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Working Paper

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The Implications for North American Exporters of Softwood Lumber Stress Grading in Europe with Particular Emphasis on British Stress Grades and the Economic Commission for Europe (ECE) Stress Grades

1984

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9 May 1984

Submitted to

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PREFACE

The information contained in this report relied principally on a search of available literature in the University of Washington Library system, reports sent in response to our letters to various European testing and research organizations, and conversations with representatives of the American Plywood Association and Western Wood Products Association. Consequently, our interpretation regarding historical background and current status of lumber grading practices in Europe may be limited by not having the opportunity to observe practices first hand or to converse with firms heavily involved in European trade. We do believe, however, that the information contained in this report is a fairly accurate description of major events and combined with the grade cross-reference will be useful to North American producers.

EXECUTIVE SUMMARY

Purpose of Study

This report presents the results of an investigation into softwood lumber grading systems used in Europe with an emphasis on systems used, or proposed, for international trade transactions. The report also presents comparisons and approximate cross-references of these systems with North American grades. This involves the use of previously published comparisons as well as new material developed during the course of this study. The study also briefly examines the nature of the European softwood lumber market and its future prospects. The information presented in this study represents a step in the direction of improving the North American manufacturer's understanding of Europe.

The Housing Markets in Europe

Traditionally, most housing construction in Europe has relied on nonwood materials. Through the 1960's, timber frame construction probably accounted for less than 5-10% of the housing market. Since that time timber frame construction has been heavily promoted with the greatest success in the United Kingdom where it presently accounts for 30% of housing starts. In some other countries this wood system has risen to 10-15%. Analysts expect the overall housing market to grow slowly if at all. The current rate of housing starts is more than 25% below the record peak levels of the early 70's of about 4 million and is expected to remain at this level. Thus, the major opportunity will be due to substitution of wood for nonwood methods rather than due to growth of the overall market.

Other Softwood Markets in Europe

The traditional use of softwood lumber in Europe has been for joinery, moulding and similar products that could be classified as being primarily decorative and, hence, a great deal of emphasis has been placed on appearance. Most softwood lumber transactions between European countries use an appearance-oriented grading system that originated in Scandinavia. This nonstructural market represents another opportunity for North American producers who are willing to learn the grading system and the mechanisms of trade that have evolved.

European Self-Sufficiency in Wood Products

Although a simple tally of import-export statistics would indicate that Europe is highly dependent on external supplies, this conclusion is misleading. A more appropriate point of view is to segregate trade between European countries from trade with non-European sources. When this is done, it is apparent that Europe is about 83% self-sufficient, a state that it probably can maintain if the predicted slow rates of economic growth prove correct. North America supplies about 44% of the deficit and should be able to increase this share as supplies from tropical sources are expected to diminish, and supplies from the USSR are expected to only increase slightly in absolute terms and decrease in relative terms.

Appearance Grading of Softwood Lumber

The major trade between European countries is based on a Scandinavian system of six grades; the top four grades are normally grouped and termed 'unsorted' and the others are termed 'fifths' and 'sixths.' The system in the USSR is similar except that their top three grades correspond to 'unsorted,' their fourth grade corresponds to 'fifths' and their fifth grade corresponds to 'sixths'. In general, these grades all have very strict wane and knot size limitations compared with North America. Appendix I presents the detailed requirements for a piece of lumber to make 'fourths' or better and to make 'fifths.' Table 6 of this report presents our cross-reference of these Scandinavian grades with the WWPA and Export R-list grades. This is based on studies by WWPA, the British Intelligence Services, and our own conclusions.

The Scandinavian system has been criticized since it lacks requirements for slope of grain, rate of growth, moisture content, manufacturing tolerances and standards for degree of manufacture. These factors have been taken into account in two ways. First, slower growth rates and smaller knots occur in more northerly timber growing regions of Europe, so shipping port has been used as an indicator of overall quality that is superimposed on the grade system. Furthermore, firms have evolved a proprietary system for taking into account the omissions of the Scandinavian system, albeit with some discrepancies in interpretation.

Generally, lumber is sold at an 18-19% MC (shipping dry) in the rough condition with an implied tolerance of -0, +2 mm for thickness and width. Growth rates for 'unsorted' must be 10-15 rings per inch or slower while 'fifths' and 'sixths' accept faster-grown timber. Much of the 'fifths' and 'sixths' lumber is used for house framing and general construction, but the omissions noted above and the lack of stress data limit rational engineered use.

United Kingdom Stress Grading of Softwood Lumber

Research and development of visual stress grading of softwood lumber in Europe seems to have been concentrated in the United Kingdom which has been involved in this work since the 1930's. Presently, a piece of structural timber found in the United Kingdom could have been graded under any of four systems.

1. The North American system for Structural Joists and Planks, Light Framing and Stud has been adopted with design values converted to metric units so imported North American lumber can be used directly.
2. British Standard Code of Practice 112 provides for four structural grades, named according to their green bending strength ratios as 75, 65, 50 and 40. These can be used for domestic or imported lumber. However, the system for knot impact evaluation is fairly complex (Tables 8-9). BSCP 112 also contain basic design data for stress grades under all of these systems.
3. British Standard Code of Practice 4978 provides for a simpler two grade system that uses a 'knot area ratio' method to simplify knot assessment. These grades are expected to eventually replace the four grade system. Table 10 summarizes the provisions of this system.
4. Machine stress grades were also developed in BSCP 4978 and incorporated into BSCP 112. M75 and M50 correspond in bending ratio to the visual 75 and 50 grades and MSS and MGS correspond to the SS and GS grades. After machine testing pieces must pass all of the visual requirement for fissures, wane, etc. in Table 8.

ECE Stress Grading of Softwood Lumber

The Economic Commission for Europe began a process in the early 1970's to develop a standardized system of visual and machine stress grades for all of Europe. The initial proposal was essentially an adoption of the BSCP 4978 (see Table 11). The British SS and GS grades were re-labeled EC1 and EC2. The only significant changes were different KAR limitations for EC1 and a slightly different rate of growth limitation. This ECE proposal was revised in 1982 and now includes three grades (Table 13); S6 corresponds to the original EC2 (or British GS) while EC1 was divided into S8 which corresponds to the British SS and S10 which is a new grade with strict limitations designed for highly engineered products. The other major change is the use of 2 meters of length rather than 3 meters in measuring distortions.

Cross-Referencing the British and ECE KAR Visual Stress Grades with North American Grades

Since the KAR method specifies the same constant percentage limits regardless of piece cross section, it differs significantly from North America where limiting grade knot sizes do not translate into constant fractions of cross section. Furthermore, the division of the cross section into the center half and margin quarters differs from North America. To examine the nature of these differences, we conducted a brief simulation study where we generated representative borderline pieces corresponding to North American grades and re-graded them using the KAR approach. This allowed us to establish equivalent KAR limitations implied by the North American grades. Table 15 presents a summary of the degree of common overlap between these systems. These data should be treated with caution since differences other than knot assessment are not included, plus we made some simplifying assumptions in simulating the North American grades. The details of the simulation are presented in Appendix V.

Section I

Introduction

Traditionally, housing construction in Europe has relied on masonry and other nonwood materials. The principal wood use has been for joinery, mill work, furniture, etc. Consequently, markets and lumber grades are primarily oriented toward appearance.

Timber-framed housing has received great publicity but has caught on only in the UK where it increased from 9% to 18% of new dwellings between 1968 and 1975 (Table 1) and currently is estimated to be about 30% (2). Elsewhere in Europe, this type of construction appears to have a small share of dwelling construction; 15% in Belgium and Luxembourg and 10% in West Germany (2). It is probably even lower elsewhere. Promotion of timber-framed housing in Europe claims several advantages over traditional stone and masonry construction including substantial savings in heating and cooling costs due to the better insulating properties of wood, faster erection time and lower construction cost (4) and the opportunity for factory pre-fabrication which is commonly done in the UK (5).

North American exporters face two potential softwood lumber markets in Europe; the traditional market with its appearance orientation and the developing timber frame housing market with a need for visual or machine stress graded lumber. Although the timber frame house accommodates sizes and grades produced by North American mills, there is a question as to how this market will develop in Europe and a question regarding the development of stress grading systems in Europe. Further, there is a question as to how North American softwood grades relate to European

Table 1. UK new dwellings and softwood usage by type of construction, 1968 and 1975.

	New Dwellings				Softwood Usage			
	1968		1975		1968		1975	
Type of construction	'000 units	%	'000 units	%	volume (m^3)	%	volume (m^3)	%
Traditional	228	68	205	58	2,100,000	76	1,231,000	57
Timber framed	40	9	65	18	328,000	12	645,000	30
Industrialized low rise	44	10	60	17	161,000	6	212,000	10
Industrialized high rise	54	13	25	7	176,000	6	74,000	5
	426	100	355	100	2,765,000	100	2,162,000	100

Source (7)

trade practices for appearance lumber. Before investigating the grade relationships in subsequent sections, this section will briefly examine the trends in European dwelling construction and examine Europe's degree of self-sufficiency in wood products as these factors affect the development of both softwood markets.

Dwelling construction in Europe peaked in 1973 at greater than 4 million units culminating a period of high economic growth that began after WWII. Since 1973 economic growth has slowed and in the early 1980's, dwelling construction was about 27% below the peak (3). Analysts do not expect much growth in housing (3,4); they believe that construction has caught up with the post WWII backlog and that new construction will remain below that of the 60's and early 70's. However, there are many substandard buildings so there will be demand for renovation, maintenance, and replacement. Changes in demographic factors and increased costs suggest a demand for different types of living quarters and smaller units than in the past (3). It has also been forecast that less sawnwood will be consumed per unit as machine stress rated lumber and smaller dimensions are used and as wood panels and nonwood materials are substituted for lumber (4).

Although detailed statistical reports for various countries are difficult to find, Tables 1-2 show 1968 and 1975 data for the UK on types of dwellings constructed, softwood usage by dwelling type, and detailed usage of various wood products per unit of dwelling type. Figure 1 puts the UK construction industry described in these tables into perspective with respect to other uses for sawn softwood. Other European countries may differ significantly in some respects from this perspective.

Table 2. UK softwood usage by end use applications in new dwellings, 1968-1975.

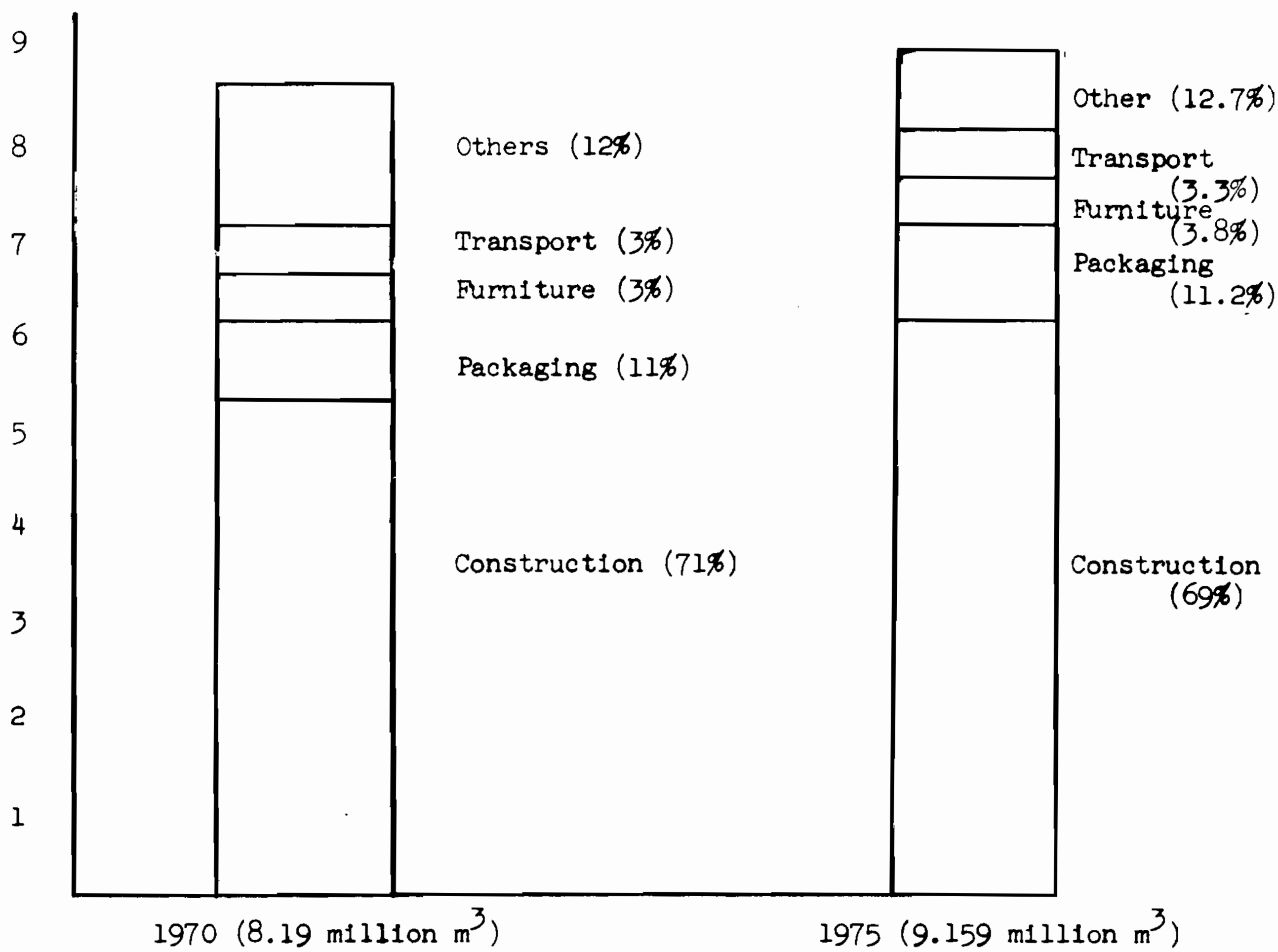
	Type of Construction							
					Industrialized			
	Traditional		Timber framed		Low rise		High rise	
	1968 m^3	1975 m^3	1968 m^3	1975 m^3	1968 m^3	1975 m^3	1968 m^3	1975 m^3
Roof	1.67	1.76	1.75	1.76	0.57	0.56	0.22	0.23
Joists	0.99	0.91	1.30	1.19	--	--	--	--
Joinery	2.32	2.21	2.32	2.21	1.09	2.10	1.98	1.87
Walls and load bearing structures	0.57	0.28	2.83	2.55	--	--	--	--
Cladding and boarding	0.85	0.28	0.62	0.62	0.08	0.08	0.06	--
Partitions	0.14	--	1.42	1.13	0.28	0.23	0.28	0.23
Shuttering wastage, site usage and misc. exterior work	0.62	0.51	0.57	0.45	0.65	0.57	0.71	0.62
Total	7.16	5.95	10.81	9.91	3.67	3.54	3.25	2.95

Source (7)

Conclusions regarding European trade opportunities depend greatly on the context in which Europe is viewed. One view is to tally the import and export statistics for the 24 European countries. If this is done using 1980 statistics as an example, Europe accounts for $24.6 billion (US) or 44% of the world's $55.6 billion of forest products exports and $31.9 billion (52%) of the world's $61.6 billion of forest products imports. The distribution of Europe's share by product category is as follows (3):

	Import %	Export %
roundwood	10.6	5.8
sawnwood	25.9	20.6
panels	10.8	10.5
pulp	17.6	13.5
paper & paperboard	35.1	49.6
	100.0	100.0

Figure 1 UK major end use industries for sawn softwood 1970 & 1975.



Source (7)

These figures can be misleading since they include the large intraregional trade among the 24 European countries. If Europe is viewed more broadly, and trade within Europe is segregated from trade with non-European regions, a different picture emerges as Table 3 illustrates for sawnwood.

Quite plainly, most of the European trade in sawn softwood is between European nations; exports to non-European sources ranged from 8-16% while imports from non-European sources ranged from 20-24%. North America comprises between 1 and 2% of all imports and 4.3-7.7% of non-European imports. Clearly, non-European nations have not captured a large portion of the sawn softwood market.

One reason for this is that in spite of dense population, and fairly high per capita consumption, Europe is presently about 83% self-sufficient in forest products as shown in the following breakdown of consumption (3).

	% of Equivalent Roundwood Volume
Removals from European forests	71
Transfer of industrial residues	10
Recycling of waste paper	8
Total domestic supply	89
Exports outside Europe	(6)
Net domestic supply (self-sufficiency)	83
Imports from outside Europe	17
Total supply	100

Table 3. European trade in sawnwood.

	Exports						Imports								
	Total			To Non-European Destinations			Total			From Non-European Sources			From North America		
	1970	1974	1980	1970	1974	1980	1970	1974	1980	1970	1974	1980	1970	1974	1980
Total sawnwood, m^3	22057	22319	25618	2821	2240	4105	31469	31901	34658	11708	11483	14321	2856	2890	4583
Softwood sawnwood, m^3	19256	19374	22283	2328	1614	3640	27408	27251	28109	6698	6350	5820	445	273	448

In 1980, about 44% of imports from outside Europe were from North America, and consisted of 50% woodpulp, 21% sawnwood, 18% paper, and paperboard, and the remainder various miscellaneous products. About 31% of imports from outside Europe were from the USSR and another 25% were from the tropics. Imports from the tropics are expected to decline in both relative and absolute terms while imports from the USSR may increase some in absolute terms but will decrease in relative terms (3). This suggests that North America should be able to increase its share of the European market.

Although North America may be able to improve its market share in Europe, the wood market is projected to grow slowly by some analysts (1) or to be in equilibrium (3). Other key features affecting market penetration are tariff and nontariff barriers to trade. Particular nontariff barrier problems in Europe are the diverse building codes and regulations and the diversity of performance specifications and product standards (3). These and the diversity of dimensions and qualities for sawnwood can create difficulties for exporters wishing to sell in several European markets.

The purpose of this study is to examine the grading systems used in European import/export transactions for softwood lumber and more particularly for stress graded softwood lumber.

Section II

The Scandinavian Grading System for Softwood Lumber

A. Origin and Use of the Scandinavian System

In Europe, the standards for softwood lumber grading vary among nations. The relative emphasis of a given standard toward the evaluation of lumber appearance, or lumber strength differentiates the standards currently in use. The variance in the intent and structure of nationally implemented standards in Europe, serve as obstructions to commerce.

The softwood lumber grading system, implemented by producers in many of the major European lumber exporting countries, is based on Swedish Hernosand rules developed in the 19th century, which are primarily appearance oriented. Since many defects which affect appearance also influence strength these rules indirectly evaluate lumber strength. The principal species graded under the Scandinavian system are Scots pine (*Pinus sylvestrus*), and Norway spruce (*Picea abies*). The most northerly grown European softwoods generally exhibit the slowest rates of growth and other desirable end-use characteristics. Therefore, shipping port has traditionally been an indication of quality which is 'superimposed' on the grade supplied. Each shipper, or group of shippers, stamps a 'shipping mark' on each piece of lumber which identifies both the shipper and the grade.

The Scandinavian grading system is comprised of six grades; the first four are normally combined, and designated 'unsorted' and the last two grades are denoted 5th's and 6th's respectively. 'Unsorted' lumber (grades 1-4) is primarily used in joinery and millwork applications such as doors, window parts, mouldings, and profile boards. Some unsorted lumber is also utilized in structural applications where appearance is of concern. Highline 5th grade lumber is occasionally utilized for millwork and joinery, but 5th grade products are generally utilized as carcassing (house framing) or other uses in which appearance is not of utmost importance. Lumber in the 6th grade is considered suitable for general construction uses and may occasionally be used for carcassing.

Table 1 of Appendix I highlights the dimensions and principal applications of lumber involved in European transactions. In Europe, lumber is shipped primarily in 30 cm (11.8") length increments starting at 1.8 m (5'11"). Many standard North American lengths are only slightly longer than European lengths. The most common cross-sectional dimensions produced are thicknesses of 50 mm and 75 mm and widths of 100 through 200 mm. Many of these dimensions are similar to those in North America but are expected to be full size.

Table 2 of Appendix I lists the provisions for grade 4, the 'unsorted' grade boundary, and 5th's. In general, the thickness and width of a piece of lumber determines the magnitude and number of defect characteristics permitted in a specific grade. Some defect allowances are expressed per unit (1.5 m) of piece length while others are limited in terms of the whole length. A piece having a characteristic that slightly exceeds grade limitations will remain in the higher grade provided that the piece is 'highline' in that grade in other aspects. Grades are determined from the better face and both edges of the piece. The 'unsorted' grade provisions are implemented with heavy emphasis on edge characteristics as grade-determining factors.

1. Knots

In general, the growth characteristics of European softwoods are such that large knots are nonexistant, and the grades generally do not accept large knots. Consequently, knot diameter limitations in a Scandinavian grade are smaller than those found in similar North American grades.

For any specific combination of thickness and width, there is a specified maximum diameter restriction for sound (red) knots on the better face. The size limitations for dead (black), bark-ringed, and unsound knots are specified as percentages of the sound knot size. Each knot type has its own quantity restriction per 1.5 m length of the piece. The number of sound knots permitted decreases in proportion to the presence of other knot types. Edge restrictions for sound knots are similarly limited with respect to diameter and number, contingent on the thickness the piece. Edge restrictions for dead, bark-ringed, and unsound knots are listed as percentages of the sound edge knot size. Knot holes are not permitted in 5ths or better grades.

2. Wane

Wane allowances for the Scandinavian grades are segregated into edge and face restrictions. Edge wane is expressed as a fraction of the thickness; 30% for fourths and 50% for fifths. Face wane is restricted in absolute terms for small sizes and as a fraction of the face width in larger sizes. These fractions are generally the same as the edge wane fractions. Both wane types are restricted to a percentage of the piece length. Two edge wane is restricted by expressing the combined wane lengths, as a percentage of the length of the piece. This percentage is only slightly larger than the limit for one edge wane. The thickness restriction for two edge wane, is slightly more restrictive than specified for one edge wane. These wane allowances are more restrictive than North American allowances for comparable lumber products.

3. Fiber Separations (Fissures)

Shakes are the only fiber separation defects considered specifically in the Scandinavian system. Shakes are assessed as longitudinal or oblique shakes and are restricted in terms of their length, and thickness expressed as percentages of the piece length, and thickness, respectively. Checks and splits are not directly addressed in the Scandinavian grading rules but it is likely that they are evaluated using criteria similar to shake assessment criteria.

4. Other Defects

Many other defects are noted in the Scandinavian rules but are only vaguely described and are often permitted subject to the judgment of the grader. This provides a great deal of latitude for interpretation.

B. Critique of the Scandinavian Grading System

The Scandinavian system has been criticized on the grounds that it does not facilitate rational and economic usage of timber. The grading rules lack efficiency for allocating lumber to specific structural end uses. The lack of documented requirements for slope of grain or rate of growth (specific gravity) requires the prospective purchaser to assume greater responsibility for confirming acceptable grain characteristics with respect to incoming shipments.

The North American and British visual stress grading systems, in contrast to the Scandinavian system, evaluate the impact of strength reducing defects on a given cross-sectional area of piece. The Scandinavian system, prescribes limitations on the number and magnitude of strength reducing defects on a more aggregate basis. The distribution of strength reducing defects relative to areas of maximum service bending stresses in a piece are not addressed in the Scandinavian system. The absence of working stresses for the Scandinavian construction grades (5th's, 6th's) implies an increased element of risk in structural design considerations. Additional omissions from the Scandinavian grading system include a lack of moisture content requirements, manufacturing tolerances, and standards for degree of manufacture.

The absence of an internationally accepted quality assurance program in Europe to support the Scandinavian grading system has resulted in discrepancies in the way exporting entities interpret the grading provisions. The problem further undermines the effectiveness of the Scandinavian system as an international quality standard.

C. Proprietary Extensions of the Scandinavian System

As a result of the difficulties with the Scandinavian system, lumber buyers and sellers have developed proprietary guidelines for evaluating the grain characteristics of lumber shipments which are contingent on the designated end use for the graded lumber products. The proprietary rate of growth specifications for the 'unsorted' lumber grades is 10-15 rings/inch. Lumber in the 5th and 6th's grades is permitted to have fewer than 10 rings per inch. Approximate proprietary values for slope of grain were not discovered during the literature review. However, the product appearance requirements for joinery suggests a grain slope value between 1:12 and 1:20.

The omission of moisture content, manufacturing tolerances and degree of manufacture standards are overcome by widely recognized traditions established through decades of trade and proprietary agreements. In European markets, lumber is sold 'shipping dry' (MC $\leq$19%) and purchasers expect full metric sizes of lumber products. Producers have responded to this expectation by tailoring their manufacturing and drying technology to the characteristics of the raw material, with the objective of minimizing manufacturing tolerances. European shipments of dry lumber are generally within 2 mm of the stated size with an extremely small proportion of scant material. The predominant volume of European lumber is shipped rough dry. A significant number of European sawmills have no planing facilities. Long lengths are found relatively infrequently as there are few European mills designed to handle long logs; consequently, these lengths command premium prices.

D. Qualitative Comparative Analysis Between the Scandinavian and North American Grading Systems

An understanding of Scandinavian grading rule provisions, proprietary extensions, and grade/end-use relationships facilitates comparison with the North American systems. Tables 4-5 present results of studies by the Western Wood Products Association (WWPA) (6) and the British Business Intelligence Services L.T.D. (BIS) (7) to cross-reference the Scandinavian, WWPA (8), and Export R-List (9) grades.

Table 4. WWPA qualitative comparison of the Scandinavian, WWPA (NGR) and export R-List Grades (6).

Sweden	WWPA	R List
1,2,3,4 (unsorted)	D & Btr. Select Upper D Select 1 Common Upper 2 Common Sel. Merch. (Alternative Board)	3 Clear & Btr. Upper 4 Clear Sel. Merch. 1 Merch.
5	3 Common Upper 4 Common Upper Const., Stand. (Alternate Board)	1, 2 Merch.
6	4, 5 Common	3 Common

Table 5. BIS qualitative comparison of the Scandinavian and Export R-List Grades (7).

Approximated Grade Equivalents of Imported Softwoods Showing Percentages of Grades I, II, III, IV in 'Unsorted Quality

	Russian Main Ports (%)	Russian Out-Ports (%)	Finnish/ Swedish Upper Zone (%)	Finnish/ Swedish Lower Zone (%)	Eastern Canada (%)	Western* Canada
Grade I Grade II	10 20	5 15	10 20	5 5	5 5	No. 2 Clear & Better
Grade III Grade IV	40 30	45 35	40 35	40 50	40 50	No. 3 Clear & Select Merchantable
Grade V	Shipped by Finland and Sweden					No. 1 & 2 Merchantable
Grade VI	Shipped by Finland and Sweden (also known as Utskott)					No. 3 Common comparable to Sixths (VI)
Grade V	Shipped by Russia (also known as Utskott) being equivalent to Grade VI from Finland and Sweden					

*Export R List.

A key distinction between the WWPA and Scandinavian systems is the closer correspondence of the WWPA grades to particular end uses. The WWPA rules explicitly address a wider spectrum of softwood species and lumber product applications than the Scandinavian grading system. The Export R list is a set of grading and dressing rules adopted by the West Coast Lumberman's Association and the British Columbia Lumber Manufacturers Association in 1929 and subsequently revised in 1951 and 1971. R list provisions evaluate the quality of lumber derived from Douglas-fir, western hemlock, Sitka spruce, and western redcedar with a greater emphasis on the impact of defects on lumber appearance as opposed to strength. In this respect, R-list grades are similar to the Scandinavian system, but the R list provisions evaluate lumber for a wider spectrum of end uses including construction components, flooring, siding, door stock, ties, and timber. The R-list, also specifies manufacturing tolerances for rough and surfaced lumber thicknesses and widths.

From the qualitative analysis (Table 4), WWPA concluded that the Scandinavian grades are stricter than the North American construction dimension lumber grades (Select-Economy, Construction-Economy) due to the following three factors: (i) the Scandinavian grading system emphasizes product appearance for lumber graded 'unsorted,' (ii) the growth characteristics of most timber entering European markets is such that large knots are not acceptable, and (iii) the strict wane allowances for Scandinavian grades penalize the North American dimension lumber grades in comparative analyses.

The WWPA grades D and Better Select listed in Table 4 are the only grades in the cross-reference which evaluate dimension lumber. The R list grades listed in Table 4 evaluate both dimension and board products.

WWPA noted that some No. 2 and Better dimension lumber would conform to the 5th grade, if it was derived from species which tend to form relatively small knots.

Table 5 presents the BIS comparative analysis between the Export R list and the Scandinavian grades, and provides insight on the quality distribution of shipments from the major European origins. Note the quality discrepancy between Russian Grade V and the Finland/Sweden Grade V. The WWPA study (6) also determined the actual correspondence of Russian Grade V lumber to Grade VI lumber exported by other European countries. Basically, Russian grades 1-3 correspond to unsorted, grade 4 corresponds to 5ths, and grade 5 corresponds to 6ths.

Table 6 consolidates the WWPA and BIS comparisons and incorporates our own qualitative comparisons between the Scandinavian, WWPA, and R-list systems. The additional relationships presented are the result of consideration of the grading provisions, and product end uses for WWPA graded lumber in relation to corresponding products, uses, and grading provisions associated with the Export R-list and Scandinavian grading systems.

Qualitative grade comparisons are an initial step toward direct grade cross-referencing. Subsequent investigations may entail the regrading of a lumber parcel of known domestic grade distribution under the foreign lumber grading system(s) of interest. The high percentages of particular domestic grades which qualify for specific foreign system grades could then be tested for significance by statistical methods. The initial qualitative comparison may help isolate those domestic grades which have the highest probability to cross-reference favorably with particular grades in the foreign system. To avoid the complexity and

Table 6. Consolidated comparison of the Scandinavian, WWPA, and Export R-List Grades.

WWPA	Scandinavian	Export R list
Factory Select No. 1-No. 3 Shop	Grade I	No. 2 Clear & Better
B and Better (1 and 2 Clear) (Supreme-Idaho White Pine)	Grade II	
	Grade III	No. 3 Clear Select Merchantable
C Select D Select Appearance Framing	Grade IV	
Select Structural Construction	Grade V Grade IV (USSR)	No. 1 and 2 Merchantable
No. 1, No. 2, Standard Highline No. 3 Highline Utility	Grade VI Grade V (USSR)	No. 3 Common

logistical problems associated with a direct statistical grade cross-referencing study, a producer might opt for such a qualitative comparison for initial production and marketing purposes. The initial cross-reference may subsequently be refined on the basis of information provided by foreign importers with regard to the ultimate foreign grade breakdown of incoming shipments. Revisions in export parcel qualities in order to target a foreign grade spectrum may involve the substitution of different domestic grades in the parcel mix or modification of certain provisions in the domestic grading rules.

Section III

Development and Standardization of Visual Stress Grading of Softwood Lumber in the United Kingdom

A. Introduction

The standardization of visual stress grading in the United Kingdom, was aided by the activities of the British Forest Products Research Laboratory, usually referred to as the Princes Risborough Laboratory (PRL). PRL is sanctioned by the Department of Industrial and Scientific Research, to develop basic and applied research programs related to wood science and technology, and the extensive data base developed by PRL is a key input to the forest product standardization and specification process. PRL publishes bulletins, records, and special reports which serve the interested public and, in some instances, serve as preliminary updates to specific British standards. Lumber product specifications are expressed in British Standard Codes of Practice (BSCP). The specific standards discussed in this section include BSCP 112 'The Structural Use of Timber,' (10, 11, 14, 15) BSCP 4978 'Timber Grades for Structural Use,' (16) and BSCP 4471 'Dimensions for Softwood Sizes of Sawn and Planed Timber.' (17) The chronological development of British visual stress grading, and the future prospects for its implementation, will be highlighted.

B. Historical Background

In the 1930's, studies by PRL were conducted to derive subdivisions of softwood lumber on the basis of predicted strength. These studies addressed the problem of strength variability within and between species.

The objective was to improve the efficiency of structural lumber applications, while providing for an adequate safety margin.

In 1938, the PRL developed visual stress grading rules which were incorporated in the first version of BSCP 112 (10) These rules were not extensively implemented as mills perceived them as too complex to apply during manufacturing. In addition, the domestic markets for structural framing lumber, had not developed extensively due to the predominance of traditional nonwood-based construction methods. BSCP 112 was revised in 1952 (11) to incorporate results of wartime research in the United Kingdom, Canada, and the United States relating to structural applications of softwood lumber. The essential elements of the 1952 code along with refinements is presented in Forest Products Research Bulletin 47 'Working Stresses for Structural Timbers.' (12)

These stress grading rules were developed by determining suitable strength ratios for various lumber categories, and specifying limitations for various defects so that the required ratios were guaranteed. This is in contrast to the North American approach in which the limitations were specified before the resultant strength ratios were determined. Five grades (Table 7) were developed for the evaluation of softwood lumber; grades I-IV and a Grade I-clear grade. The maximum bending strength ratios implied by grades I and II were 75% and 50% respectively. Grades III and IV were tentative proposals which lacked comprehensive specifications for strength- and nonstrength-related defects and maximum strength ratios. The Grade I-clear grade allows no knots or blue stain and limits the slope of grain to 1 in 20. The resultant strength ratio was estimated to be 90% of the species-dependent basic stress value. Grades I, I clear, and Grade II were not formulated solely for use as

Table 7 Permissible Defects and Characteristics of Different Grades for Home-Grown Softwoods

Defect and Characteristic	Permissible Size of Defect or Characteristic				
	Grade I		Grade II	Grade III	Grade IV
Knots:		Grade I clear to be same as Grade I—except that no knots or blue stain permitted.			
(a) Edge	¼ thickness		½ thickness	¾ thickness	Unspecified
(b) Margin of face	¼ width		¼ width	⅓ width	Unspecified
(c) Centre of face	⅙ width		⅓ width	½ width	Unspecified
	Sound knots only		Sound knots only		
Wane:					
(a) Edge	—		¼ thickness	¼ thickness	½ thickness
(b) Face	—		1/12 width	⅙ width	⅓ width
	—		¼ length	⅓ length	Length unspecified
Slope of grain	1 in 14		1 in 8	Unspecified	Unspecified
Rate of growth	Not less than 8 rings/in.		Not less than 4 rings/in.	Unspecified	Unspecified
Pitch pockets	Not allowed		Unspecified	Unspecified	Unspecified
Checks and splits	Not exceeding 6 in. in length		Exceeding 6 in. long shall not be deeper than ¼ thickness for more than ¼ length	Exceeding 6 in. long shall not be deeper than ¼ thickness for more than ¼ length	Unspecified
Bow	¼ in. in 10 ft		½ in. in 10 ft	1 in. in 10 ft	Unspecified
Spring	¼ in. in 10 ft		¼ in. in 10 ft	½ in. in 10 ft	Unspecified
Twist	3° in 10 ft		6° in 10 ft	6° in 10 ft	Unspecified
Cup	1/16 in. in 6 in.		¼ in. in 6 ft	¼ in. in 6 ft	Unspecified
Blue stain	5 per cent		15 per cent	25 per cent	Unspecified

In addition to the requirements listed in the Table, Grades I and II shall be free from fungal decay and insect attack. A certain amount of fungal decay of the "hard rot" type is permitted in Grades III and IV but "soft rot" is excluded. Loose, dead and decayed knots and knot holes shall not be permitted in Grades I and II.

Source (12)

structural grades, and consequently the permissible magnitudes for certain defects are less than that required to generate the specified strength ratios.

An important difference from the North American method of developing green basic stresses for structural members of a given species is the use of a 1% rather than 5% exclusion limit for clear specimen tests in bending, compression parallel to the grain, and shear parallel to the grain. Otherwise, the method used to adjust for duration of load parallels the method specified in ASTM D-2555 (13).

North American and British rules both recognize three locational knot types; edge knots, knots near the center of the wide face, and knots toward the extremities of the wide face. The both allow larger knots near the center than near the edges. They differ in actual knot assessment procedure in that the British defined the "center" as being the central third of the face and define "margins" as occupying one-fourth of the wide face in contrast to no such subdivisions in North America.Implicit in the British knot size limitations is a recognition of the correlation of the strength ratio of a member and its 'knot ratio' which is the ratio of the diameter of the knot to the width of the face or edge in which it occurs (Figure 2).

Working stresses for home grown softwood, and some imported softwood, and hardwood lumber designated Grade I or Grade II were published in Bulletin 47 (12). The structural sizes covered by BSCP 112:1952 were not specified in Bulletin 47 although the maximum dimensions for knots were listed for nominal widths up to 12 inches.

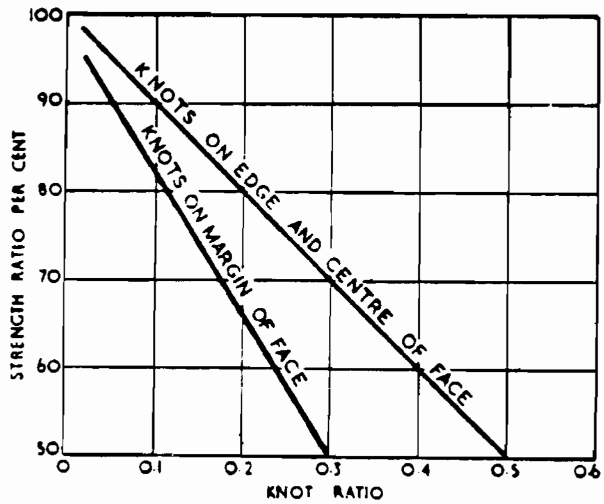


Figure 2 Effect of knot ratio on strength.

Source (12)

The building regulations for England, and Wales for timber-framed housing cited the 1952 version of BSCP 112, and not the subsequent amendments published by Princes Risborough Laboratory. These building regulations included only one 50% (Grade II) strength ratio grade. In addition, the schedule of span tables in the building regulations had clauses which were widely misinterpreted. It was incorrectly assumed that lumber quality selection only involved the selection of lumber from a particular species group and that stress grading was not necessary. This practice was not acceptable to the British authorities.

C. Development of the Current Standards

As a result of this dissatisfaction, a study group was formed to construct a revised set of grading rules with three objectives: (i), take into account the general quality of timber available in the United Kingdom for structural purposes, (ii) specify the minimum quality of lumber for use in structural applications, and (iii) design the rules to overcome industry concerns that not too many pieces would be rejected from a manufactured lot. The refinements were published in three official documents. BSCP 112 was revised in 1967 (14), amended in 1971 (15), and a new standard, BSCP 4978, was published in 1973 (16) as a supplement to BSCP 112:1971.

1. BSCP 112:1967 and 1971

BSCP 112 provides for four visual stress grades. The 1967 and 1971 editions are essentially equivalent, the latter being a presentation of the original in metric units. The 1971 version is now referred to as Part 2 of BSCP 112 while the 1967 version is now referred to as Part 1.

This section is based on the most recent copy of Part 2 uncovered in our literature search (15). It incorporates some amendments through 1976 which include working stress data for the grades developed under BSCP 4978 (16) discussed in the next section.

BSCP 112 provides for four visual stress grades for sawn timber with working bending strength ratios of 75, 65, 50 and 40% of the basic clear wood stresses. These strength ratios, based on 1% exclusion limits, were chosen arbitrarily, but consideration was given to values adopted in other countries, and to the development of adequate manufacturing yields. BSCP 112 has provisions for lumber from North America. Table 1 of Appendix II presents the softwood species groups to which these grades apply. BSCP 112 presents tables of green and dry working stresses for combinations of these species groups and the four grades. The S1 and S3 species groups yield the highest and lowest basic stress values respectively. Species within the same group are assigned the same green bending stress and MOE values based on the weakest species within the group. It is important to note that the strength ratios used as the grade nomenclature are the proportion of the green grade stress value to the green basic stress. If dry basic and working stresses are used as a measure of grade strength ratios the 75, 65, 50 and 40 grades become 70, 60, 46, and 36% percent, respectively. The latter set of strength ratios provides insight on the absolute service performance capability of the grades.

Table 8 highlights the visual grading details of BSCP 112. The distinctive changes from 1952 to 1967 relate to knot impact and fiber separation assessment, as well as the ultimate spectrum of strength ratios provided for.

Table 8. Permissible defect limits for the British 75, 65, 50 and 40 visual stress grades.

Characteristic	Grade 75	Grade 65	Grade 50	Grade 40
Knots	See limitations in table 9			
Slope of grain	1 in 14	1 in 11	1 in 8	1 in 6
Rate of growth, rings/25 mm	8	6	4	4
Fissures: max size as a fraction of thickness	.3	.4	.5	.6
	depth of fissures can be 1½ times these limits on compression members outside the middle half of the depth of the end cross section and at a distance equal to 3 times the depth of the piece			
Wane: max fraction on any edge or face	.1	.1	.2	.2
Distortion	Not specified			
Pitch pockets and inbark	Same limits as for fissures			
Insect damage	Wormholes and pinholes permitted to a slight extent. Active infestations rejected or treated with preservative.			
Other defects	Fungal decay, brittle heart and other abnormal defects affecting strength not permitted			

Source (14)

Table 9 Knot size limitations for the British 75, 65, 50 and 40 visual Stress grades

Width of surface	Beams: Edge, arris and splay knots				Beams: Margin knots				Beams: Face knots, in centre half of depth				Knots on any surface of compression member				Knots on any surface of tension member			
	75 Grade	65 Grade	50 Grade	40 Grade	75 Grade	65 Grade	50 Grade	40 Grade	75 Grade	65 Grade	50 Grade	40 Grade	75 Grade	65 Grade	50 Grade	40 Grade	75 Grade	65 Grade	50 Grade	40 Grade
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
16	4	6	8	11				6	4	7	9	10	4	7	9	10				6
19	5	7	9	13			4	7	5	8	10	11	5	8	10	11			4	4
22	6	8	11	14			5	8	6	9	11	13	6	9	11	13			5	8
25	7	9	13	16			6	9	6	10	13	15	6	10	13	15			6	9
32	8	12	16	20		4	8	11	8	12	16	18	8	12	16	18		4	8	11
36	9	13	18	22		5	9	12	9	13	17	20	9	13	17	20		5	9	12
38	10	14	19	23		6	10	13	10	14	18	21	10	14	18	21		6	10	13
40	10	15	20	24		6	10	14	10	15	19	22	10	15	19	22		6	10	14
44	11	16	22	26	4	8	12	15	11	16	21	24	11	16	21	24	4	8	12	15
50	13	18	25	29	5	9	14	17	13	19	23	27	13	19	23	27	5	9	14	17
63	16	23	31	37	7	12	18	21	16	23	29	33	16	23	29	33	7	12	18	21
75	19	28	37	43	9	16	21	25	19	27	34	39	19	27	34	39	9	16	21	25
100	25	37	50	56	13	20	29	33	25	35	45	51	25	35	45	51	13	20	29	33
125	31	47	63	69	17	25	37	41	32	43	56	64	32	43	56	64	17	25	37	41
150	37	56	75	83	20	30	44	48	38	51	66	74	38	51	66	74	20	30	44	48
175	41	61	82	88	24	34	52	56	44	59	75	84	44	59	75	84	24	34	52	56
200	44	66	87	93	28	39	59	64	50	66	85	94	50	66	85	94	28	39	59	64
225	47	70	92	97	32	44	67	72	55	72	92	101	55	72	92	101	32	44	67	72
250	51	75	97	102	35	48	75	79	60	78	99	108	60	78	99	108	35	48	75	79
300	54	79	107	112	40	59	88	92	69	91	114	122	69	91	114	122	40	59	88	92

NOTE 1. Two or more knots of maximum size are not permitted in the same 300 mm length.
NOTE 2. For members subjected to simple bending on a single span, e.g. floor joists, the knot size quoted may be increased outside the middle third of the span. These may increase proportionally towards the ends to sizes 25 % greater than the quoted values.
NOTE 3. For widths of surface other than these listed, e.g. for processed timber, the maximum size of permissible knots may be obtained by interpolation, rounding up to the nearest millimetre.

Source (14)

The focus of analysis for knot impact assessment in the current BSCP 112 includes edges, margins, and the center half (rather than center third) of the face or depth (Figure 1, Appendix II). Special knot size limitations are specified for lumber destined for tension or compression end uses (Table 9). It was assumed that the exact structural end use application would not be known when a piece was being graded. However, lumber graded initially for bending was considered suitable for compression applications. Regrading under the special knot size restrictions was recommended to evaluate potential candidates for tension stress applications.

Fiber separations are assessed in a manner different from the North American grading rules, and similar to the current Japanese softwood platform framing lumber standard. Rather than specifying distinct limitations for shakes, checks, and splits, the term fissures was defined to encompass these types of fiber separations. The maximum permitted size of the fissures, is expressed as a fraction of the thickness of the piece.

BSCP 112 (15) presents appendix tables in metric units for standard North American (Canadian) species groupings (Douglas-fir/larch, hem/fir, and spruce/pine/fir) and product groups: structural joists and planks (Select Structural, No. 1, No. 2, and No. 3 grades), light framing (Construction, Standard, and Utility grades) and studs (Stud grade). Thus, a designer can readily look up appropriate working values for these North American grades, uses, and species.

Although BSCP 112 developed prior to BSCP 4978, the current edition of BSCP 112 also presents design data for the visual and machine stress grades developed under BSCP 4978. Thus, in effect, there are four current systems of structural grades in Britain (i) the four visual grade system that culminated in BSCP112, (ii) the system of visual grades subsequently developed and described in BSCP 4978, (iii) the system of machine stress grades, and (iv) the adopted portions of North American grades for softwood structural lumber imported primarily from Canada.

2. BSCP 4978:1973--Simplification of Stress Grading

In 1973 BSCP 4978 'Timber Grades for Structural Use' (16) was published in order to simplify visual stress grading by eliminating some of the complexities, particularly knot assessments, of the earlier system. Two visual stress grades, Select Structural (SS) and General Structural (GS), were defined for softwood lumber. British authorities anticipate that the numbered visual grades established in BSCP 112 will be revised to reflect the working stresses of BSCP 4978 grades only.

a. Knot area ratio (KAR)

The knot area ratio concept was formally introduced in BSCP 4978 for the evaluation of sawn softwood. This concept evaluates the displacement of straight grained wood fiber attributable to the presence of knots in lumber. The knot displacement limitations for each grade (SS, GS) are expressed as constant fractions of the <u>total</u> cross-sectional area of the piece and the cross-sectional area of <u>either</u> margin of the cross section. Figures 1-3 of Appendix III present the sectional zones for KAR analysis, knot projection method, and examples. KAR evaluation is applied to the cross-sectional area of the piece most severely impacted by knots exceeding 5 mm diameter. At this worst cross-sectional area, the margin KAR is measured by estimating the cross-sectional fiber displacement ratio for each of the margin cross sections. If more than half of <u>either</u>

margin is displaced then a "margin condition" exists. The presence, or absence of a margin condition in combination with the total KAR of the cross section determines the grade of the piece, provided that other grading criteria are satisfied. Figure 3 presents the decision sequence using KAR for determining grades. Figure 4 presents graphs illustrating the relationship between the grades and examples of the procedure. The KAR method is distinct from the North American method due to the constant fractional displacement limitations, which are applied to any cross section size. The North American knot size limitations yield implied knot displacement fractions, which are not constant over various cross sectional sizes of particular grades.

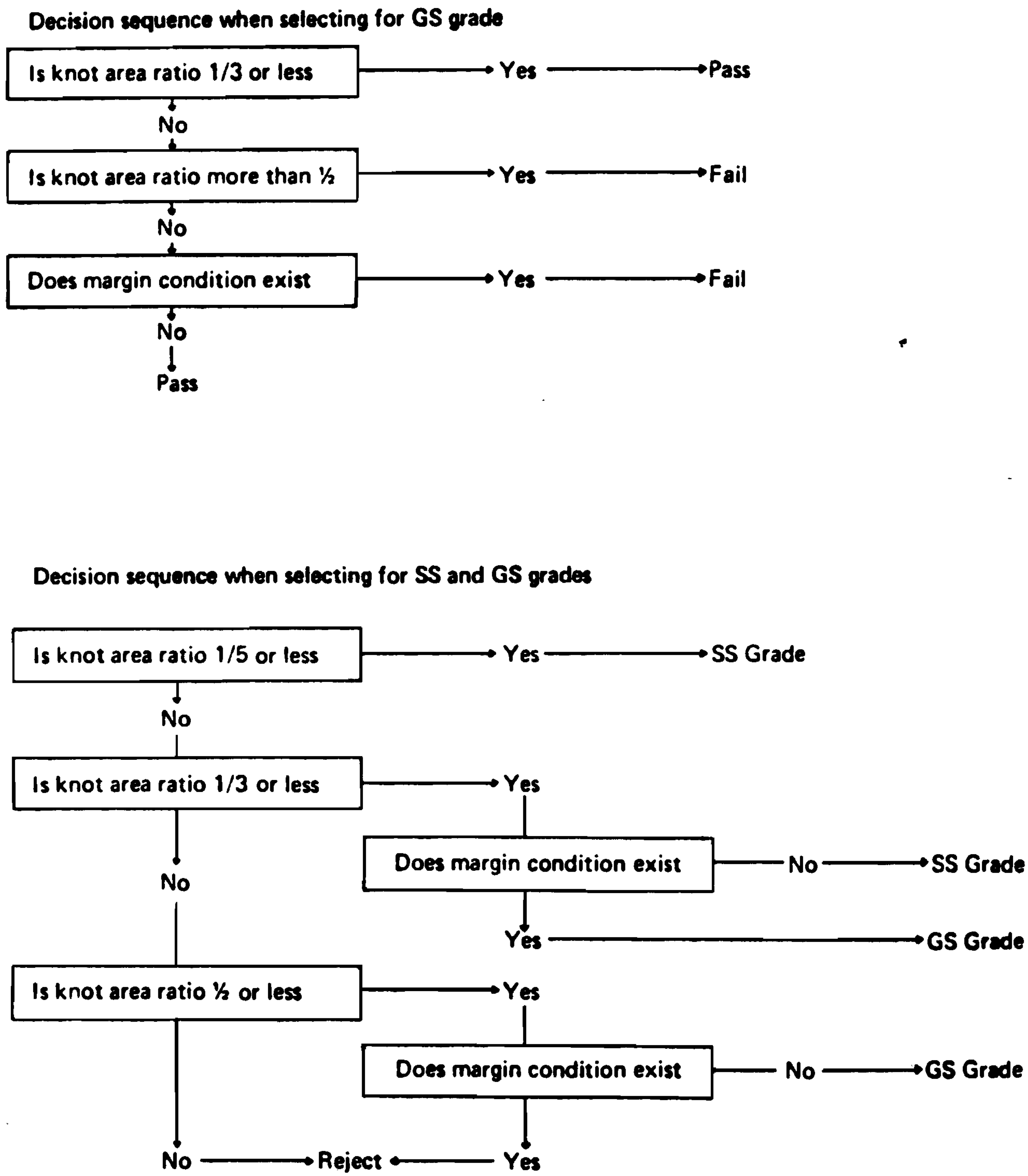
b. Other defect provisions

Table 10 highlights the provisions for other strength and non-strength impacting defects which must also be considered in determination of the SS and GS grades. Figures 4-5 of Appendix III illustrate measurement procedures for fissures and wane.

c. Bending strength ratios

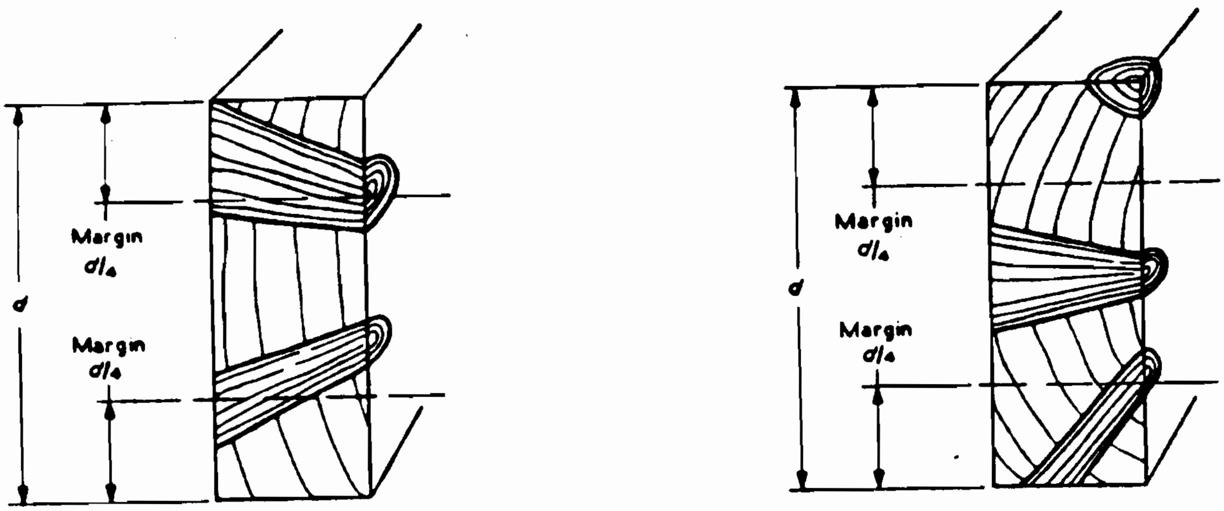
The effective bending strength ratios implied by the strength-impacting defect levels permitted in SS and GS, are 50% and 35%, on a dry (18% MC) basis. Table 1 of Appendix III presents the green, and dry stresses for SS and GS. It should be noted that these new grades apply to the same species groupings previously defined in BSCP 112.

Figure 3 KAR decision sequence for determining SS and GS visual stress grades.



Source (16)

Figure 4 Examples of KAR grading



Since more than one half of a margin area is occupied by knots, the knot area ratio must not exceed:

1/3 for GS grade
1/5 for SS grade

Since less than one half of a margin area is occupied by knots, the knot area ratio must not exceed:

1/2 for GS grade
1/3 for SS grade

Longitudinal separation. Where two or more knots, or groups of knots, both with knot area ratios exceeding 90% of the permissible ratio, are separated in a lengthwise direction by a distance of less than half the width of the piece, the piece shall not qualify for the grade.

Source (16)

Table 10. Permissible limits for the BSCP 4978 SS and GS visual stress grades.

Characteristic	Grade SS		Grade GS	
Knots				
Margin KAR	≤1/2	>1/2	<1/2	>1/2
Total KAR	≤1/3	≤1/5	≤1/2	≤1/3
Slope of grain	1 in 10		1 in 6	
Rate of growth	not less than 4 rings/25 mm (6¼ mm ring width)			
Fissures:				
Not more than half the thickness	unlimited		unlimited	
More than half but less than the full thickness	Not more than ¼ of the length but 600 mm maximum		Not more than ¼ of the length but 900 mm maximum	
Equal to the thickness	Only permitted at the ends with a length of not more than the width of the piece		Not more than 600 mm and if at the ends with a length of not more than 1½ times the width of the piece	
Wane:	1/4 of the thickness by 1/4 of the width, full length		1/3 of the thickness by 1/3 of the width, full length and in addition ½ permitted in a 300 mm length not nearer the ends than 300 mm	
Distortion:				
Bow	Should not generally exceed 20 mm in any 3 m length			
Spring	Should not generally exceed 15 mm in any 3 m length			
Cup	Should not generally exceed 1 mm per 25 mm of width			
Twist	Should not generally exceed 1 mm per 25 mm of width in any 3 m length			
Pitch pockets and inbark	Same limits as for fissures			
Insect damage	Wormholes and pinholes permitted to a slight extent in a few pieces No active infestation is permitted Wood warp holes not permitted			

Table 10., cont'd.

Characteristic	Grade	
	SS	GS
Sapstain	Permitted to a limited extent	
Abnormal defects	Fungal decay, brittleheart and other abnormal defects affecting strength not permitted	

Source: adapted from (16)

d. Machine stress grades

Machine stress grades M75 and M50 for structural softwood, were defined in BSCP 4978 to provide lumber with bending strength ratios equal to the 75 and 50 visual stress grades respectively. BSCP 4978 also introduced machine grades, MSS, and MGS with dry bending strength ratios equal to the SS and GS visual stress grades respectively. In contrast, the North American machine stress grades provide a wider selection of grades which are denoted by MOE and MOR classifications that do not necessarily correspond to particular visual stress grades. In the United Kingdom, machine stress grading is confined to a limited number of species, due to the complexities of establishing relationships between a strength indicating parameter (MOE) and a strength measure (MOR). Princes Risborough Laboratory and the Building Research Establishment (BRE) are technical advisors to the British Standards Institution in the area of machine stress grading. Problems currently being researched include the phenomenon of occasional grade change of a piece when it is graded for a second time using the same or a different machine, and the extension of machine grading to section sizes greater than 50 x 200 mm (2 x 8"). After a tentative machine grade is established, the piece is visually inspected for fissures, wane, resin pockets, distortion, wormholes, sap stain and abnormal defects. These visual requirements are outlined in Table 2 of Appendix III.

3. Sizes and Tolerances

The sizes and tolerances of sawn softwood graded under British standards are specified comprehensively in BSCP 4471 'Dimensions for Softwood Sizes of Sawn and Planed Timber' (17) which outlines three cross-sectional forms of structural timber, basic sawn, processed, and precision. Table 3 of Appendix III provides the distinction between these categories which have distinct tolerances around the basic dimensions given in Table 4 of Appendix III. Tables 3-4 of Appendix III also present the permissible variation in basic sawn cross sectional sizes attributable to lumber moisture contents above 20%. For moisture contents above 20% the tolerances are superimposed on the basic sawn size after adjustment for moisture content. The thickness and width tolerances for precision timber are designed to eliminate the need to recalculate the geometrical properties of lumber off nominal sizes for structural applications.

4. Quality Assurance

BSCP 112 did not provide standard methods for identifying and marking stress graded material nor provisions for an authority responsible for approving the qualifications of trained visual grading personnel. Without an approving authority and a comprehensive system of marking, disputes were inevitable concerning the interpretation and application of the visual stress grading rules. In 1969, the Stress Grading Management Committee was formed within the Timber Research and Development Association (TRADA), to administer training and certification of visual stress graders in the United Kingdom. TRADA is a trade association sanctioned by the British Standards Institution for conducting the approving authority functions. In 1968, the building regulations for England and Wales were revised to reflect the BSCP 112 grades in design criteria.

TRADA is sanctioned by the BSI to administer training and certification of visual stress graders (22, 23). All lumber graded to

BSCP 112 and BSCP 4978 is marked so that the grade and the origin of the finished product can be immediately identified. Companies subscribing to the TRADA quality assurance program, stamp their lumber with the TRADA mark. In 1971, there were only 30 trained and licensed visual stress graders with an annual output of approximately 5000 m^3 per person. In 1979 there were 620 visual graders licensed to use the TRADA mark (26). The increase in numbers of visual graders during the 1971-1979 period was a response to the expected and realized increases in the quantity of stress graded lumber demanded in the United Kingdom.

Machine stress rated sawn softwood is graded within the guidelines set by th BSI in the Kitemark Quality Assurance Scheme, which specifies the process by which a grading machine and its operator becomes certified (26). Upon certification, the operator must comply with the BSI regulations relating to supervision and control of machine stress grading operations such as calibration, maintenance, and product marking requirements. The mandatory marking which appears once on each piece includes grade, machine license number, BSI Kitemark, and the number of the standard, BSCP 4978. The British Business Intelligence Services (BIS) estimated the annual output of stress grading machines to be approximately 7000 m^3 per unit based on 1971 industry machine output (7). The BIS estimated operating cost of machine stress grading is approximately 4.5-5.5% of the C.I.F. price of sawn softwood which compares favorably with visual stress grading (7-7.5%). The capital investment for stress grading machines must, however, be considered along with the associated lower operating cost.

Section IV

European Standardization of Visual and Machine Stress Grading

As noted in section I, the standards for softwood lumber grading vary among European nations, and the Scandinavian system frequently used as a basis for international commerce has serious shortcomings especially with regard to economic use of structural lumber, although it will undoubtedly continue as the basis for commerce in non-stress graded lumber.

The United Nations Economic Commission for Europe (ECE), through its Timber Committee has addressed this problem by proposing international standards for structural softwood lumber for acceptance by ECE members. The provisions of these standards, are intended to encourage the rational, economic utilization of lumber and promote the profitable manufacture of softwood lumber products. The Timber Committee anticipated that the current process of regrading imported lumber would be avoided, or simplified under international harmonization of softwood lumber evaluation procedures. The development and current status of the ECE proposal for standardization of visual and machine stress grading of softwood lumber are presented in this section. The ECE includes all European nations, North American nations, and the U.S.S.R. The Timber Committee provides a forum for cooperation between members on issues related to forestry, forest products, and forest industry.

A. The 1974 ECE Proposal

The standardization process began in 1973 with a proposal developed by a drafting group of the ECE Timber Committee, which was tentatively adopted by the ECE Timber Committee in 1974, and published in 1975 (24). Adoption of this proposal, was contingent upon a evaluation period during which the results of research and practical experience associated with the proposal would be incorporated into a revised standard.

1. Grading Rule Structure

The initial ECE draft proposal was intended to standardize the quality of structural coniferous timber with basic sawn dimensions greater than 38 mm thickness and 75 mm width. Manufacturing tolerances were in accordance with those published in the International Standards Organization (ISO) document R 738 (28). Defect limitations are specified for lumber at a moisture content of 20%.

The British Knot Area Ratio (KAR) method of visual stress grading is a key element in the ECE proposal. KAR is calculated as in the British system using dead knots, live knots, and knot holes exceeding 5 mm in cross section. The ECE proposal permits the implementation of other knot assessment schemes provided that they are based on knot displacement of cross-sectional wood fiber and their equivalency with the KAR method has been established. The ECE visual stress grading standard also requires the measurement of slope of grain, rate of growth, fissures, distortions, and wane for determining the structural capability of lumber using the techniques presented in British standards BSCP 112 and BSCP 4978.

The ECE provisions stress the exclusion of lumber from a particular grade if it contains fungal decay, compression wood, or mechanical damage, which implies a decrease in strength properties to an extent which threatens its structural integrity. Lumber containing active insect infestation, or wood wasp holes, is rejected from all grade levels. Worm holes are permitted to a slight extent in a few pieces. Sapstain is not considered as a structural defect.

2. Grade Provisions

The initial ECE proposal presented two visual stress grades, EC1 and EC2, and provided for development of corresponding machine stress grades, MEC1 and MEC2. These grades correspond on the basis of working bending stress values.

Table 11 presents the grade provisions for EC1 and EC2. The EC1 limitations on margin and total knot area ratio differ from the British SS grade (Table 10). Limitations on margin and total KAR for EC1 are listed as 1/4 and 1/4 respectively. For the EC2 grade, the total KAR limitations are identical with the British GS grade. All other visual features for the ECE grades are the same as the British grades. Compare Tables 10-11.

3. Product Marking Requirements

Marking requirements for lumber graded EC1 or EC2 required the following information to be marked clearly on one face, edge, or end of each piece: (i) the company responsible for the grading, (ii) the grade of the piece, (iii) the species or species group, and (iv) the control authority where appropriate.

Table 11 Permissible Limits for the 1982 ECE S10, S8 and S6 Visual Stress Grades

Characteristic (see definitions)	Grade: EC1 1/	Grade: EC2 1/	
Knots:			
Margin KAR	$\leq$ 1/4	$\leq$ 1/2	$\geq$ 1/2
Total KAR	$\leq$ 1/4	$\leq$ 1/2	$\leq$ 1/3
Slope of grain:	1 in 10	1 in 6	
Rate of growth:	Average width of annual rings not more than 7 mm		
Fissures:			
Not more than half the thickness	unlimited	unlimited	
More than half but less than the full thickness	Not more than 1/4 of the length but 600 mm maximum	Not more than 1/4 of the length but 900 mm maximum	
Equal to the thickness	Only permitted at the ends with a length of not more than the width of the piece	Not more than 600 mm and if at the ends with a length of not more than 1½ times the width of the piece	
Wane:	1/4 of the thickness by 1/4 of the width, full length	1/3 of the thickness by 1/3 of the width, full length and in addition 1/2 permitted in a 300 mm length not nearer the ends than 300 mm	
Distortion:			
Bow	Should not generally exceed 20 mm in any 3 m length		
Spring	" " " " 15 mm in any 3 m length		
Cup	" " " " 1 mm per 25 mm of width		
Twist	" " " " 1 mm per 25 mm of width in any 3 m length		
Pitch pockets and inbark:	The same limits as for fissures		
Insect damage:	Worm holes and pin holes are permitted to a slight extent in a few pieces. No active infestation is permitted. Wood wasp holes are not permitted		

1/ For guidelines to the stress levels aimed at by these grades, see Annex 1

Source (24)

4. Acceptance Limits

On reinspection of a representative number of pieces in a parcel, not more than 10% of the sample may contain any one characteristic exceeding the limit specified for the grade by more than 15%. If the limit is exceeded, the total parcel is required to be regraded.

5. Machine Stress Grading

To qualify for a machine stress grade MEC1 or MEC2, a piece must be evaluated by an approved stress grading machine. Each piece must be visually inspected to ensure that characteristics other than knots, slope of grain, and rate of growth, conform to the requirements of the corresponding visual grade. As mentioned previously, the grade pairs (EC1, MEC1) and (EC2, MEC2) are intended to have the same design stress values. The acceptance limits for visually evaluated characteristics of machine stress graded lumber are the same as specified for visual stress graded lumber.

6. Design Stress Values

The ECE draft proposal included estimates of bending design stresses for European redwood (Scots pine) and whitewood (Norway spruce). The expected range in newtons/mm^2 for EC1 and EC2, are 8-10 and 5.5-6.5 respectively on a dry basis. These values were published as a guideline to assist the prospective consumer in selecting the appropriate grade. In Europe, there are country-specific methods for deriving design stresses. The international standardization of softwood lumber evaluation procedures must eventually include the harmonization of methods of design stress derivation in order to allow publishing of exact design values of ECE grades.

7. Implementation of the 1974 Proposal

The 1974 ECE proposal was not widely implemented in Europe. The primary factor which hindered implementation was not determined from the literature review. The acceptability of manufacturing yields of lumber conforming the ECE grades, may have been a key factor in determining the acceptability of the ECE grading system.

C. The 1982 ECE Proposal

In 1981, the ECE Timber Committee culminated the process of revising the visual and machine stress grading standards and published a new proposal in 1982 (25). A major change from the 1974 proposal is the addition of a third grade. The distinctive elements of the 1982 ECE proposal, relative to the 1974 proposal, are highlighted in the subsequent sections.

1. Grading Rule Structure

The scope of application for the 1982 ECE proposal is structural load bearing coniferous timber. The same minimum thickness of 38 mm is retained, however the minimum width is reduced from 75 mm to 63 mm.

The 1982 ECE proposal explicitly specifies the permissible reduction from the basic sawn sizes to finished sizes by processing of two opposed surfaces (Table 12). The ECE standard defect limitations are based on a 20% lumber moisture content.

The visual stress grade defined in the 1981 ECE proposal are denoted as S10, S8, and S6 and corresponding machine stress grades MS10, MS8, and MS6, respectively. Corresponding visual and machine grade pairs

(S10-MS10, S8-MS8, S6-MS6) are intended to classify structural lumber with equal working bending stresses.

The ECE guidelines for operational control of visual and machine stress grading are unchanged from the 1974 ECE proposal (Table 1 of Appendix IV).

Table 2 of Appendix IV lists definitions for terminology relevant to the ECE proposal. The only new terminology presented in the 1982 proposal distinguishes between "approving" and "control" authorities. These terms distinguish national entities with responsibility for certifying the qualifications of visual grading personnel, and machine grading operations, from national entities responsible for the performance of visual and machine stress grading. In many countries, approval and control is executed by the same authority.

Table 12. Permissible Reduction from Basic Sawn Sizes to Finished Size by Processing of Two Opposed Surfaces (25).

	Basic sawn dimension of piece		
	38 mm up to and including 49 mm	50 mm up to and including 150 mm	Over 150 mm
Permissible reductions	4 mm	5 mm	6 mm

The lumber defect types and associated measurement techniques contained in the 1982 draft (Table 3, Figures 1-7, Appendix IV) are essentially unmodified from the 1974 proposal and are little changed from British practice. The only modifications are changes in measurements of fissures and distortions. The 1982 proposal classifies fissures (shakes, checks, splits) into those extending through the thickness of the piece, and those not extending through the thickness of the piece and places restrictions on the acceptable length of each type. Surface fissures less than 300 mm in length are ignored. Distortions (bow, spring, and twist) are now measured per 2 meters of piece length basis rather than 3 meters.

2. Grade Provisions

Table 13 presents the grading provisions for the 1982 ECE grades. The three key parameters of the visual stress grades are the KAR limitations, rate of growth requirements, and slope of grain requirements.

The S10 grade was developed to provide high strength lumber for application in special engineering structures. The margin and total KAR limitations on lumber graded S10 are 1/5 and 1/5 respectively. Slope of grain and rate growth requirements are 1:10 and 6 mm average ring width (4 rings/inch).

The KAR limitations for the S8 grade are expressed as two alternatives. The total KAR limitation of 1/2 or 1/3 applies when the cross-sectional margin KAR is less than or greater than 1/2 respectively. The S8 grade is therefore equivalent on a KAR basis to the EC2 grade in the 1974 standard. The slope of grain requirement for S8 (1:10) is equal to that specified for S10 and more restrictive than the limitation for the previous EC2 grade (1:6). The rate of growth requirements, fissure impact limitations, and wane limitations for the S8 grade are the same as that specified for S10.

The S6 grade is the lowest quality grade presented in the 1982 ECE standard. The total KAR limitation of 1/2 or 1/3 depends on whether the

Table 13. Permissable Limits for the 1982 ECE S10, S8 and S6 Visual Stress Grades

Characteristic (see definitions)	Grade 1/				
	S10	S8		S6	
		EITHER	OR	EITHER	OR
Knots:					
Margin KAR	Equal to or less than 1/5	Equal to or less than 1/2	More than 1/2	Equal to or less than 1/2	More than 1/2
Total KAR	Equal to or less than 1/5	Equal to or less than 1/3	Equal to or less than 1/5	Equal to or less than 1/2	Equal to or less than 1/3
Slope of grain	1 in 10			1 in 6	
Rate of growth: Average width of annual rings	Not more than 6 mm			Not more than 10 mm	
Size and number of fissures:	Surface fissures less than 300 mm in length may be ignored				
Not through the thickness	Not more than 1/4 of the length but 600 mm maximum			Not more than 1/4 of the length but 900 mm maximum	
	On any running metre, not more than one fissure of the maximum length				
Through the thickness	Only permitted at the ends with a length of not more than the width of the piece			Not more than 600 mm if at the ends with a length of not more than 1½ times the width of the piece	
Wane	1/4 of the thickness, 1/4 of the width, full length; 1/3 in any 300 mm length, provided that at ends it is confined to one arris only			1/3 of the thickness, 1/3 of the width for full length; 1/2 in any 300 mm length, provided that at ends it is confined to one arris only	
Distortion:	Any piece which is bowed, twisted or cupped to an excessive extent having regard to the end use shall be rejected				
Approximate limits of distortion 2/					
Bow (per 2 m length)	In a thickness of 38 mm should generally not exceed 30 mm In thickness of 75 mm and greater should generally not exceed 10 mm				
	(Intermediate sizes may be determined by interpolation)				
Spring (per 2 m length)	In a width of 63 mm should not exceed 10 mm In widths of 250 mm and greater should not exceed 5 mm				
	(Intermediate sizes may be determined by interpolation)				
Cup	Should generally not exceed 1 mm per 25 mm of width				
Twist (per 2 m length)	Should generally not exceed 1.5 mm per 25 mm of width				
Pitch pockets and inbark:					
Not through the thickness	Unlimited, if shorter than the width of the piece. Otherwise the same limits as for size of fissures				
Through the thickness	Unlimited, if shorter than half the width of the piece. Otherwise the same limits as for size of fissures				
Insect damage	Worm holes and pin holes are permitted to a slight extent in a few pieces No active infestation is permitted Wood wasp holes are not permitted				

1/ For guidelines to the stress levels aimed at by these grades, see Appendix A.
2/ Distortion will largely depend on the moisture content of the timber at the time it is measured. Where for a particular reason other limits than those indicated are required, these should be subject to contract between supplier and purchaser.

Source (25)

margin KAR is less than or greater than 1/2 respectively. The slope of grain and rate of growth requirements for S6 are 1:6 and 10 mm average ring width (2.5 rings/inch) respectively.

3. Product Marking Requirements

The product marking requirements for visual and machine graded lumber presented in the 1982 ECE standard are unmodified from the 1974 ECE standard requirements.

4. Acceptance Limits

The 1982 standard specifies acceptance limits for visual, and machine stress graded lumber parcels which are more restrictive than the 1974 standard specifications. In order to classify a parcel as conforming to grade provisions, two conditions must be satisfied: (1) not more than 10% of the pieces in a representative parcel sample can exceed the permissible limits of the appropriate grade and (2) not more than 3% of the sample pieces can exceed the permissible grade limits by more than 30%. The deviation in grading is allowed only to take into account the possible differences between individual graders. The acceptance limits apply only to the visually assessed defects of machine stress graded lumber parcels.

5. Machine Stress Grading

The only revision in the machine grading requirements (Table 4 of Appendix IV) is the requirement for visual inspection of the ends of pieces, when a machine does not thoroughly grade to both ends. If a knot is present in the ungraded portions, which is larger than the maximum visual grade limit, the piece is rejected from the corresponding machine grade.

6. Design Stress Values

Table 14 presents the ECE five percentile bending strength test values for European redwood (*Pinus silvestris*) and whitewood (*Picea abies*, *Abies alba*). This reflects a change from British use of 1%. The working group of the ECE Timber Committee considers these strength values as pertinent to the North American Douglas-fir-larch, hem-fir, and spruce-pine-fir species groupings. The strength values are grade stresses for lumber graded S10, S8, and S6. International implementation of the ECE standard will require national entities to modify the five percentile test values to account for a safety factor and the effect of long-term structural loading.

Table 14. ECE 5% exclusion limit for bending strength of European redwood and whitewood.

Grade	5% value range (N/mm^2)
S10 or MS10	25 - 30
S8 or MS8	21 - 24
S6 or MS6	15 - 18

Source (25)

7. International Trade Promotion

In order to improve the prospects for international trade in structural lumber, the 1982 ECE standard presented the concept of an Approval Form which is designed to facilitate mutual national acceptance of standards of performance and control for softwood lumber grading. The

ECE recommends the use of the form when lumber product approval is sought in a foreign country. The level of product approval may involve the request of approval by a factory, factory association, or national authority to the appropriate foreign authorities.

The form consists of a two-part structure. Part one (Table 5 of Appendix IV) outlines the format for specifying the product and its properties. Part Two (Table 6 of Appendix IV) outlines the format for specifying product, production, and quality standardization. The required extent of detail presented in an approval form depends on the level of the product approval application. The drafting of the form is simplified if references to relevant national or international softwood lumber standards are made. The supporting documentation of the standards should be included with the form that is sent to the foreign entity.

8. Implementation of the 1982 Proposal

The ECE Timber Committee is currently monitoring the implementation of the 1982 proposal by member countries. The Timber Committee is developing a system for operational use of approval forms. Governments have been requested by the ECE to nominate correspondents that will assist in monitoring the implementation of the standard and "contact points" who will receive approval forms and route them to appropriate national authorities.

Section V

Cross Referencing the Current British and ECE Visual Grades with North American Grades

A. Cross Referencing Based on Knots

Because of the major differences underlying the British/ECE and North American visual stress grade systems, no meaningful direct cross reference could be established by comparing grade rule provisions. In order to gain some insight into how a parcel of North American lumber of a given grade might compare with these grades, we conducted a limited simulation study based on using knots as the primary grade determinant.

The basic process used in this simulation comparison was to first eliminate the variations implied in knot displacement:cross-section area ratios within each produced category (Light Framing, Structural Light Framing, etc.) by averaging. Thus, we calculated an average cross section based on the average thickness and width in the product category and subsequently calculated average centerline and edge knot diameter limits for each grade. For example, we calculated that the average cross-section area of a Structural Light Framing piece is 8.88 square inches and that the edge and centerline knot diameter limitations were .542 and .583 inches for Select Str., .750 and .917 inches for No. 1, .917 and 1.116 inches for No. 2, and 1.250 and 1.500 inches for No. 3. Appendix V presents the detailed calculations.

The second step involved a computer simulation which randomly placed allowable knots for a particular grade on a hypothetical piece representing the average cross section. In doing this, we made provisions to allow for proportional knot sizing and well-scattered spacing as described in the rules. After the knots were generated and located, the program used the KAR method to estimate the margin and total KAR for the piece. We then plotted total KAR and margin KAR vs. the number of knots present. The simulation was repeated a number of times to get total and margin KAR's with different numbers of knots in the piece. The resulting points were fitted by a straight line.

The third step involved estimating the number of knots of limiting size in our average cross section that could occur within the particular grade. This allowed us to enter the graphs of total and margin KAR vs. number of knots and read the total and margin KAR corresponding to the grade limitations.

The fourth step involved overlapping graphs of the margin and total KAR's implied by the North American grades with the corresponding British or ECE grade limitations. This allowed us to estimate common areas which were used as the basis for estimating percentages of each North American grade that we believe would meet the British or ECE grades. These percentages are summarized in Table 15 which presents the maximum correspondence found. Further details of the simulation are given in Appendix V. It should be remembered on examining the results that these comparisons only evaluate the effects of knots in these grades; other factors such as fissure and wane differences were not included. Thus, the values in Table 15 would overestimate the results or a degrade field study since losses due to these other differences would cause some reduction in acceptance.

Table 15. North American-British, and North American-ECE KAR Grade Conversions

North American Grade	British Grade SS	British Grade GS	ECE Grade S10	ECE Grade S8	ECE Grade S6
Select Str. (SLF)	91	100	19	91	100
Select Str. (SJP)	78	97	16	78	97
No. 1 (SF)	56	87	10	56	87
No. 1 (SJP)	57	87	10	57	87
No. 2 (SLF)	44	68	6	44	68
No. 2 (SJP)	43	68	6	43	68
No. 3 (SLF)	30	47	3	30	47
No. 3 (SJP)	29	45	3	29	45
Construction	35	56	4	35	56
Standard	26	42	2	26	42
Utility	23	37	1	23	37

Note: KAR conversion factors are the expected percentage of a unit quantity of the North American grade which will conform to the British or ECE KAR limitations.

B. Grade Cross Referencing Based on Bending Strength Ratio, Slope of Grain, and Growth Rate

Another way to cross reference the North American and British/ECE grades is to examine the status of the grades in terms of a broader measure such as the working bending strength ratios. This measure provides insight into the overall effect of permissible defects on strength of lumber classified in a particular grade.

The ratio of the allowable, or working bending strength (MOR), to the basic clear wood value, at moisture contents less than 19%, was chosen as a measure of the relative quality of a grade.

Table 16 presents the results of the bending strength ratio cross reference between the North American and British grades. The results indicate that the SLF and SJP grades with bending strength ratios of 67% and 65% respectively are superior to British SS and GS bending strength ratios (50%, 35%). From an overall quality perspective British SS occupies a niche between SLF and SJP grades No. 1 and No. 2. British GS is comparable to LF Construction grade. It is important to note the slope of grain differential between SLF and SJP Select Str. and British SS and GS. The Select Str. slope of grain limitation is 1:12; the limitations for SS and GS are 1:8 and 1:6 respectively. This differential certainly accounts for a portion of the discrepancy between the bending strength ratios. The strength of wood is affected whenever the slope of grain is greater than about 1 in 20. Table 17 presents the ASTM estimates of wood bending strength reduction as a function of slope of grain. The calculation of the bending strength ratios of North American Select Str. and British SS and GS, under the assumption of equal grain slope limitations would substantially reduce the discrepancy between the grades.

Table 16 North American and British grade bending strength ratio cross reference

North American Grade	Bending Strength Ratio	Slope of Grain	Rings Inch	British Grade	Bending Strength Ratio	Slope of Grain	Rings Inch
Select Str.	67%	1:12	4	75	70%	1:14	8
No. 1	55%	1:10	4	65	60%	1:11	6
Appearance	55%	1:10	4	SS	50%	1:10	4
No. 2	45%	1:8	4	50	46%	1:8	4
				GS	35%	1:6	4
Construction	35%	1:6	NR*	40	36%	1:6	4
No. 3	26%	1:4	NR				
Standard	19%	1:4	NR				
Utility	9%	1:4	NR				

Source (8, 15, 16, 25)

* No Requirement

Table 17 Strength Reduction in Bending Resulting from Slope of Grain

Slope of Grain	Bending Strength Reduction (%)
1 in 6	60
1 in 8	47
1 in 10	39
1 in 15	24
1 in 20	0

Source (27)

The rings/inch limitation for SLF and SJP Select Str. grade (4 rings/in.) is significantly stricter than that expressed for British SS and GS (2.5 rings/in.). The rings/inch requirement implies a level of specific gravity related to bending strength. The rings/inch value differences may also account for a portion of the bending strength ratio differences.

Table 16 includes the British visual stress grades from British Standard BSCP 112:1971. These grades were precursory to the SS and GS grades published in BS 4978. The 75 grade corresponds closely in bending strength to North American Select Str. The 50 and 40 grades correspond to No. 2, and Construction respectively.

The bending strength values for the ECE KAR grades have only been tentatively determined for North American and European species. These values have not been adjusted for long-term loading or safety factors. As a result, the working bending strength ratio values are not available for comparison to the North American and British grade values.

The ECE S6 grade has the same KAR and grain slope limitations as British GS. The S6 grade rings/inch value is less restrictive than the British GS limitation. ECE S8 has KAR and rings/inch requirements which match the British SS grade, but the ECE S8 grade has slope of grain limitations which are more restrictive than SS limitations. The ECE S10 grade slope of grain and growth rate requirements are equivalant to those expressed for S8, but the S10 KAR limitations are more severe than S8 KAR limitations. Based on the above considerations, the estimated hierarchical order of the bending strength ratios of the British and ECE KAR grades is S10, S8, SS, GS and S6 respectively.

C. Conclusions

The integration of the results of the two approaches to grade cross referencing yields the following conclusions. Due to the variability between the North American, British, and ECE grades, with respect to defects other than knots, the KAR grade conversions in Table 15 have restrictions on their potential application. The probability of KAR grade conversion accuracy is maximized when limitations on lumber defects other than knots are equivalant for the two grades involved in a conversion. KAR grade cross referencing should always involve grade pairs with bending strength ratio differences which can be attributed primarily to knot displacement limitation differences. The conversion factor for SJP Select Str. to British GS (.97%), therefore, has a contingent requirement that the Select Str. pieces were sufficiently below grade in terms of grain slope, growth rate, and fiber separation defects, in order to conform to the lower requirements for GS. Other compensating adjustments should be made for other grade pairs involved in a cross reference when significant differences in primary lumber strength indicator limitations exist.

The grain slope and growth rate requirements for the grade pairs (Construction, GS) and (No. 2, SS) are equal. The (No. 2, SS) grade pair fiber separation limitations are approximately equivalant. With regard to the (Construction GS) grade pair, the Construction grade fiber separation defects limitations are stricter than that expressed for GS, but the difference is not substantial. Therefore, the (Construction, GS) and (No. 2, SS) KAR grade conversion factors may provide a reasonably accurate approximation of the actual grade relationships.

The KAR grade conversion analysis and the bending strength ratio comparisons were attempts to develop quantitative methods by which lumber grading systems can be compared. A potentially more accurate quantative method would involve the systematic grading of lumber parcels under the North American, ECE, and British lumber grading systems.

Section VI

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APPENDIX I

Dimensions and Provisions of the Scandinavian Softwood Lumber Grading System used in European Transactions (6)

WIDTHS

Thickness	MM	MM	MM	MM	MM	MM	MM	MM
MM	75 (3")	100 (4")	125 (5")	150 (6")	175 (7")	200 (8")	225 (9")	250 (10")
16 (5/8")	S	S	0	0	0			
19 (3/4")	S	S	0	S	0			
25 (1")	<u>S</u>	<u>S</u>	0	<u>S</u>	0			
38 (1-1/2")	A	A	0		0			
44 (1-3/4")	0		0		0			
47 (1-7/8")	0	A	0		0	A		A
50 (2")	0	<u>CJ</u>	0	<u>CJ</u>	0	<u>CJ</u>		
63 (2-1/2")	0	0	0		0			
75 (3")	0	0	0	<u>C</u>	0	<u>CA</u>		

S - Sideboards (underlined indicates greatest volume in these sizes)

C - Carcassing (5ths)

J - Joinery (unsorted)

A - U.S. or Canadian lumber

O - None observed

LENGTHS

Meters		Meters	
1.8	(5'11")	4.5	(14'9")
2.1	(6'11")	4.8	(15'9")
2.4	(7'10")	5.1	(16'9")
2.7	(8'10")	5.4	(17'9")
3.0	(9'10")	5.7	(18'8")
3.3	(10'10")	6.0	(19'8")
3.6	(11'10")	6.3	(20'8")
3.9	(12'10")	6.6	(21'8")
4.2	(13'9")	6.9	(22'8")

Table 1. Common cross-sections sizes and lengths of lumber in European trade.

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Table 2. Provisions for Scandinavian grades "fourths" and "fifths."

FOURTHS

Knots: The given number of knots refers to 1.5 meters (4'11") of length. Throughout the whole length of the piece, the number of knots may be greater in the same proportion as the piece is longer than 1.5 meters. However, this does not imply that the maximum number of knots permitted in the poorest 1.5 meters may be increased. The number of sound knots permitted decreases in proportion to the presence of other types of knots.

Sound (living) knots:

Better Face:

Thickness mm	Width mm 75 (3")	100 (4")	125 (5")	150 (6")	175 (7")	200 (8")	225 (9")	250 (10")	275 (11")
16 (5/8")	5/8"	5/8"	3/4"	7/8"	7/8"	1"	1"	1-9/64"	1-9/64"
19 (3/4")	5/8"	3/4"	7/8"	1"	1"	1-9/64"	1-9/64"	1-9/64"	1-9/64"
25 (1")	3/4"	1"	1-9/64"	1-9/64"	1-9/64"	1-1/4"	1-1/4"	1-1/4"	1-1/4"
32 (1-1/4")	1"	1-9/64"	1-9/64"	1-1/4"	1-1/4"	1-1/4"	1-1/4"	1-3/8"	1-3/8"
38 (1-1/2")	1-9/64"	1-9/64"	1-1/4"	1-1/4"	1-1/4"	1-3/8"	1-3/8"	1-1/2	1-1/2"
50 (2")	1-9/64"	1-1/4"	1-3/8"	1-1/2"	1-5/8"	1-5/8"	1-3/4"	1-3/4"	1-7/8"
63 (2-1/2")		1-1/2"	1-5/8"	1-3/4"	1-7/8"	1-7/8"	2"	2"	2-1/4"
75 (3")		1-3/4"	1-7/8"	2"	2-1/8"	2-1/8"	2-1/4"	2-1/4"	2-1/4"

In 100-150 mm (4"-6") widths, 2 knots of maximum size and 3 knots 70% of maximum size permitted for each 1.5 meters.

In 175 mm (7") and wider, 2 knots of maximum size and 4 knots 70% of maximum size permitted.

In addition, a few smaller knots and normally occurring pin knots are permitted.

Wane:

Edges:

50% of thickness on one edge. If wane appears on both edges, a total of 25% more is permitted, but no wane may exceed in depth what is permitted on one face.

Faces:

32 mm (1-1/4") permitted for thicknesses up to and including 63 mm (2-1/2") and widths of at least 125 mm (5").

For thicker sizes wane is permitted to the same width on the face as given for depth on the edge. Proportionate reduction is made for widths under 5".

If wane appears on both sides of the face, a total of 25% more is permitted, but no wane may exceed in width what is permitted on one side of the face.

This is applicable to wane at the ends of the piece. Wane on the middle of the piece is more restricted.

Length:

50% if on one edge and 60% total if on two edges.

Log Blue Stain:

Streaks and spots are allowed.

Yard Blue Stain:

Permitted, but not if it also is deep penetrating and wide-spread over the whole piece.

* * *

Shakes, Oblique:

On faces and edges, but not breaking from the wide face into the narrow face or from narrow face into the wide face:

Permitted, but more restrictive than longitudinal shake.

On faces and edges, also breaking from one face to the other:

Permitted to a limited extent.

Pitch Pockets:

Permitted.

Bark Pockets:

Permitted. However, if the pocket is penetrating through the piece, its size is limited to 50% of the area of allowed sound knots, but not to exceed 25 mm (1") diameter.

Compression Wood:

Permitted.

Interlocked Grain:

Permitted, provided that reasonable solidity of the piece is maintained.

Cross Grain:

Permitted.

Water Streaks:

(Characterized by a weakness in the cohesiveness of the wood and occurs most frequently as streaks and spots, mainly in over-ripe timber.)

Permitted in spots and streaks to small extent.

Scars:

Permitted, if not deep.

Decay:

Hard rot (incipient decay) permitted in streaks or small spots on face and edges, but not penetrating through the piece.

Insect Damage:

Borer beetles:

Permitted to slight extent in small number of pieces.

Woodwasp attack:

Not permitted.

<u>Sound (living) Knots:</u>

Total both edges:

2 knots full thickness of the piece and 3 knots 70% of thickness.

In 63 mm (2-1/2") and thicker, the knot must not cover the whole edge.

In addition, a few smaller knots and normally occurring pin knots permitted.

<u>Dead Knots:</u>

Better face:

In 100-150 mm (4"-6") widths, 2 knots 70% and 3 knots 50% of permitted sound knot size.

In 175 mm (7") and wider, 2 knots 70% and 4 knots 50% of permitted sound knot size.

Edges:

2 knots 70% and 2 knots 50% of permitted sound knot size.

In addition, a few smaller knots and normally occurring pin knots permitted.

<u>Barkringed Knots:</u>

On edges (the total of both edges) and better face, considered separately:

70% of size and 100% of number of permitted sound knots.

<u>Unsound Knots:</u>

On edges (the total of both edges) and better face, considered separately:

Permitted in number and size 70% of what is allowed for sound knots, but maximum of 38 mm (1-1/2").

<u>Knot Clusters:</u>

Permitted if piece holds together well.

<u>Shakes, Longitudinal:</u>

Faces:

Permitted over the whole length, some through, provided the piece holds together well.

Edges:

Permitted on the whole length of the piece.

FIFTHS

Knots: The given number of knots refers to 1.5 meters (4'11") of length. Throughout the whole length of the piece, the number of knots may be greater in the same proportion as the piece is longer than 1.5 meters. However, this does not imply that the maximum number of knots permitted in the poorest 1.5 meters may be increased. The number of sound knots permitted decreases in proportion to the presence of other types of knots.

Sound (living) knots:

Better Face:

Thickness mm	Width mm 75 (3")	100 (4")	125 (5")	150 (6")	175 (7")	200 (8")	225 (9")	250 (10")	275 (11")
16 (5/8")	1-9/64"	1-9/64"	1-1/4"	1-3/8"	1-3/8"	1-1/2"	1-5/8"	1-5/8"	1-3/4"
19 (3/4")	1-9/64"	1-1/4"	1-3/8"	1-1/2"	1-1/2"	1-5/8"	1-3/4"	1-3/4"	1-3/4"
25 (1")	1-1/4"	1-1/2"	1-5/8"	1-3/4"	1-3/4"	1-7/8"	1-7/8"	1-7/8"	2"
32 (1-1/4")	1-1/2"	1-5/8"	1-3/4"	1-7/8"	1-7/8"	2"	2"	2-1/8"	2-1/8"
38 (1-1/2")	1-5/8"	1-3/4"	1-7/8"	2"	2"	2-1/8"	2-1/8"	2-1/4"	2-1/4"
50 (2")	1-3/4"	2"	2-1/8"	2-1/4"	2-3/8"	2-3/8"	2-1/2"	2-1/2"	2-5/8"
63 (2-1/2")		2-1/4"	2-3/8"	2-1/2"	2-5/8"	2-5/8"	2-3/4"	2-3/4"	2-7/8"
75 (3")		2-1/2"	2-5/8"	3"	3"	3"	3"	3"	3"

In 100-150 mm (4"-6") widths, 2 knots of maximum size and 3 knots 70% of maximum size permitted for each 1.5 meters.

In 175 mm (7") and wider, 2 knots of maximum size and 4 knots 70% of maximum size permitted.

In addition, a few smaller knots and normally occurring pin knots are permitted.

Water Streak:

(Characterized by a weakness in the cohesiveness of the wood and occurs most frequently as streaks and spots, mainly in over-ripe timber.)

Permitted in form of a spot or streak if the piece is otherwise of good quality.

Scars:

Small shallow scars permitted.

Decay:

Not permitted.

Insect Damage:

Not permitted.

Wane:

Edges:

30% of thickness on one edge. If wane appears on both edges, a total of 25% more is permitted, but no wane may exceed in depth what is permitted on one edge.

Faces:

22 mm (7/8") permitted for thicknesses up to and including 63 mm (2-1/2") and widths of at least 125 mm (5").

For thicker sizes, wane is permitted to the same width on the face as given for depth on the edge. Proportionate reduction is made for widths under 5".

If wane appears on both sides of the face, a total of 25% more is permitted, but no wane may exceed in width what is permitted on one side of the face.

This is applicable to wane at the end of the piece. Wane on the middle of the piece is more restricted.

Length:

30% if on one edge and 40% total if on two edges.

Log Blue Stain:

Should not occur.

Yard Blue Stain:

Superficial blue which can be expected to disappear in planing, or occasionally 1 or 2 light streaks may be allowed.

* * *

Knot Clusters:

Permitted to limited extent.

Shakes, Longitudinal:

On the faces:

The total length of the shakes on both faces must not exceed 90% of the length of the piece, but the total length of shakes on one face must not exceed 65% of the length of the piece.

Shakes single or opposite each other may not exceed 40% of the thickness of the piece.

On the edges:

Permitted on either or both edges, total length of shakes not to exceed 70% of the length of the piece.

The width of shakes must not exceed 10% of permitted depth.

Shakes, Oblique:

On faces and edges, but not breaking from the wide face into the narrow face or from narrow face into the wide face:

50% of that permitted for longitudinal shakes. Should not accept shake breaking from wide face to narrow face or vice versa.

Pitch Pockets:

Permitted provided not long or penetrating, and not plentiful.

Bark Pockets:

Permitted if not penetrating deeply.

Compression Wood:

Permitted provided it does not seriously prejudice the shape of the piece.

Interlocked Grain:

(Strongly irregular fibers running in different directions, occurring for example in curly-grain wood and also sometimes caused by powerful local growth disturbances.)

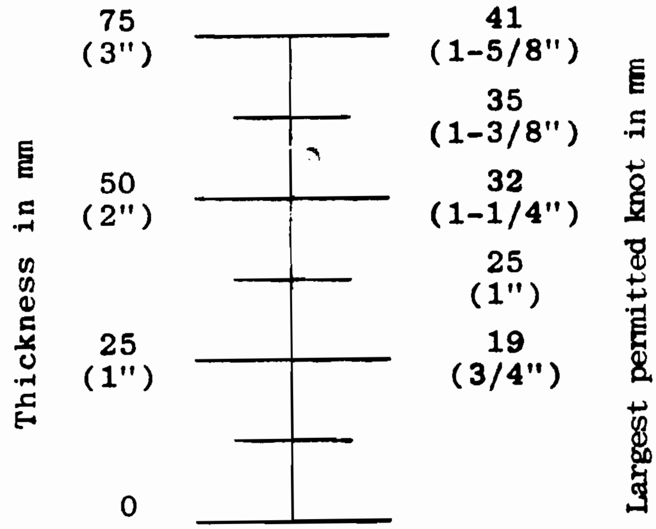
Permitted, but not to such extent that the strength of the piece is noticeably weakened.

Cross Grain:

Permitted.

Sound (living) knots:

Total on both edges:



In widths up to 125-150 mm (5"-6"), 2 knots of maximum size and 2 knots 70% of maximum size permitted.

In wider widths, rather larger knots or a greater number of knots may be allowed.

In addition, a few smaller knots and normally occurring pin knots are permitted.

Dead Knots:

Better face:

In 100-150 mm (4"-6") widths, 2 knots 70% and 2 knots 50% of permitted sound knot size.

In 175 mm (7") and wider, 2 knots 70% and 3 knots 50% of permitted sound knot size.

Edges:

1 knot 70% and 2 knots 50% of permitted sound knot size.

In addition, a few smaller knots and normally occurring pin knots are permitted.

Barkringed Knots:

On edges (the total of both edges) and better face, considered separately:

50% of size and 70% of number of permitted sound knots.

Unsound Knots:

On edges (the total of both edges) and better face, considered separately:

Over the whole length of an otherwise good piece, 1 or 2 knots with slight rot, maximum 50% of size of permitted sound knot, but not penetrating through the piece.

Appendix II

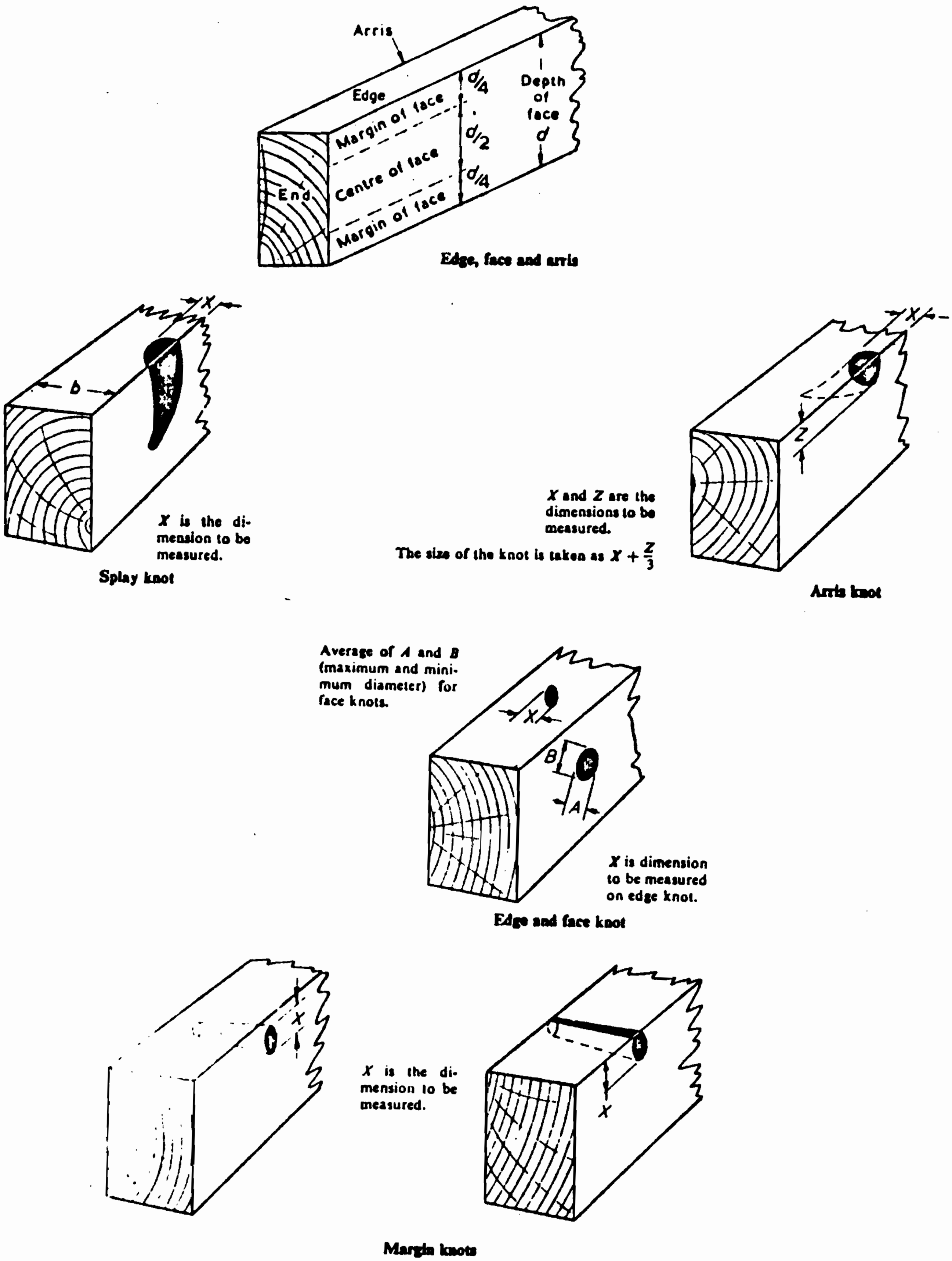
Selected Data from BSCP 112 (15)

Table 1. Softwood species groups in BSCP 112.

Species group	Standard name	Origin
S1	Douglas fir Pitch pine Douglas fir Larch	Imported Home-grown
S2	Western hemlock (unmixed) Western hemlock (commercial) Parana pine Redwood Whitewood Canadian spruce Scots pine	Imported Home-grown
S3	European spruce Sitka spruce Western red cedar	Home-grown Imported

Species group	Standard name	Origin
S1	Douglas fir-larch	Canada
S2	Hem-fir Princess spruce Western white spruce	Canada

Figure 1. Method for measuring knots in BSCP 112.



APPENDIX III

Selected provisions from BSCP 4978 (16) and BSCP 112 (15).

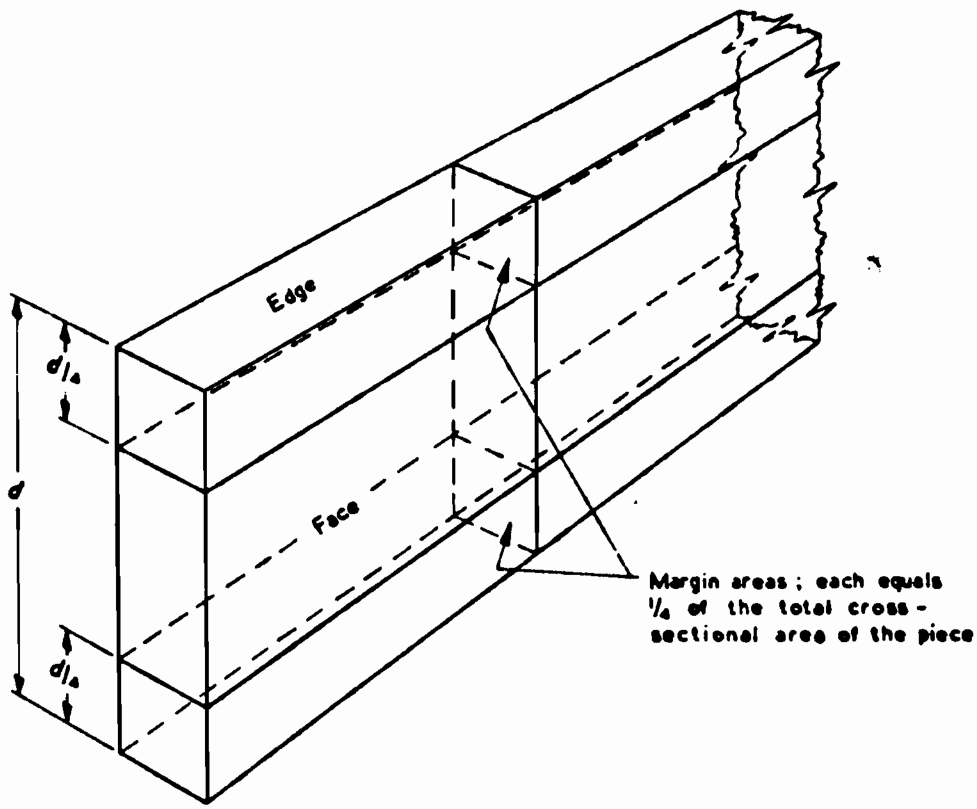


Fig. 1. Edge, face and margin areas

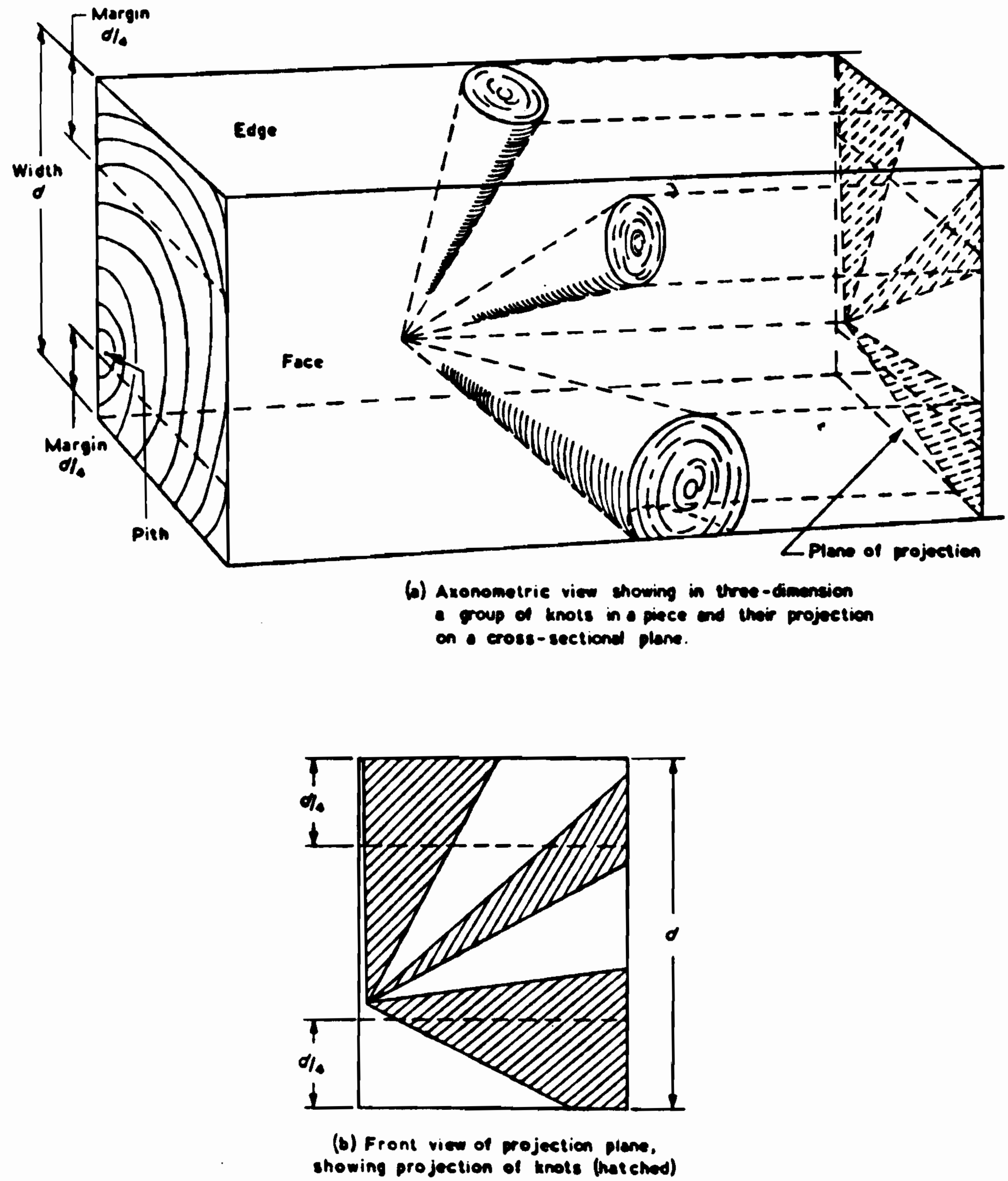


Fig. 2. Knot projection

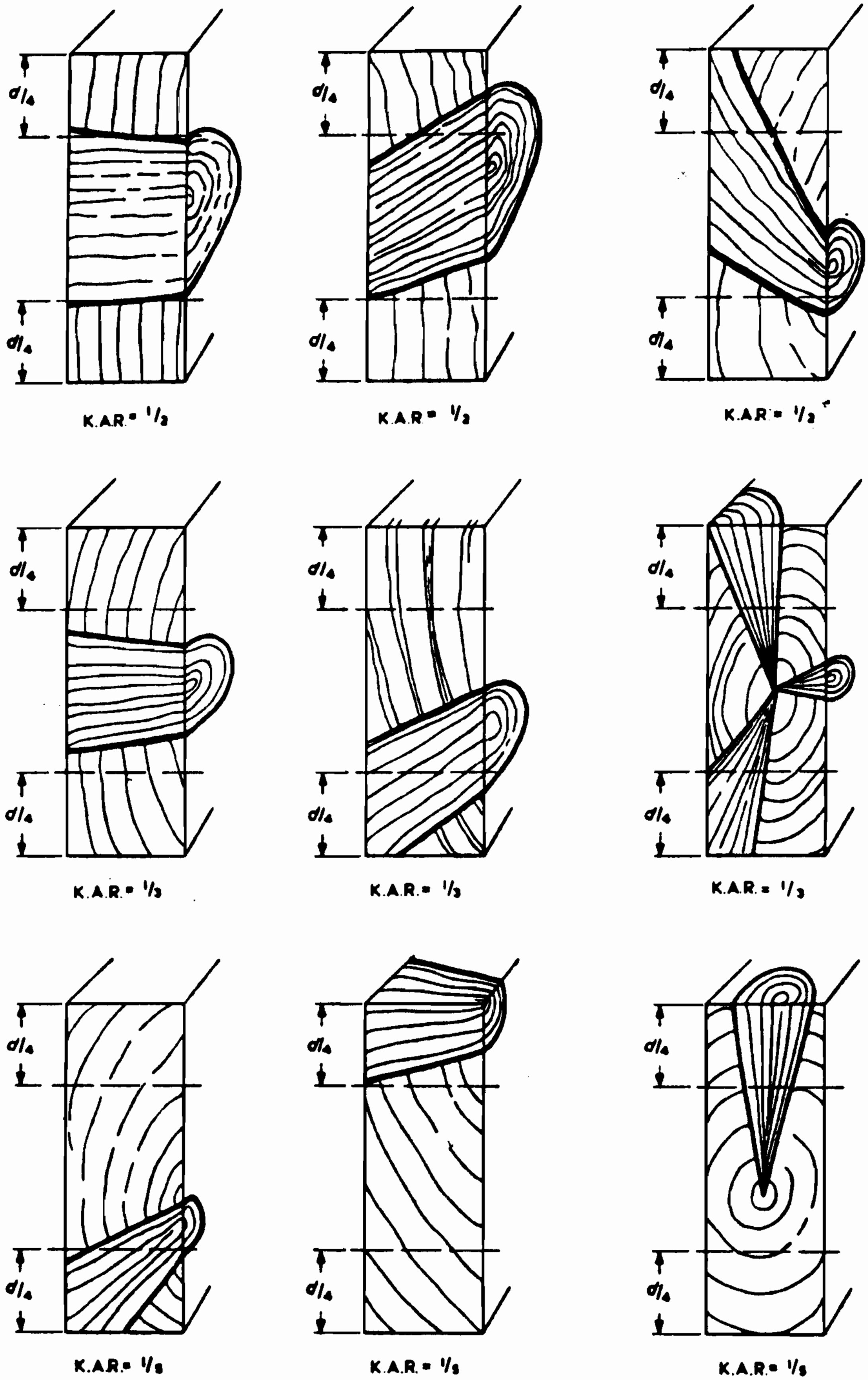
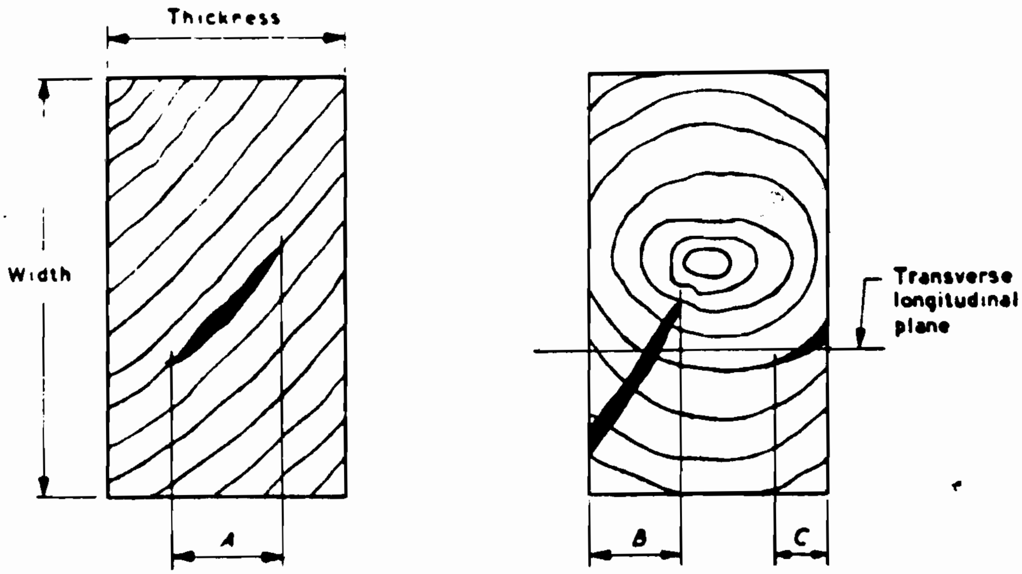


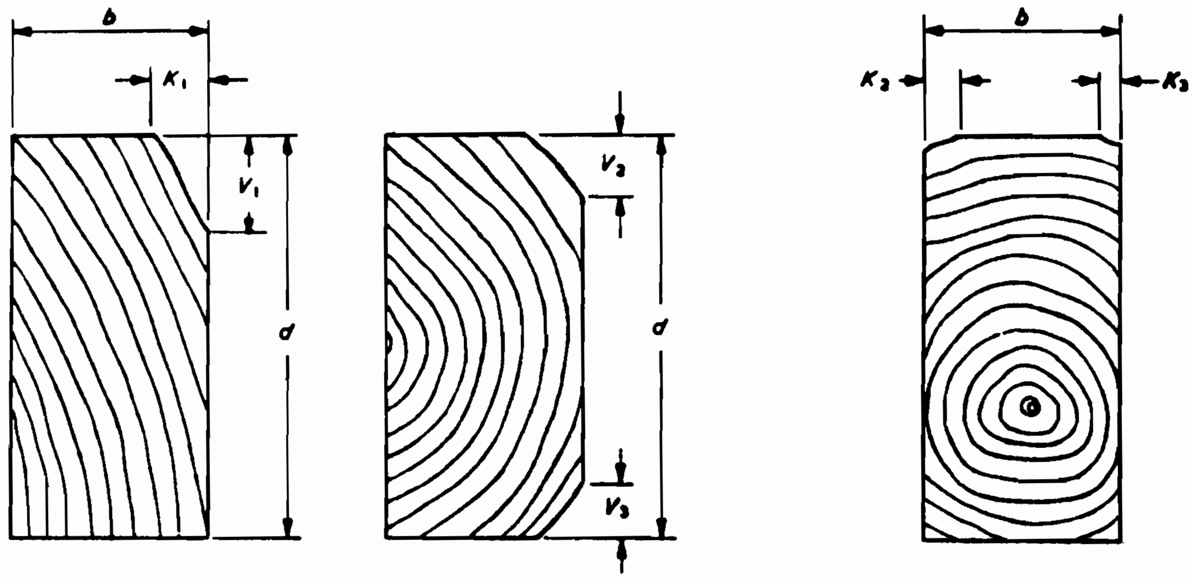
Fig. 3. Typical knot area ratios



Size of fissure is A
(a)

Size of fissure is $B + C$
(b)

Fig. 4. Fissures



Amount of wane on the face of the piece shall be expressed as the ratio

$$\frac{V_1}{d} \quad \text{or} \quad \frac{V_2 + V_3}{d}$$

Amount of wane on the edge of the piece shall be expressed as the ratio

$$\frac{K_1}{b} \quad \text{or} \quad \frac{K_2 + K_3}{b}$$

Fig. 5. Amounts of wane

Table 1 Green and dry stresses and moduli of elasticity for grouped softwoods

GREEN STRESSES AND MODULI OF ELASTICITY FOR GROUPED SOFTWOODS

Species group	Grade	Bending	Tension	Compression parallel to grain	Compression perpendicular to grain	Shear parallel to grain	Modulus of elasticity	
							Mean	Minimum
		N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
S1	SS	6·9	4·8	6·3	1·29	0·70	9 200	4 400
	GS	4·8	3·4	4·4	1·15	0·70	8 200	4 000
S2	SS	5·5	3·8	5·4	1·03	0·70	8 000	4 300
	GS	3·8	2·7	3·7	0·92	0·70	7 000	3 900
S3	SS	3·8	2·7	3·6	0·77	0·55	6 100	3 100
	GS	2·7	1·9	2·5	0·69	0·55	5 500	2 800

NOTE. These stresses apply to timber having a moisture content exceeding 18 %.

DRY STRESSES AND MODULI OF ELASTICITY FOR GROUPED SOFTWOODS

Species group	Grade	Bending	Tension	Compression parallel to grain	Compression perpendicular to grain	Shear parallel to grain	Modulus of elasticity	
							Mean	Minimum
		N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
S1	SS	8·6	6·0	8·6	1·93	0·87	10 600	5 100
	GS	6·0	4·2	6·0	1·72	0·87	9 500	4 600
S2	SS	6·9	4·8	7·0	1·55	0·79	8 900	4 800
	GS	4·8	3·3	4·8	1·38	0·79	8 000	4 300
S3	SS	5·2	3·6	5·0	1·16	0·66	7 500	3 700
	GS	3·6	2·5	3·5	1·03	0·66	6 800	3 300

NOTE. These stresses apply to timber having a moisture content not exceeding 18 %.

Table 2. Visual grading requirements for machine stress graded lumber.

	MGS	MSS and M50	M75
Fissures	Same as GS	Same as SS	. if size of the defect ≤ ½ thickness, length of the fissures ≤ 600 mm or ¼ length of piece. . if size of defect > ½ thickness, fissures permitted only at ends of piece of length ≤ width of piece
Wane	"	"	shall not exceed 1/8 of surface on which it appears
Resin pockets	"	"	same as fissures
Distortion	"	"	same as SS
Worm holes	"	"	same as SS
Sapstain	"	"	same as SS
Abnormal defects	"	"	same as SS

Table 3. Processing categories, sizes and tolerances of British lumber.

Moisture content. The sizes given in Table 53 are to be measured as at 20% moisture content. For any higher moisture content up to 30% the size should be greater by 1% for every 5% of moisture content in excess of 20% and for any lower moisture content the size may be smaller by 1% for every 5% of moisture content below 20%. For any higher moisture content than 30% no larger size will be required than at 30%.

Sawn timber. The basic cross-sectional sizes of sawn timber are given in Table 53. Minus deviations in size are not permitted in more than 10% of the pieces in any parcel. In thicknesses and widths not exceeding 100 mm the permissible deviation is -1 mm, +3 mm, and in thicknesses and widths exceeding 100 mm the permissible deviation is -2 mm, +6 mm.

The basic lengths of sawn timber are given in Table 54. On lengths, no minus deviation is permissible, but overlength is unlimited.

The geometrical properties of sawn timber are given in Table 55.

For re-sawn timber a reduction in size below the basic size of not more than 2 mm is permitted in each piece so produced. Since re-sawing will normally only be employed to produce small dimensions, the effect of this reduction on the geometrical properties, which is not allowed for in Table 55, should be taken into account in any design employing re-sawn timber.

Precision timber. Precision timber is regularized, measured and supplied at a moisture content within the range 14% to 20% with an average not exceeding 18%. A reduction of 1 mm on the basic thicknesses and widths given in Table 53 is permitted for this processing. This reduction should be neglected in calculating the geometrical properties of the sections.

The geometrical properties of precision timber are therefore the same as for sawn timber and are given in Table 55.

Processed timber. The processing of timber to accurate finished sizes involves reductions in the basic size which vary with size and with the process involved. Average reductions can be established by experience that are economic, workable and not wasteful. For timber for structural use the permitted reductions are:

for sawn widths and thicknesses up to and including 100 mm: 3 mm

for sawn widths and thicknesses over 100 mm and up to and including 150 mm: 5 mm

for sawn widths and thicknesses over 150 mm: 6 mm.

The geometrical properties of processed timber to the abive tolerances are given in Table 56.

TABLE 53. BASIC SIZES OF SAWN SOFTWOODS (CROSS-SECTIONAL SIZES)

Thickness	Width (mm)								
	75	100	125	150	175	200	225	250	300
mm									
16	x	x	x	x					
19	x	x	x	x					
22	x	x	x	x					
25	x	x	x	x	x	x	x	x	x
32	x	x	x	x	x	x	x	x	x
36	x	x	x	x					
38	x	x	x	x	x	x	x		
40*	x	x	x	x	x	x	x		
44	x	x	x	x	x	x	x	x	x
50	x	x	x	x	x	x	x	x	
63		x	x	x	x	x	x		
75		x	x	x	x	x	x	x	x
100		x		x		x		x	x
150				x		x			
200						x			
250								x	
300									x

* For 40 mm thickness, designers and users should check availability.

TABLE 54. BASIC LENGTHS OF SOFTWOODS

m	m	m	m	m	m
1·80	2·10	3·00	4·20	5·10	6·00
	2·40	3·30	4·50	5·40	6·30
	2·70	3·60	4·80	5·70	
		3·90			

TABLE 55. GEOMETRICAL PROPERTIES OF SAWN AND PRECISION TIMBER (*cont.*)

Basic size	Area	Section modulus		Second moment of area		Radius of gyration	
		About x-x	About y-y	About x-x	About y-y	About x-x	About y-y
mm	10^3 mm²	10^3 mm³	10^3 mm³	10^6 mm⁴	10^6 mm⁴	mm	mm
44 × 75	3·30	41·2	24·2	1·55	0·532	21·7	12·7
44 × 100	4·40	72·3	32·3	3·67	0·710	28·9	12·7
44 × 125	5·50	115	40·3	7·16	0·887	36·1	12·7
44 × 150	6·60	165	48·4	12·4	1·06	43·3	12·7
44 × 175	7·70	225	56·5	19·7	1·24	50·5	12·7
44 × 200	8·80	293	64·5	29·3	1·42	57·7	12·7
44 × 225	9·90	371	72·6	41·8	1·60	65·0	12·7
44 × 250	11·0	458	80·7	57·3	1·77	72·2	12·7
44 × 300	13·2	660	96·8	99·0	2·13	86·6	12·7

TABLE 56. GEOMETRICAL PROPERTIES OF PROCESS[illegible] TIMBER (*cont.*)

Basic size	Minimum size	Area	Section modulus		Second moment of area		Radius of gyration	
			About x-x	About y-y	About x-x	About y-y	About x-x	About y-y
mm	mm	10^3 mm²	10^3 mm³	10^3 mm³	10^6 mm⁴	10^6 mm⁴	mm	mm
40 × 75	37 × 72	2·66	32·0	16·4	1·15	0·304	20·8	10·7
40 × 100	37 × 97	3·59	58·0	22·1	2·81	0·409	28·0	10·7
40 × 125	37 × 120	4·44	88·8	27·4	5·33	0·507	34·6	10·7
40 × 150	37 × 145	5·36	130	33·1	9·40	0·612	41·9	10·7
40 × 175	37 × 169	6·25	176	38·5	14·9	0·713	48·8	10·7
40 × 200	37 × 194	7·18	232	44·3	22·5	0·819	56·0	10·7
40 × 225	37 × 219	8·10	296	50·0	32·4	0·924	63·2	10·7

APPENDIX IV

1982 Selected Data from the ECE Proposed Softwood Stress Grades (25)

Table 1. ECE recommended standards for stress grading and finger-jointing of coniferous sawn timber.

Operational control

Visual grading should be carried out by properly trained and qualified personnel approved by a competent approving authority and there should be adequate supervision and control to ensure that the required standards of grading are maintained.

Where grading is done by machine, the grading machine used must be of a type approved by a competent approving authority and operated by properly trained and qualified personnel.

The machine must be calibrated, maintained, licensed and operated under a scheme of supervision prepared by the controlling authority, and must be subject to periodic and unannounced inspections.

In order that machine graded softwood is acceptable when exported to any country using this standard, a method for deriving grading machine settings must be mutually approved.

Table 2. ECE 1982.

2. TERMS AND DEFINITIONS

Where timber terms are used, they have the meaning assigned to them in ISO/R 1031-1969 and in addition the following definitions apply:

2.1 Fissures. A longitudinal separation of the fibres, appearing on a face, edge or end of a piece of timber, and including checks, shakes and splits.

2.2 Total knot area ratio (Total KAR). The ratio of the sum of projected cross-sectional areas of all knots intersected by any cross-section to the total cross-sectional area of the piece

Margin. The areas adjoining the edges of the cross-section, each of which occupies one-quarter of the total cross-sectional area of the piece (see Fig. 1). Square pieces are to be graded on their most unfavourable aspect.

Margin knot area ratio (Margin KAR). The ratio of the sum of the projected cross-sectional area of all knots or portions of knots in a margin intersected at any cross section to the cross-sectional area of the margin. The methods for determining the knot area ratio in cases of dispute are set out in Appendix B.

Visually stress graded timber. A piece of timber which has been graded by visual inspection by properly trained and qualified personnel and to which stress values can be assigned.

Machine stress graded timber. Timber which has been non-destructively graded by an approved system of sensing and measuring one or more of its properties, the system being such that, together with any necessary visual inspection, stress values may be assigned.

Approving authority. A body responsible for approving the qualifications of trained visual grading personnel and for the assessment of stress grading machines.

Controlling authority. A body responsible for the performance of visual grades or for the operation of stress grading machines. In some countries approval and control may be carried out by the same authority.

Table 3. ECE 1982.

MEASUREMENT

Knots. Knots shall be assessed by their Total KAR and Margin KAR. In making this assessment, knots of less than 5 mm diameter on any surface of the piece may be ignored. No distinction shall be made between knot holes, dead knots or live knots. The method of assessing KAR is illustrated in Fig. 2.

Slope of grain. Slope of grain shall be assessed as the inclination of the wood fibres to the longitudinal axis of the piece. The slope shall be expressed as the number of units of length over which unit deviation occurs. It shall be measured over a distance sufficiently great to determine the general slope, disregarding local deviations. Where there is sloping grain on both edge and face of a piece, the combined slope of grain is illustrated in Fig. 3.

Rate of growth. Rate of growth shall be measured as the average width in mm of the growth rings, measured along the longest radial line which can be drawn at either end of the piece. If the size of the piece permits, the line should be 75 mm long. In cases of boxed heart (i.e. with pith present) the measurement line should begin 25 mm from the pith. In side cut pieces (i.e. free of heart centre) the measuring line shall be centrally located.

Wane. Wane shall be assessed as the ratio of the projection of the wane on a surface to the full thickness or width of that surface. The method of assessing wane is illustrated in Fig. 5.

Distortion. The methods of assessing distortion are illustrated in Fig. 6. Bow, spring and twist shall be assessed over a 2 m length and cup over the width of the piece.

> The amount of distortion will largely depend on the moisture content at the time it is measured. A precise definition to cover all conditions and applications cannot, therefore, be given and guidance only is provided as to what might be considered acceptable limits, but not typical of any parcel of timber.

Pitch pockets and inbark. These shall be assessed as fissures or knots according to their shape as laid down in table 2. If considered as knots, they must be taken into account when assessing KAR.

Table 4. ECE 1982.

MACHINE GRADES (MS10, MS8 and MS6)

General. Stress grading can be performed either by visual grading or by a combination of visual and machine grading. In the latter case, for each grade there should be a set of specifications for characteristics other than knots, slope of grain, and rate of growth. To qualify for a grade, each piece must be passed through an approved stress grading machine and must be classified by the machine as complying with the grade. In addition, a visual inspection of each piece must be made to ensure that characteristics other than knots, slope of grain and rate of growth satisfy the permissible limits for the grade.

It is possible to machine grade to standard strength classes which have minimum characteristic values for mechanical properties; these classes are independent of wood species. The CIB W.18 in its Structural Design Code lays down standard strength classes for solid (i.e. non-jointed) coniferous sawn timber.

Where a machine does not fully grade to both ends, a visual check for knots shall be made of the non fully-graded portion. If, upon assessing this portion, it is found to have a knot larger than the maximum permitted for the relevant grade, and if such a knot is also larger than any existing in the fully graded portion, then the piece shall be rejected.

MS10, MS8, MS6. There are three machine stress grades specified, namely MS10, MS8 and MS6, which have the same stress values in bending as the corresponding S10, S8 and S6 visual grades according to clause 4.1. 1/

For MS10, MS8 and MS6 the characteristics other than knots, slope of grain and rate of growth must satisfy the permissible limits for the grades S10, S8, S6 respectively, according to table 2.

Table 5. RECOMMENDED INFORMATION TO BE SUPPLIED WHEN SEEKING INTER-COUNTRY APPROVAL OF STRUCTURAL TIMBER

Part I. Product Specification and Strength Properties

I A-GRADING

1 General

11 Grading rules applied (Reference)

12 Authority responsible for grading rules

13 Authority responsible for strength evaluation

14 Relation of rules to national and international standards, if not clear from above

15 Any special restrictions of rules, e.g. with respect to species and sizes covered

16 Rules for approval of manufacturers

2 Timber

21 Commercial or standard names and species of timbers for approval

22 Nominal and actual cross-section sizes, (range), tolerances, etc.

3 Grades

31 Nominal grades or class assignments

4 Strength properties

Characteristic strength values (5-percentile) and characteristic elasticity values (5- and 50-percentile) at specified moisture content for the grades in question

Information on the depth used as a basis for calculating the above values

5 Marking

51 Details of mark relating to quality assurance, grade and identity of timber

6 Application

61 Particular restrictions of use in the national code of practice

7 Documentation

71 Reference to documents on which a national approval is based

I B-JOINTING

1 General

11 Jointing rules applied (Reference)

12 Authority responsible for rules

13 Relation of rules to national and international standards, if not clear from above

14 Any special restrictions of rules e.g. with respect to species and sizes covered, type of joint, type of adhesive

15 Rules for approval of manufacturers

2 Timber

21 Commercial or standard names and species of timbers for approval

3 Joints

31 Type of adhesive used and durability with reference to standard

32 Joint profiles used including restrictions with respect to cross-section dimension and stress grade

4 Strength properties

41 Stress grades permitted to be jointed according to rules

42 Possible reduction of certain grade strength values

5 Marking

51 Details of mark relating to quality assurance, grade and identity of timber

6 Application

61 Particular restrictions of use in the national code of practice

7 Documentation

71 Reference to documents on which a national approval is based

Part II. Production rules and control

II A-GRADING

II AA-VISUAL STRESS GRADING

1 Grading rules applied (Reference). Principal grading criteria

2 Training of graders. Training courses and certification. Responsible authority. Liability insurance

3 Checking of grading performance. Authority responsible for control of grading

4 Detailed description and interpretation of mark (illustration)

5 Other information

II AB-MACHINE STRESS GRADING

1 General rules for grading by machine including supplementary visual grading (Reference)

2 Type of machines used

3 Specific rules for the type of machines used, including control

4 Principle for grading programme. Authority responsible for programme

5 Production and product control

6 Authority responsible for control of machine performance and grading

7 Detailed description and interpretation of mark (illustration)

8 Other information

II B-JOINTING

1 General rules for approval and control (Reference)

2 Authorities responsible for approval and control of joints and jointing performance

3 Production lines : Grading, cutting, preheating, application of glue, pressing, planing and post-curing. Type of machines used. Capacity. (Concise description)

4 Principal rules for location (distance to knots) and spacing of joints

5 Marking performance including recording of possible marks on the input timber

6 Running control of production and joints by the manufacturer. Number of tests and testing methods (reference to standard)

7 Supervisory control, inspection and testing

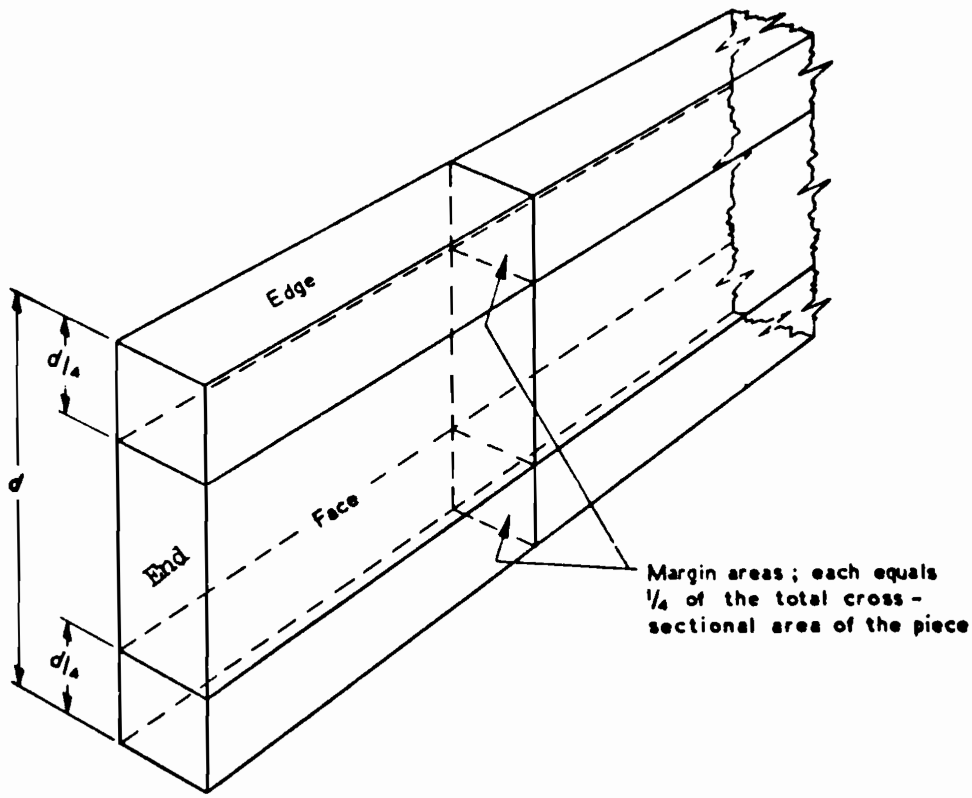
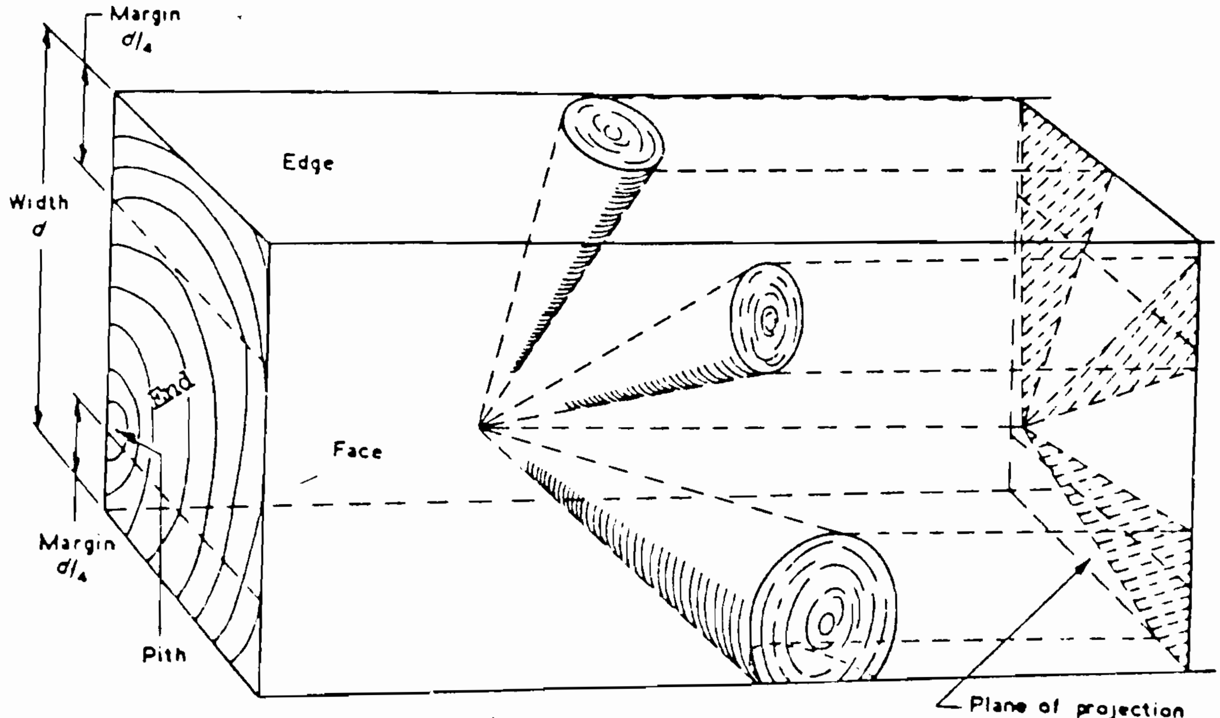


Fig. 1. **Edge, end, face and margin areas**



(a) Axonometric view showing in three-dimension a group of knots in a piece and their projection on a cross-sectional plane

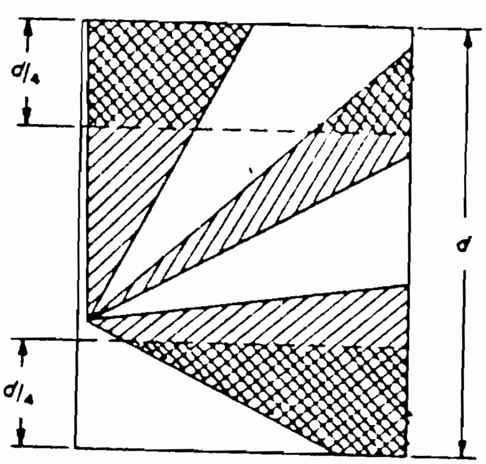
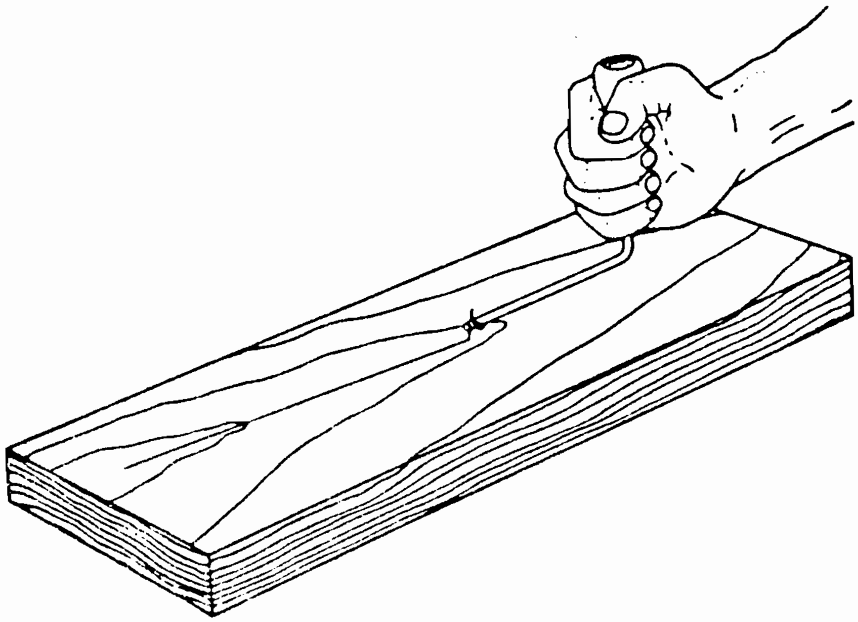
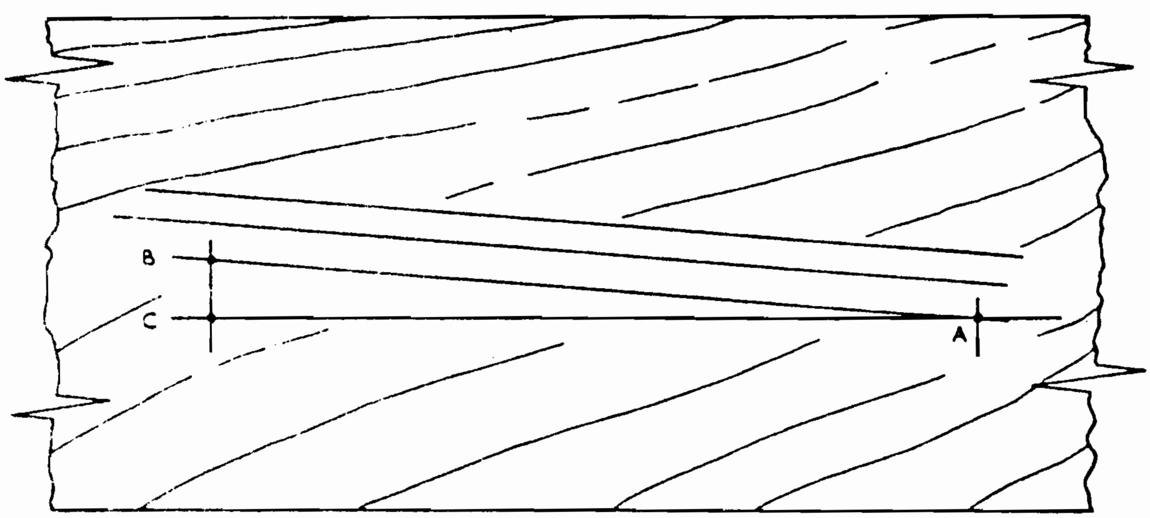


Fig.2. Knots

(b) Front view of projection plane, showing projection of knots (hatched) and those parts which fall in the margin area (cross-hatched)



Use of scribe



Slope of grain = 1 in $\frac{AC}{BC}$

Fig. 3. Slope of grain

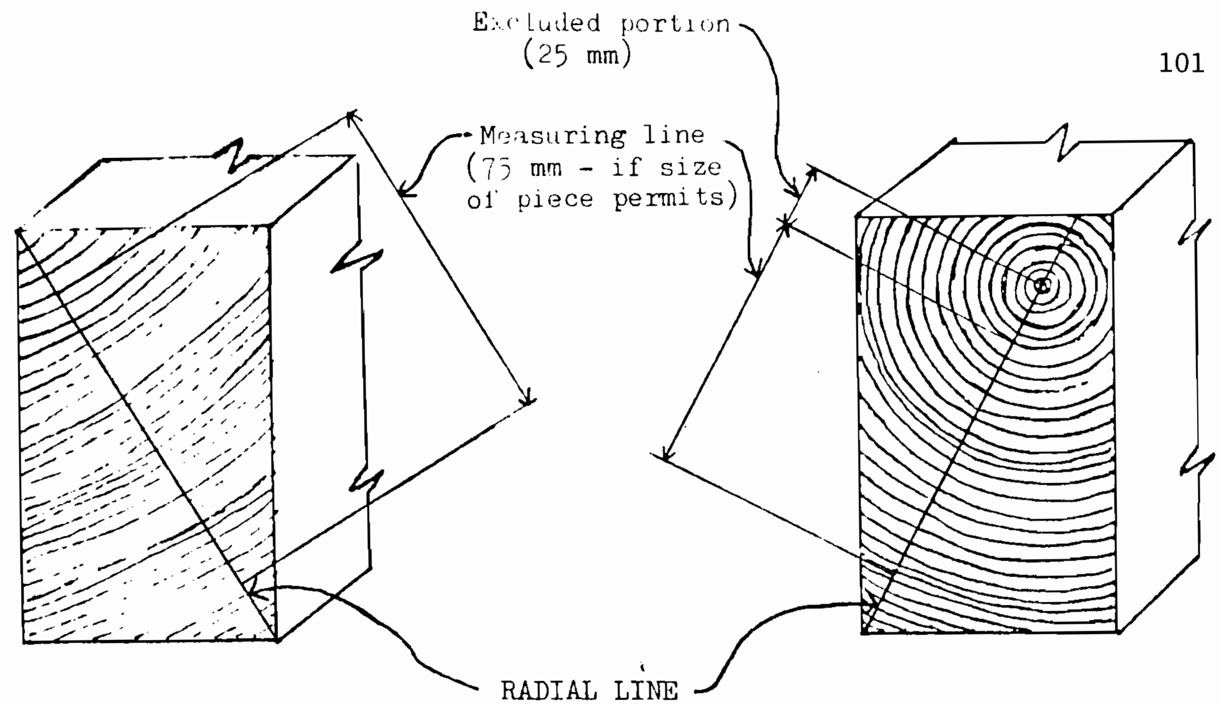


Fig. 4. Rate of growth

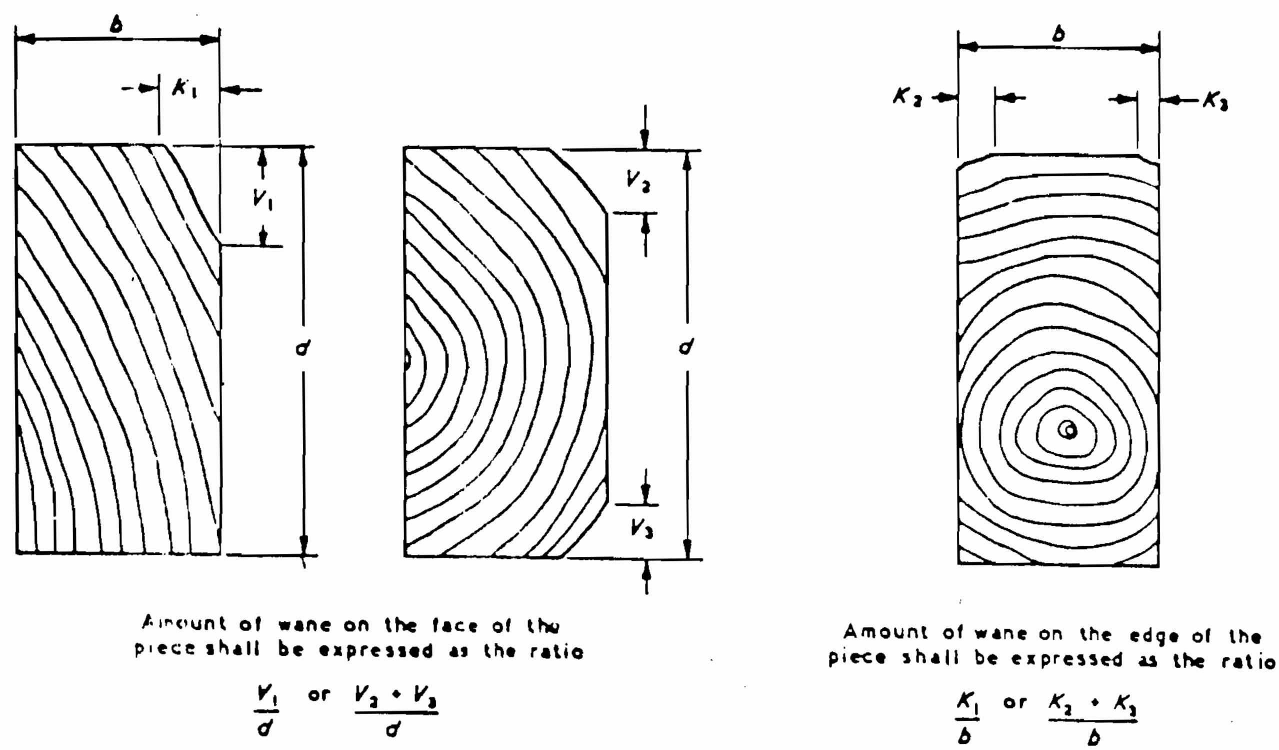


Fig. 5. Wane

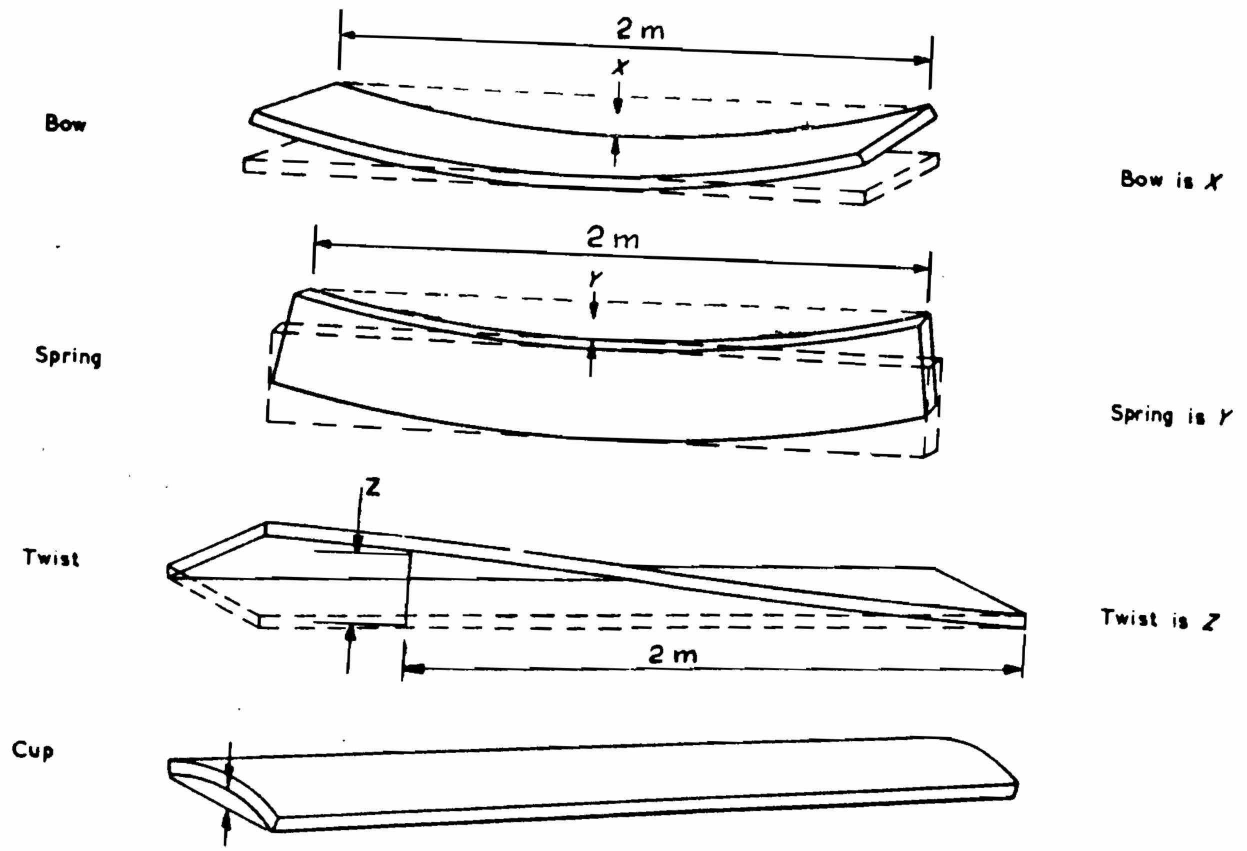
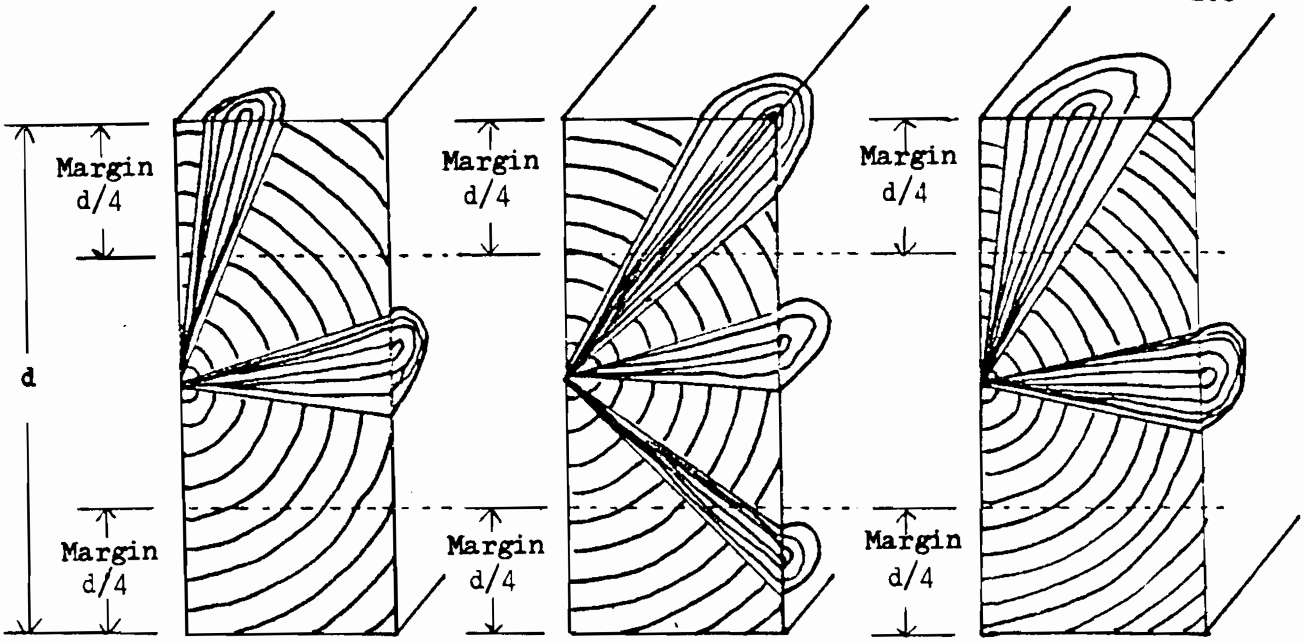


Fig. 6. Distortion



a. Margin KAR is not greater than 1/2 and Total KAR not greater than 1/3

Therefore
Grade = S8

b. Margin KAR is not greater than 1/2 and Total KAR not greater than 1/2.

Therefore
Grade = S6

c. Margin KAR is greater than 1/2 and Total KAR not greater than 1/3.

Therefore
Grade = S6

Fig. 7 : Examples of knot area ratios which determine either S8 or S6 grades

APPENDIX V

Simulation Procedure Comparing BSCP 4978 Visual Stress Grades and North American Visual Stress Grades

I Introduction

Knots are strength reducing features which have a major influence in visual determination of the structural grade of softwood lumber. British Standard 4978 and the Economic Commission for Europe (ECE) stress grading standards require estimates of knot area ratio (KAR). The grader concentrates on the most severely knot impacted cross section of the piece, estimates the fraction of the margin and total cross section occupied by knots, and compares these fractions with grade limitations. The KAR measurement technique estimates the clear wood fiber displacement attributable to knots and provides a means to quantify the impact of knots on lumber strength. The grade limitations for margin and total KAR are constant fractions of the range of framing lumber cross sectional sizes and facilitates ease of application by grading personnel.

Theoretically, knots in a log are arranged radially as cones with their apex at the pith. The angle of projection of a knot through a cross section of lumber depends on the location of the knot within the piece in relation to the pith of the log from which the piece was cut. Although the projection of knots passing through lumber at various angles is difficult to determine exactly under production time constraints, British and ECE KAR grading imply a degree of angular projection analysis in order to calculate the margin and total KAR attributable to narrow or wide face knots.

The North American National Grading Rule (NGR), as interpreted by the Western Wood Products Association, presents knot assessment procedures which imply angular projection analysis to estimate cross sectional fiber displacement for narrow face knots. However, the displacement of wide face knots is estimated as the area of a cylinder through the plane of the piece with an effective knot diameter adjusted for knot taper within the piece, and a length equal to the thickness of the piece.

For the purposes of this cross referencing study, only wide face knots are considered. In addition, vertical projection of knots through the thickness of lumber is assumed. These assumptions avoid the complications associated with quantifying the displacement of knots projected at various angles.

This study will present an approximate method to cross reference the WWPA grades of Light Framing (LF), Structural Light Framing (SLF), and Structural Joists and Planks (SJP) to the British and ECE KAR grades. The knot diameter limitations for the WWPA grades will be used as the basis for estimating their KAR equivalency. The WWPA, British, and ECE grades will be compared and cross referenced on a KAR basis.

II The WWPA Knot Assessment Technique

A) Structural Light Framing and Structural Joists and Plans

SLF ranges in nominal cross sectional sizes from 2" x 2" to 4" x 4". SJP range in thickness from 2" to 4" and the width range is 5" and wider with explicit knot provisions for widths up to 14". SLF and SJP products are evaluated for location, size, and character of knots. A knot located at the edge of a wide face has a greater impact on bending strength than the same size knot located in the center of wide face. For this reason, SLF and SJP allow an increasing gradation of allowable knot diameters from the edge to the center line of the wide face. The knot diameter limitations for each grade of SJP and SLF (excluding Economy) is also dependent on the minimal width of the piece. Narrow face knot diameter limitations, or equivalent knot displacement limits, are equal to that specified for knots on the edge of the wide face.

Knot spacing requirements for the structural framing grades are based on the "well spaced" knot definition which requires that the sum of the sizes of all knots in any 6" length must not exceed twice the size of the largest knot permitted. In addition, not more than one knot of the maximum permissible size may exist in the same 6" of length. The combination of knots must not be serious.

B) Light Framing

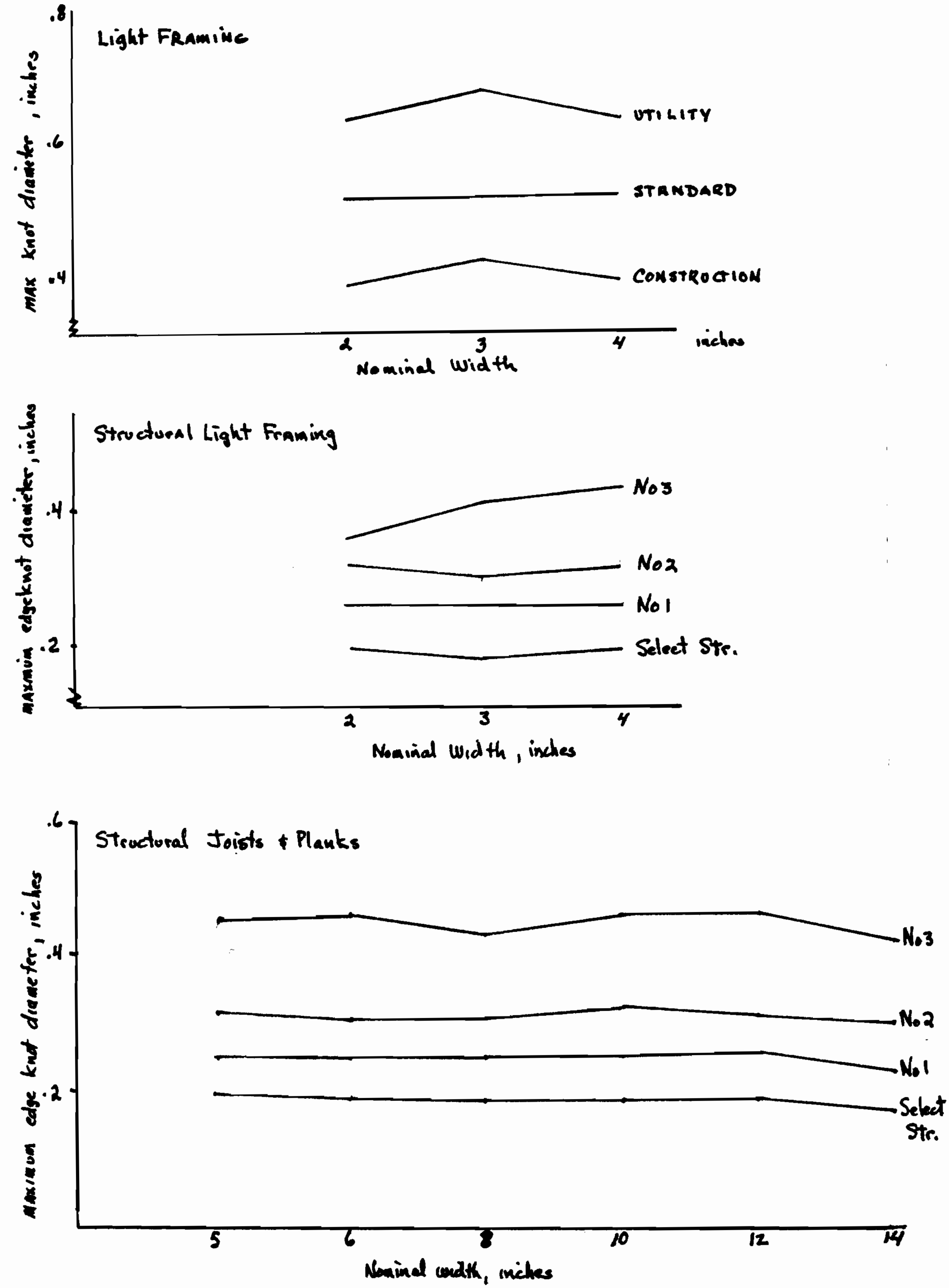
LF ranges in nominal cross sectional size from 2" x 2" to 4" x 4" and is graded according to size and character of knots. The location of a knot across a given cross section is not a factor in the knot impact analysis. The internal stress induced by compressional loading is uniform across the whole cross section. The wood fibers are uniformly stressed parallel to and along the full length of the piece. As a result, allowable sound knot sizes for the LF grades (Construction, Standard, Utility), do not vary by location across the wide face. Open face spike knots (narrow face knots exposed across the wide face) are limited more than closed spike knots (knots enclosed within the cross section).

III The Problems Associated with Cross Referencing the WWPA and UK-ECE KAR Grades

A) Knot Diameter/Nominal Width Ratios

The KAR implied by the WWPA knot diameter limitations is dependent on the width and therefore the cross section area of a piece. Figure 1

Figure 1 Comparison of Maximum Knot Diameter and Nominal Width of WWPA Structural Lumber



presents the relationship between the maximum knot diameter allowed and nominal width for LF, SLF, and SJP grades. Deviations from a constant relationship are evident for particular grades within each product category. The largest deviations exist for Utility of LF, No 3 of SLF, and No 3 of SJP.

In contrast, the British and ECE visual stress grading provisions specify grade KAR limits as constant fractions of the margin or total cross sectional area. The KAR limits are applicable over the total range of cross sectional sizes covered by the standards. The British and ECE standards refer to actual, rather than nominal, cross sectional sizes.

B) Cross Sectional Knot Spacing

The WWPA grading provisions do not explicitly specify knot spacing requirements across a given cross section. The lack of specific knot spacing requirements is an obstacle to deriving an upper limit to the expected margin and total KAR that a grade implies. The "well spaced" requirement mentioned previously applies to the length rather than cross sectional distribution of knots. There exists, however, a definition in the WWPA rules of "well scattered" knots which are not in clusters and each knot is separated from any other by a distance equal to the smaller of the two. This term is not listed in the grading provisions for framing lumber, however it provides a useful guideline for the establishment of upper limits to margin and total KAR implied by the WWPA grades.

IV Development of the Grade Cross Referencing Model

The variation in knot diameter/nominal width ratios, and therefore knot displacement/cross sectional area ratios for particular grades within WWPA product categories presents analytical problems beyond the scope of this study. This variation can be eliminated by assessing the impact of knot displacement on the average cross sectional size corresponding to LF, SLF, or SJP. The average nominal thickness and nominal width based on the range of dimensions allowed in LF, SLF, and SJP were multiplied to obtain the average product cross section. Since SJP does not have an explicit upper limitation on nominal width a 14 inch maximum was assumed because the knot size limitation data is listed for widths ranging up to 14" in the WWPA rule book.

In order to analyze the impact of knots on the average product category cross section the knot size limitation data was averaged by grade for each product category. Table 1 presents the average cross section, and knot limitation data for each product category.

Figure 2 presents formulas for calculating margin and total KAR. The calculation assumes simple perpendicular projection of the edge or centerline knot through the cross section. The edge knots were assumed to exist in the margin area of the hypothetical cross section. The centerline knots exist within the center half of the width of the face. For LF products, the edge (margin) and centerline (centerzone) knots are of equal size.

In order to simulate the occurrence of multiple knots in the center zone of hypothetical cross sections of SLF and SJP, a proportionate reduction of the maximum centerline knot sizes is required to represent the gradation of allowable knot sizes from edge to centerline (Figure 3). The calculations using the formula in Figure 3 depend on the maximum edge and center knot allowed in each grade. In performing these knot size calculations, an assumption must be made regarding knot spacing. The

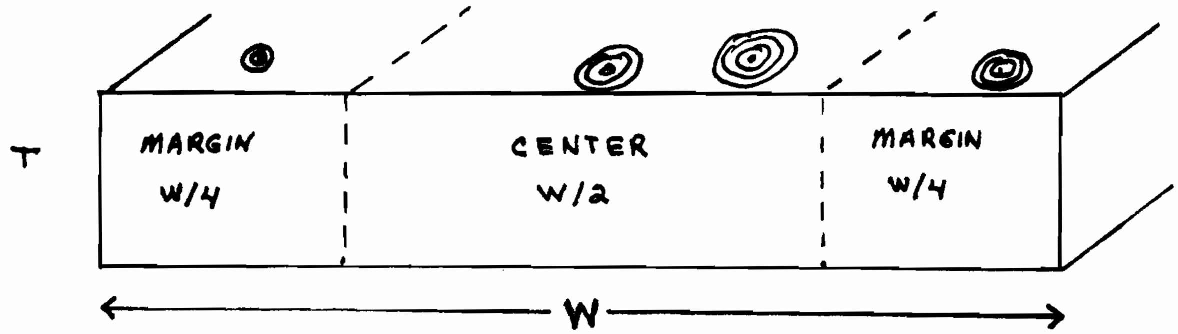
Table 1. Average WWPA Grade Values Used in KAR Analysis

Product	Grade	Average Cross Section, Sq. In.	Average Edge Knot Diameter, In.	Average Center Line Knot Diameter, In.
SLF		8.88[1]		
	Select Str.		.542[2]	.583
	No. 1		.750	.917
	No. 2		.917	1.116
	No. 3		1.250	1.500
SJP		27.5		
	Select Str.		1.688	2.416
	No. 1		2.229	2.979
	No. 2		2.854	3.833
	No. 3		4.083	5.042
LF		8.88		
	Construction		1.166	1.166
	Standard		1.500	1.500
	Utility		1.917	1.917

[1] The possible combinations of SLF are 2x2, 2x3, 2x4, 3x3, 3x4, and 4x4, hence the average dimensions are 2.67 x 3.33 which has a cross section of 8.88 in^2.

[2] The maximum knot diameters allowed at the edge of the wide face of SLF Select Str. are 3/8", 1/2", and 3/4" respectively for 2", 3", and 4" nominal widths; the simple average of these knot sizes is .542".

Figure 2 Formulas for Margin and Total KAR



1. Margin KAR

$$MKAR = \sum_{1}^{NE} \frac{DE * T_c}{A_m}$$

where

DE = diameter (in) of edge knot

T_c = thickness (in) of piece = thickness of knot

A_m = margin area = $W/4 * T_c$

NE = number of edge knots

W = width of piece (in.)

Note: calculate MKAR only for the worst margin

2. Total KAR

$$TKAR = \frac{\sum_{1}^{NEB} DE * T_c + \sum_{1}^{NC} DC\ T_c}{A_c}$$

where

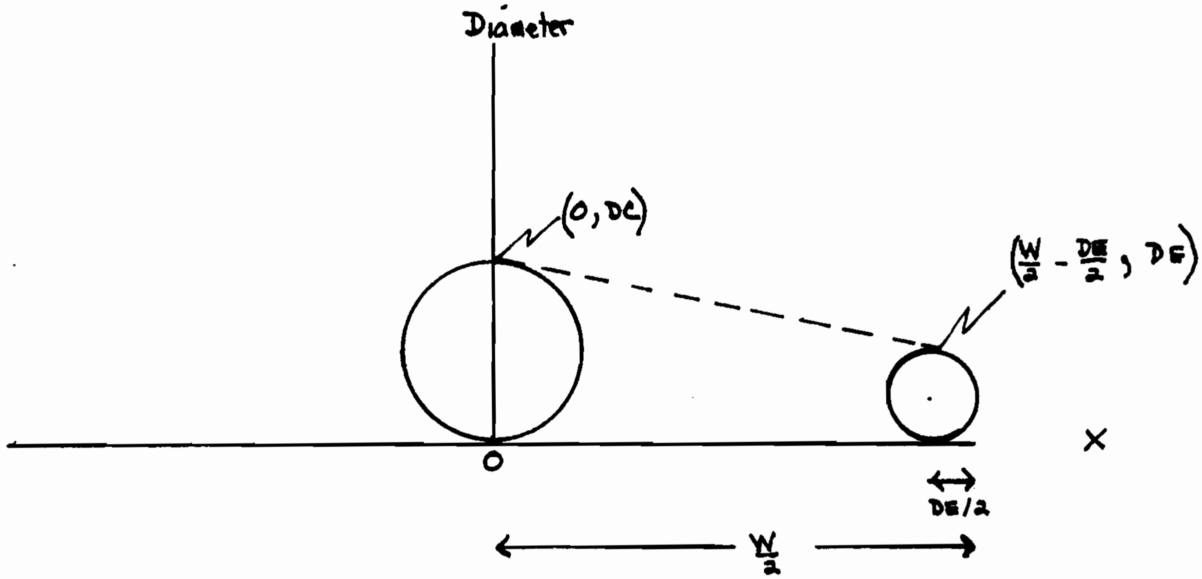
DC = diameter (in) of center knot

A_c = area of cross section = $T_c * W$

NC = number of center knots

NEB = number of edge knots in both margins

Figure 3 Calculation of the Change in Knot Diameter from Center to Edge



$$D = DC - X\left(\frac{DC - DE}{\frac{W}{2} - \frac{DE}{2}}\right)$$

D = diameter, in., of a knot at distance X from the piece center

DC = diameter, in., of center line knot

DE = diameter, in., of edge knot

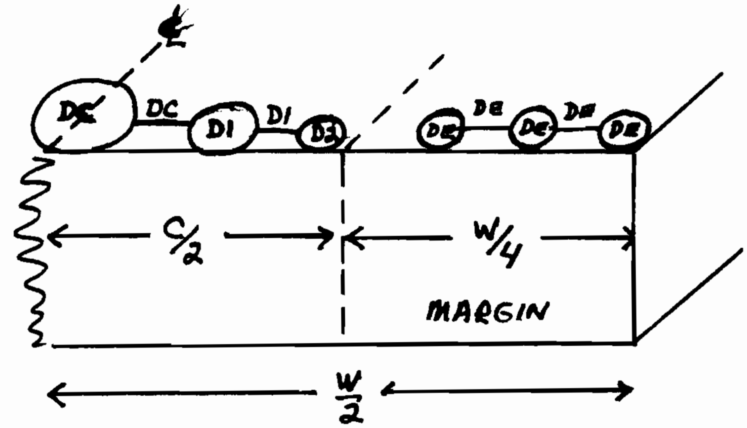
W = width of piece, in.

WWPA definition of the minimum distance between "well scattered" knots uses the diameter of the smaller of the two being compared. This is not practical in our case since we start with the diameter of the largest permitted center knot and are calculating the diameter of a smaller neighbor knot. To overcome this, we have revised the well scattered definition so that we use the diameter of the larger knot which, in our case, is always known in advance. Given the nature of the calculations and the sizes involved we do not believe that this adjustment causes serious discrepancies.

The procedure for estimating the margin and total KAR for hypothetical pieces representing the various grades of LF, SLF, and SJP is outlined in Figure 4. Although we have simplified a number of features, we believe the procedure provides a good approach to an approximate KAR conversion while avoiding numerous complexities. Others may wish to refine the process outlined in this study to obtain more refined conversion. Our goal, however, was only to obtain a first approximation. The procedure was converted to a BASIC computer program which was instructed to replicate the analysis a number of times for a given grade of LF, SLF, or SJP.

The resulting data used in subsequent analyses were combinations of margin and center zone knots yielding a total KAR (TKAR) of less tha 1.0. It is possible, however, that the margin KAR (MKAR) exceed 1.0 if the largest edge knot allowed by a WWPA grade is larger than the margin width defined by the British /ECE system.

Figure 4 Procedure for Simulating the KAR of North American Grades



A. Center zone

1. Produce a centerline knot of diameter DC; the maximum allowed for the grade being considered.
2. Randomly generate the number of additional knots for the region C/2
3. Calculate distance to the next knot; initially this is DC but thereafter it will be the diameter of the knot just previously generated.
4. Calculate diameter of the next knot with the procedure in Fig. 3.
5. Repeat 3-4 until
   a) all possible knots dictated by step 2 have been located
   b) there is insufficient room for more knots in the C/2 region

B. Margin

1. Locate a maximum size edge knot (DE) at the edge of the piece
2. Randomly generate the number of additional knots for the margin
3. The diameter of the next margin knot is assumed to also be DE
   It is possible for these margin knots to be closer together than the diameter distance
4. Repeat step 3 until
   a) all possible knots dictated by step 2 have been located
   b) there is no more room for new margin knots (they would begin to overlap)

C. Calculate MKAR of the margin modeled in step B

D. Calculate TKAR of the full cross section assuming
   1. the other margin has a negligible contribution
   2. the centerzone is symmetrical on both sides of the centerline.

V Graphical Presentation of the Margin and Total KAR Calculations

The outcomes for grades of LF, SLF, and SJP were plotted (Figures 5-10). Total KAR, was plotted against the total number of cross sectional knots. Margin KAR, was plotted against the total number of margin knots.

VI Determining WWPA Grade KAR Limitations

The next phase of the analysis involved the determination of the number of margin and center zone knots expected to exist in the hypothetical cross section of each product category. For LF, SLF, and SJP it was determined that only one maximum size center zone (center line) and one margin (edge) would be located in the hypothetical cross section. This conclusion is based on the modified well scattered knot assumption stated previously. Figure 11 presents a sample calculation of the expected number of margin and center zone knots for SLF.

In KAR grading, at the most severely knot impacted cross section of the piece, the margin with the highest KAR determines the total KAR limitation for the piece. For example, the British grade GS will allow a total KAR of 1/3 or 1/2 if the margin KAR is less than or greater than

Figure 5 Margin K.A.R versus knot quantity

Light Framing

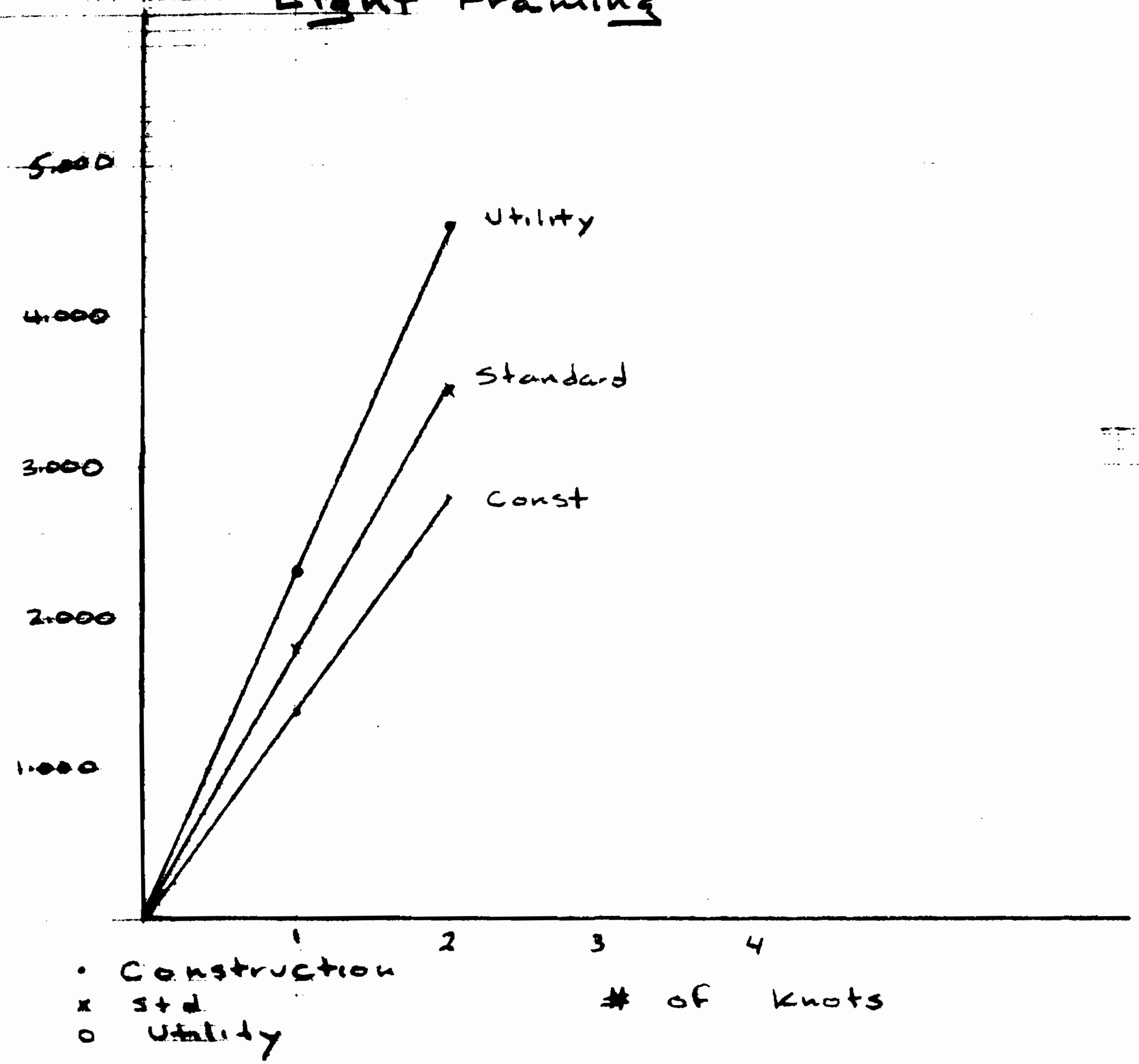


Figure 6 Total K.A.R knot quantity

Light Framing

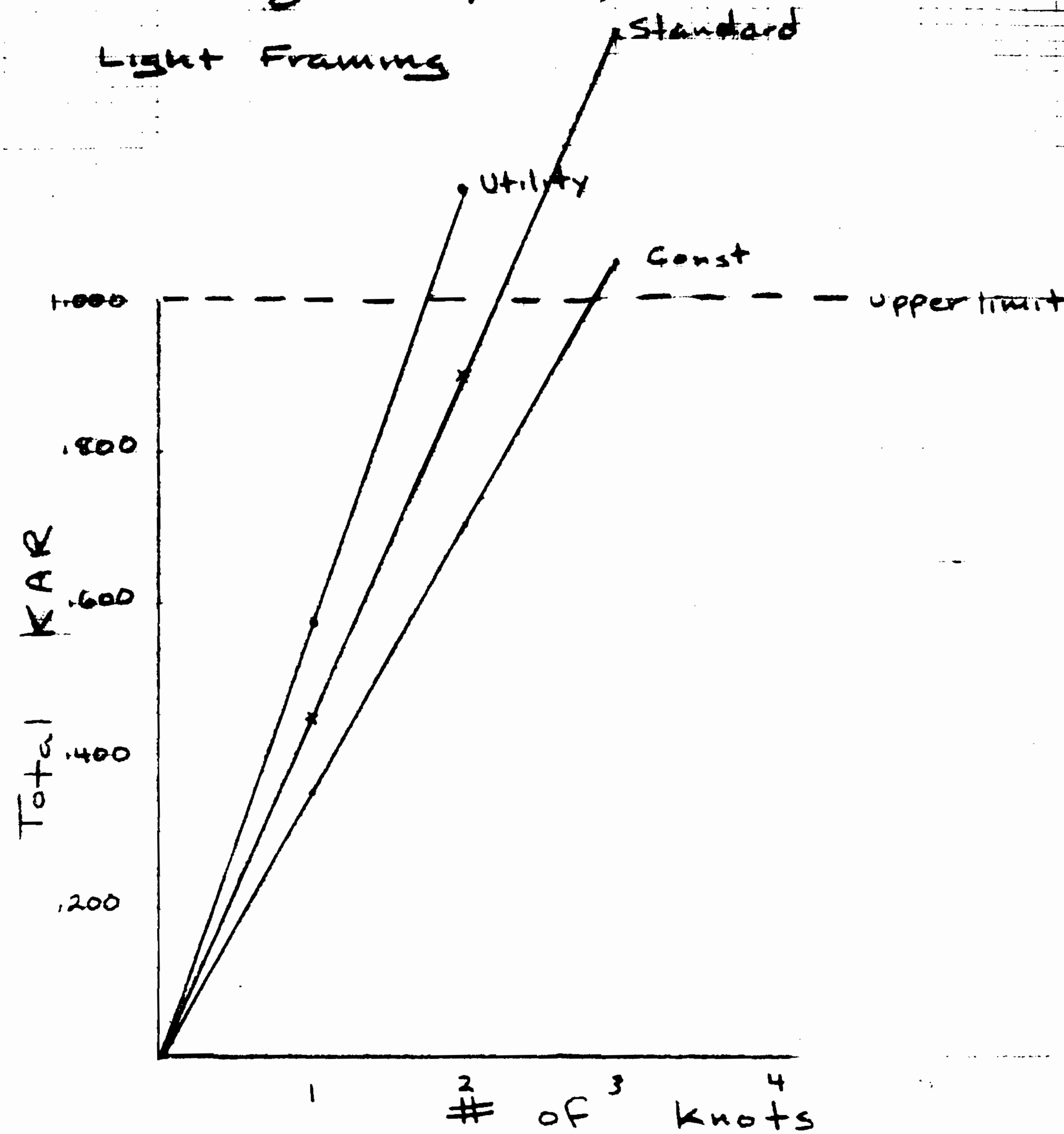


Figure 7 Margin K.A.R versus Knot Quantity

Structural Light Framing

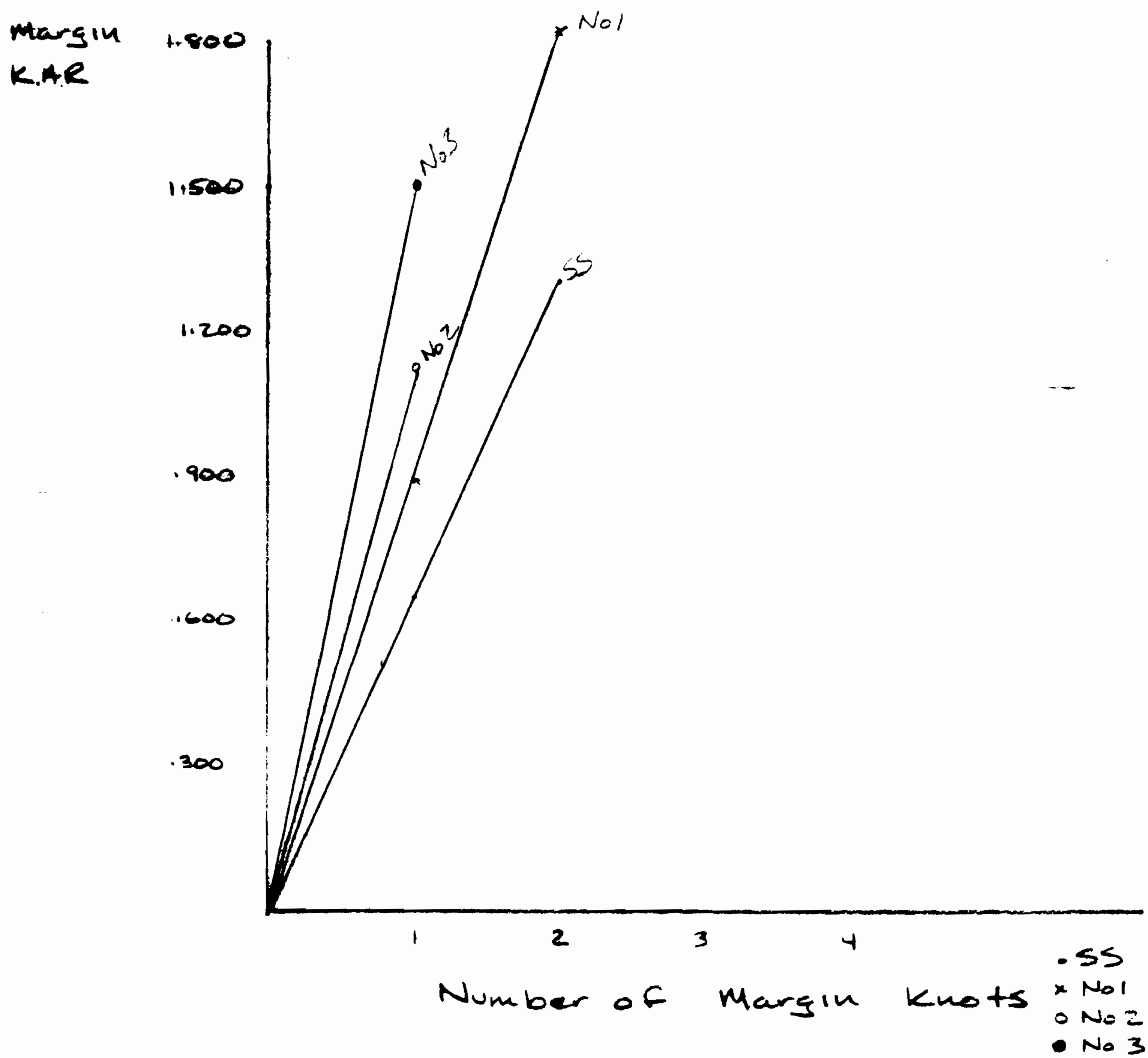


Figure 8 Total K.A.R. versus knot quantity

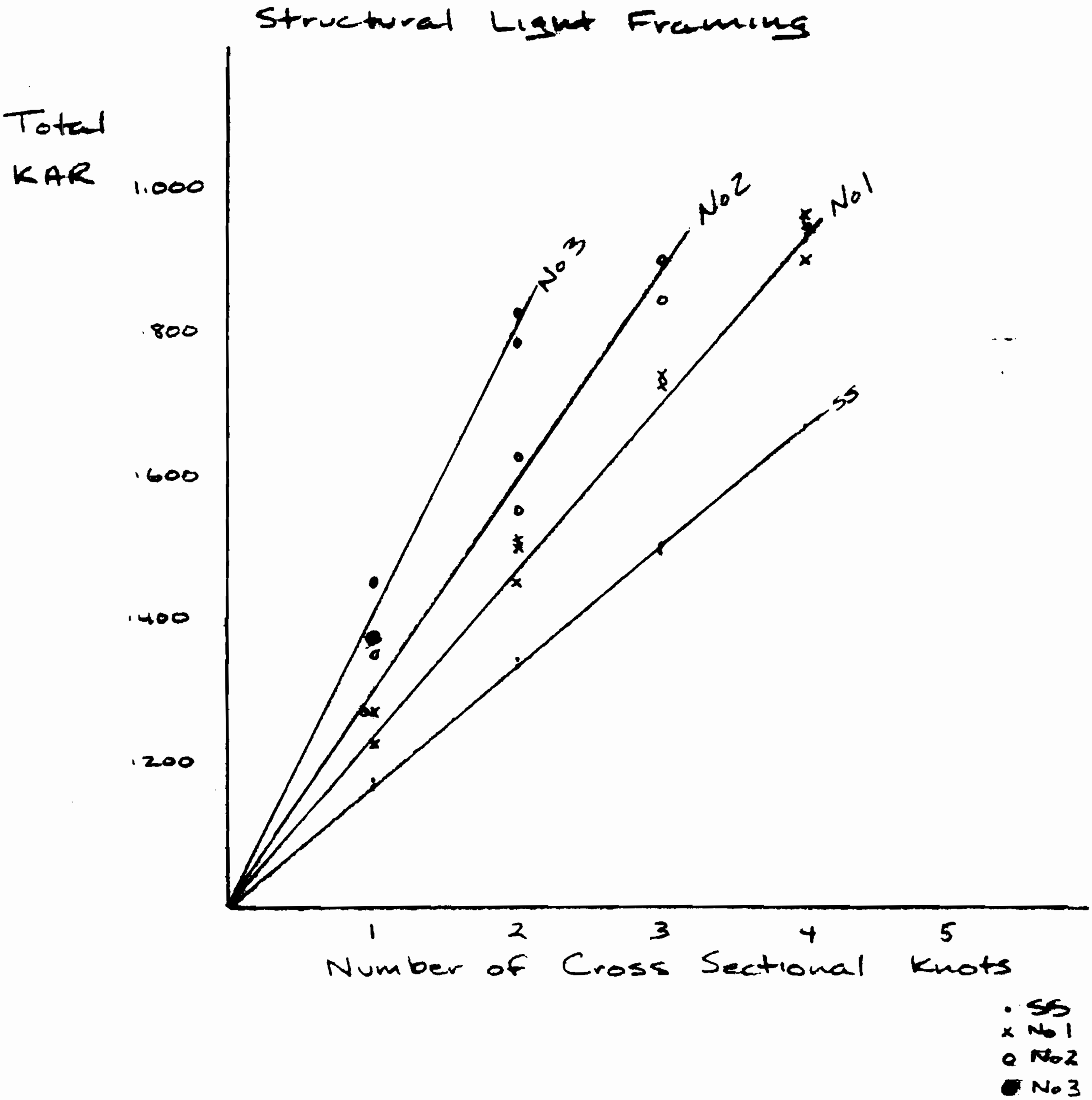


Figure 9 Margin K.A.R. versus Knot ~~[illegible]~~
Structural Joists And Planks

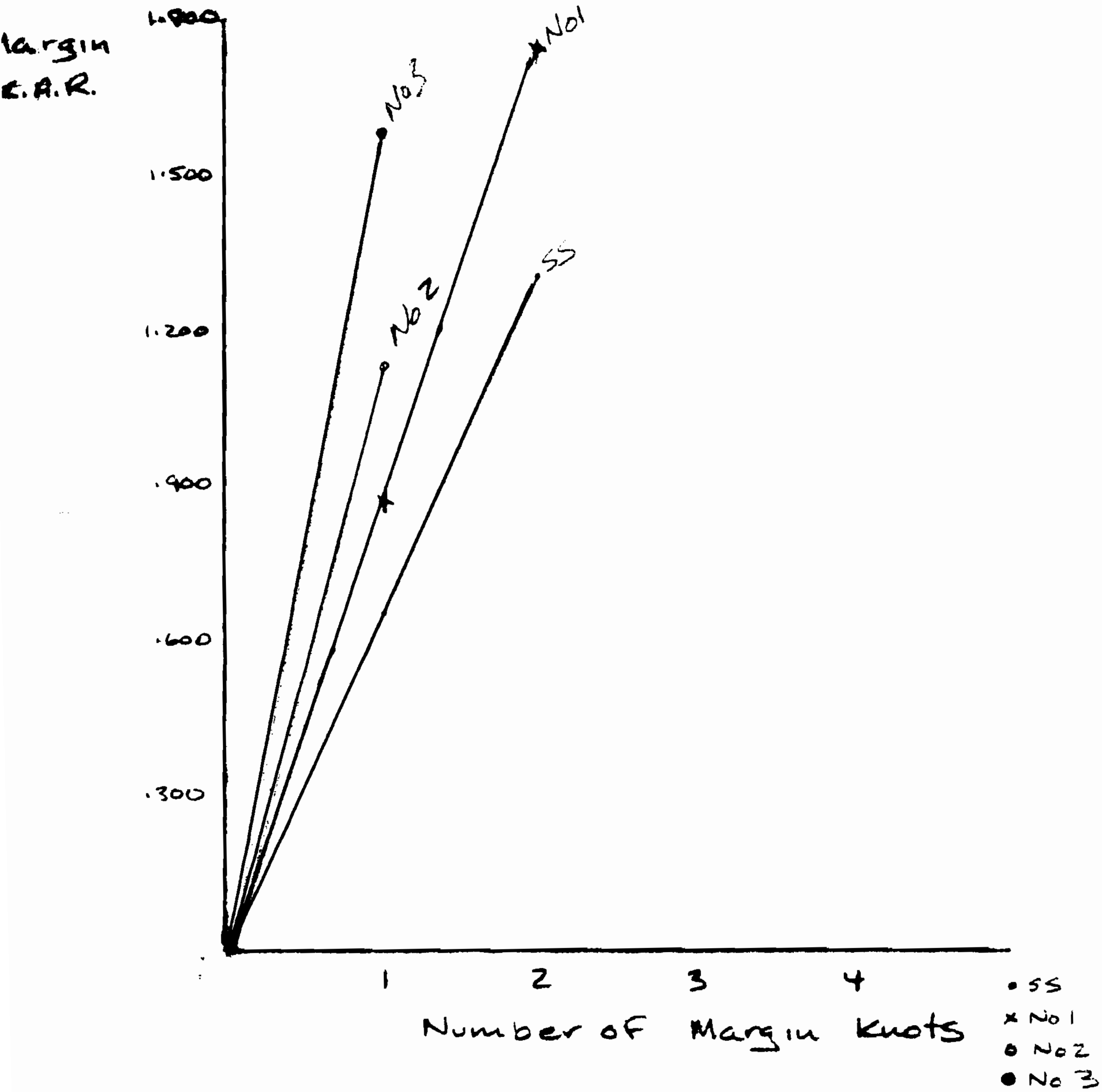


Figure 10 Total K.AR versus knot quantity

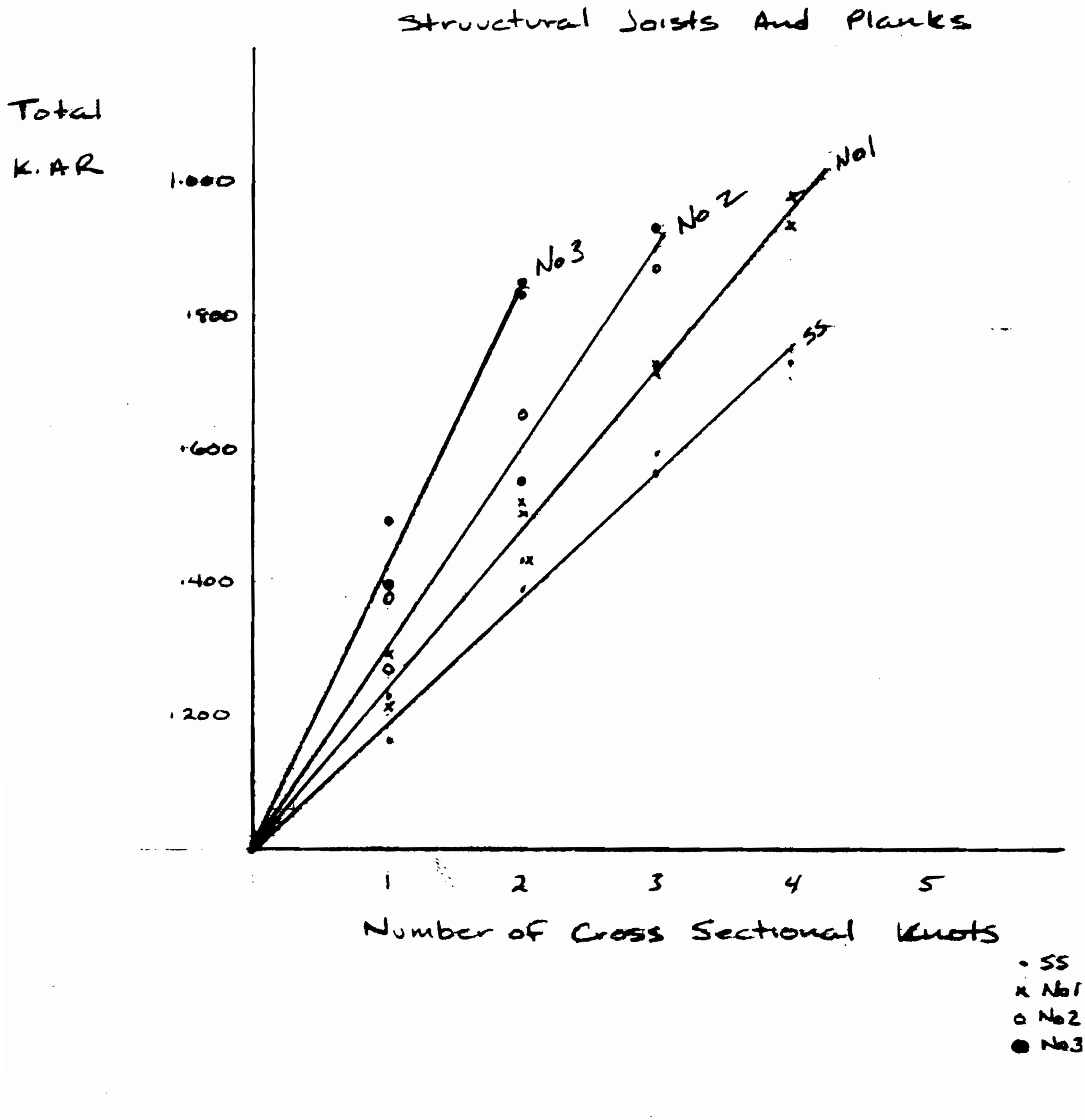
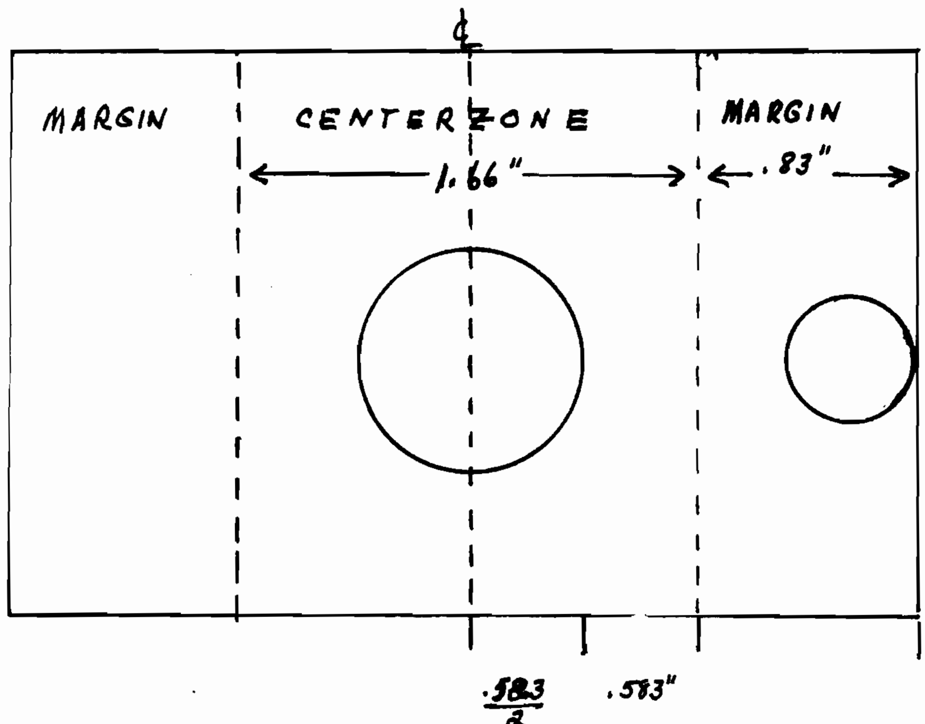


Figure 11 Sample Calculation of Cross Sectional Knot Distribution for Structural Light Framing; Select Grade

Average Cross section	8.88 in.^{2}
Average Thickness	2.66 in.
Average Width, W	3.33 in.
Margin Width, W/4	.83 in.
Center zone width, W/2	1.66 in
Maximum diameter of centerline knot	.583 in
Maximum diameter of edge knot	.542 in



Available Center zone distance for spacing $= \frac{1.66}{2} - \frac{.583}{2} = .538"$

Number of Allowable Knots in Center zone = 1 — No room for others given the knot spacing requirements

Available Margin Distance for Spacing = .83" − .542" = .288"

Number of Allowable Margin Knots = 1 — Remaining room is too small for another knot in the margin

1/2 respectively. The analysis presented here examined the effect of various combinations of center zone knots and knots in the critical margin of the cross section. The contribution of the opposite or non critical margin to total KAR was assumed to be negligible.

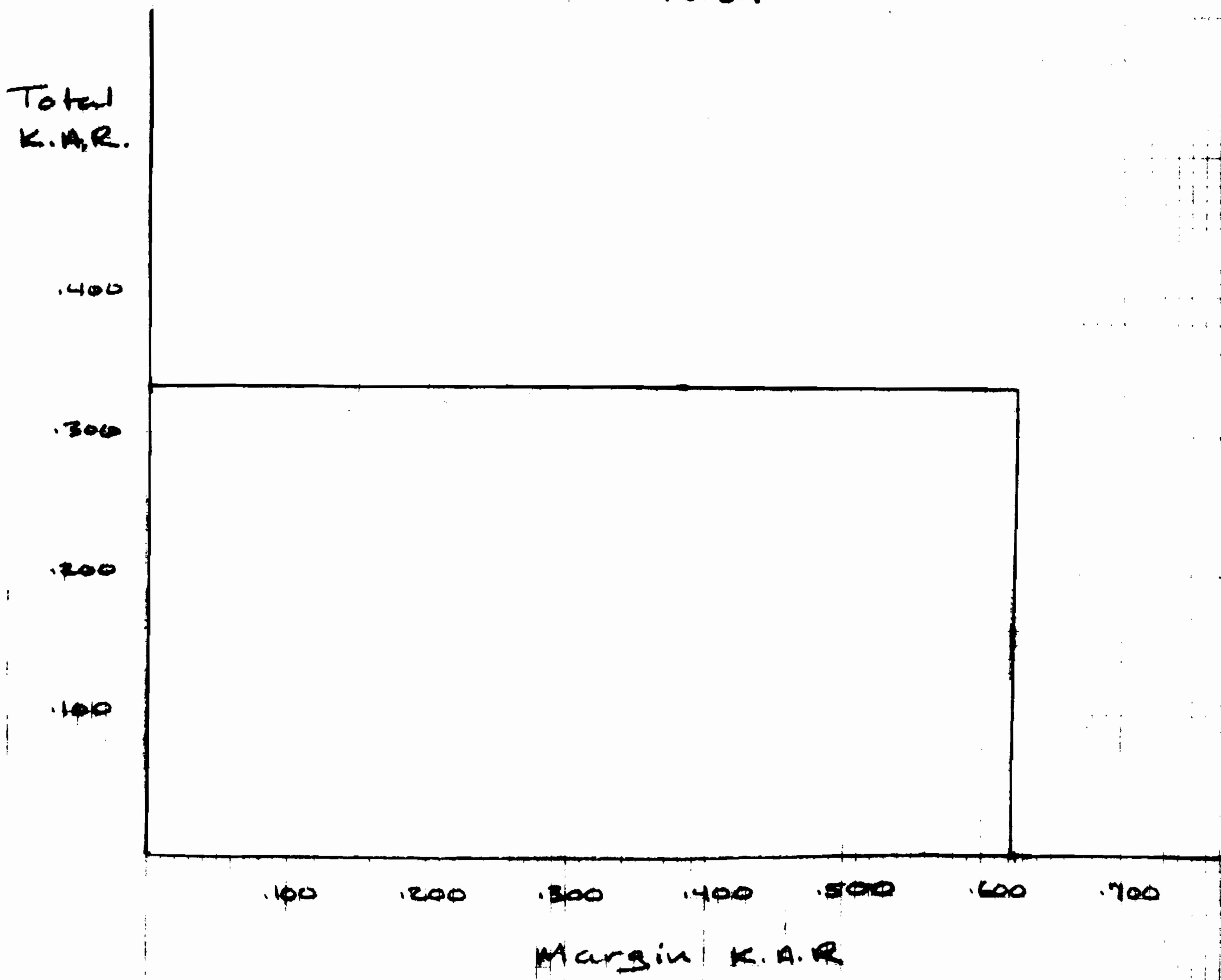
VIII Graphical Presentation of Grade KAR Limitations

The estimation of the expected number of cross sectional knots, enables the definition of the margin and total KAR limitations, for the WWPA grades. The grade limitations were determined from the KAR versus knot quantity graphs. The expected number of margin and center zone knots for a specific grade, and product category is located on the margin and total KAR graphs. The corresponding KAR limit is determined from the graph. For example, the total number of expected cross sectional knots for the Select Str. grade of SLF is two (1 margin, 1 center zone). Figure 8 reveals that the corresponding total KAR limit is .330. Figure 7 shows that the margin KAR limit for Select Str. with one margin knot is .600. Plotting these limits (Figure 12) defines the KAR region occupied by the Select Str. grade of SLF. KAR limitations for the remaining grades of SLF, LF, and SJP were similarly derived.

IX North American UK/ECE Visual Stress Grade Cross Referencing

Each of the WWPA visual stress grades has its own unique rectangular profile on a graph of total versus margin KAR limitations. The British

Figure 12 The K.A.R. domain of SLF Select Structural



and ECE KAR grades also present unique profiles. Overlapping the WWPA, British, and ECE grade KAR profiles provides a basis for converting between grades in each system. The estimated grade conversions, are determined by calculating the proportion of the rectangular area representing a grade KAR limitation profile relative to that represented by a less restrictive grade with a larger profile. This allows estimation of the percentage of the less restrictive grade that would conform to the KAR limitations of the more restrictive grade.

A) WWPA North American-U.K. Visual Stress Grade Conversions

1) Structural Joists and Planks

Figures 13 and 14 graphically present the relationship between the KAR limitations for the SJP grades and the British grades special structural (SS), and General Structural (GS). The British grades restrict total KAR to a greater extent if the margin KAR greater than 1/2. The upper limit to margin KAR in that circumstance is undefined. For the purpose of comparing individual grades, the upper limit was set equal to the North American grade margin KAR limit.

According to the results of the analysis, the British grade KAR limitations are more severe than WWPA grade KAR equivalents. The estimated conversion from SJP Select Str. to British SS and G.S is 78% and 97% respectively. That is, we would expect that 78% of a unit of Select Str. SJP would qualify as SS and that 97% of a unit would qualify as GS, using KAR as the only grading criterion. The Select Str.-GS conversion

Figure 13 Comparison of SJP grades to the British Special Structural grade

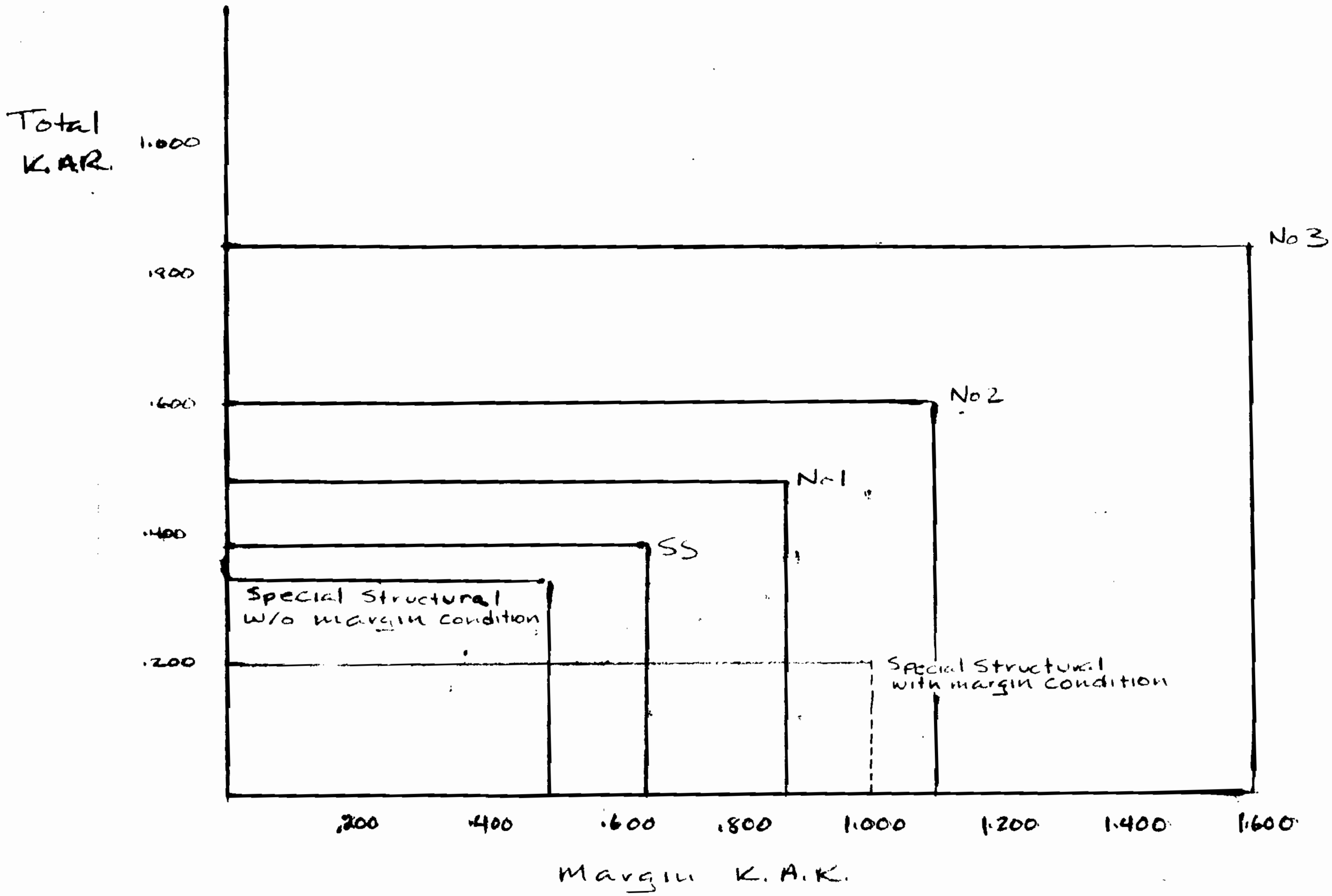


Figure 14 Comparison of SSP grades to the British General Structural grade

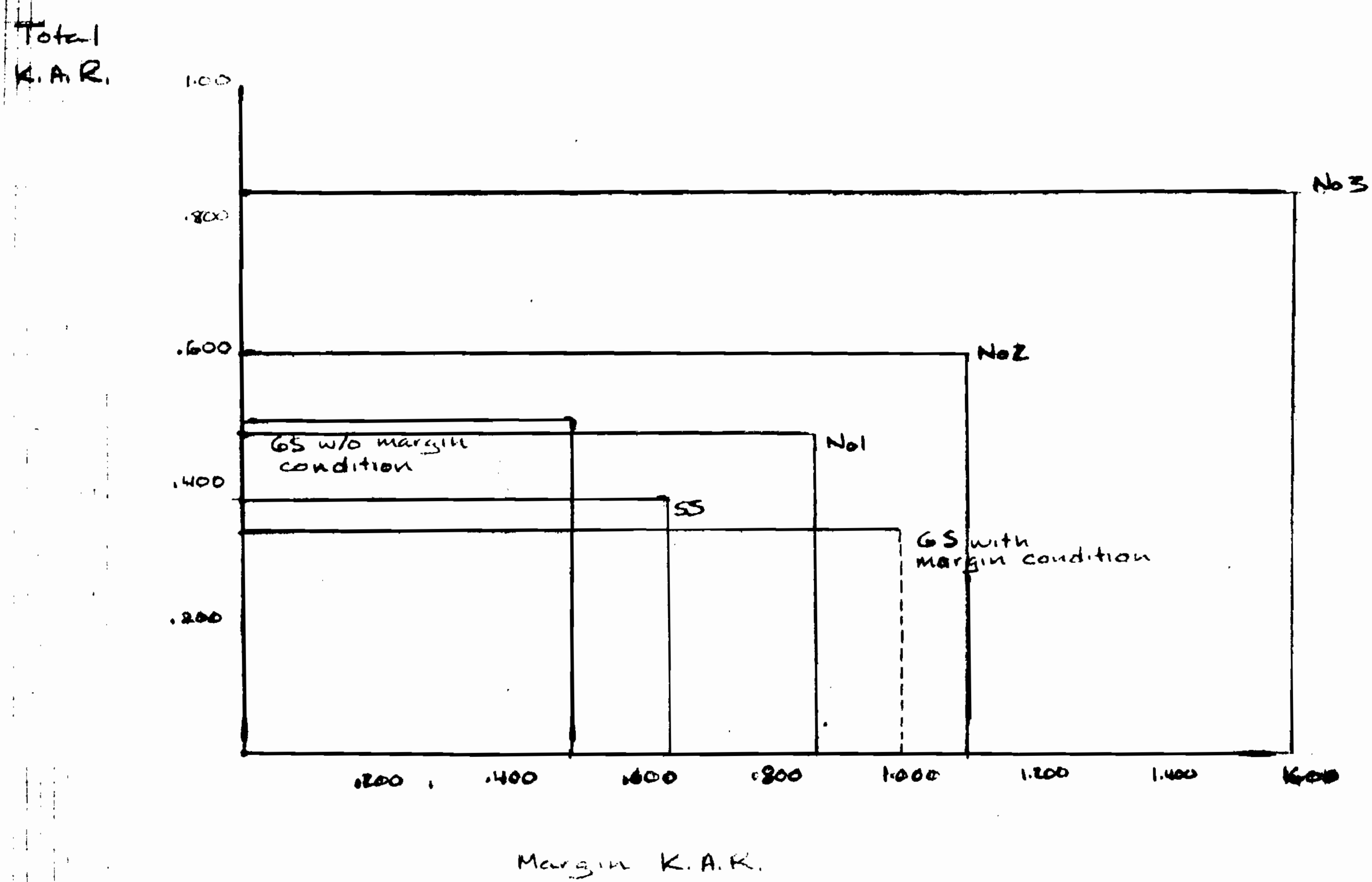
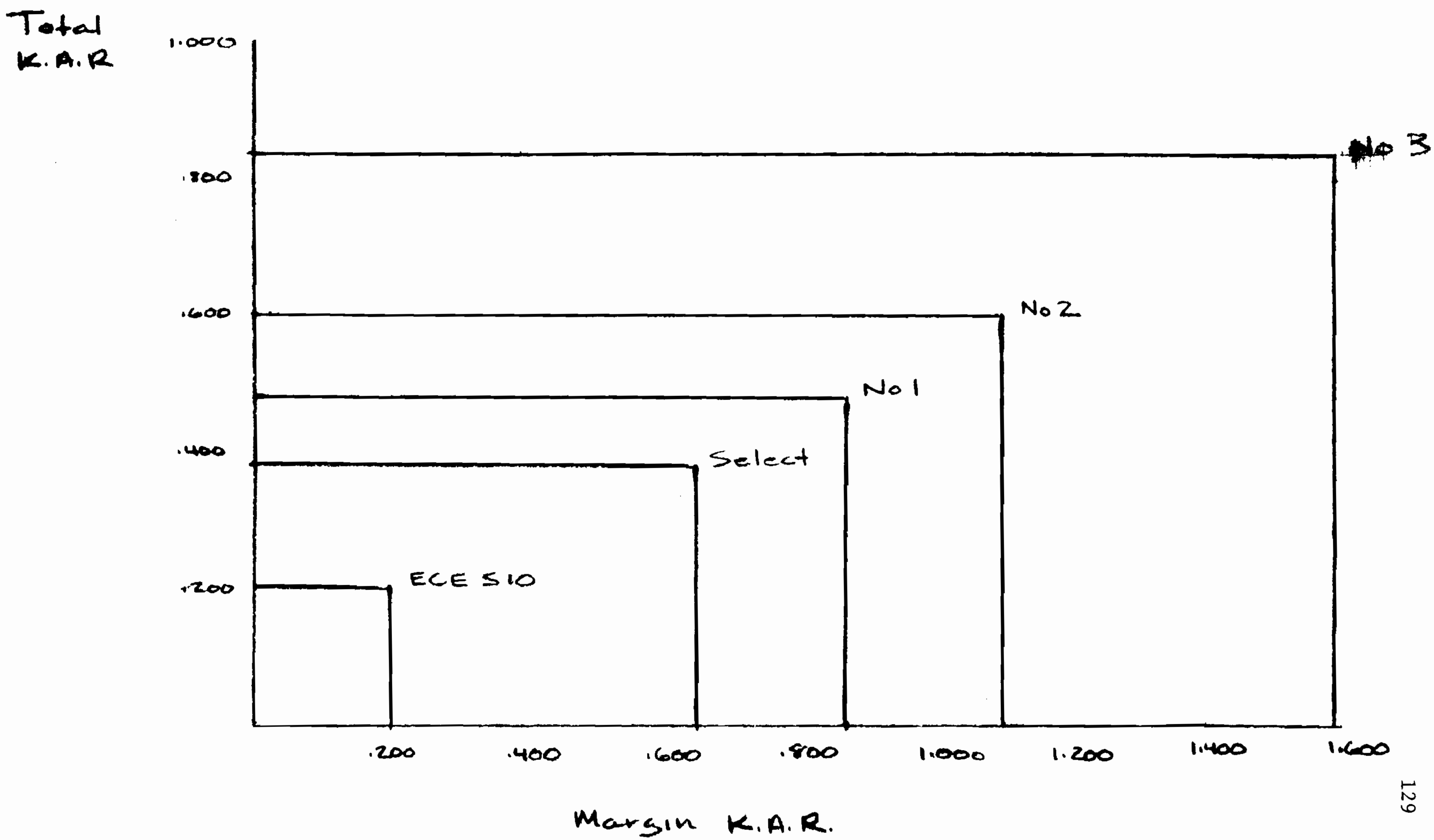


Figure 15 Comparison of SJP grades to the ECE 510 Grade



ratio is the highest expressed for the SJP product category. The lowest conversion ratios to SS and GS are generated by the No. 3 grade (30%, 47%).

The conversion of the North American grades to the KAR grades proposed by the ECE is simplified since the KAR limitations for the S8 and S6 grades are identical to the British SS and GS grades. Therefore, the North American-ECE grade conversion for S8 and S6 are equal to those of SS and GS. Cross referencing to the ECE S10 grade requires a separate graphical comparison due to the unique S10 KAR limitation. Figure 15 portrays the margin (1/5) and total (1/5) KAR limitations for S10 compared with the profits of SJP grades. Only 16% of the SJP Select Str. grade would convert to ECE S10. The conversion from SJP grade No. 3 to ECE S10 is only 3%.

2) Structural Light Framing

Figures 16 and 17 present the KAR relationships between SLF and British SS and GS. The estimated conversion of SLF Select Str. to British SS and GS is 91% and 100%. SLF grades No. 1 and No. 2 have percentages comparable to their SJP counterparts. The No.3 grade yielded the lowest conversion ratios to SS and GS (30%, 47%).

Figure 18 depicts the KAR relationship between the SLF grades and the ECE grades and Table 3 lists the conversion ratios. The results indicate that 13.5% of SLF select, converts to ECE S10. The S.LF No. 3 to ECE S10 conversion percentage is 2.0%.

3) <u>Light Framing</u>

Figures 19, and 20 present the KAR relationship between LF grades and British SS, and GS respectively. Generally, the LF grades convert less favorably into British SS and GS than the SLF or SJP grades. This can be attributed to the less strict knot size distributional requirements for LF relative to SLF or SJP. The conversion of Construction to British SS and GS is 35% and 56%. While the conversion of Utility to British SS and GS is 23% and 37%.

Figure 21 presents the graphical relationship between the LF grades and the ECE S10 grade. The LF grades have very low Conversions to ECE S10. The range of convertibility is 4% for construction to 1% for Utility. The conversion of the LF grades to ECE S8 and S6 are more favorable than the S6 conversions, but the highest conversion value is the Construction-S10 grade conversion is only 56%.

Figure 16 Comparison of SLF grades to the British Special Structural grade

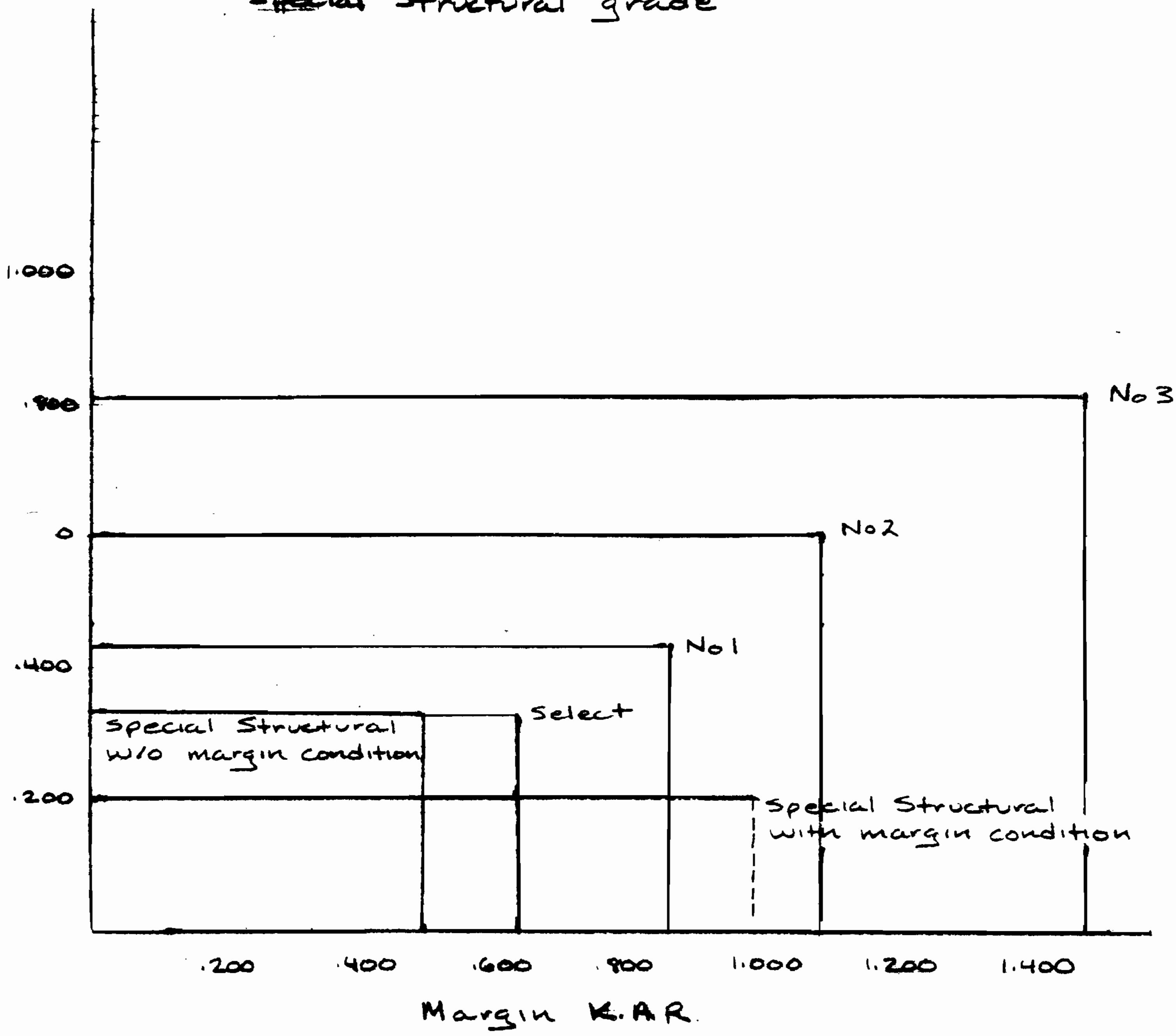


Figure 17 Comparison of SLF grades to the British General Structural grade

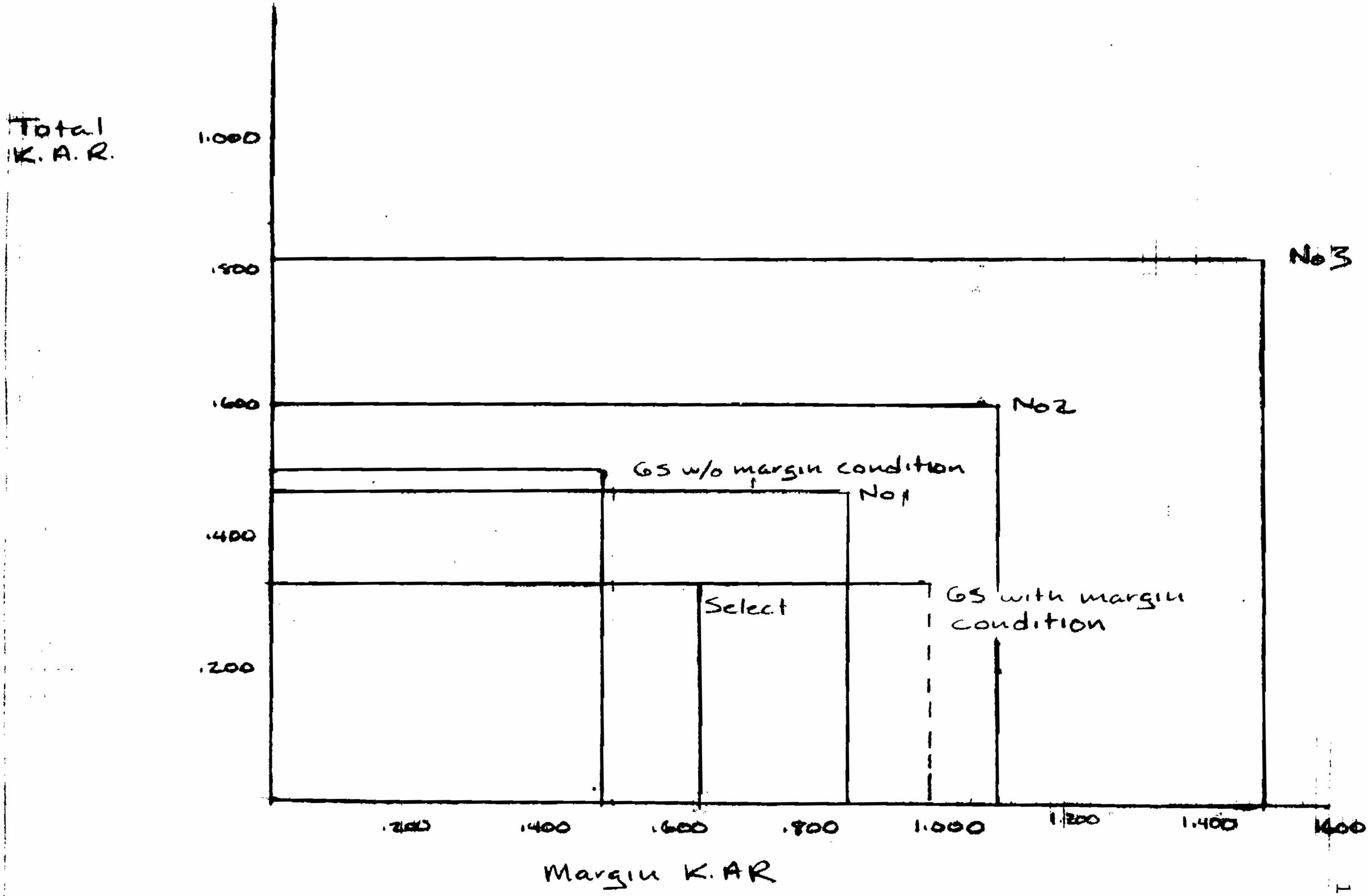


Figure 18 Comparison of SLF grades to the ECE S10 grade

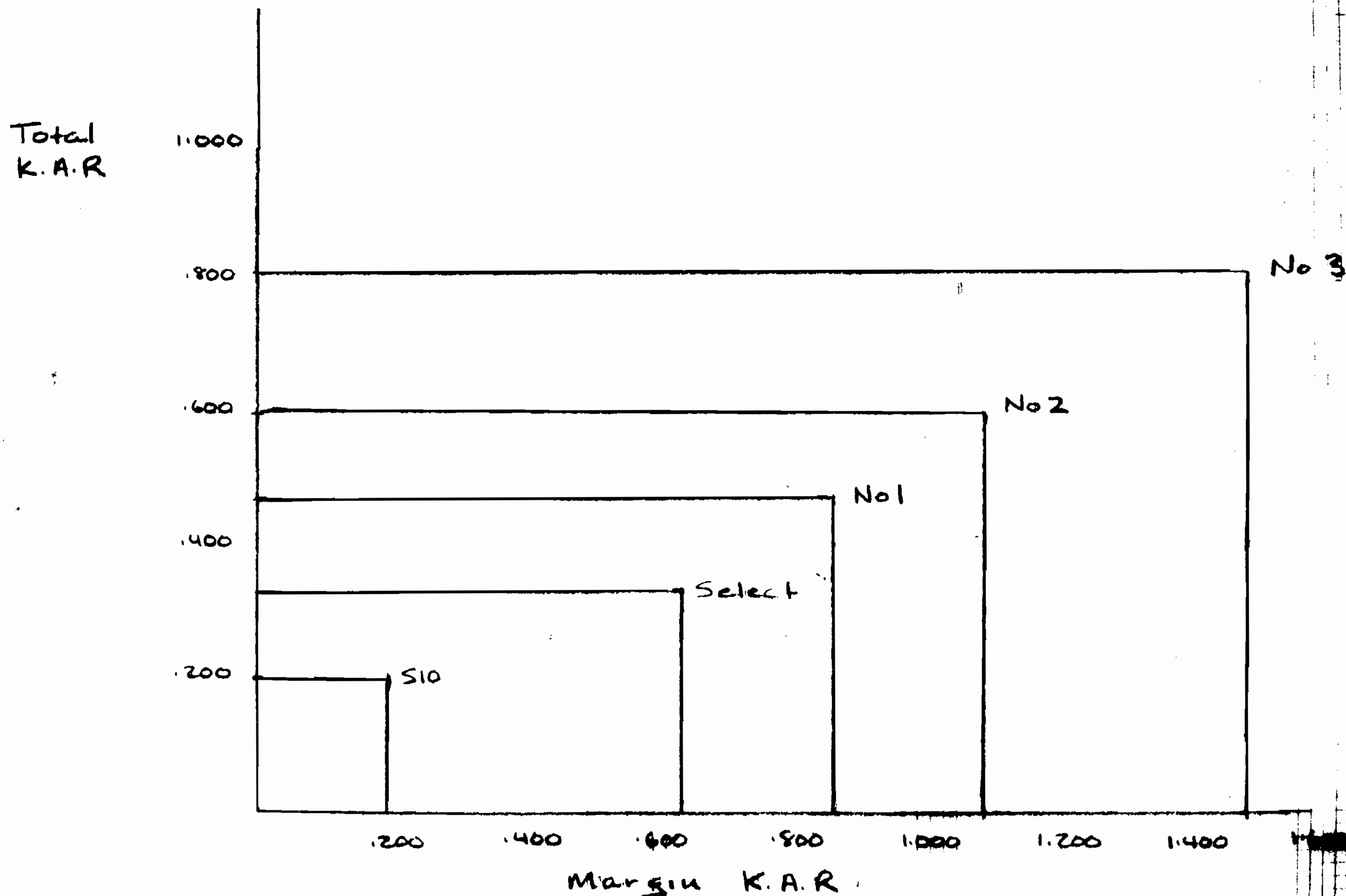


Figure 19 Comparison of the LF grades to the British SS grade

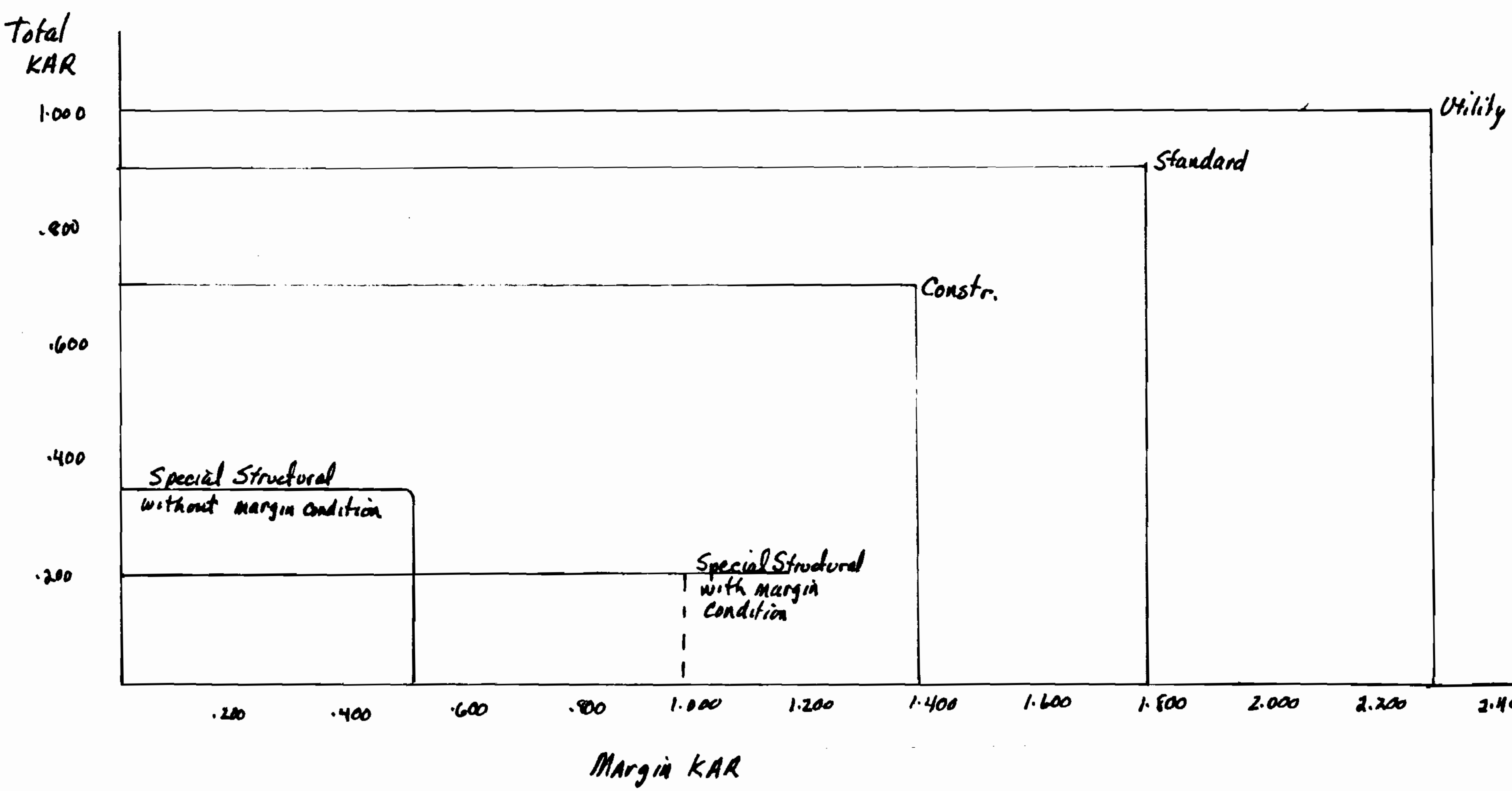


Figure 20 Comparison of the LF grades to the British GS grade

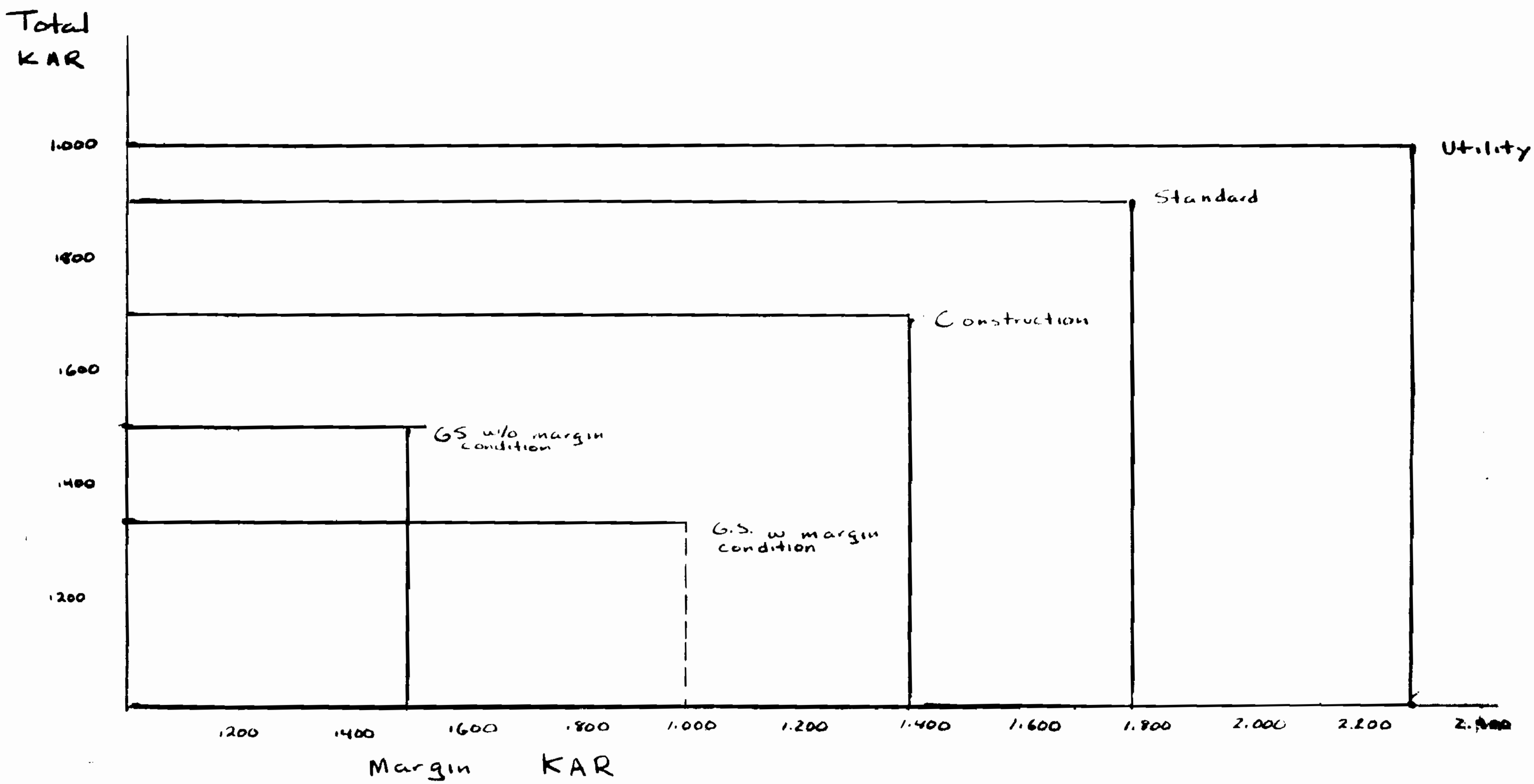


Figure 21 Comparison of the LF grades to the ECE 510 grade