Client Report :

State of the art review of incising pre-treatment technology and its potential for enhancing the value of UK-grown spruce

Client report number 208080

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Executive Summary

This report was prepared for the Forestry Commission and constitutes BRE output number 208080 under contract PPD96 "State of the art review of incising pre-treatment technology and its potential for enhancing the value of UK-grown spruce". It is the final report of this contract.

The report presents a review of international literature and practical experience with incising refractory timber species prior to treatment with wood preservatives. The review presents the potential for applying incising technology to UK-grown Sitka spruce and provides recommendations for the way forward. The recommendations include:

- Conduct of laboratory assessments of penetration and retention of CCA treated incise UK-grown spruce
- Conduct of laboratory assessments of biological durability of CCA-treated incised and unincised spruce
- Conduct of field assessments of biological durability of CCA-treated incised and unincised spruce, Douglas fir and larch
- Evaluation of the perception of incised material in the market place
- Producing demonstration material from incised UK-grown Sitka spruce and put into test - including fencing, gates and cladding
- Developing a demonstration project within a specific commodity production chain including manufacturers, UK spruce growers, sawmills and end-users.
- Producing a guidance document on incising Sitka spruce to raise the profile of the technology in the UK

In addition the preservative treatment schedules, the kiln drying and the incising process would need to be optimised prior to the full-scale practical development of incising technology in the UK.

Contents

Introduction

This report was prepared for the Forestry Commission and constitutes BRE output number 208080 under contract PPD96 "State of the art review of incising pre-treatment technology and its potential for enhancing the value of UK-grown spruce". It is the final report of this contract and presents a synthesis of international research literature and practical experience with incising refractory timber species. A number of databases have been searched in the review process include CABI abstracts, Forest Products Abstracts, the International Research Group on Wood Preservation, the BRIX database and other BRE records. In addition the World Wide Web has been utilised when gathering information on commercial products. These activities combined with the support from BRE networks, particularly in the USA and Canada have enabled a thorough and practical evaluation of the technology.

The review objectives were to:

- critically appraise the application of incising technology to UK grown spruce prior to preservative pre-treatment,
- demonstrate the cost-effective benefits of applying incising technology to a commodity,
- provide a foundation for a demonstration project of the technology in collaboration with other partners to demonstrate the viability of incising UK grown spruce.

The technical and economic feasibility of using incised spruce to achieve the level of performance required for specific commodities has so far not been assessed against commercial criteria in the UK. This review provides a basis for these evaluations by drawing together international best practice. The following have been achieved:

- Available incising technology has been reviewed and obstacles to the uptake of the technology identified.
- The economics of producing an incised commodity have been analysed and costs calculated on a comparative basis for a particular commodity - highway fence

posts. Analysis for the UK market of the costs and cost-effectiveness of incising technology has been used to validate the value of the innovative technology.

The output from the work is this state of the art review document appraising the suitability of incising technology for enhancing the value of UK grown Sitka spruce. Including a strategy for exploiting the technology to enhance the market for home grown spruce.

Background

Although the natural durability of a timber species can be enhanced by the application of a preservative treatment, in practice timber species differ greatly in their resistance to impregnation by fluids, and therefore in the ease with which they can be treated. Classification of the treatability of a timber species is dealt with in European Standard BS EN 350 -2, and this classifies the treatability of a timber on a scale of 1 ('easy to treat') to 4 ('extremely difficult to treat').

Incising timber, in which a pattern of incisions is cut in the lateral surfaces of the timber using blades, teeth or needles to improve the uptake and penetration of preservative has long been recognised as a practical method for improving the durability of timber. One of the earliest incising plants dates from the early part of this century according to Wilkinson (1979). Incising has become established as a means of improving penetration and retention of wood preservatives in timbers that are resistant to lateral penetration but have some degree of longitudinal permeability.

Sitka spruce (*Picea sitchensis*) is a timber which is commercially important in Europe and equally in the UK. It is classified as being 'Slightly durable' (Class 4) and 'Difficult to treat' (Class 3). Incising techniques potentially offer a method of enhancing its durability by improving the effectiveness of preservative treatment, through increased penetration of preservative through the lateral surfaces.

UK-grown Sitka spruce is becoming available in large quantities and in sizes suitable for the construction industry. In many ways spruce can be an excellent construction timber; it is relatively cheap, readily available, has adequate strength properties if selected appropriately and is easy to work. Also, its relatively low permeability is an advantage in reducing its propensity to become wet. However, some wider applications are precluded because of its low resistance to fungal and insect attack. Impregnation with wood preservatives by normal pressure methods achieves relatively poor penetration and therefore only modest enhanced protection. Increasing treatment pressures to improve penetration tends to cause the timber to collapse. In order to establish the potential for making better use of this resource as a treated commodity in service conditions conducive to fungal attack, a field trial was installed by BRE in 1972 (Smith & Orsler 1995) that would critically test the influence that incising has on the effectiveness of preservatives at retarding decay in treated spruce used in ground contact. The overall strategy of the present review was to combine knowledge from this UK national field trial with experience from existing international practice, to deliver an evaluation of the suitability of incising timber, prior to preservative treatment, as applied to UK grown Sitka spruce.

The review aimed to address the range of potential benefits that could be achieved from incising:

1. Enhancement of the durability of the predominantly softwood resource to maximise the sustainable use of the resource through extended service lives.
2. Increase the added value of the UK softwood resource. A resource that is growing for the next fifteen years, 60% of which is Sitka spruce a timber resistant to wood preservative treatments.
3. Provide a substitute for naturally durable timbers, the availability of which is diminishing or is politically undesirable and unsustainable.
4. Enable UK grown resistant timber species to meet European Standard specifications for penetration and retention of wood preservative (EN351; BS8417) and to provide the timber treaters with a means of easily demonstrating that a specification has been achieved.
5. To increase assurance of treated products being 'fit for purpose' to the end user.

Processes and Products

There are various techniques that are employed to improve the penetration and retention of difficult to treat refractory species such as Sitka spruce and Douglas fir. These processes are:

1. Standard, groundline or full length incising - a process using a mechanical perforation to approximately 19mm (¾") deep.
2. Deep heart incising - a process that performs a 64mm (2½") radial perforation in a diamond pattern for the groundline of Douglas fir poles and for marine pilings.
3. Radial drilling - a manual process similar to deep heart incising but up to 165mm (6½")
4. Through boring or drilling - a process involving drilling a specified number of holes completely through the poles usually in the groundline area.

This review concentrates on the first process, with mention of the second. We consider the standard incising process to be the most suitable technology for application to UK-grown Sitka spruce and the target timber markets. The radial and through drilling processes are only applicable to wood poles.

Incising as a routine technique for improving preservative penetration and retention is primarily used in the United States (Crawford et al 1999) and Canada. The techniques are also being employed to some extent in Japan for railway sleepers and South Africa for woodpoles. This review has confirmed that the techniques are employed to a much lesser extent in Europe (Sweden and The Netherlands) and Australia. Incising is applied to a variety of timber species, including Western hemlock (Bramhall 1967), Douglas fir (Perrin 1978), Japanese cedar (Hattori 1957) and spruce (Schulz 1971).

Incising timber involves making shallow, slit-like holes in the surfaces of the material to be treated. For transmission poles, the process is usually only carried out around the circumference of the pole in the ground line area (Figure 1). However, railway sleepers and other square sawn timbers are incised on all four sides completely along the length of the timber. The first commercial incising machine for square timbers was built in the USA in 1915 and the first practical pole incising machine in 1920. Modern machines for square timber consist of four revolving rollers fitted with incising teeth. The four rollers are arranged in two pairs horizontally and vertically opposed and are held against the wood by pneumatic or hydraulic pressure (Figure 2). The teeth are arranged on the circumference of the rollers to give the required pattern of incisions, which may vary according to the species of timber undergoing incising. A typical density of incisions produced is between 4,000/m^2 and 8,000/m^2.

The process produces an envelope of preservative treatment which is deeper and more even than without incising. To obtain maximum benefits from incising, the timber should be cut to size before treatment, though this is recognised as being impractical in many situations. If lateral surfaces are machined, drilled or sawn after treatment, flood brushing with an end grain product should be carried out. This is standard best practice for all preservative treatments.

In addition to the heavy timbers used for railway sleepers and piles, incising pre-treatment using toothed cutters or needles has become established in the US and Canada for fencing, some constructional timbers and laminated timber components. Needles are sometimes preferred to teeth because they produce incision marks that are virtually invisible and cause negligible strength losses to the timber (Forintek Review 1985). In addition, deep incising techniques have been investigated experimentally for the incising of round timbers (Best & Martin 1969).

Investigations in incising technology have also utilised lasers to produce incisions (Ruddick 1991; Goodell et al 1991; Hattori et al 1995). The incisions produced are small enough (less than 1mm in diameter) to make the surface of the treated timbers appear visually unchanged. Complete penetration of CCA into laser incised red spruce 50 x 100mm battens, without significant strength loss was reported by Goodell et al (1991). Laser technology has not been commercialised due to the cost of the equipment and, the high density of incisions required for effective preservative treatment. For example, incision densities of between 28,000/m^2 and 42,000/m^2 are required for Douglas fir

(Ruddick 1991). As a result, the processing time is considerably longer than conventional incising using knives or needles.

Forintek in Canada developed a double-density incisor (Morris, Ruddick & Silcock 1991; Morris 1991) producing an incision density of 12,000/m^2 through two superimposed patterns. Using this equipment, spruce-pine-fir (S-P-F) could be treated to meet the Canadian (CSA) and American (AWPA) Standards for timber by manipulating the treatment schedule time. Morris concluded that there was no technical reason why spruce should not be included in Canadian and US treated timber commodity Standards. Incising Sitka spruce prior to treatment with an ammoniacal copper zinc arsenate (ACZA) type preservative, resulted in 70 to 97% of samples in a batch exceeding the 10mm preservative penetration specification AWPA Standard C2 (Lebow & Morrell, 1993). The majority of batches had over 90% of samples exceeding the specification. Poorer results were obtained for CCA treatment of the same material; the ammoniacal component apparently improved penetration, and the treatment cycles were thought to be less optimal for CCA. Also the moisture content of the Sitka spruce prior to treatment is crucial. The Pacific Wood Preserving Company claim to be the first company to introduce double-density incising of Douglas fir into the US markets meeting AWPA standards.

Products in the United States and Canada:

The main incised products produced in the USA and Canada are Douglas fir railway sleepers, utility poles, laminated beams, timber frame components and marine piles treated with CCA, creosote or Penta-type wood preservatives (PCP in organic solvent). Incised timber has a wide range of commercial applications:

- Incising glulam in the United States is recommended for Douglas fir, western hemlock, hem-fir, red maple and yellow poplar. Incising is not considered to have a detrimental effect on the strength of the glulam, however it effects appearance (Engineered Wood Systems 2001).
- Cedartone Classic timber for decking and fencing constructions, boards, posts, rails, joists, beams and deck boards. Canadian spruce-pine-fir (S-P-F) is dried, prestained with cedartone, high density incised and CCA treated to CSA Standards and marketed by Prairie Forest Products.

- Domestic exterior lighting columns between 2 and 4m tall are made from laminated Douglas fir that is incised (¾" incisions) from the butt to 12" above the groundline then preservative treated with PCP in organic solvent (Figure 3).

Products in the UK:

In the UK there is some evidence of imported incised timber appearing on the market, though in small quantities. An example is for construction of freshwater jetties and piers as part of a range of landscaping and waterfront construction products using Weerbaar Hout incised timbers (Foreco, The Netherlands), available with a guaranteed 25 year service life. The surface incisions are used as an indicator of the suitability of the commodity for the intended end use.

In Northern Ireland in the mid-1970s Ballycassidy Sawmills of Co. Fermanagh manufactured "Perma-posts". These were agricultural fencing rounds (3 to 5” diameter) made of spruce that were incised prior to air drying and pressure impregnation with CCA. The product was promoted across the UK (see Figure 4). The product is no longer produced and it is not clear why this is the case. Contacts with Balcas Sawmills (formerly Ballycassidy) have not been able to provide further details. It is thought that the market was not ready for a high quality, higher cost, incised product back in the 1970s when cheap, easy to treat species were readily available. This emphasises the fact that any future work in the UK will need to be accompanied by a technically robust campaign promoting the benefits of the products.

Historically in the UK, incising has been applied only to large-scale timbers such as marine piles and railway sleepers in the 1950s. A section of the British Railway Track publication (1960) refers to wooden sleepers and the use of incising to ensure a sufficient quantity of creosote into the timber sleepers. The incisions are noted as localising the effects of cracking in service which was an additional benefit, minimising the occurrence of large surface checks. It is not known how extensively incising was applied to timber railway sleepers in the UK. Contacts within Railtrack were able to confirm that they were phased out in the 1960s as the replacement of timber sleepers with concrete increased.

9 Incising technology and potential for UK-grown spruce

Although very small volumes of imported incised timber are used in applications such as freshwater jetty piers, incising is not currently practised in the UK on any scale, largely because benefits have not been shown to justify the initial outlay on equipment. On the basis of past experience and this review, BRE believe that significant opportunities exist in the application of incising technology to the UK-grown timber resource.

Regulatory issues

In North America, incising technology has been exploited for decades, and National Standards, specifications and other mandatory requirements exist. Regardless of the type of wood preservative being used, incising is required by ASTM Standards when treating so-called difficult to treat species. Incising is also required for treating round timbers and sawn timber. Poles may be incised to a depth of 64 mm or even through bored in some cases (Winandy 1996).

For many authorities, incising is a necessary part of pre-treatment specifications. For example, Canadian wood preservation standard CSA 080 requires timber to be incised to ensure adequate levels of treatment. In the USA, the AWPA has a list of timbers that must be incised, including lodgepole pine, western hemlock and Douglas fir. The AWPA also include recommended incision depths suitable for the thickness of the timber commodity. In the acceptance criteria for copper-azole wood-preservative treatment, high density incising (approximately 7500/m^2) is required for Douglas fir, western hemlock and hem-fir to meet the required penetration standards (ICBO Evaluation Service Inc. 2000). However, if ammonia is used in the treating solution, then an incising density of 4500/m^2 is acceptable. Material labelled for decking use only requires that two edges and the upper face shall be incised.

American specifications for wood poles include incising Douglas fir poles, and a requirement to meet the penetration or checking specifications for preservative treatment. In addition, incising shall be accomplished in a manner that will not unduly damage the surface of the pole by splintering, raising the wood fibres or loosening the sapwood from the heartwood.

The US Standards are comprehensive in the application of incising. The requirements include that all Douglas fir, except rails and rail posts; the least dimension of which is 50 mm (2 inches) or over shall be incised by a suitable power-driven machine before treatment. Timber having a thickness of 75 mm (3 inches) and over shall be incised on all four sides. Timber less than 75 mm (3 inches) thick shall be incised on the wide faces only. The spacing and shape of the cutting teeth and the method of incising shall be such as to produce a uniform penetration. The depth of the incisions shall be not less than those specified, an example of which appear in Table 1 taken from a typical American State specification.

AWPA Standard C2 (1996) presents the treatment requirements for structural timbers. Incising is required for Douglas fir to achieve acceptable preservative treatment. In section 9 of the General requirements of the Use Class system, most timber species are included in Standard C2. Incising is required for all solid sawn softwood species expect Southern pine, Ponderosa pine, Red pine, Caribbean pine and Radiata pine, as an aid in securing more uniform penetration of preservative. Incising is in general required on all faces. High density incising is required for solid sawn Engleman spruce and Western white spruce to a minimum of 8,000/m^2.

AWPA Standard M1 has new text proposed for incising species that are difficult to treat. The specific parameters for the incising are not defined. It is set to ensure that the penetration and retention limits laid down in the C Series standards are met. Incising is also noted to reduce the strength and that adjustment factors to design values must be used. The effect varies depending on the size and shape of the material being incised, the original condition and properties of the incised material and the parameters of the incising process. Factors such as incising pattern, tooth thickness and shape, wood grain orientation, incisor maintenance and debris removal are all important considerations in assessing strength losses. Specific guidance on the magnitude of this effect is given in the US National Design Specification (AF&PA 1997). These factors are also important considerations in assessing wood damage. Incising can reduce the usefulness of the end product through excessive surface damage when patterns are too dense, incision depths exceed 10mm, or wood moisture content before incising is less than 15%.

Advantages

Hullberg (2000) in his AWPA review suggested that incising offers benefits that are direct and indirect:

- Opportunities for using more environmentally acceptable wood preservative formulations that avoid organic solvent to aid penetration,
- Energy and process time savings by reduced periods spent in pressure impregnation,
- Stress relief leading to reduced surface checking,
- Drying time benefits (although this is questionable given reports from other investigations that suggest incising has no effect on drying times or rates),
- Improved durability of non-durable resistant softwoods.

In addition a significant benefit for UK applications is:

- Ability to meet and readily demonstrate compliance with end results type specifications required in European Standards (EN351; BS8417)

The main advantage of incising lies in the possibility of producing a deeper and more uniform 'envelope' treatment of wood preservative to the depth of the incising holes. Improved penetration and retention of preservative and uniform penetration patterns, rather than the typical irregular patterns for treated Sitka spruce (Figure 5), are significant advantages. Treaters will benefit, by being able to meet, and demonstrate compliance with, the new and more demanding requirements of European standards, which call for specification using penetration and retention values rather than processing parameters. The treated incised material has readily quantifiable penetration patterns. This will provide for significant benefits in reduced claims for non-compliance with specifications, in cost savings from reduced losses due to premature failure of treated timber, enhanced sales through 'guaranteed timber' (penetration and retention will then be quantified and offered as a measure of quality) and reduced liability concerns for treated timber as the end results of treatment can be more precisely and reliably demonstrated.

The evidence from performance tests suggests that incising leads to increased service life for the treated commodity. From BRE field trials, predicted lives for CCA treated spruce (2"x2" stakes) are reported to be about 30 years for unincised stakes and in excess of 49 years for incised stakes (Suttie 1996).

The performance of incised red pine, eastern spruce, balsam fir and eastern hemlock treated with ACA or CCA both in ground contact (simulating a fence post) and out of ground contact (simulating a decking board), have been reported after 10 years exposure by Crawford et al (1999). The incised timbers showed no evidence of decay whereas many of the unincised timbers had signs of decay. Incised white pine was recorded as having actually failed the simulated decking board exposure test due to excessive checking.

Incising timber can relieve stresses within the timber generated during drying and may result in a subsequent reduction in checking in the final timber product (Richardson, 1993). Reduced checking has been found when incising was carried out before air seasoning. However, no appreciable effect was found due to incising, either before or after air drying, on the subsequent rate of drying (Harkom 1932). It should be noted that Perrin (1978) reported that incising had little or no effect on the rate of drying of the timber and the ultimate dryness of the timber. Though this effect may be influenced by the timber species as Hullberg (2000) reported drying time shortened as a result of incising. This would need to be assessed on a case by case basis for each timber species.

It has been reported that nail holding in Douglas fir and hem-fir is unaffected by incising (Kang et al 1999). Normal nailing and fixing techniques can be applied to incised timber.

There is a long-term advantage of incising through the reduced environmental impact of preservative treated commodities by producing commodities with service lives in excess of 50 years. Extending service life is the most sustainable use of the forestry resource and may result in reduced volumes of treated wood waste and certainly a reduced number of premature failures of treated wood in service. In addition, incising offers a range of broader end uses for treated Sitka spruce, a construction material which is sustainably produced with a lower overall environmental impact than any competitor material. These are clear advantages, though it is evident from this review that little data or studies of life cycle analysis (LCA) or whole life costs (WLC) were available specifically relating to incised treated timber.

For the specific commodity of UK highway fencing, current delays in meeting customers orders are due to irregularities in the supply of Douglas fir. This would be alleviated if preservative treated incised spruce were a suitable commodity as the timber is more widely available across the United Kingdom.

To summarise, the advantages of incising spruce are:

- Improved penetration and retention of wood preservative
- Uniform penetration envelope that is quantifiable
- Ability to demonstrate conformity with European Specification Standards
- Improved durability of treated commodity
- Reduced stresses in commodity (reduced checking of surface)
- Reduced drying time depending upon species
- Reduced premature failure of treated timber
- Potential for reduced timber waste
- Consistent supply of material into high volume potential end uses (e.g. highway fencing)

Disadvantages

The durability and mechanical performance of preservative treated incised timber components will depend on the following:

- Preservative type
- Timber species
- Moisture content
- Attributes of the incising process
- Orientation of grain to incising

Criticisms levelled at the incising process have been based upon two main concerns. First, the reduction of bending properties of the product and secondly that the wood preservative forms an incomplete envelope.

Incising has been demonstrated for spruce to reduce the modulus of rupture (MOR) by 16% and the modulus of elasticity (MOE) by about 13% (Table 2, Banks 1973). However, it can be argued that these initial strength reductions of incised timber will not be significant for many end-uses and in any case would be offset after a few years since the incised timber will be less effected by decay fungi and therefore stronger than an unincised similar timber (Wilkinson, 1979). Decreases in strength of 10 to 20% have been quoted but reduction in strength becomes less significant with increasing timber size. Best and Martin (1969) estimate that the strength reduction of deeply incised poles (2½") was less than 5% and Graham and co-workers (1969) found no strength loss for ¾" deep incised poles.

Perrin (1978) reviewed incising and its effects on the strength of wood and concluded that incising caused only minor reductions in the strength properties of timbers and large roundwood. However, laminated beams, 'dimension lumber' and hardwood posts were significantly weakened by the process. Although incising can significantly reduce the strength of timbers the increase in preservative penetration provides a significant extension of service life that far outweighs the initial loss of strength (Winandy 1996).

The technical literature concerned with the strength losses seems to allow for a 10 to 20% reduction in allowable design stresses for nominal 2" timber and a 0 to 10% reduction for thicker material (Kass 1974; Lam and Morris 1991). Lam and Morris (1991) carried out bending tests on double-density incised S-P-F timbers treated with CCA and found that the strength reduction was within the limits stipulated in the code on Engineering Design in Wood. Incising of green Douglas fir with moisture contents up to 70% demonstrated reductions in bending strengths but this was not correlated to moisture content and incising (Chandler and Morrell 1999).

The shear strength of 2" x 4" dimensional timber of Douglas fir, hem-fir and spruce-pine-fir has been reported by Morrell et al (1998). The research showed that incising and preservative treatment of this smaller dimension timber produced significant reductions in average shear strength. Some examples are given in Table 3. The reduction in shear strength needs to be addressed through the development of appropriate design values for users of preservative treated incised timber, when shear strength is a governing factor in the end use situation. The authors propose an adjustment factor of 0.70 for incised preservative treated timber of nominal 2" dimension.

The main users of incised timber in North America have adopted a system of adjustment factors for use in the design and specification of timber components. These account for the reductions in bending, load and shear strengths related to the dimension of the commodity. This allows the use of preservative treated incised refractory species in a variety of construction applications. They are also of much less significance for commodities where the bulk of the timber maintains the strength requirements, such as fencing and woodpoles. Size-adjustment values are published in the USA and Canada, which take into consideration the duration of loads, compression factors, fire retardant, temperature and a factor for incising when designing with structural timber. These appear in design equations for which values are provided for different species and different dimensions of timber.

It has been suggested that in incising timber, the preservative is simply moving down the incision and not diffusing into the adjacent wood, thereby still only providing a very thin preservative treated layer as protection against fungal attack. From illustrations of cross sections of incised timber pieces in Banks (1973), and reproduced in Figure 5, this would certainly appear not to be the general case, and in any case it is unimportant if it can be demonstrated directly that incising increases service life.

The marks on the surface of the timber from incising reduce the visual appeal of the timber and can be a disadvantage depending on the end use. Unless sealing and coating techniques can be developed, this is unlikely to be a technique that is suitable for timber intended for joinery applications, because the incisions detract from the surface appearance of the timber. However, for applications where this is not a concern, BRE field tests already demonstrate that incising the surface of spruce can improve both the uptake of preservative and the service life of the timber in ground-contact situations. In addition the use of needle incisions can reduce the visual impact of the incisions.

Incising of Sarawak refractory hardwoods demonstrated improved penetration of CCB wood preservative (Jenang et al 1997) but the treatments did not meet national or Japanese Agricultural Standards for treated timber. The application of incising to hardwoods has not proved to be successful. Although no indication of performance of the treated timber is presented.

The disadvantages of incising spruce are:

- Reduced mechanical properties; though these can be accounted for by using design factors related to species and dimension of the timber commodity. In larger commodities the reduction is negligible,
- The preservative only moves down the incisions; though this is not substantiated by all the practical experience and observations of complete envelopes (Figure 5),
- Incision marks are unsightly; though this can be minimised by process selection and use of needle incisors. In addition, the application of incising can be limited to exclude the decorative 'visible' face of joinery material.

UK field trials of incised spruce

In work by Dunleavy and Fogarty (1971) a 'ponding' process was used to treat spruce rounds by storage in water. This allowed the bacterial breakdown of the closed pits which eventually improved the permeability of the sapwood. As an alternative, a closed incising process was developed that did not damage the timber surface appreciably and resulted in 2 to 3 times the uptake of wood preservative compared to the unincised timber. This approach was the basis for the UK national field trials.

In 1972 a ground contact field trial was established at BRE including 280 simulated incised spruce fence posts. The spruce posts (50 x 50 x 600 mm) were sealed on their end grain surfaces either unincised or were subject to one of three combinations of incising pattern prior to preservative treatment. The incisions were cut to a depth of either 6 mm or 9 mm prior to pretreatment with either a copper/chrome/arsenic (CCA) preservative or coal-tar creosote, both applied by a full cell process. This ensured that the preservative penetrated the wood only through the lateral faces, forming an envelope of treated material and thus completely testing the effect of incising the material. At the July 2001 annual inspection the untreated spruce had a completed service life of 11 years. The incised posts treated with 3% CCA, and other treatments, reveal predicted service lives in excess of 40 years. These are predicted lives because as yet there have been only a few failures. This performance far exceeds original expectations.

<u>Experimental review of the UK national field trial</u>

<u>Timber</u>

Russian whitewood (*Picea spp*.) was used sorted into planks from the centre of the tree (putative heartwood for purposes of the trial and referred to as 'resistant') and planks cut from the outside of the tree (putative sapwood for purposes of this trial and referred to as 'permeable'). Test stakes (600 x 50 x 50 mm) were cut from the planks; 10 replicate stakes were allocated for each combination of treatment and incising pattern.

Preservatives

A copper/chromium/arsenic (CCA) type preservative was used at solution concentrations of 0.1%, 3% and 5% m/v to BS4072 and Coal-tar creosote to BS144.

Incising pattern

The incisions were cut into all four faces of the 50 x 50mm stakes. Three different patterns were selected to allow comparison of inter-pattern variations. These varied the depth of the incisions and the stagger or distance between each incision as in Figure 6 (Purslow, 1975). Details of stagger and depth of incision are given in Tables 4 and 5.

Treatment

The ends of each stake were dipped in the preservative with which they were to be subsequently treated; allowed to dry and then end sealed with an epoxy resin. Treatment with the appropriate preservative was by a full cell process to the following schedules with no final vacuum:

CCA	:	-0.9 bar for 1 hour	8.5 bar for 2 hours
Creosote	:	-0.9 bar for 1 hour	10 bar for 2 hours

Stakes were weighed before and after treatment to determine uptake of preservative, then stacked under ambient conditions to allow drying and fixation before installation in the test site.

Testing & Results

The test stakes were installed randomly in ground contact following a grid pattern, at the BRE's Princes Risborough field trial site in November 1972. The stakes were positioned 700mm apart and planted to a depth of 380mm. The field site consists of a sandy loam soil of pH 7.2 overlying chalk and supports meadow grassland that receives an average annual rainfall of 800mm (Met Office, 1989). Every six months the stakes were tested by tapping them with a wooden mallet. Over the past few years, this assessment is conducted annually. The life of a stake is given as the time period between installation and the stake being broken by the mallet strike.

The performance of incised spruce treated with creosote, 3% CCA or 5% CCA has proved better than the performance of the equivalent unincised, treated spruce. Indeed many sets of the CCA-treated incised stakes have yielded no failures after 29 years in service (Tables 4 and 5). Only in the case of CCA used at a very low concentration of 0.1% did incising not show any beneficial effect on service life. This demonstrates the value of field testing in delivering real performance differences that can feed directly into practical applications for the construction industry.

The overall results for test stakes to July 2001 are presented in Tables 4 and 5. It was noted that the failure of some samples might have been accelerated, as the end sealing epoxy resin was cracked and falling off the end grain, allowing more rapid moisture ingress. The estimated life of the stakes where less than 10 stakes had failed, was calculated using the method of Purslow (1977). Where no stakes had failed, the estimated life of the batch of stakes was based upon an assumption that the first failure will occur at the next test date - July 2002.

Statistical analysis of the data shows that the uptake of creosote in permeable samples was significantly greater than in resistant samples. In addition the uptake of creosote in incised samples was significantly greater than in unincised samples. After 29 years exposure, the only failures for the creosote treated samples were in the resistant, unincised batch. Unincised permeable timber always absorbed more CCA than unincised resistant timber. The incising of timber showed little difference between CCA absorption for the two timber types, and there was no discernible difference in uptake between incising patterns. Overall, the absorption of CCA by incised timber was approximately double that for unincised timber.

Conclusions:

Treating the stakes with 0.1% CCA increased the mean life from 11 to approximately 16 years. Treating with a higher concentration CCA solution extended this mean life still further. Treating with 3 or 5% CCA and incising increased the mean life of the stakes by about x4 to a currently estimated 40 years in most cases. Only three failures have occurred so far with incised samples at these higher CCA treatments, and they are in the 3% CCA resistant timber batches.

This review identified a difficulty in cross-comparing the effectiveness of incising for timber species or preservative types using only results from literature sources. Many of the data are not directly comparable due to the number of variables in the demonstration trials, including the wood species, the wood preservative type and the exposure conditions, incising pattern, commodity end use and the incising and treatment process. This emphasises the value of this UK national field trial and the benefits of the robust performance data that it is continuing to yield.

Applications for UK-grown Sitka spruce

In the UK, incising has been employed only on large-scale section engineering timbers such as railway sleepers and marine piles. This process used a tooth size that damaged the surface of the timber. These limitations, together with the increasing adoption of competitor materials (concrete railway sleepers) has restricted opportunities to take up the technology in the UK. With the low use of marine piling timbers and reducing uses of timber for railway sleepers, applications of incising in practice halted in the 1960s on any scale. In 1975, “Perma-posts” were manufactured by Ballycassidy Sawmills of Co. Fermanagh, Northern Ireland. These were agricultural fencing rounds (3” to 5” diameter) made of spruce incised prior to air drying and then pressure impregnated with CCA. This product is no longer available and production is thought to have ceased in the 1970s, partly because it was not price competitive with the alternatives at the time, and partly because the end use did not demand the high quality product being produced. There is evidence of incised products being imported into the UK but the application of the products in practice is minimal at present. One remaining example is for timbers for the construction of freshwater jetties and piers which are part of the HLD range of landscaping and waterfront construction products using Weerbaar Hout (Foreco, The Netherlands) which guarantee a 25 year service life.

On the basis of this review, the potential for using incising to raise the value of UK-grown Sitka spruce is considered to be high. The abundance of the timber resource across the UK and the drive to increase the scale of utilisation of timber in construction in the UK, suggest that a move to increase the percentage of self-sufficiency would be a positive step forward for the UK economy and also for environmental and social reasons. Incising should be readily adaptable for any markets where the timber component is over 25 mm thick, including the rapidly expanding spruce fencing market in the DIY retailers. In this end-use the reputation of timber is weak and incising could markedly improve it. It is perfectly possible to extend the use of incising to a broader range of applications in construction, including roofing and other structural timbers. Other examples include transmission poles (2M m^3 in service), tiling battens and anywhere where achieving enhanced durability and a more even penetration pattern is desired.

In summary, the end-use markets which would be most appropriate for incised Sitka spruce are:

- Fencing and use in timber frame constructions
- Possibly also, joinery, cladding and decking as incising can be on three faces, keeping the decorative face free from incisions

Obstacles to the uptake of incising technology are:

- Initial outlay on processing equipment
- Understanding the performance of incised products
- Lack of knowledge of the benefits of incised timber in the market place
- Added cost in a price sensitive market (cheap imports and competitor materials)

Analysis for the UK market

The largest obstacle to the uptake of incising technology for the UK appears to be the initial outlay on equipment and fitting the unit into the sawmill and treatment site. For example, a machine suitable for incising railway sleepers costs approximately £45,000 (Figure 7). This US-built machine is already operating in all the American sleeper processing plants and can process between 10 and 12 railway sleepers a minute.

Additional costs associated with incising technology apart from the plant are:

- Power inputs to incising equipment
- Extra processing time (cost) of incising the timber
- More preservative into spruce (comparable with pine)

Potential savings include:

- Reduced retort times for pressure impregnation of Sitka spruce
- Increased market for product
- Readily available and consistent supply of timber
- Increased marketability of treated products
- Increased performance of treated products

The system most likely to suit for UK spruce would use a 6 mm or 12 mm incision to meet EN351 type specifications for lateral penetration. This would cost considerably less than some commercial systems in the United States and in addition the reduce incision size would require less power to drive the machinery.

Many of the costs involved in the process of incising timber are specific to specific commodities. The treated timber fencing market has been chosen to illustrate the cost-effectiveness of incising.

<u>UK fencing market</u>

The current fencing stock is estimated by BRE to comprise of 1M m^3 of treated timber in private garden fences (assuming 50% of the 24.3M homes in the UK have a small garden), 2M m^3 in agricultural use, 1M m^3 in public utility use and 1M m^3 by local authorities. Highways fencing is estimated to have 0.5M m^3 of treated timber in service. The benchmark species are spruce in the majority of the DIY fencing market where expectations for service life are lower. Douglas fir is extensively used for highways fencing with some larch, while pine species are also used in significant volumes within most of the markets. Small volumes of oak and other hardwoods are used on high profile projects. The total timber fencing volume in the UK is estimated to be between 6M m^3 and 10M m^3 of material with a value of at least £4 billion.

The Highways Agency are responsible for 10,000 km of motorways and trunk roads in England. For their post and rail fences a total volume of 182,700 m^3 treated timber fence posts and 141,750 m^3 of treated timber fence rails are estimated to be in service. Assuming the 40 year service life is achieved an estimated 3% of the volume will need replacing each year equivalent to 10,000m^3. New roads and improvements to highway safety will increase this volume.

In terms of return on investment for the specific commodity of highway fencing posts, the timber treater should be able to recover the estimated £45,000 investment in incising equipment within 3 to 4 months of production. This estimate is based on savings of £15/m^3 in timber costs alone (£95/m^3 for spruce "green" posts compared with £110/m^3 for Douglas fir) with a through put of 750m^3 per month. The incising process is estimated to add £5 per m^3 to costs in additional electricity consumed and wood preservative costs.

Estimated costs for production of highway fence posts from UK grown timber:

Species	Size (cross section)	Treatment	Estimated service life	Estimated costs £/m^3
Douglas fir	145 x 75 mm	CCA	40 years (BS5589)	£140-£150
Pine	145 x 75 mm	CCA	40 years (BS5589)	£170
Spruce (unincised)	50 x 50 mm	CCA	11 years (UK field trial)	£125
Spruce (incised)	50 x 50 mm	CCA	>49 years (UK field trial)	£135-£145

Purchasers and users of treated fencing will benefit in the medium to long term through a more cost-effective alternative to current treated species ("green" spruce posts are approximately 15% cheaper than Douglas fir), and having an additional alternative to current treated timbers. The incised product will provide better value for money through increased service life for only modest additional processing costs compared to unincised material. Under-performance of poorly penetrated products will be replaced with more consistent extended performance from the incised product. The future projected cost of UK-grown Sitka spruce considering the current resource maturity are predicted to be stable or to reduce slightly, depending on demand and future innovative application of the material. Within the boundaries of this review the value of incising Sitka spruce is validated by these costs, though this is sensitive to the cost of the raw material.

Commercial development of the process will ultimately depend on the prices in the end product markets (and particularly of competing products and materials) and also the economics of production compared to alternatives. Imported Baltic pine presents significant competition to CCA-treated Douglas fir as companies are adding value through preservative treatment in the Baltic States before shipping cheaply to the UK markets. It has been noted that CCA treated Baltic pine posts are available at the docks in the UK for £140-£150 per m^3 compared to an estimated £170 per m^3 for UK produced equivalent and £130 per m^3 for incised spruce.

Conclusions

Incising of refractory timber species prior to preservative treatment is widely practised in the United States and Canada to ensure sufficient treatment of the product for the intended end use. It is a relatively simple and potential cost-effective additional step in the processing of sawn or round timber that can enable wider applications of the treated timber end product.

The advantages of incising timber are:

- Improved penetration and retention of wood preservative. In field trials incising spruce prior to preservative treatment doubled the uptake of preservative and appeared to double the service life of the treated stake. The treatment produces a uniform penetration envelope that is quantifiable and enables the treater or end user to demonstrate conformity with European Specification Standards
- Improved durability of treated commodity. Incised spruce stakes treated with 3% CCA can give a predicted service life in excess of 49 years.
- Reduced stresses in commodity (reduced checking of surface)
- Reduced drying time (species dependent?)
- Reduced premature failure of treated timber and the potential benefit of reduced timber waste volumes
- Consistent supply of material into potential end uses in the UK (e.g. highway fencing)

BRE's own trials are showing that incising of spruce before pressure treatment with CCA can produce a sound and durable product, and may permit higher value use of the UK-grown spruce resource.

The disadvantages of incising timber are:

- Reduction of mechanical properties – either these are insignificant depending on the size of the commodity when compared to the extension of durability the process provides or , as in the USA and Canada, design factors can be used for incised commodities to account for any reductions in mechanical properties.

- Visual impairment due to the pattern of incisions on surface – this leads either to restrictions on the application to commodities where surface appearance is not as important, or incising the commodity only on the unseen faces or needles can be used to create smaller incisions.

Incising is not currently practised in the UK largely because benefits have not been shown to justify the initial outlay on equipment.

An evaluation here of relative costs and comparative service lives indicates that the additional costs of incising would be around £10 - £20 per m^3 or about 8% - 16% of the cost of the commodity. This should not significantly affect the cost-competitiveness of treated timber fencing compared with alternative products.

BRE believe that significant opportunities exist in the application of incising technology to UK-grown timber resource and that these would be best achieved through the following series of recommendations.

Recommendations

A strategy for the exploitation of incising to enhance the market for preservative treated UK-grown Sitka spruce is presented as a series of recommendations within four distinct phases of action.

Existing UK national field trials are demonstrating impressive service lives for basic incised spruce posts. An essential first phase of the strategy should be to develop a programme of pilot trials and to demonstrate the application of incising to UK-grown Sitka spruce.

Phase 1: Performance of UK-grown incised Sitka spruce

Phase 1 of the work will provide the foundation for the development of the technology in the UK by providing the performance database specifically for the UK-grown Sitka spruce (*Picea sitchensis*) timber resource. It is essential to establish this foundation specifically for UK-grown Sitka spruce as the data available in the literature is not complete for this timber species. Most published data is for other species (Douglas fir, hemlock) or for 'spruce' of no determined species.

<u>1.1 Pilot plant production of preservative-treated, incised UK-grown Sitka spruce</u>
Produce preservative-treated incised UK-grown Sitka spruce at the BRE's pilot plant facilities to evaluate penetration and retention of wood preservative achieved. Interpret in the light of specification standards EN351 and BS8417. The material will be used in the biological evaluations of performance (1.2). The wood preservatives selected will include alternatives to CCA (e.g. a copper-azole wood preservative would be a good choice for ground contact applications) in the light of the proposed amendment to the European Commissions Marketing and Use Directive which, if passed, will restrict the future use of CCA type wood preservatives.

1.2 Laboratory biological performance tests

Laboratory tests on incised preservative-treated UK-grown Sitka spruce to evaluate biological durability in an ENV839 type test. The ENV839 test evaluates the efficacy of an envelope created by treatment with a wood preservative (Figure 5), at preventing attack from a fungal challenge. The invasion of a fungus through the uniform preservative-treated zone of 6 mm of an incised product is less likely to occur than through the irregular 1 mm treated zone of an unincised product. This would clearly be demonstrated in a laboratory investigation for UK-grown Sitka spruce.

The most reliable guide to the performance of preservative envelope treatments are field tests.

1.3 Field biological durability performance test

Perform accelerated field tests on incised UK-grown Sitka spruce to quantify the extent of improved resistance to colonisation by decay fungi compared with treated spruce, Douglas fir and larch. These will include lap-joints (ENV12037 - a simulated decking board exposure) coatings panels (EN927) and additional ground contact stakes (EN252). These tests provide the most reliable guides to performance. Though they are long term tests (minimum of 10 years) they are essential to provide the future database of performance in support of incised UK-grown Sitka spruce commodities.

Phase 2: Evaluating perceptions

2.1 Evaluate perceptions of incised material in the market place

Conduct a survey of the perceptions of incised timber in the market place including manufacturers of timber commodities, end users and specifiers of timber commodities. Test material will be produced and reviewed by targeted sector groups including large fencing contractors and end users. This will provide background information on the markets that are most likely to accept incised timber products and utilise them.

Phase 3: Demonstration commodities

3.1 Prepare and install demonstration fencing

BRE to co-ordinate production of a demonstration product with a group including a timber grower, preservative manufacture, sawmill, end product manufacturer and an end user. Through a best practice production process based on experience and the literature, fence posts will be manufactured for installation at BRE's Garston field test site (or in service elsewhere), alongside unincised spruce and Douglas fir material. Limited impact and bending strength tests will be conducted to establish the effects of incising on the impact strength of the fence posts. Alternative ground contact preservatives will be used to treat selected incised spruce posts for incorporation into the test field. The material will be inspected twice a year for durability and visual performance (extent of checking, staining and colonisation).

3.2 Produce high profile publicity or guidance document

A guidance document is envisaged describing incising processes and giving details of equipment suppliers and further information networks. It is anticipated that the guidance will be produced together with a review of supporting field performance data from the national field trial. These will be publicised by BRE through their networks and by the BWPDA. In addition a concise leaflet highlighting business benefits of increased service life and better value for money will be developed. The users of such a product will be specifically targeted with these leaflets including Local Authorities, utility companies, large landowners and timber treaters. BRE will offer the guidance document as part of its portfolio of charged publications to its mailing list of over 40,000 professionals in all sectors of the construction industry and client arenas.

Phase 4: Optimising for commercial production

4.1 Optimising the incising process

Conclusions from incising patterns in the national field trial will be used to select and test the optimal incising pattern, including the correct depth and spacing to deliver the protective envelope. The equipment will be installed with a partnering sawmill and treatment company and a suitable chain of supply for sawn spruce established. A rigorous assessment of penetration for the incised products as well as retentions will be performed.

4.2 Optimising kiln-drying for incised material

Moisture content of spruce prior to preservative treatment is important in determining the extent of the resulting treatment. The extent and duration of kiln-drying that is required to dry the outer part of what will become the incised spruce envelope will be studied. This will enable optimising of the kiln-drying period maximising the preservative treatment achieved. The extent of checking and twisting will be compared with that for unincised spruce. On-going kiln-drying work at BRE will be used to derive the most suitable schedule for incised spruce.

4.3 Optimising the preservative treatment schedule

Traditionally, use of British Standards recommends relatively severe treatment schedules for resistant species, including long pressure and vacuum periods. This may not be necessary for incised timber and shorter treatment schedules will be evaluated to ascertain the relationship between penetration, loading and schedule for incised spruce. The pilot preservation treatment plant at BRE will be used to treat incised timber fence posts without the expense of having to treat full-scale commercial charges of timber. The starting point will be the present schedule recommended for spruce in BS5589. The penetration and retention of preservative will be determined and compliance with EN351 type specifications established.

The principle impact will be to provide a platform for increasing the end use applications of UK home grown spruce. The demonstration project and the future adoption of the incising technology is expected to provide important benefits for UK growers of Sitka spruce and for the processor industries which saw and treat it. Purchasers and users of treated wood products will also benefit through a more cost-effective alternative to current treated species and through much improved service life of existing treated spruce commodities. There will also be an impact in increased service life performance and thus improved value for money for products currently only able to be treated to a lower standard than can be provided by incising (e.g. domestic fencing markets). This in turn will provide greater confidence in the treated wood market in the UK which is vulnerable to under-performance and failure to meet the expectations of customers because of the low natural durability and treatability of Sitka spruce.

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Timber Size mm (inches)	Minimum depth of incision, mm
50 x 300 (2 x 12)	9
75 x 300 (3 x 12)	11
100 x 300 (4 x 12)	13
200 x 250 (8 x 10)	14
250 x 300 (10 x 12)	16
300 x 300 (12 x 12)	19 (¾")
Intermediate Sizes in proportion.	

Table 1. Detail of incising depths allowed for timber dimensions for the preservative treatment of structural timber, pilings and posts. (State of Ohio, Department of Transportation, Construction & Material Specifications 1997)

	INCISED		**UNINCISED**	
	Modulus of rupture	Modulus of elasticity	Modulus of rupture	Modulus of elasticity
mean (of 17)	64 N/mm2	10340 N/mm2	76 N/mm2	11870 N/mm2
standard deviation	11.1 N/mm2	1590 N/mm2	10.7 N/mm2	1734 N/mm2
coefficient of variation	17.4%	15.4%	13.8%	14.6%

Table 2. Effect of incising on static bending strength (Banks 1973)

Douglas fir	Incision depth (mm)	Incision density/m^2	Higher grade shear strength (MPa)
Untreated	-	-	12.14
ACZA treated	-	-	11.00
ACZA treated	5	7000	8.24
ACZA treated	5	8500	9.27
ACZA treated	7	7000	6.21
ACZA treated	7	8500	7.41

NOTE: The scallop tooth design incisor for the 7000 density has a greater effect on the shear strength due to the tearing of the wood fibres. The blade type incisor of 8500 density cuts cleanly into the wood.

Table 3. Examples of higher grade shear strengths for ACZA treated Douglas fir reported by Morrell et al 1998.

	INCISIONS (mm)		'PERMEABLE' SPRUCE		
	Stagger	Depth	Absorption (kg/m^3)	Number failed	Life (years)
None	No incisions		-	20	11.9
0.1% CCA	No incisions		0.22	10	15.4
	3	6	0.34	10	15.1
	4.5	6	0.32	10	12.7
	3	9	0.37	10	14.3
3.0% CCA	No incisions		3.24	6	28.5*
	3	6	6.60	0	>49.8
	4.5	6	6.09	0	>49.8
	3	9	7.29	0	>49.8
5.0% CCA	No incisions		5.15	4	30.2*
	3	6	10.90	0	>49.8
Creosote	No incisions		79	0	>49.8
	3	6	136	0	>49.8

Table 4. Absorption of preservative and mean service life of incised 'permeable' spruce

	INCISIONS (mm)		RESISTANT SPRUCE		
	Stagger	Depth	Absorption (kg/m^3)	Number failed	Life (years)
None	No incisions		-	20	11.0
0.1% CCA	No incisions		0.15	10	14.3
	3	6	0.30	10	13.0
	4.5	6	0.30	9†	15.2
	3	9	0.31	10	14.3
3.0% CCA	No incisions		2.82	5	25.2*
	3	6	6.75	1	40.2*
	4.5	6	6.66	1	43.4*
	3	9	6.81	1	40.2*
5.0% CCA	No incisions		3.55	3	31.6*
	3	6	10.05	0	>49.8
Creosote	No incisions		34	5	28.7*
	3	6	89	0	>49.8

Table 5. Absorption of preservative and mean service life of incised 'resistant' spruce

* predicted service life using the method of Purslow (1977)
The service life of >49.8 is predicted using the method of Purslow (1977) assuming a stake fails at the following inspection
† one stake missing

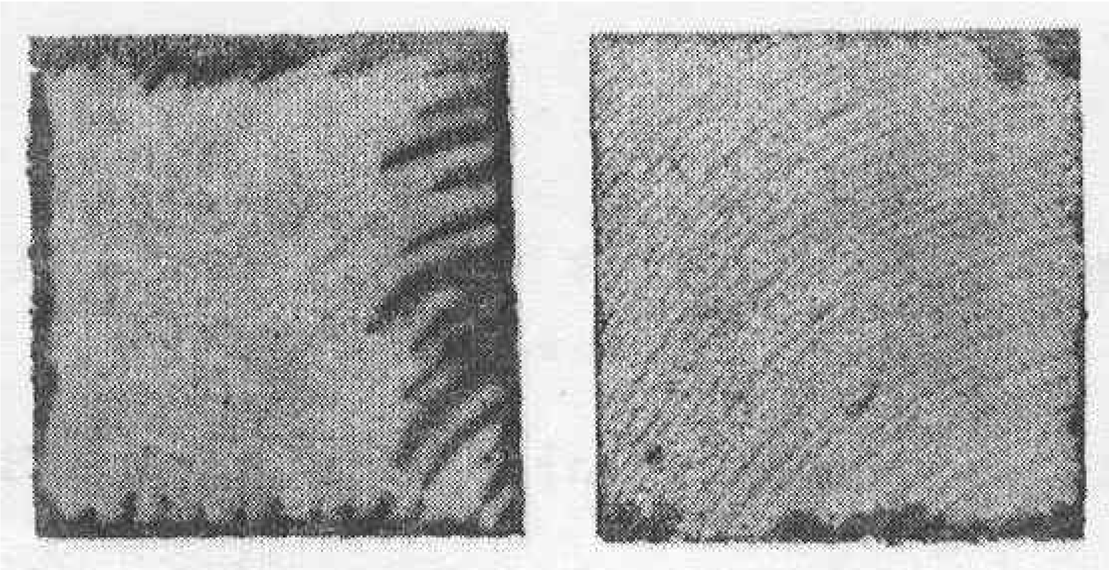
Figure 1. Groundline incising for processing utility poles.

Figure 2. Incising machine manufactured by Hyper Automation in South Africa for incising fencing, railway sleepers, mining timbers, playground equipment and round poles to allow deeper penetration of creosote and to reduce surface checking. The motors for the vertically mounted and horizontally mounted incising drums are clearly visible.

Figure 3. The incised section of a laminated Douglas fir lighting standard or lamp post (J H Baxter and Co, USA)

Figure 4. Permapost promotional material from 1975 (Ballycassidy, Northern Ireland).

Unincised spruce



Incised spruce

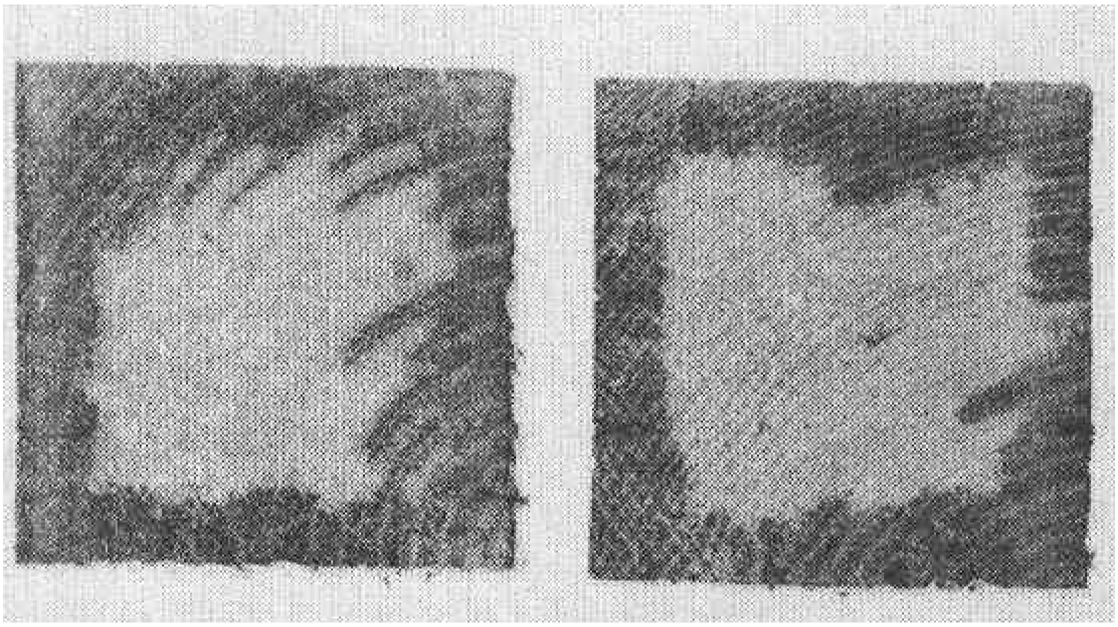


Figure 5. Penetration of CCA wood preservative into cross sections of Russian whitewood (*Picea spp*.)in the UK national field trial of incised spruce. Note the more uniform and deeper penetration of preservative into the incised timber (Banks 1973).

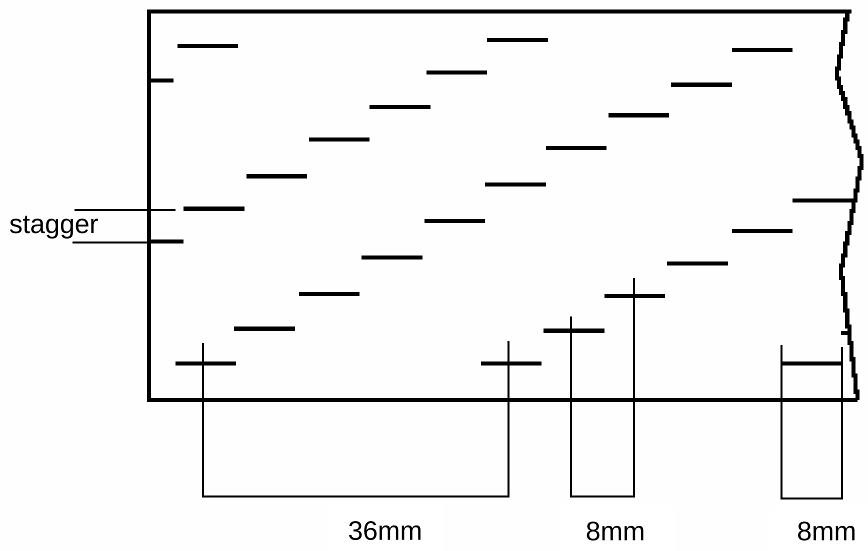


Figure 6. Diagram of the pattern used to incise spruce in the UK national field trials (Purslow 1975).

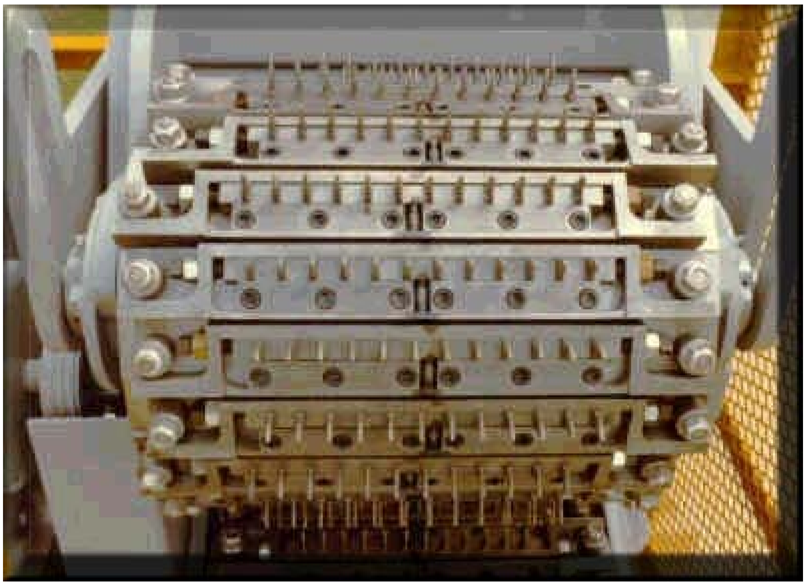


Figure 7. The TIZOR is a high speed railway sleeper incising system designed to increase incising speeds, reduce knife breakage, reduce downtime, and speed up knife replacement. The TIZOR has four identical drums that incise the sleepers, one is pictured above. Each of these drums mounts 20 removable platens, which contain 12 knives each. (Industrial Vehicles International, Inc. Tulsa, OK, USA).

Report Ends