BUILDING CONSTRUCTION

VOLUME THREE

METRIC EDITION

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VOLUME THREE

FIFTH EDITION (METRIC)

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With drawings by the authors

Orient Longman

PREFACE TO THE FIFTH EDITION

In producing this metric edition the opportunity has been taken to revise and augment certain Sections.

Many of the additions are to Chapter I, they include extra floor coverings and the use of plasterboard for partitions—a material which is probably the most widely used internal lining.

It may be emphasized that this and the two previous volumes are essentially concerned with the early syllabuses of a course, and special importance is therefore given to principles and sound methods of construction, chiefly traditional in character. More advanced building techniques, including mechanical excavating equipment; piling; steelwork and reinforced concrete; fire protection; advanced carpentry, joinery and plumbing; internal finishes; electrical and gas services and heating systems are described in Volume IV.

1973 J. K. McK.

PREFACE TO THE FIRST EDITION

THIS volume covers the latter portion of the syllabus in Building Construction, Stage Two, which appears on pp. ix, and to which reference has been made in the preface to Vol. II.

Care has been taken to exclude from these volumes details of construction which are generally accepted as being out of date. It is not, however, always easy to distinguish between obsolete and obsolescent types. Much depends upon local practice. For example, the wood roof truss is considered by many to be obsolete, and yet king post roof trusses were adopted in some districts in a number of buildings erected just before the war. As, however, the vast post-war-building programme which has to be undertaken will include the reinstatement of war-damaged property, and as many students will be engaged upon this work, it has been thought desirable to refer to one or two types of structures which, although employed extensively in the past, are now gradually falling into disuse.

It is also realised that for some time after the war there will be a shortage of certain building materials. This applies particularly to timber, as most of it is imported, and it will be imperative that timber shall be used economically. Special attention should be given, therefore, to the description of plywood and similar products which is given on pp. 117–122, and in the production of which the rarer and more valuable timbers especially are made to go as far as possible by conversion into thin veneers.

Many alternative joinery details have been provided for comparison and selection. These include both traditional and contemporary construction, examples of the latter being the flush door and the solid-balustraded stair detailed in Figs. 29 and 42 respectively.

The homework programme on p. 156 continues and completes the one begun in Vol. II.

The author's thanks are due to his colleague, Mr. E. Spencer, for his valuable assistance, especially in connection with the sections devoted to woodworking machinery. Thanks are also extended to the Director of Forest Products Research for permission to refer to several publications of the Forest Products Research Board, to the Controller, H.M. Stationery Office, for authority to include brief extracts from certain British Standard Specifications, and to various firms for particulars of new building materials and manufacturing processes to which references have been made in the text.

January 1944 W. B. McK.

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LIST OF ILLUSTRATIONS

Note: UNLESS INDICATED OTHERWISE ALL DIMENSIONS ON THE FIGURES ARE GIVEN IN MILLIMETRES

GENERAL SYLLABUS IN BUILDING CONSTRUCTION STAGE TWO[1]

Brickwork.—Extended description of the manufacture and characteristics of bricks, cements and limes; lime and cement mortars; concrete. Squint quoins and junctions, and rebated and splayed jambs in English and Flemish bonds; piers; cavity walls; circular work; reinforced brickwork; raking bonds; garden, cross, Dutch, brick-on-edge and facing bonds; recessed, elliptical, pointed and rere arches. Damp proofing of basements; dry areas. Stepped foundations. Concrete floor construction. Decorated brickwork. Fireplaces, flues, chimney breasts and stacks; bye-laws. Setting out. *See Chapter One, Vol. II.*

Drainage.—Surface water drainage. Septic tanks. Drainpipes, bends, junctions, channels, taper pipes, gullies, and interceptors. Setting out and construction of drains. Drainage for small buildings; inspection, interception and ventilation. *See Chapter Two, Vol. II.*

Masonry.—Formation and classification of stones; characteristics, tests. Quarrying, mining and machine dressing. Stone dressings to door and window openings. Cornices. Stone steps and stairs. *See Chapter Three, Vol. II.*

Mild Steel Roof Trusses.—Mild steel roof trusses up to 12 m span. *See Chapter Four, Vol. II*

Carpentry.—Extended description of the classification, structure, conversion, seasoning, preservation, defects, characteristics and uses of timbers; preparation of timber and machines employed. Double and framed floors; determination of sizes of joists; floor finishes, including boards, blocks, plywood, parquet, cork, rubber, thermo-plastic tiles, vinyl asbestos tiles, vinyl sheet and tiles, synthetic resins, pitch mastic, mastic asphalt, cement and rubber latex, magnesium oxychloride, clay tiles, granolithic screed, terrazzo, linoleum, polyvinyl chloride, composition blocks, marble tiles and quartzite. Stoothed, terra-cotta, concrete, sawdust concrete, aerated concrete, plaster, plasterboard, wood-wool cement, compressed straw, and glass partitions. Sound insulation. Double and built-up trusses. Timbering of deep trenches, centres up to 3 m span. Shoring, scaffolds. *See Chapter One, Vol. III.*

Joinery.—Doors, including fanlights, semicircular headed, glazed and flush. Windows, including semicircular headed boxed frame with sliding sashes, boxed frame with three lights, and metal. Stairs; terms; types; essential requirements; step proportions; construction and detailing of straight flight, dog-leg and open well stairs; open and solid balustrades; winders; special steps. Manufacture, characteristics and uses of plywood, laminboards, blockboards, battenboards and composite boards. *See Chapter Two, Vol. III.*

Roof Coverings.—Plain tiles, pantiles, Italian, Spanish and interlocking tiles; eaves, ridge, hip, valley and verge details; vertical tiling. Concrete tiles; asbestos-cement slates and corrugated sheets; corrugated iron sheets. Stone slating. Shingles. Copper and zinc details. Thatch. *See Chapter Three, Vol. III.*

Painting.—Preparation of surface. Priming coats, undercoats, finishing coats. Types of paint. Painting on different surfaces. Techniques. *See Chapter Four, Vol. III.*

[1] This syllabus appears in parts as Chapter headings in Vols. II and III.

CHAPTER ONE

CARPENTRY

Syllabus.—Extended description of the classification, structure, conversion, seasoning, preservation, defects, characteristics and uses of timbers; preparation of timber, and machines employed. Double and framed floors; determination of sizes of joists; floor finishes, including boards, blocks, plywood, parquet, cork, rubber, thermoplastic tiles, vinyl asbestos tiles, vinyl sheet and tiles, synthetic resins, pitch mastic, mastic asphalt, cement and rubber latex, magnesium oxychloride, clay tiles, granolithic screed, terrazzo, linoleum, composition blocks, marble tiles and quarzite. Stoothed, terra-cotta, concrete, sawdust concrete, aerated concrete, plaster, plasterboard, wood-wool cement, compressed straw, and glass partitions. Sound insulation. Double and built-up trusses. Timbering of deep trenches. Centres up to 3 m span. Shoring. Scaffolds.

TIMBER

THIS Chapter is devoted mainly to timber construction but it has been found convenient, as will be apparent from the syllabus, to include other subjects wherein this material does not predominate. A short introduction to timber appears in Chap. III, Vol. I.

Classification.—Trees are classified (*a*) botanically and (*b*) commercially.

(a) *Botanical Classification.*—Timbers are grouped into families, each family being divided into *genera* (large classes) and each genus into several *species* (smaller classes) of trees which closely resemble each other in essential features. Thus, the classification of the pine family (botanical name *Pinaceæ*) is:—

Family.	Genera.	Species.
Pinaceæ (Pine)	*Abies* (firs)	*Abies alba*, white fir; *A. balsamea*, balsam fir, etc.
	Larix (larches)	*Larix decidua*, European larch; *L. sibirica*, Siberian larch, etc.
	Picea (spruces)	*Picea abies*, European spruce or white-wood; *P. glauca*, Canadian spruce, etc.
	Pinus (pines) etc.	*Pinus strobus*, yellow pine; *P. sylvestris*, Scots pine or redwood, etc.

As shown, the Latin botanical name of a tree consists of two words, the first defines the genus to which it belongs, and the second the particular species. These names are now universal and indicate the natural relationships of the timbers.

(*b*) *Commercial Classification.*[1]—Timbers used commercially are divided into softwoods and hardwoods.

The softwoods are members of the conifer class or *Coniferæ*, and include the pines, firs, spruces, etc. These cone-bearing trees have needle-like leaves, and, with few exceptions, are *evergreens*. Most of the timber used for constructional work is of this class, as, in general, it is sufficiently strong for most purposes, is easily worked on account of its softness and straightness in the grain and is relatively cheap. A list of some of the principal softwoods is given in Table I, and the regions from which they are obtained are shown in Fig. 4.

The hardwoods belong to the broad-leaf class or *Dicotyledoneæ*, and include the oaks, mahoganies, beeches, birches, etc. Most hardwoods are *deciduous*, *i.e.*, they shed their leaves in autumn. They are chiefly used for decorative purposes, as for panelling, veneering and furniture, and certain of them are selected for constructional use because of their high strength and durable qualities. Table II includes a number of the many hardwoods used commercially, and their disposition is shown in Fig. 4.

Structure.—Wood has a complex cellular structure. The thin tubular cells vary in size and shape in different kinds of trees and their function is to (1) conduct water and soluble salts absorbed from the soil by the roots to the leaves, (2) provide storage of food during the winter and (3) give strength to the tree.

A part log is shown in diagrammatic form at A, Fig. 1. The chief structural parts are indicated at the cross, radial and tangential sections.

The diameter of the trunk and branches of a tree is increased by the addition of successive irregular concentric layers on the outside immediately within the bark. In the temperate climate of this country, and under normal conditions, a

[1] As pointed out in Vol. I, whilst the division of timbers into softwoods and hardwoods is firmly established it is conventional only, as some softwoods are harder than certain hardwoods.

fresh ring of wood is produced yearly, and the term *annual ring* which is applied to it is therefore descriptive. In the tropics the growth does not always agree with annual periods and more than one ring may be formed annually; the term *growth ring* is then a better description. A cross-section through a log may show a big variation in the thickness of the rings; thus, a narrow ring formed during a droughty season may be adjacent to a relatively wide growth ring produced under better climatic conditions. An irregularity in the thickness of a ring will be caused if the tree is exposed to more sun on one side than the other.

The growing season in this country is from April to September. During this period new wood is produced by a thin layer of cells called the *cambium* and situated between the bark and the outer growth ring. These cambial cells divide and subdivide, forming new cells on the inner and outer sides. The new inner cells gradually grow into the new wood (*xylem*) and the new outer cells develop into new bark (*bast*) which conducts the food converted by the leaves to the growing parts of the tree. The wood produced at the beginning of the growing season, known as the *spring wood*, is generally of an open nature owing to the relatively large size of the cells and the thinness of their walls; that formed towards the end of the season, called the *summer wood*, is usually denser on account of the cells being smaller and their walls thicker (see B, C, and E, Fig. 1). Hence the contrasting alternate lighter and darker layers which clearly define the growth rings in many timbers. Some woods, as shown at K, do not show a sharp contrast between spring wood and summer wood.

A cross-section through a fully developed tree will, as a rule, show a comparatively dark coloured central portion or *heartwood* surrounded by a lighter coloured zone called *sapwood*. The heartwood content of a tree increases with age. Thus, the log of an immature tree is chiefly composed of sapwood, the cells of which are actively engaged in conducting mineral salt solutions from the soil to the leaves and the sap or foodstuff manufactured from them. In course of time this work is performed by the more recently formed growth rings and the cells in the inner core become inactive, the heartwood acting as a mechanical support of the tree only. Each year the inner ring of sapwood is converted into heartwood, and as an additional outer growth ring has been formed during this period, it follows that the proportion of sapwood remains practically constant. Various substances, such as gum, resin and tannin, are formed and deposited in the heartwood cells. These substances influence the colour and increase the durability of heartwood. There is no appreciable difference in strength between sapwood and heartwood.

The structure of (*a*) softwood timbers is simple compared with that of (*b*) hardwooods.

(a) *Structure of Softwoods.*—Approximately 90 per cent. of the wood consists of comparatively long, vertical (when forming the trunk) tubular cells called *tracheids*. A cross-section through a portion of a growth ring is shown at B, Fig. 1. This shows the honeycombed nature of the structure, with the tracheids arranged in rows and separated at intervals by *rays* (see next column). The tracheids are seen to be polygonal shaped when examined under the micr
Most of them are not visible to the naked eye, and as an example the t
shown greatly enlarged at P is only 0·1 mm in diameter (see H). Thos
spring-wood zone have thin walls and relatively large cavities (see E, H
whereas the summer-wood cells have gradually diminishing cavities and
walls (see C and G). The function of the spring-wood cells is to condu
to the leaves and the chief function of the summer-wood tracheids is to
then the tree. The wood cells are approximately 3 mm long, as show
the ends of the spring-wood cells are more rounded than those of the s
wood cells (compare C and E). The cells communicate with each other
pits, of which there are many modifications. One form, known as a *bord*
is shown at C and E. Pits in adjacent cells are opposite to each ot
permit of the conduction of water, etc., from one tracheid to anoth
shown, a pit consists of a circular area of unthickened cell wall from th
of which the wall projects to form a domical-shaped covering having a
the middle. The continuous thin membrane is called the *middle lam*
this is thickened at the centre to form the *torus* (see D). Another for
called a *single pit*, is shown at N and P.

The *medullary rays*, or simply *rays*, referred to in the preceding colum
as straight, narrow, radial bands across the grain (see A and P). In s
they are hardly visible to the naked eye; thus, those of redwood vary f
to 0·3 mm high. A ray consists of cellular tissue, called *parenchy*
cells are thin-walled and rectangular in shape. The rays are irregula
buted, and each is usually only one cell wide and several cells high, as
the *tangential* section at L where the rays can be seen in section. T
as storage accommodation for food which is transmitted through *simple*
the adjacent vertical tracheids for distribution. As shown at P, these r
thin membranes which are either circular, rectangular or slit-like in sh

Resin ducts are present in certain softwoods, such as pitch pine,
spruce, yellow pine and Douglas fir (see B and L). These canals are
comparatively small numbers in the summer wood and in the ra
receive the resin (waste product) secreted by the cells immediately su
them.

(b) *Structure of Hardwoods.*—This is more complicated than the
of softwoods. It chiefly comprises vessels, fibres, parenchyma and r

Vessels or Pores.—These are long vertical tubes composed of pipe-
ended cells which extend down the trunk. Their function is similar
the spring-wood tracheids of softwoods in that they conduct water
roots to the crown of the tree. The size of the pores varies in differ
thus a cross-section through a log of oak will show comparatively l
which are conspicuous to the naked eye, the pores of beech are bar
to the naked eye, and those of box are difficult to distinguish even w
of a magnifying glass. A pore is shown in section at M. The pits a
than those in softwood tracheids.

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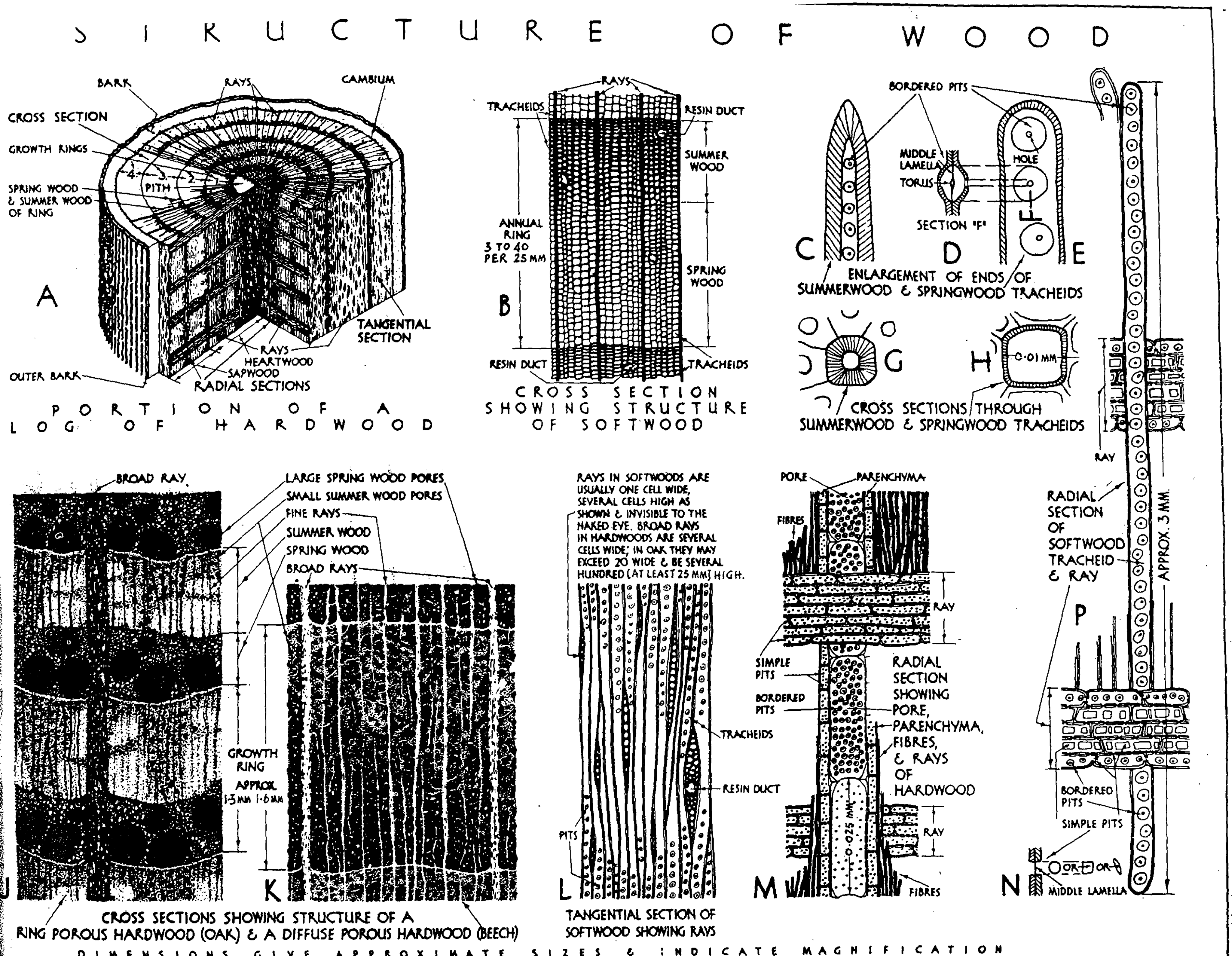


FIGURE 1

Some hardwoods, such as oak, elm and ash, have the larger pores concentrated within the spring and the smaller pores distributed throughout the summer wood; these are called *ring-porous* woods, and an example is shown at J. Hardwoods in which the pores are fairly uniformly diffused (scattered) over the whole growth ring are said to be *diffuse-porous*, examples being mahogany, beech and birch (see K); as shown, the pores gradually decrease in size with a maximum in the spring wood.

When pores cease to act as water conductors they frequently become plugged with sac-like growths called *tyloses*.

Softwoods are without pores, and therefore *the presence of pores is a clear indication that the timber is of the hardwood type.*

Fibres.—These are narrow thick-walled cells, shorter (1 mm) but somewhat resembling the summer-wood tracheids of softwoods. The bulk of the wood consists of fibres, and their function is to provide strength to the tree. They cannot be separately distinguished by the naked eye (see M).

Parenchyma of Soft Tissue.—This consists of thin-walled, rectangular cells occurring as vertical strands surrounding the pores (see M), as bands linking up the pores and as fine lines separating the growth rings. They are visible on cross-section as light coloured bands or patches in contrast to the darker coloured masses of fibres. The function of the soft tissue is to store reserves of food.

Rays.—These also store food materials. Unlike the softwood rays described on p. 2, those in most hardwoods are several cells in width. These radiating strands sometimes appear as distinct broad bands, about 15 cells wide, separated by indistinct finer rays, about 3 cells wide (as in oak and beech, see J and K), or entirely as indistinct fine rays, about 3 cells wide, as in birch. The height (as in oak) may exceed 25 mm, and the characteristic "silver grain" of quarter-sawn oak is due to the presence of these very broad and high rays.

Identification.—The identification of the more commonly used timbers does not present much difficulty to those experienced in the industry by observing such general characteristics as the colour, texture, smell, appearance of the growth rings, rays, etc. Most timbers, however, can only be identified with certainty by a close examination of the structure of a thin cross-section (cut by a sharp knife or chisel) through a *hand lens* which has a magnification of about ten times the natural size. When more reliable information is required, as is needed when distinguishing timbers which are closely allied, it is necessary to examine prepared slides of the specimens through a *microscope* which has a magnification of twenty-five to thirty diameters. For this purpose three sections from each specimen are examined, *i.e.*, cross, radial and tangential, the radial and tangential sections being necessary for the examination of the rays. Briefly, a slide is prepared in the following manner: A slice of the wood, about 12 mm square and 0·025 mm thick, is cut by a special knife called a *microtome*; the slice is stained by coloured alcohol and then pressed flat (mounted) on a piece of glass to which an adhesive (Canada balsam) has been applied.

The structure of a specimen should be methodically examined under the microscope. Thus, the group to which it belongs is first determined, absence of pores indicating a softwood; the size and distribution of the rays, type of pits and any resin ducts are diagnosed; if a hardwood (indicated by the presence of pores) the grouping of the larger pores (whether ring-porous or diffuse-porous) and the distribution of the smaller pores are noted, together with the character of the soft tissue, rays etc. As the slide is being studied microscopically, a larger specimen of the wood is examined and the general features such as the colour, weight, characteristics of the growth rings, etc., are observed.

The appearance of cut surfaces of timber is influenced by its structure, and there are several terms used to express this appearance. These include (1) grain, (2) texture and (3) figure.

1. *Grain* applies to the general *direction* of the fibres and cellular units in relation to the longitudinal edges of a piece of wood or the vertical axis of a tree. There are several kinds of grain, *i.e.*, (a) *straight grain*, when the fibres are parallel; (b) *irregular grain*, when the fibres are inclined; (c) *wavy or curly grain*, when the fibres frequently change direction and produce alternating darker and lighter wave-like stripes on the surface (such timber when split has a corrugated surface); (d) *spiral grain*, when the fibres are arranged spirally; (e) *interlocking grain*, when the fibres in successive growth rings are inclined in opposite directions; and (f) *diagonal grain*, when straight-grained timber has been improperly converted so that the fibres are inclined to the longitudinal edges. Regarding:—

(*a*) Straight-grained timber is relatively strong and easy to work. It has only a plain figure (see p. 5).

(*b*) Irregular-grained timber is relatively weak, is difficult to work, but gives an attractive figure (see p. 5). The irregularity is often due to the presence of knots.

(*c*) Wavy or curly grained timber is highly decorative on account of the irregularly curved fibres.

(*d*) Spiral-grained timber is of reduced strength.

(*e*) Interlocking-grained timber may be subjected to excessive twisting when being seasoned, and is not easy to work. The strength is not seriously affected. The figure produced is described on p. 5.

(*f*) Diagonal-grained timber is reduced in strength owing to faulty conversion.

The term *end grain* refers to the arrangement of the exposed fibres on the cross-cut surface.

Flat-sawn or *plain-sawn* timber is that which has been converted (see pp. 5 and 6) so that the annual rings intersect the cut face over at *least half its width* at *less* than 45°. It is inaccurately described as " flat grain " or " slash grain." Timber can be converted quickly, cheaply and with the minimum waste by this method of conversion.

Quarter or *rift sawn* timber (see Chap. III, Vol. I) is that which has been converted so that the annual rings intersect the cut face *in any part* at *more* than 45°. It shrinks less in width than flat-sawn timber and has less tendency to warp and split. The terms "quarter grain," "edge grain," "vertical grain" and "comb grain" are loosely applied to quarter-sawn timber.

When timber fails, due to its brittleness, it is often said to be " short in the grain." This is an inaccurate application of grain, as the condition is not affected by the direction of the fibres. Whilst it may be characteristic of certain timbers it is also due to improper seasoning and fungoid decay, such as dry rot (see p. 14).

"Even grain" and "uneven grain" are other terms which are inaccurately used (as they are not influenced by the direction of the fibres) to describe timber whose growth rings are either uniform in width ("even") or irregular in width ("uneven"). A more accurate expression is "growth rings of regular (or irregular) width."

2. *Texture* applies to the size and order or arrangement of the cells. Thus, a hardwood of *coarse texture* has large pores and/or broad rays (such as oak) and that of *fine texture* (such as beech) has small pores and/or narrow rays. Examples of intermediate grades are *moderately coarse texture* (Honduras mahogany) and *medium texture* (birch). Most softwoods are fine textured on account of their small cells, and some Russian redwood is especially so. Diffuse-porous hardwoods (such as beech) and softwoods with growth rings having slight contrasting spring and summer wood (such as white pine) are known as *even-textured* timber; ring-porous hardwoods (such as elm) and softwoods having strongly contrasting zones of spring and summer wood (such as Douglas fir) are of *uneven texture*. Sometimes softwoods are classified as "coarse grained" (or "coarse textured") or "fine grained" (or "fine textured") when their growth rings are wide and narrow respectively; such expressions are not correct, as the width of rings does not affect either grain or texture; they are best referred to as "wide" or "narrow-ringed" timbers.

3. *Figure* is the pattern on the surface of timber formed by the arrangement of the different tissues and influenced by the grain and colour. There is a big variation in the quality of the figure; thus, straight-grained timber has only a plain figure, whereas suitably converted timber will show beautiful markings when it is irregular, interlocked or wavy grained.

The nature of the figure is affected largely by the method of conversion, and when the appearance of the timber is an important consideration, as for panelling or furniture, the form of conversion adopted should expose the characteristic elements to the best advantage. Thus, oak is quarter-sawn in order to disclose relatively large sections of the conspicuous broad rays on the cut surface and which give the richly ornamental figure known as *silver grain*; pitch pine is flat or tangentially sawn to expose the distant growth rings of light coloured spring wood and dark summer wood.

Conspicuous irregularities in the direction of the fibres usually give an attractive figure. The following are examples: Irregular grain due to small elevated patches on the growth rings produces *blister figure*, which is highly decorative and common to sapele and pitch pine; the irregular grain conforming to small depressions in the growth rings gives the characteristic *bird's-eye figure* of rock maple, and the handsome figure resulting from irregular grain at the *burrs* (swellings) (see A, Fig. 47) in walnut is called *burr figure*. Interlocked grain is responsible for the *stripe figure* or *ribbon figure* peculiar to African mahogany and Andaman Padauk when quarter-sawn and for the *mottled figure* characteristic of black bean. New Zealand kaurie, etc.; interlocked grain in Queensland maple, mahogany, sapele and other tropical timbers is sometimes irregular, and the striped figure is interrupted by longitudinal darker bands to form what is known as *roe figure*. Wavy or curly grain may produce markings in walnut, sycamore, Cuban mahogany, rock maple, Indian laurel, Australian blackwood, etc., known as *fiddle-back figure* (so called as such decorated wood is usually selected for the backs of violins); this is caused by alternate dense and lighter transverse bands crossing the grain.

Highly decorative figure results from converted timber obtained from just below a *crotch* (fork) (see A, Fig. 47) or at the *stump* (base) of a tree, the disturbed curly grain producing a figure in mahogany, rock maple, etc., known as *feather curl* (as it has the appearance of ostrich feathers); another modification as a result of contorted grain sometimes seen in oak is appropriately called *ram's horn figure*, the short waves forming a series of narrow transverse stripes.

Ripple marks are the transverse sections of rays seen on the cut surface of some timbers (including sweet chestnut, sycamore, East Indian satinwood and Honduras mahogany) and arranged regularly at intervals in straight lines across the width.

Variations in colour affect the figure and increase the decorative value of timber, *i.e.*, the rich colour of walnut streaked with dark bands.

Pith-flecks are discoloured brown streaks or spots occasionally seen in birch, Rhodesian teak, etc.

CONVERSION

The methods of converting ("breaking down") timber by (*a*) radial, rift or quarter sawing, (*b*) tangential, flat or plain sawing and (*c*) slab sawing are described in Chap. III, Vol. I.

Machines are employed for felling trees on a large scale, although in this country most tree felling is done by hand. One type of machine used for this purpose is steam or electrically driven and resembles that shown at B, Fig. 2, with the reciprocating saw blade horizontal.

The sawing up of a log into baulks (squared timber exceeding 150 mm by 150 mm) planks (pieces from 50 to 150 mm thick and at least 280 mm wide), flitches (pieces not less than 100 mm by 300 mm), deals (pieces of softwood from 50 to 100 mm thick by 229 to under 280 mm wide), battens (from 50 to 100 mm thick by 130 to 200 mm wide), boards (under 50 mm thick by 100 mm and over in width) slices (thin wide pieces) etc., is performed by machinery. This machinery is power driven, usually by electricity. The power may be transmitted from its source either by shafting and belting or, preferably, by a separate motor attached to each machine or group of machines.

Logs must first be cut into convenient lengths for handling. The *reciprocating cross-cut saw*, shown at B, Fig. 2, is suitable for this purpose. The mechanically operated 2·75 m long blade has a lower cutting edge and during its reciprocating motion it cuts downwards with the inward stroke only. Logs up to 1·8 m diameter can be rapidly cross-cut by this machine.

There are several types of woodworking machines used for converting logs after they have been cut into suitable lengths. These include the (1) horizontal log band mill, (2) vertical log band mill, (3) circular saw mill, (4) horizontal log frame sawing machine, (5) vertical log frame sawing machine, (6) combined log and deal frame and (7) band re-sawing machine.

1. **Horizontal Log Band Mill** (see A, Fig. 2).—This consists of a 150 to 250 mm wide band or continuous saw, having teeth on one edge, which moves horizontally as indicated by the arrows, and is maintained in tension over two large (1·4 to 2·5 m diameter) pulleys. The log is supported on a travelling carriage (running on wheels fixed to the floor, or the carriage may be provided with wheels which run on rails) and is fed end-on

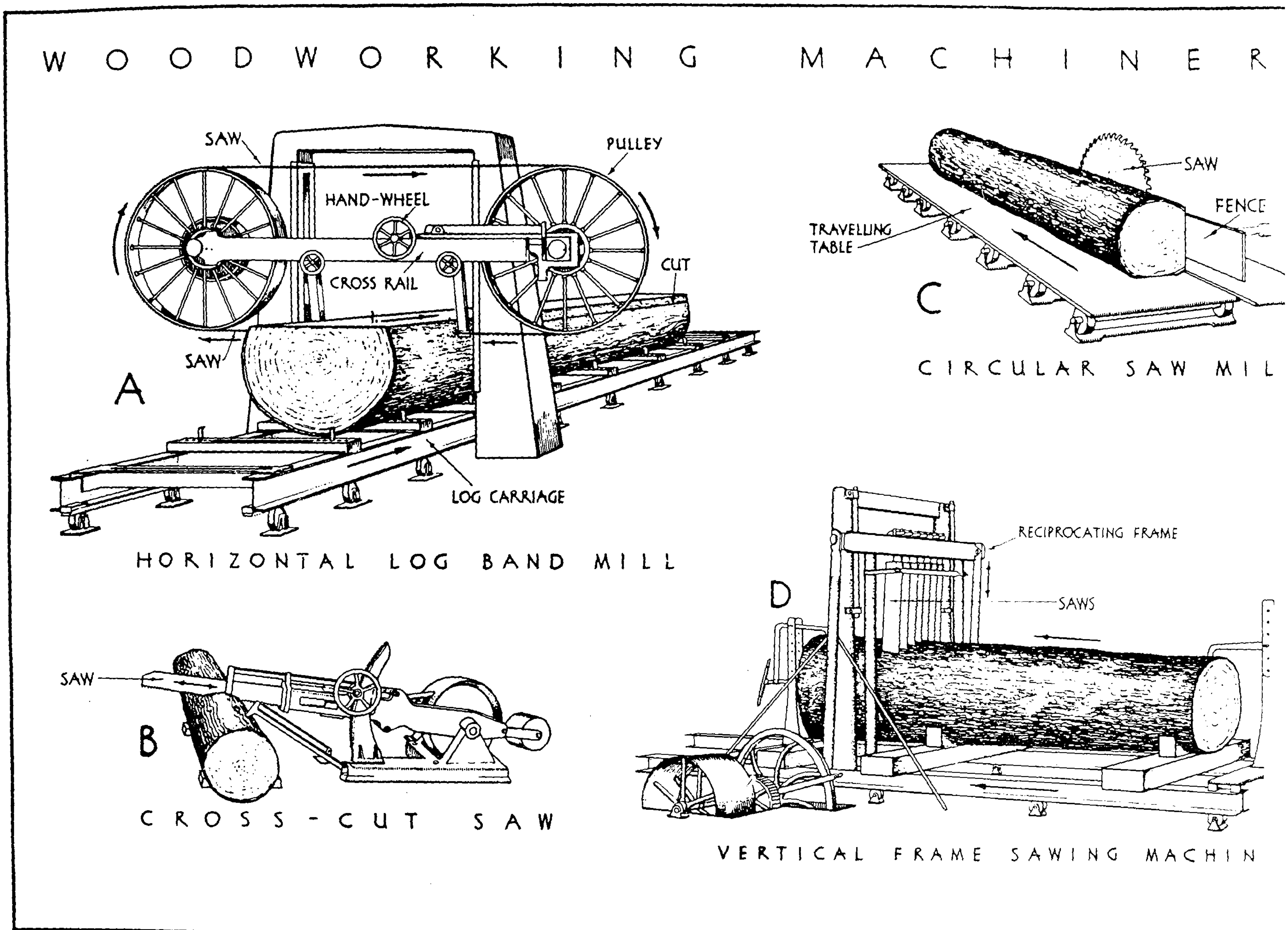
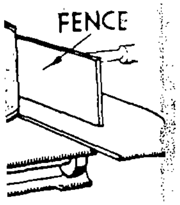

W O O D W O R K I N G M A C H I N E R
SAW
PULLEY
HAND-WHEEL
CROSS RAIL
CUT
SAW
A
LOG CARRIAGE
HORIZONTAL LOG BAND MILL
SAW
FENCE
TRAVELLING TABLE
C
CIRCULAR SAW MIL
RECIPROCATING FRAME
SAWS
D
SAW
B
CROSS-CUT SAW
VERTICAL FRAME SAWING MACHIN

FIGURE 2



in the direction of arrow "1." The continuous cutting action of the saw is capable of rapidly breaking down a log or baulk into panels, flitches, boards, veneers, etc., by a succession of horizontal cuts, starting from the top. The cross rail supporting the pulleys is lowered as required after each cut by manipulation of the handwheel. The rate of feed can be rapidly varied from 3 to 25 m per min., and the rate of return may reach 60 m per min.

2. Vertical Log Band Mill.—As implied, the band saw has a vertical travel over two pulleys, one above and the other below the log, as it rapidly breaks down the log by a succession of vertical cuts. A log carriage is provided. The diameter of the pulleys varies from 1·5 to 2·8 m and the width of the saw from 200 to 400 mm. It is well adapted for quartering logs and for accurately cutting wide boards, etc., when high outputs are required.

Both the horizontal and vertical log band mills are extensively employed and are replacing other machines (such as the vertical frame sawing machine, D, Fig. 2) because of the accuracy and high speed at which logs can be broken down, under complete control, and with the minimum of waste resulting to the converted timber.

3. Circular Saw Mill (see C, Fig. 2).—This consists of a vertical circular saw (see pp. 25, 26 and 27) of 1·2 to 2·2 m diameter and a travelling table (running on rollers) driven by a rack and pinion to feed the log end-on against the rotating saw as it forms a vertical cut. It is also known as a *rack feed saw bench*, and is used for breaking down different-sized logs, edging flitches, etc. The rate of feed varies from 2·7 to 12 m per min., and the accelerated return of the table is 37 m per min.

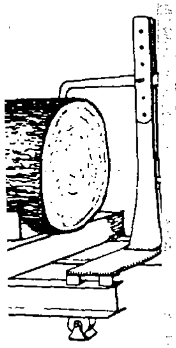
4. Horizontal Log Frame Sawing Machine.—This has a horizontal saw fixed in a reciprocating frame which cuts, in both directions of the stroke, horizontal slices off the log as it is moved forward on a metal table or log carriage end-on towards the saw. It is used for sawing logs, usually of expensive hardwoods, into boards, planks and panels where limited power only is available. The rate of feed is relatively low. The log can be examined after each cut, and thus the sawing speed can be regulated as required.

5. Vertical Log Frame Sawing Machine (see D, Fig. 2).—This comprises a reciprocating frame containing a number of vertical saws, spaced as required to a minimum distance apart of 12 mm, which works with an up-and-down motion to convert the log into deals or boards as it is driven end-on through the frame. The saws are only effective on the down-stroke. Most softwood logs were broken down by this type of machine. Whilst several pieces are cut by one operation, the conversion is comparatively slow, and, as already stated, this machine is gradually being superseded by the horizontal and vertical log band mills and band re-saws (see below) where large outputs are required.

6. Combined Log and Deal Frame.—This is of a lighter but similar type to the vertical frame sawing machine D, and is used for rapidly cutting (known as *re-sawing*) deals and flitches into boards by one or more vertical saws which work with an up-and-down motion as the timber is fed by means of horizontal and vertical fluted rollers with adjustable down and side pressures. Only one deal at a time can be dealt with in the "single" type, but the "double deal frame" converts two deals at once. The saws are comparatively thin and thus a minimum wastage of wood results.

7. Band Re-sawing Machine.—This is similar to but lighter than the vertical log band mill and is designed for the rapid (up to 75 m per min.) re-sawing of deals, flitches and battens into boards and panels with the minimum waste of wood owing to the thinness of the band saw.

Other machines are described on pp. 27–30.



SEASONING

An introduction to this subject appears in Chap. III, Vol. I.

Timber from a recently felled tree contains moisture in the form of free water in the cell cavities and absorbed water in the cell walls. Seasoning or conditioning is the process concerned with the *reduction* (not total elimination) of this moisture content ("m.c.") in the timber. Timber required for internal use should be conditioned to a m.c. approximating to the average humidity of the room in which it is to be fixed (see p. 8).

The m.c. is calculated as a percentage of the dry weight of the wood so:—

1. A small test piece or cross-section is cut off a sample of wood before being seasoned. As the extreme ends of the piece may be drier than the remainder, it is usual to cut the cross-sectional specimen at about 300 mm from one end in order to obtain representative figures, and its length in the direction of the grain need not exceed 12 mm. The section is at once weighed (usually on a physical balance) and this is recorded as the *wet weight*.

2. The specimen is placed in an oven where it is subjected to a temperature of 100 C until the whole of the moisture has been withdrawn. It is again weighed and recorded as the *dry weight*.

3. The percentage moisture is then calculated from the formula:—

$$(a)\ \text{Moisture content per cent.} = \frac{\text{wet weight}-\text{dry weight}}{\text{dry weight}} \times 100,$$

$$(b)\ \text{Moisture content per cent.} = \left(\frac{\text{wet weight}}{\text{dry weight}} - 1\right) 100.$$

Thus, as an example, suppose the specimen to be from a 175 mm by 25 mm floor board, 12 mm long, having an initial or wet weight of 42 gm and a final or dry weight of 30 gm. The

$$\text{m.c.} = \frac{42-30}{30} \times 100 = 40 \text{ per cent} \quad . \quad . \quad . \quad (a)$$

or

$$\text{m.c.} = \left(\frac{42}{30} - 1\right) 100 = 40 \text{ per cent.} \quad . \quad . \quad . \quad (b)$$

The determination of the m.c. in kiln samples is referred to on p. 10. The m.c. of samples of timber freshly cut from the log may vary from 50 per cent. or more for hardwoods to over 100 per cent. for softwoods. Much of this moisture must be removed, and the following moisture contents of timber required for various purposes are recommended. Interior joinery work, 9 to 14 per cent.; external joinery work (as for doors and windows), 15 per cent.; good class carpentry work, 20 per cent. (maximum) and rough carpentry work, 25 per cent. Although the mean m.c. of timber in centrally heated buildings is approximately 12 per cent., it is advisable to reduce the m.c. in timber to be used for panelling, etc., adjacent to the heating radiators to at least 8 per cent. It is important to note that *timber which has less than 20 per cent. m.c. is not liable to become affected by dry rot* (see pp. 14–15).

Defects or Degrades due to Seasoning.—The evaporation of the absorbed water in the cell walls during the process of seasoning does not commence until the whole of the free water in the cavities has disappeared. The term *fibre saturation point* is applied when the last of the free water has been removed and the cell walls are still saturated; the m.c. at this stage varies from 25 to 30 per cent. Shrinkage does not occur until after the free water has been totally eliminated and the removal of the absorbed water commenced. Changes in size and often in shape then occur, the maximum shrinkage taking place in the tangential direction (*i.e.*, in the direction of the growth rings). Tangential shrinkage is generally approximately double radial shrinkage (*i.e.*, at right angles to the annual rings). Thus, approximate comparative figures show that the *average tangential shrinkage of timber per* 300 *mm of original width increases from* 18 *to* 23 *mm when the m.c. decreases from* 14 *to* 9 *per cent., and the corresponding radial shrinkage increases from* 10 *to* 13 *mm.* Longitudinal shrinkage (*i.e.*, in the direction of the grain) is almost negligible. This unequal movement in the several directions is due to the difference in structure of the wood; thus, as the ray cells lie in a radial direction (see A, Fig. 1), and as cells do not vary appreciably in length, it follows that the presence of ray cells is chiefly responsible for the relative reduction in radial shrinkage. The thicker the cell walls the greater the shrinkage. From the foregoing it will be appreciated that: (1) Quarter-sawn timber is less liable to movement than that which had been plain sawn; (2) denser timbers usually shrink and swell more than lighter wood; and (3) spring wood is more static than the denser summer wood.

As stated above, timber for internal joinery work should have a m.c. as near as possible to the mean humidity of the air in the portion of the building in which it is to be permanently fixed. Otherwise, if comparatively dry wood is exposed to a damp atmosphere it will absorb moisture and swell; conversely, if the m.c. in the timber is relatively high and the air of the room is warm and dry, a certain amount of moisture will be evaporated and the timber will shrink. This movement or *working* takes place when the humidity of the atmosphere in a building is not constant, and serious defects may be caused by the alternating shrinkage and expansion due to extreme fluctuating atmospheric conditions. Such conditions are commonly met with in buildings in course of construction and especially during the winter months when the humidity of the atmosphere is relatively high. *It is therefore advisable to defer as long as possible the fixing of framed work, such as panelling and the laying of wood block and similar flooring, until the building has been well dried.* Every effort should be made by artificial heating and other means to dry newly constructed buildings as thoroughly as practicable before at least the more expensive woodwork is introduced.

Defects due to seasoning include checking, splitting and warping. These degrades are caused by shrinkage.

Checking is the longitudinal separation of the fibres which does not extend throughout the whole cross-section of the wood. It is due to unequal drying. As the moisture evaporates more rapidly from the surfaces, they tend to shrink before the inner layers, and splitting results. The various forms of checks are:—

(a) *End Checks.*—Occur on the ends, especially in large pieces. Caused by the moisture evaporating more quickly through the end grain than other surfaces and the shrinkage being held back by the greater body of wood. End checking can be minimized by painting the ends; this reduces the rate of end drying.

(b) *Surface Checks*, which form on the outer faces during the early stages of seas Later they may close and are only exposed on dressing the timber.

(c) *Honeycomb or Internal Checks.*—Appear in the interior of the timber if the conditions are too severe in the early stages. The separation of the inner fibres is the shrinkage of the dried surface fibres being resisted by the wetter core, and wh internal moisture dries out later the core fibres are prevented from shrinking by t outer layers. A condition of stress results, known as *case-hardening*, and this pr honeycombing.

Checks are usually much shorter than shakes (see Chap. III, Vol. I). The la not seasoning defects.

Splitting is the separation of the fibres which extends through a piece of timb one face to another. Splits are sometimes called *through checks*.

Warping.—The various forms of this distortion are: Bow, cup, spring and twi

(a) *Bow and Cup* are referred to in Chap. III, Vol. I.

(b) *Spring or Springing.*—A curvature of the edge of a piece of timber. The not affected and is therefore flat.

(c) *Twist or Wind.*—A spiral distortion (winding) along the length of a piece of

Collapse.—A condition which may occur during the early stages of seasoning w timber which may shrink unevenly and/or excessively. The cells are flattened as of the partial vacuum created by the evaporation of the water and its retarded repla by air. Collapse can be prevented if the timber is dried at low temperatures in t stages.

Brashness or Brittleness may be caused to timber if it has been too rapidly dried subjected to high temperature in the kiln; such timber breaks with a short fractu

Methods of Seasoning.—There are three methods of eliminating excess m from timber, *i.e.*, (1) air seasoning, (2) kiln seasoning and (3) a combination of kiln seasoning.

1. *Air Seasoning or Natural Seasoning* (see Chap. III, Vol. I).—The timber is either out of doors where the piles are roughly protected by temporary sloping roo consisting of a double layer of low-grade sloping boards which overhang the side piles) to throw off the rain, or in an open shed having a roof and one or more wall site or floor should be well drained and covered with ashes or, preferably, con prevent the growth of vegetation. The width of a pile varies from 1·8 to 3·7 height may be up to 5 m and the length depends upon that of the timber. Piles built on steel beams or rails supported at intervals by 225 mm square concrete piers, 225 mm high, and three to four rows per width of pile; in the absence of b pillars are spaced at about 0·8 m centres. If piers are not used, the timber in con the floor should be creosoted.

There are several methods of piling. Thus, that shown at C, Fig. 29, Vol. 1, is for softwood baulks. A more effective arrangement, as it ensures a better flow of reduce the number of baulks in every alternate layer. The piles are sometimes with the timbers inclined in the transverse direction; any water which may enter is thus effectively drained. Converted hardwood logs may be lagged or sticked at E in the above Fig. 29, the logs being stacked one above the other.[1] Boards piled as shown in the kiln at A and B, Fig. 3 (this volume), the 25 mm thick pil being of well-seasoned softwood and spaced at from 0·6 to 2 m apart, depending thickness of the timber to be supported.

If timber is piled in the winter the evaporation of the moisture is gradual, and surface shrinkage and checking will not occur.

The rate of evaporation in air seasoning is comparatively slow in this countr only partly controlled. The degrade, such as checking, splitting and warp above), is relatively small because of the humidity of this climate.

Under average climatic conditions it is not possible in this country to reduce of timber by air seasoning to much below 20 per cent., although during a prolon of hot weather it may be reduced to 12 per cent. As the average reduction is not

[1] End checks are reduced by coating the ends with paint. Strips of woo across the ends of the planks (see E, Fig. 29, Vol. I) *after* shrinkage has occurre the extension of any splits which may have formed; the strips should not be fix contraction has taken place.

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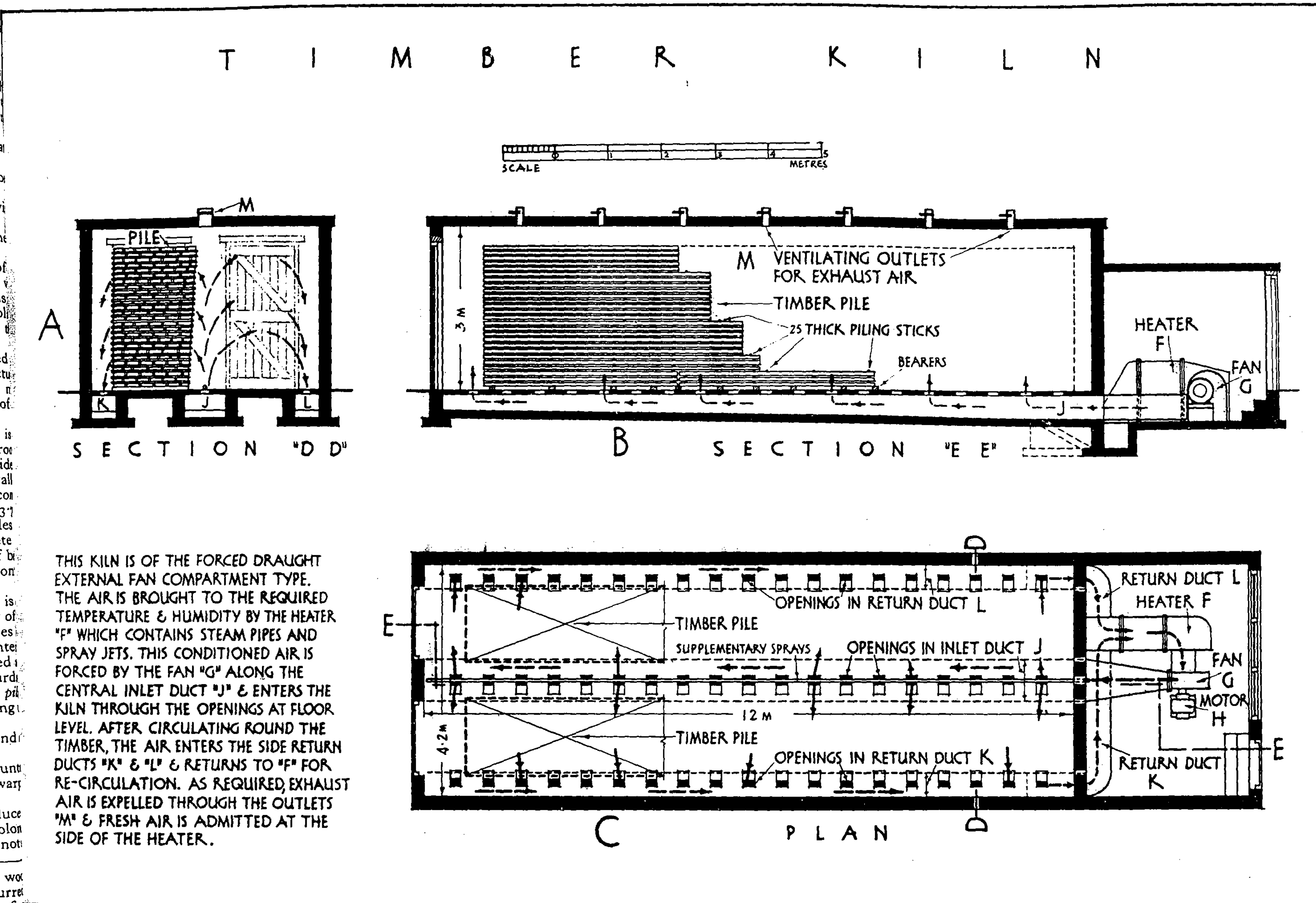

FIGURE 3

for certain internal work (see p. 7), it is clear that air conditioned timber to be used for good class joinery should be dried still further by keeping it in a heated workshop or store before being finally dressed or framed together until the required m.c. has been attained.

In order that the timber may be available for use immediately the m.c. has been reduced by air seasoning to the required percentage, it is necessary to determine the m.c. when the timber is piled and thereafter at suitable intervals. The procedure for this purpose is similar to that described for kiln seasoning, see below.

Length of Drying Period.—The time taken in air seasoning depends upon the temperature and humidity of the atmosphere, efficient stacking, and the thickness and density of the timber. On the average it may be taken as a guide that the m.c. in 25 mm thick softwood boards will be reduced to 20 per cent. within two to three months, provided they are stacked in the spring, and 50 mm thick pieces will dry to a similar amount within three or four months. Hardwoods take longer to season, thus 25 mm pieces, if piled in the autumn, will take about nine months to dry to 20 per cent. m.c. and 50 mm thick hardwoods will take about a year to dry to the same amount. Any further reduction in m.c. will, of course, take longer and depends upon the store or kiln to which the timber is transferred.

The advantages of the process of air seasoning are: (1) It is relatively cheap for small supplies; (2) it requires little attention; and (3) defects due to the process are comparatively small. The disadvantages are: (1) The rate of drying is very slow; (2) it cannot be rigidly controlled; (3) even under favourable conditions the m.c. cannot be reduced to that required for certain internal joinery; (4) large stacks of timber require considerable space; (5) much capital is unproductive for a lengthy period; and (6) damage to the timber may be caused by fungi and insects.

2. *Kiln Seasoning or Artificial Seasoning.*—This method is employed on a vast scale, as it ensures rapid drying of the timber to any required m.c. under controlled conditions. The timber is stacked in a kiln, of which there are several types, and air, heated by passage over steam pipes to the desired temperature is circulated through the piles. This hot air which accelerates the evaporation of moisture from the timber, must contain a certain amount of moisture, otherwise splitting and case-hardening of the wood will result owing to the rapid drying or baking of the surface before the removal of the requisite amount of moisture from the interior. The necessary humidity of the air is obtained by the carefully regulated admission of steam in the form of a spray. Adequate circulation of the air is essential, as stagnant air would take up moisture from the timber and gradually become incapable of reducing the m.c. sufficiently. Hence the air should be of uniform and sufficient velocity; fresh air must be admitted, and saturated or exhaust air must be removed as required.

Kilns are classified into (*a*) those in which the air is circulated by mechanical means, such as fans, and known as *Forced Draught Kilns*, and (*b*) *Natural Draught Kilns* in which the circulation of the air is due to differences of temperature which cause the warmer and lighter air to rise and colder and denser air to fall.

(a) *Forced Draught Kilns* include (i) External Fan Compartment Kilns, (ii) Overhead Internal Fan Compartment Kilns and (iii) Tunnel or Progressive Kilns.

(a) (i) *External Fan Compartment Kiln.*—This is illustrated and briefly described in Fig. 3. The timber is piled as shown, the layers being separated by 25 to 38 mm thick piling sticks spaced at from 0·3 to 0·9 m apart, according to the thickness of the timber; these sticks must be in true vertical alignment, especially if the timber consists of thin boards, otherwise the latter may become distorted. The piles are shown built up on bearers placed on the floor. Alternatively, the timber may be piled on trucks; this is economical, as the piling is done outside the kiln and therefore little time is wasted between the removal of the trucks of dried timber and the charging of the kiln with trucks of unseasoned stuff. It is desirable to leave a 50 to 75 mm space between adjacent pieces of timber if it is thick, otherwise the boards are placed with their edges close together. The face of a pile over the inlet duct is usually inclined as shown at A, as this assists in distributing the warm air throughout the pile. The width of the piles should not exceed 1·8 m; wider stacks make uniform drying difficult. As shown, the air is heated by steam pipes, humidified by sprays and circulated in the direction of the arrows by a fan situated outside the kiln. One difficulty is that of securing uniform circulation along the length of the kiln; short-circuiting at the end nearest the fan is prevented by the provision of baffles along the air-inlet duct and the adjustment of the dampers at the opening in the inlet and return ducts. This is a very good type of kiln for general work.

Careful adjustment of the temperature and humidity of the air in the kiln must be made and the moisture content of the stacked timber taken at intervals during the drying process. This m.c. is determined by testing one or two representative sample boards, which are about 1·8 m long. The procedure is as follows: A small test piece is cut from a sample board and its m.c. calculated by using either the formula (*a*) or (*b*) as explained on p. 7. The m.c. of the test piece is assumed to be that of the board. The wet weight of the sample board (less the test piece) is taken at the same time and its dry weight calculated. Thus, taking the example given on p. 7 (where the m.c. of the test piece is 40 per cent.), and assuming the wet weight of the sample board is 4·76 kg, then the dry weight of the board is found from the formula (*b*), *i.e.*

$$\text{m.c.} = \left(\frac{\text{wet weight}}{\text{dry weight}} - 1\right)100.$$

Therefore,

$$\text{dry weight} = \frac{\text{wet weight}}{\frac{\text{m.c.}}{100} + 1} = \frac{4{\cdot}76}{1{\cdot}40} = 3{\cdot}4 \text{ kg}.$$

This dry weight is, of course, constant. The m.c. of this sample can now be determined at any time during the drying operation. For example, if seasoning has been in operation some time and the sample board is removed from the pile and re-weighed

$$\text{the current m.c.} = \left(\frac{\text{current weight}}{\text{dry weight}} - 1\right)100.$$

Thus, if the current weight is 4·4 kg, the

$$\text{m.c.} = \left(\frac{4{\cdot}4}{3{\cdot}4} - 1\right)100$$

$$= 0{\cdot}3 \times 100 = 30 \text{ per cent.}$$

The drying process has thus reduced the m.c. from 40 to 30 per cent. The sample board is re-weighed at intervals until the m.c. has been reduced to that required (see p. 7 for recommended moisture contents) to complete the process.

The sample boards should be conveniently placed in the pile, and in order that they can be withdrawn readily it is usual to notch the lower edges of the piling sticks above the boards for a width slightly in excess of that of a board.

The length of the drying period and the temperature and humidity of the air depend upon such factors as the species, quality, behaviour (such as a tendency to warp) and size of the timber, and the purpose for which it is to be used. Satisfactory manipulation of the kiln is dependent upon the operator who must take these factors into consideration when regulating the supply, temperature and humidity of the circulating air to suit the changing condition of the timber, as indicated by the periodical testing for m.c. described above.

The temperature and relative humidity of the air in a kiln are ascertained by the use of a dry-and-wet bulb thermometer. The dry bulb indicates the temperature of the air, and the relative humidity is ascertained by referring the readings of both bulbs to a humidity chart or table.

The man in charge of a kiln is guided by tables or *kiln-drying schedules*. Such schedules are evolved by a qualified operator as the result of his experience of handling many kinds of timbers and after taking into account the factors of species, quality, etc., stated above. On the next page is an example of a schedule, the figures being hypothetical only.

Such a schedule is applied in the following manner: It is assumed that the timber piled in the kiln can be appropriately seasoned by adherence to the schedule and that the sample board (or the wettest of four sample boards—one on the inlet side and one on the outlet side of each pile) has a m.c. of that referred to above, *i.e.*, 40 per cent. (or between 35 and 40 per cent.). The temperature and relative humidity of the circulating air at the beginning of the drying process must therefore be 49° C. and 75 per cent. respectively, the humidity being obtained by admitting steam through the jets to the kiln until the wet bulb registers the appropriate temperature, which in this case is 44·4 C. The kiln must be gradually warmed up to the dry bulb temperature of 49° C. whilst the humidity is kept constant at 75 per cent.[2] This temperature and humidity are maintained until the sample board on re-weighing has its m.c. reduced to 35 per cent., when the temperature would then be raised to 51·7° C. and the humidity decreased to 70 per cent. When the board, after re-weighing, has its m.c. lowered to 30 per cent., the corresponding temperature and humidity would be altered to 54·4° C. and 65 per cent. respectively. These operations are repeated until the m.c. of the timber has fallen to the required percentage, after which the kiln is gradually cooled and the humidity increased to about 60 per cent. before the timber is withdrawn from the kiln. The maximum temperature may reach 85° C. and the humidity be reduced to 45 per cent., before the m.c. of certain timbers has been lowered to 14 per cent. Instruments for automatically recording the temperature and humidity of the circulating air may be used instead of the ordinary dry-and-wet bulb thermometer.[1]

Percentage Moisture Content of Timber	Temperature		Percentage Relative Humidity
	Dry Bulb	Wet Bulb	
	° C.	° C.	
60	46·1	42·8	80
40	49	44·4	75
35	51·7	46·1	70
30	54·4	47·2	65
25	57·2	48·3	60
20	60	49·4	55
etc.			

(a) (ii) *Overhead Internal Fan Compartment Kiln.*—The maximum width is 5 m, the maximum height (to the false wood ceiling which is suspended from the roof) is 2·75 m and the length varies from 3 to 12 m. Uniform circulation of the hot moist air is promoted by fans centrally along the length of the kiln above the false ceiling at 1·5 m intervals. The heat is provided by means of 25 mm internal diameter steam pipes which are distributed over the space above the false ceiling on both sides of the fans. A 25 mm steam spray pipe, perforated with 3 mm holes at 300 mm intervals and fixed centrally and immediately below the fans, provides the required moisture. The hot air is circulated from the top, down the outer sides of the stacks, through the stacks, and up between the stacks to the fans. A certain amount of the moist circulated air is allowed to escape through outlets at the roof, and fresh air is admitted at the floor through openings in a central duct. The temperature and humidity can be automatically controlled. It is considered that this kiln is one of the most efficient and economical types.

[1] Portable *electrical moisture meters* are now available for rapidly and conveniently determining the m.c. of timber. The small electrode of one type is clamped to the timber and the m.c. is read directly on the dial of the meter. Further readings are taken as needed until the required m.c. is registered on the meter.

Another type of internal fan kiln has the fans, heating pipes and sprays below the floor level.

(a) (iii) *Tunnel or Progressive Kiln.*—This somewhat resembles the tunnel kiln used for brick-burning and described in Chap. I., Vol. II, in that the kiln is in the form of a tunnel along which travel trucks piled with timber. The maximum width of the kiln is 5 m, it is from 1·8 to 3 m high and it may be 30 m or more in length. It is kept filled with loaded trucks which are gradually moved forward at a uniform rate during the drying process. It is usual for one truck of seasoned timber to be removed at the discharge end and one truck of green timber to be added at the opposite end daily. Steam from sprays fixed in a duct below the floor at the discharge end provides the requisite humidity. The air, heated by steam or hot-water pipes placed below the floor for about two-thirds of its length from the discharge end, rises between the timber and circulates along the tunnel towards the inlet end before returning below the floor for re-circulation. The flow of the hot moist air in the kiln is thus in the opposite direction to the movement of the timber. Fresh air is admitted at the discharge end and mixes with the re-circulated air. The air gradually decreases in temperature and increases in humidity as it circulates round the timber towards the inlet end, and hence it is sufficiently cool and moist when it comes into contact with the unseasoned or green timber. Some of this moist air escapes at the loading end and is discharged up a chimney which produces the necessary draught to promote circulation. Alternatively, the circulation may be promoted by a fan fixed in the duct. Whilst this kiln is economical, it is best suited for drying thin timber of uniform size and quality. It is not used extensively in this country.

(b) *Natural Draught Compartment Kilns.*—This type of kiln is approximately 4 m wide, 3 m high and 9 m long; it has a duct below the floor extending the full width and length of the kiln. The timber may be piled as shown at A and B, Fig. 3, or it may be stacked on trucks which remain stationary during the process. A group of steam pipes for heating the air extends centrally along the duct, and the necessary humidity is provided by steam from jets immediately above it. The kiln is so called because the circulation depends upon natural means; thus, the air after traversing the hot pipes passes upwards between the two piles and transversely through the piles, when it takes up moisture from the timber and, becoming denser, descends between the piles and the walls for re-circulation. Fresh air as required enters the duct from the outside and an equal amount of saturated air escapes at the floor level through vertical flues situated in the side walls. This simple type of kiln is very economical, but the circulation is uncertain and not easy to control. It is best suited for small-sized timber which has been partly seasoned.

3. *Combined Air and Kiln Seasoning.*—It is a common practice to reduce the m.c. of timber to approximately 20 per cent. by air seasoning before subjecting it to further treatment in a kiln. This considerably reduces the kiln-drying period (see below), especially for certain hardwoods. The kiln output is therefore substantially increased.

Length of Drying Period.—This varies with the size, characteristics and quality of the timber. The approximate time required in a forced draught kiln to reduce the m.c. of 50 mm thick timber from a maximum (green) to 12 per cent. is from one to two weeks for softwoods and three to twelve weeks for hardwoods. These times are increased by about half if the timber is seasoned in a natural draught kiln. Preliminary air seasoning to 20 per cent. m.c. reduces the above kiln periods to approximately one-third. These figures should be compared with those given for air-seasoning (see p. 10).

PRESERVATION

Decay in timber used for certain purposes can only be prevented if it is subjected to an effective process of preservation. Thus, timber required for piles, sleepers, fences and gates, wall plates and ends of floor joists built into walls, floor fillets partially embedded in concrete, weather-boarding, etc., for temporary buildings and unpainted external woodwork, should be treated with some form of preserving agent. B.S. 5268, Pt. 5, Timber Preservation is relevant.

Fungi (plants of the mushroom tribe) are the principal cause of decay in timber used in this country (see pp. 14–16). This low form of life requires food, a certain amount of moisture and oxygen for its growth, and the absence of any one of these prevents decay. Thus the fungi cannot exist in timber if either (1) the food supply in the form of organic matter (of which timber is chiefly composed) is poisoned by a suitable preservative such as is described below, or (2) the timber is sufficiently seasoned (to a minimum m.c. of 20 per cent.—see pp. 7 and 14) and maintained in a dry condition, or (3) air is excluded. Fungus develops more quickly in warm weather than in cold, especially if the temperature is between 27° and 32°C.; most fungi will not grow if the temperature exceeds 42°C. or is at freezing point. In addition to fungi, much damage is done to timber by insects (see p. 15).

Effective preservation depends upon the preservative employed and its application. An efficient preservative should be poisonous to fungi and insects (but not to persons handling it), permanent, able to penetrate sufficiently, cheap and readily available; it should not corrode metal fastenings, etc., nor should the timber be rendered more flammable by its use; it is sometimes desirable to have a preservative treated surface which can be painted.

Substances used for wood preservation include (1) oil preservatives such as creosote and coal-tar, (2) unleachable metallic salts, and (3) water soluble preservatives of which zinc chloride, sodium fluoride and magnesium silicofluoride are examples.

Creosote[1] is an effective general-purpose preservative being cheap and widely used for external work and, to a lesser degree now, internally. It is a black or brownish oil produced, as noted in Chap. I, Vol. II, by the distillation of coal-tar. It has most of the above requirements but it increases flammability, is subject to evaporation and creosoted wood cannot be painted. It should not be used internally if the characteristic smell would be a nuisance.

Coal-Tar as a preservative is not as effective as the creosote produced from it. Tar is less poisonous, it does not penetrate the timber because of its viscosity, it is blacker than creosote and is unsuitable for internal woodwork.

Unleachable Metallic Salts are mostly based on copper salts. One proprietary system, the *Tanalith C*,[2] uses a chemical of the copper/chrome/arsenate type where the copper and arsenical salts are the toxic preservatives which are rendered unleachable (cannot be washed out) by the chrome salts acting as fixing agents. The timber is impregnated by *vacuum-pressure* in a similar way to the full-cell or empty-cell processes described on p. 12. According to the situation of the timber and its degree of exposure, the retention of the dry salt preservatives can be regulated between 4 and 20 kg/m³. The former figure is suitable for building timbers; the higher retentions being required for ground contact, water immersion and anti-termite treatments (the last-named is essential in certain places abroad). Preservation by metallic salts is being increasingly used and the method described has the requirements given above; also, treated surfaces can be painted or glued; evaporation is negligible; the liquid is odourless and non-oily.

Water Soluble Preservatives.—These are not satisfactory for external use, as they are liable to be removed from the timber by rain. They are, however, very suitable for interior work, as they are comparatively odourless and colourless, and timber so preserved can be painted. They are obtained in concentrated form and require to be diluted with water to give from 2 to 5 per cent. solutions. Other preservatives of this class include mercuric chloride (corrosive sublimate and copper sulphate, but neither is much used in this country as the former is highly poisonous to human beings, the latter is not permanent, and both have a chemical action upon metals.

There are a number of other patent preservatives available. Some consist of poisonous chemicals (such as chlorinated phenols and naphthenic acids) dissolved in volatile oils. When such a preservative agent is applied, the oil evaporates and leaves the chemical in the timber. Their high cost limits their use.

The timber should be seasoned[3] before being subjected to a preserving process, as the presence of moisture impedes the penetration of the preservative.

To be effective a preservative must sufficiently penetrate the timber. The extent of the penetration depends upon the conditions to which the timber is to be subjected; thus, if it is to be submerged in water or embedded in the ground it should be thoroughly impregnated with the preservative, whilst certain internal woodwork may be given adequate protection by surface treatment only. Preservatives are applied by (1) pressure, (2) non-pressure and (3) superficial processes.

1. **Pressure Processes.**—There are several pressure processes and these are generally adopted for treating timber on a large scale. Maximum penetration of the preservative results from pressure treatment. In each of the several methods the timber is placed in a strong steel cylinder, 1·5 to 3 m diameter and 4·6 to 6 m long, and having a tight-fitting door at each end. The cylinder is fixed horizontally at ground level, and a storage tank containing the preservative (and steam coils for heating it) is connected to it. The timber is either piled directly in the cylinder or stacked in bogies and run into it.

Creosoting is one of the main pressure-processes, and, as is implied, creosote is the preservative used. There are two methods of application, (*a*) full-cell process and (*b*) empty-cell process.

(a) *Full-cell Process.*—This is so called because the wood cells remain filled with the preservative after the timber has been withdrawn from the cylinder; it is also known as the *Bethel Process* (after the patentee who introduced it about a century ago). The first operation, after the cylinder has been piled with the seasoned timber and the doors have been clamped, is the reduction of the air pressure within the cylinder and the removal of the air and moisture from the timber cells by a vacuum pump; the vacuum may be up

[1] B.S. 144 describes tests for creosote.
[2] Executed by Hickson's Timber Impregnation Co. (G.B.) Ltd. Suppliers of similar chemicals include: Cuprinol Ltd., and Celcure Chemical Co. Ltd.

[3] An exception to this is the Boucherie process (see later) sometimes used for the preservation of the sapwood of many softwoods (including the heart and sapwood beech and birch) when such woods are newly felled and have a high m.c.

0·6 m and is maintained for one to two hours, depending upon the size and species of the wood. The cylinder is then completely filled with creosote heated to a temperature varying from 38° to 82° C., a pressure of approximately 7 kg/cm² is applied and maintained for about two hours until the required quantity of creosote (as determined from the measuring instruments on the storage tank) has been forced into the timber. The amount of creosote absorbed depends upon the kind and condition of the timber and the use to which it is to be put, and varies from 48 (for some hardwoods) to 200 kg/m³ (for certain softwoods). Finally, the pressure is released, the creosote is drained off, and a vacuum is again applied to withdraw excess creosote from the timber before it is removed. This method is best suited for timber fixed in wet positions, timber piles,[1] telegraph poles, etc.; and where exudation of the creosote from the wood (known as "bleeding") is not objected to.

(b) *Empty-cell or Rueping Process.*—This is very suitable for treating timber required for building purposes, as it is effective, the wood is clean to handle on account of the small amount of bleeding which takes place, and it is comparatively cheap, as it only requires approximately 50 per cent. of creosote used in the full-cell process. The timber in the cylinder is first subjected to a pressure of about 2·8 kg/cm² of compressed air. This is maintained whilst the heated creosote is admitted and the cylinder has been completely filled, after which about 0·7 kg/cm² additional air pressure is applied for approximately fifteen minutes. This causes the creosote to enter the timber cells and compresses the air already in them. The pressure is then released enabling the compressed air in the timber to expand and expel much of the creosote from the cells. A partial vacuum is finally applied and this removes more creosote from the timber. The cells are therefore free from preservative although their walls have been well impregnated.

Creosoting by the non-pressure process is described below.

Burnettizing.—Patented by Burnett a little over one hundred years ago, this pressure process is still employed. It is somewhat similar to creosoting, except that the preservative is zinc chloride, one of the water soluble salts. The seasoned timber, after being subjected in the cylinder to a vacuum for about an hour, is impregnated with the solution (1 kg of the salt to 500 litres of water) at a pressure of approximately 7 kg/cm². The process takes about five hours to complete. It is cheaper than creosoting, but is less effective on account of its lack of permanence.

The *Boucherie* pressure process (impregnation with a solution of copper sulphate) is occasionally used for some kinds of *newly* felled trees (see footnote 3, p. 12). The *Carbolizing* or *Blythe's* process (which consisted of injecting creosote vapour and superheated steam into the timber, followed by creosoting) are not now employed.

2. Non-Pressure Processes.—The treatment is known as *steeping*, or *soaking* or *open tank*, and is adopted for relatively small quantities of timber when a pressure plant is not available. The apparatus simply consists of a rectangular watertight tank, open at the top, and from 0·76 to 1·5 m wide, 1 to 1·2 m deep and 3·7 to 4·6 m long; a cylindrical storage reservoir of similar capacity is sometimes provided in addition. There are three methods, *i.e.*, (*a*) hot-and-cold steeping, (*b*) hot steeping and (*c*) cold steeping.

(a) *Hot-and-cold Steeping.*—This is the most efficient of the non-pressure processes. The open tank is preferably sunk in the ground to within a few inches from the top to facilitate loading and unloading of the timber; the storage reservoir is fixed adjacent to it and at ground level. Provision for heating the preservative in the open tank must be made. This preferably takes the form of steam coils resting on the bottom of the tank and protected by horizontal bars which support the timber; alternatively, the tank is fixed on top of a furnace having a horizontal flue extending the full length of the tank and terminating with a chimney stack.

Creosote and some of the unleachable metallic salts can be applied by this method, which is similar for both liquids. If creosote is used the preserving operation is conducted in the following manner: The *seasoned* timber is stacked in the tank and held down by bars at the top; the cold preservative is run into the tank from the reservoir, gradually heated to about 93° C and maintained at this temperature for one to two hours, after which it is allowed to cool, the liquid is pumped back into the reservoir, and the timber removed. During the heating period the air in the timber cells expands and some is expelled; as the preservative cools, the air left in the timber contracts and the partial vacuum created causes the liquid to be gradually absorbed into the timber. Whilst not absolutely essential, the provision of the reservoir does make it possible for the timber to be drained before removal and reduces the loss of preservative whilst making the timber less objectionable to handle. The operation only takes a day to complete.

An improvement on the above method is effected if, after cooling, the contents of the tank are re-heated and the timber is left to soak in the hot preservative for an average period of two hours before removal. This causes much of the creosote absorbed during the cooling period to be expelled resulting in an economy of preservative.

The ends of fence posts are effectively preserved by *butt treatment*, for which only a metal barrel or drum, placed upon a crude fireplace, is required. The posts are placed vertically in the drum with their pointed ends immersed to the required depth in the cold creosote which is heated and then cooled as above described. Hot creosote is poured or brushed over the upper portions of the timber whilst it is being soaked. To meet bigger demands, a long tank, subdivided into compartments to assist in keeping the posts upright, may be used.

Ends of floor joists which are to be built into walls may also be protected by butt treatment.

(b) *Hot Steeping.*—This has been largely superseded by the more efficient, quicker and economical hot-and-cold steeping. It consists of soaking the timber in a tank of hot preservative for varying periods depending upon the species, proposed use, etc.

(c) *Cold Steeping.*—This is even less effective than hot steeping on account of the slow penetration of preservative. The absorption rate varies, an immersion of one week per 25 mm thickness of timber may be regarded as average.

Kyanizing Process.—This is seldom adopted in this country, as the preservative, mercuric chloride (corrosive sublimate), used in the process is extremely poisonous and therefore dangerous to workmen handling it. The timber is steeped in a 1 per cent. solution of mercuric chloride which is contained in a wood trough, as the preservative has a corrosive action upon metal.

Powellizing or *Powell Wood-process.*—The preservative used in this patent open-tank system is a heated solution of which the chief ingredient is sugar. The timber may be either seasoned (if required for internal woodwork or furniture) or unseasoned (for fencing, sleepers, etc.). The apparatus consists of a long (up to 30 m), open tank or chamber with removable ends. The timber is piled on trolleys and run into the tank, the ends are clamped (which make the tank watertight), the solution of required strength is introduced and heated by steam pipes, and after several hours' application this liquid is removed, the unloading door is unclamped and the timber is withdrawn. Neither pressure nor vacuum is required as the saccharine solution is readily absorbed by the timber. The process is very efficient. It is adopted chiefly in those countries where creosote is unobtainable and especially where sugar is grown. It has not been employed extensively in this country.

3. Superficial Processes.—These include (*a*) dipping, (*b*) spraying and (*c*) brush application. None of these surface treatments is as effective as the pressure and open-tank system, as the preservative only slightly penetrates the timber. The wood must be seasoned, and the surface should be dry before application. Greater penetration generally results if the preservative is applied hot, especially if creosote is used.

[1] See Vol. IV for timber, concrete and steel piles.

(a) *Dipping* is the best surface treatment, it cannot be used for timber already fixed in position. The pieces of wood are simply dipped in a receptacle containing the preservative; the longer the immersion the better.

(b) *Spraying*.—The preservative is applied in the form of a fine spray forced through the nozzle of the appliance by compressed air.

(c) *Brush Application*.—This is the most common method of treating existing exposed woodwork with creosote or other preservative. The liquid should be applied liberally with the brush and any cracks in the timber should have special attention. At least two good coats should be given, the first coat being allowed to dry before the second is brushed on. Where accessible the treatment should be renewed every three years, especially if it is external work such as fencing, weather-boarding, timber outbuildings, etc.

Fire-retarding.[1]—Whilst timber cannot be made fireproof, there are several chemical solutions and proprietary paints available for rendering it fire-resisting. One of the most effective fire-retardants is ammonium phosphate. The material is applied by any of the methods described for preservation. The timber should be well seasoned before treatment in order that maximum penetration may be effected.

DEFECTS

Defects due to seasoning are referred to on pp. 7 and 8. Other defects are described in Chap. III, Vol. I. Defects[2] caused by fungi and insects are described below.

It has been stated on p. 11 that fungi are the chief cause of decay, that the development of fungus is dependent upon food, moisture and oxygen, and that the absence of one of these prevents decay. A suitable temperature is also essential for fungoid growth. The principal decay of building timber is dry rot.

Dry rot.—This disease, which is highly infectious, causes a tremendous amount of destruction in timber. The decay is caused by several fungi, that most frequently found in buildings being the *Merulius lacrymans*. Partially seasoned wood fixed in a warm, damp and badly ventilated position is very liable to attack by this fungus. The spores (germs or seeds) of the fungus develop under the above favourable conditions and minute silky hollow threads or tubes (called *hyphæ*) are thrown out. These rapidly spread over the surface of the wood as an open network or as a closely interlaced covering or sheet which is grey coloured, relieved with blue and/or yellow patches. Under very damp conditions especially, the hyphæ may be arranged in cotton-wool like masses; such a collection is known as a *mycelium*, and its colour is snowy-white with occasional bright yellow patches. In course of time the mycelium develops into a tough, fleshy substance called a *rhizomorph*. Each of these " mushroom " growths may exceed 0·3 m in diameter; it is of a brown or dark red colour with a white edge, and its surface resembles a sponge, it being corrugated and pitted with small holes. Countless numbers of spores are produced on the surface, and

[1] Fire resisting construction is the subject of Chap. III, Vol. IV.

[2] In addition there are the marine animals (gribble and teredo) which bore into submerged timbers used for piles and harbour works, etc. Termites have to be guarded against in tropical countries.

these can be readily conveyed by air currents, rats, mice and insects and t infect timber far removed from the original site. The disease can also be spr by infected tools and clothing. The fungus produces drops of water which h from its surface, hence the derivation of its specific name *lacrymans*, w means " weeping." Another property of this fungus is its ability to pro white or grey coloured strands which spread in all directions over timber, br work, plaster and steel, and may pass through mortar joints and actually pene thick walls consisting of soft bricks or stone. These strands, which may b to 6 mm thick, are capable of conveying water from the damp original site of dry rot to comparatively dry timber, remotely situated, thereby providing able conditions for the extension of the disease. Dry rot is transmitted f one floor to another in this manner and so may spread to every part of a buil if the attack is vigorous and the conditions suitable.

During the development of the fungus the hyphæ attack the fibres o wood and feed upon the substance of the cell walls, which are gradually br down. The decayed wood becomes friable and falls to powder under pre by the fingers, it is dry (hence the name applied to the rot), the surface bec uneven, and cracks extend both with and across the grain to divide it into a pieces. The colour is brown or dirty red, the wood is reduced in weight, i little strength and the member ultimately collapses. Sometimes the dec entirely internal and there is no external evidence of it.

Prevention.—The following precautions should be taken to prevent ti from becoming affected by dry rot.

1. All timber should be sound, well-seasoned stuff of good quality. important to note that timber having a moisture content of less than 20 per is unlikely to become attacked by the disease (see p. 7), and therefore all ti required for building purposes should not exceed this percentage of mo content. Timber may have become infected during storage in the hol ships or when piled in timber yards, but adequate kiln seasoning destroys infection.

2. The timber must be kept dry, hence an additional reason why dam in buildings must be avoided. The absence of efficient damp proof cours site concrete has been a frequent cause of dry rot in ground-floor timbers; ness due to defective eaves gutters, fall-pipes, roof coverings and drains may decay. Gutter and flat-roof timbering has also been subjected to rot beca the penetration of moisture through parapet walls. Infected firewood in damp cellars or similar accommodation may be the means of intro the decay. Built-in timbers, such as wall plates, ends of floor joists etc. (esp if the walls are of cavity construction—see Chap. I, Vol. II), should be adeq treated with a preservative; solid ground floors must be provided w adequate d.p.c. membrane. A narrow band of bitumen should be appl one face of an internal wall which has a solid floor on one side and a wood floor on the other.

3. Adequate circulation of fresh air round all timbers must be provided, as stagnant moist air is particularly favourable to the growth of dry rot. Provision must therefore be made for sufficient *through* ventilation under all wood floors, especially ground and basement floors (see Fig. 32, Vol. I, and C, Fig. 20, Vol. II). The air bricks or gratings should have sufficient clear opening area. A minimum of 10 cm^2 of open area per 300 mm run of wall should be allowed; this is obtained if 215 mm by 140 mm air bricks are provided at 1·8 m intervals. Dead pockets of air must be avoided and cross-currents of air must be induced, hence the need for honeycombed sleeper and partition walls to allow the air currents through the vents in the outer walls to be unobstructed. If a solid floor prevents this (such as a concrete scullery floor at the rear of a wood living-room floor) it is advisable to embed 75 or 100 mm diameter horizontal drain pipes during the laying of the concrete floor at 1·8 m intervals between openings in the division wall and ventilators in the outer back wall. An air brick or opening must be provided at each angle to obtain free circulation at the corners. Through ventilation under wood floors of halls and corridors is often omitted and is a frequent cause of dry rot. Air spaces round ends of built-in floor joists should be provided (see S and U, Fig. 32, Vol. I). This also applies to the lower ends of roof rafters, as extensive damage to roof timbers at the eaves has been caused by solid beam-filling (especially when the walls are thick and leaks through the roof covering have caused dampness) preventing the circulation of air round the timber. Dry rot to wall panellings and skirtings is also caused by dampness penetrating through outer walls, affecting the plugs and grounds and spreading to the back of exposed woodwork.

4. Site concrete should be well brushed and pieces of wood, shavings, etc., removed before the boarding of ground floors is fixed. Outbreaks have been traced to affected debris of this description which is liable to dampness. Trench and concrete sub-floor setting-out pegs should also be removed.

5. Linoleum and similar covering should not be laid on new wood floors, especially wood-covered concrete floors, before they have had time to dry out.

Detection and Remedial Measures.—Dry rot may be recognized by the presence of any or all of the following symptoms: (*a*) The appearance of the fungus described on p. 14; (*b*) warping, "cubical rot" (caused by cracks—see above) and other signs of infected timber already referred to; (*c*) decay or collapse of timber members (the backs of skirtings and the underside of floor boards may be extensively decayed); (*d*) an objectionable musty smell indicating dampness; and (*e*) a deposition of red-coloured powder (which teems with the spores) below a floor.

The curative measures necessary to eradicate the disease depend upon its extent. Drastic steps must be taken in serious cases, and the various operations *must be thorough* if a recurrence and extension of the disease are to be prevented. Thus, taking a bad case as an example, the following would be the sequence of operation if an examination of a ground floor disclosed extensive decay.

1. The whole of the timber is removed. This includes the skirtings, floor boards, joists, wall plates, plugs and grounds; it may also be necessary to splay-cut and remove the feet of architraves. This decayed or unsound timber is carefully taken outside and immediately burnt. Any plaster behind which the fungus may have spread must also be removed.

2. The faces of the walls below the floor, including the timber pockets and the surface of the site concrete are well cleaned down with a wire brush. These sweepings, in which the spores of the fungus will be present in countless numbers, are carefully conveyed to and spread over the wood fire and destroyed.

If no site concrete exists (and there are many buildings without it), the top 100 mm. or so of the earth is excavated, removed and buried; this earth is probably teeming with the spores which have fallen from the affected timber, and its removal should therefore be done with care to prevent droppings providing sources of infection. For the same reason, care should be taken to prevent spores being carried about on the feet to other parts of the building. Sometimes the penetration of the fungus into the sleeper walls necessitates their demolition and removal. The removal of such walls and the top soil is done before the main walls are brushed down.

3. Sterilizing the surfaces of the walls and site concrete now follows. This consists of applying a plumber's blow-lamp to the *whole* of the brushed surface. This destroys the spores, provided the flame when applied slowly and for a sufficient time renders the surfaces hot to the touch. To ensure complete success, however, it is advisable to follow this heat treatment by an application of a reliable antiseptic solution, which should be liberally applied in two coats. An antiseptic which is recommended is a 4 per cent. solution of sodium fluoride; a 5 per cent. solution of magnesium silicofluoride is also effective. Neither mercuric chloride (corrosive sublimate) nor zinc chloride (blue vitriol) is now advocated, as the former is dangerous to handle and the latter is only moderately efficient.

4. Necessary structural work, such as the insertion of a horizontal damp proof course, the provision of air bricks or grates and holes in division walls to ensure adequate *through* ventilation (see adjacent column), the construction of sleeper walls and the laying of site concrete, is carried out.

5. Finally, the new floor timbers, skirtings and feet of architraves (finished with splayed joints) are fixed. The timber must be sound, well-seasoned stuff of good quality. The joists, underside of floor boards, backs of skirtings, wall plates, plugs and grounds should be treated with a preservative (see pp. 11–14). Creosoting is an effective treatment, but any good preservative may be used.

The above operations are costly and are only called for when the decay is widespread. In a mild case it may be only necessary to remove the decayed timber (together with at least 0·3 m of the adjacent sound wood) and replace it with sound preserved stuff after brush-treating as much as possible of the existing timber with preservatives. Every suspected case must be closely examined and dealt with on its merits. Any doubtful source of infection must be removed, otherwise the disease will again develop and further expense will be entailed. Experience shows that partial treatment only is a waste of money and materials, as subsequent extensive operations are usually necessary to effect a permanent cure.

Another species of fungus which produces dry rot in building timbers is *Coniophora cerebella* or Cellar Fungus. It only attacks wet timber, and the decay is usually confined to cellar, bathroom, etc. floors where there has been a leakage of water, and to leaky roofs. *Coniophora* presents a less serious problem than *Merulius*, as decay caused by it is at once arrested if the cause of the dampness is attended to and the timber is allowed to dry. The decayed wood is much darker than that caused by *Merulius* and the cracks are mainly with the grain. The strands of this fungus are brown or almost black, bunches of the mycelium are absent, the hyphæ may produce small patches of yellowish skin, and fruit bodies are rarely seen in buildings. The characteristics of the two species are thus different.

Insect Attack.—Wood-boring beetles are the insects which cause most damage to timber in this country, and of these the (1) Death-watch Beetle, the (2) Common Furniture Beetle and the (3) Lyctus Powder-post Beetle are the most important. (See also footnote 1, p. 14, referring to marine borers.)

1. *Death-watch Beetle* (*Xestobium rufovillosum*).—These chiefly attack well-matured hardwoods in old buildings; softwoods and recently seasoned timber are rarely affected. The beetles lay their eggs in cracks and holes in the wood; white larvæ (grubs) which hatch out of the eggs are about 6 mm long when full-grown, and after boring in the wood for one and a half or more years develop about August into pupæ (chrysalis) near to the wood surface; whilst the winged beetle is formed within a few weeks after pupation, it does not issue from the wood until the following spring. Much destruction is caused during the larval stage, as the grubs bore numerous tunnels of about 3 mm diameter in the timber and produce dust during the process. In advanced cases most of the interior of the affected wood members are reduced to powder. Many thousands of pounds have been expended in past years upon restoring oak roofs of churches and other ancient buildings (*e.g.*, Westminster Hall) which have been damaged very extensively by the ravages of the death-watch beetle.

The conditions of dampness and poor ventilation associated with dry rot are also conducive to attack by the beetle. Hence any treatment of infested structural timbers must include the provision of adequate general ventilation and air spaces round built-in ends of members, and the remedy of defects causing dampness. Badly infected timber must be removed and replaced by sound stuff free from sapwood. There are a number of proprietary insecticides on the market which are claimed to eradicate the beetle. The timber must be well brushed down and vacuumed to remove as much dust as possible before the solution is liberally applied by means of a brush or spray, and several applications are necessary to ensure sufficient penetration; creosote is sometimes used when discoloration and smell are not objected to. Such treatment should be renewed every three or four years.

2. *Common Furniture Beetle* (*Anobium punctatum*).—These attack both hardwoods and softwoods, and especially old unpolished furniture and panelling. The life-cycle and damage caused are somewhat similar to those of the death-watch beetle, except that common furniture beetles emerge from the wood in the summer, and the diameter of the bored holes is about 1·6 mm.

Insecticide treatment, as described above, is applied to prevent further damage by this beetle.

3. *Lyctus Powder-post Beetles* (*Lyctidæ*).—Grubs of these beetles cause extensive damage to furniture, internal joinery work such as panelling, and timber piled in yards. The sapwood only of certain comparatively newly or partially seasoned hardwoods (including ash, elm, oak and walnut) is subject to attack; softwoods are immune, and well-matured hardwoods in old buildings are not affected. The presence of holes (up to about 2 mm in diameter) on the surface of the wood, and small piles of flour-like dust cast out from the holes (hence the name of the beetle), are characteristic of infected timber. The beetles emerge from the wood during the spring and summer; eggs are laid in the pores of the sapwood and are hatched out within a fortnight into white larvæ (about 6 mm long when fully grown), and these develop into pupæ and, finally, beetles which issue from the timber within one to two years after the larval stage.

There are several proprietary solutions available for treating infested timber and which are brush-applied to the surface during the spring and summer, but such insecticides are ineffective unless several applications are made. Proper seasoning of the timber destroys any *Lyctus* present, but frequent inspection of it should be made when stacked in the yard in order that any re-infestations may be detected.

CHARACTERISTICS AND USES OF TIMBER

B.S. Code of Practice 112—The Structural Use of Timber in Buildings—classifies structural softwoods into three groups: Group S1—Douglas Fir, Long leaf Pitch Pine, Short leaf Pitch Pine and European Larch; Group S2—Canadian Spruce, Redwood, Whitewood, Western Hemlock and Scots Pine; Group S3—European and Sitka spruce, Western Red Cedar. Each group is divided into a basic grade and four other grades of differing strengths. Table 1 is an extract from the Code, it shows some of the permissible stresses when the moisture content is 18 per cent.

TABLE I.—DRY STRESSES FOR SOFTWOODS

Species Group	Grade*	Bending and Tension Parallel to Grain N/mm²	Compression Parallel to Grain N/mm²	Compression Perpendicular to Grain N/mm²	Shear Parall[el] to Gra[in] N/mm[²]
S1	75	12·1	9·3	2·21	1·14
	65	10·3	7·6	2·21	0·97
	40	6·2	4·5	1·93	0·62
S2	75	9·7	7·9	1·72	1·14
	65	7·9	6·6	1·72	0·97
	40	5·2	3·8	1·52	0·62
S3	75	6·6	5·2	1·31	0·90
	65	5·5	4·1	1·31	0·76
	40	3·4	2·4	1·10	0·45

*The grade numbers relate to the number of growth rings per 25 mm, *i.e.*, grade 75 = 8 rings, 65 = 6 rings, 40 = 4 rings.

There are two methods of determining the strength or stress grade of a p[iece] of timber: (1) by visual inspection and (2) by mechanical means.

Method (1). C.P. 112 sets out an elaborate system of visual examinatio[n] analyse the defects in timber and so assess the quality and stress capability. a costly and not very satisfactory system of grading.

Method (2). The Code also allows for mechanical stress grading where piece of timber passes through a machine which provides for a small load t[o] applied to it over successive short spans (1·8 m) throughout the length. resulting deflections are monitored by a computer and from them the stiff[ness] and therefore strength is deduced at intervals. At each measurement the p[iece] receives a short spray of colour which differs according to the grade achie[ved]. As the end of the piece leaves the machine it is dyed with a longer band of co[lour] of the weakest grade noted; the piece is then said to be of this stress grade.

There are several hundred species of commercial timbers. A sele[cted] number of softwoods used in this country are classified in Table II, and s[ome] hardwoods are listed in Table III. A few of the characteristics and uses also given in these tables. The density of timber varies with the moisture con[tent] and the proportion of wood tissue to voids; the greater the m.c. the greate[r the] density. The weights given in the tables are the average when the m.c. i[s] per cent. The m.c. also influences the strength of timber, and well-seas[oned] wood is stronger than that in the green condition.

The map shown in Fig. 4 shows the distribution of most of these tim[bers] and may be a convenient reference. Many of these selected species are g[rown] in the United Kingdom and other countries of the British Commonwealt[h of] Nations.

Cec (l
Fir, C b:
Hem fir
Kau (K
Kau Larc
Pine, pir
Pine,
Pine, Pit anc
Pine, Ot rec
Pine, chi pir
Pine,

OODS

·PRESSION NDICULAR GRAIN /mm²	SHEA PARALL TO GRA N/mm
·21	1·14
·21	0·97
·93	0·62
·72	1·14
·72	0·97
·52	0·62
·31	0·9
·31	0·7
·10	0·4

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TABLE II

SOFTWOODS

STANDARD NAME	BOTANICAL NAME	SOURCE	APPROX. DENSITY (kg/m³)	CHARACTERISTICS	USES
Cedar, Western Red (Pacific red cedar)	*Thuja plicata*	British Columbia, Western U.S.A.	384	Reddish brown, weathering to silver grey; distinct growth rings; straight grained, easy to work; very durable, brittle; stains, paints and enamels well.	General carpentry and joinery; decorative work, including panelling; roof shingles, weather-boarding.
Fir, Douglas (British Columbia, Columbian and Oregon pine)	*Pseudotsuga menziesii* *P. taxifolia*	British Columbia, Western U.S.A. British Isles	530	Pink to light reddish brown; well defined growth rings and prominent figure; straight grained with tendency to wavy or spiral grain; difficult to work, strong; available in large sections and long lengths; stains but does not paint well.	"Clear grade": first-class joinery, as for doors, windows, panelling, plywood, floor boarding and blocks. "Merchantable grade": carpentry. Home-grown (of inferior quality): rough boarding.
Hemlock, Western (grey fir)	*Tsuga heterophylla*	British Columbia, Western U.S.A.	500	Pale brown; distinct growth rings and good figure; usually straight grained, fairly even textured; not durable when subjected to alternate dry and wet conditions; stains, paints and enamels well.	General joinery; best quality for decorative work, including panelling and furniture; flooring.
Kauri, New Zealand (Kauri pine)	*Agathis australis*	New Zealand	610	Pale yellow to light brown; straight and interlocked grain producing mottled figure; strong, very durable; works easily; stains, paints and polishes well.	Good-class joinery, including floor boarding and blocks; mottled varieties for panelling, etc. Limited supply.
Kauri, Queensland	*Agathis palmerstonii*	Queensland, Australia	480	Similar to, but softer than, N.Z. Kauri.	Good substitute for N.Z. Kauri.
Larch, European	*Larix decidua*	Europe, including British Isles	590	Reddish brown heartwood, yellowish white sapwood; distinct growth rings; straight grained; very durable, tough and strong; resinous; difficult to work; stains and paints satisfactorily. Most valuable home-grown softwood.	Carpentry and heavy construction; fencing, gates, wood buildings, piles, sleepers, scaffolding.
Pine, Jack (Banksian pine)	*Pinus banksiana*	Canada, Northern U.S.A.	500	Similar to red pine (see below); inclined to be knotty.	Inferior carpentry, sleepers, boxes and crates. Similar to low-grade redwood (see below).
Pine, Pitch	*Pinus palustris*	Southern U.S.A.	657	Light red; very distinct growth rings with large proportion of summer wood which gives bold effect, occasionally has an attractive blister figure; straight grained; very strong and durable, resinous, which affects ease of working; even textured; obtainable in long lengths; subject to heart shakes; grain tends to show through paint; varnishes well.	Good-class general carpentry and joinery; church and school furniture, office fittings, piles.
Pine, British Honduras Pitch (slash, Cuban and Nicaraguan pine)	*Pinus caribœa*	Central America, West Indies.	700	Similar to pitch pine.	Similar to pitch pine.
Pine, Red (Canadian, Ottawa and Quebec red pine)	*Pinus resinosa*	South-Eastern Canada, Northern U.S.A.	530	Light red or reddish yellow heartwood, creamy white sapwood; generally straight grained, easily worked to a smooth silky finish; fairly durable; paints and stains well.	Similar to redwood.
Pine, Siberian (Manchurian and Korean pine)	*Pinus sibirica*, etc.	Siberia, Manchuria	416	Similar to yellow pine (see below).	Internal joinery. A good substitute for yellow pine.
Pine, Sugar	*Pinus lambertiana*	California, U.S.A.	450	Resembles Canadian yellow pine (see below).	General internal joinery.

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE II—*continued*

SOFTWOODS—*continued*

Standard Name	Botanical Name	Source	Approx. Density (kg/m³)	Characteristics	Uses
Pine, Western White (finger cone and mountain pine)	*Pinus monticola*	British Columbia, North Western U.S.A.	450	Similar to yellow pine, but growth rings are narrower and it is slightly harder and stronger.	Similar to yellow pin below).
Pine, Yellow (Canadian white, Canadian yellow, Ottawa white, Quebec, Weymouth and white pine)	*Pinus strobus*	Eastern Canada, U.S.A.	416	Pale straw to light reddish brown; growth rings indistinct; soft, straight grained, even textured, easily worked to a smooth silky surface; moderately durable; stains, paints and polishes well.	Good-class general i joinery; first quality sive and now used chi pattern-making, carvin similar special work Siberian pine.
Redwood (Scots pine or fir in British Isles, northern pine, red deal, yellow deal, Memel fir, Norway fir, Polish fir, Swedish pine, Baltic redwood)	*Pinus sylvestris*	British Isles, Norway, Sweden, Finland, Poland, Northern Russia	530	Pale reddish brown heartwood, light yellowish brown sapwood; distinct growth rings; straight grained, easily worked to a clean finish; very durable when preserved; tough, strong, moderately resinous; stains, paints and polishes well.	Extensively used for carpentry and joinery. (not so reliable as fo as less care taken in se of trees, and Douglas often preferred for firs work.
Spruce, Canadian (white, Quebec and New Brunswick spruce)	*Picea glauca* (white) *P. mariana* (black) *P. rubra* (red)	Eastern and Northern Canada, Eastern U.S.A.	450	White; growth rings distinct; straight grained and easily worked, but knots liable to give trouble; not durable; stains, paints and varnishes well; red variety has reddish tinge and more pronounced figure.	Better qualities used cheaper joinery; ro grade used for shut scaffolding, packing case
Spruce, Sitka (silver spruce)	*Picea sitchensis*	British Columbia, Western U.S.A., British Isles	465	White to pink; mostly straight grained, occasionally spiral grained; easily worked when free from knots, with satiny finish when planed; tougher and superior in quality to better grades of Canadian spruce; obtainable in large sizes; stains, paints and polishes well.	Imported: good-class car and joinery. Home-grown: temporary such as shuttering.
Whitewood (white deal or fir, European spruce, northern and Baltic whitewood)	*Picea abies* *Abies alba*	Northern and Central Europe, British Isles	433	Yellowish or pinkish white; distinct growth rings; straight grained; presence of many hard black knots affects working; smooth silky finish; stains paints, varnishes and polishes well.	Internal carpentry and d joinery. Rougher grades (including grown): temporary packing cases.
Yew	*Taxus baccata*	British Isles	674	Orange-brown heartwood, white sapwood; distinct growth rings; straight and irregular grained, producing attractive figure; strong, hard, durable; stains and polishes well.	Limited supply availab doors, panelling, floor furniture, gates.

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

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TABLE III

HARDWOODS

STANDARD NAME	BOTANICAL NAME	SOURCE	APPROX. DENSITY (kg/m³)	CHARACTERISTICS	USES
Ash (American and Japanese Ash)	*Fraxinus excelsior* *F. americana* *F. mandshurica*	British Isles Eastern Canada, U.S.A. Japan	700	White to light brown; ring porous, large pores distinct; growth rings distinct, rays indistinct; straight and course grained and occasional decorative burrs; very tough and elastic, not durable when exposed; stains, varnishes and polishes well. American and Japanese similar but inferior to home-grown.	Figured timber for decorative work, furniture, veneers, plywood. Chiefly for hammer, etc. shafts, hockey, etc. sticks, motor, etc. body framework.
Avodiré (olon, appayia)	*Turræanthus africanus*	Ghana, Ivory Coast	560	Golden yellow; growth rings not visible, rays indistinct; straight and interlocked grain producing rich mottled figure; tough, strong, elastic.	Veneers, plywood, panelling, cabinet work. Used as a substitute for mahoganies (p. 21).
Balsa	*Ochroma*	Central America, West Indies	112-160	Pinkish white with silky lustre; soft and spongy. Lightest of commercial timbers.	Sound and heat insulation.
Basswood (American lime)	*Tilia glabra*	Canada (Quebec, Ontario and New Brunswick), U.S.A.	416	Creamy white to light brown; fine texture; not durable when exposed.	General interior joinery; bent plywood cores.
Bean, Black	*Castanospermum australe*	Australia	785	Dark brown streaked with greyish brown; usually straight grained, but sometimes interlocked, giving a beautiful mottled figure; durable; rather difficult to work.	Panelling and decorative work, both solid and as a veneer.
Beech (American beech)	*Fagus sylvatica* *F. grandifolia*	British Isles, Central Europe South-East Canada, North-East U.S.A.	720	White or pale brown; diffuse porous, pores rarely visible; growth rings moderately distinct, rays very distinct as flecks; straight grained, fine texture, works easily; hard and very durable if wet or dry; stains and polishes well.	Block and parquet flooring, furniture, doors, piles, woodworking tools such as plane stocks and mallets.
Beech, Southland	*Nothofagus menziesii*	New Zealand	576	Pinkish brown with silky lustre; growth rings fairly distinct, rays invisible; usually straight grained and fine texture; not durable when exposed; stains and polishes well.	As above.
Birch	*Betula pubescens* (white) *B. pendula* (silver)	Europe, including British Isles	675	White to light brown; diffuse porous, pores barely visible; growth rings and rays barely visible; fairly straight grained, medium texture; strong, tough; not durable; cuts with smooth, bright surface.	Plywood, doors, furniture, motor bodies.
Birch, Canadian Yellow (American, Quebec, black, curly and yellow birch)	*Betula lutea*	South-East Canada, Newfoundland, North-East U.S.A.	700	Light to dark reddish brown; straight grained with occasional curly grain; fine texture; tough, hard wearing but not durable when exposed. Japanese birch similar.	Plywood, flooring, furniture; aeroplane construction.
Blackwood, Australian	*Acacia melanoxylon*	Australia, Tasmania	720	Golden or reddish brown with darker streaks; straight and wavy grain (fiddle-back); even texture; strong, durable; polishes well.	High-class joinery, including panelling, cabinet work, veneers.
Cedar, Central American (British Honduras, Mexican, Nicaraguan, Trinidad, West Indian and cigar-box cedar)	*Cedrelu mexicana*	Central America, West Indies	480	Closely related to true mahogany (*Swietenia*, see p. 21); light red; ring porous, large pores visible; growth rings and rays barely visible; straight grained, occasionally figured, but ripple marks usually absent; characteristic scent; easily worked, durable; readily stains and polishes well.	Panelling, furniture; best grades for similar purposes to Honduras mahogany; cigar boxes.
Chestnut, Sweet (Spanish chestnut)	*Castanea sativa*	Europe, including British Isles	560	Light brown heartwood, sapwood lighter; ring porous; resembling oak, but rays not visible and therefore silver grain figure of oak is absent; splits readily; subject to heartshake.	Fencing, gates, piles; figured timber for decorative work.
Chestnut, American	*Castena dentata*	U.S.A.	560	Similar to, but coarser than, sweet chestnut.	Similar to sweet chestnut.

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

Table III—*continued*

HARDWOODS—*continued*

Standard Name	Botanical Name	Source	Approx. Density (kg/m³)	Characteristics	Uses
Ebony	*Diospyros ebenum*	Sri Lanka, India	1187	Black, or black with brown stripes; growth rings and rays invisible; fine and even texture; very hard and durable; very difficult to work; polishes well.	Inlaying (to panelling, veneers, cabinet work, keys, etc.
Ebony, African	*D. crassiflora*	East Africa	1122		
Ebony, Macassar	*D. macassar*	Celebes	1028		
Elm (English, Dutch, wych and white elm)	*Ulmus procera* (English)	British Isles	560	*English:* reddish brown (*wych*, paler with green streaks); ring porous, large pores distinct; growth rings and rays distinct; irregular grain producing attractive wavy figure and coarse texture; tough; difficult to work; durable under water; wych is strongest; *white* is usually straight grained and not durable when exposed.	Weather-boarding, furni piles, flooring (white).
	U. hollandica (Dutch)	British Isles	560		
	U. glabra (wych)	British Isles	690		
	U. america (white)	Eastern Canada, Eastern U.S.A.	625		
Eng (In)	*Dipterocarpus tuberculatus*	Burma	880	Dull greyish brown; fairly straight grained, sometimes interlocked; hard, strong, durable; not easy to work.	Carpentry, flooring, win sills. Cheap substitute teak (p. 23).
Gaboon (okoumé, Gaboon mahogany)	*Aucoumea klaineana*	Gabon, Spanish Guinea (West Africa)	433	Light pinkish brown (paler than true mahogany—*Swietenia*); diffuse porous, pores visible; growth rings indistinct, rays invisible; straight and interlocked grain; not durable when exposed; easily worked; difficult to stain, but takes a good polish.	Veneers and plywood; furniture, and as inferior stitute for mahoganies.
Greenheart	*Ocotera rodiœi*	Guyana, North Brazil	1040	Olive green heartwood, pale yellow sapwood; straight grained; very strong, tough, durable and difficult to work; tendency to split; highly resistant to attack of sea-worms.	Heavy construction and m work (as dock gates, piles), stair treads, rods, shafts of golf clubs.
Greywood, Indian Silver (white chuglam)	*Terminalia bialata*	Andaman Isles, India	690	Yellowish brown with irregular dark markings producing attractive marbled figure; straight grained; strong, tough, moderately durable; stains and polishes well.	Superior decorative work su for panelling, furniture, terior fittings, veneers, wood.
Guarea (black guarea)	*Guarea thompsonii*	West Africa	640	Related to true mahogany (*Swietenia*). *Guarea:* pinkish brown (not so dark as Honduras mahogany); diffuse porous, pores just visible; growth rings and rays invisible; straight and wavy grain with mottled figure, fine texture, easily worked; characteristic cedar-like scent. *Scented Guarea:* similar, but slightly darker; more scented and texture less fine.	Superior joinery, panel veneers, furniture. Subst for mahoganies.
Guarea, Scented (white guarea)	*G. cedrata*		610		
Gurjun (apitong, kanyin, keruing, yang)	*Dipterocarpus turbinatus*	Andaman Islands, Burma, Sri Lanka, Siam, Malaya, Sarawak, Philippine Islands	740	Red to dull greyish brown; straight and interlocked grain, resinous; not easy to work; hard, durable.	General constructional flooring, bridge dec wagon building.
Hornbeam	*Carpinus betulus*	Europe, including British Isles	690	White; usually cross-grained; difficult to work; very hard, strong and tough.	Flooring, mallets, mill-wh cogs. Limited supply.
Iroko (odum, African teak, mvule)	*Chlorophora excelsa*	West and East Africa	656	Light to dark brown; interlocked grain producing ribbon figure; coarse but even texture; strong, very durable.	Superior joinery (doors, wind staircases, flooring, panell furniture. Substitute for
Jarrah	*Eucalyptus marginata*	Western Australia	900	Reddish brown heartwood, lighter sapwood; generally straight grained, sometimes interlocked; very hard and durable; may contain gum veins which affect workability; will take excellent polish, staining not required.	Carpentry, flooring, treads, counter tops, fencing, marine work, decking.
Karri	*Eucalyptus diversicolor*	Western Australia	950	Similar to jarrah; slightly paler in colour and less durable.	Similar to jarrah.

Note.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE III HARDWOODS—*continued*

STANDARD NAME	BOTANICAL NAME	SOURCE	APPROX. DENSITY (kg/m³)	CHARACTERISTICS	USES
Kokko (East Indian walnut)	*Albizzia lebbek*	Andaman Islands, Sri Lanka, India	640	Dull brown with darker streaks; somewhat resembles true walnut (see p. 23).	Superior decorative work, including panelling and furniture; veneers.
Lauan, Red Lauan, White	*Shorea negrosencis* *Pentacme contorta*	Philippine Islands	560	Pale to dark reddish brown; diffuse porous with distinct pores and white chalky resin ducts; straight and irregular grain producing roe or stripe figure. Allied to mahoganies.	Substitutes for mahoganies. Plywood.
Laurel, Indian	*Terminalia tomentosa*	Burma, Southern India	866	Light walnut brown to deep chocolate; straight and irregular grain, attractive figure by dark wavy streaks; coarse texture; hard, very strong and durable; not easy to work.	Superior solid and veneered panelling, furniture.
Lignum Vitæ	*Guaiacum officinale*	West Indies, Tropical Africa	1250	Dark greenish brown, nearly black; interlocked grain, fine and uniform texture; very hard and durable; very difficult to work. Heaviest commercial timber.	Turnery, mallet heads, truncheons, bowls ("woods"), electrical work (insulators).
Lime	*Tilia vulgaris*	Europe, including British Isles	560	White to pinkish yellow; growth rings and rays not very distinct; fine uniform texture, soft and easily worked.	Wood carving, turnery, furniture, parts of musical instruments.
Mahogany, African (Accra, Benin, Duala, Cape Lopez and Lagos mahogany)	*Khaya ivorensis* *K. anthotheca* *K. grandifoliola*	West Africa West Africa and Uganda West Africa	480–720	Light pinkish brown to deep red; diffuse porous, pores distinct with gum deposits; growth rings not visible, larger rays just visible; straight and interlocked grain producing roe and striped figure; moderately durable; polishes well.	Good-class joinery, including panelling, veneers, plywood, furniture and similar decorative work.
Mahogany, Cuban (Spanish, West Indian, Porto Rico and Jamaican mahogany)	*Swietenia mahagoni*	West Indies	640–800	Rich reddish brown; diffuse porous, distinct pores often containing white deposits; straight, interlocked, irregular and wavy grain producing variety of handsome figure such as blister, roe, stripe and fiddle-back; ripple marks may be present but not so distinct as Honduras mahogany; fine texture; strong; shrinks and warps little; high polish readily obtained. Is a true mahogany.	Superior joinery and decorative work, such as panelling, veneers and furniture. Most valuable of the mahoganies, but very expensive and more difficult to obtain.
Mahogany, Honduras (baywood, Central American mahogany)	*Swietenia macrophylla*	Belize, etc., Central America, Brazil, Peru	545	Similar to Cuban mahogany but colour usually lighter and texture not so fine; ripple marks distinct; dark-coloured gum deposits in pores common, white deposits rare; strong, durable, works easily; takes a good polish. Is a true mahogany.	High-class joinery, including panelling, furniture, veneers and similar decorative work.
Makoré (cherry mahogany)	*Mimusops heckelii*	West Africa	640–800	Pale pinkish brown to purplish brown; straight and interlocked grain producing rich mottled figure with occasional dark veins; polishes well.	Good-class decorative work such as panelling, veneers and furniture. Excellent substitute for the mahoganies.
Maple, Queensland (silkwood)	*Flindersia brayleyana*	Queensland, Australia	625	Light brown; similar to gaboon (p. 20), but darker, and interlocked grain produces a beautiful stripe figure.	Panelling and decorative work, including veneers, furniture.
Maple, Rock (bird's-eye, blister, curly, fiddle-back, hard, sugar and white maple)	*Acer saccharum*	South-East Canada, North-East U.S.A.	740	Light yellowish-brown; growth rings distinct as dark lines, rays distinct; straight, irregular and wavy grain producing bird's-eye, blister and fiddle-back figure; dense, tough, hard, strong, not durable; difficult to work; stains, paints, enamels and polishes well.	Flooring, stair treads, panelling, veneers, furniture.
Meranti, Red Meranti, White (yellow meranti)	*Shorea acuminata*, etc. *S. bracteolata*	Malaya Sarawak	580 560	Similar to lauan (see above).	Substitutes for mahoganies. Plywood, veneers, interior joinery.
Myrtle, Tasmanian	*Nothofagus cunninghamii*	Tasmania; Victoria, Australia	740	Similar to Southland beech.	Similar to Southland beech (p. 19).

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE III HARDWOODS—*continued*

STANDARD NAME	BOTANICAL NAME	SOURCE	APPROX. DENSITY (kg/m³)	CHARACTERISTICS	USES
Oak (English, pedunculate, sessile, durmast, Austrian and Polish oak	*Quercus robur* (*pedunculata*) *Q. petraea* (*sessiliflora*)	Europe, including Great Britain	690-850	*English:* Heartwood light yellow-brown to deep warm brown (known as "brown oak" when the colour has been deepened by a fungus), sapwood lighter; ring porous, spring wood pores distinct; growth rings distinct, very distinct broad rays give characteristic beautiful "silver grain" effect when rift-sawn; very durable, tough and strong; gallic acid present corrodes ironwork; polishes well. Best of species. *Austrian* (*Wainscot*): Straighter grained than English and therefore slightly less distinctive figure. *Russian* (Riga, Memel, etc.) and *Polish* (Volhynia): Stronger than Austrian but not so well figured; easier to work and cheaper. *Durmast* (France): Less strong and durable than English.	Decorative and superior joine (figured varieties), includir panelling, veneers, plywoo furniture; carpentry such open roofs, beams; fencin posts, gates. English supp limited.
Oak, American Red	*Quercus rubra*, *Q. borealis*, etc.	Eastern Canada, U.S.A.	740	*White* oak somewhat similar to English oak and preferred to *red* oak which is usually coarser and inferior; reddish brown heartwood sharply defined from nearly white sapwood, colour not uniform.	As above, but for inferior w
Oak, American White	*Q. alba*, etc.		770		
Oak, Japanese	*Quercus grosseserrata*	Japan	690-800	Lighter than Austrian oak (light brown tinged with grey rather than red), not so pronounced "silver grain" and not so strong; very even textured; works easily to smooth finish.	Similar to Austrian oak more suitable for interior w (such as panelling, floori furniture) than for exte constructional work.
Oak, Silky	*Cardwellia sublimis*	Queensland, Australia	610	Pinkish brown, similar to American red oak; characteristic "silver grain" figure resembling true oak (hence the name); straight grain, coarse even texture; easily worked, moderately durable; stains and polishes well; does not respond to fuming.	Panelling, veneering, furni and similar decorative wor
Oak, Tasmanian (Victorian oak, mountain ash)	*Eucalyptus obliqua*, *E. regnans*, *E. gigantea*	Tasmania Australia	820 (*obliqua*) 660 (*regnans*) 720 (*gigantea*)	Light brown, resembling American or plain-sawn English oak (above), but lacks the "silver grain" characteristic and is not durable when exposed.	Flooring, furniture.
Obeche	*Triplochiton scleroxylon*	West Africa	385	White to pale straw; interlocked grain producing striped figure, coarse even texture; easily worked; not durable.	General joinery, plywood, bl boards. Substitute for c whitewood (p. 23).
Olive, East African	*Olea hochstetteri*	Kenya	900	Light brown with dark greyish brown markings; slightly interlocked grain, fine even texture; strong, moderately durable; difficult to work.	Flooring, panelling and sir decorative work.
Padauk, Andaman	*Pterocarpus dalbergioides*	Andaman Islands, India	785	Dark reddish brown; interlocked grain producing ribbon figure; difficult to work; strong, very hard, durable; takes high polish.	Superior joinery and deco work such as panelling, fit bank counter tops, furnit
Padauk, Burma	*Pterocarpus macrocarpus*	Burma	865	Golden brown; grain, etc., as above.	As above.
Pyinkado	*Xylia dolabriformis*	Burma	990	Dull reddish brown; straight and interlocked grain; resinous; very difficult to work; exceedingly strong, hard and durable.	Heavy constructional and m work; flooring.
Rosewood, Honduras	*Dalbergia stevensonii*	Belize	960	Purplish brown with irregular black markings producing an attractive figure; straight and wavy grained; hard, dense, difficult to work; very durable; polishes well.	High-class decorative work as panelling, veneering, ture.

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

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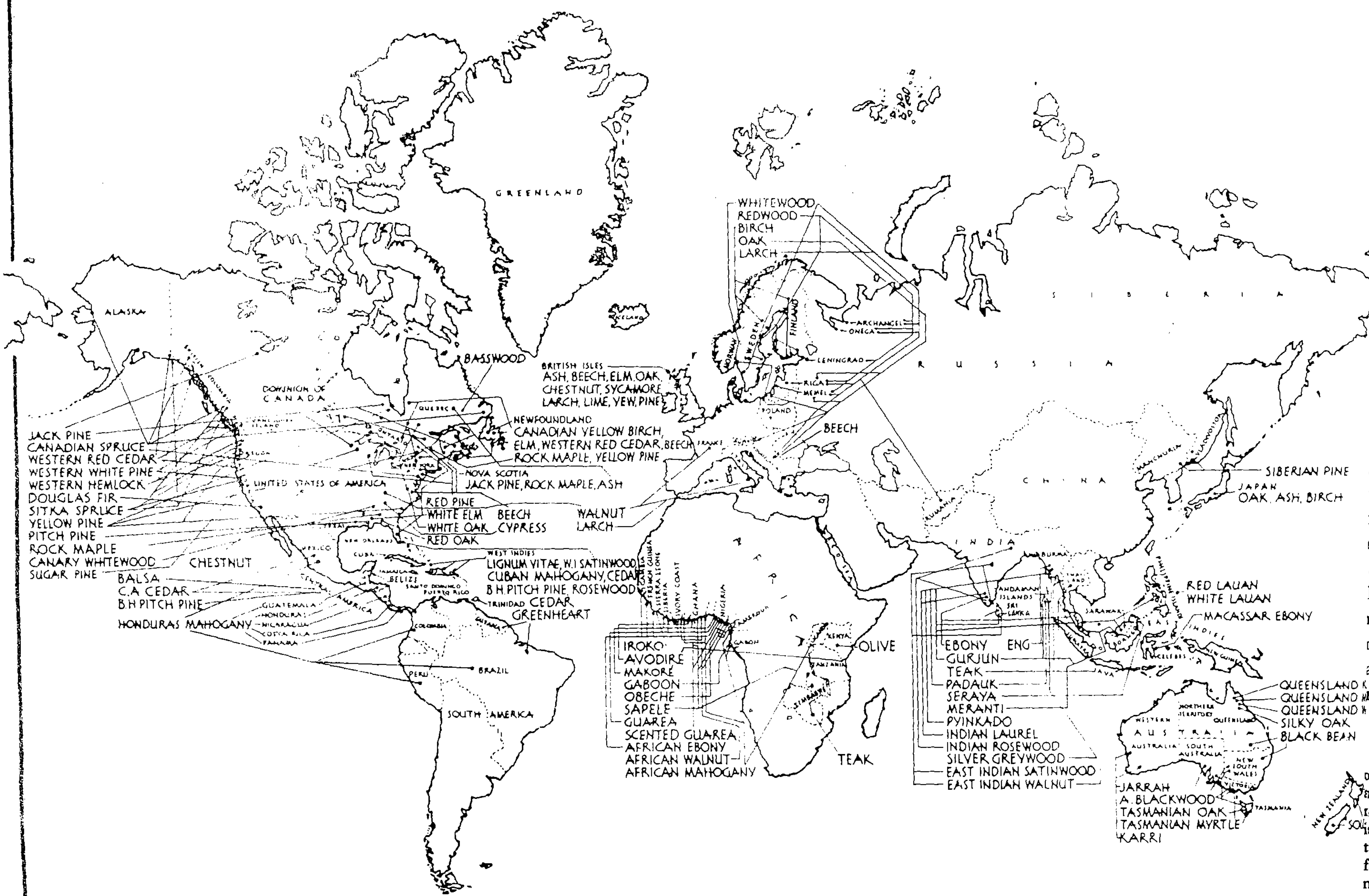
TABLE III HARDWOODS—*continued*

Standard Name	Botanical Name	Source	Approx. Density (kg/m³)	Characteristics	Uses
Rosewood, Indian (Bombay blackwood)	*Dalbergia latifolia*	India	865	Similar to Honduras rosewood; interlocked figure producing beautiful ribbon figure.	As above, including parquet flooring.
Sapele (sapele mahogany)	*Entandrophragma cylindricum*, etc.	East and West Africa	640	Dark reddish or purplish brown; interlocked and wavy grain producing attractive blister, roe, stripe and fiddle-back figure; cedar-like scent; very hard and strong; moderately durable; not easy to work; polishes well. Included amongst commercial mahoganies.	Superior decorative work as for panelling, interior fittings, furniture, veneering.
Satinwood, East Indian (flowered satinwood)	*Chloroxylon swietenia*	Sri Lanka, India	995	Golden yellow to dark brown heartwood, white to yellow sapwood; interlocked grain producing attractive ribbon and mottled figure; dense, hard, very durable; difficult to work; fine, even, lustrous texture; polishes well.	As above.
Satinwood, West Indian (Jamaica satinwood)	*Zanthoxylum flavum*	West Indies, Florida (U.S.A.)	900	Resembles East Indian satinwood, but is not so hard and is less durable.	As above.
Seraya, Red	*Shorea macroptera*, etc.	North Borneo	580	Similar to lauan (p. 21).	Substitutes for mahoganies (p. 21). Interior joinery, shopfitting, veneers, plywood.
Seraya, White	*Parashorea malaanonan*, etc.		560		
Sycamore (great maple, plane)	*Acer pseudoplatanus*	British Isles	625	White or yellowish white; distinct growth rings and rays; straight and wavy grain producing attractive rippled figure; fine, lustrous texture; strong, not durable; works fairly easily; stains and polishes well.	Superior decorative work, as for panelling, furniture, choice veneers, table tops, dairy appliances. Supplies are limited.
Teak	*Tectona grandis*	Burma, Java, Thailand	660	Golden brown, occasionally with dark markings or flecks; ring porous; growth rings and rays indistinct; straight grained, not easily worked (saws, cutters, etc., being dulled); strong, hard, very durable; fire-resistant.	Superior general joinery and carpentry, marine work, veneers, plywood
Teak, Rhodesian	*Baikiæa plurijuga*	Zambia and Zimbabwe	915	Reddish brown, occasionally with irregular black markings or flecks; straight or slightly interlocked grain; difficult to work; very hard, strong and durable. Not a true teak.	High-class flooring.
Walnut (English, European, Black Sea, French, Circassian and Italian walnut)	*Juglans regia*	Europe, including British Isles	660	Variable in colour, irregular dark veins on a greyish brown background producing beautiful figure; finely figured burrs and crotches; hard, tough, strong, moderately durable; fine texture; takes an excellent polish.	Superior decorative work, including panelling, furniture; burrs and crotches highly valued for veneers; gun and rifle stocks.
Walnut, African (Benin and Nigerian walnut)	*Lovoa klaineana*	West Africa	560	Yellowish brown background with dark markings (due to gum veins); interlocked grain producing ribbon or stripe figure. Not a true walnut.	Superior decorative work and joinery.
Walnut, American Black	*Juglans nigra*	U.S.A.	705	Similar to English walnut, but darker and more uniform in colour.	Similar to English walnut. Diminishing supplies and demands.
Walnut, Queensland (Australian walnut)	*Endiandra palmerstonii*	Queensland, Australia	736	Light or pinkish brown to dark brown, with varicoloured markings; interlocked and wavy grain producing a broken striped figure; difficult to work (dulls tools).	Superior decorative work such as panelling, veneers, furniture, plywood.
Whitewood, Canary (American whitewood)	*Liriodendron tulipifera*	U.S.A.	513	Yellowish brown with greenish tinge; diffuse porous, pores just visible; growth rings distinct, rays indistinct; straight grained, easily worked; stains and polishes well.	Joinery, plywood. High cost restricting its use, obeche (p. 22) being used as a substitute.

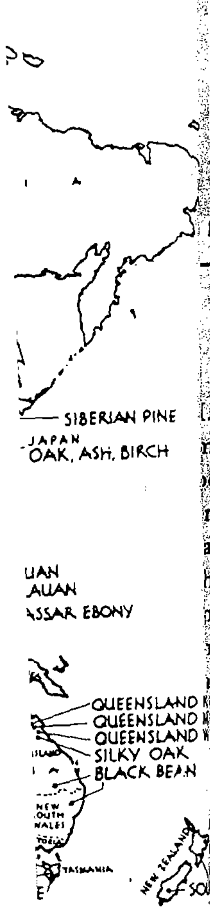
NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

MAP SHOWING THE DISTRIBUTION OF THE PRINCIPAL BUILDING TIMBERS



NOTE: THE TIMBERS INDICATED ARE SELECTED FROM THOSE USED IN THE BRITISH ISLES FOR BUILDING PURPOSES.

FIGURE 4



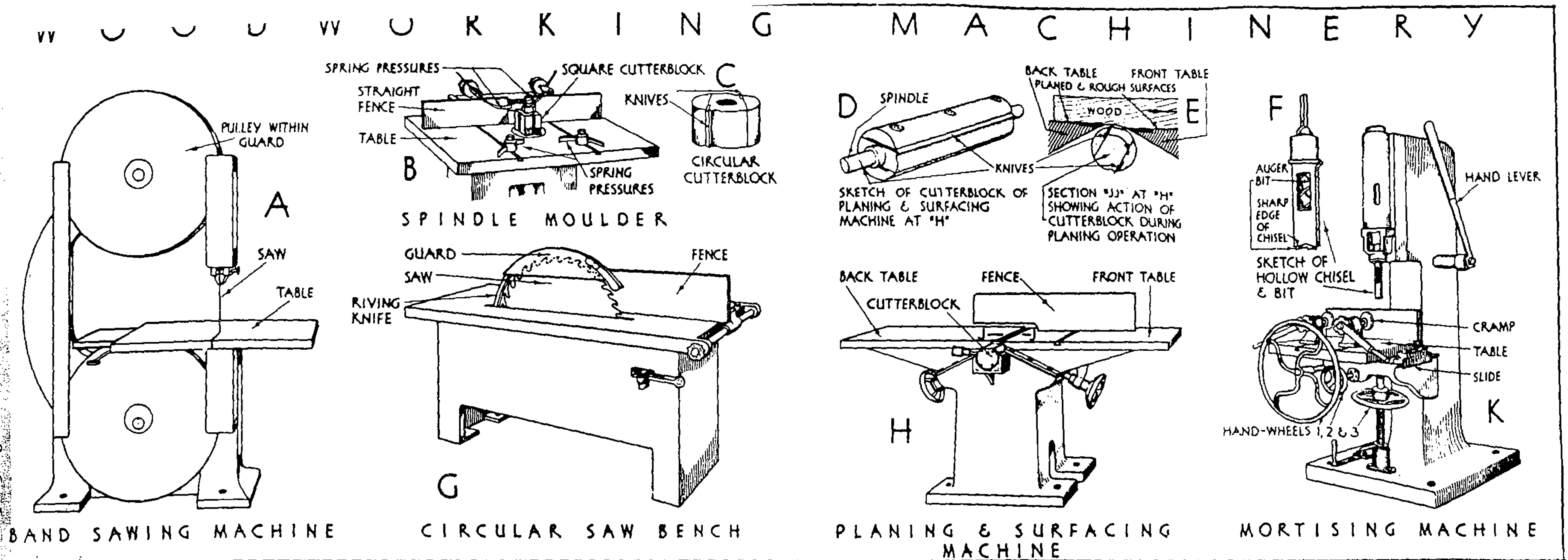


FIGURE 5

PREPARATION OF TIMBER

Hand tools used by the carpenter and joiner are described in Chap. IV, Vol. I. Most of the labours required in the preparation of timber are performed by nachine. Certain of the heavier machines used in the conversion of timber have een described on pp. 5 and 7. The following are some of the machines which re used in the preparation of timber: (1) Circular sawing machine, (2) band awing machine, (3) planing and surfacing machine, (4) surface-planing and hicknessing machine, (5) panel planing and thicknessing machine, (6) moulding nachine, (7) spindle moulder, (8) planing and matching machine, (9) mortising achine, (10) tenoning machine, (11) double-dimensions saw bench, (12) dove-iling machine, (13) lathe, (14) mitreing machine, (15) sand papering machine, 6) universal wood-worker and (17) sharpening machines.

1. Circular Sawing Machine or Circular Saw Bench (see G, Fig. 5).—This nsists of a vertical circular saw, protected by a guard to which a riving knife is attached, d a metal guide or fence. The spindle of the saw is mounted on a frame having a flat etal table. The saw varies from 230 mm to 1·5 m in diameter and the table or bench from 0·76 to 2·4 m long and 0·6 to 1·1 m wide. The revolving saw runs in a slot in e table. The fence, which is parallel to the saw, is adjustable, the distance between its ce and the saw being regulated to the width to which the timber is to be sawn. Some chines have fixed tables, whilst others have "rising and falling" tables and fences which a be canted through 45°, the latter being useful for bevelling. This machine is exten-ily employed for general sawing purposes, such as sawing baulks into planks, deals, etc. (known as *deep-cutting*), or into smaller scantlings (called *flat-cutting*), ripping, edging and cross-cutting. Each piece of timber is pressed against the fence (unless it is to be cross-cut), which has been adjusted to the required distance from the saw, and fed towards the rotating saw; the pressure is maintained as the timber slides forward on the table during the cutting operation. The riving knife, which is immediately behind the saw, widens the cut in the timber and thus prevents pressure on the saw.

Circular saws are made of crucible cast steel plates. The common form, shown at A and P, Fig. 6, and known as a *plate saw*, is a disc of uniform thickness or gauge throughout, the thickness depending upon the size of the saw and the character of the wood to be sawn; thus, the normal thickness of a saw of 600 mm diameter is 2·5 mm for hardwoods and 2·2 mm for softwoods, whilst the thickness of a 760 mm saw is 2·8 mm for hardwoods and 2·5 mm for softwoods. They are conveniently divided into *rip saws* (those which cut with the grain) and *cross-cut saws* (which cut across the grain). As the fibres of the wood are parallel to the plane of the saw during ripping and perpendicular during cross-cutting, and as timbers vary in hardness, it follows that the shape of the teeth differ in accordance with the work for which the saw is to be used.

Sketches of teeth of a rip saw are shown at B and C, Fig. 6, and those of a cross-cut saw are shown at D and E. The names of the various parts are indicated on the enlarged elevations G and M. The *hook* or *rake* is the inclination of the *front* or *face* of the tooth; in all ripping saws the cutting *point* of a tooth is forward to form a *forward hook* (see G and M); the teeth of cross-cut saws have usually a *backward rake* (see E and D) and occasionally no hook. The *gullet* must be sufficiently large and well rounded to remove the sawdust rapidly during the cutting operation.

Set.—The setting of the teeth of hand saws to produce the cut or *kerf* of greater width than the thickness of the blade is referred to in Chap. IV, Vol. I. A similar clearance or set must be given to the body of a circular saw so as to eliminate friction, otherwise the timber would bind on the saw, generating heat and causing the saw to wobble. This clearance must be equal on each side if "pulling" to one side is to be avoided. Teeth are either (*a*) *spring set* or (*b*) *swage set*.

(a) *Spring Set or Side Set.*—In this type the points of the teeth are bent over to the right and left alternately. Only the extreme points are sprung over, as shown at F and H,

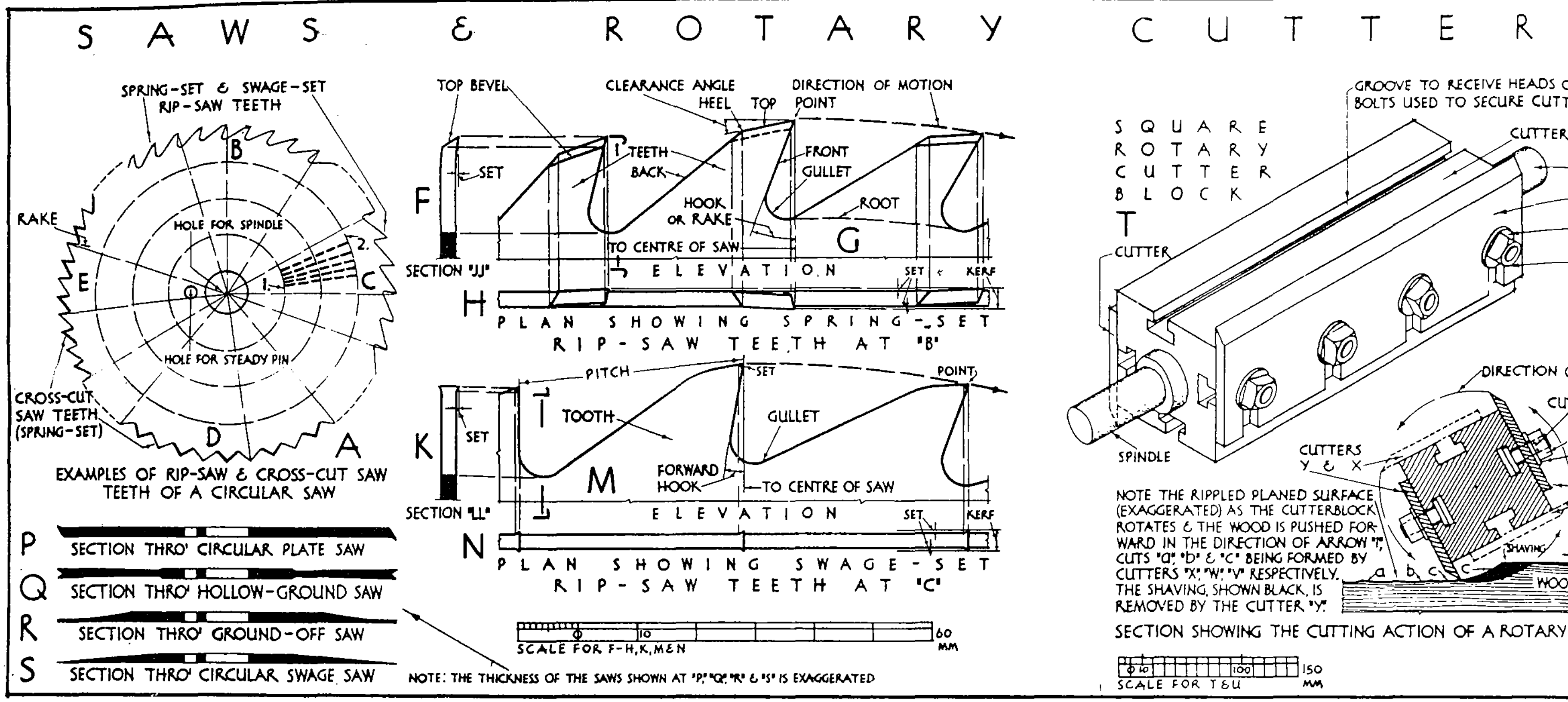


FIGURE 6

Fig. 6. The amount of set depends upon the nature of the timber. In general, hardwoods require less set than softwoods, and the set is increased when wood of a woolly and binding character is to be sawn. As a rule the set required for a 1 m diameter saw is about 1·6 mm for cutting hardwood and 2 mm for softwoods. The tool used for bending the points of the teeth is called a *saw set*. This is a small steel tool, having several notches of various widths on each of its two edges, and provided with either one or two handles. When setting, the notch in the tool corresponding to the thickness of the saw plate is fitted over the point of the tooth and bent over in the required direction as slight pressure is applied on the handle of the tool. Another tool, called a *set gauge*, is used to measure and ensure the uniform projection of the teeth on each side of the saw. This is a small piece of steel having a straight edge which is notched at the end by an amount equal to the required set. When applying the set gauge, its straight edge is held square along the centre line of the saw, and the point of the tooth should just touch the notched top of the gauge; any adjustment of the tooth is made by the saw set.

The top of each tooth of a rip saw is sharpened with a slight bevel, called the *top bevel* (see F and G); this enables the outer and higher extreme point to lead in the saw cut. The front of each rip-saw tooth has little or no bevel, but both the front and back of cross-cut teeth are bevelled on alternate sides.

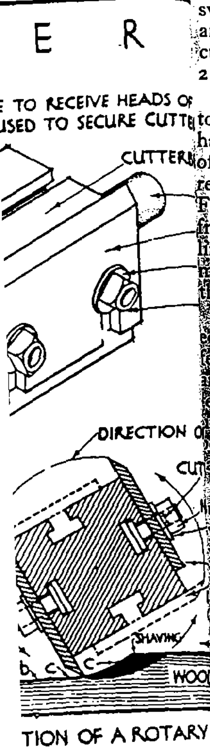
Spring-set teeth are often used for ripping and cross-cutting. Setting of the teeth can be done by the automatic saw sharpening machine described on p. 30.

(b) *Swage Set.*—The point of each tooth when swage set is pressed out so t slightly extends an equal distance on each side of the saw (see K and N, Fig. 6). each tooth clears both sides of the saw, whereas in spring set every tooth clears on and the alternate teeth the other. Two tools are used for swaging or spreading the *i.e.*, the *swage* and the *side dresser* or *swage shaper*. The former consists of a block of having a slot to admit the saw blade, and an internal anvil and eccentric die; the top tooth is pressed against the anvil, a handle is turned causing the die to apply pressu the face of the tooth as it spreads out the point. The side dresser ensures a un width across the points of the saw; this steel tool has two metal dies between whi point of each tooth is squeezed, the finished width being determined by an adju steel plate which rests on top of the tooth.

Swage set is preferred for rip saws, log band saws, re-saws and frame saws. A feed can be employed when a saw is swage set and not spring set.

The above cross cut and rip saws are of uniform thickness. Another form of ci cross-cut saw, known as a *hollow-ground saw*, is of uniform thickness at the centre (diameter of the collar—see p. 27) and, after being reduced, gradually increases in thic towards the rim (see Q, Fig. 6). It is used for accurate work. The teeth require ed

The *ground-off saw* and the *swage saw* or *bevelled saw* are two other types of cir saw which are not of uniform thickness throughout. Both are thinner at the rim t the centre, the ground-off saw (see R, Fig. 6) having a thin parallel rim of 25 to 4



width and increasing in thickness by a slight concave taper on one side only, and the swage saw (see S) is tapered on one side from the rim towards the edge of the collar. They are either spring set or swage set. Both produce thin clean saw kerfs, and are used for cutting thin boards only, the ground-off saw being chiefly used for cutting boards from 2 to 10 mm thick and the swage saw for sawing boards up to 19 mm thick.

Tensioning.—A saw after continuous use becomes stretched at the rim; if not attended to it will fail to cut true and will run noisily. This correction is obtained by a process of hammering known as "tensioning." The process is usually confined to the middle part of the saw and the *radial hammering* method is one of several which produce satisfactory results. Thus, if concentric circles are chalked off as shown by thin broken lines at A, Fig. 6, light hammering (by a round-faced or *dog-head hammer*) is performed, working from the outside to the inside, *i.e.*, from "2" to "1" as indicated by the thick broken lines. The saw is hammered on an anvil, and both sides of the saw are dealt with in this manner. This expands the metal over this area and counteracts the expanding effect at the rim when the saw revolves at a high speed.

A saw to be tested for tension is laid horizontally on a table or anvil and is raised at one edge. A metal straight edge is placed on the saw, extending from the centre to the circumference. If correctly tensioned, the ends only of the straight edge should touch the saw, and there should be a space between with a maximum at the centre. The whole area is tested in this manner and the clearance between the saw and straight edge should be uniform. Absence or deficiency of tension is indicated when the surface of the saw between the ends of the straight edge touches, or almost touches the edge, and also if the saw is convex under the straight edge.

Improper treatment of the saw whilst in operation may produce bright or blue coloured bulges on the surface, known as *lumps* or *blisters*. The exact shape of these is determined by the straight edge and marked; the saw is placed on the anvil and the lumps are removed by the gentle application of a round-faced or *cross-face hammer*.

A circular saw is fitted on the spindle of the machine between two collars (one being "fast" and the other "loose") and secured by a nut; a "steady pin" projects from the face of the fixed collar and engages in the small hole in the saw. The saw runs in a slot in the table (see p. 25). A *packing* must be placed in the slot on each side of the saw between it and the table. A good type of packing consists of a thin strip of wood round which spun yarn, afterwards oiled, is wound; this is about 25 mm wide, and its length extends from the collar to just short of the base of the teeth. The packing must just be sufficiently tight for the purpose, excessive thickness being reduced by hammering on the lapping. Correct packing prevents deflection of the saw and ensures steadiness.

Speed.—The speed of a circular saw depends upon its type, size and class of wood to be sawn. The most effective *rim speed* (that at the circumference of the saw) for general purposes is 3 000 m per min. The rim speed, divided by the circumference of the saw, gives the number of revolutions. Thus, for a 0·6 m diameter saw the revolutions per minute are 1 590 (3 000 ÷ πd), and for a 0·9 m saw, 1 060 revs. per min.

2. Band Sawing Machine (see A, Fig. 5).—This is similar to, but much lighter than, the vertical log band mill (p. 7) in that the band saw is strained over two pulleys (0·9 m dia. for general purposes) placed one above the other. The saw blade varies in width from 6 to 40 mm. The timber is hand-fed on a 0·9 m square table which is about 0·9 m above the floor. This machine is used for shaping pieces by straight or circular cuts. The table may be canted and locked in position when required for bevel cutting.

Planing and Moulding Machines.—There is a big similarity between these two classes of machines, as the function of both is to reduce each sawn piece of timber to accurate size and to produce a smooth and true finish to one or more surfaces. The planing machine shaves or planes *flat* surfaces, and, as implied, the moulding machine forms a moulded surface. Planing is achieved by steel knives or cutters. There are two kinds of cutters, *i.e.*, (*a*) rotary and (*b*) fixed.

(*a*) *Rotary Cutters.*—This type consists of knives bolted in a steel block, called a *cutterblock*, fixed on a rotating spindle, the latter being mounted on bearings. Cutterblocks are either square or circular in section.

The *square cutterblock* is shown at T, Fig. 6, and has either four knives or cutters, one fixed on each face, or two knives mounted on a pair of opposite faces. A square cutterblock, with the knives omitted, is shown in position at B, Fig. 5. A diagrammatic view showing the cutting action of rotary cutters (in this case fixed above the timber) is shown at U, Fig. 6. As the cutterblock rotates at a high speed, the projecting edges of the knives cut shavings or chips from the advancing wood. The portion of wood, shown black, indicates the chip which would be removed by knife "Y" as it rotates. It will be seen that the planed surface is composed of waves or ripples; the quality of the surface is improved as the number of knives or the speed of the spindle is increased.

Circular cutterblocks are shown at C, D and E, Fig. 5; each carries two (as shown) or more knives. The cutterblocks are placed horizontally in some machines (see E and H), vertically in others (see B), moulding machines (see p. 28) have both horizontal and vertical cutterblocks. The cutting action of the knives of a circular cutterblock is shown at E.

(b) *Fixed Knives or Cutters.*—These are fixed on certain machines, *i.e.*, the planing and matching machine (p. 28), at the bottom and sides. They shave the wood and produce a superior finish to the surfaces. The result is similar to that produced by the hand plane (see J, Fig. 67, Vol. I), but as the knives are fixed, the timber must be pressed against them as it is guided rapidly past. The speedier the feed the better the finish.

Most planing machines are designed to perform additional labours, including moulding, thicknessing, grooving, beading, chamfering, etc. (see below). Whilst a combined planing and moulding machine is an advantage in a workshop having a small mixed output, it is desirable to have an independent moulding machine when the output is large. Three reasons for this are: (*a*) The fast feed speed required on a planing machine is not desirable on a moulder when the mouldings are required to have fine surfaces; (*b*) a common cutterblock cannot be conveniently used for both purposes; and (*c*) the feed rollers best for flat planing are not of the type most desirable for working mouldings.

3. Planing and Surfacing or Planing and Jointing Machine (see H, Fig. 5).—This consists of back and front tables, a cutterblock and an adjustable fence. The overall length of the tables varies from 1·8 to 3 m, the larger type of machine being capable of planing timber of a maximum width of 0·75 m. An enlargement of the cutterblock, containing two knives, is shown at D and a section is shown at E. The tables can be adjusted by the hand-wheels to enable the back table to support the timber and the front table to regulate the depth of the cut. The section E shows a piece of timber partially planed as the cutterblock rotates in the direction of the arrow at a speed of 4 000 revs. per min. The cutterblock has a guard (not shown) to protect the operator. The fence can be canted for chamfering and bevelling. This simple hand-fed machine is used for planing, surfacing, jointing, bevelling, rebating and chamfering. If a face and edge of a piece of timber are to be planed, it is first placed flat and pressed against the table (or held down by two springs similar to those shown at B) and passed over the rotating cutter; the piece is then edged in a similar manner with the dressed face against the fence.

This machine can also be obtained with a mechanical feed. This feed unit is superimposed over the table and consists of two endless travelling chains having projecting steel points. These points grip the timber and guide it forward over the cutterblock. The maximum rate of feed is 17 m per min.

4. Surface-Planing and Thicknessing Machine.—This reduces the timber to a parallel thickness in addition to planing its surfaces. It resembles machine H with the addition of a second table, situated below the back and front tables. The bottom table can be raised or lowered, the vertical distance between the upper surface of the bottom table and the edge of the knife in the cutterblock (when immediately below its centre) being equal to the required finished thickness of the timber. If a piece of timber is to be thicknessed and planed on all four sides, an edge and one face are planed first on the top table, as explained above, after which the piece is placed with the dressed face resting on the bottom table, and the upper face is dressed by the cutterblock as the timber is fed mechanically by the rollers. The second edge is finally dressed in a similar manner. The maximum size of timber which can be dealt with is 800 mm by 230 mm and the maximum rate of feed is 14 m per min.

5. Panel Planing and Thicknessing Machine.—One form of this powerful machine consists of a table, a cutterblock having three, four or six knives, a mechanical feed of rollers, pressure bars to hold the timber firmly down on the table and a *chipbreaker* to break up and discharge the chippings. One of the heavier types is capable of dealing with timber of 900 mm maximum width and up to 225 mm thick. The cutterblock, being above the table, planes the upper face and reduces the thickness of the timber. The maximum rate of feed is 30 m per min.

Another form of this machine is provided with two cutterblocks, a bottom one (at table level) near the front, and a top cutterblock near the back. Two surfaces can be dealt with at the same time, and thus the machine acts as a double surfacer. In addition, two side vertical cutterblocks can be fitted near the back end of the machine; it thus acts as a *four-cutter planing and thicknessing machine* and is capable of planing all four sides at once.

6. Moulding Machine.—There are several types of machines used for forming moulded surfaces. The cutterblocks and cutterheads are provided with cutters shaped according to the moulded section of timber to be produced. A moulding of complicated design will require more than one cutter to form it. Moulding machines may have either four, five or six rotary cutterblocks. Thus, a *six-cutter* has the following at intervals, commencing near the feed end: A bottom cutterblock, two side cutterblocks (one at each side), a top cutterblock, a second top cutterblock or *profile head*, and a second bottom or end cutterblock or *beading head* near the back end; this is suitable for large mouldings. A *five-cutter* is similar but without either one of the bottom or top cutterblocks; the side cutterblocks may either precede or be between the two top cutterblocks. A *four-cutter* has bottom and top cutterblocks and two side cutterblocks.

The feed is by means of two pairs of rollers (the first being fluted) through which the timber is guided and propelled; the rollers are driven by gearing controlled by a three, four six or nine speed gearbox, depending upon the type of machine. The timber is pressed against the table and/or fence by *pressure* such as smooth rollers or pads over or adjacent to the various cutters. A chipbreaker is provided. The maximum size of timber which can be dealt with varies; thus, one type of six-cutter can deal with sections up to 380 mm by 150 mm, whilst another is designed to take a maximum size of 300 mm by 100 mm; the capacity of some four-cutters is limited to 100 mm by 50 mm stuff.

There is a big variation in the feed-speeds; thus, one six-cutter machine has a range of speeds up to 50 m per min., whilst some four-cutters have a maximum feed-speed of 14 m per min. only. The speed depends upon many factors, such as the size, kind and quality of the timber, number of cutters, quality of finish required, power available, etc. As mouldings of high finish are usually required, it is customary to feed the machines at much lower speeds than the maximum, otherwise ridges or "ripple marks" (see U, Fig. 6) will be more pronounced.

The latest type of "high-speed" planing and moulding machine which can be built up with either four, five or six rotary cutterblocks in addition to fixed knives, has six rates of speed varying from 7·5 to 60 m per min. The fixed knives, which produce a high quality finish, consist of two bottom knives and two side knives, and are situated between the first cutterblock and the side cutterblocks. It is necessary to use an *automatic feeding table* in order to obtain the maximum output from this high-speed machine. This may be 6 m long by 0·6 to 0·75 m wide, and has six grooved bottom rollers at intervals along its length, with two top rollers at the planing machine end; it has a fence along one side and a sloping board along the other, on to which the pieces of timber are dropped and from which they slide on to the rollers to be delivered to the moulding machine. The feed table is connected to the feed mechanism of the moulding machine and its speed is in excess of that of the machine.

7. Spindle Moulder or Vertical Spindle Moulding Machine (see B, Fig. 5).—This is a useful machine for forming mouldings on straight, curved or irregularly shaped lengths of timber; it is also used for planing, edging, recessing, tonguing, grooving, tenoning, dovetailing, and jointing. The cutterblock may be circular, as shown at C, or square, as shown at B. It is provided with a pair of straight fences and a pair of *ring* or circular fences, all of which can be moved and fixed in position on the table to suit the timber. Two adjustable spring pressures are fixed to the straight fences for holding the timber to the table and against the fences. The spindle speeds are usually 3 000, 4 500 and 6 000 revs. per min. It can rotate in either direction to suit the grain of the wood. A guard, not shown, is fitted over the cutter spindle to protect the operator. This machine is hand-fed and is known as a *single-spindle moulder*. Another type has two cutter-spindles and is hence called a *double-spindle moulder*. Both types can be mechanically fed when large outputs are required, the maximum speed-rate being 14 m per min.

8. Planing and Matching Machine.—This very powerful machine, which is at least 6 m long and 1·4 m wide, is designed to produce large and speedy outputs of accurately machined floor boarding, match-boarding, skirting, etc. The maximum output the latest type can exceed 110 m of tongued and grooved floor boarding per minute the maximum size of timber which the largest can deal with is 380 mm by 150 mm. provided with either four, five or six rotary cutterblocks. It has, in addition, either three or four horizontal fixed knives in a box immediately after the first bottom cutte for producing a first-class finish to the face; side fixed knives may also be fixed next side cutterheads. They are positioned as described for moulding machines above.

The cutterblocks fixed on the side vertical spindles which form the tongue and on the edges of floor and match-boarding are called the *tongueing head* and *groovin* respectively. The tonguing head has either six or eight cutters; each alternate forms the edge and upper portion of the tongue during rotation, and the remaining form its lower portion. The grooving head has either eight (four for edging and f grooving) or twelve (six edging and six grooving) cutters; the straight edging cutter the edge of the boarding and alternate with the projecting grooving cutters or *bits*.

For tongued and grooved and single or double vee-jointed match-boarding (see M, Fig. 42, Vol. I) the cutters of both the tonguing and grooving heads are shaped the necessary chamfers. The bead at the tongued edge of the tongued and groov single beaded matching (see N, Fig. 42, Vol. I) is formed by the second horizontal cutterblock or beading head of the six-cutter machine; if the matching is double (see O) the second bead is shaped by the second top cutterblock. Other labours edges, such as are required for the boards shown at Q, V and W, Fig. 34, Vol. I, are by suitably shaped cutters in the side cutterblocks.

One type of machine is fitted with eight feed rolls (0·5 m in diameter), tw immediately before the first cutterblock and two pairs before the side cutterblocks provided with suitable pressures. A shaving breaker is mounted below the fixed to reduce the long shaving to small particles. An automatic feeding table, desc the adjacent column, must be provided.

The rates of feed vary. Thus, one machine has twelve distinct rates of feed from 6·7 to 110 m per min. Another has nine rates varying from 20 to 135 m p Those used for production work only have minimum and maximum speeds o 160 m per min.

A four-cutter planing and matching machine will be suitable for flooring, plain ing and simple moulded skirtings. Thus, for tongued and grooved boarding, t boards are successively (1) planed on the lower face by the bottom cutterblock, (a high finish by the fixed blades (although these are not always provided), (3) pla grooved on one edge by the grooving head, and tongued and reduced to the corre by the tonguing head, and (4) finally reduced to the required thickness by the to block. Five and six cutter machines are necessary for beaded matching, more moulded skirtings, etc.

9. Mortising Machine (see K, Fig. 5).—This is used for mortising framing windows, etc. The two cutting tools chiefly used are the *hollow chisel* and the *cha*

The hollow chisel mortiser, as shown at F, Fig. 5, consists of a chisel in the f tube, square in section, and an auger bit which revolves within the chisel. The size of the chisel is up to 25 mm square (40 and 50 mm square chisels are use heavier machines), and its lower end has a fine cutting edge. The chisel is attac spindle and works with an up-and-down movement, and the stroke can be varie any depth of mortise down to 200 mm.

A chain cutter is an endless chain with links having cutting teeth on the outsi chain travels vertically at a high speed over a top sprocket (cogged) wheel fix spindle and a bottom guide wheel forming the lower end of a tension bar. The the chain varies from 6 to 40 mm and is capable of forming a mortise of 150 mm n depth.

The movement of the chisel is controlled by the hand lever. The timber is fi table by one or two adjustable cramps. The table can be raised and lowered by screw when operated by handwheel "3"; it can be moved either backwards or by a screw operated by handwheel "2," and longitudinally over the slide by handwheel "1."

Handwheels "2" and "3" are manipulated until the table is correctly posit the position of the mortise marked on the cramped timber is brought immedia the chisel, which has been lowered until it almost touches the wood. Once th been set it is not necessary to alter its transverse position and height, provided all the timber is of the same scantling and the size and relative position of the mortises are common.

Mortising is performed by the simplest type of hand-lever machines by lowering the lever to drive the chisel through the wood. The lever is raised; handwheel "1" is manipulated by the free hand to give the necessary short lateral movement of timber and the lever is again lowered. This is repeated until the mortise has been completed. If the machine is of the automatic type, the reciprocal feed motion of the chisel is controlled by the hand lever having automatic knocking-off and adjustable stops; mortises of uniform length are thus formed rapidly. In one type of automatic machine the feed of the chisel is operated by a foot lever, and the movement of the chisel continues automatically until the foot is released from the pedal of the lever.

In some machines the head carrying the hollow chisel can be quickly substituted for the chain cutter head. The mortising machine shown at K may be fitted with a chain cutter attachment in addition to the hollow chisel. Alternatively, a *boring* attachment, consisting of a spindle carrying a rotating auger, can be fitted. A boring machine is a form of mortiser, it being used to cut circular holes for dowelling, etc. The auger, like the hollow chisel, has a vertical movement and is controlled by a hand lever. Some multiple-boring machines carry four or more spindles which operate simultaneously by a hand lever or foot treadle. A boring machine may also be of the horizontal type, the auger spindle being placed at the side of the table; this is a useful machine for recessing and slot mortising, for which purpose the rise and fall tables, fitted with a fence, can be moved horizontally.

Another form of vertical boring machine is known as a *router* or *recessing machine* or *overhead spindle moulder*. This consists of a bench, a vertical cutter spindle similar to that shown at B (see p. 28) and another cutter spindle or boring tool mounted on an adjustable horizontal arm overhanging the table. The overhead cutter spindle is used for housing, recessing and trenching, as required for stair strings (to accommodate the ends of treads and risers, see p. 105), shelving, recessed panels, etc.

10. Tenoning Machine.—The single and double tenoning of members of framing is performed by a machine which has two horizontal rotary cutterblocks, two vertical rotary scribing cutterblocks, a cross-cut saw and a table which travels on rollers. The two tenoning cutterblocks, one below the other, are at right angles to the travel of the table and carry two or four knives each; they can be adjusted both vertically and horizontally to suit the required thickness and length of the tenons. A cutter is fitted to the end of each cutterblock to sever the fibres across the grain and form clean cuts at the shoulders. The two vertical cutterblocks are adjustable for both top and bottom scribing. The cross-cut saw is adjustable and cuts the end of the timber prior to or after being tenoned and scribed. The sawing, tenoning and scribing are done in sequence at each travel of the table, the scribing being the last operation as a rule. An adjustable *drunken saw* (so called because it appears to wobble when rotating) is used for double tenoning; this is attached to the bottom scribing spindle and replaces the bottom scribing block.

11. Double-dimension Saw Bench.—This is used for various classes of work (including ripping, cross-cutting, mitreing, grooving, rebating, bevelling and cutting compound angles) requiring accuracy in sawing to dimensions. The 1·1 m by 1 m table can be canted to 45°. A revolving frame carries two saws (usually a rip saw and a hollow ground cross-cut saw); that required for use is raised to the required height by turning a wheel; this operation lowers the other saw. The main fence can be accurately adjusted in any position and can be canted to 45° or swivelled to 30°. The front portion of the table can be moved laterally as required for cross-cutting, etc., and carries a mitreing and cross-cutting fence which is set to the required angle on reference to a graduated arc marked on the table or fence.

A *single-dimension saw bench* is similar to the above but carries only one saw. This saw can be interchanged.

12. Dovetailing Machine—Dovetailing of timber for drawers and similar work is done by an automatic single spindle dovetailing machine consisting of a vertical or horizontal rotary cutting spindle, mounted on a slide, and a travelling table to which the timber is cramped. The movement of the table conforms with the reciprocating motion of the spindle as the latter enters and leaves the wood to form dovetails at the required spacing. One type of multiple spindle dovetailing machine for repetition work has a table (which accommodates two boards to be joined at right angles to each other) fitted with an automatic mechanism for spacing the dovetails at the required pitch, and a complete dovetail joint is formed as the table moves past a series of cutters.

13. Lathe.—This is used for wood turning, examples being turned balusters, moulded newel caps and drops, legs of furniture, etc. The essential components are a fast headstock and a loose tailstock. These may be fixed on a wood bench or on a metal bed supported by legs. The headstock, usually fixed on the left-hand side, carries a short horizontal revolving spindle having a forked chuck to grip the timber and a three or four speed pulley. The tailstock is at the opposite end of the bench or bed and has a sliding horizontal spindle (carrying a tail centre which slightly penetrates and supports the end of the timber), operated by a handwheel; it can be moved and locked in any position along the bench.

The piece of wood to be turned is fixed horizontally between the stocks. The shaping of the wood is performed by a chisel or gouge of suitable shape which is fitted in a tool-holder and held against the wood as it revolves at a high speed; the cutting tool is held stationary or traverses the length of the timber as required during the shaving process. The tool, fixed in a holder and provided with an adjustable slide, may be used for turning long pieces; this is fitted to a sliding carriage which traverses the length of the bed.

For hand turning the tool is held and manipulated by hand, supported by a rest, various sizes and shapes of chisels and gouges being used in the process.

14. Mitreing Machine.—This is used for cutting mitres and squaring edges of timbers, is not power driven. It consists of a pedestal which supports a table and a knife which is operated by a hand lever. The timber is placed on the table, with one edge against a pivoting fence which has been adjusted to the required angle according to a graduated arc marked on the table, and the edge is cut by the knife on a downward stroke of the lever.

15. Sand-papering Machine or Sander.—Planed surfaces, especially if they have been prepared by rotary cutters, are uneven due to the presence of a series of ridges (see U, Fig. 6, and p. 27). In order to eliminate these ripples and give a smooth finish an abrasive paper is applied to the surfaces. The hand application of this abrasive is referred to in Chap. IV, Vol. I. There are three classes of machine sanders, *i.e.*, (*a*) drum, (*b*) belt and (*c*) disc.

(a) *Drum or Cylinder Sanders.*—One type, suitable for large outputs, consists of three horizontal drums which have a combined rotary and oscillating motion. Abrasive-paper is fixed to each drum, coarse grade paper being used to cover the first drum, medium grade the second and fine grade the third. These drums are superimposed over the feed mechanism, which may consist of a travelling endless belt or eight rollers. The timber is placed on the belt or feed rollers and suitable pressure bars or rollers ensure that it comes into intimate contact with the abrasive. The minimum rate of feed is 8 m per min. One or more hoods are fitted over the drums and are connected by a pipe to an exhaust fan which extracts the dust from the machine.

A smaller machine is provided with either one or two drums.

(b) *Belt Sander.*—This comprises a travelling table, 2·4 m long and a 150 or 200 mm wide endless belt above, which passes over two pulleys and travels the full length of the table. The timber is placed on the table, and the belt, with abrasive paper attached, is pressed down for close contact by means of a pad. This machine is suitable for medium outputs.

A smaller machine consists of a 2 m by 0·6 m table with two vertical rollers near the ends, on which a 200 mm high belt travels. The timber is laid on the table and pressed against the belt by hand.

A portable belt sander is shown in Fig. 68, Vol. I.

(c) *Disc Sander.*—One type consists of a pillar which supports a short revolving spindle at each end of which is a disc which varies from 0·5 to 0·9 m in diameter. A small table, which can be canted, is fixed opposite to each disc. Abrasive paper is fixed to the outer face of each disc and the work is held against it during rotation.

A combined machine, known as a *disc and bobbin sander*, carries a disc with a table, as described above, and a vertical spindle called a bobbin. The latter operates in the centre of a table and has a vertical reciprocating and rotary motion. Both tables can be canted. The bobbin, which is covered with abrasive paper, is useful for curved work.

16. Universal Woodworker or General Joiner.—This is a general utility machine capable of satisfying the requirements of smaller establishments where different classes of work are dealt with and the output is insufficient to justify the provision of separate machinery.

One type consists of two sections. The front half comprises a horizontal rotary cutter-block, front and back tables and adjustable fence (somewhat similar to those shown at H, Fig. 5) for planing, surfacing, chamfering and jointing timber up to 300 mm wide. In addition, a vertical rotary cutter spindle arranged to rise and fall as required, is fitted in the middle of the front table and thus resembles B, Fig. 5; this is used for moulding circular and irregular shaped pieces of timber up to 90 mm thick. A further addition consists of a small rise and fall table in front of this half-section for hollow chisel mortising, boring and slot mortising; the chisel is fixed horizontally to the end of the horizontal cutter-block and overhangs the small table; the timber is fixed by a vertical cramp to the table, which can be moved longitudinally and transversely; the chisel is replaced by either the boring bit or slot mortising auger as required.

The back half of the machine consists of a rise and fall table, fence and a spindle to which is attached either a circular saw or a horizontal rotary cutterblock. The maximum size of saw is 0·6 m diameter and will saw up to 230 mm deep; cross-cutting, mitreing and dimension sawing may be performed, as a steel plate to carry the timber and adjustable fence can be fitted to slide in a groove along the edge of the table. When required for tonguing, grooving, thicknessing and moulding, the saw is replaced by a horizontal cutter-block (125 mm long) carrying suitable knives. The table is lowered to bring it to the desired level below the cutterblock when the timber is to be moulded and thicknessed; the timber is first surfaced on one side and edge, and then thicknessed or moulded on the upper and opposite side; a power feed apparatus and pressures are provided for this purpose. The cutterblock is replaced by a suitable cutterblock for forming tenons, the maximum length of which is 125 mm; the timber is fixed transversely by a cramp to a plate and passed horizontally under the rotary cutter to form the upper portion of the tenon; the table, with plate and timber still attached, is then raised to the required height above the cutter over which the timber is passed to cut the opposite side of the tenon. Tonguing and grooving are performed when the cutterblock, with suitable cutters attached, is rotated against the timber, which is fixed to the table at a suitable height. For sand-papering, the cutterblock is replaced on the spindle by a small drum covered with abrasive-paper, and the operation is performed with the table adjusted at a suitable height.

17. Sharpening Machines.—These include—

Automatic Saw Sharpening Machine.—This is used for sharpening circular saws, the sharpening and gulleting (re-cutting the gullets to the correct shape, see G, Fig. 6) being done by a grinding machine which automatically grinds the whole profile of each tooth at one operation. The teeth can be ground square across or at any desired bevel. The grinding wheel, 200 or 300 mm in diameter, is fitted to a spindle which is provided with a rise and fall movement and may be canted to suit the hook or rake (see A, G and M, Fig. 6) of the saw teeth. The shape of the teeth is governed by a cam operating the rise and fall of the grinding wheel. Cams are varied in their shape to suit different sizes of teeth and are easily interchanged. The saw is fed forward under the grinding wheel by a feed pawl or finger which engages against the face of the tooth being ground. The stroke of the pawl is adjustable to suit different pitches of teeth and positioning of the face of the tooth under the grinding wheel. The saw is mounted on a spindle fitted with a self-centering cone to suit the variation in diameter of the spindle hole in the centre of the saw. This spindle is adjustable both vertically (to suit the diameter of the saw) and horizontally, according to the varying rakes of saw teeth. The rate of feed is from 15 to 30 teeth per minute, according to the pitch of the teeth.

A similar machine is used for sharpening band saws. The saw during the grinding operation is stretched horizontally and passes round two pulleys as it automatically progresses forward to bring each tooth (or alternate teeth) under the frame holding the grinding wheel.

Automatic Cutter Grinder.—This is used for grinding and shaping cutterblock and planing knives. A knife is fixed horizontally to a travelling table which traverses to and fro under a rotary abrasive wheel which grinds the knife to the required bevel. In another type of machine the knives are not removed from the block, the spindle of which is supported at each end of a table which travels longitudinally during the grinding operation.

Mortise Chain Cutter and Hollow Chisel Grinder.—This is a small machine for con[ditioning] the two cutting tools named. It is fixed to and driven by the mortising mach[ine]. The chain cutter is passed on to a sprocket mounted on a horizontal slide along whic[h it] passes to and fro under a specially shaped rotary abrasive wheel as the cutting teeth [are] ground. The machine also carries a cone abrasive wheel for sharpening hollow chis[els].

Grindstone.—This is a cylindrical disc, 0·9 to 1·2 m in diameter and 150 mm th[ick] of Derbyshire grit or similar hard natural stone which is mounted on a spindle tha[t is] rotated during the grinding operation. A finer stone disc, which gives a keener e[dge,] may also be mounted on the spindle in addition to the coarse disc. These rotat[e in] troughs which contain water when wet grinding is required to prevent overheating. T[his] machine is useful for general grinding, especially large hand tools.

A suitable machine for grinding smaller hand-cutting tools, such as chisels, gou[ges] and planing irons, consists of a frame supporting a rotary spindle which carries fou[r or] six emery or sandstone (or both) discs which are 300 mm in diameter and of vary[ing] thickness. A water tap is fixed above each disc and a trough is provided below.

FLOORS

Single floors are detailed in Chap. III, Vol. I. The other two types [of] boarded and joisted floors there referred to, *i.e.*, double and framed floors, [will] now be described.

> Attention is drawn to the fire-resisting types of contemporary constructio[n] which reinforced concrete floors (see Fig. 9 and B, Fig. 10) and hollow block or [tile] floors (see C, Fig. 10) are extensively employed and in which the minimum am[ount] of timber is used. See also Chap. II, Vol. IV.

Double Floors.—It is usual to limit the clear span of softwood brid[ging] joists to 5 m[1] and therefore when the width of a room exceeds this figure [one] or more relatively large members, called *binders or beams*, are introduced to a[fford] intermediate supports for the bridging joists. Economy in material thus res[ults] and the bridging joists, being much reduced in size, are more convenien[t to] handle.

These binders are spaced at from 1·8 to 3 m centres and are placed ac[ross] the shortest span in order that their dimensions may be kept down to a minim[um].

Mild steel and reinforced concrete beams (see Chap. II, Vol. IV) *have su[per]seded timber binders* (see below) *and flitched beams,*[2] *formerly used for long bin[ders] supporting heavy loads, except in countries having a plentiful supply of l[arge] timbers and a lack of steel and cement. Wood binders are encountered in altera[tion] work and they have therefore been detailed here* (see below).

Timber floor joist construction is included here for two reasons: (1) *to show [how] the size of a timber joist is calculated and* (2) *because in alteration work large ti[mber] binders are often encountered and one needs to be able to check the strength of f[loors] using these members.*

Plan, sections and details of a double floor are shown at A, B, C, D, E, F, G [and] H, Fig. 7. The plan at A shows the floor divided into three bays by the provi[sion] of two binders. With a view to reducing the over-all depth of the floor...

[1] This depends upon the grade of timber used and the superimposed load to be car[ried].
[2] A flitched beam consists of two wood joists (as shown at B, Fig. 8), but with a wro[ught] iron or steel plate between, all bolted together.

minimum and effecting an economy in the brickwork (to the extent of one or more courses), the bridging joists are cogged to the binders (see E, F and H). The depth of the sinking need not exceed two-thirds the depth of the bridging joists and their bearing should not exceed 25 mm; whilst such sinkings do not much reduce the strength of the binders, provided the workmanship is sound and the joists are a tight fit, the cutting and notching of bearing timbers should be restricted. The binders are shown supported on stone pads which provide sound bearings and effectively transmit the loads to the brickwork below; [illegible]5 mm thick concrete or stone lintels are also sometimes built in above the ends of the binders. The necessary circulation of air round the ends of the binders is ensured if pockets are provided, as shown at F and H.

Solid strutting of the bridging joists is sometimes resorted to, as shown at A and B, but this can safely be dispensed with (see Chap. III, Vol. I), especially when the joists are cogged to the binders.

If the ceiling of the room is required to be flush with the soffit of the binders, the necessary construction is as shown. Small fillets, not more than 50 mm by [illegible] mm, are nailed to the sides of the binders (see E, F and H) and plugged to the walls (see D and G). As shown, the ends of the 100 mm by 50 mm ceiling joists are notched to these fillets and nailed. Several alternative details, showing the ceiling attached to the bridging joists, appear in Fig. 8 (see pp. 35 and 37).

A detail incorporating a rolled mild steel beam as a binder in lieu of a wood binder is shown at M, Fig. 7. Mild steel is much stronger than timber (the allowable bending stress tension of rolled mild steel beams is 165 N/mm² and in group S1, grade 65 softwood is 10·3 N/mm² (Table I) and therefore the size of the steel beam is less than that of a wood binder; the 203 mm by 102 mm by 25·3 [illegible] steel beam shown at M will support the same load as the 380 mm by 200 mm timber binder (compare M with E). One result of this reduction in size is the corresponding decrease in the amount of walling, equivalent in this case to approximately two courses of brickwork.

Second year students attending a complete course of instruction which includes the subject of Building Science in addition to Building Construction, will probably be taught to design simple rectangular beams, but the determination of sizes of rolled steel beams is usually deferred to a later stage. The following examples are therefore stated briefly and are included for reference purposes only.

Determination of Sizes of Bridging Joists and Binders.—The sizes of wood joists and binders can be obtained by reference to tables in the Building Regulations. Thus, assuming the floor illustrated at A, Fig. 7, is that of a residential building, the sizes of the bridging joists which are spaced at 400 mm centres with an effective span (distance between bearings) of 2·75 m are computed to be 150 mm by 38 mm in group S2 timber.

Alternatively, the size of the bridging joists is determined by calculation as follows: (1) the total weight (W) that one of the joists supports is obtained; this equals the decided live or imposed load[1] plus the dead weight, multiplied by the area of the floor supported by the member. (2) The bending moment (B.M.) is found; this equals the moment of resistance (MR), and the latter equals the product of the modulus of section (Z) and the permissible stress (f). The size of the binders is ascertained in a similar manner. C.P. 112 (see p. 16) gives the permissible basic stresses for different groups and grades of structural timbers (see Table I).

[1] See adjacent column for imposed floor and roof loads.

In accordance with C.P.3, Chapter V, the imposed loads are as follows:

TABLE IV. IMPOSED LOADING

Types of Floors	Intensity of Distributed Load		Concentrated Load to be applied unless otherwise stated over any square with a 300 mm side	
	kN/m²	kgf/m²	kN	kgf
Houses, maisonettes and flats	1·5	153	1·4	143
Hotel bedrooms	2·0	204	1·8	184
Offices for general use	2·5	255	2·7	275
College and school classrooms	3·0	306	2·7	275
Corridors to offices subject to crowd loading except grandstands. Department floors	4·0	408	4·5	469
Office floors carrying computer equipment	4·5	459	to be determined	
College assembly areas without fixed seating. Hotel bars and vestibules	5	510	3·6	367
Hotel bedrooms	2	204	1·8	184
Departmental floors	4	408	3·6	367

Roofs.—On flat roofs (including those sloped up to 10°) where access in addition to that needed for cleaning and repair is provided: (a) the imposed load is 1·5 kN/m² (153 kgf/m²) measured on plan (including snow) or a load of 1·8 kN (184 kgf) concentrated on a square with 300 mm side. (b) Where the only access provided is that for cleaning or repair the imposed load is 0·75 kN/m² (7·65 kgf/m²) measured on plan or a load of 0·9 kN (91·8 kgf) concentrated on a square with 300 mm. side.

On roofs with a slope between 10° and 30° for case (b) above the loads are 0·75 kN/m² (76·5 kgf/m²) or 0·9 kN (91·8 kgf). For a slope of 75° or more no allowance is necessary.

All loads are applied vertically and 300 mm squares are measured on the roof slope.

Applying this to the floor shown at A, Fig. 7:—

Bridging Joist A′, Fig. 7.—Span 2·75 m. Douglas fir group S.1 grade 40 timber; density 530 kg/m³.

Dead loading.—25 mm floor boards $=0{\cdot}025\times1\times1\times530=13{\cdot}25$ kg/m². Assume that 150 mm by 50 mm floor joists will be satisfactory. There are 13 joists spaced over a distance of 5·26 m. If the two outer joists are placed with their centres 75 mm from the wall face the distance from centre to centre of these two outer joists $=5{\cdot}26-(2\times0{\cdot}075)=5{\cdot}11$ m. So the centres of the joists $=5{\cdot}11\div13=0{\cdot}393$ m.

Mass of one joist per lineal metre $= 1 \times 0.150 \times 0.050 \times 530 = 3.97$ kg/m.
Proportionate mass of one joist per m² of floor = mass of one joist divided by area *abcd* of floor it supports $= \dfrac{2.75 \times 3.97}{2.75 \times 0.393} = 10.1$ kg/m².
Hence toal loading $= 13.25 + 10.1 = 23.35$ kg/m². Mass is measured in kg units and has to be converted to force which is measured in Newtons. Force = mass × acceleration, where acceleration $= 9.8$ m/sec² at the earth's surface. So the force exerted by a mass of 1 kg $= 1 \times 9.81$ Newtons (N) $= \dfrac{9.81}{10^3}$ kN.

Hence in this case the total dead loading becomes $\dfrac{23.35 \times 9.81}{10^3}$

$$= 0.229 \text{ kN/m}^2.$$

Imposed loading $= 2.5$ (Office building, see Table IV)

Total loading $= 2.729$ kN/m²

Loading on one joist $= 2.75 \times 0.393 \times 2.729$ kN $= 2.95$ kN.

Bending Moment.—$BM = \dfrac{WL}{8} = \dfrac{2.95 \times 2.75}{8} = 1.016$ kNm

$BM = Zf$ where $Z = \dfrac{bd^2}{6}$ m³ (Z is a measure of the shape of a section)

$f = 6.2$ N/mm² (Table I, permitted bending stress).

Therefore, $Z \text{ required} = \dfrac{BM}{f} = \dfrac{1.016 \times 10^3 \times 10^3}{6.2} = 163.6 \times 10^3 \text{ mm}^3$

The Z provided of a 150 × 50 mm joist $= \dfrac{50 \times 150^2}{6} = 187.5 \times 10^3$, so this joist is satisfactory so far as bending moment is concerned.

Deflection.—C.P.112 states that the maximum permitted deflection $= 0.003 \times$ span $= 0.003 \times 2.75 \times 10^3$ mm. $= 8.25$ mm.

Actual deflection $= \dfrac{5 \times Wl^3}{384 \times EI}$ mm.

E for S.1 group timber is 9.7×10^3 N/mm².

Moment of inertia $I = \dfrac{bd^3}{12} = \dfrac{50 \times 150^3}{12} = 14.06 \times 10^6$ mm.⁴

Therefore, actual deflection $= \dfrac{5 \times 1.016 \times 10^3 \times 2.75 \times 2.75^3 \times 10^9}{384 \times 9.7 \times 10^3 \times 14.06 \times 10^6}$
$= 5.55$ mm = satisfactory.

Shear.—Permitted shear stress 0.62 N/mm² (Table I).
actual shear stress $= \dfrac{1.5 \times \text{max sheer force}}{b \times d} = \dfrac{1.5 \times 2.95 \div 2 \times 10^3}{50 \times 150}$
$= 0.295$ N/mm² = satisfactory.

Bearing.—The ends of the joist must bear onto sufficient area to prevent them being crushed. The permitted compressive stress perpendicular to the grain is 1.93 N/mm² (Table I). If the minimum bearing length of the 50- mm wide joist is X then: $1.93 = 1.016 \times 10^3 \times \dfrac{2.75}{2} \times \dfrac{1}{50 \times X}$ Therefore, $X = 14.5$ mm.
This is satisfactory because the joists bear onto 200 mm wide binders at one end and onto a 102.5 mm wall seating at the other end.

Binder B′ Fig 7.—

Clear span $= 5.26$ m
End Bearing $= 0.215$

Effective span $= 5.475$ m

Use group S.3. grade 75 timber. Assume a 380 mm × 200 mm binder will be satisfactory. Its mass per lineal metre $= 0.380 \times 0.200 \times 530 = 40.3$ kg/m.
The floor area carried by the binder is area *efgh*.

So its mass per m² of floor $= \dfrac{40.3}{1 \times 2.75} = 14.64$ kg/m².
Mass of 14 N°. 100 mm × 50 mm ceiling joists per m² of floor
$= \dfrac{14 \times 0.100 \times 0.050 \times 530 \times 2.75}{5.26 \times 2.75} = 7.05$ kg/m²
Mass of 12.7 mm plasterboard and 3 mm plaster skim $= 13.5$ kg/m²
Mass of floorboarding and floor joists $= 13.25 + 10.1$ (p. 31 and adjacent colum
$= 23.35$ kg/m²
Therefore, total dead loading $= 14.64 + 7.05 + 13.5 + 23.35 = 58.54$ kg/m²
$= \dfrac{58.54 \times 9.81}{10^3} = 0.574$ kN/m²

Imposed loading $= 2.5$

Total loading $= 3.074$ kN/m²

Loading on binder $= 2.75 \times 5.475 \times 3.074 = 46.3$ kN

$BM = \dfrac{WL}{8} = \dfrac{46.3 \times 5.475}{8} = 31.7$ kNm.

$BM = Zf$, $f = 6.6$ (Table I)

$Z \text{ required} = \dfrac{31.7 \times 10^3 \times 10^3}{6.6} = 4799 \times 10^3 \text{ mm}^3.$

Z of a 380 mm × 200 mm binder $= \dfrac{bd^2}{6} = \dfrac{200 \times 380^2}{6}$
$= 4{,}810 \times 10^3$ mm, which is adequate.

Deflection.—Maximum permitted deflection $= 0.003 \times 5.475 = 16.425$ mm.
E for S.3 group timber $= 6.9 \times 10^3$ N/mm².
I for 380 × 200 binder $= \dfrac{200 \times 380^3}{12} = 915 \times 10^6$ mm⁴.

Actual deflection $= \dfrac{5WL^3}{384\,EI} = \dfrac{5 \times 46.3 \times 10^3 \times (5.475 \times 10^3)^3}{384 \times 6.9 \times 10^3 \times 915 \times 10^6} = 15.7$ mm = satisfa

Shear.—Permitted shear stress $= 0.90$ N/mm² (Table I)
Actual sheer stress $= \dfrac{1.5 \times 46.3 \div 2 \times 10^3}{380 \times 200} = 0.46$ N/mm² = satis

Bearing.—Minimum bearing length required
$= \dfrac{46.3 \div 2 \times 10^3}{200 \times 1.31 \text{ (Table I)}} = 88$ mm.

215 mm bearing is provided.
If a steel beam were adopted instead of the timber binder its size would as follows:
Assume the same B.M. as above (in fact it would be less because the ma steel beam is less than that of the timber binder; the ceiling joists have a omitted—see detail at M_1 Fig. 7).
Assume a 203 mm by 102 mm by 25.3 kg steel beam will suffice. stress in the steel is 165 N/mm².
Therefore, $Z \text{ required} = \dfrac{BM}{f} = \dfrac{31.7 \times 10^3 \times 10^2}{165 \times 10^2} = 192 \text{ cm}^3.$
By consulting a steel section book it will be found that the Z value modulus of the steel section chosen is 225.8 cm³. (Note: for steel Z is give units not mm³ which is usual for timber sections.)

Steel Girder E′.— Clear span $= 7.62$ m
Effective span $= 7.95$ m

Dead loadings.—Floor boards		= 13.25 kg/m²
	150 mm × 75 mm Bridging joists	= 13.50 kg/m²
	100 mm × 50 mm Ceiling joists	= 7.05 kg/m²
	Plasterboard and skim	= 13.5 kg/m²
		47.30 kg/m²

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and adjacent colum

=58·54 kg/m²

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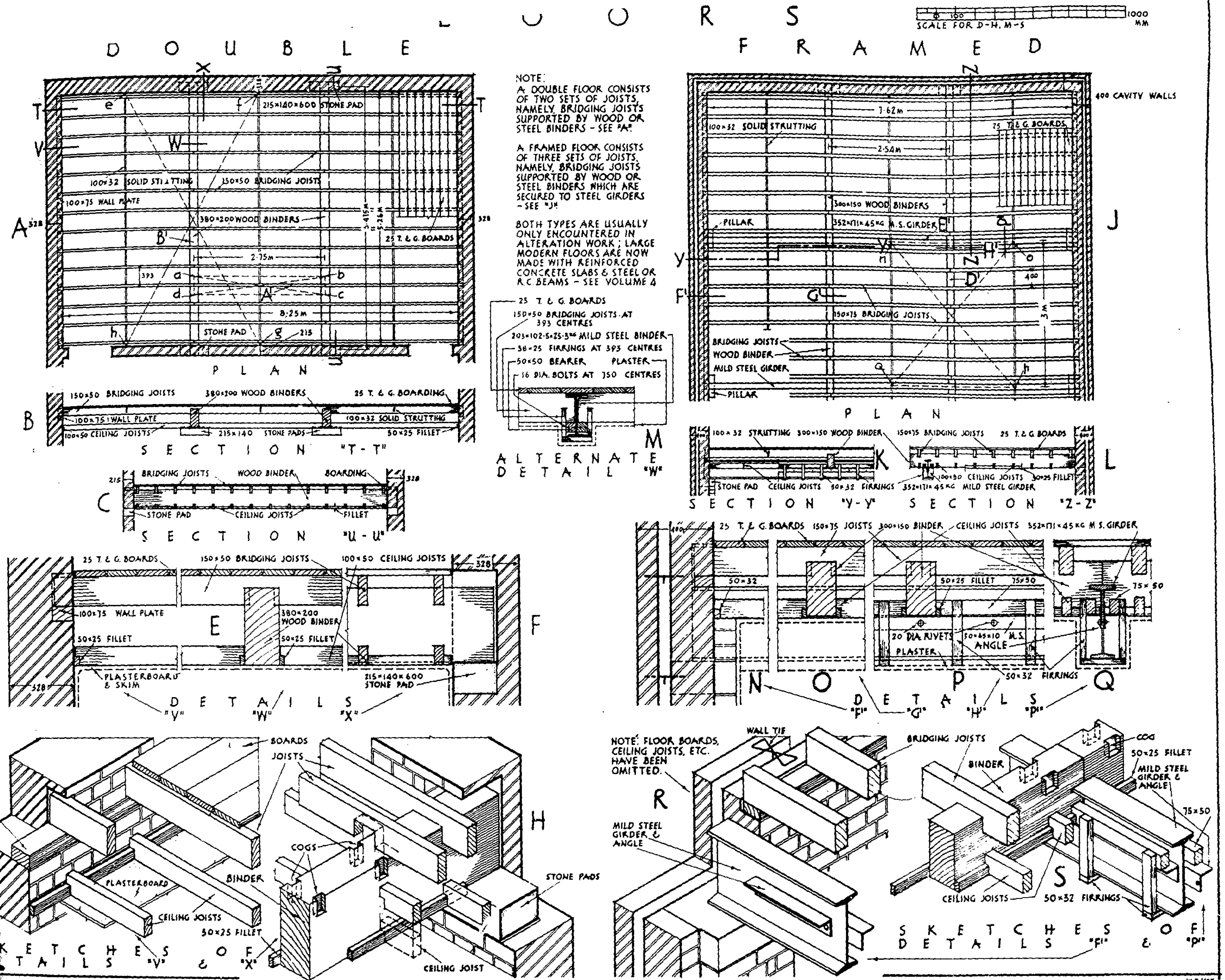
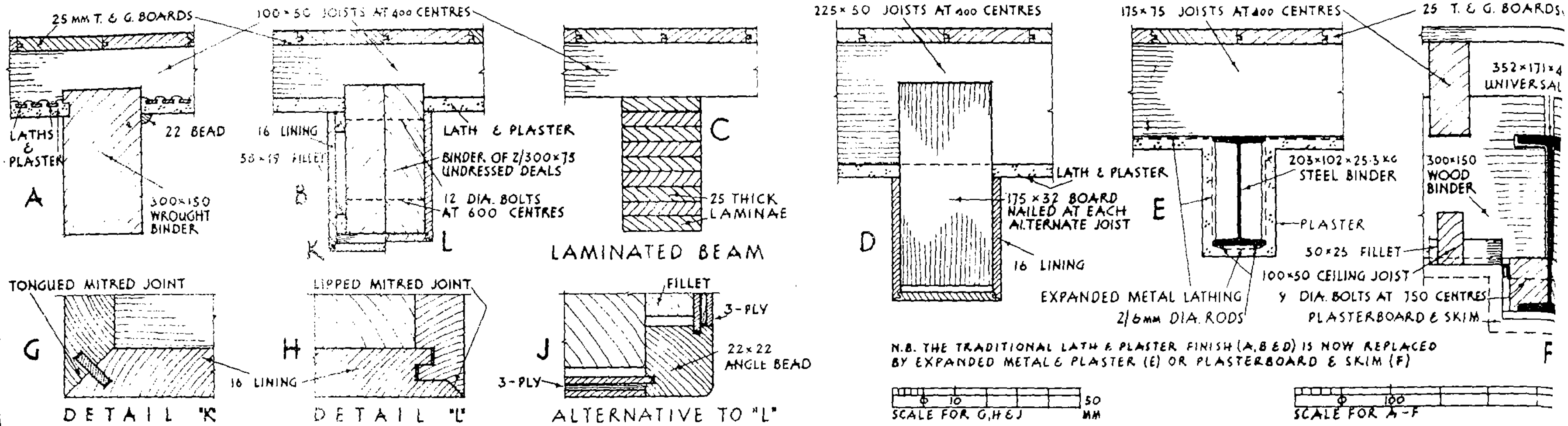
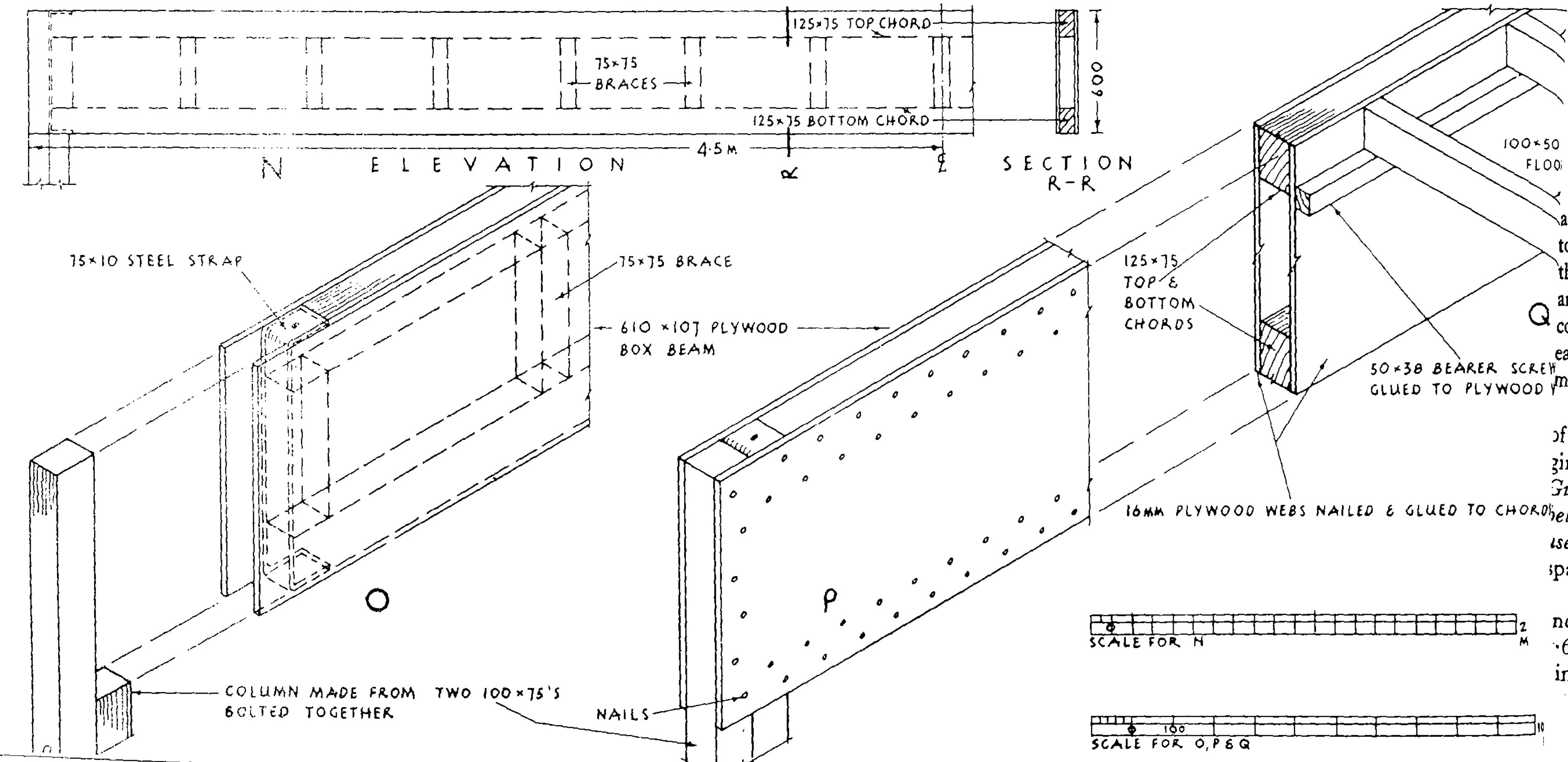


FIGURE 7

DETAILS OF DOUBLE & FRAMED FLOOR



PLYWOOD BOX BEAM



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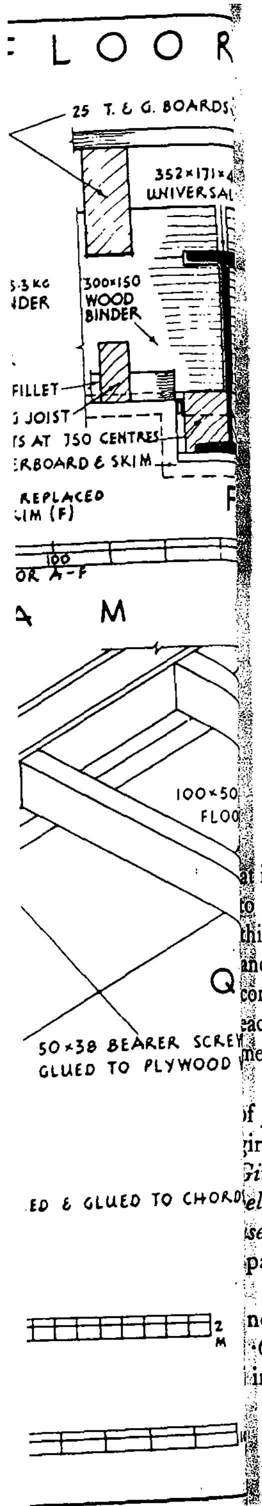

Mass of 300 mm × 150 mm binder per m² of floor

$$= \frac{7{\cdot}62 \times 0{\cdot}300 \times 0{\cdot}150 \times 530}{7{\cdot}62 \times 2{\cdot}54} = 9{\cdot}4 \text{ kg/m}^2$$

$$\text{Dead loading} = 47{\cdot}30 + 9{\cdot}4 = 56{\cdot}70 \text{ kg/m}^2$$

$$= \frac{56{\cdot}7 \times 9{\cdot}81}{10^3} = 0{\cdot}556 \text{ kN/m}^2$$

$$\text{Imposed loading} = 5$$

$$\text{Total loading} = 5{\cdot}556 \text{ kN/m}^2$$

$$\text{Loading on Binder D}' = 3 \times 2{\cdot}54 \times 5{\cdot}556 = 42{\cdot}4 \text{ kN}$$

Therefore, Girder E′ is loaded as follows

42·4 kN 42·4 kN

← 2·54 m → ← 2·54 m → ← 2·54 m →

42·4kN 42·4kN

therefore, $\text{BM} = 42{\cdot}4 \times 2{\cdot}54 = 107{\cdot}7$ kN/m.

Assume the girder is 352 mm × 171 mm × 45 kg/m.

Its mass, therefore, is $7{\cdot}62 \times 45 = 343$ kg.

$$= 343 \times \frac{9{\cdot}81}{10^3} = 3{\cdot}36 \text{ kN}$$

BM due to girder itself

$$= \frac{WL}{8} = \frac{3{\cdot}36 \times 7{\cdot}62}{8} = 3{\cdot}2 \text{ kNm.}$$

$$\text{Total BM} = 107{\cdot}7 + 3{\cdot}2 = 111 \text{ kNm.}$$

$$\text{BM} = Zf$$

$$f \text{ for steel} = 165 \text{ N/mm}^2.$$

$$\therefore Z \text{ required} = \frac{111 \times 10^3 \times 10^2}{165 \times 10^2} \text{ cm}^3$$

$$= 673 \text{ cm}^3$$

and Z of a 352 × 171 × 45 universal beam = 685 cm³, so the section chosen is satisfactory. Note the use of cm units here.

The section at M Fig. 7 shows the steel binder with the bridging joists notched at its upper flange and supported on 50 mm by 50 mm bearers which are secured to the web of the binder by 16 mm diameter bolts at 750 mm centres. In this detail, unlike that at E, the bridging joists are covered with plasterboard and plaster, and the binder is suitably finished by *firring* (or *cradling*). Firring consists of two vertical 25 or 32 mm thick pieces of wood nailed to the sides of each pair of timber joists, and a similar firring fixed to the ends of the vertical members.

Framed or Triple Floors.—As implied, a triple floor consists of three sets of joists, *i.e.*, bridging joists, binders and girders. In the past the binders and girders were of solid wood and the former were framed or tenoned to the latter. *Girders are now made of glued laminated timber or box plywood construction* (*see below*) *when loading is not excessive, whilst steel and reinforced concrete beams are used in framing large floors.* A framed floor may be adopted when the narrowest span exceeds 7 m and the superimposed (live) load is relatively heavy.

Plan, sections and details of a framed floor are shown at J, K, L, N, O, P, Q, R and S, Fig. 7. The plan shows a portion of a large room, the width of which is 7·62 m. Steel girders span the room at 3 m centres. These support two wood binders at one-third points (2·54 m centres), and the latter carry the bridging joists and ceiling joists. The details at P and Q show the binders notched over the top flange of the girder and supported on 90 mm by 65 mm by 10 mm mild steel angles secured to the web of the girder by 20 mm diameter rivets at 380 mm centres. These angles also support the 75 mm by 50 mm bearers to which the cradling is nailed. Attached brick piers are formed on the 215 mm thick inner leaf of each of the long 400 mm cavity walls to provide adequate supports for the concentrated loads transmitted by the steel girders which are bedded upon hard stone pads. This construction and the steelwork are more clearly shown in the sketch at R. The sketch at S shows the cradling and other details, the former consisting of 50 mm by 32 mm firring at 400 mm centres as fixings for the plasterboard (and plaster).

The details of the binders, bridging joists and ceiling joists are similar to those of the double floor. Each 300 mm by 150 mm wood binder may consist of two 300 mm by 75 mm joists bolted together as shown at B, Fig. 8, the double row of bolts being staggered; the use of such stock sizes may be preferred if the larger single members are not readily available. If desired, the binders may be lowered and supported by wood bearers bolted to the steel girder; the detail at Q would then resemble that at M or, alternatively, as shown at F, Fig. 8.

The plastered ceiling may be attached direct to the bridging joists, and the binders may be then dealt with as suggested in some of the details in Fig. 8.

If steel is used instead of wood for the binders, it can be shown by calculation that the size of the steel binders need only be 152 mm by 89 mm by 17·1 kg R.S.J. The use of steel would greatly simplify the details, as the 150 mm by 75 mm bridging joists would just be notched at both flanges of each steel binder, and a flush ceiling would result by simply nailing the plasterboard direct to the joists. If the bridging joists are cut carefully and fitted tightly between the webs of the binders, no other fixing need be provided for the former.

The advantages of steel over wood for girders will be appreciated when a comparison between the sizes of wood and steel members is made. Thus, a timber girder required to support the same load as that taken by the 352 *mm by* 171 *mm by* 45 *kg universal beam would have to be approximately* 500 *mm by* 300 *mm or equivalent, and its weight would be at least* 500 *kg.*

The sizes of the various members of the framed floor illustrated in Fig. 7 were determined in the same way as for the double floor.

The double and framed floors shown in Fig. 7 have the ceilings flush with the soffit of the binders. Economy results if the ceiling joists are dispensed with and the plasterboard ceiling is fixed directly to the bridging joists as shown in the several alternative details shown in Fig. 8 and described as follows.

Detail A shows the bridging joists cogged to a *wrought* binder and the laths supporting the plaster nailed to the joists. To prevent unsightly shrinkage gaps, the binder may be grooved to receive the plaster, as shown on the left, or a small quadrant bead or cover mould may be introduced (see the right side of the binder). The lower arrises of the binder may be chamfered or otherwise moulded. Note that timber laths are no longer used in plastering.

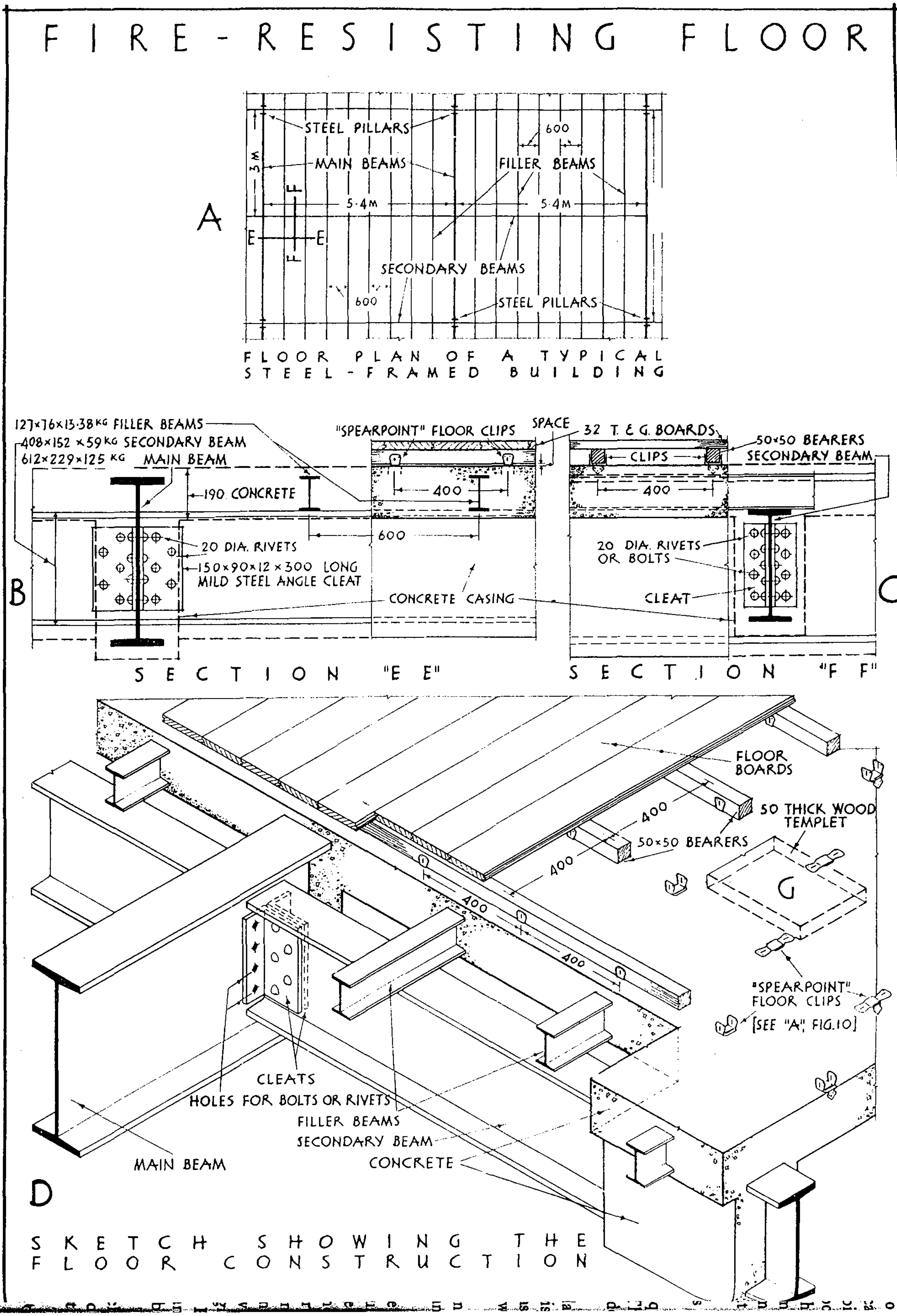
FIRE-RESISTING FLOOR
A
STEEL PILLARS
600
3 M
MAIN BEAMS
FILLER BEAMS
5·4M
5·4M
F
E
E
F
SECONDARY BEAMS
600
STEEL PILLARS
FLOOR PLAN OF A TYPICAL STEEL-FRAMED BUILDING
127×76×13·38KG FILLER BEAMS
408×152×59KG SECONDARY BEAM
612×229×125 KG MAIN BEAM
"SPEARPOINT" FLOOR CLIPS
SPACE
32 T. & G. BOARDS
50×50 BEARERS
SECONDARY BEAM
CLIPS
190 CONCRETE
400
400
600
20 DIA. RIVETS
150×90×12×300 LONG
MILD STEEL ANGLE CLEAT
20 DIA. RIVETS
OR BOLTS
B
C
CONCRETE CASING
CLEAT
SECTION "E E"
SECTION "F F"
FLOOR
BOARDS
50 THICK WOOD
TEMPLET
400
50×50 BEARERS
400
400
400
G
"SPEARPOINT"
FLOOR CLIPS
[SEE "A", FIG.10]
CLEATS
HOLES FOR BOLTS OR RIVETS
FILLER BEAMS
SECONDARY BEAM
MAIN BEAM
CONCRETE
D
SKETCH SHOWING THE
FLOOR CONSTRUCTION

FIGURE 9

Detail B shows the binder consisting of two undressed deals which are bolted ogether at 610 mm intervals and glued, the upper bolts staggering with the ower. Two methods of covering the binder are shown. That at K shows a asing or lining of 16 mm dressed boarding secured to fillets nailed to the inder; the thickness of the fillets varies according to the overall size and proortion of the binder desired. Alternatively, the lining may be fixed direct to he binder as shown at L. The joints between the side and soffit lining boards ay be either butt mitred, tongued mitred (see detail at G) or, preferably, lipped itred (see detail at H). An alternative casing, consisting of plywood, is shown J. The angle beads provide an effective finish at the arrises.

The laminated beam detail at C, consisting of relatively thin strips of timber, described below.

A mock beam or binder is shown at D. Short lengths of floor boards, or uivalent, are nailed to alternate joists and the framed casing is fixed to these. is construction does not, of course, strengthen the floor, but it is sometimes opted for dividing the ceiling into bays.

Detail E shows a variation which is an alternative to plasterboard and aster. Expanded metal lathing (X.P.M.) is nailed to the underside of the sts to receive the plaster. The X.P.M. is taken round the steel binder which two 6 mm dia. longitudinal steel rods placed along the bottom face of the er flange to give a key to the plaster behind the lathing at this place.

The detail at F is alternative to that shown at Q, Fig 7 (see p. 35). The ders are supported on continuous bearers which are notched over the lower nge of the steel girder and bolted to its web.

Laminated Beams.—Solid timber sections greater than 300 mm by 300 mm difficult to obtain but it is possible to build up beams of considerable depth by ng together relatively thin sections. In a glued laminated beam the sections usually about 25 mm thick; they can be placed horizontally as at C, Fig. 8 en a deep beam is required. Alternatively the laminae can be placed ically for beams up to about 30 mm deep in which case the permissible ding stress may be up to 25 per cent. greater than if the beam were of solid ber. The thin laminations are joined and glued at their ends by a scarf joint ng a slope of about 1 : 12. An example of a glued laminated timber portal iven in Vol. IV.

Plywood Box Beams.—These are used to make timber beams for large ns, they incorporate top and bottom solid timber chords to which plywood s are glued and nailed down each side.

The part elevation at N, Fig. 8 shows a typical example for a 9 m span; h a beam, placed at 1·5 m centres would support a normal domestic floor d. Small timber floor bridging joists would span between the beams and on timber fillets screwed and glued to the plywood webs.

The box beam shown has 125 mm by 75 mm top and bottom chords with mm plywood webs glued and pinned to them. Vertical braces of the same section as the chords are placed within the web at 600 mm intervals. The construction is shown clearly at O, P and Q; those at O and P also show the connection to a timber column made from two 100 mm by 75 mm timbers glued and pinned together. The fastening is made by making the plywood webs project so that they lap the sides of the column where they are nailed. The ends of the beams are strengthened by cranked metal plates made from 75 mm by 10 mm steel which pass down the brace and are cranked over for a distance of 100 mm.

Another type of box beam can be made by using boarding instead of plywood for the webs; the boarding is placed diagonally and the construction would resemble that shown at B and F, Fig. 18.

Fire-resisting Floors.—Reference is made on p. 30 to the fire-resisting[1] types of floor construction now employed, in which little, if any, timber is used. Whilst a close study of such construction is outside the scope of the second year curriculum, it is thought desirable to include some of its details here in order that a comparison may be made between the older and relatively modern types of floors.

A, Fig. 9, shows a part-plan of a typical floor of a steel-framed building on which the steel members are indicated in outline. This is sometimes called a *triple* floor, as it consists of three sets of beams, *i.e.*, *filler* or *primary*, *secondary* and *main beams*. The filler beams, usually spaced at not more than 760 mm centres, are encased in concrete and are either supported on, but not fixed to, the top flanges of the secondary beams or are secured to the webs of the latter beams. The secondary beams have steel angle cleats riveted or bolted at the ends, and these cleats are secured in a similar manner to the webs of the main beams. The latter are either riveted or bolted to the steel pillars. Such connections may be welded (see Chap. II, Vol. IV) in lieu of cleats and rivets or bolts. The cross-section of a pillar is similar to that of a steel beam. In addition to the filler beams, the secondary beams, main beams and pillars must be encased in concrete or other suitable non-combustible material. The sizes of the various steel members depend upon the load to be supported, span, method of fixing, etc. The method employed of determining the sizes of the beams is given briefly in the example on pp. 32 and 35.

Details of this floor are shown at B, C and the isometric sketch at D, Fig. 9.

In lieu of filler beams encased in concrete, the floor may consist of hollow concrete or fireclay blocks or beams supported on the concrete haunches of steel beams. One example of such a floor is shown at C, Fig 10. The steel bars are provided to resist tension and shear stresses.

Another type of fire-resisting floor is shown at B, Fig. 10. This portion of a reinforced concrete floor is known as a *slab*. Such a floor may resemble somewhat that shown at A, Fig. 9, with *transverse bar* reinforcement at close spacing in lieu of filler beams. Another set of bars, called *distributing* or *longitudinal bars* are placed at a greater distance apart immediately over and wired to the transverse

[1] This construction is treated in greater detail in Vol. IV.

bars. Various forms of reinforcement—such as sheets of expanded metal—are also used as an alternative to the above circular bars; the expanded metal resembles that shown at A, Fig. 16, Vol. II. The entire floor structure is usually of reinforced concrete. Thus, the secondary and main beams are of concrete, reinforced with steel bars and the concrete pillars have similar but vertical reinforcement; the pillars may be square, rectangular, octangular or circular on plan.

FLOOR FINISHES

The following coverings will be described: (1) wood boards, (2) wood blocks, (3) plywood, (4) parquet, (5) cork, (6) rubber, (7) thermoplastic tiles (8) vinyl asbestos tiles, (9) vinyl sheet and tiles, (10) synthetic resins, (11) pitchmastic, (12) mastic asphalt, (13) cement and rubber latex (fleximer), (14) magnesium oxychloride, (15) clay tiles, (16) granolithic screed, (17) terazzo, (18) linoleum, (19) composition blocks, (20) marble tiles and (21) quarzite. Note that it is important that all ground floor concrete slabs should incorporate a d.p.c. over the whole area; although the site may not be wet a d.p.c. is essential to stop rising moisture. Sandwich floor construction comprising two layers of concrete with hot asphalt in two coats (see Chap. I, Vol. II) is often used. In lieu of asphalt there are now certain cold proprietary bituminous paints which are claimed to be effective.

1. *Wood Boards.*—A description of this flooring appears in Chap. III, Vol. I. As stated, rift or quarter sawn narrow boards are preferred for first-class work, stock nominal sizes varying from 50 to 115 mm wide by 25 to 32 mm thick; the width of stock softwood boards used for general work varies from 125 to 175 mm. Stock lengths vary from 0·6 to 5 m. An attractive flooring is obtained by the use of hardwood boards of random widths, but these must be well seasoned to the correct moisture content if excessive shrinkage is to be avoided. Tongued and grooved boards are chiefly employed; most are square ended, but some of the hardwood boards (*e.g.*, Canadian yellow birch) are t. and g. at the ends.

A double floor (see "double boarded floors," Chap. III, Vol. I), now much favoured, consists of a sub-floor of 25 mm square edged (or t. and g.) softwood boarding, laid diagonally, and covered with 50 to 75 mm wide hardwood boards which are only 10 mm thick. This thin and narrow covering, which has a very attractive appearance, is known as *strip flooring*; the boards are t. and g. at the edges and ends and are usually secret nailed. One advantage of a double floor is that plastering can be completed and allowed to dry before the top flooring is laid; a common cause of damage to the finished floor is thus eliminated.

The timbers used for flooring include the following softwoods: Douglas fir, whitewood, redwood, pitch pine, slash pine, western hemlock and kauri pines and the following hardwoods: English, American, Tasmanian and Japanese oak, maple, birch, beech, teak, gurjun, jarrah, seraya and pyinkado. A brief description of these is given in Tables II and III.

Sub-floors of concrete which are finished with wood boards are referred to in Chap. III, Vol. I. The boards are shown nailed to splayed fillets or bearers partially embedded in the concrete.

An additional method of securing the bearers is to anchor them to the crete by means of *floor clips*. Two patent floor clips are the "Spearpoint" the "Bull Dog," shown in Fig. 10 at A and D respectively.

The Spearpoint clip is made of 1 mm thick mild steel, which is either anized or sheradized to prevent corrosion. It is in one piece, having two s shaped flanges or legs which are inserted into the concrete, a cross-piece an upper nailing flanges or ears between which the wood bearers are fixed. leg has three projecting holed *bosses* which assist in increasing the bond be the concrete and metal. It is obtainable with the ears bent down and in sizes, *i.e.*, for 38, 50, 75 and 100 mm wide bearers; the usual size employe the average floor is that designed to receive 50 mm square bearers. The are spaced in rows at 350 to 400 mm centres, according to the thickness floor boards and the weight to be supported, and at 400 mm centres alon rows.

The clips are fixed in the following manner: The legs of the clips are presse the concrete within about half an hour after it has been laid and levelled, and its plasticity has disappeared. Either a plank or a templet (consisting of tw boards with upper cross-pieces nailed at intervals) is used to ensure accurate s of the clips in true alignment and the prevention of damage to the surface of the concrete by the workmen The ears, being horizontal when the clips are ins lie flat on the surface of the concrete and thus present no obstruction to wh etc. operations which are usually carried out when the concrete has hardened. plank or templet is marked along its edges at 400 mm intervals or other re intervals, and the fixers standing upon it press the clips into the concrete divisions. The broken lines at G, Fig. 9 represent a portion of a templet, the of which equals the distance between the edges of the extended ears in adjacent The clips are sometimes staggered. When the concrete has hardened, the ea prised by the claw of a hammer until they are vertical (see B, C and D, Fig. 9, and B, Fig. 10). The bearers are placed in position between the ears and first through the slots; they are then levelled and, if necessary, packed with small w between the underside of the bearers and the surface of the concrete screeding, may be somewhat irregular. The bearers are finally nailed through the top hol the floor boards laid in the usual way.

Complete circulation of air round the bearers is assured, as the central p of each slip is slightly above the concrete (see B, Fig. 9), although if the scre is imperfect the space between it and the bearers is filled with cement Thus, this method of fixing is an improvement upon that described in V where partially embedded fillets are employed. Incidentally, the use of results in a saving in the thickness of screed. It is emphasized that the co must be dry before the bearers are fixed; the latter should be sound and seasoned, and, as an extra precaution against the onset of dry rot, they s be treated with preservative before being fixed.

The Bull Dog clip is of 1 mm thick sherardized sheet metal and is of H-s (see D, Fig. 10). The standard clip has 40 mm long legs, but if the screed less than 38 mm thick, clips having 30 mm long legs are obtainable.

They are fixed at the same distance apart and in a somewhat similar mann that described above. Before insertion, the two ears are folded over (s

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B, C and D, Fig. 9, and
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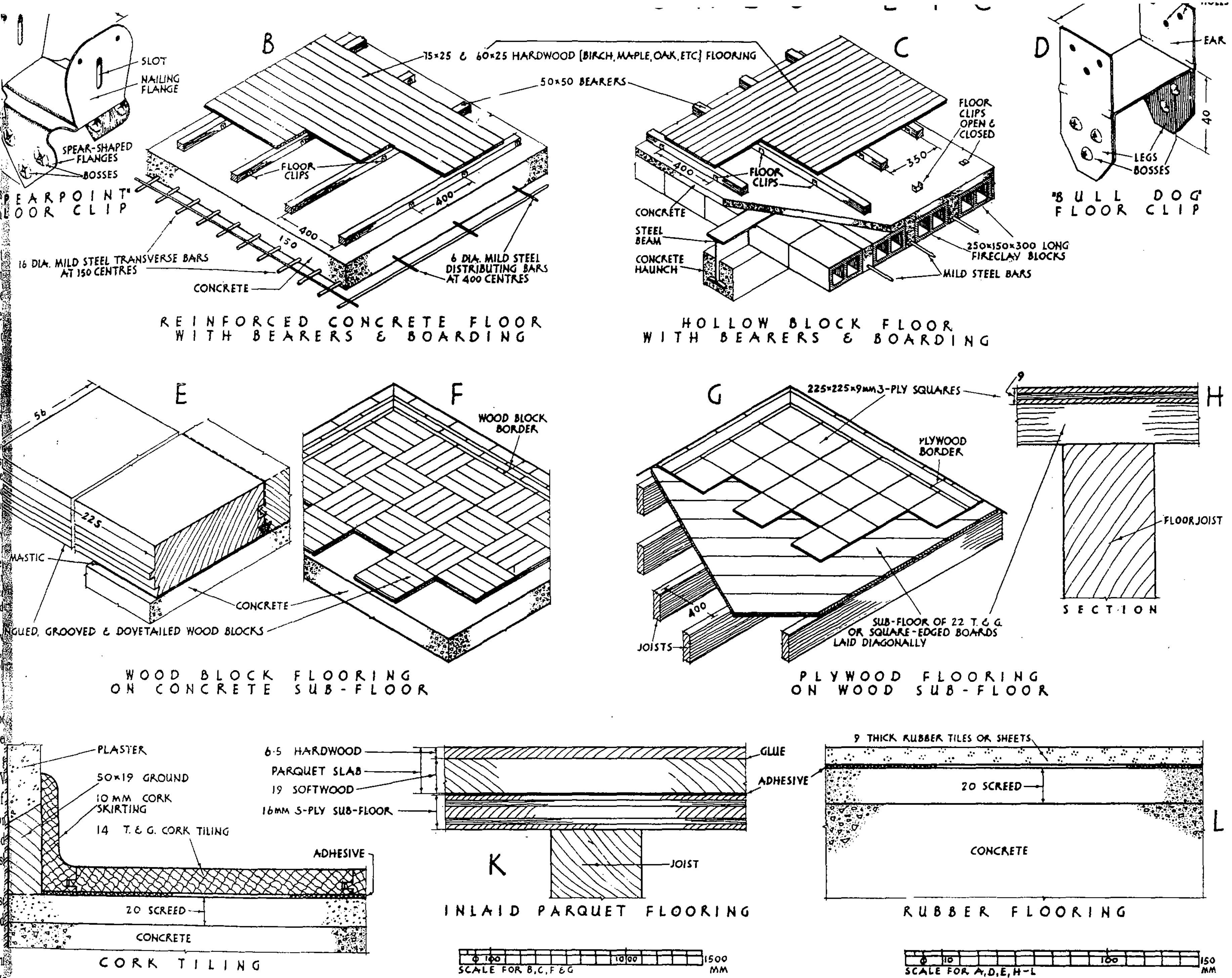


FIGURE 10

Fig. 10) and they are not raised until the floor is ready to receive the bearers; unimpeded use of the floor for walking, wheeling, etc. is thus permitted. Two nails are driven through the upper holes of each ear into the bearers. End joints between the bearers should coincide with the clips, and the lower hole in each ear is to allow an additional nail being driven through at the bearer end. An additional application is shown at E, Fig. 20, Vol. II.

A further development is the " acoustic " type of floor clip. This has a pad of rubber or other insulating material fixed on the cross-piece. The bearers thus rest upon the pads, and a reduction in the transmission of sound through the floor results.

2. *Wood Blocks.*—The following notes are supplementary to those in Chap. III, Vol. I. The tongued, grooved and dovetailed wood block shown here at E, Fig. 10, is a type which is much favoured, as the dovetail provides a good key for the hot mastic or resin adhesive, and the interlock provided by the tongue and groove prevents the loosening of blocks and the development of an uneven surface. The ends are sometimes tongued and grooved. The sketch at F shows the blocks laid to the basket-weave pattern on a concrete sub-floor, the surface of which must be truly level; another common design is the herringbone. The blocks forming the borders are arranged in a variety of designs; blocks which are stained a different colour to that of the general flooring may be used for borders, or a contrast may be afforded by the use of one or more rows of blocks of different timbers. The border blocks are usually mitred at the corners as shown.

The blocks should be quartered (rift-sawn or edge-grained) to ensure the maximum resistance to wearing action and the minimum expansion and contraction. They should be carefully kiln-dried to the required moisture content (see p. 7), and it is very essential that the building in which they are to be fixed is as dry as possible if good results are to be obtained. Hence the fixing of the blocks in a new building should be deferred until any abnormal moisture in the structure and atmosphere has been removed. Further, the mastic will not adhere to concrete which has not dried out.

One test for determining the dryness of a concrete sub-floor is as follows: Approximately $0{\cdot}1\ m^2$ of the floor is covered with crystals of calcium chloride. A sheet of glass is placed over them and its edges are sealed with putty. If the crystals are unaffected after three days, the laying of the floor can be proceeded with; otherwise this should be delayed as the dissolving of the crystals indicates the presence of moisture in the concrete. Alternatively a moisture meter can be used.

Wood block flooring is sometimes laid on a cheap wood sub-floor. The surface of the latter is generously covered with the adhesive, a portion at a time; each block is then tapped into position and further secured with panel pins which are subsequently punched below the surface, and the small holes stopped with special putty or wood mastic, coloured to conform to that of the wood. The surface is finally planed (large surfaces being usually dressed with an electrically driven portable machine planer), scraped, sand-papered, waxed and polished.

3. *Plywood* (see G and H, Fig. 10).—This is a cheap covering of good a
ance, consisting of squares and narrow strips (for borders) cut from bo
3-ply (see pp. 117–121). The stock sizes of the squares are 230, 300, 4
900 mm and from 5 to 10 mm thick; the thicker the surface veneer the
Oak, birch, walnut, maple and ash plywoods are suitable for this purpose.
plywood can be obtained with the top veneer stained as required for
thickness. The squares are usually laid with the grain alternating or w
contrasting colours can be effectively employed.

The covering is laid on a sub-floor of boarding as shown, or this may
of sheets of 16 or 19 mm softwood plywood (such as Oregon pine), a co
size being 1220 mm wide and 2135 or 2440 mm long, depending upon the s
of the joists (see sub-floor at K). The plywood should be resin bonded
119) for ground floor sub-floors as a precaution against effects from dam
the sheets should be well nailed at the edges and at about 300 mm alon
joist. The square and strip covering should be well glued and panel pin
the centre and at about 100 mm intervals round the edges, although the a
is sometimes omitted; the pins are punched and the holes stopped as de
above. The surface should be well wax polished before use and this
be maintained as a protection to the relatively thin top veneer.

This is rather a noisy covering; the " drumming " can be minim
strips of felt or similar insulating material are laid on the joists before t
floor is fixed.

Existing boarded floors which have defective surfaces can be readily re
by covering them with plywood squares. If badly worn, the existing
should be machine planed or levelled up with mastic before the new c
is fixed. This covering is cheaper than a good carpet or linoleum (see

4. *Parquet or Parquetry.*—There are two kinds, *i.e.*, (*a*) ordinary
inlaid.

(a) *Ordinary Parquetry* consists of thin, small pieces of richly de
hardwood (chiefly oak and teak) which are glued and panel pinned to a so
or plywood sub-floor, the pins being punched and the holes stopped as de
above. The thicknesses are 6·5, 9·5 and 12·5 mm, the former used in mo
and the latter when likely to be subjected to heavy traffic. The pie
square-edged and arranged according to pattern; sometimes timbers of
colours are made to conform to elaborate designs.

It is advisable to introduce a layer of (5 mm) plywood between the so
boarded sub-floor and the parquetry. The plywood boards are nailed
sub-floor, the joints between them are filled with wood mastic or putty,
off and sand-papered, and the parquetry is then fixed. The object of thi
mediate layer is to afford a perfectly level surface for the thin coveri
prevent any movement (expansion and shrinkage) and cupping of the s
boards being transmitted to the parquetry. Of course, this intermediate
not required if the sub-floor is formed of the thicker plywood boards
to above and if the joints between the latter are sealed.

(b) *Inlaid or Plated Parquet* (see K, Fig. 10) is considered to be the best form of this class of covering and consists of a surface veneer of richly figured and coloured hardwood which is is glued under great pressure to a softwood backing. The veneer varies from 5 to 9·5 mm in thickness and the backing is either 19 or 20 mm thick. It is cut into slabs of various shapes and sizes, blocks 300 to 450 mm square being common. These are glued and pinned to the softwood boarded or plywood (see detail) sub-floor already described; the pins are punched and the holes stopped.

Parquet flooring is surfaced and polished as described on p. 40.

5. *Cork.*—This is attractive in appearance, durable if properly treated, non-slip even when highly polished, resilient, noiseless, dustless, and can be readily cleaned. It is obtained in the form of (*a*) tiles and (*b*) carpet.

(a) *Cork Tiles* are in squares of various sizes, stock sizes being 100, 150, 200, 225, 300, 450 and 600 mm; special border strips are made, and these are from 50 to 450 mm wide and 900 mm long. The thicknesses are 6, 8, 10 and 14 mm. The colours range from light brown to dark chocolate. The tiles may have tongued and grooved edges or they may be square-edged.

They are laid on both wood and concrete floors. If the former, the sub-floor may be either softwood boards or plywood—see above. The sub-floor must be free from surface irregularities, and it is usually covered with felt paper to prevent any movement in the timber affecting the tiles, which are fixed with a special bituminous mastic and nailed with panel pins at the corners. If, as shown at J, Fig. 10, a concrete floor is to be covered, the screed (composed of 1 part cement to 3 parts sand) must be perfectly level, dry and free from dust; a similar adhesive is used. Skirtings, of various sections and lengths, are made of this material; these are fixed to grounds (see J) and their vertical joints are usually made to coincide with those of the border strips or squares.

After laying, the tiles, if square-edged, are surfaced to a uniform level with a planing or sand-papering machine; tongued and grooved squares do not require this. They are then wax polished.

Manufacture.—These tiles are made from the bark of an evergreen species of oak tree which grows in Portugal, Spain, France and countries bordering the Mediterranean. The bark, which grows to a great thickness, is removed every eight or ten years, softened by boiling, scraped, ground, pressed (at 8 kg/mm^2) and heated. The heat (which influences the colour) is applied whilst the cork is being pressed and maintained until the resin in it is released and binds the particles together in a dense mass; it is then cut into tiles.

(b) *Cork Carpet* is made in two grades and several qualities and thicknesses. It differs from cork tiles in that the granules of cork when heated with linseed oil, etc., are compressed by rolling on to a backing of canvas, and it is obtainable in 1·8 m wide rolls which vary from 13 to 30 m long. The colour also varies according to the pigment added during the process. It is more absorbent than the tiles and is therefore not so easy to keep clean.

6. *Rubber* provides a durable, quiet, flexible, generally non-slip and dustless floor covering which is obtainable in a wide range of attractive colours. It is used for entrance halls, corridors, banks, cinemas, theatres, reading rooms, hospital wards, restaurants, etc.

There are two classes of rubber floor coverings, *i.e.*, (*a*) sheet and (*b*) tiles.

(a) *Sheet Rubber* is obtainable in rolls up to 30 m long, 1·8 m wide and 3, 5, 6 and 10 mm thick; a minimum thickness of 5 mm is recommended for good class work subjected to average traffic. It is divided into (i) ordinary, (ii) combination of ordinary and sponge rubber and (iii) inlaid. The ordinary sheet rubber is of the same material throughout. The second consists of a facing of ordinary sheet rubber backed with sponge rubber. The inlaid variety is of tiles of ordinary sheet rubber, cut to various shapes and of different colours, and arranged to conform to an extensive range of geometrical designs on a rubber backing to which they are vulcanized (see p. 42). The sheets are invisibly jointed.

(b) *Rubber Tiles* are either cut from ordinary sheet rubber or are moulded. They are more resistant to wear and less liable to coil than sheet rubber because of the extra pressure to which they are subjected in the process of manufacture. Tiles are also made having a moulded facing which is vulcanized to an asbestos-cement backing; skirtings of this material are also available.

Rubber may be laid on either a well seasoned wood or a concrete sub-floor.

A wood sub-floor must be adequately ventilated; otherwise dry rot may occur. Plywood (see p. 117) provides an excellent foundation. If boarded, any cupping of the boards or other irregularities must be removed by planing, otherwise they will cause excessive wearing of the rubber covering; for the same reason, nails must be punched and the holes stopped.

If the sub-floor is of concrete, as shown at L, Fig. 10, the level surface of the screed should be given a rough textured finish by the application of the wood float; this gives a good key for the adhesive. The surface *must* be free from dust, and the concrete *must* be thoroughly dry. Most specialist firms give a guarantee for their work, but this will not be forthcoming unless these conditions are observed.

The rubber is secured to either type of sub-floor by a special adhesive of rubber solution or a moisture-resisting compound.

Manufacture.—Rubber is obtained from the latex (a white to cream coloured juice) tapped from certain trees grown in Malaya, Java, Sumatra, Ceylon, Borneo, Brazil and elsewhere. The latex is present in the cells between the bark and cambium of the tree. It is extracted by tapping, *i.e.*, narrow inclined channels leading to a vertical channel or cut are gouged in the bark. The released latex flows down these into a cup fixed near to the ground. The contents of the cups are collected and taken to the factory, where it is strained through sieves to remove any dirt and then coagulated by the addition of acetic acid. It is then passed through washing rollers to free it from impurities, after which the sheets are hung up to dry, smoked over wood fires and finally packed into chests ready for export.

Whilst this crude rubber is the basic constituent of rubber flooring, other ingredients, *i.e.*, fillers (which have a toughening effect in addition to cheapening the process), pigments (to influence the colour), sulphur (necessary for the hot vulcanizing process), etc., are necessary. The crude rubber is reduced to a plastic condition by passing it repeatedly between heated rollers. It is then taken to the mixer where the various ingredients are gradually worked in and thoroughly incorporated by the rollers and passed between a second set of rollers from which it emerges in a thin sheet. The sheets are now vulcanized, *i.e.*, heated in the absence of air, and pressed. This takes place in a press consisting of several steam heated platens (hollow plates) between which the sheets are placed. The temperature of the plates varies from 100° to 150° C., and the duration of heating varies from a few minutes to three hours, depending upon the degree of hardness required and the composition of the rubber. Rubber tiles are vulcanized in enclosed steel moulds.

7. *Thermoplastic Tiles.*—There are two kinds of these depending on the type of binder used; they both contain a binder, pigments, asbestos fibre and mineral fillers. The black, dark brown and red coloured tiles use an asphalt binder; lighter coloured tiles such as yellow, blue and green have a binder of plasticised resin and are often "marbled" with contrasting colours.

Manufacture.—The constituents are heated, mixed together, passed through callenders to give the required thickness and consolidation and then cut into tiles.

The tiles are made in varying sizes starting from 225 mm square, usual thicknesses are 2·5 and 3·2 mm. Before laying they are warmed and then stuck down with a bitumen based adhesive. The nature of the adhesive inhibits rising damp and this type of floor finish has been used on old concrete floors which do not have a d.p.c.; on new floors, however, a proper d.p.c. membrane is advocated. The subfloor surface should be smooth, level and dry.

Thermoplastic tiles are suitable for domestic purposes, they are laid on concrete or timber floors; they have a fair degree of resistance to grease and mild acid and alkali attack.

8. *Vinyl Asbestos Tiles.*—These contain asbestos fibres bonded with polyvinyl chloride (p.v.c.) in the ratio of 25 to 30 per cent. The manufacture is similar to (7) above. The tiles are more resilient than the thermoplastic type and usually do not need to be heated before laying. Sizes are 230 or 300 mm square and thicknesses are 1·6, 2, 2·5 or 3·2 mm, they are made in a wide range of colours and have a good resistance to grease, mild acids and alkalies. The type of adhesive and subfloor conditions are as for (7) above.

9. *Vinyl Sheet and Tiles.*—These are similar to (8) but have a higher p.v.c. content of 30 to 60 per cent. and for this reason are often referred to as p.v.c. flooring. They also incorporate fillers and plasticiser pigments giving a "flashed" effect. Available in two types, one being homogeneous where the colour effect goes right through the thickness; the other has the "flashing" printed on with vinyl ink which is covered with a transparent layer of vinyl. The latter type is suitable only for domestic purposes. The sheet length is up to 25 m with widths of 0·9 to 2 m, thicknesses are 1·6, 2 and 2·5 mm. Vinyl tiles are made in the same thicknesses 230, 300 and 450 mm square.

The sheet can be supplied in two forms: *unbacked* as described or *backed* in which case the vinyl has a built-in backing of felt, fabric, cork, or plastic foam to improve resilience and sound deadening qualities. These materials are concrete or timber floors.

10. *Synthetic Resins.*—These have been in use only since 1955 and c three types: *epoxy*, *polyester*, and *urethane*. They are made by ac measuring and mixing together a resin and a curing agent. This li poured onto the subfloor and because it can cover large areas and need small amount of trowelling to provide a true level finish the resin flo sometimes referred to as *plastic seamless* or *self-levelling*. Thickness from 2 to 5 mm, 3 mm being common. They are expensive and so th is restricted to high duty floors or where high standards of hygiene are den Resin floors provide a very hard finish (more so than granolithic, see flexible, resistant to chemical attack and have a high gloss finish which easy to keep clean. They can be applied over concrete, timber and met to which they are strongly adhesive. The sub-floor must be clean applied over concrete a screed is not required because of the self-l characteristic but it should be treated with an abrasive disc to remove and expose the aggregate. A resin floor can be made non-skid by a bauxite or other hard mineral to the surface before it has set. The fini between 8 and 72 hours after application when they are ready for immed they are often used to repair worn patches in concrete floors and because ability to withstand hard wear are widely adopted in industrial premises are used on concrete floors.

10 (a) *Epoxy.*—This resin material has the longest history of use and expensive than the following two types. It is light in colour and can be fi bauxite or ceramic chips. Adequate ventilation is needed during ap because of the acrid fumes produced. Provided an existing concrete flo excessively damp, because of the absence of a d.p.c. membrane benea slab can be covered with an epoxy resin finish to provide an effective b rising damp. Epoxies are more resistant to alkali than acid attack. floor can be filled with bauxite or fused ceramic chips.

10 (b) *Polyester.*—This is cheaper than epoxy, light in colour bu pigmented to give varying colours. Some manufacturers combine cement with the resin to act as a binder and filler. Epoxy finishes can be over damp substrates and the material is also used for bonding concr together and for grouting purposes, *e.g.*, the grouting of rag bolts for

10 (c) *Polyurethane.*—This type of resin floor is more resilient and than the other two; it offers good resistance against acid and alkali att can be filled like an epoxy floor, alternatively vinyl chips or flakes can be fillers. The flakes are scattered over a first coat of resin, further c poured on as required to give sufficient thickness and resistance to wear

11. *Pitch Mastic.*—This is one of the cheapest floor finishes pro jointless floor whilst at the same time providing an effective d.p.c. bar comprises coal tar pitch with limestone and sand aggregates laid hot; are black and brown; thicknesses are 16 or 19 mm. It is used on concre

12. *Mastic Asphalt.*—This is made from bituminous materials such as natural rock asphalt and lake asphalt; it can be laid hot as a jointless finish (12 to 25 mm thick) or in the form of tiles (16 to 50 mm thick) laid in cement mortar. Colours are black, dark red and brown.

13. *Cement and Rubber Latex (Fleximer).*—This is another jointless finish, the usual thickness is 6 mm. It has a latex or resin binder, a cement setting agent and an aggregate such as marble or granite chippings, cork or wood; obtainable in various colours. They are used on concrete floors.

14. *Magnesium Oxychloride.*—Known also as magnesite, this is a jointless floor consisting of powdered magnesium oxide and liquid magnesium chloride which are mixed with aggregates such as sawdust or asbestos; sand may also be added to increase the resistance to wear. It can be laid as a one-coat work 16 to 20 mm thick, or, preferably, as two-coat work (each coat being 12 mm thick). It can be applied to concrete or wood floors but it must be protected from rising damp and is unsuitable for floors which get wet. Metal surfaces in contact with it must be protected by a bituminous coating; the usual colour is red.

15. *Clay Tiles.*—Known also as quarry tiles, 100 to 300 mm square, 19 mm thick for the smaller sizes and up to 38 mm thick for the larger ones; they are made in a similar way to clay bricks; colours vary from buff to blue. They are laid on a concrete floor levelled with a 1 : 3 cement and sand screed; after the latter has partially set the tiles are bedded on a 6 mm thick 1 : 1 cement and sand bedding, the joints being filled with the same material. Quarry tiles produce a hard, hygienic surface.

16. *Granolithic Screed.*—Commonly known as " Grano topping " this is an improvement on the ordinary cement and sand screed. It is relatively cheap; a usual mix consists of 2 parts cement: 5 parts of 6 mm down fine granite chippings (not more than 20 per cent. of which should pass a No. 76 B.S. sieve). Thicknesses vary from 25 to 40 mm. It is important with all floor screeds to ensure a good key between the base concrete and the topping. The best way of achieving this is to lay the topping within three hours of completion of the base; in this case the usual thickness is 18 to 20 mm and the maximum bay area is 28 m².

If the topping cannot be laid immediately after the sub-floor then special precautions must be taken to ensure good adhesion between the two. These include a minimum topping thickness of 40 mm, thorough sweeping and cleaning of the base floor which should be left rough (6 mm dia. steel rods projecting 50 mm can be cast in the sub-floor at 450 mm centres, these are turned down after the base has set to give a good key to the topping). The importance of a good bond cannot be overstressed and this is further helped if, after wetting, the base floor is brushed with cement grout prior to screeding.

The topping should be laid in alternate bays to minimize shrinkage effect. Large areas should be divided into areas not exceeding 13 m² which may have separating metal strips of a depth equal to the screed thickness. Adequate curing of the surface must be given by covering with wet sand or sawdust or plastic sheeting for a period of seven days after laying. Excessive trowelling leads to crazing and dusting of the surface but careful trowelling two to three hours after laying ensures a smooth polished surface. Dusting of the surface can be avoided by including a proprietary liquid in the mixing water or by brushing the hardened surface with a silicate of soda solution.

17. *Terrazzo.*—This is similar to (16) but special coloured marble aggregates are used with white or coloured cements. The material is laid on screed floor to a thickness of about 19 mm in panels not larger than 900 mm square separated by brass, copper or ebonite strips. The hardened surface can be dressed smooth with polishing machines. Terrazzo tiles are also made, a common size being 300 mm by 300 mm by 25 mm. The material is hard and durable being easily kept clean.

18. *Linoleum.*—This can be applied to any backing but if placed on concrete this should have a d.p.c. membrane. It is made in small tiles or rolls; the latter being 1·8 m wide, 9 m long and thicknesses of 2, 3·2, 4·5, 6 and 6·7 mm; the constituents are mineral and cork fillers, and pigments with a linseed oil binder laid on jute canvas. There are innumerable colours; " lino " gives a good, hard-wearing surface at a reasonable cost. Fixing is by small sprigs, tacks or adhesive.

19. *Composition Blocks.*—These are made of compressed cement, wood, calcium carbonate, etc., linseed oil and pigment. They resemble wood blocks and are laid on a cement and sand screed. Typical sizes are 150 mm by 50 mm by 16 mm and there are several proprietary kinds.

20. *Marble tiles.*—Made of marble slabs in squares up to 450 mm side and 19 mm thick; they are laid on a cement and sand screed.

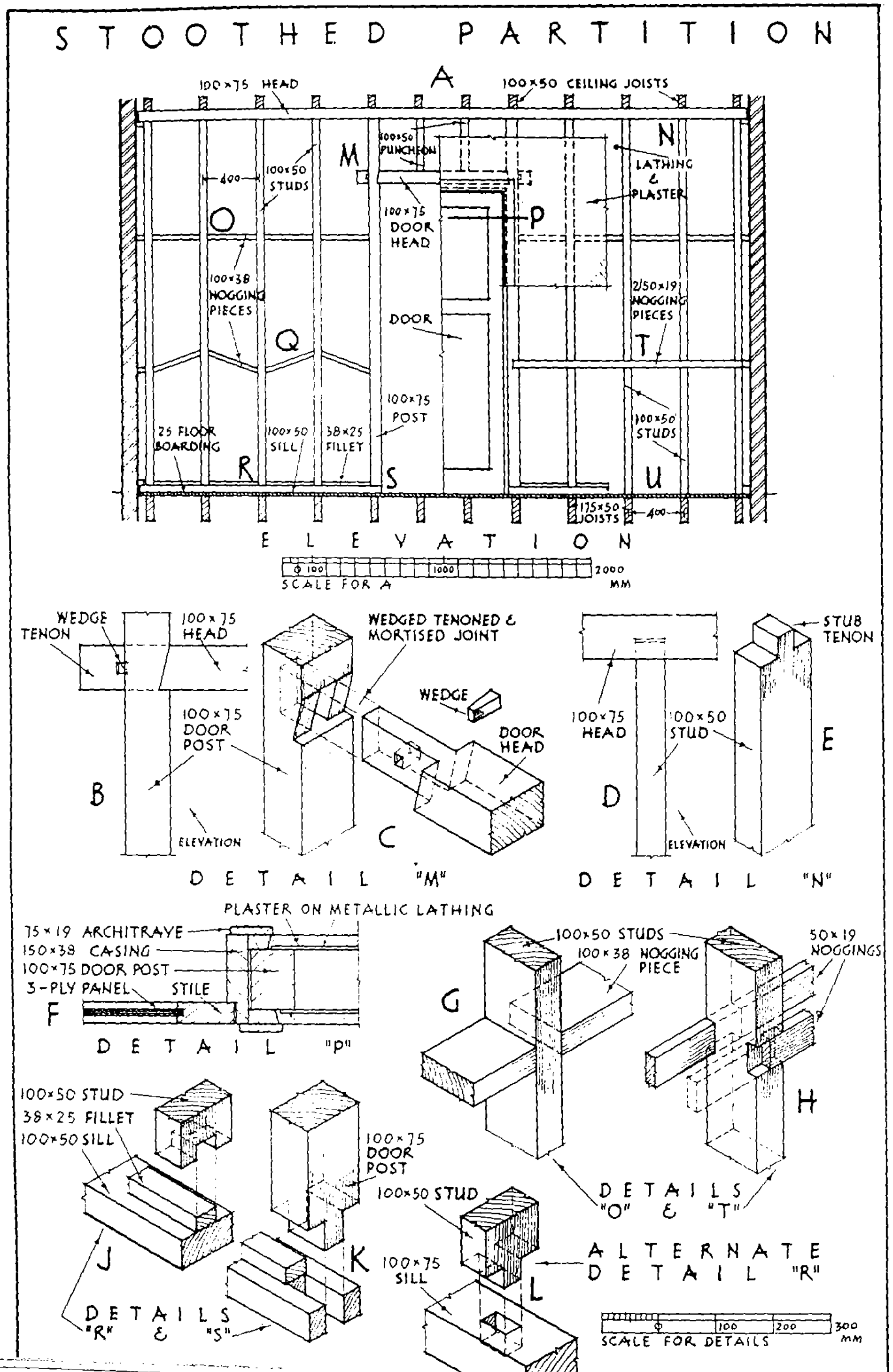
21. *Quartzite.*—This is a natural stone harder than granite in gold, silver grey and olive colours; it is made into squares of 150 to 225 mm side and 16 mm thick which are bedded on to a screed. It forms an extremely attractive surface which is non-slip when wet or dry.

Carpet.—There is a tendency towards an increased use of the ordinary woven fabric carpet as a covering material in preference to hard and noisy floor coverings. This applies to both domestic and public buildings. A comparatively cheap softwood boarded floor, together with an underlay of felt, is all that is necessary if a fitted carpet is used.

PARTITIONS

Partitions are walls, usually relatively thin and of light construction, which are used to divide buildings into rooms, corridors and cubicles. Whilst their essential purpose is to serve as divisions, partitions may also be utilized to support the joists of floors, purlins and ceiling joists of roofs, etc., and as such are load-bearing structures. Soundproofed partitions are described on pp. 54 to 56.

The many materials used in the construction of partitions include timber, plasterboard, clay and terra-cotta, concrete, sawdust concrete, aerated concrete, plaster, wood-wool cement, compressed straw, glass and metal.



PARTITIONS

1. **Timber Partitions**[1] are also known as *stoothings*, or *stoothed*, *stud* or *q* *partitions*. This type is illustrated in Fig. 11. It consists of vertical me called *studs* or *quarters*, which are secured to two horizontal lengths of t the upper being the *head* and the lower the *sill*. The sides may be covere plasterboard (see 2 below) which may or may not be plastered or covere expanded metal lath and plastered (see 3 below) or with boarding, pl sheets etc.

The studs, usually of 100 mm by 50 mm and or 75 mm by 50 mm are spaced at 350 to 400 mm centres for lathing and up to 600 mm cent boarding or panelling. Short lengths of studs, such as those above do called *puncheons*. The ends of the studs may be either stub-tenoned i head and sill (see E and L), or housed, or, as shown at J, slotted over 38 or by 25 mm fillets nailed to the head and sill. In cheap work the sill is som omitted and the studs are nailed direct to the floor (see U). The st stiffened by *nogging pieces* or *noggings* at vertical intervals of from 0·9 to These short pieces 100 or 75 mm by 50 or 38 mm, are generally fitted less horizontally and tightly between the studs, to which they are nail O and G), or inclined as shown at Q; alternatively, the noggings may co pairs of 50 by 19 mm continuous pieces let in flush with the faces of th (see T and H). The wall studs may be packed out from the walls as sho or securely plugged to the walls.

The width of the head and sill is the same as that of the studs and ferably 75 mm thick. The former is securely nailed to the ceiling (or floo and the sill is fixed to the floor. The head and sill are shown at right a the floor and ceiling joists. If the partition is to be fixed parallel to th it should be either placed immediately over a floor joist (or doubled j where this is not possible, on short 150 by 50 mm transverse bearers at about 300 mm centres between the pair of joists concerned; similar by 50 mm bearers between the joists of the ceiling or upper floor will se fixing for the head.

If provision has to be made for a door, as shown at A, the door posts be sufficiently rigid to resist the impact of the door and they should be co from floor to floor (or ceiling). Those at A are of 100 mm by 75 mm stu top of each post is tenoned to the head and the foot is usually slot ten shown at K. The wedged tenoned joint shown at A, B and C affords an connection between the door head and post. A detailed part plan of th shown at F. Sanitary fittings fitted to a studded partition will require built in at the requisite position for fixing purposes.

[1] Formerly, another type of timber partition, called a *trussed* or *framed parti* used. It may now be regarded as obsolete in this country. It was self-suppo capable of carrying one or more floors and ceilings. In its simplest form it co (1) two main horizontal members (a head and sill) with their ends bearing on the (2) two vertical posts (usually at one-third span points) connected to the head (3) two braces each inclined from the top of a post to the end of the sill, (4) about 400 mm centres) secured to the sill, braces and head, and (5) boarding or pl sides.

This class of partition is in common use being particularly suited for domestic conversion work. Because of its lightness, it is usefully employed when there is no supporting wall below.

Examples of studded partitions are shown in Figs. 15, 16 and 41.

2. **Plasterboard Partitions.**—As mentioned under 1 above plasterboard can be used to cover a stud partition, this covering material is the cheapest of all and provides a good lightweight solution. Plasterboard is manufactured to conform to BS 1230, it consists of aerated gypsum encased in paper.

Manufacture of Plasterboard.—The raw gypsum is finely ground, dried, calcined, conveyed to mixers where it is formed into a slurry after the required amount of water has been added, passed on to the bottom continuous layer of paper of the desired width to the rolling mill, evenly spread by rollers to the required thickness and over which the second paper is placed after the edges of the bottom paper have been turned up and to which the top paper is glued to form sealed edges. It emerges from the rollers in sandwich form, passes over a long roller conveyor during which time the plaster sets. It is then cut by an automatic knife to the required length, and the boards are finally fed into a drier from which they are packed into bundles.

There are four kinds of plasterboard produced by British Gypsum Ltd.: (a) Gypsum wallboard; (b) Gypsum lath; (c) Gypsum baseboard; (d) Gypsum Plank. All four types are available in the *plain grade* as described above and in an *insulating grade* which has a veneer of polished aluminium on one side. The latter type acts as a thermal insulator when applied against a cavity because the aluminium reflects heat back into the room.

There are three types of edge treatment to plasterboard according to the type of board: (i) tapered-edge as shown at H, Fig. 13 for flush seamless jointing; (ii) square-edged for use with a cover strip joint; and (iii) bevelled-edge for featured V-jointing where the 45° bevel is about half the thickness of the board.

(i) *Tapered-edge wallboard joint.*—This joint is made by applying a thin band of a special joint filler into the trough of the tapered edge, into this is pressed a length of 45 mm wide joint tape to be followed by a further application of filler to make a flush joint. When the joint has hardened a band about 225 mm wide of special joint finish is applied and feathered out at the edges by using a jointing sponge. Once the joint has set the whole surface of the board is sponged with a thin slurry of the joint finish so as to match the joint area with the rest of the plasterboard. This treatment gives a smooth flush finish.

(ii) *Square-edged wallboard joint.*—Cover strips of three kinds are used over the edges for this type of joint: Firstly, plain or embossed paper about 50 mm wide glued over the joint. Secondly, paper-faced cotton tape glued over the edges. Thirdly, a more pronounced panel effect is obtained by nailing or adhering thin strips of wood, metal or plastic onto the joints.

(iii) *Bevelled-edge wallboard joint.*—The V-groove formed by adjacent paper bound edges of the boards has a *small* amount of joint filler applied at its base in just sufficient quantity to bridge the joint. The pronounced groove remaining serves as a feature to make a panel effect.

Cut edges of the plasterboard should be placed so that there is a 3 mm gap between adjacent boards; this is filled with joint filler and paper tape applied. Joints should not be placed above door or window jambs or below window jambs.

(a) *Gypsum Wallboard.*—This material is ideally suited for direct decoration because the paper covering to one surface is smooth and ivory coloured.

Gypsum wallboard is made in 9·5 and 12·7 mm thicknesses in several sizes, the most common being 2 438 mm by 1 200 mm, 1 829 mm by 900 mm, and 1 219 mm by 914 mm.

The plasterboard is fixed vertically so that the paper covered joint centres over a stud at least 50 mm wide with the grey or foil surface at the back. All four edges of the board must be supported by timber. It is secured by 2 mm thick nails 32 mm long for 9·5 mm board and 38 mm long for the thicker board placed 150 mm apart and about 12 mm from the board edge. The nails have a small flat head with a smooth shank, they should be driven without puncturing the paper very slightly below the surface so that the decorator can apply filling to conceal the nail head. For partition work the recommended stud centres are 400 mm for 9·5 mm plasterboard and 610 mm for the thicker type; if applied to ceilings these centres are reduced to 450 mm in the case of the thicker board.

The external angles of plasterboard should be protected either by using the special perforated galvanised steel angle bead which is pressed into bands of joint filler spread down both faces of the corner. Or by using a strong paper tape to which is bonded two galvanised steel strips; when creased between the steel strips it will bend over the corner and adhere to bands of joint filler.

Because of the smooth ivory-coloured surface gypsum wallboard is intended for direct decoration and not for plastering; it forms a good base for two coats of plastic paint over a special sealing primer.

(b) *Gypsum Lath.*—This is a narrow-width plasterboard, cheaper than Wallboard and intended as an ideal base to gypsum plaster. It is constructed like Wallboard but with grey paper covering and characterised by the rounded longitudinal edges. It is made in 9·5 and 12·7 mm thicknesses, 406 mm wide by 1 200, 1 219, and 1 372 mm lengths.

For partitions the lath is laid with the long edges horizontal, these edges only need support at floor and ceiling edges. The short vertical joints should be staggered and coincide with a stud. Stud centres are 400 mm for 9·5 mm lath and 610 mm for 12·7 mm; the galvanised fixing nails are 2·6 mm thick, 38 mm long and resemble those described above. The joints do not require a scrim reinforcement except at ceiling and wall angles.

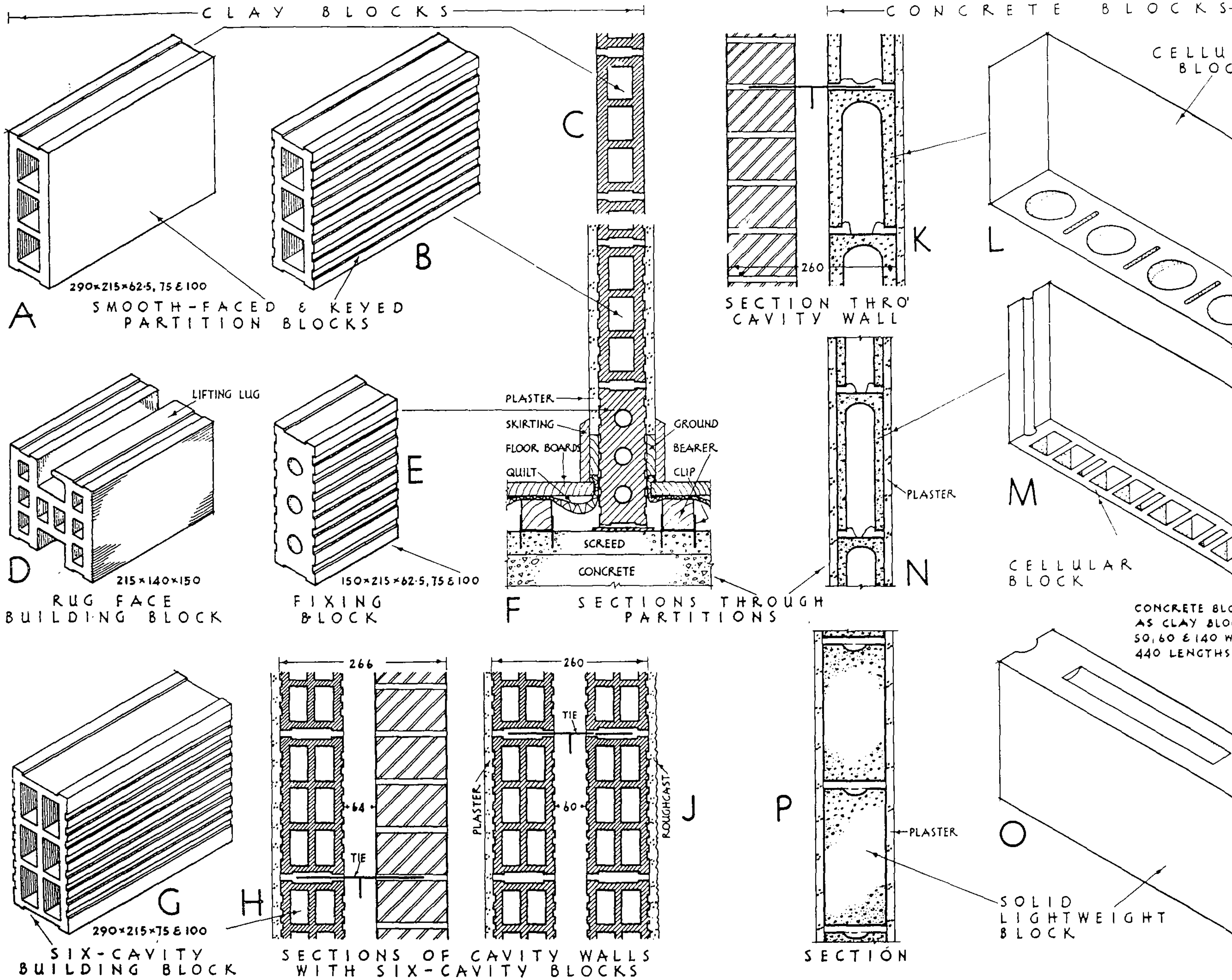
Plastering is in two-coat work (total 9·5 mm thick) using Carlite or Thistle[1] plaster, or in one coat Thistle board finish plaster[1] (5 mm thick); the joints are filled first and allowed to set but not dry out before general plastering starts. A good finish can only be obtained with single coat work if the studs are well aligned.

(c) *Gypsum Baseboard.*—Designed for a plaster finish this is made in relatively small sheet sizes (9·5 mm thick), it is a square-edged plasterboard and all joints must be scrimmed with 90 mm wide jute scrim. The sheet width is 914 mm, with lengths of 1 200, 1 219, and 1 372 mm; maximum spacing of studs is 450 mm; nails are as for the gypsum lath.

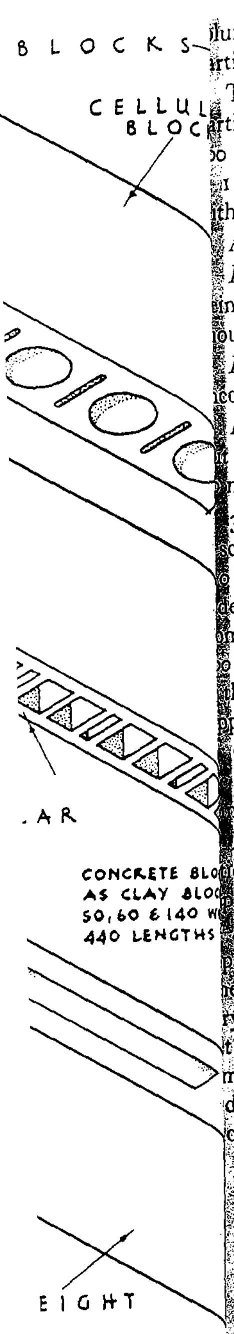
(d) *Gypsum Plank.*—This is a 19 mm thick plasterboard of two types, one for plastering and one which has one ivory surface for direct decoration. The former has square edges and the latter can have any of the edge types described above. It is used in several ways: as a dry lining to framed construction giving a higher standard of fire protection than the types previously mentioned, for

[1] Manufactured by British Gypsum Ltd.

P A R T I T I O N S



MANUFACTURERS OF BLOCKS A, B, D, E & G: LONDON BRICK CO. LTD.



lumn and beam encasement and in the construction of Gyproc laminated rtitions (see 7 below).

The plank is 600 mm wide and 2 350, 2 400, 2 700, and 3 000 mm long. rtition studs should be at centres not exceeding 760 mm and ceiling joists at o mm centres. Special nails are used which are 58 mm long, they are spaced 150 mm centres. This gypsum plank is laid horizontally across the studs h the ends placed at stud centres, support is not required at the long edges.

Additional applications of plasterboard are given on pp. 49–50.

Handling of Plasterboard.—The sheets are packaged in pairs, ivory surfaces ing together; the shorter cut edges are bound with removable tape. Sheets uld be carried in pairs on edge but stacked flat on a level surface.

Fire Resistance of Plasterboard.—The surface of plasterboard does not ourage the spread of flame and in this respect it is classified as Class O.

A studded partition with 9·5 mm plasterboard both sides and unplastered with the joints filled has a fire resistance grading of ½ hour; the same but with mm plaster achieves 1 hour.

3. **Expanded Metal and Plaster Partitions.**—Expanded metal (XPM) is cribed in Chap. 2, Vol. II. It is made in various sheet sizes, 2 750 mm by mm being common, the mesh size is small being about 20 mm by 10 mm in er to contain the applied plaster finish; the thickness of the steel sheet varies n 0·12 mm to 0·5 mm, according to the stud spacing which should be from to 600 mm; it is marketed in a galvanised or asphalt painted form. Fixing he studs is by galvanised clout nails or staples; joints in the lathing should be ped 75 mm.

Once the studs have been placed and the expanded metal applied to them plastering should be done in three coats to an overall thickness of 16 mm g a gypsum plaster specially made for the purpose.

XPM can be used on its own to form open partitions in industrial applions; for this purpose either galvanised steel or aluminium alloy sheet is ropriate.

4. **Plaster Slab Partitions.**—These are made of calcium sulphate (burnt sum or plaster of Paris). This is mixed with water, and sand may be added. e slabs are made by casting the material in wood or metal moulds. They set y quickly; one form is shown at D, Fig. 14. Whilst many slabs are cast witht tongues and grooves, the rigidity of partitions is increased if such provision made. The vertical edges are also sometimes tongued and grooved. In order decrease their weight, many of the thicker slabs are cellular and resemble that own at C; sawdust is also sometimes added to reduce their density.

There is a big range of sizes, but those specified at D are common. The slabs are bedded and jointed in lime mortar; hair (1 kg of hair to 0·2 m³ of lime) and plaster of Paris (usually 10 per cent.) may be added. Those cast in metal moulds are smooth faced and are not subsequently covered with plaster. When the partitions are to be plastered, the plaster slabs are cast with keyed or rough surfaces and only one coat of plaster is normally required. The slabs can be readily sawn.

5. **Clay and Terra-cotta Brick and Block Partitions.**—The commonest type of clay partition is, of course, the ordinary solid brick wall of 102·5 mm (or 65 mm if laid on edge) or more in thickness. Whilst such walls are relatively strong and fire-resisting, their weight precludes their use for partitions on upper floors unless provision in the form of girders or lower walls is made for their support. Hence clay blocks, which are comparatively light and yet are sufficiently strong for the construction of non-load bearing partitions are made; they conform to B.S. 3921. Lightness is obtained either by making them hollow and/or by using diatomaceous earth which produces units having a very porous structure.

The following table gives the usual range of sizes in which clay blocks are made; the length and height figures given in the " format " column include the 10 mm for a mortar joint.

Format	Actual Dimensions (mm) Length	Width	Height
300 × 62·5 × 225	290	62·5	215
300 × 75 × 225	290	75	215
300 × 100 × 225	290	100	215

To facilitate bonding half blocks, 140 mm long for all the above sizes and three-quarter blocks in the 75 and 100 mm widths are also available.

The length or height of a non-loadbearing wall made of these blocks should not exceed 3 m for 62·5 wide blocks, 3·65 m for 75 mm widths, and 6 m for 100 mm widths. For longer or higher walls brick columns must be introduced to split the wall into panels. Note that the height of one block corresponds to the height or thickness of three bricks plus two joints [$(3 \times 65)+(2 \times 10)=215$ mm] thus bonding in with brickwork is an easy matter, see H, Fig. 12.

In general, the blocks are built in either cement mortar or compo and are bonded in the usual way with staggered vertical joints.

The following are the merits of these blocks: Satisfactory mechanical strength, lightness in weight, good heat insulation, fireproof, non-shrinkable and vermin proof. Those made of diatomaceous earth can be sawn to required size and shape and provide a firm hold for nails and screws.

Several examples of hollow clay blocks are shown in Fig. 12. The smooth-faced block at A, is shown in section at C, the faces being decorated as required. The keyed block at B is illustrated in the partition at F, the 3 mm (approximate) deep sinkings forming a good key for the plaster. The rug face block at D is used for both internal and external walls and can be obtained keyed on the internal face for plastering; it can be readily handled by use of the lifting lug; reinforcement can be accommodated in the bottom indentation if the blocks are used to form lintels. The six-cavity loadbearing block at G is shown applied at H as an inner leaf of a cavity wall; these blocks are also shown forming both leaves of the cavity wall at J, the external face being roughcasted and the inner

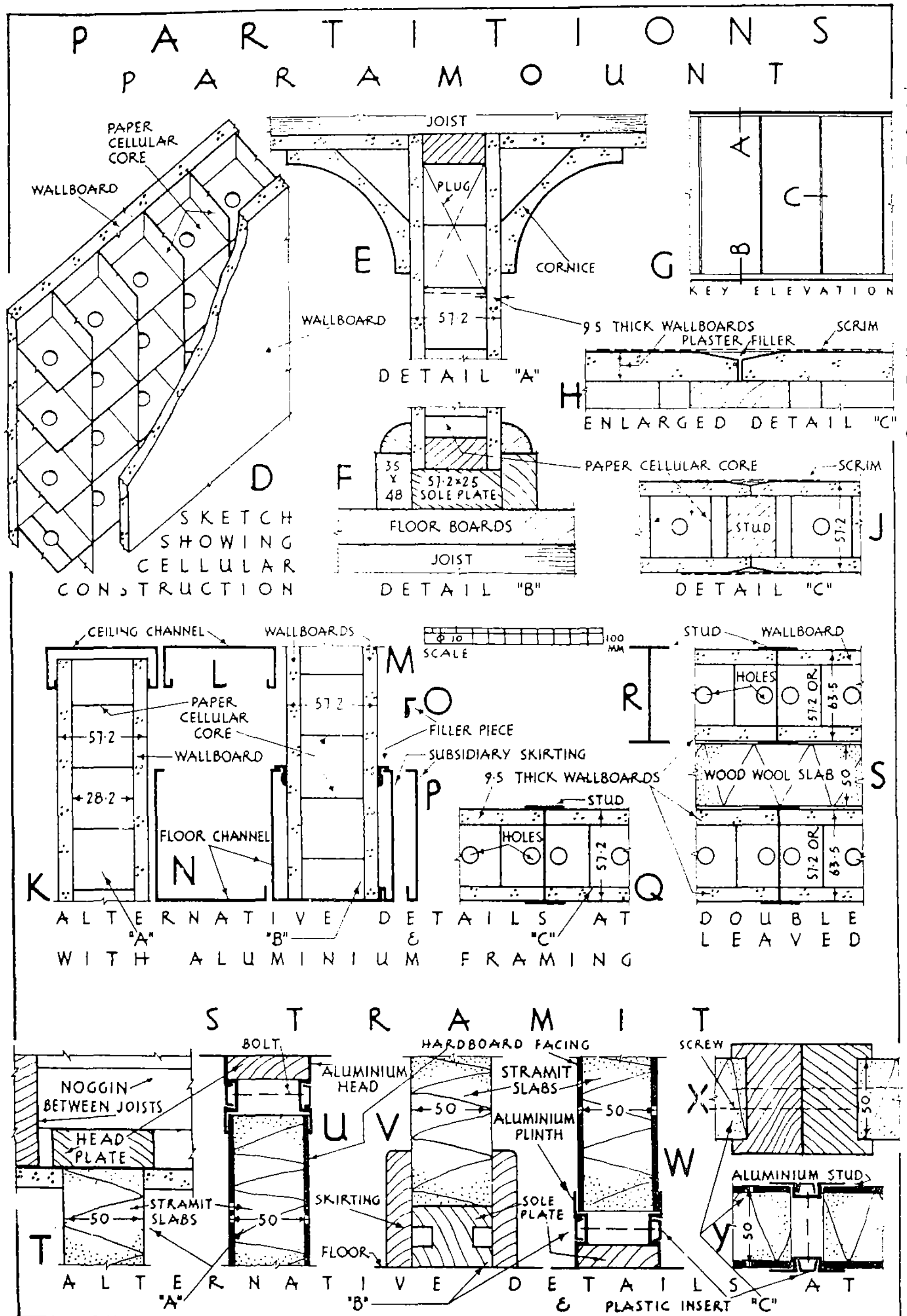


FIGURE 13

plastered. Fixings to these partitions can be by wood fillets set into
joints or by special fastenings which bolt to the thin skin of the block.
can be driven directly into the blocks E and so eliminate plugging, whi
damage the blocks—see below; they are built in to provide fixings for sk
(see F), door casings, fittings, etc.

Another example of a hollow block is shown at A, Fig. 14. The tong
grooves on the beds assist in making the joints rigid and facilitate e
The grooved faces of block B afford a good key for the plaster. Some bl
made without keyed faces, and these may be glazed on one or both si
variety of colours for use as partitions in lavatories, etc.

Special clay blocks include *conduit blocks* having a vertical groove on
side face (to receive an electric cable, water pipe, etc.) and corner
(L-shaped on plan to permit of sound bonding at corners and intersecti

Holing for plugging, etc. should be drilled and not formed with the
otherwise damage may be caused to the blocks.

6. Precast Concrete Block Partitions.—These are made to B.S.
1364, Precast Concrete Blocks which refers to three types of precast c
blocks all of which may be solid, hollow or cellular and includes aerated c
blocks.

Type A.—For general building use including below d.p.c. level.

Type B.—For general building use including below d.p.c. level in
walls, the inner leaf of external cavity walls and external walls protected by

Type C.—Mainly for internal non-loadbearing walls (*i.e.*, partitions).

The block density (weight of block ÷ overall volume, including cav
type A blocks must not be less than 1500 kg m^3; type B and C blocks
block density less than this value. The definition of a *solid block* is on
the solid material is not less than 75 per cent. of the total volume. A
block has one or more holes passing through the block and the solid ma
between 50 and 75 per cent. of the total volume. A *cellular block* has th
amount of solid material but the holes do not pass through it. An
concrete block is a high-pressure steam cured (autoclaved) one where the
structure is formed by the generation of gas within the mix (see below).

The blocks are composed of a binder which is usually cement, althou
is also used, and one of the following aggregates: natural stone, crushe
foamed or air-cooled blastfurnace slag, pulverised fuel ash (a waste produ
power stations), and various lightweight aggregates like wood particles, ex
perlite, exfoliated vermiculite, expanded slate, pumice, etc.

Sizes.—Blocks are made in the same size as given above for clay bloc
50, 60 and 140 mm widths and 440 mm lengths. A very common fac
440 mm long by 215 high with 50, 60, 75, 90, 100, and 140 mm wid
addition some blocks of the same face dimensions are made in 190, 2
and 305 mm widths. The same range but with a face-size of 440 mm
140 mm high (*i.e.*, two courses of brick in height) is also available. Som
made of the less dense aggregates have a face of 440 mm long by 290 m

Several of the lightweight blocks can be cut easily with a saw and joinery can ailed direct to them.
The face of the block may be smooth or textured.
Examples of hollow blocks are given in Fig. 12 at K to P; and at B, C and M, 14. The latter can be used for farm or inexpensive storage buildings. e blocks have a groove in both vertical edges or bed joints; others are tongued grooved as shown; these features are particularly valuable for the thinner ks in giving greater stability to the wall.
Mortar for jointing concrete blocks varies according to the type and it is ortant to follow the manufacturers instructions in this and other respects. lly a 1 : 2 : 9, cement-lime-sand, mix is adopted or a 1 : 6 cement-sand in which a plasticizer is incorporated.
The dimensions of non-loadbearing concrete block walls should be like those lay blocks given above.

anufacture of Aerated Concrete Blocks.—One way of producing *aerated concrete* or *d concrete* is to add aluminium powder to a cement mortar slurry, this produces gen, accompanying expansion and cell formation. A similar result is achieved if a liquid substance is used as a foaming agent and stirred briskly with a cement mortar

ixing of all Types of Blocks.—Special precautions should be taken to e sound fixing at doors, windows and walls. Two door details are shown nd F, Fig. 14, and two wall details are given at G and H. Detail E shows the frame rebated to receive the end of the partition consisting of slabs with e vertical edges, such as those at A, C and D. If the slabs are like B, a small fillet may be fixed to the door frame, as shown at F, and this engages in the oves of the slabs. Alternatively, metal ties with turned-up ends screwed to post may be built in at some of the bed joints. Certain slabs, such as those posed of coke breeze, pumice, wood-wool, etc., are well spiked to the frames. a chase has been cut in the main wall to receive the ends of the slabs; at H fillets are plugged to the wall and between them the tongues of the slabs ilar to B) are fitted.

Patent Plasterboard Partitions.—The following is a brief description of of these partitions made by British Gypsum Ltd. They are all based on erboard (see p. 45).

Paramount Partitions (Fig. 13).—As shown at D the basic unit is a panel 57·2 or 63·5 mm thick, it comprises two plasterboards bonded to a cellular ventilated core of resin covered cardboard. There are three types of surface: (i) ready for direct decoration, (ii) for plastering, and (iii) plastic faced "Deksheen" which is a tough covering in various colours forming a finished skin. The latter has square edges and the others any of the edges given on p. 45. The panels are made in various sizes: widths from 610 mm to 1 220 mm and the usual room heights.

The detail at J shows the vertical joint between two panels accomplished by placing a batten within the core to which the plasterboard edges are nailed; part of the core is removed to allow this. An enlargement at H shows the tapered joint (p. 45). The base detail of a panel at F shows a sole plate 25 mm deep of panel thickness fixed to the floor, 150 mm long vertical plugs are placed at 450 mm centres for skirting fixing. The treatment at the head is drawn at E, the plug is for attachment of the plasterboard cover.

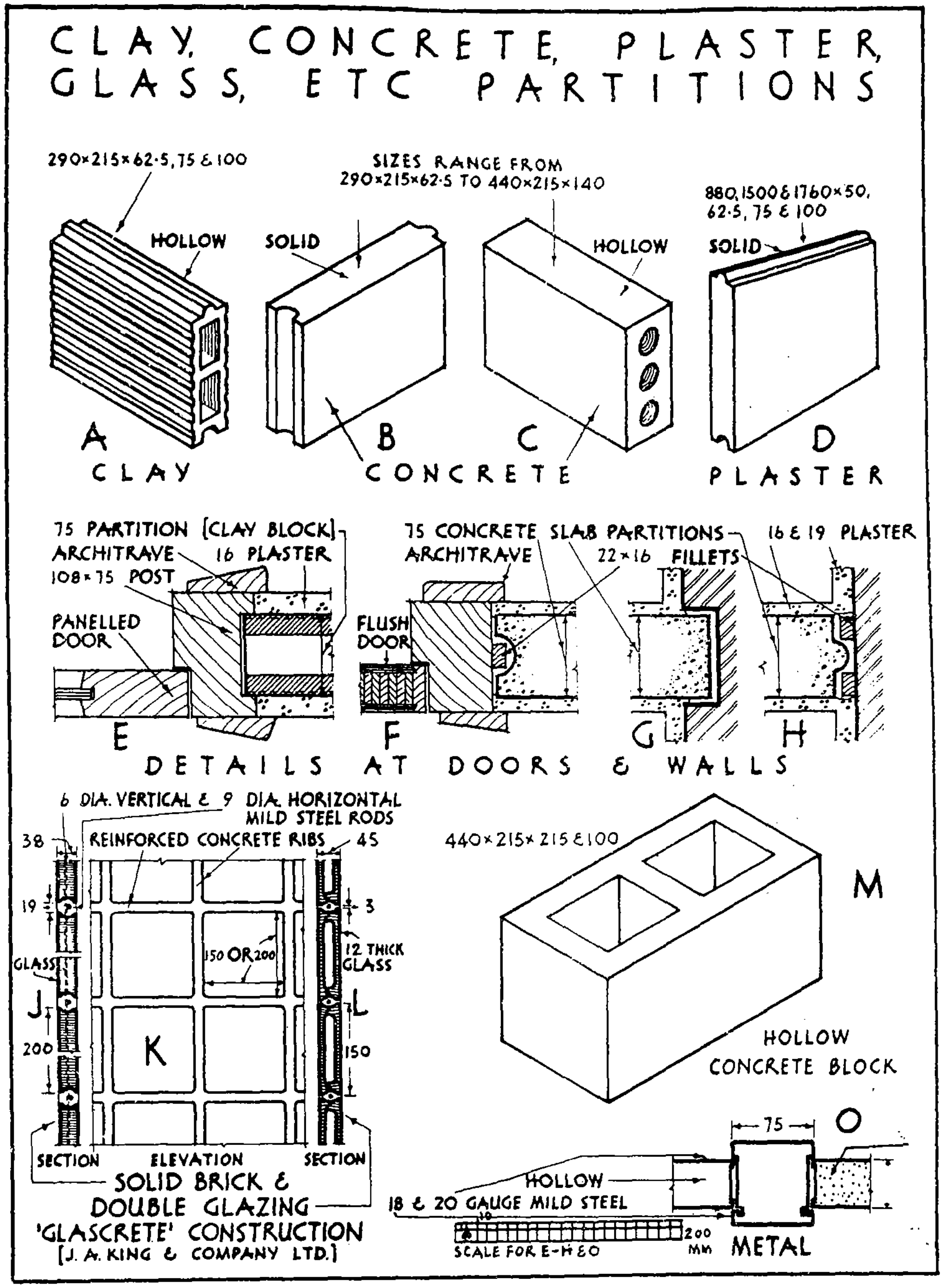


FIGURE 14

The panels can also be used to form double-leaf construction with a suspended mineral quilt in the cavity to give added sound insulation (see p. 55).

Paramount Demountable Partitions.—These use the same panel as above but because they are framed into aluminium alloy studs and channels the partitions can be taken down and remounted elsewhere. The plastered finish is not employed.

Details of aluminium framing are shown at K–R inclusive. Briefly, the sequence of erection is as follows: The aluminium ceiling channel L (shown in section at the top of a partition at K) is screwed to the joists, etc. and the aluminium floor or main skirting channel N (shown in section at the bottom of a partition at M) is secured to the floor. A panel, cut with a small clearance between floor and ceiling, is inserted into the ceiling channel and dropped into the floor channel. A vertical aluminium stud R (see also plan at Q), engaging the edge of the panel, is wedged up between its web and floor until its flanges butt tightly against those of the ceiling channel. This is repeated with panel and stud alternately, the aluminium subsidiary skirting P is screwed to the flanges of the studs and, finally, a skirting filler piece O, net length between the stud flanges, is worked in at each side between the panel and skirting. An aluminium wall channel is screwed to the adjacent wall to receive the edge of the first panel. Provision is made for doors and windows.

Where special provision against sound transmission is required as, for example, offices where typewriters are in use, a double-leaf demountable Paramount partition may be adopted. As shown at the plan at S, this partition consists of double panels with an infilling of wood-wool slabs (see below). The aluminium ceiling and floor channels are sufficiently wide to take the overall thickness of partition. This construction substantially increases the thermal insulation.

In order to obtain maximum insulation, the edges of partitions at walls, floor and ceiling should be isolated by strips of insulating board, quilt, etc.

Gyproc Laminated Partitions.—These consist of three layers of plasterboard stuck together. One type, 44 mm thick, has outer layers of gypsum wallboard and a core of square-edged plank; the other, 63 mm thick, comprises outer layers of gypsum plank with a centre layer of square edged plank. In both cases the outer board can have bevelled edges or tapered edges for a seamless surface.

Studs are not required but core battens are needed round the perimeter. The boards are stuck together on site with special adhesive.

8. Wood-wool Cement Partitions.—These are made from *Wood-wool cement* to B.S. 1105.

The material consists of a mixture of wood-wool (wood shavings) and Portland cement; gypsum may be added. Long shavings from 3 to 6 mm wide are coated with liquid cement, consolidated into slabs by means of a machine press, and then stored to mature. These slabs are very light, the average density of the material being only about 480 kg/m³ (about ¼ the weight of brickwork); they have good heat and sound insulating qualities, are fire-resistant (the cement-coating serving as a protection to the wood shavings), can be easily fixed and sawn, and provide a good key for the plaster which is applied to the surfaces after fixing. The slabs illustrated at A and J, Fig. 15, are made of this material, their dimensions vary from 1 800 to 4 000 mm long by 600 mm wide by 50, 75 and 100 mm thick; 50 and 75 mm thick slabs are recommended for single-thicknessed partitions when the height does not exceed 2·4 and 3 m respectively and for cavity walls—see J. The slabs are bedded and jointed in ordinary lime mortar or, frequently, gypsum plaster, and they are covered with two coats of plaster.

9. Compressed Straw Partitions (Fig. 13).—Clean, dry straw, usually wheat or barley straw, is compressed and encased in stout paper or cardboard to form tough, strong boards; no adhesive is used except that required to glue the cardboard or liners to the straw. *Stramit*[1] is the trade name given to this product.

[1] Manufacturers: Stramit, Ltd.

These boards are used extensively for non-loadbearing partitions, for linir
and ceilings and for covering flat roofs or decking (see Vol. IV). They ar
having a density of only 18·5 kg m² for the 50 mm thickness, and they ha
thermal and sound insulating properties.

In addition to the standard paper-faced slab the surfaces can be faced wit
board or asbestos wallboard. Stramit Ltd. produce several patent partiti
cluding the following:

Plaslin system.—This is the standard slab, plaster skimmed and 50 mr
Panel lengths are 2 200, 2 300, and 2 400 mm in 1 200 mm widths. The pa
placed vertically and the long edges of adjacent slabs are glued together
special adhesive. The base detail at V, Fig. 13 shows the panel resting on a
sole plate, the grooves allow for electric services; the panels also have hole
core for the same purpose. The head detail is shown at T where the head
shown fixed to noggins between the floor joists. Once the glue has set the p
is ready for a normal skim coat of plaster.

Timber framed.—This is the standard slab 50 mm thick which is re
immediate decoration. Lengths are 1 800, 2 400, 2 700, 3 000, and 3 600 mn
1 200 mm. The long edges of the panel have grooved timber frames as dra
adjacent panels are screwed and glued together at this point.

Metal framed.—This uses hardboard or asbestos wallboard faced Stran
of 44, 50, and 58 mm total thickness. Lengths are 2 400, 2 700, and 3 000
1 200 mm wide. The panels are held between two recessed aluminiu
framing members which are bolted together at each vertical joint, see Y. A
plastic insert fits into the recesses to conceal the bolts. The head detail of
tition is given at U. The panel surface is ready for painting

Manufacture of Stramit Board. The straw is hand-fed into a hopper
bottom of which are " fingers " which mechanically arrange the straw at
of a horizontal bed consisting of two metal plates, 50 mm apart, 1·2 m w
about 2·4 m long with enclosed edges. The straw is automatically pushed
between the plates by a ram at its forward stroke. About half-way along th
the paper liners are fed from the top and bottom and glued to the str
proceeds between the plates. The latter are heated (150 C.), sterilizing th
the extruded and continuous compressed slab is cut into lengths and, fin
paper is turned over to seal the edges of each board.

10. Glass Brick Partitions.—The details at J, K and L, Fig. 14 we
pared from particulars supplied by the manufacturers, J. A. King & C

The section at J shows a portion of a partition composed of 200 mm by
by 38 mm solid glass bricks which are grooved on all four edges to permit o
horizontal and vertical reinforced concrete ribs at the joints. All grooved
painted with a light-reflecting paint and then treated with a special bi
compound applied hot. This insulation is to permit of expansion and co
between the glass and concrete. The vertical and horizontal face joints ar
6 mm thick. Mild steel rods are embedded in the concrete at the joints; n
the horizontal and vertical rods are 6 and 6 mm diameter respectively, and
wired at the intersections. The bricks are plain on one face with an
" flemish " pattern on the other.

The section at L shows a portion of a partition consisting of glass units
with horizontal and vertical reinforced concrete joints. It is a double-glaz
tion, each unit being hollow and having two 12 mm thick pieces rebated at
These edges are treated as above. The dimensions of the lenses are 200
200 mm and 150 mm by 150 mm by 45 mm when fixed. The joints are on
thick.

The above are two examples of " Glascrete " construction. Such se
parent partitions are being employed for corridors, staircase wells, etc.
temporary buildings.

Another form of glass brick is shown at X, Fig. 5, Vol. II.

11. **Metal Partitions.**—Mild steel and bronze are two of several metals ...ch are used in the manufacture of partitions.

These may be designed to consist of a series of panels, secured to posts, walls, etc., or the whole of both surfaces may be flush: some of the panels may be prepared for glazing. The hollow panels vary from 25 to 50 mm thick and may be of 1 mm thick mild steel which is painted or m.s. to which a plastic film is bonded or 3 mm thick bronze: The panels are sometimes packed with insulating material (see below). Partitions may also be constructed of bronze or nickel alloys extruded over wood panels or cores; this construction is detailed in Vol. IV.

SOUND INSULATION

...ound insulation, or the prevention of sound transmission from one part of ...ilding to another, is an important subject and one which presents several ...cult problems. It is one of the least understood factors affecting archi...ural design. There are many reasons for this among them being:—(1) ... lack of appreciation of the scientific principles involved. (2) The difficulty ...lating laboratory insulation values to those in the building. (3) Sound ...urement has an accuracy of about 10 per cent. only. (4) The nature of the ...and its differing sensitivity over the range of sounds. (5) It is often un...ssarily confused by technical jargon.

...The speed of sound in air is approximately 341·38 m/sec; in brickwork, ...forced concrete and steel it is respectively 10, 10·7 and 14·7 times faster. ...ce the adoption of steel or R.C. framed buildings (which is essential for large ...ctures—see Chap. II, Vol. IV) where the construction is more or less con...ous, aggravates the problem.

Terms and Units.—Sound is created by a vibrating surface which produces ...pressions and rarefactions in the air having a to and fro' motion. The ...ance from one compression to another is the *wavelength* and the vibration ... is the *frequency* of the sound in cycles per sec. or Hertz (Hz), hence wave...gth

$$= \frac{\text{velocity}}{\text{frequency}}\ \text{m}$$

A sound having a single frequency is known as a *pure tone*, most sounds ...sist of a large number of pure tones.

The ratio of two sound pressures [*e.g.* the pressure at source (p_1) and that ...the recipient (p_2)] is most conveniently expressed on a logarithimic scale and ...uals 20 log ($p_1 \div p_2$) decibels (dB). This unit, the *decibel*, measures the magni...le of the sound. If sound pressure in a room is twice that in an adjoining ...m, then the reduction (*e.g.* the insulation of a wall between the two) = 20 log ... = 6 dB, which is the airborne insulation value of the wall. Hence the ...ibel is used to evaluate sound levels and also as a measurement of sound ...ulation. Noise levels are given in dB, *i.e.* a certain number of dB above ...eference pressure of 2×10^{-5} N/m², this is just below the *threshold of hearing* ...ich has been taken as zero level on the dB scale. A sound of 10 times this ...rgy = level 1 = 1 bel = 10 decibels; one of 100 times (*i.e.* 10^2) = 2 bels = 20 dB, etc. The *threshold of pain* in the ear is about 130 dB.

Sounds of differing frequencies can have the same pressure but the sensation of loudness conveyed by the ear to the brain would not be equal for such sounds. The unit of loudness is the *phon* and by definition, at a frequency of 1 000 Hz, a 1 dB change in pressure level is equivalent to a 1 phon change in loudness; at a frequency of 100 Hz a 1 dB change is about 1½ phons. This illustrates the fact that the ear is not equally sensitive to sounds of different frequencies—it being more sensitive to those in the middle frequencies (3 000 to 4 000 Hz). Only at 1 000 Hz is the loudness level equal to the pressure ratio, *e.g.* at this frequency 60 phons = 60 dB. In order to compare sounds of all frequencies another unit of loudness, the *sone* is introduced; by definition 1 sone is the loudness of a sound whose loudness level is 40 phons. Each time the level in sones is doubled it increases by 10 phons. The loudness in phons of some common noises is as follows:—large jet air-liner 38 m high—140, heavy road traffic at kerb—85, conversation 1 m away—75.

The *sabin*, the unit of absorption, is defined on p. 52.

Transmission of Sound.—Sound originates in two ways:—(1) airborne, *i.e.*, by voices, radio, etc., or (2) by impact (sometimes known as "structure-borne"), *i.e.*, by footsteps, hammering, etc. The noise of a door slamming is transmitted by the air and the structure.

A noise generated in a room divides into four components, the first three of which may be transmitted to an adjoining room:—(1) Part may pass through the pores or joints in a party wall[1]. (2) The wall[1] is vibrated causing re-radiation of the noise (low- and medium-frequency noises being the main offenders). (3) Part is converted to structure-borne vibration—particularly high-frequency sounds. (4) A portion is reflected (some having been absorbed). The relative values of these components depends on the weight of the wall and its material, its stiffness, thickness, nature of its surface and the frequency of the sound. About 95 per cent. of the sound is reflected—dependent on the part directly absorbed. Part (1) above can be eliminated by the provision of an impervious surface. Parts (2) and (3) (the balance of about 5 per cent.) is then transmitted.

Consider now the junction between a wall and floor: shown at H, Fig. 15, and the paths by which a sound can travel to an adjoining room. (a) There is, firstly, the direct vibration by sound through the wall, path 1. (b) The part of (a) which is transferred to the floor and emerges in the room, path 2. (c) The part of the sound which enters the floor and passes into the wall and hence into the room, path 3. (d) The part which enters the floor and emerges in the room, path 4. Part (a) is direct, the remainder are indirect and difficult to assess—they are absent in laboratory tests. If the wall is bedded solidly to the floor (d) is reduced, it is reduced still further if the wall is thicker than the floor. If a resilient layer is introduced between the two, then (b) and (c) are reduced. For low-frequency noises a rigid fixing is preferable, with high pitches the nature

[1] Or floor or ceiling.

of the joint is of no consequence. In general, it is recommended that a rigid fixing is best, certainly for solid single skin walls. As described below in reference to multiple partition walls, the insertion of a resilient layer between the wall and the floor may be desirable.

Sound is thus received in three ways:—(1) By direct air paths. (2) By reflection from surfaces which cause *reverberation*, the echo is the extreme example of the latter. (3) Re-creation of the sound by a surface which has been vibrated by a directly impinging sound; light, flexible partitions are more susceptible to this than stiff, heavy ones. As mentioned above, much of the sound is reflected, reflections can be reduced by having absorbent surfaces, but it is important to realise that sound-proofing by absorbents has only a *very limited effect.* Such treatment is only worthwhile if the room is barely furnished, *e.g.*, having plastered walls and no carpet. The reverberant sound pressure in a room can be *halved* (*i.e.*, reduced by 6 dB only) if the amount of absorption is *doubled*; obviously the surface areas available will limit the extent of this method of reducing sound. Treatment by absorbents is described below, it must not be confused with *insulation* which is the prevention of transmission.

Transmission by the direct air paths is reduced if good construction is adopted in avoiding cracks, partially filled mortar joints and badly fitting doors and windows. Transmission by vibrating walls acting as diaphragms gives rise to the main cause of complaint, particularly for low- and middle-frequency airborne sounds which are the most troublesome. The greater the mass, stiffness and density of a wall, the less does it vibrate. A graph made by plotting the weight of a partition against the reduction in decibels it affords shows the following:—by doubling its weight the insulation is similarly increased, giving an improvement of about 6 dB. *Weight is therefore an important factor in improving insulation.* Transmission by vibrations within the structure travel by indirect paths and are difficult to measure, they can be eliminated by providing discontinuity within the structure (see below). The best way of doing this and providing good insulation is to adopt a discontinuous system of construction, *i.e.*, " a box within a box "; but this is expensive and generally only applicable to sound-proofed laboratories and studios, the floating floor (see below) is an example. For most buildings, it is sufficient to ensure that there is adequate mass, good construction and the selective use of absorbents.

An increase in length of the direct air path is the most obvious way of lessening the nuisance from noise. In the open air, by doubling the distance between the source and the recipient, the sound intensity is reduced to one-quarter—an application of *the inverse square law.*[1] Therefore in planning a

[1] Sound emanating from a source occupies a spherical wave front. The area of the wave front at a distance r from the source $= 4\pi r^2$; at a greater distance R the same amount of sound has a wave front area $= 4\pi R^2$. The ratio of the two intensities is $\frac{r^2}{R^2}$ because 4π is a common factor.

Hence if $r = 2$ and $R = 4$, the intensity ratio $= \frac{2^2}{4^2} = \frac{4}{16} = \frac{1}{4}$, the inverse square law.

district or building there should be segregation of the noisy elements fr quiet. Externally, the use of screens to deflect sound; trees and grassed in preference to hard paved areas, for greater absorption are beneficial. nally, the noisy rooms should be kept separate from the more quiet ones a latter should be kept away from busy streets where traffic noises predo

Absorbents.—Stiff non-porous surfaces are poor absorbers, those wh soft and porous and also those which are flexible and can vibrate, absor sound. Examples of good absorbents for internal use are slag wool, glas asbestos spray, wood wool, acoustic felt (cabot's quilt) and perforated fib (one of the best, but it should not be used at eye-level because it has a d appearance—slotted fibreboard does not have this defect), acoustic plast effective. Good external absorbents which are unaffected by weather ar difficult to find, glass fibre behind perforated aluminium or copper she been used.

Materials are given an *absorption coefficient* to denote their comparativ hence if the coefficient is 0·4, 40 per cent. of the incident sound is absorb coefficient of 1 denotes 100 per cent. absorption, *i.e.*, as for an open wind equals 1 *sabin*, the unit of absorption. The coefficient differs with the fre of the incident sound as shown in the table on p. 53. It is therefore im to select the correct material for the noise frequency concerned and it is ob wasteful to continue to add middle-frequency absorbents when deali high-frequency noises.

Canteens, restaurants, typing offices, entrance lobbies and corrid places where the noise level can be reduced by absorbent treatment.

Absorbents are used in auditoria to give acoustical correction and to the *reverberation period*, this is the time taken by a sound to die away by It is important to prevent the overlapping of successive sound syllab achieve the correct reverberation period which ensures distinctness in th The *optimum reverberation period* (t) is specified according to the use of t and its volume. In a small office $t = 0{\cdot}75$ secs., in an average lecture classroom $t = 1$, the rooms being unoccupied. If the volume of an aud is such that it has 2·3 m^3 per seat, then providing the room is properly p little or no extra absorption is generally required. The actual rever period is given by Sabine's formula as follows $T = 0{\cdot}16V \div A$, whe volume of room in m^3. A = the total absorption in sabins in m^2, o by adding together the products of each separate area times its coeffi absorption. If T is more than t then absorbents are added so that the equal; the back of the ceiling, the back wall and the side walls (startin back of the hall) above dado height are covered in that order until co has been achieved.

The following are the different kinds of absorbents:—(1) Porous abs (2) Panel absorbents. (3) Cavity resonators. (4) Perforated panel abs

1. *Porous absorbents.*—The compressions and rarefactions in the sou create a to and fro' movement in the restricted pores of the material

ABSORPTION COEFFICIENTS

Material	Approximate Absorption Coefficients — Frequency of Sound (Hz) 125	500	2,000
Acoustic plaster (19 mm) on brick	0·15	0·25	0·3
Asbestos spray (25 mm) on brick	0·15	0·6	0·75
Carpet on felt (both 6 mm) on solid floor	0·07	0·5	0·65
Curtains, medium fabric	0·05	0·3	0·5
Fibre board (12 mm) on battens providing 25 mm air space in front of solid wall	0·3	0·3	0·3
Glass wool or slag wool 50 mm thick on battens on solid wall	0·35	0·91	0·95
Glass (4 mm) in windows	0·3	0·1	0·05
Hard plaster (20 mm) on brick	0·03	9·02	0·04
10% perforated hardboard on battens providing 25 mm air space filled with acoustic felt, solid backing	0·15	0·75	0·75
Perforated fibre board tiles (20 mm) bedded solidly	0·2	0·65	0·8
Plywood panelling over 25 mm air space and solid backing	0·3	0·15	0·1
Ditto with air space filled with acoustic felt	0·7	0·25	0·1
Wood boarded and joisted floor	0·2	0·1	0·1
Wood-wool bedded solidly	0·1	0·4	0·6
Ditto but on 25 mm air space	0·15	0·6	0·6

gy is thus converted to heat by friction. The efficiency of this class improves e porosity, resistance to air flow and thickness increase; it is also affected e way in which the material is mounted. Examples of this type are items (3), (6), (10) and (14) in the table above.

. *Panel absorbents.*—The porous absorbents are not universally applicable use they are difficult to clean; thus in hospitals, where a high standard of ene is demanded, their use is open to objection. An alternative is the panel orbent which can have a porous or non-porous surface and is fixed on framing an air space between it and the backing wall. Ordinary timber panelling n example of a non-porous panel absorbent, the panel is vibrated by the d wave causing dissipation of energy, it is most efficient at low-frequencies o 250 Hz and can be improved by an absorbent lining on the wall behind panel. Panel absorbents are also known as *resonant absorbents*, *resonance* tually an increase in the intensity of a sound caused by vibration of surfaces, a desirable feature in concert halls and resonant panels are placed behind sound source to overcome any sensation of deadness and lack of intensity. If a note is sounded near a wall then it vibrates and if the same note is continued for a sufficient time the wall itself becomes a secondary source of sound. As soon as the original note ceases, so does the secondary one and the wall acts as an absorber. Resonant panels are thus particularly valuable for they act in the dual capacity as an absorber of sound and a magnifier of intensity.

3. *Cavity resonators.*—These are also known as Helmholtz resonators and comprise a chamber with a narrow entrance. They are designed to act as absorbers over a single special frequency and the air in the cavity resonates to give loss of sound energy. They are not universally applicable for sound absorption but can be designed to reduce the noise from individual machines. The principle is, however, used in the next type which are more widely adopted.

4. *Perforated panel absorbents.*—These are metal or wood panels having small holes or slots and mounted on battens so as to leave an air space between them and the backing wall. The holes act as the entrance to the resonating chamber (the air space at the back). Increased absorption is provided if the cavity is filled with porous material like mineral wool to act as a "damping agent." The area of the holes varies between 10 and 20 per cent. and the coefficient from 0·6 to 0·9, item (9) in the table opposite is an example. Thick plates with large holes and thin plates with small holes are used for the low- and high-frequencies respectively.

Selection of Structure.—Reference has been made on p. 51 to the increased speed of sound in steel and reinforced concrete buildings, insulation is thus more difficult in such buildings because of the continuity provided by the frame. Continuity is a valuable structural device for it reduces bending moments (see p. 31) in certain members; *e.g.*, the B.M. in a uniformly loaded simply supported beam is $WL \div 8$ but only $WL \div 10$ in a continuous beam. There is thus a conflict between structural economy on one hand and discontinuity, which is an aid to insulation, on the other.

It is not easy to provide much discontinuity in a frame but there is one way which would be practicable by using cantilever beams. If the columns of a frame are placed at a distance of 3 units apart and a cantilever beam (of a span of one unit) is projected outwards from each column, there are thus three spans to the frame of lengths 1 : 3 : 1. Due to this proportion the section of the beam will be constant over the total length of 5 units (the differing spans compensate for the differing bending moments). This frame can be repeated along the main axis of the building so that a joint will occur at every 5 units of length, providing discontinuity at these intervals. This gives valuable sound insulation for impact and structure-borne noises; a gap of 50 mm. can be left and there is no point in filling this with a resilient packing except where necessary.

Steel stanchions having hollow fire protection, such as brick casing, can first be sprayed with asbestos for insulation. The noisy parts of a building such as workshops and boiler houses should be placed in a separate frame for insulation. In determining the overall dimensions of a building, a tall narrow one is much more susceptible to vibration from traffic than a lower more compact structure.

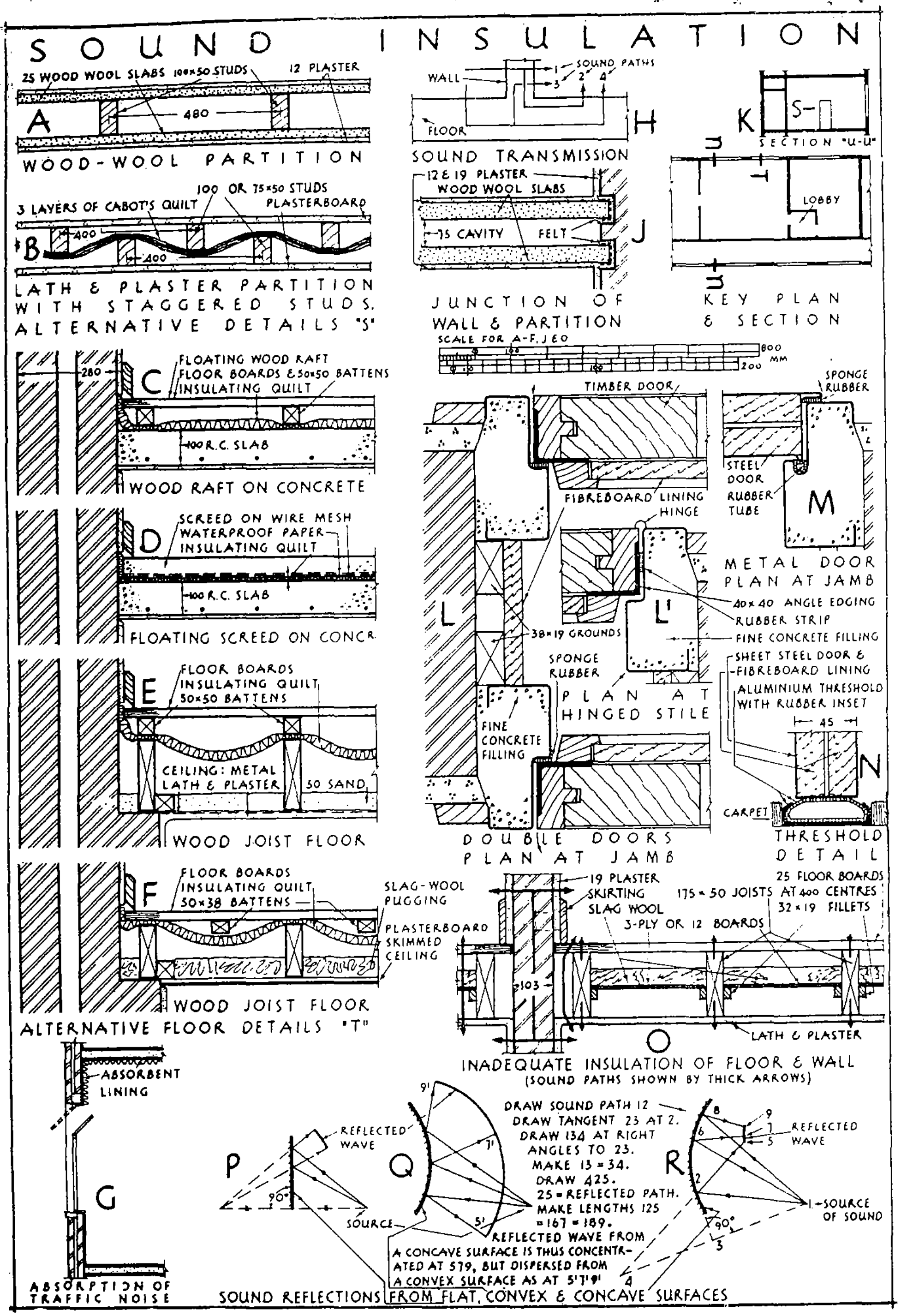


FIGURE 15

SOUND INSULATION

The latter has a better inertia value and resistance to vibration. It is li[…] trouble from vibration will become more important than noise fro[…] because, undoubtedly, engine noises will someday have to be limited b[…]tion. The use of say 1 m thick mass concrete raft improves the inert[…] preferable to separate pad foundations.

There have been cases where the designer has resorted to the use o[…] when this has not been justified. Frames were introduced to elim[…] need for the thick walls that were demanded by earlier byelaws for tall b[…] These wall thicknesses were obtained by empiricism and were extrava[…] much more economical method is to design them in accordance with […] as described in Chap. IV, Vol. IV. For example, it is practicable to des[…] no thicker than 280 mm for a five-storey domestic building provided […] bricks and mortar are selected.

STANDARDS OF INSULATION FOR DOMESTIC BUILD[…]

Good planning and adequate segregation are obvious prelimin[…] insulation and the measures on p. 59, to reduce plumbing noises, etc.,[…]

The standard of insulation required in a room is partially dependen[…] amount of background noise. The latter may be attributable to traffi[…] the activities within the room and has the effect of *masking* incoming no[…] an adjacent room. Masking may thus reduce the amount of insulation[…] between rooms; *e.g.*, in offices, lighter partition walls are needed in […] sites (unless double glazing is used, see p. 59) than in rural areas. If t[…] of traffic is prevented from entering the room, noises from other par[…] building may predominate and this would entail an improved partitio[…]

The standards suggested for various types of building are now g[…] several references to details are to Fig. 15.

Houses and Flats.—Insulation grades are specified in C.P. 3, Ch[…] there is a house standard (or party-wall grade) and grades 1 and 2[…] As previously explained, insulation varies with frequency, this can be[…] the *slope* of the insulation and is given as the number of decibels pe[…] Three slopes are mentioned:—A (low) = less than 4 dB, B (average)[…] 6 dB, and C (steep) = more than 6 dB per octave. Slope B is satisfa[…] the insulation values between 30 and 50 dB average. The average soun[…]tion in dB is given over the frequency range of 100 to 3 200 Hz for th[…] standards. The desirable insulation for walls and floors is 50 dB.

Houses, party wall grade.—This is based on the 215 mm thick brick p[…] plastered both sides, this is satisfactory for houses and Grade 1 for flats;[…] average reduction of 50 dB, slope B.

[1] Minimum sound insulation is also demanded by the Building Regulati[…] (i) a wall separating dwellings should have an insulation at least equal to that of[…] brick wall plastered on one face weighing not less than 415 kg/m² and (ii) a floor s[…] dwellings should be (a) of concrete weighing not less than 365 kg/m² covered w[…] cork (or 4·5 mm rubber), or (b) of concrete weighing not less than 220 kg/[…] floating floor over it (see p. 56), or (c) a timber-joisted floor with a 19 mm mini[…] plaster ceiling and floating floor (see p. 57) so that the total mass of ceiling *and*[…] 120 kg/m² minimum.

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tal mass of ceiling and

Flats, grade 1.—This is based on concrete floor construction with a floating or (see p. 56), this has a reduction of 50 dB, slope B.

Flats, grade 2.—Insulation of this grade is that given by an ordinary timber ted floor; it is quite inadequate for flats.

Floor construction must meet the grades for both airborne and impact sounds walls need only be satisfactory for airborne insulation.

In the case of blocks of flats, those people in the middle stories are most cted by noise, those on the top floor being less disturbed. The most notice- e noise is that emanating from the flat above, it is least from the flat below. ts on either side of a party wall suffer more noise from next door than from w, the noise from above still predominating.

Wall Construction.—The 280 mm cavity wall may offer slightly better lation than the 215 mm solid wall. If the cavity wall is used it must have at t a 50 mm wide air space and only light butterfly wall ties should be used. ight is the governing factor in insulation (see p. 52), certainly with single leaf ls, but as the 50 per cent. increase in weight from the 215 mm to the 328 mm y gives an improvement of about 3 dB this step is seldom justified.

The following table[1] gives typical insulation figures of single leaf partitions:—

Construction	Approx. Weight (kg/m²)	Average Sound Reduction (100–3 200 Hz) dB	Slope	Grade
(1) 50 mm strawboard, plaster skimmed both sides	26·8	30	B	
(2) 100 mm hollow plaster slab	59	27	A	
(3) 50 mm wood-wool slab unplastered	29·5	8	A	
(4) 50 mm wood-wool slab, 12·5 mm plaster both sides	68·5	35	A	
(5) 3 layers of 19 mm plasterboard	54	33	B	
(6) 50 mm hollow clay block plastered as (4)	83	35	A	
(7) 75 mm " " " " " "	108	36	A	
(8) 100 mm " " " " " "	122	37	B	
(9) 50 mm clinker block plastered as (4)	108	37	B	
(10) 75 mm " " " " "	147	41	B	
(11) 100 mm " " " " "	186	43	B	
(12) 200 mm hollow dense concrete block plastered as (4)	245	45	B	2
(13) 102·5 mm brick plastered as (4)	269	45	B	2
(14) 225 mm " " " "	488	50	B	1
(15) 328 mm " " " "	710	53	B	1
(16) 175 mm dense concrete plastered as (4)	465	50	B	1

[1] Being extracts from C.P. 3, Chap. III.

Stud-framed Partitions (see p. 44).—These are often used to divide large floor areas, they are satisfactory and can give a reasonable standard of insulation particularly where there is already a masking noise (*e.g.*, from traffic) entering the room which would ensure privacy of speech (a minimum insulation of 25 dB is necessary for this). The partition should extend to the ceiling and if this is suspended then the partition should continue to the solid floor above.

Except for item (8) the examples in the following table are of single stud partitions like A. If double or staggered studs (as at B) are used there is a gain of about 2 to 3 dB. A similar gain obtains if an absorbent quilt is placed in the cavity. The two can be combined as at B to give a total gain of about 5 dB.

Examples of the insulation of stud partitions are:—

Construction (both sides of 100 mm studs)	Approx. Weight (kg/m²)	Average Sound Reduction (100–3 200 Hz) dB	Slope
(1) 12 mm fibreboard	7·3	20–22	A
(2) 3·2 mm hardboard	14·6	23	C
(3) 12 mm asbestos-cement wallboard	14·6	28–30	C
(4) 9·5 mm plasterboard, joints filled	15	31	B
(5) 9·5 mm plasterboard, 5 mm plaster skim	29·3	33	B
(6) Metal lath with 3-coat plaster	78	35–37	B
(7) 50 mm strawboard, 5 mm plaster skim	44–48	35	B
(8) 9·5 mm plasterboard, 12 mm plaster, 25 mm quilt, staggered studs as A, Fig. 15	30	40	B

Double-leaf Walls and Partitions.—Double walls are satisfactory for middle- and high-frequency noises and give a slightly better insulation than is obtained by the mass relationship. Each leaf is connected by the airspace between and by the mechanical linkage at the edges where they are fixed to the structure. The air linkage predominates when the panels are light and is lessened by the insertion of an absorbent in the cavity because sound is absorbed at each reflection. Mechanical linkage is greater for heavier panels and so the edge insulation by cork strips or felt as at J, Fig. 15, gives a greater reduction in this case. The air between the faces acts as a spring and when they vibrate the second one is less affected. Increasing the separation decreases the pressure difference in the space and the movement of the second face.

When the weight has to be limited then the double-leaf wall can be satisfactory. For example, for a total weight of 245 kg/m² as with twin walls of 15 mm thick clinker block (plastered), the average reduction is 50 dB; this is the same for a 225 mm brick wall (plastered) twice as heavy.

Examples of the insulation of double-leaf walls and partitions are given in the following table:—

Construction (both sides of 50 mm cavity)	Approx. kg/m²	Average Sound Reduction (100–3 200 Hz) dB	Slope	Grade
(1) 50 mm wood-wool slab, 12 mm plaster	98	42	B	
(2) 50 mm clinker block, ,,	186	47	C	2
(3) 75 mm ,, ,, ,,	245	50	B	1
(4) 102·5 mm brick, 12 mm plaster, (*i.e.* 280 mm cavity wall)	488	50–53	B	1
(5) Unplastered Paramount double leaf partition with 25 mm quilt (see pp. 49–50) with 63·5 mm thick panels	52	43	B	1

It is sometimes necessary to improve the insulation of existing walls. The application of wall lining is beneficial for this when the original reduction does not exceed about 40 dB. The lining must be flexible and non-porous, *e.g.*, 9·5 mm plasterboard, plastered, on 50 mm battens at 400 mm centres.

Floor Construction, Concrete Floors.—The ordinary reinforced concrete floor weighing not less than 220 kg/m² has a sound reduction of only 45 dB. Proprietary floors with pre-cast floor beams and the hollow block floor with reinforced concrete ribs of the same weight have similar values. Floors must satisfy the grades for both airborne and impact sounds.

The *wood raft floating floor* at C consists of 50 mm deep (or 38 mm) by 50 mm wide battens to which the boards are fixed. The battens are laid on a 25 mm thick paper-covered insulating quilt such as glass wool which is made in 1 m wide rolls 55 m long. Adjacent pieces of the quilt are butt jointed and it compresses to about 9 mm under the battens. It is important to turn up the edges of the quilt at the edges of the floor so as to completely separate the raft from the structure, and the skirtings should be fixed to the walls only. This floor is one of the best for insulation, being grade 1, 50 dB.

The *concrete screed floating floor* at D is frequently used. It consists of a 65 or 75 mm 1 : 1½ : 3 concrete screed on a 25 mm thick mineral wool quilt, as above, which compresses to about 19 mm. The quilt is covered with waterproof paper (sometimes this is only in 150 mm wide strips over the butt joints of the quilt) to prevent seepage to the structural floor below. 20 to 50 mm wire mesh reinforcement is laid over the waterproof paper. This type of raft cannot be used in areas greater than 13–18·5 m² or where the room dimension is more than 6 m because of the tendency of the screed to curl up at the corners. Note that the quilt extends up the edges of the raft.

Another type which has been found satisfactory and is relatively cheap consists of 22 mm thick *in situ* pitchmastic flooring laid on insulation board has been stuck down to the structural slab.

The addition of a carpet to any floor will contribute substantially to the insulation; by this means it is possible to improve the grading from 2 to

Suspended ceilings can add to the *airborne* insulation of a floor provid are of the jointless type (*i.e.*, plastering on expanded metal, see Cha Vol. I) and weigh not less than 24·4 kg/m². For instance, an ordina crete floor with a suspended ceiling below and provided it is covered carpet becomes grade 1.

Floating floors should be confined to each room and partitions sho be built on them.

The insulation values of some concrete floors are shown in the fol table[1]:—

Construction	Average Sound Reduction (100–3 200 Hz) dB	Slope	Sound Insulation Grade: Airborne	Impact
(1) 220 kg/m² R.C. floor, hard floor finish	45	B	2	4-dB worse than grade 2
(2) R.C. floor with floor finish of thick cork tiles or rubber on rubber underlay	45	B	2	probably 1
(3) R.C. floor with floating concrete screed and any surface finish (as at D, Fig. 15) *or* R.C. floor with wood raft (as at C, Fig. 15)	50	B	1	1
(4) 150 mm R.C. slab with floor finish as (2)	48	B	1	1

Wood Joist Floors.—Insulation of these is affected by the amount of ing transmission via the walls—a factor which is not so noticeable in co floors because of the greater rigidity these impart to the wall. When a flo been sufficiently insulated so that the energy passing through it does not that going through the walls, then additional floor insulation will serve n pose unless the walls are improved. This can only be done by reduci wall vibration by increasing its thickness or weight and stiffness. Hen considering the efficiency of the insulation of a timber floor, due regard be paid to the thickness of the walls beneath it. Two thicknesses are de thin—102·5 mm brick or less, and thick—215 mm brick or more. A adequately insulated floor is shown at O, Fig. 15.

[1] Being extracts from C.P. 3, Chap. III.

An important feature in the insulation of these floors is the floating construc- achieved by using a 25 mm thick mineral wool quilt which is draped over joists and turned up at the edges of the boards. Further improvement over plain joist floor is obtained by increasing its weight with *pugging* between the . The detail at E shows the best type of pugging and consists of clean dry 50 mm thick (83 kg/m^2 minimum) laid on the plaster and expanded metal g. The 22 mm thick t. and g. boards are nailed to 50 mm wide by 50 mm (38 mm minimum) battens which are placed over the quilt at the joist es. Neither the boards nor the battens must be nailed to the joists.

A less effective detail is shown at F, this only gives grade 2 insulation provided used with thick walls. The 14·7 kg/m^2 pugging (*e.g.*, slag wool) on the med plasterboard ceiling, being lighter, is less effective than the previous . The raft at F is an alternative to that at E, the battens being placed llel to and mid-way between the joists; the boards are joined together in s about 1 m wide with the battens projecting about 150 mm so that adjacent s can be screwed together at the junctions.

The additional weight of the floor due to the pugging should be considered termining the size of the floor joists. Unless the joists are relatively deep, ng bone strutting cannot be used and solid strutting must be adopted ad; the strutting should be kept clear of the quilt and pugging.

The insulation values of some timber joist floors are shown in the table[1] on :—

STANDARDS OF INSULATION FOR OTHER BUILDINGS

As mentioned on p. 52, good planning and segregation are obvious pre- sites and the measures given on p. 59, relating to plumbing noises, etc., apply.

In general, the desirable standard for walls is insulation of the order of 40 to dB according to the use of the room and the building type; as there is a siderable difference in weight and cost between the 75 mm clinker block and 15 mm brick wall which have these respective values, then further amplifica- is necessary. A lower standard may be adequate in some cases. The ation of floors should be a minimum of 45 dB (*e.g.*, a rubber covered 100 mm slab) but this is inadequate for quiet rooms. Auditoria (see below) are al cases requiring higher values.

Doctor's Surgeries.—The weak point here is the communicating door between the lting room and the waiting room. The separating wall between the two should a value of 45 dB, and the two doors should have a 2 m wide lobby between—see as shown in the key plan at K, Fig. 15.

Educational Buildings.—The optimum reverberation period in seconds (see p. 52) he different rooms (empty) should be:— for assembly halls—1·25 to 2·25; rooms, gymnasia, baths, etc.—1·25; classrooms and dining-rooms—1. Rooms be divided into four categories according to the noise level created in them, *i.e.*, oise producing, (2) as (1) but needing occasional quiet, (3) average, *e.g.*, classrooms, (4) rooms needing quiet, and (5) rooms needing privacy. According to C.P. 3, Chap. III, the minimum sound reduction in dB between rooms of the same category is as follows:—(1) 25, (3) and (4) 35, (2) and (5) 45. The minimum between rooms of different categories should generally be 45 dB, but more for workshops; about 35 dB is suitable for most corridor walls and classroom walls in schools (where classes change at the same time), in other educational buildings they may change at different times and so a higher standard is needed.

Factories.—These are often inherently noisy and the noise climate should not be allowed to exceed an approximate overall level of 65 dB; if it is over 95 dB, the ear may be damaged. The insulation of the machinery at source is the first step—(see p. 60.) Rubber doors and rubber tyred trolleys are beneficial. The roof is frequently the weak point even though legislation demands that new factories must be thermally insulated (see Chap. XII, Vol. IV); concrete roofs are better than those of light sheeting.

Hospitals.—These require a high standard of insulation, floors should be grade 1 as for flats (see p. 55) and walls 45 dB (50 dB if a noisy room is unavoidably placed next to a ward). Doors should be of metal giving about 40 dB (see p. 59). Rubber wheeled trolleys for stretchers and food should be adopted and the latter should have rubber covered shelves. Ward kitchens and sluice rooms, etc., are noise sources and should have 45 to 50 dB walls with good doors; linen closets placed between such rooms and a ward contribute to the insulation. Rubber covered draining boards and plastic sinks are helpful. The use of individual radio and t.v. speakers for patients are much better than a common speaker per ward.

Hotels.—The vulnerable parts are (1) bedroom floors requiring at least grade 2 air-borne and grade 1 impact insulation, and (2) bedroom and corridor walls requiring 45 dB with heavy doors. Bedroom doors should not be placed opposite to each other in corridors and borrowed lights are undesirable. The liberal use of flush-fitting carpets with thick felt, and sufficient separating lobbies between public rooms and those demanding quiet, are well justified. Boiler houses and kitchens (see p. 60) are the noisiest parts and the public rooms must be well insulated.

Offices.—The main sources of complaint are the typing rooms, canteens and telephones; in cities traffic noises are a nuisance. The maximum reverberation period is 0·75 sec. in private offices and 1·25 sec. in larger ones (both empty). Typing offices should include absorbent surfaces with resilient pads under the machines. The use of double windows (see p. 59) which should be associated with air conditioning is necessary to exclude traffic noise. Insulation of 45 dB is generally needed between rooms of differing usage and for quiet rooms, but masking (see p. 54) may reduce this to 40 dB. A value of 25 to 30 dB is tolerable between adjoining general offices. In all cases a 45 dB floor is the minimum requirement.

Auditoria.—These form part of a study of acoustics which is beyond the scope of this book. Some general principles are, however, of interest including the further examination of sound in concert halls and theatres. The requirements for satisfactory hearing in such places include:—uniform and sufficient loudness, clarity (or definition), and lack of distortion.

In order to provide uniform loudness there must be an absence of deaf points and sound foci. Deaf points arise as a result of the compression in a sound wave being neutralised by the rarefaction in a subsequent wave of the same length; similarly, if the compressions in successive waves coincide there will be a magnification of sound. These undesirable effects give rise to what is termed *interference* which is avoided if the sound syllables decay sufficiently quickly (*i.e.* by having the correct reverberation period—see p. 52) and in the absence of curved surfaces. Excessive reverberation or prolongation of sound is a common defect that can be cured by the application of absorbents. Sound foci are the result of reflections from concave surfaces, which produce unwanted concentrations[1] of sound, such surfaces[2] must not be used. The behaviour of sound reflected off flat, convex and concave surfaces is shown at P, Q and R, respectively, in Fig. 15. To be adequately loud, a sound must have a pressure level of 35 dB over any disturbing sounds.

[1] Being extracts from C.P. 3, Chap. III.

[1] A well known example of this phenomenon occurs in the "whispering gallery", St. Paul's Cathedral, London.

[2] Parabolic surfaces have been used where the source is at the centre of focus of the curve so that reflections from it are parallel and not converging.

TIMBER JOIST FLOORS

Construction	Average Sound Reduction (100–3 200 Hz) dB	Slope	Sound Insulation Grade: Airborne	Impact	Overall
(1) Plain joist floor, plasterboard skimmed ceiling (no pugging)					
Thin walls	34	C	8-dB worse than grade 2	8-dB worse than grade 2	—
Thick walls*	36	C	4-dB worse than grade 2	5-dB worse than grade 2	—
(2) Plain joist floor, lath and plaster ceiling and 83 kg/m.^{2} pugging					
Thin walls	45	B	2	2	2
Thick walls*	48	B	2, possibly 1	2	2
(3) Floating floor, plasterboard skimmed ceiling and 14·7 kg/m^2 pugging (as at F, Fig. 15)					
Thin walls	43	C	2-dB worse than grade 2	2-dB worse than grade 2	—
Thick walls*	48	C	2, possibly 1	2, possibly 1	2 or 1
(4) Floating floor, lath and plaster ceiling and 14·7 kg/m^2 pugging					
Thin walls	45	C	possibly 2	2	possibly 2
Thick walls	48	C	2 or 1	1	2 or 1
(5) As (4) but 83 kg/m.^{2} pugging (as at E, Fig. 15)					
Thin walls	49	B	probably 1	probably 1	probably 1
Thick walls*	50	B	1		1

* At least 3 of the walls below the floor must weigh not less than 42 kg/m^2.

Clarity is the freedom from the overlapping of successive sounds and is
the application of the correct amount of absorption in providing the optimum
tion period. Clarity is also obtained by avoiding echoes. If the indirect so
a reflection) reaches the ear $\frac{1}{15}$-sec. after the direct sound then both are disting
this is an echo. The length of the indirect sound path would thus be 341·38 ÷
hence the ceiling height above the speaker or orchestra should not exceed
11·4 m; but to provide a margin of safety and to aid distinctness, the ceiling he
be between 6 and 10 m high. It is, of course, possible to increase the ceilin
the portion of the hall remote from the source, but even so, reflections which
the effect of making the indirect sound path more than 15 m longer than the
are an anathema. Offending reflecting surfaces must be lined with an absorb

Adequate reverberation is particularly important in large halls for music
adds to the fullness of tone and the blending of notes; insufficient reverberat
deadness. Halls designed for speech, on the other hand, require a shorter re
period because the blending of syllables would lead to indistinctness. Hal
speech and music (theatres) require a compromise reverberation period (*i.e.*,
long for speech and too short for music). It is here that the resonant panel
(p. 53) are of value since they reduce the reverberation (necessary for speec
compensated, to some extent, by the increased intensity they afford to m
music can be further reinforced if the platform is of timber with a space of abo
below it, the platform thus acts as a sounding board.

Reflecting surfaces near to the source are used to reinforce the sound at the
hall and are needed to direct sound to those areas which are greater than about
the source. Galleries are used to bring the audience nearer to the platform
shaped hall plan (but with a flat rear wall) is preferred for the same reason.
rear wall, even if lined with absorbents, will direct sufficient sound to cause fo
it may be used if it is broken up by small convex surfaces to create diffusion.
and side walls are splayed to reinforce the sound, by reflections, to distant se
between the back wall and the ceiling beneath a gallery is most useful to give
to the back rows of the body of the hall. Echoes are avoided as described ab
necessary, by having absorbents on the back wall and rear part of the ce
alternative to the true fan shape is the hall with stepped surfaces on plan l
greater hall width at the back than at the front.

DOORS AND WINDOWS

In considering the overall insulation of a wall, much depends on
tiveness of the doors and windows. These are the vulnerable area
nullify the efficiency of the wall itself by the air spaces, alone, round t
example, a hole 25 mm square in a 215 mm thick wall reduces the
from 50 to 40 dB. Doors must be sufficiently heavy, windows must
glazed and both must have adequate edge seals (Fig. 15). Metal
better than timber ones for they can be filled with fine concrete whic
with the wall and eliminate cracks.

Single Doors.—A 44 mm flush panelled door with a solid core an
about 24 kg/m^2 has an insulation of about 25 dB providing it has
seals (there is a loss of about 5 dB if the edges are not sealed).

Sealing can be provided by rubber tubing or by rubber strip havin
non-porous surface. The detail at M shows a double seal by means
rubber on the outer and tubing planted in the rebate of the fra
draught strip is also used but this is a less satisfactory solution bec
extra force required to shut the door. The sealing must extend all
door. One arrangement at the threshold is to have a recessed cha

bottom of the door rail containing a tongue which drops down as the door closes; an alternative is shown at N, consisting of an aluminium sill planted on the floor which has a rubber or plastic seating which deforms when the door is shut. Another way of preventing sound transmission at door edges is to leave the normal clearance gaps and have perforated edges to the door which itself is filled with an absorbent. Sound entering the gaps is thus absorbed within the door, this method is only worthwhile with doors at least 150 mm thick.

A door which provides not less than about 40 dB reduction is desirable but lower standards are often accepted because of the cost. Whilst many attempts have been made to design a well insulated timber door they have not been satisfactory due to the excessive thickness needed to provide adequate weight. A timber door cannot be guaranteed to be strong enough to remain true under the pressure needed to close it against the rubber beading, particularly as the pressure is at one place, *i.e.*, at the lock; such a door is also liable to warp. The only practicable solution is to use metal, and the one illustrated at M and N consists of two skins of 2 mm thick steel with two sheets of 19 mm thick insulation board in the cavity—this has a value of about 47 dB. The fibreboard provides good absorption at the resonance frequencies; loose infilling materials are not suitable because they tend to fall and consolidate.

Quiet action latches (*e.g.* with nylon bearings) should be selected and they should be better than average to ensure even pressure on the rubber seals. A suitable type has a wedge-shaped latch which can be moved by the door handle to exert pressure after the door has been shut.

Double Doors.—The simplest type of these consists of two doors having a minimum separation of 150 mm. An absorbent lining can be placed round the interspace and on the inside faces of the doors themselves which should have edge seals. Two 24 kg/m² timber doors used in this way, 200 mm apart, have a value of about 37 dB, but it is advisable to stiffen the edges by an angle as at L and L′; note the different positions of the rubber sealing strips for the opening and hinged sides.

A better arrangement, requiring more space, is to have a lobby about 2 m square between the doors as in the key plan at K—the lobby can be surfaced with an absorbent. This gives an insulation of about 45 dB, using 50 mm solid doors with stiffened edges and edge seals.

A revolving door (see Vol. IV) at the main entrance to a building assists in preventing the admission of street noises to the hall.

Windows.—Weight and edge seals are equally important here. Since additional weight can only be provided by using thicker glass and because this treatment is limited, single windows offer little protection. Double windows must therefore be adopted for effective insulation and, preferably, these should not be closer together than 200 mm; separate frames are advantageous. The following is the insulation value of different types of window:—(1) ordinary closed openable window—20 dB, (2) closed window with edge seals and 3 to 4 mm glass—23 dB, (3) as (2) but 6 mm plate glass—27 dB, (4) closed double window with edge seals, 4 mm glass and 200 mm air space with absorbent lined reveals—40 dB, (5) as (4) but 6 mm plate glass—42 dB.

Where only single windows are used, some absorption of external noise can be obtained by lining the ceiling near the window and the wall above it with an absorbent as at G. The method of opening the light is better than that shown by the broken line which would reflect sound directly into the room.

If timber windows are used, the lipped section (detailed in Fig. 55, Vol. I) is an improvement over the ordinary sash section.

The following table[1] shows the insulation of 215 mm thick brick wall having different areas of glazing; the single window is type (1) above, and the double one type (4):—

Percentage of Glazing	Single Window dB	Double Window dB
100	20	40
75	21	41
50	23	43
25	26	45
nil	value of a 215 mm brick wall = 50 dB	

MISCELLANEOUS NOISE

Plumbing.[2]—The noise from pipes, water-hammer, W.C.'s and cisterns can all be reduced as follows.

Pipes readily transmit plumbing noises and so they can produce vibrations in surfaces to which they are fixed, particularly if these are light and flexible. The vibrations can act as secondary sound sources. As always with noise problems, the trouble should be minimized at source by using quiet fittings. Plastic tubes are better than those of metal, but can only be used for cold water pipes which are sometimes under greater pressure than hot pipes; excessive pressure from the mains intensifies the noise. The use of gradual bends instead of elbows is preferable. Pipes can be rigidly fixed to thick walls so as to dissipate the energy; when fixed to lightweight partitions, a short length of flexible tube placed in the pipe near the source is helpful and fixing clips should be insulated by a resilient covering.

Water-hammer occurs in badly designed installations and is usually confined to pipes at main's pressure; it happens when a tap is closed too quickly, where bends are too sharp and at valves which cannot be closed gradually. The enclosure of the pipes in a chase, covered by a board and with felt wrapping, will reduce the noise, prevent frost damage and heat loss. Pipes that pass through a wall should be within a pipe sleeve, the space being caulked with asbestos rope.

The siphonic W.C. pan is quieter than the wash-down type, it can be set on a rubber pad and the void beneath it and the floor can be filled with a mix of 1 cement: 8 sawdust to deaden the noise. The W.C. cistern should be fixed to the wall with screws in rubber sleeves. The B.R.S. type ball-valve (see Vol. IV) is quieter than older kinds of valve; this can also be used for the storage cistern. Siphonic cisterns are reasonably silent.

The inlet to the cold water storage tank should be submerged to prevent the noise of splashing water, but it must have a hole at the top, above water level, to prevent

[1] Being extracts from C.P. 3, Chap. III.

[2] This subject is introduced in Chap. VI, Vol. I and fully described in Chap. X, Vol. IV.

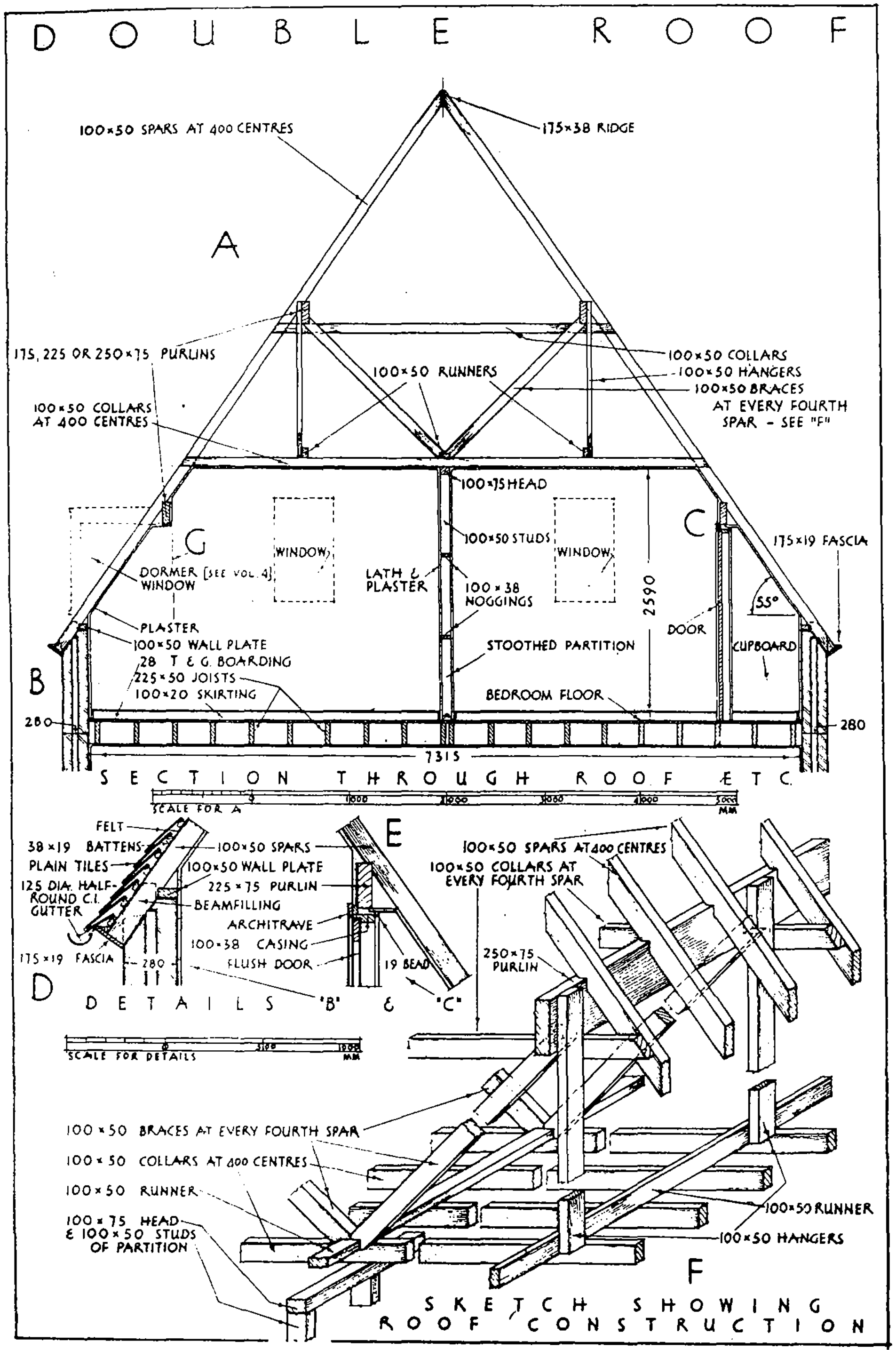

FIGURE 16

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The vibration of machinery can be reduced and often entirely use of resilient mountings such as cork, rubber or springs. If vibration of a machine is F Hz and that of the loaded mountings is ably, $F \div f$ should be greater than 4; a ratio of 4·5 corresponds to reduction of 25 dB. Other values are given in the following table

$F \div f$ (approx.)	Reduction of Energy Transmitted
1·4	0
2·5	13
4·5	25
7	34
10	40

Note that if the ratio is less than 1·4 a *magnification* of vibration occ facturer of the machinery will know F, and $f = 1 \div \sqrt{4h}$ where h is in metres for a rubber mounting for loads between 244 and 488 reduction can be calculated for a particular selected value of h.

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ROOFS

Single, double trussed rafter and framed roofs are describ Vol. I.

Double Roofs.—Two examples of a double trussed rafter not previously considered, are illustrated here in Figs. 16 and

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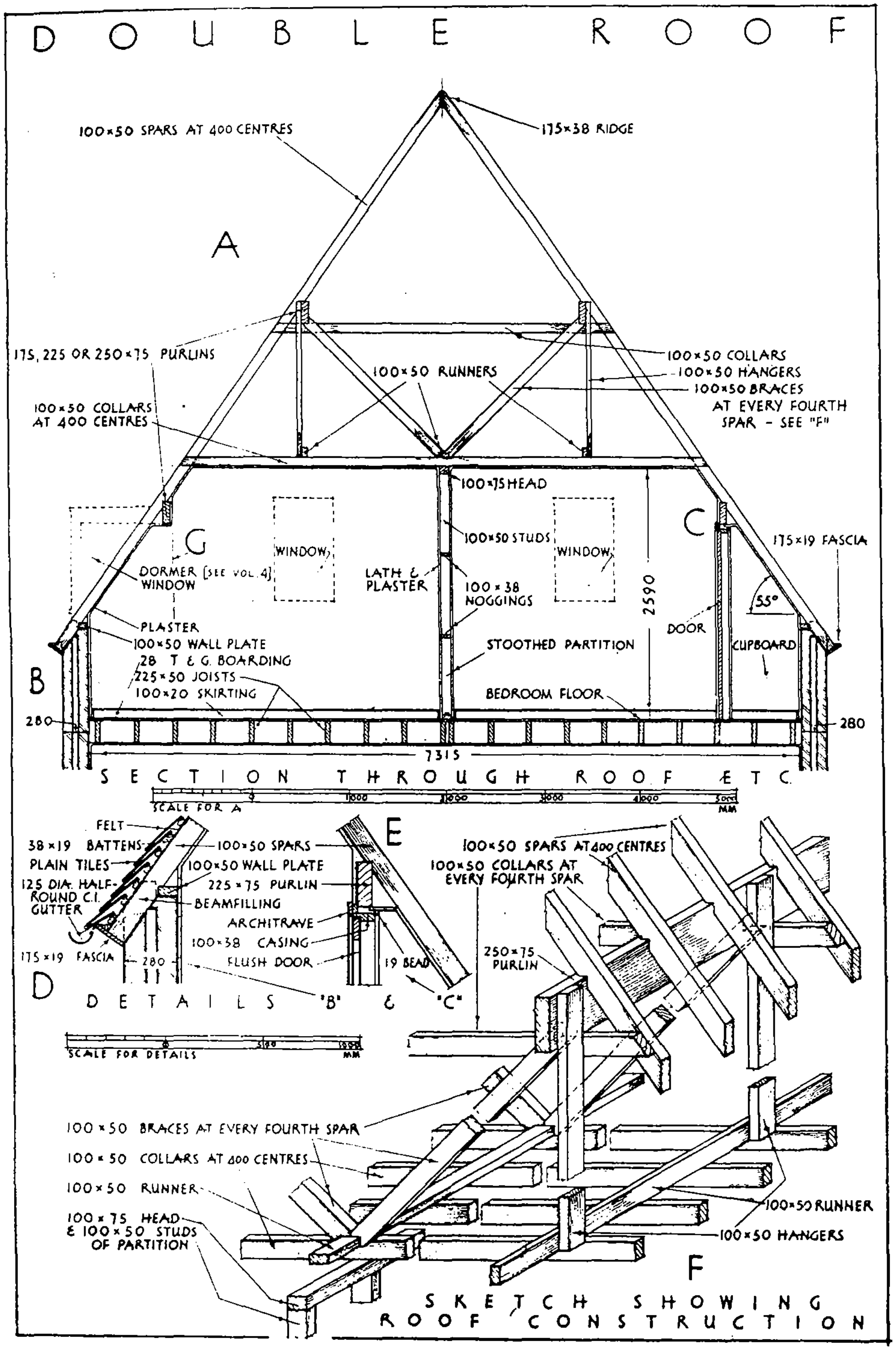

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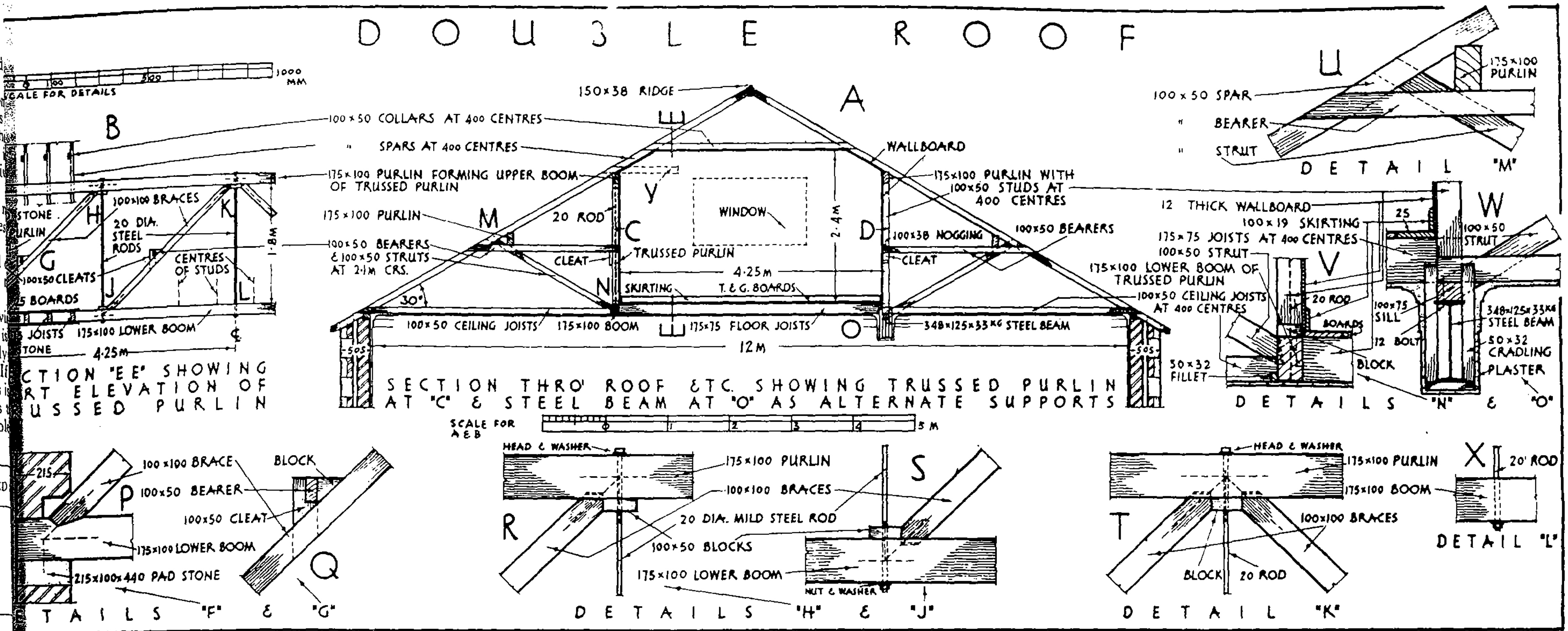


FIGURE 17

aining the necessary height of rooms when the roof has such a pitch. It con-s of spars, supported by two sets of purlins, and lower or principal collars. e spars and these collars are spaced at 400 mm centres. There is, in addition, econd set of collars supporting the upper pair of purlins; these collars are vided at every third, fourth or fifth pair of spars, to which they are securely led and preferably dovetail halved jointed (see Chap. III, Vol. I). The tion of roof between the collars is triangulated by braces or struts, birds-uthed to the purlins, and a central runner nailed to the ceiling joists and ced immediately over a stout stoothed partition (see Fig. 11). Hangers and ners are provided as intermediate supports to the ceiling (see Chapter III, . I), the former being spiked to the purlins and runners. Alternatively, the gers may be placed with their edges adjacent to and notched over the purlins runners, and nailed to the spars, etc. It will be noted that, like the upper lars, the braces and hangers are spaced at every third, fourth or fifth spar rt.

To ensure complete rigidity, it is advisable to provide an adequate support for the partition in the form of double floor joists, as shown at A, or a single joist of sufficient thickness.

The sketch at F shows more clearly much of the construction described above.

The section at A shows two alternative methods of treating the sides of the room. The shape of such a room is improved if, as illustrated on the right, a studded partition is fixed along the side below the purlin. The space between the outer wall, roof and partition may be utilized for storage. The door is detailed at E. *Ashlaring* is the term applied when studding is used for this purpose, especially when the floor is at the level of the eaves. A dormer window[1] is shown in broken outline on the left. If required, studding may also be employed here below the lower purlin, returned studded ends being provided at the window; the plastered face of the side studding would then be as indicated by the partly broken line at G.

[1] Dormer windows are detailed in Vol. IV.

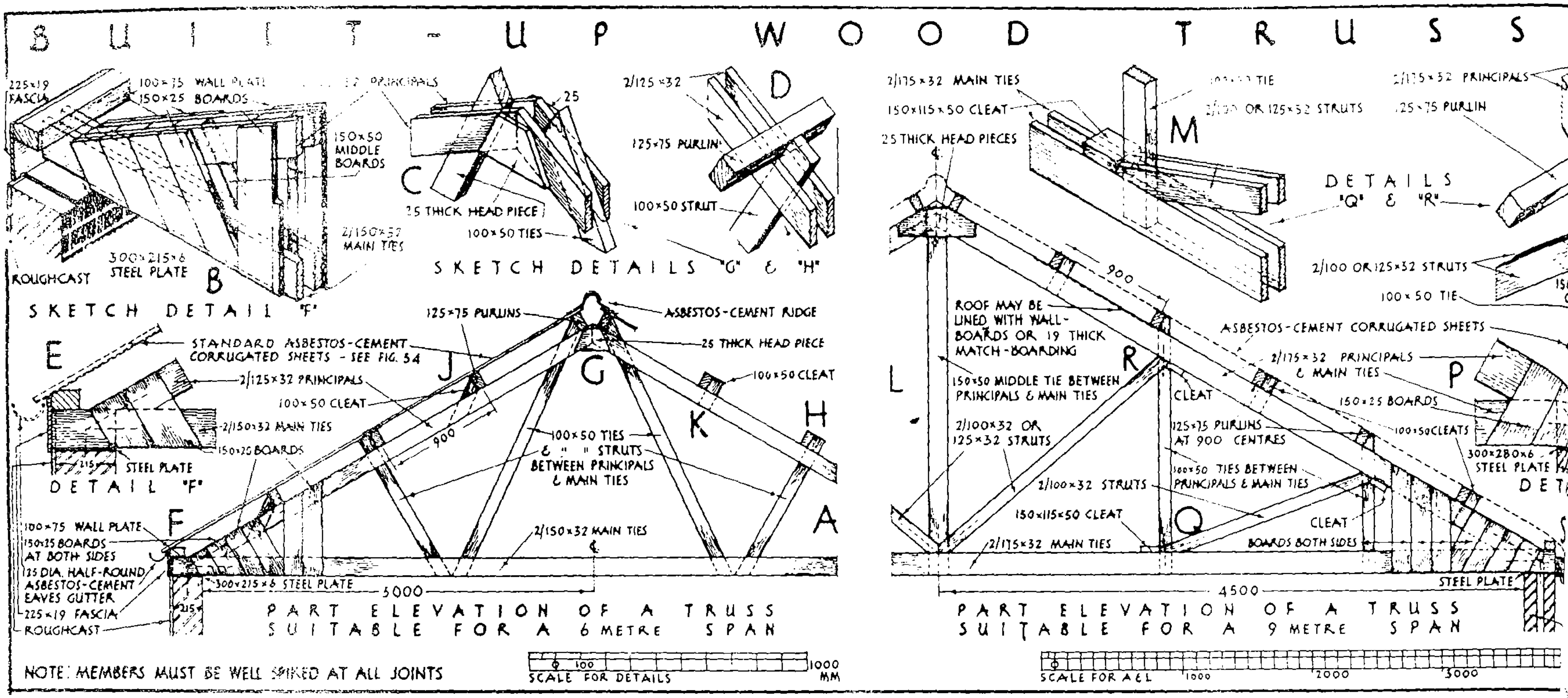


FIGURE 18

It is explained in Vol. I that it is usual to limit the unsupported length of purlins to 4·9 m and that roof trusses are provided when this span is exceeded. Whilst this conforms to the general practice, it is possible to dispense with roof trusses, provided some suitable alternative construction is adopted. The double roof shown at A, Fig. 17, is an example of a structure of moderate span in which roof trusses are not employed, although the distance between the cross walls is assumed to be 8·5 m. This shows two alternative means of support for the purlins, *i.e.*, a *trussed purlin* at C and a mild steel beam with a partition at D.

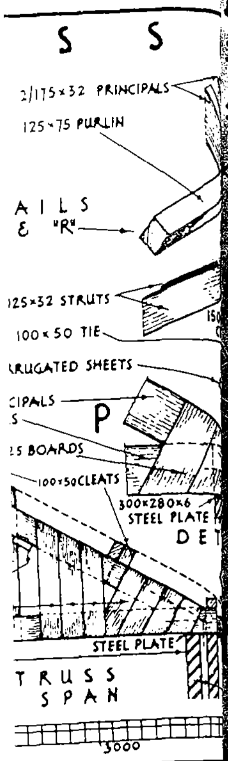
As shown at A, the central portion of the roof is so constructed as to provide bedroom, etc., accommodation which is lit by means of windows in the gable walls. Collars are placed at a sufficient height to give adequate headroom, and the partitions and ceiling are either plasterboarded and skimmed or covered with wall board (as shown), match-boarding, plywood, etc. If this space is only to be used for storage, the collars may be lowered to the position shown by broken lines at Y.

An elevation of a little more than half of the trussed purlin is shown at B. This is of lattice construction consisting of two longitudinal me *booms*, compression members or braces or struts, and tension me form of steel or wrought iron rods. The top boom is, in effect, a p vertically, which supports the spars birdsmouthed to it. The supports the ceiling, floor joists and partition (see V). In addition purlin supports part of the load from the lower purlin, which is t it by bearers placed at approximately 2·2 m centres (see B, C, Q an bearers are nailed to the spars at one end (see U) and to the brace (see Q). The structure is triangulated hereabouts by 100 mm by nailed to the spars (see U) and oblique mortised and tenoned to th (see V).

The studs provided at the trussed purlin are indicated at B b in order not to confuse the detail; these are fixed as explained on

Details of the trussed purlin are shown at P to V and X. Some that the centre-line principle has been observed in setting out the

The detail at P shows the structure to be supported on a pad



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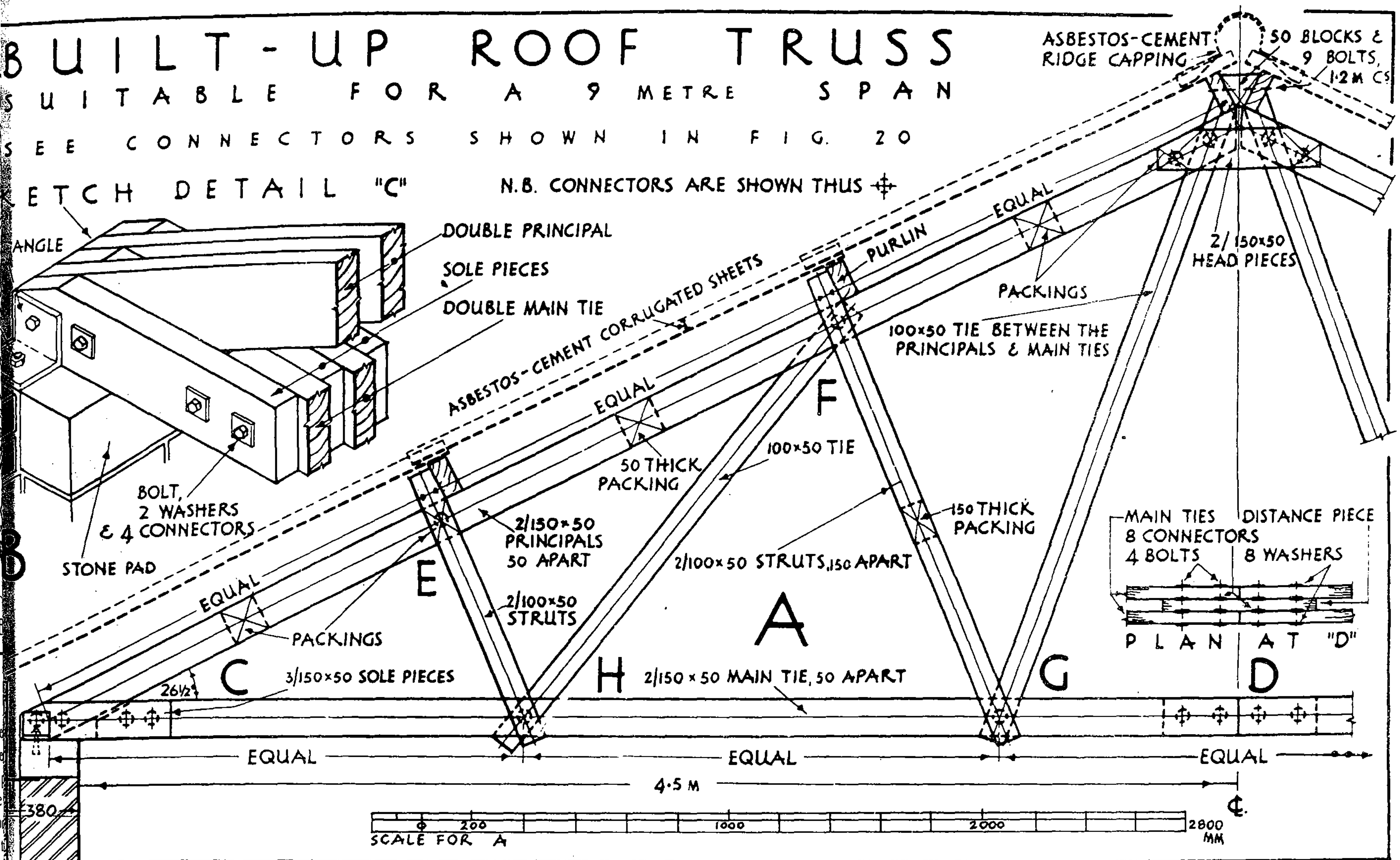

FIGURE 19

nd the foot of the brace is bridle jointed and well spiked (or bolted) to the boom. The detail at Q shows the bearer supported by a cleat notched to it and nailed to the side of the brace and purlin; a triangular block, to the back of the brace and to the bearer, assists in making a rigid con-. The opposite end of the bearer is spiked to the side of the spar (see U); ail halved joint (see Z, Fig. 36, Vol. I) may be used. The upper end of each end brace is tenoned to the purlin (see R), and a block, well spiked to the purlin, increases the abutment. Details at the ends of the middle braces are shown at S and T. Details at the ends of the rods are shown at R, S, T and X; the rods are provided with nuts and washers at their lower ends (see S and X), and details at R and T show the heads and washers. The rods are finally tightened after the trussed purlin has been erected and the roof covering fixed. The

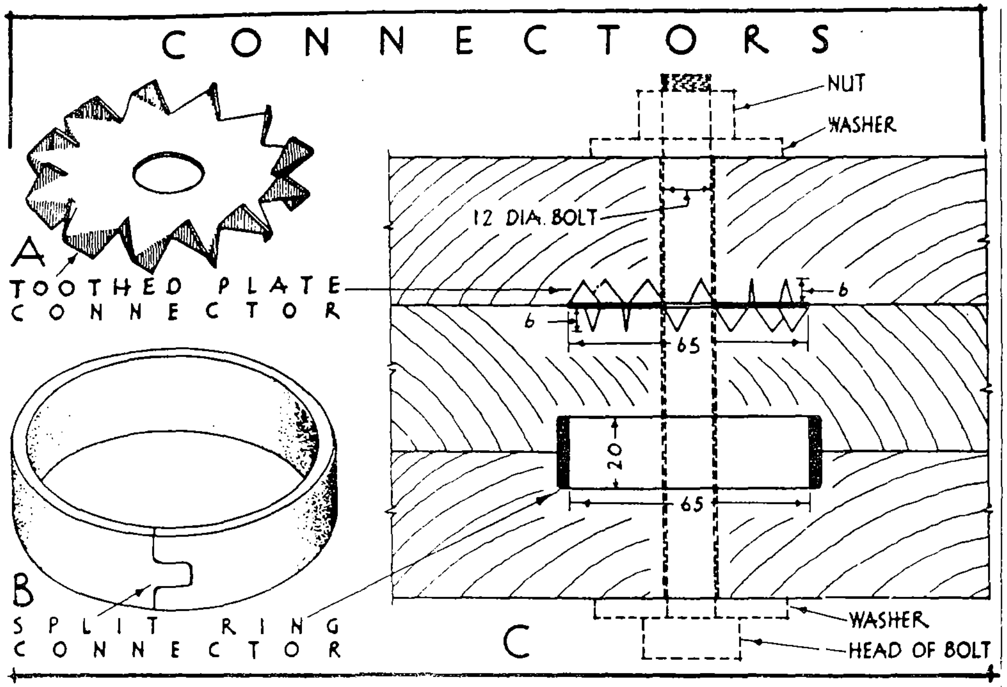

FIGURE 20

detail at V shows the ends of the floor joists dovetail housed (see M, Fig. 34, Vol. I) t^ the lower boom, and the ceiling joists are notched over a fillet well spiked to the boom.

The alternative support for the purlins is shown at D and detailed at W. The latter shows a section of a mild steel beam, which has a bearing at each end on a pad stone built into the cross wall, and to which the 100 mm by 75 mm sill of the stud partition is secured by 12 mm diameter bolts staggered at 610 to 900 mm centres. Cradling (see p. 35) is fixed for the plasterboard. The ends of the floor and ceiling joists have a 100 mm bearing on the sill to which the lower ends of the 100 mm by 50 mm struts are birdsmouthed. The top ends of the struts are secured to the spars, as are also the 100 mm by 50 mm bearers; the construction is therefore similar to that shown at U. The opposite ends of the bearers are supported on cleats fixed to the studs (see D). These struts and bearers are provided at every third, fourth or fifth spar.

Built-up Wood Trusses.—This form of truss is so called as its members are built up of thin timbers. *It is only employed when the covering material is light in weight*, such as corrugated sheets or large tiles of asbestos-cement (see pp. 139 and 140) or corrugated iron sheets. Roof construction of this type is most efficient and economical. These trusses are often used for farm buildings (stables, byres, sheds, etc.) and huts, and also for so-called semi-pe buildings, including certain schools.

Two examples are illustrated in Fig. 18. That at A is suitable fo preferably not exceeding 6 m. Details are given at B, C, D and E. Th light scan'ings which are simply *securely spiked* together at the joint principal rafter consists of two 125 mm by 32 mm timbers and the comprises two lengths of 150 mm by 32 mm stuff. The struts and s ties are single members and pass between each of these double member joint at the apex is made rigid by nailing a 25 mm thick board at each side This may be longer, as shown at L, and 25 mm boarding nailed at both the feet in addition to either 50 mm thick middle boards or short packin (see B) increase the rigidity of the structure. The spacing of the purlins upon the size of the covering and for asbestos-cement sheets this is usu centres. Provision must be made to prevent the purlins from tilting. the upper ends of the struts and subsidiary ties are continued as shown a (the purlins being omitted from the former for the sake of clarity); c provided as side supports of the intermediate purlins, preferably as sh or, alternatively, as at K.

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A detail at the eaves is shown at E. A deep fascia, plugged to the nailed to the wall plates, etc., is adopted to cover the ends of the main t the external wall is only 215 mm thick, and in order to prevent damp external face is covered with two coats of cement and sand mixture o casted[1] as indicated. An enlarged eaves detail is provided at K, Fig. 5

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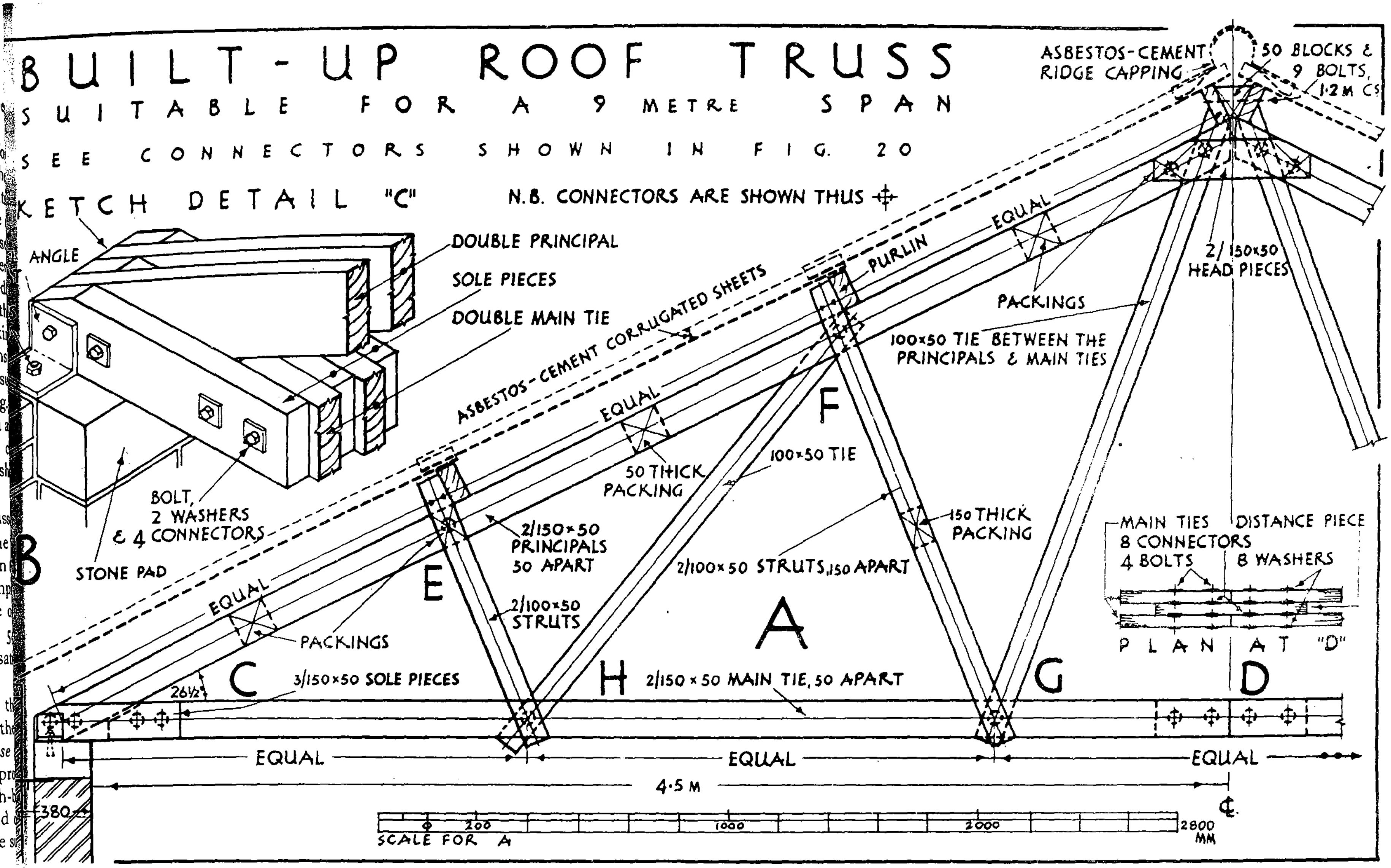

FIGURE 19

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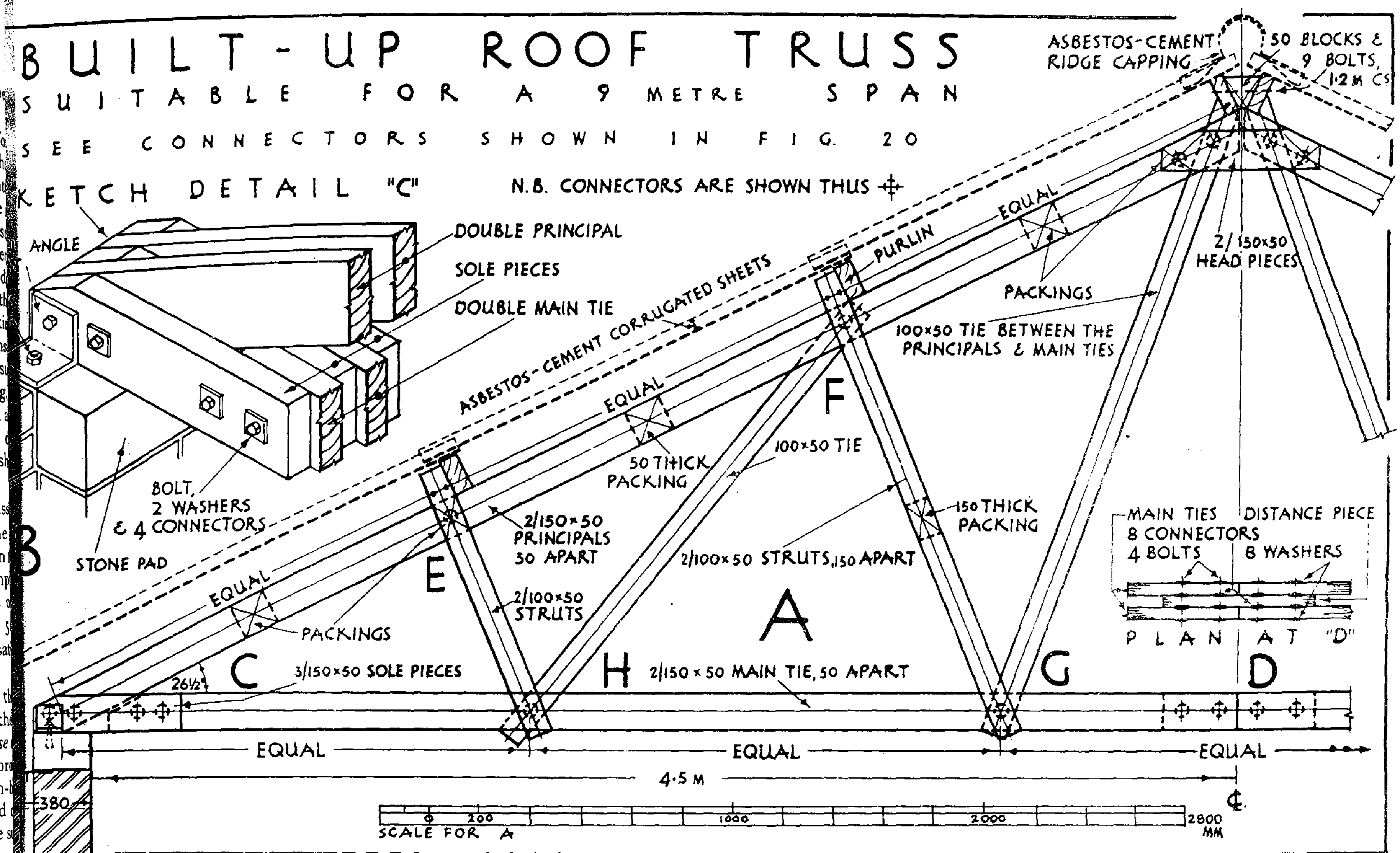

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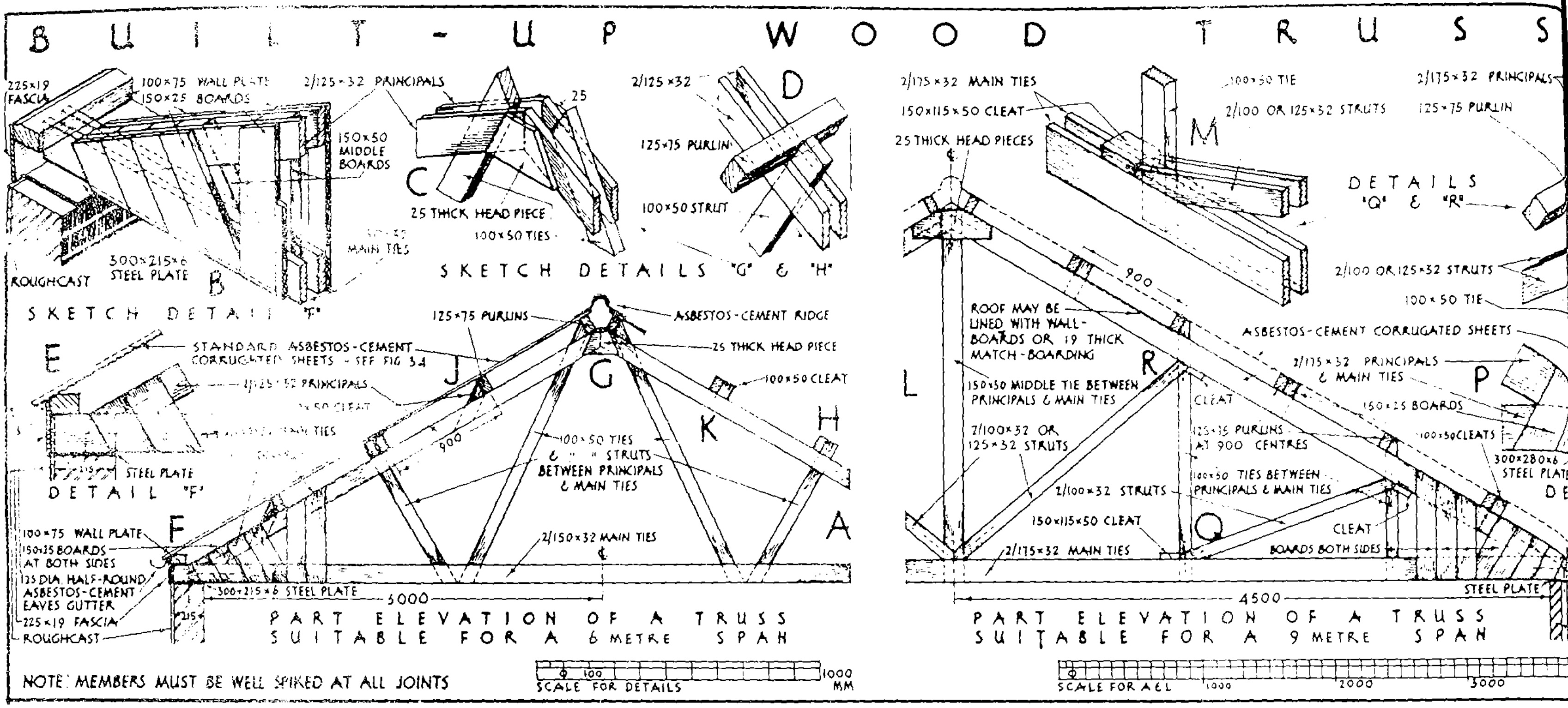

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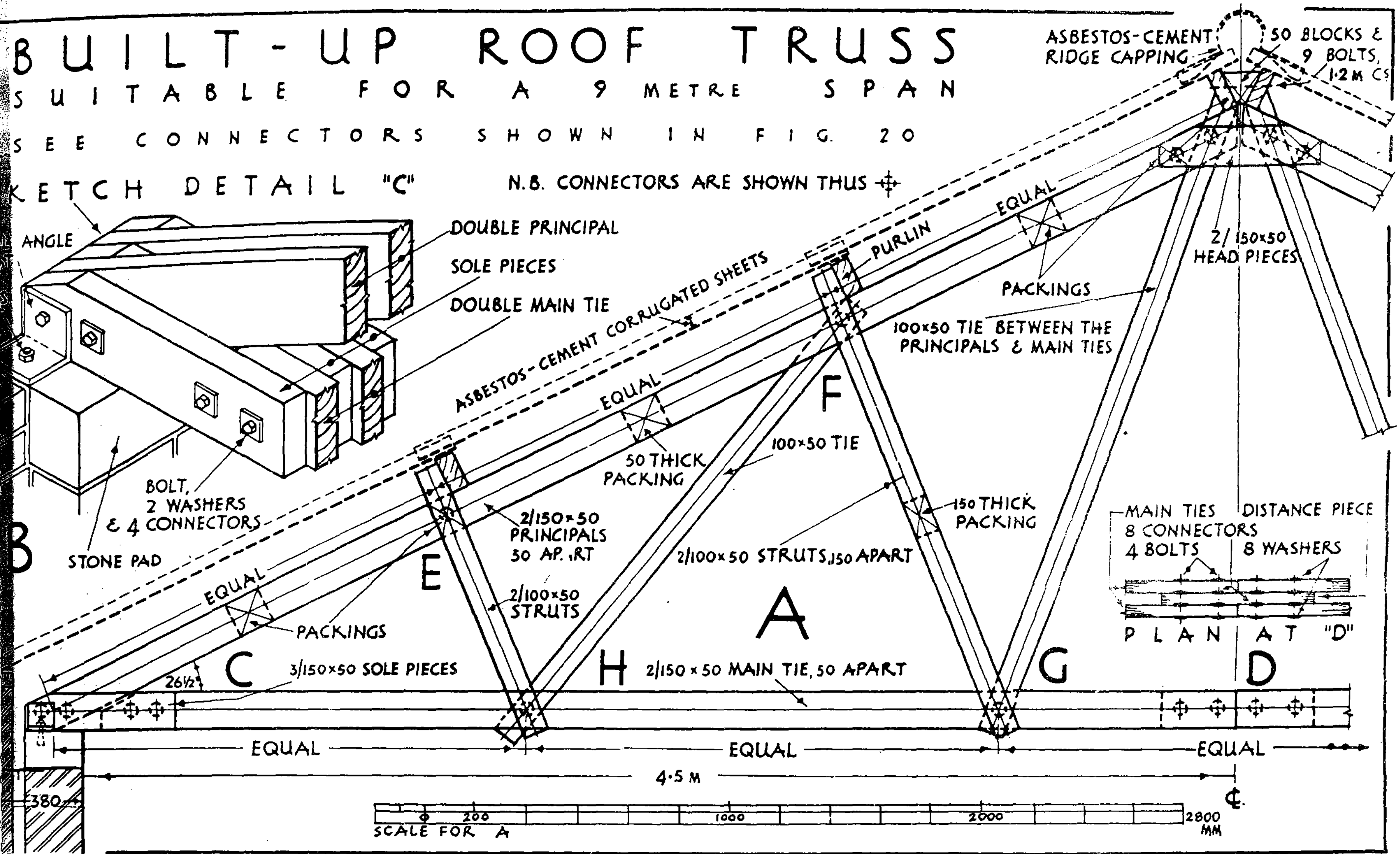

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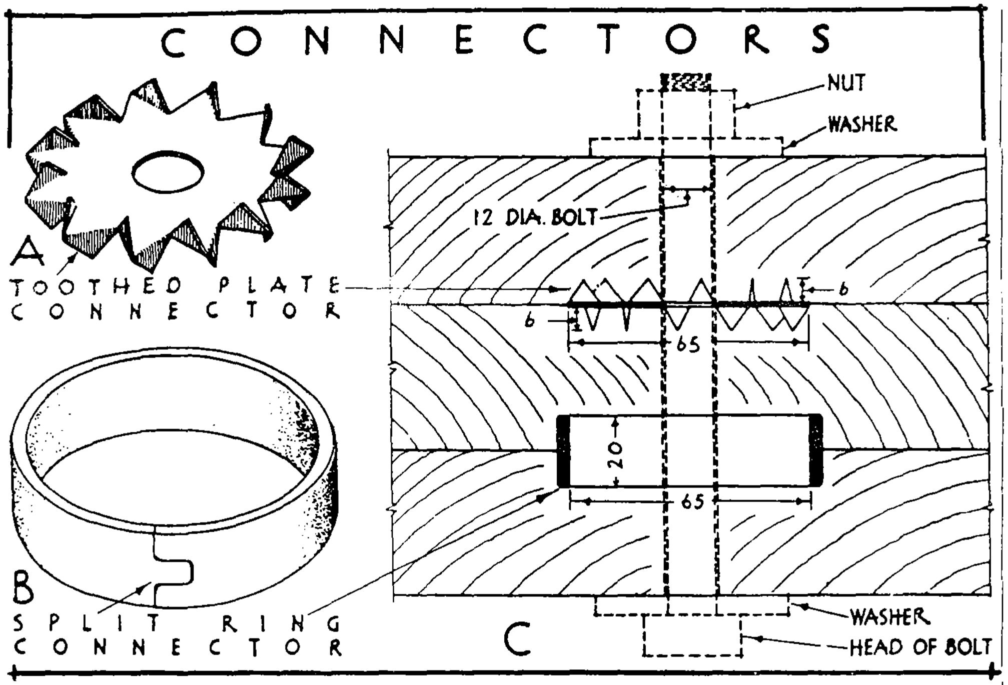

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Built-up Wood Trusses.—This form of truss is so called as its members are built up of thin timbers. *It is only employed when the covering material is light in weight*, such as corrugated sheets or large tiles of asbestos-cement (see pp. 139 and 140) or corrugated iron sheets. Roof construction of this type is most efficient and economical. These trusses are often used for farm buildings (stables, byres, sheds, etc.) and huts, and also for so-called semi- buildings, including certain schools.

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[1] Rendering is specified in Vol. I.

nother example of a *built-up roof truss* is given in Fig. 19. It is similar to ast-mentioned but *timber connectors* (see below) and not nails are used n the members. This type is more economical than the king post[1] and post[1] roof trusses, especially in the labours involved at the joints, and can d for spans up to 14 m. The design and size of members depend upon an, distance apart of the trusses, quality or grade of the timber employed e weight of the covering material. That shown is typical for a clear span , truss-spaced at about 3·7 m centres and supporting a light roof covering; ch is one-quarter (26½°).

connector is required at each interface. Thus, four connectors are needed h of the joints E, F, G and H, eight at D, and sixteen each at C and the apex.

The foot is strengthened by three sole pieces—see B. As shown, the truss is cured by a 100 mm by 100 mm steel angle cleat (one at each side) with a 12 mm . bolt through the main tie (and connectors) and a 16 mm by 400 mm long lewis lt let into the stone pad.

The principals at the apex are secured by a head piece (or *gusset*) at each side. e purlins are bolted to the projecting ends of the struts (see also D, Fig. 17); those the apex are either bolted or spiked to the ends of the ties and, as indicated, 50 mm ck shaped blocks at 1·2 m intervals are bolted to the purlins as a further safeguard ainst the latter tilting. Purlins should be spliced over trusses.

Main ties may be in two half-lengths and spliced together with a distance piece packing between—see D, Fig. 18; this also enables a truss to be conveniently nsported to the job from the workshop in two halves which are then joined together the site. Trusses for large spans may have two splices at one-third points in the in ties, and one splice at mid-point of each principal; gussets (as at B) may be used e as stiffeners.

Principals and long struts are stiffened by packings, as shown, of thickness equal the distance between adjacent members, and securely nailed. These packings are uired also at E and the apex (for the two outer sets of connectors only).

nber Connectors.—Made of galvanized steel, these patent devices are r joining together members of built-up roof trusses and similar framed res. In the ordinary bolted connection most of the stress is concentrated outer contact surfaces of the members, whereas in a connector joint the is distributed over a wider area of timber and therefore the load is ffectively transmitted from one member to another. Hence a connector more efficient, and stronger than an ordinary bolted one.

There are several forms of connectors, two in common use being shown in Fig. 20. That at A and C, called the *toothed plate* or "*Bulldog*" metal connector, is from 50 to 95 mm diameter, that shown being a 65 mm ring of approximately 1 mm thickness and having twenty-four pointed triangular teeth (twelve on each side) turned off at right angles to the plate. Assuming that a simple joint between two members is required, as shown at C, a toothed ring connection is made in the following manner: With one member placed above the other, a hole is bored through both at the desired position, the top member is removed, a toothed ring is placed centrally over the hole in the bottom timber, and the top member is returned. Force is now exerted to embed the connector and bring the surfaces of the timbers together; a special strong bolt, with nut and washers, is used for this purpose; this bolt is placed in the hole, and after the nut has been tightened, a long-handled spanner is applied to its head until the joint is closed. This special bolt is replaced by an ordinary 12 mm (or 16 mm or 19 mm) dia. bolt with nut and washers. A connector is required at each interface and thus two are needed at C, Fig. 20.

The 65 mm circular *split ring* connector shown at B and C is 3 mm thick, 100 mm dia. is also available; it has a tongued and grooved split which enables the ring to open slightly when the structure is loaded, causing both sides of the ring to bear against the timber and thus transmitting the load over a relatively wide area. A special grooving tool is used to form a circular groove (half ring-depth) on the face of each adjacent timber to accommodate the ring.

Mild steel roof trusses, suitable for relatively small spans, are illustrated in Vol. II. The roofing of wide span buildings is described in Vol. IV.

TEMPORARY TIMBERING

The use of timbers for the temporary support of trenches and newly constructed arches is dealt with in Vol. I and extended here. A description of shoring follows on pp. 72–75.

TIMBERING OF EXCAVATIONS

Whilst this work is not carried out by carpenters, but by those actually engaged on the digging operations, it is convenient to include it here.

Reference should be made to the typical methods of supporting the sides of shallow trenches described in Chap. III, Vol. I. The various members there mentioned are also used for deep trenches. These include poling boards, walings, struts and sheeting.

The object of the timbering is, of course, to retain the sides of the excavations and thereby (*a*) provide safe conditions for the men engaged upon the digging operations and the subsequent construction work, and (*b*) prevent damage occurring to adjacent buildings, road surfaces, and drain, gas, water, etc., pipes.

Several methods of timbering employed for comparatively deep trenches are illustrated in Fig. 21. *These are typical only.* The sizes and disposition of the members are subject to considerable variation, according to the nature of the soil, the earth pressure to be resisted, the time occupied between the start of the work and the filling in of the excavations, and the stock of timber which is readily available.

There are many kinds of soils, varying from a sound rock in a cutting through which no timbering is required, to silt or mud in which excavations can only be made with difficulty and after close boarding or the equivalent has

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[1] e *king post roof truss* is obsolete like the *queen post truss*; they were in use prior to elopment of built-up trusses.
king post truss was used for spans up to 9 m. It consisted of a tie beam and a centre king post which was connected to the meeting point of the principal rafters mid point of the tie beam.
queen post roof truss was adopted for spans up to 14 m; it consisted of a tie beam, ical queen posts at one-third span spacing, horizontal straining beam connecting f posts, principal rafters from tie beam to heads of posts, horizontal straining sill feet of posts and nailed to tie beam, and two struts (inclined from near feet of mid-principal rafters); each principal rafter supported two purlins (at heads of d post).

been provided. Extreme conditions may exist on one site, and therefore a common system of timbering cannot always be adopted throughout.

Earth pressures are also variable. Thus, a dense clay when subjected to heavy rain may expand and exert a considerable pressure on the struts in a newly timbered excavation, but the same soil may shrink in dry weather to such an extent as to cause the timbering to collapse if precautions—such as the tightening of the struts and regular inspection—are not taken. In most soils the pressure does not increase with the depth of the excavation, and therefore in a deep cutting in soil which is the same throughout, the size and spacing of the timbers at the bottom need only be the same as those provided near the surface.

Trenches which are to remain open for a long time usually require more poling boards and larger walings and struts than those cuttings which are to be refilled quickly. The less the distance apart of the struts, the smaller the sizes of the walings and struts required.

The timbers are roughly sawn, and the following are commonly used: Spruce for poling boards and runners (see p. 68); pitch pine or Douglas fir for large squared members such as walings, struts and props; larch for circular struts and props; and beech or pitch pine for wedges.

Trenches in Moderately Firm Ground (see A, B and C, Fig. 21).—The section at B is that of a trench in which a drain is to be constructed and shows approximately 1·2 m depth of loamy soil or dry chalk, which does not require close or heavy timbering, overlying a bed of loose gravel which needs to be timbered more closely.

The upper 175 mm by 38 mm poling boards, placed at 450 mm centres (see C) are held in position by a single waling along the centre, and they are accordingly known as *middling boards*. Struts are placed between the walings at a minimum distance of 2 m so as not to unduly impede the digging operations.

The lower set also consists of middling boards. These are wider than those in the upper "setting," although the narrow boards may also be employed, provided the distance between them is that considered to be necessary, *i.e.*, 150 mm.

A pair of walings, together with their struts, is known as a *frame*, and it is advisable to support these by vertical props or *puncheons*, wedged between the walings at or near the ends of the struts. Puncheons are necessary, especially in deep excavations where the ground is uncertain, to prevent the walings from dropping. They are often dispensed with when the ground is reasonably firm and the trench is to be left open for only a short while. In this example, each puncheon is placed between the walings and continued with a short piece supported on a *sole plate*, partially embedded in the ground, to distribute the weight. As shown more clearly at D, a pair of *driving* wedges (or a pair of folding wedges as used for centering, see Fig. 22) are used to tighten the lower puncheon, and the upper puncheon is brought tightly up to the top waling by driving wedges between its foot and the lower waling (see A).

A *platform* or *staging*, necessary to receive the soil as the excavation proceeds, is shown at B, C (by broken lines) and a portion at A. This necessary is referred to in the next column.

The following is the usual procedure adopted in fixing this type of The ground is excavated to a sufficient depth to allow the top setting to A waling is placed along each side in the correct relative position and by temporary puncheons. A pair of middling boards is placed be walings and the sides of the excavation at approximately 2 m centre wood packing pieces are placed between the boards and the walings, pieces are afterwards replaced by small wedges called *pages*. A fitted between the walings opposite each pair of boards and tightened in wedges at *one side only*. The rest of the polings are now placed between the walings and soil and forced tightly against the sides of the by driving down pages between the boards and walings. The exc continued to the required depth and timbered as described above. I of the middling boards of the lower setting are level with the feet of th all the former can be placed in position by forcing their lower end ground and nailing them at the top to the boards above. The w struts of the bottom setting are then placed and wedged, and the are finally fitted and wedged.

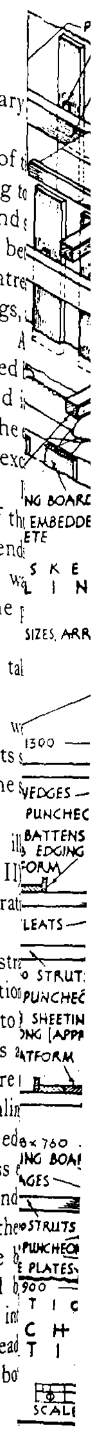
The struts should be tightly wedged, although care should be ta disturb the sides of the excavation by overdriving the wedges.

The timbering should be regularly examined and any slack w pages, due to the shrinkage of the soil, etc., tightened. If the struts of bending, due to the extra pressure caused by the expansion of the very wet weather, the wedges should be eased as required.

The sketch at A shows more clearly the timber details and il portion of the drain, embedded upon concrete, (see Chap. II, Vol. II

Middling boards are only suitable for trenches dug in comparat ground.

Trenches in Doubtful Ground (see F, G and H).—These illustr of poling boards, called *tucking boards*, which are used for excavatio soil, such as made-up ground (soil, etc. which has been tipped into the ground and levelled over) and soft clay. The section shows a wide trench required for a sewer, and three settings of boards are The boards in each setting are secured at both ends between walin of the middle and lower walings has a continuous wood fillet nailed with its upper edge (see V); this is called a *liner*, and its thickness of the boards. The upper boards are "toed" into the soil behind of the middle walings until their feet are approximately level with the of the walings. Pages are driven down at the top between the walings and, as required, at the bottom between the liners and H and V). The boards forming the second setting are "tucked" in (hence their name) by placing them diagonally and fitting their head the waling and the feet of the upper boards, and forcing their bo



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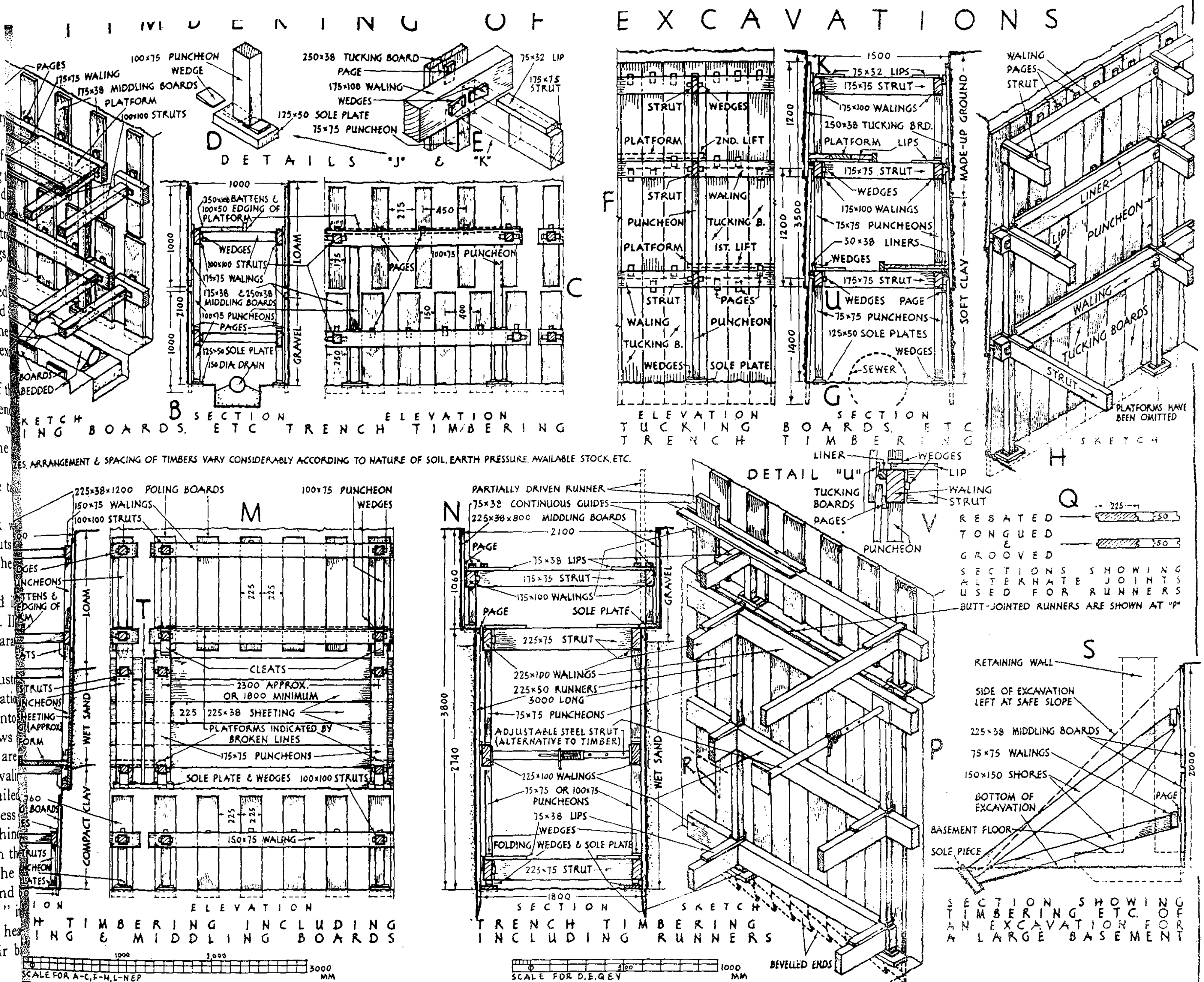


FIGURE 21

into the soil behind the liner nailed to the lower waling until they assume a vertical position. Pages are inserted to fasten any loose boards. The boards in the bottom setting are placed and held in a similar manner. The walings are supported by puncheons and the struts are tightened by wedges, as described on p. 66.

To facilitate the handling and fixing of heavy struts, it is customary to nail short strips of boards at their ends (see E, G and H). These are called *lips* or *lipping blocks*. The struts are placed in position with their lips supported on the walings, and wedges are then driven in horizontally between one end of each strut and the waling. Temporary props may be used in lieu of lips.

Two platforms are shown in the section at G. The limit to which men can conveniently throw the excavated soil is considered to be 1.5 m. Hence platforms or stages to receive the soil must be provided at approximately 1·5 m vertical intervals, and the top stage should preferably be not more than 1·2 m below the surface in order that the earth deposited on it may be thrown well away from the sides of the trench Platforms consist of stout planks placed upon struts which are either cleated (see L) or propped. An edging to a platform as shown, assists in retaining the heap of deposited material. They are usually arranged on alternate sides (see G and L) and staggered, as shown by broken lines at F and M. The soil excavated from the lower level of a deep trench is therefore shovelled from one platform to another and until finally disposed of at the ground level. Thus, at F and G the earth would be thrown on to the bottom platform (known as the *first lift* or *throw*), a man working on this platform shovels the material on to the top platform (or *second lift*) from which it is thrown out of the trench. In large excavations the soil is often shovelled into receptacles which are lifted by a crane and deposited where required on the site or emptied direct into a lorry in which it is conveyed to the nearest convenient tip.

Trenches in Loose and/or Waterlogged Soil.—Great care must be exercised to prevent the caving in of trenches formed in bad ground. The soils which come under this class are soft plastic clay, certain conditions of sand, silt, wet chalk and peat. Damp sand is not difficult, but it can be most troublesome if it is in a very wet condition or is fine and dry. The latter is not easy to confine, as it readily " flows " through small spaces between timbers; the escape of such loose material may cause settlement and the total collapse of the timbering. Such bad ground is retained by either (*a*) horizontal sheeting or (*b*) vertical timbers called *runners*.

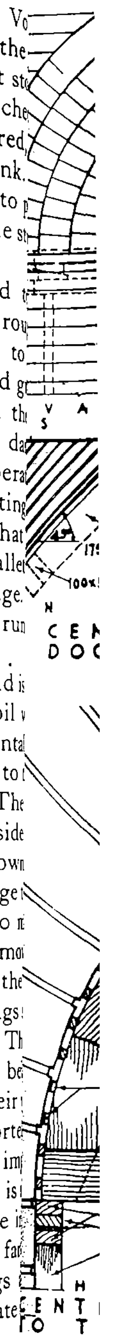
(a) *Sheeting* (see L and M).—The section at L shows a stratum of wet sand between two beds of moderately firm ground. This, therefore, shows the application of a composite system of timbering.

The lower portion is timbered with middling boards, as described on p. 66, the upper setting may also consist of these boards. As an alternative, poling boards with two frames instead of one have been shown as the support in the upper setting.

The sheeting is fixed in easy stages, as described in Chap. III, Vo
small openings between the boards, as at T, should be *stemmed* by the
wads of grass or straw between the timbers. Whilst this does not st
of water, it does prevent the infiltration of particles of sand. Punche
be used, as indicated. The sides of the trench are shown battered
which is sometimes adopted if there is a tendency for the soil to shrink
this does not prevent the struts from working loose, it does tend to p
collapse of the timbering. Careful supervision is necessary, and the st
must be adjusted as required.

(b) *Runners* (see N and P).—These are generally preferred
especially for deep excavations in bad ground. Runners are ro
timbers from 50 to 75 mm thick, 150 to 225 mm wide and up to
They may be square edged, as shown at P, rebated, or tongued and g
Q). Rebated runners are very effective for close timbering, but th
type is not now favoured, as the grooves and tongues are readily da
small stones are apt to clog the grooves and impede the driving opera
lower ends or toes are bevelled and shaped as shown to give a cutting
facilitates insertion and forces each runner against the edge of that
driven. These runners are driven in by blows from a heavy malle
heads are often bound with hoop iron to protect them from damage.
are also sometimes shod with steel or hoop iron, especially if the run
be driven through a hard stratum.

In the section at N, the upper 1·2 m of soil is moderately firm and i
by a setting of middling boards. But below this, wet clay or soil
cohesion necessitates the employment of close timbering. Horizonta
guides, consisting of two 75 mm by 38 or 50 mm stuff, are nailed to
with a space between through which the runners are passed. The
for the runners is fixed, the walings being packed out from the side
the runners to pass behind them. The runners are driven dow
time, as far as possible without exerting such force as would damage
The excavation is then proceeded with, leaving about 225 to 300 m
lower ends buried. Driving is recommenced, followed by the remo
soil. When the excavation has been lowered to some 1·2 m below the
frame, a second frame is fixed and puncheoned; the lower walings
additional guide and ensure the vertical driving of the runners. Th
driven in this manner until the necessary depth is reached, frames be
about 1·2 m intervals. In some soils, the runners, because of their
be forced into the ground for several feet before driving is resorte
sides of the excavation must always be supported, and hence the im
not exposing the feet of the runners. A partially driven runner is
and P, the toe of which is about a foot below the bottom of the t
cutting indicated by a broken line at R; the pile must be driven fa
more soil is excavated. Pages are inserted behind the walings
(see N). These and the strut wedges are slightly eased to facilitate



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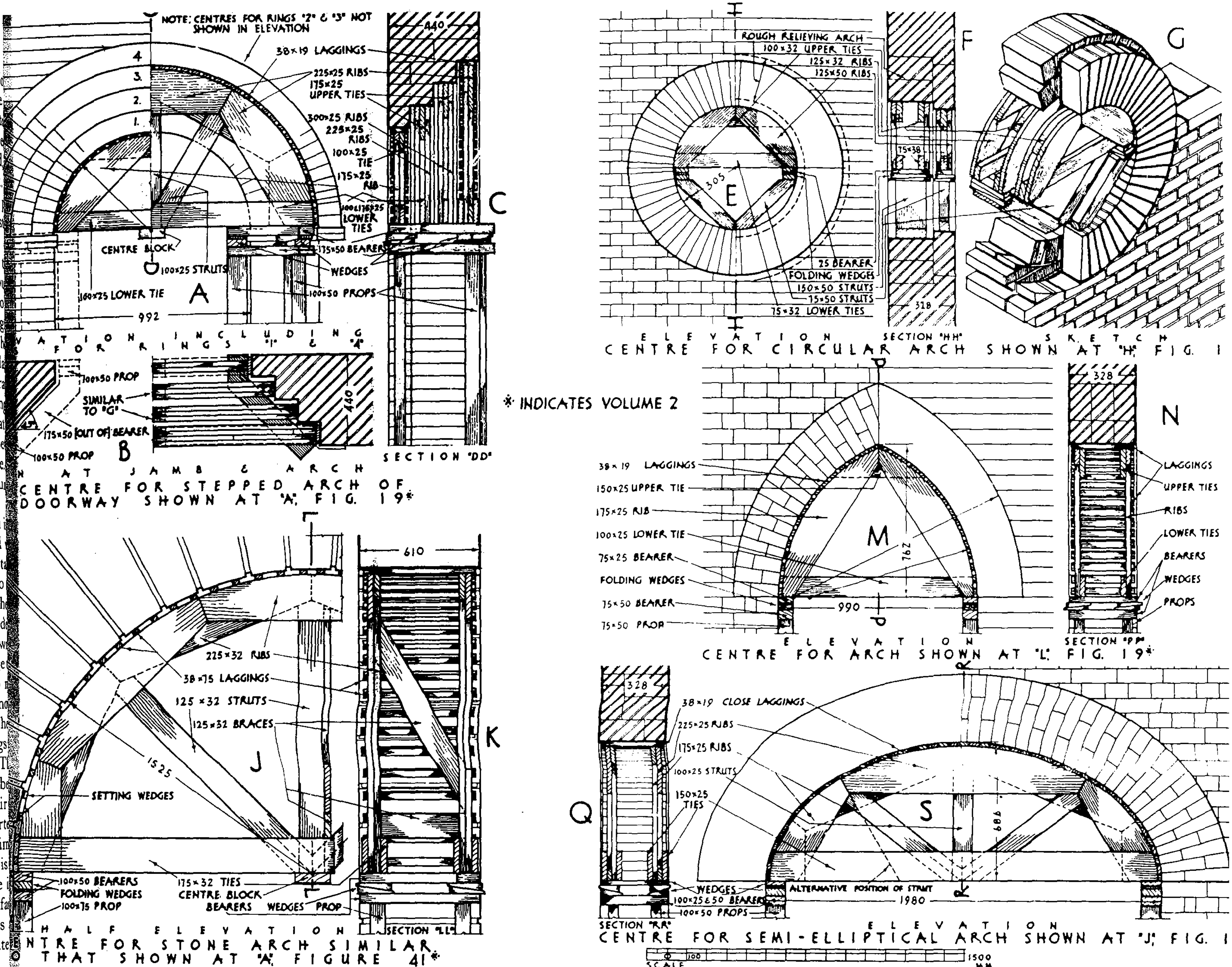

FIGURE 22

and prevent disturbance of the walings and struts. It is often necessary to provide scaffolding for the men when driving the runners. Such may be dispensed with if the ground will permit the use of an upper setting of middling boards and correspondingly reduced length of runners. If the runners are required to extend for the full depth of the excavation, the top frame is fixed at the surface, and the continuous guides are strutted at some 600 or 900 mm above the ground.

The drawing at N, also shows the use of steel adjustable trench struts; by turning a lever these can be shortened or lengthened as required. They are an alternative to timber struts.

Drainage.—The admission of water to trenches will cause discomfort to the men working in them (and thereby affect adversely the quality of the work) and may cause the timbering to collapse by converting the soil (such as loamy clay or chalk) into a liquid consistency. Steps should therefore be taken to exclude surface water, and remove any which would otherwise accumulate in the trenches. Surface water is dealt with by cutting small channels or *grips* which are given a fall away from the excavations. A trench in a waterlogged soil is usually drained by means of a grip cut at the bottom and along one side of the excavation, and given a fall towards a convenient point where a hole or *sump* is formed to receive the water which is removed by pumping.

On seriously waterlogged sites it may be necessary to resort to the use of dewatering —see Vol. IV.

Large Excavations (see S).—This shows the application of timbering to the sides of an excavation such as is required for the construction of the basement of a large building. As much of the ground as possible is excavated, the sides being sloped off at a steep inclination (see thick broken line). The excavation near the sides is then proceeded with, the vertical faces being supported temporarily by middling boards, etc., depending upon the nature of the soil. These are supported by walings which, in turn, are maintained in position by inclined struts or *shores*. The feet of the latter abut against stout timber sole pieces, or wood platforms, well anchored into the ground.

Sometimes patent interlocking sheet piles of steel (see Chap. I, Vol. IV) are used instead of timber. These are driven in, like runners, trenches are excavated, the retaining walls are constructed and the bulk excavation is then carried out.

The sides of smaller general or site excavations are often supported by runners, walings and long baulk timber horizontal struts propped vertically at intervals.

These methods are described more fully in Vol. IV.

CENTERING

Centres up to 1·8 m span are described in Chap. III, Vol. I. Most syllabuses of Building Construction, Second Stage, include centering suitable for spans not exceeding 3 m, and typical examples of these are illustrated in Fig. 20 of this volume.

The construction of centre differs widely according to the sha
width of soffit and the material of which the arches are to be constr
addition to the scantlings of the timber available.

A centre must be of sufficient strength to temporarily support the l
imposed without distortion, and it must therefore be designed to resist
pression and tension stresses set up during and after the construction of
(see p. 72). Being a temporary structure, a centre must be econo
material and capable of quick construction. Folding wedges must be
to permit vertical adjustment, such as the slight raising or lowering of
into correct position prior to the construction of the arch, and for its su
easing and striking with the minimum vibration.

Centres for Pointed Arches.—An example, suitable for the Vene
illustrated at L, Fig. 19, Vol. II, is shown here at M and N, Fig. 22. Ea
which laggings are fixed, is well nailed to upper and lower ties or *stretch*
construction is similar to that shown for the semicircular arch at J, Fig.

Centre for Circular or Bull's-eye Arch (see E, F and G).—This o
to receive a fixed or pivoted light, the frame of which is fixed in the rece
lower half of the brickwork is constructed as explained in Chap. I, Vol. I
must be allowed to set before the centre is placed in position. Th
consists of two portions, one for the external purpose-made arch and
for the rough arch,[1] and it rests upon wedges supported by struts.
be noted that no laggings are used for the external arch, as they are not
when the width of soffit is only 102·5 mm. Neither have they been
for the inner arch on account of the small span. If necessary, a short cr
may be nailed centrally to the underside of the upper ties. The oute
consists of a pair of ribs nailed to upper and lower ties; sometimes
rib is used for such a small span. Because of the greater width of
inner centre requires two ribs, placed at approximately 175 mm centres,
two pairs of ties. In lieu of struts the wedges of each portion may be s
on a ring of bricks laid dry on the lower half of the arches.

The elevation of the inner portion of the centre has been omitted
for the sizes of the members this is similar to that of the outer portio

Centre for Semicircular Arch with Orders.—The centre illus
A, B and C, Fig. 22, is suitable for the head of the entrance shown at A
Vol. II. In effect, this is a compound structure consisting of a centre
of the four rings. The centre for the inner ring, which is first erected,
to that shown at J, Fig. 41, Vol. I. Laggings, as shown, are sometimes
as the soffit is only 102·5 mm wide it is usual to dispense with them and
centre similar to those shown for rings 2 and 3; when the span is
latter type may be further simplified by the omission of one of the
indicated on the plan B, the centres for rings 2 and 3 may be of the ty

[1] The lower half of this rough arch need only consist of one ring (see sketc
internal face is to be plastered; otherwise it may be formed of two rings as su
the broken lines at E.

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M and N, Fig. 22. E
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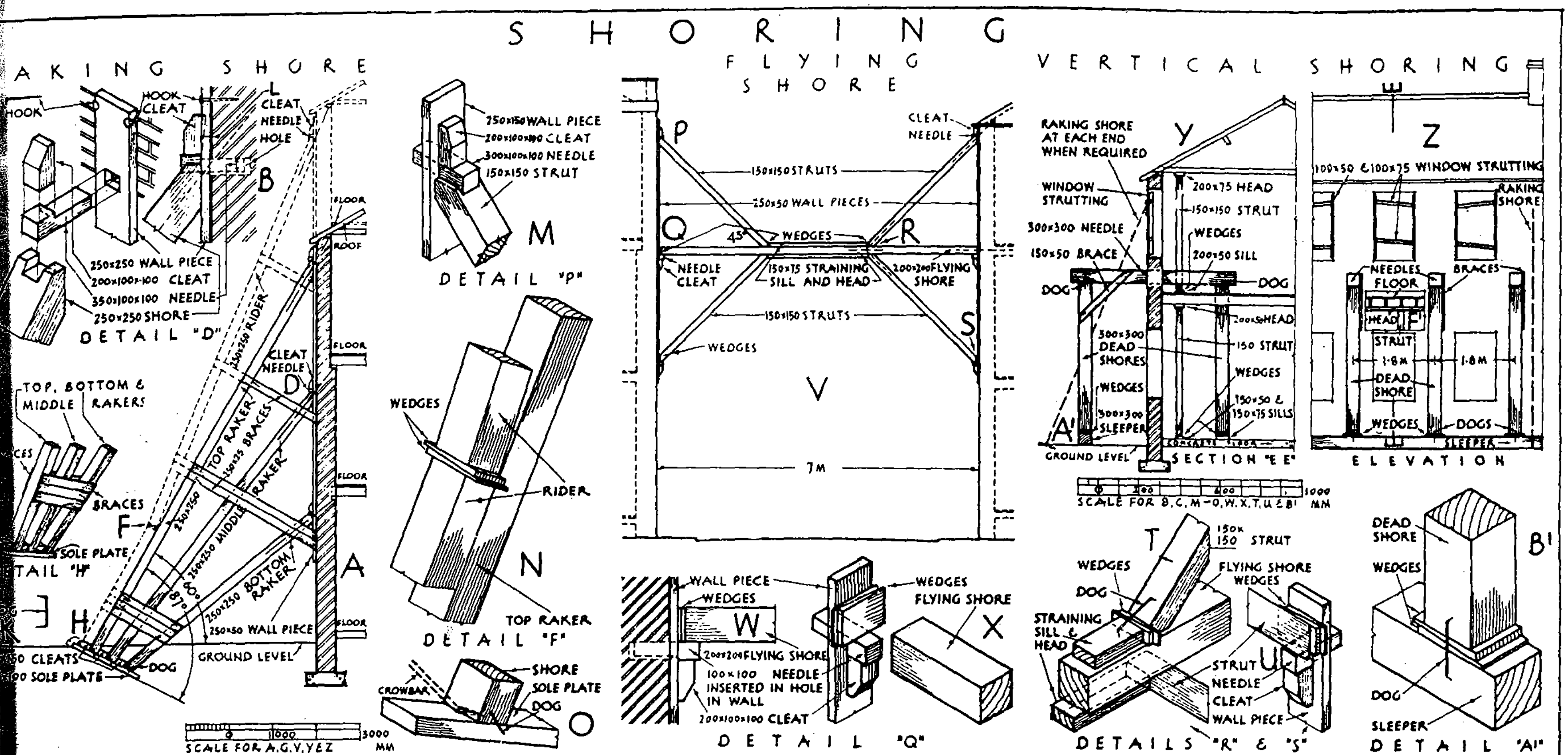

FIGURE 23

the outer arch at G, described above. The centre for the outer ring 4 the type shown at M, Fig. 41, Vol. I, and needs no further description; again the laggings may be omitted.

Because of the projecting tiled impost (see A, Fig. 19, Vol. II), the lower are slightly above the centre to which the voussoirs of each ring radiate. therefore desirable to use a short centre block for each wood ring centre, a space between each (see broken mines on plan) to permit of the use of s rods or lines, as described in Chap. I, Vol. I. In order to simplify the ing, these blocks have been omitted from section D-D.

Some bricklayers prefer to bring into use each centre only as required. s, that needed for ring "2" would not be placed into position until ring was built, and the outer centre would not be placed on its supports until the construction of ring "3." This provides for greater accessibility and there is less likelihood of the brick voussoirs being stained from extruded mortar during construction. This also enables the individual adjustment of the centres preparatory to the construction of each ring, as the upper bearers would not be continuous, as shown, but each centre would have a short bearer nailed to each end of the lower ties, with small wedges between it and the lower continuous bearer.

Centre for Semicircular Stone Arch (see J and K).—This arch is similar to that shown at A, Fig. 41, Vol. II, the span being increased to 3 m in order to illustrate a centre having the maximum span stated in the syllabus. The construction closely resembles that of the centre shown at M, N and O, Fig. 41, Vol. I. Each built-up rib of 225 mm by 32 mm stuff is connected at its feet by two 175 mm by 32 mm ties. Two inclined struts or braces and a vertical central strut or post are provided in addition to an inclined cross-brace and a horizontal cross-brace. The members must be well nailed at the joints to ensure rigidity. Two stout laggings per voussoir are shown. Setting wedges may be used (two are shown supporting the second voussoir at J) instead of laggings, four (two supported on each rib) small hardwood wedges being required per voussoir. As each stone voussoir is accurately dressed to the required shape, the centre merely serves as a support and need not necessarily be cut to the true shape of the soffit if setting wedges are used to bring individual voussoirs to the correct bedding position.

It has been stated above that a well designed centre must be capable of resisting the stresses produced during the construction of the arch. These stresses vary as the work proceeds. Thus, in the early stages of construction, the weight of the haunches is partially resisted by the ribs and the inclined compression members or struts; the load tends to distort the ribs by thrusting their lower ends inwards and their upper ends upwards, and the downward forces acting along the struts tend to depress the lower end of the central vertical post or strut. The latter, being well nailed to the rib at its top end, resists these forces and at the same time restrains the upward thrust through the ribs; the post is in tension. During the construction of the upper portion of the arch the additional weight has a tendency to depress the crown and force the lower ends of the ribs outwards. This is resisted by the ties (which are now in tension) and the struts.

Centre for Semi-elliptical Arch (see Q and S).—The arch is illustrated at J, Fig. 19, Vol. II. The construction follows closely that described above. The joints between the pieces forming the built-up ribs are normal to the curve. The struts may also be fixed as normals to the intrados (see thick broken line) as an alternative to those shown. Close lagging is shown as an alternative to the open lagging indicated in the other examples. The geometrical construction of the intrados and extrados is described in Chap. I, Vol. II.

For spans exceeding 4·25 m the larger members of the centres are usually framed together like a roof truss, and the joints are made rigid by the employment of 12 mm diameter bolts in lieu of nails.

SHORING

A *shore* is a member, generally of timber, used temporarily to prop a wall which is either (a) defective and likely to collapse, or (b) liable to become so when alterations are made to adjacent property, or (c) being altered by the removal of its lower portion for reconstruction—*e.g.* to receive a shop front. *Shoring* is the supporting or propping of a structure with shores.

There are three types of shoring:—(1) raking, (2) horizontal or flying and (3) vertical, dead or needle—see Fig. 23.

Raking Shores.—These are inclined struts chiefly used to support a wall which shows signs of failure such as cracks or a bulge; these defects may be due to thrusts from one or more upper floors, or from the roof (perhaps because the feet of the spars are inadequately tied), or because of unequal settlement of its foundation.

In its simplest form this shore consists of one strut only, togethe
suitable support at the foot and fixing at the head. Thus, referring to
would be an inclined member or raking shore, supported at ground le
piece of wood called a *sole plate*, and secured at the top by a wood *needle*
in the wall. In addition, and to prevent the shore sagging, a short stru
be provided extending from the middle of the shore to the wall or w
(see below).

The inclination of the shore depends on site conditions. If the wall
a street, the distance between the foot and the wall may be restricted in o
traffic will not be interrupted. Preferably, the angle between the sh
the ground should be about 60° and should not exceed 75°. As far as p
and as indicated at A, the centre line of the shore should intersect the c
the bottom of the wall plate. The angle between the shore and the s
must be *slightly less* than 90° to ensure a tight fit when the foot of the
levered into position; this angle is shown at A to be 87°.

Details at the head of the shore are shown at B and C.

The wood *wall piece* provides a suitable abutment for the shore an
for the lower end of the strut or brace. It is from 150 to 225 mm wide (
ing on the size of the shore), usually 50 mm thick and holed for the
The wall piece is attached to the wall by metal *wall hooks* (see B, C and
are driven into the joints of the brickwork, one pair being placed near
and bottom and at approximately 2·75 m intervals.

The *needle* (known also as a *tossle* or *joggle*) is shaped out of 100 mm
stuff and is from 300 to 360 mm long. Approximately at the inte
between the centre line of the shore and the face of the wall a brick h
removed, leaving a hole about 225 mm by 125 mm by 90 mm. The w
is then fixed and the needle inserted. The needle is strengthened to r
upward thrust from the shore by the provision of a wood *cleat* (see B
nailed to the wall piece. Occasionally the cleat is bevel-housed into
piece, as indicated by the broken line L at B.

The head of the shore is notched to fit the underside of the needle (s
C). This facilitates erection and prevents the shore from being blown
the event of it becoming loose.

The *sole plate* or *footing block* is usually 75 to 100 mm thick and of t
width as the shore. If this bearing is inadequate (as on a yielding soil) th
increased by using a timber *platform* of planks (say, six 225 mm by 75
1 m long pieces) laid transversely and upon which the sole plate rests.

After holing the wall, fixing the holed wall piece, inserting and clea
needle, and placing the sole plate on the ground, excavated to receive it, t
is erected with its head clasping the needle and its foot (cut to the bevel
forward by a crow bar. A heavy maul must never be used for this pu
this may cause the building to collapse. Levering is assisted if, as sho
a groove is formed in the shore foot. When the shore fits tightly against
plate, a wrought iron dog (K) is driven into the edge of the plate and th

e strut only, togethe
Thus, referring to
pported at ground l
top by a wood *needle*
: sagging, a short str
ore to the wall or w

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the sole plate rests.
ce, inserting and cl
avated to receive it,
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be used for this p
is assisted if, as sh
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e of the plate and t

ore, one at each side. Finally a shaped cleat abutting the shore is spiked sole plate. The short strut (of the same scantling as the shore) would then d with the ends fitted against the wall piece and underside of the shore; t would be approximately at right angles to the shore and either dogs or sed for fixing.

hore would be required at each end of the wall and at intervals of from 4·5 m.

aking shore system comprises two or more shores, together with needles, ates, braces, etc. A three-shore system is shown by full lines at A. The ng should be noted: (1) The centre lines of the shores intersect the middle nderside of the wall plates, and the position of each needle coincides with rsection between the shore centre line and the wall face; (2) the top shore the *top raker*) is inclined at 60° to the ground level and 87° to the sole 3) *braces*, of 25 or 32 mm stuff are nailed at both sides of each strut (see (with the exception of those near the foot) to the edges of the wall piece; e at right angles to the top raker, with the lower ends of the top and braces coming just below the heads of the middle and bottom rakers; feet of the shores are kept apart with cleats or blocks. The feet should ch, as ample leverage space must be allowed, if they are in contact it is t to remove the lower or middle raker (as is sometimes required) without ing that adjacent. These blocks (see G) are nailed to the sole plate. ottom raker is fixed first, followed in turn by the middle and top rakers.

wo-shore system has top and bottom rakers, together with a wall piece, , cleats, sole plate and braces.

our-shore system has a *rider shore* in addition to top, middle and bottom The rider is shown at A by broken lines. It may be of less scantling e rest and is generally made to spring from the back of the top raker as ed; this is more economical and the rider is easier to handle than if in one it is continued to the sole plate by a lower portion nailed or dogged to the er (or, alternatively, it may be supported on a long cleat fixed to the raker). er to ensure a tight-fitting rider, vertical adjustment is provided by two od folding wedges which must be gently driven together as shown at N.

ng Group SI timbers (see p. 16), the following table gives the approxi- zes and number of shores per system when they are placed at centres 3·7 to 4·5 m.

HEIGHT OF WALL (m)	NUMBER OF SHORES	SIZE OF SHORES (mm)
4·5 to 9	2	150 × 150
9 to 12	3	200 × 200
12 to 15	4	225 × 225
15 plus	4	300 × 225

Horizontal or Flying Shores.— These are commonly applied as temporary supports to either (a) two gable walls adjacent to a building which is to be re-moved and re-built, or (b) a dilapidated wall fronting a relatively narrow street and opposite which a building is available as an abutment. In these cases raking shores are unsuitable as they would impede building operations or inter-fere with traffic. Besides not requiring ground support, flying shores are more efficient (because, as a rule, their thrust is immediately opposite to the disturbing force) and economical than raking shores.

A simple example of flying shoring is shown at V. It spans a narrow street 7 m wide and it is assumed that the upper portion of the building on the right shows signs of failure. The flying shore is in line with the top floor and is sup-ported at each end on a needle strengthened by a cleat. A pair of hardwood folding wedges is driven in between one of the ends of the shore and the wall piece; this must be done carefully to avoid excessive vibration. Details showing a support and wedges are given at W and X. The shore is strengthened and its bearing surface increased by the provision of two members inclined at about 45°, called *struts* above and below it; the upper ones are similar to raking shores and their top ends abut against cleated needles (see M). The feet of these struts are restrained by a *straining sill* nailed to the top of the shore and they are tight-ened by a pair of wedges and fixed by dogs as shown at T. The bottom ends of the lower struts abut on cleated needles and their top ends thrust against a *straining head* nailed to the underside of the shore; folding wedges are *carefully* driven home at the lower ends (see U); dogs, similar to that shown at T, provide a top fixing for the lower struts.

The usual method of constructing a flying shore is as follows:. Needle holes are formed in the wall, the holed wall pieces are fixed, the shore needles are inserted and cleated, the shore is raised and placed on these supports and end-wedged, the lower struts are then fixed followed by the upper.

Flying shore systems are placed near the ends of the opposite walls and at from 3·7 to 4·5 m intervals; typical sizes (using Group SI timbers) are as follows:—

SPAN (m)	SIZE OF FLYING SHORE (mm)	SIZE OF STRUTS (mm)
up to 4·5	150 × 100	100 × 100
up to 12	150 × 150 to 250 × 250	150 × 100 to 250 × 100

Vertical, Dead or Needle Shoring.— This class is required when (a) the lower portion of a building has become defective, probably on account of unequal settlement affecting the foundations, and the necessity arises of supporting the upper portion of the building until the foundations and defective walling have

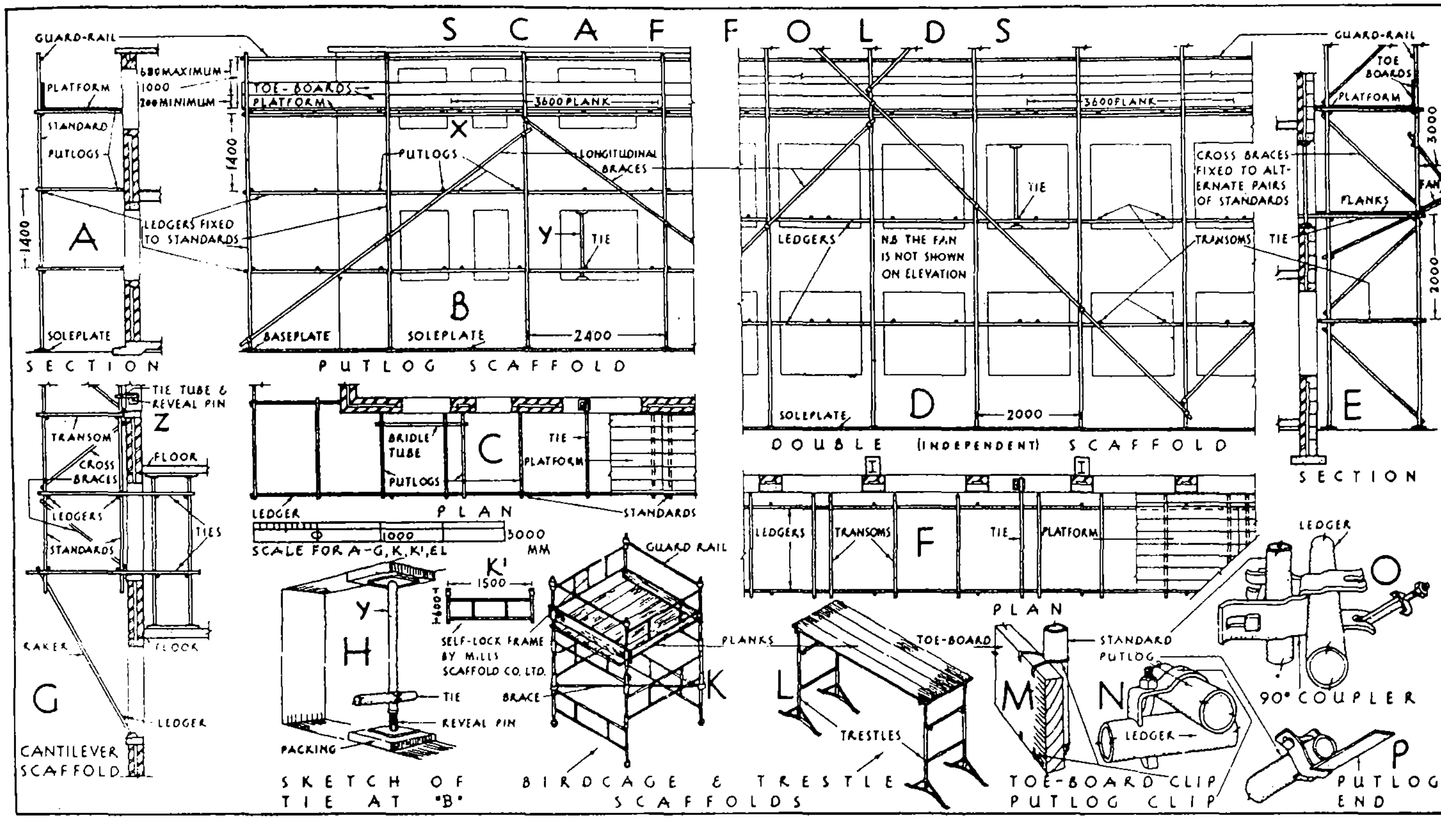


FIGURE 24

been rebuilt (an operation known as *underpinning*)[1]; or when (b) an alteration is to be made to a sound building, such as the conversion of a house into a shop, or the substitution of an existing shop front by a new one, or the replacement of a supporting wall by a beam to convert two rooms into one larger one.

The work entailed is illustrated at Y and Z and the following is the sequence of operations:—

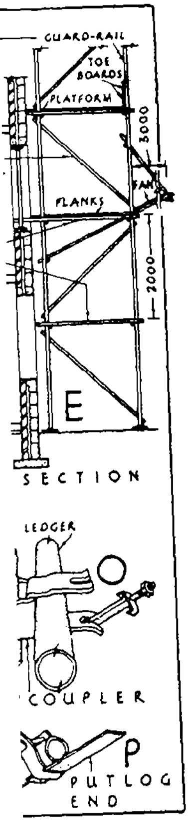
(1) The windows are strutted with 100 mm by 50 or 75 mm timbers as prevent them becoming deformed if unequal settlement occurs.

(2) The roof and floors are supported by struts down to the ground floor to relieve the wall of as much weight from the roof and floor as possibl are in sections from floor to floor (or roof), one immediately over the other, e on a continuous sill and having a continuous head (see Y and F' at Z); fo carefully driven in between the foot of each strut and the sill, render th These struts are placed from 1·2 to 1·8 m apart.

(3) Horizontal members, called *needles*, are inserted through holes ma (to support it) at from 1·8 to 2 m intervals and just above the first floor or gi being necessary if a new shop front is being fitted); sound brickwork will be ing over this span. In the example shown the needles have been placed c the piers between the upper windows. Needles are generally of 300 mm sq short lengths of steel beams. Each needle is carried on a pair of vertical *dead shores* resting on continuous sills; the outer sill is often of baulk stuff a a *sleeper*. Dead shores are usually 300 mm square baulks; the top of each i sides to the needle and the outer angle is braced. Hardwood folding wedge driven in at the feet of the shores to tighten the needles against the unders work, after which dogs are hammered in as shown at Z and B'. The weigh part of the wall is thus transmitted to the ground floor and ground.

[1] In the simple cases of underpinning involving the renewal of defective foundations, the extending of walls below ground level to a better load-bearing strata or the provision of a basement below an existing building, such work could be carefully performed without the need for shoring:—

Suppose a wall 9 m long has defective foundations and it is decided to lower the foundations and rebuild them at an increased depth of say 1·2 m. The procedure would be as follows. Divide the wall into 5 bays each 1·8 m long, number each bay 1, 2, 3, 4 and 5 from the left. Starting at the centre bay 3 cut out the old concrete footing, excavate to the new depth and lay the new concrete footing. Construct a 1·8 m length of new wall on this and ensure that it is tightly pinned up to the existing brickwork. Repeat this procedure in the following bay order:— 5, 1, 4 and 2. Adjacent panels of the new wall should be toothed to bond into adjoining sections. The edges of adjacent pieces of the new concrete footing should include reinforcing bars to key the concrete together. If a new d.p.c. is required the best kind to use consists of two courses of slate in cement mortar.



or 75 mm timbers as
ent occurs.
down to the ground
of and floor as possible
iately over the other,
see Y and F′ at Z);
nd the sill, render th

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ove the first floor or gi
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on a pair of vertical
often of baulk stuff a
ulks; the top of each
rdwood folding wed
lles against the under
Z and B′. The weig
or and ground.

The wall below the needles is now removed. In the case of underpinning, the rebuilt tight up to the old. If a shop front is required, piers are constructed at s of the opening and a steel girder supported on them; the brickwork between the nd the old work above is built, and the floor joists of the first floor are connected irder.

A few days later, the shoring is removed in this order: (a) needles, (b) window g and (c) floor strutting. This should be done in easy stages, the wedges below d shores being *eased* (their points—thin edges—being knocked in slightly) and a day or so before being withdrawn and the shores removed.

further precaution against accident, raking shores, in addition to dead shores, are ed on tall or defective buildings. These are placed close to the dead shores (or the ends of the building only); they are the first to be erected and the last to be d. One is indicated by broken lines at Y and Z.

mwork or temporary timbering to support concrete until it has attained nt strength is described in Chap. II, Vol. IV.

SCAFFOLDS

caffold is generally temporary and used to support workmen during the ction of a building; it is important that it be adequate and safe for the e. In earlier times scaffolding was made from 125 mm dia. fir poles ogether; although these are used occasionally they have been superseded t cases by metal tubes; such tubular scaffolding is strong and quickly . B.S. 1139, Metal Scaffolding, describes certain types; the 48 mm sed are of steel or aluminium alloy; it is inadvisable to mix the two kinds b; tubes range in length from 1·5 to 6·6 m.

luded in The Construction Regulations is a section devoted to scaffolds h the following is a summary:

Scaffolds must be provided for work which cannot be done safely from the , a ladder or part of the building. They must have a safe means of access.

Materials for a scaffold must be inspected before use and the erection sed by a competent person. It must be inspected every seven days n use.

Timber for a scaffold must be stripped of bark and unpainted.

Metal parts must not be corroded.

The standards or uprights must be vertical or lean slightly to the building. must be secured at the base by sinking into the ground or by fixing to a e to prevent displacement.

The working platform normally consists of planks which must rest on ts not further apart than 1 m if 32 mm thick nor 1·5 m if 38 mm thick. must not be less than 200 mm wide, or 150 mm wide if thicker than A plank must not project beyond its end support a distance exceeding its thickness unless it is secured to prevent workmen being tripped up; r to assist the movement of barrows bevelled pieces are to be used where overlap. The platform is to be as close as practicable to the building; if es sit at the edge a 300 mm space is allowed. When persons are liable to fall more than 2 m from a scaffold the minimum width of the working platform must be as shown in this table:

TYPE OF SCAFFOLD	MINIMUM WIDTH (mm)
Outside a sloping roof	432
Platforms suspended from or supported by roof and used only by painters for light work	432
Suspended scaffolds used as a footing only	635
Suspended scaffolds used for deposit of materials	864
Other suspended scaffolds as defined later	432
Ladder and trestle scaffolds used for light work only	432
Temporary platforms passing between two adjacent glazing bars of a sloping roof and used only for work near to the bars	432 if space does not permit 635
Other scaffolds:	
Used only as a footing	635
Used as a footing and for deposit of materials	864
Used to support a higher platform (except the upper tier of a trestle scaffold)	1070
Used to dress or roughly shape stone	1296
Used to support a higher platform and for dressing or roughly shaping stone	1500

7. The next table shows that, where persons are liable to fall more than 2 m, certain scaffolds must be provided with a guard-rail to a height of 1 m above the platform and also a toe-board at least 200 mm above it; such a rail and board are fixed to the inside of the uprights so that the vertical distance between them does not exceed 680 mm (see B, Fig. 24).

8. When it is impracticable to follow the legal requirements for scaffolding safety nets must be used.

The following are the main types of scaffold, see Fig. 24:—(1) Putlog or single scaffold. (2) Double or independent scaffold. (3) Cantilever or truss-out scaffold. (4) Birdcage scaffold. (5) Suspended scaffold. (6) Ladders, trestles, boatswain's chair, etc.

1. Putlog Scaffold.— The section A, elevation B and plan C show the arrangement of a putlog scaffold made with tubular metal. This type is the most usual one for brick walls and is supported partly by the building. It consists of an outer row of verticals (*standards*) to which longitudinal tubes (*ledgers*) are coupled. Cross members (*putlogs*) are clipped to the ledgers or standards at the outer end and rest on the wall (between the brick joints) on the

Type of Scaffold	Guard-rail	Toe-board
Ladder scaffold	Not required if secure hand-hold is provided along platform	Not required if hand-hold is provided
Trestle scaffold	Not required if platform is on folding trestles or step-ladders	Not required
Suspended scaffold, workers sitting at platform edge	Not required on wall side if rope or chain handhold is provided	
Other suspended scaffolds	Required, but height on wall side can be reduced to 656 mm	Required
Scaffolds used by steel erectors	Not required if:—platform is at least 864 mm wide, there is adequate handhold, work is of short duration and tools and materials are kept in boxes to prevent them falling	
Platforms on outside of sloping roofs	Suitable rails required, height not specified	Not required unless tools and materials must be prevented from falling
Temporary platform passing between two adjacent glazing bars on a sloping roof	Required except when glazing bars or roof framework provides handhold	Required unless the nature of the work renders it impracticable
Platforms suspended from or supported by roof and used only by painters for work of short duration	Not required if the handhold is adequate and normal precautions are taken	

inside. The platform is carried on the putlogs. When a putlog coincides with an opening in the wall it is supported on a *bridle tube* attached to two outer putlogs, as shown at C, by right-angle couplers only (see p. 77). Longitudinal braces are required as drawn at B, for reasons of clarity these are not shown on plan or in section; braces should connect as near as possible to the junctions between ledgers and standards and are placed on the outside of the latter. The foot of each standard is provided with a baseplate which rests on a soleplate.

The various connecting couplings are described on p. 77.

In the example shown the standards and ledgers are at 2·4 m and 1·4 m centres respectively; these are the usual spacings for a bricklayer's scaffold. Note that by having 38 mm thick planks for the platform and followin above, the overhang at the end of a plank must not be greater tha 152 mm, hence the closely spaced pair of putlogs shown at X at B.

The scaffold must be tied to the building, one tie being used 5·7 m² of its elevation. The tie tube is coupled to the ledger and to tube Y (see B) placed between the window head and sill. This illustrated in the sketch at H where a *reveal pin* fits inside the foot of t the pin comprises a threaded bolt with nut and collar which is used as ing jack to secure the tube in the opening. A baseplate is provide pin and another plate fits in the top of the tube; timber packings a between the base-plates and the structure.

2. Double Scaffold.— The elevation D, section E and plan F show of a scaffold for a multi-storey building. This, another tubular meta is self-supporting; although it must be tied to the building, as describ it is independent of it. Longitudinal bracing is also used and additi bracing (see E) is fixed to alternate pairs of standards; these are show the elevation and section respectively so as not to confuse the draw short horizontal members fixed to the ledgers and supporting the pla known as *transoms*. An alternative system is the use of H-frames co two verticals (the inner and outer standards) to which a cross mem transom) is welded.

The standards at D are shown at 2 m centres, this is usual for a scaffold which has to support heavier loads than that for brickla independent scaffold for ordinary access work by bricklayers and oth have standards at 2·4 m centres. Inner standards are normally placed to 300 mm from the face of the building but this clearance depend thickness of stones which are often hoisted up the face of the build independent scaffold is used for steel and reinforced concrete framed (see Chap. II, Vol. IV); wherever practicable, workmen prefer th scaffold because this does not have an inner row of standards wh obstruct operations on the face of the building.

3. Cantilever or Truss-out Scaffold.— This is shown in section is used to provide access for operatives repairing or extending the upp of a building; a cantilever scaffold eliminates unwanted scaffolding levels. The system is similar to the double scaffold in the treatme base (as shown) and the fact that additional ties are required. Tw shown at the base, these pass through the window and are fastened pair of uprights which have reveal pins enabling them to be jacked be solid floors. The scaffold standards are coupled to these ties and the is also supported by a raker tube which rests on a wooden block (if po a convenient window sill, string course or cornice; the feet of the raker nected to a ledger tube. Further ties are required on higher floors as at Z where the reveal pin is placed in a horizontal tube, alternatively th could be fixed to another tube bearing against the back of the windo

. **Birdcage Scaffold.**— This is shown in the sketch at K, it is used mainly ternal work and also to support formwork (see Chap. II, Vol. IV) for floors. n be built up from ordinary tubes or, more simply, by using Mills self-lock ld frames; these are 1·5 m by 0·6 m as drawn at K′ and have a slot at the o receive adjoining sections. A diagonal brace is provided near the bottom; prights can rest on baseplates or wheels (as drawn).

. **Suspended Scaffolds.**— Instead of supporting a scaffold from the ground building it is sometimes more convenient and economical to suspend it. new external work a suspended scaffold is usually cheaper than a double ld when the height exceeds 30 m. Suspended scaffolds are of three types:

) *Scaffolds suspended by wire ropes, other than those which can be raised or ed.*—An internal scaffold hung from a roof is an example of this kind; wire , chains or tubes are attached to the roof trusses above and the ledgers ; transoms and planking are used as before.

) *Suspended scaffolds operated otherwise than by winches.*—The cradles used indow cleaners and painters are examples of this kind. The platform guard-rails) is at least 432 mm wide and is raised by block and tackle. The ension wires pass over pulleys at the end of outriggers fixed to the building must be arranged to prevent tilting of the platform; the operative raises or s the cradle from within.

) *Suspended scaffolds operated by means of winches.*—These are the heavier used to construct external walls of a building; the platform is hung by from temporary outriggers fixed to the building frame. Winches are d on the platform to allow it to be raised as the work proceeds.

. **Ladder and Trestle Scaffolds, Boatswain's Chairs.**— The *ladder ld* consists of planks supported by brackets attached to ladders or on the of ladders. This hardly merits the name scaffold and must be used for work only.

he *trestle scaffold*—see L, comprises planks placed on metal or timber es or on step ladders or tripods. Its working platform must not be higher 4·6 m above ground or the surface on which it is erected. If it is placed on n scaffold it must be braced and attached thereto; also, the main scaffold be sufficiently wide to allow the passage of materials. The metal trestles shown can be adjusted in height from 1·4 m to 1·8 m by placing steel pins in holes of the extending tubular legs.

A *boatswain's chair* is used instead of a suspended scaffold where such would be unreasonable or impracticable and when the work is of a short duration. The chair must be at least 760 mm deep and of strong metal construction.

Metal Fittings[1] for Tubular Scaffolds.—These are of aluminium alloy or steel and are accessories to the tubes of the same materials; the following are the main types:

Baseplate.—This is fitted at the bottom of a standard, it has a spigot for insertion into the tube and two holes for fixing to the soleplate.

90° *coupler.*—See O. Used to connect the ledger to the standard, it automatically ensures that the one is at right angles to the other; the two square-shanked bolts have nuts and clips for securing the joint.

Putlog end.—See P. This is a 50 mm wide piece of metal coupled to the wall end of the putlog and placed in the bed joints of the wall.

Putlog clip.—See N. Used to connect the outer end of a putlog to a ledger, or the ends of a transom to a ledger.

Swivel clip.—This resembles the 90° clip but the two halves can rotate; it is used to fix an inclined tube (such as a brace) to a standard.

End-to-end coupler.—This is a sleeve for jointing tubes end-to-end, it fits over adjacent lengths and has a nut and bolt for tightening; used to make long runs of ledgers, braces, etc.; an alternative type has an internal spigot.

Reveal pin.—See H. This has been described on p. 76.

Toe-board clip.—See M. Used to fasten the toe-board to the inside of a standard. Similar clips secure the platform planks to the putlogs and transoms.

Fans.—On city sites or places where the public pass below or alongside a scaffold it is important to give protection from falling objects. This is accomplished by constructing a *fan* made of planks or metal sheeting fixed to additional tubes as shown at E. The fan should be raked towards the building and extend about 3 m (depending on site conditions) beyond the outer line of standards.

[1] Those illustrated in Fig. 24 are by Mills Scaffold Co. Ltd.

CHAPTER TWO

JOINERY

Syllabus.—Doors, including fanlights, semicircular headed, glazed and flush. Windows, including semicircular headed boxed frame with sliding sashes, boxed frame with three lights; skylight; metal windows. Stairs; terms; types; essential requirements; step proportions; construction and detailing of straight flight, dog-leg and open well[1] stairs; open and solid balustrades; winders; special steps. Adhesives. Manufacture, characteristics and uses of plywood, laminboards, blockboards, battenboards and composite boards.

THIS chapter is concerned mostly with joinery but metal doors and windows are also included.

TIMBER DOORS

B.S. 4787, Pt. 1 deals with the door leaf, its frame and attached ironmongery—defined as a door set. It specifies: (a) the co-ordinating size which is the size of the opening into which the door and frame fit; (b) the overall size of the door and frame, and (c) the door leaf size. It enumerates standards of dimensional and functional performance for (i) Category A doors for residential buildings, and (ii) Category B doors for other buildings. The various standard tests which the doorset has to satisfy include: strength, surface finish, twist, resistance to wear and deformation, etc.

The B.S. 4787 gives the following widths for external doors: 726, 826, 926, and 1 126 mm, and for internal doors: 726 and 826 mm. Both types are 2 040 mm high and 40 mm thick, the latter is little enough for good class external doors which ought to be 45 mm thick. The following kinds of door are specified: flush panelled with and without glazed panels; doors made with stiles cut from 100 mm by 50 mm timber and with solid or glazed panels, double leaf doors and doors with fanlights (these are described as ceiling height sets).

Panelled and other types of doors are described in Chap. IV, Vol. I, and students should re-examine the details of the joints between the members of frames and doors before studying the types described below, *i.e.*, (*a*) doors with fanlights, (*b*) semicircular headed doors, (*c*) glazed doors and (*d*) flush doors.

(*a*) **Doors with Fanlights or Transome Lights** (see Figs. 25 and 26).—The former shows at A, B and C a two-panelled door with a glazed upper portion, called a *fanlight* or *transome light*. The essential object of a fanlight is to lighting to an outer lobby, hall, etc., and sometimes to provide ventilatio horizontal member separating the door and fanlight is called a *transome*, of which is double tenoned to the frame. This fanlight is fixed, the seve of glass being secured between small hardwood outer beads (see detail and M). The glass is bedded in putty before the inner beads are fixed.

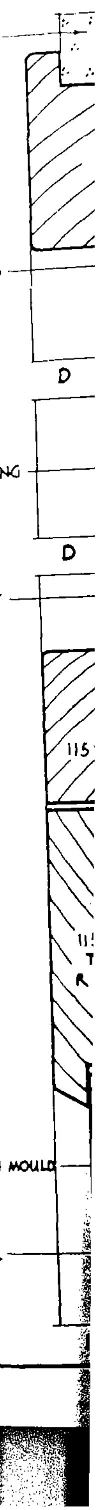
The curved glazing bars and beads are bent in the following manner: T to be bent are placed in a steam chest where the wood is rendered pliab action of steam. This softening process takes approximately three-quar hour per 25 mm thickness of wood. Immediately each piece is removed chest, it is curved over a stout wood templet, shaped as required, and shaped templet or *caul* is placed over it. All three are tightly clamped tog left until the piece has dried out. As the pieces are apt to spring back slig being bent, it is advisable to allow for this and use lengths of timber a litt than the finished thickness; the pieces, after being bent, are then work required section.

The transome is weathered, grooved, throated and rebated (see M door has two equal 19 mm panels, bolection moulded on the external chamfered stuck moulded on the other (see M, N and P). There are, o many alternative finishes to panels. Thus, stuck mouldings on both shown at M, Fig. 26, and at O in the same figure a planted mould is s one side and a stuck mould on the other; further finishes may be selec those shown in Figs. 46, 47, 48, etc., Vol. I.

It will be observed that a wood architrave is not required when t projects slightly beyond the face of the plaster (see K). As shown, the fra be grooved to receive the plaster, otherwise shrinkage gaps will occu further examples are shown at K and P, Fig. 26.

In order to prevent the access of water at the floor level, a hardwood is securely screwed to the floor. Any water blown in is caught by th and escapes through two bore-holes, indicated by broken lines. The

[1] Consideration of the open well type of stairs is often deferred until the third year of the course.



th sliding sashes, boxed
tailing of straight flight
f plywood, laminboards

›bject of a fanlight is
es to provide ventilatio
ht is called a *transome*,
ınlight is fixed, the se
outer beads (see deta
e inner beads are fixe

ı the following manner:
e wood is rendered plia
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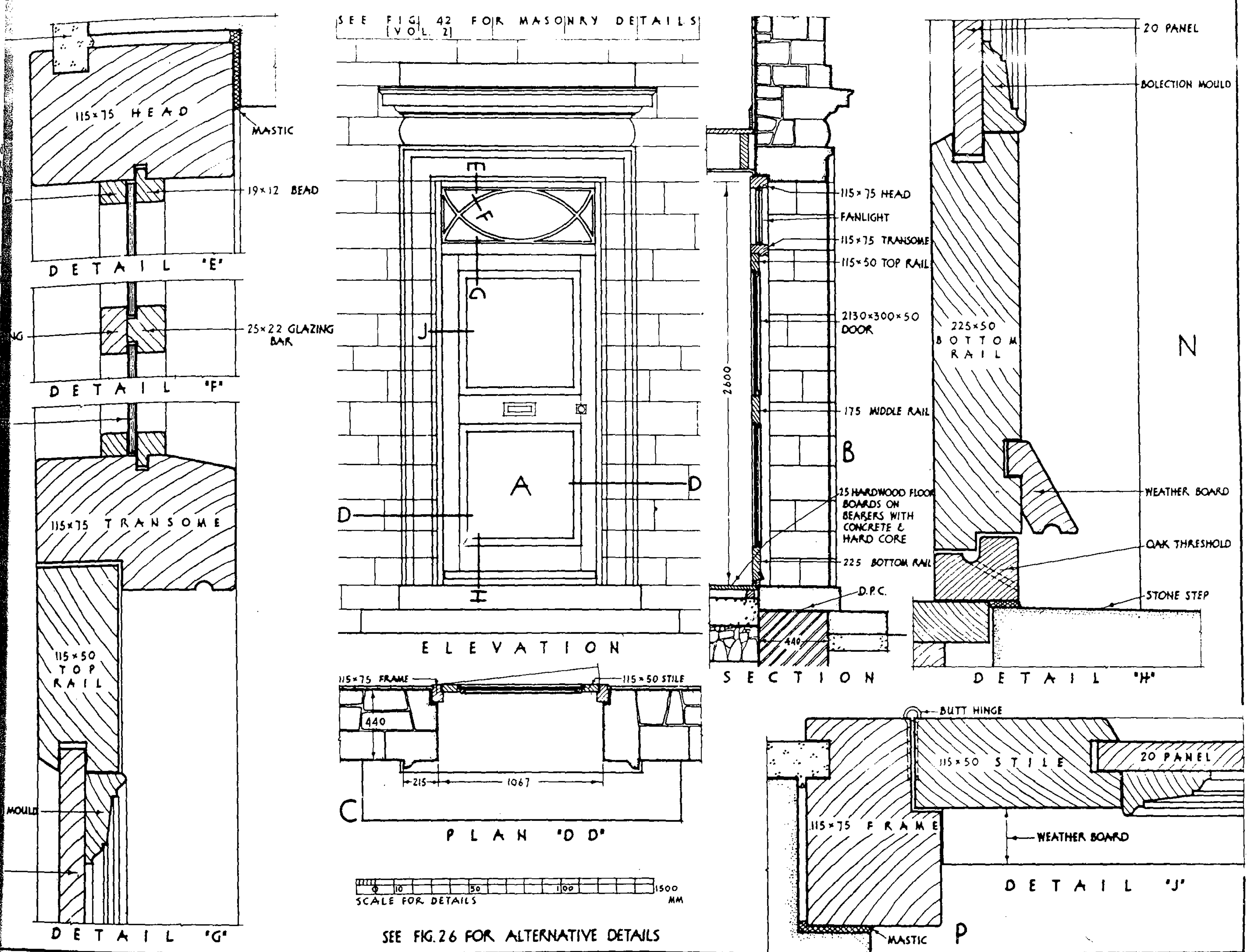
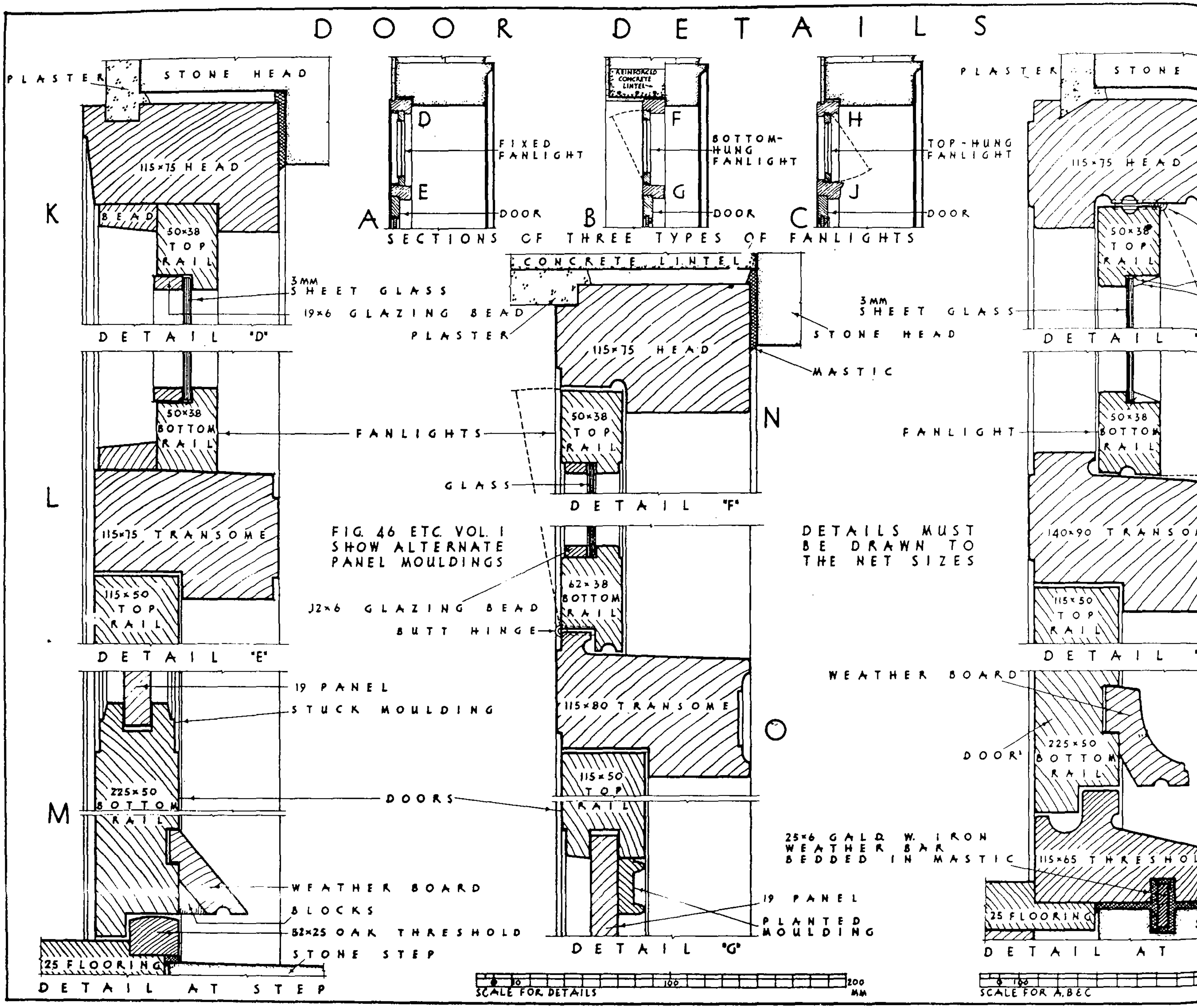
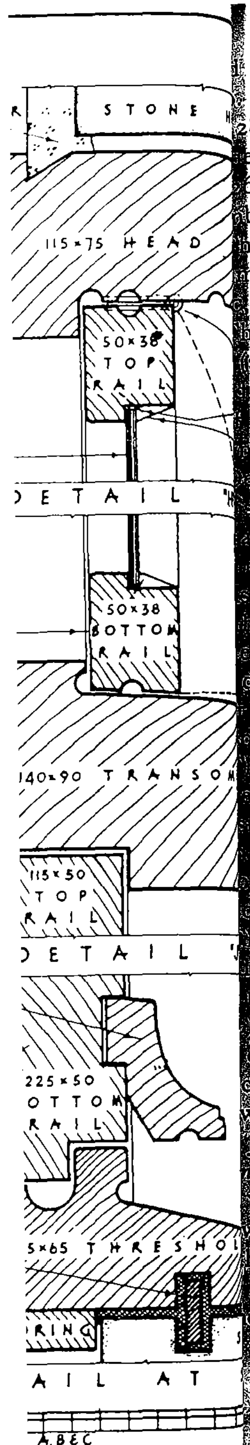


FIGURE 25


DOOR DETAILS
PLASTER
STONE HEAD
115×75 HEAD
BEAD
50×38 TOP RAIL
3MM SHEET GLASS
19×6 GLAZING BEAD
K
DETAIL "D"
D
E
FIXED FANLIGHT
DOOR
A
REINFORCED CONCRETE LINTEL
F
G
BOTTOM-HUNG FANLIGHT
DOOR
B
H
J
TOP-HUNG FANLIGHT
DOOR
C
SECTIONS OF THREE TYPES OF FANLIGHTS
CONCRETE LINTEL
PLASTER
115×75 HEAD
STONE HEAD
MASTIC
50×38 TOP RAIL
GLASS
N
DETAIL "F"
50×38 BOTTOM RAIL
FANLIGHTS
L
115×75 TRANSOME
115×50 TOP RAIL
DETAIL "E"
FIG. 46 ETC. VOL. I SHOW ALTERNATE PANEL MOULDINGS
DETAILS MUST BE DRAWN TO THE NET SIZES
12×6 GLAZING BEAD
62×38 BOTTOM RAIL
BUTT HINGE
115×80 TRANSOME
O
115×50 TOP RAIL
19 PANEL
STUCK MOULDING
M
225×50 BOTTOM RAIL
DOORS
WEATHER BOARD
BLOCKS
52×25 OAK THRESHOLD
STONE STEP
25 FLOORING
DETAIL AT STEP
19 PANEL
PLANTED MOULDING
DETAIL "G"
PLASTER
STONE HEAD
115×75 HEAD
50×38 TOP RAIL
3MM SHEET GLASS
DETAIL "H"
FANLIGHT
50×38 BOTTOM RAIL
140×90 TRANSOME
115×50 TOP RAIL
DETAIL "J"
WEATHER BOARD
DOOR
225×50 BOTTOM RAIL
25×6 GALD. W. IRON WEATHER BAR BEDDED IN MASTIC
115×65 THRESHOLD
25 FLOORING
DETAIL AT SILL
0 10 100 200 MM
SCALE FOR DETAILS
0 100
SCALE FOR A, B & C



throws water, streaming down the door, clear of the threshold (see IV, Vol. I). Alternative details are shown at M and R, Fig. 26, and J, 8. Small triangular blocks are sometimes placed at intervals between r boards which are thin and have a relatively big projection (see M, , and J, Fig. 28). The hardwood threshold shown at R, Fig. 26, somewhat les a window sill detail; it is most effective but costly.

e stonework of this entrance is detailed at A, Fig. 43, Vol. II.

all scale sections showing various types of fanlights are shown at A, B Fig. 26.

at at A, like the fanlight in Fig. 25, is fixed, the glass being received in a ee details at K and L). The front edge of the transome has a narrow panel flush with the posts of the frame.

a fanlight is required to open the sash may be either bottom-hung (as at B), top-hung (as shown at C) or pivoted (as illustrated in Fig. 60, Vol. I). tails of the former type are shown at N and O. The bottom rail of the fixed to the transome by a pair of hinges. The head of the frame and the il of the sash must be slightly splayed, as shown, to give the necessary g clearance. One of several types of opening gear for the fanlight s of a small ratchet wheel and bar arrangement, the small wheel fitting e bar being fixed at one side (preferably the " hanging side " of the door) top of the sash and to the frame respectively, and operated by a cord. etails show the usual rebates and capillary grooves necessary to exclude and draughts between the sash and frame. The front edge of the me is sunk-panelled as an alternative to that at L.

e top-hung transome light at C is detailed at P and Q. The sash is fixed head of the frame by a pair of hinges and opens outwards. A casement ay will serve to maintain the sash in an open position; alternatively, a opener similar to that described above may be preferred. The transome lded, as shown, as a further alternative to those at L and O. All three mes may be throated, as shown at M, Fig. 25.

e glass may be secured by either putty, as shown at P and Q, or beads d in putty and secured with small brass screws with cups), as shown , N and O.

Semicircular Headed Door (see Fig. 27).—The construction of the f the frame is detailed at D, E and F. These show it built-up of two ribs or knesses," glued and either screwed together or secured by 12 or 16 mm ood dowels; the outer rib consists of three pieces and the inner of two. oints at the springing between the posts and the head are formed of *er-headed key tenons*. These tenons are shaped on the posts and the is morticed to receive them and the glued wedges (see F). When the edges are tightly driven in at each joint the shoulders are brought close er and an exceptionally strong joints result. The maintenance of a tight urther assured if two small glued *shoulder tongues* (see footnote to p. 89), wn, are employed, but these are often dispensed with. These springing joints may be formed of loose hammer-headed keys similar to that used at the crown of the door (see J, K and L) or by handrail screw bolts (see Q, Fig. 30) and hardwood dowels, but these are less effective than the tenon shown at F.

The construction of the head of the door is shown at J, K and L. The head consists of two pieces which are jointed at the crown. The joints between the stiles and the head are similar to those of the frame, the hammer-headed tenons being formed on the stiles; the upper tapered portion of the tenon (and mortice) is commonly cut square (and not radial as shown) to facilitate the entry of the tenon. It will be observed, however, that these radial joints are slightly (32 mm) above the springing. This is necessary because of the presence of the top rail which is, of course, tenoned into the stiles. Very weak joints would result if they coincided with the springing. Shoulder tongues are not necessary because of the reduced thickness of the framing. A hammer-headed key joint is shown as the crown. This is tightened up by means of the four small glued wedges. A handrail screw bolt and dowels or pins may be used in lieu of the key (see Q, Fig. 30).

One or more of the central panels of the door may be glazed, as shown at A, B and C. The small glazing bars are stub-tenoned (see K). Enlarged details of the door are shown at G and H. These indicate an entire absence of mouldings, the arrises of the rails, muntins, stiles, frame, etc., being pencil-rounded, *i.e.*, rounded off by sandpapering. The small simple architrave conforms. A weather board is not considered to improve the appearance of a door, and in this example it has been omitted, as it is assumed that the door opens into an outer lobby.

This entrance is also illustrated at A, B and C, Fig. 19, Vol. II. Because of the reduced thickness of the splayed brick jambs at the door frame, it is especially necessary for the brickwork to be constructed of sound materials and workmanship if dampness is to be avoided. If the doorway is exposed it may be desirable to increase the thickness by 102·5 mm for the full width of the lobby.

(*c*) **Glazed or Sash Doors** (see Fig. 28).—These may be wholly or partially glazed. Several designs, most of which are of doors now mass-produced on a large scale, are illustrated at A to H inclusive.

The joints between the stiles and rails of the door framing are either morticed and tenoned or dowelled; the joints between the glazing bars are usually tenoned and scribed, these joints are detailed in Vol. I.

The details on this and other sheets show architraves, panel moulds, etc., of various shapes and sizes. The reason for this is to provide for reference a wide range of sections, and it must not be assumed, therefore, that any particular moulding is the most appropriate for the detail concerned. Further, whilst for the above reason, two different architraves are shown in each of the details K, T *and* P, *it is customary in practice to adopt a common section throughout a building or for similar rooms on the same floor. Glass shown fixed with glazing beads may also be secured with sprigs and putty.*

The five horizontal panels of the door A are of glass. The weather board is

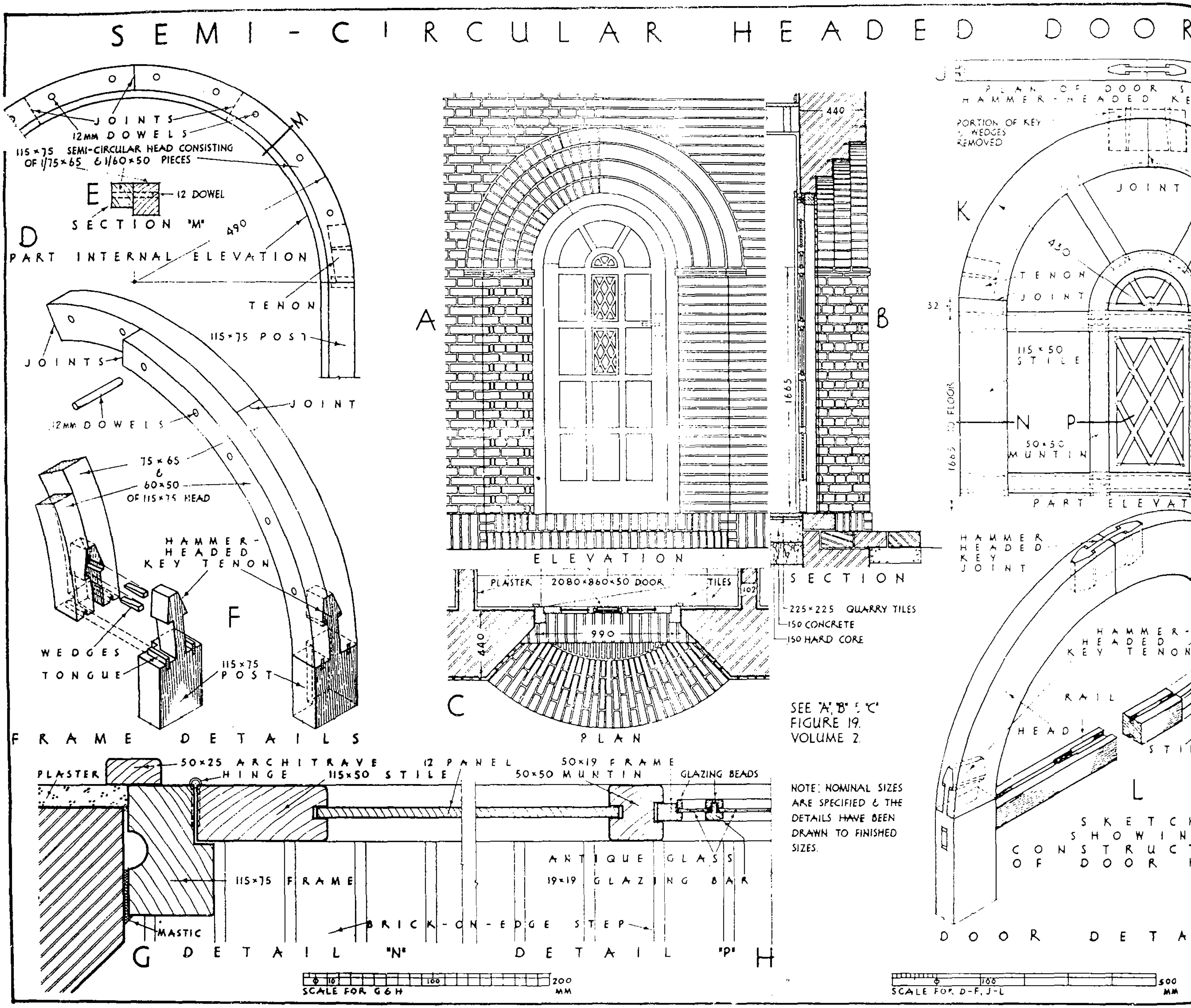
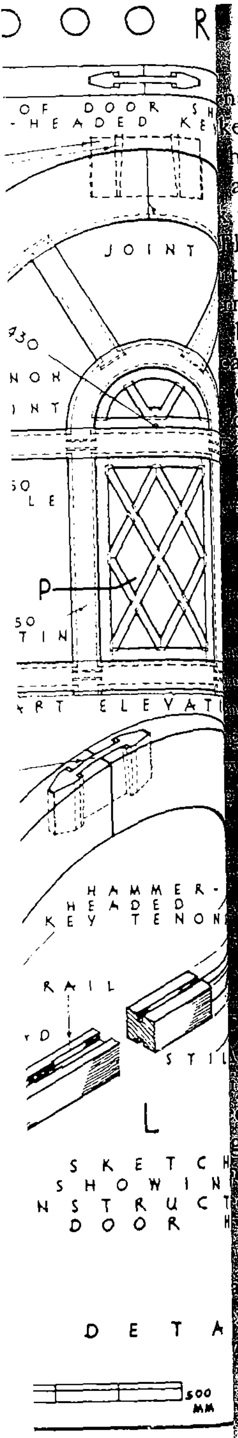

SEMI-CIRCULAR HEADED DOOR
JOINTS
12MM DOWELS
115×75 SEMI-CIRCULAR HEAD CONSISTING OF 1/75×65 & 1/60×50 PIECES
E
12 DOWEL
SECTION "M"
D
PART INTERNAL ELEVATION
490
TENON
115×75 POST
JOINT
12MM DOWELS
75×65 & 60×50 OF 115×75 HEAD
HAMMER-HEADED KEY TENON
F
WEDGES
TONGUE
115×75 POST
FRAME DETAILS
A
B
440
1665
ELEVATION
SECTION
PLASTER
2080×860×50 DOOR
TILES
225×225 QUARRY TILES
150 CONCRETE
150 HARD CORE
990
C
PLAN
SEE "A", "B" & "C" FIGURE 19. VOLUME 2.
NOTE: NOMINAL SIZES ARE SPECIFIED & THE DETAILS HAVE BEEN DRAWN TO FINISHED SIZES.
J
PLAN OF DOOR SH
HAMMER-HEADED KE
PORTION OF KEY & WEDGES REMOVED
JOINT
K
430
TENON
JOINT
32
115×50 STILE
N
P
50×50 MUNTIN
1665 TO FLOOR
PART ELEVATI
HAMMER HEADED KEY JOINT
HAMMER-HEADED KEY TENONS
RAIL
HEAD
STIL
L
SKETCH SHOWIN CONSTRUCT OF DOOR H
DOOR DETA
50×25 ARCHITRAVE
PLASTER
HINGE
115×50 STILE
12 PANEL
50×19 FRAME
50×50 MUNTIN
GLAZING BEADS
ANTIQUE GLASS
19×19 GLAZING BAR
115×75 FRAME
BRICK-ON-EDGE STEP
MASTIC
G
DETAIL "N"
DETAIL "P"
H
SCALE FOR G & H
200 MM
SCALE FOR D-F, J-L
500 MM

FIGURE 27



ative to those shown in Figs. 25 and 26, and the wrought iron water bar, ed with lead and covered with cement (see Chap. IV, Vol. I) is alternative ardwood threshold. It is again noted that persons are more apt to trip a bar, which has only a small projection, than over the more conspicuous wood threshold.

he fifteen glass-panelled door at B is detailed at K. The small half-round rave is shown with a plinth block to provide a suitable finish for the skirting. atively, if a thicker skirting is used, as shown by the broken line, the blocks be dispensed with and the skirting finished with a curved end against sing; the feet of the architrave would then be mitred to the upper splayed of the skirting. The ovolo moulded glazing bead conforms with the stuck ding on the opposite side.

ch of the eighteen glazed panels of the door at C is proportioned in accord- with the construction shown at T, Fig. 58, Vol. I, *i.e.*, the height equals the enuse of a square which has a length of side equal to the width of the pane. alternative details of the wide bottom rail are shown at M, N and O. That hows a compound rail, the lower portion being sunk-chamfered both sides noned into the upper. Alternatively, as shown at M, the lower rail may be ed into the upper and finished flush on one side with a double bead, and a similar beaded mould inserted in the other. The alternative finish at a similar beaded mould inserted in the other. The alternative finish at g a similar beaded mould inserted in the other. The alternative finish at ws a narrow 12 mm thick panel. As an internal door should be kept m from the floor to allow it to swing clear of a carpet with underfelt, hts may be minimized if, as shown at N, a splayed hardwood slip is well ed to the floor. Of course, such provision is not necessary if the doors are with rising butt hinges (see Z, Fig. 43, Vol. I). The details at M and N the glass fixed with glazing beads; alternatively, the glass at O is shown ed and puttied.

e single panel of the door at D is of glass. The detail at L shows that archi- have been dispensed with and the projecting casing finished with rounded The casing is grooved to receive the plaster and a 12 or 19 mm stop is to it. Because of the large size of the sheet, 5 mm float glass has been ed.

e upper panel only of the door at E is glazed; a detail is provided at S. portion of the door at F is glazed. The detail at T shows a thick (25 mm al) panel finished with large bolection mouldings on both sides. The sash, divided into four small panes, is grooved on its outer edges and ed in the panel. The architrave at the bottom of the detail is shown d on the splay of the skirting. Alternatively, the latter may have the same tion and a similar moulding as the architrave, to provide a mitred joint.

e old-fashioned *diminished stile door*, still occasionally used, is illustrated It has either one or two wood panels at the bottom, and the upper portion zed. In order to provide the maximum area of glass, the width of the portions of the stiles which receive it is decreased. Hence the terms *shing stiles* or *gun-stock stiles* which are applied to these vertical members.

The joint between the middle rail and stile is shown at R. the latte diminished from 115 to 75 mm nominal. The development in this presents a somewhat peculiar appearance due to the opposite shoulders not being parallel. If required, a stuck moulding of width equal to the depth of the glazing rebate could be worked on the rails and stiles, and parallel shoulders would result. A vertical section through the middle rail is shown at Q, and a detail at one of the jambs above this rail is illustrated at P.

An external entrance is shown at H. The brickwork at the jambs has three 38 mm deep recesses (see inset plan) which are continued at the head formed of purpose-made voussoirs. The door has an octagonal shaped glazed panel divided by glazing bars. A detail of this door and frame is shown at U. It is bolection moulded on one side only and the thick panel is raised and fielded. In the detail it is assumed that the frame is set back slightly from the inner recess. If, as shown in the part plan at H, the door is set farther back, the detail at the frame will be similar to either of those shown at P, Fig. 25, K and P, Fig. 26, or G, Fig. 27.

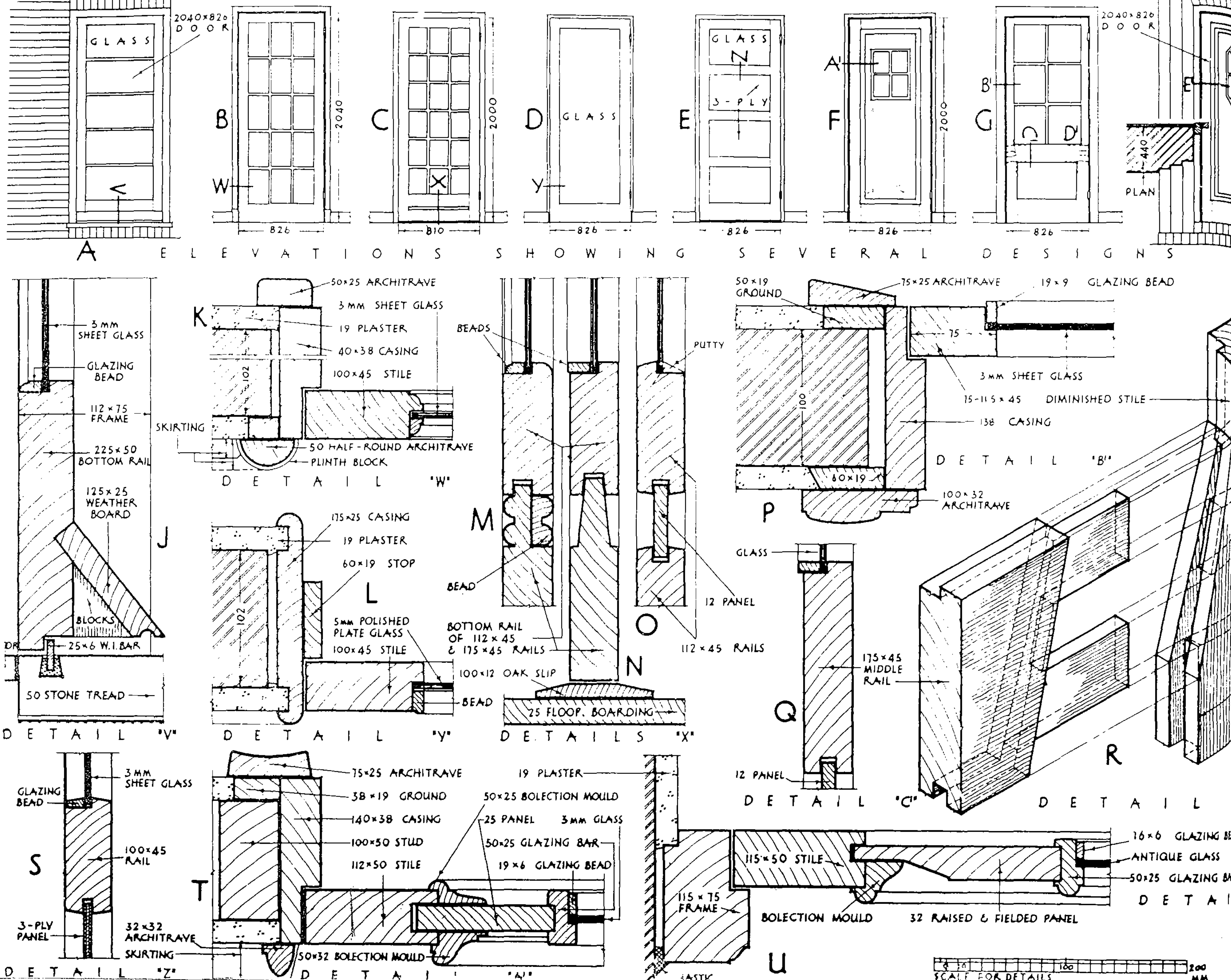
(*d*) **Flush Doors** (see Fig. 29).—These doors, faced with plywood,[1] (or more cheaply, hardboard) are described in Chap. IV, Vol. I. A selected few of the various types are illustrated at A to E inclusive. The usual sizes are given on p. 78.

A flush door may consist of either a skeleton or hollow frame covered both sides with plywood (see A, B, C and E), or it may have a solid core throughout with plywood facings (see D). Most mass-produced flush doors are of the skeleton framed type, chiefly because of the economy in timber content.

The hollow framed flush door shown at A is detailed at F. The frame consists of 100 mm by 40 mm (nominal) stiles, top and bottom rails, and 50 mm by 40 mm intermediate rails at 150 to 225 mm centres; alternatively, 75 mm wide intermediate rails at approximately 300 mm centres may be employed. The top and bottom rails are tenoned and glued to the stiles, the tenons preferably extending the full width of the stiles as shown at Q. The intermediate rails are glued, tenoned and cramped into the continuous grooves formed in the stiles (see F and R). Ventilation holes, as shown, should be provided to ensure a thorough circulation of air within the framing; care should be taken to see that those in the top rail are not subsequently "stopped" with putty by the painter. For good class doors the plywood facings should be 6 mm thick; 4·8 mm 3-ply is only employed on cheap doors. Edging slips, especially on the striking stiles, are necessary; they are fixed on all edges of good class doors. Several forms of these are shown at F, H and J. If, as shown at G, no such provision is made and the plywood is continued to the outer edges of the stiles, the plywood is readily damaged by splintering, especially if the door swells on account of the absorption of moisture, and a tight fit between it and the casing results. A lock block should be provided, as shown at A, to allow for the insertion of a mortise

[1] A description of the manufacture, characteristics and uses of plywood, laminboard and blockboard is given on pp. 117–122.

G L A Z E D   D O O R S



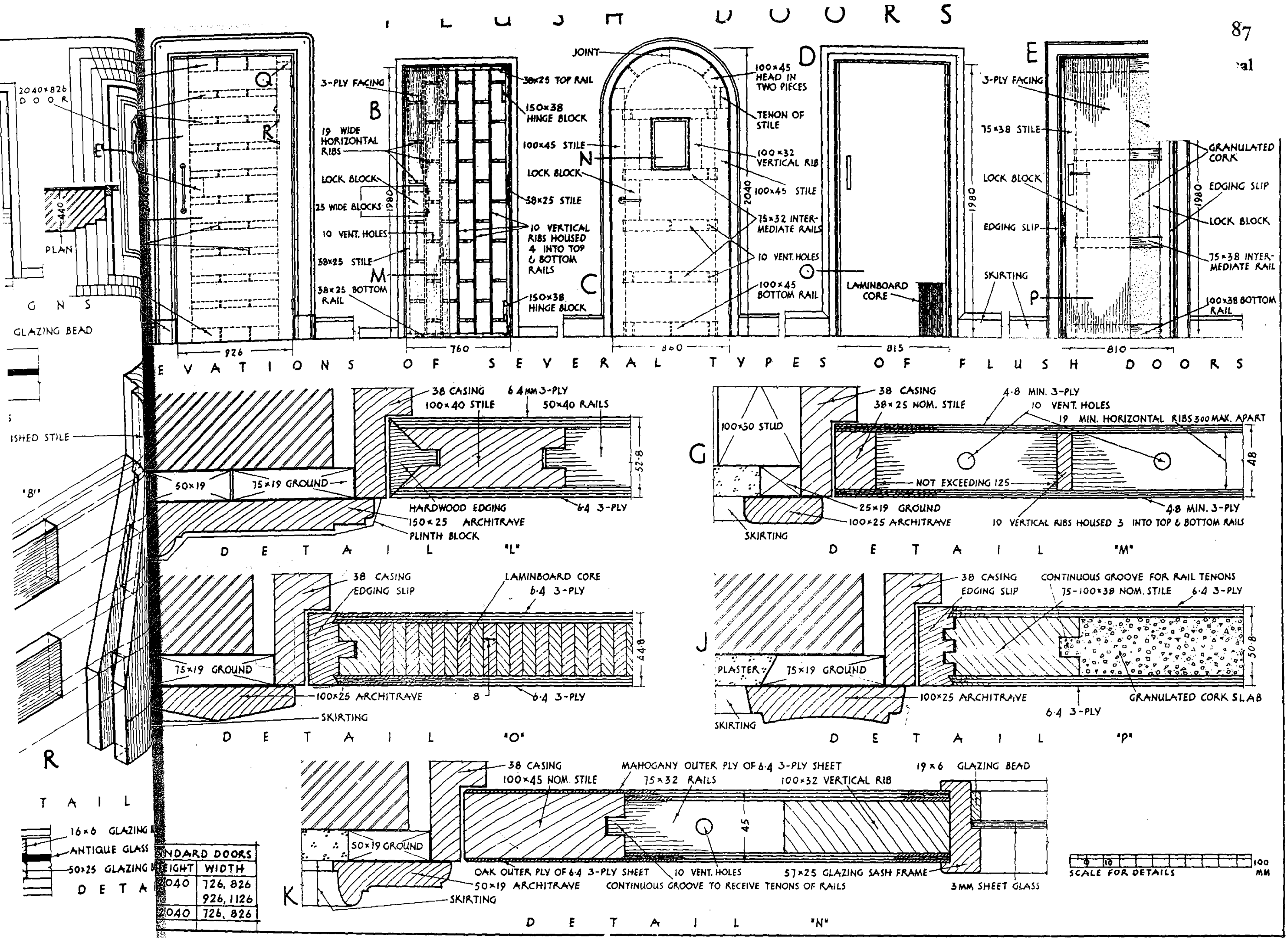

FLUSH DOORS
JOINT
B
C
D
E
Q
R
N
M
O
P
3-PLY FACING
38×25 TOP RAIL
150×38 HINGE BLOCK
19 WIDE HORIZONTAL RIBS
LOCK BLOCK
25 WIDE BLOCKS
10 VENT. HOLES
38×25 STILE
38×25 BOTTOM RAIL
10 VERTICAL RIBS HOUSED 4 INTO TOP & BOTTOM RAILS
100×45 STILE
100×45 HEAD IN TWO PIECES
TENON OF STILE
100×32 VERTICAL RIB
75×32 INTERMEDIATE RAILS
100×45 BOTTOM RAIL
LAMINBOARD CORE
75×38 STILE
GRANULATED CORK
EDGING SLIP
SKIRTING
75×38 INTERMEDIATE RAIL
100×38 BOTTOM RAIL
1980
2040
926
760
860
815
810
ELEVATIONS OF SEVERAL TYPES OF FLUSH DOORS
38 CASING
100×40 STILE
6.4 MM 3-PLY
50×40 RAILS
52.8
50×19
75×19 GROUND
HARDWOOD EDGING
6.4 3-PLY
150×25 ARCHITRAVE
PLINTH BLOCK
DETAIL "L"
G
100×50 STUD
38×25 NOM. STILE
4.8 MIN. 3-PLY
10 VENT. HOLES
19 MIN. HORIZONTAL RIBS 300 MAX. APART
48
NOT EXCEEDING 125
25×19 GROUND
100×25 ARCHITRAVE
4.8 MIN. 3-PLY
10 VERTICAL RIBS HOUSED 3 INTO TOP & BOTTOM RAILS
DETAIL "M"
LAMINBOARD CORE
6.4 3-PLY
44.8
100×25 ARCHITRAVE
8
DETAIL "O"
J
CONTINUOUS GROOVE FOR RAIL TENONS
75–100×38 NOM. STILE
50.8
PLASTER
GRANULATED CORK SLAB
DETAIL "P"
K
MAHOGANY OUTER PLY OF 6.4 3-PLY SHEET
19×6 GLAZING BEAD
100×45 NOM. STILE
75×32 RAILS
100×32 VERTICAL RIB
45
50×19 GROUND
OAK OUTER PLY OF 6.4 3-PLY SHEET
50×19 ARCHITRAVE
10 VENT. HOLES
CONTINUOUS GROOVE TO RECEIVE TENONS OF RAILS
57×25 GLAZING SASH FRAME
3MM SHEET GLASS
DETAIL "N"
SCALE FOR DETAILS
100 MM

FIGURE 20

lock. The position of this should be indicated on the outside, otherwise a block is provided at each side as shown at E; in mass-produced doors these lock pieces are increased in length in order that the position of the lock may not be unduly restricted. The wide architrave (which should be in at least two pieces, if it exceeds 150 mm, to prevent splitting if shrinkage occurs) is shown at A with rounded corners. To prevent opening at the mitres the joints should be either cross-tongued (see footnote to p. 89), or the horizontal members should be tenoned into the verticals and screwed from the back.

The framed flush door shown at B and G has a skeleton framing of very light members, *i.e.*, 38 mm by 25 mm stiles, top and bottom rails, 10 mm vertical ribs at not more than 125 mm apart housed 3 mm into the outer rails, and 19 mm (minimum) wide horizontal ribs, not exceeding 300 mm apart, glued to the vertical ribs and stiles. The top and bottom rails may be either dovetailed into the stiles, or the latter may be double tenoned into the rails, or the corners may be *combed jointed*, *i.e.*, corrugated metal saw-edge fasteners (see Fig. 66, Vol. I) are driven in. The framing is reinforced with 25 mm wide blocks at the hinges and lock block. Each side is covered with plywood of a minimum thickness of 4·8 mm. This covering is shown at G finished flush with the edge; as explained above this may result in the fraying of the edges of the plywood. As a protection against damage, an external door has a 225 mm by 4·8 mm (3-ply, resin-bonded) *kicking plate* fixed at the bottom at each side. This plate or ledge has its top edge bevelled.

The semicircular headed door at C, detailed at K, has a small glazed panel. The head of the door framing may be in two pieces only, with the central joint combed or cross tongued; or alternatively, it may be built-up in two thicknesses like the frame at D, Fig. 27, described on p. 81. The joints between the head and the stiles may be either tenoned, as shown, or they may be combed jointed; hammer-headed key joints (see Fig. 27) are not necessary, as the joints are not exposed to view and because of the stiffening effect of the plywood facings. The treatment at the edges shown at K is an alternative to the details at F, H and J. The outer veneer only of the 3-ply facing covers the framing. This veneer may be highly decorative. Its edges are vulnerable to damage, especially at the striking stile, and, as shown, they are bevelled to minimize this tendency. The detail of the glazed panel is similar to those shown in Fig. 28. The top of the skirting is assumed to be moulded with a fillet and curve similar to the architrave; this results in a mitre and a satisfactory finish (see C).

The solid or laminated core type of flush door is shown at D and detailed at H. The laminæ are only 8 mm wide and this detail therefore shows an application of laminboard (see p. 121). Blockboards (the laminæ are not greater than 25 mm wide, see p. 121) are also used as cores. The tongued edging slips are also dovetailed to receive the edges of the plywood facings which, after being glued, are sprung into position and pressed. In order to provide a contrast in colour, these slips may be of a different wood to the plywood facings. An effective appearance results if the section of the skirting is similar splay of the simple architrave; the resulting mitres are shown in at D. This is a good type of door, although heavy, and is more and sound-insulating[2] than the skeleton framed variety.

Another form of fire-resisting and sound-insulating door is sh detailed at J, compressed granulated cork being filled between the the skeleton frame. A lock block is shown at each side, and the stile may be hung.

The timbers used in the manufacture of mass-produced flush alder, beech, birch, Columbian or Oregon pine, Canadian red pine These are usually painted or stained. The outer veneers of the ply of superior doors are generally of hardwood. They are often left in colours, the decorative effect depending upon the grain and texture Oak, walnut, mahogany, Indian silver greywood, sycamore, black bean and ash are a few of the many hardwoods used for this outer veneer may consist of a single sheet or it may comprise pieces arranged in squares or rectangles. Cross-bandings (narrow of a dark wood—such as black bean—are effectively used to coloured woods into panels.

METAL DOORS AND FRAMES

Metal Doors.—Two types of standard Module 100 metal doo in Fig. 33. Note that in this type the sizes in mm given on the co-ordinating sizes which are 6 mm greater than the actual work finished size; hence the 2 100 mm by 900 mm wide door at V, Fig. 2 094 mm by 894 mm overall. The bottom and centre panels of filled in with two thicknesses of sheet steel in which an insul incorporated. The doors are made in hot-dip galvanised steel.

In Fig. 33 the detail section at D shows how a fanlight can b bedded in mastic to the top of the door frame through a transom each coupling increases the overall dimension by 5 mm. Detail this shows the bottom rail of the door, outer frame and threshol detail at Z is of the meeting stiles of double doors. A plan detai drawn at W; this shows the extension hinge which permits the doo against the wall face; it also shows the 1:3 cement and sand mort to the outer frame and the external mastic pointing which ar exclude weather.

Another type of metal door, purpose made, sometimes adopt use (particularly where sound-proofing is important—see p. 58) and N, Fig. 15. This is made of 2 mm sheet steel in which fib bonded.

Metal Door Frames.—These are an alternative to timber fra

[1] See Chap. III, Vol. IV.

[2] See p. 58.

used conveniently in schools and other places subject to above average wear tear. Some kinds are specified in B.S. 1245. In Fig. 35 the elevations to L show the usual range made by several manufacturers all for doors o mm high; of these, the ones at H to L also incorporate a fanlight. The hs shown are between rebates and allow 5 mm clearance for 526, 626, 726 326 mm wide doors. The co-ordinating size (or size of opening into which rame fits) for these is 2 100 mm high and 600, 700, 800 and 900 mm wide. frames are made in the four profiles A, B, C and P shown at the top right side of the Figure to suit different wall thicknesses. They are out of mm thick zinc-coated mild steel sheet; those for internal use are electro-d and primed, external ones are galvanized or metal sprayed and primed. frames are suitable for door thicknesses of up to 45 mm and it is important te the door thickness when ordering so that the appropriate hinge (which tably cranked for different door thicknesses) can be supplied; one leaf of inge is welded to the frame and the other is assembled with a loose pin. djustable striking plate, to suit different types of locks and latches, is porated and this is centred 1 067 mm down from the top rebate. Also on triking plate side there are three rubber buffers (see B) set into the rebate otect the door when it is slammed shut. Several kinds of plate steel fixing are made to suit different kinds of walls; one of these of T-shape is shown roken lines at A, it lies in the bed joints of the wall and keys in behind the m wide flanges of the frame. Three lugs are provided for each jamb; er provision for fixing to wood floors is made by a holed plate welded on nside of the frame at each foot. In addition, each frame is provided with a hable adjustable base tie screwed to and spanning between the feet; this be made to project up to 38 mm below the frame to suit different floor nesses. The base tie locates the frame at the correct level and is removed to the laying of the floor finish.

he frames are strong enough to support the wall over them without the for a lintel except where there is also a load from floor joists, etc., which is ional to the weight of the wall itself. Some manufacturers make a pressed lintel for profile C, as shown at C; the lintel projects 100 mm either side of rame and is an alternative to a reinforced concrete lintel.

ike metal windows, the space between the back of the frame and the wall ed in with 1:3 cement and sand mortar as the wall is being built.

TIMBER WINDOWS

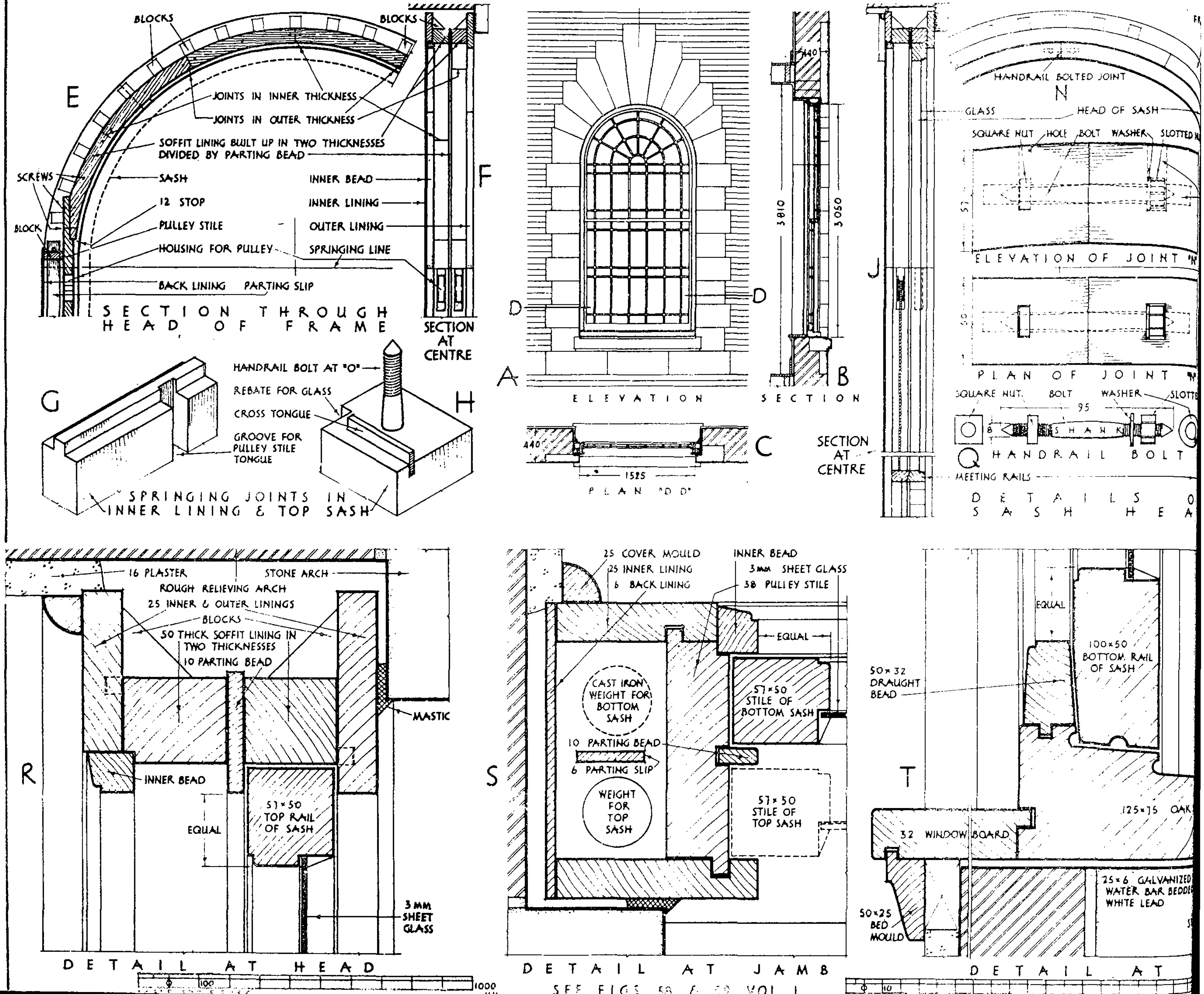
description of casements, dead lights, window with cased frame and cal sliding sashes, window with pivoted sash and window with horizontal g sash is given in Chap. IV, Vol. I. The following types are dealt with (*a*) Window having a semicircular headed cased frame and vertical sliding s, (*b*) three-light windows and (*c*) a skylight. Metal windows are described p. 91 to 95.

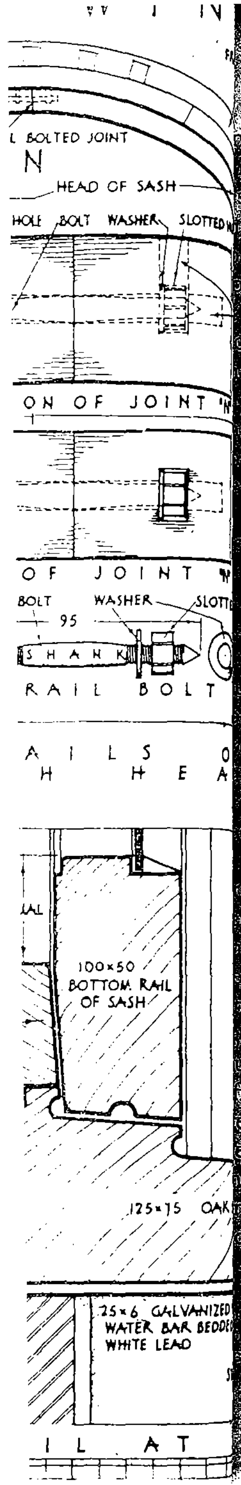
(*a*) **Window with Semicircular Headed Cased Frame and Vertical Sliding Sashes** (see Fig. 30).—The elevation, section and plan at A, B and C show a large window of this type fixed in an opening in a brick wall with stone dressings. The Figure shows the application of cast iron weights to counterbalance the weight of the window sashes, but sash balances (see p. 91) may also be used for this purpose.

With the exception of the head, the construction of the frame is similar to that described in Chap. IV, illustrated in Figs. 58 and 59, Vol. I. The usual construction of a semicircular head is shown here at E, F and R, Fig. 30. The soffit lining is built-up in two thicknesses of 50 mm thick segments, divided by the parting bead, sawn to the required curve and glued and screwed together to overlap with joints normal to the curve. The inner and outer linings are glued and blocked to the soffit lining, the tongues and grooves (indicated by broken lines at R) being often omitted because of the thickness of the head, which exceeds that of the tongued pulley stiles. In lieu of the tongued edges shown, the pulley stiles are sometimes square edged; the edges are well painted to protect them before the stiles are nailed to the linings; the inner lining is slightly rebated to receive the square edge of the stile and the outer edge of the latter is butt jointed and nailed to the outer lining. The upper ends of the pulley stiles are rebated and continued above the springing line to receive the lower ends of the head. The members are glued, well screwed from the back and blocked. Attention is drawn to the projection of the end of the curved head beyond the face of the pulley stile (see E). The purpose of this 12 mm stop is to restrict the upward run of the bottom sash and thus prevent it being jammed in the head; it also prevents damage to the glass in the upper sash which may otherwise occur if the latter was forced tightly against the crown of the frame. The joints between the segments of the inner and outer linings are either tongued and grooved or cross tongued and grooved; G shows a t. and g. springing joint in an inner lining; the ends of the wider outer linings are similarly shaped, although the tongues are usually stopped short of the outer edge. The parting slip is suspended from the block shown at E.

An alternative curved soffit lining consists of a *veneer* (a thin sheet of wood, 3 to 6 mm thick and a little wider than the finished soffit, planed on the face and prepared on the back with a toothing plane to surface it for glue), shaped over a *cylinder* and backed with *staves* (narrow pieces of wood slightly longer than the width of the soffit 25 to 38 mm wide and of equal thickness). The cylinder resembles a centre consisting of two built-up ribs, cut to the semicircular curve and closely lagged; the back of the laggings is planed to a true curve of the required radius of the soffit. The veneer, face downwards, is secured at one end of the cylinder by a stave placed across it and screwed at both ends to the cylinder. The veneer is gradually bent over the cylinder, temporary staves being screwed across it to the cylinder at required intervals and at the opposite end. The whole of the back is now staved. Commencing at one end, the staves are glued to the veneer and to each other, and the ends, having been previously holed, are screwed temporarily to the cylinder. After the glue has thoroughly set the veneered soffit is removed by unscrewing the ends of the staves, sawn to the required width and then screwed to the pulley stile as explained above. Before bending, hardwood veneers must be softened by steaming or by soaking in hot water; softwood veneers can usually be bent dry.

SEMI-CIRCULAR HEADED CASED WIN





Details of the top sash are shown at J and K. The sash, indicated by thick ...es, has a semicircular head in one thickness which comprises two segments ...nted at the crown and either at the springing O or, preferably, above it ...pecially if the pulleys are fixed just below the springing line) as indicated by ... broken radial line at P. These butt joints are formed with *handrail bolts*, ...called because they are invariably used to ensure tight fitting joints between ...tions of handrails; they are also applied more widely. The handrail bolt ...Q consists of a square nut, a round slotted nut (as it has five or six shallow ...s cut in its outer edge) and a washer, in addition to the bolt which has ...eaded ends. Details showing the application of this bolt at the crown joint ...he sash are shown at L and M. A hole, slightly larger than the diameter of ... shank, is bored centrally in each of the adjacent ends of the segments for ... bolt. Two holes are also made from the top, one just sufficiently large to ...eive the square nut and the other for the washer and slotted nut. The joint ...ormed in the following manner: The square nut is placed in its hole and the ...t is inserted and screwed on to the nut until half its length only projects. ...er gluing the ends, the washer and slotted nut are put into the hole in the ...er segment and the free end of the bolt is slipped into the drilled hole. The ...t is next tightened by means of a *handrail punch* (a chisel with its edged end ...htly curved) or similar tool, which is engaged in the notches of the slotted ... to turn it, this is continued until the ends of the segments are brought ...ether and a tight joint ensues. The joint is strengthened by means of a ...*ss tongue*[1] which is grooved into the ends at the rebate side; this prevents the ...ces of timber from twisting. Two or three small (5 mm diameter) hard-...od dowels serve the same purpose. A sketch of the springing joint with pro-...ting bolt and tongue is shown at H.

Enlarged details at the head, jamb and sill are shown at R, S and T. These ... self-explanatory, especially if those in Figs. 58 and 59, Vol. I, have been ...died. Note that: (1) Thick-pulley stiles are employed (which take most of ... weight of the large sashes); (2) the pulley stiles and soffit lining are slightly ...ated to receive the inner beads (this ensures the correct re-fixing of the beads ...d a free run for the bottom sash on being replaced after cord replacements); ... the outside of the groove for the water bar at T is in line with the inside of the ...ter lining (and thus water passing along a defective bedding joint will only ...ect a small portion of the wood sill); (4) a deeper draught bead than the inner ...ads is employed to enable the lower sash to be raised slightly to permit ...tilation at the meeting rails (if the width of the draught bead is still further ...reased, the bottom rail of the sash should be correspondingly deeper to ...sure, as shown, the margin between the top of the sash and the bead being ...ual to those shown at R and S) and (5) this draught bead and the bottom rail are bevelled to prevent vibration of the sash by ensuring a tight fit between it and the parting bead (the slight clearance shown between the sashes, outer lining and beads is to allow for three coats of paint).

[1] Cross tongues are about 4 mm thick and so called because they are cut across the ...in of the squared end of the board from which they are made. Cross tongues are ...onger than *feather tongues* (used for similar purposes), as the latter are cut diagonally ...oss the grain.

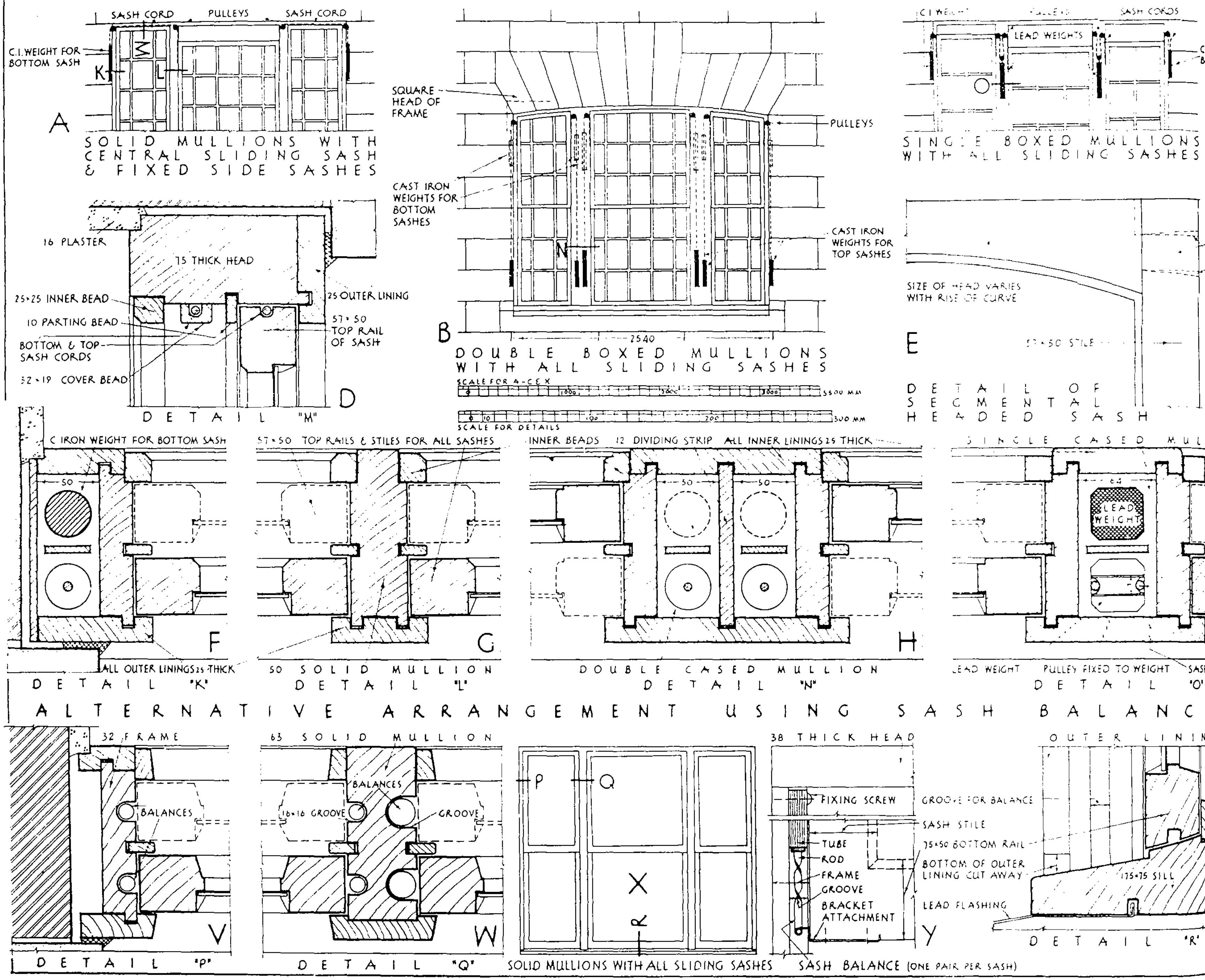
Segmental-headed Windows.—The heads of the frame and sash of a window curved to the form of a segment having a relatively large rise may be constructed as described above, the number of joints depending upon the span and the amount of the rise. If, however, the rise is small, it is usual to provide the window with a square head, as indicated by broken lines at B, Fig. 31. The construction of the head, with its inner, outer and soffit linings, is as shown in Figs. 58 and 59, Vol. I, except that the *outer* lining of the head is of wider stuff and swept to the curve of the segment. Thus, whereas the external appearance of the head is segmental (parallel to the intrados of the arch), that internally is the same as a square head above which a lintel and not an arch is provided to support the wall over the opening. The head of the sash is as shown at E, Fig. 27, the lower edge of the top rail being shaped to the sweep of the outer lining. This rail is tenoned and wedged to the stile of the sash as indicated.

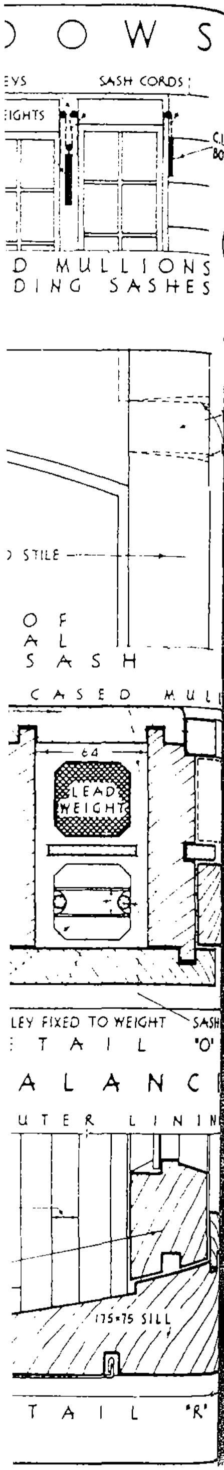
(*b*) **Three-light Cased Windows** (see Fig. 31).—Like casements (see B, Fig. 54, Vol. I), windows with vertical sliding sashes may each consist of two or more lights or pairs of sashes separated by vertical members, called mullions. A wide opening may be divided into three lights, and as shown at A, B and C, it is usual to make the central pair of sashes wider than the adjacent side lights. All the sashes are made to open.

In the part elevation at A, the side lights are fixed, being screwed to the frame, and the central pair of sashes only are free to move. As the mullions are solid (see detail at G) the weights for the central sashes must be accommodated in the frame at the jambs. Four *pairs* of pulleys are therefore required, four pulleys for each of the top and bottom hung sashes. At A the weights for the bottom central sash are shown in full for clarity, and portions of the sash cords are indicated by broken lines. The cords from the sashes to the weights pass over the pulleys fixed at the top of the mullions and then secured to the head of the pulley stiles at the jambs. The pulleys must be fixed as high as possible, and to permit this a portion is removed from the top of each pulley cover or face plate. The cords between the pulleys pass immediately under the head of the frame at the side lights, those fixed to the top sash being accommodated in grooves in the top rails of the two upper side sashes, and the other two cords are hidden from view when, as shown at D, grooved cover beads are screwed (in order that they may be removed readily when broken cords require attention) to the heads of the side lights.

The solid mullions, which vary from 38 to 50 mm in thickness, are double tongued or housed to the outer lining (see G), rebated to receive the inner beads and grooved for the parting beads. The side boxes are constructed in the usual manner, *i.e.*, the 32 mm pulley stile is tongued (see p. 87) to the 25 mm inner and outer linings, a 6 mm back lining (often omitted) completes the box, and a 6 mm parting slip is provided to separate the weights (see F).

THREE LIGHT CASED WINDOWS





The head is usually solid (see D) with an outer lining (or it is the full width he frame and an outer bead is planted on). The mullions (G) are tenoned wedged to the head, and the pulley stiles (F) are housed into the latter.

Another way of hanging the central sashes is to have cased or framed mullions leu of the solid mullions, and solid 75 mm thick jamb posts instead of the lt-up side boxes. The mullions resemble that shown at J, except that the rnal width need only be 50 mm and the thickness of the stiles next to the d side light may be reduced to 25 mm.

The whole of the sashes of the window at B are made to open. The boxes he jambs are as shown at F. The mullions are double boxed or cased, *i.e.*, nged to accommodate two sets of weights as shown at B and detailed at H. ach mullion the weights of the central sashes are separated from those of the sashes by a 12 mm dividing strip, and the top and bottom weights of each are separated by the usual 6 mm parting slip. The finished width of the lions is 200 mm.

The part elevation of the windows at C also shows each light to consist of ing sashes. A detail of one of the cased mullions is given at J. It accomdates two large weights, one to balance the sum of half of the weights of the tral and side bottom sashes and the other to counterbalance half of the cent top sashes.[1] A pulley is fixed at the top of each weight, and four leys are screwed to, and near the head of, the pulley stiles of each mullion— for each of the adjacent top and bottom sashes. Each cord passes under the ght pulley, over the two mullion pulleys and fixed to both of the central and top (or bottom) sashes (see broken lines at C). Cylindrical cast iron weights preferred, but if heavy weights are unobtainable from stock, specially cast l weights are employed. This is an alternative arrangement for hanging the hes to that shown at B and H and results in a reduction of 50 mm. in the width he mullions. The construction of the side boxes is as shown at F.

An *alternative arrangement* for suspending vertical sliding sashes is shown at bottom of Fig. 31 where the elevation at X is of a three-light window having the sashes (without glazing bars) made to slide. The system adopts Unique[2] ral balances. This is a less bulky method than that described above, and ause solid mullions are used less timber is needed. The part elevation of alance is given at Y; it consists of a metal tube enclosing a torsion spring d spiral rod. The rod is threaded through a bush attached to the spring and ses the spring to be wound or unwound when the sash is raised or lowered. ere is a bracket attachment fixed to the bottom of the rod which is screwed the underside of the bottom rail of the sash. The tube is screwed to the top the frame mullion. Two types of balances are made to suit different weights ash and they have a final adjustment for correct setting. One pair of balances equired for each sash and they are housed in grooves as indicated at V, W and Y. e grooves are 16 mm wide for the smaller balance and 25 mm for the larger; they are shown in the outer frames and mullions an alternative and less satisfactory way (unless wider sash stiles are used) is to groove the stiles of the sashes. The detail at Z shows the typical treatment at the sill.

(*c*) **Skylight.**—This is a window in a roof used to light an attic or landing in a house. A typical example in a slated roof (the construction is similar for a tiled roof) is shown in Fig. 32; it is made to open, fixed lights are also made.

The first step in the construction is to form an opening between the roof spars; this is done by having 100 mm by 100 mm trimmer spars along the top and bottom which tusk-tenon (see Fig. 34, Vol. I) into the side trimming spars of the same section. A 175 mm by 50 mm framed curb is fixed along the top of the trimmer and trimming spars.

The plan of the skylight is given at A and the section at B. A section at the side of the light is drawn at H; the curb is protected by a lead flashing and soakers—see Fig. 75, Vol. I; alternatively a secret lead gutter could be formed like that at K. The stile of the light is a 150 mm by 50 mm piece to which a weather fillet is tongued, screwed and glued with waterproof adhesive (see p. 116). The rails are tenoned into the stiles with double tenons and the glazing bars are tenoned into the rails.

The section detail at the top of the skylight is drawn at K; the construction is similar to H except that a gutter is used and the position of the brass hinges (one pair) is shown.

The section detail at the bottom is given at J, note that the bottom rail of the light is not as thick as the top one for the glass must be carried over it to prevent rain from lodging. The bottom rail is grooved on the top to provide outlets for condensation as shown by the broken lines at A. The bottom edge of the glass is held by copper clips and rain is prevented from blowing under the light by the galvanised steel weather bar. The light can be held open by the stay shown in broken lines.

A section through the 50 mm by 36 mm glazing bar is drawn at G. Patent metal glazing bars are detailed in Vol. IV.

A dormer window, also used to provide roof lighting, is drawn for a tiled roof in Vol. IV; other means of providing roof lighting for flat, etc., roofs are also given in Vol. IV.

METAL WINDOWS

Metal windows have been introduced in Chap. IV, Vol. I, and there in Fig. 62, examples of simple types are shown.

The various ways in which metal windows can be made to open are shown at A–N, Fig. 34; of these, tye types at A, B, E, F, and G are the most popular and are standard products of the various manufacturers; the remainder are generally specially made. Opening methods are described on p. 94.

Most metal windows are made of galvanized mild steel or aluminium alloy; bronze is also used but less frequently. Metal windows may be divided into

[1] See Chap. IV, Vol. I, regarding the determination of weights for sashes.
[2] Manufactured by The Unique Balance Co. Ltd.

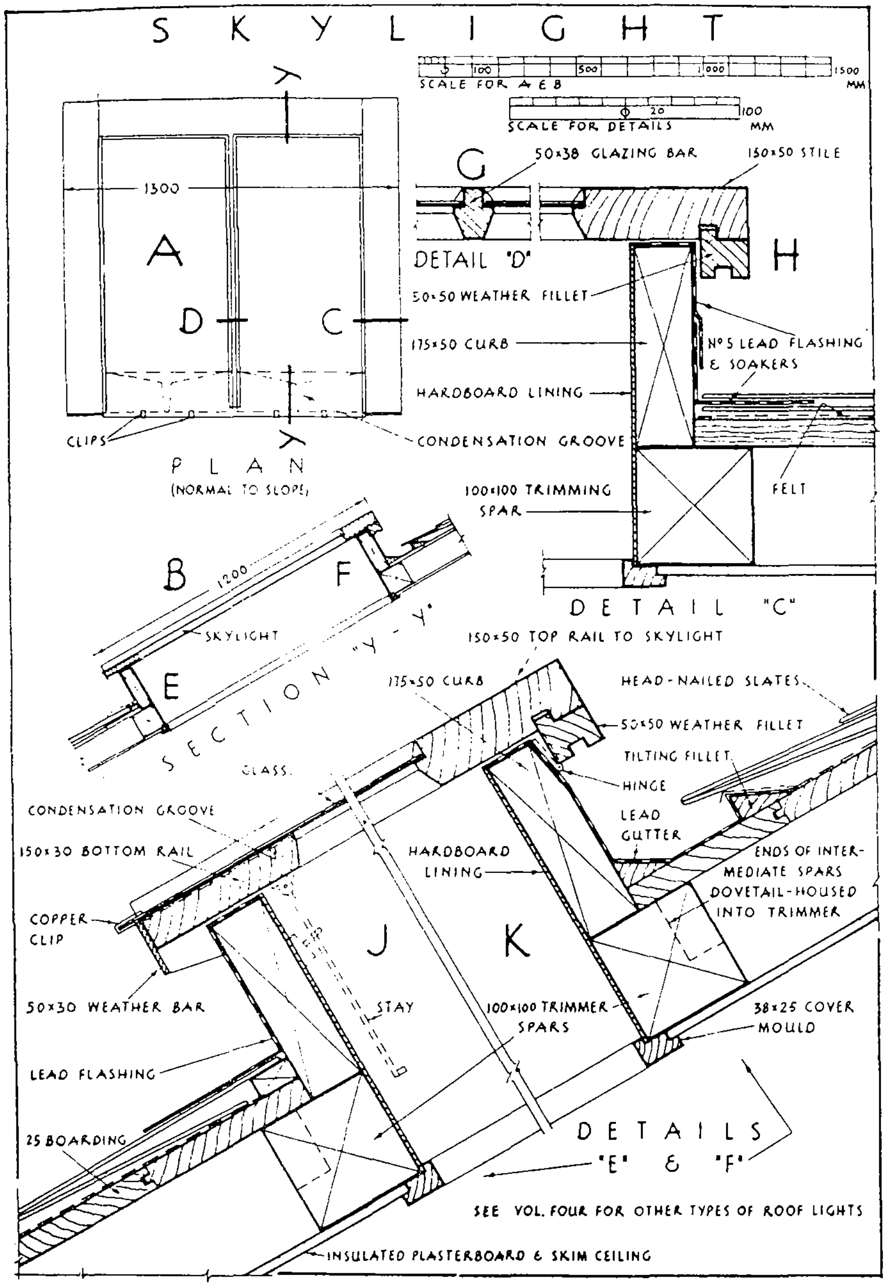


FIGURE 32

two groups: Module 100 range of standard windows, and purpose-made windows.

1. **Module 100 Windows** (Fig. 33).—This is an extensive range of windows to B.S. 990 suitable for most purposes. Each window is given an identification mark which immediately describes its type; this mark has two numbers, the first of which denotes the width and the last signifies the height; letters are included in the mark to indicate how the window opens. When the windows are ordered a final suffix is added (L or R to determine the "handing" or side at which a side hung window is hinged, see W). Thus, for example, take window 15FCV11; the first number shows that it is 1 500 mm. wide and the last that it is 1 100 mm high, letter F stands for fixed light, C for side-hung open-out vent and V for full-width top-hung open-out vent. When ordering this window the suffix L would be added to show that the opening light is on the left; if the opening light were required on the right the suffix R would be used. Note that in all cases of side-hung vents the hinges are attached to the outside of the frame. Other letters used in the identification mark are: B for bottom-hung open-in vent; T for top-hung open-out vent at the side of C or F; R for horizontally pivoted, fully-reversible vent; S for fixed sublight, and D for open-out door.

The metal sections used for the windows are detailed at V (the tubular mullion is used in bay windows—see below); both the outer frame bar and the inner ventilator bar have the same section. Where the outer frame abuts brick or similar wall its back must be filled with 1:3 cement and sand mortar and the outside pointed with mastic as shown at Y. All these windows are normally placed so that the centre line of the outer frame is 51 mm back from the outer wall face. The windows are attached to the wall round their perimeter with lugs as described in Chap. IV, Vol. I.

Where windows are set into externally rendered walls a wider outer frame is preferred. This is shown at X, the outer frame is 12 mm wider than the standard one shown at V.

The windows can be coupled together to form composites by means of transom and mullion couplings in a similar way to that shown at D′; each coupling adds 5 mm to the length or height.

These windows are frequently set into timber frames (75 mm by 62 mm) see Fig. 62, Vol. I; although this adds to the cost it is good practice for the metal windows fixed to brick, stone or similar walls.

Bay Windows (see Fig. 33).—The standard windows can be combined to make bay windows of five plan types:—(i) square splayed—see G, (ii) circular—see H, (iii) oriel—see J, (iv) splayed—see K and (v) square—see L. The junction between the side and front parts of the window may be made with timber, stone, concrete or metal posts. The latter, in the form of a 43 mm overall dia. steel tube, is detailed at V; it shows the plan at the corner N of the square bay L; the treatment is similar for the other bays—the tube forms a convenient abutment for the flanges of the window frame, bedding mastic being used to seal the joint. As well as forming the link between the side and front 115 mm dia. cap and base plates. The safe load that a 43 mm dia. tube

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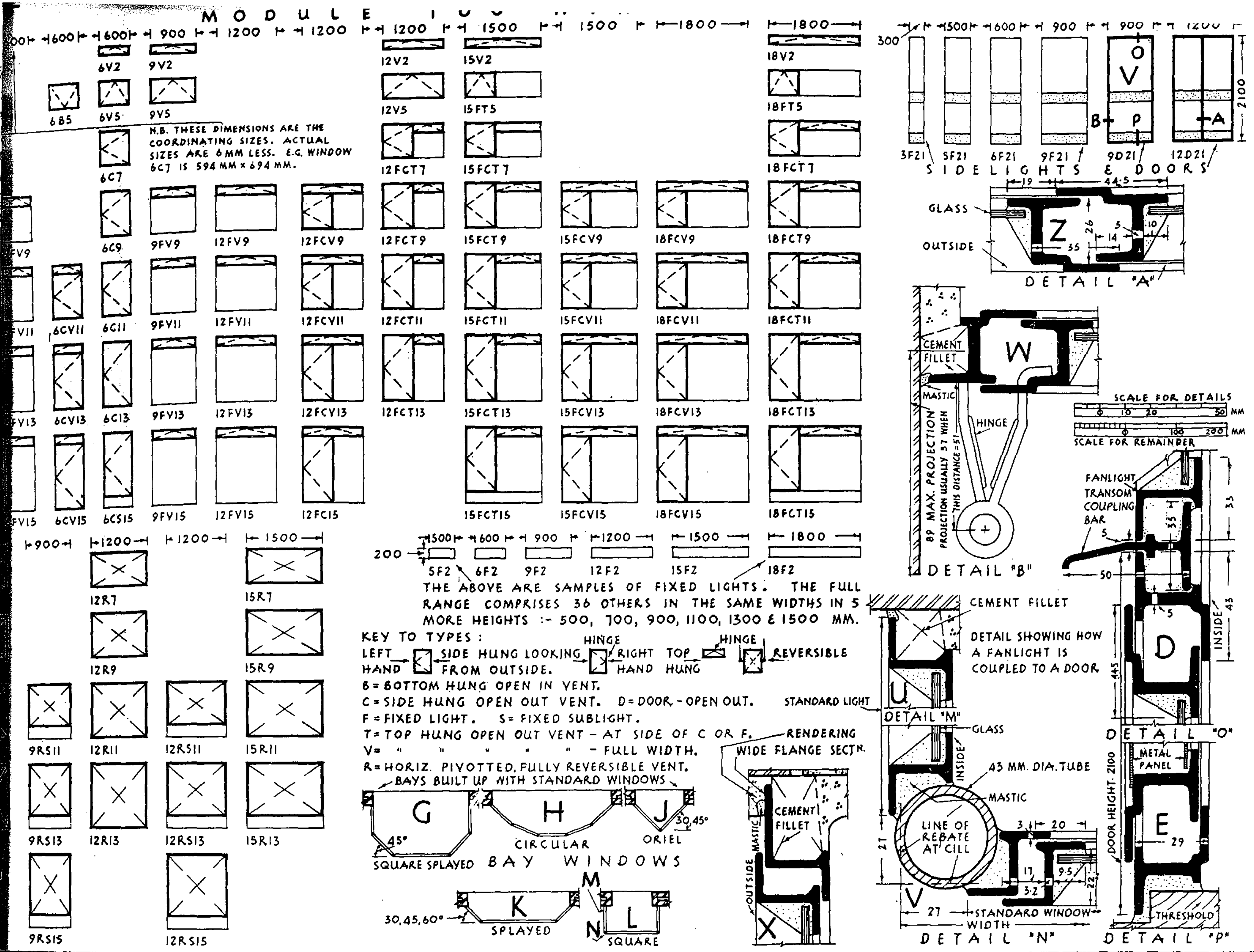


FIGURE 33

carry for different heights is as follows:—up to 900 mm–1 000 kg, 900 to 1 100 mm–750 kg, 1 100 to 1 500 mm–500 kg; larger tubes and solid round mullions are available for heavier loads.

Purpose-made Windows (Fig. 34).—When the size and type of opening of a window cannot be obtained from the standard range in Fig. 33 then it has to be purpose made and selected from the range shown from A–N. The views there shown are the external elevations of 13 different types. All except K are made from *universal sections* in three sizes:—small, medium, and large to suit the window area. The basic sections of the outer frame and the ventilator are drawn at O and in the table above the measurements are given of the three sizes. The outer section can be provided with an extended leg as shown by the broken line; this is for use against rebates and also in rendered walls. The detail at O is at an opening light; a medium universal section for a fixed light is like that shown at P.

Types A and B are the normal side-hung (open out) windows. The window at C and the double one at D are pivoted vertically so that one-third of the light opens inwards and two-thirds outwards. Type E is top-hung (open out). Type F is horizontally centre-hung—an arrangement generally considered to be the cheapest way of hanging a casement; this type can be made completely reversible to facilitate window cleaning from the inside of the room. Type G is bottom hung (open in).

Types H to N are more expensive than those in the row above. Type H, a *balanced window* has two horizontal centre-hung lights coupled on the inside by a pair of rods; another kind of balanced window, the *austral* is drawn at J. The advantages of balanced windows are that they give a 100% ventilating area, both sides of the glass are easily cleaned from the inside, both casements are opened in one movement and they are held open in any position by friction ring pivots in the lower casement. The austral window has two lights coupled by a pair of pivot arms; the top light opens outwards and the bottom one inwards; the top rail of the top light and the bottom rail of the bottom light each have a pair of rollers which move vertically in the outer frame. The *projected window* at L, which is outward opening, also has rollers in the top rail which move in a channel slide placed in the top part of the fixed frame; the angle of opening is controlled by side arms which pivot at both ends; the ventilator is held open in any desired position by friction. The projected window has the advantages that it does not interfere with curtains and is easily cleaned from the inside.

The *vertical sliding window* at K has several desirable features:—as well as being capable of being cleaned from the inside it provides a good circulation of air, it projects neither in nor out and so does not encroach upon space nor interfere with curtains. This type, in timber—see Fig. 58, Vol. I and Figs. 30 and 31, this Volume, are a feature of Georgian architecture.

The example[1] at K, in Fig. 34 here, is in aluminium alloy. The two sliding sashes are suspended by spring balances like those at Y, Fig. 31. The plan

[1] Manufactured by The Crittall Manufacturing Co. Ltd.

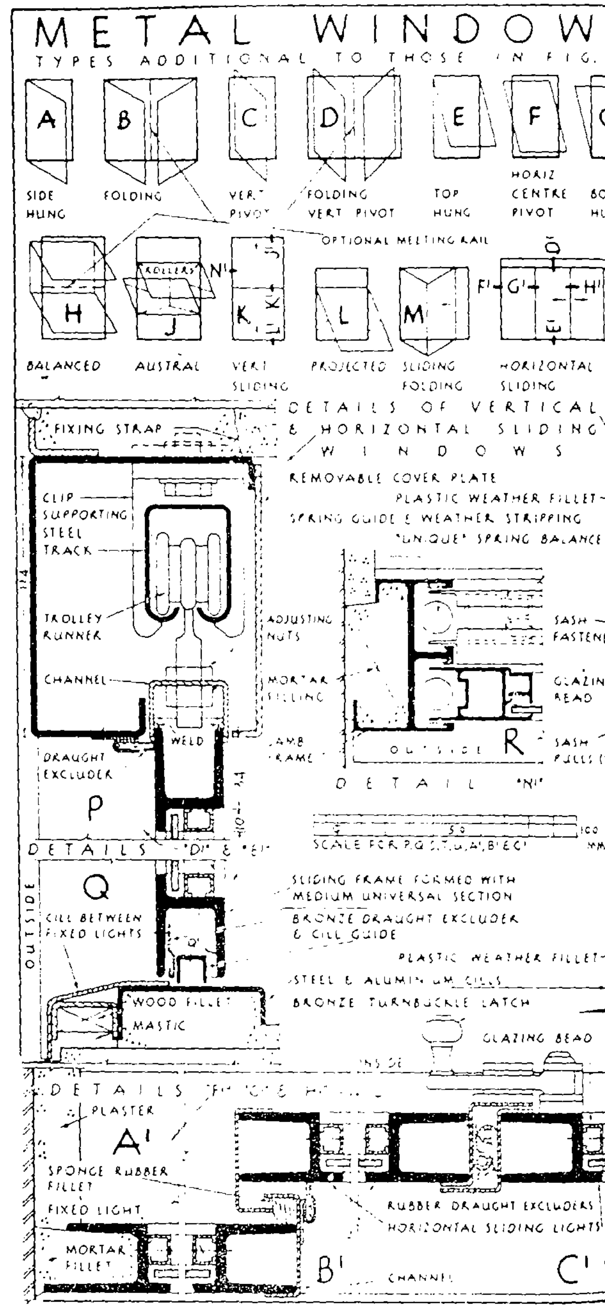


FIGURE 34

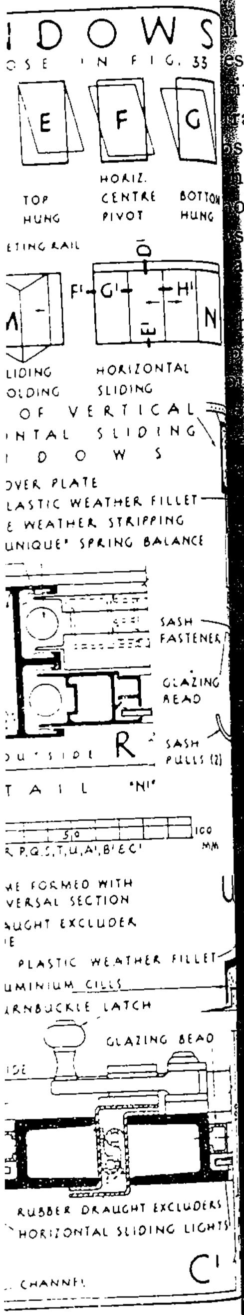


FIGURE 34

at R is at the window jamb and shows the outer frame in which t'.e sliding s move. The faces of the sashes slide against spring metal gi,.des which itute weather stripping and prevent rattling. The head detail at S shows ame held by fixing straps to the lintel (the straps are also used down the s); the top rail of the upper sash is provided with a plastic weather fillet also acts as a cushioning. The meeting rails are detailed at T, here there ther smaller plastic fillet and also a sash fastener. The sill detail at U the bottom rail of the lower sash which has a pair of attached sash lifts. luminium sill is bedded in cement mortar[1] and screwed down to the stone The outer edge of the window is pointed all round with mastic.

e *sliding-folding window* at M is one of many kinds which, when opened, rovide a wide uninterrupted view. The example has a side-hung light ld also be vertically pivoted like C) to which the second light is hinged at ft and suspended from above at its right so that it can slide horizontally. are several variations of this scheme; *e.g.*, a window 6 000 mm wide have four units opening to the left and four to the right—each light being m wide. For a window 3 750 mm wide four units could slide and fold left, one light being hinged at the right.

e *horizontal sliding window* at N has a fixed pane at each end behind the central panes slide. The detail at P is the section at the head of the w where the suspension gear for the two sliding lights is housed in a m by 95 mm pressed steel casing secured by fixing straps to the lintel. ight has two trolley runners fixed to a channel welded to the top rail. The s move in a track clipped into the housing. The detail at Q shows the f the window with a bronze sill guide screwed to the sill; a draught excluder d inside the bottom rail of the sash. The small member marked Q' is a of spring copper 50 mm long; one of these is placed at each extremity of l to act as a rubbing face for the rail. The details A', B' and C' are plans jamb, junction between fixed and sliding lights, and at the meeting espectively. The exposed edges of the medium universal sections g the window stiles are closed with the steel channel (and Z-shaped) gs shown hatched.

mposite Windows.—The basic window types A to N, Fig. 34 (but ing the type at K) can be coupled together to form larger, *i.e.*, *composite s*, by means of the various couplings shown at V. The size of the coupling ll depend on the area of the composite window and the wind pressure; er being determined by reference to B.S. Code of Practice, CP 3, Loading. w manufacturers will provide a suitable section when informed of the of the window above ground level and the degree of exposure. Com- may be formed with horizontal (transoms) or vertical (mullions) gs or both. The mullion is often the primary member (its ends being fastened to the structure) to which the transom is cleated or tenoned. The T-shaped mullion at V is generally satisfactory for units 2 m high; of the cruci-form-shaped bars, the 75 and 100 mm types are usually suitable for heights of 2·75 and 3 m respectively; steel flat bars, tubes and channels are used for larger composites.

[1] uminium should not be allowed to come into contact with cement; hence it is protect the aluminium with bitumastic paint or, as is done here, by coating it with This also protects the window from mortar droppings.

Pressed Steel Sub-frame for Windows (Fig. 35).—Steel windows may be fixed direct into brick, concrete or stone openings; but in the best class of work it is usual to provide a surround (or sub-frame) of timber (see E, Fig. 62, Vol. I) or steel. Timber surrounds are considered in Vol. I; the more expensive steel ones are described below.

Steel sub-frames can serve as an accurate template for the bricklayer; when so used they are built into the wall before the windows are delivered hence damage to the latter from subsequent work is avoided. It should be noted that the use of a sub-frame does not eliminate the need for the outer frame of a window having ventilators; the sub-frame is merely an additional frame to the normal metal window construction. Window frames are screwed and bedded in mastic to the sub-frames.

Standard cavity sub-frames to suit standard domestic metal windows are described in B.S. 1422; they are designed so that at the window jambs part of the sub-frame fits into the cavity of brick cavity walls—see O. Hence the cavity is not closed at the jambs and, although a d.p.c. is not needed at this point, one should be provided at the head in the normal way—see M. Sub-frames are made of 1·26 mm thick steel which can be hot-dip galvanized, aluminium- or zinc-sprayed, or sherardized. The detail at X shows the treatment at the window sill; it also shows the use of a pressed metal sub-sill. The dimension X varies to suit different types of wall construction.

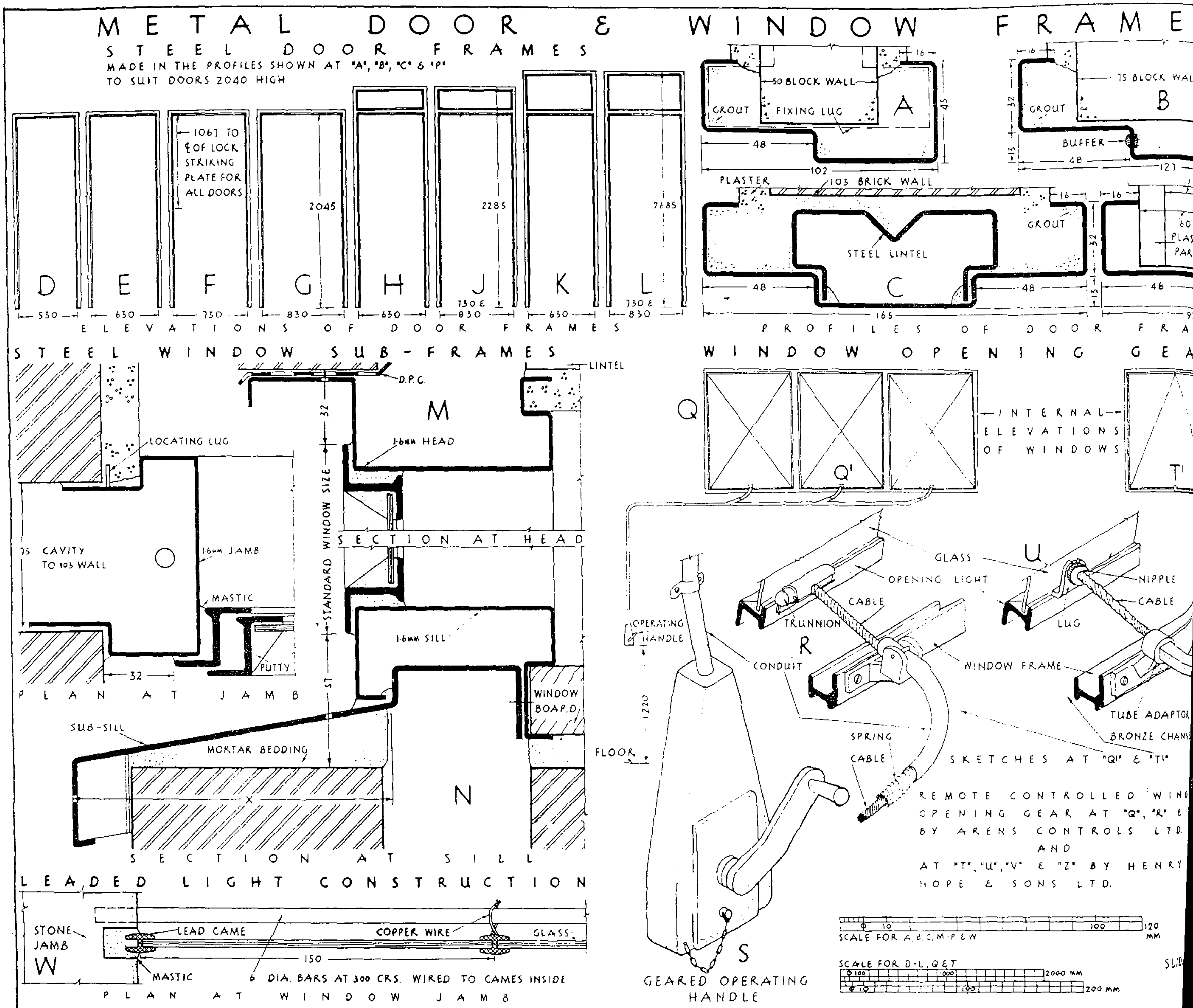
Leaded Lights.—Once widely used when glass sizes were restricted and for making stained glass windows in ecclesiastical buildings, leaded light windows are rarely adopted for new buildings.

The glass panes are bedded into *lead cames* with a putty based cement treated with lamp black to make it inconspicuous. The cames are soldered together at the intersections and in order to stiffen such light construction 6 mm dia. steel saddle bars are placed on the inside of the window; the saddle bars are leaded into holes at jambs, head and cill. The bars are normally placed at about 300 mm centres and the cames are wired to them with copper wire soldered to the lead—see W, Fig. 35.

If the panes are sufficiently small (up to 150 mm by 100 mm) then the saddle bars can be omitted provided steel cored lead cames are used. The steel strip reinforcement in the cored cames is rolled into the web of the came during manufacture.

Panes as large as 450 mm by 300 mm have been used, and in this case saddle bars would have to be used as steel cored cames would not be strong enough.

Lead cames can be made in any size having a face dimension from 6 mm to 32 mm; two types are used, one with a rounded face as at W and the other with a



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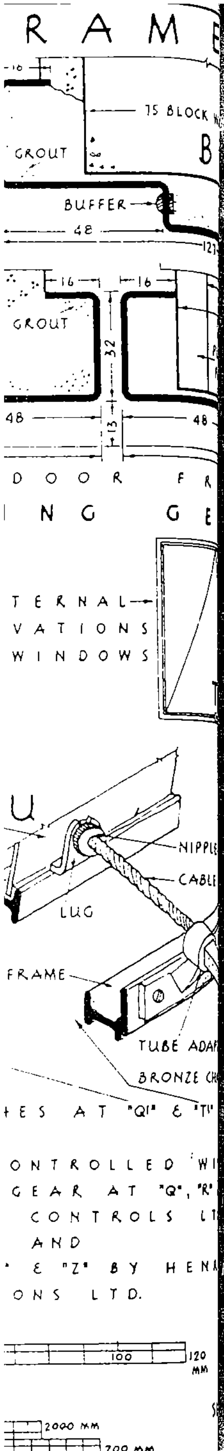

face but having a small bead up each edge.

WINDOW OPENING GEAR

Domestic windows are normally within reach and if fitted with friction es they only require a handle of the kind shown in Fig. 62, Vol. I to open ; the friction hinge maintains the window open in any position; if the es are not of this type then the windows are held open by a casement peg like that shown in Fig. 57, Vol. I. Windows in other buildings which are nd reach have to be remote controlled by one or other of the following ods: (*a*) By a pole, (*b*) by a cord, (*c*) by tension gear, (*d*) by special cable or y shafts and levers. These different systems are now described.

) *Pole operated.*—Friction hinges are fitted to the window which has a g latch bolt to fasten it in the closed position; there is a ring on the latch the window is opened by a pole having a hook at the end which engages e ring. This is the cheapest method of opening windows but is not so enient as subsequent ones.

) *Cord operated.*—This costs a little more than (*a*) and is widely used e appearance is secondary and the aspect of the hanging cord (which ates a pulley on a ratchet to open the light) is not found objectionable.

) *Tension gear.*—This is of several kinds adopting single or double tension or cables; it is used mainly in factories. The single rod system can be rolled by a hand chain operating a traversing screw; the ventilators being ed by cranked levers on pivoting brackets linked to the rod. The double on rod arrangement is used for long runs of ventilators (up to 120 m). The are coupled to triangulated operating arms which move the windows; there push-button control panel with an electric motor and a worm reduction unit. The cable gear method is manually operated from a rack and worm box which transmits the force by a cable moving on pulleys.

) *Cable gear*, (i) *By Arens Controls Ltd.*—Some details of the method used is firm are shown at Q, R and S, Fig. 35. The system has a close-coiled g in compression surrounding a cable in tension. The compression in the g is maintained at the geared operating handle (S) used to open and shut ght. The spring abutment at the window end is provided by a trunnion h is punched on to the cable after this has been stretched and the spring ressed—see R. This ensures sufficient flexibility inside the conduit unding the cable to give easy movement combined with adequate stiffness e exposed portion of the spring which acts as a stay at the opening end. ough slight adjustment can be made on site it is essential that the manu- rer should know the shape and size to which the control is to be made.

The conduit is of brass or aluminium alloy and square or circular in cross on; the inner member is 6, 8 or 10 mm dia., depending on the window size. length of travel (*i.e.*, amount of window opening) is from 75 to 450 mm. The control can be for single windows or groups. The elevation at Q shows three horizontally-pivoted opening lights in the same frame; they push out from the bottom by means of branch controls off the parent control.

(*d*) (ii) *By Henry Hope & Sons Ltd.*—This is another hand-operated cable controlled gear which can be used for one or more ventilators. Movement is obtained by a steel cable held in tension within a steel conduit housed within a square conduit. The simplest type for small single windows is controlled by a knob sliding in a bronze channel which is narrow enough to be fixed to the window frame. For larger single windows a bronze grip handle is used in lieu of the knob. For two or more ventilators the operation is by multiple control gear from a gearbox. The latter operates a rotating screw with traversing connector to which the steel cables are attached.

A simple arrangement for one window is shown at T, the details of the window end of the cable being given at U and V. At V the end of the conduit sweeps round to connect to a terminating adaptor screwed to the frame surround. The cable protrudes from this and engages in a lug welded to the opening light—see U. The end of the cable is fitted with a plate situated on the far side of the lug; on the near side of the lug is a nipple which can be used to disengage the cable from the lug so that the ventilator is free to open fully for cleaning.

(*e*) *Shafts and Levers.*—This method consists of a vertical screw rod actuated by hand or electric motor gearbox. The rod moves a horizontal shaft to which operating arms are coupled to open the window. In a similar method for larger installations hydraulically motivated gear is used.

STAIRS

The materials used in the construction of stairs are stone, steel, wrought iron, cast iron, reinforced concrete, reinforced brickwork, and wood. Stone and timber stairs have been briefly introduced in Vol. I. Stone stairs are illustrated more fully in Vol. II. Reinforced concrete steps are described in Vol. II and also in Vol. IV. Steel fire-escape stairs are shown in Vol. IV. Timber stairs are considered in greater detail here.

A stair is a set of steps leading from one floor to another. A continuous series of steps forms a flight, and there may be two or more flights, separated by flat portions called landings, between two floors. A stair, together with the part of the building accommodating it, is known as the staircase. The horizontal portion of a step, called a tread, is usually connected to a vertical riser and these are supported by inclined boards termed strings. The Building Regulations give dimensions of the parts of a stair which vary according to the building type. The dimensions given here are for: (*a*) a private stair exclusive to one dwelling and (*b*) a common stair used in connection with two or more dwellings. B.S.C.P. 5395 for stairs is relevant.

Apron, Apron Lining or Fascia (see G, Fig. 39, and C, G, M, and N, Fig. 43) is a board which covers the trimmer, etc., joist of a landing, providing a suitable finish to it and the adjacent plaster.

Balusters (see Figs. 36, 39, 40, 41, 43 and 45) are short vertical bars which support the handrail and protect the open side or sides of a stair.

Balustrade or Banister.—An *open* balustrade comprises the balusters, handrail, string and newels (if any) (see Figs. 36, 39, 40, 41 and 43). A *solid* balustrade consists of panelling in lieu of balusters (see M, Fig. 36; Fig. 42; H and O, Fig. 43 and Fig. 44). The Building Regulations require that *all* stairways be guarded on each side by a wall or balustrade extending at least 840 mm. above the pitch line (see below). Landings must be similarly guarded, the heights above the landing are 900 mm and 1 100 mm for a private and common stairway respectively.

Bearers.—Inclined 100 mm by 50 mm or 100 mm by 75 mm members which support the steps. Those which serve as intermediate supports are also called *carriage-pieces, rough carriages, rough strings* (as they are not dressed) or *spring-trees* (see Figs. 38, 43, and 45). The short supporting members placed immediately below winders (see p. 100 and Fig. 45) are also called bearers.

Blocks are fixed to the upper edges of bearers and provide additional support to the treads (see Fig. 45). The term is also applied to the small pieces of wood of triangular section which are glued to the inner angles between treads and risers or strings (see F, Fig. 37, Figs 38, 39, etc.).

Brackets or Rough Brackets are more commonly employed and serve the same purpose as blocks, the 25 mm thick pieces of wood being nailed alternately to the sides of the bearers (see Figs. 37, 38, 39 and 43).

Caps.—See " Newels."

Cappings are covered mouldings planted on the upper edges of strings (see F, Fig. 39, and J and K, Fig. 41), handrails (see D, Fig. 42), panelling (see B and C, Fig. 42) and newels.

Carriages.—See " Bearers."

Commode Step.—See " Steps."

Cover Fillets are small members fixed to the underside of outer strings and trimmers to provide a satisfactory finish to the adjacent plaster (see G, Fig. 39, N, Fig. 41 and M and N, Fig. 43).

Curtail Step.—See " Steps."

Dancing or Balancing Steps.—See " Steps."

Dog-leg Stair.—See p. 100 and Figs. 36 and 39.

Drop.—See " Newels."

Easing is a curved upper portion connecting two strings of different inclinations or a string with a skirting (see C, Fig. 37 and B and G, Fig. 45).

Flier.—See " Steps."

Flight.—A continuous set of steps extending from floor to floor, or floor to landing, or landing to landing.

Going or Run of a step is the horizontal distance between the edges of two consecutive nosings (see below and F, Fig. 37; D, Fig. 38 and F, Fig. 39) and the going of a flight is the horizontal distance between the face of the bottom riser of the flight and that of the top riser.

Handrails, provided to afford assistance and a safeguard, are fixed convenient height to walls (see C, H and J, Fig. 37) or at the top of balus (see Figs. 39 to 44 and Fig. 46); they should be of a satisfactory size and to enable them being easily grasped by the hand; of the many design simple *mop-stick handrail* illustrated at F, Fig. 46, is one of the most eff The Building Regulations require that *any* stairway rising more than 60 shall have a continuous handrail fixed at a height between 840 mm and vertically above the pitch line (see below) (a) on both sides of the stair 1 m wide or more; or (b) on one side of the stair in any other case.

Headroom is the height measured vertically from the line of nosing below) to the lower outer edge of the apron (see C, Fig. 37) or to the soffi flight immediately above it. The Building Regulations demand that this not be less than 2 m for *all* stairs.

Landing is a platform between two flights provided to serve as a res when required, to make effective provision for turning a stair; it also the portion of the floor adjacent to the top of a stair. A *quarter-space* l is one on which a quarter-turn has to be made between the end of one fli the beginning of the next (see Figs. 36, 43 and 44). If the landing exte the combined width of both flights and a complete half-turn is necessar known as a *half-space landing* (see Figs. 36, 39, 41 and 42).

Pitch Line is that drawn to touch the projecting edges or nosings treads (see C, Fig. 37 and D, Fig. 38).

Margin is the portion of a close string (see p. 100) between its upp and the line of nosings (see D, Fig. 32). This term is also applied to the p of treads and risers between the strings and the carpet or other covering

Newels or Newel Posts (see Figs. 36, 39, 40 to 46) are substantial members placed at the ends of flights to support the strings, handrails, tr and bearers. The upper moulded end is called the *cap* and the projectin end is known as a *drop*.

Nosing (see Figs. 37 to 39, etc.).—This is the front edge of a tread projects beyond the face of the riser below it; it is also applied to the pr upper member of an apron (see G, Fig. 39).

Pitch or Slope is the angle between the pitch line and the floor or l according to the Building Regulations it should not exceed 42° for a stair and 38° for a common stair.

Rise of a step is the vertical distance between the tops of two con treads (see F, Figs. 37 and 39), and the rise of a flight is the total heig floor to floor, or floor to landing, or landing to landing.

Riser is the front member of a step which is connected to the tread Fig. 37, etc.). The Building Regulations limit the number of risers in flight to 16.

Run.—See " Going."

Scotia is a concave mould used to provide an additional finish to th

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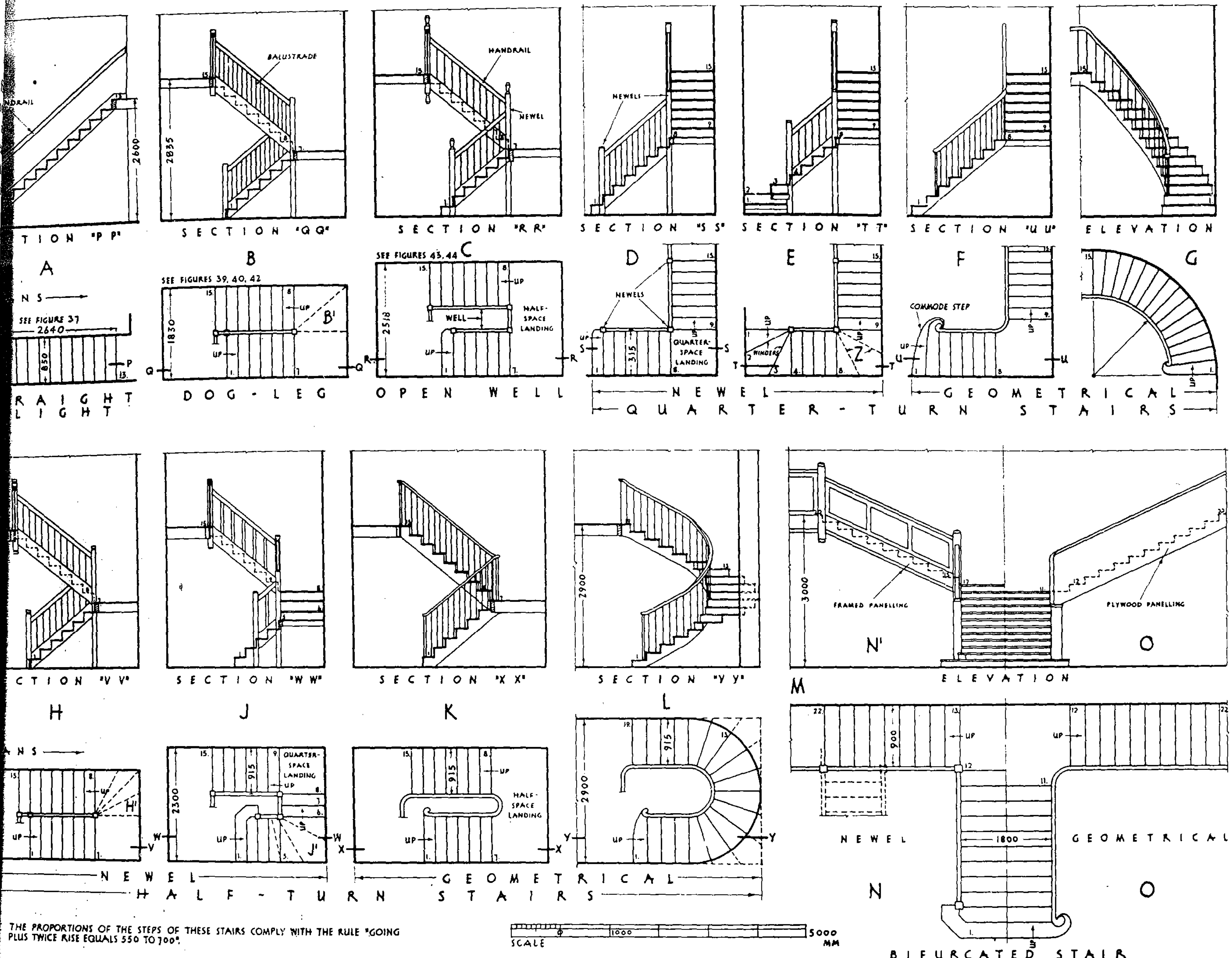

FIGURE 36

of a tread (see D, Fig. 38). A *scotia board* is cut from a relatively wide board and used at nosings of treads forming bull-nosed and similar rounded bottom steps (see Fig. 46).

Soffit or Planceer is the under surface of a stair which is often plastered (see C, Fig. 37, E, Fig. 39 and D, Fig. 43).

Spandrel or Spandril is the triangular surface, either plastered or panelled, between an outer string and the floor (see C, Fig. 39).

Stair.—As stated on p. 97, this consists of a set of steps which leads from one floor to another. Stairs are classified as follows:—

(*a*) Straight Flight Stairs.

(*b*) Turning Stairs, including (i) quarter-turn, half-turn, three-quarter-turn, and bifurcated, and (ii) newel and geometrical.

(a) *Straight Flight Stair* (see A, Fig. 36 and Fig. 37).—This continues throughout its entire length in one direction and may consist of a single flight only or two or more flights in its length which are separated by landings.

(b) (i) *Quarter-turn Stair* (see D, E, F and G, Fig. 36).—This type changes its direction either to the left or right, the turn being affected either by a quarter-space landing or by winders (see next column).

Half-turn Stair (see B, C, H, J, K and L, Fig. 36) has its direction reversed either by a half-space landing (as at B, C, H and K), or a quarter-space landing and winders, or two quarter-space landings and a short flight (as at J), or completely by winders (as at L), etc.

Three-quarter-turn Stair has its direction changed three times with its upper flight crossing the bottom one.

Bifurcated Stairs (see M, Fig. 36) is a type common in public buildings in which it appears as a prominent feature. The bottom wide flight is divided at a landing into two narrower flights which branch off to the right and left. That shown is also known as a *double quarter-turn stair*; if each side flight is continued with an additional quarter-turn (as shown by broken lines at N), the complete structure is called a *double half-turn stair*.

(b) (ii) *Newel Stair* (see B, C, D, E, H, J and N, Fig. 36) has a newel at the foot and head of each flight of the stair. Newels are therefore conspicuous features.

Geometrical or Continuous Stair (see F, G, K, L and O, Fig. 36).—Both the strings and handrails are continuous and are set out in accordance with geometrical principles. A newel may, for reasons of design, be introduced at the bottom and top of such a stair, but is not an essential part of the construction. Those at G and L are also called *winding stairs*. Geometrical stairs, circular on plan and with the steps radiating from the centre, are called *circular* or *spiral* or *helical* stairs; the wall string of a circular stair may be octagonal on plan as an alternative to the more expensive circular form. An *elliptical stair* is of this type, the plan of its outer string being in the form of an ellipse with its wall string parallel to it.

Stairs in class (*b*) include the *dog-leg* (see B and H, Fig. 36 and Figs. 39, 41 and 42) and *open well* (see C, J, K and L, Fig. 36 and Figs, 43 and 44).

Staircase.—This, as previously stated, includes a stair and the part of building which encloses it.

Stairway is the opening or space occupied by the stair.

Step.—As applied here, it consists of a tread and riser[1] supported by str[ings]. The following are the types of step employed: *Bull-nosed step* (see D, Fig and B, G, H and J, Fig. 46) is situated at the bottom of a flight, projects be[yond] the face of a newel or newels and has one or both ends rounded. A *com[mode]* *step* (see step " I " at F and L, Fig. 36) has a curved riser and tread nosing; *curtail*, *round* or *scroll step* (see F, Fig. 36, and C, K, L and, M Fig. 46) has o[ne or] both ends which are semicircular or spiral on plan. *Dancing* or *balancing* [steps] are winders (see below) which do not radiate from a common centre; [those] of this type are shown by broken lines at J', Fig. 36. *Fliers* are those which [are] chiefly employed; they are of uniform width and are rectangular on plan, [e.g.] all of those shown in Fig. 37; *diminished fliers* are those immediately adj[acent] to dancing steps, the width tapering towards the outer string (see J', Fig. A *splayed step* has one or both ends splayed as shown at A, Fig. 46. *Wi[nders]* are tapering steps, such as those which radiate from a point usually sit[uated] at the centre of a newel (see Fig. 45) and those which comprise a geome[trical] stair of the type shown at G and L, Fig. 36; because of its shape the centr[e of] three winders is called a *kite winder* (see also E, Fig. 36).

Storey Rod, Post or Lath is a dressed piece of wood, of approximately 38 square, or 50 mm by 19 mm scantling, sufficiently long to extend from [floor] to floor, on which is marked the exact floor to floor height of the part of building which is to receive the stair; this rod is accurately and equally di[vided] into the requisite number of steps and is then used in their setting out (see p.

Strings or Stringers are the inclined members which support the steps. [The] following are some of the various forms: A *close* or *housed string* has both [top] and bottom edges parallel and the treads and risers are housed into it (s[ee] B, C, E, H and J, Fig. 36, and Figs. 37, 38, etc.). A *cut* or *open string* or *board* has its lower edge parallel to the pitch of the stair and its upper ed[ge] cut or notched to receive the ends of the treads and risers (see D, F, G, K a[nd] Fig. 36 and N, Fig. 46). A *rough string* is a carriage-piece or bearer. T[hose] fixed to walls are called *wall* or *inner strings* and are usually close strings; [those] on the outside are known as *outer strings* and may be of either the close or [cut] type.

Tread is the horizontal member which forms the upper surface of a [step] (see F, Fig. 37, etc.).

Walking Line represents the average line of travel taken by a person ascending or descending a stair, and is usually taken to be 450 mm from [the] centre of the handrail or newel (see D, Fig. 45).

[1] There have been several recent examples of principal stairs, constructed in [...] etc., buildings, which resemble ladders in so far as risers have been omitted and the treads have been connected direct to steel strings.

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Well or *Well-hole* is the space between the outer strings of the several flights stair (see C, J, K and L, Fig. 36 and F, Fig. 43) known as an *open well stair.*

Width of Stair.—Building Regulation min. width for a private stair is mm; 900 mm for a common stair.

Winders.—See "Steps."

Several of the above definitions will be amplified on the following pages.

Essential Requirements.—In addition to the Building Regulation stipulas given above (others are included below) a well-designed stair should nply with the following:—

1. It should be constructed of sound materials and workmanship, the treads risers being properly tongued and grooved together, wedged, glue blocked adequately supported. The strings should be well secured to walls, newels, nmers, etc. A bearer or carriage, of sufficient size, should be provided if the r is more than 915 mm wide, with an additional bearer for every 380 mm in lth, otherwise excessive deflection will occur and the stair will creak.

2. Its ascent should be relatively easy, and the proportions of treads and rs should conform to the rule stated below. The pitch must not be essive if undue fatigue is to be avoided, and it should not be less than 25° in er to prevent a tedious ascent and the occupation of excessive space. The R.s state that the pitch of a private stair should not exceed 42° and that of a nmon stairway 38°.

3. All the risers must be of the same height, and the treads should be of form width if accidents are to be avoided.

4. It should be well lighted, especially at turnings. A solid balustraded stair Figs. 42 and 44) requires a larger window than one with balusters, as the mer offers a greater obstruction to light. Two-way electric switches (which ble a light to be controlled from two points) should be provided at the head foot of the stair (see Vol. IV).

5. The maximum number of steps in a flight is preferably twelve; this specially desirable for stairs used by invalids and the aged; stairs in public ldings should conform to this. Such limitation requires the provision of dings, but when space is restricted these cannot be provided and hence the mber of steps often exceeds the desired maximum, as seen in Fig. 37. The R.s permit no more than 16 risers in a flight.

What would otherwise be a half-space landing should not be divided into quarter-space landings by a single riser; such an arrangement has been a quent cause of accidents, especially to unaccustomed users.

6. It must be of adequate width. A satisfactory width for the average-sized use is 915 mm from wall to wall, or wall to centre of outer string. A narrower ir has a mean appearance and the conveyance of large pieces of furniture, ggage, etc. is likely to damage its balustrade and walls. The width of landings ould be at least equal to that of the steps; an increased width is preferable.

7. Adequate headroom must be provided as mentioned on p. 98.

If the minimum height were not attained it would be difficult to move large furniture along the stairway; also if the height were ...... might be caused to tall persons, especially when descending the stairs.

8. Winders, unless they are of the type shown at G and L, Fig. 36, or are arranged as dancing steps (see J', Fig. 36), may be a source of danger, especially to young children, and they should therefore be avoided. This is not always possible when the going is greatly restricted and winders may then have to be utilized either at the top or, preferably, at the bottom of a flight; in cramped positions there may be no alternative to the provision of winders at both the head and foot of a flight.

When used, it is usual to divide what would otherwise be a quarter-space landing into three winders, as shown in Fig. 45. If four are used, as shown by broken lines at H', Fig. 36, the average width of each tread is inadequate; if two only are provided, as shown at B', Fig. 36, the average width of the treads is excessive, they are difficult to carpet, and the corner between the riser, lower tread and wall string is not easy to clean.

9. The Building Regulation provisions as to the height of handrails and balustrades given in the earlier glossary items should be observed.

10. A stair should be in such a position that it can be conveniently approached from the lower rooms and afford a ready access to the upper rooms. Doors should be situated at least 310 mm from the head and foot of a stair. A door which opens immediately off a top step is least desirable as it creates a potential danger especially to visitors.

11. **Step Proportions.**—A well-designed stair, even when the floor space is limited, should entail the minimum expenditure of energy in its ascent, and it must be therefore be neither steep nor inadequately pitched (see 2, above). The step of the average person measures approximately 600 mm and it has been computed that about twice the effort is required in climbing to walking horizontally. The following rule (a B.R. requirement), based apparently upon the foregoing, has been proved by experience to give a satisfactory ratio between the rise and going of a step:

Going plus twice rise is between 550 and 700 mm.

The B.R.s demand that (a) in the case of a private stair the rise of a step should be not more than 220 mm and its going not less than 220 mm; and (b) in the case of a common stairway the maximum rise is 190 mm and the minimum going 240 mm. For both stairs the minimum rise is 75 mm.

The nosing is, of course, additional to the going, and the projection of the tread beyond the face of the riser should preferably not exceed the thickness of the tread, as an excessive projection may cause a person to trip when ascending.

A stair with very narrow treads cannot be descended comfortably, as more than the usual care has to be taken to clear the nosing with the heel to obtain adequate foothold on the tread below. For this reason the preferred minimum going is 230 mm. A satisfactory proportion for house stairs is 250 mm going and a 165 to 178 mm rise, but a common size for the going is 220 mm with a rise of 220 mm.

In public buildings, where the stairs are a prominent feature and ample space is usually available, it is common to employ a 300 mm going and a 140 to 150 mm rise.

Stair Design.—The essential requirements specified on p. 101 should be kept in mind when designing a stair. The type of stair depends a good deal upon the space available for it.

The number of steps to be decided upon is governed to a large extent by the total going available. If the height from floor to floor is fixed, as it usually is, and the going is unrestricted, the number of steps is determined in the following manner: Assuming that the proposed rise is to be between 165 and 178 mm, say 170 mm (which, as stated above, is satisfactory for a house stair), the number of risers equals the height divided by 170 mm. Thus, if the floor to floor height is 2 820 mm, the number of steps equals 2 820 mm$\div$170 mm$=$16 or 17. Adopting the latter figure, the exact rise is 2 820$\div$17$=165\frac{15}{17}$ mm. The going will then equal (550 to 700 mm)$-2\times165\frac{15}{17}$ mm$=218\frac{4}{17}$ to $368\frac{4}{17}$ mm, say 250 mm. It should be noted that the number of treads is one less than that of the risers, as the surface of the upper floor forms the tread for the top step.

If the going of the flight is so restricted that the minimum going of 220 mm (see above) can only be adopted, then the number of steps equals

$$2\ 820\div\frac{(550 \text{ to } 700 \text{ mm})-220 \text{ mm}}{2}=11 \text{ to } 17.$$

Adopting 14 as the number, the rise of each step equals $\frac{2\ 820 \text{ mm}}{14}=201\frac{6}{14}$ mm. This will be satisfactory, as it conforms to the rule on p. 101.

i.e., 220 mm$+2\times201\frac{6}{14}$ mm$=622\frac{12}{14}$ mm.

The construction of straight flight, dog-leg and open well stairs will now be considered in detail. In the B.S. for domestic stairs a number of standard flights are specified; one of them is the straight flight stair below.

STRAIGHT FLIGHT STAIR

One of these is detailed in Fig. 37. Being the cheapest kind of stair to construct the straight flight stair is the most usual one for dwellings.

The ground floor and first floor plans of a small house are shown at A and B. Owing to the restricted width available, the straight flight stair shown is the only type which can be adopted; an excess in the preferred maximum number of steps in a flight (see requirement 5, p. 101) is unavoidable. Useful storage accommodation is afforded when, as shown, the space under the stairs is utilized as a cupboard. The foot and head of the stair are approximately 380 mm from the living-room and bedroom No. 1 doors respectively (see requirement 10, p. 101).

Enlarged plan, longitudinal and cross-sectional elevations of the stair are shown at D, C and E.

Construction of Steps.—Owing to the limited going of the flight, the width of the step is 220 mm (*i.e.*, the minimum required by the Building R tions) and it will be seen that only thirteen steps can be provided. As the from floor to floor is 2 600 mm (see C), the rise of step equals 2 600 mm 200 mm. This proportion of step agrees with the rule given on p. 10 220 mm+(2$\times$200 mm)=620 mm.

The nominal thickness of the treads should not be less than 32 mm[1] a of the risers is usually 25 mm. The enlarged detail at F shows one good of connecting the treads to the risers, both edges of the latter being t into the grooved treads and screwed (preferably) as shown, or nailed nosing, as previously explained (p. 101), should not project more th thickness of the tread. This simple nosing—the square edges are just papered—is all that is necessary for this type of stair; if the stair, having as shown, is not to be carpeted, it is advisable for the treads to be of har (such as teak or oak) and not softwood, as the edges are apt to be da Another good method of jointing treads and risers is shown at E, Fig. 42, the treads are tongued at their inner edges into the risers; this also sh alternative simple nosing. Another nosing is shown at D, Fig. 38, a sc cavetto mould being used; as this moulding is fitted into the grooved there is no need for the riser to be tongued; alternatively, the top outer the riser is tongued to fit the grooved tread, and the moulding is just glu sprigged to the tread. A common nosing is the half-round, such as is ind in Fig. 46. A cheap and second-rate method of jointing is shown at P, F here the members are just butt-jointed and nailed together, hence any sh of the risers and especially the treads, results in unsightly gaps occurring t which dust passes.

The treads and risers are supported by two 300 mm by 32 mm wall which are securely plugged to the walls (see C, D, E and detail at G). As at G, the upper edge of the string is rounded and rebated to provide a but effective finish between it and the plaster.

The ends of the treads and risers are housed into the wall strings, the a of housing varying from 9 to 16 mm—usually 12 mm (see G, Fig. 37) grooves, trenches or housings to receive these ends are tapered and sufficient width to permit of the insertion of tapered wedges. These (see L, Fig. 38), after being dipped in glue, are driven in from the back tread wedges thus bring the treads tightly against the upper cuts of the ho and the riser wedges cause the faces of the risers to fit against the outer housing (see G, Fig. 37, C, and D, Fig. 38, F, Fig. 39, etc.).

Additional rigidity is obtained by the provision of small triangular termed *glue blocks*, which are glued in at the inner angles formed betw treads and risers. These are spaced at 75 or 100 mm apart (see C, F

[1] Wood treads of stairs for offices, etc., subjected to heavy traffic are sometimes to 50 mm thick

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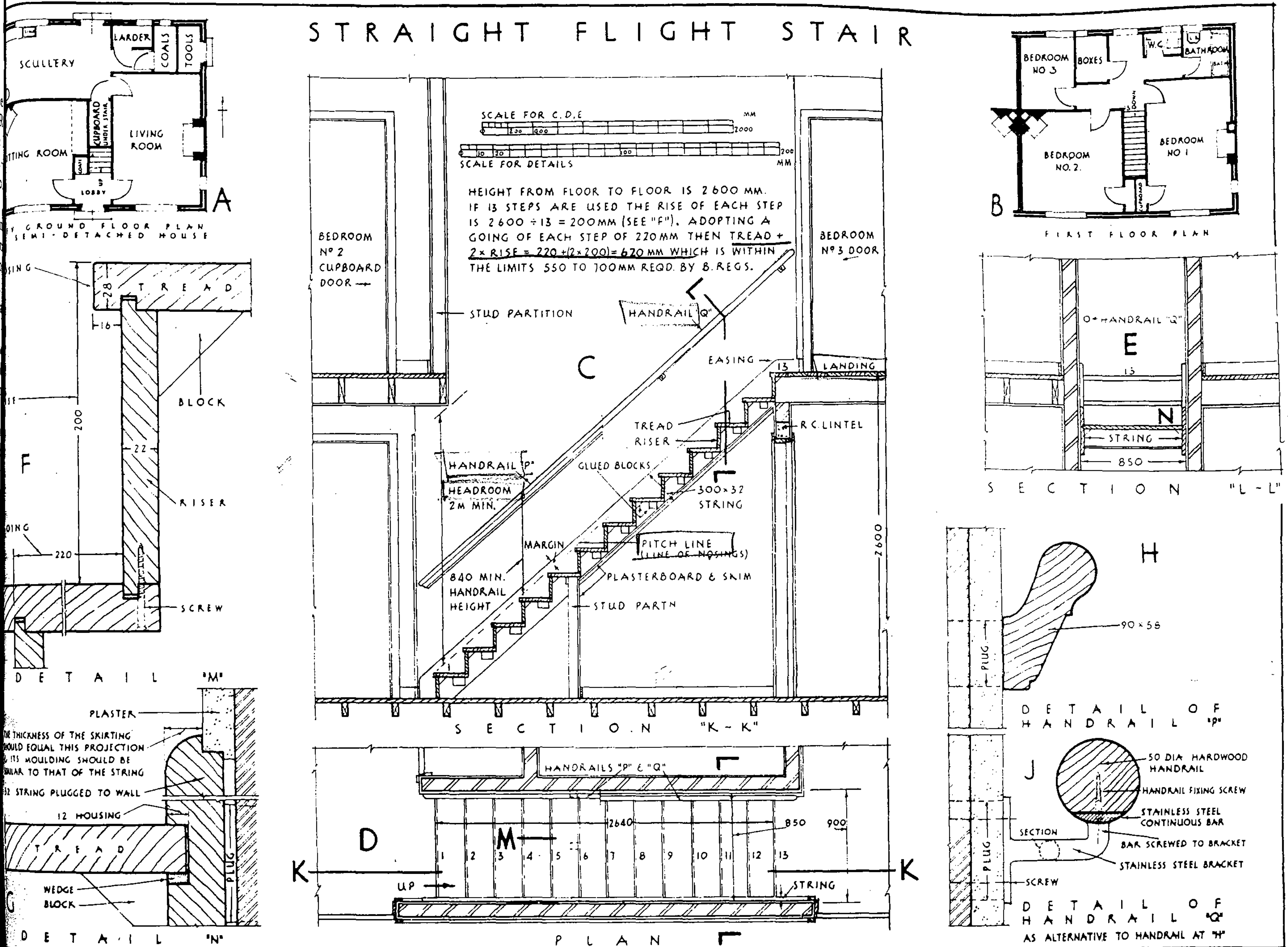


FIGURE 37

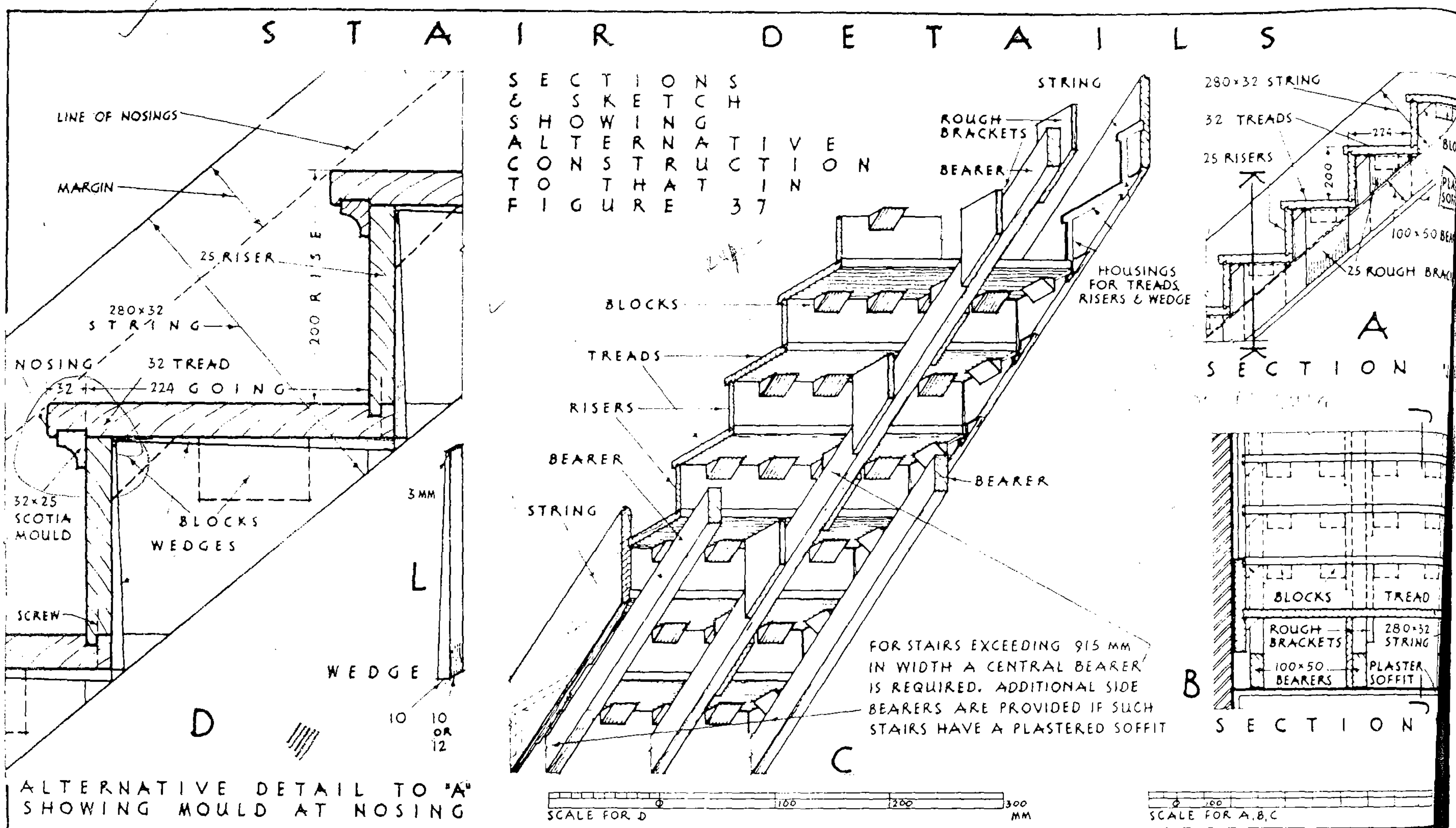


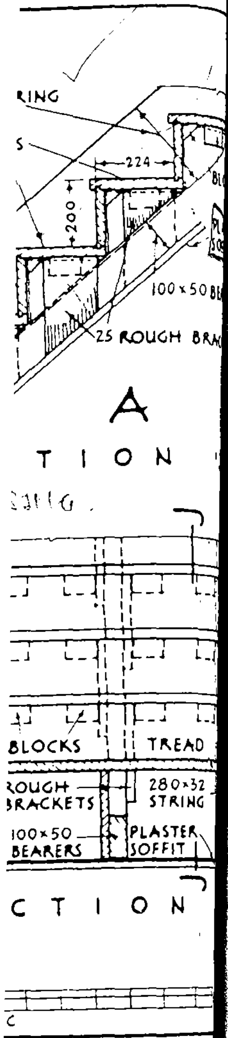
FIGURE 38

Fig. 37, and A, B, C and D, Fig. 38, etc.). They are also glued to the strings and treads, and occasionally at the angles between the risers and the strings.

The construction of the upper floor at the landing is shown at C, D and E, where the ends of the joists could be supported on a wall plate. The 32 mm thick nosing forming the top step is either tongued and grooved or splay-jointed to the adjacent floor board(s); see G, Fig. 39.

Handrail.—A handrail should be of suitable size and shape in order that it may be readily grasped by the hand, and it should be fixed at the minimum height of 840 mm above the pitch line (see p. 98;) sharp arrises on a moulded handrail must be avoided to prevent injury to a person's hand. Two forms of handrail are shown at C and these are detailed at H and J. The former is a very common wall handrail and is securely plugged to the wall; it is usually of pine or a hardwood. That shown at J is of hardwood, circular in section, screwed to metal brackets, secured at approximately 1·2 m intervals to As this latter handrail projects at least 75 mm from the plaster, it is not a su form for narrow stairs (see p. 113).

Headroom.—Adequate headroom is most important, and it is an es which is occasionally overlooked. As stated on p. 98, it should be a 2 000 mm. In this example the upper floor is continued over the "l (see A) and the space thus available is utilized to provide a cupboard or wardrobe to each of the bedrooms Nos. 1 and 2 (see B). Such provisio not encroach upon the headroom, which is adequate (see C). As show



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rtition across the stair is a stoothing consisting of 100 mm by 50 mm vertical uds, secured to the floor and ceiling joists, and plasterboarded both sides (see 45); the partition between the cupboards is a similar stoothing, but the studs ed only be 75 mm by 50 mm.

Cupboard under Stair.—It is usual to utilize the space under the stair by oviding useful storage accommodation as shown at A, C and D. The door, course, opens outwards. The lintel above it is shown supporting brickwork; ernatively, four 100 mm by 50 mm short vertical studs may be used, nailed the lintel and wall plate. A low stoothed partition consisting of three 75 mm 50 mm studs is fixed to block out a corner which would be otherwise difficult keep clean and a portion of the floor which would serve no useful purpose.

Setting Out on Paper.—In setting out the stair on paper the student should first draw the plan, the nosings (or faces of risers) being spaced by the accurate application of the scale. The longitudinal section is then developed from the plan. The height shown in this section can be expeditiously divided into the requisite number of steps in the following manner: Draw a line representing the landing level at 2 600 mm above the ground floor. Using any convenient scale, place it at an angle on the paper with the zero division intersecting the landing (or ground floor) and the thirteenth division coinciding with the ground floor level (or landing, depending upon the end from which the scale reads), and carefully tick off the intermediate divisions 1 to 12 inclusive. Horizontal lines drawn through these points give the treads, and when connected with the vertical lines developed from the divisions on the plan the required thirteen steps are set out. It is advisable to number each step on plan as shown and also on the section during its development. The direction " up " should be indicated on the plan at the foot of the stairs; this removes ambiguity and facilitates the reading of a drawing, especially when a stair consists of several flights. The rest of the details can be completed without much difficulty, an adjustable set square being useful for drawing the string, line of nosings (to check for accuracy) and handrail. The importance of ensuring adequate headroom is again emphasized.

Setting Out and Construction in Workshop.—The fixing and trimming (if any) of the floor joists will have been completed and the floor boards laid before the construction of the stairs is commenced. As there is usually some discrepancy between the dimensions taken from a plan and those of the building, it is necessary to obtain the exact total rise and going of a stair from the actual building. A storey rod (see p. 100) is used for this purpose. To obtain the correct height from floor to floor, the rod, resting on the ground floor, is held vertically (a plumb-bob being used to ensure this) against the end of one of the wall landing joists. The height of the upper floor boards is carefully marked on the rod and the word " rise " is written below it; the point where the suspended bob touches the floor is marked. This height is checked by taking a measurement near to the opposite wall.

The position of the face of the bottom riser is marked on the ground floor (or wall) and the horizontal distance between this and the " bob " point previously marked is measured and marked on another face of the storey rod, and the word " going " is written on it. On being taken to the shop, the " rise " face of the rod is divided by compasses into fourteen equal parts, being the number of risers required. The distance that the face of the top riser is to be from the edge of the landing is marked from one end of the " going " face of the rod, and the net going is then divided into twelve equal parts.

The next operation is the trenching or housing of the strings.

Trenching.—Simple machines are available for the rapid setting out and complete trenching of straight strings.

One type of stair trencher consists of a vertical cutter spindle, the cutter of which travels within guides (adjusted to the required going and rise) as it forms the trenches in both strings during a continuous operation.

There are several methods employed in assembling the various parts of a stair, depending upon local practice, if mass-produced, etc. In one method all of the treads are first fixed to the strings, followed by the risers. In another each step, with its tread and riser, is framed together; the steps are then fitted in the trenches of one string, after which the second string is fitted and cramped.

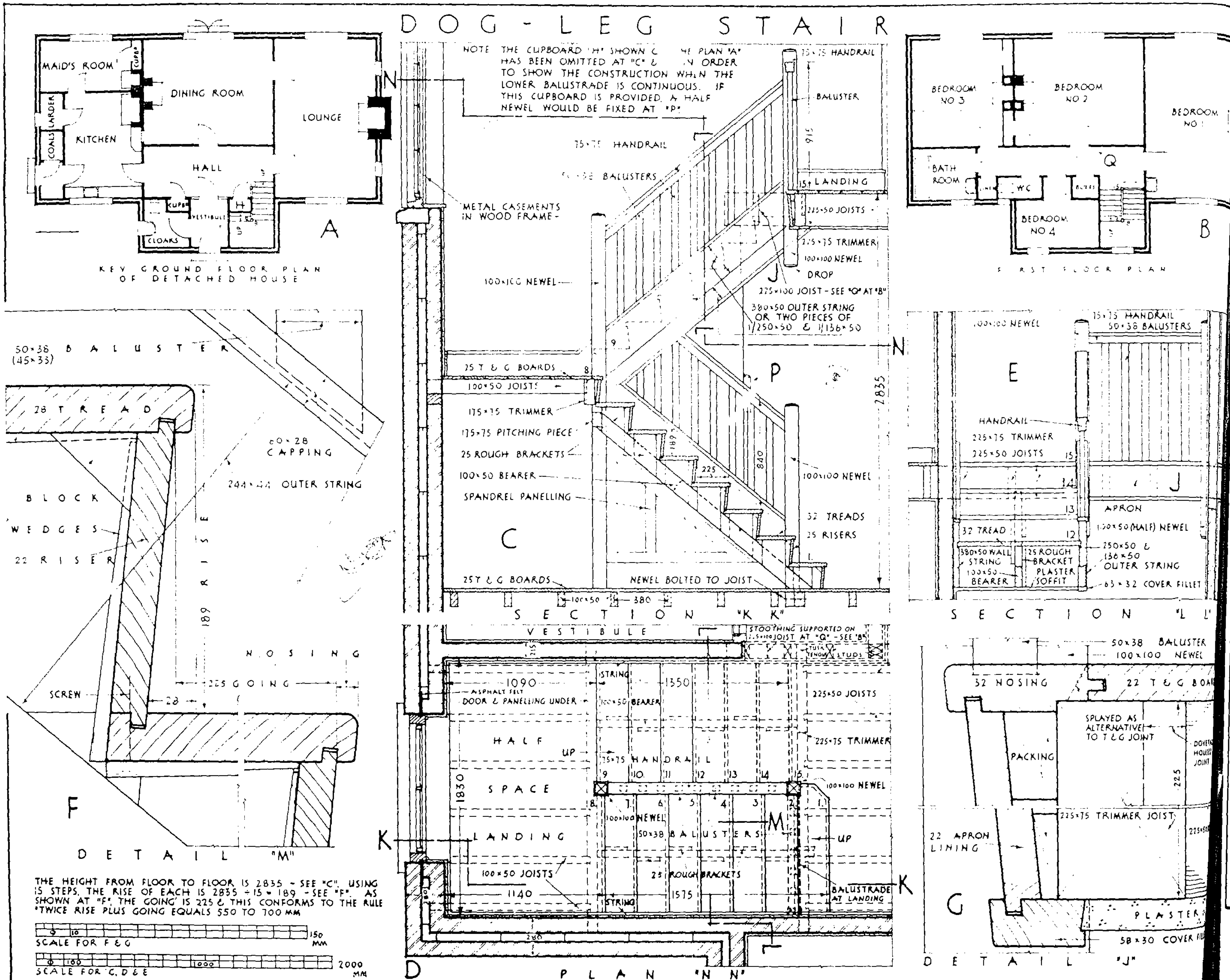
Briefly, the sequence of operations in the first method are: After the strings have been trenched and the treads and risers have been prepared (*i.e.*, tongued, grooved, nosed, cut square to correct length and dressed), the first and last treads are housed into the corresponding trenches of both strings, cramped after being tested for squareness, nailed and wedged. The strings are now placed with their front or upper edges resting on the bench, and the remaining treads are inserted between the trenches, each being tested, cramped and glue wedged in turn. After the outer ends of the wedges have been removed as required, the risers are inserted and wedged. The treads and risers are then screwed (in best work—see F, Fig. 30) or nailed and glue blocks are fitted to the inner angles. The treads may also be skew screwed or nailed to the string. Scotia mouldings, if required, are glued and sprigged to the treads.

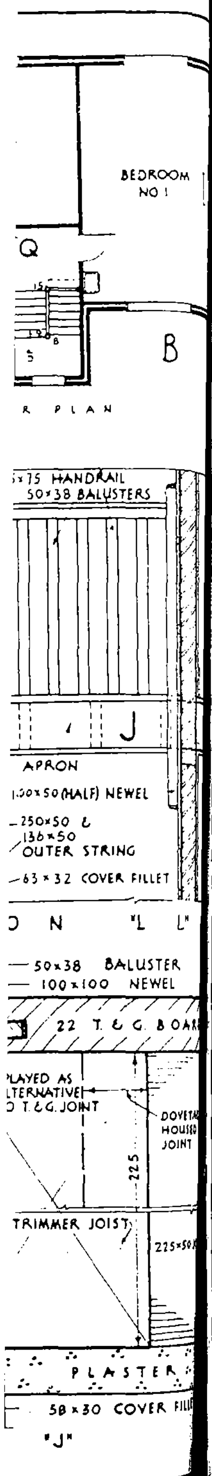
In the second method the steps are made separately before being fixed to the strings. One simple appliance, called a *cradle*, which is employed to ensure that the riser is fitted at right angles to the tread, consists of two angle brackets, each being a 75 mm by 50 mm by 450 mm long wood bearer to which a shorter piece of similar scantling is securely fixed vertically and squarely at one end; each upright or leg is notched on its inner edge where it joins the horizontal bearer, the size and shape of the notch being similar to the nosing of the tread (and scotia, if needed); the brackets are screwed to the top of the bench about 300 mm apart, the horizontal members being parallel to each other and at right angles to the base of a try square used for ensuring squareness. The tread, outer face downwards, is placed on the bearers with the nosing engaged in the notches of the uprights. The upper tongued edge of the riser is glued and fitted into the groove of the tread as the riser is held against the uprights. The blocks are then glued and fitted to the inner angle. If required, the scotia is glued and inserted before the riser is fitted. When the glue is sufficiently dry, the step is carefully removed and allowed to set. After all the steps have been formed in this manner, the next operation is to fix them to the strings. A string, with its trenched face uppermost, is placed on the bench and each step is placed vertically with its lower end fitted into the trench. When all the steps have been housed, the second string is placed in position with the upper ends of the steps engaging in the trenches. The stair is then cramped; if the flight is assembled on a bench specially equipped for this purpose, the cramps employed will be of the overhead type; otherwise ordinary T-cramps are used. The treads and risers are now wedged, care being taken to see that each tread is driven tightly against the trench nosing before the tread wedge, well glued, is driven home. To ensure that none of the nosings are out of winding, a straight edge is applied to them and any nosing not touching it is driven tighter as required. Glue blocks are fitted between the treads and strings, and treads are screwed to risers, etc., as described above. The top nosing is neatly tongued and grooved or splay jointed to the adjacent floor boards after the stair has been fixed.

As previously mentioned, the stair is well secured by nailing the strings to plugs which have been driven into the joints of the brickwork. The ends of the strings are cut to the required length—any easings having been previously formed—and the skirtings are neatly fitted to them. Attention is drawn to the note at G, Fig. 37, to the effect that the moulding on the skirting should conform to that on the string, and its thickness should be equal to the projection of the string beyond the face of the plaster. A clumsy finish frequently results because of inattention to this detail.

Fixing of the handrail to the wall, at the required height, completes the stair.

When the width of the stair exceeds 915 mm the use of an intermediate support or bearer below the flight is needed; this form of construction is shown in Fig. 38, it strengthens and prevents the stair creaking under traffic. It consists of a 100 mm by 75 mm (or 50 mm) bearer or carriage piece which


DOG-LEG STAIR
MAID'S ROOM
CUPD
DINING ROOM
LOUNGE
LARDER
COALS
KITCHEN
HALL
CUPD
VESTIBULE
CLOAKS
UP
H
A
KEY GROUND FLOOR PLAN OF DETACHED HOUSE
NOTE THE CUPBOARD "H" SHOWN ON THE PLAN "A" HAS BEEN OMITTED AT "C" & "D" IN ORDER TO SHOW THE CONSTRUCTION WHEN THE LOWER BALUSTRADE IS CONTINUOUS. IF THIS CUPBOARD IS PROVIDED, A HALF NEWEL WOULD BE FIXED AT "P"
75×75 HANDRAIL
BALUSTER
915
75×75 HANDRAIL
50×38 BALUSTERS
LANDING
225×50 JOISTS
METAL CASEMENTS IN WOOD FRAME
225×75 TRIMMER
100×100 NEWEL
DROP
100×100 NEWEL
J
225×100 JOIST - SEE "Q" AT "B"
380×50 OUTER STRING OR TWO PIECES OF 1/250×50 & 1/136×50
N
25 T & G BOARDS
100×50 JOISTS
P
2835
175×75 TRIMMER
175×75 PITCHING PIECE
25 ROUGH BRACKETS
100×50 BEARER
SPANDREL PANELLING
189
225
840
100×100 NEWEL
32 TREADS
25 RISERS
C
25 T & G BOARDS
NEWEL BOLTED TO JOIST
100×50
380
SECTION "K K"
BEDROOM NO 3
BEDROOM NO 2
BEDROOM NO 1
BATH ROOM
WC
Q
BEDROOM NO 4
B
FIRST FLOOR PLAN
100×100 NEWEL
75×75 HANDRAIL
50×38 BALUSTERS
E
HANDRAIL
225×75 TRIMMER
225×50 JOISTS
J
APRON
32 TREAD
100×50 (HALF) NEWEL
380×50 WALL STRING
25 ROUGH BRACKET
250×50 & 136×50 OUTER STRING
100×50 BEARER
PLASTER SOFFIT
63×32 COVER FILLET
SECTION "L L"
50×38 BALUSTER
(45×33)
28 TREAD
60×28 CAPPING
244×44 OUTER STRING
BLOCK
WEDGES
22 RISER
189 RISE
NOSING
SCREW
28
225 GOING
F
DETAIL "M"
VESTIBULE
STOOTHING SUPPORTED ON 75×100 JOIST AT "Q" - SEE "B"
STUDS
1090
STRING
1350
ASPHALT FELT
DOOR & PANELLING UNDER
100×50 BEARER
225×50 JOISTS
HALF
UP
225×75 TRIMMER
75×75 HANDRAIL
SPACE
1830
100×100 NEWEL
100×100 NEWEL
M
K
LANDING
50×38 BALUSTERS
UP
100×50 JOISTS
25 ROUGH BRACKETS
BALUSTRADE AT LANDING
K
1140
STRING
1575
D
PLAN "N N"
50×38 BALUSTER
100×100 NEWEL
32 NOSING
22 T & G BOARDS
SPLAYED AS ALTERNATIVE TO T & G JOINT
PACKING
225
225×75 TRIMMER JOIST
22 APRON LINING
G
PLASTER
58×30 COVER FILLET
DETAIL "J"
THE HEIGHT FROM FLOOR TO FLOOR IS 2835 - SEE "C". USING 15 STEPS, THE RISE OF EACH IS 2835 ÷ 15 = 189 - SEE "F". AS SHOWN AT "F" THE GOING IS 225 & THIS CONFORMS TO THE RULE "TWICE RISE PLUS GOING EQUALS 550 TO 700 MM"
SCALE FOR F & G
150 MM
SCALE FOR C, D & E
2000 MM



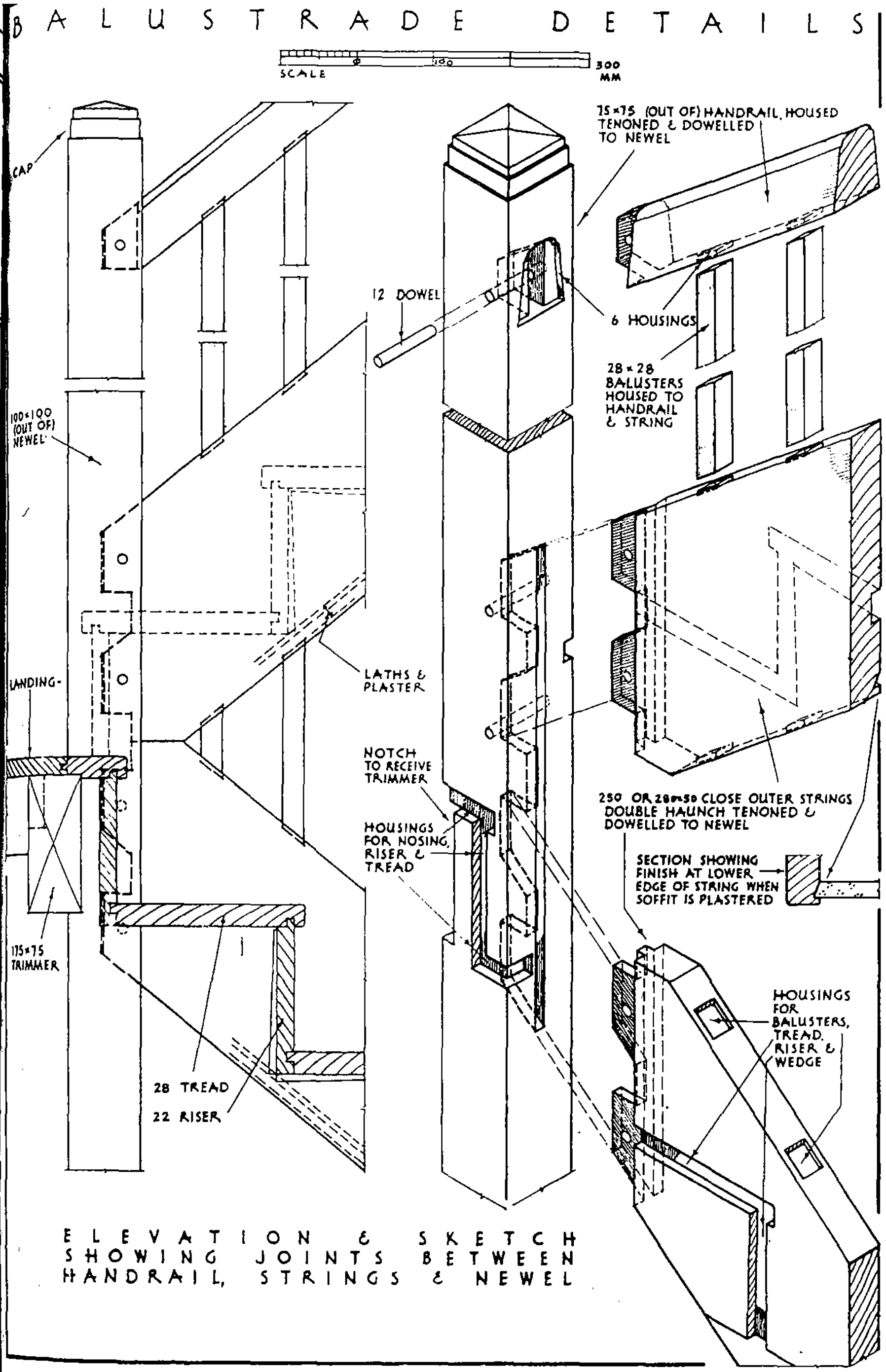


FIGURE 40

is birdsmouth notched and nailed to a short fillet at the foot (or it may be continued through the floor and notched to a deep conveniently placed floor joist) and similarly secured to the wall plate at the head. In order that the carriage-piece may afford the maximum support, 25 mm thick short pieces of wood (often pieces of floor board), called *rough brackets*, and shaped as shown at C, are nailed to the sides with their upper edges cut square and brought tightly up to the underside of the treads to which they are nailed; these brackets are fixed on alternate sides of the bearer (see C, Fig. 38). As an alternative to these brackets, triangular blocks are nailed on the upper edge of the carriage as shown at A and G, Fig. 45. In the illustrated examples, the inner edges of the treads or risers (depending upon the type of joint) are shown resting upon the carriages, but sometimes the latter are slightly notched to receive the steps.

DOG-LEG STAIR

This is so called because of its appearance in sectional elevation. It is a convenient form when the going is restricted and sufficient space equal to the combined width of two flights only is available. It is illustrated at B and H, Fig. 36, and in Figs. 39, 40, 41 and 42.

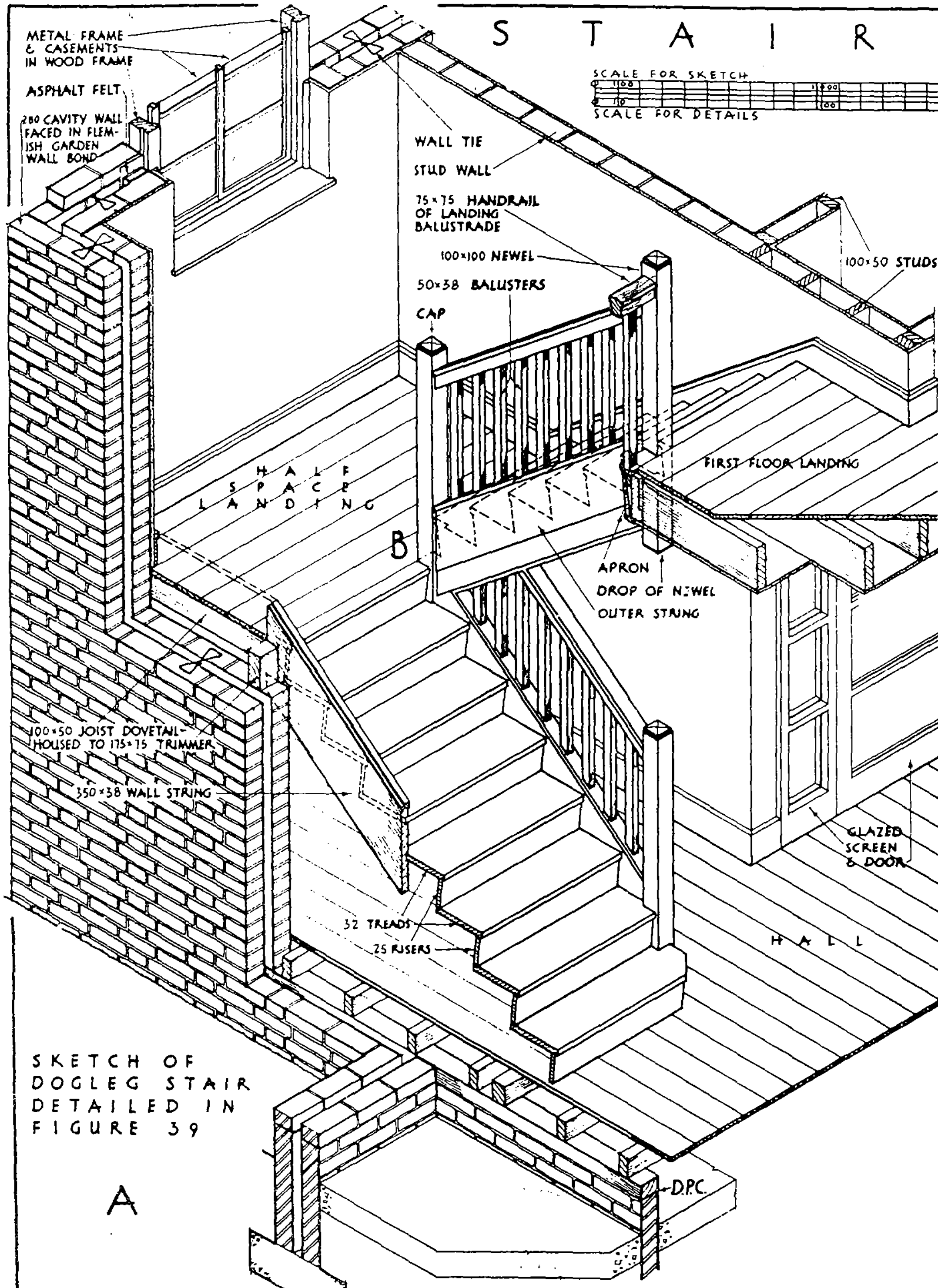
Small scale plans of a house showing the application of this type of stair are given at A and B, Fig. 39, and a larger scale plan and sections are shown at C, D and E. Reference to the isometric sketch of this stair at A, Fig. 41, will give a better idea of its appearance. It will be seen that the balustrade of the upper flight is immediately over that of the lower.

Steps.—A detail of the steps and a note upon their proportions are given at F, Fig. 39. The inclined risers are an alternative to the more usual vertical form already described and give an attractive appearance to the stair, especially if a simple nosing is employed. The edge of the nosing is parallel to the riser, the slope of which should not be too flat, otherwise the projection of the nosing beyond the bottom of the face of the riser will be excessive (see p. 101). The jointing, housing, wedging and blocking of the steps are as described for the straight flight stair. The bottom splayed step is detailed at D and E, Fig. 46.

Strings and Newels.—The outer ends of the steps are housed into the outer strings, the thickness of which is usually 12 mm more than that of the wall strings, *i.e.*, 50 mm. As the stair is 865 mm wide and the upper flight at least has a plastered soffit, the upper string is necessarily wide (see L, Fig. 41), but the lower outer string need only be 250 mm (nominal) wide (see F, Fig. 39), as the spandrel is panelled (see C). This outer string of the upper flight may be in one piece, 380 mm wide (see M, Fig. 41), more usually it will consist of two tongued and grooved pieces (see B and L, Fig. 41); for narrower stairs, when a rough carriage is not required, the plasterboard soffit may be nailed direct to the steps and parallel to the pitch (shown by broken lines in the detail in Fig. 40). Both outer strings are secured to 100 mm by 100 mm newels placed at the foot and head of each flight. The strength of the stair depends a good deal upon the rigidity of these newels and the method of jointing the strings to them. The

STAIR DETAILS

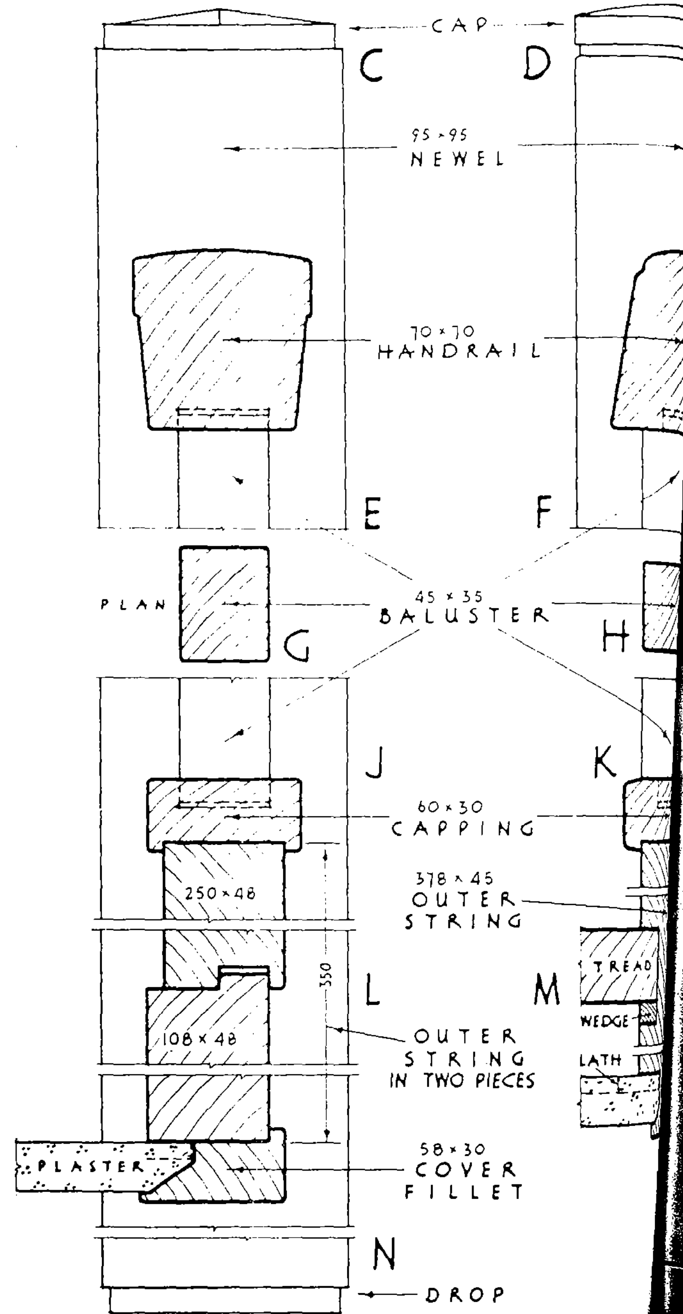
SCALE FOR SKETCH
SCALE FOR DETAILS
2000 mm
200



SKETCH OF DOGLEG STAIR DETAILED IN FIGURE 39

A

ALTERNATE DETAILS OF BALUSTRADE



DOG-LEG STAIR

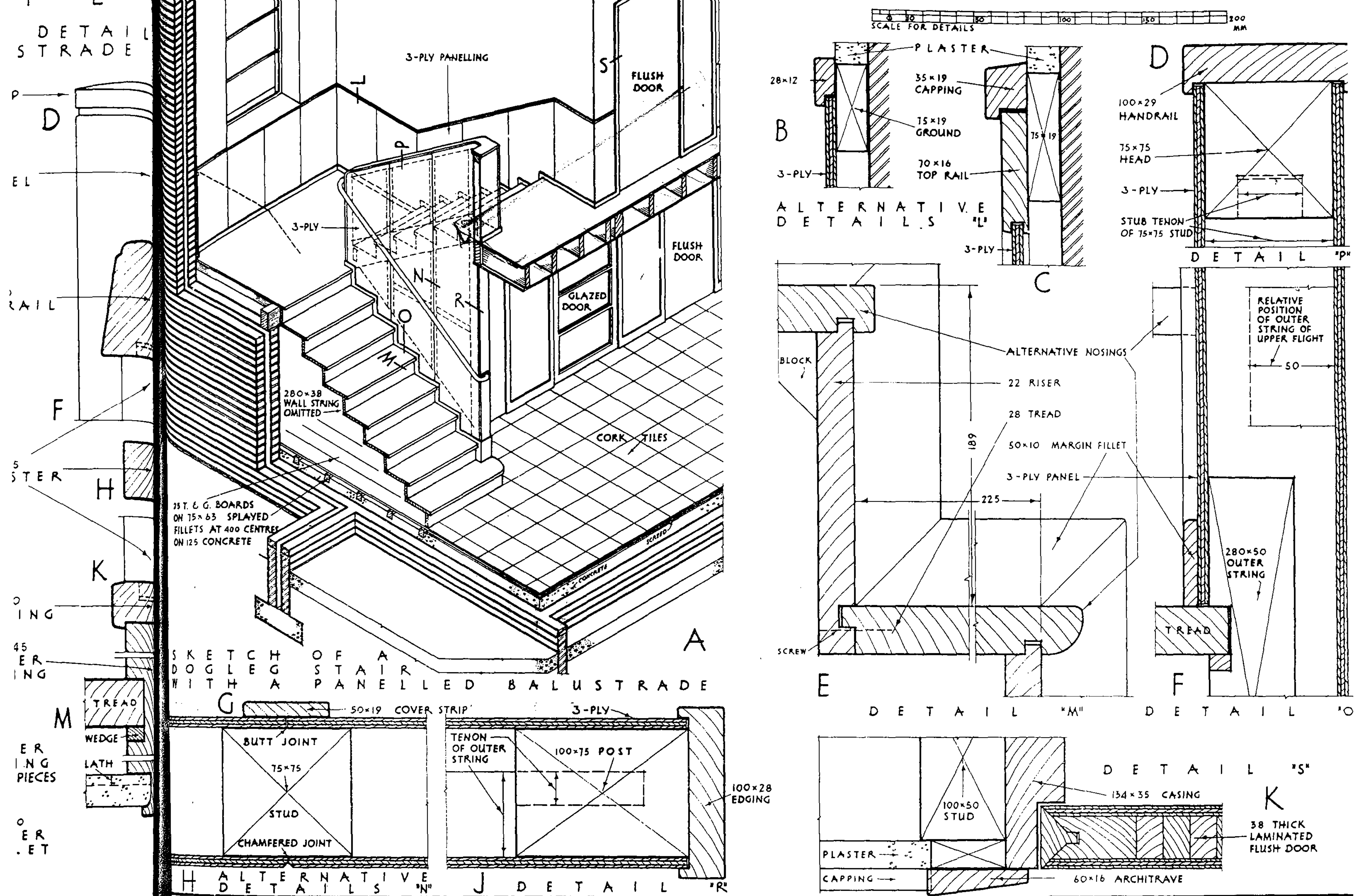


FIGURE 42

bottom newel is continued through the floor and well nailed or bolted to a 75 mm thick joist (see also C, Fig. 43). The central newel is continued to the floor (see C, Fig. 39) to which it is nailed; whilst this is a common practice, greater rigidity is obtained if it is continued through the floor and secured to a convenient joist, this newel is also notched to the trimmer joist to which it is securely nailed or bolted (see also Fig. 40). The upper newel is also notched to the 225 mm by 75 mm trimmer (see C and G, Fig. 39).

Details of the draw-pinned joints between the newel and the strings at B, Fig. 41, are given in Fig. 40. These show at the end of each string two oblique haunch tenons which are fitted into mortises formed in the newel and secured by a pin or hardwood dowel at each tenon. The tenons are formed in the centre of the strings (see sketch in Fig. 40), and if the tenon holes for the dowels are bored slightly nearer to the shoulders than the distance the newel holes is from the edge of the newel, a tight fit between the shoulders and the newel will be assured when the slightly tapered glued dowels are driven in. An alternative but inferior joint, adópted in cheap work, is to form barefaced tenons on the outside of the strings with shoulders on the inside.

Note that the nosings of the treads are set slightly back from the edges of the newels.

Landings.—The half-space landing is constructed of 100 mm by 50 mm joists, supported by the wall at one end and dovetail housed at the other to a 175 mm by 75 mm trimmer which spans the opening and is carried by the walls (see C and D, Fig. 39, Fig. 40 and A, Fig. 41); the narrow top tread of the lower flight is rebated over the trimmer and is tongued and grooved to the floor board. The construction at the top landing is similar (see C, D, E and G, Fig. 39), but one end of the 225 mm by 75 mm trimmer joist is tusk tenoned into a 225 mm by 100 mm joist (see Q at B) supported on the wall between the dining-room and hall and that dividing the vestibule and stair; this latter joist also supports the 100 mm by 50 mm vertical studs forming the small box-room partition (see also A, Fig. 41 and p. 42). The 100 mm by 50 mm bearer or rough carriage of the lower flight is well nailed at the foot to the floor and joist below, and its upper end is birdsmouthed and nailed to a 100 mm by 75 mm *pitching piece* or trimmer which is tenoned to the newel at one end and supported by the wall at the other (see C). The upper carriage is well secured to the trimmers.

Handrail.—The handrail for the upper flight is housed, tenoned and dowelled (draw-pinned) to the two newels (see C, Fig. 39 and Fig. 40). The interception of the upper end of the lower handrail by the upper outer string is unavoidable. Besides the unsatisfactory appearance thus presented, the absence of a handrail at the top of this flight is inconvenient, if not dangerous, and therefore an additional handrail (similar to that shown at H, Fig. 37) is sometimes fixed to the wall at the lower flight. The handrail of the balustrade provided at the top of the landing is 915 mm high (see p 98.) and is fixed between a 100 mm by 100 mm newel and a 100 mm by 50 mm newel (known as a *half-newel*) plugged to the wall (see C and E, Fig. 39).

Alternative details of the balustrade are shown in Fig. 41. Sections through handrails are indicated at E and F. The strings at L and M have already been referred to; the cover fillet at the lower edge of the string at L provides a suitable finish to the plaster, the groove being sufficiently deep to cover the plasterboard which is nailed to the string; this has a better appearance than the cheaper alternative at M, where the string is grooved to receive the plasterboard. An alternative finish, suitable when the plasterboard is fixed direct to the steps, is shown in section in Fig. 40. The appearance is also improved if a capping is fixed to the upper edge of each string; two simple cappings are shown at J and K, Fig. 41; the strings shown in Fig. 40 are without cappings.

It will be noted that in all these details no unsightly gaps will be caused if the timber shrinks.

Two plain, but effective, solid moulded caps to the newels are shown at B and D, Fig. 34, and a drop, similar to C, is shown at N.

Balusters.—The 50 mm by 38 mm balusters shown in Fig. 39 are detailed at G and H, Fig. 41. They are usually spaced at 75 to 100 mm apart and arranged so that one is central at the intersection between the lower handrail and the upper string. If square balusters are used, they should be out of not less than 32 mm stuff (see A and B, Fig. 45), as 50 mm square balusters look spindly when dressed. Balusters may be either housed (as at F, Fig. 41) or tenoned (as at E) into handrails, and housed (see J) or tenoned (see K) into the cappings or strings (see also Fig. 40). A continuous groove is sometimes formed in the underside of the handrail and the upper ends of the balusters are slid into it. Alternatively, especially when the balustrade is to be painted, a continuous groove is formed in the upper edge of the string; after the balusters have been fixed, the portions of the groove between them are filled in. For inferior work, and owing to the difficulty of housing or tenoning the balusters, they are cut to the pitch of the handrails and strings and simply nailed to them.

Additional balustrade details are illustrated in Figs. 42, 43, 44, 45 and 46.

Bronze or similar metal balustrades are sometimes employed for wood stairs. Some details of this type are shown in Vol. II, and could be applied here if modified to show the bottom of each baluster secured to a continuous bar (provided with a flange) and screwed to the string, etc.

A detail showing a suitable finish to the upper floor, where the balustrade is returned to the wall, is shown at G, Fig. 39. The trimmer is covered with an apron lining, which is sloped to conform to the risers, and tongued and grooved to the nosing and cover fillet; the lining may be of 3-ply. As the nosing is only slightly set back from the edge of the newel, it is advisable to provide small packing pieces as shown; a solid bearing for the balustrade is thus afforded. The nosing is rebated over the trimmer and either tongued and grooved or splay-jointed to the floor board. Note that there is a slight margin between the edge (adjacent to the plaster) of the cover fillet and the edge of the newel. Alternative apron details are shown at M and N, Fig. 43.

The spandrel and the area between the long newel, wall, floor and the

plastered soffit of the upper flight are shown panelled (see C and D, Fig. 39).
The isometric sketch of this staircase (Fig. 41) shows a portion of the window placed in the external cavity wall. This must be large enough to light both the staircase and hall. Additional lighting to the latter is provided by the glazed door and screen, and, if necessary, the door into the kitchen may be partially glazed with figured or similar glass. The cupboard "H" has been omitted for the reason stated below the title of Fig. 39.

Setting Out and Construction.—Much of the description on p. 105 is applicable. In addition to the net height and going, the position of the half-space landing trimmer will be noted on the storey rod, the width of stairway will be taken and the angles between the walls will be checked.

If a cradle is used to frame the treads and risers together (see p. 105), the two legs will be inclined to conform to the slope of the risers. The strings are fitted to the newels at the shop, they are then dissembled, transported to the job and finally fixed after any necessary adjustments have been made.

Contemporary Treatment.—A more modern treatment of this dog-leg stair is shown in the isometric sketch A, Fig. 42. The balustrades illustrated in the previous figures are of the *open* type, *i.e.*, balusters are employed. These open balustrades are not always favoured, principally on account of the extra labour entailed in dusting, cleaning and polishing. To meet this objection an increasing number of stairs is constructed with *solid* or panelled balustrades. This is particularly effective when applied to dog-leg stairs because of its improved appearance compared with the somewhat ugly effect produced by the upper string intercepting the lower open balustrade. As this is a matter of opinion, students may draw their own conclusions by comparing the sketch of the open-balustraded dog-leg stair in Fig. 41 with that of the solid-balustraded type illustrated at A, Fig. 42. It must be emphasized, however, that solid balustrades obstruct a good deal of natural light and will cause the interior of a building (especially the hall) to be dark unless larger windows are provided than those which are adequate when open balustrades are employed.

The whole treatment is simple, and therefore elaborately moulded nosings, handrails, etc., must be avoided. The steps may be constructed as shown at F, Fig. 39, or as illustrated at E, Fig. 42, where two alternative nosings are indicated. They are housed and wedged in the usual manner (see F). The strings, which are undressed, are secured to two rough 100 mm by 75 mm posts which are continued and securely fixed to the ground floor and landing trimmers. The ends of the strings are barefaced tenoned to the posts (see J). Note at F that the outer strings are not in the same vertical plane, the inner faces being flush with those of the posts to provide fixings for the boards of 3-ply. The posts are connected at the top by a 75 mm by 75 mm head (see D and A). Two vertical 75 mm by 75 mm studs are stub-tenoned to the head and strings. Both sides of this framing are covered with 3-ply (see A, D, F, H and J). Two alternative joints between the plywood boards are shown at G and H. The former shows the boards to be butt or square jointed; the thin wood strip which covers the joint is secured by panel pins which are punched and the holes made good with suitably coloured wood mastic or stopping to render them inconspicuous. When chamfer-jointed (H), the boards are panel pinned, and these fixings are concealed in a similar manner; this joint can be safely employed under normal conditions, as the better graded plywoods shrink very little (see p. 119).

The handrail at the top flight is shown at D. Whilst this simple treatment is effective in appearance, it is rather wide, and therefore a tapering handrail, such as that at F, Fig. 41, is sometimes adopted; alternatively, a chromium plated circular tube, or one similar to J, Fig. 37, secured by short vertical standards to the rail at D, may be used. The handrail for the lower flight, indicated at A, Fig. 42, is of circular section as above; this is bent at the ends and screwed to the newels; two additional intermediate brackets would be required. The rail at D is continued down the post at the half-space landing, and a similar edging is fixed to the longer post (see J) in order to protect the edges of the plywood and provide a suitable finish.

The difficulty of making a good finish between the plywood and the steps is overcome if thin, narrow *margin fillets* are planted on the face, and these short horizontal and vertical pieces are mitred (see A, E and F, Fig. 42).

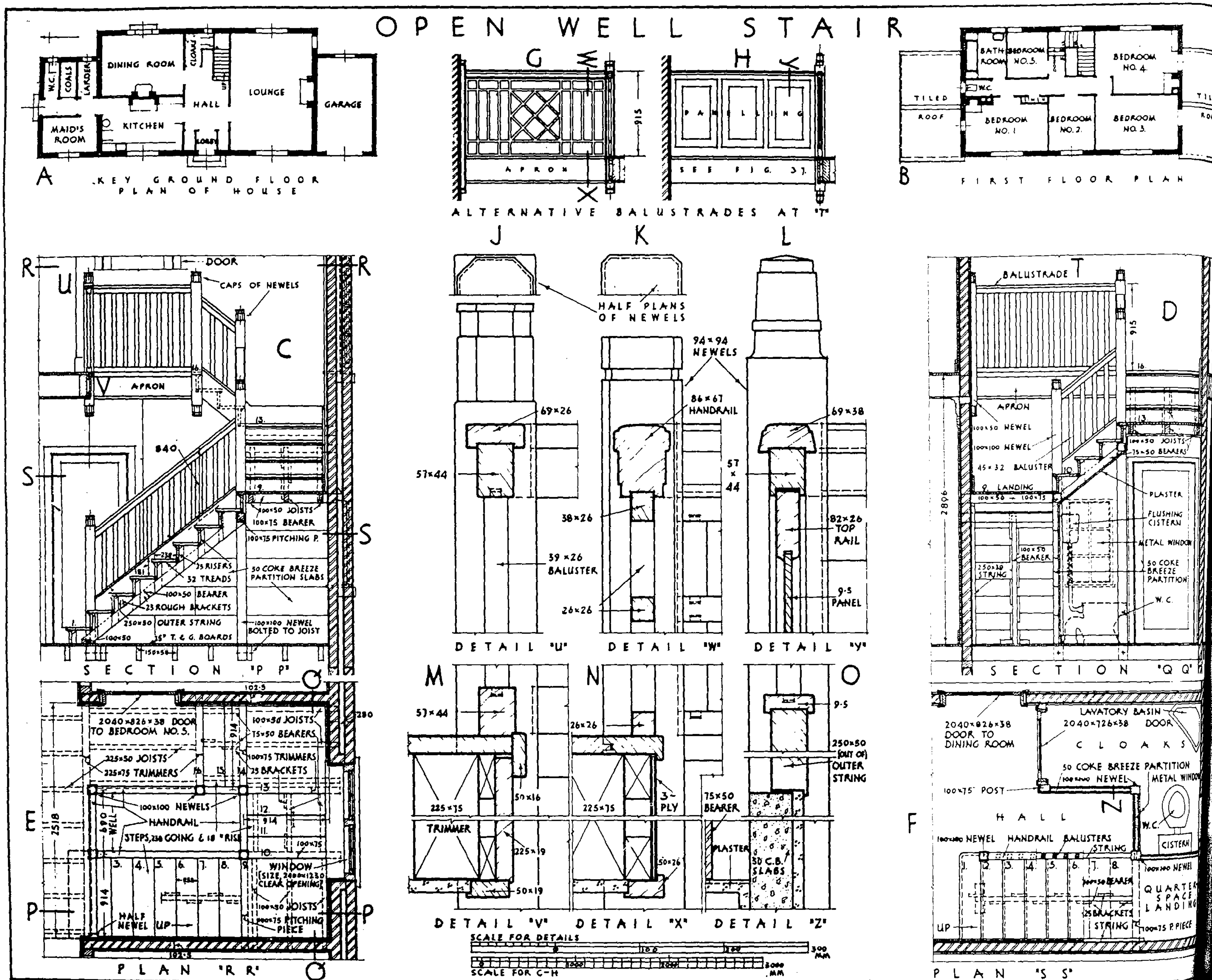
The bottom step is bull-nosed (as shown) or splayed (see Fig. 46).

If desired the walls of the stairway may be panelled to conform with this balustrading.[1] As shown at A, the height of this dado panelling is the same as that of the handrail; the capping (see detail at B), of similar projection and depth as the handrail, lining through with the window board. This detail shows the plywood and capping to be fixed to 50 mm by 19 mm grounds plugged to the wall. The skirting is of the same size and section as the margin fillets.

An alternative detail to B is shown at C. Here the panelling consists of 3-ply panels with top and bottom rails and stiles, the top rail being finished with a plain splayed capping. The balustrade should conform (see Fig. 44).

The sketch at A, Fig. 42, shows that the flush door is in keeping with the general design. A detail of a laminboard (see p. 86) door is given at K. The architrave may be as shown or, alternatively, the section may be the same as that of the simple skirting. Another example of a plywood covered balustrade is shown at O′, Fig. 36, and serves as a contrast to the traditional framed panelling at N′.

[1] Panelling is more fully detailed and described in Vol. IV, as this subject is generally deferred until the third and fourth years of the course. It is only briefly referred to here in order to draw attention to recent developments and to enable students to make a comparative analysis.



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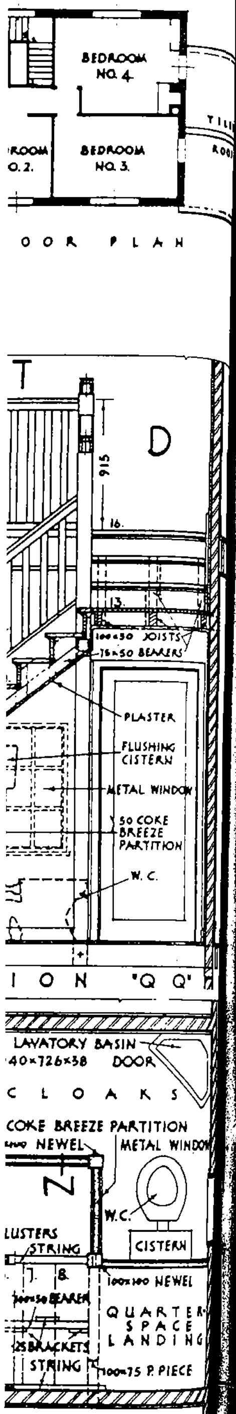


The open well stair has a space or well between the outer strings, and in this spect it differs from the dog-leg stair. This separation of the strings greatly hances the appearance of the stair. More space, of course, is needed to commodate it, but the extra width over that required for the dog-leg stair ed not exceed 150 mm, and when planning a staircase it is well worth while ying to obtain this additional width.

Key plans of a house showing the application of an open well stair appear A and B, Fig. 43. Enlarged plans of the stair are shown at E and F, and two ctions developed from them are illustrated at C and D.

Much of the construction is similar to that already described. The plan at shows three flights, each 914 mm wide, with two quarter-space landings.

But for the presence of the door to bedroom No. 5 (see B and E), an alternative arrangement would be somewhat similar to that shown at C, Fig. 36, where a half-space landing is provided. This latter arrangement, however, would make impossible the provision of the cloakroom.

The going of each step is 228 mm. The floor to floor height is 2 896 mm ee D), with sixteen steps, the rise of each equals 2 896 mm÷16=181 mm. hus the going, plus the rise, equals 590 mm (see rule on p. 101).

Three of the newels are bolted to joists at the ground level, and the balustrade continued at the first floor to two newels and a half newel having shaped ops similar to the caps. The headroom is approximately 2 235 mm if, as hown at C, the balustrade is returned with the newels in line with the centre the dining-room door. Although the soffits of the middle and top flights are lastered (see D), only 250 mm wide outer strings need be used, provided three earers are employed at each short flight (see C, D and E). A simple but satisctory treatment results (see O), which detail shows a slight projection of the ring beyond the face of the plaster; wider strings would give a less effective ppearance.

Details of the balustrade are shown at J, M and O. Note the simple treatment the handrail consisting of two members. A rail to which the balusters are enoned is also fixed to the floor of the landing (see M), and a 50 mm by 16 mm llet is used to cover the floor board, etc. The newel caps and drops are ctagonal shaped out of the solid.

Cloakroom.—The plans at A and F show that some of the space under he stair has been utilized to form a cloakroom in which there is a wash basin nd a W.C. The partitions consist of 50 mm thick concrete or 38 to 50 mm hick plaster slabs (see also C and D, and p. 47) which are jointed in mortar and ailed to the floor, newels, etc.; stoothings may be used as an alternative. A indow provides the necessary lighting and ventilation (see also Fig. 44).

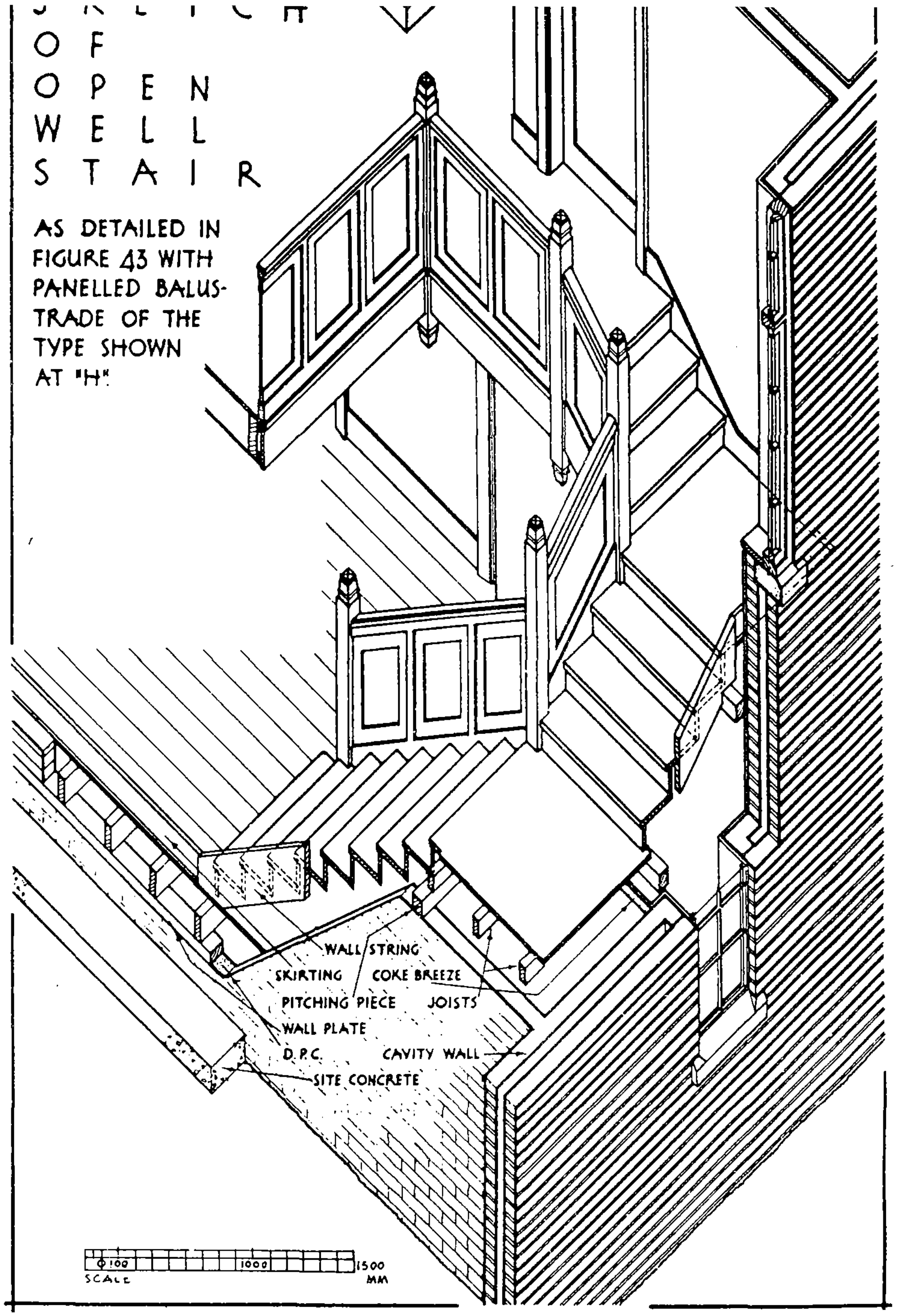


FIGURE 44

The open balustrades illustrated in these sections and in previous figures show plain vertical balusters, spaced at 75 or 100 mm apart. Whilst such simple treatment of this type of balustrade is generally preferred, the balusters can be arranged to give a big variety in design. One design is shown at G, Fig. 43, and this is an alternative to the elevation of the balustrade at T (see D). Details of this alternative balustrade are given at K and N. With the exception of that housed into the moulded handrail, the whole of the balusters are out of 32 mm square stuff, the vertical members being stub-tenoned into the horizontal.

The application of a solid panelled balustrade to this open well stair is shown at H, Fig. 43. This is an example of framed panelling and is an alternative to the type illustrated in Fig. 42. It shows the balustrade at T divided into three panels. A detail is given at L; the 9·5 mm thick panels are framed to top and bottom rails; the handrail consists of a moulded member surmounting a rail into which the top rail of the panelling is housed.

Some idea of the general appearance of the open well stair detailed in Fig. 43, but with a solid balustrade conforming to the detail at L, is given by the sketch shown in Fig. 44. When designing a balustrade of this type, it is sometimes difficult to obtain panels of uniform width, although a slight re-adjustment of the position of the newels will assist in avoiding a big variation. Note that a portion of the large window is shown. The need for increased natural lighting when a stair has a solid balustrade is stated on p. 111.

The use of laminboard or blockboard (see p. 121) housed into the newels and string for the construction of solid balustrades is an alternative. A detail incorporating this material is shown at F, Fig. 46. The old-fashioned plain mop-stick handrail has been included, as this affords a firm grip; a moulded rail similar to that at L, Fig. 43, would be equally suitable.

WINDERS

Attention is drawn to the references to winders tapered treads on pp. 100 and 101. The plan of a portion of a stair, having three winders at the foot, is shown at D, Fig. 45. Two sections, an elevation developed from the plan, and a sketch of the necessary framing are also shown.

Treads should be of uniform width. The minimum tread going at the newel is 75 mm with 220 mm elsewhere. Going plus twice rise, and pitch to be as given on pp. 98 and 101; these dimensions being measured at the centre of the tread.

Winders are set out on plan thus: see D and the enlarged plan diagram at H which, for clarity, shows only the riser faces and newel. The newel must be a minimum of 100 mm square. Draw centre line of the handrail. From centre T of newel at 75 mm to the left draw ZU being the 4th riser face. Bisect UV at S to give ST as line of 3rd riser face. Draw line TWX making TW=WX=75 mm. Draw XY as face of 1st riser. Bisect VY at R. Draw RW as face of 2nd riser. Slight adjustment to riser lines 2 and 3 may be needed to ensure that the treads

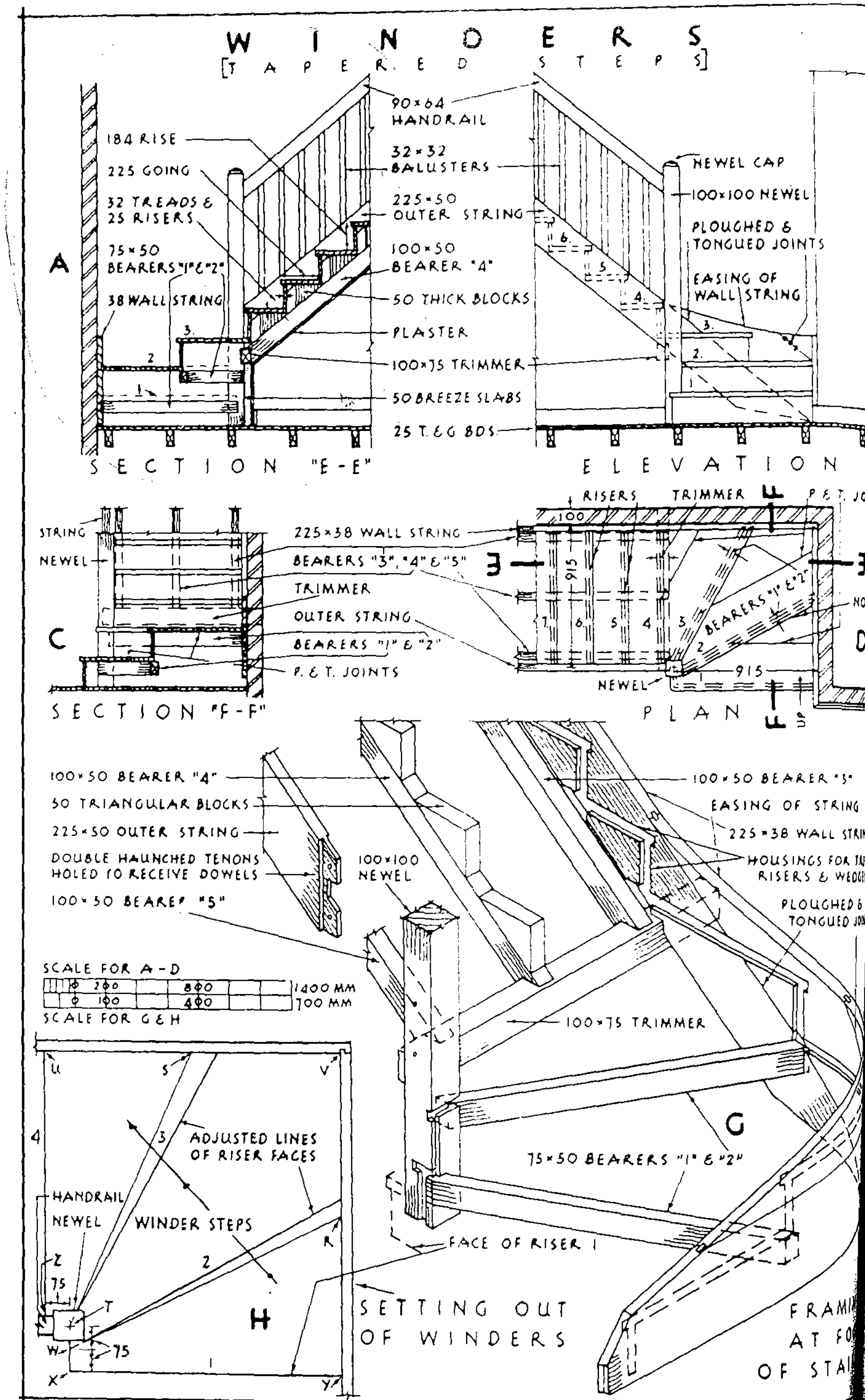
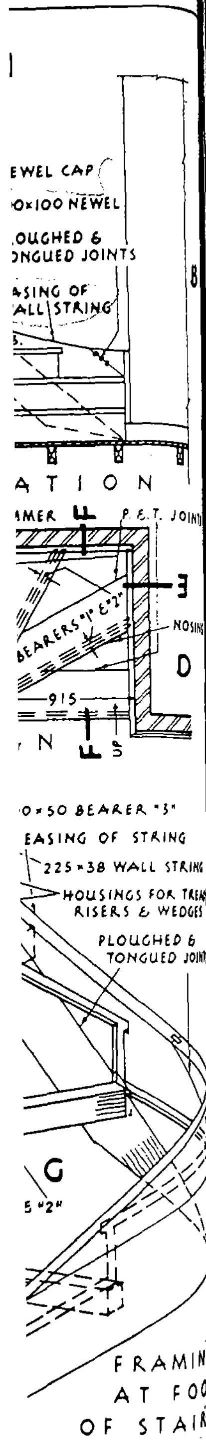


FIGURE 45



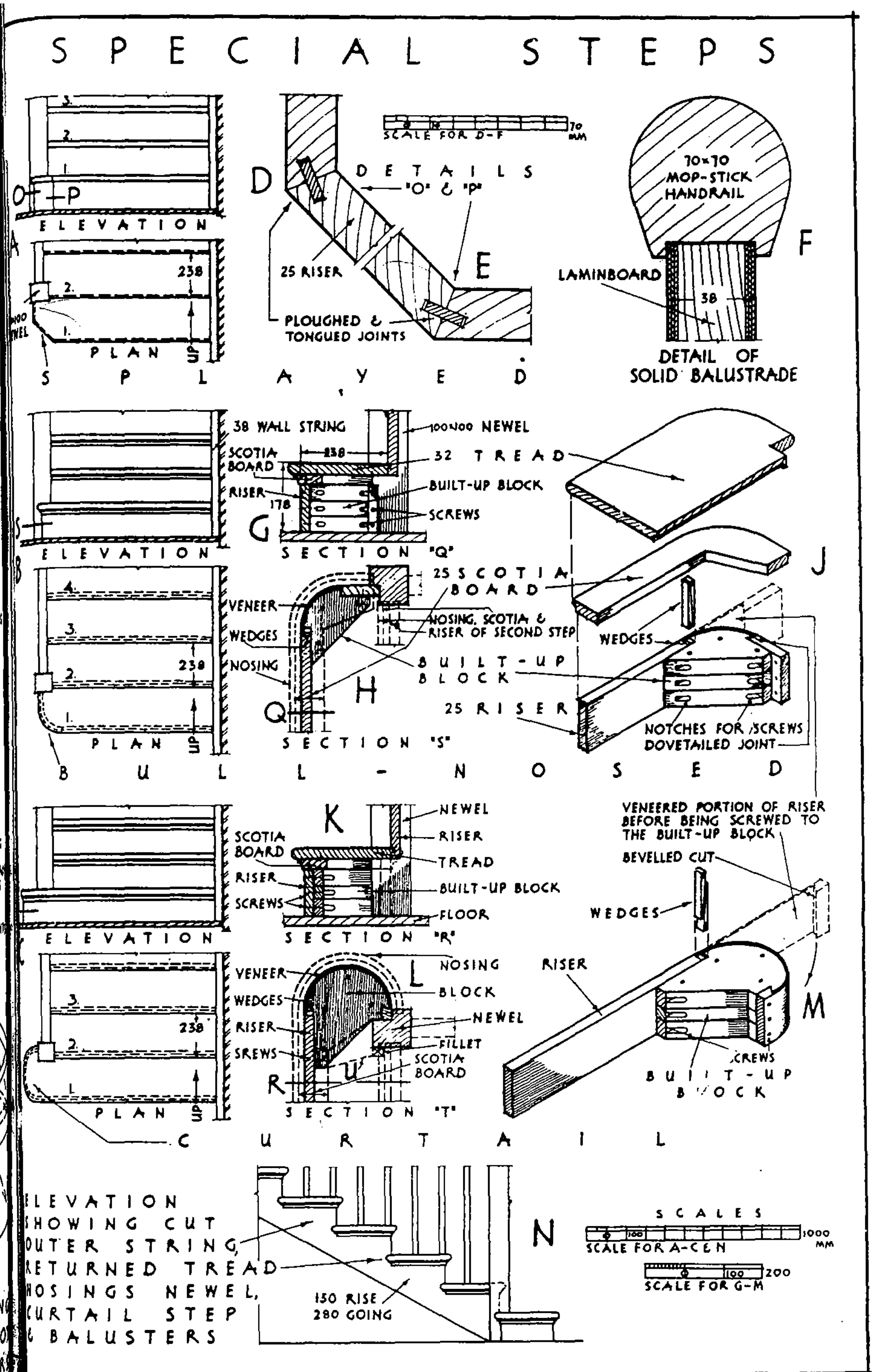


FIGURE 46

have a uniform going when measured at the central point of the tread lengths whilst maintaining the 75 mm dimension.

The construction in Fig. 45 is as follows.

It will be seen at G that the 100 mm by 50 mm bearer "4" or carriage cannot be continued to the floor but is supported by a trimmer which is notched into the newel and built into the wall. Therefore other means of support for the winders must be obtained; hence the provision of bearers immediately below the second and third risers. As shown at A, C and D, a 75 mm (or 100 mm) by 50 mm bearer marked "1" is housed into the newel and wall string, and its outer face is in line with that of the riser of step 2 immediately above it (see also G). Similarly, the outer face of bearer "2" is directly below that of the third riser. Winder treads because of their greater width have to be jointed; these are preferably ploughed and tongued (known as cross tongued) joints and are shown at A, C and D. The short returned wall string is similarly tongued to the main wall string, the upper edge of which is cut to a curve or easing. Both strings must be increased in width to accommodate the winder threads; the boards used to build up the strings are jointed in the same way.

SPECIAL STEPS

Sometimes the step of a stair is specially shaped, see Fig. 46.

Splayed Step.—This is shown in the part plan and elevation at A and is detailed at D and E. The bottom step projects beyond the newel. Its riser is in three pieces, the vertical edges of which are mitred, ploughed (grooved), hardwood tongued and glued. The nosing of the tread is shaped to conform. The outer ends of the two bottom steps at J, Fig. 36, are splayed and constructed in this manner, and both ends of the two steps at the foot of the central flight at N are similarly treated (see also C, Fig. 36, D, Fig. 39 and A, Fig. 41).

Splayed steps may also be made by constructing the riser as described below.

Bull-nosed Step (see part plan and elevation at B and the details at G, H and J).—The round end of the step consists of the riser (which is in one piece and has its thickness reduced near the end to enable it to be bent round a wood block shaped to the required quadrant curve), a shaped scotia board (if required) and the tread shaped at the end conform. The curved portion of the riser is called a *veneer*, as it serves as a thin covering to the block. Its reduced thickness depends upon the curve; the sharper the curve, the thinner the veneer; in the given example the thickness is approximately 2 mm, although for clarity this has been exaggerated in the details. The block strengthens the riser and prevents the veneer from being damaged. This block must not be in one piece only, as this would tend to shrink to such an extent as to leave a space between it and the veneer; the latter would then be readily damaged because of lack of support. Accordingly, the block is built-up of three or more pieces, and, in order to reduce still further the liability to shrinkage, the pieces are arranged "cross-grained," *i.e.*, the grain of one is opposite to that of the adjacent piece.

The step is constructed in the following manner: The block is built-up to the required height by gluing and screwing or nailing the pieces together, the top and bottom surfaces are planed flat and the block is cut to shape, as shown at H and J; the block is double rebated one edge being square cut and the opposite edge (nearest to the newel) being bevelled cut or dovetailed. The riser (which should be of carefully selected straight-grained timber, free from knots) is then prepared by marking off the position of the bevelled and square cuts, the length of the veneer being found by placing the dovetailed edge of the block opposite to the corresponding mark on the riser and revolving the block on the back of the riser until the square edge of the block rebate touches the riser, which position is then marked; an extra 20 mm is measured on the riser to provide room for the pair of folding wedges. A marking gauge (see 4, Fig. 67, Vol. I) is now used and the thickness of the veneer marked on the riser. Cuts are made across the back of the riser to form the shoulders, and the chisel and router plane are used to remove the core and form the veneer. The cutting of the veneer is often done on the circular saw and sometimes on the band saw. The shape of the veneered end of the riser, before it has been fixed to the block, is shown by broken lines at J. The back of the veneer and the outer face of the block are then roughened by the toothing plane or file to give a key for the glue. The latter is now liberally applied to the back of the veneer (after its face has been wetted with boiling water) and the face of the block. With the dovetailed shoulder of the veneer engaging in the dovetailed rebate on the block, the riser is pressed against the block; the glued wedges are inserted and driven home in order to bed the veneer tightly on the block, and the latter is secured to the riser by means of screws from the back, the notches for these having been previously prepared.

The scotia board, after being reduced in width and shaped, is screwed to the riser and tread.

The foot of the newel is notched out, as shown, and the riser is screwed to it.

A bull-nosed step is also illustrated at D, Fig. 36, A, Fig. 42 and F, Fig. 43.

Commode Step (see F, Fig. 36).—This has a curved riser built up with narrow vertical strips covered with a veneer.

Curtail Step (see C, K, L and M).—The construction of this semicircular ended step is similar to that described above. The back of the block is sometimes shaped as shown at U (see L) and a vertical fillet (shown crossed by diagonals) is screwed to it and the newel. The end of a curtail step may also be of a spiral form (see the bottom step at O, Fig. 36). Because of the side projection of this step it should not be used if the width of the floor at the side is restricted.

Cut String (see N).—This has been included to show the difference between it and all of the close strings illustrated. The upper edge of the string is notched out to receive the treads, and the moulded nosings are returned. There are usually two balusters per step, with a face of one vertically over a riser.

ADHESIVES FOR JOINERY

The main adhesives[1] (known also as glues or cements) used to stick timber parts together are:—

(*a*) Synthetic Resins
- (1) Phenol/Formaldehyde
- (2) Urea/Formaldehyde (Aminoplastic)
- (3) Resorcinol/Formaldehyde
- (4) Polyvinyl Acetate (PVA)

[1] **The following B.S. are available from The British Standards Institution: 745, Animal Glue; 1203, Synthetic Resin Adhesives for Plywood; 1204, Synthetic Resin Adhesives; 1444, Cold Setting Casein Glue, 5442, Pt. 3, Adhesives for Use with Wood.**

(*b*) Casein Glues

(*c*) Vegetable Glues
- (1) Soya Bean
- (2) Starch Derivatives

(*d*) Blood Albumin Glues

(*e*) Animal Glues (Scotch Glue)

Depending on the location, an adhesive will need to satisfy one or more of the following requirements:—be (1) completely, or (2) partially resistant to wet, withstand (3) heat and (4) mycological attack (m.a.) from micro-organisms which can occur in damp places. Hence it is possible to select a glue for any given purpose[1] but the following other factors have to be considered: (i) The thickness of the "glue-line;" this is dependent on how closely the parts to be joined can be brought together. Accordingly glues are divided into two kinds. *Close-contact* (CC) glues used mainly for plywood manufacture and similar purposes where heavy pressure ensures tight joints and where a glue-line thickness exceeding 0·13 mm can be avoided with certainty; and *gap-filling* (GF) adhesives used for general joinery and large assembly work when a thin glue-line cannot be guaranteed, they are suitable for glue-lines up to 1·3 mm thick. (ii) The ease of preparation and application of the glue; for example, an animal glue has to be heated before use and other kinds require mixing with a hardener before they are ready. (iii) The storage-life and pot-life (the time for which the glue remains usable after it has been prepared); some glues require special storage conditions and must be used within a limited time after mixing. (iv) The length of time for which adequate pressure must be maintained varies with different glues. (v) The resin glues have to be used within prescribed conditions of temperature and humidity. (vi) Some glues stain the timber; this is obviously undesirable for veneers and other exposed work. (vii) Certain resin adhesives have to be used carefully to avoid the risk of skin infections to operatives.

Knowing the degree of exposure of the joined timbers and whether GF or CC types are needed, further valuable advice can be had from the adhesive manufacturer whose instructions for storage and application must be carefully followed.

The following is a brief description of the adhesives listed above:—

(*a*) (1) *Phenol/Formaldehyde Resin.*—This is a chemically produced resin derived from a reaction between carbolic acid (phenol) and an aldehyde. It is made in WBP, BR, MR and INT grades either GF or CC and is practically indestructible. Both hot and cold-setting types are made, the former for plywood manufacture and the latter for general joinery. It is not liable to m.a., is fire-resisting and does not normally stain the wood. The resin can be had in liquid or powder form and

[1] In B.S. 1204 the following classification is used:—WBP—a weather and boil-proof glue which withstands severe weather exposure, heat and m.a.; it is practically indestructible and more durable than wood. BR—boil resistant; has good resistance to weather but fails under prolonged exposure that WPB survives. MR—moisture and moderately weather-resistant, not boil-proof or as durable as WBP; withstands full weather exposure for a few years; it resists cold water for a long time and hot water for a limited time; resistant against m.a. INT—suitable for interior use; not boil-proof nor necessarily resistant to m.a.; it resists damp and cold water for a limited period.

kinds require mixing with a separate liquid hardener; careful temperature control is needed; the cleaning of tools is difficult, it being only soluble in alcohol; there is a danger of dermatitis to operatives.

A similar adhesive is the melamine/formaldehyde type usually obtained as a white powder resin to which water is added; it is normally only suitable for CC work; resistant to m.a. and classed as BR.

(*a*) (2) *Urea/Formaldehyde* (*Aminoplastic*) *Resin*.—This is also synthetically produced and made from a reaction between urea and formaldehyde. It is made in all the grades given in (*a*) (1) above; the resin (syrup or powder) and the hardener (liquid or powder) being either combined ready-mixed or available separately for subsequent mixing. The separate application method (both parts being in liquid form) is used for plywood manufacture where the resin is added to one surface and the hardener to the other; the surfaces are then brought together and if a quick-setting hardener is used the work is completed rapidly. Slower-setting types are used for general joinery. Pot-life varies from 20-minutes to 24-hours for the cold- and hot-setting types respectively. It does not normally stain timber and is good against m.a. and heat. Care must be taken to use the glue at the temperature stipulated by the maker and within the specified time limits. There is less danger from dermatitis than with the phenolic types; it is water soluble prior to hardening.

(*a*) (3) *Resorcinol/Formaldehyde Resin*.—This is chemically made from resorcinol and formaldehyde; it is more expensive than (*a*) (1) and (2) being less sensitive to temperature, whilst being applied, than these two. A top class cement classed as WBP; is normally GF and so useful for general joinery (also for glued laminated work—see Chap. V, Vol. IV); proof against m.a. and is water soluble until hardened. The resin is in liquid form requiring the addition of a powder hardener; it has a long storage-life; pot-life is from 1½ to 4-hours.

(*a*) (4) *Polyvinyl Acetate* (*PVA*).—This is classed as INT; it is a ready-mixed white syrupy liquid being increasingly used by joiners in lieu of the once universal animal glue. It is non-staining, easy to use but must be stored at a temperature above 4° C and not used below 16° C. Water soluble and immune to m.a.; it sets within an hour.

(*b*) *Casein Glues*.—Casein is a milk derivative. Rennet, or acids such as hydrochloric, is added to skim milk to hasten the separation and precipitation of the curd. The latter is finely ground after it has been washed, pressed and dried and borax or other chemicals added. Obtained in powder form, to which water is added before use, it is soluble in water. Widely used for general joinery and also for plywood making. It can be described as moderately gap-filling and is satisfactory for glue lines up to 0·8 mm thick. Some caseins are liable to stain certain hardwoods such as oak and mahogany; some have a limited resistance to water and others none; they are susceptible to m.a. and classed as INT.

(*c*) (1) *Vegetable Glues*.—The main vegetable used is (1) *Soya Bean* grown in the U.S. and Manchuria for its oil content. Other oil seed residue glues are obtained from ground nuts. They are made as a white powder (some kinds contain caustic soda and other chemicals) requiring the addition of water for application. They are moderately moisture-resistant having properties similar to casein; not much used in the U.K. but widely used for the manufacture of Douglas Fir plywood.

(*c*) (2) *Starch Derivative Glues*.—This vegetable glue is derived from cassava (tapioca) flour and incorporates some caustic soda. It is applied cold; has reasonable strength but is only suitable for interior use; liable to stain some woods; seldom used in the U.K.

(*d*) *Blood Albumin Glue*.—Produced from blood obtained from slaughterhouses; some kinds incorporate chemicals like paraformaldehyde. It has fair water-resisting qualities but is subject to m.a. and will stain certain hardwoods. Whilst it is used for the hot-press manufacture of plywood it is seldom encountered in the U.K.

(*e*) *Animal Glues*.—Known also as *Scotch Glue* it is the oldest of adhesives but quite unsuitable for external work; it is non-resistant to heat and m.a. Due to the amount of preparation required before it is ready for use and the fact that it has no gap-filling characteristics it is no longer the most widely used glue although it is very strong. It is prepared from the skins and bones of cattle, horses, etc. The skins are steeped in liquid lime for two or three weeks, washed, dried and the glue (glutin) is extracted by boiling. The bones are cracked in a mill, placed in benzol or other solvent to remove the fat, taken to a steam boiler where the glue is extracted, and finally purified by heating with alum, etc. Another kind is *fish glue* obtained from fish offal.

Animal glue is prepared for use by softening it by several hours' immersion in from two to three parts cold water; it is then melted by heating in water-jacketed glue pots and applied hot at an approximate temperature of 60° C; it should not be boiled. It does not stain the wood, although care has to be taken when applying it to sycamore, maple and similar light coloured woods to prevent discolouration.

PLYWOOD

A brief description of the manufacture of plywood is given in Vol. I. As plywood is now used extensively as a building material, a more detailed description of its manufacture, characteristics, uses and types is given below.

Plywood or Laminated Wood is a compound wood made up of several thin layers or plies of veneers, glued together under pressure, and usually arranged so that the grain of one layer is at right angles to the grain of an adjacent layer or layers.

Plywood is obtainable in many kinds of wood and there are different grades offering varying resistance to weather; some are classed as weatherproof—others are only suitable for internal use. From the previous section on adhesives it will be apparent that the glues used exert a strong influence on its suitability for a particular location. Whilst some glues are weatherproof, wood is not; hence if plywood is used externally it should be protected by paint or other preservative (see pp. 152 and 11–14).

A sheet or board of plywood usually consists of an odd number of plies, *i.e.*, "3-ply," "5-ply," etc. Those which have more than three layers are known as *multi-ply boards*—see C and D, Fig. 47 (5-ply) and E (7-ply); the number of layers may be increased as desired, but boards having more than nine plies have to be specially ordered.

A 3-ply board consists of two outer or *face plies* with a middle *core*. It is important to observe that these plies are *cross-grained*, *i.e.*, the grain of the core of a 3-ply board is at right angles to that of each of the face plies (see B to E, Fig. 47, and p. 119). The thickness of the veneers varies from 1·6 to 6 mm. An example of a 5-ply board is shown at D; this 19 mm thick board has two 2·5 mm thick face plies, a 6 mm central ply and two 4 mm intermediate layers of *cross bandings*. Examples of equal ply boards are shown at C and E.

There is a wide range of board sizes, 2 440 mm by 1 220 mm is a popular size; thicknesses are 3·2, 4, 5, 6, 6·5, 8, 9, 9·5, 12·5, 16, 19, 22 mm etc. up to 47·5 mm.

Manufacture of Plywood.—The various processes are: (1) Preparation of logs, (2) conversion, (3) trimming, (4) drying, (5) gluing, (6) pressing, (7) re-drying and (8) finishing.

1. *Preparation of Logs*.—Logs of certain timber, such as alder, beech, Gaboon mahogany and oak, are first either steamed or boiled to render them pliable. This softening of the fibres takes place in large covered-in concrete pits containing water heated by hot-water pipes situated on the floor; the logs are kept submerged for at

least two days—depending upon the size and hardness—until thoroughly saturated. Other timbers, including British Columbia pine and European birch (Finnish, Polish and Russian), do not require this preliminary treatment. The logs are then cross-cut into lengths (2 100 or 2 400 mm or according to the size of the converting machine), the bark is removed by hand or machine (called a ***barking lathe***), hard knots are cut out and any irregularities removed.

2. *Conversion.*—The prepared logs are now converted into veneers by either (*a*) rotary veneer cutters or (*b*) veneer slicing machines.

(a) *Rotary Cutting Method.*—More than 90 per cent. of veneers are cut by this method. A *rotary veneer cutter* or *peeler* is a powerful lathe with a very sharp fixed knife slightly longer than the log (see J and K, Fig. 47). The log, prepared as described, is conveyed by a crane to the peeler, lowered and then clamped between two centres or chucks which penetrate the ends of the timber at the "centres" previously marked. The horizontal log is revolved and a continuous ribbon of veneer, uniform in thickness, is cut by the knife and emerges—like a roll of paper being unrolled—between it and the *pressure* or *nose bar*. This bar prevents the wood from splitting, and the distance between it and the knife is regulated according to the thickness of the veneer. Logs converted in this manner should be not less than 250 mm diameter, straight grained and reasonably free from knots and other defects; the diameter of Gaboon mahogany and Douglas fir (both extensively used for plywood) logs varies from 0·6 to 1·8 m or more. The veneer deteriorates in quality as the log unrolls owing to the increase in the size and number of the knots towards the centre. Hence the veneer is sometimes increased in thickness as the peeling proceeds and is used for cores, the thinner and better veneers being used as face plies. The peeling process is continued until the diameter of the log has been reduced to about 150 mm.

A modification of rotary cutting, used to produce highly decorative veneers from rarer woods, is known as the ***half-round*** or ***stay-log cutting*** method. The log is divided longitudinally by a circular saw, a half log is secured to a strong bar fixed between the centres of the rotary cutter and with its sawn face against the long knife. Thus, commencing from the heart, a series of veneers is produced as the half log swings round and descends on to the knife. As the conversion is not tangential to the annual rings, the resulting figure is generally richer than that produced by the first method.

(b) *Slicing Methods.*—Decorative veneers are obtained from certain valuable richly figured rare timbers by slicing in order that the attractive figure may be shown to greater advantage than that produced by the rotary cutter. Burls, crotches and stumps (see A, Fig. 47, and p. 5) are often converted in this manner. There are two types of machine used for this purpose, *i.e.*, the (i) horizontal veneer slicer and the (ii) vertical veneer slicer.

(i) *Horizontal Veneer Slicing.*—The slicer is a heavy, powerful machine which has a fixed bed in addition to a wide knife with pressure bar in a movable frame. The log is divided into two down its length, and one-half is fixed to the bed with the sawn face uppermost and level. The knife cuts the veneer to the required thickness as the frame is forced forward over the fixed timber. During the slicing process the veneer passes upwards between the knife and pressure bar and over the frame. On completion of the cut the knife is returned to its original starting point and the timber is automatically raised by an amount equal to the thickness of the veneer. This process is repeated until the half-log has been converted. The thickness of the veneers varies according to requirements and the nature of the wood, but 0·9, 0·85, 0·7 and 0·6 mm thick veneers are common. In addition to burls, crotches, etc., boles of satinwood, sycamore, teak, walnut and several other timbers are sliced, as rotary cutting is apt to cause splitting. Each veneer is numbered as it leaves the machine and stacked in that order. This ensures correct matching. Flitches are also converted into veneers by slicing.

(ii) *Vertical Veneer Slicing.*—This machine has a fixed knife and the log is secured to a movable bed. The slicing operation is therefore the reverse to (b) (i) above, the veneers being produced as the bed travels along the knife.

The above methods are known as *flat cut* and the veneers show a straight grain on each side of the central heart. Whilst avodiré, silver greywood, Cuban and Honduras mahogany, sapele, and timbers (such as oak) which have the medullary rays well developed, are sliced as above described, more highly figured veneers are produced when the timber is radially sliced, *i.e.*, the logs are first quartered and each quarter is placed at an angle on the slicer.

Formerly veneers were sawn by either the band or circular saw. Whilst sawing has been largely superseded by slicing, certain few timbers—such as black bean and African mahogany (for curl veneers)—are sawn, as they are difficult to slice.

3. *Trimming.*—As the continuous veneer emerges from the peeler, it either winds on to a spindle which is afterwards taken to the trimming machine, or it is conveyed to the latter along a table which may be some 60 m in length. The trimming machine is called a *clipper* or *guillotine* as it consists of a long knife which slides vertically in a frame fixed above and across the conveyor table. The band of veneer passes under this knife and is cut transversely into widths[1] on each descent of the knife.

In many factories the veneers are cut to standard widths and these depend upon the sizes of the presses (see p. 119). Any serious defects, such as splits and large dead knots, are eliminated by cutting out the defective sections.

4. *Drying.*—Veneers for good class work must now be dried to a predetermined moisture content, varying from 4 to 10 per cent. This is known as the *dry-cemented process.* There are many types of dryers. One of the latest, over 30 m long, is heated by hot water or steam pipes and the air is circulated by fans. The veneers are passed in at one end between rollers which propel them at the desired speed—depending upon the thickness of the veneers, desired moisture content, etc.—through the chamber towards the exit, where they are cooled before emerging and then removed by hand. This operation only occupies approximately a quarter of an hour.

Jointing.—Veneers required for large panels, sliced decorative veneers and those used for cores are jointed in the following manner: The edges must be perfectly straight and clean to ensure a close joint. Hence the veneers are piled to a thickness of about 25 mm, clamped together, and the edge of the pile is sawn by a circular saw and spindle with cutterblock—the latter producing a good finish; in one machine the veneers are held flat on a fixed bed by a heavy clamp and a travelling circular saw, followed by a cutterblock of the spindle, traverses the pile to effect the cut.

The two veneers to be jointed have their opposing edges painted with glue. The sheets are placed flat on the table of the jointing machine, one type of which consists of a series of narrow rollers operating over a heated plate and in front of which is a small rotating wheel which dips into a trough containing a solution of formaldehyde. The sheets are fed towards the machine over the solution wheel which moistens the glued edges, and as they are drawn through the machine between the rollers and plate the edges are forced together to form a tight joint.

In another type of machine, called a *taping machine*, a narrow strip of gummed perforated tape (***kraft tape***) is passed over a heated roller which moistens the glue and is pressed over the joint by a second heated roller. Sufficient glue is thereby forced between the joint. This tape is subsequently removed by damping and scraping.

Repairing.—Defects, such as pitch pockets and large unsound knots (especially those liable to become loose) must be removed and replaced with sound veneer. The operation is known as ***patching*** or ***plugging***. The defective portions are removed by a metal hand punch of oval, circular, etc., section which is smartly tapped to give clean cuts. These spaces are immediately filled in with plugs or patches of sound veneer of similar size, shape, colour and grain so as to render the repairs as inconspicuous as possible. The patches have their edges glued prior to placing them in position; pressure is then applied to secure them.

5. *Gluing or Cementing.*—The dried veneers are placed on a long belt conveyor and inspected for quality. Those suitable for face veneers and cores are sorted; the sheets are also arranged into sizes. Any defective sheets are sent to be repaired as described above. The sound veneers are conveyed to the gluing machine or ***glue-spreader***. This consists of a pair of steel grooved rollers which dip as they rotate into troughs containing the adhesive; these rollers are specially designed

[1] The length is in the direction of the grain and the width is tangential to the

evenly spread the glue over one or both faces of the veneers as they are passed between them. The sheets are placed by hand between the rollers, and, on emerging, are assembled according to the type of press which is to be applied in the next operation.

If cold pressing (see below), is to be employed, 3-ply boards are assembled in the following manner: A 75 mm thick wood board, called a *caul*, of size slightly larger than the sheets of veneer, is placed on a low truck standing at the discharge side of the glue-spreader. A sheet of face veneer (not glued) is placed on the caul with its face-side[1] (or outer surface when assembled) down. The core ply is passed through the machine, which spreads a uniform layer of adhesive on *both* sides. An operator then quickly places this glued core upon the face veneer, taking care that its grain is at *right angles* to that of the face ply. The second face ply is now carefully laid over the core with its face-side up and its grain *parallel* to that of the first face veneer (see p. 117). This operation is repeated until a sufficient number of boards have been assembled to form a pile of about 900 mm thickness. A thin (about 19 mm) plywood caul is placed between the boards at approximately 300 mm intervals during the piling, and a thick caul is laid on top of the batch which is at once taken to the press.

A multi-ply board is built up in a similar manner, each *alternate* ply being glued on *both* sides and cross-grained assembled. Thus, a 7-ply board would be assembled in the following sequence: Face veneer (face-side down and longitudinal-grained), glued cross-banding (cross-grained), veneer (longitudinal-grained), glued core (cross-grained), veneer (longitudinal-grained), glued cross-banding (cross-grained) and face ply (face-side up and longitudinal-grained).

Boards which are to be hot pressed (see below) are assembled in a similar manner, but thin aluminium or zinc cauls are generally used instead of plywood cauls and two are placed between each board.

This gluing process is one of the most important in the manufacture of plywood. An inferior or unsuitable adhesive will cause plywood to be a most unreliable building material, even if best quality timber is employed. The plies must be strongly united together and must remain so when subjected to the conditions of service. The production of waterproof adhesives has been largely responsible for the high repute now held for the better graded plywood.

The adhesives used in plywood manufacture are the following types listed on p. 116:—(*a*) (1) and (2), (*b*), (*c*), (*d*) and (*e*).

6. *Pressing*.—The glued plywood boards must now be subjected to the necessary pressure to effect a sound bond between the glued sheets. This operation takes place in either a cold press or a hot pressure machine operated by hydraulic power.

Cold Pressing.—The cold press has a movable lower cast iron plate (called a *platen*) which operates between four corner vertical pillars secured at the base and supporting a heavy iron headpiece. Both the top of the platen and the underside of the headpiece have machined flat surfaces. The pile of glued boards, assembled between the thick cauls, as described in the previous operation, is placed in the centre of the press upon transverse steel beams laid at intervals on the platen; a similar number of steel beams is placed on the top caul and immediately over the lower beams. The press is now operated, the platen being raised by hydraulic rams to bring the upper steel beams in contact with the headpiece. As the pressure is gradually increased, operators fix vertical clamps or turn-buckles to the projecting ends of the steel beams; each pair of beams (the lower and upper) is thus connected by two clamps. When the desired pressure has been reached—indicated by a pressure gauge—the clamps are uniformly and finally tightened. The platen is then lowered and the batch, *still clamped*, is removed to the drying room; the clamps are not removed until the glue has set.

The maximum pressure and the time during which the boards are clamped depend upon a number of factors, such as the type of glue used, the area and thickness of the boards, the nature of the wood and the moisture content. Thus, valuable decorative veneers, casein glued, may only be subjected to a maximum pressure of 6 kgf/m² for two hours in order to avoid staining; ordinary commercial plywood batches soya bean glued, may be subjected to a maximum pressure of 10 kgf/m² and the clamps should not be removed within eight hours. The normal practice is to leave the clamped batches overnight and to remove the clamps during the following morning.

Hot Pressing.—Resin cemented and hot glued plywood boards must be hot pressed to ensure a strong bond between the plies; some manufacturers also use hot presses for casein glued boards.

A hot press consists of a bottom metal table, pressure head and a dozen or more intermediate hollow steel platens spaced at regular intervals. Not more than two assembled boards, with their zinc or aluminium cauls (see preceding column), are placed between each pair of platens, and the latter are heated by steam admitted to them through flexible-jointed pipes. The press is then closed, *i.e.*, the bottom table is raised, and this in turn lifts the platens and reduces the spaces between them; the pressure is increased until the boards are subjected to that required. Meanwhile the heat from the platens is transmitted to the plywood to effect a strong bond between the glued surfaces of the plies. The pressure is maintained for several minutes, this "bonding time" being variable according to the type of glue employed, nature of the wood, etc.

The temperature varies from 60 °C. (for animal glued boards) to at least 180 °C. (for certain resin cemented boards). The pressure also varies between 10 to 20 kgf/m². There is also a big variation in the size of presses; thus, the largest in this country produces 5 m by 2 m boards.

On removal from the press the plywood boards are sticked (see p. 8), *i.e.*, pieces of 25 mm. square laggings (or sticks or skids) are placed at intervals between the boards and directly over each other; the latter is necessary to ensure flat boards. A heavy steel beam is placed on top of the pile.

7. *Re-drying*.—The boards absorb moisture during the gluing and hot-pressing processes and the moisture content must therefore be reduced. Hence the sticked piles from the hot press are taken to a re-drying chamber and the m.c. is reduced to the desired percentage—usually 8 per cent. Cold pressed boards, after the clamps have been removed, are sticked and the piles re-dried. This operation must not be hastened, otherwise the boards will be permanently warped or twisted.

8. *Finishing*.—After re-drying the edges are trimmed as the boards are accurately sawn to the desired length and width. There is a considerable variation in the sizes. Examples of stock sizes of two softwood and two hardwood plywoods are listed at L, Fig. 47. Special sizes can be obtained.

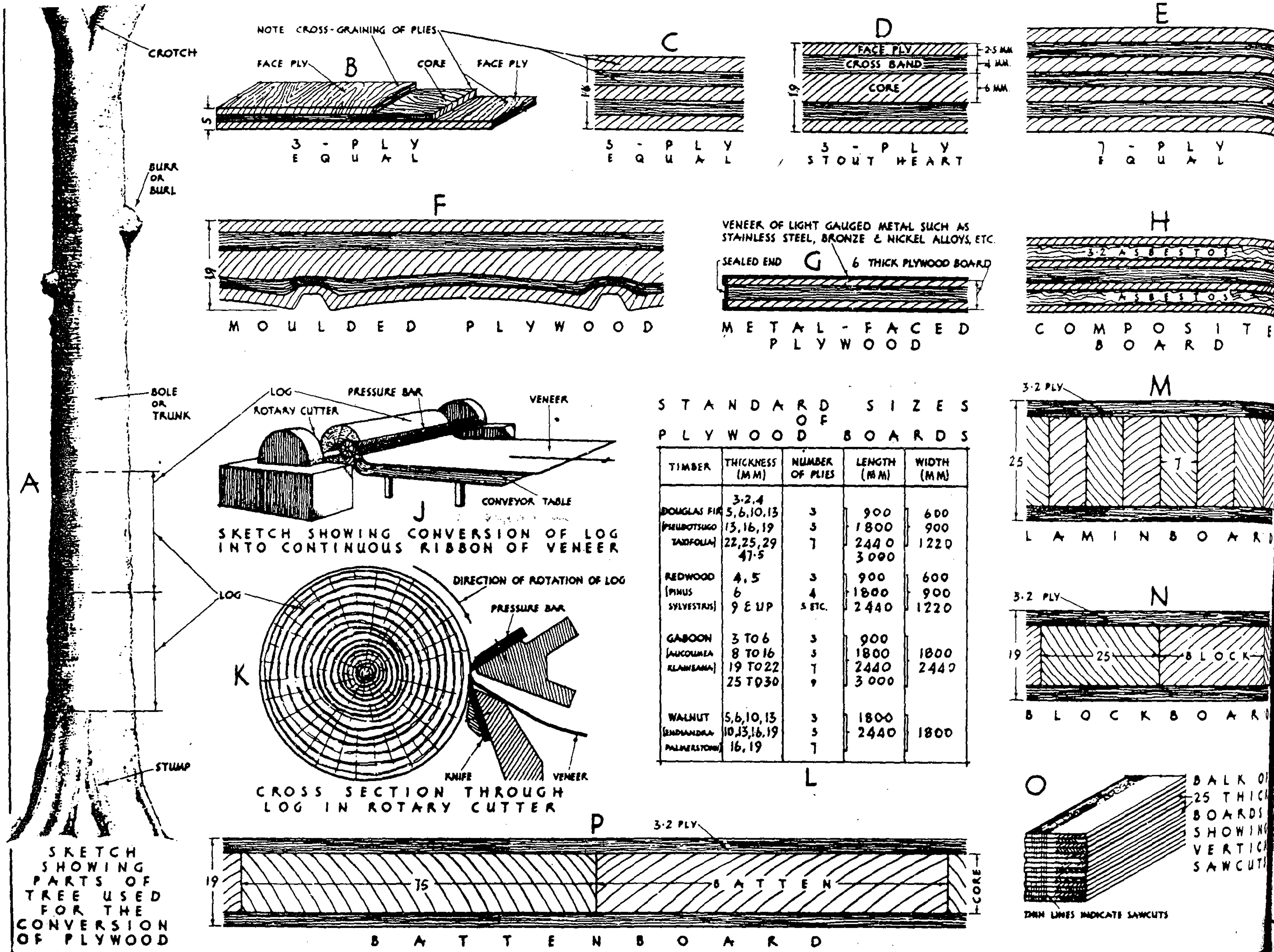
Finally the plywood boards are planed and sanded to remove surface imperfections and give a smooth finish to both sides. The planing machine or *scraper* has a fixed knife at the bed of the machine (see p. 27) and the boards are fed between rollers against it, one side being scraped at a time. Boards which have been patched (see p. 118) are not scraped. The sanders are of the drum and belt types (see p. 29).

Merits of Plywood.—1. The shrinkage and expansion of best grade plywood is almost negligible. *This is due to its cross-grained construction.*

It is stated on p. 8 that the maximum shrinkage of timbers occurs in the tangential direction (*i.e.*, in the direction of the annual rings) and that longitudinal shrinkage (*i.e.*, in the direction of the grain) is very small indeed. Thus, an unrestricted sheet of rotary-cut veneer will *work* (*i.e.*, shrink or expand) in its width and there will be comparatively little movement in its length. When, however, the sheet is one of several forming a plywood board it is restricted, and accordingly movement is considerably reduced. Thus, the tendency for the core of a 3-ply board to increase or decrease in width as the humidity changes, is practically neutralized by the two

[1] During conversion in the rotary cutter, the fibres on the concave or inner surface of the veneer tend to separate longitudinally; such splits do not extend to the convex or outer surface and are called *checks*. These are unavoidable if the thickness of the veneer exceeds 2·8 mm. Therefore, if the outer veneer is placed "face-side down," as stated above, any checks will be concealed. The outer surface is marked during the cutting operation to ensure correct assembly.

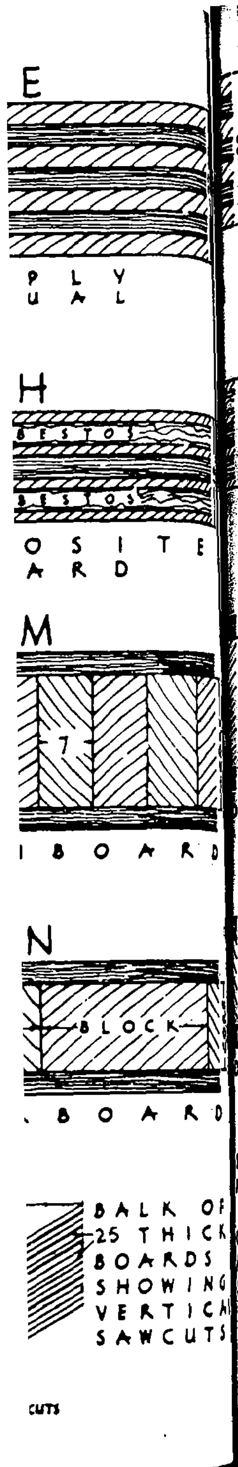
A sheet of veneer straight from the rotary cutter will assume a curved shape. If the sheet is pressed flat the outer surface will be subjected to a compression strain and the inner surface will be under tension which tends to cause the fibres to separate. The term "tight-cut" is applied to the outer surface of a veneer and "loose-cut" to the inner.



STANDARD SIZES OF PLYWOOD BOARDS

TIMBER	THICKNESS (MM)	NUMBER OF PLIES	LENGTH (MM)	WIDTH (MM)
DOUGLAS FIR (PSEUDOTSUGA TAXIFOLIA)	3.2.4, 5,6,10,13, 13,16,19, 22,25,29, 47.5	3, 5, 7	900, 1800, 2440, 3000	600, 900, 1220
REDWOOD (PINUS SYLVESTRIS)	4.5, 6, 9 & UP	3, 4, 5 ETC.	900, 1800, 2440	600, 900, 1220
GABOON (AUCOUMEA KLAINEANA)	3 TO 6, 8 TO 16, 19 TO 22, 25 TO 30	3, 5, 7, 9	900, 1800, 2440, 3000	1800, 2440
WALNUT (ENDIANDRA PALMERSTONI)	5,6,10,13, 10,13,16,19, 16,19	3, 5, 7	1800, 2440	1800

FIGURE 47



face veneers to which it is securely glued; the face veneers, having the grain at right angles to that of the core, will not move in the direction of the width of the core and will therefore restrain the latter. Similarly, any tangential movement of the outer plies will be restrained by the longitudinal grain of the core.

2. A plywood board is stronger than a piece of unlaminated timber of the ame area and thickness. This is also due to its cross-grained construction.

The tensile strength of wood is much greater with the grain than across it, and its shear strength across the grain greatly exceeds that with the grain. Hence, as a well-constructed board of plywood has the grain of one ply at right angles to the grain of adjacent layers, maximum strength in both the width and length of the board results. Further, certain cements, such as resins, increase the strength of plywood.

3. A plywood board, because of its cross-grained construction, does not eadily split when nailed near to its edges.

4. As rotary cut plywood can be obtained in large sizes, it may be applied s wall panelling without recourse to framing composed of rails and stiles. ence the modern tendency to use this product for this purpose in order to btain large flush surfaces.

Prior to the introduction of rotary cutting the width of solid wood panels was restricted because of the limitations of timber, and therefore framing formed an essential feature of traditional panelling.

5. The modern trend of using thin veneers, instead of relatively thick panels d framing, for panelling, furniture, etc., has resulted in the economical employ-ent of rare and valuable timbers.

Perhaps the only demerit of plywood is the unattractive figure of most mbers when rotary-cut, although this does not apply to certain timbers, such birch and Queensland walnut. As already stated (p. 118), veneers of many mbers are sliced in order to show the grain to the best advantage.

Uses of Plywood.—It is used extensively for (*a*) covering or panelling alls (see Fig. 42), partitions and ceilings, (*b*) doors (see Fig. 29), (*c*) stair balus-ades (see Fig. 42) and (*d*) furniture. Its use as a floor covering has already en referred to (p. 40). It is being used to an increasing extent for temporary ork, such as shuttering for concrete. It is also in big demand for railway ach, bus, motor car, etc., construction. The cheaper varieties are used on a ge scale for boxes, chests, barrels, etc.

Moulded Plywood.—A development of ordinary plywood is that which moulded on one surface. Such is used for decorative wall panelling. There a wide range of patterns, one of which is shown at F, Fig. 47.

The moulded surface is formed in the press. The plain board, having been glued and assembled as described on p. 118, is put into the press. A metal or solid wood mould (called a *form*), having a surface shaped to the reverse of that required on the board, is placed on top of it, and the moulded contour is imparted to the upper surface when pressure is applied.

Plywood boards can be bent to concave and convex curves by machinery and other means (including the vacuum process). These methods are discussed in Vol. IV.

Metal-faced Plywood.—Another development is the plywood board faced on one or both sides with metal. The metals employed are aluminium, bronze alloys (such as gilding metal), nickel alloys (*i.e.*, monel metal), galvanized and stainless steel, etc., and the sheets are rolled to a very thin gauge. The metal is bonded to the plywood by special waterproof cements. When metal-faced on both sides, the edges of the boards are sealed (one finish is shown at G, Fig. 47) in order to exclude moisture and prevent corrosion of the inner surface of the metal.

Metal-faced plywood is used for wall panelling (single metal faced), counter tops (bars), partitions between public bath and water closet cubicles, etc. The metal increases the rigidity of the boards, preventing buckling, and it can be easily cleaned. Metal angles are used as a protection at the edges and external angles of counters, panelling and laminboard (see below); these, in addition to narrow vertical, etc. metal bands when inlaid flush with (or screwed to) the ply-wood surface, provide an effective treatment to wall panelling, counter fronts, etc.

Laminboards or Laminated Boards (see M, Fig. 47) are a development of plywood and are used extensively for panelling, furniture, partitions, doors (see H, Fig. 29), etc. A laminboard consists of a core built up of thin strips or slats (or laminæ) not exceeding 7 mm wide and glued between two or more outer plies. The slats are glued together and, as in plywood, the grain of these core slats must be at right angles to the adjacent plies. The strips forming the core are cut from built-up sheets which have been rotary cut (see p. 000).

The following is a brief description of the manufacture of laminboards: The peeled veneers, having been cut to width and dried to 7 to 10 per cent. m.c., are glued and assembled to form a pile approximately 600 mm thick between two thick cauls (p. 119), only every alternate sheet is passed through the glue-spreader. The pile is taken to the press and clamped as described on p. 119. The adhesive is usually casein, and the pile (or " block " or " balk ") is generally cold pressed. The balk is then converted into slabs of various thicknesses by passing it through a frame saw or a horizontal or vertical band saw, the cuts being at right angles to the layers—similar to O, Fig. 47. Two or more slabs are edge glued to form the necessary width of core, which is then re-dried to the required m.c., planed to the necessary thickness, and finally glued (resin adhesive may be used), assembled between the two or more face plies (which have been previously jointed to the required width), pressed re-dried, trimmed and sanded as previously described.

The standard dimensions of laminboards vary with different manufacturers, a common size being 1 800 mm long, 5 000 mm wide and 12 to 50 mm thick.

Blockboards.—These resemble laminboards, the only difference being in the construction of the core which is built up with blocks of wood not exceeding 25 mm wide (see N, Fig. 47). They are cheaper than laminboards and are used for similar purposes, although laminboards are preferred for first class richly veneered work.

With exception of the preparation of the core, the various operations of manufacture are similar to those of laminboard. Logs from which the timber is obtained for making the cores are converted into boards by a large vertical band re-saw (see p. 7). These boards are at least 250 mm wide and approximately 25 mm thick. The boards must be carefully seasoned and dried to the required m.c. (4 to 7 per cent.); the ends are then cut by a cross-cut saw and any large knots or defective portions are removed. The boards are assembled into piles, the lengths being built up as required and the joints staggered. Gluing, re-assembling, pressing, sawing (see O, Fig. 47), re-drying and planing operations are carried out, care being taken in re-assembling to ensure that the *boards are arranged heart side to heart side in pairs to neutralize warping* (see p. 8). The cores are then glued, assembled between the outer plies, pressed, etc.

The standard sizes of blockboards are similar to those of laminboards.

Battenboards (see P, Fig. 47).—With exception of the core these are similar to blockboards. The core is comprised of close-grained battens, not exceeding 75 mm width, which are edge glued. They are not used extensively in this country, laminboards and blockboards being preferred.

Composite Boards.—A composite board consists of several wood plies with one or two layers of asbestos fibre (p. 138) or other insulating material (see H, Fig. 47). Soft asbestos board is a good non-combustible and sound insulating material, and is light in weight. The sheet of asbestos is soaked in weak glue size, dried, and casein glued between sheets of wood ply. When used for covering ceilings, walls and partitions, this material improves insulation and renders rooms cooler in summer and warmer in winter.

CHAPTER THREE

ROOF COVERINGS

Syllabus.—Manufacture and characteristics of clay and shale plain tiles, pantiles, Italian, Spanish and interlocking tiles; eaves, ridge, hip, valley and verge details; vertical tiling. Concrete tiles; asbestos-cement slates and corrugated sheets; corrugated iron sheets. Stone slating. Shingles. Copper and zinc details. Thatch.[1] Roof insulation.

PLAIN TILING

Plain and interlocking tiling are introduced in Chap. V, Vol. I.

Manufacture of Clay and Shale Plain Tiles.— The several processes of tile manufacture are similar to those employed in the production of bricks (see Chap. I, Vol. II). These processes are (1) preparation of the earth, (2) moulding, (3) drying and (4) burning.

1. *Preparation.*—The machinery required to reduce the clay or shale to a fine plastic condition depends upon the nature of the material. Thus, a soft plastic clay may be brought to a satisfactory condition by passing it through crushing rolls and a pug mill, whereas hard clays and shales may require to be crushed, ground to a powder in an edge-runner, screened, mixed with water and passed through a pug mill. This machinery is described in Chap. I, Vol. II. The material is then soured for the reasons stated in Chap. I, Vol. II; that used for hand-made tiles being sometimes left to mature for at least a year before being used.

2. *Moulding.*—Like bricks, tiles are (*a*) hand-moulded and (*b*) machine-moulded.

(*a*) *Hand-moulding.*—A wood mould, similar to that described for bricks (*see* Vol. II), is used. The standard size of a hand-made tile is 265 mm, by 165 mm by at least 10 mm thick (see E, Fig. 48), and the mould is of these dimensions, plus shrinkage allowance. Both sand-moulding and slop-moulding are carried out. Blocks of the prepared clay, approximately 300 mm by 275 mm, are taken as required to the moulder's bench and sliced by means of a taut wire by the assistant into *bats* or *clots* which are at least 16 mm thick. The moulder takes a bat, sands or waters it, dashes it into the sanded or wet mould and forms the tile in the manner described for brick manufacture (Chap. I, Vol. II).

The nibs may be formed in the mould when suitably shaped at one end for the purpose or by bending over projecting pieces formed at the end. If the nibs are of the continuous type (see K, Fig. 48) the mould has one end higher than the rest of the sides, and when the strike used to level the surface is worked towards it, an increased thickness of clay occurs at the end and this is consolidated to form the nib.

The two holes are formed by the use of a *punch* consisting simply of a piece of wood having two projecting pins which is pressed into the clay. Another device consists of a hinged arm having a specially shaped free end with two projecting pins. Both the nibs and holes are formed when the arm is rotated and the free end is pressed into the raised edge of the clay slab in the mould.

The slab is turned out of the mould on to a sanded board. The set or camber is then imparted by piling six of the moulded slabs with heads and tails alternating on to a three-legged stool or *horse* which is convex-curved to the required radius of the camber. A two-handled wood block, having its lower surface curved to the reverse of the horse, is then brought down several times on to the batch. The cambered tiles are then stacked and dried. Alternatively, the slabs from the mould are stacked to a height of about 600 mm on a *pallet* consisting of 900 mm long laths spaced at intervals and nailed to the concave-curved top edges of two end cross-bearers which are about 330 mm long. The stack is weighted with a couple of bricks, and the tiles gradually assume the desired shape.

Special tiles, such as purpose-made hip and valley tiles and bonnet hip tiles, are sometimes hand-moulded.

(b) *Machine-moulding.*—Tiles made by machinery are either wire-cut or pressed.

Wire-cut tiles, like bricks of this class (Chap. I, Vol. II), are produced by a pug mill or auger having a die or mouthpiece similar to that shown at A, Fig. 1, Vol. II, but with a cross-section conforming to that of tiles. A continuous thin band of clay is extruded through the die and passed over rollers to the cutting table where it is cut transversely by wires spaced at tile-length apart in a frame. Nibs are produced by a special attachment on the auger which may take the form of an indented roller fixed in front of the mouthpiece, the nibs being formed at intervals on the extruded column of clay. Nail holes may be formed by a lever-operated punch containing two pins and fixed as an extension to the cutting table. The nibbed and holed slabs are then stacked on curved pallets, cambered and dried.

Plain tiles are moulded by the pressure process as explained for bricks (Chap. I, Vol. II), the die-boxes being, of course, of the appropriate shape and size. The nibs are formed by the plunger as it descends and presses each slab. Holes are formed automatically when the plunger is released.

3. *Drying.*—The drying of bricks is described in Chap. I, Vol. II, and much of this may be applied to tiles. Artificial drying is chiefly employed, although hand-made tiles are often allowed to dry gradually on racks by the natural process. There are several methods of stacking the tiles when artificially dried. In one, the tiles are placed upon pallets (see above), each of which holds four tiles. The pallets are stacked in rows one above the other in the drying shed or chamber to a height of at least 1·5 m. Moisture is gradually eliminated from the tiles as the heated air circulates round them. Natural drying (Chap. I, Vol. II) is still adopted on a small scale.

4. *Burning.*—After being properly conditioned the tiles are stacked and burnt in kilns of the intermittent, continuous and tunnel types (see Chap. I, Vol. II). The form of setting varies, depending upon the type of kiln. If it is continuous, it is usual to set the tiles in *cupboards* one above the other. A cupboard consists of four fireclay slabs, one at the bottom and two vertical side slabs which support that at the top. Each holds about twelve tiles placed on edge at nib distance apart to permit of the circulation of the hot gases.

General. Tiles should be well burnt throughout, free from firecracks, dense and tough, and should show a clean fracture when broken. A well-burnt tile is generally indicated by a clear ring when it is struck with a metal bar; a dull note suggests an underburnt or cracked tile.

[1] Asphalt covered flat roofs are detailed in Vol. IV together with other lightweight roof coverings like asbestos and aluminium decking.

Although machine-made tiles from reputable firms are of excellent quality, it is generally considered that hand-made plain tiles are tougher and more durable. Machine-made tiles are more liable to lamination, a defect described in Chap. I Vol. II.

The appearance of sand-moulded hand-made tiles, due to the slight irregularities in shape and a rough textured surface, is superior to that of the regular shaped and smoother surfaced machine made tiles. In this respect they also resemble bricks (see Chap. I, Vol. II). This texture is imparted to the tiles by the coarse sand used to cover the mould and bats; the sand is impressed when moulded and during the burning process particles drop out, leaving the characteristic and attractive surface roughness. Some machine-made tiles are sand-faced by the several methods described in Chap. I, Vol. II. Like bricks, tiles are produced in a wide range of colours (see Chap. I, Vol. II).

TESTS.—In accordance with B.S. 402: Clay Plain Roofing Tiles and Fittings, tiles must comply with two tests:—transverse and water absorption.

The transverse test consists of applying the load from the machine along the centre line at right angles to the length of the tile which has been immersed in water for twenty-four hours and which is supported on the rounded edges of wood bearers placed at 190 mm centres. Six tiles are tested, and the average breaking load shall not be less than 79·5 kg.

To comply with the water absorption test six tiles are dried in an oven; when cool the specimens are immersed in water for twenty-four hours, removed, wiped dry and then weighed. The absorption per cent by weight after twenty-four hours' immersion equals $\frac{100\,(B-A)}{A}$, where A is the weight of the dry specimen and B is the weight of the specimen after twenty-four hours' immersion.

The sizes, shapes, etc. of pantiles, double Roman tiles, flat interlocking tiles, and ridge, valley and verge tiles are given in B.S. 1424: Clay Single-lap Roofing Tiles and Fittings.

PLAIN TILING DETAILS

The terms used in slating are also applicable to tiling. Students are therefore referred to Chap. V, Vol. I, for definitions of these terms, for a description of the groundwork and for the introduction to the subject of plain tiling.

The various tiles used in plain tiling are illustrated in Fig. 48. According to the B.S.S. No. 402, the standard size of plain tiles is 265 mm by 165 mm (see E and K) by a thickness of between 10 and 15 mm. Some tile manufacturers make 280 mm by 180 mm and 250 mm by 150 mm tiles, and the thickness of hand-made tiles may be as much as 16 mm. Normally, each tile has two or three short nibs or stubs (see E and L) or a continuous nib as shown at K; tiles without nibs can be obtained. Each tile is pierced with two holes. The object of the camber to which plain roofing tiles are shaped (see F) is to cause the tails of the tiles to closely contact those under them and thus assist in preventing the entrance of driven rain and snow. In addition to this longitudinal camber, some hand-made tiles are *hatched*, namely, are given a slight curve in their width. Whilst such hatched tiles enhance the appearance of a roof on account of the small undulations produced, rain and snow can be more readily driven up between them.

Special short tiles are manufactured for eaves and ridge courses and wide tiles for verges and certain hips and valleys. Thus the *eaves under tiles* (see G) are 165 mm to 180 mm long by 165 mm wide and form the bottom course of a double eaves course. The *ridge under tiles* (see H) are 230 mm long and 165 mm wide and are used to maintain the normal gauge at the ridge instead of using longer cut tiles. The *tile-and-a-half tiles*, as implied, are one and a half times wider than the normal tile and are therefore 265 mm long and 248 mm wide (see L). As explained later, they are employed at gable verges, bonnet hips, and swept and laced valleys.

Like slates, plain tiles are laid in regular bond (see J).

Lap, Gauge and Pitch.—In Vol. I it was stated that the lap for a slated roof should be 76 mm when the pitch was 30°. For smaller units, such as plain tiles, the lap usually employed is reduced to 65 mm, and the gauge is therefore

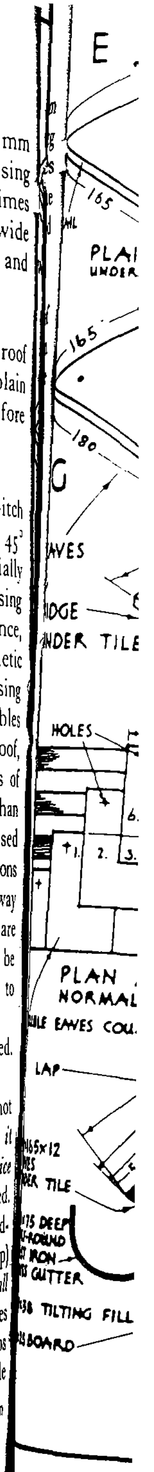
$$\frac{\text{length of the tile} - \text{lap}}{2} = \frac{265 - 65 \text{ mm}}{2} = 100 \text{ mm}^{1}$$

This reduced lap necessitates a corresponding increase in the *minimum* pitch of plain tiled roofs to 45°. This slope should, however, be avoided, as a 45° pitched roof presents a very unsatisfactory appearance, which is especially noticeable at gables. The draughtsman should therefore refrain from using the 45° set square when designing a roof, even if this causes inconvenience, especially when an adjustable set square is not available! Hence, for æsthetic reasons, the desired minimum pitch is considered to be 47½°. A more pleasing effect is produced when the pitch is between 50° and 55°, and for narrow gables the roofs can, with advantage, be increased in pitch to 60°. The area of a roof, and therefore its cost, is increased as the pitch increases. If, for reasons of economy, a 45° pitch cannot be exceeded, it is recommended that, rather than adopt this angle, the pitch be reduced to 42½° or even 40°, and the lap increased to at least 70 mm. The pitch of plain tiled roofs, including sprocketed portions (see p. 126), should not be less than 40°, as the water does not get away quickly on flat pitched surfaces, and on north-east slopes especially the tiles are liable to lamination on account of slowness in drying. If roofs are likely to be exposed to exceptionally severe weather conditions, it may be necessary to increase the lap of the tiles to 75 and sometimes 90 mm.

Nailing.—Copper or composition nails (see Chap. V, Vol. I) should be used. Normally, 38 mm long nails are used (45 mm for thick hand-made tiles).

As plain tiles have nibs which enable them to be hung on battens, it is not necessary (except as stated below) to nail every tile. *For normal exposures, it is usual to specify that every tile in each fourth or even fifth course shall be twice nailed.* In fairly exposed situations every third course of tiles may be nailed. In very exposed positions, especially if the roofs are steeply pitched and hand-made tiles (the nibs of which are often misshapen and afford an insecure grip) are to be employed, it may be necessary to have every tile nailed. Further, *all* tiles must be twice (and sometimes thrice) nailed which comprise:—double eaves courses (both the under tiles and those immediately above them), verges, hips (including those adjacent to the hip tiles), valleys (including the tiles each side

[1] It will be noted that, unlike that for head-nailed slates, the gauge *includes* the portion of tile between the holes and the head.



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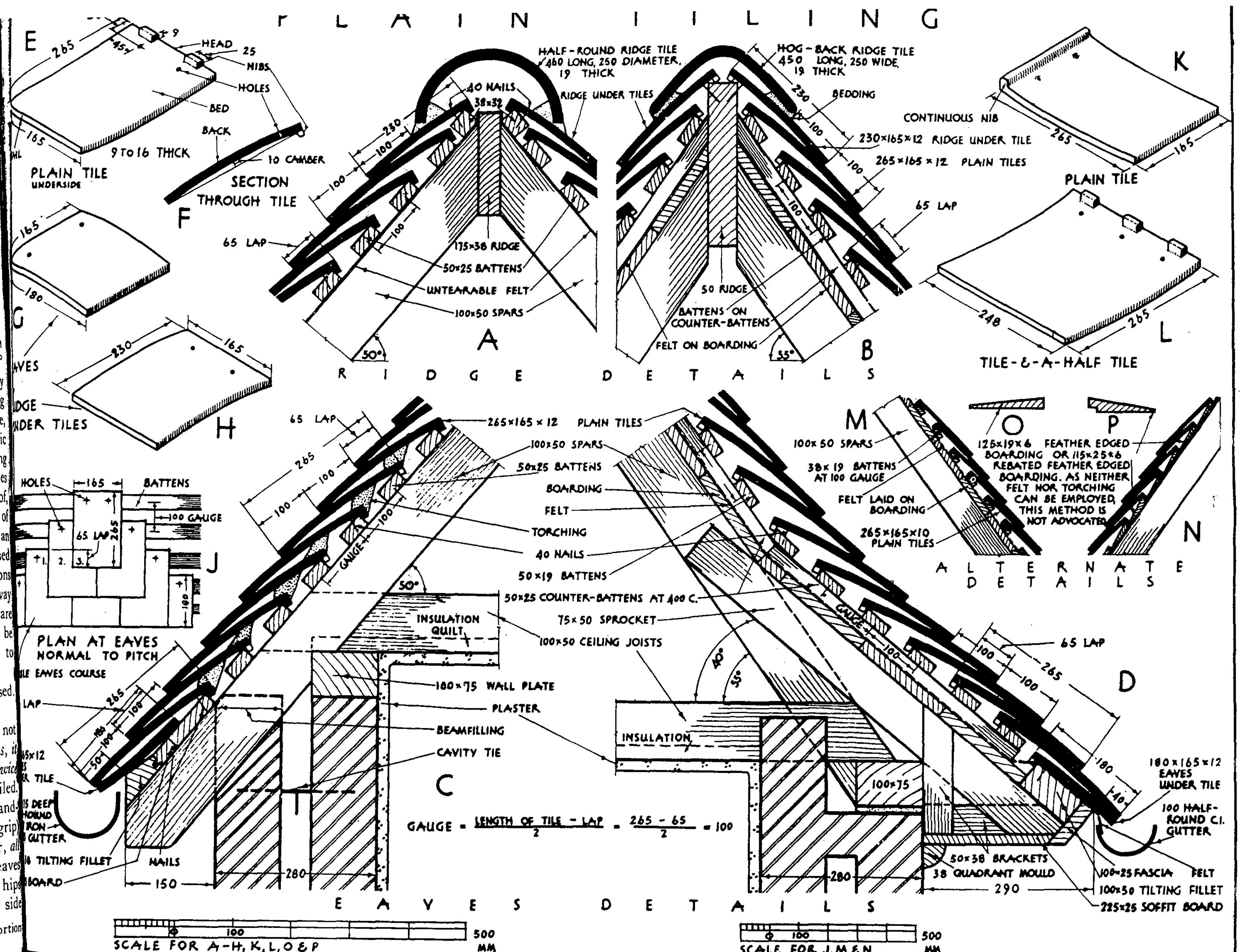


FIGURE 48

of purpose-made valley tiles, those adjacent to the tile-and-a-half tiles employed in laced valleys, and those required to form swept valleys—see Fig. 49) and ridge under tile courses

Battens.—It is common to specify either 50 or 38 mm by 25 or 19 mm sawn redwood battens at gauge centres secured with galvanized wire nails. Counter-battens are usually of 50 mm by 25 mm or 19 mm redwood spaced at 380 to 400 mm centres and nailed. The length of nails should be twice the thickness of the battens, thus 50 mm nails are used for 25 mm thick battens and 38 mm nails for 19 mm battens.

Eaves Details.—A simple open eaves is detailed at C, Fig. 48. This shows the spars at a pitch of 50° overhanging a 280 mm cavity wall. The groundwork consists of battens only, and the underside of the tiles is torched. Alternatively, untearable felt (see Chap. V, Vol. I) may be nailed direct to the spars, as shown at A. Counter-battens, as shown at D, may also be employed. In addition to the double eaves course the tiles are shown nailed at every fourth course, which, as explained above, is the usual practice. The eaves under tiles are shown to be nibless and fixed with their backs lowermost to ensure a close contact between the tiles in this double course; the common practice is to fix the under tiles as shown at D.

The detail at D shows a sprocketed closed eaves having a minimum depth at the gutter which, in most cases, is a desirable feature. The spars are pitched at 55° and, for the reasons already stated, the sprockets are given a 40° pitch. The sprocket reduces the rate of flow of water which in a storm, and when the roof is steeply pitched, would tend to overshoot the gutter. The bell-shaped finish also enhances the appearance. Whilst a slightly flatter pitch of 35° (90° − 55°) may be preferred (see L, Fig. 37, Vol. I), it is emphasized that the normal minimum pitch of any part of a plain tiled roof is 40°, and if this is to be reduced (especially at the eaves where the water passing over it may be considerable) the materials and workmanship must be of the best quality and the lap should be increased beyond 65 mm. The tiles are shown nailed at every fifth course, which agrees with the minimum requirements (see above). The groundwork complies with that advocated for best work, namely, boarding (covered with bituminous felt), counter-battens and battens. The soffit is closed with 225 mm by 19 mm boards nailed to 50 mm by 38 mm brackets fixed to the spars, and a narrow fascia (backed by a tilting fillet) finished flush at the soffit. A simple quadrant bead is scribed to the wall and nailed to the soffit boards. As an alternative to previous details, the wall plate is shown bedded on the outer leaf of the wall. The cast iron gutter would be supported in the usual manner either by straps screwed to the backs of the spars or brackets secured to the fascia (see M and N, Fig. 77, Vol. I).

Ridge Details.—That shown at A includes a half-round ridge tile. The ridge under tiles are nailed to 32 mm thick battens which give the required tilt to the tiles to ensure the tails biting the tiles below (although, unlike slating, this is often unnecessary for cambered tiles). The margin between these tiles and the ridge mortar pointing is equal to the gauge of 100 mm. This mortar should tone with the colour of the tiles.

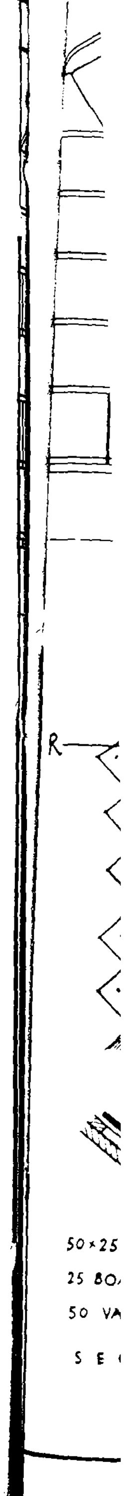
A hog-back ridge, closely bedded down, is shown in the detail at B. Here the ridge under tiles are nailed direct to the wood ridge as an alternative to the above. Note that the tiles are shown nailed at every fourth course.

A V-shaped ridge, as shown at F, Fig. 49, may be used. *Lead covered ridges* (see B, J and H, Fig. 75, Vol. I) *should never be employed for plain tiled roofs.* Exposed leadwork clashes with the colour of most tiles. Also, the uniformly straight hard "roof-line" presented by such a ridge is the very opposite to what is required for association with richly textured plain tiles. Little, if any, lead is visible on plain tiled roofs of good-class buildings.

The details at M and N, Fig. 48, show alternative groundwork for tiles. That at M shows boarding, felt and battens. It is not satisfactory, as decay of the battens may result by the lodgment on their upper edges of driven rain and snow. The detail at N shows the employment of two forms of *feather-edged boarding.* One type is rebated (see P) to receive the thin edge of the adjacent board (see N) and the other is of section shown at O. The latter boards are laid to overlap (as indicated at N) by a varying amount according to the gauge. These boards are nailed along both edges to prevent them warping and tilting the tiles. Neither form of this boarding is recommended, for, whilst it has a certain insulating value, felt cannot be conveniently employed, and thus snow and rain may gain access, causing dampness and possible decay of the timber. It is used for cheap speculative or competitive work.

Hip Details (see Fig. 49).—The *granny bonnet hip tile*, shown at B and applied at A, C and D, is generally preferred to the angular type (see E, F, G and H) because of its rounded form and the bold effect which it produces. Its name is expressive of its appearance. As shown, these hip tiles are bonded with the general plain tiling. Each hip tile is well bedded down with haired mortar (1:3) on to the back of the tile below and is secured with a sufficiently long nail to the hip rafter. This mortar adds to the attractive appearance of the hip, especially if its colour conforms with the brickwork jointing below, and is given a rough textured surface which is cut back at least 12 mm to produce a shadow. The adjacent side plain tiles are cut and mitred to the sides of the hip tiles, tile-and-a-half tiles being often used for this purpose to ensure that each is secured with two nails. Such cutting is sometimes unnecessary with suitably pitched hip tiles. A side view should show these hip tiles well tilted, namely, the tailed edges should be given an adequate inclination to ensure the top of each curve well above the back of the tile below. Flat bedded tiles (those which fit closely to each other and show only the minimum of bedding material) greatly detract from the appearance.

A suitable finish of a hipped end at the ridge is shown at C. The top pair of bonnet hip tiles is mitred under the ridge, which may be of the hog-back (as shown) or half-round type. The end length at least of the ridge is given a slight tilt upwards and the open end is either filled with mortar cut back at least



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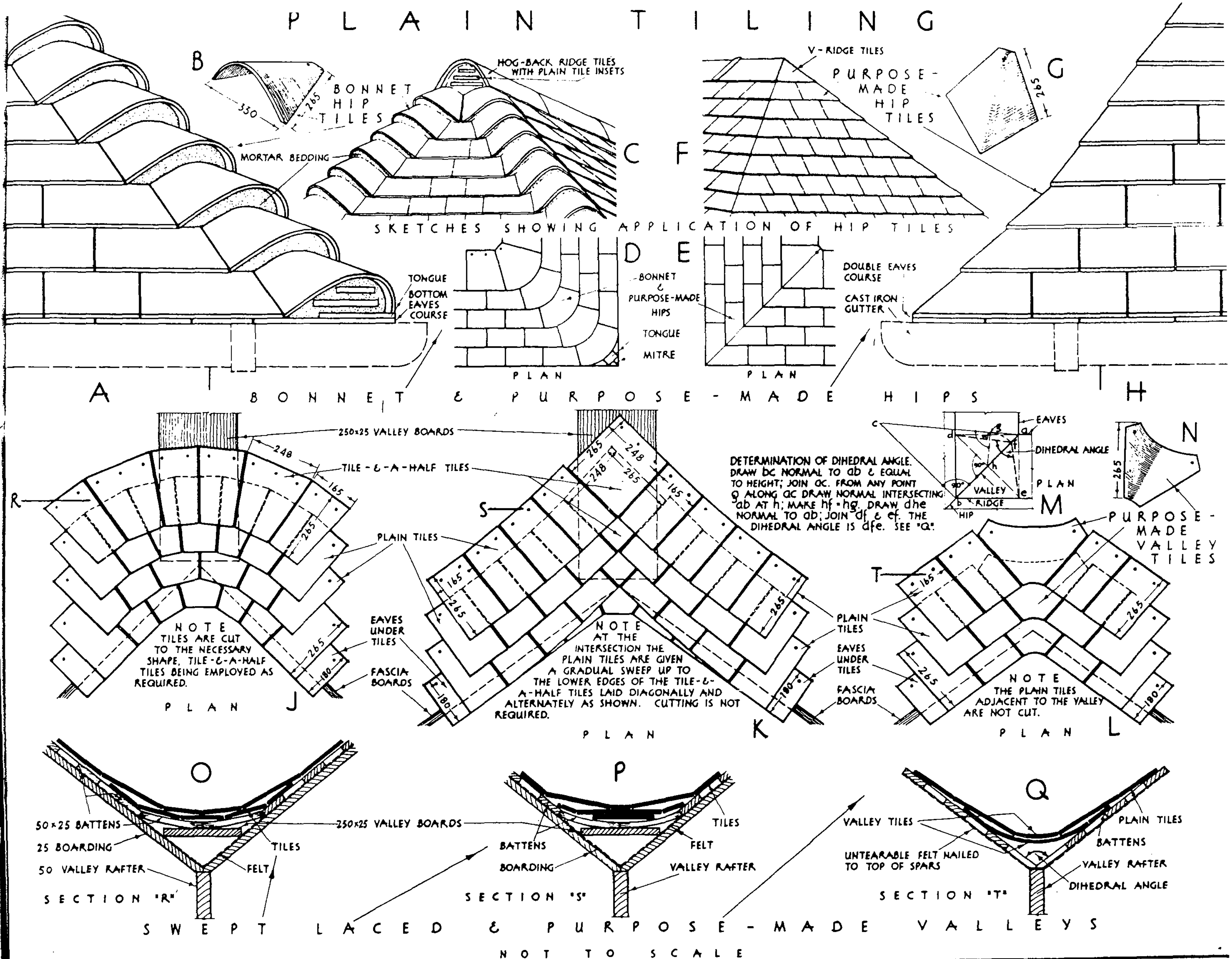


FIGURE 49

12 mm or preferably partly filled in with pieces of plain tile (as shown) or a small section of the upper curved portion of a ridge tile. Care should be taken during fixing to prevent the edges of these insets being stained with the mortar, and the latter should be cut back slightly; this gives a more interesting finish than that provided by a solid-ended ridge tile (compare with F). The slight tilting of the end ridge pieces is also desirable at chimney stack intersections and at verges (see p. 130).

A satisfactory treatment of the lower end of a bonnet hip is shown at A and D. The eaves under tiles are mitred at the intersection (see the plan D) and partly covered with a 50 to 75 mm wide piece of plain tile, called a *tongue*, which is tailed into the mortar. Alternatively, the eaves under tiles may be rounded off at the external angle to the curve of the hip tile. In addition, a relief to the mortar infilling at this lower hip tile is obtained by two plain *tile insets*, described above, or by the insertion of a piece from the upper portion of the tail of a bonnet.

The *cone hip tile* is another type which produces a rounded hip. This tile is 265 mm long and has a segmentally curved tail, 225 mm wide, which tapers towards its head like the bonnet tile. The plain tiles of each slope at the hip are cut to an open mitre and the cone hip tiles are bedded upon them; they are nailed at their heads to the hip rafter. In appearance this hip is much inferior to the bonnet hip.

Half-round hip tiles, similar to those for ridges, are also used (see H and K, Fig. 70, Vol. I). When used for this purpose the effect is distinctly unsatisfactory.

Purpose-made hip tiles, known also as *angular hip tiles*, are often adopted. Such a tile is shown at G. An enlarged elevation of the lower portion of a purpose-made hip, slightly sprocketed, is shown at H; a plan and a sketch of a portion of an angular hipped end are shown at E and F. As these hip tiles are bonded in with the general tiling, it is necessary that they conform within certain limits to the dihedral angle of the roof. The method of determining this angle is similar to that for valleys and is briefly explained at M. To ensure the proper bedding of these tiles, and to allow for twisting which may occur during the drying and burning processes of manufacture, the angle of the hip tiles used is generally 5° less than the geometrically determined dihedral angle. Each tile is nailed at its head. The appearance of this form of hip, with its hard angle and neat mechanical line, is unattractive.

Cut and Mitred Hip Tiles with Lead Soakers.—Whilst this type is excellent for slates (see F, G and J, Fig. 70, Vol. I), it is one which is not advocated for tiling, partly because of the difficulty in making such work watertight (especially in exposed positions) and partly on account of the neat and mechanical appearance which it presents.

Valley Details.—The *swept* or *circle valley*, illustrated at J and O, Fig. 49, is undoubtedly the most attractive of the several types adopted, its effective appearance being due to the irregularly shaped units so arranged as to link up the courses of the intersecting slopes by a series of easy curves. When formed by a skilled craftsman, a swept valley is watertight and lead is not required. It is expensive because of the large amount of tile-cutting involved. As much as possible of the dihedral angle is blocked out by the use of a 225 mm by 250 mm by 25 mm valley board fixed up the valley to the boarding, and the battens are brought over it, as shown. The tiles are cut to the required shape, tile-and-a-half tiles being employed whenever necessary; in this process the head corners with the nail holes should not be removed in order that the tiles may be adequately nailed. The radii of the curved courses gradually increase from the eaves until a satisfactory curve is obtained at about the fourth or fifth course, after which the radius is more or less constant. Valleys in roofs covered with ordinary slates or stone slates (see Fig. 56) are also swept in good work.

The *laced valley* is another very satisfactory form in the construction of which a valley-board is used to pack out the angle (see K and P). No lead is required. Apart from its appearance, a laced valley differs from a swept valley inasmuch as none of the tiles is cut, and the only tile-and-a-half tiles used are those immediately over the valley board; hence less skill is required in its construction and its cost is much reduced. The battens and tiles are given a gradual sweep upwards so that each pair of courses intersects at a tile-and-a-half tile laid diagonally and alternately right and left handed as shown. As indicated at K, the lower corners of these tile-and-a-half tiles are exposed to form a continuous row of diapers up the valley.

Purpose-made or angular valley tiles (see N), like those for hips, are specially shaped to suit the required dihedral angle, the geometrical development of which is explained at M. Allowance is made for any warping that may occur by moulding the tiles at an angle which is approximately 5° greater than that developed. The plan and section at L and Q show a portion of this valley, which is comparatively inexpensive but much less pleasing in appearance, because of its mechanical neatness, than either the swept or laced valleys. Lead is not used.

Lead valley gutters.—Open and secret valley gutters and those formed with cut and mitred tiles with soakers as described for slated roofs (see Chap. VI, Vol. I) are unsuitable because of the uniformity of the hard angles presented at the intersecting surfaces and the inappropriate colour and texture of this covering material.

Verges. (see Fig. 50)—The roofing tiles at a verge should project 50 to 75 mm beyond the face of the wall, the overhang and thickness of the verge increasing with the height of the building. The tiles should be given an upward tilt to prevent the roof water from running down the gable. This also improves the appearance. An undercloak, consisting of one or more courses of projecting plain tiles, butt-jointed, is necessary to provide a satisfactory finish. These tiles are placed transversely and bedded on the wall in cement mortar, the straight ends (and not the cambered edges) being therefore exposed to view. Two verge details are shown at H and J. That at H incorporates vertical plain tiling (see p. 129) and shows the end pair of spars at a slightly higher level than the rest of the rafters in order to impart the required tilt. The battens are brought over the single tile undercloak to within 25 mm from the face of the wall. The space between the undercloak and the tiles above is filled in and pointed with mortar either flush or cut back 12 mm; the tiles are also pointed (see H, K and O). The tile edges should be free from mortar stains. The end roofing tiles in alternate courses must be tile-and-a-half-tiles and *not half tiles*, as the latter cannot be securely fixed. The end rafters are shown in the detail at H to be approximately 115 mm from the outer face of the wall in order to reduce the projection of the battens, although the usual practice is to fix the rafters close to the inside face as shown at J.

An alternative method of obtaining the necessary tilt is to arrange the end pair of rafters level with the top of the wall; the undercloak tiles are then bedded and the battens are bent over them.

The detail at J, showing a cavity wall, is suitable when only a slight tilt, provided by the mortar bedding, is required. The thickness of the verge is increased if a cement fillet between the wall and undercloak (shown by a short broken line) is formed. A double tile undercloak, which gives a bold effect, is shown at S.

VERTICAL PLAIN TILING

Vertical tiling, also known as *weather tiling* and *tile hanging*, is applied to walls as a protection against rain penetration and for æsthetic reasons. It is especially suited to walls subjected to severe exposure, as it affords a very effective protection, and plain tiles, particularly if they are hand-made and skilfully handled, can produce a pleasing contrast to brickwork.

Details of vertical tiling are illustrated in Fig. 50. The key elevation of a gable wall of a house, finished with facing bricks up to the head of the ground-floor window and plain tiles above, is shown at A. The nails are nailed to either (*a*) battens as for roof tiling, (*b*) coke breeze concrete bricks or slabs built in courses at gauge intervals, (*c*) direct to the mortar joints of the brickwork or (*d*) battens fixed to studs.

(*a*) The detail at Q shows the tiles fixed to 38 mm by 19 mm battens which are plugged to the brickwork. It will be observed that, like roof tiling, *there are three thicknesses of tiles at the lap*. The latter is much reduced, a 39 mm lap being common and all that is necessary. The gauge therefore equals

$$\frac{\text{length of tile} - \text{lap}}{2} = \frac{265 - 39}{2} = 113 \text{ mm}.$$

Every tile in each course is fixed with 38 mm copper or composition nails. The sawn laths should be of sound well-seasoned redwood and treated with preservative, otherwise when fixed in this position they are liable to decay. Sometimes 50 mm by 25 mm counter-battens are provided; these are, of course, fixed vertically, being plugged to the wall at 400 mm centres, and the tiling battens are nailed to them.

As in roofing, a double eaves course is provided, the first course consisting of eaves under tiles. That shown at Q is tilted out by the top course of tile creasing. This creasing consists of six courses of tiles with bed joints, or three courses of tiles per course of brickwork. The three top courses project with an equal oversail. After bedding, the edges of these tiles should be well cleaned to remove any mortar stains. A part elevation of this finish is shown at P. A more pronounced bell-cast, and one which is usually preferred, is obtained by fixing the tiles in *both* of the courses comprising the double eaves course with the camber uppermost, as shown at R. The latter detail shows a tilting fillet or sprocket and is an alternative to that at Q for providing the required tilt. Another alternative, which serves the same purpose, is a projecting brick course.

(*b*) The section at R shows the tiles nailed to coke breeze concrete bricks or slabs bonded in between alternate heading and stretching brick courses. These so-called *fixing bricks* are made of concrete composed of cement and an aggregate of coke breeze (a product of coke ovens and gas retorts, see Chap. I, Vol. II) in the proportion of 1 part cement to 6–10 darts breeze. The size is 215 mm by 100 to 125 mm by 32 to 40 mm. These bricks may project to afford a ledge for the nibs, or they may be built flush. Both are shown. Nibless tiles, which can be obtained from some manufacturers (otherwise the nibs are removed), are used if the concrete bricks do not project.

Although coke breeze concrete bricks are often preferred to wood battens on account of the tendency for the latter to decay, the bricks do not afford such a secure nail hold and a preference is therefore given for wood battens for tiling walls in exposed situations. Further, the sulphur present in breeze corrodes the nails, and whilst the rust is claimed to increase their holding power, it is also responsible for their comparatively rapid destruction, especially when in damp localities the corrosion is accelerated.

(*c*) Nailing tiles direct to the mortar joints was formerly a common practice, but it is one which has fallen into disfavour because of the uncertain nail hold provided. As the bed joints of the brickwork must be at the required gauge apart, it is usual for it to consist of bricks-on-edge, the rat-trap bond illustrated at F, Fig. 18, Vol. II, being useful for this purpose, as an approximate gauge of 112 mm is thereby obtained. The thickness of the bed joints is commonly 10 mm. Stout galvanized wrought iron or composition nails, 50 mm long, are used for such direct fixing, copper nails being too soft for this purpose. Tiles without nibs are used, otherwise the length of nail must be increased. The rigidity of the tiles is increased if they are bedded in mortar. The nails are apt to work loose in the mortar, and direct nailing is therefore particularly unsuited for work which is likely to be subjected to the effects of high winds.

(*d*) The fixing of vertical tiling to studs is the traditional method, as such covering was originally associated with timber-framed buildings. A typical wall of such a building consists of a frame having a head, sill and two outer posts with intermediate posts or studs. The plain tiles are hung and nailed to 38 mm by 19 mm battens fixed horizontally at the gauge apart to the studs.

The battens may be of redwood, although oak battens, being less liable to be split by the nails, are sometimes used, In order to exclude draughts and to provide adequate insulation, it is necessary for bituminous felt to be nailed to the studs before the battens are fixed. Such construction is very commonly applied between the head of a bay window and the sill of that above it.

In the example shown in Fig. 50, the whole of the tiled area may be studded and constructed in this manner. Alternatively, the brickwork of the gable, covered as shown, may extend to the level of the bedroom ceiling joists, and the upper triangular space completed by 100 mm by 50 mm or 75 mm studs at 400 mm centres, fixed to a sill bedded on the wall and to the outer pair of spars, battened and tiled.

Because of the protection afforded by the tiles, the normal thickness of external brick walls can be reduced when covered with vertical tiling. Thus, at R the 328 mm brick wall is reduced to 215 mm at the bedroom floor level. In the alternative detail at Q, the lower portion, not being tile-hung, consists of a 280 mm cavity wall. As there is no need for the cavity to extend beyond the tiling, it is dispensed with as soon as practicable, namely, at the bedroom floor level, and the wall is continued as a 215 mm thick solid structure. Incidentally, this increases slightly the internal dimensions of the upper storey.

Angles.—The treatment of external angles is shown at P, where special angle tiles are employed which course in with the adjacent tiling. These are purpose-made right and left-handed for alternate courses, as shown at N. The size varies according to the tile; thus, if a greater bell-cast is required at the eaves, the tilt of the angle tiles would have to be correspondingly increased. In lieu of these special angle tiles, the plain tiles at the angles are cut and mitred; in addition, lead soakers are provided underneath at the intersections for adequate protection. Such construction is similar to that adopted for hips and described in Chap. V, Vol. I. Internal angles of wall tiling may also be finished with either purpose-made angle tiles or cut and mitred tiles with lead soakers.

Verges.—Two methods of treating the vertical tiles at the verge intersection are shown at O, K and S. That at O and K, known as the *Winchester cut* method, gives much the better appearance, the fan-shaped effect being produced by cutting at each end of each course the end tile and adjacent tile to the required splay and tilting the end tile. This tilt should not be excessive in order to ensure that one nail hole and nib of the adjacent splayed tile are preserved. The intersection between the vertical tiling and the undercloak is pointed in mortar, as shown. The alternative finish at S shows that only each end tile in each course is splay cut, and this method is therefore cheaper than that of the Winchester cut, which necessitates the cutting of two tiles at each end. This second method is only possible if, as shown, a tile-and-a-half tile is used at the end and a nib and hole made available. The intersection between the undercloak and the vertical tiling is neatly pointed with cement mortar.

Eaves.—The finish of the vertical tiling at the eaves of the roof depends upon the projection. The detail at O is one method where a hard stone corbel supports the brickwork. It will be observed that the intersection between the bottom tilted tile and the angle tile coincides with the bottom of the corbel.

If the gable is not hung with tiles, an interesting feature is provided by tile corbels, such as is shown at T.

Ridge.—The detail at K shows the appearance of the apex of the gable when the two top tilted tiles are mitred under a half-round ridge tile with tile insets.

Window Openings.—Details at the head and sill of the upper window are provided at L and M. The former shows a single projecting tile soffit at the head of the window and a proper double course of vertical tiling. The soffit may consist of two courses of tiles, projecting as shown at Q. Alternatively, like that at R, a tilting fillet or sprocket may be used and a pronounced bell-cast imparted. The edges of the tiles at the reveals must be well bedded and pointed with cement mortar. Tile-and-a-half tiles, and not half tiles, should be used at alternate courses at the reveals, especially in exposed positions.

The detail at M shows a sound and effective method which ensures water-tight construction at the sill of the window. The desirability of not exposing lead to view when associated with plain tiling is referred to on p. 126. Hence, in this detail, a *secret apron* has been employed. The apron, hooked over the ledge of the water bar before the window is fixed, is dressed over the tile course.

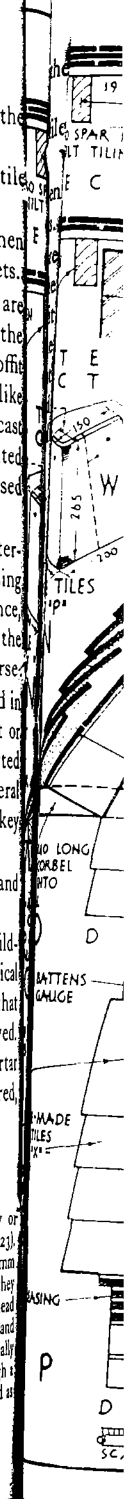
If a water bar is not provided the upper edge of the apron should be tucked in the groove of the sill. A course of short tiles is then well bedded in cement or haired lime mortar spread on the lead apron. The heads of the tiles are inserted in the groove provided in the sill, and their tails should line with the general tiling. The lead apron should be well scored (scratched) to give a better key for the mortar.

A cheaper method is to dress the lead over the top course of the tiles, and it is therefore exposed to view, as in slating (see A, B and E, Fig. 75, Vol. I).

Vertical Slating.—Slates are also used to cover walls, especially of buildings where severe weather conditions are likely to be met. Whilst vertical slating affords an excellent protection, its appearance is less pleasing than that of vertical tiling, especially if large, thin, smooth textured slates are employed. Like plain tiles, slates may be fixed to battens, concrete bricks, direct to mortar joints or to studs. The slates at external and internal vertical angles are mitred, and soakers are provided as explained on p. 129.

PANTILING

Manufacture of Clay and Shale Pantiles.—The preparation of the clay or shale, and the drying and burning processes are as described for plain tiling (p. 123). Pantiles are from 330 mm to 360 mm long, 225 to 250 mm wide and 12 to 19 mm thick (see A, Fig. 51), They are not cambered but are flat from head to tail, and they are curved transversely to a flat-wave or S-section. One nib is provided at the head on the underside of the trough of the wave, a nail hole is formed below the nib, and two of the opposite diagonal corners are splayed or rounded. Pantiles are usually machine moulded by the wire-cut process, the band of clay is extruded through a mouthpiece shaped to the required cross-section, cut to length, nibbed and holed as described on p. 123.



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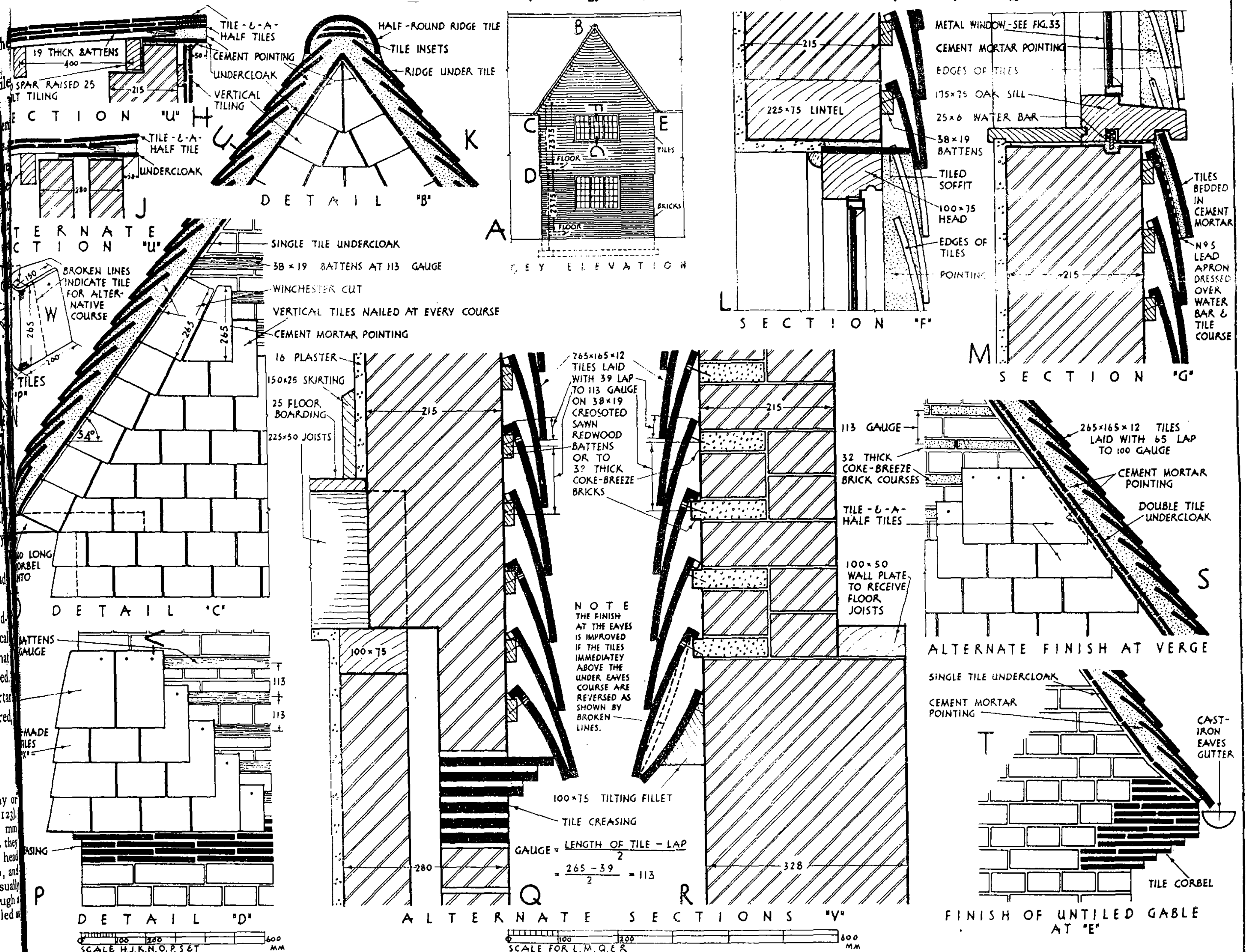


FIGURE 50

Details.—There are several differences between plain tiling and pantiling. Plain tiles are laid with butt side joints, three thicknesses at the lap and two thicknesses between laps; pantiles are laid with *overlapping side joints* with *two* thicknesses only at the head joints and a single thickness at the unlapped portions. Whilst plain tiles have a bonded appearance, pantiles are unbonded, having continuous side joints from eaves to ridge. Pantiles are thus described as being *single-lapped*, as distinct from plain tiles which are *double-lapped*.

Pantiling is detailed in Figs. 51 and 52. A cross-section through two adjacent pantiles at C, Fig. 51, shows the side lap which varies from 38 mm to 50 mm. A plan, to a reduced scale, of these tiles is shown at D.

The head (longitudinal lap) varies from 75 to 100 mm, according to the roof pitch and the degree of exposure. Gauge equals the length of tile − lap; thus, that of 360 mm long pantiles, having a 75 mm lap$=360-75=285$ mm. The pitch varies from 30° to $47\frac{1}{2}$°; if the latter is exceeded there is a tendency in a storm for the water streaming down the shallow channels to overshoot the eaves gutter.

The comparative gauges being 100 mm for plain tiles (see p. 124) and 285 mm for pantiles, the covering capacity of the latter is greatly in excess of that of plain tiles. The average weight of pantiles, when fixed, is about 37 kg/m^2, and is therefore much lighter than a plain tile covering which may reach 70 kg/m^2. Hence smaller roof timbers may be used for pantiles (or the distance between purlins may be increased) than those required for plain tiling, and therefore pantiling results in an economy in roof timber.

The two diagonally opposite corners or *shoulders* are splayed off to the depth of the lap, as shown at D, Fig. 51, to permit a reasonably close fit between the tiles; otherwise four thicknesses of tile would occur at the corners, resulting in open joints due to the tilting or overriding of the tiles. The joining of the bottom left-hand corner of a tile with the top right-hand corner of the tile below and to the left is called *shouldering*—see H.

Pantiles are nailed as required and as specified for plain tiling (see p. 124). The greater the exposure, the more frequent the nailing. The groundwork for both types is also similar, usually 38 mm by 19 mm tiling battens.

Eaves Details.—(J and L, Fig. 51). That at J shows a simple closed eaves. Untearable felt is nailed to the backs of the spars and the tiling battens are fixed at 285 mm gauge. Although an under-eaves course is not essential it provides a good finish. Both details show a course of eaves under tiles; a course of ordinary plain tiles is sometimes adopted. The bottom course of pantiles is bedded on mortar on the plain tiles.

The alternative eaves detail at L shows the external leaf of the cavity wall finished with six projecting courses of uncambered plain tiles. The groundwork conforms to the best practice, namely, tongued and grooved boarding covered with felt, counter-battens at 380 to 400 mm centres and tiling battens at gauge centres. The spars are slightly sprocketed and the bottom course of pantiles is bedded on a course of nibless eaves under tiles. A part elevation of this eaves is shown at K. The eaves gutter has been omitted. Small plain tile insets (see p. 128) provide a relief to the mortar bedding; the application of these small pieces of tile is shown at A and C, Fig. 49, K, Fig. 52 and Q, Fig. 53.

Occasionally three or four courses of plain tiling are provided at the gauge (100 mm) apart in the usual manner at the eaves of a pantiled roof. This treatment is traditional, and its object is to distribute the flow of water from the channels of the pantiles above and so prevent it from overshooting the gutter.

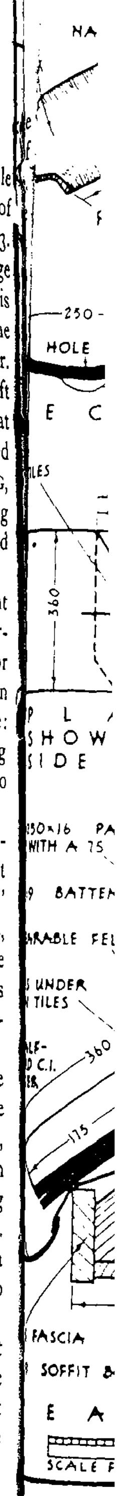
Ridge Details.—Two are shown at F, Fig. 51, the groundwork on the left being similar to that at J, and the timbering and felting on the right are drawn at L. *Galleting* is shown in both, namely, two small pieces of plain tile are bedded in each channel and finished level with the top of the corrugations (see also G, Fig. 51, and E, Fig. 52). Besides providing an interesting feature and reducing the amount of bedding mortar, this packing up to the ridge ensures a level bed throughout for the latter.

Verge Details (see G and H, Fig. 52).—That at H shows the usual treatment of a right-hand verge when the groundwork consists of boarding, felt, counter-battens and tiling battens, an undercloak consisting of three courses of plain or flat tiles providing a suitable finish to the verge pantiles which are bedded on and pointed with cement mortar or compo consisting of 1 cement: 1 lime: 4 sand. The undercloak projects 50 to 75 mm, depending on the building height. The width of the upper course of plain tiles is reduced, as shown, to permit the hanging and nailing of the verge tiles to the tiling battens.

The detail at G shows a left-handed verge. The narrow curved purpose-made verge tile shown is necessary at each course to balance the roof and present the same appearance at both verges. Alternatively, purpose-made double "roll" verge tiles are used; as these can be hung on and nailed to the tiling battens, in addition to being bedded, they are preferred to that shown at G where only the narrow verge tiles are bedded. One of the two verges at a gable will be as shown at H, and the other on the opposite slope will be finished with purpose-made tiles; the thickness of the pointing should be the same at both verges.

Abutment Details.—Formerly, when purpose-made verge pantiles were not available (and therefore symmetrical treatment at the verges was not possible unless the verge tiles on one slope at each gable were cut and the rolls removed), it was a common practice to finish gable walls with low thin parapets as shown at D, Fig. 52. A brick-on-edge coping, surmounting a double plain tile creasing which oversailed a cement fillet splayed down to the pantiles, was provided. Sometimes the parapet was only 102·5 mm thick. Whilst this provided a pleasing appearance the construction was not sound, as water was liable to penetrate the wall, as indicated by the thick broken arrows.

Sounder construction, presenting the same external appearance, is shown at B, where the cavity of the gable wall extends to the tile creasing. An isometric sketch of this detail is shown at E. This also illustrates a satisfactory treatment of the roof at a chimney stack. Galleting is shown at the ridge and at the three channels of the pantiles intercepted by the stack. Cut plain tiles are bedded



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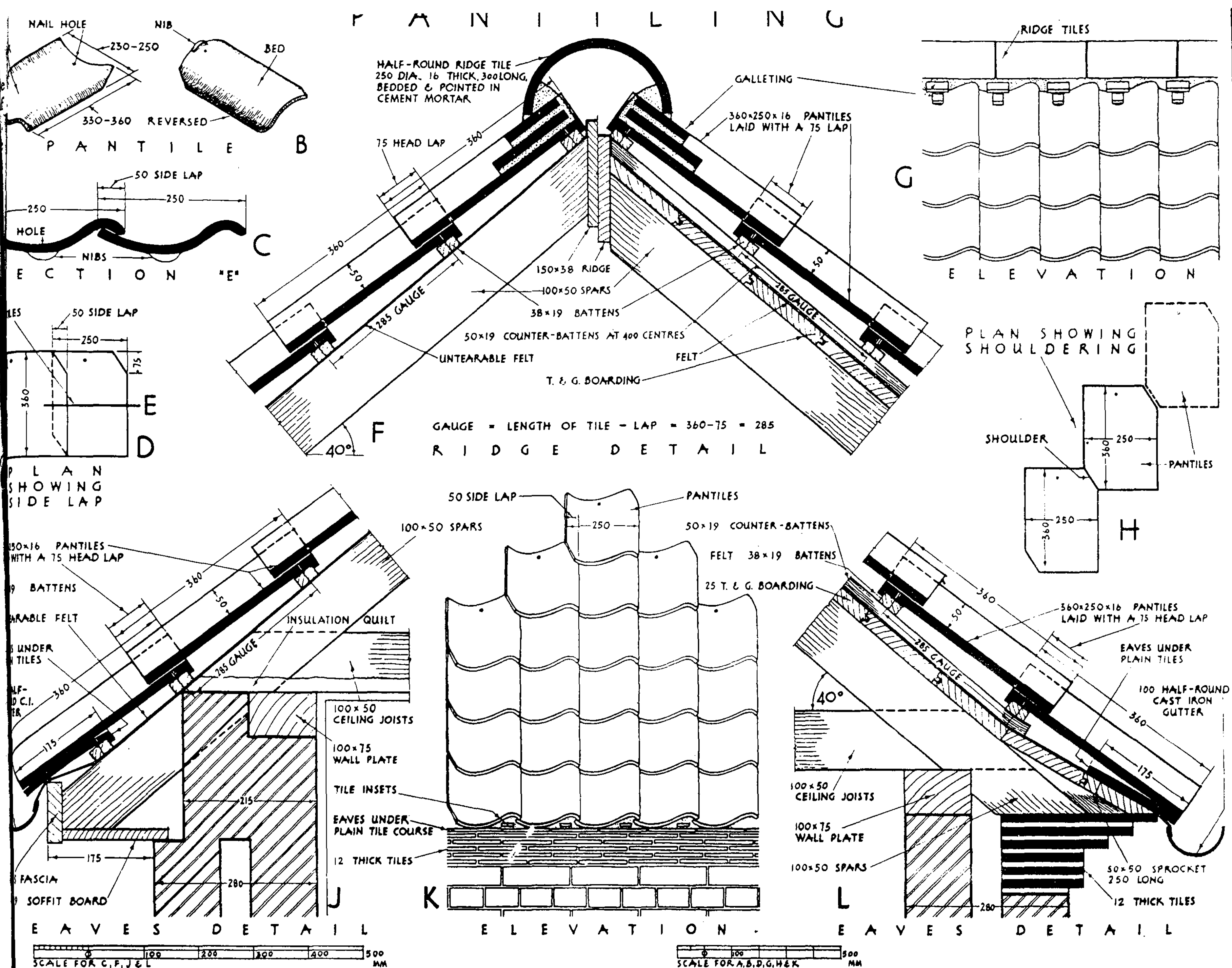

FIGURE 51

on the latter galleting and continued up the slope where the upper end is covered by the ridge tile. A neat mortar fillet is formed over these cut tiles and at the ridge intersection. This sketch also shows the groundwork described on p. 132 in connection with the detail at H.

An alternative detail, showing a cavity wall finished with a stone coping, is given at A. This also shows a cement fillet, neatly splayed or rounded off, covering the intersection between the tiles (and the ridge) and the wall.

In the above abutment details, cement fillets have been shown at the intersections. It is advisable to use waterproofed cement (see Chap. I, Vol. II) in the mortar. Whilst these fillets present a satisfactory appearance when associated with pantiles, mortar is a very unreliable material for this purpose, as the fillets have a tendency to crack and fall away. They therefore require occasional attention, and the making good of any defects, if water is to be excluded.

Undoubtedly the provision of lead flashings at abutments, in lieu of mortar fillets, is the soundest practice. But, as already pointed out, leadwork does not harmonize with tiles in general because of its colour and texture. The section at C shows, as an alternative to the cement fillet at A, a lead apron flashing which is dressed over the tiles.

Hip Details.—The cutting of pantiles is both difficult and expensive, and therefore intersections resulting from hips, valleys, dormers, etc., should be avoided or reduced to a minimum.

The detail at K, Fig. 52, shows an elevation of a portion of the roof illustrated at K and L, Fig. 51. The hip is of half-round tiles bedded on the pantiles on adjacent slopes which have been cut to form an open mitre up the line of the hip. Conical hip tiles are also employed.

Valley Details.—A typical valley is shown at J, Fig. 52. The lead forming the gutter is dressed over the valley board and up each slope, where it is either turned over at the edge, as shown on the left, or dressed over a tilting fillet as indicated on the right (see Chap. VI, Vol. I). A layer of flat plain tiles is laid up the slope at each side, butt-jointed in mortar at their ends, and the cut pantiles are bedded on them. Pieces of tile may be embedded in this bedding to form tile insets. The roofing felt is brought over the plain tiles as shown. The somewhat unusual appearance of the pantiles is due to the vertical section being taken normal to the line of the valley.

Purpose-made valley tiles, slightly curved or V-shaped in cross-section, are now available. Lead is not required when these are employed, the roofing felt being continued over the valley board, and the valley tiles, laid with a 75 mm lap, are nailed to the board. The cut pantiles are bedded on the sides of the valley tiles. A very satisfactory appearance results.

ITALIAN OR ROMAN TILING

The various forms of this class of tiling include (*a*) Old Roman, (*b*) Single Roman and (*c*) Double Roman. They are illustrated in Fig. 53.

(*a*) **Old Roman Tiling.**—This is also known as *Basilican tiling*, and, more commonly, as *Italian tiling*. It is another example of single-lap tiling. The tiles consist of flat *under* tiles (abbreviated to *unders*), which alternate with convex curved *over* or *top* tiles (or *overs*).

An under is shown at B. It is flat, tapered, with upturned edges or flanges at the sides, and is provided with two nail holes. Its length is 400 mm, its width varies from 235 to 240 mm at the tail and 270 to 280 mm at the head, and it is 12 to 16 mm thick. Some are provided with two transverse grooves near the head; these capillary grooves are effective in minimizing updrift. The end views of the head and tail show that the flanges are tapered, with a slight increase in depth towards the head.

An over (see A) is also 400 mm long, tapered on plan, half-round at the tail, slightly less in height at the head, and is provided with one nail hole. As shown, the tile may be slightly shouldered to allow it clear the unders in the course above at the head lap.

The head lap varies from 65 to 75 mm, depending upon the pitch (see L). The minimum pitch is 35°. The side lap is 50 mm (see G).

The groundwork may consist of 50 mm by 25 mm battens, fixed at the gauge apart to the spars which have been previously covered with untearable felt. Alternatively, 25 mm boarding, covered with felt, may be used. The gauge equals length of tile—lap=400 mm—75 (or 65) mm=325 or 335 mm. In addition, a 75 mm by 22 mm vertical batten is fixed between each pair of unders at about 292 mm centres (see G), otherwise very long nails would be required to secure the overs. A vertical batten is fixed immediately a row of unders is completed. The unders are fixed to the battens or boarding with 38 mm copper nails, and 75 mm nails are used to fix the overs to the vertical battens. A true plan of a portion of two courses, showing the setting out, is given at H, a part elevation at K and a section at an eaves at L. The detail at T (see p. 136) may be adopted also.

As shown at K and L, it is usual to provide a course of plain eaves under tiles at the eaves. Besides presenting a satisfactory finish, this affords a suitable bed for the unders and the mortar which is used to fill in the hollows of the eaves over tiles. The mortar should be cut back for about 25 mm to give a shadow.

The finish at the ridge is similar to that shown for pantiling, half-round tiles and galleting being usually employed. The hip, valley and verge details are also similar. A balanced effect at the verges is obtained by using overs upon plain tile undercloaks.

These tiles, which are highly textured and obtainable in several colours, present a bold and distinctive appearance especially suited for large roofs.

(*b*) **Single Roman Tiling.**—A single Roman tile is shown at D, Fig. 53. It is rectangular on plan and is 343 mm long by 254 mm wide by 12 mm thick. A flat portion, 170 mm wide at the head, tapering to 150 mm at the tail, has one edge slightly upturned and its opposite side is in the form of a fairly bold

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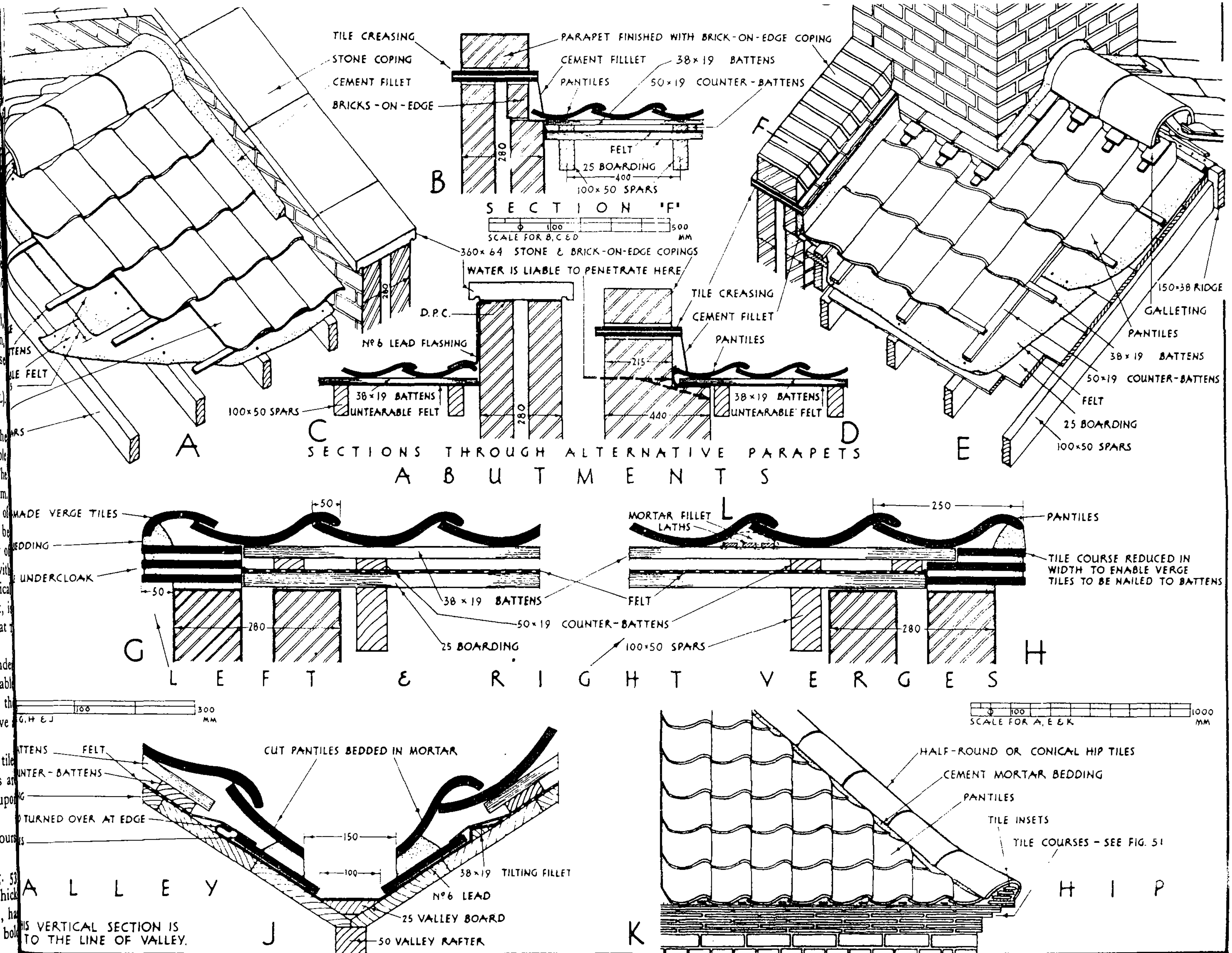


FIGURE 52

slightly tapered roll. It is thus a combined under and over Italian tile. Like a pantile the tile has its two opposite diagonal corners splayed. Some are provided with two holes on the flat near the head, whilst others are without holes. Each has a continuous nib.

The head lap is 65 to 75 mm and, as shown at C, the side lap is 50 mm. Being another example of single-lapped tiling, the gauge is 268 mm when the head lap is 75 mm (see M). The minimum pitch is 35°.

A detail showing a suitable finish at the eaves is given at M. Here the groundwork is simply battens nailed to the spars which are covered with untearable felt. Other groundwork may consist of tiling battens fixed to felt-covered boarding, or tiling battens nailed to counter-battens nailed to felt-covered boarding. Vertical battens are not required, as the tiles, when nailed, are not secured at the 50 mm high rolls.

The finish at the ridge, hips, valleys, abutments and verges are as described above. To present a balanced appearance at verges, purpose-made single Roman tiles are available, each having a double roll, for the left-hand verges.

In appearance, a roof covered with these tiles is similar to, but less vigorous than, an Italian tiled roof.

(*c*) **Double Roman Tiling.**—These tiles, shown at E, are 380 to 418 mm long by 280 to 342 mm wide. Each has two rolls, hence the name. The left-hand tail corner is splayed and a portion of the middle roll is shouldered at the head, as shown. As indicated at E, these tiles are laid with "break joints," and therefore special half tiles are required at alternate courses at verges to complete the bond. Purpose-made left-hand verge tiles, provided with three rolls, are available to give a symmetrical roof.

The head lap is usually 75 mm and, as shown at F, the side lap is at least 38 mm. The minimum pitch is 35°. Nailing is not required, as the tiling is tightly fitting and cannot be lifted by the wind.

Groundwork and finishes at the ridge, eaves, hips, etc., are as described above.

SPANISH TILING

Spanish or *Sicilian tiling* is very similar to Italian tiling, the only difference being that the under tiles are not flat like the Italian type but are concave-shaped.

An over is shown at N, Fig. 53, and an under at O. The length of each is 356 mm. The overs taper down from the tail to the head and the unders from the head to the tail (see the dimensioned end views). The width of each is not standard, there being a slight variation in some of the tiles produced. They are hand-made. Like Italian tiles, each Spanish under is secured by two copper nails and each over by one nail. "Vertical" battens must be provided to take the 75 mm nails securing the overs; the unders are also skew nailed (40 mm nails) to these 75 mm by 50 mm battens (see S and the heads at N and O). The spacing of the vertical battens for tiles of the dimensions indicated is 270 mm centres (see P and S). As shown, the top edges of these battens are slightly chamfered to provide the necessary clearance for the unders; sometimes these battens are tapered to 25 mm at the top.

NOTE:—*The space between the head of the bottom over tile and the tail of that above it is exaggerated and is due to the clearance at the laps of the unders which has been shown purposely to make the detail clear.*

The minimum pitch is 35°, and the head lap varies from 65 to 75 mm. The gauge is therefore either 291 mm (356—65) or 281 mm (356—75). Groundwork is like that for Italian tiling.

The bold character of the appearance may be gauged by the part elevation at Q. This appearance is sometimes modified by the use of shorter overs at the eaves (and correspondingly longer ones at the ridge) and thus their tails are lower than those of the unders except at the eaves line.

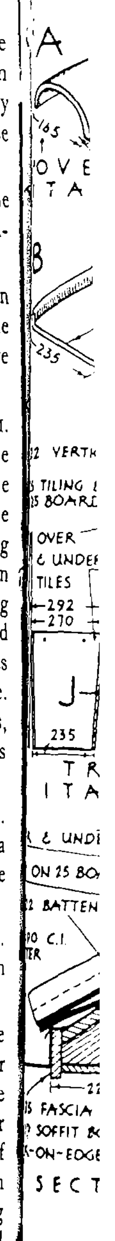
The treatment at the eaves may be as shown for Italian tiling at L and M. Alternatively, a very attractive appearance is obtained when, as shown at T, the tiles are brought over the outer edge of the eaves gutter. In this detail the bottom course of plain eaves under tiles and the bottom course of unders are purpose-made and provided with holes (see also Q) to allow the water passing down the channels to enter the gutter. The gutter, which is given a minimum fall, must be well screwed to the fascia. The double top tile course forming part of the soffit is provided to ensure that the wood fascia will not be exposed to view at the highest part of the gutter. A lead flashing, as shown, ensures watertight construction, and the roofing felt is brought over its upper edge. The hollows of the over tiles at the eaves are filled with mortar, and tile insets, shown at Q, add to the appearance. The lower ends of the "vertical" battens are cut short (see T and Q) to permit this.

The ridge is usually finished with half-round or segmental ridge tiles. Conical or tapered hip tiles which course in with the Spanish tiles provide a suitable finish at the hips. Verges, valleys and abutments, are treated as before described.

There are several forms of tiles manufactured to resemble Spanish tiles. Thus, the overs are sometimes hog-back in shape, and in another type both unders and overs are much flatter than the traditional form.

Interlocking Tiles[1].—A number of tiles (to B.S. 473, 550) are now made which have patent locking devices, the object of which is to prevent their dislodgment even in the most exposed positions. Some of these do not require nailing, whilst others are secured to battens by means of wire. Thus, for example, one device consists of two lugs formed on the underside at the tail of an Italian over, which closely engage the shoulders at the head of the over which it overlaps. In the "wired" variety, which has usually a head and side locking device, a piece of wire is passed through a hole formed in a nib and twisted round the batten.

[1] One kind is detailed in Fig. 39, Vol. 1.



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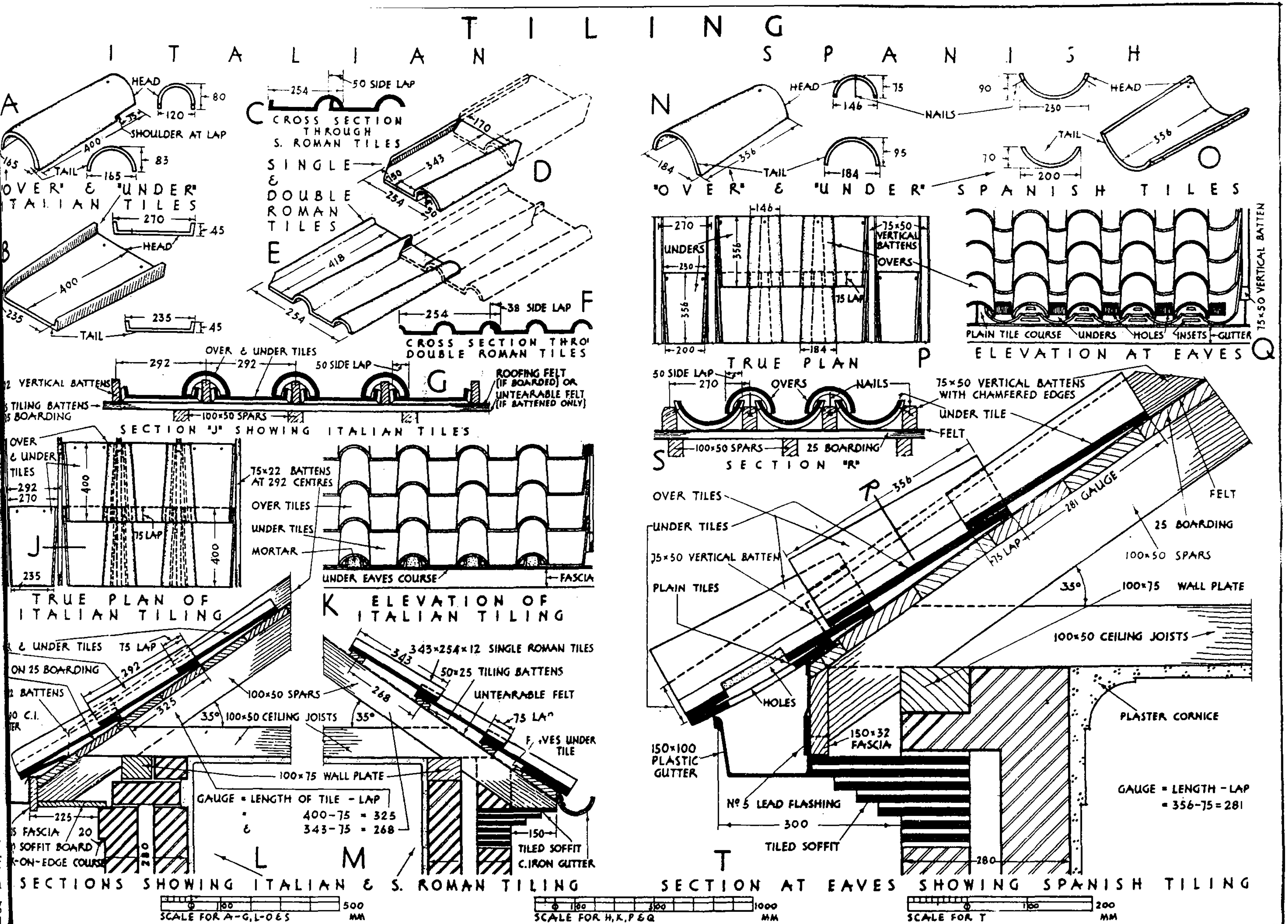

FIGURE 53

Most tiles of the interlocked type are machine-made. Some of these, of continental origin, have stamped on them a central ornament in relief, such as a rib or diaper.

CONCRETE TILES

Within recent years there has been an increasing demand for roofing tiles made of concrete. Plain tiles, pantiles, Roman tiles, interlocking tiles, and ridge, hip and valley tiles are made of this material. The mixture is composed of normal Portland cement and clean well-graded sand. The body may be coloured throughout or, preferably, be surface treated with mineral granules which have been coated with colour by a vitrification process.

The quality of concrete tiles is covered by B.S. 473, 550 Concrete Plain Roofing Tiles and Concrete Interlocking Roofing Tiles. These define the sizes and provide tests for strength and durability.

The average size of concrete plain tiles is the same as that of clay plain tiles, namely, 265 mm by 165 mm by approximately 12 mm thick; they are cambered and sometimes cross-cambered (hatched—p. 124); each has two nibs and is twice holed. They are made in a variety of colours.

The usual lap for plain tiling is 65 mm (100 mm gauge). The minimum pitch of roof is 37°. It is recommended that for pitches between 37° and 50° the tiles in every fifth course should be once nailed for normal exposure and up to twice nailed in every third course if the exposure is very high; for pitches up to 60° the tiles should be twice nailed in every third course to once nailed in each course; for pitches exceeding 60° all tiles should be twice nailed. The nails are usually 38 mm long and may be either galvanized wrought iron, zinc, copper or composition. The groundwork is similar to that for clay tiles.

Manufacture of Concrete Tiles.—Briefly, the process of manufacture of plain tiles in an automatic machine is as follows: After the cement, sand and water have been thoroughly incorporated in a batch mixer (Chap. I, Vol. II) a double row of oil-sprayed cambered pallets, end-to-end, is moved in turn under separate parts of the machine where it is charged with the concrete mix which is compacted by a process of extrusion, the continuous layer is divided longitudinally down the middle by a rotating knife, the double band is divided transversely into units by a drop-and-rise knife, the nail holes are pierced, the edges are trimmed and the coloured mineral granules are blasted on; the tiles are charged upon racks and taken to the enclosed curing chamber, in which the air is conditioned to the required temperature and humidity, left for twenty-four to forty-eight hours, de-palleted and finally removed to an open shed where they are stacked to mature.

Formerly, concrete tiles were criticized for their smooth texture, liability to bloom or effloresce and non-durability of colour. Now, soundly manufactured concrete tiles have an agreeable texture and are free from efflorescence; it is claimed also that when coloured granules are applied the degree of colour endurance far exceeds anything previously secured.

These granules which have considerably influenced the colouring of concrete tiles in recent years have a mineral base, such as stone, and are cleaned, crushed and closely graded to the required size. They are coated with pigment and are gas-fired in a rotary kiln. The heat fuses the coloured enamel coating to the mineral grains, the temperature varying with the colour required.

An indication of the soundness of concrete roof tiles is that one large firm of manufacturers gives a guarantee of fifty years against lamination (a defect to which the cheaper machine-made clay tile is subject) or decay and covers full maintenance of the tiling for ten years.

ASBESTOS-CEMENT SLATING, TILING AND SHEETING

Asbestos-cement is now widely used in the manufacture of many building materials, including roofing slates, tiles and corrugated sheets, wall boards, rainwater goods, felt, etc.

As implied, this material is composed of asbestos and ordinary Portland cement. Asbestos is a silky fibrous mineral existing in veins in metamorphized volcanic rocks. It is found chiefly in South Africa, Rhodesia, Canada, America, Russia and Cyprus. There are several varieties, but white asbestos (a compound of magnesia and silica), is that principally used.

Manufacture.—The first stage is to separate the fibres of asbestos. This is accomplished after the quarried rock has been broken into smaller pieces, dried, crushed and passed through a vibrating screen. The fibres are mixed with water and cement, in the approximate proportions of 1 asbestos: 7 cement in a machine having a revolving drum with blades attached; the operation is continued until the asbestos is closely blended with the cement and the fibres are arranged in a uniform direction.

The mixture is now transferred to another machine which has a revolving cylinder of fine sieve wire. The excess water drains through the sieve, leaving on the cylinder a thin film of the mixture, which is then transferred to an endless moving blanket. The film is conveyed by the blanket to a large forming cylinder, where a sheet of asbestos-cement is gradually built up, layer by layer, to the required thickness. As the mixture passes over the blanket and forming cylinder, the asbestos fibres are uniformly distributed and drawn lengthwise in the direction of the movement to form a tough-woven fabric.

An operative slits the sheet, which is then removed to a platen where it is allowed to mature in the form of a flat sheet, or the sheets are stacked ready for further processing. Partly matured sheets required for slates, tiles and corrugated sheets are submitted to high pressure in a powerful hydraulic press.

Roof coverings made of this material[1] are tough, durable, non-combustible and light in weight. The average weight of asbestos-cement covering is only 17 kg/m² (compared with 49 and 71 kg/m² for slates and plain tiles respectively) and therefore an economy in timber results when it is applied to wood roofs, as the spars to which the battens are fixed may be spaced up to 760 mm centres. The larger units, such as corrugated sheets and tiles, are especially suited for large span buildings of the factory type, where steel trusses are employed, as the covering is fixed direct to the purlins. Here, again, because of their lightness they economize in the sizes of the members of the trusses. Compared with hand-made clay tiles, the chief demerits of asbestos-cement slates are their

[1] Asbestos-Cement slates are specified in the B.S. 690 Part 4 and Asbestos-Cement corrugated sheets in Part 3.

The asbestos-cement products described in this book are made by Turner's Asbestos Co. Ltd.

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chanical appearance and lack of texture; on the other hand they are cheaper n tiles.

The sizes and methods of fixing some of these asbestos-cement coverings are luded in the following description.

Asbestos-cement Slates.—These are made rectangular in shape in varying s from 508 mm by 254 mm to 610 mm by 356 mm and 4 mm thick. The ndard colour is blue. They are laid to give a bonded appearance, and the nciple is similar to that described for ordinary slating in Chapter Five, Vol. I. e same terms also apply. Thus, as shown here at A, Fig. 54, each slate is tre-nailed with two nails and the lap is 100 mm. The gauge is found in the al manner and, as indicated at A, equals $\frac{\text{length of slate} - \text{lap}}{2} = \frac{508 - 100}{2} =$ mm (205 mm) for the 508 mm slates and $\frac{610 - 100}{2} = 255$ mm for the mm slates. The nails should be of copper 32 mm long. In addition to being e nailed, each slate (excepting the two courses of under-eaves slates—see ow) is secured at its tail by means of a copper *disc rivet* (see enlarged sketch B). hown at A, the discs are placed on the course of slates next but one below that he slates to be riveted with the upturned rivets between the side joints of the es immediately below. The rivet is passed through the hole formed near the of the slate to be fixed and bent over it, after which the slate is nailed. These rivets ensure rigidity and, in exposed districts especially, prevent the slates oming dislodged in heavy storms.

A further difference between asbestos-cement and ordinary slating occurs he eaves. Whereas the latter is provided with a double eaves course, an stos-cement slated roof has three thicknesses at the eaves. As shown at A, e are two short courses below the top course of full size slates. Two of these er-eaves slates are obtained from one of full size by means of a saw, the cut g made at the gauge plus 12 mm distance from one end.

The preferred minimum pitch, depending on exposure, is $22\frac{1}{2}°$ for the larger s and 30° for the smaller.

The groundwork for these slates is that described for ordinary slating, but, ready stated, on account of their extreme lightness the spars may be spaced greater distance apart up to a maximum of 760 mm centres.

Hips and ridges are finished with a half-round ridge capping of asbestos- nt.

Corrugated Sheets.— Two examples of these are shown in Fig. 54, namely, AC Bigsix " Corrugated Sheets and Standard Corrugated Sheets; in Fig. 55 C Doublesix M Corrugated Sheet is illustrated.

TAC Bigsix " Corrugated Sheets.—These are 1 086 mm wide, 1 525 to o mm long, and 6 mm thick. There are 8 corrugations per sheet and their all depth is 54 mm. A part cross-section is shown at Q, and the boldness of the design may be gauged by comparing it with the standard corrugated sheets shown at R and having an average depth of corrugation of 25 mm only. The end or head lap depends on the roof pitch and degree of exposure on the site (see below), at L it is shown as 150 mm and the side lap is 70 mm (see Q). They are supplied in several colours.

These sheets are fixed direct, with the smooth surface uppermost, to either wood or steel purlins. The detail at L shows the method of fixing to timber purlins. The latter are secured to the principal rafters of the mild steel trusses by angle cleats, as described in Chapter Four, Vol. II. The maximum centres of the purlins is 1 375 mm, and, because of the light weight of this covering material, the 200 mm by 75 mm wood purlin shown will be adequate for trusses spaced up to 4·25 m centres. The sheets are always fixed through the crowns of the corrugations; 10 mm diameter holes being drilled by an ordinary brace and bit to receive the 8 mm diameter galvanized screws which are 115 mm long (see enlarged sketch J). These are driven in, and a watertight joint is assured if, as shown, a plastic washer and cap above it are employed. A sheet is secured at six positions, namely, two at the head, two at the tail and two at the intermediate purlin, the screws being adjacent to the side laps and in similar positions to those shown at Q.

The alternative connection to a steel purlin is shown at L, M and Q. An 8 mm diameter *galvanized hook bolt* F is used for this purpose. The length of this bolt depends upon the size of the purlin and is either 75 mm (for intermediate fixings) and 90 mm (for lapped connections) longer than the flange of the purlin. Thus, for the 100 mm by 75 mm by 10 mm purlin shown (which is adequate for trusses spaced up to 4·25 m centres), the hook bolts are 180 mm long. The hook is engaged in the edge of the purlin and is made secure by a nut; a plastic washer and cap are again used to ensure watertight joints. Each sheet is fastened at six points as stated above. The cross-section at Q shows two hook bolts at the side joint.

The eaves detail at K includes an *eaves filler piece* which is used to fill in the underside of the corrugations. A sketch of this unit is shown at O. The depth and pitch of the corrugations are similar to those of the general sheeting, and when hook bolted (or screwed, if the purlin is of timber) a tight fit results and weather is effectively excluded. The unsupported overhang of the sheets should not exceed 225 mm and therefore, as shown, the bottom purlin should be placed well down the slope.

The asbestos-cement ridge shown at N is in two pieces; the left-hand piece (see sketch at P) has an external collar or flange and is slightly longer than the small roll wing which has an internal collar. The corrugations of the wings fit closely those of the sheets. These wings and the upper ends of the sheets are secured by either hook bolts (see on the left of the detail N) or driving screws shown on the right. The top purlins must be correctly positioned, and, as shown, the fixings should be 165 mm from the centre.

These sheets may be fixed from left to right or vice versa, commencing at the eaves and preferably at the end opposite to the direction of the prevailing wind. If laid from left to right, the first sheet is fixed uncut, but the remaining sheets in the eaves course must have the top left corner splayed. An ordinary hand saw is used for this purpose. The remaining sheets (with certain exceptions, such as at verges and ridge) have both top left and bottom right corners also cut. Each splay cut removes a corner which measures 150 mm (head lap) along the " vertical " edge and 70 mm (side lap) along the " horizontal " edge. The sheets can be thereby correctly shouldered or mitred.

These corrugated sheets, because of their strength, durability and fire-resisting qualities, are particularly suited for large roofs of buildings such as factories, workshops, etc. Low initial and maintenance costs and speed of construction are additional merits.

The roof pitch depends on the degree of exposure.

On *exposed* sites for a pitch of 25° and over the end lap (or head lap—see L, Fig. 54) is unsealed. For 17½°–25° pitch this end lap is sealed with extruded mastic placed between the overlapping sheets. For 15°–17½° pitch this end lap is sealed, so is the side lap. For 10°–15° pitch both laps are sealed and the end lap increased to 300 mm.

On *sheltered* and *normal* sites for a pitch of 22½° and over use an unsealed 150 mm end lap. For 15°–22½° pitch 300 mm unsealed or 150 mm sealed end lap. For 10°–15° pitch a 150 mm sealed end lap is needed with the side lap sealed.

Double skin insulated construction can be adopted with these sheets like that described for the TAC Doublesix M sheets.

TAC Standard Corrugated Sheets.—This is a smaller version of the " Bigsix " with an overall depth of corrugation of 25 mm. The cross-section at R is through the side lap. The width is 750 mm, the lengths vary from 1 225 to 3 050 mm, and the thickness is 5·5 mm. There are 10½ corrugations per sheet. The end or head lap is 150 mm and the side lap is equal to approximately 1½ corrugations or 102 mm. The spacing of the purlins is up to a maximum of 925 mm centres.

These sheets are fixed as described for the " Bigsix " sheets, two 6·4 mm diameter hook bolts or driving screws being provided near the side lap at each purlin. The ridge capping, in two pieces, is slightly smaller in the wing than that shown at N, and the top purlins are arranged to allow the fixings to be 140 mm from the apex.

Curved sheets to a radius from 900 mm upwards are available.

The figures for minimum pitch depending on the degree of exposure for this sheeting is the same as that given for TAC Doublesix sheet.

TAC Doublesix Corrugated Sheets (Fig. 55).—These are 1 300 mm wide, 1 525 mm to 3 050 mm long and 6 mm thick. There are 5 corrugations per sheet of overall depth 91 mm; a cross-section of the sheet is given at A. The side lap is 100 mm, the end lap depends on the pitch and degree of exposure.

On *exposed* sites the minimum pitch is 25° using 150 mm unsealed end lap of 150 mm as at B. For 15°–25° pitch the same lap must be sealed as described for Bigsix. For 10°–15° this lap is sealed, so is the 100 mm side lap. For 5°–10° pitch the end lap is 300 mm sealed, the side lap is also sealed.

On *sheltered* and *normal* sites the minimum pitch is 22½° using 150 mm unsealed end lap. For 15°–22½° a 300 mm unsealed end lap is needed. For 10°–22½° the 150 mm end lap must be sealed. For 5°–10° pitch the same applies and the side lap is also sealed.

The sheets are fixed in the same way as Bigsix.

Insulated asbestos-cement roof.—By placing another sheet beneath the Doublesix M and putting an insulation quilt between the two the roof can be insulated (see B). The lower sheet of asbestos-cement has small corrugations. The space for the insulation is obtained by 20 mm thick battens located along the line of the hook bolts. This detail is of the ridge (an alternative to L, Fig. 54).

All types of corrugated sheet can be associated with translucent plastic sheet to provide daylight penetration—see C (a horizontal section at the side lap).

The verge section at D is self explanatory.

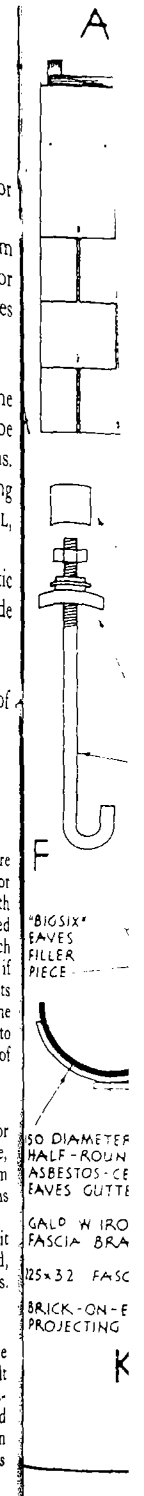
Other systems of decking which are being adopted extensively in flat roof construction are described in Vol. IV.

" *Everite* " *Promenade Tiles*.—These form a protective walking surface and fire resistant finish to a flat roof. They are 305 mm square, 9 mm thick tiles used for covering flat roofs, such as reinforced concrete flats which have been finished with asphalt or two or three layers of asphalt felt. Cracks and other defects may be caused to concrete roofs covered with asphalt or felt, by the expansion and contraction which occurs, unless precautions are taken. The absorbed heat from the sun is reduced if the black asphaltic roof surface is covered with a light-coloured material which acts as a reflector. Hence, grit or tiles such as these, are used as a final covering. The tiles, which are butt-jointed, are bedded on bitumen; hot bitumen is brushed on to portions of the roof in turn to a thickness of about 3 mm and each tile, with a dab of bitumen placed in the middle of the bed of a tile, is pressed firmly down.

Galvanized Corrugated Iron Sheets.—These have been used extensively for covering roofs of sheds, workshops, huts, etc. The standard sizes are 610 mm wide, 1 372—3 000 mm long and in various thicknesses from 0·5—1·25 mm; some 750 mm wide sheets are also made. They are fixed through the crowns of the corrugations by hook bolts, screws and nails, with curved washers.

Such covering rusts comparatively quickly, especially at the connections, unless it is protected by painting at suitable time intervals. It has been largely superseded, particularly for better class work, by the aforementioned asbestos-cement products. The latter are more durable and do not require to be painted.

Protected Metal Corrugated Sheets.—These consist of a light gauge steel core which is adequately protected against corrosion by being entirely encased by asphalt saturated asbestos felt, the latter being securely bonded to the steel under high pressure. The natural colour is black, but aluminium and other colours can be imparted by an additional outer coating. This roofing material is strong, durable, light in weight and heat insulating. Cellactite and Robertson Protected Metal are examples of this covering.



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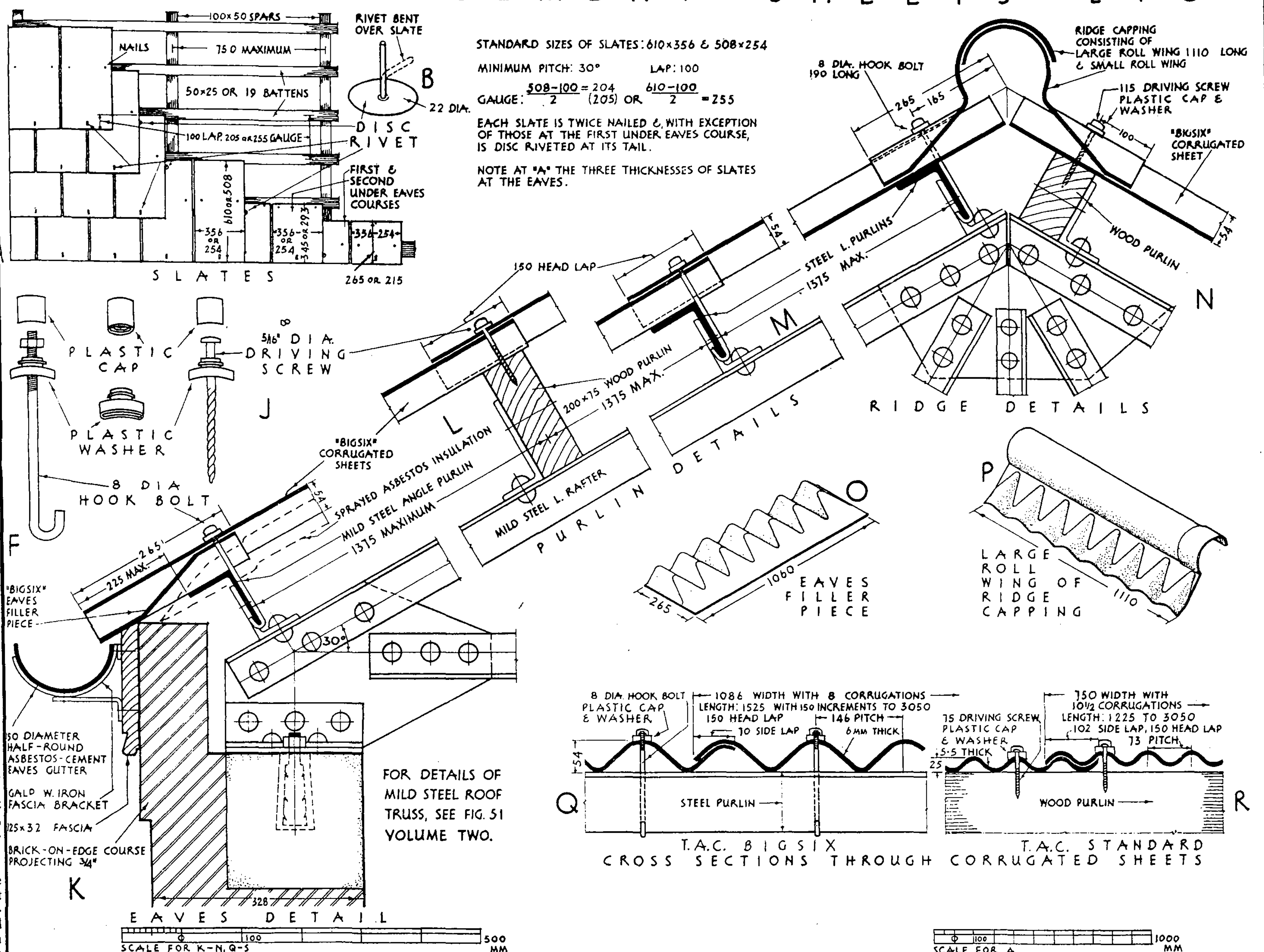


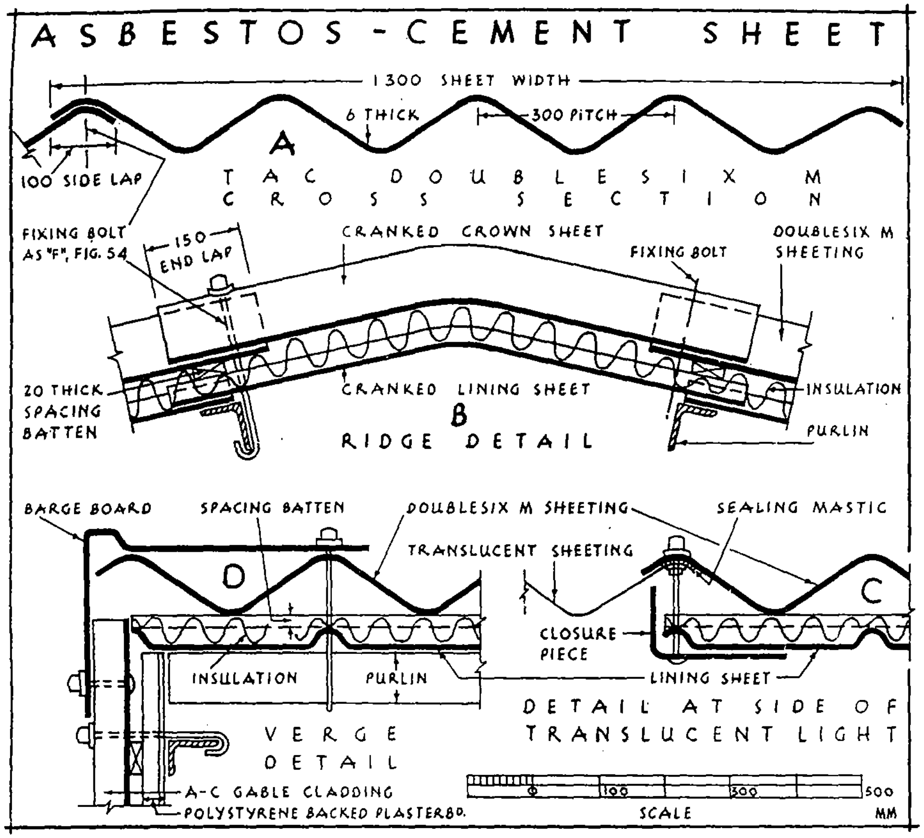


FIGURE 55

STONE SLATING

The material used for *stone* slated roofs is either sandstone or limestone and *not slate.* As explained in Chap. III, Vol. II, a true slate is a metamorphic sedimentary rock, and slates are produced by splitting the block of slate along the cleavage planes (see also Chap. V, Vol. I). Sandstones and limestones are sedimentary rocks (see Chap. III, Vol. II), and those converted for roofing purposes are highly stratified and capable of being split (known as *fissile*) along the natural bed or bedding planes (see also "Tilestones," Chap. III, Vol. II).

Some of the quarries from which these stone slates are obtained exist in Yorkshire, the Cotswold district, Northamptonshire, Rutland, Somerset, Dorset and Sussex. The Yorkshire stone is sandstone, and that from the Cotswolds is an oolitic limestone.

Whilst true slates of good quality are practically impermeable, those used in stone slating are not. It is for this reason, and also because the blocks of stone cannot be readily cleft into very thin slabs, that stone slates are much thicker than true slates. Yorkshire stone slates, grey to brown in colour, which often darken on exposure, are obtained by splitting the blocks along their bedding planes with hammer and chisel or wedges. Cotswold stone, greyish-brown in colour and coarse grained, is readily split by a hammer after the blocks have been allowed to stand during the winter and exposed to frost action.

Stone slates vary considerably in size, shape and weight. Yorkshire sandstone slabs are the largest, thickest and heaviest. The limestone slates from Sussex are also thick and heavy. Those from the Cotswold district and Northamptonshire are generally lighter, as they are smaller and thinner. They are all used in random sizes. They are rough in texture, uneven in thickness, and some of the Cotswold slates especially are very irregular in shape. The exceptional beauty of well designed roofs stone slated by skilled labour is due to these qualities and to their agreeable colour.

Hanging and Pitch.—The old method of hanging these stone slates was by wood pegs. Sound oak pegs were tightly driven into holes drilled near the heads of the slates to receive them. The number of pegs per slate varies from one to three, according to the size and weight of the slates. Whilst this method is still adopted, there are certain objections to it. Thus, the pegs may decay, or they may work loose on account of shrinkage, or they may be broken by shear stress, especially if the slabs are exceptionally heavy and steeply pitched. It is therefore considered preferable to use for this purpose either brass screws or stout copper or composition nails.

The pitch given to stone slated roofs depends upon the weight of the covering. Thus, those covered with heavy Yorkshire stone slates, especially if pegged, are given a pitch varying from 25° to 35°. Steeper pitches are given to roofs when lighter stone slates are used. Thus, in the Cotswolds, the pitch varies from 47° to 60°, 55° being common.

The slates are of random sizes in width as well as length; the latter may vary from as much as 915 mm to less than 150 mm. They are sorted on the job. the slater using a special rule for the purpose.

The longest and thickest slates are laid at the eaves and the lightest and thinnest at the ridge. The gauge varies accordingly. The diminution is not regular. Thus, there may be three courses laid to a 200 mm gauge, followed by two at 178 mm gauge. Occasionally the gauge of a course may be slightly in excess of that preceding it.

Lap.—This depends upon the pitch, degree of exposure and size of slates. A common lap is 100 mm, although for a steeply pitched roof it may be much less. A uniform lap is not always maintained; it may vary from 78 mm near the eaves to 75 mm at the ridge.

Eaves Detail.—A typical example is shown at B, Fig. 56. This shows a stone wall and a cast iron gutter supported by adjustable brackets on bars driven

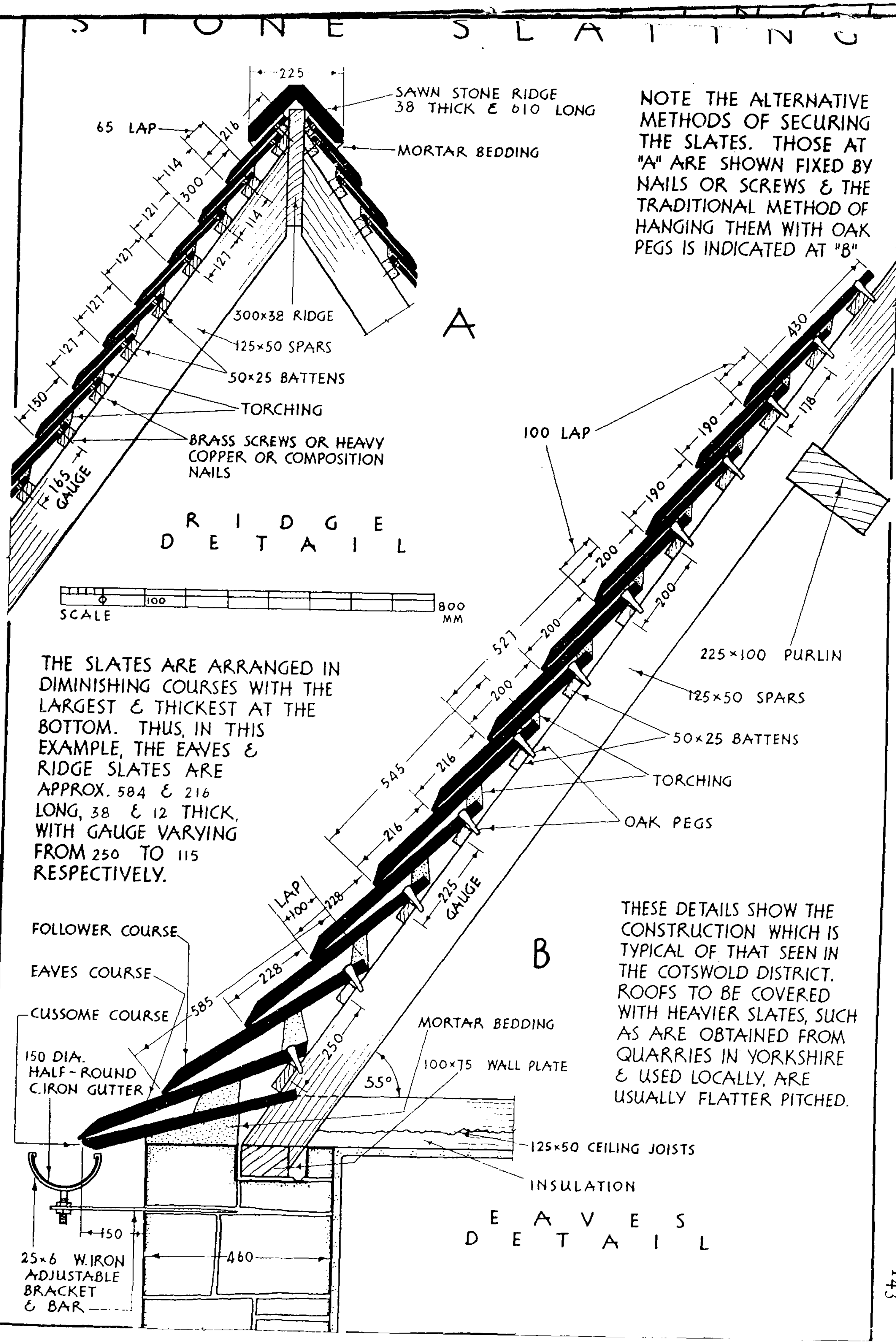

STONE SLATING
225
SAWN STONE RIDGE 38 THICK & 610 LONG
65 LAP
216
114
300
121
127
114
127
127
127
127
150
165 GAUGE
MORTAR BEDDING
NOTE THE ALTERNATIVE METHODS OF SECURING THE SLATES. THOSE AT "A" ARE SHOWN FIXED BY NAILS OR SCREWS & THE TRADITIONAL METHOD OF HANGING THEM WITH OAK PEGS IS INDICATED AT "B"
300x38 RIDGE
125×50 SPARS
50×25 BATTENS
TORCHING
BRASS SCREWS OR HEAVY COPPER OR COMPOSITION NAILS
A
RIDGE DETAIL
SCALE
0
100
800 MM
430
178
100 LAP
190
190
200
200
527
200
200
225×100 PURLIN
125×50 SPARS
545
216
50×25 BATTENS
216
TORCHING
OAK PEGS
THE SLATES ARE ARRANGED IN DIMINISHING COURSES WITH THE LARGEST & THICKEST AT THE BOTTOM. THUS, IN THIS EXAMPLE, THE EAVES & RIDGE SLATES ARE APPROX. 584 & 216 LONG, 38 & 12 THICK, WITH GAUGE VARYING FROM 250 TO 115 RESPECTIVELY.
LAP 100
228
225 GAUGE
228
FOLLOWER COURSE
EAVES COURSE
CUSSOME COURSE
585
B
THESE DETAILS SHOW THE CONSTRUCTION WHICH IS TYPICAL OF THAT SEEN IN THE COTSWOLD DISTRICT. ROOFS TO BE COVERED WITH HEAVIER SLATES, SUCH AS ARE OBTAINED FROM QUARRIES IN YORKSHIRE & USED LOCALLY, ARE USUALLY FLATTER PITCHED.
MORTAR BEDDING
250
150 DIA. HALF-ROUND C.IRON GUTTER
55°
100×75 WALL PLATE
125×50 CEILING JOISTS
INSULATION
150
460
25×6 W.IRON ADJUSTABLE BRACKET & BAR
EAVES DETAIL

FIGURE 56

in at the bed joints (see Q, Fig. 77, Vol. I). Heavy slates, sometimes called *cussomes*, are used to form the under-eaves course. These are bedded on mortar, slightly inclined (about 15°) and projecting 125 to 200 mm. They are tailed down by the first batten, as shown, and the heads are notched at the spars as required. Tilting is thereby prevented. The next course, providing the double eaves course, is followed by a course of *followers*. The traditional method of hanging by oak pegs is shown.

Ridge Detail (see A, Fig. 56).—Comparing this with B, it will be seen that the slates at the ridge are much smaller than those at the eaves, the lap is 65 mm and the slates are shown fixed with either screws or nails.

The thickness of the slates at the eaves is about 38 mm (these often taper as shown) and that at the ridge is only about 12 mm. Note that the gauge varies from 254 to 114 mm.

The finish at the ridge is traditional, and as such is considered most suitable. These stone ridges are produced from 230 mm wide blocks of stone which are from 610 to 910 mm long; a series of parallel cuts, 38 to 44 mm apart, are made by the saw and each V-shaped unit is then cut square at the apex and lower edges. These are bedded, jointed and pointed in mortar. Half-round clay ridge tiles, buff coloured, can be used with good effect.

Comparatively large timbers are necessary to support the heavy weight of this covering. In the example, 125 mm by 50 mm spars are used at 400 mm centres. They must be strongly purlined.

In both details the traditional method, still employed, of torching is shown. Untearable felt, nailed to the backs of the spars, may be used in lieu of torching, provided pegs (which would penetrate the felt) are not used. For first class work, and in order to maintain an equable temperature within the buildings, the roofs may be boarded, felted, counter-battened and battened, as previously described.

Verges and Abutments.—Verges may be open, with the undercloak projecting some 50 to 75 mm, as described for tiling. Alternatively, a very satisfactory finish is provided by a low parapet wall, having a simple coping under which the slates are flaunched with mortar fillets (see Fig. 52). This is known locally as *tabling*, and is often finished with apex stones and kneelers similar to those shown in Fig. 21, Vol. I.

Valleys.—Unquestionably, the most suitable form is the swept valley. This is formed in a somewhat similar manner to that shown in Fig. 49, a valley board being used to block out the angle, and two or three stone slates in each course are cut to a wedge shape as required. Usually, courses having three cut slates at the valley alternate with courses each having two specially shaped slates. In the "three cut" courses, the middle slate or *bottomer* has both sides cut to form a wedge shape and the tail may be slightly curved to the sweep; the slate on each side, called a *skew* or *lye-bye*, has its edge next to it cut to fit. The next course has two wide *skews*, cut and mitred centrally over the bottomer below, with their tails sometimes slightly curved.

Laced valleys (see Fig. 49) are occasionally preferred.

Hips.—These are preferably avoided, but if adopted, the adjacent slates should be neatly mitred and lead soakers inserted (see F and G, Fig. 70, Vol. I).

Whilst this form of covering has a most attractive appearance and has, in the past, been employed most effectively in many parts of the country, it has been largely superseded by materials which are cheaper than those obtained locally.

SHINGLES

Shingles are thin slabs of wood used to cover roofs and walls. Although they are used extensively in Canada and the U.S.A., where a suitable timber is readily available, they have not been employed to any extent in this country. There are several reasons why, in the past, they have not found favour here, including a scarcity of satisfactory local material, the plentiful supply of many other roof coverings and the added danger from fire; although American experience has shown that only a small percentage of fires has been directly attributed to the covering. Further, shingles can now be rendered fire-resisting by a fire-resistant treatment on both sides.

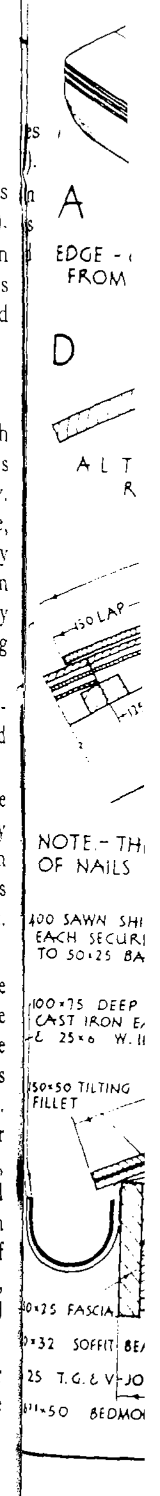
Formerly, the shingles used in this country were usually of oak and occasionally of elm and teak. They were split or rent, and such hardwood slabs required to be bored to receive the nails.

Within recent years such shingles have been practically superseded by those of western red cedar, imported from Canada. This timber (see Table II) is very durable, light in weight, straight grained and of a reddish-brown colour which assumes an agreeable silver-grey tone when exposed to the weather. It is reputed to shrink less than any other softwood and is resistant to insect attack.

Cedar shingles are either sawn or split.

Sawn shingles are used chiefly. A sketch of one is shown at B, Fig. 57. The length varies from 400 to 415 mm, 400 mm being the standard. They are obtained in random widths, varying from 64 mm to 356 mm. They are approximately 10 mm thick at the tail or *butt edge* and taper to 3 mm or less at the head. They are cut from quartered logs and should be rift sawn (see p. 4). Such shingles, commonly known as *edge grained*, should always be used for good work for the reasons stated at A. This also shows a sketch of a quarter log, 400 mm long, and a few slabs to indicate that they are sawn with their butts and heads alternating and at right angles to the annual rings. Flat or plain sawn (see p. 4) shingles, known as *slash grained* and produced by a cheaper method of conversion, should never be used except for inferior work, as the shingles, being sawn tangential to the annual rings (see C), will quickly warp, shrink and split when exposed, and they are liable to decay.

Split, cleft or rent cedar shingles are generally considered to be of better quality than the above, but relatively few are used in England. They are certainly stronger than sawn shingles and are regarded as being more durable.



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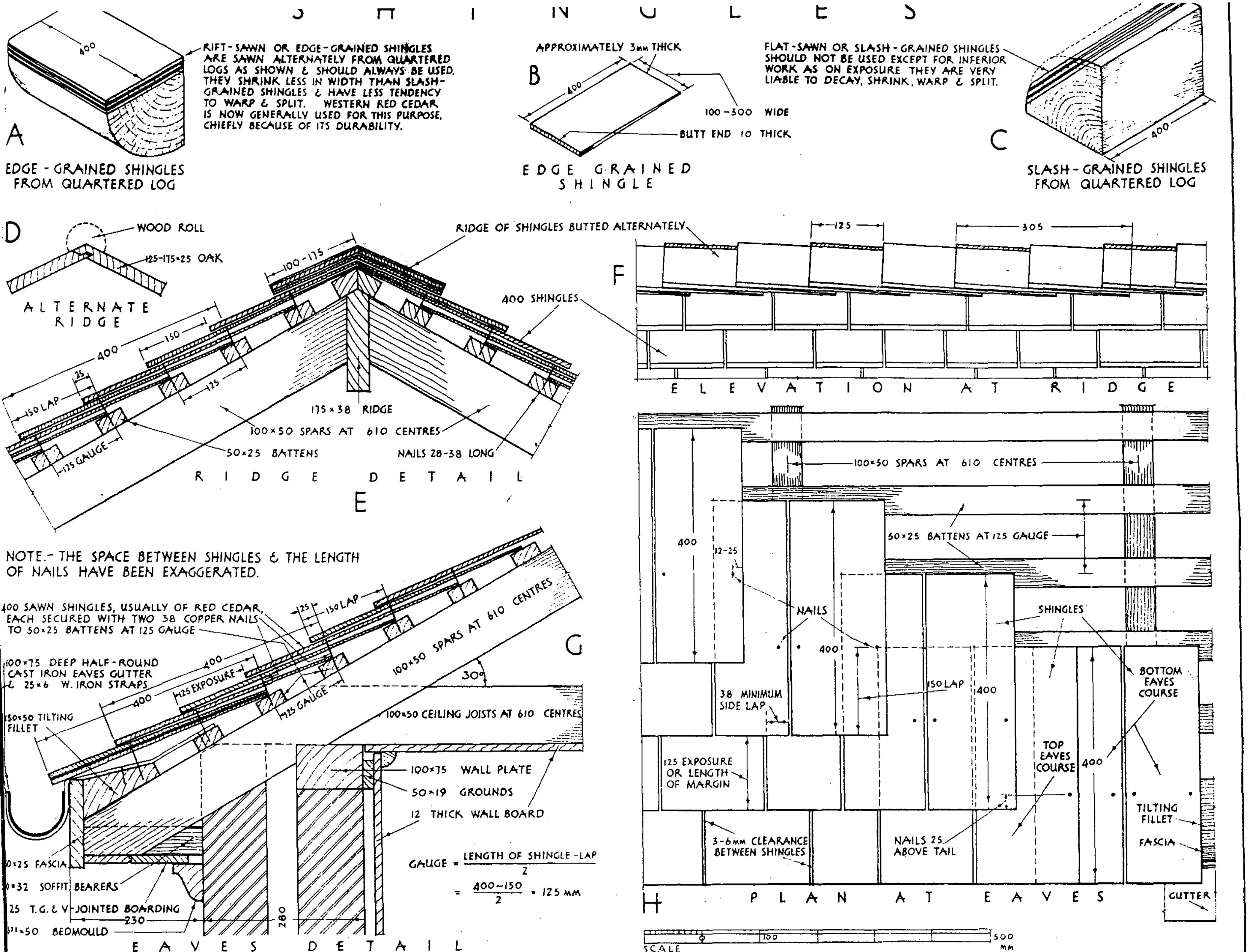


FIGURE 57

They are also thicker and longer, the length being up to 640 mm.

Oak shingles are generally hand-split. The size of these varies from 300 to 690 mm by 100 to 150 mm by 2 to 13 mm. They are, of course, very strong and durable. Cypress shingles have also a good reputation, but, like those of the oak variety, they are not generally used.

Details (see Fig. 57).—Whilst these refer to cedar shingles, the principles of construction also apply to those of other timbers. As already stated, cedar is very light in weight (shingles weigh approximately 7 kg/m² or about one-tenth that of plain tiles) and consequently a big economy results in the size and/or number of spars. Thus, if 100 mm by 50 mm spars are used, they are usually spaced at 610 to 760 mm centres. Neither close boarding nor roofing felt should be used for cedar shingles[1] to ensure a free circulation of air round them. The groundwork is therefore battens fixed direct to the spars. The size of the former varies according to the spacing of the rafters, and 50 mm by 25 mm battens are commonly specified when, as shown, the spars are at 610 mm centres.

The shingles are laid in random widths. Those wider than 250 mm should not be used, as these tend to curl, and such are therefore split in half. A gap of from 3 to 6 mm should be left between the sides of adjacent shingles to allow for any swelling which may occur (see H). Each shingle is secured with two nails. Pre-boring (forming holes to receive the nails) of cedar shingles is unnecessary. As shown, the nails pass through the shingle immediately below and barely clear the head of the third. Copper (for best work) and galvanized iron nails are used; the length varies from 28 to 38 mm. These are driven at from 12 to 25 mm from the sides and at least 25 mm above the *exposure line.* The " exposure " is the exposed portion or margin of a shingle, and, as in slating or plain tiling, the length of margin equals the gauge. The latter length is often referred to as the exposure.

The gauge varies with the pitch. A 30° pitch is common, for which a minimum gauge of 127 mm is recommended. This may be reduced to 95 mm for pitches less than 30°.

On reference to E, it will be seen that the construction differs from slating or plain tiling in that there are at least three thicknesses of shingles (with a possible exception at the eaves, see below) and four thicknesses where the top shingles cover the nails immediately below. The lap is considered to be equal to the distance from the butt (tail) end to the nail holes; in the example the lap is shown to be 152 mm.

Eaves (see G).—This is closed and has an overhang of 230 mm. As in slating, a double course is provided, having a 38 mm projection. Sometimes a triple eaves course is formed. Unlike slating, all the double eaves course shingles are of the full length of 400 mm. The upper eaves course must break joint with the lower, and the minimum side lap is 38 mm (see H). The battens are spaced at the gauge apart. It will be observed that the heads of the shingles in each course are at the centre of the batten and that the nails also pass through the middle.

Note.—In order to make the construction clear, in both details E and G a relatively wide space has been shown between each course. This has resulted in an exaggerated length of nail. Actually the shingles fit closely, and rarely is a longer nail than 38 mm required, 28 mm being common.

The ceiling and walls are lined with wall board.

The plan at H shows a typical arrangement of the shingles and will help to make clear the above description. Note the random widths, minimum side lap, position of nail holes and the head lap.

Ridge (see E and F).—The usual finish is shown composed of narrow widths of 300 mm shingles, each pair being butt jointed alternately.

An alternative treatment consists of *saddle boards*, which are long lengths of tongued and grooved or elm narrow boards (see D). The end joints should be dovetail rebated or half-lapped. In addition, the joints of the saddle boards may be covered with a wood roll, as shown by broken lines.

Lead-covered ridges are also adopted. These are of the type shown at H, Fig. 75, Vol. I, a wood roll being covered with No. 5 or 6 lead secured by lead tacks at about 900 mm intervals.

Hips.—One form is similar to the ridge shown at E and F; the shingles in adjacent courses being cut-mitred and covered with shingles, lapped alternately at their edges.

A cut and mitred hip with lead soakers is another type, wide shingles being used at the intersection and lead soakers introduced as explained for slating in Chap. V, Vol. I. A wood roll may be added.

Lead-covered hips, similar to ridges, is an additional finish.

Valleys.—These may be of wide shingles, cut and mitred, with lead soakers. An open lead gutter (see Chap. VI, Vol. I) is another form, boards being provided at each side to receive the lead. Swept valleys, as described for tiling (p. 128), are also occasionally used.

Abutments.—Intersections at gable parapet walls, chimneys, etc., are treated with lead flashings, as described for Plumbing, Chap. VI, Vol. I.

Vertical Shingles.—External wall surfaces can be treated quite attractively and rendered damp-resisting by nailing shingles to battens plugged to the wall at 150 mm to 180 mm gauge (see vertical tiling, p. 128).

COPPER ROOFING

Manufacture.—Copper is obtained from ores found, on a small scale, in this country (Cornwall) and extensively in the U.S.A. and elsewhere. There are several methods of extracting copper from its ores, depending upon their character. In one, a preliminary operation consists of roasting or calcining the ore which has been previously ground. This eliminates the excess of sulphur. The roasted ore is then smelted (reduced to a fluid condition by intense heat) in a furnace. The crude molten metal is run off into a special bogie or settler where the slag or scum is eliminated. The material which remains (a mixture of copper, iron and sulphur) is granulated in water, cooled, broken up and ground. It is again roasted, smelted

[1] Oak shingles are usually fixed to close boarding.

and re-granulated. This refining process is repeated until the iron and sulphur are removed, when the final product is cast into bars, called *pigs*. The last operation depends upon the form required. For roofing purposes the copper is either hot or cold rolled into thin sheets. In hot rolling, which is usually required for roofing, the heated pigs or ingots are passed backwards and forwards between rollers until sheets of the required thickness are obtained.

Characteristics.—Copper is exceedingly durable, tough, non-corrodible, very light in weight, resistant to fire, malleable, ductile, soft, and an excellent conductor of heat. It has a reddish-brown colour, which, when exposed to the atmosphere for several years, often assumes an attractive pale green colour called the *patina*. This greenish film of carbonate of copper acts as a protecting coat to the metal below its surface. Copper has a relatively small coefficient of linear expansion, being 0·0000168 per °C., compared with 0·0000292 per °C. for lead. Unlike lead it does not creep when laid on steeply pitched or vertical surfaces.

The material for general roofing is made from fully annealed copper sheet or strip conforming to B.S. 2870.

Copper sheet is made in 1·8 m lengths, 600 mm wide for 0·45 mm and 0·6 mm thicknesses and 750 mm wide for 0·6 mm thickness. Most roofs are made with the 0·6 mm grade 600 mm wide.

Groundwork.—Copper sheets are laid upon t. and g. or butt-jointed boarding.[1] Because of its light weight the size of the timber bearers or spars may be less than those required for lead covering, or, alternatively, the spacing of these timbers may be increased. If used on flat roofs the minimum fall is 1 in 60 and the boarding is preferably laid in the direction of the fall, or diagonally, in order that any warping will not obstruct the flow of water. The heads of the nails securing the boarding should be punched below the surface and the boarding planed smooth. The boarding is then covered with felt (butt jointed and fixed with *copper* nails) to serve as a cushion and an insulating layer to deaden the sound of falling rain. Copper must not be allowed to contact other metals (e.g. steel nails) as this would create electrolytic action and decay.

Copper sheet can be fixed to vertical surfaces.

Joints.—Although the expansion and contraction of copper, due to changes of temperature, is relatively small, such must not be entirely ignored. Provision must therefore be made for this movement, especially at the side joints. Drips (see Chap. VI, Vol. I) are not necessary, except in parapet gutters (see adjacent column), and instead the *transverse*, *end to end* or *cross joints* consist of (*a*) welts. The *side* or *vertical joints* are in the form of (*b*) wood rolls or (*c*) standing seams.

(a) *Welts.*—That most favoured for jointing sheets *end to end* is known as the *double lock cross welt;* it is placed across the roof slope. Four stages in the development of this joint are shown at A, Fig. 58.

[1] Concrete roofs are also sometimes covered with copper.

In the first stage the edge is turned up about 25 mm. In the second operation a portion of this edge is turned down. An edge of the adjacent sheet is turned up and engaged in the fold of the first sheet (see third stage). In the final stage these edges are folded down to form the welt, which is about 12 mm wide. The sheets are welted together in this manner until the required total length is obtained. Such a linked up sheet is called a *string*. The welting operation is generally completed in the shop. The strings are then in turn placed in position on the roof. It is usual for the welts to be staggered. This avoids awkward thicknesses appearing at the vertical (side) joints. *Single lock cross welts* (similar to that shown at E) are sometimes used for stringing sheets required for steep pitches or vertical surfaces.

(b) *Wood Rolls.*—These are employed at *side joints* on flat roofs, or those with a pitch of 5° or under, which may be subjected to traffic; they run parallel to the roof slope. Five examples are illustrated in Fig. 58, all of them providing efficient watertight side joints and permitting lateral movement of the sheets.

The *conical roll* shown at B is much favoured. Copper *clips* or *straps* (similar to the lead tacks described in Chap. VI, Vol. I), 38 to 50 mm wide, are placed under the rolls at about 900 mm centres. The rolls, secured by copper or brass screws, are spaced at a distance apart equal to 100 mm less than the width of the copper sheets, *i.e.*, 500 mm for 600 mm wide sheets—the latter being a common width. The three stages of development are shown at B, a welt being formed on one side, as shown, in the final stage. Alternatively, the clips may be as shown at D, each secured at the undercloak side by two copper flat-headed nails[1] at least 25 mm long and not less than 2·6 mm thick.

The four rolls at C differ from the above in so far as each is covered with a strip of copper called a *capping*. In each case the upturned edges of the sheets are welted to the capping. Copper clips (not shown) are provided at 915 mm intervals, as described above. The *undercut roll* is a good expansion joint. The *square roll* is commonly applied in Scotland. The *round top roll* and the *ornamental roll* are suited, because of their appearance, for pitched roofs; the shape of the latter roll is only one of several mouldings.

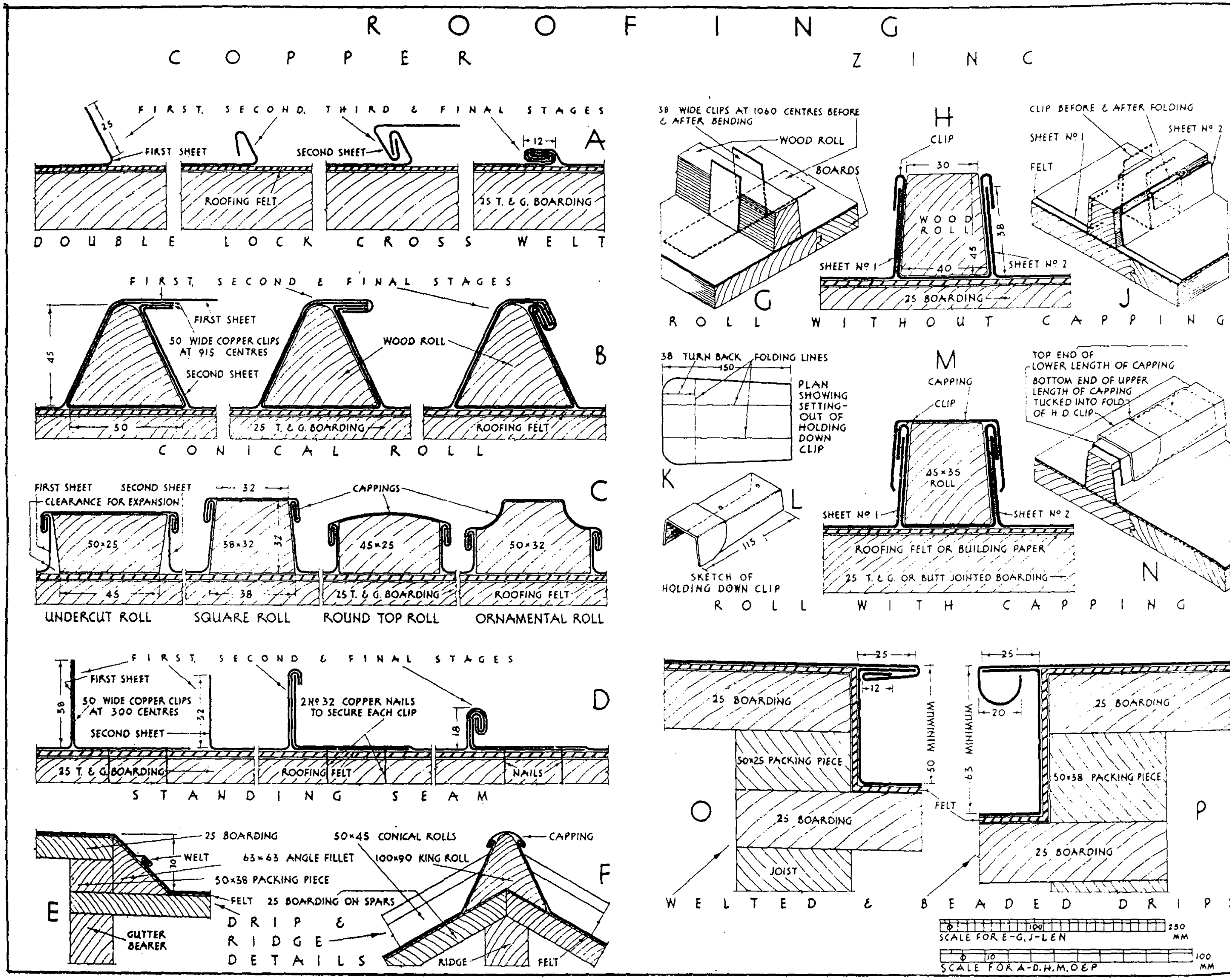
(c) *Standing Seams or Stand-up Welts.*—These are suitable for *side joints* on pitches of 6° or over or flats which are not likely to be subjected to traffic; they run parallel to the roof slope. It is a good expansion and watertight joint.

The sheets are first welted end to end, as described above, the strings are then placed in turn on the roof, and the standing seams formed by means of wide lipped pliers (called *seamers*) or dressers (like A, Fig. 79, Vol. I). The stages of development of this joint are shown at D. Copper clips, 38 to 50 mm wide, are shaped as indicated in the first stage and fixed in alignment at 300 mm centres, each clip being secured with two copper flat-headed nails. The edge of the first sheet is turned up 38 mm that of the second strip is turned up 32 mm, all the clips and first sheet are turned over the standing edge of the second sheet (see second stage), and all three are bent over to form a double lock welt, as shown in the final stage. The height of the finished joint is approximately 20 mm.

The setting out of a copper covered roof, therefore, somewhat resembles that of the lead flat shown at A, Fig. 74, Vol. I, the *side joints* consisting of rolls or standing seams, and the *cross joints* being welts, staggered, instead of drips.

Drips.—As mentioned above, drips are only provided in parapet gutters

[1] These nails should be without shoulders (enlarged connections between the head and stems), which latter tear the copper when the nails are driven home. The nails have a 6 mm diameter head and the shank is barbed.



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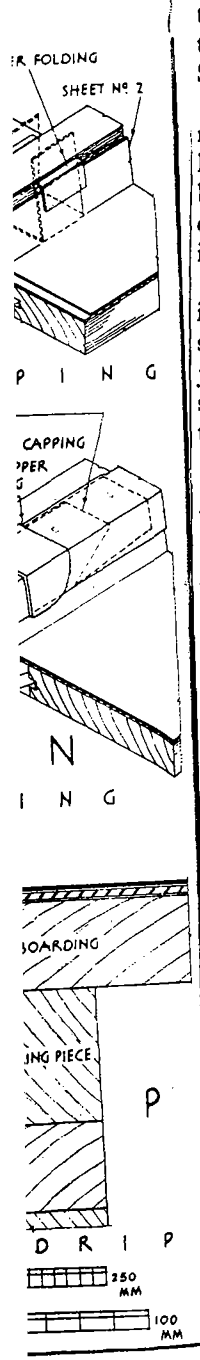

in order to increase the flow of water towards the outlet. As shown at E, the timber construction is similar to that of a lead drip (see Fig. 74, Vol. I), except that an additional 45° angle fillet is fixed. The adjacent copper strips covering the gutters are jointed by a *single* lock cross welt at the centre of the fillet. Sometimes the welt is formed at the top of the fillet.

Ridges.—A satisfactory treatment at a ridge is shown at F. Here the ridge roll or *king roll* is higher than the adjacent wood rolls. The copper covering the king roll is as described on p. 147 in connection with the rolls at C, a capping being provided and welted to the upturned sheets. The overcloaks of the conical rolls (or the cappings if the rolls are of type C) are widened and welted into the king roll capping.

If the side joints of the copper roof covering are of the standing seam type D, it is usual for the sheets covering the two slopes to be welted at the ridge intersection and dressed down on one side over the felt covered boarding (butt jointed as shown at F and without the roll). The standing seams forming the side joints are gradually flattened for a distance of about 150 mm down from the apex and folded into the ridge welt.

Hips are formed as described for ridges.

Valleys.—The woodwork is of the usual construction (see J, Fig. 52). Welted joints are formed between the copper strip covering the valley and the sheets covering the slopes. If wood rolls are adopted for the side joints the ends of the rolls are cut short of the intersection and bevelled back, the copper is dressed round the ends and the welted undercloaks and overcloaks are continued and tucked into the valley welt. If the standing seam method has been employed the seams are gradually flattened at the ends and linked into the valley welt.

Stepped, etc., Flashings.—These are very similar to those executed in lead and described in Chap. VI, Vol. I.

Note.—*In the details shown in Fig.* 58 *the space between the copper at the welts has been exaggerated.*

ZINC ROOFING

Rolled zinc sheet is made from commercial zinc or from an alloy of zinc with small amounts of copper and titanium included. The properties of both are similar but zinc alloy has better tensile and creep strength.

Manufacture.—Zinc is extracted from certain ores, the chief of which are the dark coloured *blende* and the light coloured *calamine*, found in England (on a small scale in Cornwall, Cumberland, Derbyshire and Somerset), Wales, Canada, Poland, Spain, Sweden and the U.S.A. Several methods are adopted for extracting the metal. In one the powdered ore is roasted in a furnace and then heated in horizontal retorts. Here the zinc is volatilized and the vapour is condensed in receivers. The condensed zinc is removed and poured into metal moulds, when it is commercially known as *spelter*. The metal at this stage is brittle. The spelter is re-heated and made malleable, after which it is re-cast into rectanguler cakes, allowed to partially cool and finally rolled. It is passed between two sets of rollers until the required thickness is obtained, the direction of rolling in the finishing mill being at right angles to that in the first or roughing mill. The sheets are finally trimmed (sheared) to size.

Sizes.—The standard size of sheets is 2 130 and 2 450 mm long and 910 mm wide, the latter length being usually adopted. For best work, 1 mm thick sheet is used, but the 0·8 mm thickness is commonly used.

Characteristics.—Zinc is a white metal with a bluish-grey tint. When exposed to the atmosphere a carbonate is formed which forms a protective coating to the underlying metal. It is brittle at ordinary temperatures. Zinc is a very light roofing material, although the sheets are heavier than copper. It is fairly durable, provided it is used for roofing purposes in atmospheres free from smoke, but it has a relatively short life if subjected to acids. In average urban conditions 0·8 mm thick sheet will last 40 years. Its initial cost is low.

The coefficient of expansion of zinc is higher than that of copper and is 0·0000291 per °C., or practically the same as that of lead. Therefore, when applied on flat roofs both rolls and drips must be used to permit of expansion. The minimum fall for flat roofs is 1 in 60. Zinc does not creep and it is therefore suitable for steeply pitched roofs.

Joints.—The roof is divided into panels using (a) rolls, (b) drips, and (c) welts similar to that for lead flat roofs (see Vol. I). The length of a panel can be 6 m for widths up to 600 mm using commercial grade zinc (9 m long for the alloy). Bays can be wider if the length is reduced; e.g., 4 m long for ordinary sheet and 6 m long for the alloy with widths of 725 mm. Using the standard width sheets the bay width is 850 mm by about 2·4 m long.

The boarding should not be less than 19 mm thick and, like that for copper and lead covering, it should be laid diagonally or in the direction of the fall. Nails should be well punched down. Building paper or felt is used to cover the boarding. This provides thermal and sound insulation, and acts as a cushion.

(a) *Rolls.*—These are placed parallel to the roof slope, continuously from eaves to ridge. See G, H, J, M and N, Fig. 58.

The wood rolls are slightly tapered, and the zinc sheets placed between them have each side turned up 38 mm. Zinc clips 38 mm wide, are spaced at about 1 m centres under each roll and the latter is then nailed at 500 mm intervals, every alternate nail passing through a clip. Zinc or heavily galvanized wrought iron nails must be used for fixing the rolls; copper or plain wrought iron nails are unsuitable as electrolytic action may arise resulting in decay of the metal. A clip before and after being turned up is shown at G.

The sheets, with their long edges turned up 35 mm, are then placed in position and the clips are hooked over the edges as shown at J and the enlarged section H. It will be observed that adequate space is provided to permit of expansion.

The rolls and the turned up edges of the sheets are now covered with standard machine formed zinc cappings. A capping is shown in the section at M. This shows the edges of the capping turned in slightly. The cappings, not exceeding 1·1 m in length, are secured by *holding-down clips.* Such a clip is illustrated at L and is formed from a piece of zinc set out as indicated at K; the lower edge is turned back 38 mm and the sides are bent down. A clip is secured by two or three nails to the roll over the top end of the lower length of capping, and the bottom end of the upper length of capping is slipped into the fold or turn-back of the clip. A watertight joint, permitting expansion, is thus assured. A portion of completed roll, including a clip, is shown at N.

In a flat roof, divided by drips as explained below, each roll will be covered with two lengths of cappings secured by a holding-down clip at the centre.

(b) *Drips.*—These are placed across roof slopes having a pitch below 15°; the spacing of these transverse joints is 60 mm less than the length of sheet employed. There are two forms of drips, (i) welted and (ii) beaded.

(i) *Welted Drips* (see O).—The depth must be at least sufficient to allow the welt to clear the cappings of the rolls below, 50 mm being a minimum.

The top edge of the lower sheet is turned up and then out 25 mm in line with the top of the drip. A welt is formed along the bottom edge of the upper sheet by first bending the edge back 12 mm (which stiffens the welt) and then folding this bent edge back 25 mm. The joint is then completed by engaging the turned out edge on the lower sheet within the fold of the upper.

(ii) *Beaded Drips* (see P).—The depth must be at least 64 mm to allow of adequate clearance between the bead and the cappings below.

The edge of the lower sheet is turned up and out, as described above. A 19 mm bead is formed on the bottom edge of the upper sheet by first bending the edge back slightly for 12 mm, followed by turning the edge down 38 mm at right angles and then dressing it over a 16 mm diameter rod (called a *beading rod*). This beaded edge is finally fitted over the turned out edge of the lower sheet.

Beads, welts, etc., are formed by the use of a dresser similar to that used for lead and shown at A, Fig. 79, Vol I.

(c) *Welts.*—These are used as described below (parallel to the roof slope) and also to join the ends of panels when the roof pitch is 15° or more; in the latter case they run across the slope. Cross welts should be staggered to avoid joint difficulties at the corners of sheets.

Steeply Pitched Roofs.—Drips are dispensed with if the pitch of a roof exceeds 15°. The transverse joints are then of the *single* lock cross welt type as used in copper roofing (see p., 148). They are formed in the following manner: The top edge of the lower sheet is folded over 25 mm. This sheet is secured by two 100 mm by 75 mm zinc clips spaced along its upper edge, each being twice nailed to the boarding after its lower edge has been bent and engaged in the fold of the sheet. The bottom edge of the upper sheet is then folded under 25 mm; this turn-back is engaged in the fold of the lower sheet and the welt is then completed by applying the dresser.

Flashings are somewhat similar to those described for leadwork in Vol. I. The lower edge of a cover flashing is stiffened by forming a 12 mm bead or fold along its lower edge. Similar beads are sometimes formed on the edges of the up-turns of the gutter or roofing sheets.

THATCH

This roof covering consists of bundles of reeds or straw secured to battens and spars. The thickness of the thatch varies from 230 to 400 mm, according to its quality and the pitch of roof. The latter should not be less than 45°. Thatch affords a watertight cover when skilfully applied and undoubtedly the appearance of thatched buildings can be delightfully picturesque. It has, however, several serious demerits, chief of which are its liability to destruction by fire and its tendency to become infested with vermin. It is claimed that reed thatch will last at least sixty years if properly attended to, and many old roofs produce evidence of this. The life of straw thatch is not more than about twenty years. It is significant that many local authorities will not permit the use of thatch (not even when treated with so-called fireproof solution), that there are few skilled thatchers available, and that when thatched roofs on existing buildings become defective the covering is often replaced by other materials.

Thatching.—Reeds, such as are obtained from the Norfolk Broads, are best used for thatching. They are much longer (up to 2·7 m) than wheat or rye straw, which latter is also used. The material is formed into bundles and tied with tarred twine. The spars are spaced at from 600 to 750 mm centres, and 50 mm by 25 mm battens are nailed to them at 200 to 300 mm gauge.

There are several different methods of fixing the thatch, varying with local practice. The reeds or straw must be well soaked with water or fire-resisting solution to facilitate packing, and the bundles are laid with their butt ends pointing towards the eaves. A slope of a roof is thatched in a series of *beds* or strips, the width of a ladder, and extending from eaves to ridge. The thatcher, working on a ladder from right to left, commences at the eaves and packs the bundles tightly sideways and downwards from the right across to the side of the ladder to complete the width of bed. The next course of bundles is packed in a similar manner at 200 to 300 mm above the first (depending upon the length of reed or straw), and this is continued until the ridge is reached. *Withies* (twisted rods of pliable willow twigs, sometimes called *osiers*) are interlaced through and over the bundles at about 600 mm apart as the thatching proceeds, and these are secured to the spars with tarred twine. In some districts tarred twine is used instead of withies; a needle is "threaded" with the twine, the latter is pulled tightly over the straw, passed round a batten and withdrawn to complete the stitch; an assistant or under-thatcher often assists in this operation. Each bed is raked or combed down to remove loose reeds or straw. Beds are formed in this manner until the slope has been covered. Additional security is provided at verges by placing short horizontal withies (called *scallops*) on top of the thatch at about 600 mm intervals and securing them with wood *staples* (pieces of withies bent to a U-shape) which are driven into the thatch at about 300 mm apart. The eaves project from 450 to 600 mm and a horizontal soffit is formed by cutting to a line with a sharp knife.

Ridges are formed of straw. One of several methods of thatching a ridge is as follows: The bundles, about 450 to 600 mm long, are stretched over the apex and caused to overlap the thatch on both sides until a 1·2 m long section has been covered to the required thickness. This is secured with either one or two scallops and staples (or twine) at each wing. The ridge is completed in sections in this manner, and the edges are then cut and trimmed with shears or a long-handled knife. Sometimes additional withies are arranged diagonally to pattern from wing to wing and attached to the horizontal scallops. If a chimney stack intercepts a ridge, it is usual to begin at each side of it and work towards the hips or gables. As a precaution against fire, chimney stacks should be constructed of walls which are at least 225 mm thick.

Scallops, as described above, are provided at hips at about 300 mm apart and bent to form a sweep. The thickness of thatch is increased at valleys in order to give a swept appearance.

Roof Insulation.—This aspect has been introduced in Chap. V, Vol. I and clauses in the Building Regulations are relevant. The B.R.s require a roof (alone or in conjunction with its ceiling) to have a U-value (see Chap. XII, Vol. IV) ot more than $1{\cdot}42\ W/m^2\ {}^\circ C$.; they also lay down types of construction which re satisfactory, for example:

Any roof should be insulated within the roof or associated ceiling by:—a) 50 mm thick woodwool slabs or (b) 25 mm thick expanded vermiculite, orkboard, fibreboard, quilt of glass wool, rock wool or slag wool; or (c) 19 mm hick expanded polystyrene.

A pitched roof of slates or tiles on sarking felt insulated by one of the materials given above as may be appropriate to the construction, but the woodwool need only be 38 mm thick; and the quilts of fibreboard 19 mm thick; alternatively 21 mm thick t. & g. boarding is satisfactory. The roofs shown in this volume are insulated by some of these means.

CHAPTER FOUR

PAINTING

Syllabus.—Preparation of surface. Priming coats, undercoats, finishing coats. Types of paint: oil, synthetic, water, emulsion, and cellulose paints; varnishes; special paints. Painting on wood, iron and steel, non-ferrous metals, plasters, concrete, masonry and building boards. Painting technique by brush and spray.

Paint preserves, protects and decorates surfaces and enables them to be cleaned easily.

Paint is composed of *pigment(s)* suspended in a ***liquid***. Pigment gives colour and opacity. The liquid (known also as a ***medium*** or ***vehicle***) is composed mainly of a ***binder*** and ***thinner***; the binder fixes the pigment to the surface being painted and is responsible for the gloss and waterproofing characteristics, etc.; thinners reduce the viscosity of the paint and aid its penetration; a ***drier*** is included in the medium to hasten drying. Natural pigments include iron oxides, ochres, umbers, etc.; chemically manufactured pigments include chromes, Prussian blue, zinc oxide, etc. Mediums used are oils, varnishes, resin, bitumen and cellulose derivatives. The most common thinner or solvent is turpentine; its substitute white spirit is also used.

Adequate preparation of the surface to be painted is essential for success. The surface should be smooth (not shiny for this would not give an adequate key), clean, dry and stable. The paint film is built up with more than one coat, *e.g.*, a priming coat, undercoats and a finishing coat. The selection of a suitable type of each of these coats depends on the material of the surface and its location (internal or external)—see p. 153. Each coat must be dry, hard and rubbed down with fine abrasive paper before the next is added.

Priming coat.—This is the first layer of paint; it must suit the background and adhere to it; it must be compatible with subsequent layers. A primer may also have to satisfy one or more of the following requirements:—to penetrate porous surfaces (*e.g.*, wood and plaster), to inhibit corrosion (*e.g.*, on ferrous metals), to seal chemically active surfaces (*e.g.*, on new lime plaster and cement) and thereby prevent them from disrupting subsequent layers of paint, and to be heat-resistant.

Undercoats.—These obscure the primer, bond it to subsequent coats and build up an adequately thick paint film; they must be of a suitable tint to match the final coat.

Finishing coat.—This gives the desired colour and finish to the surface; colours are innumerable; finishes vary from flat (matt) to eggshell to oil-gloss to enamel (high gloss)—gloss paints are more durable for exterior use than flat paints. A flat paint is sometimes adopted for walls, as, unlike gloss paint, it does not emphasize slight irregularities. Textured paint finishes can be obtained with special paints or by stippling.

Types of Paint.—There are seven groups of paint:—(*a*) oil paints, (*b*) synthetic paints, (*c*) water paints, (*d*) emulsion paints, (*e*) cellulose paints, (*f*) varnishes and (*g*) special paints. The following is a brief description of them.

(*a*) *Oil Paints*.—These are the traditional type having a linseed oil medium. The various coats are constituted as follows: Priming coat—linseed oil, white lead, a small amount of red lead and *extender* (a white pigment used to increase bulk, prevent sedimentation and improve spreading); the lead base is particularly suitable for external work; leadless pigments are for internal use. Undercoats —linseed oil, white lead (tinted if required) and a high quality drying oil. Finishing coat—oil varnish, pigments of the desired colour and perhaps extenders, and thinners; finishes vary from flat to oil-gloss. If a medium of a special drying oil is used then a high gloss paint results. Oil paints dry by evaporation of the solvent and by oxidation; they have been replaced by synthetic paints.

(*b*) *Synthetic Paints*.—The medium for these is a chemical compound, one type being an oil-modified alkyd resin. They have the advantages over oil paints in setting more quickly and offering greater durability where corrosion is a danger; they also have a better flow and are easier to apply. Drying is by evaporation of the solvent, by oxidation and chemical change.

(*c*) *Water Paints*.—Known also as *distempers* they are used mainly on internal walls and ceilings and most of them give a flat finish. There are several kinds and are prepared on the site by adding water to make a paste. They have a drying oil or varnish medium emulsified in water containing glue or other fixatives; barytes is a common pigment along with tinting pigments. The cheapest type, known as *soft* or *ceiling distemper*, contains only a glue size vehicle and tinted powdered chalk; it can be removed by washing or brushing and so is only used for ceilings. Oil-bound distemper is a better quality having a mixture of linseed oil, pigment and extenders; it will withstand limited careful washing. Emulsion paint has superseded water paint.

Another type are ***cement paints*** often used externally; they contain white or coloured Portland cement with a waterproofer, accelerator and extender.

(*d*) *Emulsion Paints.*—An emulsion paint has the pigments and the medium dispersed as small globules in water; oil, synthetic resin and bitumen are common mediums. Among the different emulsion paints are alkyd, bitumen, polyvinyl acetate and styrene emulsions; they are used mainly on wall surfaces. Oil-bound distemper in (*c*) above is a type of emulsion paint.

Alkyd emulsion paints contain pigments, oils and synthetic resins; they give a flat finish. *Bitumen emulsions* are those of bitumen in water plus pigments and extenders; they are for use on asphalt and bituminous surfaces. *Polyvinyl acetate* (*p.v.a.*) *emulsion paints* have a p.v.a. medium and give a finish from flat to eggshell gloss. *Styrene emulsions* incorporate the synthetic resin styrene in several forms and have a medium gloss.

(*e*) *Cellulose Paints.*—These are synthetically reproduced from cellulose compounds and most of them have to be applied as a spray (see p. 155) for they dry very quickly by evaporation of the solvent. Apart from some kinds containing metal powders (aluminium and bronze) they are not satisfactory for general building work but can be used for furniture and fittings in houses; they are widely used in the motor car industry.

(*f*) *Varnishes.*—These are of two kinds, oil varnish and spirit varnish; they are used to give a transparent film to a surface.

Oil varnishes contain linseed oil or other drying oils, driers, synthetic or natural resins and solvents such as white spirit or turpentine; they dry by evaporation of the solvent and oxidation of the oil. The relative proportions of the oil and the resin control the usage; if the oil is predominant a more elastic varnish results for external work; if the solvent is the major ingredient a high gloss, which dries out rapidly, is obtained for internal work. Copal varnish is a good quality type. *Spirit varnishes* are solutions of shellac and other spirit resins dissolved in commercial alcohol (methylated spirits); they are only suitable for internal surfaces like furniture (*e.g.*, in French polishing).

Polyurethane varnish is a type of resin varnish producing a very durable finish.

(*g*) *Special paints.*—Among the many kinds of these are:—

Aluminium Paints.—These are often used as a primer on resinous woods like Columbian and Oregon pine because they have a good sealing effect; they contain aluminium powder in a quick drying medium.

Anti-condensation paints.—These contain a cork filler and whilst they are not a substitute for adequate ventilation (the best safeguard against condensation), they afford some relief by reducing the transfer of heat.

Bituminous Paints.—The vehicle for these is mostly bitumen; they provide a cheap method of protecting steel where appearance is secondary.

Chlorinated Rubber Paints.—Instead of oils or resins used in the others, paints of this kind contain chlorinated rubber combined with pigments and special thinners. The paints offer good resistance to acids and alkalis and can be used where fumes from these chemicals arise. They are suitable for internal use on brickwork, concrete and steelwork.

Fire-resistant Paints.—These are used to increase the resistance to fire of wood and certain building boards; there are several proprietary types incorporating ammonium phosphate.

Fungicidal Paints.—These include special ingredients which render them resistant to mildew and other fungoid attack; useful in humid surroundings.

Gold Size.—Used as driers and binders and as a fixative when applying gold leaf for gilding.

Heat-resisting Paints.—Used on radiators, etc.; they incorporate special varnishes and pigments which do not discolour on heating.

Imitation Stone Paint.—This imitates natural stone, it contains stone granules in an oil or emulsion medium.

Knotting.—This is a spirit varnish containing resin and a solvent; shellac is a good medium. It is used to prevent exudation of resin from knots (see below).

Texture Paints.—These contain different powders and pigments with glue; used in a stiff consistency to make textured surfaces on which patterns can be formed by brush or special implements.

Wood stains.—There are many kinds of these containing dyes of various shades in an oil, spirit or water medium.

Painting of Different Surfaces.—The importance of adequate preparation of a surface to be painted is mentioned on p. 152. Having selected a brand of paint, the same manufacturer should supply the paint for the whole of the job. The various surfaces should be treated as follows:—

New wood.—This should have a moisture content not exceeding 15 per cent. After the timber has been cleaned, smoothed, dust removed, any grease cleaned off with white spirit and nails punched down, the usual specification is that it should be " knotted, primed and stopped "; it is important that these labours be executed in this order. Careful treatment of knots is essential; loose dead knots and those which are particularly resinuous should be cut out and replaced by sound timber. Other knots should be coated with knotting, to prevent the exudation of resin, in two coats allowing each coat to dry thoroughly. The whole of the surface is then primed with a good quality primer[1]; a primer for hardwoods should be thinner than that for softwoods. (Two or three coats of boiled linseed oil is a frequently specified treatment for external hardwood.) The next operation is to stop or fill any cracks and nail holes with *stopping*[2] one type of which consists of red lead and gold size.

The two undercoats and the finishing coat are then applied; the undercoats being rubbed down with fine abrasive paper after they have dried; at least two undercoats are required—three or four in exposed areas. The finishing coat can

[1] A lead-based primer is best for exterior work, *i.e.*, one containing 10 per cent. red lead. A lead-based paint should not be rubbed down dry for the dust is poisonous, instead the wet method using water and an abrasive paper must be used. Lead paints should only be used outside and they should not be sprayed (see p. 155) because of the danger of poisoning.

[2] If the stopping is done before the priming it might work loose.

be an oil or alkyd resin type in any kind of finish except matt which should be reserved for internal use only.

All external joinery should be primed before being brought out to the building site.

Other preservative treatments for wood are described on pp. 11-14

Previously painted wood.—If the paint has not deteriorated too badly it is only necessary to wash the surface and rub it down with waterproof abrasive paper (or with a patent pumice block) dipped in water. Any bared wood should be re-primed; painting can then proceed as on new wood.

If the painted surface is in bad condition or the film is very thick a fresh start should be made by removing the whole of the paint. Removal can be by *burning off* (actually the paint is merely softened by a blowlamp flame or electrically heated scraper and scraped off) or by the application of a spirit solvent which is brushed on to soften the paint and followed by scraping. The bared surface is then painted as described above for new wood.

It is undesirable to mix the two processes on a job—a decision must be made at the outset between rubbing down or complete removal of the old paint.

Iron and Steel.—Corrosion is responsible for much damage to, and expensive maintenance bills for, these materials; hence, wherever possible it is more economical to have them galvanized[1] at the outset and then painted. As with all surfaces adequate preparation is an important prerequisite; in the case of ferrous materials this includes removal of mill scale and rust.

Workshop preparation can include *pickling* in hot dilute hydrochloric acid to remove scale and rust and *phosphating*; a phosphate dip provides good resistance to rusting. On the site there are certain proprietary liquids that can be used which are rust inhibiting; a wire brush is useful for removing rust; an organic solvent will remove any grease.

Ferrous metals should be primed before being delivered to the site. A red lead[2] linseed oil primer gives a good foundation; chromate and zinc primers are also adopted. The primer can be followed by good undercoats and oil or alkyd resin finishing coats.

Non-ferrous metals.—Many of these have a shiny smooth surface which must be roughened before priming. A good key for the paint is essential and can be obtained by etching primers or phosphating; aluminium can be treated by chromate processes. The priming paint differs for the various metals and paint manufacturers have types suitable for each. Zinc chromate is good for external aluminium and zinc oxide internally. Copper is usually only painted when it is used inside in which case an oil-modified alkyd resin paint with an aluminium pigment is satisfactory. Lead and zinc surfaces require a good etching primer.

Plaster.[1]—The painting of *dry* plaster surfaces does not present any problems and the ordinary sequence as for woodwork can be adopted. Depending on the time of the year and the amount of internal heating in the building, the *complete* drying out of plaster and brick, concrete or masonry backing walls takes from six to twelve months. It is seldom practicable to wait as long as this before decorating and a sensible temporary measure is to apply an emulsion paint which can be redecorated at a later date. Plastering can be done with lime plasters or, more usually nowadays, with calcium sulphate plasters; the painting technique differs slightly for each method.

Lime plasters are alkaline[2] and if damp will attack oil paints and prussian blue and brunswick green pigments; hence oil medium paints and such pigments must not be used in paints on damp lime plaster. The best method is to apply a temporary coat of soft distemper; but if the background is of dry construction (*e.g.*, timber studding) and the plaster has dried out for a few weeks then an oil-bound distemper can be used which forms a reasonable surface for subsequent decoration with the same paint or a flat oil paint. If a lime plaster surface is left until it and the backing wall have completely dried out an oil gloss paint (or similar) finish can be given provided an alkali-resisting primer has been used. Cement paints may also be used on lime plasters if these have not been gauged with a calcium sulphate plaster.

Calcium sulphate plasters.—When damp these do not have the deleterious effect on paint as do lime plasters, nevertheless moisture cannot be tolerated if they are to be painted, and a reasonable drying-out period is required. Painting methods are similar as for lime plasters except that an alkali-resisting primer is not needed: cement paints cannot be used on calcium sulphate plasters. Lime is sometimes incorporated with calcium sulphate plasters, the procedure is then the same as for lime plasters.

Concrete surfaces and cement renderings.—These are alkaline and so oil paints cannot be used if the surfaces are damp; such paints are compatible if an alkali-resisting primer is used and the surface is dry. Cement paints and bituminous emulsion paints are satisfactory.

Brickwork.—Painting is not a good finish for brickwork but is sometimes done to improve waterproofing or the reflection of light; like all painted surfaces, once done, it requires continual maintenance. Efflorescence and damage by sulphates are common dangers; alkaline attack may also occur. An adequate drying-out period is necessary; cement paints provide the best results particularly for external walls; bituminous emulsion paints are reasonably satisfactory; a more recent method is to apply a colourless silicone solution if a cure for

[1] Newly galvanized surfaces must not be painted immediately unless they are first treated with a mordant solution to neutralize the zinc in the galvanizing, to improve adherence and to give a phosphate coating. Alternatively they can be painted in the normal way if first allowed to weather for six months.

[2] Red lead is an oxide of lead having good corrosion inhibiting qualities; it should not be confused with red oxide (oxide of iron) which does not have this quality but is inexpensive and often used for undercoats on steel.

[1] The different kinds of plastering are described in Vol. I.

[2] The presence of alkalinity as given by lime can be ascertained by applying wet red litmus paper to the wall surface which will turn blue if the plaster is alkaline.

dampness only is required. Oil paints can be used inside.

Stone masonry.—Old masonry is sometimes painted for decoration or waterproofing or to prevent decay. Oil paints can be used externally (with an alkali-resisting primer); distempers can be used internally; regular maintenance is important.

Building boards.—Asbestos-cement boards require a paint specially made for the purpose; the primer must be alkali-resisting.

Soft fibreboards are treated as wood but flat paints are recommended; emulsion paint can be used; if a gloss finish is desired then additional undercoats are required because these boards are very absorbent; if moisture is likely to arise, the edges and backs of the boards should be painted; fixing nails should be galvanized. Hardboards can be painted like wood; oil and alkyd resin paints give the best results; some hardboards contain oil in the surface and therefore require a special primer.

Wood-wool slabs should be sprayed (see below) with distemper or flat oil paint (with an alkali-resisting primer).

Painting Technique. *By brush.*—Having correctly prepared the surface and using a good quality brush (hog's hair bristle is considered to give the best results), the tip of the brush is dipped in the paint and the excess removed by drawing it against the edge of the tin. Working from right to left a narrow strip of the work is covered with vertical brush strokes, the area is then " crossed " (*i.e.*, brushed laterally to ensure even distribution of the paint). The surface is then finally " laid-off " (*i.e.*, lightly brushed vertically once more). A strip must be joined to its neighbour as soon as possible and the work so arranged that the surface is finished without interruption. Mouldings require careful attention; adjacent painted surfaces such as at the edge of a door should be finally laid off down the angle to disperse the bead of paint which accrues at this place.

Spray Painting is an alternative technique essential for cellulose paints. Simple spray equipment comprises a motor and fan giving a current of air delivered by tube to a container and spray gun. The gun has a nozzle from which the paint is forced in a fine spray when a trigger is depressed. An air compressor is used in larger equipment.

Painting by spray is quicker for large areas than brushing; it also uses less paint for this has to be thinner; it is not recommended for the application of primers (except for cellulose ones) because priming by brush gives better penetration and adhesion.

Spray painting demands the use of masking paper or other material to protect surfaces from paint which are adjacent to those being decorated.

Painting Defects.[1]—*Bleeding.*—This is a disruption and staining of the painted surface by chemical action; it happens when an incorrect paint is applied over another such as bituminous one; the remedy is to remove the old paint and renew with a like one.

Blistering is a common failure caused by poor adhesion or by resin or moisture pushing off the paint; it is prevented by having a dry background, proper priming and removal of very resinous knots.

Blooming is the mistiness which can appear on varnished or highly glossed surfaces; it is due to the presence of moisture, draughts or frost during application or condensation on newly painted areas; painting should not be carried out if these conditions prevail. The remedy is to repaint.

Brush marks may be due to the paint being too stiff, by poor workmanship or by brushing over paint which has partially set. They are removed by rubbing down with waterproof abrasive followed by repainting.

Chalking is the powdering of a paint film usually on exposed outside surfaces; it is a sign that repainting is necessary and may be due to poor quality paint.

Cissing is the shrinking of a paint film usually in quite small, but sometimes large, areas; it is often due to a greasy undercoat or lack of key between coats—repainting is the cure.

Cracking, crazing or checking starts as fine hair cracks and may turn to flaking. It can be due to lack of elasticity in the finishing coat (brittleness) or unequal elasticity between coats of a paint containing excessive driers or the use of a hard drying paint on a softer undercoat or insufficient drying time between coats of paint; the remedy is to repaint.

Crinkling, curtaining or sagging is due to incorrect application and excess of paint which forms " runs " on the surface, the remedy is to rub down and start again.

Flaking or peeling due to poor adhesion or presence of moisture during painting or the ingress of moisture at timber joints or brittleness in the paint film or inadequate cleaning and preparation; the defective areas must be redone.

Flashing is an uneven finish manifested by glossy streaks showing on a matt painted surface; it may be due to a poor type of paint or uneven application.

Grinning is the insufficient obscuration of an undercoat by a finishing coat; it may be due to lack of opacity in the finishing coat or an incorrect undercoat colour.

Lack of opacity or body is attributable to a shortage of pigments in the paint or over-thinning or inadequate stirring of the paint.

Lifting is the disruption of a coat by the application of a subsequent one; it can be caused when a paint containing cellulose thinners is laid on another type of paint or because the drying period between coats has been too short.

Pin-holes are caused by air bubbles when a paint covers small cavities; the bubbles burst to leave small craters; the surfaces should be level to prevent this defect.

Saponification is the formation of soap caused by damp alkalis in a wall attacking the paint; the paint is destroyed and a sticky brown liquid appears.

Slow-drying. Alkyd resin paints dry more quickly than oil paints. Slow-drying may be the result of painting during damp weather or on a greasy surface or on an unhardened undercoat.

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[1] Many defects on painted surfaces are due to efflorescence from the background—see Chap. 1, Vol. II.

HOMEWORK PROGRAMME

THIS programme continues and completes that begun in Vol. II.

Joinery details should be drawn preferably to full size. This is possible in most cases if the details are broken. Finished sizes and not nominal sizes should be indicated, the usual allowance for *each* dressed surface being 1·7 mm and 0·8 mm for planing and sandpapering respectively (see Chap. IV Vol. I).

Sheet Number. Number of Lectures per Session. 24	25	26	27	Subject of Drawing.	Reading (Pages).
13	13	13	14	FLOORS.—(*a*) Draw one-fifth full size details A, B and C, Fig. 8, and portions of sections at B and C, Fig. 9 sufficient to show the application of floor clips. (*b*) Sketch details at H, J, K and L, Fig. 10.	1-6, 30–43.
	14	14	15	PARTITION.—Draw 1:20 scale elevation A and one fifth full size details at B, C, D, E, F, J and K, Fig. 11.	6-13, 43–51.
14	15	15	16	SOUND INSULATION.—Draw 1:10 scale details at B, C, D, E, F and L, Fig. 15.	51–60.
15	16	16	17	DOUBLE ROOF.—Draw 1:20 scale elevation A and 1:10 scale details at D, E and F, Fig. 16.	60–64.
16	17	17	18	TEMPORARY TIMBERING.—(*a*) Draw, to 1:20 scale, cross and part longitudinal sections through a 1·2 m wide and 3 m deep trench; assume 1 m depth of hard ground overlying a 1 m thick stratum of loamy soil, below which the soil is loose; show the application of middling and tucking boards (see Fig. 21). (*b*) Draw to 1:10 scale, centre J and K, Fig. 22.	65–70.
17	18	18	19	DOOR.—Draw: (*a*) 1:20 scale elevation A and plan C, Fig. 25; (*b*) full-size details at K, L, M and P, Fig. 25 and R, Fig. 26. *OR* (*a*) Draw 1:20 scale elevation A, section B and plan C, Fig. 27, together with full-size details at G and H. (*b*) Sketch the hammer-headed key joint at F, Fig. 27.	78–81.
18	19	19	20	DOORS.—Draw: (*a*) 1:20 scale elevation C and full-size details at N and P (showing a 100 mm by 38 mm stile), Fig. 28; (*b*) 1:20 scale elevation A and full-size details at F and H, Fig. 29.	81–86.
19	20	20	21	METAL WINDOW.—Draw 1:10 scale elevation N, Fig. 34, together with full-size details at P, A′, B′ and C′.	91–95.
20	21	21	22	STRAIGHT FLIGHT STAIR.—Draw 1:10 scale plan D and section C, Fig. 37, together with full-size details at F, G and H.	97-105.
21	22	22	23	DOG-LEG STAIR.—Draw: (*a*) 1:20 scale plan D and section C, Fig. 39, amended to include the solid balustrade shown in Fig. 42; (*b*) full-size details at H, J, D and F, Fig. 42, and either detail at E, Fig. 42, or at F (including margin fillets), Fig. 39.	107–113.
			24	OPEN WELL STAIR.—Draw: (*a*) 1:20 scale plan E and section C, Fig. 43; (*b*) half full-size details at J and M, Fig. 43, and at E and G, Fig. 41.	113–114.
22	23	23	25	PLAIN TILING.—(*a*) Draw one-fifth full-size details at A and C, Fig. 48. (*b*) Sketch details at A, J and O, Fig. 49.	123–129.
23	24	24	26	PANTILING, SPANISH TILING AND ASBESTOS-CEMENT SHEETING.—Draw one-fifth full size details at F (right side) and L, Fig. 51, H, Fig. 52, T, Fig. 53, and M and N, Fig. 54.	130–140.
24	25	25	27	COPPER AND ZINC ROOFING.[1]—Draw full-size details A, B, C, D, M, O and P, Fig. 58.	146–150.
		26	28[2]	VERTICAL TILING.—Draw: (*a*) To a scale of 1 m to 100 m, elevation A, Fig. 50; (*b*) one-fifth full size details at L, M and Q (showing reversed under eaves course), Fig. 50; (*c*) one fifth scale details at H, K, O, P and S, Fig. 50.	129–130.

[1] In lieu of this, preference may be given to a sheet on windows concerned with either Fig. 31 or Fig. 33.
[2] If length of session permits.

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