators, in addition to the above, the longitudinal energy absorption is required to exceed 1.4M (1.4 x mass) joules for the longitudinal load.

The draft ISO/DIS 12117-2 for excavators over 6,000 kg gives a table numerically different to that found in the ACoP.

When analysing the structure, all aspects of the relevant standard, with the exception of the physical test requirement, must be adhered to, including load application points, loading sequence, material requirements and DLV acceptance criteria.

3. Analysis method

3.1 General

For a Grade 3 structure, the designer must have the skills and resources to model structures computationally. This requirement may be satisfied with a finite element program that features elastic-plastic material behaviour, and change of geometry after each load increment. The load application in one direction is a discrete load step, and several increments may be needed within that step. At the end of that step, the required load must be resisted and the required energy must be absorbed. After each load step the structure must be unloaded, and reloaded in a different direction with the stress state at the end of the previous load step used as input to the next discrete load step. The designer may choose beam, shell, continuum shell, or solid elements for the finite element mesh. Beam elements at yielding joints are unlikely to be satisfactory unless experimental data are available. The mesh density is vitally important as vastly different results can be obtained with different densities.

ROPS, COPS, TOPS, FOPS and OPS are unusual in that they are intended to perform their function only once, and whilst they may bend in doing so, they must not break.

The ACoP states that when auditing an existing frame the engineer should base calculations on the minimum yield strength of the material and apply an appropriate safety factor, then goes on to suggest a working stress of 165 MPa. This suggests working stress design, in which case an appropriate standard is AS 3990-1993 Mechanical equipment – Steelwork. This will be satisfactory for parts designed to remain elastic, but not for those parts designed to deform and absorb energy.

3.2 Load distribution

In a rigorous analysis the load-distributing device should be modelled using contact which allows the structure to deform relative to the rigid load applicator. The contact should prevent local buckling but must not add any stiffness to the structure. Lateral and longitudinal forces applied to the edge of a plate may not require any distributor.

3.3 Boundary conditions

Care must be taken to realistically model the boundary conditions at the supports. On some machines the points where the OPS is fixed are stiff, but most require substantial reinforcement to ensure the loads are transferred into the main body of the machine. Hence the analysis model should include substantial amounts of machine structure.

3.4 Quality assurance

The quality assurance practices need to conform to a recognised standard. NAFEMS is an international association representing the engineering simulation community, and its document QSS 001:2007 describes a quality management system intended to be used as a supplement to ISO 9001:2000.

3.5 Other methods of calculation

IPENZ recognises the possibility that other calculation methods may exist that include plastic deformation in two directions and energy absorption.

Simple hand calculations are typically required in the analysis process, but should not be used as the sole tool. The ability of the frame to deform and absorb the energy of the roll cannot be determined by simple hand calculations. While simple hand calculation may give the energy absorbed in deforming a certain distance, it cannot reliably determine the plastic strain in the structure and whether the strain is approaching or exceeding the material's safe levels. One of the hardest parts of designing a frame on a heavy machine is not exceeding the material's minimum guaranteed strain.

3.6 Grade 3 Upgrades

The ACoP allows Grade 3 structures to be upgraded to Grade 2 under certain circumstances approved by IPENZ's structural section.

3.7 Grade 4

For a Grade 4 structure, the ACoP gives no guidance on the required type of analysis. The designer must be an experienced CPEng registrant, but is not limited to any particular practice field. IPENZ suggests that the analysis be as rigorous as that required for Grade 3, but that the frame is designed to provide only limited protection, such as tip-over but not full roll-over protection.

4. ROPS Frames

4.1 Frame selection

To determine the type of protection required, the engineer must identify the risks inherent in the plant, and then the risks presented by the ground and the task. To aid this process the ACoP provides two tables, reproduced here in Appendix B. These tables outline the minimum requirements for machinery in construction and forestry. It is the responsibility of the machine owner to provide the engineer with the necessary information to make a correct assessment of the required protection.

4.2 Frame design

The most common frame designs are two- and four-post structures, and each has its own advantages and disadvantages.

One of the most important factors is mounting points. Using what seems to be the obvious mounting location does not always enable the ideal frame to be employed. If there are no mounting points around the operator then a two-post design makes it difficult to gain the necessary coverage over the DLV. Offset loadings in the lateral and vertical directions on cantilevered portions on the frame over the operator significantly increase the frame stresses. This can make the two-post option prohibitive. Figure 1 shows a two-post frame with a cantilevered overhead portion on a light machine.

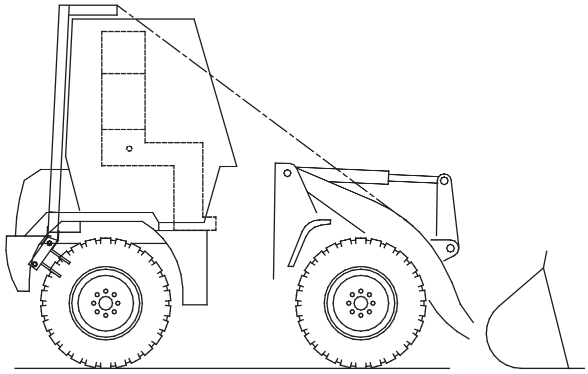


Figure 1: Two-post design with cantilevered roof for DLV coverage on a light wheeled loader.

If falling-object protection (FOPS) or a front grill (OPS) is required then this may also influence the structure type used. The energy requirement for a FOPS is significant and a substantial two-post frame is required to support the overhead structure needed to gain adequate DLV coverage (see Figure 2).

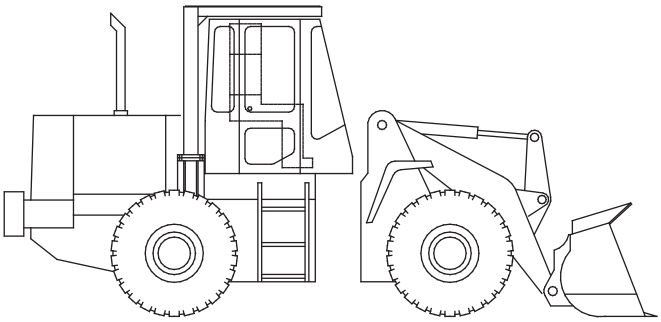


Figure 2: Two-post design with FOPS roof on a heavy wheeled loader.

4.3 Designing for energy absorption

When designing the frame it is important to carefully consider the energy component. It is a mistake to think that stronger is automatically better. It seems obvious that by using diagonal bracing or shear panels you can significantly increase the strength of a structure. But gaining the necessary movement from the frame to meet the energy requirement becomes almost impossible. This type of design induces potentially huge impact loads and removes the predictability of the frame. A frame designed to deform allows the designer to apply realistic loads to the welded and bolted connections, and the machine base. A frame that incorporates bracing or shear panels to achieve its strength is unlikely to be able to plastically deform in order to absorb the energy of the roll. If the frame is not specifically designed to deform, and the substance that the frame impacts on has little ability to move, then the frame is likely to fracture at its weakest point.

For example, the ACoP requires a 12-tonne excavator to absorb 16,328 J of energy. A correctly designed frame will move around 180 mm at the load application point to meet the lateral energy requirements, and reach a force in excess of 90 kN in achieving this. A cross-braced frame may only be able to comfortably deflect 10 mm, which would induce loads more than 30 times that of the correctly designed frame. Loads of this magnitude will cause even the most robust connections to fail (see Figure 3).

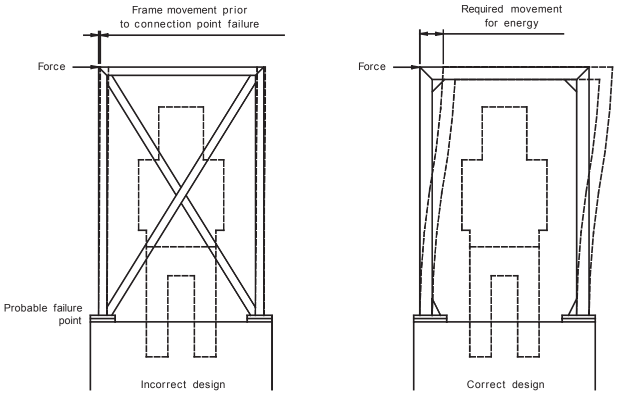


Figure 3: Frame deflection schematic.

Figure 4 compares the energy absorbed by deformable and rigid frames on a force versus deflection graph. The graph shows that in a correct design the corners will reach their elastic limit and then plastically deform, thus allowing the large plastic movement to absorb the energy. This deformable frame reaches the point of full plasticity at x, but is still structurally sound and able to resist a gradually increasing load with substantial deflection. The rigid frame, however, reaches a very high static load but is unable to make use of the large deflections necessary to achieve energy absorption.

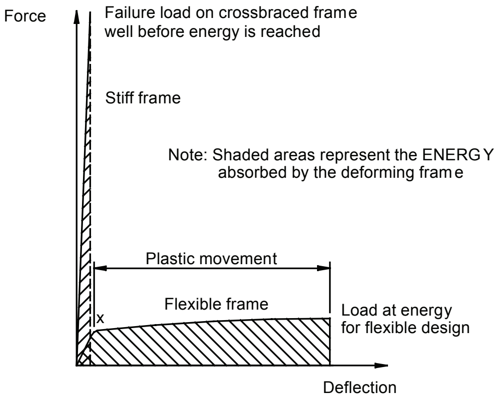


Figure 4: Force v deflection graph for a rigid and flexible frame.

4.4 Mounting options

4.4.1 PINNED MOUNT

Design actions must be taken from the analysis. This type of mount induces the smallest loads into the connection but can generally only be incorporated in four-post designs. It is an effective means of minimising the loads transferred into the machine mounts and base. It does, however, transfer more bending into the upper corners of the frame, which requires a stronger frame construction in those areas (see Figure 5).

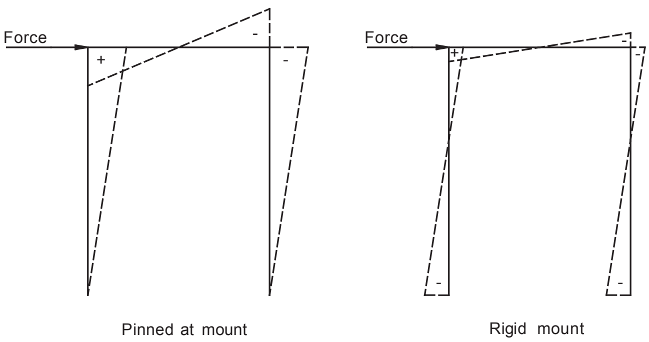


Figure 5: Bending moment diagrams for pinned & rigid mounted frames.

4.4.2 PLATE MOUNT

Design actions must be taken from the analysis. A flat plate mount orientated with the weak direction normal to the lateral load, acting as a plastic hinge, induces significantly smaller loads into the machine base than the rigid type. The moment transferred to the base is dependent on the load needed to cause the plate to form a plastic hinge. This type of mount can be used on two- and four-post designs, but must be carefully designed to ensure it behaves as intended (see Figure 6).

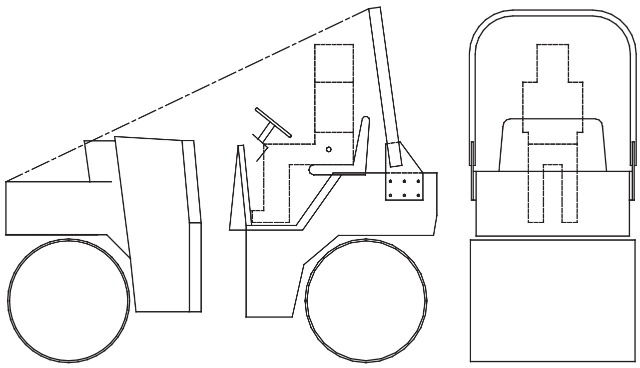


Figure 6: Typical plate mount design.

4.4.3 RIGID MOUNT

Design actions must be taken from the analysis. This type of mount transfers the highest loads into the machine and is only useful if the mounting points on the machine can resist the additional bending moments. The higher moments at the mounts effectively reduce the moments in the upper corners of the frame allowing a lighter construction than the pinned or flexible plate mount designs (see Figure 7).

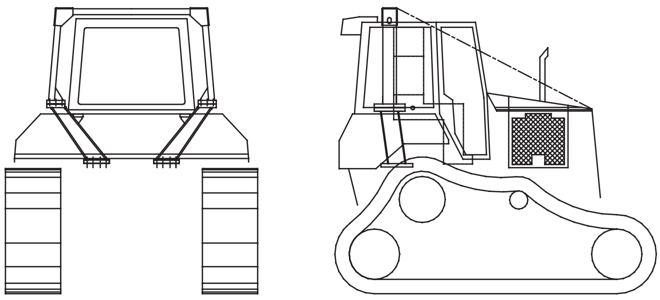


Figure 7: Rigid mount incorporated in a heavily constructed chassis.

4.5 Design Considerations

4.5.1 MATERIAL SELECTION

The ability of the frame to deform is critical. It is also important that the design of the frame allows the deformation to occur as intended. For example, designing a frame constructed from rectangular hollow sections, care must be taken to ensure that sidewall bucking does not cause the frame to collapse. This is a potential problem when using thin wall sections which have little ability to absorb the necessary energy while maintaining structural soundness. NZS 3404 discusses sections for which the full plastic moment can be reached and maintained without any decrease in section capacity due to local buckling effects. Figure 8 shows the extreme case of a frame suffering from sidewall collapse in all corners.

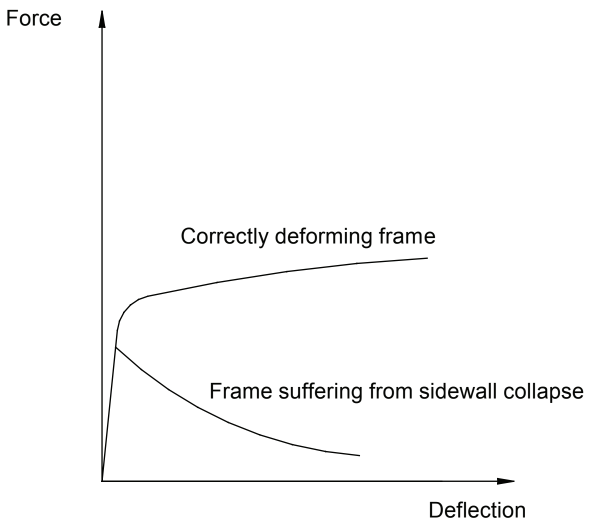


Figure 8: Force v deflection plots for a correctly deforming RHS frame and a frame suffering from sidewall collapse.

Materials with low Charpy values and low ductility should be avoided. Materials must have a minimum Charpy V-notch impact strength at -30°C of or not less than:

- 11 J if the specimen is 10 mm x 10 mm
- 9.5 J if the specimen is 10 mm x 7.5 mm
- 7.5 J if the specimen is 10 mm x 5 mm
- 5.5 J if the specimen is 10 mm x 2.5 mm.

Typically most low- and medium-strength plates will comply with these Charpy requirements. The Charpy V-notch strength of high-strength materials should be verified.

4.5.2 ATTACHMENT TO MACHINE

Care must be taken to ensure that the energy of the roll over is absorbed by the deflection of the safety frame, rather than the machine base frame. To achieve this, the base frame deformation should be limited to that of minimal plastic strain, and if possible elastic only. Small amounts of plastic strain are sometimes necessary to help distribute the loads amongst the base’s structural members.

4.5.3 WELDED CONNECTIONS

Careful thought must be put into designing welded connections, especially those close to areas where the frame has been designed to deform. If the weld strength is less than that of the deforming section it connects, then the weld may fail prematurely. This may be avoided by using gussets to increase the weld area and therefore reduce the stress in the weld to safe levels. Welds may be designed by the limit state or alternative methods of NZS 3404. The structural purpose category SP or better should be specified.

4.5.4 BOLTED AND PINNED CONNECTIONS

For most COPS, all connections must stay intact to enable the frame to do its job rather than part from the machine. Bolted and pinned joints may be designed by the limit state or alternative methods of NZS 3404.

Exceptions will occur in cocoons which are designed to break away whilst completely enclosing the operator, but the design of these connections is beyond the scope of this Practice Note.

4.5.5 ERGONOMIC CONSIDERATIONS

It is important to avoid "designing in" additional hazards that may make other aspects of the machine unsafe. The engineer should avoid:

- visually obstructing the frame – this can be achieved by aligning the frame with existing cab pillars
- blocking emergency exits on cabs – while it is often hard to stay completely clear of exits this should be a design consideration
- obstructing access into and out of the machine
- introducing overhead hazards that the operator could hit their head on when getting into and out of the machine – on a two-post frame it is preferable to have the overhead portion roughly in line with the seat backrest so the operator does not hit their head when standing
- excessive frame height which interferes with overhead structures during transport.

The engineer should consider:

- egress of the operator should the machine tip over
- physically being able to open and close guarded doors – think about 30° cross-slope and a door weighing hundreds of kilograms
- being able to clean glass so the operator can see out.

5. FOPS roofs

5.1 Standards

The two applicable Standards for FOPS roofs are ISO 8083 for forestry machines, and ISO 3449 for construction machines. DOL's ACoP for cranes also requires ISO 8083-type FOPs and ISO 8084-type side grills for cranes used in demolition-ball operations. These require a test object of a defined mass to be dropped onto the roof of the frame from a prescribed distance, over the operator. Neither the object nor the frame may enter the DLV.

5.2 Energy absorption

The nature of the test requires that the frame has the ability to absorb the falling object's kinetic energy. This can be achieved in a number of ways:

- Overhead grills. The grill members absorb the energy of the fall through the bars' bending resistance. The bars must plastically deform a significant distance.
- Thin FOPS plate. The plate is welded to the frame so it is not pulled through into the DLV. Typically, the frame itself will be distorted slightly to allow the plate to deflect to absorb the energy. With this design the frame must be compliant enough so that plate edges can pull in as the plate deforms, or there is a risk that the plate may tear.
- Thick FOPS plate. A sufficiently thick plate can deform adequately without the edge restraint. Points to consider are that the edges do not buckle due to compressive loads induced, and the plate overlap onto the frame is adequate to stop it being pushed through into the cab.

A dynamic analysis is needed to strictly simulate the physical test. However, it is possible to approximate it with a static analysis that absorbs the kinetic energy existing in the test object immediately before impact.

6. OPS Side Grills

Under the heading "Special structures" the 1999 ACoP mentions "any...situation where an operator could be subjected to side/rear intrusion hazards." DoL has published a forestry case study in which they concluded that fitting side intrusion bars to an excavator was a practicable and reasonable step. The relevant standard is ISO 8084, but this excludes broken chainsaw teeth from its scope.

7. General requirements

7.1 Deflection limiting volume (DLV) compliance

The DLV must be located in the machine according to the ACoP. ISO 3471 specifies that this space is reserved for the operator only and must not be entered by the frame or lateral and vertical simulated ground planes (LSGP and VSGP) during any loading phases. The manipulation of the DLV is limited to less than 15° sideways rotation, or forwards unless limited further by interference with machine components or controls, as defined in ISO 12117.

7.2 Frame identification

The type of protective structure provided must be identified. A label must be permanently attached in a location where it can easily be read and is protected from damage or weather.

The label must contain the following information:

a) the name and address of the structure's manufacturer
b) the structure's type and serial number if any
c) the serial number, make and model of the plant that the structure is designed to fit
d) the maximum machine mass (M) for which the structure has been designed
e) the relevant ISO or other performance standard for which the structure meets all performance requirements
f) other information as deemed appropriate (for example, installation date, repair or replacement information).

7.3 Operator station protection

If the machine does not have doors, drivers sometimes tend to operate outside the protected space, and therefore some system to eliminate this hazard needs to be part of the structural design. The ACoP states that seatbelts must be provided as part of an operator protective structure and gives performance requirements in an appendix. The ACoP on tractors recommends seatbelts fitted in accordance with AS 2664.

7.4 Who may design?

The Approved Code of Practice for Operator Protective Structures on mobile plant defines a Grade 3 structure without specifying the qualifications of the designer.

IPENZ is of the view that the designer may be any engineer who has the skills and resources to model the structures computationally.

The ACoP at section 7.6 requires all reference material for the design analysis to be kept on file together, but does not specify the location. IPENZ recommends that the reference material for the design analysis remains with the certifier.

7.5 Who may certify?

The ACoP at section 7.1 requires the design, construction and attachment of each model of the protective structure to be certified by a Registered Engineer. IPENZ has agreed with the regulator that the term "Registered Engineer" is to be interpreted as a New Zealand Chartered Professional Engineer (CPEng). The certifier may also be the designer, or may take a computer model produced by a drafter and subject this to appropriate structural analysis, or may take responsibility for design work carried out by others.

The ACoP at section 8 requires an identification plate with certain information, discussed elsewhere in this Practice Note.

7.6 Who may assess a damaged structure?

The ACoP at section 9 requires the original designer or another suitably qualified CPEng registrant to assess a damaged structure.

7.7 What remedies are available for a damaged structure?

7.7.1 ACOP FOR OPERATOR PROTECTIVE STRUCTURES

The ACoP at section 9 mentions rust, side wall buckles, and cracked welds as examples of damage that must be assessed. The regulator has advised that the assessment must include seeking advice, if any, from the manufacturer of the damaged structure.

If a slightly bent structure is proposed to remain in service, it would be necessary to show, by plastic analysis of the deformed geometry, that it could sustain the forces and absorb the energy required by the original design standard.

If a slightly bent structure is proposed to be straightened, it would be necessary to ensure that weld imperfections are made no worse, and that metallurgical changes such as strain hardening do not reduce the energy absorbing qualities. AS/NZS 1554.1:2011 gives guidance on weld repairs[1].

7.7.2 ACOP FOR SAFETY AND HEALTH IN FOREST OPERATIONS

The more recent ACoP for Safety and Health in Forest Operations[2] at 14.8.4 requires FOPS and OPS on yarder cabs, and at 14.8.3 permits structural repairs provided certain criteria are met. The regulator has confirmed that structural repairs that comply with advice, if any, from the OPS or FOPS manufacturer are permitted.

This ACoP at section 14.8.3 requires a CPEng to ensure modifications and structural repairs

- Do not reduce the original safety factor of the equipment
- Are recorded on an identification plate showing the name and address of the CPEng and the date of the modification.

IPENZ has no objection to CPEng registrants providing their names and addresses on repair identification plates. Because the list of CPEng registrants is publically available on the IPENZ website, and since 2013 has been searchable by number as well as name, IPENZ believes the registration number continues to be sufficient identification.

7.7.3 DAMAGE TO NON-STRUCTURAL ITEMS

Damage to non-structural items such as removable panels, doors, windows, and attachments may be repaired without a CPEng being involved.

1 AS/NZS 1554.1:2011 Structural steel welding Part 1; Welding of steel structures

2 Approved Code of Practice for Safety & Health in Forest Operations, Ministry of Business, Innovation and Employment, December 2012.

8. Wheeled tractors for agriculture

Currently there is no standard that allows roll-over frames on wheeled tractors in agriculture to be verified by any means other than physical testing.

Due to the "one off" nature of the New Zealand market and the need for protection on existing tractors, in 2001 DoL published the *Approved Code of Practice for Roll Over Protective Structures on Tractors in Agricultural Operations*.

ROPS fitted to tractors used in agricultural operations must be manufactured to one of two grades, depending on the method of design validation. The ACoP states that, where practicable, a Grade 1 protective structure should be used. Where a Grade 1 protective structure is not available, a Grade 2 structure may be used.

PRIORITY GRADE CHART FOR FITTING OF ROLL-OVER PROTECTIVE STRUCTURES FOR AGRICULTURAL TRACTORS

Grade 1 – A roll-over protective structure that complies in all respects with an approved performance standard or code, including all frames approved under the provisions of the (repealed) Machinery Act 1950.

Grade 2 – A roll-over protective structure manufactured in New Zealand and certified by a suitably experienced professional engineer registered under the Engineers Registration Act. Type certification of a unique design for fitting to a number of identical machines is permitted.

For certification, a roll-over protective structure must be the best practicable means of providing an appropriate level of protection for an operator. Full details of all design assumptions, computational models, calculations and results, together with specifications, manufacturing and quality control procedures where applicable, are to be retained by the certifying engineer and made available for review if required.

As the Engineers Registration Act has been repealed, IPENZ suggests that those words be replaced with Chartered Professional Engineers of New Zealand Act.

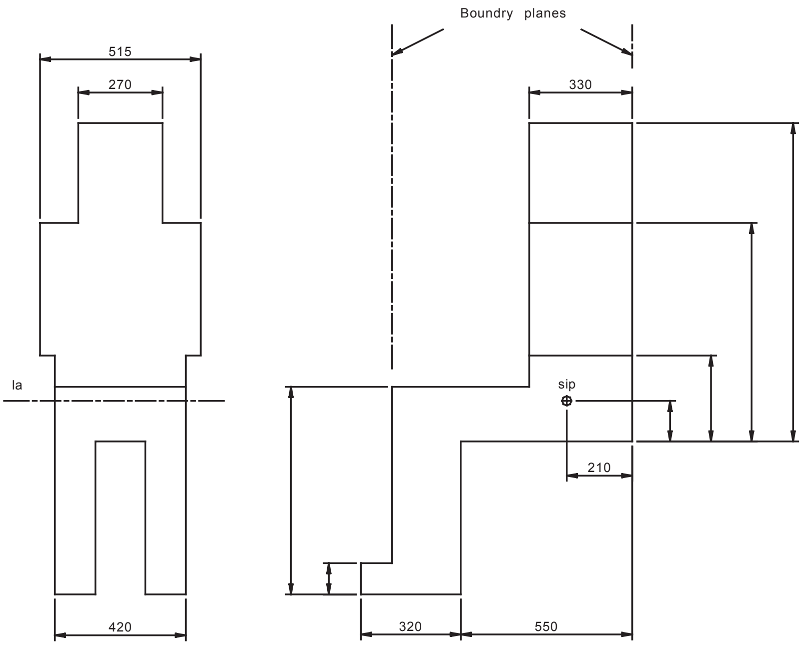
Because Grade 1 ROPS require physical tests, they are unlikely to be designed for individual tractors. The ACoP does not specify any particular method of design for Grade 2. IPENZ recommends the methods discussed above be used for Grade 3 construction and forestry machines.

The ACoP is based on several standards including:

- ISO 3463 – Tractors for agriculture and forestry – Roll-over protective structures (ROPS) – Dynamic test method and acceptance conditions
- ISO 5700 – Tractors for agriculture and forestry – Roll-over protective structures (ROPS) – Static test method and acceptance conditions.

These standards specify operator space requirements and allowable deformations that differ from those for heavy machinery. Refer to the above ISO codes and Appendix C.

Appendix A



Deflection Limiting Volume (ISO 3164:1995).

Appendix B – Extract from the ACoP

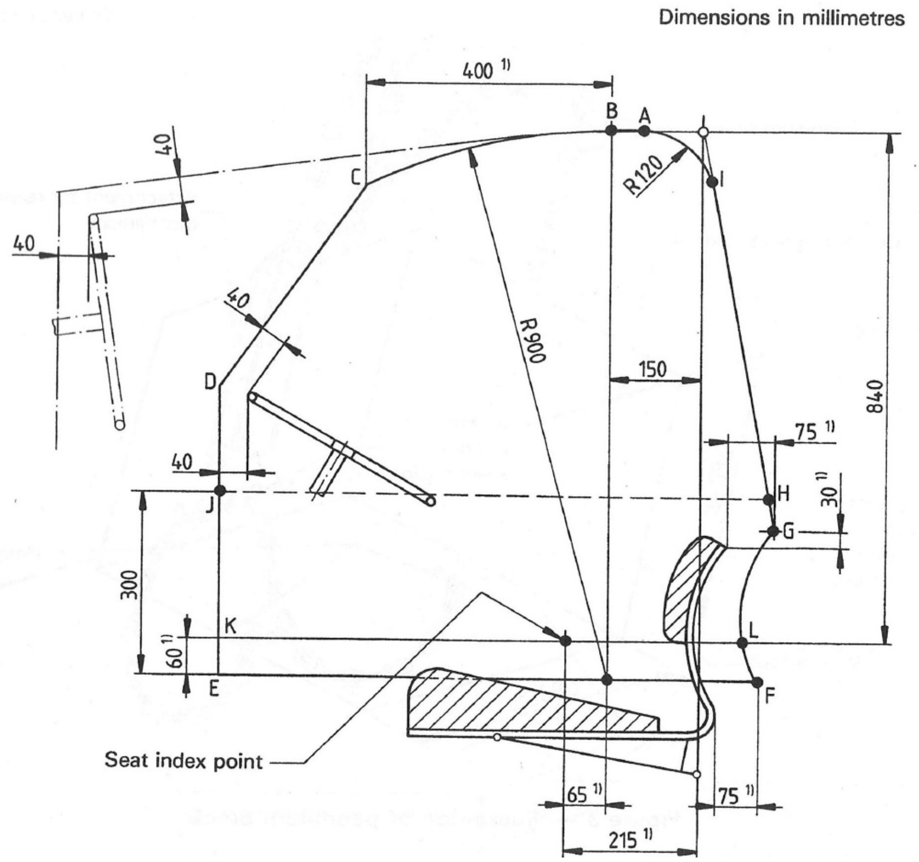
RISK OF WORK SITUATION / RISK OF PLANT	LOW	MEDIUM	HIGH
	Level stable ground	Road shoulders Stock piles Low embankments	Steep and/or unstable ground Clearing operations Demolition
CATEGORY 1 (High) Rollers Loaders Skid Steer Motor Scraper	TOPS/FOPS/COPS Caution required. Protective structure advisable.	TOPS/ROPS/FOPS/ OPS/COPS Protective structure strongly recommended.	ROPS/FOPS/OPS Extreme risk. Protective structure strongly recommended.
CATEGORY 2 (Medium) Excavators Dozers Tractors Commercial Lawn mowers	Not essential.	TOPS/ROPS/FOPS/ OPS/COPS Protective structure advisable.	TOPS/ROPS/FOPS/ OPS/COPS Protective structure strongly recommended.
CATEGORY 3 (Low) Graders Road sweepers	Not essential.	TOPS/FOPS/COPS Caution required. Protective structure advisable.	TOPS/ROPS/FOPS/ OPS/COPS Protective structure advisable.

Table 1A: Recommendation For Operator Protective Structures In The Construction Industry
Note that ROPS, TOPS and COPS may also include FOPS and OPS.

EXCAVATORS HIGH-RISK	Machines used for log extraction, mechanical harvesting, shovel logging, mobile tail holds, land preparation, including road construction and maintenance.	COPS designed to Grade 3, including OPS and FOPS
ALL OTHER PLANT HIGH-RISK	Machines used for log extraction, tree felling, mechanical harvesting, shovel logging, mobile tail holds, construction of forestry roads/maintenance tracks, fire breaks and landings where there is danger from falling debris and trees. Machines used for land preparation.	ROPS, FOPS, OPS
MEDIUM-RISK	Machines including excavators, used on landings, log yards and shelter belt maintenance.	OPS, FOPS
LOW-RISK	Cable haulers (all areas), purpose-built log stackers, ie wagners (log yards).	FOPS, OPS

Table 1B: Recommendation For Protective Structures In The Forestry Industry

Appendix C



Clearance zone side profile (ISO 3463:1989), for agricultural tractors.

VERSION HISTORY

This document was first issued in March 2008.

Version 1.1, dated July 2009 adds:

- notes of the boundary conditions between the new frame and the existing structure
- notes on OPS side grills for forestry and demolition ball operations
- further ergonomic considerations.

Version 2, dated April 2014 adds:

- clause numbers
- notes on who may design, certify, assess a damaged structure, and remedies for a damaged structure.

LEGAL INFORMATION

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