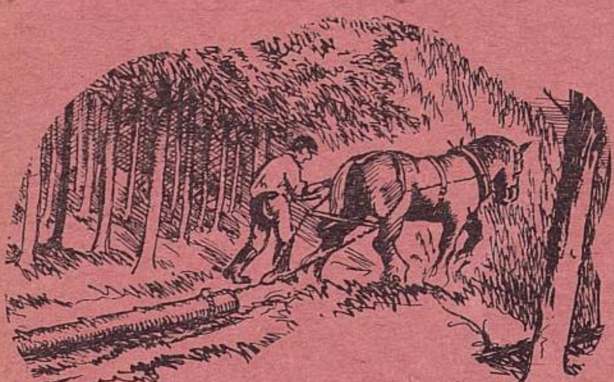
FORESTRY COMMISSION

BOOKLET No. 11

Extraction of Conifer Thinnings

By R. E. CROWTHER



EDINBURGH

HER MAJESTY'S STATIONERY OFFICE

FIVE SHILLINGS NET

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NOTES ON TERMS USED

(*a*) The hoppus foot (h. ft.) used for volumes of round timber throughout this text is equivalent to 1·27 true cubic feet, or 0·0361 cubic metre, solid measure.

(*b*) One cubic metre=27·7 hoppus feet.

(*c*) All measurements of round timber are over-bark.

(*d*) Costs represent average levels at the date the investigations were carried out, and are intended mainly for purposes of comparison. Unless stated otherwise, they are inclusive of labour, labour overheads, and machine costs.

(*e*) "Tushing" implies the dragging out of poles, logs, etc., by chains secured to a horse or a tractor, without the aid of a sledge or a wheeled carriage.

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I. INTRODUCTION

The present time is opportune for a review of extraction methods in Great Britain because the thinning programmes are expanding and new pulp and chipboard industries are commencing or being planned. A summary of Forestry Commission experience on extraction, since large-scale thinnings started in 1948, married to the more detailed findings of the Work Study section over the last six years, should provide a useful platform on which to build further developments.

The main ground types upon which work study has been applied to extraction methods are:

(*a*) *Highland:* Steep slopes usually broken, often rock-strewn, represented by work in North Wales and West Scotland. Generally high rainfall, over 70 inches per annum.

(*b*) *Border:* Gentle to moderate slopes, typically rolling country covered with six to nine inches of peat, represented by work in South Scotland and Northern England. Rainfall about 50–60 inches.

(*c*) *Heathland:* Level ground, sandy soil, represented by work in Thetford Chase. Rainfall under 30 inches.

Extraction may be defined as the movement of forest produce from the stump to roadside and is used here in preference to other terms which, though defined in the *British Commonwealth Forestry Terminology* (1953 and 1957) are either less precise or too specific in their meaning. For instance "skidding" is described as "a loose term for hauling timber, more particularly from stump to roadside" but it implies that all or part of the timber is in contact with the ground which is certainly not always the case. "Hauling" is also unsatisfactory, as this includes the main-road haul, as well as the movement from stump to road, though "off-road haulage" could be regarded as a definition of extraction. "Logging" is a general term which covers both felling and extraction.

Extraction accounts for between 25 per cent. and 75 per cent. of the total costs of production, that is all costs up to roadside ready for despatch, but excluding growing the trees; this percentage, however, depends on the amount of conversion (crosscutting and peeling) and the length and difficulty of the extraction. For this reason, and because extraction is generally more easily mechanised than felling, examination and improvement of extraction methods is likely to be a fruitful way of reducing costs.

This publication on extraction is one of a series on work in conifer thinnings; other aspects already described are felling and conversion by hand, Crowther and Rothe (1963); the use of chain saws, Zehetmayr (1962); and aids to working, Forrester (1962).

The long-term forecast of felling and thinning in conifers for Great Britain, Forestry Commission (1961), is summarised in Figure 1.

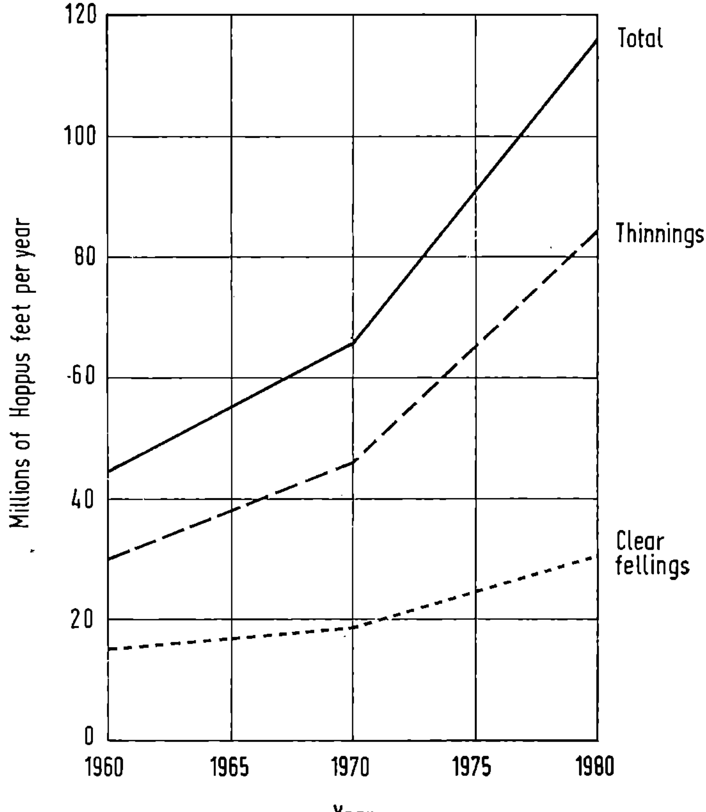


FIG. 1. Long-term forecast of fellings and thinnings for forests in Great Britain. Both Forestry Commission and private woodlands are included.

At present thinnings are providing two-thirds of the total cut and this proportion will remain the same in 1980. During this period it is expected that the production from thinnings will more than double, rising from 40 million to 85 million hoppus feet per year. Although thinnings are of greater importance as far as volume is concerned, the extraction techniques are less well developed than those for the clear-felling of either hardwoods or conifers; Huggard and Owen (1959) devote a chapter to extraction machinery and Shaw (1953 to 1961) has tested and described many items of equipment under development, but apart from these accounts there is a lack of literature describing and comparing methods applicable to various conditions in Britain.

Much work has been carried out in other countries on extraction problems, but for several reasons only small parts of this work are directly applicable to conditions in this country. The problem we are concerned with is the extraction of coniferous thinnings from plantations in Great Britain. This makes work in other countries concerned with natural forest, clear felling, or work in snow or in tropical conditions of little direct relevance as far as details are concerned, though the principles are often generally applicable.

The work of Söderlund and Helmers (1957) on the pull requirements on bare ground of various types of horse equipment, and that of Samset on double drum winches in Norway, have had most influence on the work study of extraction in this country. Aspects of work on coniferous fellings in eastern Canada are well covered by Silversides (1959) with copious illustrations of various useful techniques. Work in the tropics is treated by Cermak and Lloyd

Table I

EXTRACTION METHODS EMPLOYED IN FORESTRY COMMISSION WOODS IN 1960

Country	Total extracted Million hoppus feet	% Extracted by various means					
		Hand	Horse	Tractor	Lorry	*Other	†Total %
Great Britain .	18·3	16	53	40	22	1	132
England . .	8·5	27	24	56	31	2	140
Scotland . .	6·5	5	81	25	18	1	130
Wales . .	3·3	11	69	29	5	–	113

* Other includes ropeway, winch, etc.

† Percentages over 100 indicate the amount handled by a second extraction; for example, 32 per cent. of the 18·3 million hoppus feet extracted in Great Britain was extracted in two stages, e.g. hand plus horse, hand plus tractor, horse plus tractor, and tractor plus lorry, etc.; the actual amounts handled by the various combinations of methods are not known.

Half of the total 18·3 million h. ft. was worked by the Forestry Commission and half by merchants; these figures exclude forests with less than 10,000 h. ft. felled in 1960.

(1962) who give descriptions of various techniques which help to keep the problems of extraction in coniferous thinnings in perspective.

Table I gives the result of a survey on extraction methods in Forestry Commission areas in 1960, Zehetmayr (1961). It includes both Forestry Commission work, of which the breakdown into various methods is known accurately, and standing sales, for which the proportions by various methods were estimated. At the same time a census was taken of the numbers of various extraction equipments that were actually in use during the first week of October 1960. This information is given in Table II. The link between equipment and volume worked is not a very precise one; for instance some forests may have had no work in progress during that week but a substantial programme already completed, and vice versa; this point needs to be borne in mind when examining these figures.

Table II

EXTRACTION EQUIPMENT EMPLOYED IN FORESTRY COMMISSION WOODS IN 1960

Country	Numbers			Thousand hoppus feet extracted in Forest year 1960 per equipment in use at Oct. 1960	
	Horses	Tractors			
		Wheeled	Tracked	Horses	Tractors
Great Britain .	396	275	94	24	20
F.C.: Merchants	157 : 239	124 : 151	25 : 69		
England . .	80	159	61	26	21
Scotland . .	208	70	17	25	19
Wales . .	108	46	16	21	15

Note: F.C. = Forestry Commission.

The main features revealed by this survey were as follows:

(1) The predominance of the horse as the main means of extraction in the hill country, with high rainfall, of the north and west, and the larger part played by lorry and tractor in south and east England with its comparatively level ground and lower rainfall.

(2) The higher proportion of hand extraction as more extraction is undertaken by tractor rather than by horse.

(3) The small part played by other extraction methods, i.e. ropeway and winch.

(4) Table I shows the varying amounts in the three countries that were extracted in two stages, that is, by one or more of the

following methods: hand and horse, hand and tractor, tractor and lorry, etc. This is expressed as a percentage above 100 per cent.; for instance, of the Great Britain total, 18·3 million hoppus feet felled, 32 per cent. or about 6 million hoppus feet was extracted in two stages.

(5) A point not covered by the Tables I and II but included in the survey was that two-thirds of all lorry loading was carried out by hand.

(6) The apparent low output per horse or tractor suggests either inefficient methods or else a great deal of part-time working. One would expect double the output for a full year's work.

This survey confirms the experience of the Work Study Section that the main features of extraction that will yield the biggest returns from improvements are:

- (*a*) Hand extraction and/or the correct preparation of loads by the feller.
- (*b*) Improvement to horse extraction methods.
- (*c*) The development of double-drum winch extraction.

All those major points are dealt with in the following pages but before considering various extraction methods in detail it is convenient to discuss a number of general principles affecting the operation.

II. SOME GENERAL PRINCIPLES

1. Planning

The cost of an extraction operation can be greatly increased by failure to plan comprehensively at an early stage. Such planning must include not only the more obvious points such as road and rack layout, but also some aspects of forestry that at first sight appear to have little relevance to extraction.

Time-studies on felling have established that far more work is required to obtain one hoppus foot of timber from small trees than from large ones; the same effect occurs with extraction, because smaller trees require more handling of individual pieces than do large ones. For example, in dragging by horse a change of pole-size from one to two hoppus feet may result in an increase in output of 45 per cent. This is an extreme example, and the effect is not nearly so marked when considering the difference in output when working trees of average volumes of two and three hoppus feet respectively. Clearly then it is necessary to decide at the planning stage whether the extra costs of felling and extracting small trees are going to be recompensed by a high value of the products when sold, or by a worthwhile benefit to the standing crop when the small trees concerned have been removed.

The total volume removed per acre may also have as important an effect upon the cost of extraction as does tree-size. A light thinning of 150 to 200 hoppus feet per acre will involve more work in making up loads for extraction than will a heavier thinning of 400 to 500 hoppus feet per acre. This is not only true of horse dragging, but can be a vital factor with the double-drum winch, where the frequency of non-productive setting-up time is very much greater with low volumes per acre.

In addition to tree size and volume per acre, the total volume of a particular cut can have an effect, because a larger programme may ensure full use of equipment which will bring the operating cost down and so reduce costs of extraction. It may even make it possible to mechanise certain parts of the job simply because a small programme cannot justify an expensive piece of equipment, whilst a large one can.

All these points emphasise that the silviculturally desirable practice of early thinning as stands become ready, resulting in small pole-size, low volumes felled per acre, and small programmes, is likely to make for high costs, particularly for extraction; what is desirable from the silvicultural aspect may have to be modified by the requirements of economic extraction.

Equally important is the effect of the end product on extraction methods and costs. For instance a market that requires pole lengths dictates "pole-length" extraction. But if small pieces are sold the forester has greater freedom of choice over the size of piece extracted, and as to whether conversion is at stump, at roadside or in a depot. The decision on place of conversion depends in turn on extraction methods that are practicable for the ground conditions and topography under consideration. For instance a full conversion at stump into small billets (for example four-foot lengths of pulpwood) is only practicable if an efficient method of extracting these pieces exists. At the present time this means a wheeled tractor and trailer with its rather limited cross-country performance. On ground where wheeled tractors cannot operate, full conversion at stump into small products is in fact rare, and the usual procedure is to extract in the pole length by horse dragging or, less commonly, by crawler tractor with sledge or logging arch.

Pole length extraction has the disadvantages that it tends to cause damage to standing trees and the making-up of loads for the extraction equipment is difficult. A specification that can be cross-cut at stump will avoid these disadvantages, provided piece size is not so small as to complicate extraction. A length of 10 to 17 feet is ideal for Scandinavian horse equipment or a double drum winch.

It is possible therefore to effect considerable improvements in extraction by making modifications to the product; this of course is more difficult or even impossible when an industry has already been developed dependent on a certain specification, but at the planning stage of new plants this opportunity does occur.

2. Movement, Terminal Times and Costs

It is useful when considering extraction and transport problems to break the operation into the following components:

(a) Direct

(i) **Movement** times or costs are those which are directly related to distance. Because no journey loaded can be made without a corresponding return empty, it is convenient to refer to movement times and costs in terms of the distance the produce is moved, rather than the distance actually travelled by the extraction equipment. This also helps to clarify cases where the extraction equipment adopts a circular route or takes a longer way back to avoid climbing a steep gradient. Thus total times or costs incurred by the equipment while moving during each round trip must be included, although the distance refers only to that over which the produce is moved.

(ii) Terminal times or costs are those which are independent of distance and are mainly concerned with loading and unloading. They include not only costs associated with labour, standing charges of the vehicle and loading equipment, but also costs of preparatory work such as the making of bundles and sling loads which will also need to be taken into account. Both loading and unloading are included, and strictly speaking, time taken to turn and manoeuvre extraction equipment is a terminal charge, because it is the same regardless of the length of the journey.

(b) Indirect

These are the costs that cannot be directly related to individual loads such as the cost of construction of racks, tracks, and roads and associated stacking space. The decisions on expenditure under this head are made prior to the actual extraction, and the factors that need to be taken into account are considered under "Roads" on page 13. Construction of stacking space is an indirect terminal charge, whilst roads are an indirect movement charge; but there is little point in making this distinction unless stacking space construction is very costly and various alternatives are being considered.

The breakdown into movement and terminal charges enables extraction time and costs to be predicted for distances and systems other than those for which data are immediately available. For example an extraction by wheeled tractor and trailer might cost 4d. per hoppus foot for an average haul of 200 yards. If the terminal portion of this cost was 3d., and the movement cost ½d. per 100 yards, one could assume, with some certainty, that a haul of 400 yards would cost 5d. (Terminal cost 3d., plus movement 2d., i.e. 400 yards at ½d. per 100 yards.)

Examination of extraction methods must take into account the relative importance of terminal and movement costs. Thus for short hauls improvements in movement time by increased speed or load size will have relatively little impact in reducing costs, while reduction of terminal times will be far more effective. Where long hauls are involved, improvement of movement times will be more important. Also where movement costs are low in comparison with terminal costs, economies to be achieved by reducing the length of haul may not be great.

Table III shows the effect of reducing movement and terminal times respectively in the case of the wheeled tractor quoted earlier.

Table III

EXAMPLE OF THE EFFECT OF REDUCING MOVEMENT AND TERMINAL TIMES

Basic data: Wheeled tractor and trailer, load 60 h. ft.
Terminal cost 3d. per h. ft.
Movement cost ½d. per h. ft. per 100 yards.
Average load 60 h. ft.

Haul in yards		Cost in pence per hoppus foot	Movement cost reduced by 20%	Terminal cost reduced by 20%
100	Movement . .	0·5	0·4	0·5
	Terminal . .	3·0	3·0	2·4
	Total . . .	3·5	3·4	2·9
	% saving on total .	—	3%	17%
400	Movement . .	2·0	1·6	2·0
	Terminal . .	3·0	3·0	2·4
	Total . . .	5·0	4·6	4·4
	% saving on total .	—	8%	12%

With an average haul of 100 yards, a reduction in the movement cost of 20 per cent. would give only a 3 per cent. reduction in the total cost; but a 20 per cent. reduction in the terminal cost would reduce the total cost by 17 per cent. If a haul of 400 yards is involved, the savings achieved by a 20 per cent. reduction in movement time becomes more important, at 8 per cent., whilst the terminal charge drops to 12 per cent.

3. Access

Access routes into the forest for extraction can be broadly classified:

(*a*) *Roads* that are designed for vehicles whose main function is to operate economically on public roads.

(*b*) *Racks or tracks* intended for extraction equipment that can operate within the stand; the only preparation being the removal of trees and a small amount of work on obstacles such as rocks and soft places, where these cannot be avoided.

(a) Roads

It is not intended to consider in any detail here the engineering aspect of forest road construction, but it is perhaps useful to emphasise the functions the forest road has to perform. Primarily it is intended to enable main road vehicles to reach into the forest to pick up their loads and to reduce the distance and cost of extraction, subject to limitations of optimum road spacing. In the early stages of a forest, transport of labour may be an important consideration, as well as transport for various management purposes, inspection, fire protection and so on, but these do not detract from the main function which sooner or later will be the transport of forest produce.

(i) Road Spacing. Road construction costs are relatively high compared with those for racks, but against this the movement costs by lorry are between 0·10 and 0·30d. per ton-mile, and these figures must be compared with "off-road" movement costs which lie between 0·5 and 1·0d. per hoppus foot per 100 yards or about 2/– to 4/– per ton-mile.

Obviously there will be a good case for reducing the "off-road haulage" by constructing roads, but there is a tendency when considering extraction costs to think only of direct costs (movement and terminal) and to forget the indirect costs, namely those connected with the construction and maintenance of roads and stacking space. There is a balance between the two, and though direct costs can be reduced by closer-spaced roads this may be more expensive than having wider-spaced roads and higher direct costs.

This question of optimum road density is of considerable importance when a road network is being planned on a fairly substantial scale. It will be of less importance where a road network is already in existence, though it may be useful in considering whether additional spurs are likely to pay their way. On smaller areas and in difficult situations the question is not one of density but whether to have a road or not.

The calculation of road density can be carried out by using a formula which takes into account the annual yield, the annual interest on the initial cost of road construction, the cost of road maintenance and the cost of haul from stump to road. Derivation of this formula is given by Grayson (1958).

It is well to remember that such calculations can only be a guide, and that they do depend on extraction costs increasing proportionally with distances. This is not the case with the double drum winch which has a definite limit to its range. The Isachsen for instance has a range of about 150 yards and clearly in this case roads should not be more than 300 yards apart.

It is suggested in the section on "Racks" (page 17) that, where slopes are sufficiently steep to affect the extraction method, racks should be laid out at right angles to the contour. From this it follows that, in theory, roads should be constructed generally along the contour; roads that run up or down hill should be kept to the minimum necessary to link these contour roads effectively. But the number of roads required on a particular hillside will be controlled not only by road density calculations but by ability of extraction equipment to work uphill as well as downhill. If horses are being relied on, then on the steep slopes the amount of uphill work that is possible may be limited or non-existent, in which case a road at the foot of each slope is essential. However the double-drum winch is rapidly altering this picture because it can work as effectively uphill as downhill, so that if horses are still used for the downhill work the double-drum can work the lower slopes without the necessity for a road at the hill foot. This may make it possible to dispense with one contour road on a hillside. All these considerations have to be reviewed in relation to the terrain concerned; it may often be unduly costly to follow contours precisely.

There is no advantage from the point of view of extraction in linking up spur roads to form loops; doing this will enable vehicles to circulate but does little to reduce the average stump-to-road extraction distance. Except for the fire protection aspect, there is no advantage in running spur roads right out to the forest boundary. Normally, forest roads should not be constructed along the boundary, as in this location extraction can only take place from one side. Spur roads can be of lower specification than the main forest road which serves several spurs, because traffic is infrequent and the distance any one lorry has to travel on them is small. Conversely a road that serves several spurs, or is the main forest road serving as an approach road to a large area, should be of higher specification because it will be carrying more frequent traffic.

(ii) Standard. If distances to markets are great, say over 100 miles, then considerable economies are achieved in running vehicles with the maximum pay load permissible by law (about 16 tons). There will be considerable benefit if these vehicles can use the whole forest road network. If they cannot do so, extra costs are incurred either in an intermediate transport operation from forest road-side to county road-side, or small loads have to be run uneconomically over long distances. Such considerations affect the specification of road and costs, and in turn the optimum road spacing; for example it might well pay to have rather more elaborate roads at wider spacing in a remote forest than in a similar forest adjacent to markets.

A forest road then should be so constructed that it can take the largest road vehicles allowable by law, and gradients, curves, culverts and bridges should be laid out and constructed with this in view.

The Motor Vehicle (Construction and Use) Regulations 1955, limit the total weight of vehicles to 24 tons. This means in practice that payloads cannot exceed about 16 tons, assuming the weight of vehicle to be about 8 tons.

(iii) Stacking Space. Passing and turning places necessary for the road construction traffic, usually of short wheel-base type, may be quite inadequate to turn the long wheel-base vehicles which will move the timber. Similarly space left on either side of the road for engineering reasons, such as drainage and settlement of cut and fill, may be insufficient to stack the timber coming out; both enlarged turning places and extra stacking space are more cheaply provided when construction equipment is on the site, than at a later date. In making calculations of space requirements the 50 per cent. rule is a useful aid. It is approximately true that each 50 *hoppus* feet of timber will occupy 100 true cubic feet of space, so that doubling the hoppus timber volume will give the true volume of stack.

The following is an example of a calculation of stacking space requirements.

Data: Thinning 500 hoppus feet per acre.
Stacks average 3 feet high over the ground area occupied.

Then area occupied for each acre thinned will be:

$$\frac{500 \times 2}{3} = 333 \text{ square feet} = 37 \text{ square yards.}$$

Depending on the road spacing, this will require a varying amount of space along the road. For instance, if roads are 300 yards apart then each chain of road will serve $\frac{300}{22}$ square chains$=1{\cdot}4$ acres and will require $(1{\cdot}4 \times 37) = 52$ square yards of space; this is equivalent to $2\frac{1}{2}$ yards of extra width throughout the length of the road. Alternatively the same amount of space could be located at intervals of 2 or 3 chains if ground conditions made the construction of continuous extra width impossible.

A calculation on the above lines will give some indication of stacking space requirements, but in practice these may be considerably modified by three factors:

(1) *Speed of despatch.* At the one extreme there is the pulpwood operation which can be organised so that despatches take place as soon as complete lorry loads are available; in these circumstances it is possible to make do with the minimum of space as it can be used several times in each thinning. At the other extreme is peeled pitwood which not only requires extra space for crosscutting and

peeling but has to be stacked separately according to size and may take many months to clear. An intermediate condition is a product that is left at roadside until despatched but does not have to go through any intermediate crosscutting and peeling.

(2) *Extraction Methods.* To some extent the extraction method used affects the amount of space required and certainly may affect its location. The method most tolerant of stacking space is probably horse extraction, where space not precisely located at rack ends may be used by travelling short extra distances either through the wood or along the road. The double-drum winch does appear to be one of the most intolerant methods in its stacking space requirements, because space is needed at the end of each rack, and the moving of produce along the roadside involves an extra handling and is expensive. Tractors usually require space to enable them to draw off the road before dropping a load; individual spaces therefore have to be larger, though this is compensated by the tractor being able to travel along the road for some distance to reach a stacking space.

(3) *Cost of provision of space.* Space is most expensive to provide on a steep, regular, rocky slope where a large amount of material has to be removed by drilling and blasting; costs will be lower if advantage can be taken of places where the slope is less or the amount of rock is reduced. Provision of stacking space will be cheaper on rock-free ground and will present no problems on gentle slopes.

Obviously full roadside conversion involving crosscutting and peeling on a site where the provision of extra stacking space is expensive, would lead to a very high production cost; it should be possible to modify methods on such sites, so that the stacking space available is adequate to do the necessary extraction, restricting the full conversion jobs to places where adequate space can be provided relatively cheaply.

(b) Racks

Racks are extraction routes through the forest which enable timber to be gathered and brought to roadside. They may evolve as the extraction equipment works through an area, and the operator selects the most favourable route; on the other hand a pattern of racks may be laid out before felling commences. Both practices are followed in British forests; in steep broken country selection of the route is often left to the horseman, whilst in level areas such as of Thetford Chase (Plate 8) a regular pattern is achieved by cutting out rows of trees, and a similar practice is adopted on steep regular slopes in South Wales. Whatever the practice, some form of rack system is essential because the passage of each load helps to clear vegetation and brash and reaps the benefit of any clearance work on stumps, stones and soft places carried out for previous loads. Racks then are a necessity, and there are several advantages in planning these rather than letting them grow, the principal one being that, if racks or their location are visible at the time of felling, trees can be directed towards them to facilitate extraction. This becomes even more important when the feller is also responsible for crosscutting at stump, and for making the various pieces up into loads at the side of the rack ready for the extraction equipment (Plate 1). Such a system cannot work if the position of racks is left undefined. A well defined rack pattern will restrict damage to a limited number of trees; if racks are not defined extraction damage will be widespread throughout the crop.

The only justification for leaving the location of racks to the horseman is that he can select the best route in really difficult country—as he is usually the owner of the horse, decisions as to whether or not he takes the animal over a dangerous section must be left to him. In such circumstances, if the horseman is working in close conjunction with the fellers, for instance as a member of a team producing pulpwood, questions of route and felling direction can be resolved on the spot.

One of the most time-consuming parts of extraction can be the first gathering-together of the load from stump. If this is left to the operator of the extraction equipment, the equipment is not only idle whilst he does it but there is a tendency to take small loads. Correct preparation by the fellers, of loads of the right size in the right place in advance of extraction, is therefore a fruitful method of reducing extraction costs. If full benefit is to be obtained from new methods of extraction, such as Scandinavian horse equipment and double-drum winches, the preparation of loads by the fellers is essential.

Hand extraction needs to be kept to a minimum in both weight and distance; hence a proportion of conversion at stump is a positive advantage and the close spacing of racks is essential.

(i) Spacing of Racks. The question of spacing should be decided on the following grounds:

An average height, to cut-off-point of two inches in diameter, of an early thinning might be thirty feet. If trees are felled at 45° to the rack (see Figure 2) all trees that are within twenty-one feet will either touch the rack or lie partly across it. Racks spaced fourteen yards apart would mean that all trees either touched the rack or lay partly along it. In these circumstances crosscutting to reduce lengths of

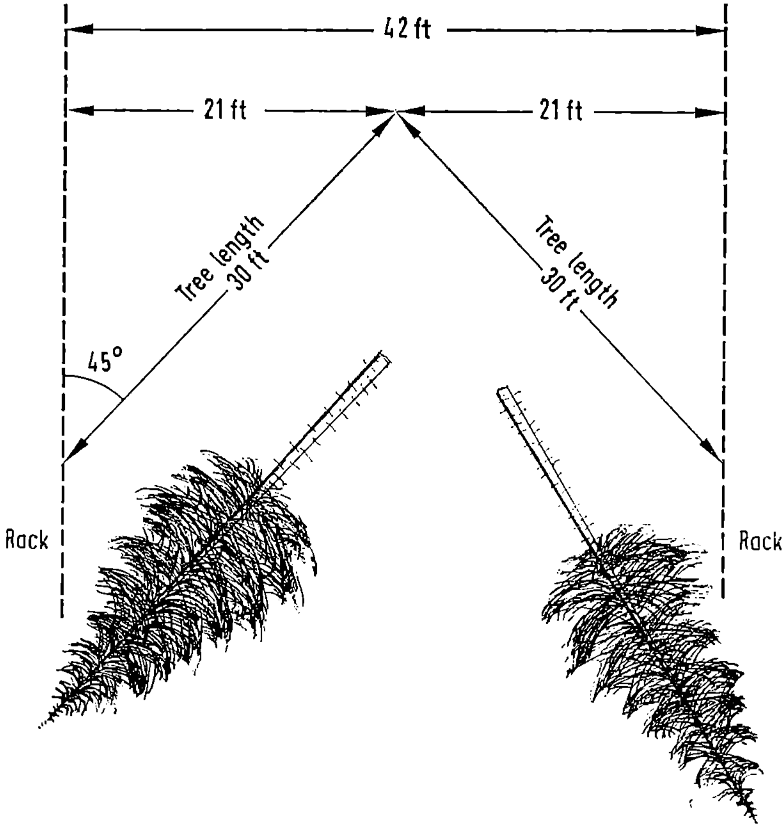


FIG. 2. Rack Spacing. If trees are thirty feet long then with racks fourteen yards (forty-two feet) apart, every tree can be felled so as to either touch the rack or lie partly along it, and hand extraction distance will average about five yards. See Table IV for other spacings and average extraction distances.

exceptionally long poles will be all that is necessary to make hand extraction to the racks a simple matter; and the maximum distance that any piece will have to be moved will be ten yards. Rack spacings of fourteen yards are perhaps too close, and there is a danger that volume of products in the rack may reach a critical low level, making it necessary either to drag pieces down the rack to make up loads, or causing the extraction equipment to make frequent stops to complete each load, or to work underloaded. A low volume removed per acre will have the same effect; light thinnings will inevitably lead to longer hand extraction distances to make up loads. On the other hand rack spacings of two or three chains involve more hand work on extraction, which ought to be kept to a minimum. In the heavier thinnings, such wide spacings may place such a quantity of material in the racks that passage of extraction equipment is hampered.

Table IV

EFFECT OF RACK SPACING ON AVERAGE EXTRACTION DISTANCE

Rack spacing, distance apart in		Average hand extraction distance	Maximum hand extraction distance	Volume per chain of rack assuming 350 h. ft./acre
Yards	Chains	Yards	Yards	
14	0·7	5	10	24
22	1·0	8	15	35
33	1·5	12	23	52
44	2·0	15	31	70
55	2·5	19	39	88
66	3·0	23	46	105

Table IV shows the effect of rack spacing on average hand extraction distance. Generalisations on rack spacings are not easy to make, but spacings between one and two chains are likely to be better than wider or narrower ones.

(ii) Width of Racks. For both horse and winch work, racks need to be about ten feet wide; this can be attained by the removal of one row of trees where the direction of rows coincides with that required for racks, and spacing between trees is five feet. Where lorries or tractors are to work in racks, a width of fifteen feet is necessary. Where direction of rows bears no relation to road direction, and this is usually the case, these widths will not be precise. There will be a tendency to leave a large tree of good form if it intrudes upon the rack, but as this usually leads to it being damaged by the extraction equipment such trees are better cut in the first instance.

(iii) Location. Exact location of racks depends on a number of factors, the conflicting demands of which have to be reconciled.

Extraction Method. For a winch, racks must be straight, but for horse or for tractor, deviations from a straight line are acceptable, so that obstacles such as rocks, drains or soft ground may be avoided. Racks will suit both methods provided they are basically straight lines and any deviation returns to this line once the obstacle has been circumnavigated; this would enable first thinnings to be worked by horse and later ones by winch. See Figure 3.

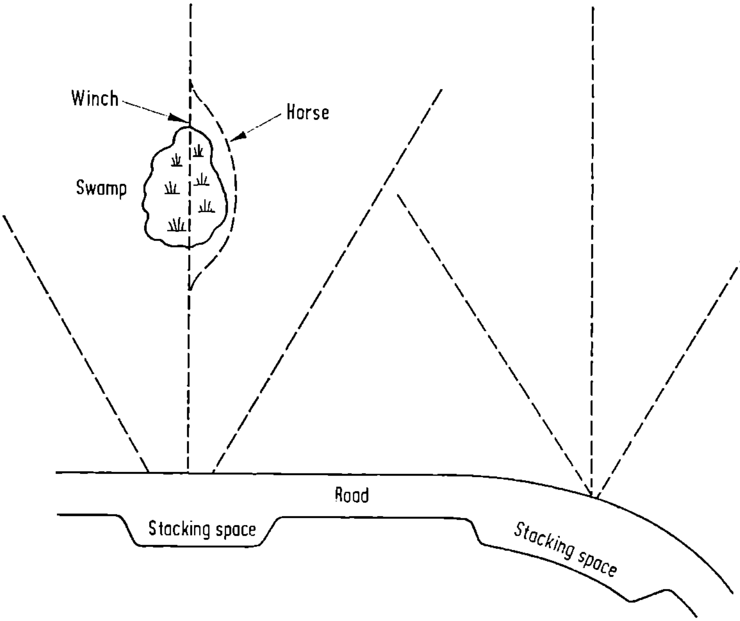


FIG. 3. Rack layout: Fanwise racks. Racks can be laid out fanwise to make full use of stacking space, for instance on steep rocky ground where provision of space is expensive. Racks should be straight if winch extraction is a possibility; diversions to avoid obstacles should return to the same straight line, if these are necessary for horse work.

Slope. On gentle slopes (up to 10°) direction of the rack in relation to the slope is not vital, but on slopes steeper than this it becomes essential to lay racks within 10° of *right angles* to the contour. Otherwise the extraction equipment is likely to overturn or constantly foul trees on the lower side of the rack.

Topography. On flat ground, or on regular slopes, a rectangular pattern of racks will be most suitable (see Figure 4); but on broken ground the pattern should vary to use advantageous features and to avoid difficulties. For instance one should avoid making racks emerge on steep roadside banks, and one should take full advantage of roadside stacking space. This can be done by accepting a somewhat variable spacing of racks, and allowing two or more racks to converge onto a suitable stacking place at roadside. See Figure 3.

(iv) Drains. Racks should cross drains as infrequently as possible and when they do, at right angles. Where drains are so frequent as to be an embarrassment to the layout of racks, slopes are likely to

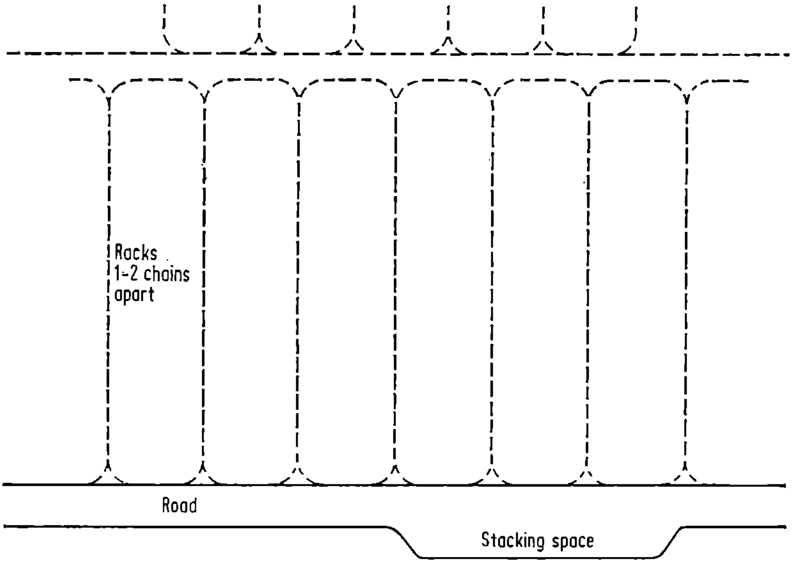


FIG. 4. Rack layout: Parallel racks. This rectangular pattern can be adopted on level ground. Racks should be curved at the ends to enable extraction equipment to enter and leave easily.

be gentle enough not to make the cross-slope a problem when racks are laid out along the low sides of drains.

(v) **Rack Details.** Apart from removing trees up to the required width, some other points require attention.

With horse sledges, tractors with trailers, or lorries, the exit points of racks should be widened to facilitate turning in the direction of the nearest stacking place, so that vehicles can travel up one and down the other without having to turn round in the rack (see Figure 4). Stumps should be cut as low as possible; and this problem may be eased by cutting racks early in the life of the crop. Pulling of stumps, preferably by cutting the roots and pulling over the tree, is one solution, but in peat country the holes left by the stump fill with water, making extraction by horse more difficult than where stumps have been cut low. On hard ground which has been ploughed, a crawler-mounted loading shovel can remove stumps effectively and cheaply.

Removal of tops from the rack is advisable, though *branches* should be left, as these support the horse on soft ground. Where rocks are an obstacle, some blasting may be justified.

Details of instructions on rack layout laid down by the Swedish

Forest Service are described in *Skogsägaren* (Anon. 1961) and broadly confirm this view.

It is worthwhile summarising at this stage, the advantages and disadvantages of laying out racks at the time of planting:

Advantages

(i) A stump-free and unploughed rack results.

(ii) It is easy to see the ground and to take this into account when laying out racks.

(iii) Some savings in establishment costs are achieved.

Disadvantages

(i) The difficulty of predicting, with any certainty, that the layout of racks is correct for extraction techniques in twenty years' time.

(ii) Roads may not be constructed in twenty years' time on the alignments planned at the time of planting.

(iii) Rack-side trees are likely to be more heavily branched than those in the crop.

(iv) Absence of the root network to give support to equipment on soft ground.

Conversely, racks laid out at the time of thinning fit the extraction methods exactly, and difficulties with stumps can be reduced by cutting the racks at the first thinning.

Racks at twenty yards apart, ten feet wide and involving a removal of one row of trees, form one-twelfth (or 8 per cent.) of the standing volume; the effect of cutting them on increment will be negligible provided the marking of the crop follows the marking of racks. In other words the yield from racks must be integrated into the allowable cut from first thinnings.

4. Costing of Mechanical Equipment

If costs of extraction are to be properly compared so that decisions can be made on the best method for particular circumstances, a considerable amount of detailed figure work is essential. If all the factors are not taken into account, apparent differences may be due to variations in costing procedure and not due to equipment or methods used. With manual operations a straightforward comparison of output, or time per piece, will give a reliable indication of the effectiveness of different methods. But as soon as mechanical equipment is employed, not only will its operating cost have to be taken into account, but also labour overhead figures as well, because different jobs will have a varying labour content. A standard procedure (Anon. 1956a) has been drawn up by the Joint Committee on Forest Working Techniques and Training of Forest Workers of the United Nations Food and Agriculture Organisation; it is quoted in full in Huggard and Owen (1959). This is summarised below:

I. The Estimated Irreducible Costs

(*a*) Annual interest averaged.
(*b*) Insurance premium per annum (third party, fire and theft).
(*c*) Motor vehicle tax where applicable.
(*d*) Garaging costs per annum.

II. The Estimated Depreciation and Repair Costs

(*a*) Depreciation.
(*b*) Repairs.

III. Vehicle or Machine Costs Incurred when Working

(*a*) Cost per operating hour of petrol or diesel oil.
(*b*) Cost per operating hour of lubricants.
(*c*) Cost of cleaning and maintenance (wages and materials).

IV. Wages and Associated Expenditure

(*a*) Wages per hour/mile of the vehicle or machine operator(s).
(*b*) Health insurance and similar expenditure, e.g. pensions, paid holidays, sick pay, etc.

The important factor that this costing procedure emphasises is that there are certain parts of the cost which occur regardless of the extent the machine is in use. These are the irreducible costs given in Section I above, and comprise the interest charges, tax and insurance. These will remain constant if the machine is in use *one* hour per day or *nine*, though in terms of cost per hour they decrease the more the machine is used.

For example, the Irreducible Costs in Table V are £45 per year or, assuming the tractor is operating 1,000 hours per year, 0·9 shillings *per hour*. But if the tractor only operated 100 hours per year the Irreducible Costs would remain £45 per year, but would be 9/- *per hour*.

It can be argued that the depreciation (Section II above) continues to some extent even if the machine is lightly used. This is certainly true of that part of the depreciation that reflects the fact that the machine becomes obsolete after a number of years, and cannot compete in output and running costs with machines of more recent manufacture. A good example of this is mechanical equipment that is in a stage of rapid development, like the chain saw, where saws of five years ago, even when new, cannot compete in lightness, reliability and speed of cutting with those on the market today.

Similar rapid obsolescence is likely to occur whenever there is a major technical development, and so far as extraction is concerned the commercial development of hydraulic drive for wheeled tractors is one that may have a profound effect. For this reason, calculations of operating cost which assume a long depreciation period may be optimistic.

Table V

CALCULATION OF THE OPERATING COST OF A WHEELED TRACTOR

Purchase price of tractor = £600
Operating hours per year = 1,000 hours
Operating life = 10,000 hours
Interest rate = 5%

Section	Description	Method of Calculation	Amount per year	Amount per hour
			£	sh/hr. (decimals)
I	*Irreducible costs*			
	(*a*) Annual interest, average	5% on half purchase price	15	
	(*b*) Insurance, (*c*) Motor tax, (*d*) Garaging	10% ,, ,, ,, ,,	30	
			45	0·9
II	*Depreciation*			
	(*a*) Depreciation	Purchase price £600 / Operating life 10	60	
	(*b*) Repairs (tyres included)		84	
			144	2·9
III	*Machine costs incurred when working*			
	(*a*) Diesel oil	0·3 gals./hr at 1/9 per gal.	23	
	(*b*) Lubricants		5	
	(*c*) Driver maintenance		16	
			44	0·9
		Machine Total		4·7
IV	*Wages and associated expenditure*			
	(*a*) Wages per hour of operator(s)	55/- per day of 8 hours	—	6·9
	(*b*) Health Insurance, pensions, paid holidays and sick pay and wet time	15/- ,, ,,	—	1·9
		Total Operator		8·8
		Total Machine and Operator		13·5

Note: Figures at (II*b*), (III*a*), (*b*) and (*c*) are from Forestry Commission records of 254 wheeled tractors operated in Forest Year 1962.

As an example, the F.A.O. Joint Committee method has been used to calculate the operating cost of a 35 horse-power wheeled tractor in Table V. The purchase price has been taken as £600, and it has been assumed that the time in use per year will be 1,000 hours, and that its working life will be 10,000 hours.

Information from Forestry Commission records of 254 diesel-engined wheeled tractors operated in 1962 has been used where applicable. The average number of hours in use for these machines was 1,020 per year, and costs of repairs and tyres averaged £84 per year per machine. The result of the calculation in Table V is a cost of 13s. 6d. per hour for "tractor and driver" or 4s. 8d. for "tractor alone".

These particular figures can be criticised, but the merit of setting them down in this way is that the effect of alterations in the various factors can be assessed. For instance the ten-year depreciation period could be considered too long, and it might be more realistic to depreciate the tractor over five years. This would double the depreciation figure in section IIa in Table V from £60 to £120 per annum and add 1·2 shillings per hour to the operating cost. But there would be compensating savings in repair costs if major overhauls could be reduced by disposing of tractors earlier, and the second-hand value could also be significant.

Similarly, the effect of variations in fuel costs can also be examined. For example if fuel oil were to cost 4s. instead of 1s. 9d. this would cause an increase in operating cost of 0·7 shillings per hour.

This costing procedure emphasises that expensive mechanical equipment needs to operate for a high proportion of the working time available if operating costs are to be kept to a reasonable level per hour. In the above example variation in hours in use per year would give the following results:

Hours/year	*Operating cost per hour*
500	5s. 7d.
1,000	4s. 8d.
1,500	4s. 5d.

It is worthwhile remembering that figures derived from a machine on one job may be quite different from those on another, for instance a tractor which works in a forest nursery may spend a large proportion of its time on ground cultivations where fuel consumption and tyre wear might be much higher than that found when operating a winch, where the tractor only runs at full power intermittently and is virtually static.

5. Some Elementary Mechanics of Extraction

The pull required to move a load over the ground is dependent on the resistance due to friction and to the gradient. The frictional resistance depends upon the nature of the two surfaces in contact and the force pressing them together—in this case the combined weight of the load and vehicle. It is usually expressed as a co-efficient of friction, which is the resistance divided by the total load. Thus a frictional resistance of ½ ton on a load of 1 ton has a co-efficient of friction of 0·50. The frictional resistance is not affected by speed of movement but usually has a higher value, momentarily, at starting, this may be 20 to 30 per cent. higher than the normal value.

The slope affects the pull required to move the load in two ways; firstly the weight of the load tends to make it move downhill, and depending on whether the load is to be moved uphill or downhill this either increases or decreases the pull required to move the load. Secondly a load lying on a slope does not exert its full weight at right angles to the slope, and the force pressing the two surfaces together is less than the weight of the load, so the effect of friction is reduced.

These two forces are affected by the angle of slope and can be expressed in trigonometrical terms as in Figure 5. If the slope is $\theta°$ and the load is L, then the resultant forces, one acting parallel to the surface, S, and the other acting vertically, to it, V, can be expressed in terms of L as follows:

$$\text{Sine } \theta = \frac{S}{L}, \text{ so } S = L \sin \theta$$

$$\text{and Cosine } \theta = \frac{V}{L}, \text{ so } V = L \cos \theta$$

So for pulling *uphill* the force P required to move the load will be:

$$P = \text{force due to friction} + \text{force due to slope}$$

$$P = f\ L \text{ Cosine } \theta + L \text{ sine } \theta \quad \text{(where f is co-efficient of friction)}$$

and *downhill* $P = f\ L \text{ Cosine } \theta - L \text{ sine } \theta$

The effect of slope can be important in the layout of forest roads and tracks, because a generally favourable gradient should enable larger loads to be drawn by the extraction equipment. Adverse gradients can be a limiting factor in size of load, and it will obviously be worthwhile to avoid these if possible. In theory adverse gradients should be spread out so that they are as gentle as possible, but in practice a short moderately steep gradient with a straight approach can be rushed. This allows loads rather greater than theoretical maxima indicated by slope, friction and tractive effort calculations.

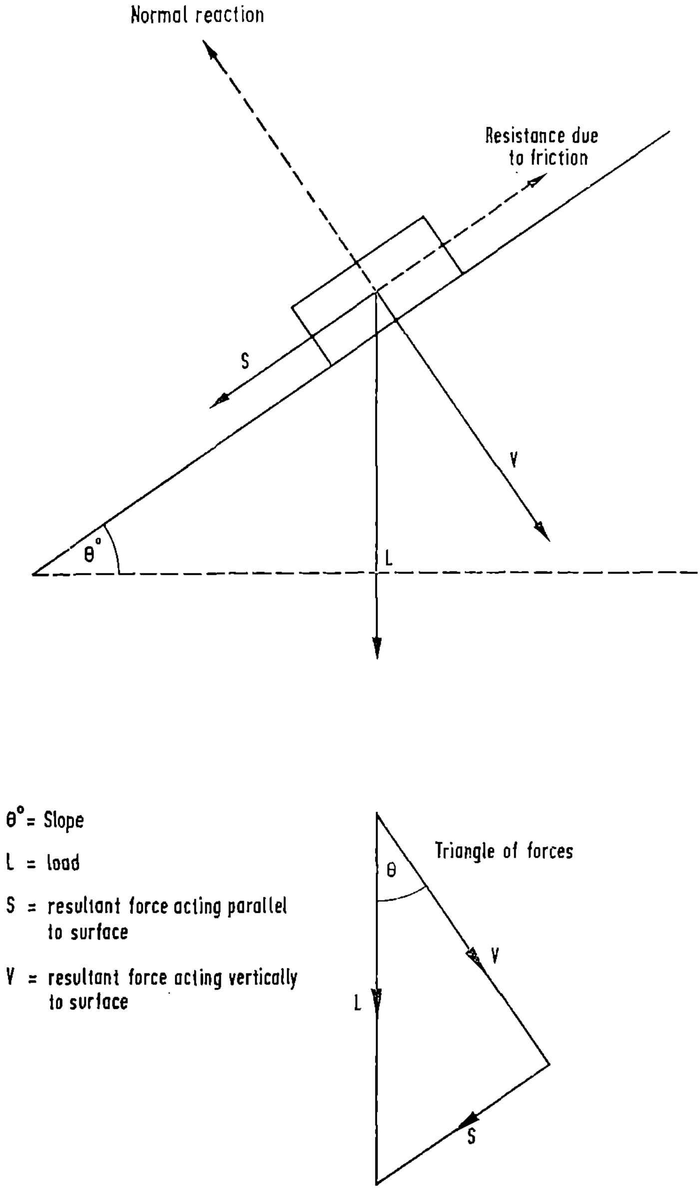


FIG. 5. Forces acting on a load on a slope.

To obtain the load that can be taken by an extraction equipment where pull P is known, these two formulae can be expressed:

Uphill $$L=\frac{P}{f\cos\theta+\sin\theta}$$

Downhill $$L=\frac{P}{f\cos\theta-\sin\theta}$$

In this case the weight of the extraction equipment has an effect, as part of its pulling capacity will be absorbed in moving itself uphill. This is expressed as: W sin θ (where W is weight of the equipment) and has to be deducted from the pull P for uphill hauls, and added to it for downhill hauls, so the formulae become:

Uphill $$L=\frac{P-W\sin\theta}{f\cos\theta+\sin\theta}$$

Downhill $$L=\frac{P+W\sin\theta}{f\cos\theta-\sin\theta}$$

As an example a horse weighing 1,500 lbs. and exerting a pull of 350 lbs., dragging poles on the ground with a coefficient of friction 0·7, would be able, according to these formulae, to pull the loads indicated in the graph, Figure 6.

These figures suggest that the amount of uphill hauling that a horse can do is limited, and that over a slope of about 15° the horse has no spare capacity to pull any load. In practice a horse is only able to walk up the very steep slopes by taking frequent rests. On the steeper downhill slopes the theoretical load rises very steeply with increase of slope, but in practice loads are not only limited by the minimum gradient on the route but also by snags such as rocks, stumps and trees that will be encountered on the way. However the gradient may have an effect which, though not as great as theoretically possible, is nevertheless important. For example horsemen working on very steep slopes of 25° to 30° in Ebbw (South Wales) and Drummond Hill (Scotland), regularly achieve loads of thirty hoppus feet for dragging on the ground, which is about four times as much as can be dragged on the level; and this compensates for the slow walk uphill in these extremely difficult conditions.

The forces involved in other aspects of extraction can be examined in similar fashion. For example it is rare for the pull to be exerted parallel to the ground surface; horses exert their pull at an angle of 15° to 20° to the surface, and similar effects are obtained with tractor winches and logging arches. The effect on a load of an angled pull is to reduce the weight bearing on the ground and so reduce the

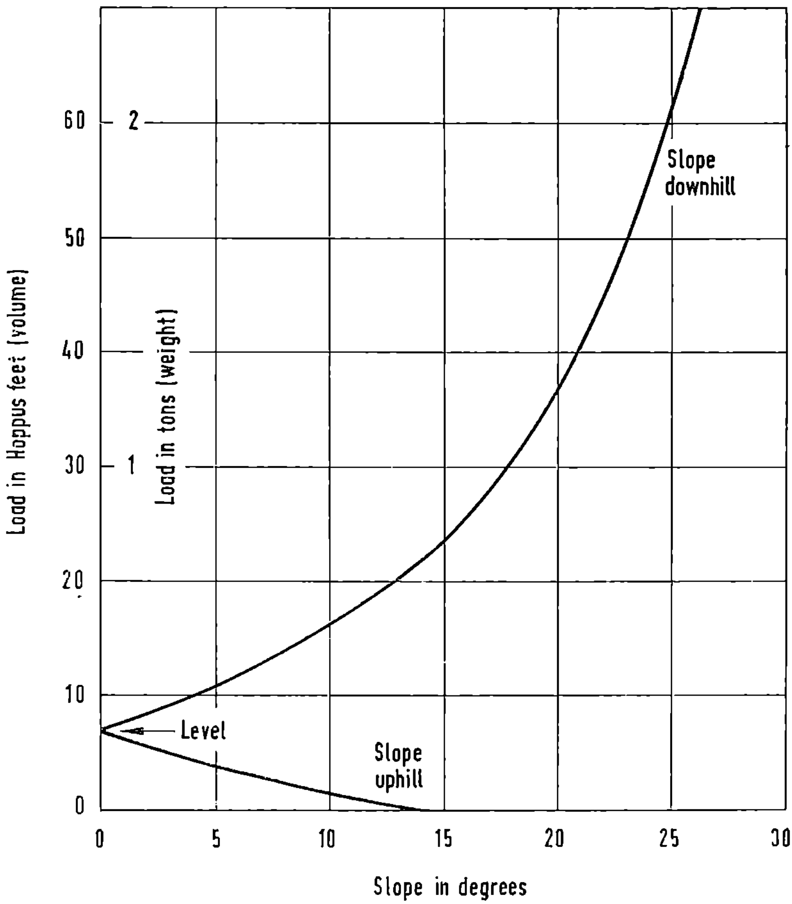


FIG. 6. Theoretical loads for a horse weighing 1,500 lbs., exerting a pull of 350 lbs. and dragging poles on the ground where co-efficient of friction is 0·7, downhill and uphill.

frictional resistance. A similar force, downwards, is exerted on the extraction equipment and the real advantage obtained in this way is to reduce the weight where there is a high co-efficient of friction and add it to the equipment which has runners, tracks or wheels, with a lower coefficient.

Obviously the effect of gradient and friction is not the complete picture because snags such as rocks, stumps, drains and soft going are always features of the extraction route. The forces necessary to overcome these range from the comparatively small ones when the load makes a glancing blow against the obstruction and bounces clear, to the occasions when the load is completely held and even the full tractive effort of the extraction equipment will not free it. The effect of soft going is to lessen the effective tractive effort as well as to increase the pull requirements of the load, because resistance increases when wheels or runners sink into the ground.

The whole question of pull requirements for extraction has been thoroughly investigated in Sweden by Söderlund and Helmers (1957) with particular reference to horse extraction. From this work it is clear that design of extraction equipment has to be a compromise between following factors:

(*a*) Low frictional resistance. Various methods arranged in order of decreasing resistance are:—

dragging on the ground
sledge runners
small-diameter wheels with trailing load
load fully supported on wheels
large-diameter wheels.

(*b*) Good performance over obstructions (stumps, stones, soft places).

(*c*) Light construction—reduced weight.

(*d*) Low height—low centre of gravity for stability; minimum height for easy loading.

(*e*) Good manoeuvrability.

The recent development in Sweden of a tracked sledge for a horse has the advantages of low frictional resistance, good performance over obstructions, and low height; but its weight and manoeuvrability are not so good.

Large diameter wheels which give a low frictional resistance and good performance over obstructions (Shaw 1953) have the serious disadvantages of height, weight and lack of manoeuvrability.

Table VI

PULL REQUIREMENTS

	Pull required to move load expressed as % of load + equipment	*Type of Ground*
Dragging poles along the ground	60–70%*	Level moist peaty ground with grass vegetation (*Molinia*)
One end of load supported on sledge .	40–45%*	do.
Sledge with small wheels . . .	20–25%†	Even and stoneless with ground flora "moist"
Fully on small wheels	10–15%†	Even and stoneless with ground flora "dry"

* Figures from a trial at Kielder Forest by the author.
† Figures from Söderlund and Helmers (1957).

From the above it is clear that dragging poles or logs along the ground is a most inefficient way of using available tractive effort because friction is greatest and ability to clear obstacles is poor. It is surprising therefore that it is so widely used.

III. HAND EXTRACTION

1. The Place of Hand Extraction

It has already been emphasised that a certain amount of hand extraction is necessary if extraction by horse or other mechanical means is to be efficient. At the same time hand extraction is heavy work and needs to be kept to a minimum and made as easy as possible. There is no doubt that the feller is the right man to do this work, because hand extraction is greatly facilitated by the careful felling of trees in the right direction, and if it is left to the horseman or tractor driver his equipment stands idle whilst he does it. However, except in the earliest thinnings, some crosscutting at stump will be necessary to break down poles into a reasonable size to handle, and this operation should also be added to the feller's task.

The maximum weight of timber that a man can safely *lift* is about 80 lbs. Assuming that in handling larger poles or billets it is not necessary to lift both ends off the ground together, the maximum weight a man can *move* is in the region of 160 lbs. Freshly felled coniferous timber weighs about 72 lbs. per hoppus foot which implies that the upper limit for hand extraction is about two hoppus feet. Where slopes are favourable it is possible to drag larger pieces for short distances, but obviously the larger timber lengths will be beyond the size that a man can handle and these will have to be left at stump; even so the fact that these are felled in the right direction does help the subsequent extraction (Plate 1).

In this paper therefore hand extraction is taken to mean the preparation of loads for extraction. The smaller pieces are moved by hand over distances of a few yards; the close spacing of racks and directional felling making this operation easy. Occasionally on very steep slopes hand extraction over longer distances may be a possibility, but it is unusual for hand extraction to cover the whole operation from stump to roadside. It is generally a preparatory operation for other extraction methods; failure to carry it out correctly can cause the failure of mechanised extraction.

2. Tools and Methods

There are several tools that make hand extraction easier and these are described by Forrester (1962).

They are:

(*a*) *Rope:* A fourteen foot loop of rope noosed over the butt of the tree.

(*b*) *Hand tongs:* Either the spring-loaded pattern or the scissor type.

(*c*) *Long-handled tongs:* Used for both pulling the tree down and for hand extraction.

(*d*) *Skid pan:*

(*e*) *Sappie:*

All these handling devices aim at giving a better grip to the pole or billet than can be obtained with the bare hands.

3. Output and Costs

Time study is the only way to derive a precise figure for the output of hand extraction, because to be carried out efficiently it should be an integral part of the operation of felling and crosscutting at stump. It has been found that the work involved in making up loads in racks spaced at one chain apart is between 5 per cent. and 10 per cent. of the total work of felling and crosscutting and costs between $\frac{3}{4}$d. and $1\frac{1}{2}$d. per hoppus foot.

Some difficulty may be experienced in getting hand preparation of loads correctly carried out by fellers accustomed to regard their job as finished once the tree is trimmed, and this may involve extra payments above that indicated by the work content of the job. An alternative is to integrate felling and extraction to road, so that the same team of men are responsible for the whole job. This can work well, once the difficulties of forming a team are overcome, because the team quickly realise the importance of correct preparation for extraction. Team-working, with 4 or 5 men, a chain saw and a horse, has proved particularly successful in the working of pulpwood in North Wales. With more elaborate extraction equipment with a high output, it is not possible to form a single team because the team size would then be unwieldy; but it *is* possible to let the equipment serve several fellers each of whom in turn helps to extract his own fellings with the tractor and driver.

IV. LORRY EXTRACTION

Depending on ground conditions the first choice of extraction method is a lorry, and in descending order of preference, wheeled tractor, horse, or winch. The usual pattern of extraction comprises three stages:

(i) Preparatory hand work—hand extract to rack.
(ii) Extract from stump to road.
(iii) Transport from roadside to mill.

Clearly if a lorry can pick up produce in the rack, to which it has been hand-extracted by the fellers, then the operation of loading on to some other form of extraction equipment, and unloading again at roadside, is eliminated. The lorry will deliver direct from rackside to consumer, avoiding a double handling. Ground conditions in this country do not usually permit lorry extraction to be adopted except in dry weather in the eastern and southern part of the country, but at one place, Thetford Chase (Plate 8), this method of extraction is in regular use on a large scale.

Five-ton lorries, fitted with Hiab hydraulic hoists, load in the racks and deliver to a large conversion depot. The extraction really starts with the layout of racks about fifteen feet wide, which follow a simple rectangular pattern at about two-chain intervals. The feller makes his contribution by felling the trees so that they fall towards the rack, and he crosscuts them into certain main categories. The feller carries the smaller pieces by hand to rack and stacks them, in sling loads on a bearer, ready for the Hiab hoist to pick up. Pole lengths and timber lengths too large for hand extraction are brought out by a wheeled tractor fitted with tongs and placed at rack-side or ride-side. All products from the thinning are thus positioned ready for the lorries.

For transporting poles, a two-wheeled trailer fitted with timber-carrying bolster and pins is attached, and a turntable with bolster and pins is fitted to the lorry platform. The vehicle then becomes, in effect, an articulated pole-wagon. For short lengths the trailer is left behind, and the vehicle used as a normal platform lorry.

Table VII

COSTS OF EXTRACTION BY LORRY AT THETFORD CHASE: BASIC DATA

TERMINAL

	Time Hours	Cost Shillings	
1. *Loading*			
(*a*) Lorry and driver at 20/- per hour	1·1	22·0	
(*b*) Mate at 7/- per hour	1·1	7·7	
(*c*) Hiab hoist at 2/- per hour in use		2·0	
Per load		31·7	
Per ton			5·8
2. *Unloading*			
(*a*) Lorry and driver at 10/- per hour	0·2	2·0	
(*b*) Crane at 20/- per hour	0·2	4·0	
(*c*) Crane driver at 8/6 per hour	0·2	1·5	
(*d*) Crane mate at 7/- per hour	0·2	1·4	
Per load		8·9	
Per ton			1·6
3. *Movement in forest* (*in* + *out*)			
(*a*) Lorry and driver, average 2 miles at 5 m.p.h. at 20/- per hour	0·4	8·0	1·5
Total per load		48·6	
Total per ton			8·9

MOVEMENT ON PUBLIC ROADS (to and from the depot)

4. (*a*) Lorry and driver at 10/- per hour + 11½d. per mile. Average speed 25 m.p.h.			
Time for range of 10 miles $= \frac{20 \text{ miles}}{25 \text{ m.p.h.}}$	0·8	8·0	
20 miles at 11½d.		19·2	
Total per load		27·2	
Total per ton			5·0

TOTAL COSTS: 9/- per ton + 5/- per ton per 10 miles of range

Notes: 1. (*a*) "Commercial Motor" minimum weekly charge for 5-ton lorry used to cover cost of engine running to operate hoist.

(*b*) Lorry mate does other work whilst lorry travels to and from depot.

1. (*b*), 2. (*c*), 2. (*d*) Includes labour overheads (insurance, holidays, sick pay, wet time).

2. (*a*) Commercial motor "Time+mileage" minimum charge, as hoist is not used.

4. (*a*) "Commercial Motor" figures.

The loading team consists of the lorry driver and an assistant; the driver operates the hydraulic hoist controls, and his assistant places the end of the hoist wire round two or three poles or billets at their point of balance. The hoist is raised and the poles guided into position by the assistant. The driver uncouples the rope, returns the hoist for the next lift, and makes any necessary adjustments to the load on the lorry, whilst his mate fits the rope to the next lift. The driver normally stands on the lorry platform, which enables him to see clearly where to drop each lift, and makes it easy for him to reach the rope to uncouple it.

Experience has shown that wear and tear on lorries used in this way is heavy, particularly on springs and tyres, and that loads have to be kept down for this reason. Use of large lorries is not a solution because their cross-country performance and manoeuvrability is not as good. This small load-size would be an uneconomic proposition if the main road haulage was a long one. The question of transhipment to larger vehicles then arises, and this can be performed cheaply when large quantities are processed in a fully mechanised depot.

If correct decisions are to be taken on this question, and others, then costing of the extraction operation is necessary; this has been attempted in Table VII.

Table VII is not a record of actual costs because certain assumptions have had to be made, but for purpose of making comparisons with other methods of extraction, it is valid because the same basis has been used throughout.

Times for the various operations are derived from time study, wages are those in force in 1962 and an allowance of 50 per cent. has been included for labour overheads and local supervision. Lorry charges are derived from the *Commercial Motor Tables* (1962).

The result is that lorry extraction costs 9s. 0d. per ton, plus 5s. 0d. per ton per ten miles of range. The 9s. 0d. per ton covers the terminal costs of loading and unloading, and to simplify the calculation an average distance travelled in the forest has been assumed and included as part of the terminal costs. Costs of hand extraction and preparation of the loads has not been included. As a comparison, movement costs by a sixteen-ton lorry are about 3s. 3d. per ton per ten miles of range, so that where long distances to consumers are concerned it will pay to tranship to the larger vehicle.

Assuming that the cost of loading and unloading a sixteen-ton vehicle in a depot is about twice the unloading cost shown in Table VII paragraph 2, that is about 3s. 0d. per ton, then the break-even point between the two methods will occur at about the twenty-mile range. This is calculated as follows:

Terminal Costs

1. Extract by 5-ton lorry	9s. 0d. per ton
2. Load and unload 16-ton lorry	3s. 0d. per ton

Movement Costs

10 mile range	3s. 3d. per ton
20 mile range	6s. 6d. per ton
30 mile range	9s. 9d. per ton

Total Costs	5-ton+16-ton	5-ton alone (See Table VIII)
10 mile range	15s. 3d. per ton	14s. 0d. per ton
20 mile range	18s. 6d. per ton	19s. 0d. per ton
30 mile range	21s. 9d. per ton	24s. 0d. per ton

Table VIII

COSTS TO DEPOT BY LORRY AT THETFORD CHASE: CALCULATED FOR VARIOUS DISTANCES ON PUBLIC ROADS

Distance from forest to depot miles	Terminal costs per ton shillings	Movement costs per ton shillings	Total Terminal and movement per ton shillings	Cost in pence per h. ft.	Time per round trip hours	Trips per day	Output per lorry per day h. ft.
10	9	5	14	5½	2·5	3/4	450 to 600
20	9	10	19	7½	3·3	2 or 3	300 to 450
30	9	15	24	9½	4·1	2	300

This table is built up from the costs derived in Table VII, namely 9s. per ton plus 5s. per ton per 10 miles of range; 1 ton is assumed to contain 30 h. ft.

Assuming that one ton contains thirty hoppus feet, the cost can be expressed in terms of pence per hoppus feet for varying distances as shown in Table VIII. A haul of ten miles costs 5½d. per hoppus foot and one of twenty miles 7½d. per hoppus foot. The number of trips possible in a nine-hour day varies with the mileage from a maximum of four, and the output per lorry from a maximum of six hundred hoppus feet, per day.

Plate 1. A view of loads prepared for double-drum winch extraction. The hand extraction to prepare these loads has been reduced to a minimum by spacing extraction lanes at about twenty yards apart and cutting poles into ten-foot lengths. South Strome Forest.

Plate 2. Extraction of first thinnings by a horse using trace harness on very steep slopes at Ebbw Forest. Here a load of about fifteen hoppus feet is being dragged tip-first. Note the bundle of poles is held in two places by the chain to prevent it slipping off.

Plate 3. Extraction in a windblown stand in Thornthwaite Forest. Trace harness is used and the complete pole is extracted.

Plate 4. A simple type of horse logging arch developed in Norway being tried at South Strome Forest. Harness of Scandinavian pattern illustrated in Figure 10 is used.

Plate 5. A view of the horse logging arch shown in Plate 4 being loaded. The advantage of this Norwegian logging arch over the numerous types of sledge available from Scandinavia is that a simple lifting device raises the ends of the poles so that they do not have to be lifted by hand.

Plate 6. The Thetford tractor tongs picking up a pole. The driver operates the tongs from his seat without dismounting. The end of the log is lifted off the ground by raising the hydraulic draw-bar to which the tongs are fitted.

Plate 7. Tongs used in conjunction with a chain and grab hook. The driver has to dismount to fix the load but this is worthwhile for longer hauls.

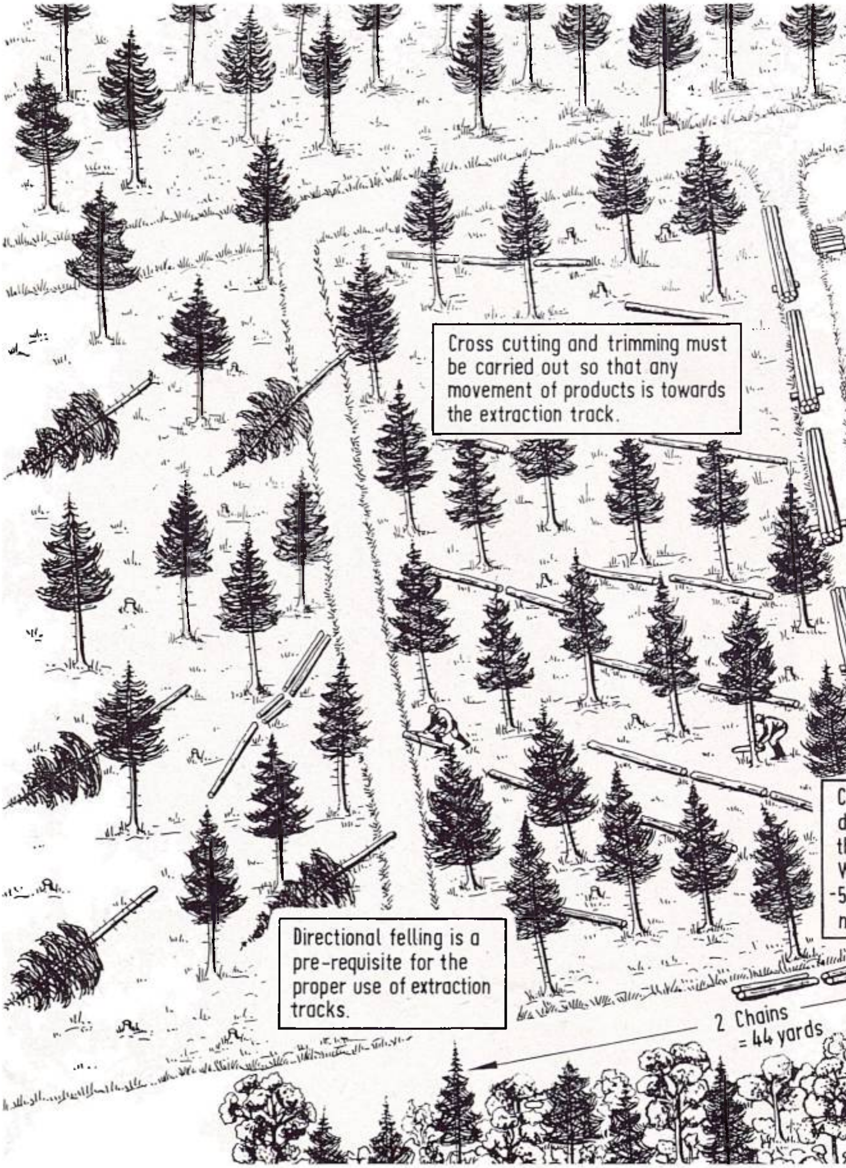
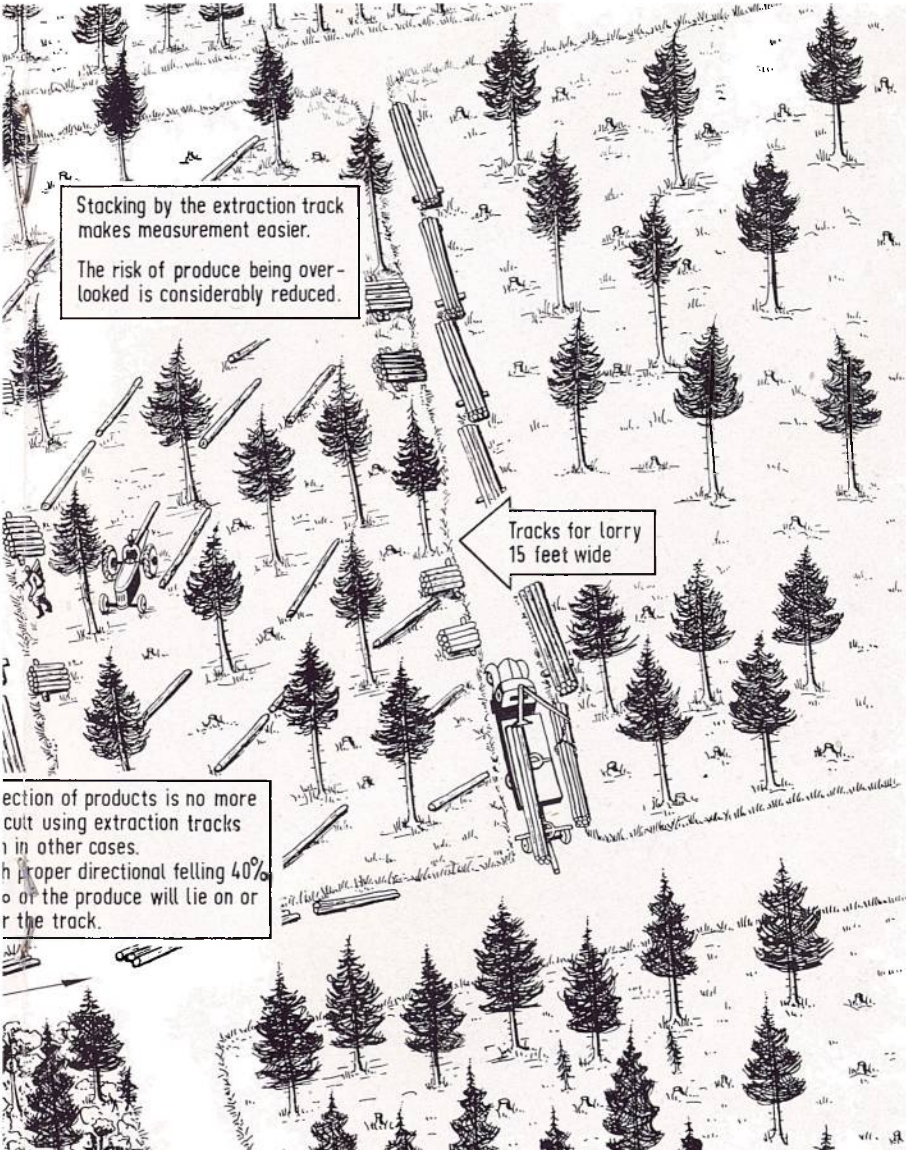


Plate 8. Lorry and wheeled tr



ctor extraction at Thetford Forest.

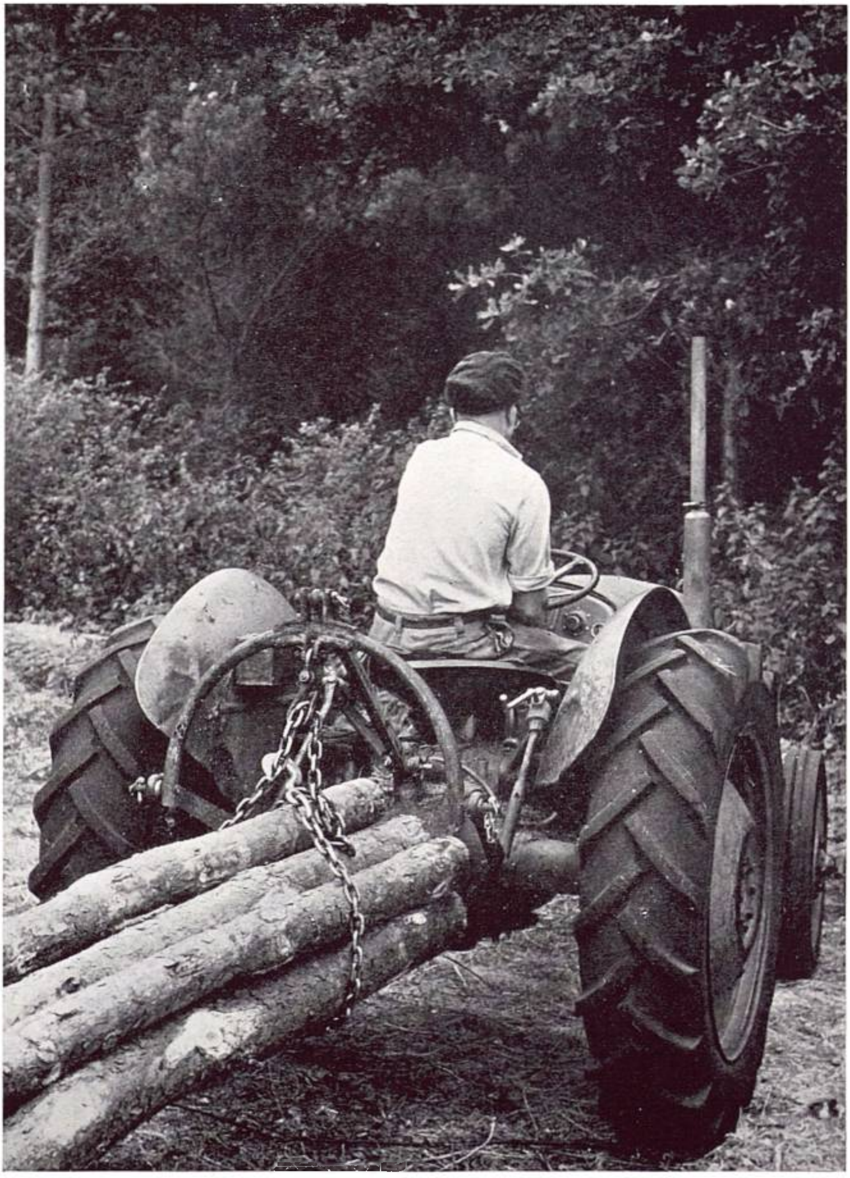


Plate 9. This arched attachment to the hydraulic drawbar of a wheeled tractor enables a larger load to be carried. Thetford Chase.

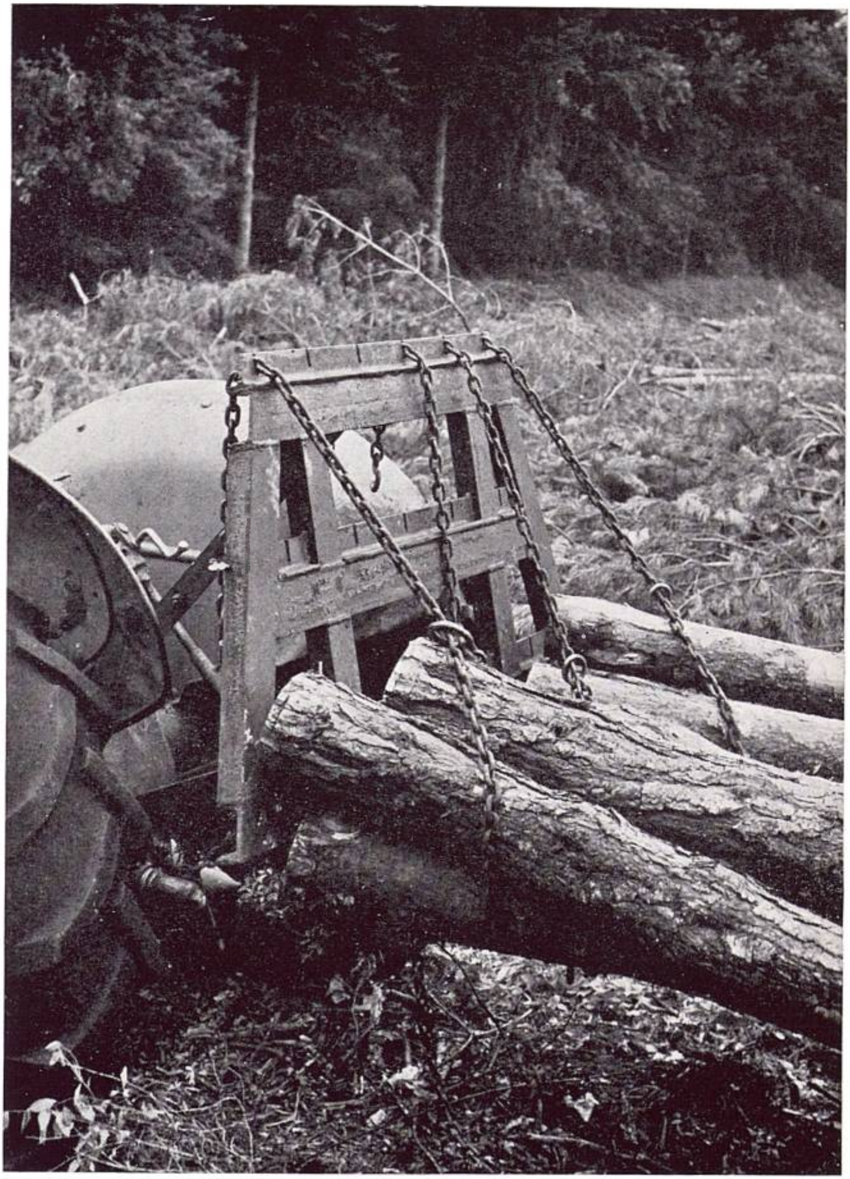


Plate 10. An alternative to the attachment shown in Plate 9 is the Alice Holt drawbar which enables several chain-slings holding poles to be quickly and easilv picked up.

Plate 11. A small crawler tractor using a flat bottomed sledge to extract thinnings over peat; Kershope Forest.

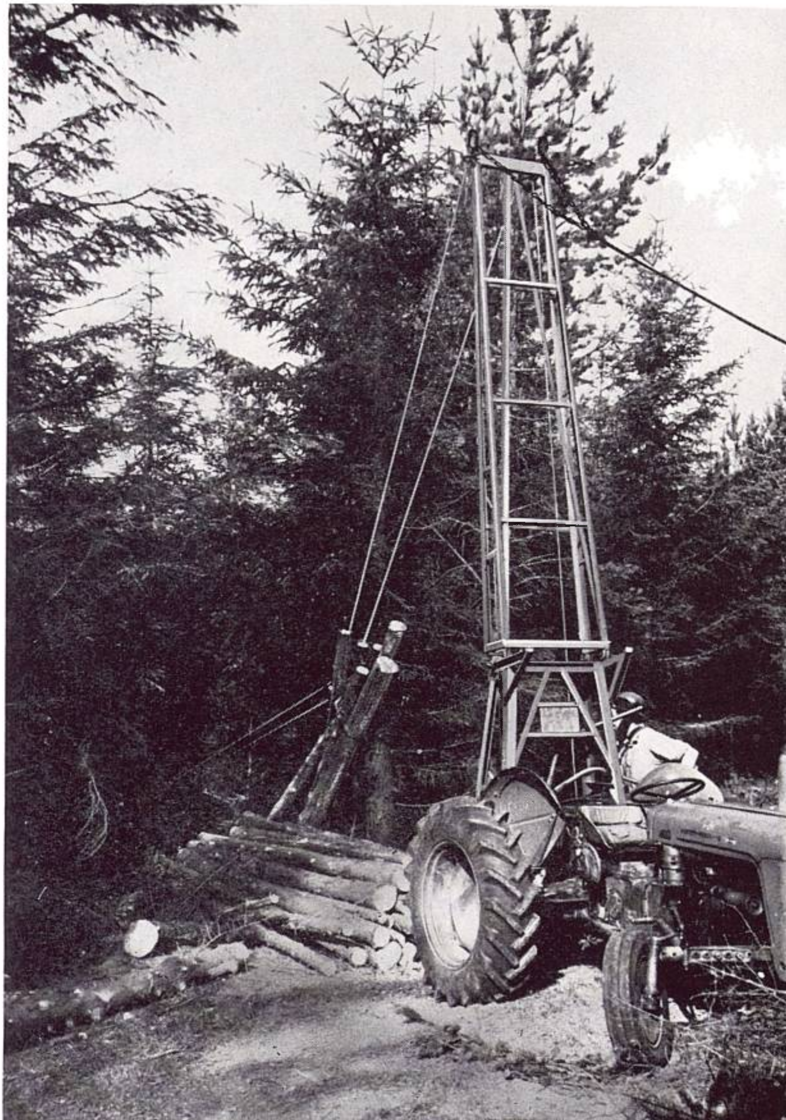


Plate 12. The Isachsen double-drum winch extracting ten-foot lengths uphill at South Strome Forest. Note the effective use of this machine on a narrow forest road.

Plate 13. A further view of the Isachsen double-drum winch operating on a more level site. Note two drums at rear of tractor.

Plate 14. The Hiab Elefant loading ten-foot pulpwood at South Strome Forest; here shown loading pulpwood that has been stacked parallel to the road; it can load equally well material stacked at right angles as shown in Plates 12 and 13. Obviously the extraction operation must end with the material ready for loading.

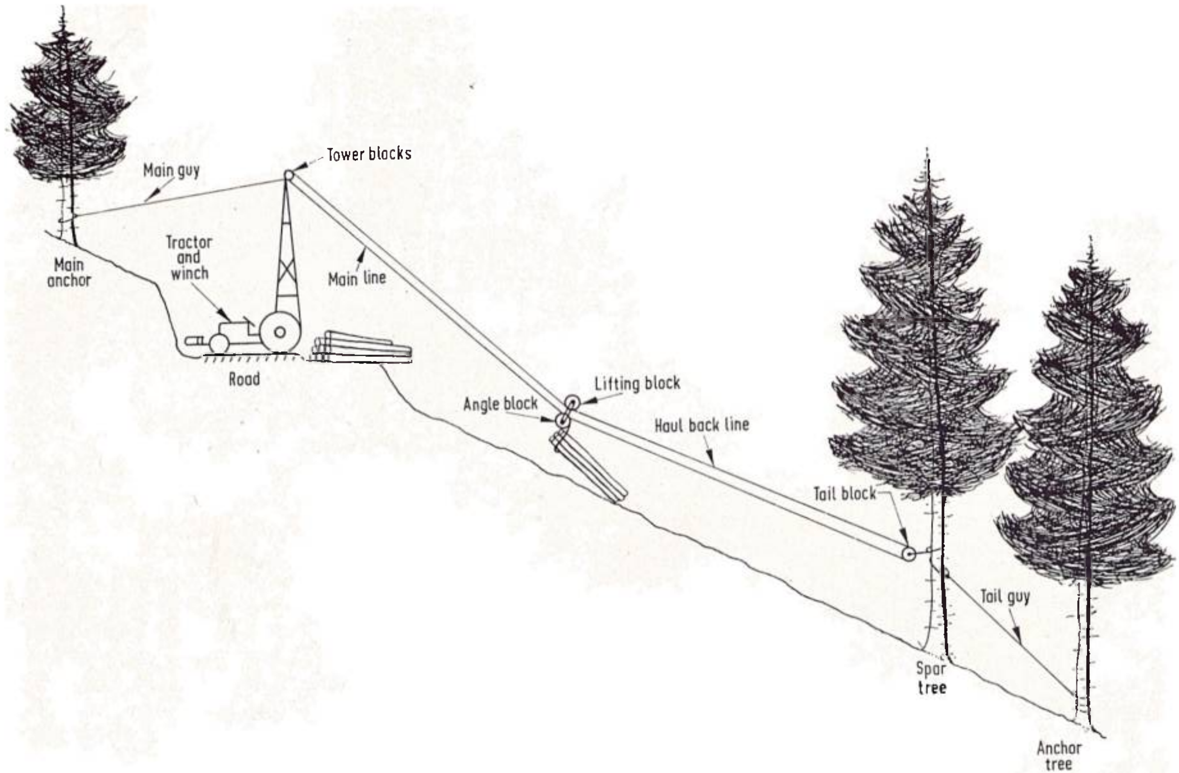


Plate 15. General view of a double-drum winch.

V. TRACTOR EXTRACTION

It is convenient to classify tractors used for extraction into two main categories, wheeled and crawler; not only does this broadly classify performance, but also operating cost. The wheeled tractors designed and mass-produced for agriculture have the advantage of a relatively low purchase price (£500–£700) and an operating cost of about 5s. 0d. per hour. Their performance in the forest is limited by steep slopes and soft ground; only in exceptional conditions such as the level and firm ground of Thetford Chase can they operate in the wood, and in more difficult conditions they are restricted to prepared tracks in drier periods of the year. They have an advantage that they can run on forest roads at speeds of ten to fifteen miles per hour without causing damage to the road surface.

The crawler tractor has a more versatile performance on soft ground and on steeper slopes, but has the serious disadvantage that even the smaller types used for extraction are expensive (round the £2,000 level or over) and operating costs are correspondingly high (20s. 0d. per hour and over), particularly because track maintenance and replacement is an expensive item. Although crawler tractors are used extensively for clear falls of large timber, usually in combination with a logging arch, their use in thinnings is very limited because of the high operating cost and the difficulty in obtaining loads up to the capacity of the tractor. This seriously limits output, and so raises costs.

The present trend in Scandinavia and Canada is away from the plate-type track with a driving sprocket, towards either chain-type track on rubber wheels or to large wheels with four-wheel drive. Where these machines are similarly priced to crawler tractors, the advantages are unlikely to be large enough to make them applicable to thinnings.

The conversion sets of chain-type track, of Norwegian origin, for wheeled tractors are promising because they are relatively cheap and give a good cross country performance. An idler wheel may be fitted between the front and rear wheels of the tractor and is spring-loaded so that it will keep the tracks at the correct tension. The tracks run over the normal rear wheel tyres, and over the front wheel fitted with a broad treaded tyre, instead of the usual ridged one. Steering is dependent on the rear wheel brakes, which are connected to the steering wheel—the normal steering action of the front wheels being locked. Certain steering difficulties have, however, yet to be solved. A half-track version which leaves the front wheels free to steer in the normal way is also available.

As with other methods of extraction, the layout of racks and preparation of loads by the fellers is vital to the success of any developments in the purely mechanical field.

1. Wheeled Tractors

(a) Tractor and Trailer. The simplest application of the agricultural wheeled tractor to the extraction of thinnings is to use a wheeled trailer. Within the limitations of the cross country performance of the tractor, this can be a practical and cheap method of extraction. Usually the trailer is loaded and unloaded by hand, which necessitates crosscutting at stump into billets of sizes that are easily man-handled. The output that can be achieved by this method, with a team of two men and loads of about two tons of four foot long billets, is given below:

Average distance yards	*Cost per hoppus foot pence*	*Output per day hoppus feet*	*Output tons fresh felled*
100	2·4	850	28
200	2·7	750	25
300	3·0	680	23
400	3·3	620	21

The merits of this method are that ordinary farm equipment is used, which can be readily hired. Disadvantages are the amount of hand loading, and unloading, and the relatively poor ability to traverse soft ground. Figure 7 illustrates how the amount of handling can be kept to a minimum at the unloading point when lorries are subsequently loaded by hand.

FIG. 7. Reduction of lifting: Once a stack has been formed, the amount of lifting can be reduced by unloading the top of the trailer load on to the top of the stack and unloading the lower layers of the trailer load on to the ground, moving the tractor to avoid having to carry. The same procedure is followed in reverse for loading a lorry from the stack.

A possible improvement in the use of wheeled trailers is to increase the load and fit adequate brakes, so that the equipment can run on public roads. A development on these lines is the Shawnee-Poole Trailer which enables a five-ton load to be brought out from the wood, and carried on public roads at a speed of twelve to fifteen miles per hour. The advantages of this method are the same as with lorry extraction from the wood, because a handling at roadside is eliminated; but because of the low road speed a break-even point occurs where it pays to change over to lorry transport. A comparison of the Shawnee-Poole Trailer delivering four-foot hardwood pulp-wood from stump to a mill, was made with a tractor and trailer working from stump to roadside, feeding a five-ton lorry delivery from roadside to mill. In this instance the break-even point occurred at about thirty miles range from the mill; below this range the Shawnee-Poole was cheaper; above it the orthodox two-stage extraction was the better method.

Because of the high initial cost of the equipment and the few areas within a 30-mile radius of a large consumer in Great Britain, this method has nowhere been adopted in practice.

(b) Thetford Tong Method. In Thetford Chase wheeled tractors fitted with a form of tongs on the hydraulic lift, are used for the extraction of pole lengths and logs from thinnings. The fittings are shown in Plate 6 and Figure 8. The handle of the tongs is within reach of the driver when he turns in his seat, and for short distances (say up to fifty yards) he picks up single poles or logs, one at a time, and extracts them from stump to rack or ride without dismounting. Some stacking of poles can be accomplished by running the tractor over poles already extracted, and logs can be closely positioned side by side, by nudging them with the front wheels of the tractor whilst bringing out the next log.

Obviously bringing out full tree lengths is not feasible by this method because it would be very difficult to manoeuvre them past standing trees; but the work is facilitated by crosscutting at stump into logs, poles, about twenty-five feet long, and tops, the latter being extracted by hand to racks by the fellers.

When it is necessary to extract for distances over about fifty yards, it is worthwhile making up batches of poles or logs. As an alternative to using tongs, the tractor places poles or logs on to a chain laid on the ground in the rack, and when four or five logs have been brought out the driver closes the chain round them and attaches the free end to the chainlink hook on the drawbar of the three-point linkage (Figure 8 and Plates 7 and 9), raises it, and proceeds with this load.

Time studies show that there is little variation in time taken to extract pieces of different volumes, and the main causes of variation in the number of pieces extracted are: the number of standing trees per acre, the amount of bramble and lop-and-top, and the distance

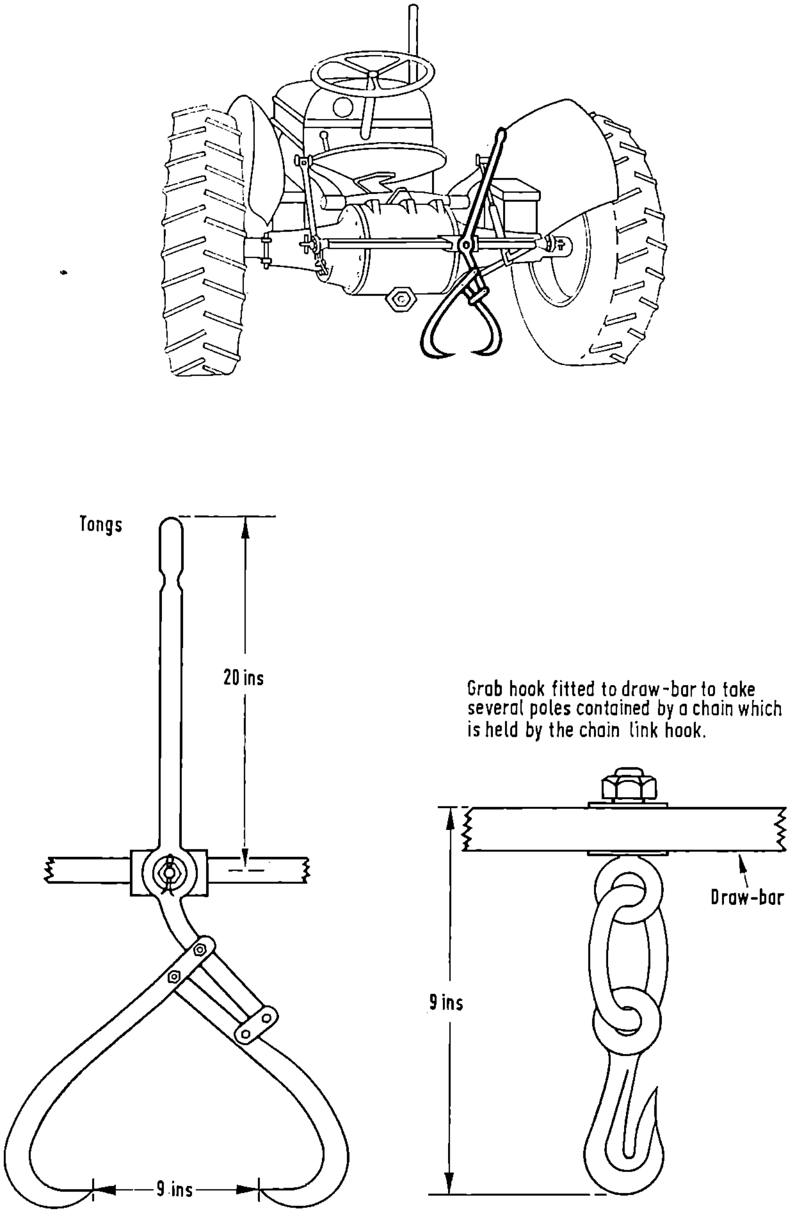


FIG. 8. The Thetford tractor tongs fitted to the hydraulic draw-bar of a Ferguson tractor and used for extracting poles from thinnings on level and firm ground. The maximum opening between the jaws of the tongs is 14 inches. Alternatively a chain-link hook is used.

over which the load is extracted. Table IX gives details of output per day and costs for tractor and driver using these methods.

Table IX

WHEELED TRACTOR WITH THETFORD TONGS, CHAIN AND HOOK OR ALICE HOLT DRAWBAR—EXTRACTION FROM STUMP TO RIDE: OUTPUT AND COSTS

Average distance in yards along rack	Normal brash and bramble				Heavy brash and bramble			
	1st and 2nd Thinnings		3rd and subsequent		1st and 2nd Thinnings		3rd and subsequent and Clear Fell	
	Output per day h. ft.	Cost per h. ft. pence	Output per day h. ft.	Cost per h. ft. pence	Output per day h. ft.	Cost per h. ft. pence	Output per day h. ft.	Cost per h. ft. pence
To Rack	380	3·5	530	2·5	330	4·0	460	2·9
100	260	5·3	320	4·2	230	5·9	280	4·7
200	230	5·7	280	4·8	210	6·4	250	5·3
300	210	6·3	250	5·3	190	7·0	230	5·8
400	190	6·8	230	5·9	180	7·5	200	6·4

Note: The above table takes into account single pole extraction from stump to rack and the making up of batches for the extraction down the rack for distances over 60 yards.
1st and 2nd Thinnings—over 600 trees standing per acre.
3rd and subsequent—under 600 trees standing per acre.

For a haul of 100 yards along the rack, costs in 1st/2nd thinnings are 5·3d. per hoppus foot, assuming an average pole size of two hoppus feet. For third and subsequent thinnings—4·2d. per hoppus foot. Clearly with work in the later thinnings, where piece size can exceed two hoppus feet, and there is more space to manoeuvre, costs lower than this should be possible.

The main advantages of the method are that it is worked by one man and that poles are picked up from stump so movement of poles by hand is rarely needed.

(c) Alice Holt Drawbar. This device shown in Plate 10, also makes use of wheeled tractor's hydraulic lift and three-point linkage, and is more effective than the arched drawbar shown in Plate 9.

Like the chain and hook it becomes worthwhile to change over to the Alice Holt drawbar when extraction distances exceed about 50 yards. The poles or logs are attached to the drawbar by chains, one or more pieces per chain depending on their size. The load is between 15 and 20 hoppus feet.

2. Crawler Tractors

A Bristol tractor of thirty-five horse-power has been used for a number of years for extraction of thinnings at Kershope Forest, playing an important role before the forest was adequately roaded (see Plate 11.) The ground conditions in this forest are typical of the Borders, with a peat layer about six inches deep over-lying boulder clay, etc.; this combination coupled with a rainfall of fifty to sixty inches per year makes for particularly difficult extraction conditions. The tractor is fitted with a heavy-duty winch, the rope being attached to a flat-bottomed sledge. The sledge carries a swivel bolster and pins, and a load of about forty to fifty hoppus feet of poles is secured by chain and chain-binder. The tractor either works from rideside following horse extraction from stump, or in first thinnings from racks following hand extraction. The team consists of a driver and mate, and the sledge is loaded by hand. Unloading is achieved by releasing the chains and drawing forward; the load drops off because the bolster is rounded. Stacking of poles can be achieved by the tractor winching the loaded sledge up over the stack, releasing the chains and pulling forward the empty sledge, leaving the poles behind on top of the pile.

This combination of tractor, sledge and winch can cope with extremely soft conditions, or adverse slopes, by the tractor going forward alone and then winching the load after it; but output under these circumstances is low and costs are high, ranging from 7½d. to 10½d. per hoppus foot for a haul of 100 yards, depending on slope and ground conditions as shown below:

Distance, yards	*Favourable slopes firm surface Pence per hoppus foot*	*Adverse slopes soft surface Pence per hoppus foot*
100	7·6	10·6
200	9·8	15·8
300	12·0	21·0

VI. HORSE EXTRACTION

1. The Place of the Horse in Extraction of Thinnings

It has already been emphasised in the introduction that the horse plays a very important part in extraction in the hill country of the north and west, and that over the country as a whole 50 per cent. out of 18 million hoppus feet extracted in 1960 was worked by horse; for Scotland the figure was 80 per cent. (see Table I). The total number of horses employed in Forestry Commission woodlands is about 400 (1960) and their distribution is given in Table II. We are not alone in our reliance on the horse for extraction, for many other countries are in a similar position; Scandinavian countries are very largely dependent on horses and in Eastern Canada 35,000 horses were employed in 1959 (Silversides 1959). Horses are still the most popular motive power for skidding small timber in many parts of the United States (Simmons 1962).

It is worthwhile to examine the reasons for the continued use of horses in the woods, and to try and assess whether they will continue to play their part for many years to come. Where a wheeled tractor can work it has almost entirely replaced the horse in Britain; this is true of the more gentle slopes and firmer ground of the south and east. Tractors with tracks can overcome the difficulty of soft ground to a considerable extent, but steep slopes limit their effectiveness quite apart from the fact that they are much more expensive.

The principle advantages of the horse are as follows:

(*a*) *Manoeuvrability.* Though low-powered compared with a tractor, the horse can be manoeuvred right to stump in early thinnings and its ability to work between trees is most valuable.

(*b*) *Performance on Difficult Ground.* The horse's high ground clearance and ability to lift its feet are positive advantages in difficult ground conditions. Its ability to traverse steep or broken ground is good.

(*c*) *Training.* The horse can be trained to work in a particular way; this factor can of course be a disadvantage if a horse is badly trained, or if radical changes in methods are to be introduced; re-training will then be necessary.

(*d*) *Capital Cost.* The purchase price of horse is relatively low (£70–£100 in 1962), within the resources of a skilled forest worker.

(*e*) *Costs per Unit.* For steep or soft ground the horse is still the cheapest method of extracting thinnings.

The main disadvantages of the horse are:

(*a*) *Maintenance.* The horse must be fed and watered before and after working hours and during the weekends and holidays; it is often difficult to find someone prepared to do this.

(*b*) *Lack of Horsemen.* At the present day it is usually more difficult to find an experienced horseman than to find a horse, largely on account of (*a*) above.

(*c*) *Laying-up.* A horse still requires to be fed, though on a reduced scale, if there is no work, and when it starts again some time must elapse before it becomes fully fit.

These three disadvantages can be largely overcome by the appropriate financial incentive and training. This will raise the cost of maintaining the horse but there is ample scope for improvement in horse working methods; such improvement should increase output and more than compensate for any extra cost.

In the long term, say over ten years, new machines will probably be developed that will carry out successfully the extraction at present carried out by horses. Also, if present trends continue, the cost of producing and operating machines will decline relative to the costs of labour and animal fodder, a factor that favours the tractor rather than the horse. But for the immediate future, efforts to improve the productivity of horses are likely to yield worthwhile returns.

Table X shows an estimate of the costs of keeping a horse based on information obtained from various horsemen in different parts of the country (Crowther 1960). This figure of £300 per year does not include an element of profit for the man keeping the horse. Assuming an average year to consist of about 200 working days, then on the basis of the above figures a daily hire charge of between 30s. 0d. and 35s. pd., allowing for holidays and wet weather, would be appropriate.

2. Current Equipment and Techniques

The usual method of working is for the horse to drag pole-lengths along the ground; an operation variously termed tushing, snigging or dragging. The load consists of up to eight or nine hoppus feet, made up of from one to six or seven pieces (Plates 2 and 3).

Large trees usually have the butt length cut off, at stump, to reduce both the weight and length of the load. The main disadvantage of working pole-lengths in this way is that it is difficult to make up full loads without the horseman doing a good deal of handling.

Also damage to standing trees tends to be severe when long lengths are extracted from thinnings.

The horses most favoured for this work are Clydesdales or Clydesdale type. In the Scottish Highlands the Garron is often preferred while in mining areas (notably South Wales) horses of the pit pony type may be used. Generally horses are over five years old and veterans of eighteen years and over are seen, although output of such old horses is rarely satisfactory.

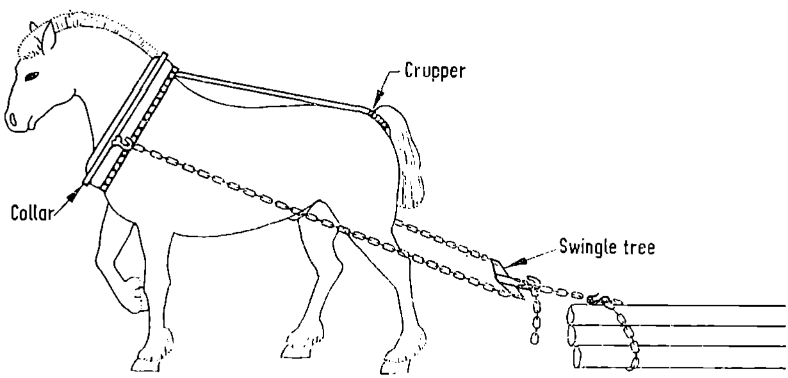
Table X

ESTIMATED COSTS OF KEEPING A HORSE

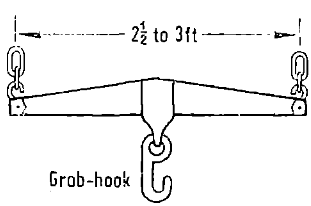
Item	Prices	Frequency or rate of use	Cost per year
	£ s. d.		£
Horse—Buy	80 0 0	Working life estimated at 5 years.	8
Sell	40 0 0		
Shoes— Supply and fit	1 15 0	Sets per year—2	7
Re-fit	1 12 0	Times per year—2	7
Harness	Estimated £10 per year for supply, repairs and replacement		10
Veterinary Surgeon's services per visit	6 0 0	Visits per year—½	3
Stabling	0 7 6	Per week	18
Feed—Hay per cwt.	1 0 0	Summer—none Winter—36 weeks 2 cwt./week	72
Oats per cwt.	1 10 0	Summer and winter 1 cwt./week	78
Grazing per horse per week	0 10 0	Summer—16 weeks	8
Feeding and watering Mon.-Fri.	Day rate 4/5 per hour	2½ hours per week at 1¼ day rate	
Sat. and Sun. per hour		2 hours at double rate	85
		Total	£296 per year. £5 16s. per week

HARNESS FOR

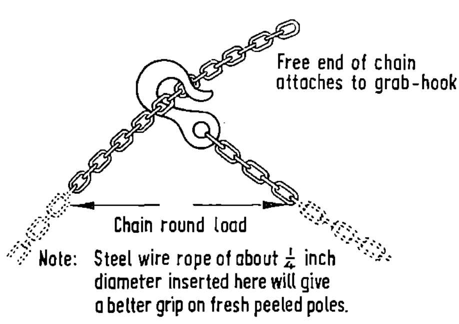
COLLAR CHAINS AND SWINGLE TREE



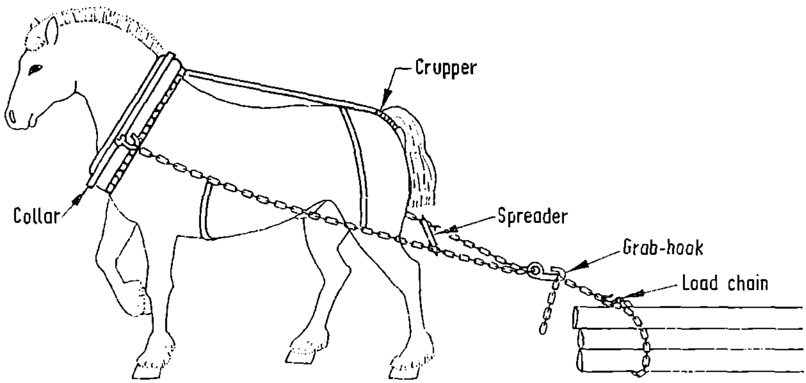
SWINGLE TREE



LOAD CHAIN



TRACE HARNESS



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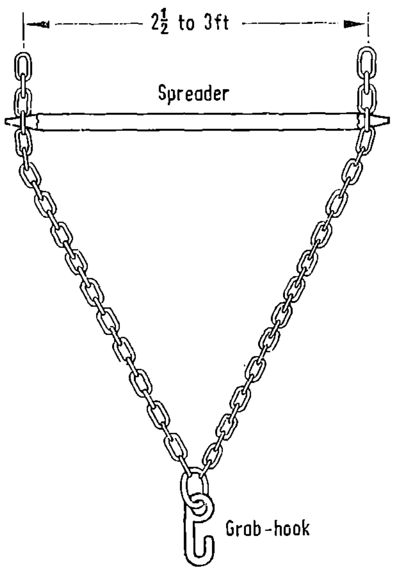


FIG. 9. Horse harness without shafts. Two types of tackle used for tushing. The modified trace harness has the advantage of lightness.

CART HARNESS

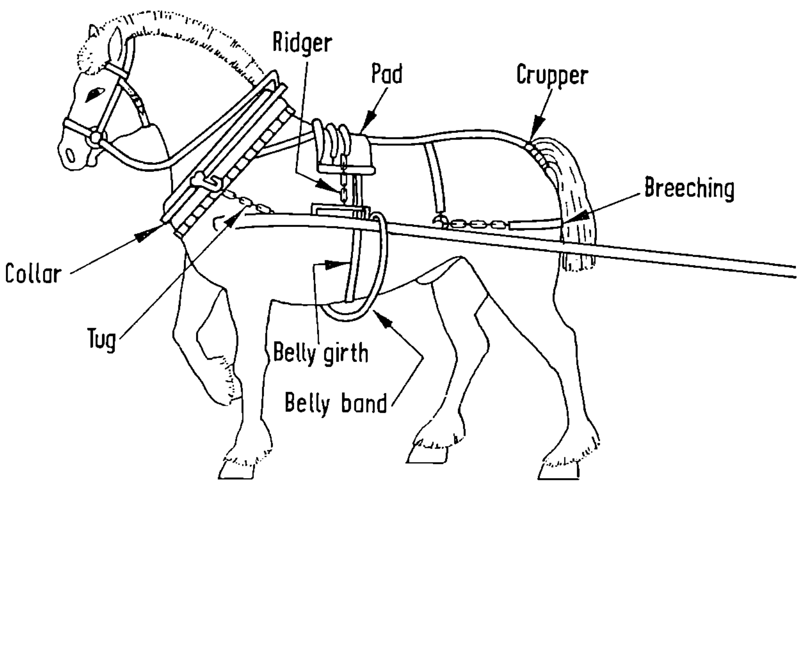
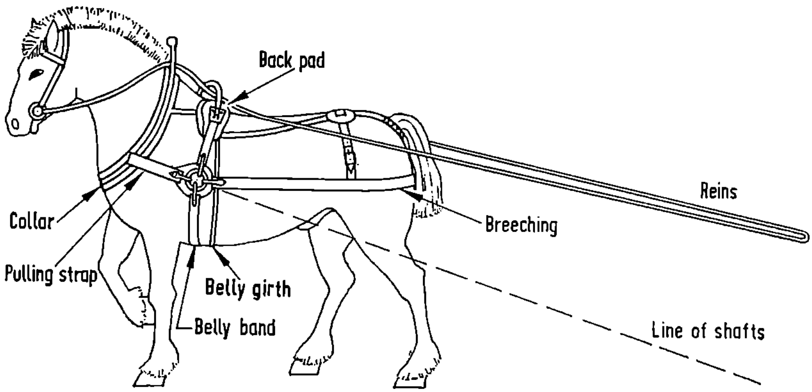
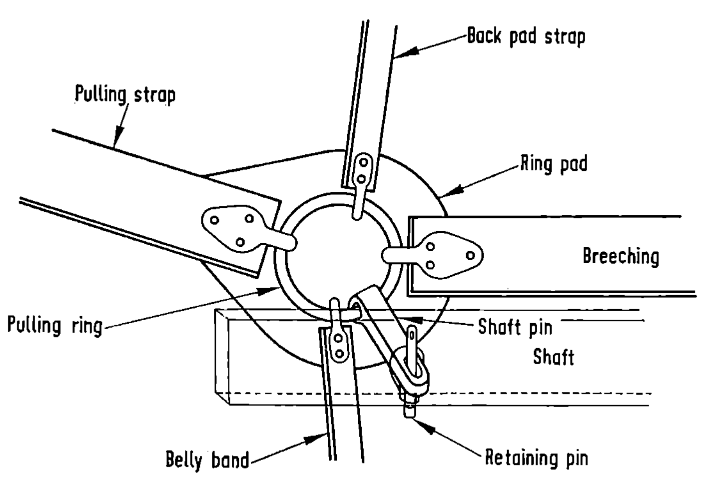


Fig. 10. Horse harness for shafts. The essential differences between the traditional cart harness above and the Scandinavian harness designed for forest work are shown here. The Scandinavian harness opposite has the advantage of a single point of attachment to each shaft.

SCANDINAVIAN HARNESS



DETAIL OF SHAFT ATTACHMENT



Harness usually consists of a collar, of the type used for draught horses pulling carts, and chains run from either side of the collar to a crossbar or swingle tree (see Figure 9). A length of chain with a hook at one end is used to hold the load together, and the free end of the chain is held by the grab-hook at the centre of the swingle tree. When travelling light the swingle is trailed along the ground.

An alternative arrangement is for the two chains from the collar to terminate at a hook which attaches to the load-chain (see Figure 9). The drag-chains are separated by a spacing bar (often a stout stick cut where convenient) which prevents the chains fouling the horses feet; this spacing bar is raised above the ground by straps over the horse's rump. When travelling light the chains can be hooked on to the harness out of the way. This equipment is an adaptation of trace harness—the harness used on trace horses placed ahead of the horse in the cart shafts to help it up steep hills.

Cart harness, designed to fit shafts, is not used very often in the woods, though a few two-wheeled sulkies are in use (see Figure 10). The main disadvantage of the normal cart shafts is that they protrude on either side of the collar, and in the wood there is a continual danger of a tree getting jammed between shaft and horse.

Horses usually are fitted with bridle and bit and a short rein; they are not normally led except in difficult situations, but are controlled by voice from the horseman.

Table XI

HORSE EXTRACTION—TUSHING, OUTPUT AND COSTS

Average pole: hoppus feet	Average distance in yards: 50		100		150		200		250	
	Output h. ft. per day	Cost pence per h. ft.	Output h. ft. per day	Cost pence per h. ft.	Output h. ft. per day	Cost pence per h. ft.	Output h. ft. per day	Cost pence per h. ft.	Output h. ft. per day	Cost pence per h. ft.
1·0	150	8·0	135	8·9	125	9·6	115	10·4	110	10·9
2·0	230	5·2	200	6·0	180	6·7	170	7·1	150	8·0
3·0	280	4·3	240	5·0	210	5·7	190	6·3	170	7·1
4·0 and over	280	4·3	240	5·0	210	5·7	190	6·3	170	7·1

Table XI gives the output that can be expected from a man and a horse when tushing thinnings that have been crosscut at stump; this cross cutting is assumed, where appropriate, to have removed a saw log from the butt end. The figures are based on a series of time studies in West Scotland, and are for tushing downhill on ground that is usually fairly broken with rocks and soft places. Obviously these outputs will be modified by increase in such difficulties, and they do not apply to uphill work. They also take into account that felling direction is in the direction of extraction, and that separate stacks of saw logs and thinner material have to be made at roadside. Outputs are low and costs are high for poles under three hoppus feet because of the handling necessary to make up loads.

3. Scandinavian Equipment and Technique

From the mechanical point of view dragging poles along the ground is the least efficient method (see Plates 2 and 3). A change to runners (Plates 4 and 5) or runners-plus-wheels will greatly reduce friction and allow larger loads. At the same time reducing the friction presents some danger of the load running into the horse on steep slopes, and except on gently sloping country the collar-and-chain harness becomes unsatisfactory. Shafts, with the correct harness, enable the horse to control any tendency for the load to run away, and the Scandinavian type harness with the shafts that fit closely to the horse's sides, so preventing trees lodging between the shafts and the horse, are far better suited to forest work than the normal pattern available in this country. The ends of the shafts trail on the ground so that if the sledge starts to run away it rides up on the shaft-ends, driving them against the ground and effectively braking the sledge. A further good feature is the design of the attachment to the shafts that enables them to be quickly released in the event of an accident.

Considerable increases in load are achieved by this equipment; for instance sledges take fifteen hoppus feet, wheeled sledges twenty, tracked sledges thirty. Thus outputs per horse-day are considerably larger than by ordinary tushing. For instance, at a distance of 100 yards, the tracked sledge can extract 240 hoppus feet per day, compared with the 200 by tushing.

It must not be forgotten, however, that this equipment requires loads to be made up in advance, preferably by the feller; otherwise the horse stands idle whilst the horseman gathers together the load. Limitations on piece size are similar to those with hand extraction and the average size of piece, if green, should not exceed two to three hoppus feet. The various aids to handling described by Forrester (1962), notably the tongs, sappie and unloading trestle are particularly useful for working with sledges. The correct layout of racks is as vital to the success of this equipment as it is to the success of tractors or winches.

This increase in output naturally means that the horseman has more hand loading and unloading than if he were tushing, and for this reason introduction of this equipment is not always easy.

Further a horse that is trained to use chains will have to be re-trained to use shafts. A steady pull is required for shafted sledge equipment, which is different from that required for tushing since this usually proceeds in a series of short spurts and rests. Once a horse becomes accustomed to shafts, these can be used for tushing as well as sledge work.

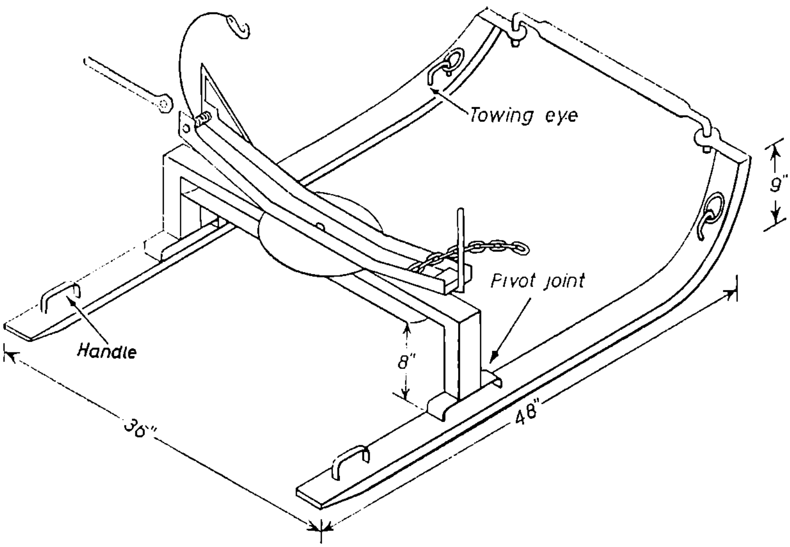


FIG. 11. Border Sledge.

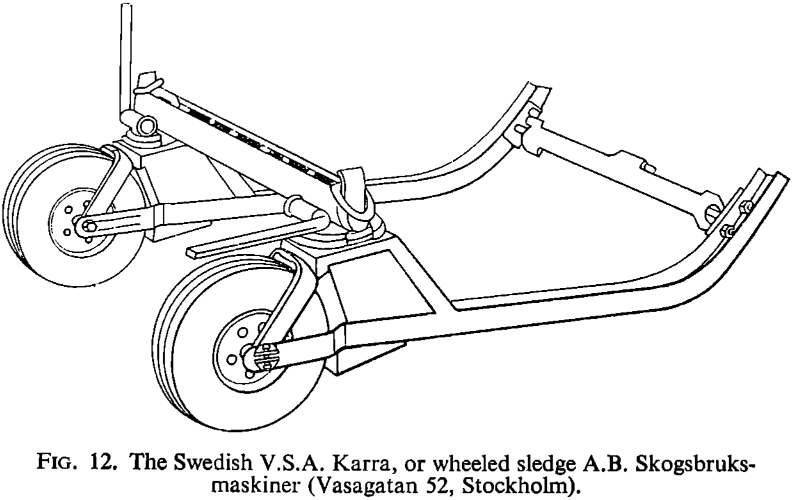


FIG. 12. The Swedish V.S.A. Karra, or wheeled sledge A.B. Skogsbruks-maskiner (Vasagatan 52, Stockholm).

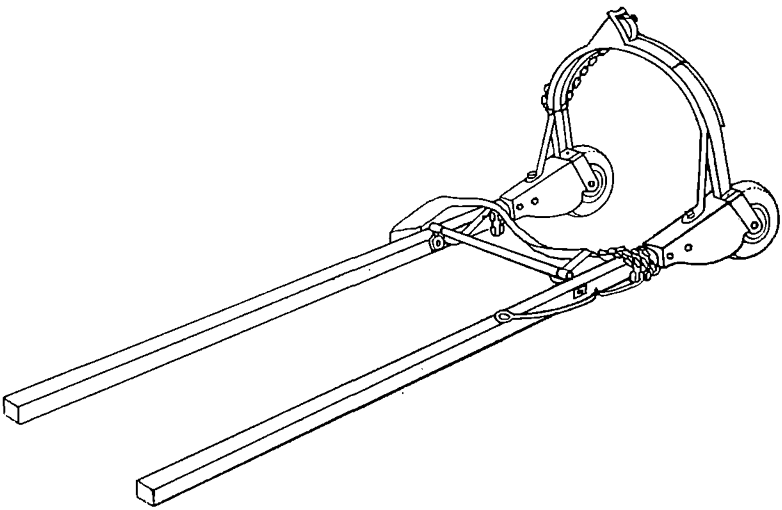


FIG. 13. The Norwegian Skogforsøksvesenets Buntedoning arch for bundles of logs. (Produced by Treschow-Frizøe, Larvik.)

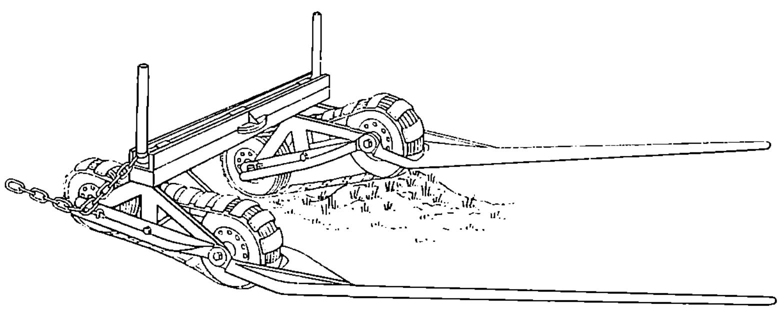


FIG. 14. The Swedish Band-Karra, or crawler-tracked sledge, produced by the Mellan och Sydsvenska Arbetsstudier (M.S.A.).

Border Sledge (Figure 11). This is an adaptation from Scandinavian patterns of sledge, but is made in Britain. It incorporates the flexibility between runners and bolster that makes for much easier riding over obstacles. It is intended for use with dragging chains rather than shafts, and works well on the soft peats and gentle slopes of the Scottish Border Country. Full details and a drawing are given by Forrester (1962).

"V.S.A." Sledge (Figure 12). This sledge has small diameter rubber wheels at the trailing ends of the runners which reduce the resistance on firm ground. The connection between shafts and sledge is designed so that if the sledge runs forward it "rides up" on the end of the shafts, which bear on to the ground and check it. This equipment is especially suited to steep ground.

Bundle Yarder (Figure 13). This Norwegian horse logging arch was designed primarily for moving bundles of small pieces from the forest. But it is equally effective on poles or larger pieces, and its main advantage is that the small hand winch on top of the arch makes loading easier.

"M.S.A." Tracked Sledge (Figure 14). This has a high load capacity and good performance over soft or rocky ground. It is heavier than other items of equipment and is at a disadvantage on steep slopes, but for long hauls over difficult ground it is excellent.

4. Deployment of Horses

Apart from improvement to equipment and working methods, output can be increased by ensuring that the horse can put in a full working day (Crowther 1960). Stabling and someone to feed the horse before work starts, may be impossible to provide at or near the work site. A solution to this problem is to provide a horse box, and these, pulled by the lorry carrying the men to work, are used in several Border Forests. A horse-box not only saves time but the horse arrives fresh on the job, which is not the case if it has had to walk 2 or 3 miles.

In summer it may be possible to put horses out to grass during the night and week-ends, and to keep them in the forest on suitable open areas enclosed by an electric fence.

When a horseman owns his own horse there is a strong incentive for him to feed it properly and look after it, which may not be the case if the horse belongs to the employer. On the other hand there are obvious economies to be achieved in stabling several horses together, particularly in feeding and attending to them outside the normal working hours; but such a system will only be practicable in areas with a large programme in a reasonably compact area. For instance a horse employed 200 days a year and averaging 200 hoppus feet per day would extract about 40,000 hoppus feet per year. The range from a stable that one could expect a horse to work, even when transported by horse box, will not exceed the range that labour is normally transported, about ten miles, so the opportunities for running a stable of several forest horses are not numerous in Britain; but one or two examples exist.

VII. WINCH EXTRACTION

1. Single-Drum Winches and Methods

Table I shows the relatively small amount extracted by winch methods in 1960, less than 1 per cent. of the total or at the most 200,000 hoppus feet. The main types of winch used at that date were single-drum winches of the following types:

(a) Heavy-duty winches mounted behind crawler or wheeled tractors. These are designed for pulls of 5,000 to 10,000 lbs., have heavy steel wire rope of ½ inch to 1 inch diameter, and a correspondingly slow wind-in speed. Though capable of extracting large logs of several tons each, they are poorly adapted for work in thinnings. When so used they are usually employed in extracting logs from steep gulleys where the job cannot be tackled any other way.

(b) Light portable winches. These are designed to be transported by a van and carried by two men, and are built round small engines of the motor-cycle type. Their pull is limited to a maximum of 1,500 lbs., and their speed is 70 feet per minute with a maximum range of 100 yards—$\frac{5}{16}$ inch diameter wire rope is used. As with the heavy winches, the light winches are usually employed in extracting logs up steep slopes which cannot be tackled in any other way. Performance is improved by using a "high lead", usually a tree situated on the upper side of the road. Quick-release snatch blocks are used to help work the poles when they are being extracted through the standing crop. Output tends to be low because of the slow working speed, and the fact that the second man has to haul out the rope by hand. Operating costs of the equipment, in spite of relatively low purchase price (about £200), tend to be high because its actual utilisation is low. The conclusion is that this equipment has a place for small-scale operation on difficult sites (for which it was designed) but it is inferior to the tractor-mounted types for large scale working.

2. Double Drum Winches (see Plates 12, 13 and 15)

At least four types of double drum winches are now under trial. The following paragraphs are based mainly on the Work Study Section's trials with the Isachsen, which was developed in Norway by Professor Samset of the Norwegian Forest Research

Institute at Vollebek, as an alternative to the horse. In Norway, horses are traditionally owned by small farmers and used for agriculture in the summer and on forest extraction in the winter; they are largely being displaced in agriculture so their availability for extraction is declining—at the same time tractors are increasing in numbers. This Isachsen winch has therefore been designed for mounting on a farm tractor.

The wheeled tractor alone is not an alternative to the horse in the forest except in very easy country, and the double-drum winch aims at making it more versatile. A measure of success is that over 1,000 are in use in Norway, but it should be remembered that Norway, with older forests, has a high proportion of clear fellings and late thinnings, a rather different problem to Britain with its preponderance of early thinnings.

The principle of the double-drum winch is that one drum hauls in the "main-line" with load attached, the other draws it out again by pulling in the "haul-back line" which passes round the "tail block" and so to the end of the main line (see Plate 15). The tower on the tractor, and a tree supporting the tail block, raise the lines off the ground, and this combined lifting effect is transmitted to the load by running the "lifting" block on the haul-back line, so supporting the load on the end of the main-line.

Each drum has both a clutch and a brake, so that when hauling-in a load with the main line, an application of the brake on the haul-back winch tightens the haul-back line and lifts the load. This balance between application of clutch and brake is a skilled technique that takes time to learn, and the inexperienced operator tends to fight a running battle between the two. It is hoped that a hydraulically driven winch will be designed, which will be much easier to operate in this respect.

By using a pulley block, "the angle block", on the end of the "haul-back line", the main-line can be pulled by hand to either side for a distance of 20 to 30 yards. This distance is limited by the time and effort required, and loss of lift.

The normal maximum operating distance between tractor and tail block is 150 yards. This is determined by the high lead effect, which only persists about ten times the height of the blocks, so that each end of the rope would need to be raised over twenty feet to obtain some lifting action over the full distance of 150 yards. No intermediate supports are practicable, and this is another factor that limits the maximum haul.

The tractor is held by a single "main-guy" rope from the top of the tower to a suitable tree, stump, or artificial holdfast, and the tail-block is similarly anchored. No other anchorage is necessary provided the tractor can be set up in line with these two anchors.

One Norwegian make of double-drum winch, the Isachsen (16 inch drum model No. 3), had extensive trials in various parts of Scotland in 1961 and 1962 and has proved successful on thinnings as well as on windblown areas. Another Norwegian make, the "Vinsje" marketed by the Jo-Bu Firm, is also on the market.

Two British double-drum winches are currently under development, one by Messrs. Boughton of Amersham, and the other by the Automower Engineering Co. Ltd., of Norton St. Phillip, Bath.

Work in thinnings (Crowther 1962, Forrester 1963) has shown clearly that, for a double drum winch extraction system to be successful, considerable modifications to usual techniques in felling are essential. These are as follows:

(*a*) A minimum cut of 400 hoppus feet per acre.
(*b*) Racks are spaced at 1–1½ chain intervals.
(*c*) Crosscutting at stump into lengths easily handled by one man, e.g. 10–15 foot lengths and sawlogs.
(*d*) Felling to be done herring-bone fashion towards racks (either butts or tips).
(*e*) Hand extraction into "tushes", so that each tush is either in the rack, touches it, or points to it along a line clear of obstructions. Average volume of tushes should be at least seven hoppus feet, preferably more.
(*f*) That subsequent loading (e.g. Hiab hoist) can accept poles laid at right angles to the road.

Trials have shown conclusively that deviation from these conditions puts the costs of double-drum winch extraction beyond that which is acceptable in thinnings. Subsequent work at South Strome Forest, where all these conditions have been fulfilled, has achieved average outputs of 600 hoppus feet per day; this approaches the Norwegian figure of 550 to 700 hoppus feet per day. The cost, including the cost of hand extraction to the winching point, is under 5d. per hoppus foot. In windblow, with a high volume per acre and unrestricted movement, this output should be attained easily, and by inference a similar output should be possible on clear felling.

This is the first piece of mechanical equipment that has shown itself to be a strong competitor to the horse in the wet and hilly regions of the north and west. The costs in terms of pence per hoppus foot are lower in thinnings than those of the horse, and the winch has a further advantage that it is easier to find men prepared to work a tractor than it is to find horsemen. The winch and tractor also has the advantage that its standing charges are lower than a horse which has to be fed when not working; further the winch and tractor can be transferred from one forest to another without its crew, provided skilled men are available at its new station.

It should be emphasised that skill of operators plays a large part in successful working of the double drum winch and this takes time to acquire. Further details of working technique are being prepared for publication as Booklet No. 12 of the Forestry Commission, entitled *Double Drum Winch Technique.*

VIII. COMPARISON OF EXTRACTION METHODS

Seven different methods of extraction were time-studied between 1958 and 1962 in different parts of Great Britain, and in spite of variations in conditions, the products handled, the methods adopted, and the lapse of time, some conclusions can be drawn. The methods are:

(1) Lorry, five-ton. Racks at two chains apart to which partly crosscut poles are extracted, either by hand or by tractor and tongs. Lorry (with two-wheel trailer for longer poles) fitted with Hiab one-ton hoist, picks up poles and billets from rackside. Ground conditions are level, firm, sandy.

(2) Thetford Tractor Tongs. Poles and saw logs are picked up from stump, singly, and either taken to rack-side where they are combined into loads of about fifteen hoppus feet before continuing to roadside, or taken direct to road over short distances. Ground conditions as for (1) above.

(3) Tractor and Trailer. Billets or props hand-extracted to rack and hand-loaded. Ground conditions: gentle slopes, usually firm, but some softer conditions.

(4) Isachsen Winch. This machine has a normal maximum working range of 150 yards, works uphill or downhill on steep slopes. Poles are crosscut at stump and made up into loads near close-spaced racks.

(5) Horse Tushing. Tushing, from stump, of poles and saw-logs on steep slopes with some rock, drains and soft patches.

(6) Horse with Sledge. An extrapolation has been made, using a load volume of twenty hoppus feet and assuming horse speed is the same as for tushing. Hand-extraction to racks is necessary

(7) Crawler Tractor. Hand-extraction of poles to racks or horse-extraction to ride. Hand-loading on to sledge. Gentle to steep slopes, soft peat over clay.

For all these methods alike, the important factors affecting costs of extraction are:

(*a*) Operating cost of equipment.
(*b*) Number of men in extraction team.
(*c*) Load size.
(*d*) Speed.

The operating costs of the seven different types of equipment are calculated in Table XII.

Table XII

RELATIVE COSTS OF EXTRACTION EQUIPMENT: EXTRACTION OF CONIFER THINNINGS

Equipment	Machine operating cost, shillings		No. of men in team	Team earnings per day, shillings	Labour overheads per day, shillings	Total operating cost per day, shillings	Cost per standard minute, pence
	per hour	per day					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Lorry, 5-ton	11½	90	2	110	30	230	5·8
2. Thetford tractor tongs	5	40	1	55	15	110	2·8
3. Tractor and trailer	5	40	2	110	30	180	4·5
4. Isachsen winch	7	55	2	110	30	195	4·9
5. Horse tushing	—	30	1	55	15	100	2·5
6. Horse with sledge or arch	—	35	1	55	15	105	2·6
7. Crawler tractor with sledge or arch	20	160	2	110	30	300	7·5

Notes: (i) Incentive rate of pay: 55s. per man-day.
(ii) Labour overheads (wet time, sick pay, holidays, insurance) 15s. per man-day.
(iii) 8-hour working day.
(iv) "M.S.A." and "V.S.A." sledges are shown in Figures 14 and 12.

The machine operating costs, Cols. (2) and (3) of Table XII are derived from calculations of the type described in Section II, page 23. The rate of team earnings (Col. 5) per day based on a wage of 55s. 0d. per man per day, has been selected as an example; it presumes incentive payment (usually piecework). The labour overheads per day (Col. 6) cover wet time, sick pay, holidays and insurance. The operating cost per "standard minute" (Col. 8) is based on a working time of eight hours per day. The salient feature of this part of the comparison is the important effect that team size has on the total operating cost, because labour costs are high relative to machine costs. The horse, and the wheeled tractor with tongs, have a big advantage in that they are worked by one man.

Table XIII breaks down the extraction into two portions, the terminal times and costs, which are those associated with loading and unloading, and the movement times and costs that are directly related to distance. This breakdown is discussed in greater detail in Section II, page 23. It is particularly helpful in this comparison because it shows that a substantial part of the extraction differences are associated with loading and unloading. Column (7) suggests that variation in loading and unloading times are associated with the method used. Loading a lorry (0·47), a tractor and trailer (0·45), Table

COMPARISON OF EXTRACTION ME

Equipment (1)	Conditions (2)	Job (3)	Team Operating cost pence per minute (men and equipment) (4)	Volume of load, hoppus feet (5)	Terminal Data: Time to load and unload, Team—Minutes, per load (6)	per hoppus foot (7)	ho (N
(1) LORRY. 5 ton with 1 ton HIAB hoist	Level Firm	Rack to Road	5·8	165	78·0	0·47	
(2a) WHEELED TRACTOR+tongs+Alice Holt drawbar	Level Firm 3rd and sub.	Stump to Road	2·8	15	19·0	1·29	
(2b) WHEELED TRACTOR+tongs+Alice Holt drawbar	Level Firm 1st/2nd	Stump to Road	2·8	15	26·0	1·72	
(3) WHEELED TRACTOR+trailer	Firm tracks Level to moderate	Rack to Road	4·5	60	27·0	0·45	
(4) ISACHSEN WINCH	Level to very steep Smooth to very rough	Rack to Road	4·9	5·20	—	—	
(5) HORSE: Tush	Level to steep Soft and rough	Stump to Road	2·5	10	16·0	1·60	
(6) HORSE OR ARCH sledge	Level to mod. steep Soft and rough	Rack to Road	2·6	20	32·0	1·60	
(7a) CRAWLER TRACTOR+V.S.A. sledge	Gentle slopes; Soft	Rack to Road	7·5	45	26·0	0·58	
(7b) CRAWLER TRACTOR+sledge	Steep and/or very soft	Rack to Road	7·5	45	26·0	0·58	

Notes: 1. The team operating cost in Col. 4 is derived from Table
2. Cols. 10 and 11—these times include both the outward a
3. Figures in brackets in Col. 8 include hand extraction cos

XIII

THODS BASED ON TIME STUDY

	Movement Data				Total Cost for 100 yard haul			
Cost ence per opus ft. ote 3)	Equipment speed: miles per hour	Time per load per 100 yds.: minutes	Time per h. ft. per 100 yds.	Cost per h. ft. per 100 yds.: pence	Pence per hoppus foot	Hand extraction included pence per hoppus foot	Year and Forest where time studies were taken	Remarks
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
2·7 (3·7)	2·0	3·4	0·02	0·12	2·8	3·8	1962 Thetford	Poles; 1 ton Hiab hoist fitted to lorry
3·6	2·4	2·8	0·19	0·5	4·2	—	1962 Thetford	Single poles; stump to rack; batch of 15 h. ft. rack to road
4·8	2·4	2·8	0·19	0·5	5·3	—	1962 Thetford	Do.
2·0 (3·0)	2·0	3·4	0·06	0·3	2·3	3·3	1960 Wentwood	4-ft. billets
—	—	—	—	—	3·8 3·7	4·8 4·7	Av. 50 yds. 0–100 Av. 75 yds. 0–150	Maximum range is 150 yards
4·0	1·2	6·0	0·60	1·5	5·6	5·6	1959 Cowal	Poles and sawlogs
4·2 5·2	1·2	6·0	0·30	0·8	5·0	6·0	—	Extra-polation
4·4 5·4	0·5	13·5	0·30	2·2	6·6	— 7·6	1958 Kershope	Poles
4·4 (5·4)	0·2	31·5	0·70	5·2	9·7	— 10·7	1958 Kershope	Poles

XI.
nd the return journey.
of 1·0d. per hoppus foot.

and a crawler tractor sledge (0·58) needs a similar time in each case. This is a reflection of the fact that two men take roughly the same time per hoppus foot to load from rackside. The one-ton Hiab hoist enables two men to load big poles—a job they would find extremely difficult alone, but it does not give any saving in total time as compared with the hand-loading of billets on to a trailer behind a wheeled tractor. The tractor tongs, and the horse which gathers poles at stump, have each a considerably longer terminal line (1·30 to 1·72), reflecting the extra work involved in gathering several poles together to make up a load.

The time per load per 100 yards (Col. 10) covers both the inward and outward journey. Col. (9) has been calculated from Col. (10) merely to give a comparison of speed in the familiar units of miles-per-hour. Col. (12) reflects the effect of load size, speed and operating cost on the costs of moving produce 100 yards. The total terminal plus movement cost for a haul of 100 yards is given in Col. (13) and in Col. (14) an extra penny per hoppus foot has been added to those methods that involve hand-extraction to rack.

The data in Table XIII are shown graphically in Figure 15.

Using the figures, various alternatives can be considered. Assuming that road spacing is 300 yards, so that the Isachsen can operate, the alternatives are:

	Uphill and Downhill Average haul 75 yards pence per hoppus foot	*Downhill only Average haul 150 yards pence per hoppus foot*
Horse Tush	5·2	6·4
Horse Sledge	5·8	6·2
Isachsen Winch	4·7	—
Isachsen up plus horse tush down	5·0	—
Isachsen up plus horse sledge down	5·2	—

These figures suggest that the Isachsen winch is the best method, as it is cheaper than horse tushing except for very short distances.

When the ground is too steep for the horse to work uphill, say over 15°, then the margin in favour of the double-drum winch widens considerably. Costs can be reduced by winching uphill and tushing downhill, and road spacings could exceed 300 yards where this was indicated by calculations of optimum road density, or for topographical reasons.

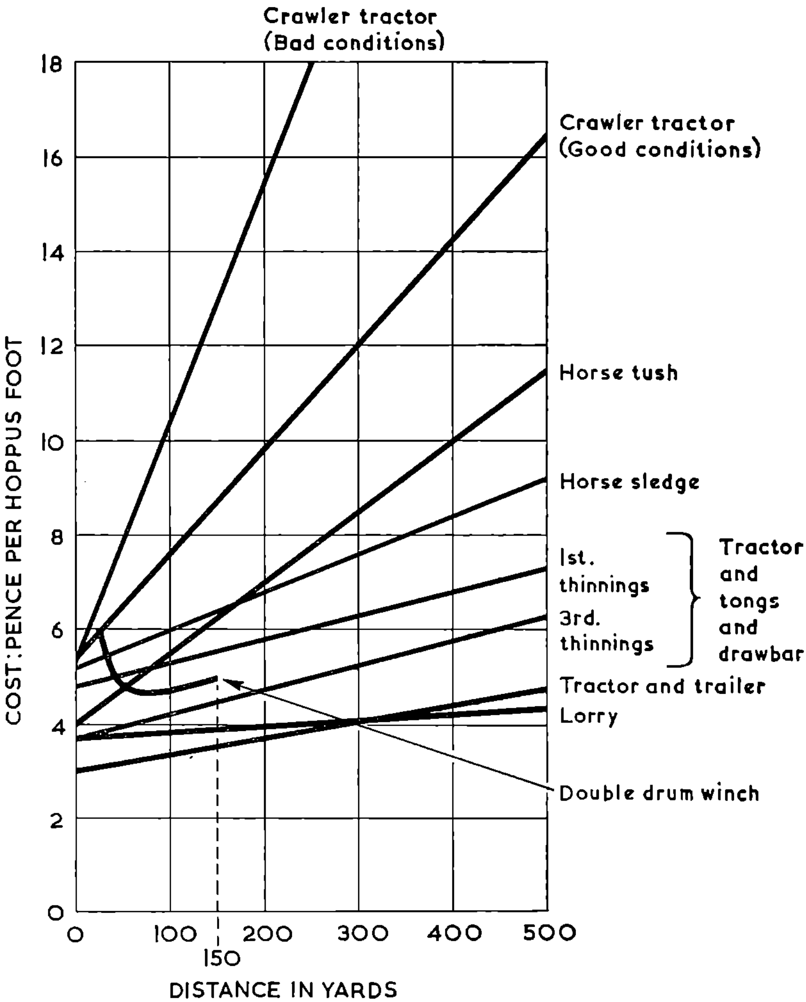


FIG. 15. Relative costs of extraction by different methods. This graph is based on Table XII and hand extraction is included where appropriate.

(1) On flat firm ground the wheeled tractor and tongs is the cheapest method for distances up to about 150 yards; for longer distances than this, a tractor and trailer, or a lorry, is better. If tractor and trailer, or lorry, can be used for the road haul as well as for extraction, then they will be cheaper than the tractor and tongs in all circumstances.

(2) On more difficult ground, where wheeled tractors cannot operate, horse extraction is the best method for short distances.

(3) An alternative to the horse is the double-drum winch. This is more competitive than the figures indicate, because it works uphill which the horse cannot, and it can tackle ground impossible for horses. This winch or a combination of winch uphill and horse downhill appears to be the cheapest at present.

(4) Crawler tractors are not an economic proposition under any circumstances, for thinnings.

Before leaving this comparison, it is relevant to raise several possible improvements to methods that could be expected to reduce costs. For example the terminal cost of the crawler tractor is higher than that of any other method, because a relatively expensive piece of equipment is standing idle whilst loading takes place. Clearly a method of loading or preloading that reduced this to say five minutes per load, instead of twenty-five minutes, would have a profound influence on output. But even if this was achieved the relatively slow speed, moderate load and high operating cost make the movement cost high, and the longer distances still remain too costly. If this sort of extrapolation is made for the crawler tractor it is only fair to make similar assumptions for the horse. In this case the use of the Norwegian horse arch carrying twenty hoppus feet, makes a radical reduction in costs. However, the difficulties of obtaining horsemen is a factor that may offset this, and tip the balance in favour of the double drum winch, which is already competitive on costs.

IX. OTHER EXTRACTION METHODS

This section is intended to cover various methods of extraction that have been tried in thinnings during the past ten years and proved *unsuccessful*. The reason for including this negative chapter is that by discussing their shortcomings, and the extent that they have been tried in the past, it is hoped to save others treading the same rather barren paths.

Generalisations are difficult to make, but the reason for failure of these methods can be attributed to certain main causes. The most important of these is that they nearly all involve erecting some fixed structure on the site, extracting the timber within reach, dismantling and moving the "fixture" to another site.

The erection and dismantling is expensive, usually taking several man-days, and the amount that can be extracted at each set-up is limited. Even if "hauls" are as long as half a mile, the total area served is not large, for hand-extraction to the mechanical conveying device is only possible for two or three chains; hence the device only serves an area of 8 to 12 acres, or a volume per "set-up" of 4,000 to 6,000 hoppus feet. The cost of setting-up alone may be in the region of 2d. or 3d. per hoppus foot extracted for labour and overheads, apart from the irreducible costs of the equipment which will mount up in terms of cost per hoppus foot the more frequently the equipment is moved and the lower the output achieved. This affect is accentuated in the case of the Wyssen and Lasso cable-ways, and any light railway, by the high capital cost of the equipment (£2,000 to £3,000).

None of this equipment really gets to grips with the problem of mechanising extraction of thinnings from as near to stump as possible, and it is in effect performing the function of a road with the serious disadvantage that it lacks a road's versatility for other traffic, and that it introduces extra handling.

With the intensive silviculture practised in this country, the thinnings at frequent intervals, and a topography that permits their construction at a moderate price, roads are a better proposition.

1. Ropeways

(a) Wyssen Powered Ropeway. The view of Professor Steinlein, who has considerable experience of ropeways in Switzerland, is that none of the forests he visited in Scotland (Zehetmayr 1961) were sufficiently difficult topographically, to warrant the use of ropeways of the Wyssen type as a general extraction method.

He gave the minimum specification for a successful Wyssen operation as:

(i) A concave slope, 1,100 yards long with 13,000 hoppus feet to be extracted, reaching 150 yards each side of the line.
(ii) Tree size, and load size, thirty to forty-five hoppus feet.

This cable-way would have three or four pylons and would take 450 to 500 man-hours to instal with an experienced crew—the key to the successful use of cable-ways. It would be used mainly for the extraction of big trees from protective selection forest, and the area covered would be about 35 acres and the volume extracted 300 to 350 hoppus feet per acre.

In contrast to the lower prices obtained for our coniferous thinnings, the value on roadside would be about 6s. 6d. per hoppus foot, and costs (peeled) as calculated "on roadside" including cable erection, capital, and labour overheads would be 1s. 9d. to 2s. 0d. per hoppus foot.

The obvious features militating against the use of cables in Scotland were convex slopes, and small timber. The relatively high increment and reasonable road construction conditions make roads a better proposition than cable-ways in Britain.

A Wyssen cable way was tried in West Scotland in the early 1950's; a lighter and cheaper ropeway has also been tried, with the aim of reducing costs by reducing capital cost and setting-up time. Though some improvement was achieved this was not enough to justify the use of a ropeway as a standard method of extraction, except in a few exceptionally difficult situations (Shaw 1957).

(b) Lasso Powered Ropeway. This endless single cable is supported on special pulleys mounted on trees and it circulates continuously. Billets are hooked on to the cable as it passes, with special hooks, and are detached at roadside. The equipment has been tried on thinnings in North Scotland, and though it was able to extract from situations that were inaccessible, costs were not competitive with normal extraction methods (Shaw 1957). Capital cost is high (£2,000 to £3,000) and erection and dismantling time considerable. Unlike Wyssen and other cable cranes, there is no means of dragging from the side, so each billet has to be carried by hand and hooked on to the cable, and the billet size is thus limited to about 1¼ hoppus feet. The length of cable is 2½ miles, operating depth ¼ mile, and the output per day, 300–450 hoppus feet (Cermak and Lloyd 1962).

(c) Single Strand Gravity Ropeway. A simple gravity ropeway is described in articles in *Scottish Forestry* (Forrester 1961, Cramb 1961 and Anon. 1956b). It is simple to erect and has a low capital cost, but is limited in its application because it requires topography that will give it a maximum unsupported run. Also the steepness of slope is critical, if too gentle (below 12°) loads refuse to run, if too steep (over 30°) they run so fast that they overshoot the stacking place at the bottom. Difficulty in picking up loads at intermediate positions is a further disadvantage. Its only economic place in extraction of thinnings is at a bottleneck caused by cliffs or rock which prevent normal extraction methods (horse or tractor) reaching the road.

2. Chutes

Chutes made from poles cut from thinnings, or from aluminium or steel sheeting, have been fairly extensively tried in thinnings on steep slopes; but like the single strand ropeway they are only effective in certain situations such as an extraction bottleneck, where normal methods are prevented from approaching a road. Erection costs are considerable in relation to the volume available from one site, though the capital cost is not high. Chutes made of thinnings poles have a low capital cost, but absorb much more labour in their erection, and although an attractive proposition initially, do not work out any cheaper than the metal types (Shaw 1953).

Chutes are more critical over gradient than the single strand ropeway, and trouble with logs travelling too fast and jumping out of the chute is common, while stopping the billets at the bottom can be a real problem. Minimum gradient should be 20°.

3. Monorail

This consists of single rails, in sections with telescopic supports which are easily erected and dismantled, upon which travels a self-driven truck which runs unattended and is stopped by a device fitted to the rails (Shaw 1960). This equipment has been tried on a small scale for thinnings, but it is unlikely to be competitive with orthodox extraction methods because of the high costs of frequent erecting and dismantling for small volumes of timber brought out.

4. Light Railway

Narrow-gauge railway of the type used by civil engineering contractors can be used for extraction, but it is most unlikely to be an economic proposition in thinnings because of relatively high capital cost of the equipment and the amount of work involved in setting up and dismantling for small amounts of material. It can serve as an alternative to a road network, but suffers from the extra handling involved and the fact that it cannot be used by road transport for other purposes—for instance fire protection. It can safely be dismissed as a serious extraction method for thinnings in Britain.

5. Floating

Floating is an alternative to other means of long-distance transport of timber in various parts of the world. In Northern Europe and Canada its success is dependent on river size, and on regular spring floods from melting snow. The complication of hydro-electric schemes on many rivers has led to the adoption of bundles instead of free floating, and has necessitated considerable capital investment in improvements to river beds and in constructing elaborate lifting devices to pass the bundles over the dams. Historically in this country a small amount of river floating took place, notably on the Spey in Scotland. Our relatively small and scattered forest areas, shallowness of rivers and close network of other transport methods, particularly roads, make floating in rivers a most unlikely practical proposition in this country.

X. FUTURE DEVELOPMENTS

Having examined various extraction methods and problems in detail, it is worthwhile to consider which trends are likely to continue in the future. The first of these concerns the forest, and the return to more clear felling has already been noted. In absolute terms this is considerable—a "clear fell" programme of 30 million hoppus feet by 1980 is predicted, though this will still be only a quarter of the total to be logged in the whole country. Machines that combine felling, trimming and crosscutting are already in use in America and Russia and there is little reason to doubt that these could be applied in this country to the easier sites, provided the scale of work was large enough to keep fully employed a piece of equipment costing around £30,000.

The other important trend will be the increasing tree size in thinnings from the older plantations. This is likely to react favourably on extraction costs. But the proportion of first thinnings to second and subsequent will still be high, about a quarter instead of a third, owing to the large areas planted in the decade 1950 to 1960 which will be reaching the thinning stage in the early 1980's. Obviously the extraction of early thinnings will remain a major problem for very many years throughout Britain.

A further problem arises in connection with the thinning of crops planted on ploughed land. Some settlement of the ridge-and-hollow effect of ploughing on the peat areas will probably take place, through the drying-out and subsequent decomposition of the peat, but it will nevertheless constitute an extraction hazard. No such marked ameliorating effect is likely on hard-soiled heath lands ploughed with ploughs of the "R.L.R." type. The effect of this problem has not yet been felt, but there are indications that both plough furrow and stumps can be eliminated for a reasonable cost by a loading shovel mounted on a crawler tractor.

Turning to the mechanical field, there are a number of new developments whose application to extraction will have to be kept under review. The helicopter, the hovercraft principle, hydraulic drive and remote control are four obvious examples. The helicopter is already physically capable of extraction but high operating costs (about £50 per hour) mean that it is not an economic proposition (Shaw 1956 and 1961), though its economic use for spraying forest weed growth with herbicide (Stewart 1960), and transport of fencing to difficult sites (Winchester 1961) has been proved.

The hovercraft principle does not appear at present to have any application to thinnings. A test model has shown its ability to reduce friction, but the problems of passing over stumps and drains, and control on slopes, have so far prevented any practical application.

Hydraulic drive is likely to make a considerable improvement to extraction equipment by driving the loaded wheels of trailers as well as all four wheels of the tractor. When applied to double-drum winches, hydraulic drive gives a freedom of choice over the mounting position on the tractor, as well as easier control; initially the extra cost involved is a disadvantage, but ultimately reductions should be possible.

Remote control, either by radio or by wire, is already used in Sweden, notably on small portable winches and to control tractor winches used to load trailers. The merit of the system is that in both cases it enables the job to be carried out by one man instead of two, with considerable reduction in costs. One would expect remote control to have its application in this country for the same reasons.

For loading pulpwood on to lorries, an encouraging development is the Hiab "Elefant" grab shown in Plate 14 which can also be mounted on a tractor.

In conclusion, increases in productivity in extraction are more likely to come from the careful review and improvement of existing techniques, rather than from some revolutionary break-through in the way of mechanical equipment. The conditions of topography and crops vary so extensively over Great Britain that there can be no universal answer to all the various extraction problems. The most promising fields for improvement seem to be:

(*a*) Planning (scale of operation, tree-size, piece-size, rack lay-out, preparation by fellers).

(*b*) Refinement of existing or known equipment.

(*c*) Reduction of team-size to one man wherever possible.

(*d*) Raising machine utilisation.

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