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T 263

BALLOT NO. 02 SARG

DRAFT NO. 02

DATE 6/1/2023

WORKING GROUP
CHAIR Walter Rantanen

SUBJECT
CATEGORY Pulp Properties

RELATED
METHODS See "Additional Information"

Identification of wood and fibers from conifers

(Five-year review of Standard Practice T 263 sp-16)

(Changes from Draft 1 incorporated - WGC only added clearer imaging)

1. Scope

1.1 This method (*1*) deals with the identification of wood from conifers and also permits determination of the coniferous origin of fibers in pulp and paper.

1.2 The majority of the species described are found in the continental United States and Canada; however, several exotic species found in commercial channels are also included.

2. Summary

2.1 The characteristics of coniferous pulpwood fibers are discussed.

2.2 Instructions are given in the sequential use of primary diagnostic features in the identification of coniferous woods. These may be used from the data chart supplied or by sorting marginally perforated cards.

3. Significance

This method can be used to determine the species of wood (conifers) that are present in either pulp or paper. Since the fiber strength and physical properties are species dependent, knowledge of the species is important in predicting the ultimate strength of paper or paperboard produced.

4. Apparatus

4.1 *Knife or razor blade*, either for freehand or mechanical sectioning.

4.2 *Microtome* (optional), for mechanical sectioning.

4.3 *Magnifying lens*, approximately 15 power.

4.4 *Microscope*, capable of magnifying up to 400X or more.

4.5 *Hot plate*.

4.6 *Microscope slides and cover glasses*.

4.7 *Wood specimen*s (optional but desirable). An authenticated collection of wood specimens for confirming identification of unknown specimens.

4.8 *Marginally perforated cards* (optional). A set of cards (one card for each species) V-notched for identifying features.

5. Reagents

5.1 *Sodium hydroxide*, 1% solution NaOH.

5.2 *Alcohol-glycerin*, a 50-50 solution of glycerin and 95% ethyl alcohol.

6. Sampling and test specimens

Because identification may be made from a piece of wood, a pulp sample, or a paper sample, two different methods are used in preparing the specimens for examination.

6.1 *For wood*:

6.1.1 It is necessary to examine both radial and tangential sections because most of the diagnostic features will be seen from these surfaces. Prepare these sections by cutting thin slices freehand with a razor blade or microtome knife.

NOTE 1: It is usually desirable to wet the surface prior to cutting, or in some cases it may be desirable to boil the block for a short time in order to cut sections that are thin enough to be transparent at the higher magnifications of the microscope.

6.1.2 Place the sections on a microscope slide, add a few drops of alcohol-glycerine mixture, and apply a cover glass. Heat the prepared slide to the boiling point on the hot plate for a minute or two to expel air from the sections. After cooling for a few minutes, the slide is ready for examination.

6.2 *For pulp and paper* (see also TAPPI T 401 "Fiber Analysis of Paper and Paperboard" for quantitative estimation):

6.2.1 For pulp, place a few drops of the suspension on a microscope slide and apply a cover glass.

6.2.2 For paper, boil a small quantity of the sample for a few minutes in a 1% NaOH solution to remove sizing materials. Wash the sample to remove the alkali and shake vigorously in water to make a suspension. Place a few drops of the suspension on a microscope slide and apply a cover glass.

6.2.3 It may be desirable to stain the fiber with C-stain.

7. Procedures

7.1 *Procedure for differentiating between softwoods and hardwoods*. The distinguishing difference between wood from coniferous trees commonly called the softwoods, and wood from deciduous trees (other than conifers such as larch or bald cypress which also lose their leaves in winter), commonly called the hardwoods, is the presence of vessels in the latter, which appear as pores in the transverse section (Figs. 1 and 2). Wood from conifers is characterized by the absence of pores in the transverse section (Fig. 1). In such wood, the tracheids, the principal structural elements or fibers, appear in transverse section as polygonal in earlywood and rectangular in latewood. As a rule, the tracheids are thinner-walled and have larger radial diameter in earlywood than in latewood (Figs. 3 and 4).

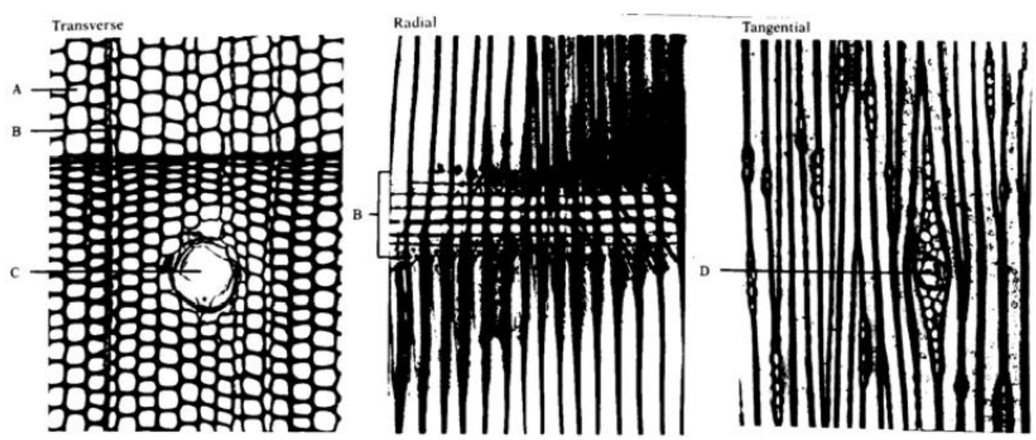

Fig. 1. Thin sections of eastern white pine magnified about 100 times. The cross section (transverse view) is dominated by rows of tracheids (A); also visible are the narrow rays (B) and a single resin canal (c). In the radial view, a longation of the tracheids is apparent, and the rays (B) appear as brick-like bands of cells. In tangential section, the rays are seen in end view. One ray, called a fusiform ray (D), has a horizontal resin canal through its center (figure from 2, used by permission).

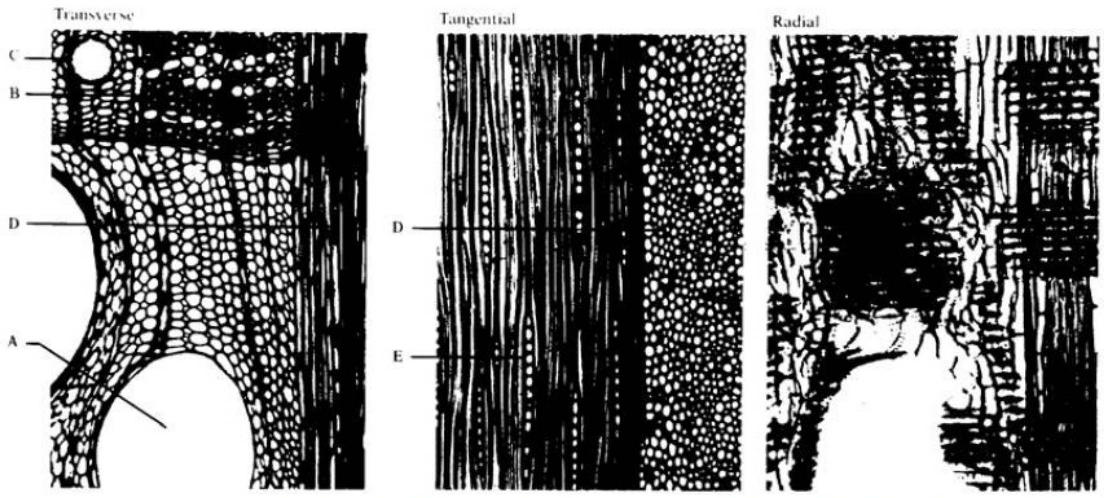

Fig. 2. Red oak, a ring-porous hardwood, magnified about 100 times. Large, thin-walled pores (A) are concentrated in the earlywood and are many times the diameter of the thick-walled fibers (B) abundant in the latewood. The pores are surrounded by small-diameter, thin-walled tracheids (C). Large multiseriate rays (D), easily visible to the naked eye, are a distinctive feature of oaks. Uniseriate rays (E), seen only with a microscope, are also numerous (figure from 2, used by permission).

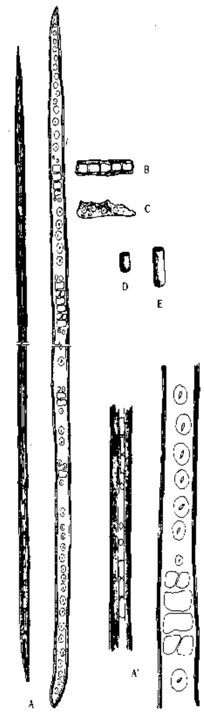

Fig. 3. Some coniferous cell types: tracheids (A, enlarged view, A') comprise more than 90% of the wood volume. The remainder is mostly ray tissue, either ray parenchyma cells (B) or ray tracheids (C). Some species also have a very small percentage of epithelial cells (D), which line resin canals, or longitudinal parenchyma cells (E) (figure from 2, used by permission).

7.2 *Procedure for diagnostic and microscopic identification*. Detailed descriptions of the various species are not included; however, the presence of diagnostic features is shown in Table 1, and attention is called to the supplementary notes on the various genera. In the following notes, the diagnostic features selected for their value in identification are defined and their significance discussed. The majority of the anatomical features used in this key are also illustrated. Most of the features refer to microscopic structure; however, there are also included certain general or gross features that are of value in specific instances.

7.2.1 *Resin canals.* When resin canals are present, they occur in both the vertical and horizontal system. On smoothly cut transverse surfaces they appear to be solitary or infrequently paired. Resin ducts vary appreciably in size and abundance and in most species can be detected with the eye. They are largest and most abundant in *Pinus* and of smaller size and fewer in number in *Picea*, *Larix*, and *Pseudotsuga*. In some instances they appear as short scratch marks on the longitudinal surfaces of the wood or may become more pronounced because of resin stains in adjacent areas. Exudation of resin from the end grain, the presence of pitch pockets, or pitch streaks are additional indicators of the presence of resin canals. The presence of normal ducts can always be verified by an examination of transverse or tangential sections under the microscope.

7.2.2 *Epithelial cells thick-walled*. In freehand sectioning or sectioning without embedding the wood, species that possess resin canals with thin-walled epithelial cells (resin secreting tissue) will show the fusiform wood rays containing the canals to be devoid of an epithelium layer and, in many instances, the adjacent ray parenchyma (food storage cells) will also be removed in the process. This condition is shown in Fig. 5, center, where the canal as well as the thin-walled parenchyma (epithelial) cells have been torn out in sectioning without embedding. Figure 5, left, shows a similar-type fusiform (spindle shaped) ray which had been embedded and all of the cells are intact. Figure 5, right, illustrates the thick-walled type of epithelium which has remained intact even though the section was cut freehand.

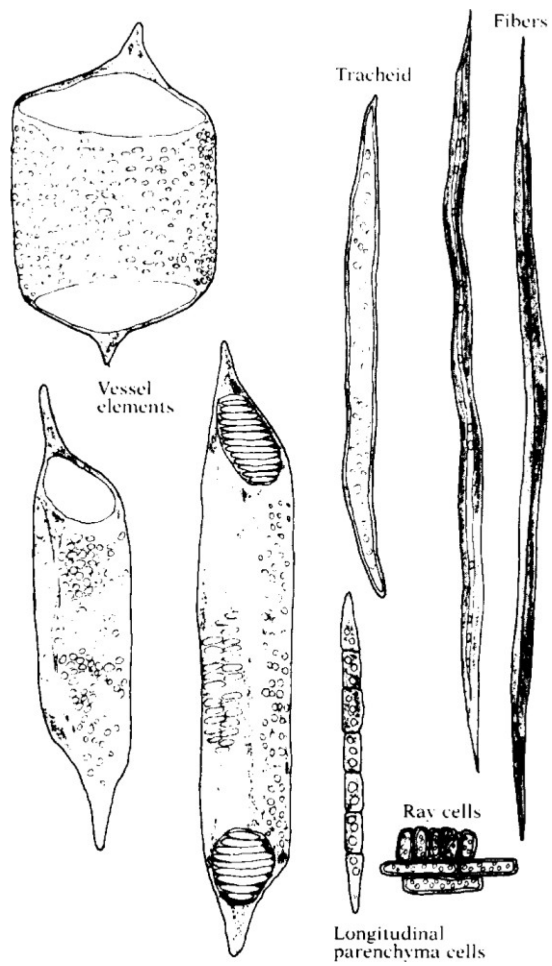

Fig. 4. Hardwood cell types are extremely varied. The drawing indicates their relative size and shape (figure from 2, used by permission).

7.2.3 *Ray tracheids common.* Ray tracheids may be found in many species if a careful search is made, but their rare occurrence in such cases suffices to distinguish those in which they are immediately seen. In certain genera they may be confined to the margins of the wood rays, as in *Tsuga* and *Larix*, while in others, for instance *Pinus*, they may be both marginal and interspersed. When the ray tracheids are nondentate (without tooth like projections) they may be differentiated from the ray parenchyma by the presence of small bordered pits in the end walls and will be seen there in sectional view.

7.2.4 *Ray tracheids dentate*. Ray tracheids exhibiting tooth like projections of the walls are referred to as dentate (Fig. 6, left), and where they appear fused they are known as reticulate. Dentate ray tracheids occur in the genus *Pinus* and are associated with those species which show 1-6 pinoid (pine-like) cross-field pitting. They may also occur in combination with 1-2 large, fanstrate, or window-like pits as in *Pinus resinosa* and *Pinus sylvestris*. Minute denticulations are regularly present in *Picea*, sporadic in *Larix*. These should be observed from radial sections in the latewood or summerwood portions of the growth rings.

Table 1. Identification chart and data for preparation of card keys

		Resin canals present													Resin canals absent																				
		Epithelium thick-walled						Epithelium thin-walled							Ray tracheids present			Ray tracheids absent																	
																		End walls of ray cells nodular								End walls of ray cells smooth									
Diagnostic features	Feature number	Pseudotsuga	Larix laricina	Larix occidentalis	Picea sitchensis	Picea spp.	Picea spp.	Pinus spp.	Pinus spp.	Pinus resinosa	Pinus strobus	Pinus monticola-lambertians	Pinus spp. (*foxtail*)	Pinus spp. (*pinyon*)	Chamaceyparis nootkatensis	Tsuga heterophylla	Tsuga canadensis	Abies balsamea	Abies spp. (*white firs*)	Abies lasiocampa	Juniperus spp.	Juniperus spp.	Fitzroya cupressiodes	Libocedrus decurrens	Cupressus arizonica	Taxus brevifolia	Torreya taxifolia	Thuja plicata	Thuja occidentalis	Cupressus lusitanica	Chamaecyparis lawsoniana	Chamaecyparis thyoides	Taxodium distichum	Sequoia sempervirens	Araucaria-Agathis
Canals																																			
Present	1	+	+	−	+	+	+	+	+	+	+	+	+	+																					
Epithelium thick-walled	2	+	−	−	+	+	+																												
	3																																		
Rays																																			
Tracheids present	4	+	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+																		
Tracheids dentate	5							+	+	+																									
Indenture	6	+	+	+	+	+	+									+	+	+	+	+	+	+	−		+			+	+						
End walls nodular	7	+	+	+	+	+	+				+	+	+	+	+	+	+	+	+	+	+	+	−	+	+										
Crystals	8																		−																
	9																																		
Cross-field pitting																																			
1-6 pinoid	10							+	+																										
1-2 fenestriform	11									+	+	+																							
Piceoid	12	+	+	+	+	+	+						+	−		+	+																		
Cupressoid	13														+						+	−	+	+	+	+	+			+	+	+	−		+
Taxodioid	14																	+	+									+	+				−	+	
	15																																		
	16																																		
	17																																		
Tracheids																																			
Pits 2-4 opposite	18		+	+	+												−																+	+	
Pits 2-4 alternate	19																																		
Spirals	20	+																								+	+								−
	21																																		
Vertical parenchyma																																			
Present	22	+													+	+	+	+	+	+	−	+		+	+			+	+	+	+	−	+	+	
Transverse walls nodular	23	+													+	+	+	+	+	−	+	+	+	+	+			+	+	+	+		+		
	24																																		
	25																																		
General																																			
Heartwood	26	+	+	+	+			+	+	+	+	+	+								+	+	+	+		−		+	+	+		+	+	+	
Odor	27	+													+						+	+		+	−		+	+	+	+	+	+	+		
Greasy	28																																+		
Dimpled	29																																		
Transition abrupt	30	+	+	+				+	+	+							+						+					+	+				+	+	
	31																																		
Origin																																			
Exotic	32																						+							+					+
Eastern	33		−			+		+		+	+						+	+			+								+			+	+	+	
Western	34	−		+	+		+		+			+	+	+	−	+			+			+		+	+	+	+	+			+				

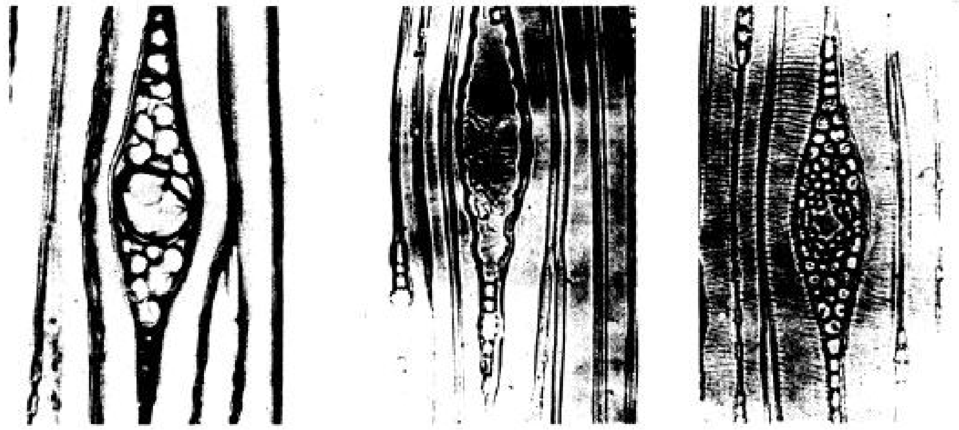

Fig. 5. Left, thin-walled epithelium and ray parenchyma intact after sectioning of embedded specimen. Center, thin-walled epithelium and ray cells torn out in specimen that was not embedded. Right thick-walled epithelium intact after freehand sectioning of untreated specimen.

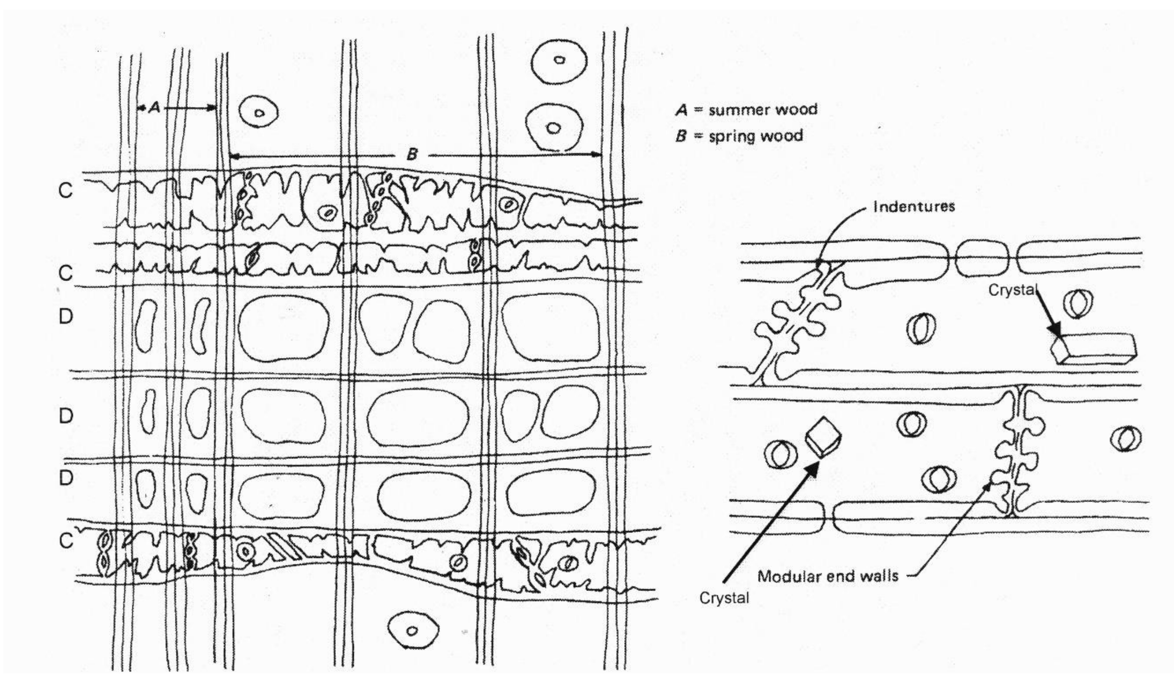

Fig. 6. Left, sketch of radial section of *Pinus resinosa* showing two rows of denate ray tracheids (C) on the upper margin of the wood ray and a single row on the lower margin; the three center tiers of ray parenchyma (D) illustrate 1-2 large, simple, crossfield pitting. Right, radial section of *Abies magnifica* showing nodular end walls of the ray parenchyma cells in pit-like hollows of the horizontal walls. These hollows are referred to as indentures. A solitary crystal appears in each cell.

7.2.5 *Indenture*. Depressions at the corners of the ray cells, as observed from radial sections, are referred to as indentures. They appear as very small, pit like hollows in the horizontal walls in which the ends of the vertical walls stand (Fig. 6, right). These should be observed at a magnification of about 400 times and used as an identification feature only if they are definitely present. Of our native species, this feature is of greatest diagnostic value in the cedar species.

7.2.6 *End walls of ray parenchyma nodular*. Beadlike thickenings are sometimes present on the vertical walls of the ray parenchyma cells and can be observed from radial sections. Similar thickenings may occur on the transverse walls of the vertical parenchyma cells (Fig. 6, right).

7.2.7 *Crystals present.* Crystals appearing in the form of regular prisms, cubes, or octahedra are of common occurrence in one group of the genus *Abies*, and occur sporadically in *Picea sitchensis and Libocedrus decurrens.* The crystals are generally confined to the ray parenchyma cells, although they may also be found in the vertical parenchyma in *Abies*. Figure 6, right, illustrates two of the crystal shapes that may occur in Abies.

NOTE 2: *Cross-field pitting*. The pits occurring on the areas of contact between the ray parenchyma cells and the adjacent vertical tracheids are referred to as cross-field pitting. This may vary from a single large pit that occupies most of the area of the cross-field, as in the case of the white pines, to very small pits that occupy only a small portion of the cross-field areas, as in the case of the spruces. Because the number of pits per cross-field as well as their shape will vary within a given growth ring, it is necessary to limit observations of this feature to the first two or three rows of earlywood or springwood tracheids.

7.2.8 *Cross-field pitting, 1-6 pinoid.* Pitting of the 1-6 (most commonly 2-4) pinoid type may be without a border or show narrow borders. The individual pits are irregular or variable in shape and size and there may be one to six pits per cross-field. Pitting of this type is limited to the genus *Pinus* and is associated with dentate ray tracheids.

7.2.9 *Cross-field pitting, 1-2 (Note 2) large, simple.* Within the category of 1-2 pits that are large, simple, or nearly so are included the large window-like pits of the white pines, red pine, scotch pine, and the uniformly oval and more numerous pits of sugar pine (Fig. 6). In the case of the white pine and red pine there may be one or two pits per cross-field, whereas sugar pine there may be two or four pits per cross-field.

7.2.10 *Cross-field pitting, piceoid.* Piceoid pits show a narrow and often slightly extended aperture. The aperture in this instance is distinctly narrower than the distance from the aperture to the border (Fig. 7d).

7.2.11 *Cross-field pitting, cupressoid.* Cupressoid pits are those in which the aperture is avoid and included. The aperture is slightly narrower than or as wide as the space on either side between the aperture and the border (Fig. 7f).

7.2.12 *Cross-field pitting, taxodioid.* Taxodioid pits have a large, ovoid-to-circular included aperture that is wider than the space on either side between the aperture and the border (Fig. 7e).

7.2.13 *Bordered pitting of tracheids multiseriate and opposite.* This feature of pitting of tracheids biseriate (two rows) or triseriate and opposite applies tot he common occurrence of 2-4 bordered pits throughout the length of the tracheids and not to occasional groups that may occur at the overlapping portions of the tracheids. This feature is most pronounced in *Sequoia* and *Taxodium* and of infrequent occurrence in other genera (Fig. 8, center).

7.2.14 *Bordered pitting of tracheids multiseriate and alternate*. Tracheid pitting may be 2-4 seriate in this group but in alternate arrangement. This feature separates *Araucaria* and *Agathis* from all other conifers (Fig. 8, right).

7.2.15 *Spiral thickenings in tracheids.* Spiral thickenings of tracheids occur only in *Pseudotsuga*, *Taxus*, and *Torreya*. In *Torreya* the thickenings tend to occur in pairs which helps to separate this genus anatomically from *Taxus*. Spiral thickenings should not be confused with the spiral checks that characterize compression wood. Figure 5, right, illustrates the spiral thickenings in *Pseudotsuga*.

7.2.16 *Vertical parenchyma present.* When present, parenchyma cells are usually detected without difficulty because of their dark contents. The cells may be limited to the growth ring boundary as in *Abies* and *Tsuga* or may be interspersed throughout the growth ring as in *Taxodium* and *Juniperus*. The dark contents of vertical parenchyma are shown in Fig. 8, left.

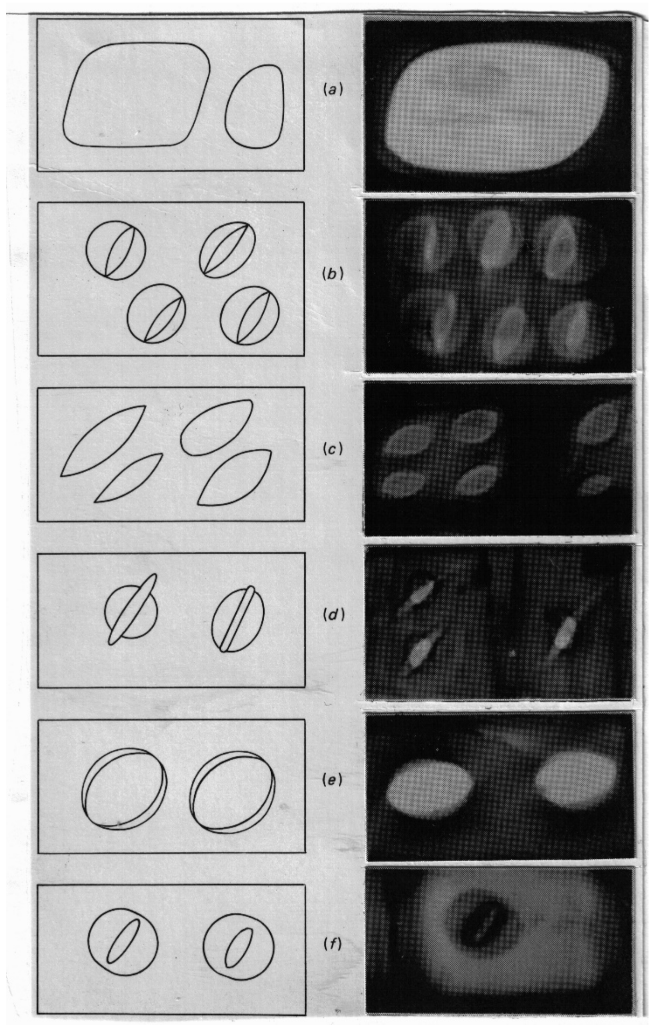

Fig. 7. Types of pit pairs occurring in the cross-fields of coniferous woods; (a) Window-like pit pairs of the type that characterize the three commercial soft pines and red pine (*P. resinosa Ait.*). A border may (b) or may not (c) be present. (D) Piceoid pit pairs of the type encountered in *Picea, Larix,* and *Pseudotsuga.* (E) Taxodioid pit pairs of the type that feature *Sequoia* and *Taxodium* of the Taxodiaceae, *Abies* of the Pinaceae, and *Thuja* of the cupressaceae. (F) Cupressoid pit pairs of the type that occur in *Chamaecypairs*, *Calocedrus*, and *Juniperus* (but not in *Thuja*) of the Cupressaceae, and in *Tsuga* of the Pinaceae (from *Textbook of Wood Technology*, Volume 1, fourth edition, by Panshin and DeZeeuw; copyright 1979, McGraw-Hill Book Company; used with the permission of McGraw-Hill Book Company).

7.2.17 *Transverse walls of vertical parenchyma nodular*. Beadlike thickenings on the transverse walls of vertical parenchyma, similar to those that may occur on the end walls of the ray parenchyma cells, are best observed from tangential sections. The presence of these thickenings and their relative size are very helpful to differentiating between certain species. *Sequoia* and *Taxodium* are readily separated anatomically on this basis (see Fig. 8, left).

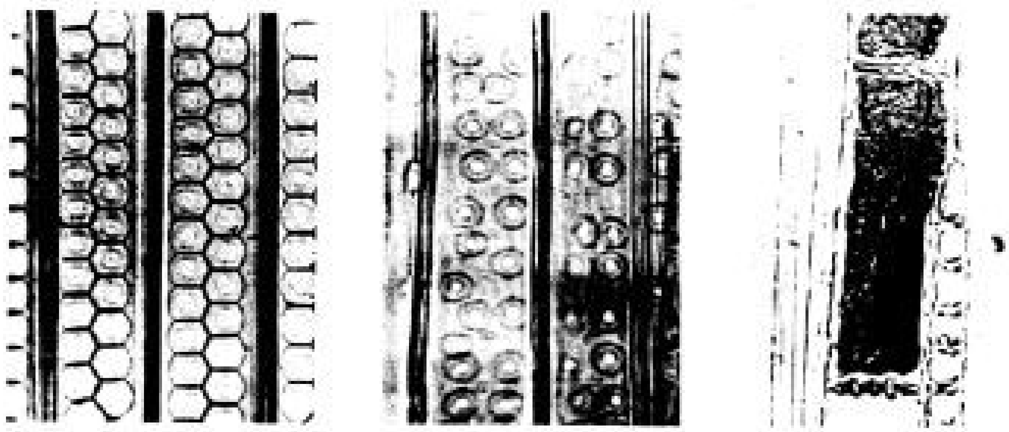

Fig 8. Left, nodular thickenings of the transverse walls of vertical parenchyma in *Taxodium*; note dark-colored contents. Center, bordered pitting of tracheids multiserate and opposite in *Sequoia*. Right, bordered pitting multiseriate and alternate in *Agathis*.

7.2.18 *Heartwood colored.* This characteristic is used only with those species that possess a strongly colored heartwood, not where the heartwood exhibits only a slightly darker color than the sapwood. This feature is to be used in the positive sense only.

7.2.19 *Distinctive odor.* Distinctive odors will range from the rank odor of Abies lasiocarpa to the sweetly aromatic odors found in *Thuja plicata* and *Libocedrus decurrens*. Faint odors may be accentuated by moistening a freshly exposed heartwood surface or by heating a moistened surface. This characteristic is to be used only in the positive sense and to best advantage in those woods in which resin canals are absent.

7.2.20 *Greasy feel*. A characteristic greasy feel is found in *Taxodium* and in some specimens of *Pinus ponderosa*. This feature is to be used only in the positive sense.

7.2.21 *Dimpled grain*. Dimpled grain is due to the indentations of the cambium produced by resin cysts in the bark. Thin-barked species such as *Pinus contorta* show this feature prominently on flatsawn surfaces. Dimples also occur frequently in *Pinus ponderosa*, *Picea sitchensis*, and sporadically in several other species.

7.2.22 *Transition abrupt*. Abrupt transition refers to the sharp definition of the earlywood and latewood of the same growth ring. Figure 9, left, illustrates the abrupt transition in *Larix* and Fig. 9, right, shows the gradual transition of *Pinus strobus*. Species that regularly show an abrupt transition may show a gradual transition in wide growth rings; hence, this feature should be used only in the positive sense.

7.3 *Procedure for classification by geographic origin.*

7.3.1 *Exotic*. Species originating outside the boundaries of the continental United States and Canada are known as exotic.

7.3.2 *Eastern United States.* Species whose natural range is east of the Great Plains are listed as from the eastern United States.

7.3.3 *Western United States*. Species whose natural range is west of the Great Plains are classified as from the western United States.

7.4 *Procedure for identification by use of Table 1 and card key (Fig. 10).* The data in Table 1 may be used independently as a key or the data may be transposed to cards and the identification may be accomplished by sorting. The suggested layout of the card key is shown in Fig. 10.

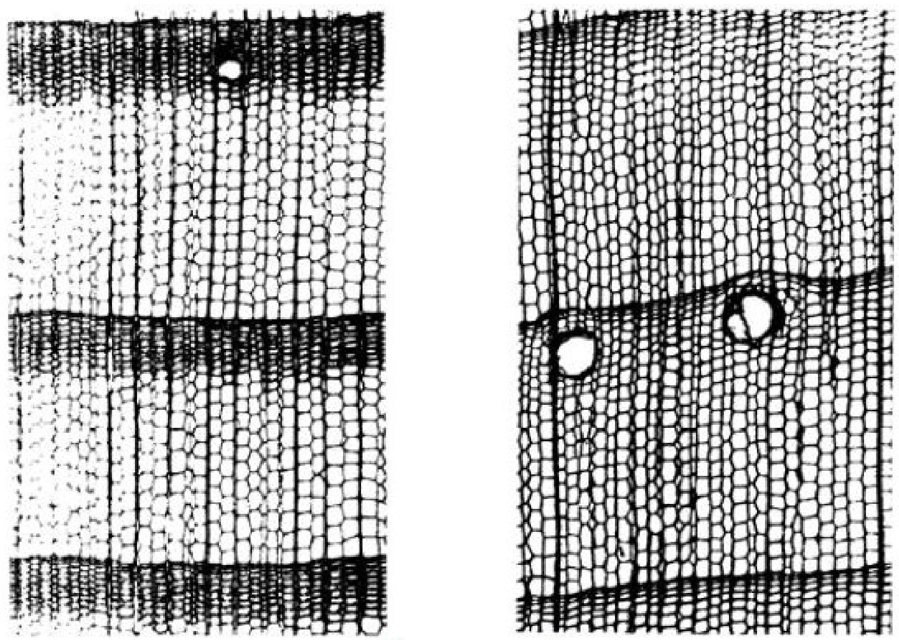

Fig. 9. Left, abrupt transition in *Larix* and one small vertical resin canal in the latewood. Right, gradual transition in *Pinus strobus* and two large vertical resin canals at the margin of the latewood.

7.4.1 *Use of tabulated data as a key*. The plus marks in Table 1 represent the presence of the given characteristic for a particular species or group of species. Blank spaces indicate the absence of the feature. The data are so tabulated that the species and groups are reduced to a small number within each category, which permits easier comparisons leading to identification. Under the heading "Resin canals present" and the subheading "Epithelium thin-walled" we find all the pines. Further separation may be accomplished by means of the presence or absence of dentate ray tracheids and still further by means of the cross-field pitting. This elimination may be continued until the identification is pinpointed to a single group.

7.4.2 In transposing the data from Table 1 to marginally perforated cards, the features marked with a plus (+) are to be indicated on the card by a notch. Features which are shown as blanks in the table remain unnotched on the card. For example, perforation no. 1 is designated as "Resin canal present" and, if notched, indicates the presence of this feature; if left unnotched, this indicates the absence of resin canals. Upon inserting a needle or thin rod into a pack of cards, those which are notched at a particular perforation will fall from the pack when the entire series is lifted and gently shaken. This process is repeated for a succession of the more important characters of the sample until a single card falls from the pack and the determination is accomplished. When the region of growth is positively known, it is usually desirable to start sorting at this point; in so doing the card pack will be reduced by about one half and will permit more accurate diagnosis.

7.4.3 *Preferred sequence of operation for woods with resin canals:*

7.4.3.1 Region of growth if positively known.

7.4.3.2 Resin canals present or absent: cards falling from pack are those woods in which canals are present.

7.4.3.3 Sort for thick-walled epithelium: cards falling from pack are woods with thick-walled epithelium and those remaining on needle are those with thin-walled epithelium.

7.4.3.4 If epithelium is thin-walled, then sort for ray tracheids dentate: those falling from the pack have dentate ray tracheids and those remaining on needle have smooth or non-dentate ray tracheids.

7.4.3.5 Next sorting should be in cross-field pitting, followed by any other feature which is presented by the particular sample.

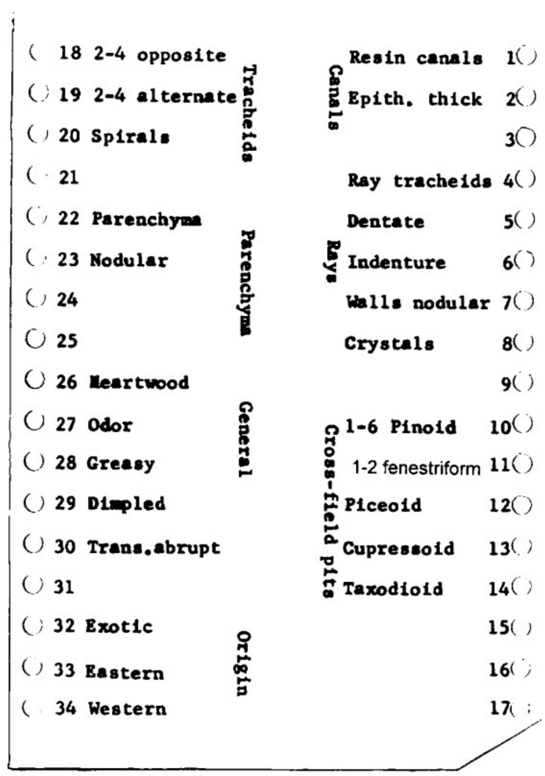

Fig.10. Suggested layout of features for card sorting key.

7.4.4 *Preferred sequence of operation for woods without resin canals*:

7.4.4.1 Region of growth if positively known.

7.4.4.2 Resin canals present: the cards remaining on the needle are the woods without resin canals.

7.4.4.3 Ray tracheids common: cards falling from pack are those in which ray tracheids are commons and those remaining on needle are without ray tracheids.

7.4.4.4 End walls of ray cells nodular: cards falling from pack contain this feature and cards remaining on needle are those woods in which the end walls are smooth.

7.4.4.5 Continue with type of cross-field pitting, vertical parenchyma present, vertical parenchyma if present with or without nodular transverse walls, bordered pitting 2-4 seriate and whether alternate or opposite, indenture, followed by any other feature pertinent to the specimen.

7.4.5 Species having highly distinctive characteristics can be sorted very quickly without going through the above operations. Douglas fir, for example, can be arrived at in two sorts, the first for spiral thickenings present in the vertical tracheids and the second for resin canals present. The red pines can likewise be removed in two sorts - for ray tracheids dentate, and cross-field pitting 1-2 (Note 3) large. A single sort at tracheid pitting multiseriate and alternate will immediately bring out the *Araucariaceae* (*Agathis* and *Araucaria*).

7.5 *Procedure for evaluating anatomical features supplementing Table 1.* Summarized here are the important anatomical features of the various genera of conifers contained in the key and supplementing the data in Table 1. Means of distinguishing the individual species are given here because such specific identifications often depend on characteristics that are insufficiently precise for inclusion in the list of key features. The distinctive features of each genus and the degree to which the genus may be subdivided in anatomical or other features are also noted.

7.5.1 *Abies*

7.5.1.1 Nine species of *Abies* are native to the United States and Canada. The only eastern species of commercial importance is balsam fir [*A. balsamea* (1.) Mill.]. The other eastern species, Fraser fir [*A. fraseri* (Pursh.) Poir.] is extremely limited in its distribution and hence of little importance. The western species, Pacific silver fir [*A. amabilis* (Dougl.) Forbes], white fir [*A. concolor* (Gord. & Glend.) Lindl.], grand fir [*A. grandis* (Dougl.) Lindl.], subalpine fir *[A. lasiocarpa* (Hook.) Nutt.], California red fir [(*A. magnifica* A. Murr.)], and noble fir (*A. procera* Rehd.) are of considerable importance from the production standpoint. The bristlecone fir (*A. bracteata* D. Don) is limited to Monterey County, Calif., and does not enter commercial channels. The latter species may be readily recognized by the very frequent occurrence of traumatic (from an injury) resin canals.

7.5.1.2 Woods belonging to this genus may be readily recognized anatomically by the following combination of features: resin canals lacking, ray tracheids lacking, end walls of ray parenchyma nodular, and cross-field pitting taxodioid.

7.5.1.3 The woods of this genus may be further subdivided into two groups on the basis of the color of the ray cell contents. In the eastern species and in subalpine fir the ray cell contents are colorless or at most a very pale yellowish color and frequently tend to form a reticulum (network) within the cells so that detection of the end walls may be somewhat difficult. These three species are further characterized by the lack of crystals in the ray parenchyma. The wood of *Abies lasiocarpa* frequently has a rather foul odor and the knots are distinctly yellowish in color.

7.5.1.4 The remaining species, all western, have ray cell contents that are distinctly reddish-brown. Crystals may be found in all species of this series but are common to abundant in *A. magnifica* and *A. concolor* and sparse or infrequent in *A. amabilis*, *procera*, and *grandis*. For practical considerations, the western species are classed collectively as "white fir."

7.5.2 *Araucariaceae*. In the *Araucariaceae* family are three species that enter commercial channels: Brazilian araucaria or "Parana pine" [*Araucaria angustifolia* (Bert.) O. Ktze.] of Brazil; klinki pine (*Araucaria klinkii* Lauterb.) of Borneo; and almaciga or "sakar" (*Agathis philippinensis* Warb.) of the Philippine Islands. The group as a whole is easily separated from all other coniferous woods by the 2-4 seriate bordered pitting of the vertical tracheids which is in alternate arrangement (Fig. 8, right). The two *Araucarias* are separated from *Agathis* by the presence of leaf traces in the *Araucarias*. These traces appear as tiny pin knots arranged obliquely as seen on the surface of flatsawn boards. Brazilian araucaria tends to be yellowish in color and frequently shows reddish or pinkish streaks, while klinki pine is pinkish in color, is lighter in weight, and does not show reddish streaks. In color and luster, klinki pine is very similar to Sitka spruce [*Picea stichensis* (Bong.) Carr.]. The lack of growth rings in the family also helps to separate these imported woods from native softwood species.

7.5.3 *Chamaecyparis*

7.5.3.1 Three species of *Chamaecyparis* occur within the United States and Canada: Atlantic white-cedar [*C. thyoides* (L) B.S.P.], of the coastal plain from southern Maine to Mississippi; Port-Orford-cedar [*C. lawsoniana* (A. Murr.) Parl.] of southwestern Oregon and northwestern California; and Alaska-cedar [*C. nootkatensis* (D. Don) Spach], which ranges from southeastern Alaska to northwestern California.

7.5.3.2 The three species vary appreciably and possess no features in common that would distinguish the genus. The heartwood of *C. nootkatensis* is yellowish and that of *C. lawsoniana* ranges from yellowish-white to a pinkish brown or very pale brown. In both species there is no sharp contrast in color between heartwood and sapwood. The heartwood of *C. thyoides* is a light brown with a pinkish or reddish cast and is sharply demarcated from the sapwood.

7.5.3.3 From the standpoint of odor, the three species differ rather markedly. The heartwood of *C. thyoides* is aromatic and resembles that of northern white-cedar (*Thuja occidentalis* L.); the heartwood of *C. lawsoniana* is strongly aromatic with a pungent, gingerlike odor; and the heartwood of *C. nootkatensis* has an odor that resembles that of raw potatoes.

7.5.3.4 Anatomically they may be separated as follows: *C. nootkatensis* has ray tracheids that are quite large and frequently comprise the entire wood ray; the end walls of the vertical parenchyma are nodular, as are also the end walls of the ray parenchyma cells; and indenture is present. *C. lawsoniana* and *C. thyoides* are similar in that they lack ray tracheids and the end walls of the ray cells are smooth and without indenture. They differ in that the transverse walls of the vertical parenchyma are nodular in *C. lawsoniana* and smooth in *C. thyoides.*

7.5.4 *Cupressus*

7.5.4.1 Of the various species of *Cupressus*, only two are occasionally encountered: Arizona cypress (*C. arizonica* Greene) of the southwestern United States and Bentham cypress (*C. lusitanica* Miller) of Mexico and Guatemala. The heartwood of *C. arizonica* is not differentiated from the sapwood, is yellowish in color, and aromatic. The heartwood of *C. lusitanica* is a pale reddish brown in color and is distinctly separated from the light-colored sapwood. The heartwood of *C. lusitanica* is also aromatic.

7.5.4.2 Anatomically *C. arizonica* has many of the features common to *Juniperus*; however, *C. arizonica* tends to have lower rays and the end walls of the ray parenchyma cells are not as conspicuously nodular as in *Juniperus*. When heartwood is present, the two genera can be readily separated.

7.5.4.3 *C. lusitanica* differs from *C. arizonica* in that the end walls of the ray cells are not nodular in *C. lusitanica* and indenture is lacking or obscure.

7.5.5 *Fitzroya*. The single species of *Fitzroya* alerce [*F. cupressoides* (Mol.) Johnston] is native to southern Chile. Superficially the wood resembles that of redwood [*Sequoia sempervirens* (D. Don) Endl.] but may be differentiated when split radial faces of the two species are compared. In redwood the rays are two to three times higher than those of alerce. Anatomically, alerce may be separated from redwood by the presence of indenture, the end walls of the ray cells are nodular, cupressoid pitting is present, and the wood rays are usually under 12 cells in height.

7.5.6 *Juniperus*. The heartwood of the various species of *Juniperus* is readily distinguished from all other conifers by its distinctive odor that is generally classified as "cedar-chest" or "pencil" odor. On the basis of heartwood color, two groups may be differentiated: (a) those with a deep-red or purplish-red color as in eastern redcedar (J. *virginiana* L.), southern redcedar [*J. silicicola* (Small) Bailey], and Rocky Mountain juniper (*J. scopulorum* Sarg.) and (b) those with a brownish-colored heartwood that includes all of the western species except *J. scopulorum*. Anatomically, *Juniperus* may be distinguished from other woods with a highly colored and aromatic heartwood by its abundant vertical parenchyma with nodular transverse walls, ray parenchyma with abundantly nodular end walls, indenture, dark-colored ray cell contents, and intercellular spaces between the vertical tracheids.

7.5.7 *Larix*. Three species of *Larix* occur in the United States and Canada: Tamarack or Larch [*L. laricina* (Du Roi) K. Koch] of the northeastern United States and from southeastern Canada to the Yukon; western larch (*L. occidentalis* Nutt.) of the northwestern United States and southeastern British Columbia; and subalpine larch (*L. lyallii* Parl.), which is a high-elevation species having the same range as *L. occidentalis* but not of commercial importance. On the basis of anatomical structure, *Larix* is readily separated from other genera that have resin canals with thick-walled epithelium cells. This separation is made on the basis of the abrupt transition from earlywood to latewood and the bordered pitting of the vertical tracheids, which is frequently biseriate. Western larch may be separated from tamarack using the following combination of features: Heartwood of *L. occidentalis* is russet brown, whereas in *L. laricina* it is a yellowish brown; latewood is generally wider and more pronounced in *L. laricina* than in *L. occidentalis;* growth rings are generally more uniform in *L. occidentalis* than in *L. laricina,* and bordered pitting is more commonly biseriate in *L. occidentalis* than in *L. laricina*. The locality of growth affords a very reliable means of separation of these two species.

7.5.8 *Libocedrus*. The single American species of *Libocedrus* incense-cedar (*L. decurrens* Torr.), occurs from western Oregon to southern California. The heartwood is reddish brown to dull brown and sometimes has a purplish cast. The odor of the heartwood is distinctly aromatic and rather similar to that of western redcedar (*Thuja plicata* Donn). Anatomically, it may be distinguished from other genera that have nodular thickenings on both the end walls of the ray cells and the transverse walls of the vertical parenchyma since *Libocedrus* lacks indenture which is present in the other genera.

7.5.9 *Picea*

7.5.9.1 Seven species of *Picea* occur in the United States and Canada, although only five are of commercial importance. The most important species are white spruce [*P. glauca* (Moench) Voss] and black spruce [*P. mariana* (Mill.) B.S.P.], which range from the northeastern United States across Canada to Alaska; red spruce (*Picea rubens* Sarg.) which ranges from the Middle Atlantic States to Nova Scotia; Engelmann spruce (*P. engelmanii* Parry) of the Rocky Mountain region; and Sitka spruce [*P. sitchensis* (Bong.) Carr.], which ranges from southern Alaska to northeastern California. Brewer spruce (*P. breweriana* S. Wats.) of southwestern Oregon and northern California and blue spruce (*P. pungans* Engelm.) of the Rocky Mountain region do not enter commercial markets.

7.5.9.2 The heartwood of *P. sitchensis* is pinkish in color and is sharply demarcated from the white sapwood. The heartwood of the other species is light colored and there is not difference between heartwood and sapwood. Anatomically *P. sitchensis* can be separated from the other species on the basis of the abundant yellowish-brown deposits in the ray cells and the frequent occurrence of biseriate bordered pitting of the vertical tracheids. The other species only show occasional pale yellowish-colored deposits and the tracheid pitting is uniseriate. *P. sitchensis* occasionally has crystals in the ray cells, which is a further aid in separating this wood from the other spruces. Split tangential faces of *P. sitchenis* commonly show dimpled grain. Separation of the other species is not practical except in some instances where the geographical source is known.

7.5.9.3 Anatomically, *Larix* and *Picea* are very similar; however, separation may be accomplished by the abrupt transition from earlywood to latewood in *Larix* and gradual in *Picea*, and by the presence of minute denticulations on the walls of the ray tracheids in *Picea* but rare in *Larix*.

7.5.10 *Pinus*. The members of the genus *Pinus* have readily separated thin-walled epithelium cells. Specific identification is generally not possible; however, the genus can be subdivided into five groups on the basis of the ray tracheids and the type of cross-field pitting.

7.5.10.1 *Ray tracheids nondentate; cross-field pitting 1-2 large, simple, or nearly so* (Fig. 7a and b).

Eastern white pine (*P. strobs* L.).

Western white pine (*P. monticola* Dougl.).

Included here are the stone pines of small economic importance which are: whitebark pine (*P. albicaulis* Engelm.) and limber pine (*P. flexlis* James.).

7.5.10.2 *Ray tracheids nondentate; cross-field pitting 2-4 ovoid* (Fig. 7b).

Sugar pine (*P. lambertiana* Dougl.).

7.5.10.3 *Ray tracheids nondentate; cross-field pitting piceoid* (Fib. 7d).

Species of little importance and comprising two groups: bristlecone pine (*P. aristata* Engelm.) and foxtail pine (*P. balfouriana* Grev. & Balf.).

Pinyon pines: Mexican pinyon (*P. cembroides* Zucc.); pinyon (*P. edulis* Engelm.); singleleaf pinyon (*P. monophylla* Torr. & Frem.); and Parry pinyon (*P. quadrifolia* Parl.).

7.5.10.4 *Ray tracheids dentate to reticulate; cross-field pitting 1-2 large, simple, or nearly so* (Fig. 7a).

Red pine (*P. resinosa* Ait.) and the European Scotch pine (*P. sylvestris* L.).

7.5.10.5 *Ray tracheids dentate to reticulate; cross-field pitting 1-6 pinoid* (Fig. 7b).

Western species, principally ponderosa pine (*P. ponderosa Laws*.), Jeffrey pine (*P. jeffreyi* Grev. & Blaf.), and lodgepole pine (*P. contorta* Dougl.)

Eastern and southern species, principally jack pine (*P. banksiana* Lamb.); slash pine (*P. elliottii* Engelm.); longleaf pine (*P. palustris* Mill.); shortleaf pine (*P. echinata* Mill.) and loblolly pine (*P. taeda* L.).

In this group characterized by 1-6 pinoid pitting, separation of the eastern and western species may generally be

made by the more prominent latewood found in the eastern species and particularly in the more important southern species. *P. elliottii* and *P. palustris* frequently show multiple latewood bands within individual growth rings which aids in separating these two species from all the others. *P. palustris* can also be separated from the other eastern and southern species when pith is present in the specimen. In this species the pith is commonly 5 mm (0.2 in.) in diameter while in the other species it is 2.5 mm (0.1 in.) in diameter or smaller.

Dimpled grain is distinctive of *P. contorta* and occurs rather frequently in *P. ponderosa*. In the latter species, however, the dimples are larger and fewer per unit than those of *P. contorta.*

7.5.11 *Pseudotsuga*

7.5.11.1 The Douglas fir of commerce is the product of *Pseudotsuga menziesii* (Mirb.) Franco, occurring from southwestern British Columbia southward through California, and *P. menziesii* var. *glauca* (Beissn.) Franco, which is native to the Rocky Mountain region.

7.5.11.2 Another species, bigcone Douglas fir [*P. macrocarpa* (Vasey) Mayr] is limited to the mountains of southern California and is not commercially important.

7.5.11.3 Generally, *Pseudotsuga* can be distinguished from all other native conifers by the combination of resin canals present and the occurrence of spiral thickenings of the vertical tracheids. Pacific yew (*T. brevifolia Nutt*.) also has spiral thickening (7.5.14) but lacks the resin canals of Douglas fir.

7.5.11.4 The heartwood of Douglas fir is reddish or pinkish and occasionally may have a russet-brown color. The odor of the heartwood is highly distinctive for this species but difficult to describe.

7.5.12 *Sequoia*

7.5.12.1 One species of *Sequoia*, redwood [*S. sempervirens* (D. Don) Engl], is of commercial importance. The other species, giant sequoia [*S. gigantea* (Lindl.) Decne.], occurs in protected groves. Both species are native to California.

7.5.12.2 The light red to deep reddish-brown heartwood readily separates redwood from other conifers with colored heartwood. The wood is without odor.

7.5.12.3 Anatomically, it is identified by its biseriate or triseriate bordered pitting, end walls of ray cells without nodular thickenings, taxodioid cross-field pitting, and relatively inconspicuous nodular thickenings on the transverse walls of the vertical parenchyma. Anatomically, it is very similar to *Taxodium* which differs from *Sequoia* in that the transverse walls of the vertical parenchyma are conspicuously nodular (see *Fitzroya* for difference between that genus and *Sequoia*).

7.5.13 *Taxodium*

7.5.13.1 Baldcypress [*Taxodium distichum* (L.) Rich.] and the variety *nutans* (Ait.) Sweet supply the cypress of commerce. *T. distichum* occurs in the coastal plain from southern Delaware to southeastern Texas and in the Mississippi River valley as far north as Missouri and southern Illinois. The variety *nutans* occurs in the coastal plain from southeastern Virginia to southeastern Louisiana.

7.5.13.2 The heartwood of *Taxodium* is quite variable in color and ranges from yellowish to dark brown, reddish brown, or almost black. The heartwood is further characterized by its greasy or oily feel and often by a rancid odor.

7.5.13.3 Anatomically it is very similar to *Sequoia* but has more conspicuous nodular thickenings on the transverse walls of the vertical parenchyma. The cross-field pitting of *Taxodium* may be taxodioid or cupressoid.

7.5.14 *Taxus*. Two species of *Taxus*, Florida yew (*T. floridana* Nutt.) and Pacific yew (*T. brevifolia* Nutt.), are native to the continental United States; however, only the Pacific yew enters the market. *T. floridana* is rare and local in Gadsden and Liberty Counties of northwestern Florida. *T. brevifolia* occurs from southeastern Alaska to northern California and in the northern Rocky Mountain region. The heartwood ranges in color from bright orange to russet brown and is without odor. Anatomically it can be separated from all other American conifers except *Torreya* by its spiral thickenings in the vertical tracheids and lack of resin canals. In *Taxus* the cross-field pits are 8 to 10 µm in diameter while in *Torreya* they are about 6 µm in diameter (see *Torreya*).

7.5.15 *Thuja*

7.5.15.1 Two species of *Thuja* occur in the United States and Canada. Northern white-cedar (*T. occidentalis* L.) is found in southeastern Canada and northeastern United States to the Lake States region, while Western red cedar (*T. plicata* Donn) ranges from southeastern Alaska to northwestern California and also in the northern Rocky Mountain region.

7.5.15.2 The heartwood of *T. occidentalis* is a pale brown with a faint but characteristic cedary odor; the heartwood of *T. plicata* is reddish or pinkish brown to dull brown with a much stronger and spicy aromatic odor.

7.5.15.3 Anatomically the genus is defined by taxodioid cross-field pitting, end walls or ray cells smooth, indentures distinct, transverse walls of vertical parenchyma nodular. *T. occidentalis* may be separated anatomically from *T. plicata* by the more frequent biseriate bordered pitting and the more abundant parenchyma of *T. plicata.* The end walls of the ray cells may occasionally show nodular thickenings, particularly near the growth ring boundaries. In *T. occidentalis* the ray cell contents appear reticulate and tend to obscure the end walls, while in *T. plicata* the contents of the ray cells are more uniformly distributed and do not obscure the end walls.

7.5.16 *Torreya*

7.5.16.1 The genus *Torreya* consists of two rather rare species: Florida torreya (*T. taxifolia* Arn.) of southwestern Georgia and northwestern Florida and California torreya (*T. california* Torr.) of central California.

7.5.16.2 The heartwood is a clear yellow color and has a rather distinctive and somewhat unpleasant odor.

7.5.16.3 Anatomically *Torreya* is very similar to *Taxus*; however, it may be separated from *Taxus* by the paired appearance of the spiral thickenings, and the smaller (about 6 µm) size of the cross-field pits.

7.5.17 *Tsuga*. The genus *Tsuga* consists of four species: western hemlock [*T. heterophylla* (Raf.) Sarg.] and mountain hemlock [*T. mertensiana* (Bong.) Carr.] of the northwestern United States and southwestern Canada, and eastern hemlock [T. *canadensis* (L.) Carr.] and Carolina hemlock (*T. caroliniana* Engelm.) of the eastern region. *T. canadensis* occurs in the Lake States, northeastern United States, and southeastern Canada, and *T. caroliniana* is of limited occurrence in the Central Appalachians. The woods of this genus show no difference between sapwood and heartwood and bear a close resemblance to the wood of the western *Abies* with which they are frequently confused. Anatomically they are readily separated from the *Abies* by the ray tracheids which are always present in *Tsuga* and rarely present in *Abies*. The eastern species may be separated from the western species by the more abrupt transition from earlywood to latewood and the frequent biseriate bordered pitting that occurs in the former species. The western *Tsuga* may be separated from the western *Abies* by its more uniform and somewhat purplish color as seen on smooth cut end-grain surfaces and finer texture as seen with a hand lens. In the *Abies* species the color change from earlywood to latewood is more abrupt and the latewood generally is light brown. The texture of the western *Abies* is distinctly coarser than that of *Tsuga heterophylla*.

8. Report

Report the species of coniferous wood as determined.

9. Precision

9.1 The identification of wood from conifers is generally regarded as being more difficult than for the hardwood species. Conifers are more elemental in their structure, and, as a consequence, the number of diagnostic features that may be employed is proportionately smaller.

9.2 Procedures used in this method are based mainly on features visible with a microscope and are intended primarily for wood technologists who have access to an authenticated collection of wood specimens. These microscopic features are necessarily emphasized because of the greater accuracy obtainable through their usage.

9.3 A precision statement is not applicable for this qualitative procedure.

10. Keywords

Wood, Fiber, Identification, Softwoods, Microscopy

11. Additional information

11.1 Effective date of issue: To be determined.

11.2 This procedure, using an identification chart and marginally perforated cards, has been developed so far only for the coniferous species. Until a method for the hardwood species becomes available, a dichotomous type key for these woods, such as that published (*3*), is recommended.

11.3 This procedure was reclassified as a Standard Practice in 1997.

11.4 The principal changes made in the 2011 revision are editorial and updates to some of the figures.

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Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■