Broad Lane, Sheffield, S3 7HQ
Telephone: 0114 289 2000
Facsimile: 0114 289 2500

HEALTH & SAFETY LABORATORY

Stability of stacked logs

P K Swift, I.Eng, FIMinE and B Roebuck, BSc

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Project Leader: P K Swift

Engineering Control Group

HEALTH AND SAFETY LABORATORY

An agency of the Health and Safety Executive

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Summary

Objectives

The Health and Safety Executive intend to provide guidance for the timber processing industry for the safe storage and movement of logs. Logs are stored in stacks both in the vicinity of the area where they are cut and at sawmills. This report is concerned with the timber once it is at the sawmill. The Health and Safety Laboratory was asked to conduct a survey of a variety of sawmills to determine current practice, to identify both good and bad practice and to identify the factors which affect the stability of log stacks. The project would produce recommendations for best practice, including alternative methods of stacking, whilst taking into account the variation in risk at different types of site.

Main Findings

1. Much of the advice in HS(G)172 remains relevant and it defines good practice for log stacking, particularly in areas where pedestrians are likely to be at risk from log stack collapse. A risk-based approach, however, shows that the most effective control measure to reduce the risk of injury from log stack collapse is to restrict pedestrian access to log stacks and their immediate area. The survey found that this was done at many of the sawmills visited.

2. No examples were found where derrick cranes were used to move timber. The most common method seen was the use of wheel loaders with grab attachments which were used to lift several logs at once. Generally, this was thought to be the safest method of stacking, destacking and transporting logs, primarily because it eliminates the need for slinging and therefore the need for workers to operate in the vicinity of the log stacks.

3. Log stacks should not normally be higher than the length of the logs which they contain. Stack height should also be limited by the height from which the grabber can take logs from above the stack and by consideration of the safety of the grabber driver. This would normally limit stack heights to 3 m to 4 m. The maximum stacking angles recommended by HS(G) 172, 45^{O} generally and 35^{O} in pedestrian areas, should be implemented more widely.

4. There are a number of other factors which may increase the risk of a stack collapsing, including:

- sloping ground, which could result in logs sliding from a stack or rolling down the slope;
- debarked logs, which may be slippery, particularly if they are recently harvested. Extra care should be taken when transporting debarked logs which may slip out of a bundle;
- logs stacked with their butt ends to one side of the stack so that the angle across the top of the stack is likely to cause logs to slide off. Particular care needs to be taken if the logs are also debarked;
- logs stacks stored on soft ground may sink into the ground on one side and could become unstable.

Where these additional risks are present, consideration needs to be given to reducing the stack height or to preventing movement of logs, for example, by containment in bunkers or by using stanchions.

Recommendations

1. Log storage areas should be separated from both pedestrian and vehicle routes to reduce the risk of persons being in the area in the event of a log stack collapsing.

2. Wheel loaders with grab attachments should be used to stack and destack logs. This should eliminate the need for workers to climb onto log stacks.

3. Stack height should be less than the log length and compatible with the methods of stacking and destacking. Normally this will limit stack heights to 3 m to 4 m. Stacks should comply with the maximum stacking angles recommended by HS(G) 172, that is, 45^{O} generally and 35^{O} in pedestrian areas. If other risk factors are present, including sloping ground, debarked logs, soft ground or logs stacked with butt ends together, then consideration needs to be given to reducing the stack height further or to controlling the risk by other methods, including containment of the stacks in bunkers.

4. Where separation of persons and log stacks is not possible then the guidance given by HS(G) 172 must be used to control the risk of stacks collapsing. Specifically, stacking angles should not exceed $35^{O}$and wedges should be used to fix the logs at the front of stacks and prevent them from rolling. Good control of other risk factors, as identified, should also be expected.

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1. INTRODUCTION

The Health and Safety Executive intend to provide guidance for the timber processing industry for the safe storage and movement of logs. Logs are stored in stacks both in the vicinity of the area where they are cut and at sawmills. This report is concerned with the timber once it is at the sawmill. The Health and Safety Laboratory was asked to conduct a survey of a variety of sawmills to determine current practice, to identify both good and bad practice and to identify the factors which affect the stability of log stacks. The project would produce recommendations for best practice, including alternative methods of stacking, whilst taking into account the variation in risk at different types of site.

2. BACKGROUND

In considering the safety of a log stack, it is necessary to consider both the risk of the log stack collapsing and of the likely consequences if the stack does collapse. If, for example, the stack is in an area which has no pedestrian access and has a system of work which results in a low risk of injury to the driver of the stacking/destacking equipment, then the overall risk of an injury resulting from the collapse may be low. In these circumstances, a higher risk of the stack collapsing may be tolerated than in an area where there was regular pedestrian access. This means that the layout of a sawmill site, how the layout limits access and the system of work used for stacking/destacking may be of overriding importance in assessing the risk of injury in the event of a log stack collapsing.

A primary source of guidance on safety at sawmills is the HSE publication 'Health and Safety in Sawmilling', HS(G)172. Some of the advice on log stacking is as follows:-

- The storage area should be level, capable of supporting the intended load and be adequately drained. Bare earth may not meet these requirements.
- Uniformity of size, quantity and state (i.e. raw or debarked) of timber to be stacked need to be considered.
- Each log should be placed in the saddle created by two logs below.
- Specific advice on the shape of pyramid stacks is that the angle of the slope at the ends of the stack should not exceed 45° if pedestrians are prohibited from the area and 30° if pedestrians are permitted.
- Wedges with a minimum angle of 35° should be placed against the end log at ground level.
- The largest logs should be placed at the base of the stack, carefully securing the bottom layer with substantial wedges.

HS(G)172 draws on detailed guidance on log stacking from advice produced in 1981 by HGB, the Employers Liability Assurance Association for the woodworking industry in what was then West Germany. The advice in HS(G)172 is still relevant in that it defines good practice for log stacking, particularly in areas where pedestrians are likely to be at risk from log stack collapse. A literature search carried out by HSE's Information Service produced no further publications covering the stability of stacked logs or methods of stacking logs

HSL were supplied with a list of 63 accident reports from HSE's MARCODE database in the period 1986 to 1996. The reports had been retrieved using keywords *stack* and *struck by*.

Only one of these accidents was associated with logs, however, most of the remainder being associated with stacks of sawn timber. In this case, a log had rolled from a stack causing the employee to suffer a broken leg. A later search updating the data for the period to January 1999 produced no further incidents involving log stacks. Other incidents involving collapse of log stacks are known to have occurred pre-1985, including fatalities and a serious crushing injuries. Two involved children climbing on stacks when they collapsed. Two occurred when the stack was disturbed, one by placement of logs on the stack and one by a passing truck. Again, the first of these involved an employee standing on the stack. The final incident resulted from a log which had been propped against a stack toppling over. Clearly, persons climbing on log stacks are at risk, as are persons close to log stacks when vehicles are in the area. Fencing of stacking areas to prevent public access also seems to be advisable.

3. VISITS TO SAWMILLS

Seven sawmills were visited in Scotland. Their principal product was sawn timber from Scottish-grown softwood and was mainly used for pallets, fencing, shed timber and a small proportion for construction purposes. The sawmills ranged from highly automated factories with an output of thousands of tons of sawn timber per week to small sawmills with three or four employees producing only a few tons of sawn timber per week.

One of two sawmills visited in England produced only sawn hardwood, mainly from imported timber. The other produced a mixture of sawn soft and hardwood, the hardwood being primarily English oak.

Sawmills vary in size and the throughput can vary from a few tonnes per week to around 20,000 tonnes per week. In the softwood industry log diameters vary between 150 mm and 600 mm. In the hardwood industry, logs can be up to 1.5 m in diameter.

Specific observations of the significance of the various factors affecting the stability and safety of log stacks are summarised below.

3.1 Delivery and storage areas for logs stacks

With a high throughput of timber logs, large softwood mills prefer not to store logs at all. Logs can be loaded into the mill directly from the incoming transport, which often incorporate their own hydraulically operated loader with a three jaw grab, see Figure 1. This type of equipment eliminates any need for manual intervention, eg, for slinging, or for workers to climb onto the delivery vehicle.

In practice, some timber will be stored over the summer months for processing later in the year. Harvesting is not always practical during the winter when freshly cut timber can freeze. The photograph in Figure 2 was taken at a medium-sized sawmill in July and it can be seen that there is room for considerably more timber. This site was well away from normal pedestrian routes and access was only needed by the delivery vehicle and the wheel loader user to carry logs within the site. This represents good practice. The type of stacks, as on most sites, were of the pyramid type with logs stacked unrestrained, largely with upper logs sitting within a saddle produced by two lower logs. It is also evident that stacking angles of 45^{O} and lower were generally achieved. In one case, logs which had been mechanically sorted were stored in concrete bunkers prior to being moved on to the next stage of processing. Where pedestrians could otherwise be at risk, the use of bunkers to restrain log stacks might be considered, where it is practicable.

Figure 3 shows an example of the storage area at a mill where the storage area was limited. Heavy duty fabricated steel posts had been set into concrete adjacent to a boundary fence along a public road, Figure 4, in order to increase the storage capacity. This allowed logs to be stored safely up to approximately 3.5 m high, adjacent to the fence, even though the mill faced a row of houses, Figure 5. Conditions inside the mill were not so good. There was one entrance and one exit from the mill with the log stacks bordering the connecting driveway between the two. As a result, employees and the public alike had to pass by the log stacks. Customers were observed leaving their vehicles parked in front of the logs stacks. A wheel loader with grab attachment was used to move logs, Figure 6, and was also working in the area. In the author's opinion, the consequences of the collapse of a stack at this site would be severe, requiring a high level of stack safety.

3.2 Ground conditions

The ground should be level, capable of supporting the load and be adequately drained. A properly constructed hard standing area is ideal because it will remain level in all weathers. Nevertheless, perhaps for financial reasons, bare earth is commonly used, particularly by smaller sawmills. The consequence can be severe rutting caused by the movement of lorries and lifting equipment, as illustrated by Figure 2, and this is likely to result in uneven and sloping storage, particularly in wet conditions. In these circumstances, the height of a log stack may need to be restricted to keep the ground pressure low and to ensure a margin of safety for stability against leaning of the stack.

Where there is a significant slope, risks resulting from logs rolling down the slope from the front of a stack or from logs sliding sideways from the stack need to be considered. Terracing to produce flat areas could be an option.

The centre of gravity of a stack may not be along the longitudinal centre line of the stack due to the distribution of the position of the butt ends, the flared out base of the trunk. Logs stacked on soft ground can therefore become unstable with time if the stack sinks into the ground on one side. The surface of the stock yard shown in Figure 7, was of soft, muddy ground. The logs were well stacked, but the stack was too high (around 6 m) for the ground conditions and the mill was arranging for the supplier to return and re-stack the logs. Most stacks at this mill were stored at a height of no more than 3 m to 4 m. These stacks were stable and the height limit appeared to result in a sufficiently low ground pressure such that the logs were less likely to sink into the ground and become unstable. The operator had obviously recognised that the ground under the stack in Figure 7 was sloping and some bearer logs had been placed longitudinally under the first layer of logs at the low side of the stack.

Although soft ground is not ideal for log storage, the likelihood of the front logs rolling away from the front of the stack may be lower than with a stack placed on hard standing. The main risk is of the stack tilting sideways or of movement causing logs higher in the stack to roll. The need for good control of stacking angles is clear.

3.3 The use of wheel loaders with grab attachments

Wheel loaders with grab attachments, Figure 6, are commonly used to move logs within a mill. They are said to have replaced derrick cranes, largely because of cost savings. They have the added advantage of removing the need for slinging or for workers to climb onto stacks. Their use has also placed limitations on the way in which logs are stored. Irrespective of safety considerations, the limited reach of wheel loaders means that stack heights cannot be generally greater than approximately 4 m if the logs are to be removed from above. Operators preferred this method of removal, but logs can also be taken from the base of a stack as shown in Fig ure 8. The logs further back and higher up in a stack tend to fall down the slope as the front logs are removed. This is quite acceptable if the stack is not too high, but the stack nearest the camera in Figure 8 (and also shown in Figure 9) is nearly six metres high and a driver and machine withdrawing logs from the bottom of the stack would be at risk from logs cascading down the slope. Although the use of wheel loaders has considerable safety advantages, their use must be accompanied by a stack height limit which allows the driver to remain safe in the event of a cascade of logs down the front of the stack. A maximum stack height of 3 to 4 metres is considered appropriate.

3.4 Stacking angles

Stacking angles can only be safely controlled by mechanical means and is best done from above, so that both people and equipment are out of harms way if logs roll down the front of a stack. It is forseeable that this will happen and the system of work should take this into account. Good practice should enable the operator to place or select a load in a way which leaves the stack safe, ie, with an angle below 45^{O} in storage areas, or 35^{O} in areas where pedestrian access is allowed. If the operator has doubts about the safety of a stack, he should be able to disturb the front of the stack to produce a shallower stacking angle.

An example of an unsafe stack can be seen in Figures 10 and 11. The stack on the left of Figure 10 is nearly 6 m high and the angle at the front of the stack, Figure 11, is much greater than 45^{o}. The logs in the stack on the right of Figure 10 are also poorly stacked. At the lower end of the stack, not only is the angle too steep, but, as seen in Figure 11, there is at least one log which is only just locked into the stack. If it became dislodged several other logs from above could roll down the front of the stack.

The mill in Figures 10 and 11 was small and did not own a wheel loader. A fork lift truck was used to transport logs from the stacks to the mill. With the truck at the side of the stack, the forks were used to free off a few logs from the top of the stack, having first placed some logs at the front of the stack against which freed logs would roll. The fork lift truck then went to the front of the stack to pick up the logs. Use of a fork lift truck to remove logs from a 6 m stack is virtually impossible without putting the driver at risk, mainly because of the size of the truck relative to the stack. Using a fork lift truck to pick up and transport logs on a rough surface is also not good practice unless they are lashed onto the forks. It was also noted that one of the stacks was directly in front of the gates into the mill from the public road. In addition workers at the mill were likely to pass close to both of these stacks because of the restricted storage space.

3.5 Wedging

HS(G)172 recommends that the front of log stacks are wedged to prevent the front logs rolling and resulting in a cascade of logs. We support this guidance for situations where pedestrians may be at risk, but in some situations we consider it unecessary and a possible risk factor itself. At some storage areas, as seen in Figure 2, soft wood log stacks can be very long. Re-wedging every time logs are removed from the front of a stack would create a greater hazard for the person doing the wedging than allowing the stack to settle into its own shape as the shovel loader withdraws from the stack, particularly if the loader operator leaves a satisfactory stack angle. As long as log stacks are remote from pedestrian routes, the use of wheel loaders largely negates the need for pedestrians to be in the vicinity of stacked logs. It is therefore considered that, if a log stack has an acceptable height and stacking angle, it does not present a significant risk when a shovel loader is used to take the timber from the stack. Where there is pedestrian traffic at the front of stacks, wedging will significantly reduce the risk of stack collapse.

3.6 Surface condition of the logs

Harvesting wood in the rapid growing season in the spring, when the bark can be easily removed from the trunk during the harvesting process, can result in the slippery sap wood being exposed. This freshly cut timber can be a hazard even on low stacks. Lubrication from the sap can allow logs to be displaced easily, as appears to have occurred to the logs in the stack in Figure 12. Debarked timber consequently increases the risk of log movement within a stack and is a particular problem if other risk factors, such as slopes across the stack, are present. In circumstances where pedestrians may be present, lower height limits, wedging and other protective measures would need to be considered.

3.7 Stack construction

HS(G) 172 suggests that logs in a stack should be of a uniform size and that each log should be placed in the saddle formed by logs below. For logs with large diameters, eg in hardwood timber yards, this advice holds good. In softwood mills, however, logs are unloaded and stacked by moving several logs at once in a grab. It is not economically practical to sort logs into a range of diameters and stack by diameter, ensuring that the logs are 'placed in the saddle formed by logs below', however desirable this may be. Logs are generally placed as well as they can be and effort is taken to try to ensure that the logs are placed parallel to one another. Figure 13 is a typical example of the distribution of log diameters found in softwood stacks during the survey. It is inevitable that the diameter of logs will vary between 150 mm and 500 mm, this being the typical change in diameter of the trunk of a tree between the base and the smallest diameter that will be useful to a sawmill. In these circumstances, the risk must be reduced either by isolation of the stacks from people, or by limiting the risk of collapse in other ways, for example by strictly limiting stack height and angle and by wedging.

In HS(G) 172, the maximum stack angle recommended is 35° when pedestrians can go into the vicinity of the log stacks and 45° when pedestrians do not normally frequent the area. The end of a stack will be naturally at 45° if the logs are of similar diameters. A mix of diameters of logs inevitably leads to a natural stacking angle greater than 45°. It is only possible to reduce this either by carefully sizing successive rows of logs to have reducing diameters up the height of the stack (as shown in diagrams in HS(G) 172) or by reducing the mean angle at the end of a stack in a succession of steps, some of which will be steeper than 45°. The latter method is acceptable and was the most common situation seen in the survey.

In practice, the logs will initially find their natural nesting position, depending upon their diameter and surface condition and of those against which they nest. This is particularly true when a wheel loader is being used to move logs in the mill. Some logs may also be crossed and, as Figure 13 shows, at some positions spaces may occur which could result in later, internal movement of the stack. Such movement is most likely to occur when the stack is disturbed, either when logs are added or taken away. It becomes necessary for the operator of the stacking/destacking machine to ensure that the stack is left in a safe condition. This will largely be a matter of judgement but the issue of guidance on this, eg for training purposes, should be considered. If a stack is not considered safe, it is assumed that the machine operator can safely disturb it to produce a safer condition.

3.8 Orientation of the logs

The inherent shape of a log is that it tapers from the base, or butt end, to the top. In the case of softwood logs, the change in diameter can be of the order of 2 to 1. Logs are normally stacked at a sawmill by the supplier and are usually unloaded by an hydraulic boom-mounted grabber with a rotary facility. Logs will normally, therefore, be orientated randomly in a stack.

Randomly built stacks tend to remain level across the width of the stack as the height increases. The changes in diameter will also cause a locking action which will help the stability of the stack. It is often to the advantage of the mill, however, if the timber is stacked by the supplier with butts to one side only so that they are correctly orientated for feeding into the mill. The logs will nest well with each other and the stack would remain reasonably level across its width if the stack were allowed to curve as it got longer. It is more likely, however, that the stack will be maintained straight. This type of stack will slope increasingly in the lateral plane as the stack gets higher and logs at the top will be at a greater risk of sliding off. Hence, straight stacks with butts to one side should not be built as high as randomly built stacks if there is any risk to pedestrians in the area. The height limit will depend on the change in diameter of the logs along their length. We suggest a maximum height limit of 2 m. Alternatively, logs sliding off the stack could be accepted and an exclusion zone produced on the low side of the stack to reduce the risk. The risk would be particularly high if the timber were debarked.

Stacks of long logs will contain a high proportion with butt ends. This can result in a severe slope to one side of the stack, even if it is only moderately high. An extreme example of this can be seen in Figure 14 which demonstrates how this can result in the logs tending to fall down the slope (particularly freshly harvested debarked logs). Many of the logs in the stack shown in Figure 7 also have the butt ends to one side of the stack. This stack consists of logs 3 m long stacked to 5 m high.

3.9 Log length

The stability of a log stack can be significantly affected by the uniformity of the length of logs, particularly if shorter logs are to be placed near the base of a stack. It is therefore important that, within reason, all logs in a stack are of similar length. This was generally found to be adhered to.

A stack of very short logs will be less stable than a similar height of longer logs. A useful way of overcoming this is to stack short logs side by side and intersperse the shorter logs with longer logs which act as ties. Figure 15 shows a short stack of oak logs where this has been done.

3.10 Stack height

The height and width of a timber stack (dictated by the length of the logs) affects its stability. For a given width, the stability of a timber stack reduces as the height increases. Experience suggests that the height should never exceed the width when the stack sides are not supported.

This would, for example, suggest a height limit of up to 6 m for logs typically 6 m in length. However, stacks seen in this survey were rarely carefully constructed, particularly where 7 stacks were built using wheel loaders. Normally several logs were placed together, rather than individually, resulting in untidy and therefore less stable stacks. Taking this together with the height limit of 4 m if logs are to be removed from the top of a stack by a wheel loader, a height limit of 3 m to 4 m appears reasonable for unwedged stacks. The height of a stack may be determined more by the available storage space and the maximum practical height relative to the method of mechanical handling than considerations of stability. If it is necessary to make a stack higher than the length of the logs, an alternative means of ensuring the stability of the stack should be used. Use of bunkers or stanchions are possible solutions provided both the risk of logs rolling off the front of the stack and the risk of logs sliding from the side of a stack are considered.

For stacks of large diameter logs, careful building of the stack will be necessary and individual placement of logs should ensure proper nesting. Provided that stacking angles are within the limits recommended by HS(G) 172 and that wedging is in place, heights above 4 m may be acceptable.

3.11 Hardwood sawmills

Two mills which deal in hardwood products were visited. The size of timber, the method of timber storage and the throughput at one of these mills did not differentiate it from the softwood sawmills.

The other sawmill primarily used imported hardwood, much of which was larger in diameter, up to 1.5 m, Figure 16, than most soft wood timber. The timber was also likely to be nearer to a circular cross section than soft wood. In addition, the throughput of timber was much lower. The size and value of the timber meant that, rather than the timber being picked up in bundles of logs by a wheel loader, individual logs were moved and placed on the stack. There are other differences with high value hardwood. It normally comes debarked because of transport and bulk costs, and the logs are less likely to have large surface irregularities where branches have been cut off.

Hardwood logs therefore present a greater hazard due to their large diameter, high mass and more regular shape, which is smooth and without significant irregularities. The stacks, however, were more carefully constructed, usually wedged at the front of the stacks and logs placed individually. There were, nevertheless, significant examples of poor practice as shown in Figure 16 in which the end two columns of logs in the stack are badly nested with each other. The angle at the end of the stack is in excess of 60º despite the stack being next to a roadway.

The stack in Figure 17 is an example of what appears to be a reasonably well built stack. The end logs are at an angle of approximately 45º due to their diameters being similar, and they are well nested and wedged. However, as the stack is next to a roadway along which pedestrians pass, the stack still falls outside the guidance given in HS(G) 172.

4. OTHER RISKS

4.1 Moving the logs in the stock yard

When a bundle of logs is picked up from a randomly built stack, i.e. with the flared out butts at either side of the stack, the jaws of the shovel loader should ideally be positioned on the centre of gravity of the bundle so that the bundle will sit level on the jaws and the tendency for looser logs to fall out sideways will be minimised. This is a particular hazard if the logs are partially or wholly debarked, Figure 18. Debarked timber is more slippery and is more likely to be displaced sideways from the side of a bundle.

When butts are at one side of the stack, the logs will be less likely to fall out of the bundle if the jaws are positioned nearer to the butt end of the bundle so that there will be a tendency for the butt ends of the logs to lock together Care needs to be taken to ensure that this is done.

4.2 Loading logs into the mill

As well as loading softwood logs into the mill with a delivery lorry's own grab, a mill may also utilise similar hydraulically operated lifting equipment attached to the mill loading deck. In Figure 19, logs are shown being fed into a mill using a mobile grabber. The grab on the left of Figure 19 is part of the mill machinery. It is used to orientate the logs with all the butt ends to one side, but it can also be used to feed the mill from the pile next to the conveyor as shown in the photograph, or from a lorry. When logs are fed into a mill, they are usually orientated so that the butt ends are to one side.

With a high throughput, timber must be dealt with quickly and effectively. An alternative way of feeding a mill can be seen in Figure 20, where a wheel loader is feeding the mill with logs. Bundles of logs can be accurately placed onto the deck with the logs well nested together. This type of vehicle is very commonly used to feed logs into mills and has superseded the use of derrick cranes at many mills. It can be seen here how the forks are well over the log deck so that the logs can be dropped onto the deck with ease. By comparison, the log deck at the mill in Figure 21, is too high and it has been necessary for a short ramp to be built to raise the height of the front of the wheel loader. Space restrictions on the site meant that the level area at the top of the ramp was shorter than the wheelbase of the loader. When loading onto the deck, the vehicle was therefore at an angle to the deck and the forks had to be dragged from under the logs to release them. The driver reported that logs (particularly slippery logs, freshly cut in the summer) could fall off the deck as they were being deposited and hit the framework of the hydraulic equipment of the wheel loader. This situation had arisen because the deck was part of an old installation which was not intended for the loading of logs into the mill by a shovel loader. A similar situation could arise if a wheel loader operator was making a stack higher than the jaws of the vehicle could sensibly reach.

5. SUMMARY OF IDENTIFIED HAZARDS AND RISKS

Logs will always present a hazard. Even at ground level, a rolling log can cause injury to people in the vicinity. The greater hazard results, however, from logs at height from the ground and their potential to cause serious injury and even death.

5.1 Log stacks

Risks associated with log stacks can be minimised by recognising the factors which increase the risk of them becoming unstable and understanding how these risks can be minimised. The following risk factors have been identified:

- **Layout** - good planning can remove or limit the need for pedestrians in the log storage area. Log stacks should be away from site entrances and exits. Traffic routes for log movement should be as short as possible . Pedestrian routes should be seperated from log movement routes and from log stacking areas. Routes for other site traffic should also avoid log stacking areas.
- **Ground conditions** - firm, level ground standing will increase stack stability and reduce the risk of stack movement due to over-high ground pressure. Avoid soft ground, Figure 22.
- **Sloping ground** - sloping ground will result in sloping stacks and a higher risk of logs sliding from the stack. Terracing may help to avoid sloping stacks, see Figure 23.
- **Height** - height limits will in turn limit ground pressures, will limit the energy of falling logs and will limit the effects of other risk factors, such as changes in log diameters and debarked logs.
- **Stack angle** - limited stack angles will reduce the risk of logs rolling down the front of stacks, where the risk to passers-by is normally highest, see Figure 24.
- **Diameter variations** - logs, particularly softwood logs, which vary significantly in diameter from one end to the other, will not nest well together within stacks. This is a particular risk if butt ends are stacked at one end of the stack resulting in stacks with cross slopes, see Figure 25.
- **Multi-log stacking** - use of wheel loaders or overhead grabs for stacking means that logs are not individually placed on stacks. This can result in badly nested logs. A higher standard of stack control or of pedestrian control is needed to compensate for this.
- **Debarked logs** - debarked logs can be slippery, making them more likely to slide from stacks or to move if they are poorly nested.
- **Log length** - short logs in high stacks can cause stability problems. Stacks should not generally be higher than the shortest log length. In some cases, longer logs can be used to stabilise stacks of shorter logs.
- **Wedging** - wedging will normally improve the stability of stacks and is considered necessary in areas where pedestrian access is allowed. Where there is no pedestrian access, the risk to persons inserting wedges may be higher than the risk of injury if a stack does collapse.

5.2 Stacking, destacking and movement of logs

The highest risks associated with log stacking are likely to be when the logs are placed onto or removed from stacks. Use of wheel loaders removes the need for persons to stand on log stacks and will significantly reduce these risks. Use of wheel loaders or overhead grabs for lifting several logs at once does, however, introduce the hazard of individual logs coming loose from the grab or falling whilst being lifted from or placed onto a stack. It is therefore essential that there be an exclusion zone around the operation to prevent access by persons not involved in the operation. This is particularly important in smaller mills where pedestrian and vehicular access into the stacking area is normally allowed. These comments equally apply to the loading of logs into the sawmill and to movement of logs within the premises.

6. CONCLUSIONS

1. Much of the advice in HS(G)172 remains relevant and it defines good practice for log stacking, particularly in areas where pedestrians are likely to be at risk from log stack collapse. A risk-based approach, however, shows that the most effective control measure to reduce the risk of injury from log stack collapse is to restrict pedestrian access to log stacks and their immediate area. The survey found that this was done at many of the sawmills visited.

2. No examples were found where derrick cranes were used to move timber. The most common method seen was the use of wheel loaders with grab attachments which were used to lift several logs at once. Generally, this was thought to be the safest method of stacking, destacking and transporting logs, primarily because it eliminates the need for slinging and therefore the need for workers to operate in the vicinity of the log stacks.

3. Log stacks should not normally be higher than the length of the logs which they contain. Stack height should also be limited by the height from which the grabber can take logs from above the stack and by consideration of the safety of the grabber driver. This would normally limit stack heights to 3 m to 4 m. The maximum stacking angles recommended by HS(G) 172, 45^{O} generally and 35^{O} in pedestrian areas, should be implemented more widely.

4. There are a number of other factors which may increase the risk of a stack collapsing, including:

- sloping ground, which could result in logs sliding from a stack or rolling down the slope;
- debarked logs which may be slippery, particularly if they are recently harvested. Extra care should be taken when transporting debarked logs which may slip out of a bundle;
- logs stacked with their butt ends to one side of the stack so that the angle across the top of the stack is likely to cause logs to slide off. Particular care needs to be taken if the logs are also debarked;
- logs stacks stored on soft ground may sink into the ground on one side and could become unstable.

Where these additional risks are present, consideration needs to be given to reducing the stack height or to preventing movement of logs, for example, by containment in bunkers or by using stanchions.

REFERENCES

HS(G)172 - Health and Safety in Sawmilling, HSE, 1997

HGB News 26, July 1981, Storage and Stacking of Round and Sawn Timber (HGB is the Employer's Liability Assurance Association, Woodworking Industry, West Germany), HSE Translation No. 13064.

MEPKS9807-2/4

Figure 1 - Incoming transport to a mill.

MEPKS9807-1/18

Figure 2 - Log storage area in a medium sized mill.

MEPKS9808-1/09

Figure 3 - Supports for one end of log stacks.

MEPKS9808-1/08

Figure 4 - Supports for one end of log stacks - the boundary next to a public road.

MEPKS9808-1/10

Figure 5 - Supports for one end of log stacks - the houses on the other side of the road to the mill.

MEPKS9808-1/13

Figure 6 - A wheel loader with grabber attachment.

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MEPKS9806-1/20

Figure 7 - Logs stacked on soft ground.

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Figure 8 - Logs being removed from the base of a stack.

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Figure 9 - An excessively high stack of logs.

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Figure 10 - A stack close to where pedestrians are likely to walk.

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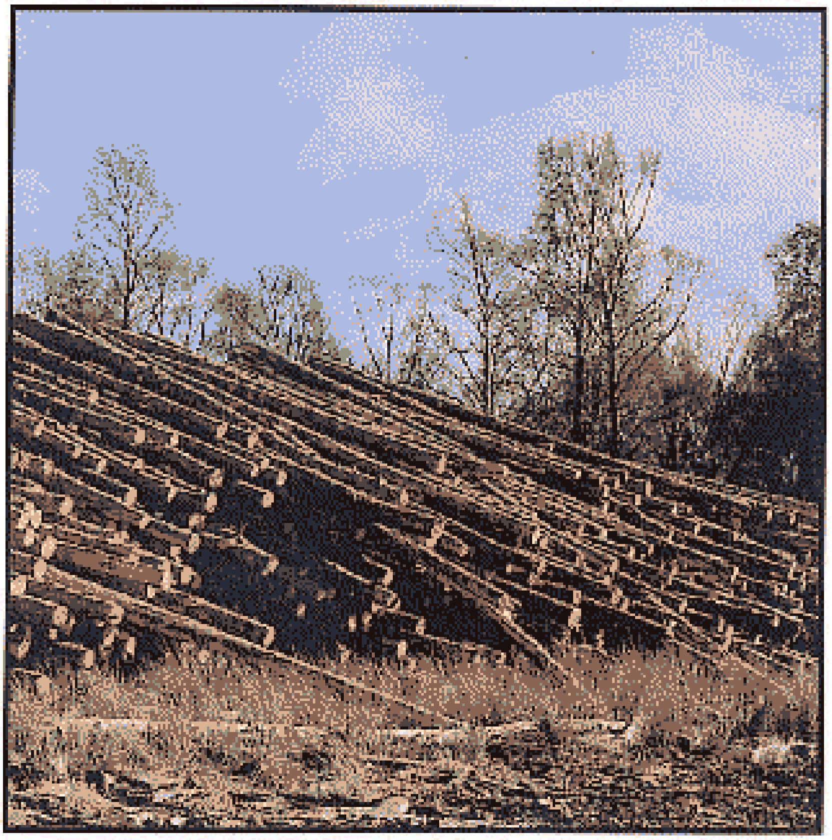
Figure 11 - Another view of the stack shown in Figure 10.

MEPKS9807-03/3

Figure 12 - Slippery logs which have slipped off the stack.

MEPKS9808-2/11

Figure 13 - Diametral size distribution of logs in a stack.



9704-028/70

Figure 14 - Long logs with butt ends to one side of the stack.

MEPK59608-01/16

Figure 15 - Short logs in a stack.

MEPKS9806-03/01

Figure 16 - Hardwood logs stacked with a steep end angle.

MEPKS9808-02/36

Figure 17 - A well constructed hardwood log stack.

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Figure 18 - Slippery logs being moved by a wheel loader.

MEPKS9807-2/25

Figure 19 - Logs being fed into the mill using a mobile grabber with rotary jaws.

9704-026/2

Figure 20 - Feeding a mill with a wheel loader.

MEPKS9807-03/1

Figure 21 - The loading deck for a mill which is too high for a shovel loader.

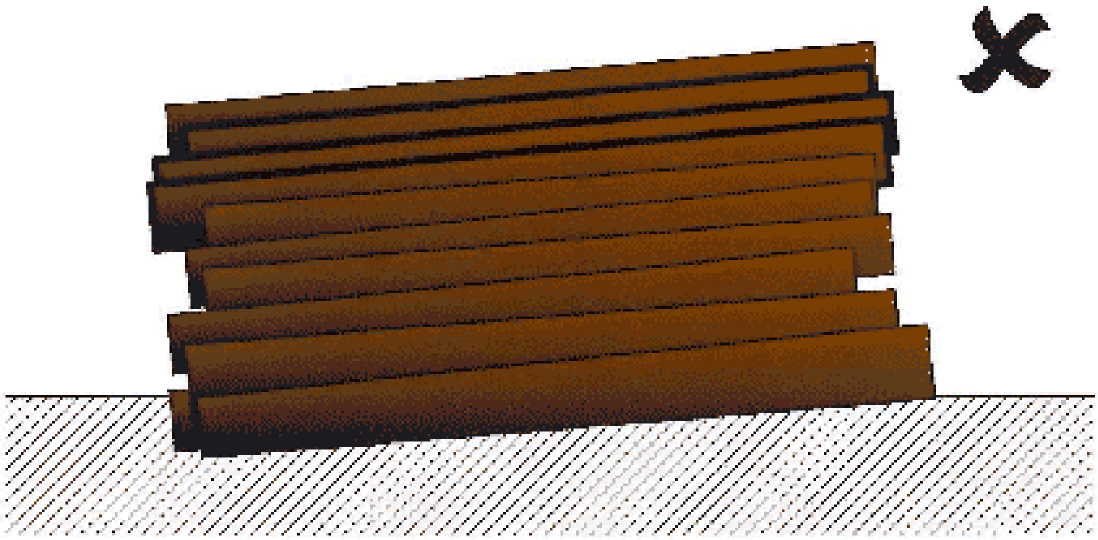
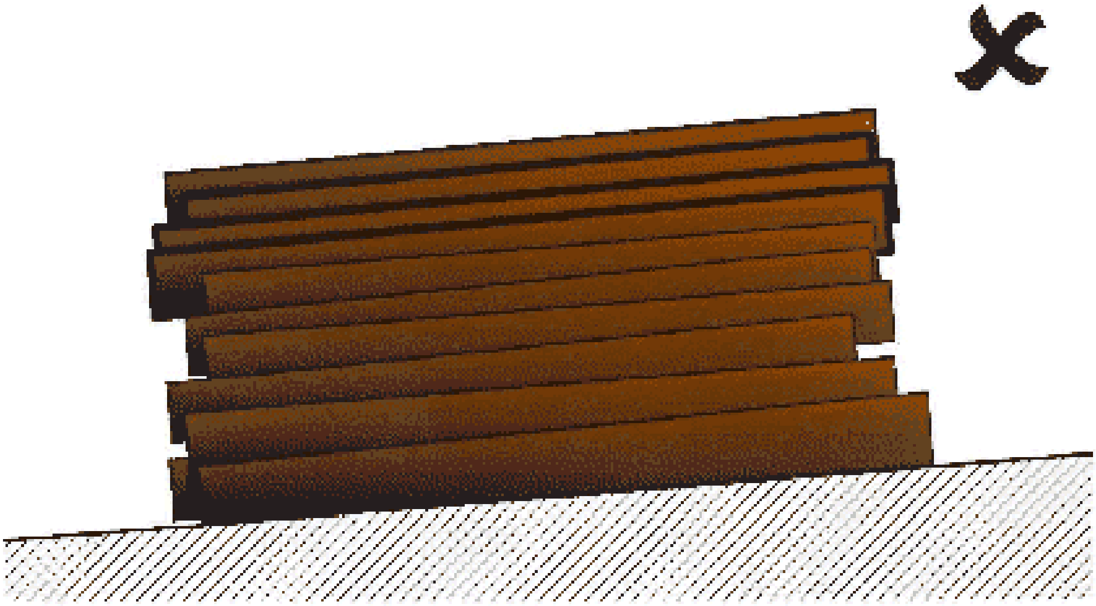


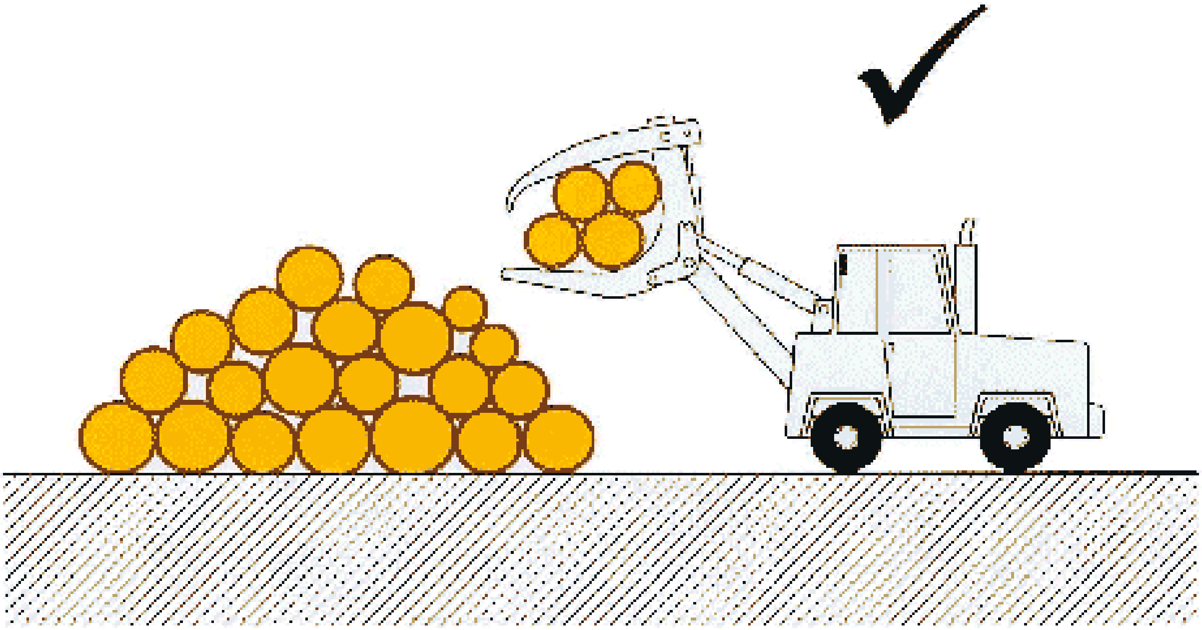
Figure 22 Avoid soft ground, use hard standing if possible



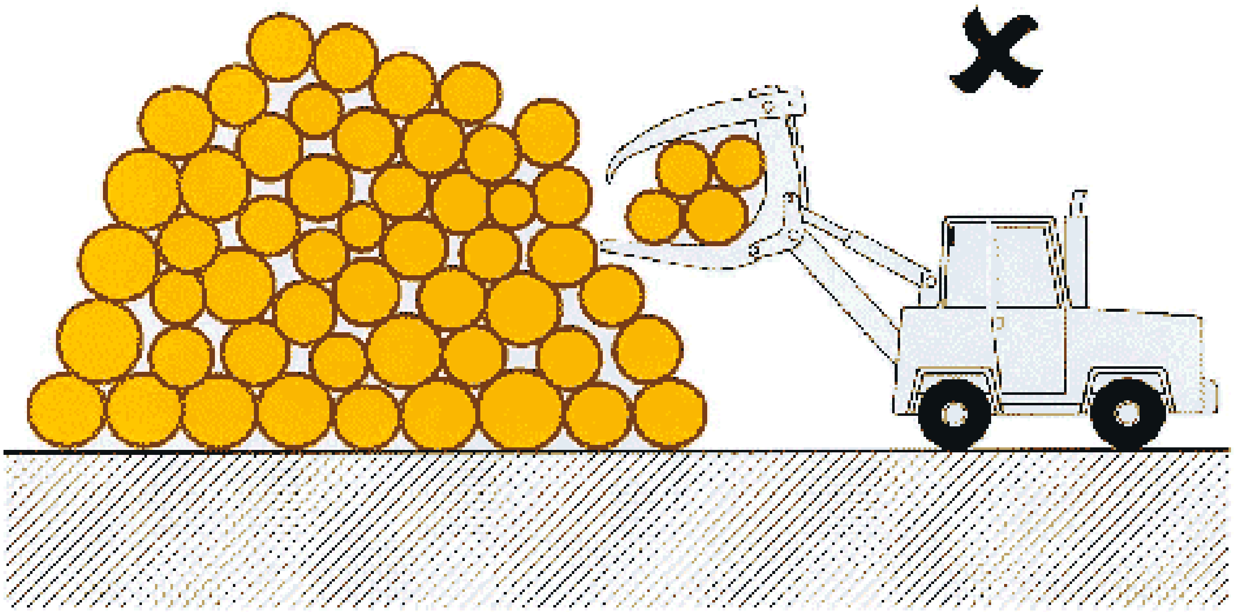
a) Avoid sloping ground, especially cross-slopes

b) Use terracing to provide level standing

Figure 23 Avoid sloping ground



a) Keep stack heights/angles low. Remove from top of stack



b) Avoid high stacks/high angles

Figure 24 Stack heights and angles

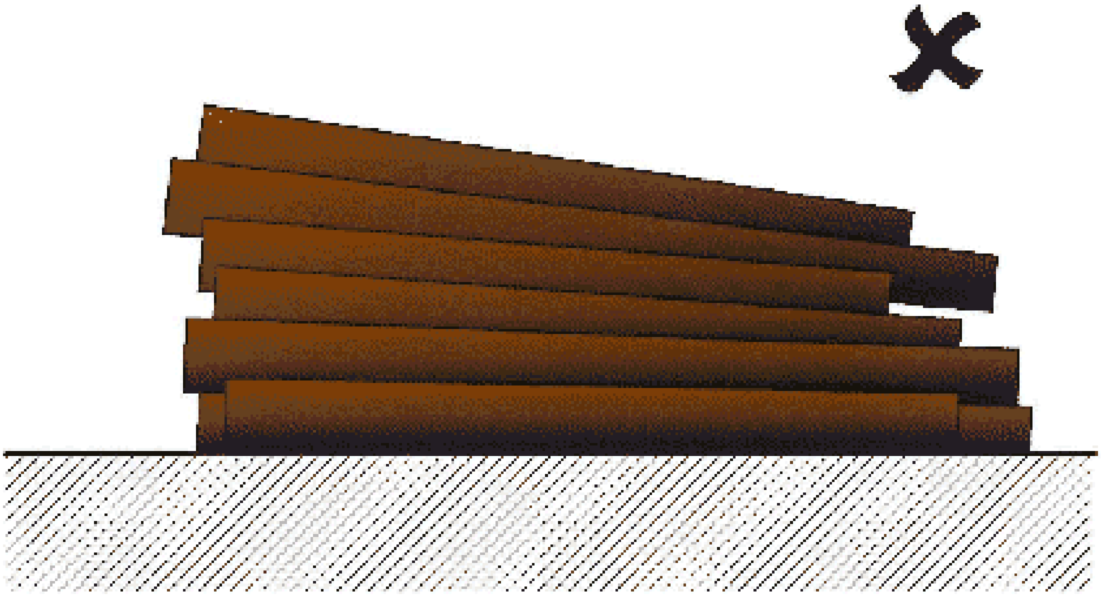


Figure 25 Avoid butt ends together, alternate butts