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EDITORIAL

The present issue of the News Bulletin gives an account of recent research in wood anatomy at the Wood Structure Section of the Forest Products Research Laboratory, Princes Risborough, England. We are glad to publish an up to date report of that institution which is a pioneer for the introduction of new methods in wood research. As far back as 1938 the « Multiple-Entry-Perforated-Card-Key » has been propagated, and recently the beta-radiation is used as a tool for density measurements on a microscopic base.

It is our intention to acquire similar reports from other laboratories for research of wood structure and we hope that this innovation will find the approval of our members. If such an account will be accompanied by a similar general introduction as that at the head of this number, no Editorial will be necessary any longer.

A. Frey-Wyssling

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THE WOOD STRUCTURE SECTION AT THE FOREST PRODUCTS RESEARCH LABORATORY

PRINCES RISBOROUGH

by

Dr. E. W. J. Phillips

Very few wood anatomists have opportunities to visit the laboratories of other members of our Association and have little idea of the day-to-day activities of their fellows in this field. The present brief introductory article and the other papers in this issue of the Bulletin are aimed at giving a picture of some of our activities at Princes Risborough, and we look forward to seeing accounts of the activities of other laboratories in later Bulletins.

The Forest Products Research Laboratory at Princes Risborough was set up in 1927 and now covers research in wood structure, mycology, entomology, chemistry (and pulping), wood preservation; this group comprises the Science Division; in addition, the Engineering Division deals with timber mechanics, seasoning, woodworking and composite wood. The total staff consists of some 180 people, of these about one-third have scientific or technical qualifications. From its inception until the beginning of 1965 the Laboratory was administered by the Governmental Department of Scientific and Industrial Research but, since then, by the new Ministry of Technology. This recent administrative change has the object of developing research into matters of direct value to industry and, in our case, to the timber-producing and timber-consuming industries. This will include a certain amount of basic applied research as well as ad hoc items; investigations of a purely academic character, more appropriate to the Universities, will no longer be carried out here though steps may be taken to encourage such research in the appropriate academic institutions.

My own professional interests in wood anatomy started in 1930, at about the time our Association was formed, when I joined B.J.Rendle and S.H.Clarke, two founder members of the Association, at the Laboratory. The former was in charge of the Wood Structure Section until 1961 and it is largely due to his persistent efforts that the fine collection of timber specimens, now numbering about 28'000, was amassed to provide the basis for our researches into methods of identification and reference material for day-to-day advisory work. Mr.Clarke, after making valuable contributions to the developing science

of wood anatomy, left in 1940 to take up a series of high administrative posts in various other branches of scientific research. The present permanent staff of the Section consists of three scientific staff (Phillips, Brazier and Dinwoodie), three experimental staff (Adams, Franklin and Patterson) and two assistants. From time to time we have, in addition, vacation and overseas students and other short-term workers.

Our research on methods of timber identification culminated with the publication in 1961 of Forest Products Research Bulletin No. 46, "Identification of Hardwoods: A Microscope Key", following our earlier Bulletins (Nos. 22, 25 and 26) dealing with the identification of softwoods, and of hardwoods using macroscopic (lens) features. Since then, this kind of anatomical research has occupied a minor part of our research programme being confined to ad hoc investigations largely to meet the needs of commercial development. With the growing availability of computers consideration is being given to the possibility of fitting our accumulated anatomical data into suitable form for use with such machines for purposes of identification and correlation of anatomical features with each other and also with timber properties. In this connection, spade work carried out by a subcommittee of the Association during the meetings in Paris in 1954 may prove useful as a starting point (see News Bulletins, September 1954). In our current research programme wood anatomy features in investigations of the variation within and between trees of various species of softwoods now maturing from the large-scale plantings of the Forestry Commission set up in 1919. Allied to this work is the selection of potential parent trees of superior timber quality with a view to long term improvement by controlled breeding. This involves studies into the effect of environment on structure with the object of differentiating between the effects of genetic and environmental factors and also of the relationships between juvenile and adult structure so that forecasts can be made of the character of mature timber from the examination of comparatively young stems. It is mainly in connection with these series of investigations that we originally developed the special beta-ray density techniques for studying the patterns of density variation in growth rings and apparatus for rapidly measuring and classifying fibre length.

Latterly it has been possible to recommence the study of the relations between wood anatomy and technical properties and, in the first place, a re-examination is being made of the influence of anatomy on the manner in which wood fractures when stressed in different ways.

The establishment of research units in several of the developing countries with large timber resources has relieved us of the need to devote so much time to the investigation of overseas timbers as in the past. Nevertheless, some work on selected species is still carried out here and the preliminary appraisal of the potentialities of untried timbers from anatomical examination is frequently called for.

Our various research projects do not occupy all our time, an appreciable effort being devoted to advisory work (including timber identification), and other non-research items. Teaching forms only a small part of our programme, lectures on wood anatomy being contributed to the Laboratory Wood Technology Courses held seven times a year, attended by nearly 200 students, and in addition members of the staff give courses in the subject at local Evening Class Institutes.

It is clearly impracticable to discuss in detail the whole range of our activities but three aspects of our work are dealt with in the following papers.

Acknowledgement

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TIMBER IDENTIFICATION

by J. D. Brazier

Summary

The multiple-entry perforated-card keys developed in the Wood Structure Section at Princes Risborough are in regular use to deal with the 1'000 or so specimens received for identification and appraisal every year. A selection of cases of topical interest are briefly discussed and it is suggested that items of this kind might usefully form a regular feature of the News Bulletin.

The Wood Structure Section at Princes Risborough pioneered the use of the multiple-entry perforated-card for timber identification. This system was first put into use about 1935 and in 1938 CLARKE (4) described the card designed for the identification of hardwoods. Since then card keys for the determination of softwoods and hardwoods have been in almost daily use and the data necessary for their formulation were published, at first for the softwoods (6), followed by a key to hardwoods using lens features (1), and finally a microscope key to hardwoods (3).

Undoubtedly one of the outstanding advantages of the card sorting technique is that it readily enables comparative observations to be made using coded descriptive records. Comparative and not simply descriptive anatomy is the basis of timber identification and this fact has always been kept in mind in the preparation of the Princes Risborough keys. Many comparative studies were made during their preparation, some were published separately but for the most part they are incorporated in published Bulletins.

With the publication in 1961 of the microscope key to hardwoods many of the problems connected with the identification of the more familiar woods met on the United Kingdom market were resolved, so far as was feasible on the basis of their wood anatomy, and, since then, studies in comparative anatomy have ceased to be a major item in our research efforts. Nevertheless identification remains an important activity as it forms part of the Laboratory's advisory service to industry. More than 1'000 wood specimens are identified every year and although the enquiries come mainly, although not exclusively, from Britain, the timbers submitted come from all parts of the world. This advisory demand provides a continuous review of the identification technique but more particularly, it quickly brings to notice new timbers, for a new timber is rarely on the United Kingdom market long before information is being sought about it from the Forest Products Research Laboratory. And before advice can be given about an unfamiliar timber, determination or confirmation of its identity is essential and an appraisal of its physical and anatomical characteristics very desirable.

Thus in order to provide an efficient advisory service many determinations are made and some of the more topical of these are described below in the hope that they are of interest to others faced with similar problems.

In Britain, as in other European countries, there is a fashion for rosewood, particularly for furniture. This was met at first by the use of Indian rosewood (*Dalbergia latifolia*) but, as demand increased, Brazilian or Rio rosewood (*D. nigra*) became the principal source of supply. Separation of these timbers on their anatomical structure and alcohol extract (3) is usually feasible although both are somewhat variable in character and there is occasionally some uncertainty. However, as demand and consequently price increased so other timbers were introduced as rosewood. One, from Brazil, was *Machaerium scleroxylon*, closely related to species of *Dalbergia* and very similar in appearance to Brazilian rosewood but readily distinguished by its finer texture and more conspicuous and regularly banded parenchyma. It was,

however, a most unfortunate choice as it is particularly unpleasant to work (2), causing such severe skin irritation to operatives as to be unacceptable for any purpose involving extensive machining or sanding of dry timber. A note on this timber and its effects is being published (7). Another Brazilian wood with some resemblance to rosewood has been introduced as arruda rajada. Through the courtesy of Dr. Mainieri of the Instituto de Pesquisas Tecnologicas, Sao Paolo, this has been determined as a species of *Swartzia* and is of potential interest as a decorative timber, although some care may be needed in its selection as specimens examined have varied somewhat in colour and figure. Species of *Swartzia* commonly have a highly coloured heartwood and, from Africa, the timber of *S. fistuloides* and *S. madagascariensis*, with a superficial resemblance to rosewood, is marketed as pau rosa; it is readily distinguished from rosewood by a conspicuous banded arrangement of its parenchyma.

In Africa there are many species of *Dalbergia* but few are trees and true rosewood is only exploited in Malagasy (Madagascar), although in East Africa the much sought after *Dalbergia melanoxylon* is highly prized for its black, ebony-like wood. It is perhaps, the absence of a true African rosewood that has resulted in the marketing of various so-called African rosewoods. This name has been used in the past for species of *Guibourtia* with timber of the bubinga type and perhaps less understandably for *Copaifera salikounda* with its lustrous, red-brown wood. In recent months "African rosewood" has been used for timber of *Combretodendron macrocarpum*, more familiar as esia or minzu. Seen mainly as veneer it is a medium red-brown, rather coarse-textured wood which, although of some decorative value, lacks the character and distinctive appearance of true rosewood. Anatomically esia is readily distinguished from rosewood by its very high, non-storied rays which give a characteristic ray figure on quartered surfaces.

Although interest, for the time being, is mainly in rosewood for decorative purposes, there is, too, a demand for walnut-like woods. For many years supplies of true walnut (species of *Juglans*) have been insufficient to meet demand and other timbers such as "African walnut" (*Lovoa trichilioides*) and "Australian walnut" (*Endiandra palmerstonii*) have become so well established commercially that they are accepted as walnut although quite unrelated to the genuine timber. The demand is for a grey to brown, figured wood devoid of a reddish colour. "New Guinea walnut", closely related to and possibly the same species as Philippine paldao (*Dracontomelum dao*), has a timber of this type and is a popular veneer, although its figure is somewhat regular

in comparison with that of true walnut. Another figured wood, for a while marketed in Britain as "olive walnut" but now familiar as mutenye, comes from the Congo and is produced by Guibourtia arnoldiana. Similar in appearance is G. ehie, known as ovankol from Gabon and amazakoué from the Ivory Coast and seen mainly as veneer. It has also been shipped from Ghana, where it is known as hyedua, a name used for copal-bearing trees and, in particular, for species of Daniellia, with which G. ehie is sometimes confused. So far as their timbers are concerned, however, there is little resemblance, for daniellia has a comparatively plain appearance and is characterised by the presence of axial intercellular canals and storied rays, features absent from G. ehie. Guibourtia arnoldiana and G. ehie although similar in appearance are readily separated, the former having many, small pores, not visible to the unaided eye and the latter fewer, larger pores which are just visible.

From East Africa veneer has been seen of a plain, pale brown to almost yellow wood known as Tanganyika walnut. Its identity has not been determined for certain although it clearly belongs to the family Sapotaceae and is probably a species of Aningeria, Chrysophyllum or Sideroxylon, a group which is botanically confused and anatomically very similar. Other so-called walnuts have been received as Brazilian walnut or imbuya (Phoebe porosa) and yellow walnut (Beilschmiedia bancroftii) from Queensland, the latter with a bright yellow, un-walnut like wood. Both belong to the Lauraceae family, characterised by the presence of oil cells, although these are not an invariable feature of B. bancroftii.

Finally, in this group of brown timbers, there has been interest in species of Cordia. Although somewhat plain in appearance, they provide solid wood matching not only walnut veneered surfaces but also with a superficial resemblance to teak. Freiyo (C. goeldiana) from Brazil, although rarely seen in quantity is a familiar timber and salmwood or Ecuador laurel (C. alliodora) from Central and Tropical South America has been marketed in the past. Recently, timber of C. trichotoma has been offered, mainly in the form of veneer. It comes from Southern Brazil where it is known by the confusing name louro, commonly used in South America for timbers of the Lauraceae family. An attractive, warm brown timber, it is often characterised by deposits of a white crystalline substance, with a cotton-wool like appearance, on its surface. This is a natural component of the wood, which has been investigated chemically at the United States Forest Products Laboratory (8). It is readily removed and disappears on standing by sublimation. From Africa,

also, there has been trade in species of Cordia, mainly from Nigeria where the timber is believed to be principally C. millenii although some C. platythyrsa may also be included. It is known by the local name omo, but to avoid confusion with omu (Entandrophragma candollei) the name African cordia or Nigerian cordia is suggested. Species of Cordia have a characteristic end-grain structure, typically with broad rays and tylosed vessels. It is often possible to distinguish the African commercial species from the American as the former commonly have larger pores, often very heavily tylosed and with banded parenchyma moderately to well developed. In the American species (C. alliodora, C. goeldiana and C. trichotoma) the pores are typically smaller, sometimes in clusters or with a tendency to a tangential arrangement and with parenchyma associated with the pores but confluent only by virtue of the closeness of the pores.

Most of the timbers noted so far are of interest for their figure. There is, particularly in the furniture industry, a very large demand for plain, featureless easy working hardwoods which lend themselves to mass production techniques. This group is typified by beech and birch, and among tropical timbers by ramin (Gonystylus spp.) and abura (Mitragyna ciliata). There have, in the past year or so, been two interesting new timbers of this type, both belonging to the botanical family Myristicaceae and although coming from different parts of the world, very similar in character. The first to appear was mtambara, produced by Cephalosphaera usambarensis from Tanganyika but it has been followed, recently, by virola from Brazil and Colombia. In Brazil virola is produced by species of Virola, mainly V. surinamensis, familiar in some European markets as baboen from Surinam, with some V. sebifera, but in Colombia virola is the product of species of Dialyanthera. Timbers of the three genera are superficially similar; they are pale, pinkish-brown in colour, almost featureless with a fairly fine texture and straight grain, and typically moderately light to light in weight. Mtambara, at about 37 lb/ft³ when dry is somewhat heavier than virola which varies a little according to its origin, Colombian species of Dialyanthera having a somewhat softer, finer-textured wood than the Brazilian species of Virola. Anatomically the genera are similar, and Garratt's (5) 1933 descriptions and key still provide the best guide to their separation. Dialyanthera with predominantly if not exclusively scalariform perforation plates is readily distinguished from Cephalosphaera and the species of Virola considered here which have predominantly simple perforations. Cephalosphaera and Virola are not always separable especially when only small specimens are available

but, with larger pieces, Virola commonly shows some tendency to growth-ring development due to somewhat denser bands of fibres often with associated parenchyma or parenchyma-like tissue; this has not been observed or recorded (5) for Cephalosphaera.

Some of the above determinations were possible using the accumulated data on timber identification, sometimes published, as in the case of the Myristicaceae timbers, many years ago. For others, a new comparative study was necessary, although, because of the time required for a comprehensive review, this was usually of limited scope and designed to resolve only the immediate problem. Nevertheless, such studies and appraisals of the anatomical and physical characteristics of unfamiliar woods contribute to our knowledge, although it is only occasionally that this warrants recording for an individual timber. Over a period of time, however, the examination of many, often economically important species means that a considerable fund of information is accumulated, although rarely made available in published form mainly because of its fragmentary nature. Yet it is surely of interest to a large number of technologists concerned with timber identification and it is in this belief that this article is presented. It is hoped that others will bring to the attention of I.A.W.A. members new or interesting timbers in use elsewhere in the world, and, it is suggested, that the News Bulletin could become a useful medium for the presentation of such information and meet a need not available since "Tropical Wood" ceased publication.

Acknowledgement

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RESEARCH ON YOUNG PLANTATION TIMBER

by J. D. Brazier

Summary

The procedures for investigating the structural features of home-grown timbers are described together with the results of selected studies on spruce (Picea abies and P.sitchensis), larch (Larix decidua and L. leptolepis) and lodgepole pine (Pinus contorta).

Research on home-grown timber and, in particular, on the structure of young plantation growth softwood is an important aspect to the work of the Wood Structure Section at Princes Risborough. The reasons for this are to be found in the development of forestry in Britain during this century. Up to 1919 the State had been little concerned with forestry and it was only following the heavy fellings of the First World War and the necessity for an extensive national replanting programme that a State forest service, the Forestry Commission, was established. Extensive plantings were made in the 1920s and 1930s, mainly of exotic softwoods such as Sitka spruce (Picea sitchensis) and Norway spruce (P. abies), European larch (Larix decidua) and Japanese larch (L. leptolepis), Douglas fir (Pseudotsuga taxifolia) and Corsican pine (Pinus nigra var. calabrica), but also the native Scots pine (Pinus silvestris) and, in comparatively small quantities, some native hardwoods. Some of the earlier plantings were felled during the Second World War (1939-45) but much was still too young at that time to yield saw timber and is only now assuming commercial importance. However, as often appears to be the case, exotic species when established and managed under plantation conditions on a comparatively short rotation, produce a timber different in many respects from that of old growth from natural forest, and in the maritime conditions, particularly of western Britain, growth of species such as Sitka spruce and Douglas fir can be very rapid, such that their timbers differ markedly from those of North American origin. There is a need therefore to appraise such timbers, to review their properties and consider their utility both in relation to the more familiar imported product and also in their own right.

It would be misleading to suggest that such investigations at Princes Risborough are of recent occurrence only, for since its establishment in 1927, the Forest Products Research Laboratory, although always independent of the Forestry Commission, has been concerned with the State forest service in the appraisal of home-grown timber. However, this work received a considerable stimulus in 1958 when a joint committee, with representatives of the Forestry

Commission and the Forest Products Research Laboratory, was set up with the special responsibility for co-ordinating the work on home-grown timbers. There was a need to obtain adequate information on the relative merits of the timber of various species not only as a contribution to their more efficient utilisation but also as a factor in the determination of future planting policies.

Investigations at the Forest Products Research Laboratory cover all aspects of the assessment and utilisation of home-grown timber. They involve research in all fields of timber technology and the contribution of wood anatomy has been in determining the basic structural characteristics of the plantation timber, its variability within and between trees, the study of the relationship between structure and properties, and the application of this assembled data to timber improvement studies. The form and scope of the observations have varied according to the problems under investigation, but, as a rule, each has involved the examination of a large number of trees, sampled by means of discs taken usually at two, or more rarely three heights in each tree, one at breast height and the others at fixed proportions of the total tree height. The anatomical properties studied include fibre length variation, compression wood development, incidence of spiral grain, extent of sap- and heart-wood formation and the pattern of growth of the tree as shown by its radial increment. The quantity of work involved is often considerable and new techniques for either assembling or recording the data have been developed. One such is the examination of density variation which is the topic of another paper in this issue; others which are referred to briefly here are concerned with the measurement of fibre length and spiral grain.

Fibre length is determined on individual rings of both the juvenile and adult wood, typically on the north facing side of the tree. Whole rings are sampled as this is considered to give a figure of more practical significance than one based only on the last formed tracheids of the late wood. The whole ring is sampled by means of a thin chip cut at an angle of 45° to the radial direction so as to give tracheids derived from a large number of cambial initials and representative of the complete year's growth. This chip is macerated and after washing the tracheids are deposited in water on a clean slide; the water is removed using absorptive paper and after very gentle warming for final drying the fibres are covered with a glass slip held by a short length of clear adhesive tape. Such a dry,

unstained mount is not only quick and easy to prepare but, also, on projection, a fibre is seen with such contrast that even at low magnifications there is little difficulty in deciding whether or not it is complete at its ends. Measurements are made on 25 fibres for each sample and for this purpose a fibre length measurer and classifier has been designed (1). Measurement is by means of a small diameter tracing wheel which produces an electrical impulse on each rotation. When the wheel is run along the projected image of a fibre, the impulses produced are counted by a relay and counter circuit and the number stored, a procedure which is repeated until the required population of fibres is measured when the total number of impulses is printed and the equipment automatically reset to zero for a fresh count. This procedure has done much to reduce the tedium of fibre length measurement as well as making it a simple one-man operation.

Grain inclination in the tree is a structural feature of interest and importance. Grain is rarely straight relative to the axis of the stem for any considerable distance and our studies have shown, in agreement with those of many other workers (2), that in most softwoods there is some tendency to a spiral development. Spiral grain, if well developed, has a marked effect on the technical behaviour of wood, notably on its strength, its tendency to distort, and the ease with which a satisfactory machined surface is obtained, all factors which affect its general utility. For comparative studies of timbers and the examination of the effect of grain inclination on technical behaviour, a numerical assessment of spiral grain is required. This presents some difficulty for not only does grain inclination differ from tree to tree but also it commonly changes during the growth of a tree; thus a single observation on the surface of a log is of limited significance and an estimate needs to be made of the average grain inclination across the stem. Such an estimate, called the spiral grain index, has been developed and its relationship to certain technical properties demonstrated (3).

The purpose of the anatomical studies undertaken have been varied and it is possible here to refer only to a few and review briefly some of the results obtained. Many have been or are being published elsewhere, usually as part of the review of the range of technical properties and behaviour of each timber (4).

Spruce. Spruce is of increasing importance in both British forestry and timber production. The area of forest under spruce exceeds that of any other conifer and although Scots pine, because of the large area of old-growth forest,

notably in Scotland, is a more important timber producer at present, it must ultimately be overtaken by the more vigorous spruce. Of particular importance is Sitka spruce (*Picea sitchensis*), extensively planted on wet and often exposed sites of western Britain where it has been particularly successful. It grows faster and is a larger volume producer than Norway spruce (*P. abies*) although this, too, is a very important component of British forests.

Both species have been the subject of studies in recent years. Young plantation timber of an age and size sufficient to yield saw timber (30-37 years in Sitka spruce, 40-47 years in Norway spruce) has been examined to determine its anatomical characteristics, to compare the general character of the wood of the two species, and to study the effects of site and quality class on their timber properties.

In both species, adult wood had an average tracheid length of well over 3 mm (see Table 1), marginally longer in Sitka spruce compared with Norway spruce. Compression wood, which in all studies using disc material is determined by examining a 3 mm thick cross-section over a bright light source (5), was found to be of extensive occurrence in both timbers although not often of intensive development. Spiral grain was present, to some extent, in every tree. It commonly had a tendency to a well-marked left-hand twist in the juvenile wood, thereafter decreasing in inclination with increase in tree size - a pattern repeated in other softwoods examined. The extent of grain inclination in the juvenile wood was sufficient to cause severe twist but outside this central core it was not such a serious feature. Differences between the species in average grain inclination was small (see Table 2) and may be attributed, in part, to a difference in age because with the characteristic pattern of grain inclination described, the average inclination can be expected to decrease with age.

Differences attributed to quality class and site were for the most part small and sometimes conflicting. Thus fibre length in Sitka spruce was found to increase from south to north for two quality classes and decrease for another, while for Norway spruce there was little evidence for a regional pattern of variation. For other features, also, while there were sometimes differences between sites, there was again little evidence for a regional pattern of variation. But, if differences between quality classes or sites are small, differences between trees on a site are often considerable and undoubtedly some of the most interesting anatomical observations that have come from this series of investigations are the data on between tree variation, data which

give some indication of the potential for improvement in timber quality which might be effected by a process of selection and breeding.

Table 1. Mean and observed variation in fibre length in some plantation softwoods grown in the United Kingdom

Species	Juvenile wood		Adult wood		
	Age, from pith.yrs.	Fibre length (microns) Mean (underlined) and range	Age, from pith.yrs.	Fibre length (microns) Mean (underlined) and range	No. of trees
Norway spruce	11	2000- <u>2310</u> -2750	26	2450- <u>3160</u> -3770	75
Sitka spruce	8	2230- <u>2890</u> -3480	20	2670- <u>3210</u> -3860	40
European larch	11	2460- <u>2930</u> -3380	29	2430- <u>3600</u> -4710	40
Japanese larch	11	2470- <u>3010</u> -3500	30	2480- <u>3730</u> -4570	40
Lodgepole pine	11	2090- <u>2660</u> -3290			
Yellow pine	11	1900- <u>2200</u> -2500	31	2690- <u>2940</u> -3330	13

Table 2. Grain inclination in some young plantation softwoods grown in the United Kingdom

Species	Average and standard deviation of spiral grain index *)	No. of trees examined	Average age of trees. yrs.
Norway spruce	2.79 ± 1.24	136	41
Sitka spruce	2.97 ± 1.44	170	32
European larch	3.26 ± 1.30	40	29
Japanese larch	2.40 ± 0.97	40	30
Lodgepole pine	1.24 ± 0.51	45	18
Yellow pine	2.01 ± 0.68	13	41

*) The spiral grain index is a weighted average for the grain inclination across a stem - see (3)

Larch. European larch (Larix decidua), although not a native species, has been grown in Britain for more than 200 years and its timber is well known. Japanese larch (L. leptolepis) is a comparatively recent introduction, having been planted extensively only during the past 50 years, so that much of the timber that has been available has been from young growth. The relative merits of the timber of the two species have been a matter of controversy since the first Japanese larch appeared on the market and an investigation was recently undertaken to determine the comparative properties of the two species. In general, the conclusions of the study were that the species were similar for a range of technical properties when wood of comparable age and growth rate was compared and there was little reason to market them separately. They were similar in appearance although both showed some variation in heartwood colour from pale yellow-brown to a moderately dark red-brown with, on the whole, paler wood more common in the European and darker wood more common in the Japanese larch. Sapwood was appreciably wider in European larch, with the greater width attributed, at least in part, to persistence for a longer time in this species.

Like most softwoods, the larches tend to grow vigorously in the early years following establishment but thereafter growth rate falls and, in mature timber with commonly ten or more rings per inch, becomes slow in comparison with many other plantation softwoods. Japanese larch had a rather more vigorous growth when young compared with European larch but this was not maintained in older growth. The extent of spiral grain varied appreciably from tree to tree in both species (see Table 2) with a somewhat greater variation in European larch which, on average, also developed more extensive spiral grain than did Japanese larch. Fibre length in juvenile and adult wood of both species was long (see Table 1) with no significant difference between them, nor was there evidence that the incidence of compression wood differed markedly between the species. An interesting observation was that many trees of both species sampled from throughout Britain had a marked tendency to eccentric growth, particularly in the lower part of the bole. The extra growth occurred mostly on the side between north and east, away from the prevailing southwest wind, and suggests that larch is particularly responsive to wind action.

Lodgepole pine. Lodgepole pine (Pinus contorta) has been planted extensively in Britain only during the past ten years or so. It is of interest, in particular, for afforestation of exposed sites on very poor peat which are otherwise unplantable but it is also suitable for less exacting sites. On these it must be considered in comparison with other plantable species and

the character of its timber is thus important. Furthermore it is a species for which many provenances are recognised and, although provenance is likely to be chosen mainly on silvicultural considerations, the character of the timber could influence the choice. As yet, there are only isolated small stands of large trees and provenance experiments are still at a young stage but timber from both these sources has been studied to examine the potential of lodgepole pine.

In comparison with Scots pine, its main competitor on less exacting sites, lodgepole pine is of somewhat more vigorous growth up to forty years with a greater percentage of heartwood and a more uniform texture at comparable growth rates because of a more uniform growth ring structure with less contrast between early wood and late wood. Fibre length studies showed that lodgepole pine at 11 years has a fairly long fibre (see Table 1) and, although observations on older growth are based on few trees, that fibre length continues to increase up to the 26th ring. It compares closely with Scots pine and may well approach the average length, 3.1 mm, recorded for mature growth lodgepole pine from America. Compression wood was of extensive although not often of intensive development; it was commonly found on the side of the stem away from the prevailing wind and there seems little doubt that the establishment of lodgepole pine on exposed sites must result in compression wood development. Like North American timber the plantation growth commonly had a dimpled grain but perhaps one of its most important characteristics is the low incidence of spiral grain. This was rarely well developed and the low figure as shown in Table 2 is all the more remarkable when its age is considered. A feature of some interest was the presence of interlocked grain in some trees; this is of rare occurrence in most softwoods but was rather more frequent than is usual in lodgepole pine.

A comparison of the timber characteristics of different provenances has only been possible using young, 15-20 year old trees. This preliminary appraisal suggests that differences occur between provenances in growth rate, percentage heartwood, density and fibre length, but that in no case were the timber properties such as to make it unacceptable, although a final appraisal of provenance differences and their comparative merits must await the examination of more extensive material of mature growth.

These are a few of the studies assessing anatomical and other properties. They give an appraisal of the timber at present being grown, but in Britain, as in most countries with a long term commitment to afforestation, there is concern for the improvement of timber quality, in part by management

techniques but also by a programme of selecting and breeding from those trees with a desirable combination of growth and timber characteristics. Where timber improvement is sought co-operation is necessary between the forest geneticist and the timber technologist, and such work is carried out in Britain as a joint project by the Genetics Branch of the Forestry Commission and the Wood Structure Section of the Forest Products Research Laboratory. At present particular attention is being given to Sitka spruce, a tree of generally good stem form and one for which an improvement in certain timber characteristics could do much to improve its general quality. Trees of outstanding form and vigour are sampled by means of large increment cores or borings, 11 mm in diameter and extending from bark to pith, and on the basis of these an appraisal is made of the timber properties for each tree. Particular importance is attached to increasing density with the improvement to come, if possible, by increasing early wood density. This could result in a more uniform texture and should do much to improve working and finishing properties as well as reduce the tendency for collapse to occur on drying - among the most unsatisfactory aspects of fast-grown Sitka spruce. It is for such studies that the beta-particle absorption techniques described elsewhere in this issue have been of particular value.

The above are some examples of the contribution of the wood anatomist in assessing the characteristics of young, plantation timber. They are necessary, in part as a descriptive account of the material examined, but more particularly as the basis for an effective understanding of its technical properties and behaviour. Such information is the basis of efficient utilisation now; it also contributes to decisions on the character of the forests of the future, and the wood anatomist, with his assistance in the selection of the trees which may ultimately stock these forests, thus performs a dual service, not only in purpose but also in time.

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THE USE OF BETA-PARTICLE RADIATION METHODS IN TIMBER RESEARCH

by
Dr. E.W.J.Phillips

Summary

A brief review of the applications of beta-particle techniques in timber research in the past decade is followed by an account of the particular problems studied at Princes Risborough. These include some of the problems connected with the development of the carbon-14 apparatus and its application in the selection of parent trees for breeding to improve timber quality, and in the early recognition of suitable types of progeny. Other applications include the assessment of the proportion of late wood, the calculation from nitrogen determinations of the absolute amounts of this element in different parts of the annual ring, comparison of the texture of various timbers, and the determination of packing density of the cell wall. A recently developed apparatus provides a semi-automatic means of measuring the density of individual annual rings for studies of patterns of within-tree variations.

It is about ten years ago since the possibility of using beams of beta-particles ("beta-rays") for density determination on wood and wood products was appreciated and research became active in various countries in the following years. The various investigators approached the matter from rather different points of view. Some were originally concerned with the larger scale applications such as sawmill grading (BERSENEV and FOKINA, 1958; LAKATOSH, 1956,1958), others with automatic measuring of the width of the growth rings (SANDERMANN, SCHWEERS and GAUDERT, 1960) and others with the semi-micro-assessment of density variation within the growth rings (CAMERON, BERRY and PHILLIPS, 1959; PHILLIPS, 1960; PHILLIPS, ADAMS and HEARMON, 1962). Most investigators based their work on the adsorption of beta-particles as the beam was transmitted through the wood but the possibility of the backscatter method, so potentially useful for examining timber *in situ* where two opposite faces are not accessible, was not overlooked. This was examined by LOOS (1957) who found, however, that results of useful precision could not be achieved in this way. The work appears to have been of a preliminary nature, carried out with apparatus which happened to be available but not well suited for the purpose. The Geiger counter used was operated above its normal maximum counting rate and the source energy, for some unaccounted reason, tended to drift. A repetition of this work with more refined apparatus seems worth doing before abandoning such a potentially useful method.

The general principles involved in beta-particle absorption techniques are described in the paper by CAMERON, BERRY and PHILLIPS, 1959, and theoretical considerations aimed at improved resolution are reported by LLOYD and ADAMS, 1961,

KEYLWERTH and KLEUTERS, 1962 and KLEUTERS, 1964.

Several other applications of beta-particle absorption methods have now been reported, all depending on assessment of wood density. These include moisture content determination (NOACK and KLEUTERS, 1960), especially useful where continuous observation of samples is necessary as, for example, in humidity cycling experiments, and in the determination of fibre saturation point (from the change in shape of the beta-ray absorption versus moisture content curve) (BERSENEV and FOKINA, 1958); also resin content location and assessment, measurements being made on the wood before and after resin extraction (NIEMANN and SCHWEERS, 1958; SANDERMANN, SCHWEERS and HOHEISEL, 1963). GILLWALD (1960) has reported their use in measuring thickness of wood and composite boards, and in the study of diffusion and the movement of liquids including preservatives, and ZITKOV (1958) using specimens impregnated with phosphorus-32 (a source of beta-particles) determined the density of compressed wood.

Most investigators have used a strontium-90 source, the high energy beta-particles from which give useful absorption values with specimens such as those cut from "king-size" increment cores (up to 12 mm diameter). For thinner samples, for example, the 0.1 mm (100 micron) sections used by PHILLIPS, ADAMS and HEARMON, 1962, a special carbon-14 source was used giving a comparatively high output of low energy particles.

In the following pages some account is given of research carried out at Princes Risborough in connection with the improvement and application of beta-particle methods of density determination.

Published descriptions of the basic pieces of apparatus and of their development have already appeared elsewhere (CAMERON et al., 1959; PHILLIPS et al., 1962) and a diagram shown in Figure 1. will suffice here to show the essential components of the carbon-14 apparatus with which most of our investigations have been carried out.

Our earlier work was concerned with examining the possibility of using a beta-particle method for density determination on a semi-micro scale with the particular object of studying density variation in trees of genetic interest (PHILLIPS, 1963); so far this work has been confined to Sitka spruce (*Picea sitchensis*). These home-grown trees are being selected in the first place on morphological features such as good stem form and slender horizontally placed branches as well as growth vigour, all features which

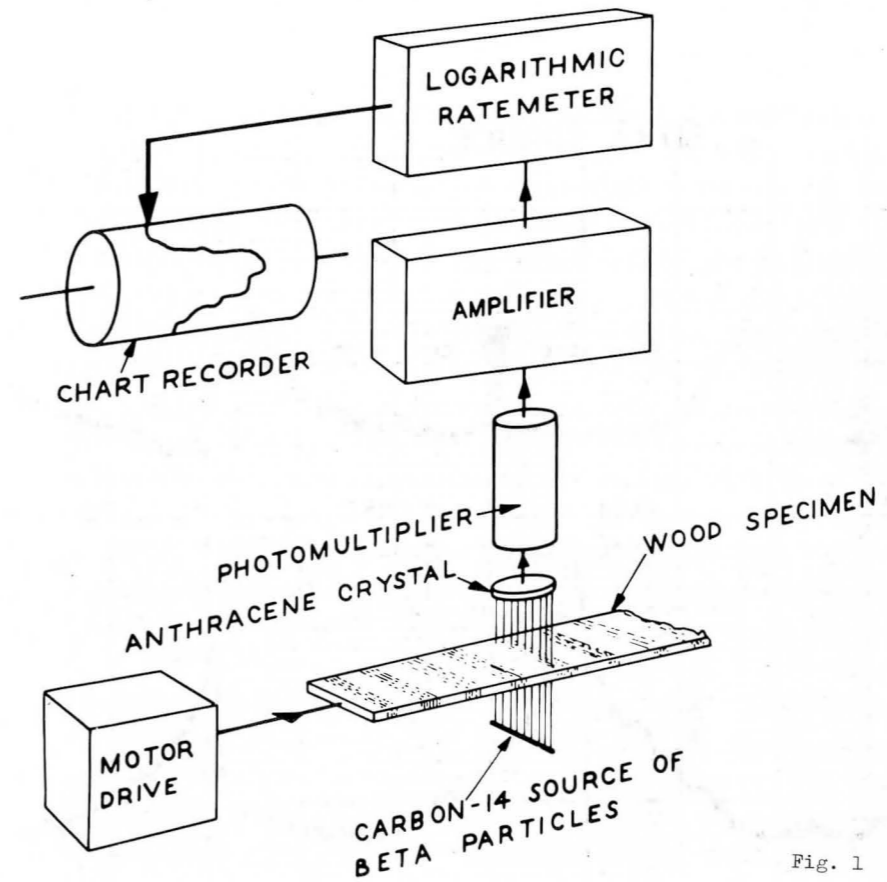


Fig. 1

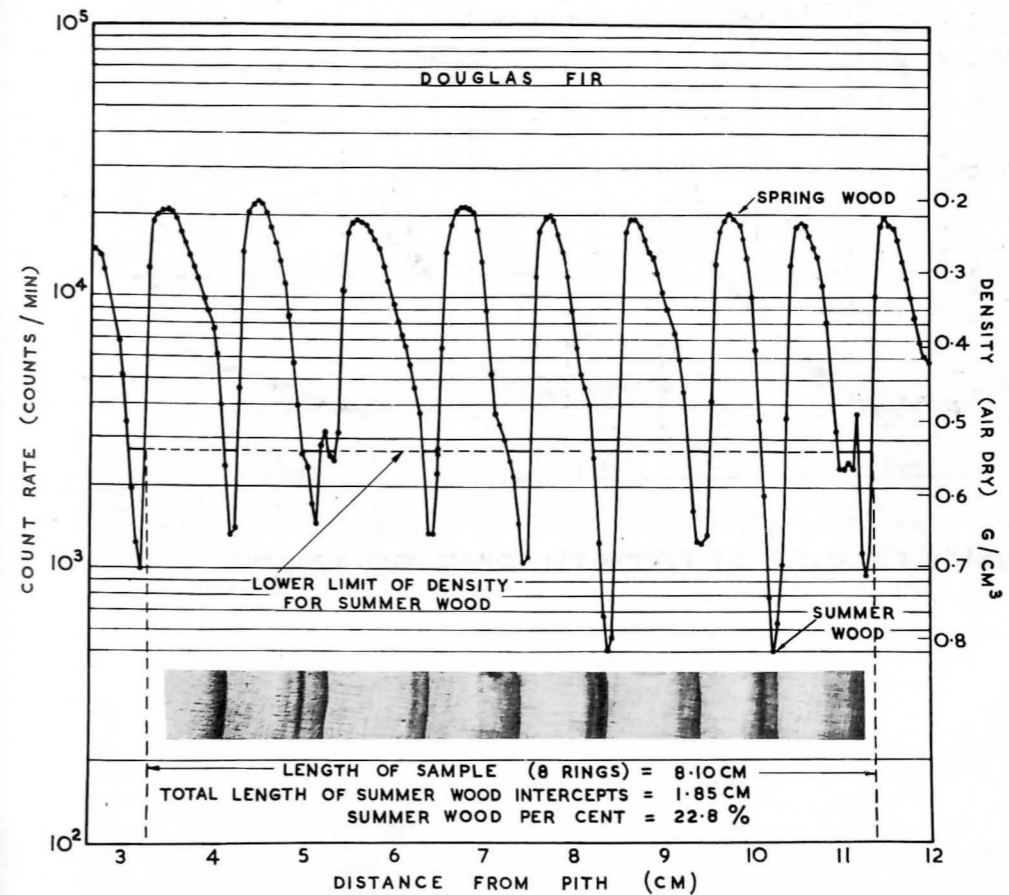


Fig. 3

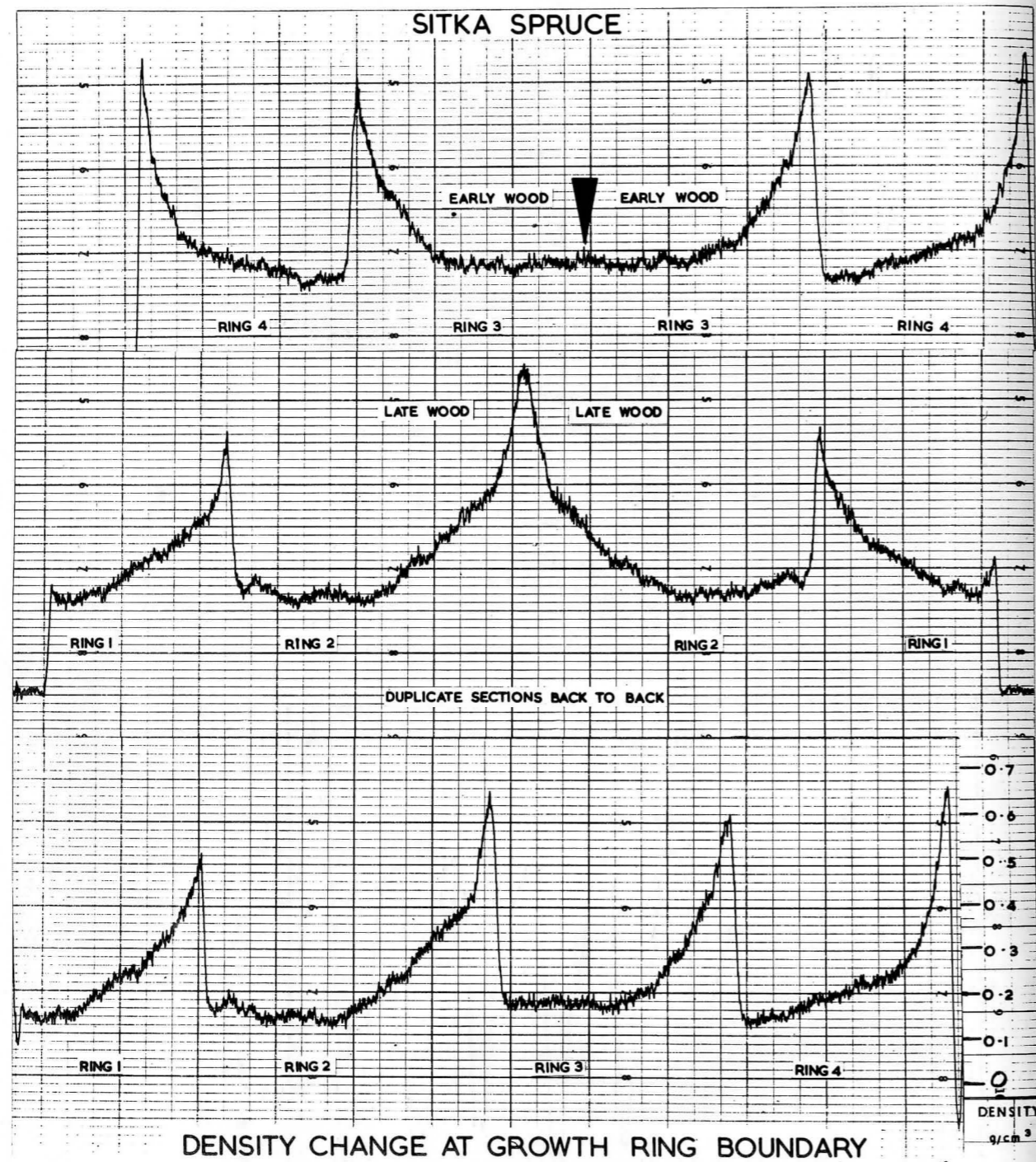


Fig. 2

are desirable for the economic production of timber of improved quality. Before finally accepting these "candidate" trees for seed production it is necessary to examine the character of their timber; this has to be done on small samples since obviously these potential parent trees must not be felled. The necessary samples are taken in the form of "king-size" (12 mm diameter) borings from bark to pith by means of a hand-operated Pressler-type borer supported in a special jig strapped to the trunk at breast height. The original intention was to determine the form of the density variation within each annual ring across the actual borings. In the first place a strontium-90 source was selected to produce the high-energy beta-particles with a suitable penetrating power needed for dealing with these comparatively thick samples. It was soon found that the round borings after drying to the standard 12 per cent moisture content were not satisfactory for obtaining precise measurements since slight distortions and surface irregularities produce significant variations from the true diameter along the length of the sample. To overcome this difficulty the borings were carefully machined to have parallel flat radial faces and a uniform thickness of 8 mm. This type of sample gave improved results but failed to give meaningful values with rings near the pith showing appreciable curvature or with other rings in which the boundaries presented an oblique target to the beam. It was for this reason that the use of much thinner samples, in which ring curvature would have no appreciable effect, was considered. Radial longitudinal sections 100 microns thick were prepared from the fresh boring using a sledge microtome and placed between strips of glass so that their thickness could be checked by viewing them on edge under a low-power microscope fitted with an eyepiece micrometer. The sections were then allowed to dry out, still held between the glass strips which ensured that they remained flat and so easy to mount on the special carrier used to convey them slowly past the beam in the beta-particle densitometer.

These comparatively thin samples were virtually "transparent" to the high-energy beta-particles from strontium-90 and it was necessary to select a source providing particles of sufficiently low energy to give a useful, measurable range of attenuation. A high activity carbon-14 source in the form of crude lipid from the alga *Chlorella* grown with activated CO₂ was found very suitable from this point of view.

KLEUTERS (1964) has made a careful mathematical analysis of the effects of most of the factors which cause loss of resolution. This work, like our own earlier research, was based on experience with a strontium-90 source used

on fairly thick samples. The objections to this method, already considered above, led to the development of the carbon-14 method which gives a much higher resolution. The principal error is likely to be found where there are sharp discontinuities in density. These mainly occur at the ring boundaries and are brought about chiefly by the forward motion of the specimen and by the collimated beam spanning the discontinuity. Under optimal conditions of time constant, beam width and sufficiently slow forward travel, the distortion is extremely small. A demonstration of this is shown in Figure 2 in which successive 100-micron sections were charted and then carefully mounted back-to-back so that in one case duplicate early wood zones of the same ring and in another case the duplicate late wood zones of a second ring were adjacent to each other, thereby largely eliminating the sharp discontinuity. Comparison of the normal curves and those for the back-to-back sections indicates that the original tracing gives values for the early wood and late wood densities very close indeed to those obtained when the putative source of distortion is largely (late wood) or completely (early wood) removed. In another experiment the motor drive was dispensed with and the specimen advanced past the beam in very small steps (about 40 microns or $1/3$ of the width of the beam) by rotating the driving screw a part revolution (15°) at a time by hand. This removed the slight forward slope of the recorded trace normally observed at the ring boundary (due to the continuous motion of the specimen) but did not otherwise detectably affect the shape of the curve, thus confirming the fidelity of the method normally employed. It is recognised that the carbon-14 method employing comparatively thin sections is best suited to the study of timbers composed of narrow elements like those found in coniferous species. In most Dicotyledons, the diameter of the vessels is large enough to result in holes being present in sections of this thickness so that considerable care is required in interpreting the density graphs in such cases; preferably thicker samples should be used in conjunction with a higher energy source.

We can now return to considering the application of the carbon-14 apparatus to the problem for which it was originally developed, viz. the assessment of the form of density variation in potential parent trees selected with a view to the production of progeny of improved timber quality. Apart from providing visual records of the characteristics of the density variation across a radius of each tree for purposes of routine comparison, a number of illuminating facts emerged from the detailed analysis of these records. In Sitka spruce, as in other species of *Picea*, the annual ring typically comprises a rather large proportion of early wood elements with a gradual

transition towards the narrow late wood boundary zones. In fast-growing stems the wide early wood zone is often low in density and this is associated with technical difficulties such as "collapse" during the early stages of seasoning and poor woodworking properties. Some stems showed early wood with above-average density despite the fact that in some cases they were of fast growth. The timber from such stems would appear to be of adequate quality for successful utilization without technical difficulty. As might have been expected, since the early wood constitutes a large proportion of the annual ring and the late wood so little, it was found that the overall density of the wood (as assessed at rings 21-25 from the pith) is more closely related to that of the early wood than to maximum late wood density. This finding points the way to a simplification of the problem of choosing suitable parent trees, since selection on the basis of high overall wood density should ensure satisfactory early wood density. It is appreciated that the heritability of these features has yet to be established but selection in this way seems prudent in view of the accumulating evidence for the heritability of wood density in other species of conifers.

Another important aspect of timber improvement work is the establishment of a forecasting method for selecting potential parent trees at an early age and also for assessing wood quality in youthful progeny from previously selected parent trees. In this case also, study of the beta-particle density graphs has yielded useful results with particular reference to the question of early wood density. An examination of a sample of 80 Sitka spruce stems showed that there is typically a fairly rapid decrease in early wood density in successive rings from the pith, and a value similar to that found in adult wood is reached within the first 5-10 rings. Some fluctuation often occurs in these early rings but by taking the minimum early wood density reached in the first 10 rings a close correlation with that in the adult wood (21-25 rings from the pith) was obtained. This finding offers promise that examination of quite young trees can serve to detect those likely to develop above-average early wood densities in later life. In the same way trees likely to produce low values can be recognised and if necessary culled at an early age.

The density charts present a picture of the distribution of wood substance that has proved applicable to a number of other problems. One of the earliest, originally worked out with our old strontium-90 apparatus, was to develop an objective method of assessing the proportion of late wood present in the annual rings. This entailed a preliminary assessment of the position of the early

wood - late wood transition on a few rings using the well known Mork criterion (i.e. the point where the radial width of the tracheid lumen becomes equal to the width of the double wall between radially adjacent tracheids). The points so determined were transferred to the corresponding density charts and an average of the density values so obtained for the transition zones. In subsequent work a line representing this average density was drawn parallel to the abscissa on the charts. The intercepts made across the late wood portion of each annual ring shown on the density chart gave a measure of the amount of late wood. In this way a density value rather than a visual criterion could be objectively applied in the estimation of late wood. The method has been fully described elsewhere (PHILLIPS, 1960). An example of the use of this method on a sample of Douglas fir is illustrated in Figure 3.

Another application is in the study of the chemical constituents present in different parts of the growth ring, knowledge of the density variation enabling the analytical values (based on percentage of dry weight) to be corrected to give the absolute amounts of the substances present in different parts of the annual ring. This method was applied in investigation into the effects of the amount and distribution of nitrogen on the growth and activity of wood-boring insects.

Use has also been made of the density charts in demonstrating the texture of a number of coniferous species and of special interest was a comparison of the home-grown timber of Pinus strobus with that of the same species grown in its natural habitat in North America. In these cases a simple analysis of the within-ring density differences enabled a revealing numerical comparison to be made. The observations are summarised in Table 1.

The difference in the within-ring density range between the home-grown and Canadian adult material amounts, on average, to about 60 per cent and the home-grown timber is clearly inferior where uniformity of texture is important.

Similar observations made on a home-grown tree of Pinus holfordiana showed this to have a significantly less variable density than home-grown Pinus strobus and even superior to the Canadian-grown wood in this respect. Pinus holfordiana is a fast-growing, lightly branched natural hybrid between Pinus ayacahuite (Mexican white pine) and Pinus wallichiana (Bhutan pine) found in the famous Weston birt arboretum in 1932. It is frost-hardy but unfortunately, like Pinus strobus, is susceptible to attack by pine blister rust and requires to be grown isolated from species of Ribes, the alternate host for this fungus.

Table 1. Comparison of the texture of home-grown and Canadian-grown Pinus strobus

Site and tree number	Mean ring width(mm)	Rings from pith	Average density difference between early & late wood
<u>1. Home-grown Pinus strobus</u>			
<u>Adult wood</u>			
Windermere: No.5	3,5	31-40	0,23
Ardgoil: No.13	2,5	25-35	0,21
Delamere: No.7	1,1	24-54	0,215
			Average <u>0,218</u>
<u>Juvenile wood</u>			
Delamere: No.7	6,6	11-22	0,25
Windermere: No.5	5,0	14-19	0,225
Ardgoil: No.13	2,5	10-23	0,13
<u>2. Canadian Pinus strobus</u>			
(Adult wood) specimen no.			
2951	2,0	-	0,145
2951	1,8	-	0,195
2951	1,5	-	0,13
11224	1,0	-	0,145
11224	0,5	-	0,065
			Average <u>0,13</u>

These preliminary studies of texture measurement on timbers of special topical interest have pointed the way to a more fundamental study aimed at developing a precise measure of texture in numerical terms that correlates closely with those woodworking and possibly other technical properties which can be expressed in numerical form. Up till now texture has been a widely-used descriptive feature but has defied numerical expression.

A further application of beta-particle density records is in the study of the variation in cell wall density between different parts of the annual ring in coniferous wood. Observations made here several years ago on Douglas fir showed that cell wall density (for which the term "packing density" has since been coined by JAYME and KRAUSE, 1963), far from being fairly constant as has been commonly supposed, varied considerably. In early wood it may be as low as 0.70 whereas in late wood values of 1.40 were obtained, i.e. a difference amounting to 100 per cent of the early wood value. Some earlier work on Sitka spruce flour using the benzene displacement method (PHILLIPS, 1941) showed that wood substance derived from late wood was no more than 3.5 per cent denser than that from the early wood. It would, therefore, appear probable that the large difference observed in Douglas fir is accounted for mainly by variation in the character of the pitting rather than in ultramicroscopic

physical structure and chemical composition. Variation in the number of pits per tracheid across a ring were recorded by PHILLIPS (1933) for a number of conifers, the number in early wood being at least four times that in the late wood and, in some cases, considerably more: the variation in the volume of pit voids per unit volume of cell wall is clearly greater even than this since the late wood pits are very much smaller than those in the early wood.

In a recent study on Sitka spruce density variation across annual rings was determined by the beta-particle method and the volumetric proportion of cell wall by Ladell's random-spot method (LADELL, 1959). The observations again showed marked variation in packing density between early wood and late wood, and further that this variation was not as closely related to bulk density as would have been expected; in other words, tissues having the same bulk density may differ in their packing density. It may be supposed that they differ also in their physical and mechanical properties. There is clearly much more remaining to be learned about the manner in which the cell wall substance is distributed within the tissues comprising the annual ring. Such knowledge may lead to a better understanding of why the relationship between density and technical properties is much better in some cases than others, and also why the values for any single property may differ widely amongst samples of the same density. Packing density is a convenient measure for expressing the within-tissue distribution of cell wall substances in numerical terms and the beta-particle method of revealing the density variation in considerable detail opens the way to exploring further this fundamentally important line of research.

Our most recent development in the beta-particle field has been the construction of semi-automatic equipment to measure the average density in whole annual rings taken from 12 mm diameter increment cores. This kind of determination is particularly useful in studying the relationships between the density of a ring, its growth features, and its position in the tree. The accurate dissection of the increment core into individual rings has presented considerable difficulties but these have now been overcome by using a specially constructed circular saw, duplicate cores being used and alternate rings taken from the two samples to avoid error due to loss of wood in the saw kerf. In some investigations it is convenient to use radial strips sawn from cross-sectional discs taken at various heights in the stem rather than increment cores.

The prepared samples are conditioned to 12 per cent moisture content and their thickness (in the radial direction) measured with a micrometer. They are then mounted on a conveyor belt and moved in turn between a beam of beta-particles and a scintillation-counting apparatus which records the number of emerging particles. Each sample is exposed to the beam for 100 seconds, the particle count is passed to a print-out recorder, and then another sample is moved into place, an electrically-operated escapement mechanism being used for this purpose. The whole sequence of operations is automatically controlled by a programming unit and, at present, up to 70 samples are dealt with at each loading. This number could be increased if necessary by extending the length of the conveyor-belt unit. The density of each sample is read from a calibration chart after the particle count has been corrected for sample thickness (i.e. ring width). A strontium-90 source is employed in this apparatus and provides a beam suitable for softwood samples between about 1 and 12 mm in thickness. Since we are concerned with determining the overall density of each annual ring only the previously mentioned difficulties of getting good resolution with this kind of source do not arise.

So far, most of the papers published on beta-particle work have dealt with the development of techniques and comparatively little has been published about the results obtained. This is a reflection of the fact that very few wood anatomists and other biologists have yet had experience with these modern techniques. The apparatus needed for beta-ray studies on wood is necessarily rather costly, although no more than comparable with a well equipped research microscope in this respect. Most of the expenses relates to items that are standard equipment in laboratories concerned with physical investigations, and the remainder of the apparatus can be made even in a modest laboratory workshop. To judge from enquiries received for advice on preparing such apparatus it seems likely that results will be forthcoming from various parts of the world in due course.

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