Machinery ADCO Recommendations for improving the safety of Firewood Processors

INTRODUCTION

This non-confidential document has been produced for and endorsed by the October 2015 Machinery ADCO meeting to assist:

- members states in acting consistently when undertaking market surveillance concerning these machines;
- those responsible for the design and placing them on the market, to promote safety improvements that meet the 'state of the art' for safety, and so reduce the risk of injury;
- CEN, as a source of information and impart Regulators' views, to assist with the preparation of the proposed new part of EN 609 concerned with these machines;

so that all Firewood Processors placed on the market meet the essential health and safety requirements as outlined in Annex I of the Machinery Directive 2006/42/EC to the 'state of the art', and are safe in use.

BACKGROUND

European market surveillance authorities participated during 2012 -14 in a Machinery ADCO project surveying existing Firewood Processor machinery on the market:

- looking at a range of machine types to establish the 'state of the market';
- analyse the extent of compliance with the Machinery Directive, particularly in relation to key safety issues associated with product feed and discharge; and
- begin to consider what the 'state of the art' for safety for these machines should be to reduce the risks they present, and prevent future accidents;

as there was some history of significant (eg finger amputation) injuries both to users and others assisting or nearby, arising from poor design and foreseeable misuse.

The ADCO Working Group reported by draft Report the project findings and provisional recommendations at the May 2015 Machinery ADCO meeting of European Market Surveillance Authorities. Following consultation during the spring and summer of 2015 a final confidential report was presented to the Machinery ADCO meeting in October 2015, together with this 'open' Annex to meet the purposes stated above.

The recommendations made here are not legally binding (only the provisions of the Directive 2006/42/EC as implemented into member states' national law), but nevertheless represent the collective view of the Machinery ADCO which wishes to promote the safety of these machines through improvements in design. As discussed, improvements in certain areas appear necessary to adequately manage risk of foreseeable injury and so advance the 'state of the art' for Firewood Processor safety by design and construction.

Manufacturers are therefore encouraged to take a fresh and fundamental look at the design of their machinery, particularly in areas where this report identified deficiencies in risk management, and make improvements which push the 'state of the art' forward in the interests of the safety of all users.

Summary of measures necessary for Firewood Processor Safety

MEANS OF STOPPING

All machines powered by electricity should be fitted with one or more emergency stops which stop all moving parts. Machines operated by an integral combustion engine may achieve a stop by shutting down the combustion engine. Machinery powered by means of power take off (PTO) mechanisms should also be capable of being stopped quickly by the operator at his normal operating position, eg by employing mechanical clutch, valve or other systems to achieve power disconnection.

Where hydraulic systems are employed automatic means of preventing dangerous movement should be provided (eg by blocking stored energy), however in the event of product jamming manual means for dissipating stored energy may also be required. Automatic means for dissipating stored energy from pneumatic systems may be required.

Circular saw cutting means should stop within 10 seconds or guards effectively preventing access remain locked in position until the saw blade comes to a rest.

Moving parts associated with splitting should come to a stop immediately when access is gained, and any stored energy 'dissipated: if not guard locking will be required until movement has ceased and any stored energy been dissipated.

IN- AND OUT-FEED SAFETY

Mechanically fed firewood processor machines (normally by means of a horizontal conveyor) should be fitted with either in-feed guards of at least 850 mm length (from the 'opening plane' to the nearest hazard: means of cutting or gripping if not solely manual applied), unless fitted with a hinged 'pressure plate' which closely fits the internal profile of the guarding such that it and the guard surrounding it effectively prevents access to the dangerous parts, in which case the guarding may be reduced in length (but probably not less than 650 mm).

On machinery with a mechanical out-feed mechanism (typically a conveyor which may be moveable: inclined and/or rotating) discharge guarding for the splitting zone should completely prevent access to both the means of cutting and also provide an 850 mm safety distance to the front 'cutting' edge of the splitting blade (guarding should be interlocked to provide safe easy access for foreseeable operations: blade changing, unjamming).

Machinery should be designed to be of sufficient length to achieve this, or provided with suitable guarding which extends along the conveyor in all deployable positions (eg where 'short' machines are designed for carrying by means of tractor 3 point linkage). Removable parts of such extended guarding should be interlocked (this should be possible at the 'state of the art' where machinery is electrically or integral combustion engine powered, or where a low voltage electricity supply is available for a safety circuit from a tractor providing power via a PTO mechanism, in conjunction with means for disconnecting power (see above).

Only where the above is impossible may shorter permanently affixed or interlocked discharge guards be tolerated (manufacturers' will need to justify this fully in their technical file, showing why machinery design changes cannot meet the 'state of the art' described above). In no circumstances should permanently affixed or interlocked discharge guarding

afford a safety distance to the cutting edge of the splitting parts of less than 550 mm, and 'drop on' guarding to be 'fixed' in position when the machine has been deployed should be provided to extend the minimum safety distance to 850 mm. Interlocking should afford easy means of undertaking safe interventions, safe methods of working be described in the instructions, any necessary tools (eg for unjamming) provided, and other robust means provided to effectively discourage access, including warnings of the residual (significant) hazard.

Manually feed (and where no conveyor discharge on out-feed) firewood processor guards should be at least 850 mm long (from the 'opening plane' to the nearest hazard: means of cutting, gripping, or sharp edge of splitting plate), with robust moveable guards where access is necessary for interventions such as blade changing and unjamming, which operate reliably and are interlocked with all moving parts stopping dangerous movement before access can be gained (this may require guard locking where moving parts do not come to a rest quickly, or braking means): with the exception that:

where the wood is actively manually lifted and thrust into the machine (typically those which employ a rotating blade with spike to cut and split the wood in a single operation), in-feed guards should be fixed in position and at least 1100-1200 mm in length because of the active thrusting nature of the in-feed, with a lower boundary effectively constraining body positioning because of the risk head/shoulder access in these larger feed apertures.

LOG HOLDING DEVICES

Log holding devices (for the cutting zone) operated on a hold-to-run basis where the in-feed aperture is in full sight of the operator (whether mechanically or manually operated) can be ignored for the purposes of determining the in-feed safety distance (guarding is still required for the other hazards).

Log holding devices operated solely on a manual basis (not powered) where the in-feed aperture is in full sight of the operator need not be considered as a hazard (guarding is still required for the other hazards).

CONVEYOR SYSTEMS

Feed and discharge conveyors should be safeguarded to remove all hazards from in-running nips and any transmission/drive parts, in all positions of operational deployment (this may require guards fitted on the undersides etc).

PERSONS OTHER THAN OPERATOR

Because of the foreseeable presence of other persons around these machines and their higher throughput rates compared with simple splitters, two-hand activation control devices cannot be considered a substitute for effective guarding of dangerous parts, even where a machine is designed for single person operation.

DISSCUSION OF SPECIFIC ISSUES

Sequential cutting and splitting machines

Most machines are of this type, where the splitting action occurs directly after the cutting action without direct operator intervention. Some form of feed zone leads to a chainsaw or circular saw, the cut logs then usually dropping directly into the splitter, usually comprising a hydraulic ram pushing against a fixed splitting plate, and finally being discharged, frequently by inclined elevating conveyor.

Most of these machines are intended for use at work and the price point (often over €10,000) means that few private customers will purchase them. Some are large 'industrial scale machines. Others are more modest but as tractor powered intended for farm/agricultural use (Figure 1).

Figure 1 Tractor Power take off (PTO) shaft driven professional Firewood Processor

Stability & Transportation

To facilitate transportation many machines have folding inclined conveyors, usually for the out-feed, sometimes for the in-feed (or at least an in-feed table that also needs to fold or be detached). These affect the fundamental stability of the machine:

- when in use, when loadings may be higher, uneven due to pre- and processed material, and dynamic as material moves along them,
- when being transported, usually in a folded (static state), and also
- when being erected, where the loadings will be dynamic and potentially uneven.

Many machines are intended to be used in rural or forestry settings where the ground conditions are variable, often resting directly on soil with uncertain load bearing capabilities, even if some are still partly supported, eg by a tractor providing power.

To ensure stability during all the phases mentioned above the machine needs to be appropriately designed, particularly with large enough 'feet' to spread the load adequately to prevent unintended movement, especially when being 'folded', with sufficient structural strength for all possible configurations and loadings, and with any connections to other equipment, such as the power

source. Means of anchoring may also be required. Suitable instructions should be provided to ensure safety during these phases of transport, deployment and use.

Some machines are intended to be static by design, where they can be positioned or even secured on a suitably specified base for stability (which may also have benefits for the adjacent work environment). Most were designed variously for crane or fork lift to unload from standard vehicular transport to the use position, and were provided with facilities to enable this to take place safely (fork slots or lifting points).

Some machines were intended to be towed which meant that whilst overall width is restricted this did not appear to have an adverse effect on safety provision (eg in-feed guard length) because overall length was not (significantly) limited. Suitable means (eg jacking points) should be provided for safe wheel/tyre maintenance where this may be necessary, eg for those with means for towing on road.

Some machines had demountable wheels to enable greater stability when in position and in use. The design of these mechanisms needs to ensure risk is adequately managed by avoiding instability when they are removed or affixed.

Finally, it was noted that in order to be carried sideways by a standard tractor 3 point linkage, some machines were more limited in size. This particularly affects the length of the processing zone and any guarding provided, whilst still enabling conveyor(s)/feed tables to fold sufficiently within a certain width restriction (eg to fit through standard agricultural gate widths). Given the potential restriction on the length of guards that can be easily fitted to such machines this fundamental design should only be adopted by manufacturers where unavoidable, and where adequate additional physical safety measures can easily be deployed to ensure guard lengths are sufficient to prevent access to the cutting and splitting hazards (EHSR 1.3.7), because of the significant dangers they present. (see later for more discussion of this fundamental guarding issue).

Energy sources

Three main energy sources are used: on board internal combustion engines, single or three phase electric power, or connection to an agricultural tractor, which may be through the mechanical power take off shaft or a hydraulic power system. In most cases safe isolation from power was possible by physical disconnection, or via a key switch/lockable isolator. Where stated, the ingress protection rating was a minimum of IP44, although IP55 was stated by a number of manufacturers, and IP56 by one.

The ability to safely isolate and ensure isolation is maintained (eg via key switch and lockable means, including because of blind spots with larger machines) to perform essential maintenance, including unblocking operations, is essential. In some cases where tractor powered these means may be part of the tractor and so will need to be described in the instructions for setting up and use.

Where the energy source ‘stores’ power (potentially with some hydraulic and any pneumatic systems), suitable means to 'dump' such stored energy should be provided unless the hazard is avoided by design (manual means to dump residual stored energy may still be required where automatic provision is made, in case of failure of automatic systems).

These machines are mostly designed to work outdoors so where they use electricity or incorporate an electrical control system, they need designing with an appropriate degree of protection from mechanical and other foreseeable hazards, including to a suitable Ingress Protection (IP) rating: an

absolute minimum of IP44 is recommended. Residual Current Detection/Earth Leakage Circuit Breakers (RCD/ELCB) may be required at the point of supply to give additional protection in the event of an electrical fault (this may be a requirement for the User Instructions, and could also be subject to National Provisions).

Control System Safety Performance & Interlocking

No analysis of control system performance was undertaken. Even a detailed examination of a manufacturer's technical file (which was not undertaken) can only reveal certain indicators for compliance. But it is clear that the majority of the machines are relatively simple, often with straightforward interlocking, often just mechanical in nature. Anecdotal evidence (and at least one investigated accident) suggests that even mechanical interlocking systems may not necessarily have the required level of integrity and reliability. They may be susceptible to mal adjustment, misalignment, or easy interference (eg debris, or deliberate by passing adversely affecting interlocks, especially in 'negative' mode, has been reported).

Some machines appeared to have more sophisticated control systems with photoelectric 'log' sensors suitable positioned to at least to activate or inhibit certain functions, although these may not be safety related components or part of the safety system. Some machines were fully manual, others had semi-automatic features so continued for some parts of the process on activation of the feature. A few were almost or fully automatic in operation.

Some tractor driven machines derived a 24V supply for the firewood processor control system from the host tractor which could enable a low voltage safety system. This opens the possibility of a greater range of possible interlocking options and configurations, eg for guards which might have to be removed to enable folding for transport. It is possible therefore that the 'state of the art' traditionally possible for static machinery is becoming technically feasible for mobile equipment, and at reasonable cost for the hazards found.

These machines frequently work in 'difficult' outdoor environments which can challenge aspects of the safety system, eg water ingress as mentioned above. Some mechanical interlocking devices found were easier to defeat (with a small piece of wood) or more prone to failure than others, this has contributed to at least one serious incident.

Emergency Stop: Some machines (electrical and on board combustion powered) were provided with the traditional red mushroom Emergency Stop button. But delivering the emergency stop function is less easy with tractor powered machinery, particularly with mechanical power take off shaft connections. Traditional methods here include a cable arrangement set up to stop the tractor when pulled. But these rely on being set up correctly each time the machinery is deployed, and maintained on a regular basis.

A further question arises, linked to the performance requirements of EHSR 1.2.4.3 dealing with emergency stop: "The following exceptions apply: — machinery in which an emergency stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken." With circular saws the run down time, even with traditional braking, may be such that danger cannot be averted. Which means that the primary safety features (guarding from all approaches and the safety distances created) must be adequate to manage risk. However, these machines are coupled with a splitting means which is almost universally hydraulically powered. Stopping hydraulic ram movement quickly is easily possible, and given the currently provided discharge guards often being too short (see later

discussion), and access foreseeable with often irreversible consequences, perhaps effective supplementary means (E Stop) for at least stopping ram movement are essential.

What Category of Control System is reasonable to expect for such machines, and for which parts of systems (Emergency Stop, Interlocking, Conveyor movement compared to ram movement, Saw (and if fitted Clamp) movement? An analysis in accordance with EN ISO 13849-1 should be undertaken to determine if there are common generic requirements for all similar machines, such that these can be stated to assist manufacturers and MSAs. But it is likely that a minimum performance level 'PL c' will be required for the key aspects of these machines because of the serious, normally irreversible, nature of injuries (S2) coupled with the short exposure time (F1) and the possibility of avoiding harm (P1). Where machines are manually fed unless the physical constraints are such that frequent access is not possible, what implications does this have for that part of the safety control system?

Control systems need to be robust for the expected environment of use. Those machines driven by PTO mechanical drive with mechanical interlocking have more limited options than those which have a 240/415V electricity supply and standard electrical interlocks, where a standard emergency stop function should always be provided. Any interlocking/hold-to-run system should be designed so as not to be easy to defeat or fail in use.

In some cases a form of two-hand control was provided, but may not meet the two-hand control standard. And even where fully implemented they may not afford protection to persons other than the operator, who may foreseeable be present for a variety of reasons. It is considered that as protection means two-hand control devices are much less effective than guarding which prevents any person from accessing dangerous parts. Two-hand control devices are not considered as 'state of the art' protection for firewood processors.

Electric and combustion powered machinery can easily, and so should, be provided with one or more traditional emergency stop buttons. But what is the 'state of the art' for emergency stopping of tractor power: can you deploy a clutch brake on a mechanical PTO shaft system?, or if using (or converted to) hydraulic power inside can you shut off certain elements using valves to deliver a function similar to emergency stop? It is considered that more can now be done at the 'state of the art' than previously. Where they can be fitted all forms of power should be subject to emergency stop provisions, such as by means of blocking valves or clutches. Risk exists throughout the machines, with conveyors as well as the primary dangers from cutting and splitting, and the provision of means of stopping in emergency should take account of all aspects. In some cases guard locking may also be required.

Some machines are large enough for second persons to be easily present, assisting even where not intended by the manufacturer (foreseeable behaviors), in positions where they may not be easily seen by the operator. In all cases one or more emergency stop button(s) should be located following careful assessment to respond to actual or impending danger.

Where Circular saws are used for cutting they should be braked to limit run down time, preferably stopping within 10 seconds as with other woodworking machinery.. Alternatively guard locking should be provided. Similarly, those employing a chainsaw should have an integral braking system (like found on hand-held chainsaws, albeit modified to suit use in these machines), or guard locking may be required.

Interlocking systems should preferably work in the positive mode, be robust, activate early to prevent access, not easy to defeat, and avoid mechanical designs with long linkages which require adjustment to maintain effectiveness. No movement should be possible, so guard locking may be required unless danger can be removed quickly (eg splitting ram pressure dump linked to guard

operation, braked cutting elements). The relevant harmonized B standard for interlocking should be met to ensure reliability and integrity for this part of the safety system.

The nature of machine control, fully or partly manual, semi-automatic or fully automatic operation needs careful assessment as different types of hazardous situation can develop at different points of the cycle, in particular where activation of an operation such that the operation continues until the end of its cycle (ie semi-automatic, not hold-to-run), which may apply to one or more aspects of machine operation, but not to others. These also need to be carefully explained within the instructions, especially where they may affect foreseeable interventions, misuse, and maintenance activities.

Ergonomics

Various types of controls are used to initiate or maintain machine movements. Controls should be logical and intuitive. Designs should be avoided which could cause a hazard through their inadvertent operation, eg by falling or leaning against the machine.

Manual handling issues also exist with most machines unless fitted with a log handling/feed table which is mechanically loaded. Optimum in–feed heights to reduce lifting and yet avoid poor bodily positioning should be determined, taking account of the natural variability of operator height, whilst not compromising the safety distances provided by in-feed guards. Manual loading/unloading should be avoided with high throughput machines.

Machinery combinations

Some machines are specifically designed to interface with other equipment, log feed mechanisms in particular, which may reduce ergonomic hazards associated with manual handling. However, these interfaces may give rise to risks in addition to those for the basic Firewood Processor. Where intended to be combined with other equipment, the base machinery should take account of interface issues, and their effect on safety provision. Where not specifically designed as such to interface with other handling machinery, information on the potential risks arising from combining machines should be included in the instructions. Combined machinery may need linkage between emergency stop systems, eg continuously running conveyors associated with hold-to-run for the main processor, to ensure residual risks out of operator sight can be mitigated (the main risks should be managed by adequate guarding).

Maintenance

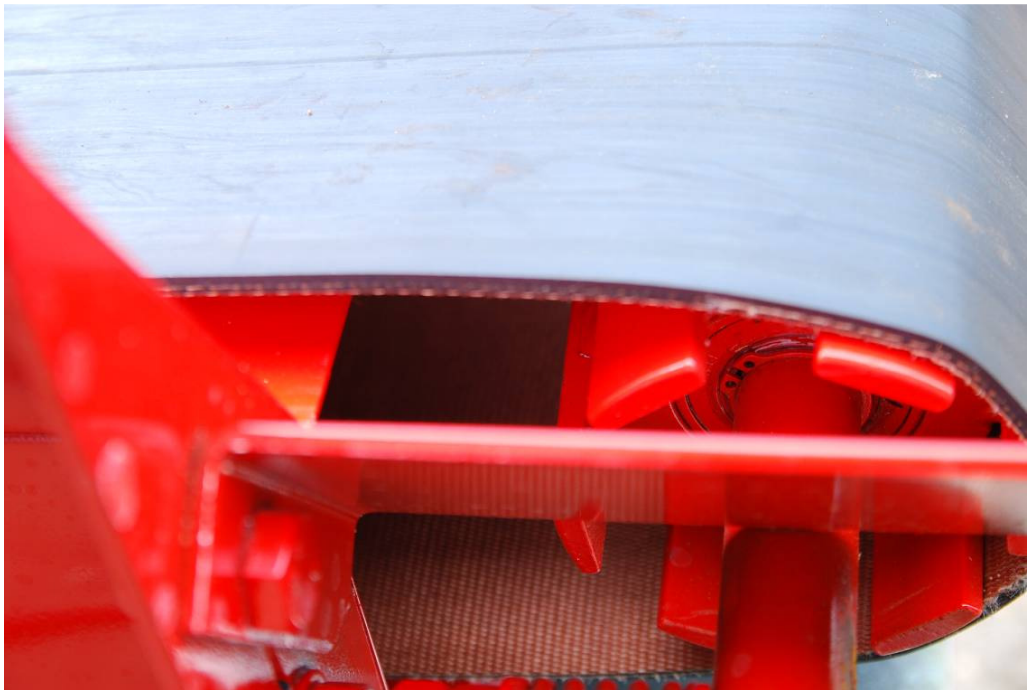
Most machine manuals referred to maintenance and replacement parts to keep the machinery working, but did not always deal with how to undertake maintenance safely, particularly how to deal with foreseeable blockages such as part split logs jamming on the wedge in the splitting zone. Few appear to provide specific tools for dealing with foreseeable blockages. There appear to have been some accidents during the clearing of blockages where hands have been crushed or fingers severed, sometimes due to stored energy rather than an intended movement of the ram.

The minimum content of user instructions should include detailed measures on how to safely undertake examination and maintenance, especially foreseeable interventions such as unjamming/blocking the machine, with any essential tools being provided. And the means by which the provided safety measures can be checked and maintained, including where appropriate, suitably adjusted for safety.

Log holding/support on entry into the machine

Most machines were conveyor fed reducing the need for the operator to actively hold the log (in some cases the need to operate two levers, although not necessarily at the same time, largely prevents this). This may also help improve the ergonomics and reduce the manual handling risks. Where power fed they may reduce the need for operator access into the in-feed zone approaching the cutting means. Various methods were employed to 'hold' the log as it enters the cutting zone. Some may 'occupy' one hand of the operator through being manually applied, others were more automatic in nature and so gave rise to significant hazards in themselves. These are discussed further in the next section. However, examples of poor conveyor guarding were found such as shown in Figure 2, where the in-running nip was exposed. Other cases of poor guarding to the undersides of discharge conveyors in positions within easy reach were found. All ***c***onveyors should be guarded to the usually expected high standards of safety (as described by the relevant harmonized standards).

Figure 2 Example of unguarded in-running nip on conveyor



Log cutting issues

Because of the greater need for dimensional stability with circular saw blade means of cutting (to avoid the blade being 'gripped' or deformed by the log which may result in premature wear or blade overheating) these machines often had some form of automatic or manual log holding device. These, positioned in advance of the main cutting zone, can in themselves create additional hazards (see figure 3). Some were fully automatic in operation, other semi-automatic, some purely manual.

Chain-saw cutting machines may be slightly more tolerant of log misalignment and some log movement, possibly because the nature of the cutting process that 'pulls' the log towards the rear of the machine where it may be 'held' during the cutting process against a surface, although not perhaps as ‘rough’ as the ‘dogs’ found on hand-held chainsaws, as these would probably inhibit the feeding of the log ready for the next cut, after the previous cut.

Figure 3 Log gripper near chainsaw

Figure 4 In-feed pressure plate

Some machines employed a form of automatic pressure plate (see figure 4) which also partially obstructed access to the cutting zone and may assist to some degree with log holding, although in a less positive way as too much ‘pressure’ would inhibit the feed process.

The assessment of safety distances and provision of measures for safety around the cutting zone must take account of any additional log holding mechanisms, particularly where powered or automatic means are employed, as their positioning’ before’ the main cutting hazard can reduce the effective basic safety distance provided by the guarding. Where the log holding device is operated on a hold-to-run basis and the operator has full sight of the hazard zone it creates it may be permissible to ignore the hazard effect from the log holding device in determining guard lengths for safety.

Guidance on to what extent ‘pressure plates’ and their specific design (eg closeness to surrounding guarding) mitigate the ‘safety distance’ as normally defined by EN ISO 13857 should be developed as these may, if properly designed, effectively reduce the ability to reach dangerous parts, and so usefully permit shorter guards for safety (and so enable shorter overall machine lengths while maintaining a high level of safety. However, it is thought unlikely that guards providing a safety distance of less than 650 mm in conjunction with a pressure plate will adequately prevent access).

Splitting issues

Wedge design varies a great deal, some with interchangeable parts, others being moved upwards to present a different ‘cutting’ pattern. All need to be rigidly mounted to resist the ram pushing force. Many are inherently sharp, or need to be maintained as such for efficient machine operation. The weight of some is not insignificant particularly if they are removable for sharpening or just changing the splitting pattern/numbers of split parts.

Many users report that easy drop of the cut log into the splitting zone is not always facilitated by the feedstock being processed, which may be irregular in shape, and this can then result in blockages as out of alignment logs get stuck on the splitting plate (see example in figure 5). Blockages can occur also where feedstock is heavy ‘knotted’, perhaps also if the cut lengths are too long.

Figure 5 Logs jammed around splitter (here a six-way splitter with double rams)

User instructions should deal with the quality of feedstock and issues that may arise, and ways of minimizing problems. In addition to unblocking instructions (mentioned above) details should be given for the safe removal, handling and where necessary tools for manipulating/removing splitting assemblies.

On at least one machines it appeared possible for the ram to keep moving to the end of its stroke even when the adjacent guard was opened (the interlocking only preventing the ram starting, not finishing, movement). The speed of movement of either the splitter or ram, in both cases pushing logs into the splitter that was found varies quite a bit: from 100 mm/s to 600 mm/s. Even at the slower end dangerous movement is much too fast to respond to if caught, which is why broken bones or amputation are common outcomes from being caught in this area.

Rams should be designed to minimise hazards during return, eg to avoid catching debris which might cause a blockage. Also a means of avoiding the hazard from stored energy should be provided so that where interventions are required unexpected movement does not occur. All interlocking should prevent hazardous movement, or guards remain locked until such movement has ceased, and stored energy dissipated, preferably automatically (although a back-up manual means for releasing stored energy may also be required).

Log feeding/discharge conveyors

The feed and discharge conveyors of many machines were reasonably well guarded, although where these folded on occasion there were residual safety issues as they often did not effectively prevent access by other persons (even if safe by position for the operator at the controls). It was noted however on a few machines that the guarding of the undersides of conveyors, in-running nips (eg see figure 2), or associated transmission parts was not effective.

Guarding of all dangerous parts of conveyors and associated transmission drive systems should be effective and meeting the relevant harmonized standards (especially EN ISO 13857 for reach distances). Means of fixing should use retained fixings for all fixed guards where the customer may have to remove them for maintenance. Debris build-up (pieces of bark, chips of wood, soil & stones) may be foreseeable, so means to allow this to preferably 'fall' out whilst preventing access, or be safely removed, may also be required.

Guarding of cutting/splitting zones

The consequences of access in this area because of the cutting and splitting means employed will usually be serious, finger/hand amputation being highly likely, although if inadequately guarded other parts of the body could be at risk (eg foreseeably, a foot in the splitting zone trying to 'kick' a jammed log free). Most machines therefore came with guarding, often interlocked, although of variable quality and effectiveness. However, in-feed and out-feed guards on some machines did not prevent all access to dangerous parts by hands or feet, and the positioning of saws and chainsaws were such that if not adequately safeguarded any person leaning into the machine would be placing their upper body and head into extreme risk of very serious injury.

Some machines had some form of internal guarding when the cutting means was not deployed (saw blades and chainsaws retracting into a housing which also protected them from being knocked and damaged by material being fed into the machine), but at least one incident involved a hand touching a rotating saw as the person reached further into the machine past the saw blade. Some manufacturers of machines employing circular saws claimed compliance with EN 1870-6 for the circular saw part of the machine.

Many machines required some form of one or two hand operator control which by having to hold the controls effectively limited to degree to which the operator could reach into the machine. Whilst this gives some protection to the operator, it does not prevent another person who is foreseeably in the area.

Quite a few machines specified "for use by one person only, keep others out of the way", or similar, and in many cases when working as expected did function without the need of a 2nd or 3rd person. However, it is foreseeable that other persons could be in the vicinity of these machines, especially where the in-feed requires some manual intervention (eg no adjacent log handling table - although a common option for some machines it was not universal), or bagging discharged split product.

Anecdotally operators and other persons have intervened, particularly in the splitting zone, reaching in through discharge area and guarding, and there have been a few reported injury incidents (in one case where interlocked guard failure occurred). Out-feed points are typically lower down than the in-feed to allow for the cut log to drop into the splitting zone within the machine, so easy access may be harder to prevent without substantial guarding which may interfere with the discharge conveyor folding facility. Foot access to 'kick' jammed material may therefore be more possible and foreseeable.

For the principle risks arising from cutting and splitting, where frequent access for maintenance and dealing with miss-feeds (log jams etc) is foreseeable, guarding provided should be interlocked of robust designs that are not prone to failure and suitable for the intended environment of use (so mechanically as well as electrically suitable). Furthermore, safe access to these parts for interventions should be as easy as possible through well designed guarding and interlocking, so as to minimize system modification.

Because of log size the in-feed openings on these machines are typically 400-500 mm wide/high, such that it is not possible to prevent head/part torso access, although most were at a height and 'in' the 'body' of the machine so that to some extent bodily approach is limited largely to hand/arm reach towards the danger zones (cutting, and where fitted, log holding devices). A few machines also employed a 'pressure plate' which prevented head/torso, and to some extent restricted arm/finger, access to danger points.

As stated above in-feed (and out-feed) areas have to be of such a size to permit the processing of logs, so they are larger than the standard 'reach through' apertures for the straightforward determination of safety distances using the key harmonized standard EN ISO 13857 (tables 3-6). Although bodily approach may be limited to some extent by the geometry of the machine and ergonomic constraints on operators (which tables 1-2 cover to some extent), to achieve meeting the objectives of EHSR 1.3.7 that EN ISO 13857 sets out may require a 'C' standard style of interpretation (such has been taken in other machinery fields like packaging, see EN 415-3, where it gives requirements for product discharge apertures over 120 mm in size).

In-feed guards of 800-900 mm length were common on many machines, although a few were shorter than this (several at 500-650 mm, two only 380 & 400 mm in length), particularly if the machine was intended to be carried sideways on tractor 3 point linkage. These shorter guard lengths were inadequate on their own to prevent access to the cutting and, where provided, log holding means. Some came with a pressure plate which may compensate to some extent for guard length – in a couple of cases it was just 650 mm, but with a pressure plate.

It would appear that for most machine of this type (particularly static and towed where length is not inherently constrained) it is possible to fit an in-feed tunnel guard (fixed, or if required, interlocked to permit easy access to the cutting mechanism) of at least 850 mm length from the opening to the nearest danger point (corresponding to the full arm reach of EN ISO 13857, even though on these machines the aperture opening is typically much larger than 120 mm). This is a commonly accepted level of safety for many other machines with not dissimilar cutting, entanglement and trapping hazards, and should represent the 'state of the art' for Firewood Processors.

However, due to machine size constraints (the main one being restricted width for sideways carrying on tractor 3 point linkage), this may not always be possible. In these cases the fitting of a pressure plate on the in-feed which closely matches the profile of the tunnel guard may compensate for some shortening of the guard (around 650 mm being achieved with one such model, such that ergonomically it was very difficult to reach through to the cutting means, so may be considered acceptable). The characteristics of any such pressure plate should be determined (force exerted by spring etc to control its movement, fit closely within surrounding guarding that is designed to accommodate its full movement) to ensure that, in conjunction with the in-feed guard and any other physical protective measures that protect any persons (and not just the operator), the combination does effectively prevent access to dangerous parts.

Moveable guards were common on those machines employing circular saw moving tables. Suitable means to prevent a moving table from moving inwards inadvertently should be provided, perhaps some form of lock (whether one or two hand operation). This may be affected by the potential relationship of the harmonized standard EN 1870-6 which currently can give presumption of conformity to aspects of some circular saw cutting Firewood Processors (see later). Saw guarding should only expose the blade for the minimum period of time necessary, automatically covering the blade afterwards.

Ram speed is such that in most cases hold-to-run as a primary safety measure is not possible for these parts (too fast), and in any case with logs often falling into the splitting zone from the very closely located cutting zone, guarding of this area is required to prevent access to the cutting means too. Whilst the nature of the hazard here is different to the in-feed, the end result if injured may be

as serious (finger amputation to surgically tidy up) as if coming into contact with a circular or chainsaw.

The longest out-feed guard lengths (to the hazard zone created by the leading edge of the splitting wedge) were 600-700 mm long (so significantly shorter than the in-feed). There were many more machines with shorter guards than this (typically 400-500 mm), a few with almost no guarding at all! A few machines had a 'flap', some with 'clear' flexible plastic parts to allow a view, dropping under gravity which whilst in position partly restricted access to the danger zone, and may discourage access. But as these can usually be propped or tied up, or easily reached through, they are of very limited safety value (they can also be subject to wear and damage and removal by virtue of their position in the split log discharge path).

Figure 6 Flap 'guard' on splitter discharge and easy hand reach to splitter cutting edge

Where machine size is not constrained (as discussed earlier) ram/discharge guarding should be at least 850 mm long from the cutting edge of the splitting plate (so overall length taking account of the space for the splitting process may be 1200 mm or more), in these cases the base machine just has to be a little longer. And any stored energy in the ram system should be design be dissipated before intervention is possible, so interlocking which makes safe access easy should be provided. Such guarding probably needs to be 'see-though' so the operator can easily determine if a blockage has occurred.

However, there may be an unintended effect of a longer machine in this area on the way split logs fall onto the usually provided discharge conveyor. If so this safety distance may be achieved instead by extending the guarding up the usually fitted inclined conveyor. These usually fold so any guarding here needs to be designed to accommodate that, yet fill the gaps with the conveyor at all intended inclinations (usually fully flexible and not at fixed points). Or a guard be added to this zone once the machine has been deployed, and interlocked in such a way that machine use without proper fixing is not possible. That may be easier to achieve and realistic with electrically powered machinery than the others.

If not what is acceptable, given that the 'flaps' provided on some machines do not prevent access (see figure 6), are more easily damaged and can be removed or tied up negating their discouraging effect? Jams on the splitting plate are common and the temptation to intervene without following safe systems of work, even circumnavigating existing but not fully effective guards, very high, whether by the operator or other persons who may be working nearby. Merely stating "one person use, others keep away" is no substitute for proper safeguards for a significant risk of finger/hand amputation.

Whilst not fully effective at preventing access to dangerous parts, discharge guards of at least 550 mm ('elbow length', see Table 3 of EN ISO 13857) coupled with good quality interlocking and ease of opening seem practicable in almost all cases (where 850 mm is impossible to provide). Although 'flaps' add little safety value, they could be a useful location for a warning discouraging unsafe access, if of sufficient durability.

While 850 mm may be possible, and considered the 'state of the art' for most machines where there is no physical constraint to length (ie towed or static), it will be a major challenge to the machines carried sideways on tractor 3 point linkages. Typical out-feed guard lengths to danger point here were very short 300-400 mm, and because these are usually tractor powered easy interlocking of a separate guard laid on after machine deployment may be a challenge, unless designed to work with tractor 24V systems and suitable means of stopping (clutch/brake, hydraulic valve). Where a form of mechanical interlocking is possible it should be a minimum requirement, extending guarding to at least 850 mm, with the manual fixing of a guard extending to 850 mm as part of deployment instructions a second best.

Foot access into the out-fed from the splitting zone may be possible due to the splitting zone often being nearer the ground level, and foreseeable if it is possible to easily 'reach' in the 'kick' a blockage. The ability for feet to be at risk in the discharge area needs to be considered and managed. Simple application of EN ISO 13857 may not be possible. Suitable easily used interlocked guarding for the discharge area should be provided, along with explicit instructions for dealing with blockages to minimize this foreseeable activity.

Relationship to EN 1870-6 Circular sawing machines

EN 1870-6 currently gives some presumption of conformity for the circular saw parts of some types of Circular Saw Firewood Processor (although not combustion powered). So the situation is complex and potentially confusing – it was noted that three manufacturers apparent claimed conformity with this standard even though their machines did not use a circular saw as the cutting means! Compliance with EN 1870-6 may not prevent all foreseeable access to the splitting zone, nor inadvertent access to saw blade. The combination of cutting and splitting in a single machine changes the nature of foreseeable access, in part depending on the type of cutting means employed and the way the cutting means is deployed.

It is suggested that to avoid confusion it would be better if Firewood Processors of all types were completely excluded from EN 1870-6 and only covered by the proposed new part of EN 609, which specifically deals with the complete design of the common types of Firewood Processor, including those employing a circular saw, regardless of the means of power employed.

There is currently some uncertainty over the status with regard to Annex IV of the Machinery Directive 2006/42/EC of Firewood Processors employing a circular saw as the cutting means where they are manually loaded/unloaded. This is because certain sawing machines using a circular saw are in scope of Annex IV, and so for compliance must follow particular conformity assessment procedures, the choice of which may depend on the availability of a suitable harmonized standard. This issue is not resolved here, but is proposed to be put to the Machinery WG for consideration, and a decision on interpretation, after initial discussions at the October 2015 ADCO meeting.

Emissions

Wood dust is a known and significant health hazard and certain processes, especially circular saw cutting, may produce copious quantities: chain sawing may produce fewer 'fines', but nevertheless could be a significant hazard. Suitable provision for controlling the hazard from wood dust may be

required, particularly in those machines producing finer dust, eg those employing circular saws as the cutting means.

Combustion powered machinery also generate exhaust fumes, which in addition to creating a risk from their heat, may prove fatal if machinery is used indoors or a similar confined space. Prominent warnings on the siting and ventilation requirements of combustion powered machines, or where this option could be deployed, should be given both on the machinery and in the instructions. Some were in effect 'substitute tractors' transferring power through a PTO shaft which may have implications for any emergency stop function (see earlier discussion on emergency stops).

Instructions for Use

Most machines came with reasonably comprehensive instructions, some employing diagrams to help overcome the language issues. Almost all stated that the machinery was designed for one person use only, 80% with a warning to be used by only one person. However it is known that other persons may be in the vicinity and the measures, especially at the splitter discharge, did not always prevent second person access, so there appears (as with simple wedge log splitters), an over-emphasis on warning of residual risk. This seems less appropriate for these often much larger higher throughput automatic and semi-automatic machines.

Some did not appear to adequately cover connection/disconnection from the power source, around a third did not deal with the hazards presented by feedstock from irregularities (knots, shape, etc).

A few machine instructions did not appear to cover such basics as PPE, testing of safety devices and checking the work area is clean before starting, or not leaving the machine unattended while energised.

No comment is made here on compliance with noise (or where relevant vibration) as these were not part of this project, although, if the findings of the Machinery ADCO NOMAD project reported elsewhere (80% non-compliance on noise information) are to go by, this is likely to be a major issue which manufacturers need to address. However, clearly many of these machines can be very noisy, an inherent feature of cutting wood, and/or from the means of powered them. There may be limits as to what noise reduction is possible (although with guarded enclosures perhaps possibly more can be done than traditionally has), and because of the long duration of worker exposure, noise is almost certainly a very significant risk and must be adequately declared.

Certain instructions and warnings go beyond the basic list given in EHSR 1.7.4 and any standard should define the minimum additional contents of any user instructions. Meanwhile it is suggested that at minimum the following specific instructions over and above the basic list in the Directive are required:

- Power drive parameters necessary for safety (max rpm, PTO shaft guarding, RCD and other electrical protection, safe siting of combustion engines)
- How the safety system work, should be checked, adjusted or otherwise maintained for safety
- Means for effecting a stop in emergency where no traditional emergency stop buttons can be provided
- Full description of residual risk because physical means does not prevent access
- How to minimise second person access, unless this is impossible by inherent machine design
- Minimum and maximum size of logs the machine can process
- Safe means for dealing with 'last' (probably short) part of feedstock
- How to avoid blockages by selecting and feeding material to be processed
- How to safely deal with blockages, including tools or techniques which avoid damaging the machinery and any related safety features

Machines which cut & split in a single operation

There seem to be two key variants on these, distinguished essentially on their cost, which makes one type very attractive to the domestic fire wood user, and throughput, where the higher capacity machines are attractive to 'industrial' processors. Both have a blade which cuts the log to length:

- the larger higher-throughput machine typically uses a spike on a rotating blade, to pre-split the log, which is then cut to length in a single operation (rotation). These are often tractor mechanical power take off (PTO) driven, using the three point linkage for support and movement. They also usually have a foldable conveyor on the out-feed.
- the other smaller lighter and much less expensive machine employs a hydraulically driven cutting blade to cut to length with a side mounted wedge form which splits the leading edge of the log as presented to it (so similar to the simple wedge log splitter, but cutting to length at the same time).

Rotary split and cut machines

These machines are typically tractor powered and mounted, with mechanical PTO shaft directly driving the rotating cutting blade which incorporates a spike for splitting and cutting the wood to length in one process (see fig 7). One example had a powered in-feed conveyor, the others were manually fed (with potentially significant manual handling and operator hand/finger safety issues). All seen had inclined discharge conveyors (see figure 8). Typically they can process material with speed with throughputs that may be higher than the other machine design already discussed, although limited to a 'single' split.

Figure 7

Figure 8

Many of the issues with regard to stability, transportation, power/energy, interface with fed tables and conveyers are the same or very similar and so are not repeated here. The main new issue with this design appears to be related to the in-feed and guard design to safeguard the obvious and if exposed, unavoidable danger, and the potentially high frequency of approaching danger. One of these machines claimed conformity with EN 609-1 which was inappropriate as that standard is for a completely different type of machine.

Ergonomic and other handling issues from manual loading

The basic design of the manually fed machines is such that when presenting the last piece of a log the operator's hands may closely approach the danger zone. Again, because of log size and the need to be able to present the log easily, the fed aperture tends to be quite wide and deep, even though it reduces further in (see later for details). Log size and length (effectively only limited by length of trunk) can be such that they present a significant manual handling risk. Feed height also affects this risk, obviously if too high it is unnecessary extra effort. Although a lower feed height reduces lifting, if too low the operator will be forced into unnatural crouching or leaning postures which are as undesirable.

Tractor three point linkage mounting offers the possibility of adjust the feed height such that where there is no feed table it can be optimised for the particular operator. But this may require supplementary adjustable means of supporting the machines load to ensure machine stability as presenting a log to the machine may impose dynamic loadings. Non-tractor mounted manually loaded machines should be provided with suitable means to adjust the in-feed height to optimize the ergonomic aspects for the operator, or provided with a means of feed (eg a table, which could be inclined) that overcomes this issue. Alternatively, powered in-feed mechanisms could be employed (see later), provided their inherent hazards are managed and the interface does not introduce other risks. Mechanical loading is preferred to reduce the operator handling load, which may be considerable due to the high-throughput nature of these machines.

Control System Safety Performance

The speed of rotation is such that should fingers or hands be exposed to danger (which appears a real possibility with the manually loaded designs) there would be no chance of avoiding serious irreversible injury. Frequency of access is potentially high, at the last piece of each log, such that a crude analysis of Performance Level from EN ISO 13857 would be PL e**.** It is highly desirable for such basic machines to try to manage this down to something more reasonable and realistically achievable by following the principles of EHSR 1.1.2.

Those machines which are conveyor fed avoid frequency personnel access towards the danger zone (so may only need PL c), and as stated above may also have other ergonomic benefits**.** Frequency of exposure can be reduced by design where manual loading takes place, but only essentially though distancing the operator (and others who may be in the vicinity) from the risk by effective guarding (see below).

Cutting & Splitting Zone

The in-feed on these machines is typically guarded by a '2 sides and top' guard of about 600 mm length, around 500 mm wide at the outer end with a smaller support plate 'directing' material placed here and pushed in to the split/cut zone (see 1st sketch diagram in Figure 11 below, and Figure 9). The entire guard is located around 800-1000mm from ground level, and fixed in position (doesn't seem to need to be routinely removed). Logs are manually fed by lifting and holding with both hands, and pushing in against an adjustable length stop behind the rotating spike/blade to determine cut length. Log parts once split and cut to length fall, usually onto the lower edge of an inclined conveyor for discharge.

Figures 9 & 10 In-feed guard & support roller, easy access to rotating spike/blade!

Most of the guarding seen to date does not prevent access to the obvious danger zone where amputation of fingers/hand or depending how far you reach in, lower arm, would be the foreseeable consequence. Additionally the slots seen in at least one guard close to the danger zone did not meet the harmonised requirements of EN ISO 13857 (eg see figure 10). Any such apertures in this guard should strictly meet the relevant reach through aperture size for the safety distances they afford, as determined by tables 3 and 4 of EN ISO 13857.

It is not known what the accident history is, but the short length of guard and no lower constraint coupled with wide and high in-feed aperture means that particularly shorter stature or longer-armed operators could reach well inside and up into the dangerous moving parts. Even at the traditional 850 mm length, because of the 'thrusting' nature of the feed operation and wide aperture, which may not constrain access at the lower edge, this basic safety distance may not be a sufficient to prevent accessing the danger zone and sustaining injury. As with the other machines already discussed, aperture size is such that simple application of EN ISO 13857 for reaching into the machine is not usually possible.

A support at the lower edge of the opening into the cut/split zone appears necessary to help guide manually loaded logs which may be of any length and so of considerable weight. It would not seem unreasonable that this lower support be extended further out (along with the guarding) so as to constrain access by the lower body and better limit the extent of reach by hands/arms when feeding in logs. It may be that the leading edge of such a support would need to be formed of a rotatable cylinder of some diameter to more easily allow logs with inherent roughness and projections to be 'rolled' over and into the machine (such projections are already overcome in some way, eg by twisting/lifting, with the smaller existing support plate, but facilitating this may reduce handling risks).

What should the state of the art' for guards on these machines be for the manual in-feed? It may not be practicable to comply with table 2 (high risk) of EN ISO 13857. So what should the in-feed guard length be? It is suggested that a guard length of at least 1100 mm is required (so another log or push stick/device may be required to push the residual stub of the last log in if cutting to short lengths), which is fully enclosing, with a defined maximum aperture width/height, and a lower edge/plate constraining upper body access and helping to guide the log in towards the processing zone (such as illustrated by the sketch diagram in Figure 12 below), because in theory more than arms can enter the guarded zone.

Figure 11 Example of current in-feed guard

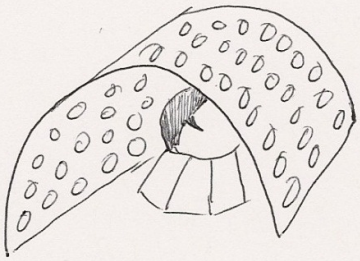
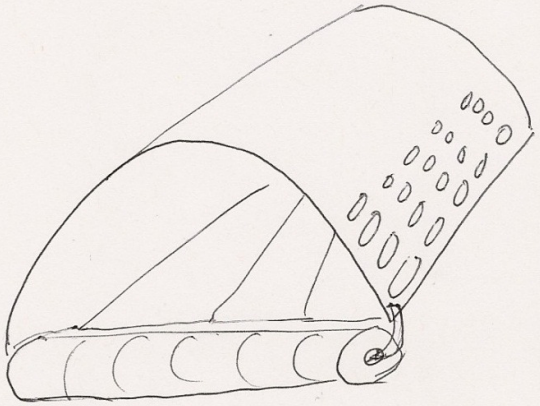


Figure 12 Possible improved design



In the case of conveyor fed machines the need for manual access is lower, although at the in-feed still foreseeable in cases of miss-feeds, so a high standard of protection is still required. Additionally the feeding of a large log in may create a hazard between the log and the guard itself so in-feed guards may have to be significantly larger than the largest log size, which may be exacerbated by projections on logs.

EN 349 would suggest adding 120 mm all way round on three sides to give clearance for a hand/arm, so the guard aperture, at least at the in-feed end, may need to be 240 mm larger than the largest log diameter.

One example seen had a conveyor in-feed with tunnel guarding eliminating the potential for hand/arm access, although may present issues with poorly 'dressed' feedstock fouling on the in-feed guard (Figure 8).

Out-feed

Regarding the out-feed (see figures 13 & 14), the design and guarding is similar in nature to the other sequential Firewood Processors, fixed guarding not preventing access (and this is an area to some extent not necessarily in the operator's line of sight, who because needs to use both hands for log feeding cannot easily stop the machine – in fact the stop position may be inside the tractor some distance away). Substantial improvements appear necessary to the guarding here, along the same minimum lines as for the other mechanical driven firewood processors because of the folding nature of the out-feed conveyors, and their potentially low position.

Figure 13 In-feed conveyor with tunnel guard

Figure 14 'Flap' on entry to discharge Conveyor not prevent access to danger

Guillotine style cut and splitting

These machines are typically slower and less heavy than the rotary tractor powered ones, many being little more than a lightweight frame/table feeding through to a vertically mounted hydraulic ram to cut logs to length (Figure 18). What distinguishes them from wedge type log splitters is that the wedge is integrated with the cutting blade, see figure 19 below (the wedge may be on one or both sides of the blade). They may have wheels to enable towing or moving them 'in-line' and can be of relatively low cost, so more attractive to private users (some €1500-2000).

Many traditionally did not have any guarding even though were operated by one hand on a hold-to-run basis, the second hand being used to hold the log (see Figure 20 was taken from one manufacturer's website). Although these machines are not dissimilar to wedge type log splitters (see EN 609-1), in that they have a vertically orientated hydraulic ram, their function is more than splitting and the horizontal nature of the log means that the danger zone is more exposed, and less appropriate for two hand control.

Ergonomics issues

Many of these machines, which are manually loaded, have rollers to assist with log in-feed. So the main issue is the height of the feed 'table', not too high to require excessive effort or make access to the cutting zone easier, but high enough to avoid 'stooped' loading and provide enough split log fall distance. This 'fall distance' will affect any guarding fitted to the discharge side as for any guard and its 'skirt' to prevent most access to the blade cutting zone, there still needs to be sufficient residual height for a small pile of logs to accumulate.

Control System Safety Performance

These machines tend to have simple systems, a motor driving hydraulic pump which operates the ram controlling the movement of the blade. High integrity two-hand control appears unrealistic with such simple machines, and with frequent foreseeable hand access on the feed side to hold logs the risks are such that dangerous contact should be prevented by design, preferably with fixed guarding (which would keep costs down).

Performance level PL c appears reasonable practicable. In most cases a form of emergency stop seems practicable and should be fitted. However, if operated by hold-to-run control (stop, not retract) with adequate in and out-feed guarding, an emergency stop may not be necessary on the simplest machines. If ram movement is never more than 10 mm per second on a hold-to-run basis and the operator has full sight of the entire danger zone, guarding may not be required. Means of preventing gravity descent of the hydraulically powered blade should also be provided.

Cutting & Splitting Zone

The danger from the moving blade is obvious and recent Swedish market surveillance authority action has been taken against a number of manufacturers who have as a result fitted fixed tunnel guards. In most cases interlocking does not appear necessary. Even full two-hand control to EN 574 (which is unlikely given the relatively low cost of these machines) is not considered appropriate because fixed guarding is generally practicable and in any case it would not protect other persons (including family members of private users) who may foreseeable be nearby or assisting with split log removal.

Although the in-feed aperture size is likely to be greater than 120 mm (the limit in EN ISO 13857 for simple safety distances for reach through apertures), the traditional 850 mm safety distance appears practicable at the in-feed in conjunction with fixing these tunnel guards in position. Short material can be pushed through using a 'pusher' tool. 'See-though ability' is almost certainly necessary on the in-feed side, at least for the upper part of the guard, so perhaps the lower parts should be smooth 'plates' as projections from logs may catch on mesh etc and cause obstructions.

However, at the out-feed is different in that there is nothing to prevent reaching up and under towards the rear of the blade. Whilst log jamming on the blade may be released by the blades' upward movement (assuming the machine has features to assist this happening without operator intervention), this is also an area where split logs fall and may accumulate, and foreseeable second person access occur (eg to remove and stack split logs).

The out-feed aperture by necessity needs to be sufficiently large to allow split logs to move and drop away, perhaps to form a small heap. Provided the vertical end of the guard is 'closed' could the out-feed guard be shorter than 850 mm? The dimensions (width and depth below the feed table level) of guarding required to minimize risks and yet allow split products to clear, given that these machines may be used by family members less aware of risk, would need to be carefully analysed to maximize safety, as it may be impossible to prevent access to danger without an full exit 'tunnel'. Too much depth will interfere with log clearance, too little will not adequately prevent or restrict access by reach under and up.

A flat or gently inclined exit table with an enclosing 850 mm long tunnel guard with closed sides/top so material doesn't catch and obstruct appears to be possible at the 'state of the art' for the discharge on these simple machines. Such a tunnel guard fixed in position is likely to be more robust than the type of mesh guard seen.