PRODUCTION OF PREFABRICATED WOODEN HOUSES

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

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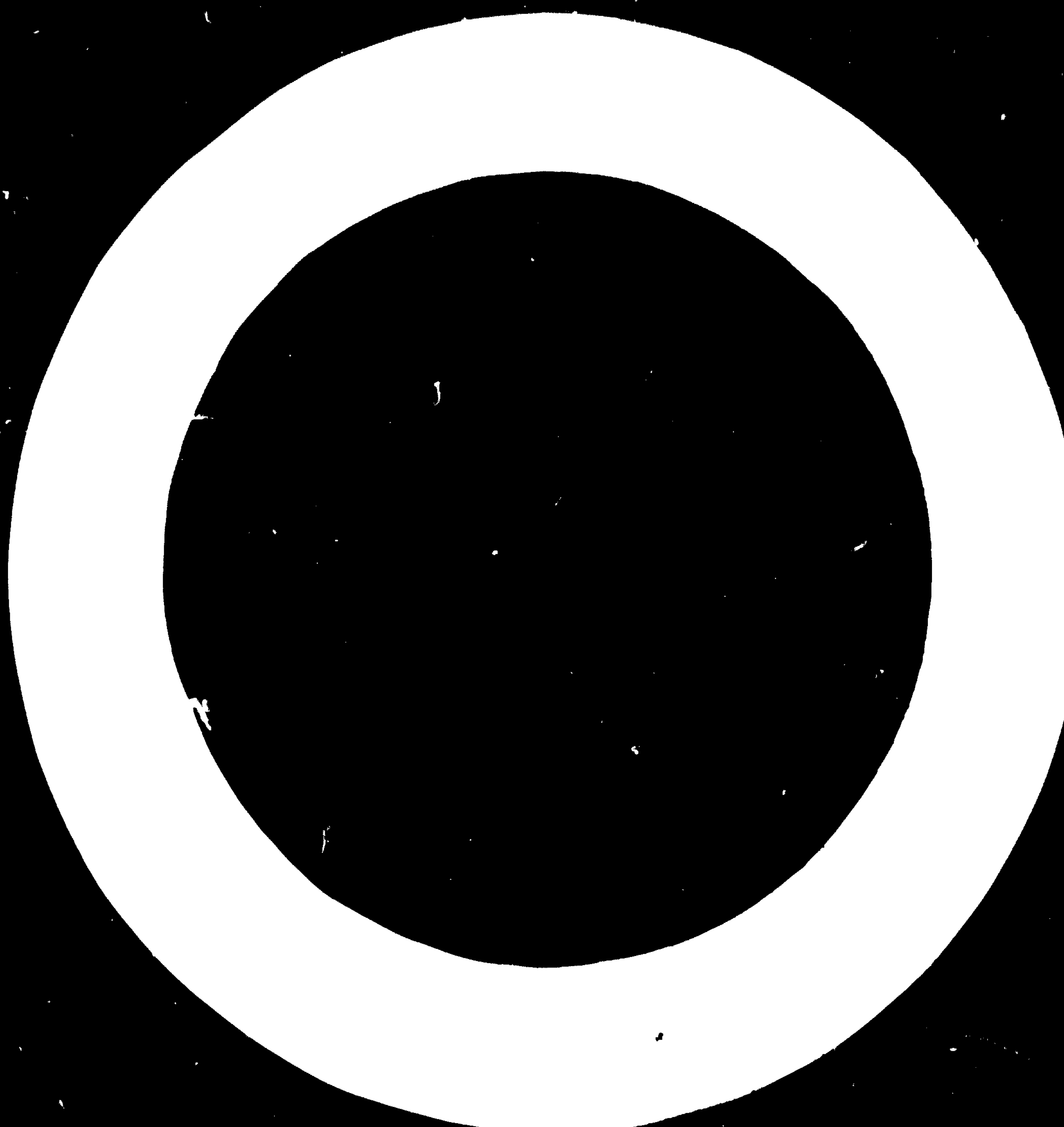
Preface

This paper was prepared by Keijo N. E. Tiusanen, Director of Product Development, Oy Wilhelm Schauman AB, Jyväskylä, Finland (formerly, Director, Research and Development Department, Puutalo Sales Association for Prefabricated Houses, Helsinki, Finland) as a consultant to UNIDO, and presented by the author to the Study Group of Production Techniques for Use of Wood in Housing Under Conditions Prevailing in Developing Countries, which met in Vienna in November 1969.

The meeting was convened by UNIDO in collaboration with FAO and the United Nations Centre for Housing, Building and Planning. It was the first meeting to be arranged by UNIDO on the subject of wood processing industries.[1/]

1/ The report of the meeting has been published under the symbol ID/10 (United Nations publication, Sales No.: 70.II.B.32).



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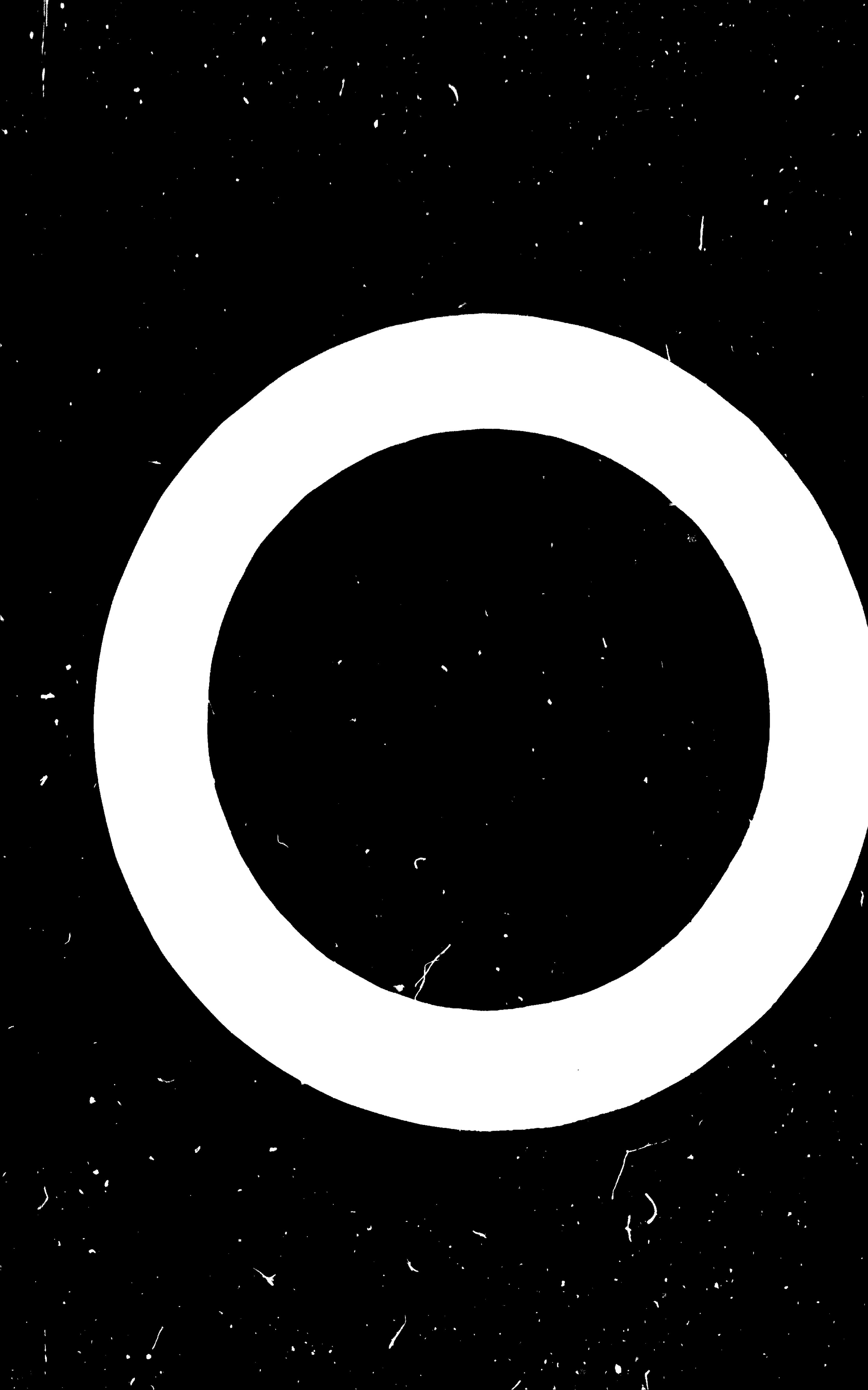


INTRODUCTION

This study is concerned with some of the problems involved in the planning and production of prefabricated wooden houses, a subject about which little has been published. The material and concepts presented in this paper are based on information obtained from manufacturers of prefabricated wooden houses and on the general experience of the Puutalo Sales Association for Prefabricated Houses of Finland. An attempt has been made to present the particular problems of production in tropical countries, but this aspect has not been considered in detail.

The percentage of annual production of new dwellings in most European countries is equal to less than 1 per cent of their population, according to the Annual Bulletin of Housing and Building Statistics published by the Economic Commission for Europe (see table 1). The average usable floor area of new dwellings in the countries considered varies considerably - from less than 50 square metres in eastern European countries to approximately 100 square metres in certain countries of Central Europe. The average usable floor area in some parts of the United States is as much as 150 square metres for new dwellings.

Because of its excellent thermal insulation properties and availability, wood is commonly used for housing in the northern countries of the temperate zones of the world, while in countries to the south, where the climate is warmer, stone gradually replaces wood. Wood is commonly used to build row houses; small, single houses of one or two storeys; and in the interiors of dwellings of more than two storeys it is used for floors, stairs, partitions and the like.

Prefabricated wooden houses have been manufactured in Scandinavia since the early 1920s, but the industry did not gain importance until after the Second World War. At this time the increased production of mineral wool permitted the manufacture of wooden building panels constructed with light thermal insulation, which, in turn, boosted the production of prefabricated houses.

Table 1

Housing statistics for Europe, the United States and selected European countries

	Population (thousands)	New dwellings, 1969: Dwellings (thousands)	New dwellings, 1969: Per 100 inhabitants	New dwellings, 1969: Average usable floor area (m² per dwelling)	Dwellings with wood frame (per cent of total): 1959	Dwellings with wood frame (per cent of total): 1969	1- or 2-family dwellings (per cent of total): 1958	1- or 2-family dwellings (per cent of total): 1969	Prefabricated wooden houses (per cent of 1- or 2-family dwelling houses): 1967
Europe (total, ECE)	731,409	5,626.5[a]	0.77[a]	...	...	...	...	...	...
Denmark	4,910[b]	49.7	1.01	107.7	...	...	51.0	59.2	...
Fed. Rep. of Germany	58,707	499.7	0.82	82.1[c]	...	...	46.8	43.7	...
Finland	4,703	36.78[a]	0.78[a]	66.9[a]	45.3	24.3[a]	30.0	35.6[a]	10[d]
France	50,330	426.0	0.85	76.5	...	0.1[e]	31.0	37.5	...
Netherlands	12,873	123.1	0.95	69	...	1[e]	57.0	71	...
Norway	3,851	33.0	0.86	86.0[c]	64.6	64.6[c]	66.7	67.8[c]	...
Poland	32,555	197.0	0.61	52.7	...	...	...	28.0	...
Sweden	7,978[b]	109.0	1.37	79.0	...	10.0[f]	27.9	31.3[a]	52[d]
USSR	240,600	2,250.0	0.94	45.5	...	...	...	...	...
United Kingdom	55,534	378.3	0.69	...	...	9.2	65.0	71.3	...
USA	203,216	1,321.9[f]	0.67[f]	150.0[f]	...	75 [f/d]	84.0[g]	67.6[f]	...

Sources: ECE: Annual Bulletin of Housing and Building Statistics for Europe 1969
United States Savings and Loan League: Savings and Fact Book

a/ 1966
b/ ECE Secretariat estimate
c/ 1968
d/ Author's estimate
e/ 1963
f/ 1967
g/ 1959
... Not available

PREFABRICATED SYSTEMS

Prefabricated wooden houses constitute a large percentage of present-day housing in Sweden, making this country a leader in the field of housing developments composed of small houses built on a turn-key basis. In Finland, however, prefabricated wooden houses represent only a small percentage of present-day housing. Small, single dwellings can still be built individually on a profitable basis only because small entrepreneurs make use of timber in falling lengths,[2] which is cheaper than timber in fixed lengths.

The Puutalo Sales Association has gained its widespread reputation not from the sale of prefabricated houses in Finland, but rather from its export of prefabricated houses throughout the world. With the rising standard of living in Finland, the skill of building houses individually without professional assistance will diminish and the production of prefabricated wooden houses will increase.

PRE-CUT

The pre-cut method is probably the oldest method of prefabrication. Sawn goods and building boards are cut to specified lengths and notched at the factory, marked with the identification numbers indicated on the construction drawings, bundled into units and delivered to the building site. When the foundation slab of the building is ready, external walls can be assembled almost horizontally on the slab, raised into place, and then connected together; or they can be assembled vertically in their permanent position.

Roofs can be self-supporting (roof trusses supported only by the external walls) if special trusses have been constructed according to specification at the factory. Some partition walls can be made as load-carrying walls thus permiting roof constructions of lighter design.

2/ Falling lengths - sawn wood of a given cross section and grade whose length is no. fixed but falls within certain limitations (not less than an agreed upon figure, increasing in established increments).

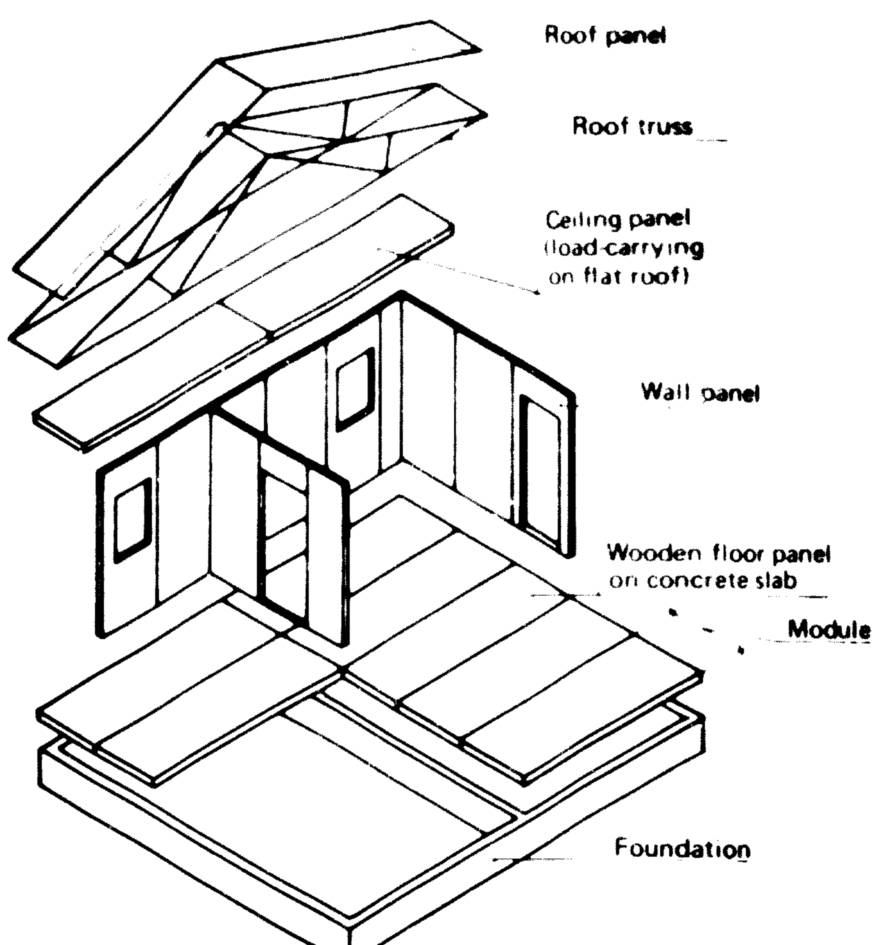
The pre-cut construction method, as compared with construction using timber in falling lengths at the building site, offers exactitude of measurement and considerable saving of raw material because the timber that remains is used profitably after the desired lengths have been cut from it, whereas waste often occurs when cutting is done at the building site.

As pre-cut timber requires less space for delivery than prefabricated panels, the pre-cut method is popular for intercontinental deliveries. In the United States and in other highly developed countries the pre-cut method is not considered industrialized enough to be profitable; therefore the method is not even included in prefabrication housing statistics.

MODULAR PANEL SYSTEM

Building components made for the modular panel system are so constructed that they can be handled by two men without the use of cranes or other lifting devices (see figure 1). External wall panels constructed under the modular panel system are made in uniform sizes using a module ("M") as a unit of measure.

Figure 1. Modular panel system



For wooden elements the minimum size is usually 3M, i.e., 30 cm; a normal panel is then 12M or 120 cm. Partition walls are also made in panels or pre-cut components in order to facilitate electric installations. Floor, ceiling and roof construction elements are delivered to building sites in falling lengths or as modular panels. Under the modular panel system, a concrete foundation is laid and on it sleepers, thermal insulations and floor boards are constructed.

Architects familiar with the system can design a wide variety of houses with many different floor plans using modular panels. Such panels can be prefabricated by a highly mechanized procedure and kept in stock by manufacturers. The system, however, is not a practical one to use for large building operations because small components can be easily lost at the building site, causing delays in construction. The modular panel system is widely used in Finland because of the popularity of building houses individually. Since the end of the Second World War, some 10,000 dwellings made by the modular panel system have been delivered annually to the Union of Soviet Socialist Republics.

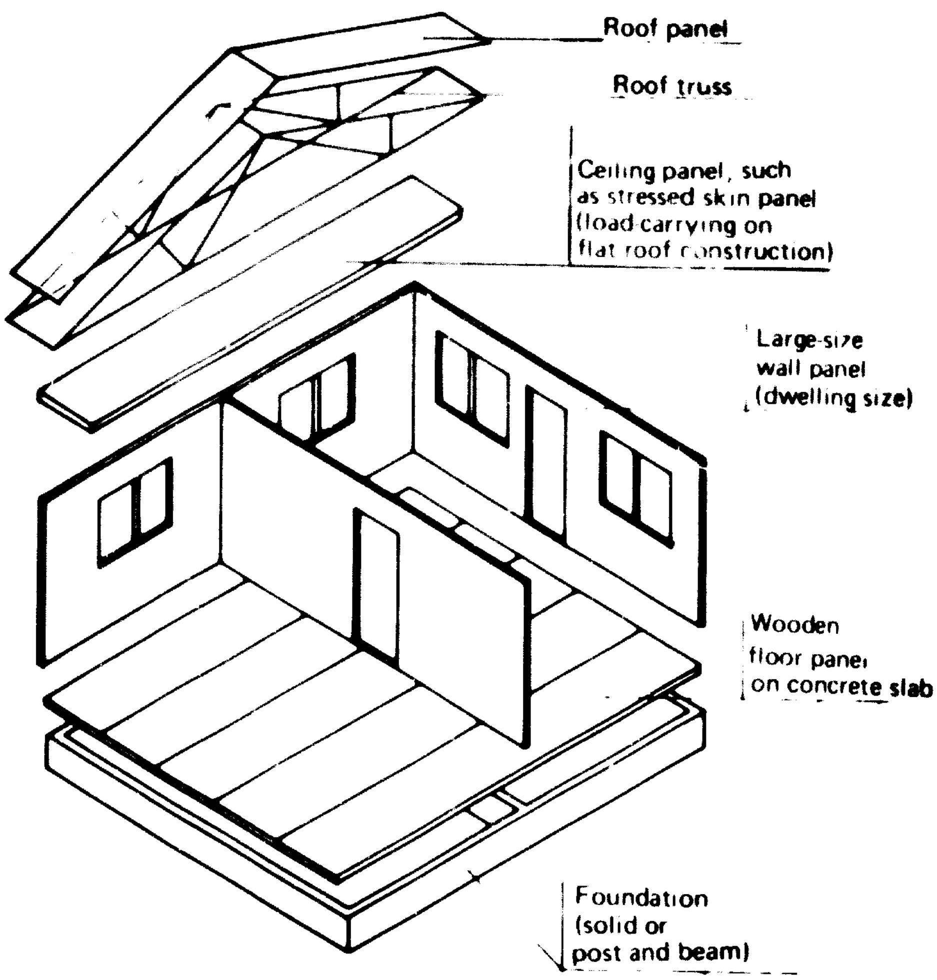
LARGE-SIZE PANEL SYSTEM

At the present time the large-size panel system (see figure [illegible]) is used most frequently to construct a large number of small houses at the same time. Under this system, owing to the lightness of wood, external wall panels can be made the length of an average dwelling - 11 to 1[illegible] metres - and weighing under 1,000 kg. Floors made of either wooden panels or a concrete slab are used, and partition walls and roofs are made of prefabricated large-size panels.

In Scandinavia two types of large-size panel system are being used successfully. In one system used to construct row houses, concrete foundations are laid and on these are assembled the large-size panels for external walls and for party walls. As roofs constructed of stressed skin panels with a span the size of each dwelling are used, the houses are quickly under a waterproof roof. Once the roof is on, concrete slabs can be laid and interior partitions built. Units of row houses with four to six dwellings can be erected in one eight-hour day by a team of four men.

Using another system, floors are constructed from large-size wooden panels set on foundation beams. These beams, and not a concrete slab, support the external and partition-wall panels and the roof. Although more prefabrication is involved in this system, erection takes more time and requires more favourable climatic conditions than those of the other system. In the United States almost all prefabricated houses are made of large-size panels, but thermal insulation, electric wiring, and finishing of interior walls (usually with gypsum board) are normally completed on the building site.

Figure 2. Large-size panel system



The large-size panel system is especially suitable for building operations where cranes are available. With the exception of some mouldings, no small components are used so there is no danger of their being lost. Prefabricated panels made from gypsum board are transported vertically from the factory with glazed windows already installed and external walls painted. As one of the biggest problems in the use of prefabricated panels is joining them satisfactorily at the building site, the use of large-size panels reduces the joining problem to a minimum.

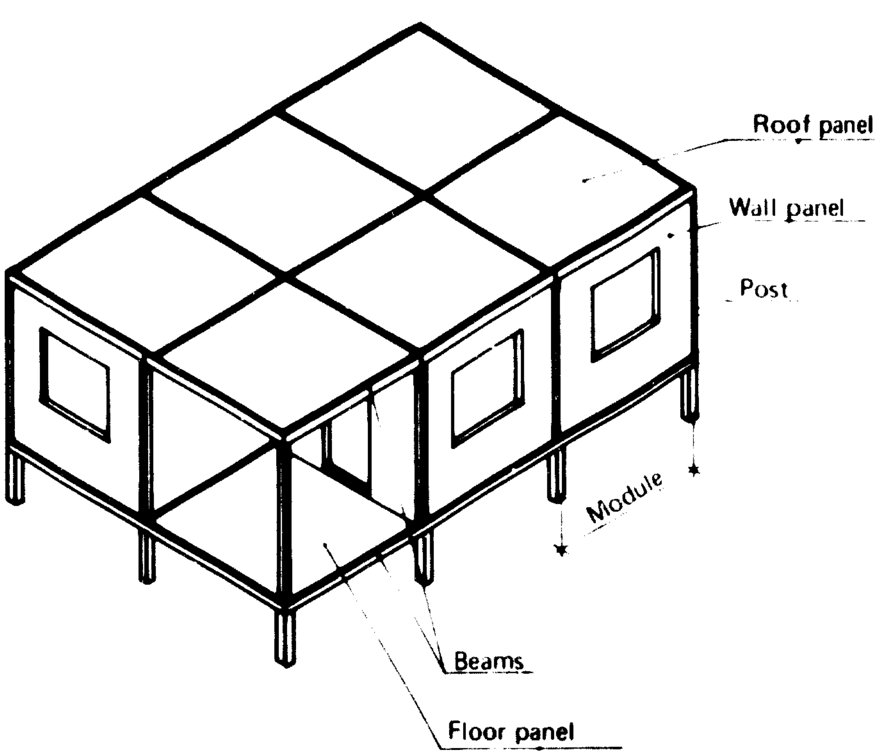
When a large production series is involved, architects need not depend solely on conventional-size modules but may take certain liberties in their designs. The use of standard-size building boards, however, does avoid waste. In this system the number of joints to be tightened has been reduced to a minimum.

POST-BEAM PANEL SYSTEM

At the moment, the most common and most economical external wall construction is not the post-beam panel but rather one made by attaching building boards to both sides of a 2 in x 4 in frame structure insulated with mineral wool. When studs are erected 50-60 cm apart, these walls can withstand the heaviest snows and most severe wind loads, such as occur in Scandinavia, without needing special posts as reinforcement.

For aesthetic and structural reasons, however, both the post-beam panel system (see figure 3) and the modular panel system are also being used at present and only time will tell which system proves to be more favourable. If the wall panels used in the post-beam system could be mass-produced in a sandwich construction at a lower cost than the above-mentioned frame construction, this method could be developed for large building operations. Unfortunately the details of this method of construction are not dealt with in this study.

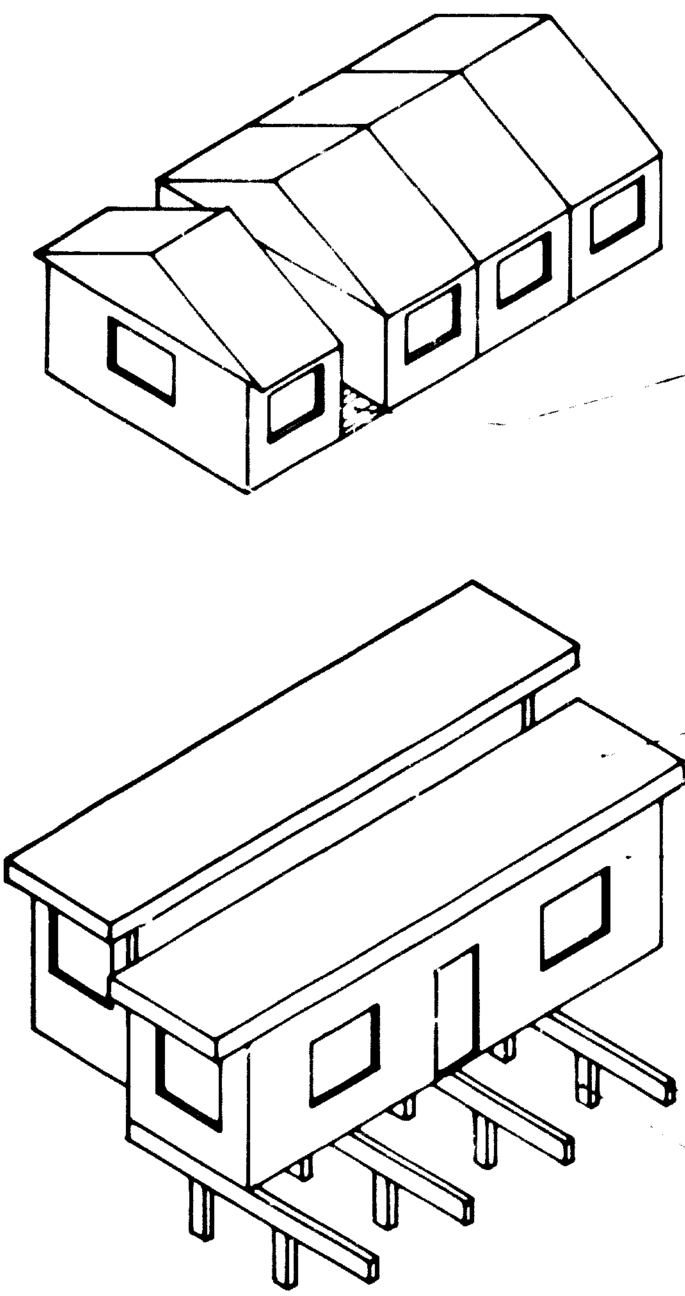
Figure 3. Post-beam panel system



VOLUME ELEMENT SYSTEM

In the volume element system (see figure 4) of prefabricated housing, dwellings are completely finished at the factory; building of foundations and installation of utilities is the only work done at the building site. In the United States the production of automobile trailers has developed into the manufacture of complete mobile homes; in 1969 more than 400,000 such units were produced. A double-width mobile dwelling that resembles a normal house is now in production. In Europe, however, such volume elements have usually been manufactured only for schools, hospitals, barracks and the like, but recently houses have also been manufactured by this method.

Figure 4. Volume element system



Floor areas of volume elements may vary from ten square metres to 50 square metres. Using this system, dwellings are completed at the factory to such an extent that the cost of work at the building site now represents only 20 per cent of the total price of each house.

Volume element housing permits a home buyer to see exactly what his house will look like before it is built. After the foundation has been laid, a house can be erected in a matter of days at any time of the year in most climates. The period of financing during construction is brief. Because of high freight costs and limited possibilities to sell large numbers of identical houses in Europe, the volume element system has not reached a stage of profitable mass production.

It is possible to combine the above-mentioned systems in one house. Architects have been working on plans for some time that would permit the post-beam construction of frames of steel or concrete to be fitted successfully with factory-finished volume-produced elements. Factors influencing such construction will be considered later in this paper.

PLANNING

Before a choice of prefabricated building system is made, the construction methods mentioned earlier should be considered carefully. Among the various factors affecting the choice of systems are: raw materials available, production capacity, transportation and erection facilities, planned output, architectural requirements, purpose of the building, climatic conditions and building regulations.

If both sawn wood and wood-based building boards are available, suitable combinations can be considered according to cost and quality requirements. If sturdy building panels such as those made of plywood are not available, the volume element system is impractical for large-scale operations. If particle board or hardboard are forbidden for use under continual stress conditions, stressed skin panel roofs and floors cannot be used.

The size of the working area of the factory, the types of machinery and cranes available, and the capacity of loading facilities all affect the choice of construction method to be employed. A basic machinery department with electric saws, planes, tenoners and the like for sawn wood and building boards is normally required for all methods. Pre-cut frames and modular building boards can be assembled into modular panels by hand on simple work benches in a comparatively small area. As the weight of a large panel is about one ton, a crane and considerable space are needed in a factory to move such a panel. An assembly room for volume elements, however, needs even more space.

The roofs used in volume element construction are delivered in completed units and can be stacked in the open air, provided that the joining elements are well protected. Interior finishing work, such as painting, can be done if some form of temporary heating is provided.

Pre-cut construction material delivered in "package" form requires a minimum of space in transport and modular panels can be delivered by any ordinary means. Large, prefabricated building panels and volume elements must be transported on specially designed vehicles. If delivered by ordinary means of transport, the shipments would be too high for bridges and highway underpasses.

The modular panel system of manufacture provides year-round employment, but construction of houses on an individual basis, and erection of their modules are exposed to seasonal delays. The use of large-size panels and volume element construction overcomes these delays if used on large building operations, as these units can be produced in the factory on schedule and delivered precisely as needed to the building site. The modular panel and volume element systems are the most restrictive for architects whereas the large-size panel system permits architects more freedom of design.

The intended use of a building affects the choice of system used to construct it. If the building is constructed for temporary use in one location and is to be relocated later, a small-volume element system is considered the most practical. If the climate at the building site is very rainy, the building has to be assembled and the roof put on as soon as possible as the stocking of wooden components on a wet building site is impractical. For wet climates, either the large-size panel or the volume element system is recommended.

In many countries regulations control the height of buildings, the foundation construction, the nature of the façade, and the standards for joining elements of structures together. Such regulations influence the choice of construction method. One of the most important factors in completing prefabricated buildings successfully is the use of a satisfactory method of joining panels on the site. In cold countries precise joining of panels is a protection against wind, cold and rain, and in hot climates it protects against heat, insects, sandstorms and rain. The number of joints to be connected should always be kept to a minimum - a factor to consider when choosing a building system.

SPECIFYING

Wooden houses are basically designed and built as single dwellings or as row houses. Recently low priced row houses have become popular wherever the cost of land is high because each owner has a garden area of his own. Row houses are constructed with the fullest utilization of the building site and operational costs are kept at a minimum because utilities, heating and air-conditioning are communal.

In many developed countries the financing of large housing projects is under the direct or indirect supervision of government institutions. Strict building regulations govern the placement of a house on the plot of ground, the size of rooms of the house, quality of materials used and many other pertinent factors affecting construction. These factors must all be taken into account in drawing up specifications.

The standards of living and dwelling habits of a country greatly influence building specifications. In tropical countries, for example, a wide roof and broad eaves provide the best and cheapest shelter against torrential rains and the burning rays of the sun. To change these design features by introducing a completely different roof or eaves concept is extremely difficult in the tropics.

When the factors mentioned above have all been given careful consideration, the architect draws plans to a scale of 1:100 including floor plans, elevations and sections, and makes detailed drawings to a scale of 1:50.

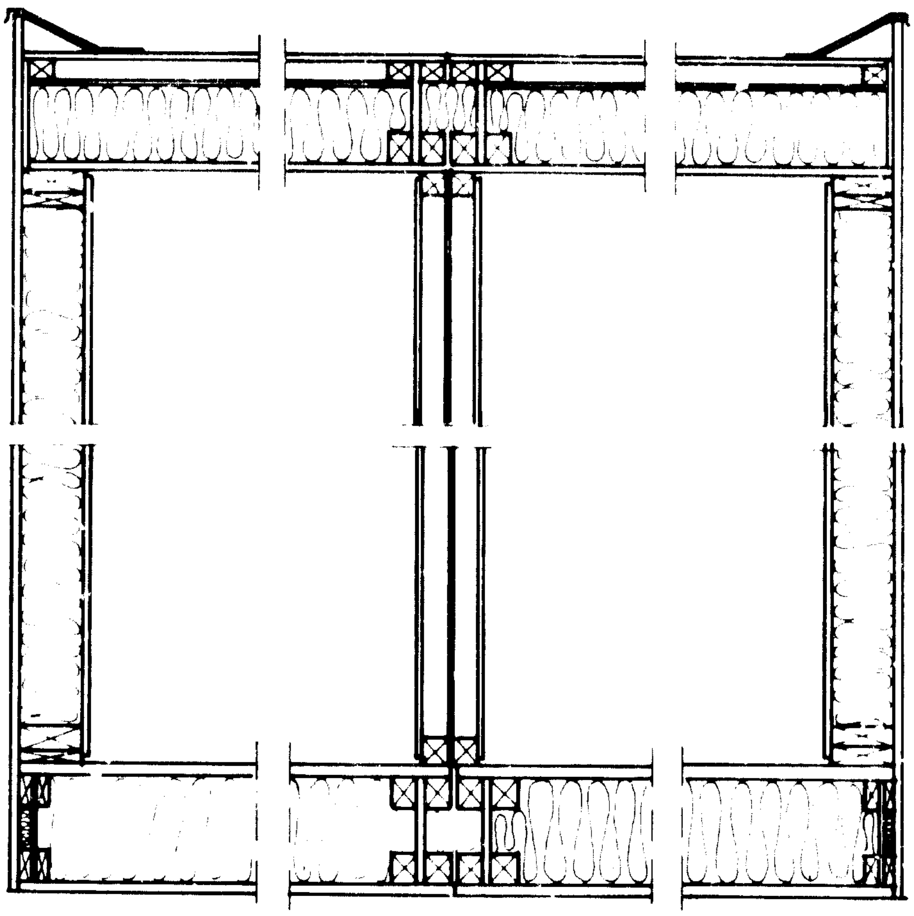
PLANNING, CONSTRUCTION, ELECTRICITY, HEATING AND PLUMBING

After completion of the architect's plans and detailed drawings, building technicians make their detailed drawings of components and panels. Calculations for load-bearing factors are figured at this time taking into consideration standards set for loads and stresses. Many countries set such standards as a protection against the elements as well as for assuring the construction of a dwelling safe for normal living. In certain areas of the tropics, wind loads play a dominating role. Engineers usually estimate the dead weight of construction fairly accurately, but sometimes the dead weight is found to be higher than estimated and calculations must be redone.

The strength of many species of wood from all over the world has been tested and results published indicating maximum permissible loads determined on the basis of these tests. Wood-based building boards have also been tested and only plywood has been found to be suitable for use in the construction of load-bearing members because other building boards lose their strength when placed under continual load.

In designing components and panels, building technicians must take into consideration the hazard of fire that may occur depending on the intended use of the building. If a fire hazard is forseeable, gypsum board or brick is prescribed. The problem of sound-proofing is one that must be solved by the architect, particularly in designing party walls between dwellings and partition walls within dwellings. In addition to thermal insulation, designers must consider insulation against vapour, which normally seeps from a warm area to a cold area, and must make provision for ventilation to prevent rot; for construction details, see figures 5 and 6.

Figure 5. Construction and thermal insulation in a volume element



Materials from warm side to cold side:

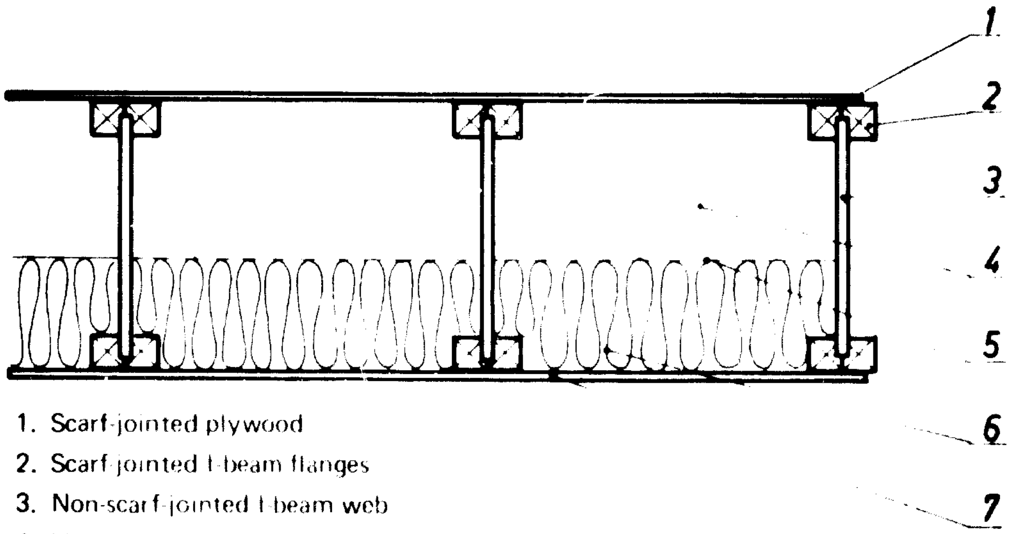
Floor
- vinyl, parquet or carpet flooring
- 15 mm plywood or 22 mm chipboard, screw glued
- floor beams cc 50 - 60 cm and mineral wool insulation
- 4 mm plywood, nailed

Wall
- 6.5 mm plywood, nail-glued, painted or wallpapered
- frame and mineral wool insulation
- 3 mm fibre board
- vertical boarding with open seams

Flat roof
- 6.5 mm plywood, nailed, painted
- roof beams and mineral wool insulation
- 3 mm fibre board
- 5 cm ventilation, 2 in x 2 in ribs cc 50 cm
- 9 cm plywood
- roofing mat

Partition walls
- 6.5 mm plywood on both sides of the frame or honeycomb core

Figure 6. Insulation in stressed skin panel construction



1. Scarf-jointed plywood
2. Scarf-jointed I-beam flanges
3. Non-scarf-jointed I-beam web
4. Ventilation space
5. Building paper or building board
6. Thermal insulation
7. Scarf-jointed plywood

Plans are drawn concurrently for the systems of heating, air-conditioning and ventilation; plumbing; and electric wiring and installations. These are made on the detailed drawings of 1:50 scale. The architect takes into consideration the above systems in drawing up his plans and adjusts them in accordance with the most functional installation of these systems.

Because all information cannot be shown on plans or drawings, the architect submits a written description of the structure he has designed, and detailed written specifications are drawn up by specialists in plumbing; heating, air-conditioning and ventilation; electric installations and painting. The type of prefabrication system chosen for the dwelling will determine the nature and method of installation for each of the above-mentioned. With the use of the pre-cut method, normal installations of utilities can be made on the building site.

With the use of the modular panel system, a number of modifications of normal installation procedures must be made. If installations are built into small panels at the factory, there are too many joints to be connected at the building site.

When a concrete floor is laid, pipes can be installed directly in the concrete. When panels are used as flooring, one end of the construction is left open so that pipes may be run in at the building site. In row-house construction, thermal insulated canals can be built parallel to the houses below the floor level. From this main installation, branches are brought into each dwelling as needed under the floor panels.

In sloped roof houses electric wiring that is strung horizontally can be installed in ceiling constructions at the building site. In flat-roof houses such lines can be installed with the aid of curtain boards. The installation of vertical wiring in prefabricated modular wall panels, however, presents a problem of manufacturing and stocking a sufficient variety of all of the various kinds of external and partition wall panels each installed with electric wiring. Partition walls, therefore, are delivered as pre-cut units. One possible solution to the wiring problem, still to be developed successfully, is the use of hollow, plastic baseboard and door mouldings which act as pipes for the wiring. This method is feasible when the modular panel system is used.

If it is economically feasible to install individual units of electric heating, the work of installation is considerably reduced as a heating circuit is not required and the house can be made ready for occupancy in less time.

The installation problems for heating and plumbing are practically the same in the use of the large-size panel system and the modular panel system. Plastic pipes carrying electric wiring can be easily installed in wall panels at the building site because of the relatively few joints to be connected. In volume element construction installations may be easily synchronized with other assemblies at the factory if a practical simple method of coupling floors, walls and ceiling has been developed.

PREFABRICATED PANELS, COMPONENT LISTS AND ERECTION DESCRIPTIONS

If a small house is constructed of timber in falling lengths, a skilled carpenter is able to build it on the site following the architect's plans and certain detailed working drawings based on strength calculations. When wooden components and the panels to be assembled on them are manufactured at the factory, every unit must be designed separately and marked with an identification number. There may be more than 100 separate identifications involved in a medium-size, modular panel, one-family dwelling. Component and panel drawings are made according to exact calculations and designs. Certain tolerances are indicated on the drawings to facilitate the erection of the dwelling and to avoid making adjustments on site.

The following tolerances are permitted in the production of modular panels:

Dimensions of external walls	-2 mm
Dimensions of ceiling panels	±2 mm
Dimensions of roof trusses	±4 mm
Cutting, notching, tapering	±1 mm
Dimensions of planed components	+1 mm
Unfinished sawn components	-2 mm

When specifying production tolerances, possible variations in raw materials used, such as changes in the dimensions of wood that can occur from moisture content, should be taken into consideration. For example, wooden panels supported only at the ends warp because their warm side dries and shrinks. This phenomenon is especially harmful to floor panels supported at the ends. Warping caused by humidity can be solved by constructing floor panels as continual beams supported at many points.

Because of changes in the moisture content in wood-based building boards used for interior walls, butt joints should not be tightly fastened together, painted or decorated, because if they are the joints will open. Best results are obtained by leaving open joints between the boards. Various kinds of glass fibre cloth have been glued to building boards or gypsum board with satisfactory results, but this process increases the price of the finished panels.

The specifications indicating the various components and panels that have been designed to complete the house describe specifically items such as hardware that can be purchased ready-made. A loading specification is prepared indicating the precise order of arrival of these components at the building site. The list of components can be drawn up only after the choice has been made of finish hardware, accessories and other ready-made inputs.

Erection drawings and detailed instructions for the sequence to be followed at the building site must be issued by the designer. These drawings provide identification numbers for the positioning of panels.

Depending on the construction system used, the erection instructions will indicate methods for synchronizing electric wiring, heating and plumbing installations. The installation of air-conditioning systems, especially in tropical countries, requires special instructions for ducts, insulation and the like. These factors must be taken into consideration in the planning stage. An example of erection instructions for a modular panel house delivered to Scotland by Puutalo in 19[illegible] is given in annex 1.

The factory price of a house, as a percentage of its completion price, can be estimated roughly as follows depending on the production system used: modular panels: 15 to 40 per cent; large-size panels: 30 to 45 per cent; volume elements: 80 to 85 per cent.

The degree to which panels are completed before leaving the factory varies considerably. The quantity of timber and wooden building boards required to build a modular house with a floor area of 75 square metres is indicated in table 2.

It is difficult to give estimates of the various costs involved in prefabricated housing that would have universal application. If a factory manufacturing prefabricated houses is part of a large company that has its own saw mill and produces its own building board, the price of these components will be equivalent to the prevailing market price. The simplest pricing method is found when a factory functions primarily as an assembly plant purchasing its building materials as completely pre-cut as possible. Under this arrangement, costs could, for example, be estimated as follows:

<u>Direct costs</u>:			
Cost of building materials calculated according to plans and specifications:	$		
Direct wages (for assembly at site):	$		
Total direct costs:		$	
<u>Indirect costs</u>:			
Indirect wages (for mechanics, cleaners and the like) (... per cent of direct wages)	$		
Social benefits: (social security etc.) (... per cent of direct and indirect wages)	$		
Other indirect costs (power, water, service charges, etc.) (... per cent of direct wages)	$		
Total direct costs:		$	
<u>Overhead expenses</u>:			
Departmental overhead expenses (capital, amortization, insurance, salaries etc.)	$		
Company overhead expenses	$		
Total overhead expenses		$	
Total direct and indirect costs and overhead expenses			$ ....
Sales costs			$ ....
Profit			$ ....
Taxes			$ ....
Sales price ex works			$ ....

The management of a company can greatly influence its direct costs by purchasing material at a profit and through rationalization of assembly, but profit margins are controlled to a high degree by market prices.

Table 2

Quantity of timber and wooden building boards required to build a modular house with a floor area of 75 square metres

Components or groups of components		Building board m^2	Timber Std a/	Timber m^3	Timber Per cent of house
Floors			0.0801	0.3742	1.9
External walls		66	0.7062	3.2994	16.8
Partitions		120	0.0929	0.4340	2.2
Main roof			0.4128	1.9286	9.9
Ceiling			0.3325	1.5534	8.0
Windows and exterior doors, including mouldings			0.2635	1.2311	6.3
Partition doors			0.2235	1.0442	5.3
Cabinets			0.0396	0.1850	1.3
Separate roofs			0.0553	0.2584	1.3
Loose timber in falling lengths	Std a/		1.9651	9.1809	47.0
Weather-boarding	0.4758	2.2229			
Roof boarding	0.6633	3.0989			
Floor boarding	0.5089	2.3776			
Mouldings	0.0612	0.2859			
Planed timber	0.0569	0.2658			
Sawn timber	0.1990	0.9297			
Total			4.1715	19.4892	100

a/ [illegible] Standard (Petrograd) 165 ft^3 (4.672 m^3).

PRODUCTION

The location of a factory is frequently determined either by economic factors or by the labour available. In order to provide employment in a certain area of a country, frequently a government will assume complete responsibility for the establishment of an industry in the region, or will grant highly favourable conditions, such as tax exemption, to private industries.

If political influences are not the determining factor in the establishment of a factory, and its establishment can be made on a purely free enterprise basis, the main factors of influence in order of importance are: market for the product, transport facilities, raw materials and labour and power.

When the cost of all the prefabricated components has been determined, the price of the completely finished house can be estimated. This price is then compared with the general price level of housing in the area, and the radius of profitable transportation of the elements from the factory can be calculated. Truck transport is the most common method used for short hauls, whereas train or boat are employed most advantageously for long distances. The cost of raw materials as well as freight charges for delivery must be taken into account in planning.

Sawn wood is used as raw material for house construction almost everywhere, but building panels suitable for large-scale housing are not yet available in all parts of the world, a fact that should be given consideration when choosing a factory site.

The power needed to run a factory can be supplied by the local distributing company or the factory can build its own power plant. The amount of power required depends on the types of machines used. The machinery and electric power needed to run a factory with an annual production of 500 to 1,000 dwellings are indicated in table 3 below.

As skilled labour is not available in all areas, a factory may have to provide housing or provide opportunities for private building. Many factors must be considered in choosing a site, but in tropical countries skilled labour, raw materials and transportation usually present very difficult problems that must be solved before a factory can be suitably located.

Table 3

Machinery and electric power requirements needed to run a factory with an annual production of 500 to 1,000 dwellings

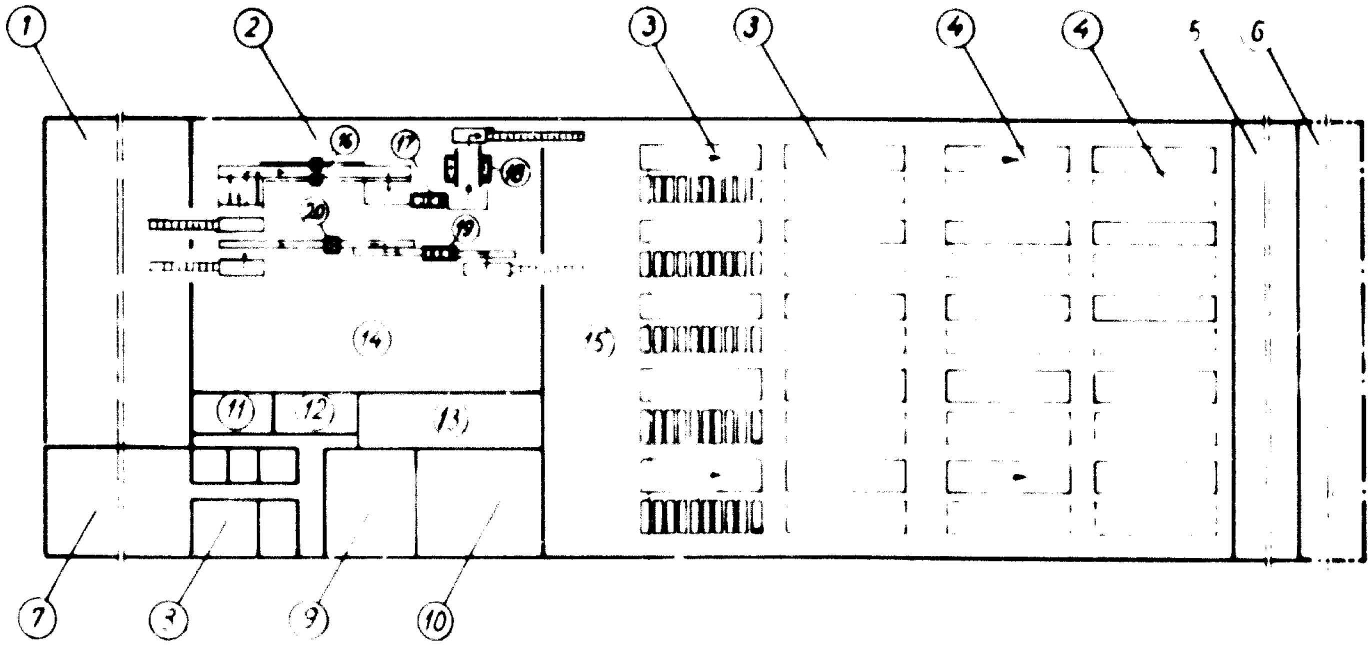
Activity	Units	kW
Transportation		
Fork lift truck, 7 tons	1	-
Overhead crane, 5 tons	4	40
Waste chip and dust transportation system	1	20
Machining (cutting, moulding, planing, etc.)		
Moulding planer with 5 heads	2	60
Cut-off saw	2	12
Double-end tenoner	1	40
Air compressor	1	80
Rip saw	1	16
Internal transportation systems) Transportation of timber) Unloading of timber)		60
Hand trucks for timber	4	-
Sharpening		
Circular sawblade sharpener	1	1
Plane edge sharpener	1	1
Cutter head sharpener	1	1
Grinder	1	1
Adjustment equipment	1	1
Repair shop for machinery		
Hand tools for machinery maintenance		-
Electric welding unit	1	10
Gas welding unit	1	-
Grinder	1	1
Portable grinder	1	1
Portable drill	2	2
Electric power required for machinery		350 kW
Electricity for illumination (40W per 10 m^2)		60 kW
Total electric power required		410 kW

Hand tools for assembly

Pneumatic hammers
Pneumatic screwdrivers
Pneumatic grinder
Pneumatic drill
Electric hand saw
Miscellaneous tools

The annual production of factories producing prefabricated houses can vary from several hundred houses to several thousand. To be considered as operating on a reasonably profitable basis, a factory should produce at least 500 dwellings per year, or two units in a working day. A typical layout of a factory producing 500 to 1,000 prefabricated wooden houses per year is given in figure 7. The personnel required to operate such a factory is listed in table 4.

Figure 7. Layout of a factory producing 500–1,000 prefabricated wooden houses annually



No.	*Department*	*Area (m²)*	*No.*	*Machinery*
1.	Storage for sawn goods	2,000	16	Cut off saw
2.	Machine (cutting, moulding, planing etc.)	900	17	Moulder
3.	Panel assembly	1,900	18	Double end tenoner
4.	Surface finishing	1,900	19	Moulder
5.	Storage for components	2,400	20	Rip saw
6.	Volume element assembly (also 5)	2,000		
7.	Office	600		
8.	Production offices	140		
9.	Machinery repairs	140		
10.	Storage for secondary raw materials	200		
11.	Sharpening	50		
12.	Electric installations	50		
13.	Pipe installations	150		
14.	Roof truss and beam production	400		
15.	Storage for building boards and joinery	500		
	Total floor area*	13,330		

*Plus: relaxation area, toilets, washing and dressing rooms, and cafeteria required by law according to number of employees.

Table 4

Personnel required for factory producing 500 to 1,000 prefabricated wooden houses annually

Position	Number	Qualification	Years of experience
Workers on monthly salary			
Chief foreman	1	Technician	5-10
Production planner	3	Technician	
Foreman	5	Technician	
Warehouse clerk	1		several years
Time clerk	2		
Office clerk	1		
Hourly wage earners			
Machining			
Wood-working machinist	3	Professional school	3-4
Wood-working machinist	3	Professional school	1-2
Assistant wood-working machinist	3		
Assembly			
Assembly worker	20	Professional school or 3-4 years experience only	1-2
Materials handler	8		
Overhead crane operator	2	Experienced	
Painter	5	Professional school	1-2
Electrician	4	Professional school	1-3
Plumber	4	Professional school	1-3
Inspector	2	Professional school	3-4
Repair shop			
Fitter (plant maintenance)	2	Professional school	2-4
Welder	1	Welding course plus experience	
Sharpening			
Saw-doctor	2	Sharpening course	1-2
Fitter	1	Professional school	4
Raw materials storage			
Foreman	1	Knowledge of timber	
Truck driver	1	Experienced	
Assistant truck driver	1	Experienced	
Truck loader	4		
Product storage			
Foreman	1		
Storage worker	8		
Crane operator	1		
Dispatching			
Dispatcher	1	Experienced	
Bookkeeper	1		
Assistant bookkeeper	4		
Secondary raw material storage			
Foreman	1	Experienced	
Assistant foreman	2		

The amount of floor space devoted to offices in a factory depends on whether dwellings individually ordered are to be produced, or dwellings are to be produced in quantity from a few designs. More office space is needed for designing and producing plans for dwellings when individual orders are being produced than when the same type of house is being produced in quantity. To produce 500 dwellings per year, a factory of 500 square metres is required employing from 30 to 50 workers.

The amount of floor space needed by a factory depends on how the raw materials, building components and accessories that arrive at the factory are handled, the method of prefabrication used, the degree of mechanization employed to make the panels, and the amount of space required to stock the work produced. In principle, the factory should be a place for assembling only, but if certain building components cannot be obtained elsewhere, a special department must be established to produce them.

The following primary raw materials are needed: sawn wood, thermal insulation materials, building papers and plastics, doors and windows, and weatherboardings. Secondary materials required are: cupboards and wardrobes, plumbing fixtures and household gadgets, paints, hardware and nails.

Since the factory should concentrate on planning and production of houses only, primary raw materials should be obtained as far as possible in the form in which they will be used, that is, pre-cut, dried, treated with wood preservatives and surface-finished. The most advanced supply of this kind has been developed in the United States by the manufacturers of mobile homes. For these volume elements very little machining or surface finishing of the primary raw materials is needed at the factory either before or after the assembly.

In Europe, many factories producing prefabricated houses are actually departments of wood-working companies whose primary raw materials are supplied by other departments of the parent company. The manufacturing processes involved for the production of various primary raw materials are well known and consequently will not be dealt with in this study. It must be pointed out, however, that many factories are now finger-joining all frame timber and cutting it into lengths to avoid waste in off-cuts.

Suppliers of building boards produce standard sizes to facilitate surface finishing and even pre-cut them according to customers' wishes. As such material must be stored under cover, the area of sheds needed for storage depends upon the quantity contracted for from the suppliers and the frequency of delivery.

For a factory producing 500 dwellings per year, the annual consumption of sawn wood can be estimated at 2,500 standards (11,680 m^2). For storage of components, between two and five thousand square metres of floor area are needed, with a clear height of from six to eight metres. In tropical countries sawn wood and building boards must be carefully protected from insect attack not only in storage areas but also in the mills that produce them. Measures for protecting a wooden house against termites are given in annex 2.

MACHINING

Machining, in accordance with the requirements indicated by the technical drawings, is the first process applied to primary raw materials after they have been measured, dried and treated with wood preservatives, if treatment is necessary. Machining of sawn wood involves cutting, notching and tenoning. This process is done with radial saws or double-end saws or tenoners. Because building boards vary in length and door and window openings vary in size, standard size building boards cannot always be used without sawing and notching them before assembly.

As the machines used for this process, with their dust absorbers, are rather noisy and require approximately 400 square metres of floor area, a department separate from the assembly hall should be established for this function. Alternatively, machines can be sound-insulated in individual compartments if it is technically possible. After raw materials have been machined, they are transported to assembly tables on pushcarts. Other primary raw materials should also be stocked as near as possible to the assembly table.

As pre-cut deliveries are packed only after machining, the consideration below concerns the assembly methods of modular panels, large-size panels, and volume elements.

MODULAR PANEL ASSEMBLY

The use of modular panels is the oldest method of prefabricated house production, a system still widely employed in Scandinavia. The panels are constructed by placing the timber for the frame on a horizontal jig table where it is securely tightened by cams or hydraulic devices. Building board is nailed to one face of the frame by hand, or with nailing guns that use ordinary or hooked nails. The panel is then turned over on the worktable or moved to trestles where thermal insulation and vapour barriers are installed and building board is nailed onto the other face. The panel is marked with an identification number and if need be, it is packed before being transported to a storage area. If required, vertical weather-boarding, except near the joint areas, can be nailed to the panel at the factory.

The surfaces of finishing board to be used on the interior of buildings, and weather-boarding, can be painted or treated with wood preservatives at the factory in a special department adjacent to the assembly plant. Because modular panels can be moved with a minimum of mechanization, their manufacture is well suited to piecemeal production. At least one factory in Sweden employs this production method using also high frequency gluing for tightening the joints of panels and in the production of floors, walls and plain roof panels.

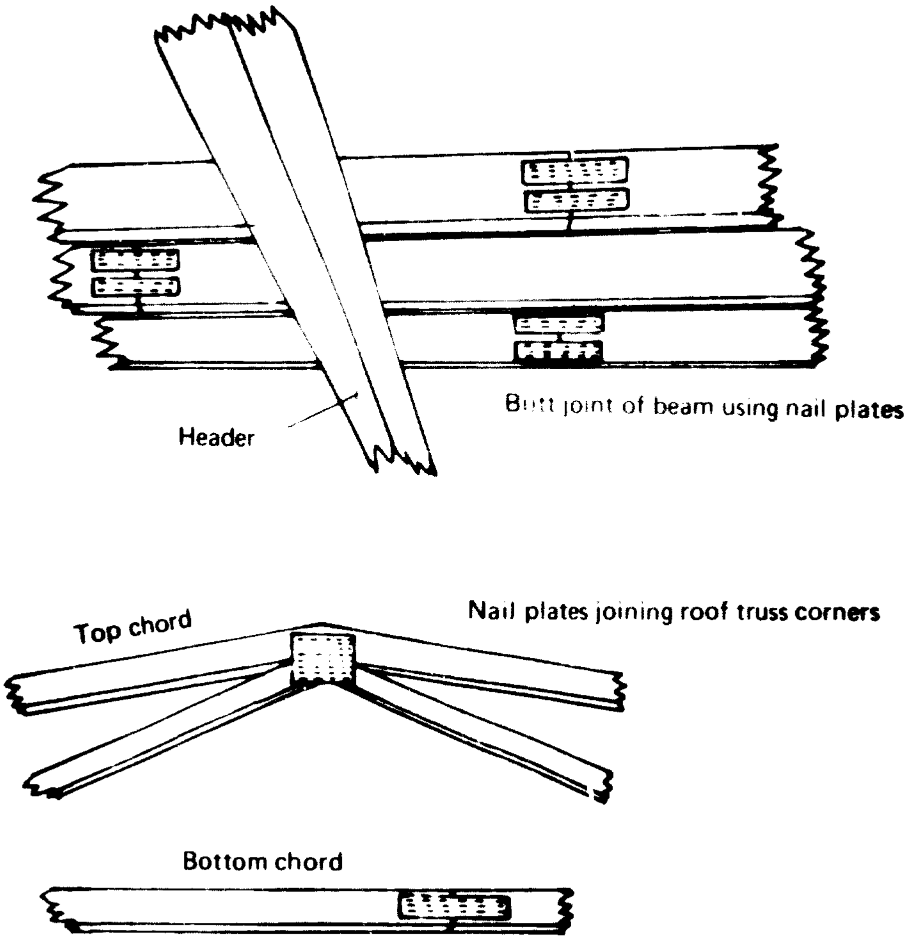
The tenoned timber frame used in this method is assembled without nails. The frame passes through gluing rollers onto a building board where thermal insulation is installed by hand, and a second building board is lifted into place by a pneumatic suction apparatus. The panel then passes through a high frequency pressing machine for curing the glue. Following this operation, circular saws cut the panel to exact measurements and the joint profiles of the sides are tenoned; finally the corners of the panels are strengthened by adding nails. An assumed production of several thousand units and a demand for high wages for nailing the panels are prerequisites for the introduction of the mechanized assembly process described above.

The frames of doors and windows can be installed in the panel in the assembly stage when the manual method of production mentioned above is employed. In the mechanized method both internal and external surfaces of the panels are finished before they are prepainted; glazed windows are then fitted into place. Surface finishing is easily accomplished when panels have been glued together rather than nailed because the resulting surface has not been marred by nail heads or nail holes.

Roof trusses fabricated for sloped roof houses require meticulous care in installation, especially in regions such as northern Scandinavia where snow loads of up to 200 kilograms per square metre remain for long periods on the roofs. In general, roof trusses are installed either at 60-centimetre intervals or 120-centimetre intervals according to the size of the roof and the total floor area of the building.

If labour is cheap and a building operation requires comparatively few trusses, they can be made by hand in a jig. If many trusses - 10,000 or more - are needed annually, mechanized production using nail plates and presses should be considered. As in the case of panel elements, roof trusses can be transported on pushcarts. Figure 8 illustrates the use of nail plates.

Figure 8. Nail plates and their use



An air-conditioned painting unit for painting panels should be located adjacent to the assembly room. Panels with painted or otherwise finished surfaces should be packaged with protecting lath and if necessary wrapped in plastic. For a small-size panel factory, the only crane that may be needed is one in the panel storage area to facilitate loading.

Approximately two to four thousand square metres of floor area each are required for the assembly room and for the storage area in a plant assembling 500 dwellings annually. For this number of houses, 40 to 50 workers using manual nailing are needed, whereas only 20 employees can produce 1,000 dwellings when the mechanized gluing system is employed.

Layout, equipment, materials handling and other information pertinent to establishing a well planned shop for producing prefabricated wood-frame houses under Canadian conditions has been set forth in annex 3 - a reprint of an article published in the Canadian Builder.

LARGE-SIZE PANEL ASSEMBLY

In the large-size panel system, wall panels are made the complete length of the dwelling with electric conduits installed and surfaces finished as completely as possible. Panels are assembled on a jig table in the same way as small-size panels, but as the length of the panels vary, the table must be large enough to accommodate the longest panel made. The panel can be worked on in a horizontal position, or it can be raised to an almost vertical position where workmen, standing on a platform, nail building boards to the frame. In both positions workmen can use either manual or pneumatic hammers.

For automated production of large-size panels, work tables should be equipped with hydraulic frame-holders and rollers to push the panel from one phase to another. Door and window frames are fitted into place. In the first phase of assembly, an automatic nailing machine fastens, from the side, the lower and upper wall plates to the posts of the panel. The entire framework of the wall passes through this machine. In the second phase, building boards are attached to the vertical posts of the frame by pneumatic nailing.

If the panel is to be equipped with plastic pipes for encasing electric wiring, thermal insulation and internal surface boards at the factory, it must be turned on the assembly table or lifted from one jig to another. It can be turned either by hydraulically operated devices from beneath, or by a fairly light (1 ton) electric crane fitted to the ceiling. For turning and handling, nuts can be fastened to the upper, inner side of the panel and to these, special hooks can be screwed. With these hooks the wall panel is easily loaded and assembled on the building site; the hooks are then removed.

In the mechanized production of large-size wall panels with windows, frames can be completely covered with inexpensive standard gypsum fastened to the frames; window openings can then be cut afterwards using an electric saw suspended from the ceiling. Weather-boarding of various kinds can be fastened to the large-size panels at the factory.

In Sweden, nailable bricks, one inch thick and weighing about 40 kilograms per square metre, have been successfully fastened to large-size panels on assembly tables before the panels are transported to the building site. Ducts for electric wiring and outlet boxes are installed in the panels before final surface boards are attached either at the factory or on site. Flat or sloping roof constructions, as well as floor panels in some cases, in the large-size panel system are, in principle, similar to those in the modular panel system.

Panels of considerable size are feasible to construct where cranes are available on site to handle them. Problems of transportation can arise however, if panels are made broader than the maximum width permitted on roads and highways. Gantry cranes are the type best suited for handling large-size panels at the factory. The amount of floor space needed for a mechanized production line is larger than that needed for producing modular panels.

VOLUME ELEMENT ASSEMBLY

The highest degree of mechanization in prefabricated housing is found in volume element production. Factories in the United States making mobile homes are operated on a principle that greatly resembles that of an automobile factory. Mobile homes, which are seldom moved from their permanent location, have been developed from large trailers which, by definition, have a maximum length of 29 feet.

In volume element production transportation is a problem of great importance that must be solved before a factory can start production on a profitable basis. Wooden volume elements are comparatively light. The largest "boxes" produced - up to 60 or 70 square metres of floor area - weigh some six to eight tons depending on their heating and plumbing installations. For a volume element of this weight, standard trucks are too heavy and too expensive to be used for transport. Factories engaged in volume element production should employ their own transport trailers. Such trailers can easily function as bases for internal transport during assembly of the elements, thus eliminating the need for expensive cranes and the danger of breakage through frequent liftings. A low-wheeled car moving only inside the factory can be used in assembly-line fashion and from it the finished elements can be lifted onto the transportation vehicle.

In the manufacture of volume elements, the first phase of production at the factory is very similar to that of large-size panel production, but in order to make frames rigid, building boards are glued in place as well as nailed. In principle, the same factory can make and deliver large-size panels, or it can assemble panels into volume elements at the factory. As each system involves its own methods of joining, surface finishing, and utilities installation, it would prove impractical to try to operate the two systems at the same time.

Floors, walls, ceilings and roofs of volume elements are assembled on horizontal or vertical jig tables and equipped with electric wiring, heating and plumbing installations. When all surfaces of the elements are finished, walls and roof are lifted onto the floor where the roof is waterproofed; the volume element is then moved out-of-doors for finishing.

In order to ensure satisfactory drying during cold or damp weather, painting must be done in a heated building. A dwelling consisting of several volume elements can be put together on trial at the factory to ensure easy assemblage on site. If the dwelling is equipped with its own heating system, or is heated by electric units, these can be used on a trial basis for temporary heating.

In the production of a more complex volume element, surface-finished building boards are fastened to the frame by nails with heads coloured to blend with the finish of the surface. In order to save floor space in the area used for assembly, frames of long external panels can be assembled on almost vertical jig tables and equipped with surface-finished interior panels. The wall panels are then lifted onto the finished floor and fastened from the external side which has no thermal insulation or cladding.

Partition walls and roof are installed next. Electric wiring followed by thermal insulation are then installed from the outside and weather-boardings and roofings are attached. The cupboards, wardrobes and sanitary equipment are placed inside prior to assembling the walls; when they are secured in place, the volume element is considered completed and ready to be furnished.

An effective means of speeding up production on the assembly line of a large-volume element factory is through the use of electric cranes positioned on carefully planned steering rails above the heads of the workers. The labour time needed for assembly can be greatly reduced and work well synchronized when floor, wall and roof elements are moved about on these cranes. The assembly line in a large-volume element factory is often U-shaped with supervisory and other non-work areas in the centre of the U. Approximately six to eight thousand square metres of floor space are needed for the layout of such an assembly line.

SURFACE FINISHING

Pre-finished building boards can be used to advantage if the delivery calls for painted or decorated surfaces, but as yet no satisfactory way has been developed to fasten them to frames nor are pre-finished boards available in great quantities. A special department to paint and finish the surfaces of the panels must be set up in connexion with the assembly area, or as a separate department. Surface finishing of volume elements can be done in the open if the weather permits.

PACKING

Depending on the distance panels are to be transported and the kind of surface finish, protective packing of some kind, such as crating, bundling, or paper or lath protection, is necessary for both pre-cut and modular panels. Large-size panels can be transported vertically or horizontally if they are covered with a tarpaulin and secured to each other to avoid damage from chafing. The joint side of volume elements should be especially well protected by plastic, and in wet weather when roads are muddy the whole element should be covered.

STOCKING AND DISPATCH

As large-size panels are usually made only on order, and volume elements are stocked in the open air, only pre-cut and modular panels need to be stocked in a special way. Stock should be piled according to identification number so that collection for dispatch of the panels can be accomplished as quickly as possible. Gantry cranes are used for stock handling.

PLANNING OF WORK

Seldom is adequate time or attention given to the details of planning the machining and assembly phases of the production operation. After detailed drawings and component lists are received from the design department, purchase orders with requested delivery dates are given to the purchasing department by the department responsible for scheduling work.

When delivery dates of all materials are known, a time schedule can be drawn up indicating anticipated production. It is possible to predict production accurately because of the information gained from work and time studies conducted under a precise schedule of materials arrival.

A typical sequence of events in product planning and four different kinds of work orders are listed below:

<u>Product planning</u>. After the factory receives an order from the sales department and the drawings and specifications from the designers, the following action takes place before and during production:

1. A decision is made on the quantity of units to be produced;
2. A work order is drawn up;

3. Materials are ordered (based on competitive tenders);
4. Production is programmed and scheduled;
5. Work order is circulated;
6. Material arrivals are timed according to production needs and storage capacity;
7. Production is inspected at various stages;
8. Production is inspected with specific reference to scheduled delivery dates.

WORK ORDERS

Raw materials work order: This order indicates when and how much of a specific material is needed at the factory. A foreman delivers the materials to the indicated production operation in the factory according to the time schedule of this order. After delivery, the order goes back to the production planning department.

Machining work order: This order indicates material according to size, amount and delivery date for assembly. The machining foreman is responsible for the various stages of material delivery; after they are completed the work order is returned to the production planning department.

Assembly work order: Information concerning the assembly of the various components is given in this order. After complete assembly of the series of components, the order is returned to the production planning department.

Dispatching work order: The dispatcher is informed by this order when and where various kinds of house packages are to be dispatched. The loading specification accompanies the delivery to the customer. After delivery, the order is returned to the production planning department.

SUPERVISION OF PRODUCTION

As in other forms of mass production, a factory producing prefabricated houses must be closely supervised as to quality of its product, quantity produced and costs involved. The supervision of quality by foremen involves inspection for apparent or latent defects of products caused by workmanship or by faulty materials. The management of a factory can estimate the profitability of its product by a continual control of costs. The quantity of stock on hand is controlled by careful supervision of production and dispatches.

TRANSPORTATION

Deliveries of pre-cut and modular panel "house packages" can be made by normal means of transportation, but modular panel houses of approximately 120 square metres of floor area normally require two long trucks for transport. As these elements are very seldom surface-finished, they can be packed and transported horizontally. When unfinished, they can be transported stacked one on top of the other because of the durability of the building board used to make large-size panels. If gypsum board is used in the panels or if the surfaces are prefinished at the factory, it is safer to transport them in a vertical position securely bundled as a unit. Panels thus packaged can be easily unloaded by a crane and directly positioned in place at the building site. Transportation problems connected with volume-element production should be solved during the planning stage before production begins. The most satisfactory solution for transportation is factory ownership of a fleet of trailers which may also function as bases for internal transport during the period of assembly.

Each country has specific regulations concerning profiles allowed in rail or road transport. For road transport, the width is limited by law while the height is governed by the limitations posed by bridges, viaducts, ferries and the like.

ERECTION

A foundation exactly measured and precisely made according to specifications is necessary for the successful erection of a prefabricated house. It is most important that measures influencing the erection of the prefabricated components be given in the erection instructions. The foundation must be absolutely level in order for the panels to be joined correctly. As this condition is difficult to achieve using ordinary methods of laying concrete, pressure impregnated differential beams (usually 2 in by 4 in) are anchored into the foundation walls. The various methods of erection of the different prefabrication systems have been described earlier in this paper.

In principle, anyone able to read plans and skilled in the use of a hammer should be able to erect a house using modular panels. However, in order to get a house under its roof as quickly as possible, a team of workers familiar with the system should conduct the erection. To lay the foundation and erect the components of a dwelling of approximately 100 square metres of floor area, requires 3 to 4 men working about 100 days when the building is constructed individually. The erection time per dwelling is greatly reduced for the same house constructed in area building.

A building company can purchase large-size panels ex works and arrange for its own transportation and erection. A house factory may also transport and erect a dwelling but not contract for its finishing if such an agreement is made with the entrepreneur.

All responsibilities must be carefully specified in a contract when the dwelling is purchased. The responsibilities of volume element deliveries may be specified in precise detail when the factory manufactures, transports and erects houses on acceptable foundations connecting all plumbing, heating and electric installations and the like. Such houses are delivered on a turn-key principle.

PRICE STUDIES

In Scandinavia the price of newly built, single-family dwellings and row houses, excluding ground, averages between 500 and 800 Finnish markka per square metre (US$1 = 4.20 Finnish markka, January 1971). In Finland the current top price for government financed, single-family dwellings and row houses is approximately 630 new markka per square metre. The difference in price, which is considerable, if compared with prices in warmer climates, depends mainly on the amount of accessories furnished with the house.

The price comparison based on usable floor area may be misleading as certain parts of heated areas or non-heated service areas can be included in the comparison. In Scandinavia the kitchen is equipped with cupboards whereas in Central Europe the purchaser of the house must supply his own.

The breakdown of costs for a single-family house in Finland, exclusive of land, is as follows:

	Per cent
Foundation	9.0
Exterior walls	11.7
Partitions	5.2
Floors	10.0
Ceilings and roof	13.6
Windows	3.9
Doors	4.0
Kitchen cabinets and cupboards	4.6
Plumbing installations	8.2
Electric installations including range	5.8
Heating (boiler, hot water heater, oil burner)	12.0
Painting	5.5
Miscellaneous (sauna, ironwork, sheet metal work, supervision, plans, insurance)	6.5
Total	100.0

The percentage of the elements in a cost breakdown varies according to factors such as dwelling habits and construction regulations in different countries. In warmer climates ceilings and roofs are not as costly to construct as they are in climates where snow loads must be taken into consideration; a smaller percentage of cost is also allotted to foundations and heating systems. Where electricity can be used economically for heating, percentages also vary.

In preparing an estimate of costs for the customer, the following breakdown can be made to identify the cost of each item: description of material and quality; quantity; cost of material; cost of labour involved; total cost. Details should be given for items for which the labour cost is proportionately high.

PRICE COMPARISON

For the construction of small houses, one of two systems of responsibility is usually followed: the system of building individual houses for which the entrepreneur acts as the main contractor; or the turn-key principle in which everything is supplied by the contractor. With the rising standard of living, the percentage of turn-key houses produced is expected to increase since entrepreneurs who lack the craftmanship of the building industry no longer want to take the responsibility for the purchase of raw material or the supervision of the work.

If an owner-builder does not include the cost of his work, materials and supervision in the price of the house, the cost of the same house purchased on a turn-key principle would be 50 per cent higher, especially when only one house is involved. If an owner-builder erects his house of timber in falling lengths, it will be cheaper than if he uses prefabricated panels, as in this case he will compromise on the quality of the building materials or he will purchase certain materials at a reduced cost.

With rising standards of living in Scandinavia, area building, favoured by contractors, has become increasingly important and prefabricated wooden construction also continues to grow. As a contractor faces the problem of getting his house roofed as quickly as possible and getting rid of material on the building site in order to avoid waste, prefabricated house construction is the easiest solution to his problem. Furthermore, factory wages are considerably less than those paid to construction carpenters on a building site. A competitive house industry presupposes production runs in a large quantity and preferably based on only a few models.

MARKETING

The construction of prefabricated wooden houses becomes more profitable and competitive than building with timber in falling lengths only when 500 to 1,000 dwellings - depending on the construction method - are produced by a factory unit per year.

Through research on growth and movement of population and market research the number of new houses needed annually is revealed. In developed countries it has been estimated that the number of houses needed annually is approximately equal to one per cent of the population, but with the development of industry it is expected that this figure will soon increase to more than one per cent in certain areas. When specific data are revealed, they can be used as a factor influencing the choice of site for the establishment of prefabricated house factories and in sales predictions.

In order to produce readily salable houses, market research produces information concerning the living habits of people, the general price level they can afford, their standards of living, and the most popular size and types of dwellings.

SALES

Prefabricated wooden houses are sold by agents working on a commission basis, or by salesmen working for fixed salaries employed by the manufacturer. The fixed salary basis is more generally employed when competition is keen.

In order to plan production, a prediction of sales for the region covered by the manufacturer is estimated annually by the salesmen. Salesmen should be familiar with the principles of small-house construction from the foundation up, and should also be well versed in what it takes to bring customers to a buying decision.

Prefabricated wooden house delivery may be: house package, volume element, or turn-key delivery. A house package composed of wooden components may also contain hardware and accessories, roofing materials, insulating materials, paints and sanitary installations. In most instances the customer is responsible for supplying the foundation of the house and in volume element delivery the foundation is the customer's only responsibility.

Regardless of the construction method used, an entrepreneur prefers to sell houses on a turn-key basis if marketing and financing permit it, especially when houses are sold after they are completed. It is preferable to sell completely finished houses in order to avoid the annoyance of having to make changes in order to satisfy customers. Alterations of the original design can make a house less habitable for future occupants and the disruption caused by making changes affects the progress of the routine of construction. When sales competition is keen, in order to increase sales, producers may offer to arrange for the financing procedures for their customers.

PUBLICITY AND PROMOTION

Sales of prefabricated wooden houses may be boosted through advertising or other forms of publicity. After the design department has completed its plans, an experimental house is built to see if the design is completely functional and salable. Experts then offer their opinions concerning changes and the necessary alterations are made.

Before the house is actually offered for sale, a trial house is built and is often completely furnished. Photographs are taken of the interior and used in brochures or other forms of publicity. Frequently scale models of the house are constructed in "natural surroundings" and are photographed for use on television, in newspaper advertising, sales brochures and the like. Such forms of publicity have proved to be very effective aids to selling houses. In the United States, sample volume element houses are open for inspection on main roads and may be examined as automobiles are examined in a showroom. To be effective, an advertising campaign to sell houses must be planned well in advance of the normal buying season.

TRAINING OF LABOUR

Few if any public institutions offer courses specializing in planning, production, erection and sale of prefabricated wooden houses. Consideration should be given, therefore, to training workers when a factory is being established as the efficient execution of all phases of this form of home-building requires special skills.

Professional architects, construction engineers and specialists in heating, plumbing and electricity should be able to combine their knowledge with that of well trained draughtsmen to produce suitable plans for prefabricated wooden houses. The chief of such a team should be familiar with the possibilities and restrictions of the various prefabrication systems and be able to explain them to his team.

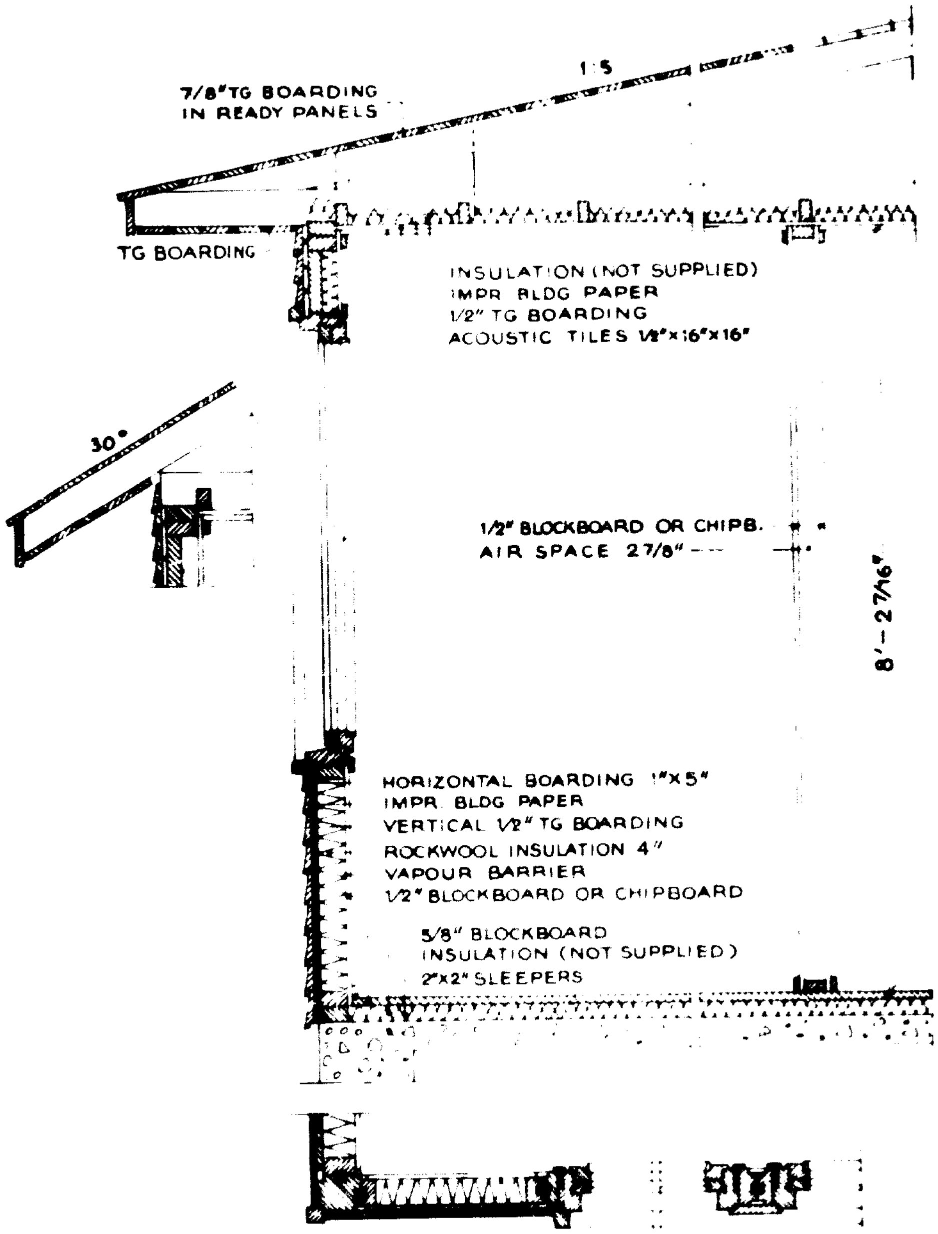
The production department should have members skilled in purchasing, planning, stocking materials, dispatching and all other phases of the work as the conscientious efforts of workers and management greatly influence the quality of the houses produced.

In volume element production specially trained workers and management are essential to the finishing phase of the product. The building contractor can overcome many difficulties if he has a trained group familiar with the system to undertake the erection work of wooden elements and deliver a completely finished dwelling to the buyer.

A good salesman can sell almost anything for awhile. For extensive, successful marketing of prefabricated wooden houses, however, highly trained salesmen who are experienced in all phases of house production techniques are essential. Salesmen should also be well informed of the regulations controlling production, and for ultimate sales success, they should be able to assist customers in making arrangements for the financing of their houses.

Annex 1

TECHNICAL DESCRIPTION; ERECTION INSTRUCTIONS AND ARCHITECT'S DRAWINGS; AND LOADING SPECIFICATION FOR A MODULAR PANEL HOUSE*



* Type 5492-2 (ROK/L)30 - Puutalo Sales Association for Prefabricated Houses, Helsinki, Finland. The material presented in this annex is the copyright of Puutalo.

Technical description

The basic delivery includes all wooden parts above the foundation, thermal insulation for walls, caulking material, building paper (except roofing felt), hardware for doors and windows and nails, as mentioned in this description:

Floor

The house is designed for concrete slab foundation.
The basement roof is of reinforced concrete.
- Sleepers, 2 in x 3 in, 1 ft - 7 11/16 in o.c.
- Subfloor of 5/8 in thick blockboard, as base for linoleum or PVC floor covering

Sleepers are delivered in falling lengths, bundled blockboards cut to size.

External walls

Construction from outside:
- Horizontal weather-boarding 1 in x 5 in
- Impregnated building paper
- Vertical TG-boarding, 5/8 in
- Frame 2 in x 4 in
- Glass wool or rock wool insulation, 4 in
- Vapour barrier, aluminium or PVC-coated paper
- Chipboard or blockboard, 1/2 in

The walls are delivered in prefabricated panels, width 1 ft - 11 5/8 in to 7 ft - 10 1/2 in.

The weather-boarding and building paper are supplied loose to be fixed on site; weather-boarding in falling lengths, bundled, building paper in rolls.

Note: In certain types of houses the weather-boarding may be vertical instead of horizontal. The weather-boarding is then ready-nailed to panels at factory.

Gables

The frame is delivered in ready-assembled halves.
Horizontal weather-boarding as in external walls

Partitions

Posts 1 1/2 in x 3 in, 1 ft - 11 5/8 in o.c.
Sills and top plates 1 1/2 in x 3 in

All frame components are delivered cut to length, bundled. 1/2 in chipboard or blockboard delivered cut to size on both sides of the frame.

Party walls or brick walls

Internal chipboard or blockboard lining on 7/8 in x 2 in nailing strips

Roof

Roof trusses, 3 ft - 11 1/4 in o.c., delivered in ready-assembled halves
- 7/8 in raw TG-boarding, delivered in ready panels, width 1 ft - 11 5/8 in, length 5 ft - 10 7/8 in,

- 7 ft - 10 1/2 in and 9 ft - 10 1/8 in
- TG-boarding for the soffit, delivered cut to length
- Fascia boards delivered cut to length

Ceiling

- Acoustic tiles 1[illegible] in x 1[illegible] in of porous wood fibre board, in carton packing
- 5/8 in raw TG-boarding in ready panels
- Impregnated building paper, in rolls

Doors

Exterior oak doors are insulated and faced on the outside with profiled boards, brass hardware fittings, mortice lock with 5 keys, letter-drop plate. Interior doors flush type, paint-grade, thickness 1 3/4 in, thresholds of oak

All doors are ready-fitted into frames, provided with hardware and primed. Protruding hardware packed separately.

Windows

Double windows, provided with hardware fittings, ready-fitted into frames, primed. Protruding hardware packed separately.

Cupboards

- Wardrobes with a clothes rail and 2 shelves
- Other cupboards with 6 shelves

All parts ready-painted, delivered knocked down.

Mouldings

All interior mouldings ready for fixing. Skirtings and cornices are delivered in falling lengths, bundled. Exterior architraves for doors and windows are supplied ready for assembly, bundled.

Kitchen cabinets

Painted and provided with hardware fittings. Sink top of stainless steel, with two bowls. Plastic laminated surface on the working table.
Enamelled hardboard (1 ft - 5 3/4 in high) is delivered for the walls above the working levels.
Range and refrigerator are not included in the delivery.

Bathroom

Enamelled hardboard is delivered for the walls and ceiling.

Basement stairs

Delivered ready for assembly.

Porch

All joists, beams and posts delivered ready for assembly.

Garage

- External wall panels as elsewhere in the house but without insulation and 1/2 in vertical boarding
- Garage door side hinged, provided with hardware fittings

- Roof as elsewhere in the house
- Windows with single casement
- Without ceiling

Miscellaneous

The delivery includes also:
- Copper drip caps for the horizontal external architraves of the windows and doors where needed
- All nails and screws, galvanized, required for erection
- Pieces of steel tube for porch posts

Impregnation

Sleepers, bottom plates, frames of the external wall panels and roof trusses are impregnated against rot and insects.

Weather-boarding and roof boarding are dipped into or sprayed with preservative solution.

Extras

The following items are obtainable at extra cost:
- Oak parquet flooring, "RI-LA" brand instead of sub-floor
- Interior doors with gaboon mahagony surfacing
- For the ceiling, painted TG-acoustic tiles ("PIHLA" brand instead of tiles with shaped edges only)
- Tile battens on the roof boarding for roofs with 30° slope

The following alterations reduce the price:
- Weather-boarding is omitted (lining with local material)
- Lining for brick walls is omitted; the walls can be plastered instead (see p.46, "Party walls or brick walls")

Erection instructions

Erection instructions and drawings as well as structural calculations are delivered with the house.

Time of erection

The house is to be erected by the buyer.
The time required for the erection of the component delivered by Puutalo is about 2 hours per 10 square feet.

List of the most important materials to be obtained locally by the buyer

All materials for the foundation
Basement windows and doors
Thermal insulation for the floor and ceiling
Roofing cover, e.g. corrugated asbestos cement sheets
Flooring
Paints and wallpapers
Window and door panes
Kitchen range and refrigerator

Electrical fittings
Sanitary fixtures
Plumbing and drainage
Gutters and downpipes
Heating fixtures
Anchor irons for the brick walls, if required.

All timber measurements are nominal, i.e. rough dimensions before planing.

The module of the construction is 1.20 m = 3 ft - 11 1/4 in and a half module 0.60 m = 1 ft - 11 5/8 in.

Erection instructions and architect's drawings

These instructions describe in brief the erection and assembly of wooden parts and other building material delivered by Puutalo. Related operations, such as plumbing, electric wiring, concrete and masonry work are to be done according to local building regulations and methods of work.

Foundation

The foundation is to be made of concrete, in accordance with the measurements given on the foundation drawing. In order to secure the rectangularity of the building, the diagonal measurements are to be checked carefully. The top surface of the foundation must be absolutely level. Any irregularity in the foundation will result in an irregular and unsightly ridge line at the peak of the building. The top surface of the foundation is to be coated with a hot mopping of coal-tar pitch, particularly at the points where timber parts are to be placed.

External walls

1. Place weather strips of 10 cm width on the border of the concrete slab. See page 74, "General sections", section K4a.

2. Position wall sills 1-10, 1-13 and 1-15 (see page 58, "Wall sills and floor sleepers") on the weather strips. Check the measurements and level the top accurately all around the house. Use plywood strips for levelling. Fix the joints with five 60 x 25 (2 1/2 in) nails and to the foundation with steel nails.

3. Place weather strips of 10 cm width on the wall sills and fix with tacks. See again "General sections", section K4a.

4. Erect corner posts 2-01 (see page 62, "Walls and partitions") on the house corners and fix with 75 x 28 (3 in) nails.

5. Erect the wall panels near the corners (one of each side) strictly according to the positioning scheme. (See again "Walls and partitions".) Fix from the outside to the sill with three to four 60 x 25 (2 1/2 in) nails and toe-nail from the inside with three 75 x 28 (3 in) nails. Strut the corners rigidly with temporary braces. After the corner posts and panels are secured in place, erect the remaining wall panels. Note the +, ++ and letter marks behind the window and door items. Make sure that the joints between panels are equal by using an internal joint strip 20-90 as pattern. Fix as instructed before, and strut the wall construction with temporary braces.

6. Place guiding strips 2-81 from top end of the wall panels into the joint grooves by forcing with a hammer or mallet. See page 75, "Horizontal details".

7. Place weather strips (8 x 100 mm) in the groove on top of the walls and fasten with tacks. See page 74, "General sections", K1a.

8. Place wall top plates 1-10, 1-13 and 1-15 (see page 58, "Wall sills and floor sleepers") around the top of the wall construction to keep all the wall panels in alignment and bind them together around the top. Fix securely to each wall panel and corner post below, the lapped joints with four 60 x 25 (2 1/2 in) nails and between them with one to four 100 x 34 (4 in) nails.

9. Put caulking ribbons (25 x 25 mm) into the internal joint grooves of the wall panels and fix the internal joint strips 20-90 and 20-91 to cover the joints. (See page 75, "Horizontal details".) Use 50 x 21 (2 in) finishing nails for fixing.

10. Cover the exterior wall panel joints with insulating board strips (1/2 in x 46 x 2,568 mm). See again "Horizontal details".

11. Cover the walls from outside with impregnated building paper as soon as possible after the walls are erected. Use tacks or staples for fixing. The paper joints should overlap at least 10 cm.

Roof construction

1. Assemble the ready-made roof truss halves (40-54) to each other by fastening the connecting pieces (plywood gussets 4-64 and 4-65). (See page 67, "Assembly of roof trusses".) The nailing must be done precisely on both sides of each truss and must accord with the nailing points marked on the ridge part and at the middle of the ceiling joist. Provide the middle of assembled truss with ledger strip S-329. Use 60 x 25 (2 1/2 in) nails, spaced at 20 cm for fixing. See section B.

2. Slip the trusses over the side walls one by one and position (120 cm on centre) just above the wall panel joints. (See page 64, "Roof construction".) Secure by toe nailing from each side to the top plate with 100 x 34 (4 in) nails and further from one side with fastening irons No.2. Make sure that the trusses are plumb and properly placed and that the eave and ridge lines are straight.

3. Lift up gable triangle panels 40-541E and 40-542E (see again "Roof construction") and fasten securely to the top plate with 125 x 42 (5 in) nails.

Make sure that the panels are plumb. Provide the lower end with ledger strips S-329 (see page 74, "General sections", section K2a) and fix with 60 x 25 (2 1/2 in) nails, spaced at 20 cm. Cover the panel joint with joint strip M-304/1 and fix with 60 x 25 (2 1/2 in) nails.

4. Place ceiling panels 5-11, 5-12, 50-11 and 50-12 as well as attic door 5-20 (see page 64, "Roof construction") between the ceiling joists. Make sure that the panels lie at the same level. Fix with 75 x 28 (3 in) and 100 x 34 (4 in) nails.

5. Cover the ceiling panels with impregnated building paper and fasten with tacks. See again "General sections", section K1a.

6. Heat-insulate the attic. Mineral wool covered with felt paper is used for this purpose. Not included in delivery.

7. Position duckwalk boards S-640 (see page 64, "Roof construction") on the ceiling joist and double nail to each nailing point with 75 x 28 (3 in) nails. See also page 74, "General sections", section K1.

8. Erect terrace posts 10-22 on the 3 in-diameter iron pipes inserted in the terrace foundation. Plumb and brace rigidly to the wall and to each other. See again "Roof construction".

9. Lift terrace purlins 10-33 and 10-35 (see again "Roof construction") on the posts and fix from the inside with angle irons.

10. Lift roof joists 10-81 on the purlins (see again "Roof construction") and support to the wall with hanging irons No.21. Toe nail to the purlins with 100 x 34 (4 in) nails.

11. Position roof panels V-4, V-5 and V-7 (see page 66, "Roof panels") and fix with 60 x 25 (2 1/2 in) nails. Cut where necessary and remove one board from each side at the ridge. See also page 74, "General sections", section K1a.

12. Cover the eaves with boards (P-300) (see page 64, "Roof construction", Trellis). Use 60 x 25 (2 1/2 in) nails for fixing. Secret nailing is to be recommended.

13. Fix fascia and barge boards 4-820, 4-840 and 4-760. Double nail to each nailing point. See pages 64 ("Roof construction") and 74 ("General sections", sections K1a, K2 and K6).

14. Cover the roof. Materials are not included in the delivery. When the chimney is reached a sheetmetal cap and base flashing must first be fitted

around the brick to seal the opening. Enough roof cement should be used to provide good flashing work and to prevent water from seeping behind the flashing.

External architraves and siding

1. All external architraves should be positioned and fixed. See pages 73 ("Architraves"), 74 ("General sections", sections K1a and K4a) and 75 ("Horizontal details").

2. Fix window flashings (copper) with copper nails. (See again "General sections", section K1a.) Note that the upper flashings should be fixed at the gable wall windows only.

3. Fix cover boards 6-882 between two living room windows with double nailing. See page 73, "Architraves".

4. Cover the wall surface below living room windows (3 pieces, side by side) with weather boards P-246 by using 60 x 25 (2 1/2 in) nails for fixing. See pages 56 ("Architect's drawing") and 73 ("Architraves").

5. Fix corner strips 2-80 on at the corners of the building vertically with ten 100 x 34 (4 in) nails as shown on page 75, "Horizontal details", detail H7a.

6. Begin fixing wood siding M-614. Application of bevel siding should start at the foundation, 3/4 in below the bottom of wall sill. The courses should be laid out, or "storied", so that the shadow lines coincide directly with the upper and lower lines of the windows and doors. It is beneficial to work to a chalk line and to see that each course is kept level. Nailing should always be directly over each wall-panel frame stud, approximately 60 cm o.c. Nails 75 x 28 (3 in).

Floors, partitions and ceiling

1. Cut floor sleepers S-763 to suitable lengths and position on the concrete slab. (See page 58, "Wall sills and floor sleepers".) Make sure that the sleepers are level. Any irregularity must be corrected and the sleepers fastened to the concrete slab with steel nails.

2. Insulation for the floor. 2 in-thick mineral wool is recommended. Not included in delivery.

3. Lay floor panels KP-5 and K-9 (see page 60, "Floor panels") on the sleepers. Cut where necessary and fasten with 60 x 25 (2 1/2 in) finishing nails spaced 10 cm apart.

4. Partitions. See pages 62, ("Walls and partitions"), 68 ("Framing of partitions") and 70 ("Partition details - floor panels").

> Note: Erection of the assembled partition frames should be in accordance with the circled numbers on page 62 ("Walls and partitions") and the chipboard lining fastened immediately.

Assemble the partition frames on the floor by cutting the sills, top plates and headers from batten S-628 to suitable lengths and thereafter spike posts 3-46 between them with 100 x 34 (4 in) nails. Follow strictly the measurements in the framing scheme, page 68 ("Framing of partitions").

Lift the frames into place according to the measurements given on the drawing on page 62 ("Walls and partitions"). Plumb and fasten to the floor and ceiling as well as to the wall and partition beneath with 100 x 34 (4 in) nails.

Set interior doors 7-81K+P, 7-81K++P, 7-82K+WJ and 7-91K+P in the openings and fasten the frame members to the studs and headers with 75 x 28 (3 in) nails. See pages 62 ("Walls and partitions") and 68 ("Framing of partitions").

Cover the partition frames with chipboard lining Z-1 etc. strictly according to the drawing on page 68 ("Framing of partitions") and fasten with 50 x 21 (2 in) finishing nails spaced 15 cm apart. Note that the chipboard joints must lie on the posts indicated by black dots.

5. Fix the acoustic tile squares (40 x 40 cm) to the ceiling with 30 x 17 ($1\frac{1}{4}$ in) finishing nails. The tiles should be neatly and carefully fixed. If the ceiling is to be finished with other material (profiled boards, chipboards etc.) the placing and fixing should be done according to the local methods of work.

> Note: The bathroom and WC ceiling should be finished later with enamelled hardboards.

6. Line the bathroom and WC ceiling with enamelled hardboard and fasten with plastic strips and small nails.

7. Finish the bathroom floor with cement mortar. Materials are not included in the delivery. See page 71, "Bathroom wall finishing and flooring".

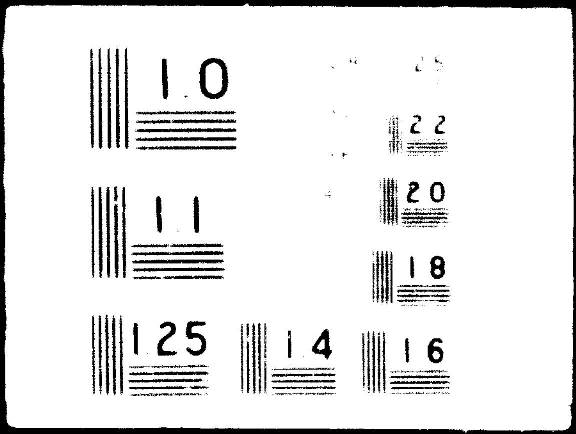
8. Fix plastic skirting (basestrip) to cover the joint of bathroom wall where it meets the floor. Use contact mastic for fixing. See again "Bathroom wall finishing and flooring".

5. 7. 72

2 OF 2

DO

0715



Cupboards

The cupboards should be positioned according to page [illegible], "Walls and partitions". Assemble the cupboards on site from [illegible] made parts by fastening their screws. [illegible] front side. Cover the gap between [illegible] with [illegible].

Finishing work

1. [illegible] the bathroom walls with enamelled hardboard as shown on page [illegible] "Bathroom wall finishing and flooring", fix with plastic strips and small nails.

2. Fit ceiling strips [illegible] and skirtings [illegible] suitable [illegible] mitre join at the corners and fix with [illegible].

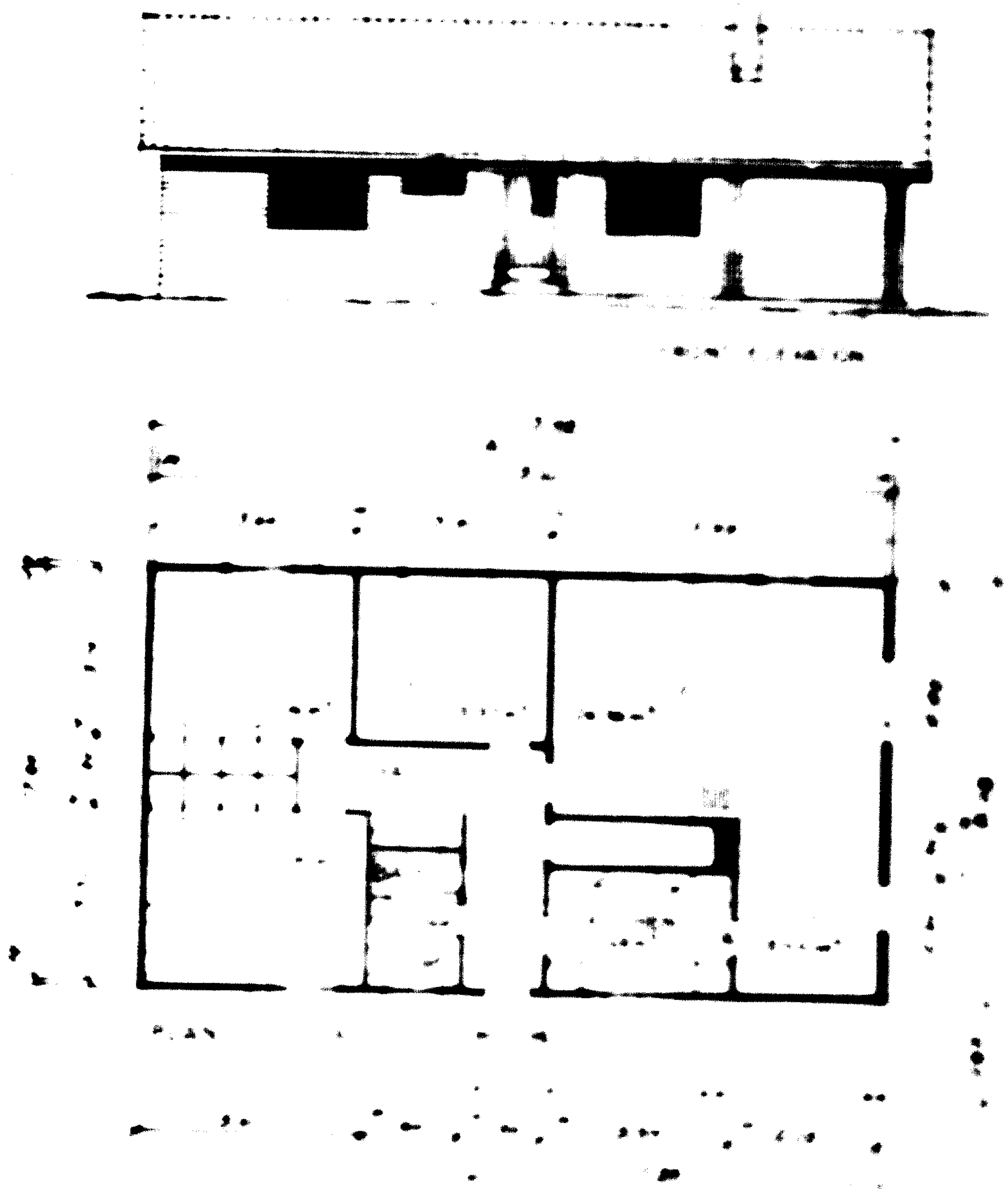
3. Fit interior architraves [illegible] A etc., see page [illegible], "[illegible]" [illegible] suitable lengths and mitre [illegible] at the corners. [illegible] and fix with [illegible] nails. [illegible], after [illegible] wall-papering work, around the interior [illegible].

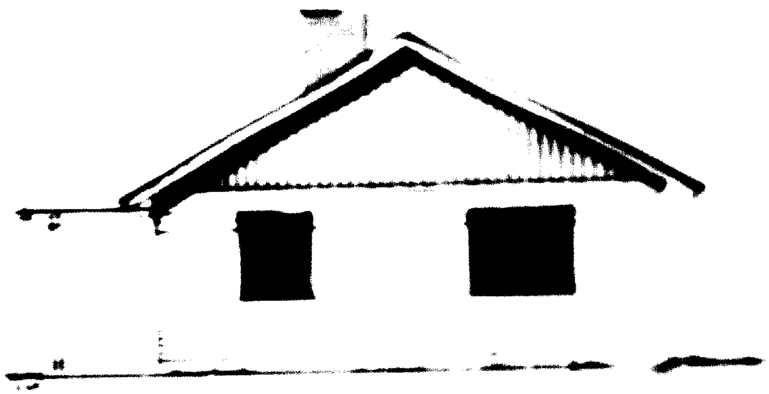
4. Fasten flower boards K- and K-1 below the [illegible] windows with [illegible] holes and wood screws. See pages [illegible] "Walls and partitions" and [illegible] "General sections", section K1a.

5. Position kitchen equipment according to the drawings [illegible]. [illegible] enamelled hardboard is constructed. Put the stainless steel top [illegible] fastening first the base frame to the top of the floor units below. Install the kitchen ventilator in place and connect to the air flue with flexible connecting pipe.

6. Position hardware accessories, according to the list of contents of the case.

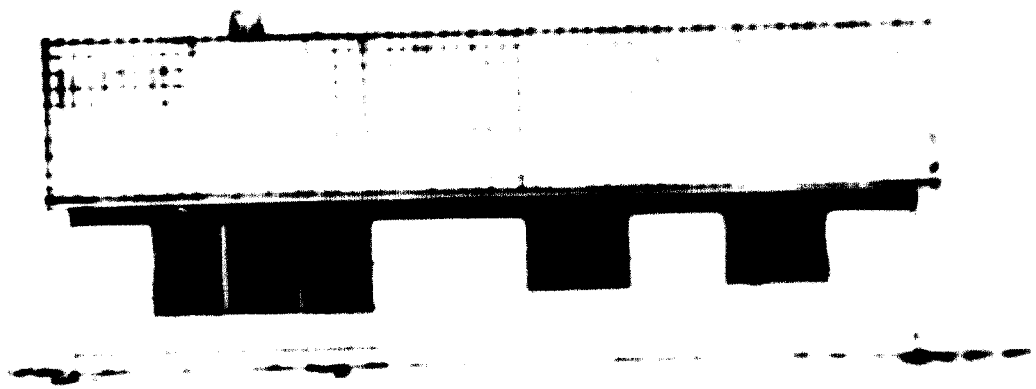
ARCHITECT'S DRAWING FOR A MODULAR PANEL HOUSE



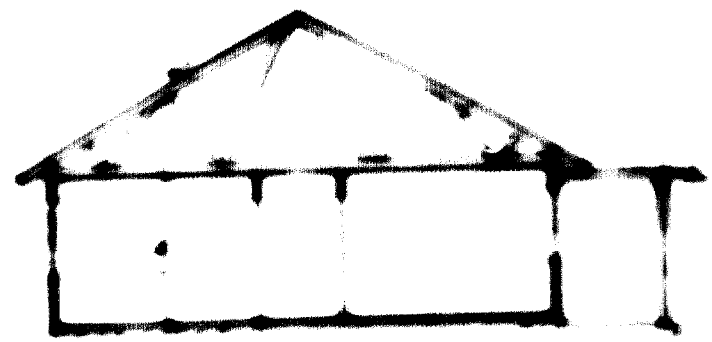


GABLE ELEVATION

GABLE ELEVATION

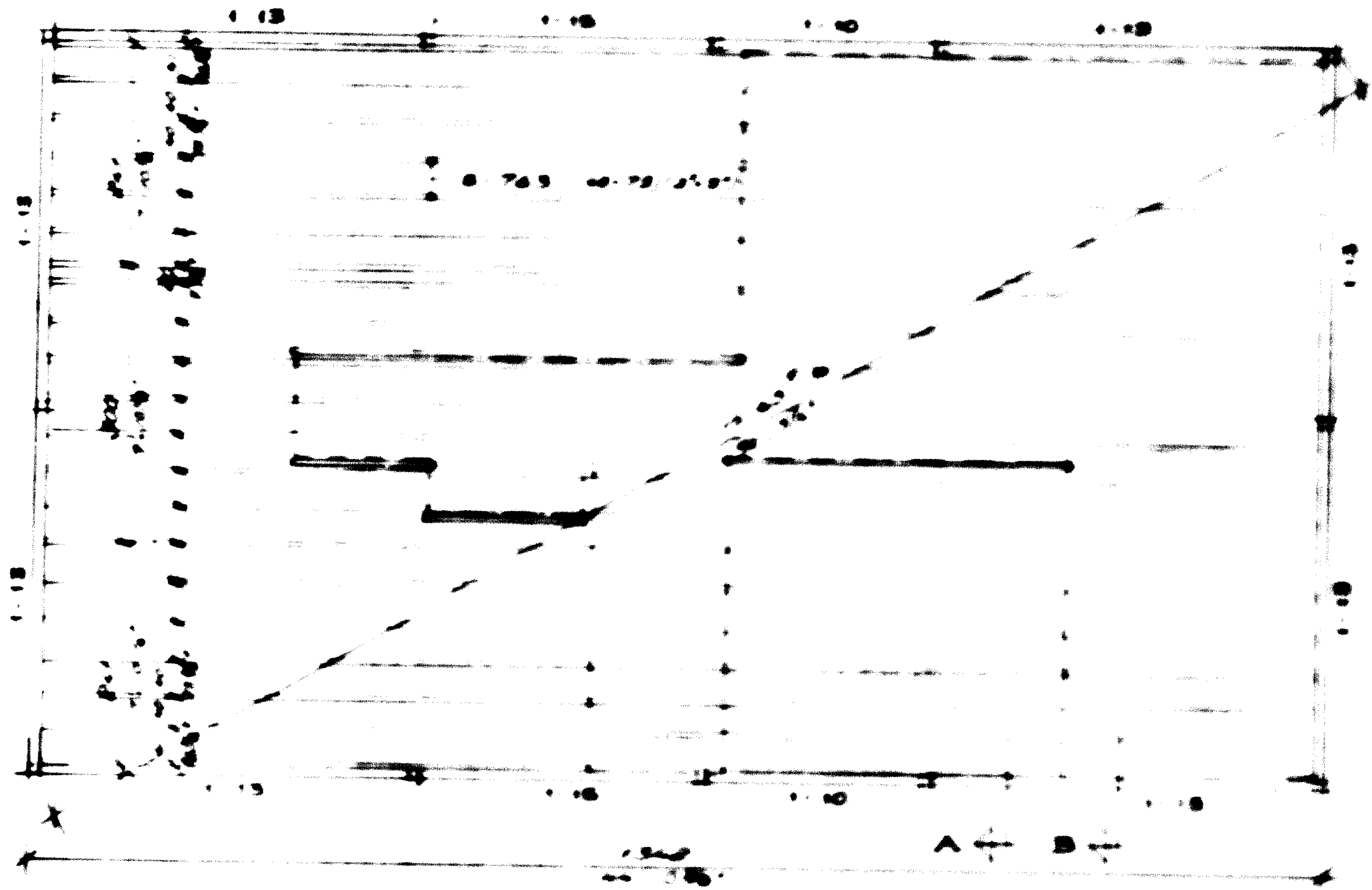


REAR ELEVATION



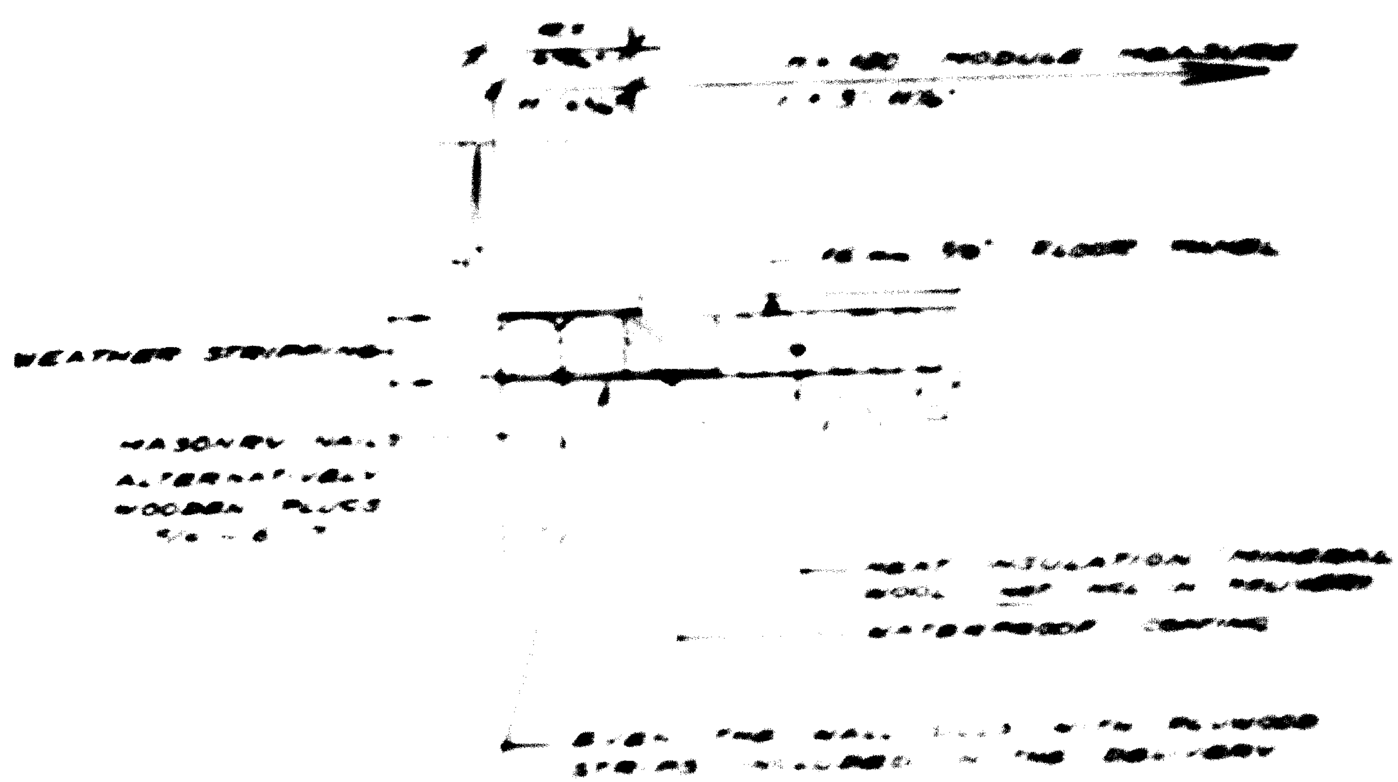
SECTION

WALL SILLS AND FLOOR SLEEPERS

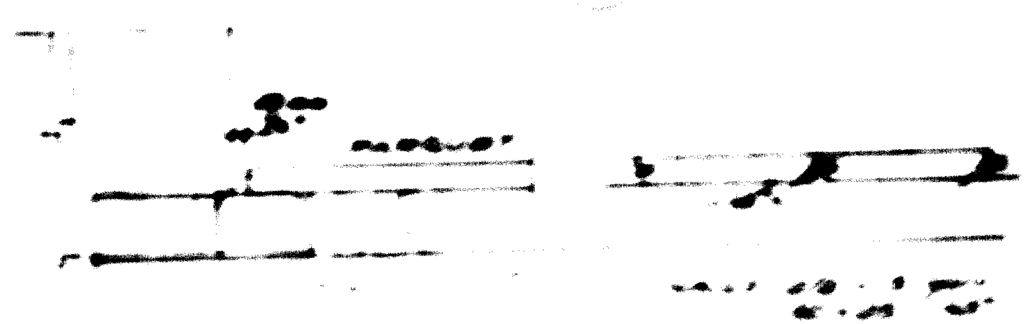


NOTE [illegible]

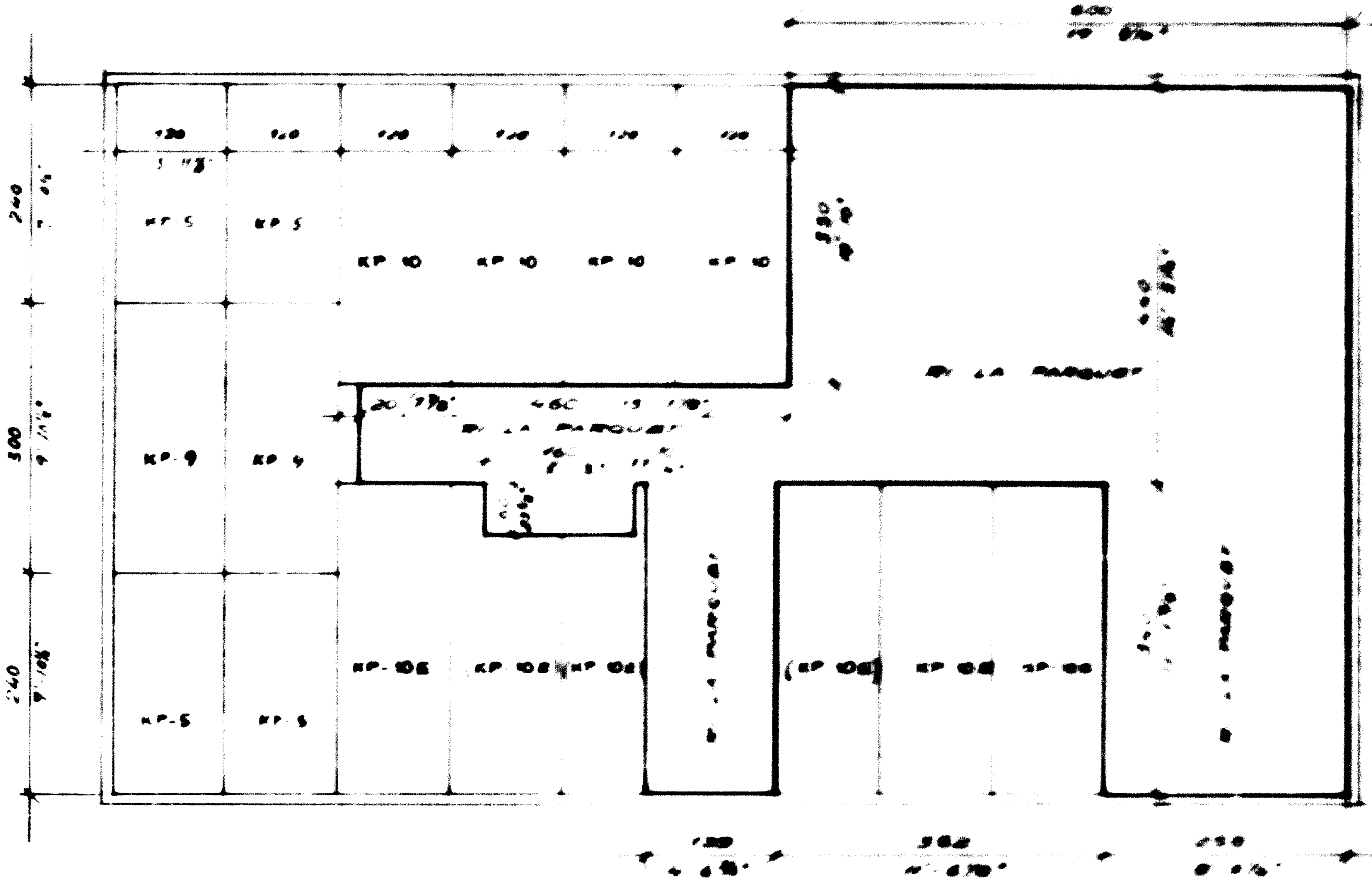
A


WEATHER STRIPPING
MASONRY NAILS
ALTERNATIVELY
WOODEN PLUGS

B

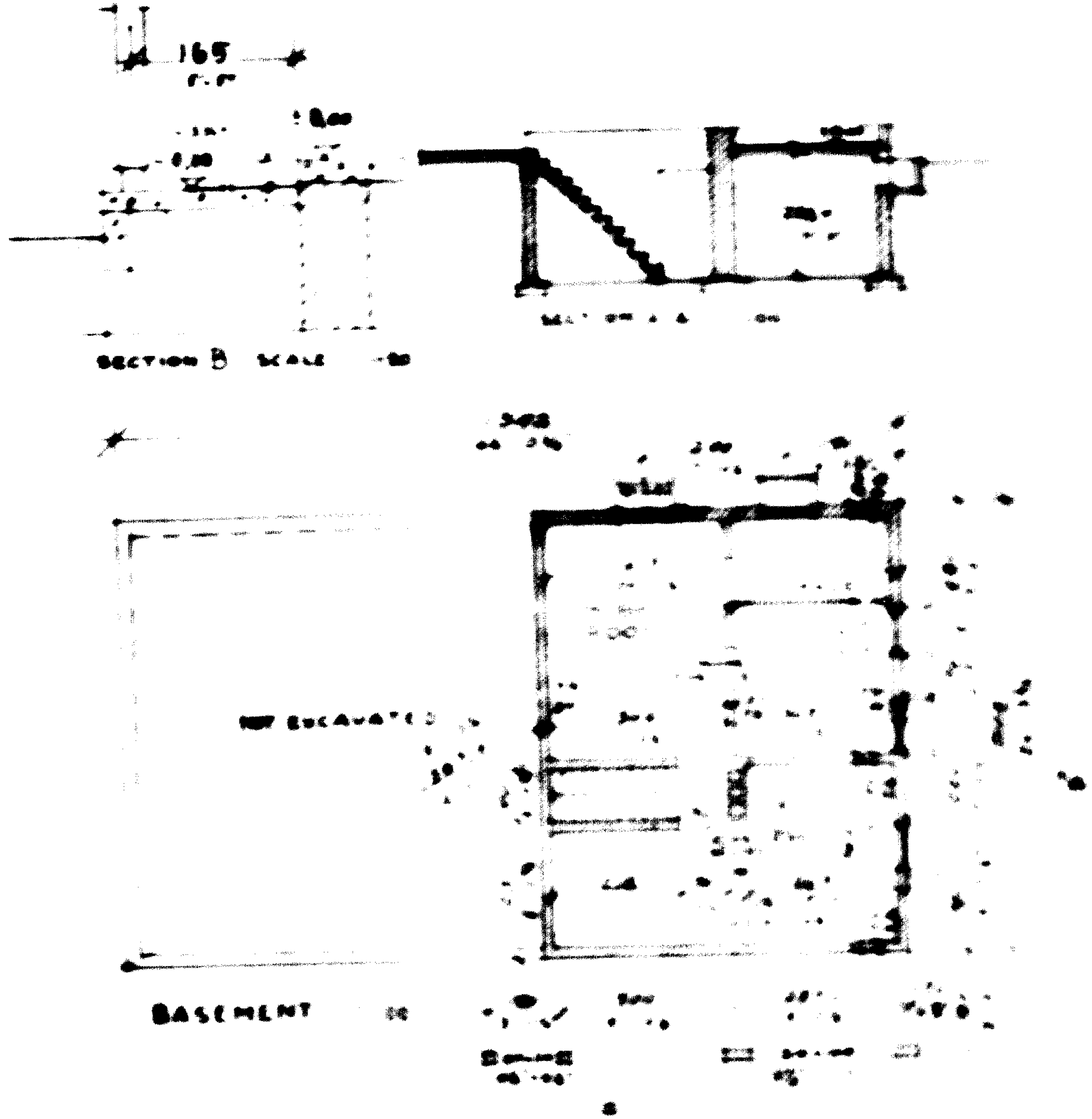


FLOOR PANELS

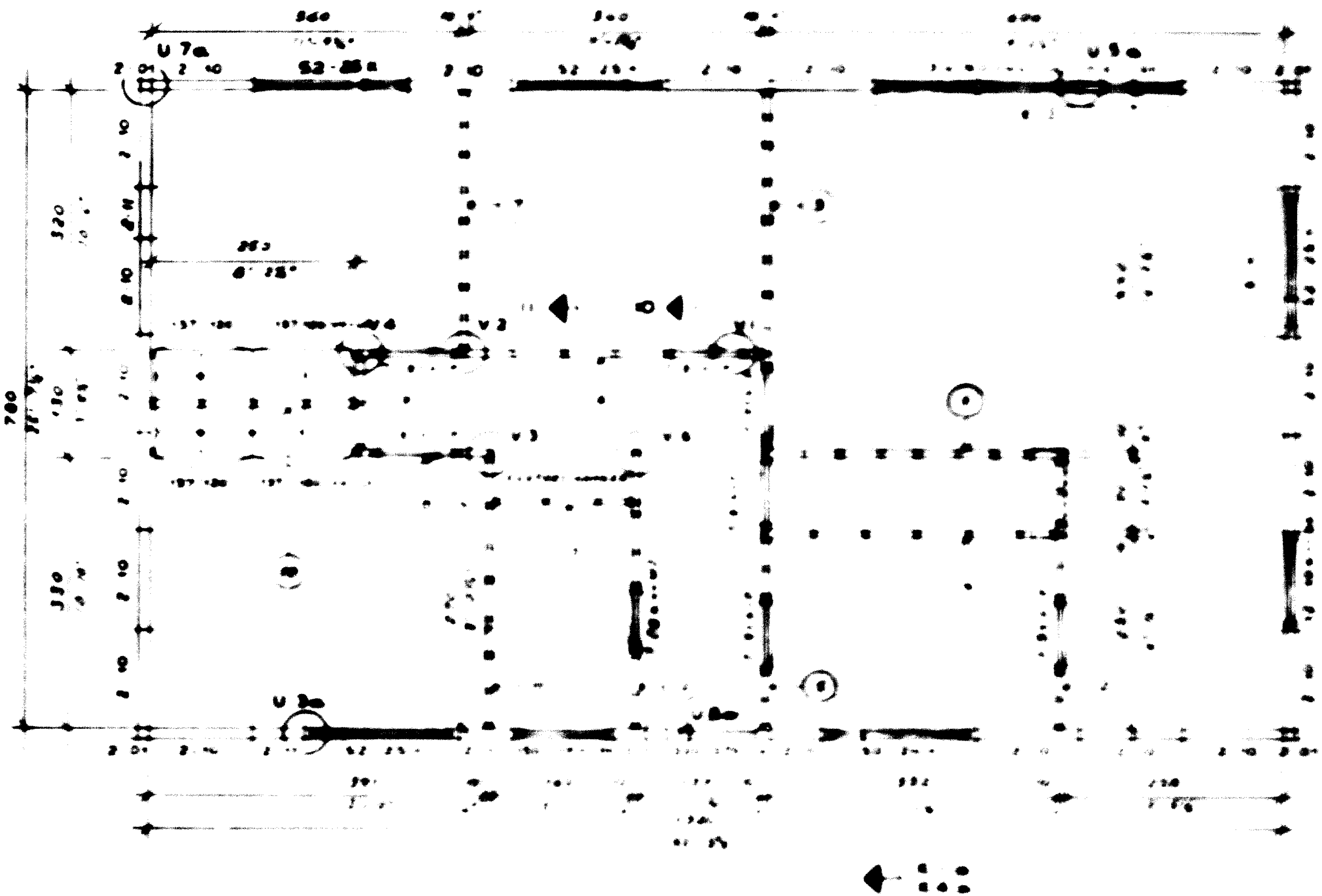


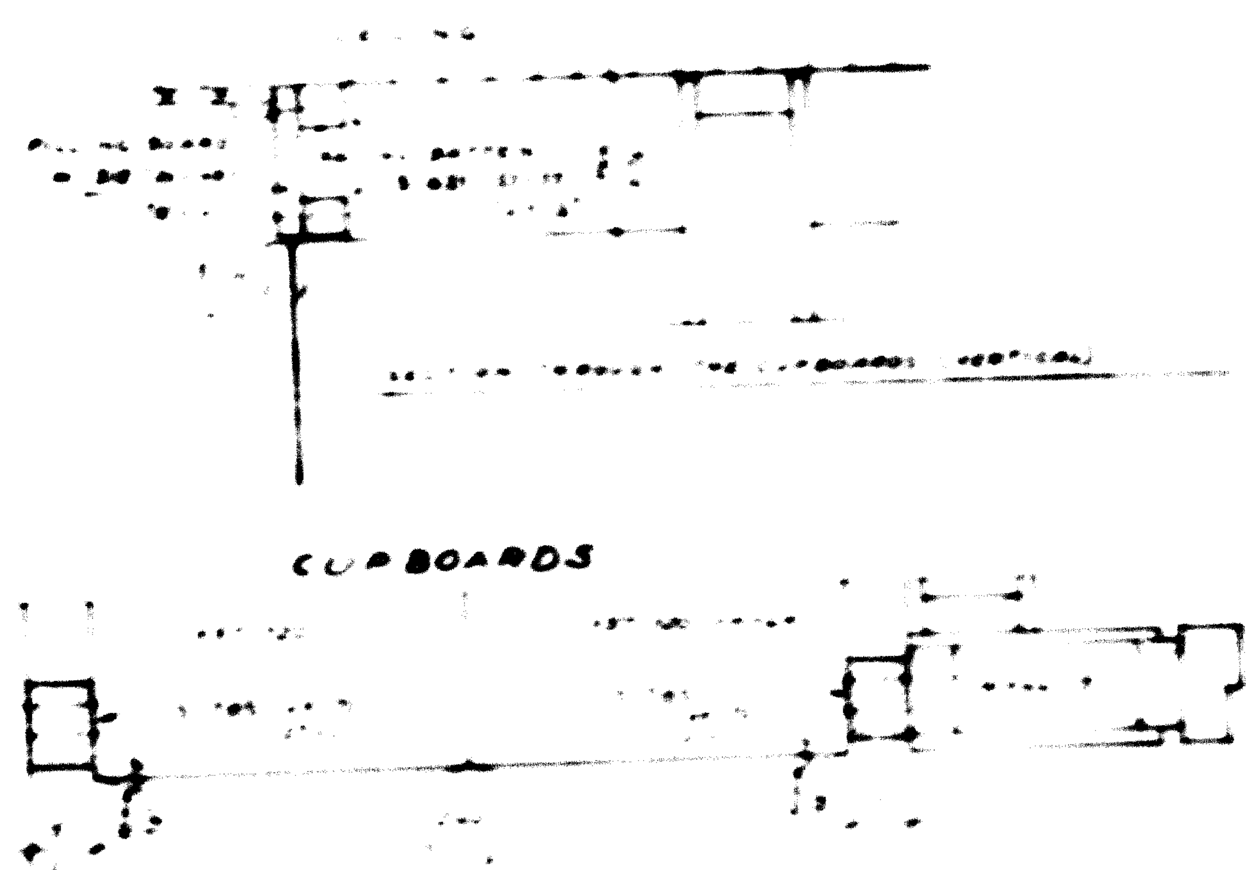
ITEMS IN PARENTHESIS SHOULD BE CUT ON SITE

BASEMENT

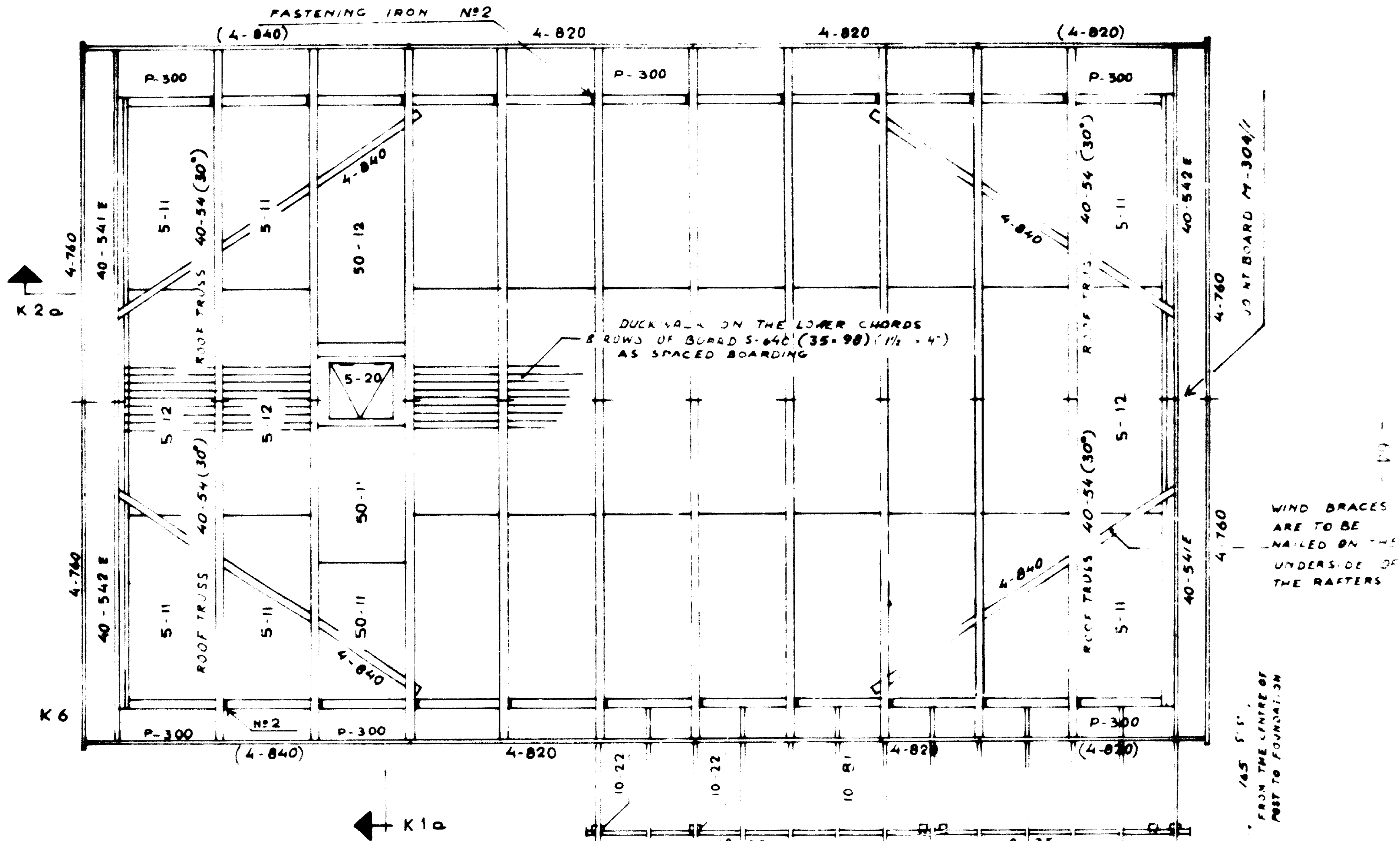


WALLS AND PARTITIONS




CUPBOARDS

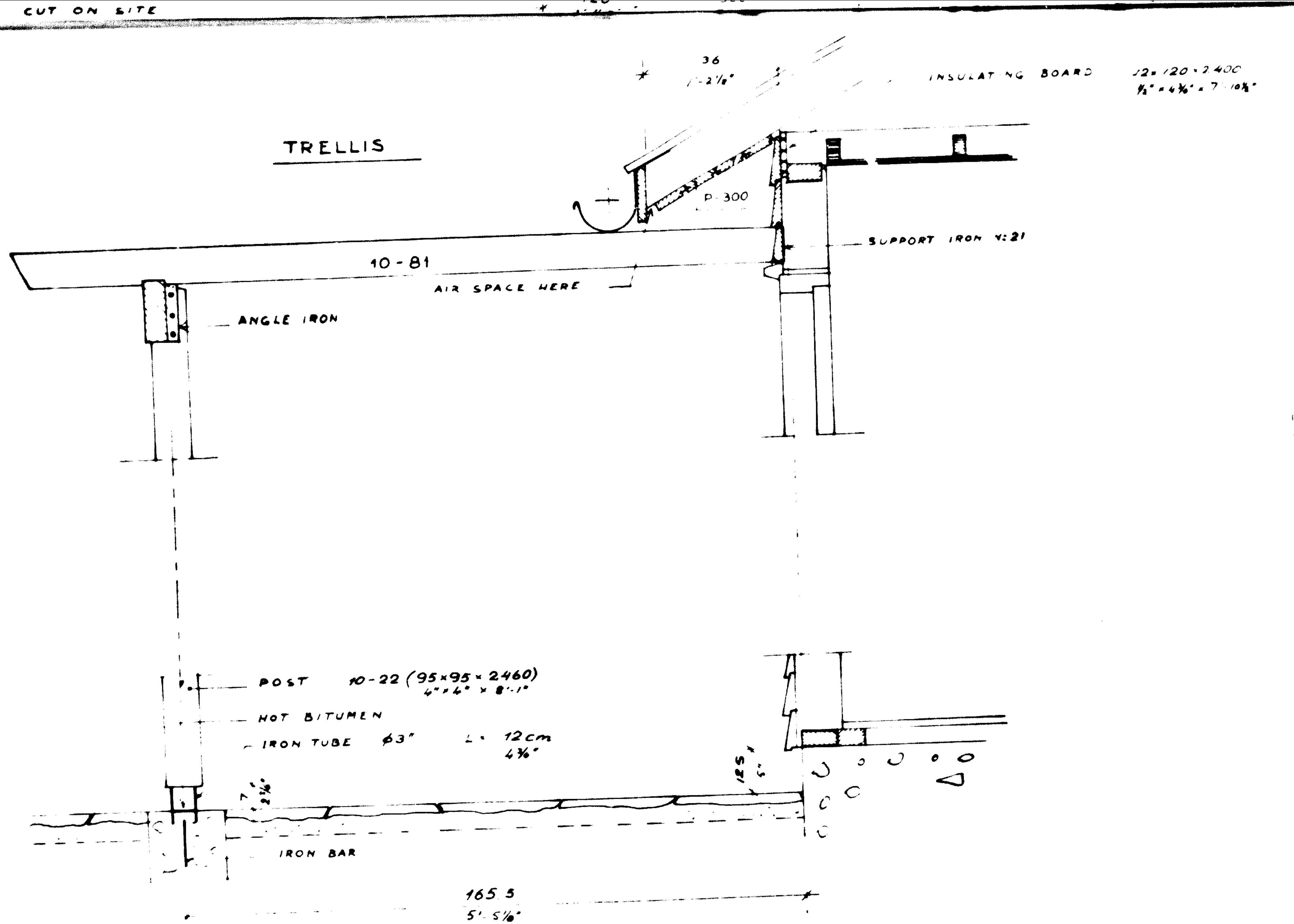
ROOF CONSTRUCTION



SECTIONS AND DETAILS ARE SHOWN IN "GENERAL SECTIONS", PAGE 74

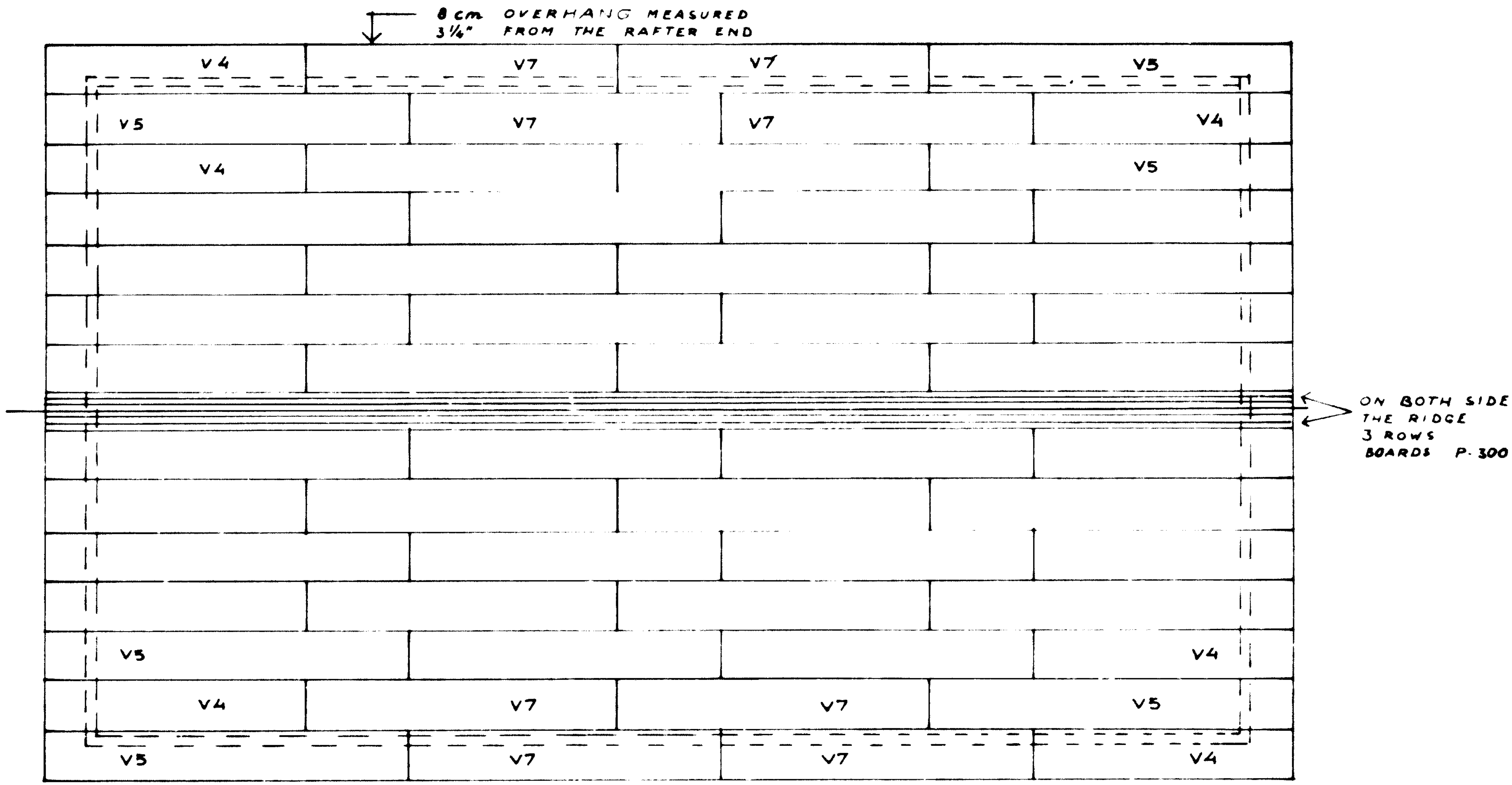
THE ITEMS IN PARENTHESES ARE TO BE CUT ON SITE

TRELLIS



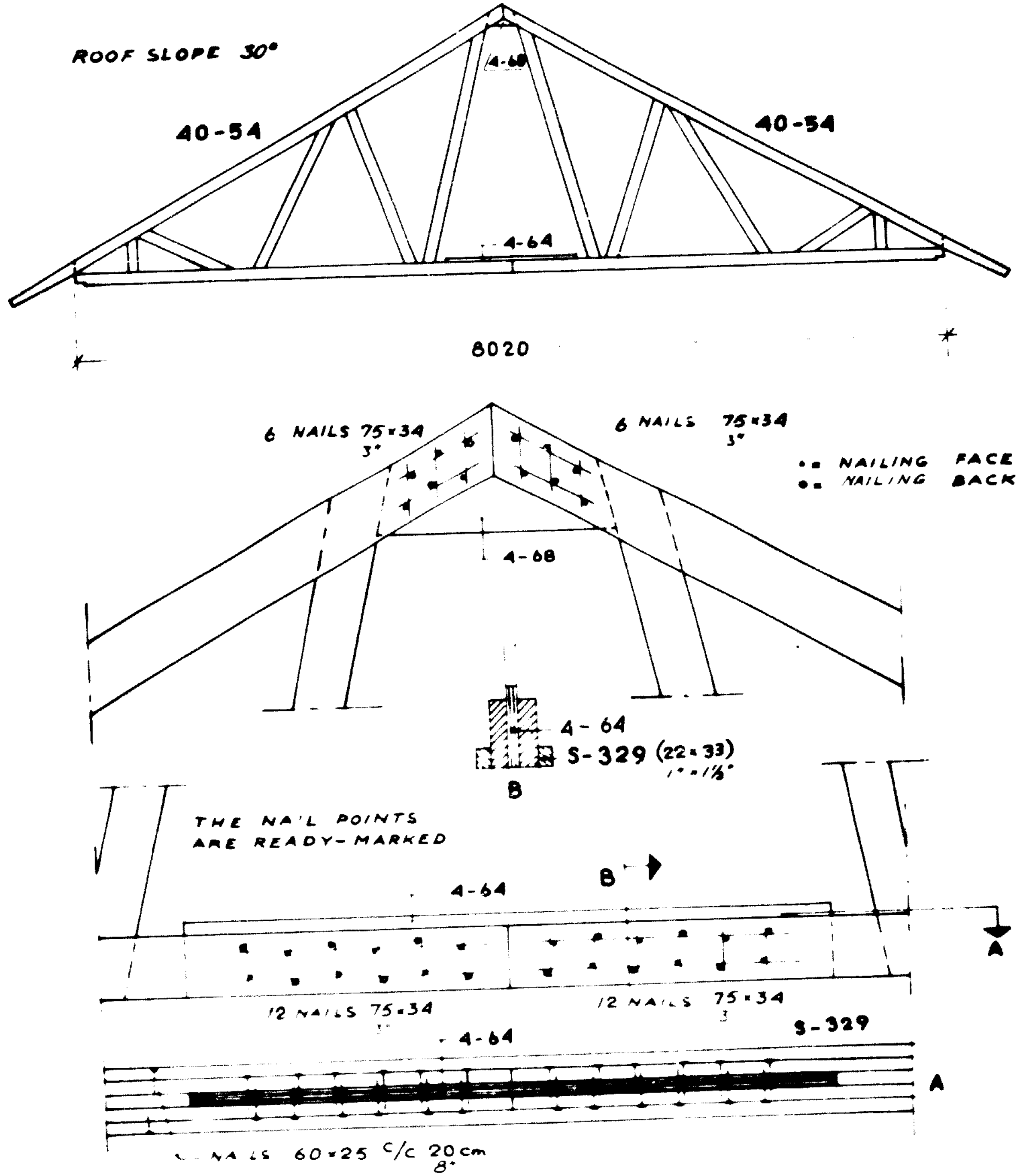
CUT ON SITE
36
1'-2⅛"
INSULATING BOARD
12×120×2400
½"×4¾"×7'-10½"
P-300
SUPPORT IRON 4:21
10-81
AIR SPACE HERE
ANGLE IRON
POST 10-22 (95×95×2460)
4"×4"×8'-1"
HOT BITUMEN
IRON TUBE ϕ3" L= 12cm
4¾"
125
5"
IRON BAR
165 5
5'-5⅛"

ROOF PANELS

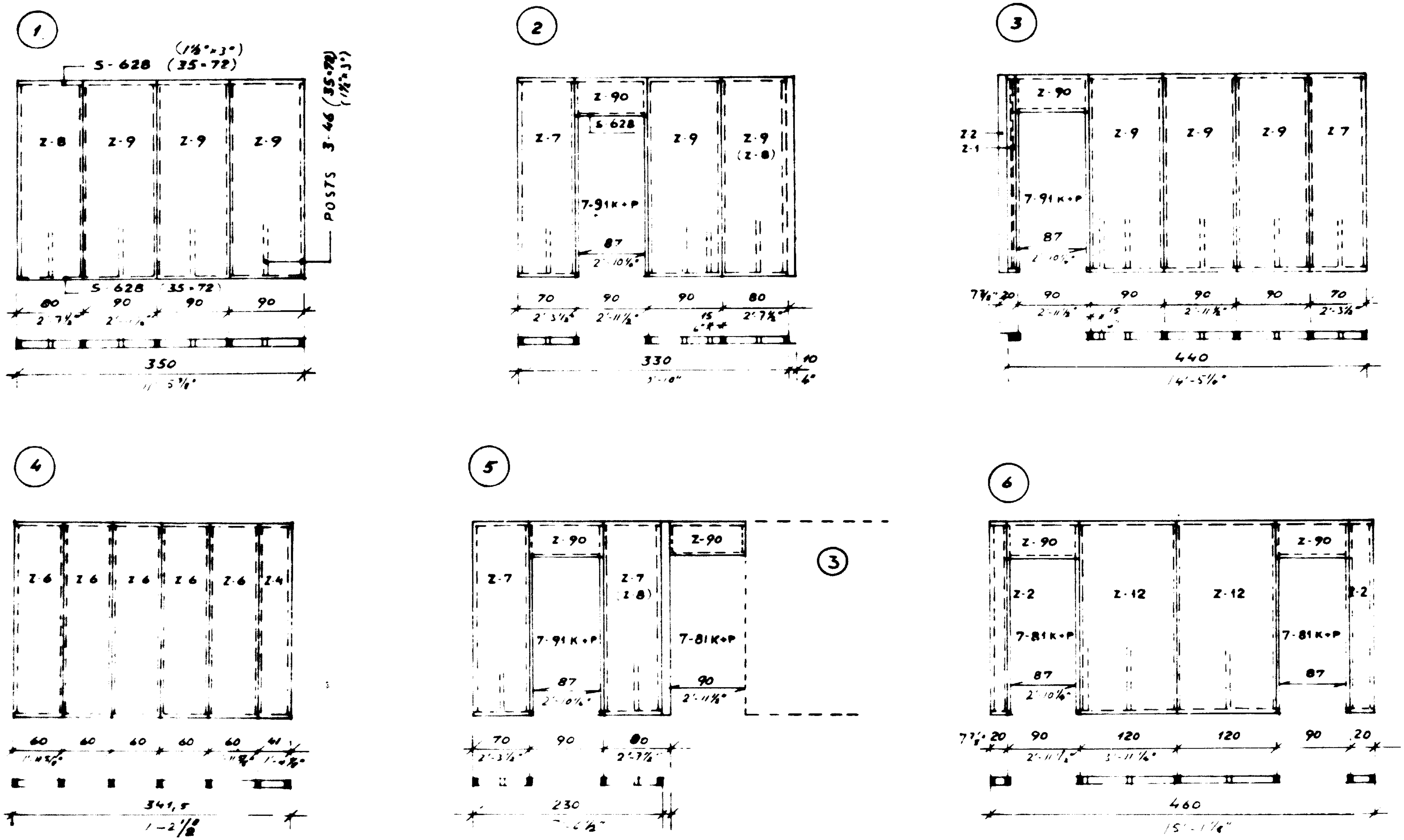


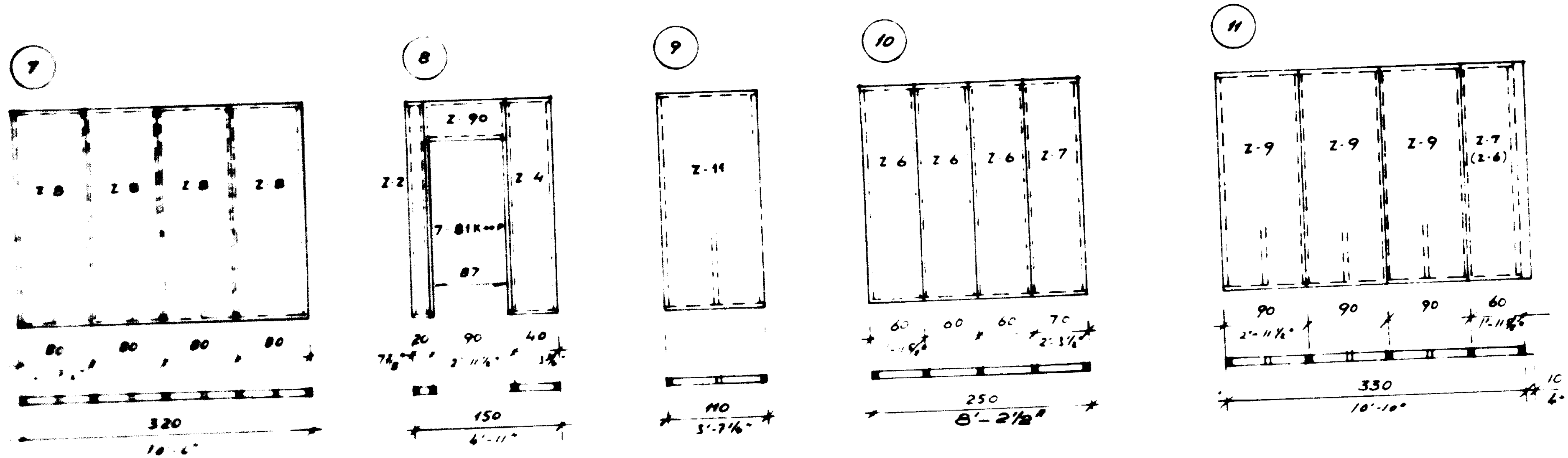
BEGIN PLACING ROOF PANELS AT THE EAVE

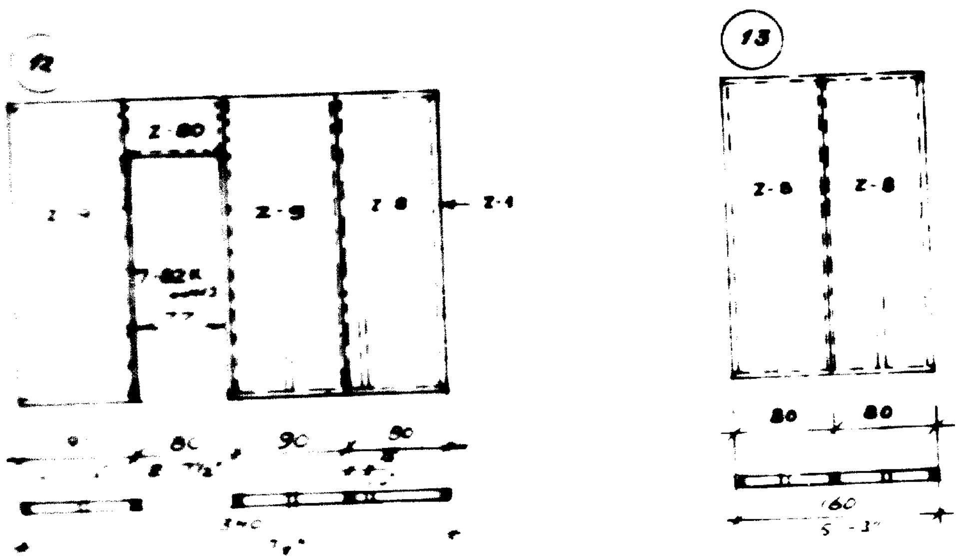
ASSEMBLY OF ROOF TRUSSES



FRAMING OF PARTITIONS







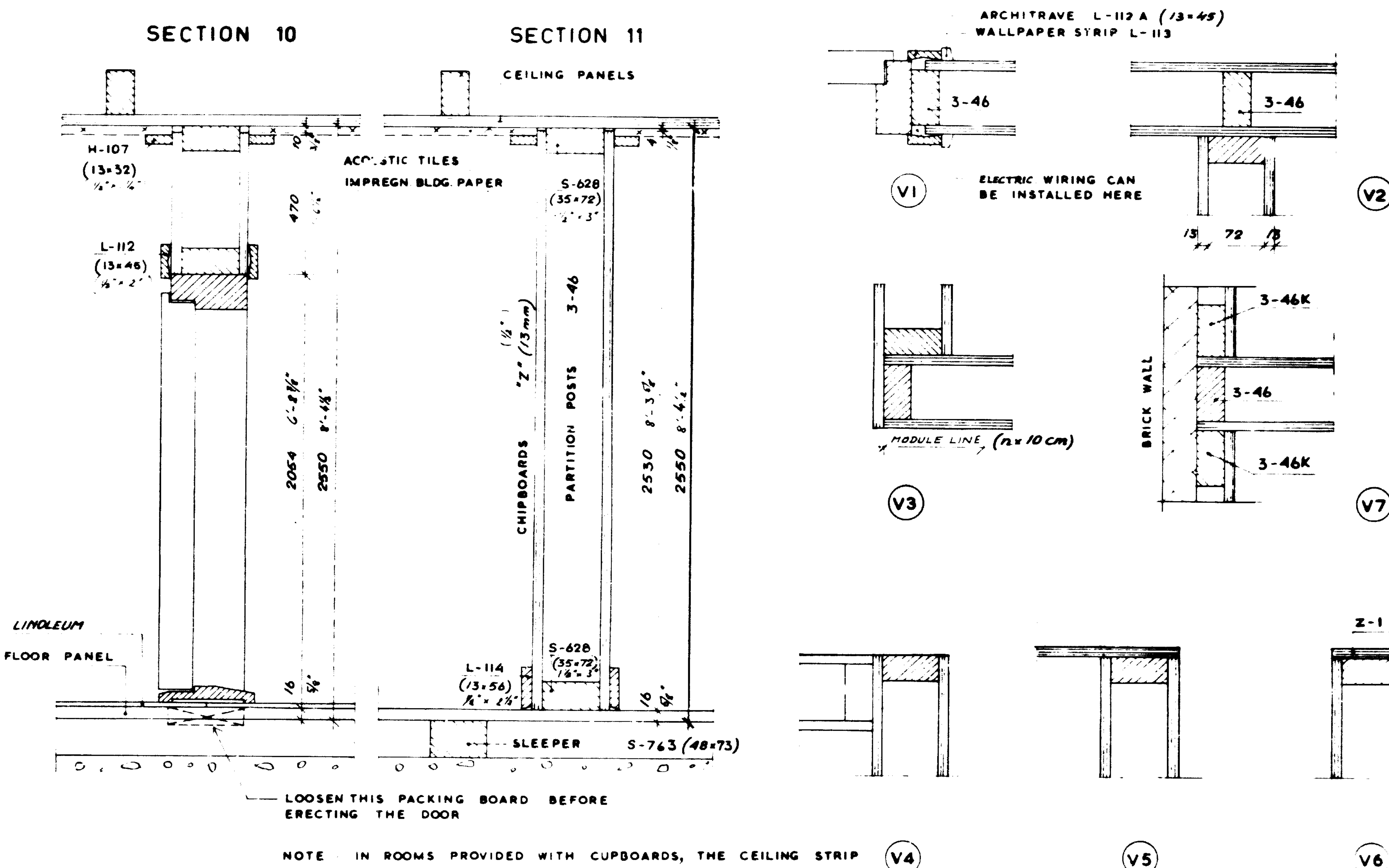
THE PANEL ITEMS IN PARENTHESES SHOULD BE FASTENED ON THE BACK OF THE FRAME

THE JOINTS OF THE CHIPBOARD PANELS MUST LIE ON THE POSTS INDICATED BY BLACK DOTS

THE PARTITIONS, SILLS AND TOP PLATES SHOULD BE CUT TO SUITABLE LENGTH ON SITE

ALL POSTS ARE SIMILAR [illegible] ERECTION DETAIL TO ITEM 3 - 46 "PARTITION DETAILS — FLOOR PANELS" (PAGE [illegible]

PARTITION DETAILS (ON FLOOR PANELS)

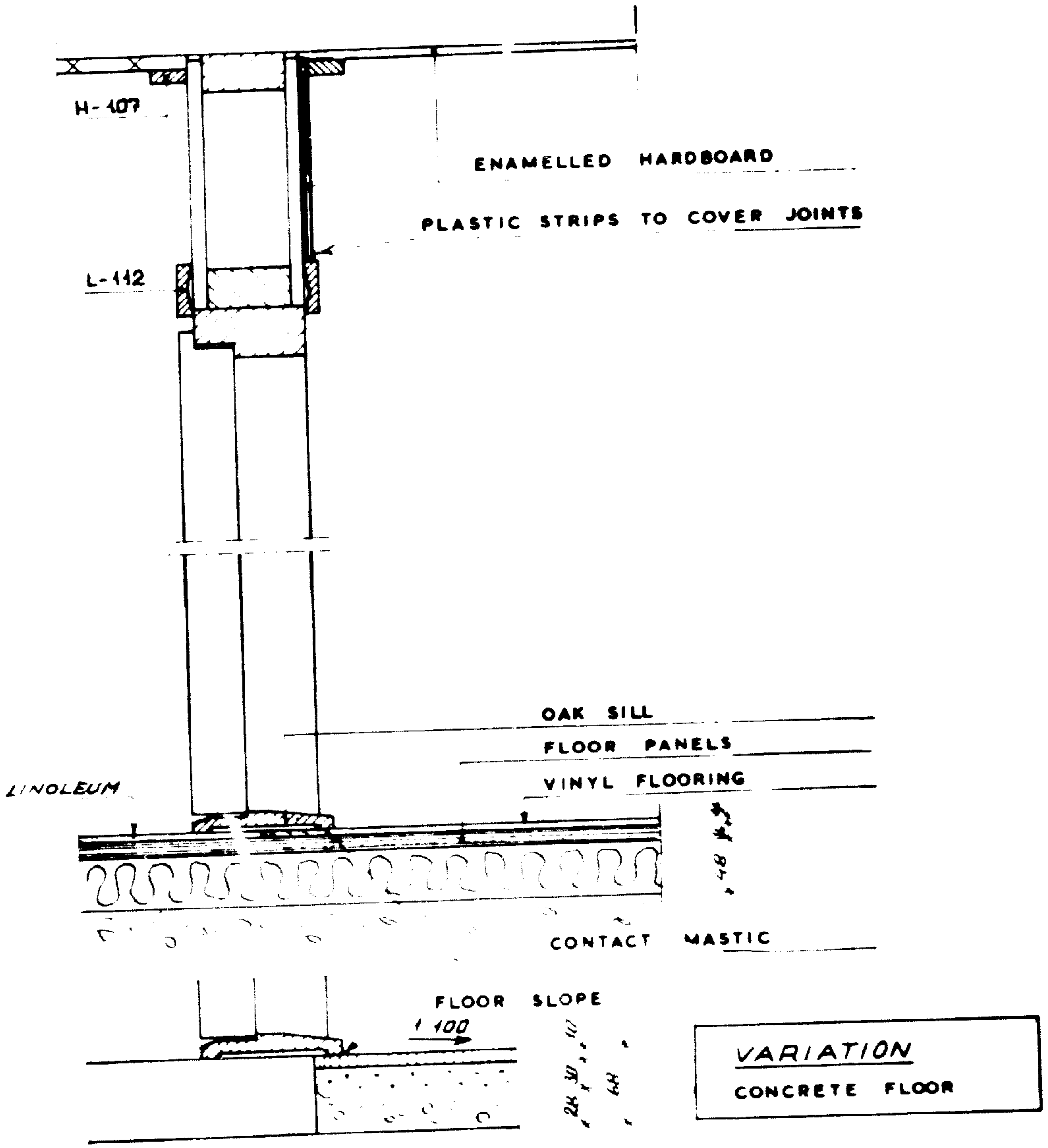


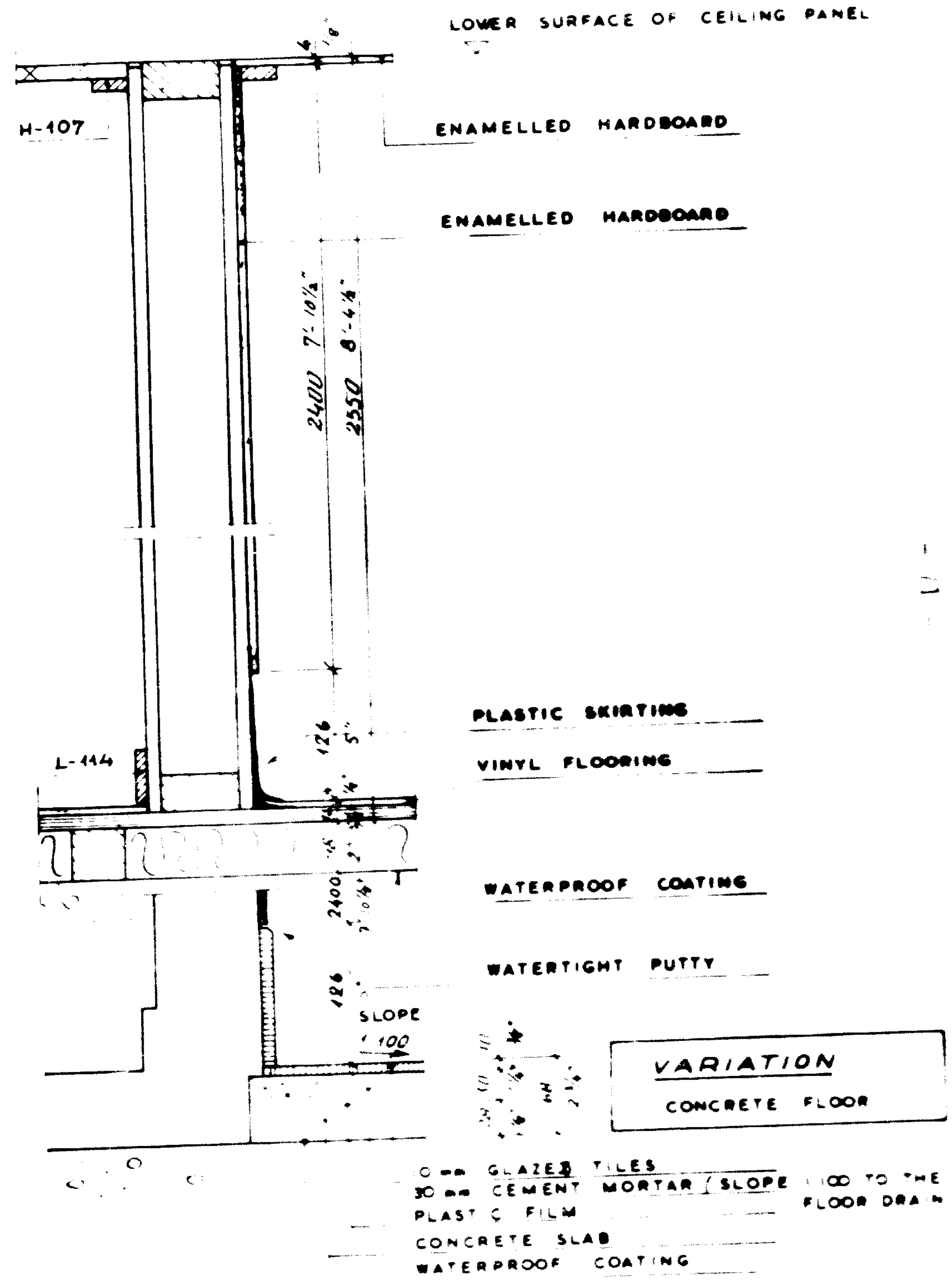
LOOSEN THIS PACKING BOARD BEFORE ERECTING THE DOOR

NOTE IN ROOMS PROVIDED WITH CUPBOARDS, THE CEILING STRIP SHOULD BE PLACED EDGEWISE

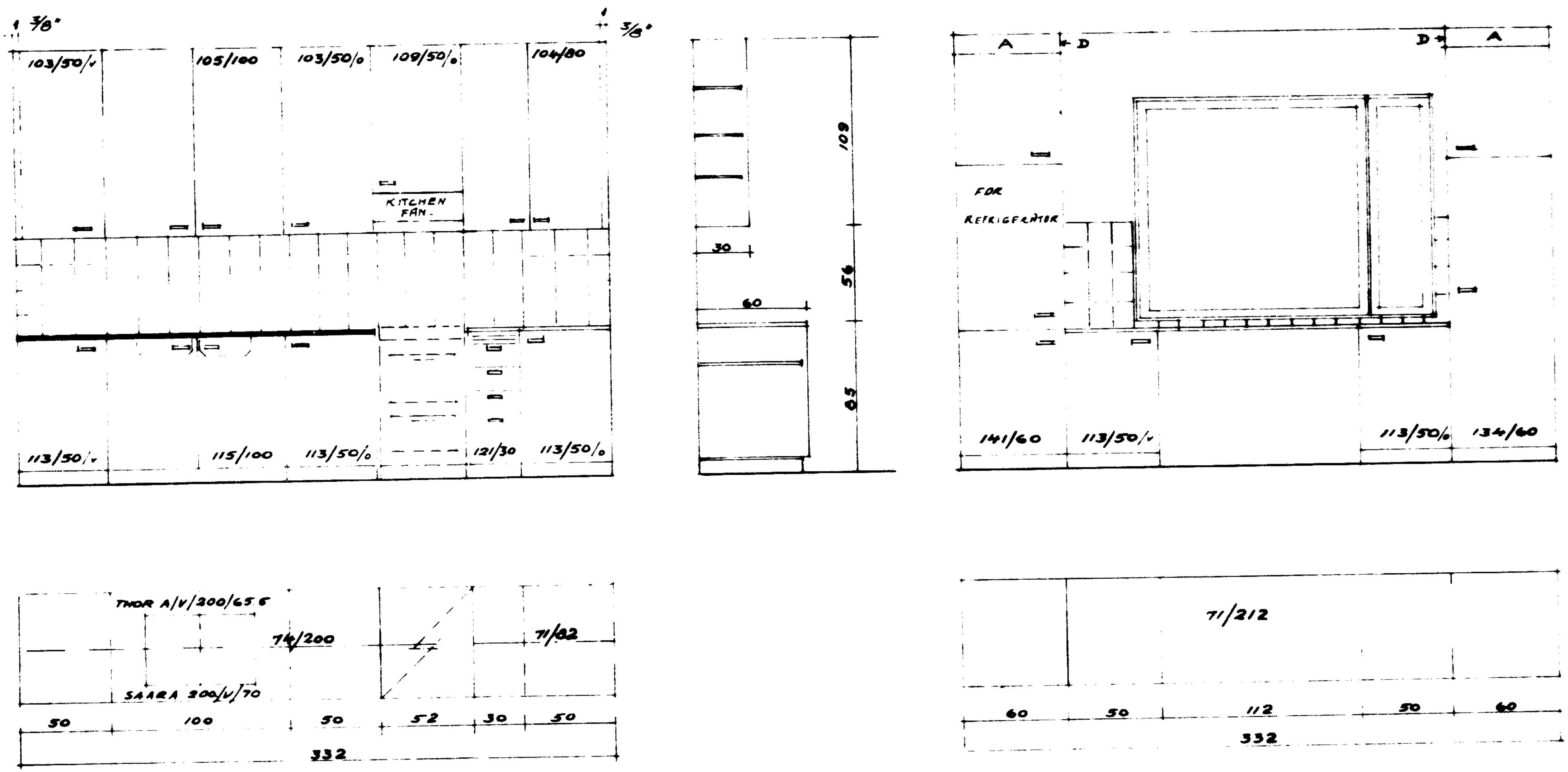
DOOR SILLS SHOULD BE PLACED AFTERWARDS

BATHROOM WALL FINISHING AND FLOORING

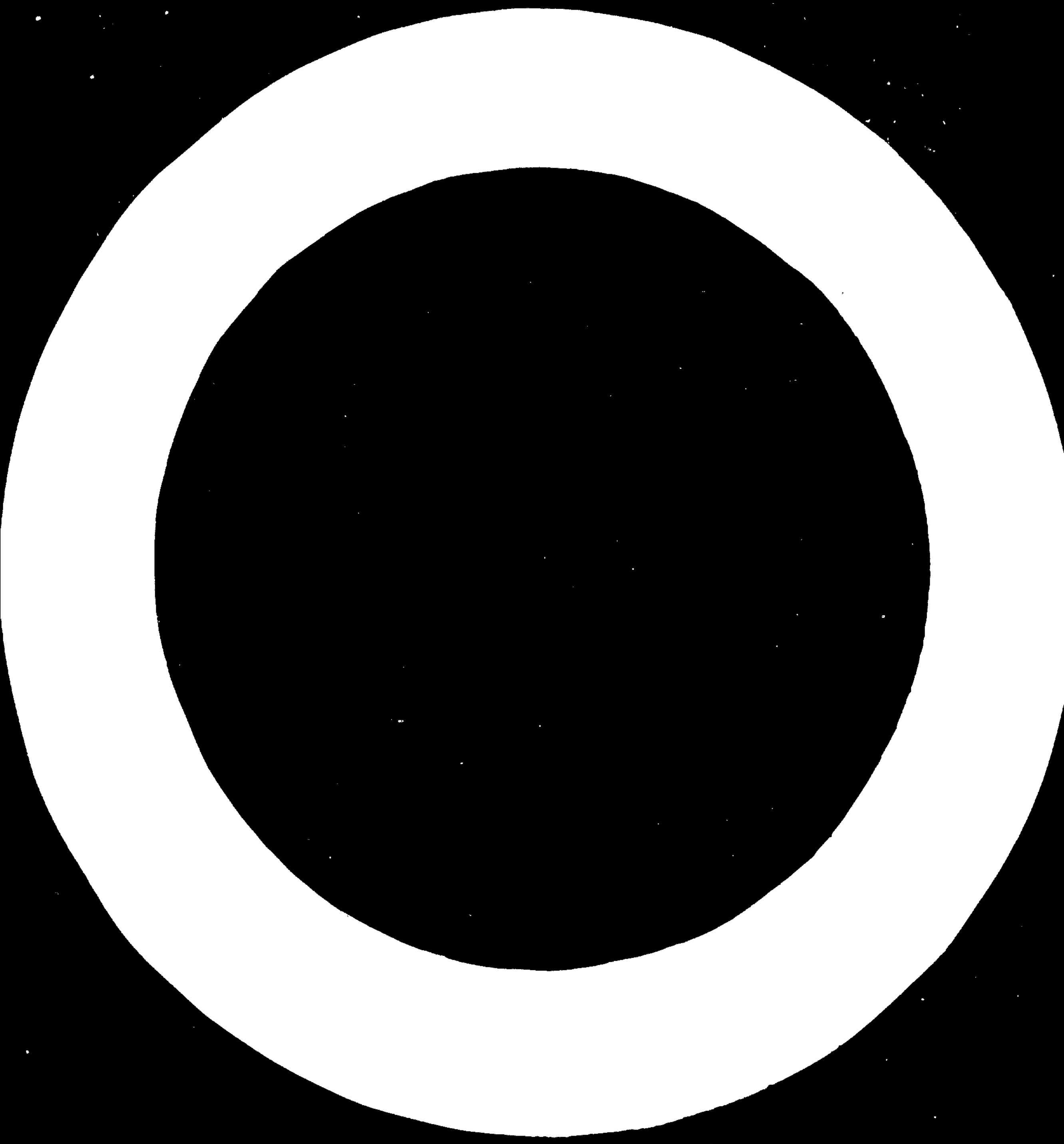




KITCHEN EQUIPMENT

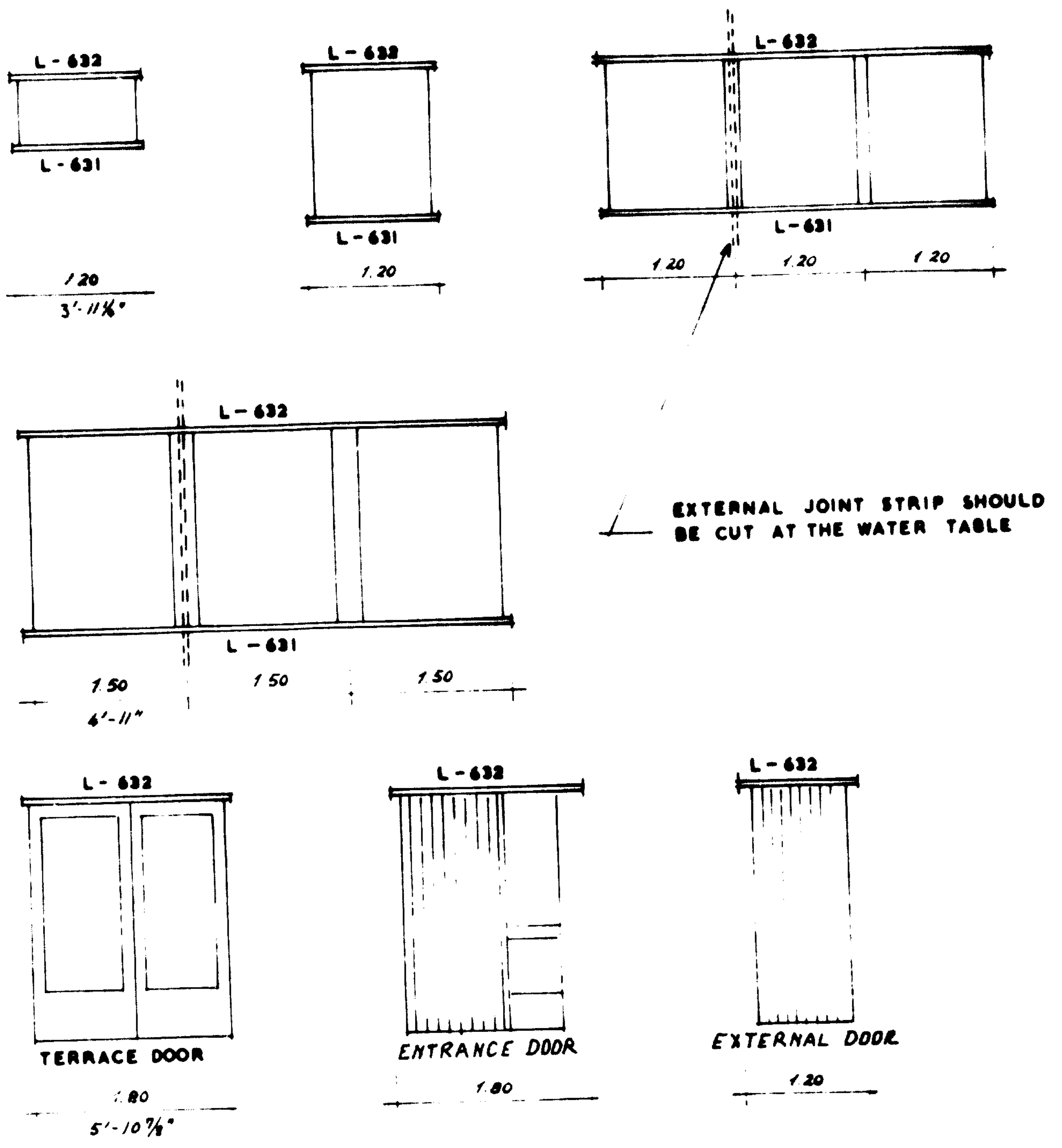


NOTE: ELECTRIC STOVE AND REFRIGERATOR NOT INCLUDED IN DELIVERY



EXTERNAL ARCHITRAVES FOR WALLS WITH VERTICAL SIDING

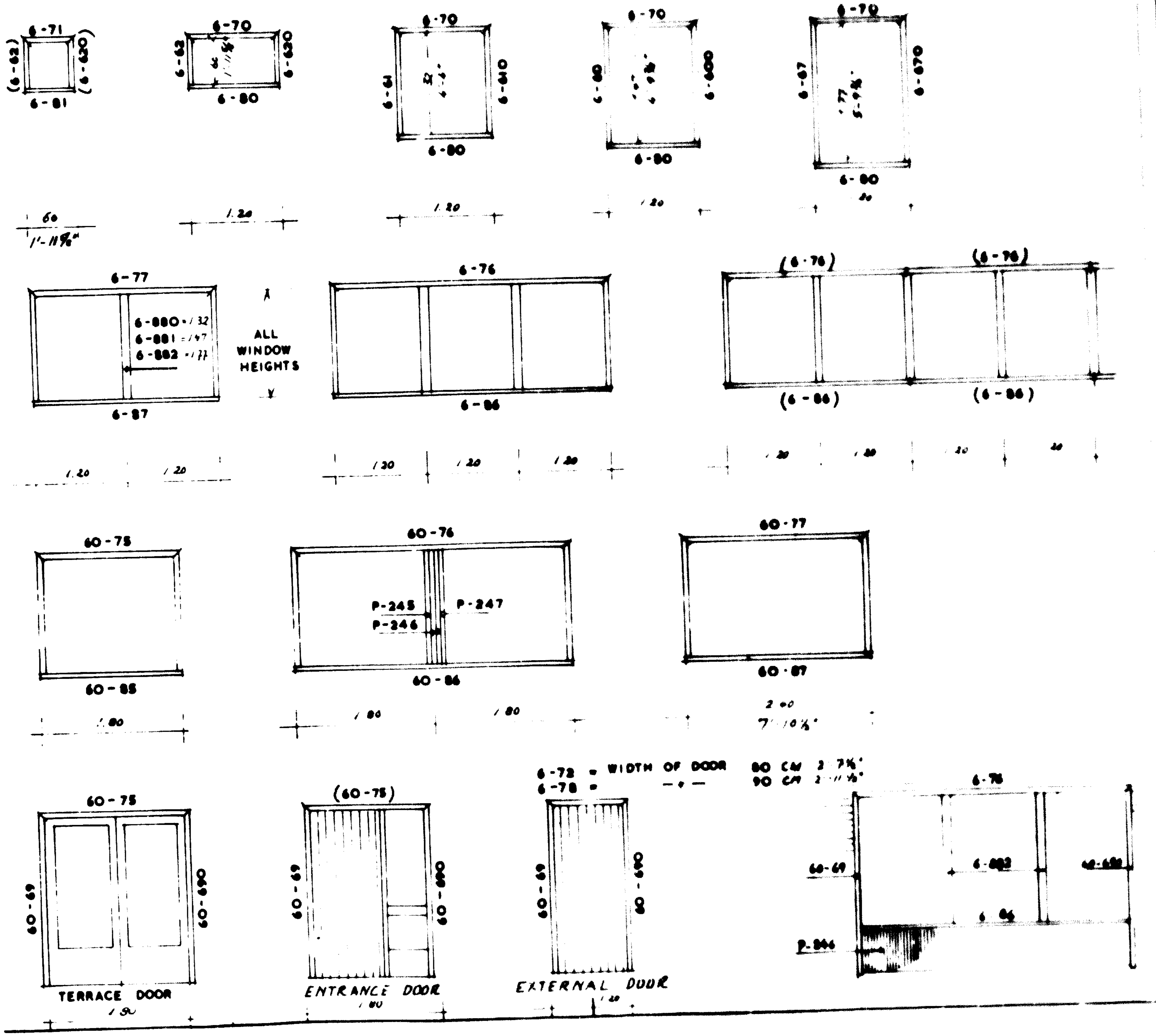
ALL HORIZONTAL ARCHITRAVES SHOULD BE CUT ON SITE



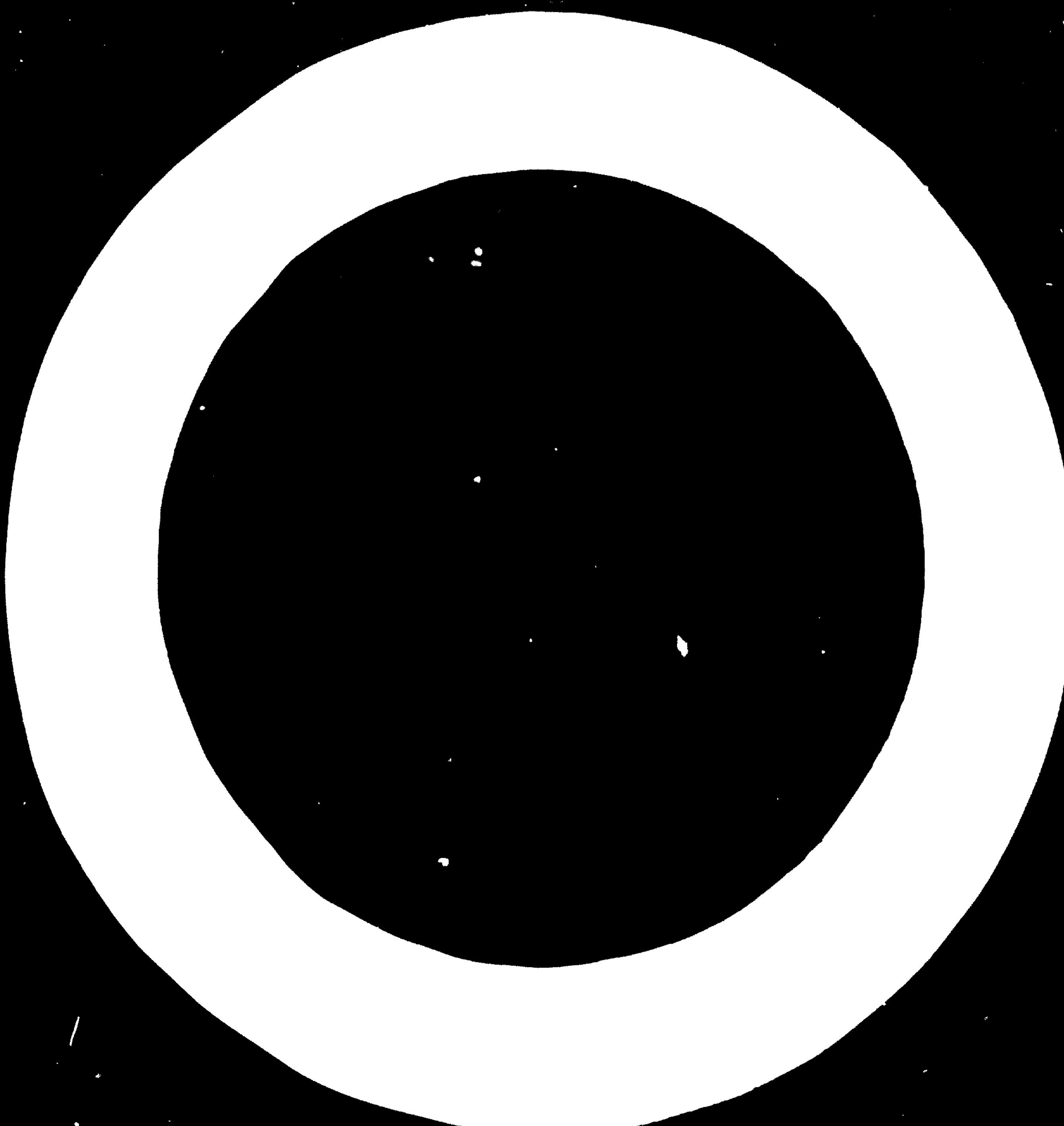
EXTERNAL ARCHITRAVES FOR WALLS WITH HORIZONTAL BEVEL SIDING

(ALSO FOR WALLS WITHOUT SIDING, BUT WITH ARCHITRAVES)

ITEMS IN PARENTHESIS SHOULD BE CUT ON SITE



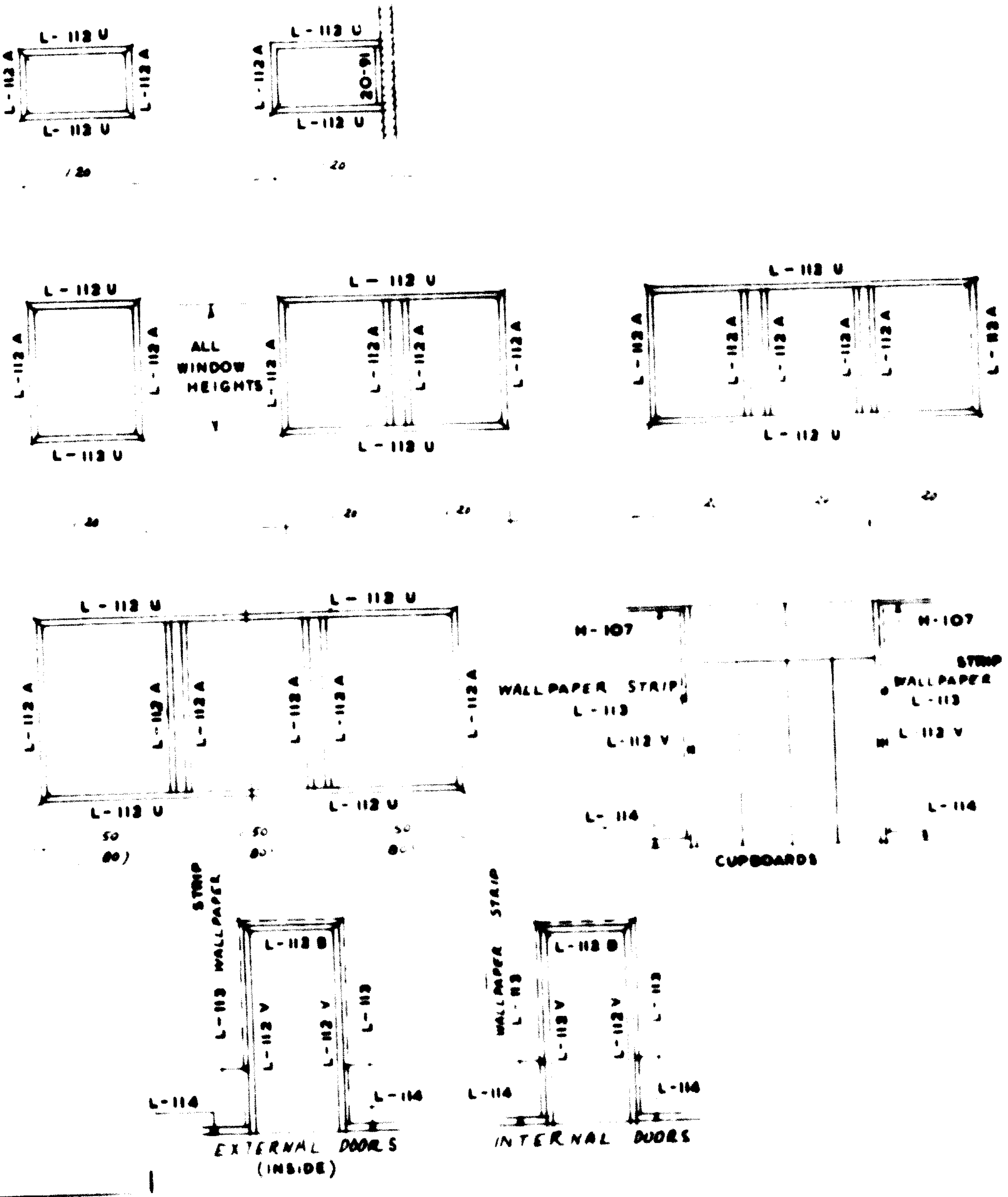
ARCHITRAVES

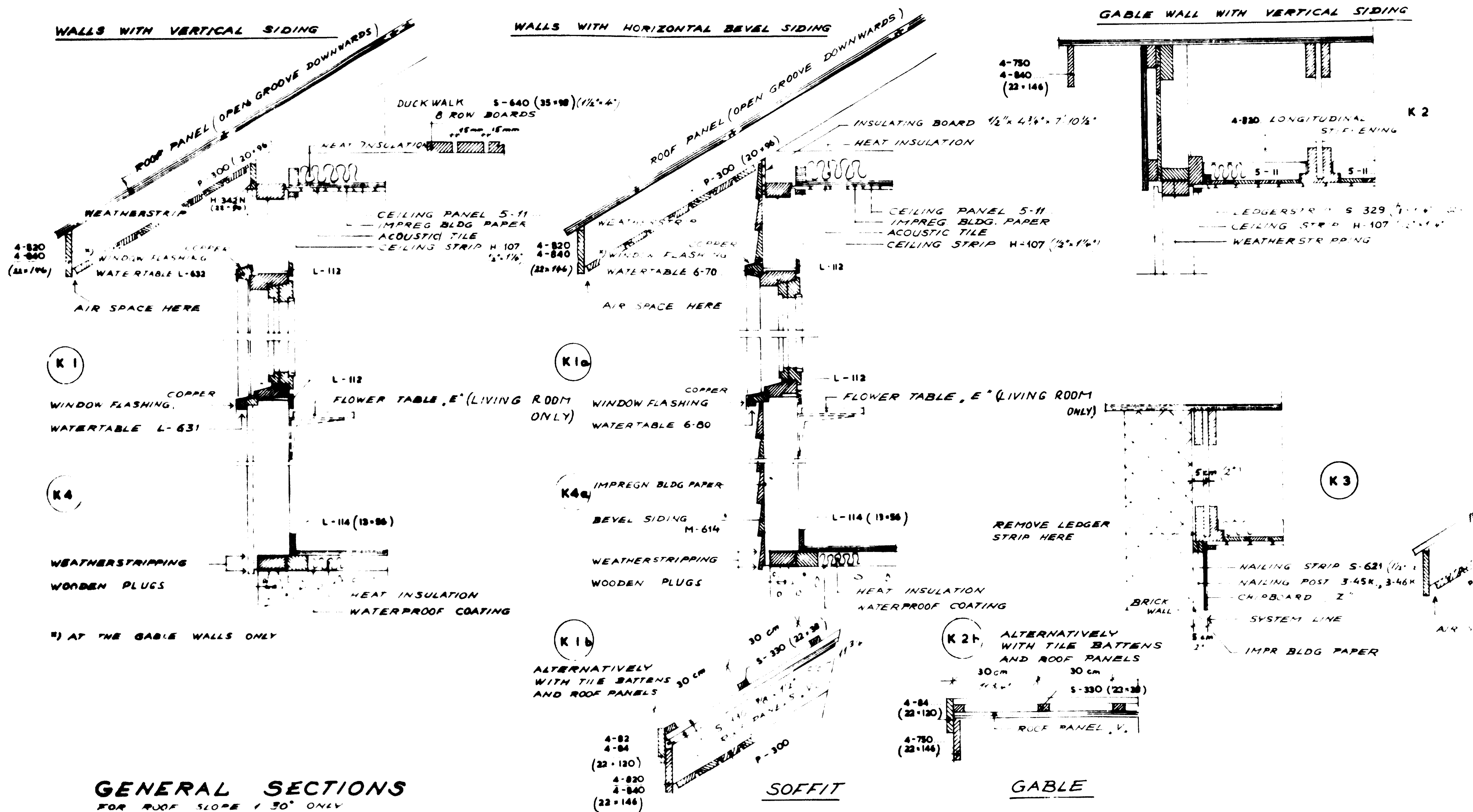


INTERNAL ARCHITRAVES

USE MITREBOX BY CUTTING THE ARCHITRAVES INTO AN EVENLY DIVIDED ANGLE

WALLPAPER STRIP L-113 AROUND ALL DOOR ARCHITRAVES

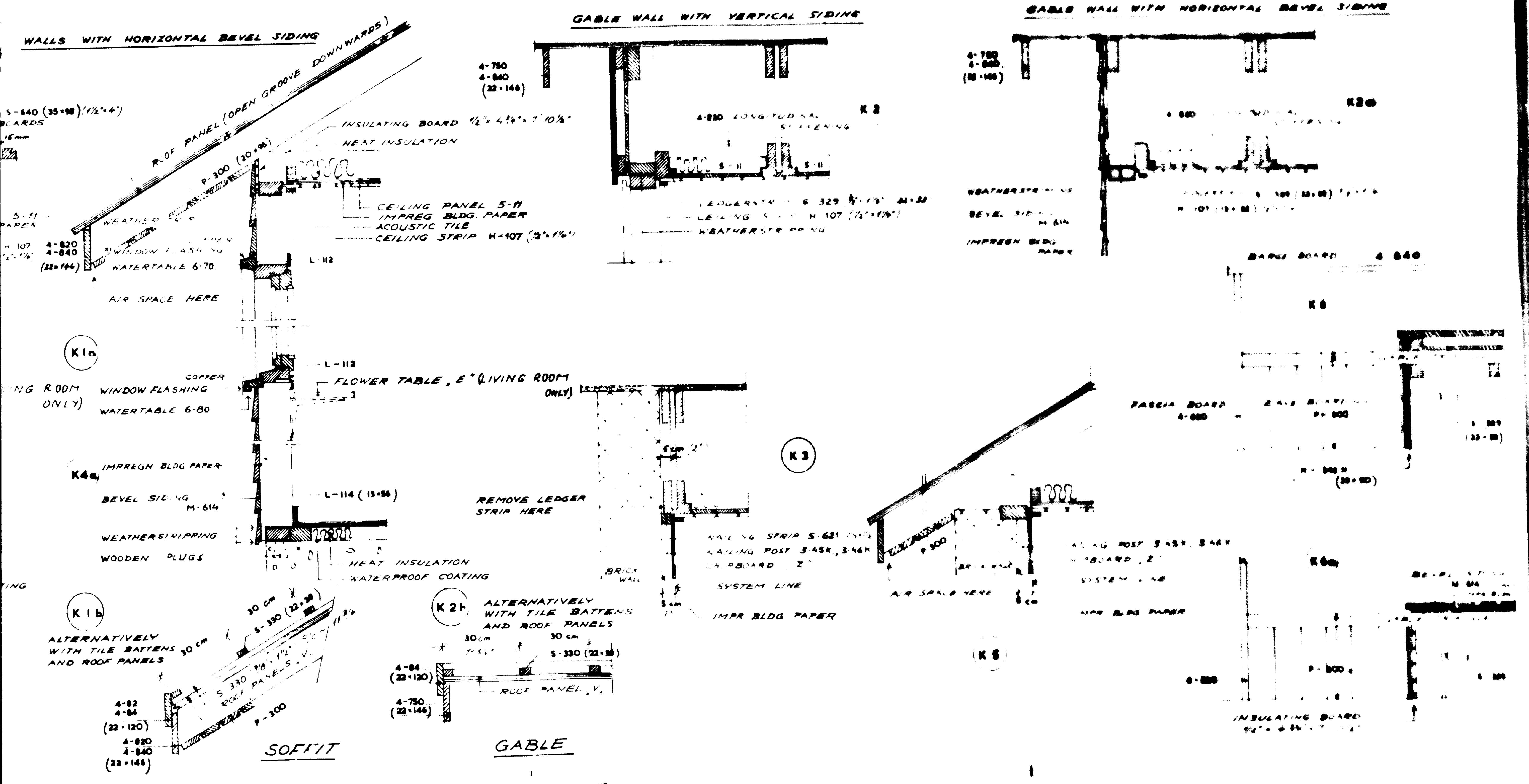




GENERAL SECTIONS

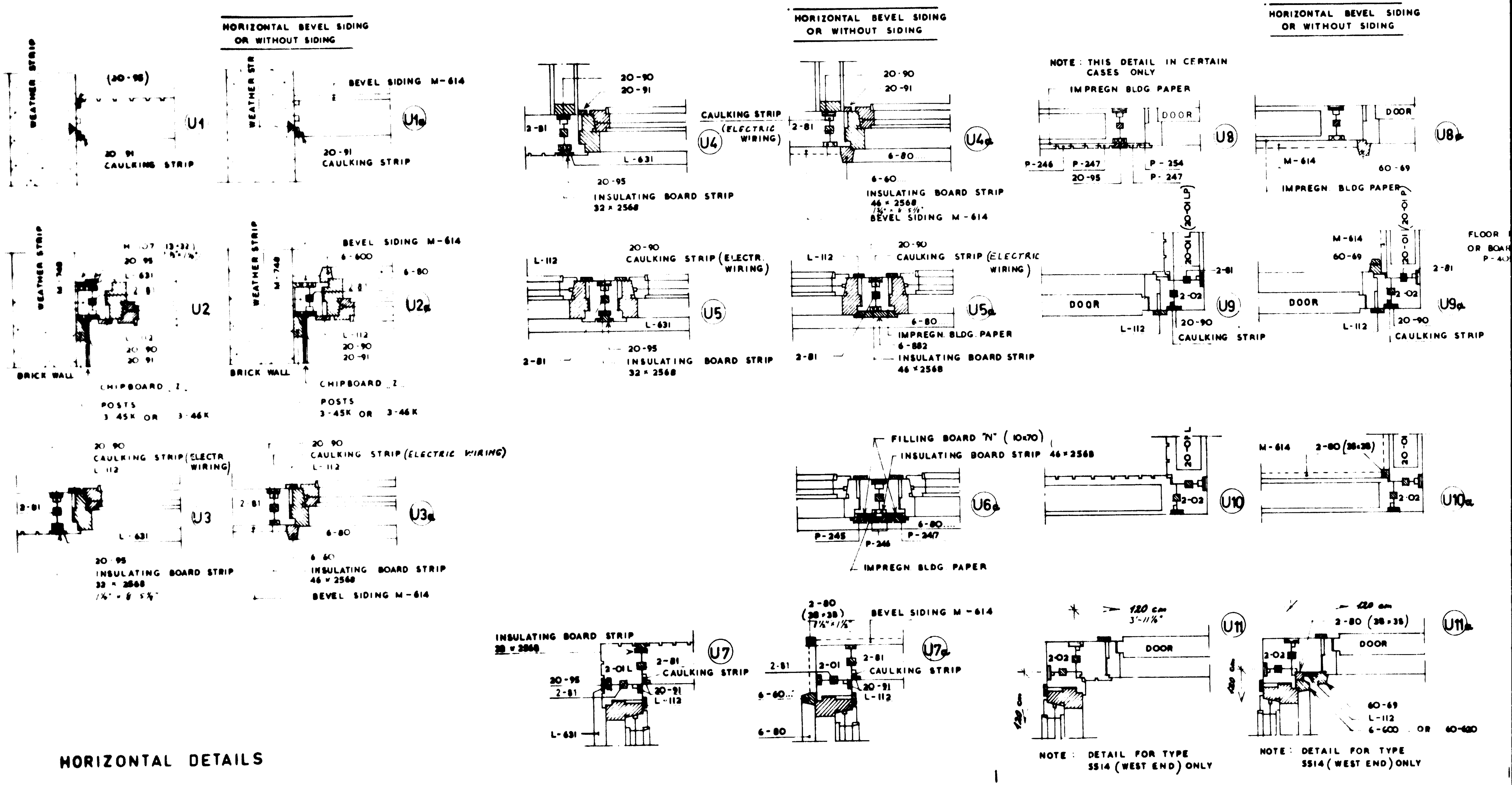
FOR ROOF SLOPE < 30° ONLY

SECTION 1



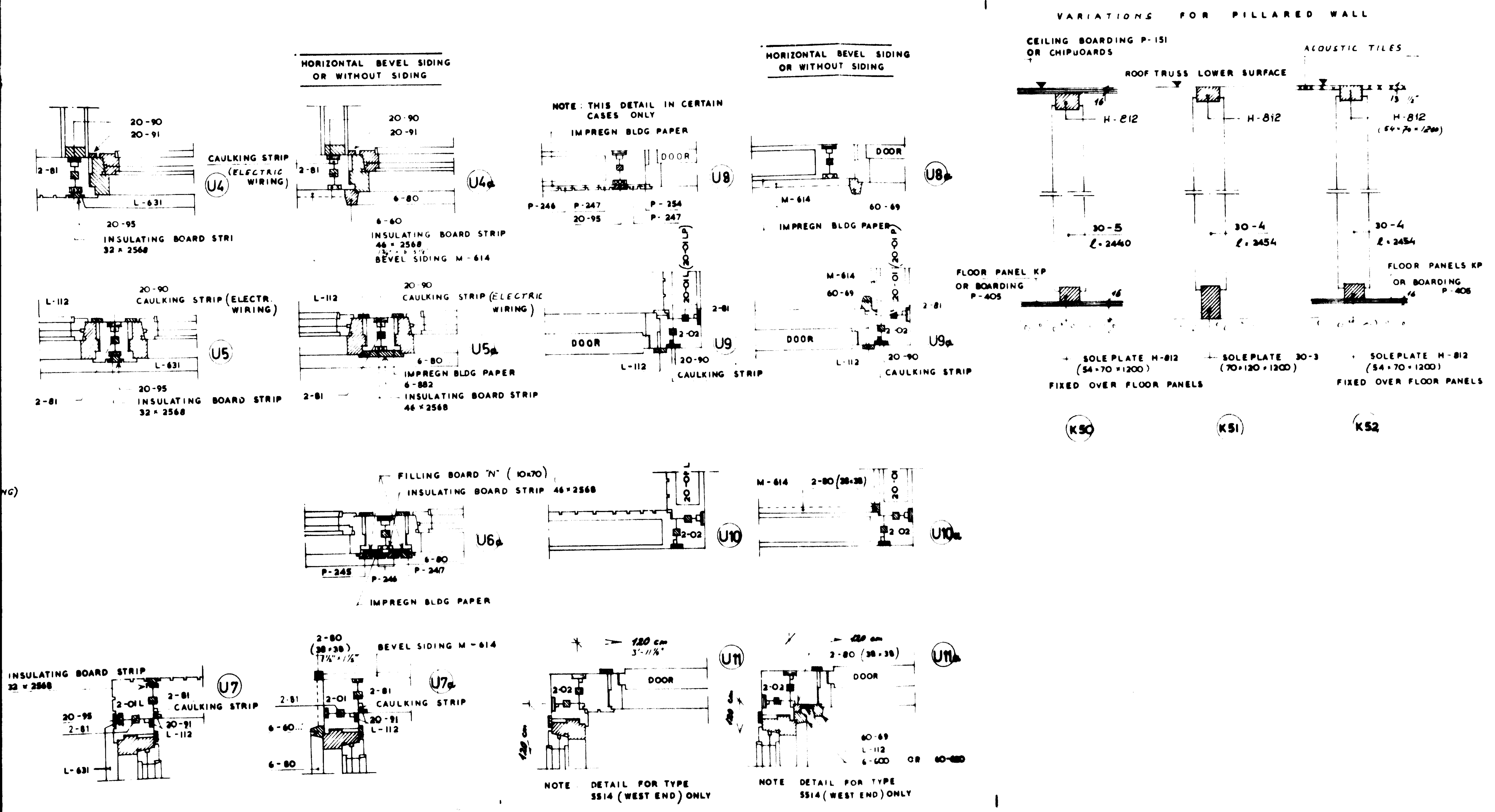
General Sections

SECTION 2



HORIZONTAL DETAILS

SECTION 1



Horizontal Details

SECTION 2

Loading specification

Example of shipping form

Steamer: B/L No Hold/Deck cargo (Please specify whether hold or deck cargo)

Port of loading: Date of loading

Port of unloading:

Shipper: Factory

The number of parcels should be checked against the loading specification during unloading.

Parcel No.	Description	Item	[illegible] per parcel	Parcel [illegible]		Weight of parcel [illegible]	[illegible]
				[illegible]	[illegible]		
1	Wall sill and top plate	1-10	[illegible]	[illegible]		[illegible]	Bundle
	Wall sill and top plate	1-1[illegible]	1				
						84	[illegible]
2	Wall sill and top plate	1-1[illegible]	[illegible]	[illegible]		[illegible]	Bundle
3	Corner post	[illegible]-01	4	1			
4	Wall panel with window	1[illegible]-10K+[illegible]K	1	1		1[illegible]	Bundled together
	Wall panel	[illegible]-10	1				
[illegible]	Wall panel with window	12-11K+[illegible]K	1	[illegible]		1[illegible]	Bundled together
	Wall panel	-10	1				
[illegible]	Wall panel with window	1[illegible]-1[illegible]K+[illegible]K	1	1		1[illegible]	Bundled together
	Wall panel	[illegible]-10	1				
[illegible]	Wall panel with window	[illegible]0-[illegible]4K	1	1		[illegible]	Bundled together
	Wall panel	2-10	1				
	Wall panel	2-11	1				

Parcel No.	Description	Item	Comp. per parcel	Parcel per house sent	Weight of parcel (kg)	Packing
8	Wall panel with window	52-25k	1	4	269	Bundled together
	Wall panel	2-10	1			
	Wall panel	2-11	1			
9	Wall panel with door	300-570++A	1	1	194	Bundled together
	Wall panel	2-10	1			
10	Wall panel	2-10	2	4	176	Bundled together
11	Plywood strips for levelling		110	1	30	Bundled together
12	Internal joint strip	20-90	34	1	39	Bundle
	Internal joint strip	20-91	10			
13	Guiding strip	2-81	42	1	25	Bundle
14	Corner strip	2-80	4		120	Crate
	Weather board below window	P-246	16			
	Cover board between two windows	6-882	2			
	Window architrave	6-60	5			
	Window architrave	6-600	5			
	Window architrave	6-61	1			
	Window architrave	6-610	1			
	Window architrave	6-62	1			
	Window architrave	6-620	1			
	External door architrave	60-69	2			
	External door architrave	60-690	2			
	Window architrave	6-70	2			
	Window architrave	60-75	5			
	Window architrave	6-76	1			
	External door architrave	6-78	1			
	Window water table	6-80	2			
	Window water table	60-85	5			
	Window water table	6-86	1			
	Joint strip for gable ends	M-304/1	3			
15	Roof truss half	40-54	1	20	54	Loose
16	Connecting piece	4-68	12	1	43	Bundle
	Connecting piece	4-64	10			

Parcel No.	Description	Item	Comp. per parcel	Parcel per house sent	Weight of parcel (kg)	Packing
[illegible]	Cable triangle	40-541E	1	2	[illegible]	Loose
[illegible]	Cable triangle	40-542E	1	2	[illegible]	Loose
[illegible]	Ceiling panel	5-11	2	10	[illegible]	Nailed together
20	Ceiling panel	50-11	2	1	90	Nailed together
	Ceiling panel	50-12	1			
21	Ceiling panel	5-12	2	5	68	Nailed together
[illegible]	Ledger strip	6-329	70 m	1	28	Bundle
[illegible]	Attic door	5-20	1	1	25	Loose
24	Duckwalk board	S-640	53 m	2	100	Bundle
25	Roof panel	V-4	7	2	157	Bundled together
26	Roof panel	V-5	7	2	220	Bundled together
27	Roof panel	V-7	7	4	189	Bundled together
28	Eave board	P-300	8 m^2	2	88	Bundle
29	Eave board	P-300	[illegible] m^2	1	77	Bundle
30	Fascia board	4-820	[illegible]	1	38	Bundle
31	Fascia board	4-840	[illegible]	1	51	Bundle
32	Barge-board	4-760	[illegible]	1	58	Bundle
33	Porch post	10-22	[illegible]	1	66	Bundle
34	Porch purlin	10-33	1	1	42	Bundled together
	Porch purlin	10-35	1			
35	Porch roof joist	10-81	13	1	68	Bundled together
36	Bevel siding	M-614	8 m^2	12	76	Bundle
37	Bevel siding	M-614	7 m^2	1	67	Bundle
38	Floor sleeper	S-763	50 m	6	96	Bundle
39	Partition sill and top plate	S-628	45 m	2	61	Bundle
40	Partition post	3-46	21	4	72	Bundle
41	Partition post	3-46	24	1	82	Bundle
42	Side post for cupboards	S-785	4	1	26	Bundle
	Nailing strip for cupboards	S-621	12 m			

Parcel No.	Description	Item	Comp. per parcel	Parcel per house sent	Weight of parcel (kg)	Packing
43	Chipboard (Partition)	Z-1	2	1	73	Export packing
	Chipboard (Partition	Z-2	[illegible]			
	Chipboard (Partition)	Z-4	4			
44	Chipboard (Partition)	Z-6	5	1	68	Export packing
45	Chipboard (Partition)	Z-6	6	2	81	Export packing
46	Chipboard (Partition)	Z-7	5	2	80	Export packing
47	Chipboard (Partition)	Z-8	6	3	107	Export packing
48	Chipboard (Partition)	Z-9	5	5	142	Export packing
49	Chipboard (Partition)	Z-11	2	1	186	Export packing
	Chipboard (Partition)	Z-12	5			
50	Chipboard (Partition)	Z-80	2	1	56	Export packing
	Chipboard (Partition)	Z-90	14			
51	Floor panel (chipboard)	KP-5	4	1	107	Export packing
52	Floor panel (chipboard)	KP-9	2	1	70	Export packing
53	Floor panel (chipboard)	KP-10	4	1	145	Export packing
54	Floor panel (chipboard)	KP-10E	6	1	220	Export packing
55	Internal door and loose oak sill	7-81K+P	3	1	128	Bundled together
56	Internal door and loose oak sill	7-81K++P	1	1	82	Bundled together
	Internal door and loose oak sill	7-82K++WJ	1			
57	Internal door and loose oak sill	7-91K+P	3	1	120	Bundled together
58	Internal architrave	L-112A	20	1	220	Crate
	Internal architrave	L-112B	17			
	Internal architrave	L-112U	16			
	Internal architrave	L-112V	36			
	Wallpaper cover strip	L-113	90 m			

Parcel No.	Description	Item	Comp. per parcel	Parcel per house sent	Weight of parcel (kg)	Packing
	Skirting	L-114	120 m			
	Ceiling strip	H-107	140 m			
	Cover strip (cupboard)	H-312	2			
	Flower board	E-2	1			
	Flower board	E-4	1			
	Mitre box		1			
59	Clothes hanger	"BODA"	1	1	40	Crate
60	Insulating board $\frac{1}{2}$" x 48 x 2,568		44	1	40	Crate
	Insulating board $\frac{1}{2}$" x 120 x 2,400		12			
61	Impregn. bldg. paper	No.1	280 m^2	1	85	Crate
	Protecting paper		100 m^2			
62	Acoustic tile $\frac{1}{2}$" x 40 x 40 cm		200	3	128	Crate
63	Acoustic tile $\frac{1}{2}$ x 40 x 40 cm		50	1	32	Crate
64	Enamel hardboard 60 x 180 cm	VS	5	1	104	Export packing
	Enamel hardboard 60 x 240 cm	SVV 10	14			
65	Plastic strip	P-91	10	1	30	Case
	Plastic strip	P-92	16			
	Plastic strip	P-94	5			
	Plastic skirting	P-144	10 m			
66	Copper flashing	L=1,200	4	1	34	Case
	Copper flashing	L=1,800	7			
	Copper flashing	L=2,400	1			
	Copper flashing	L=975	5			
	Copper flashing	L=1,140	5			
	Copper flashing	L=320	5			
67	Weather strip	8 x 100mm	160 m	1	30	Crate
	Caulking ribbon	25 x 25mm	110 m			

Parcel No.	Description	Item	Comp. per parcel	Parcel per house	Parcel sent	Weight of parcel (kg)	Packing
68	Wire nails	125 x 42G	3 kg	1		50	Case
	Wire nails	100 x 34G	8 kg				
	Wire nails s.h.	100 x 34G	2 kg				
	Wire nails	75 x 34G	3 kg				
	Wire nails s.h.	75 x 28G	3 kg				
	Wire nails	60 x 25G	7 kg				
	Wire nails s.h.	60 x 25G	4 kg				
	Wire nails	45 x 17G	2 kg				
	Wire nails s.h.	30 x 17G	4.5 kg				
	Wire nails	20 x 12G					
	Tacks	16 x 1.6	0.4 kg				
	Steel nails	4 in	4 kg				
	Copper nails	20 x 15	0.4 kg				
69	Wire nails	75 x 28G	10 kg	1		55	Case
	Wire nails s.h.	75 x 28G	10 kg				
	Wire nails	50 x 21	30 kg				
70	Case of accessories, (see page 84)		1	1		40	Case
82	RI-LA parquet	TN	$2.52m^2$	8		63	
83	RI-LA parquet	TN	$2.76m^2$	1		31	

Kitchen equipment

Parcel No.	Description	Item	Comp. per parcel	Parcels per house	Parcels sent	Weight of parcel (kg)	Packing
71	Floor unit	113/50/v	1	1		113	Export
	Floor unit	113/50/oOS	1				
	Floor unit	115/100	1				
	Working table	71/212	1				
	Drawer unit	121/30/VS	1				

Parcel No.	Description	Item	Comp. per parcel	Parcels per house	Parcels sent	Weight of parcel (kg)	Packing
	Floor unit	113/50/o	1	1		51	Export
	Floor unit	113/50/oVS	1				
	Floor unit	113/50/vOS	1				
	Working table	71/82	1				
73	Wall unit	105/100	1	1		115	Export
	Wall unit	103/50/v	1				
	Wall unit	103/50/oOS	1				
	Wall unit	104/80VS	1				
	Wall unit	109/50/o	1				
74	Refrigerator cupboard with door and shelves	141/60/vOS	1	1		40	Export
75	Cupboard	134/60/o HK VS	1	1		48	Export
76	Top cupboard	Yk 60/vOS	1	1		44	Export
	Top cupboard	Yk 60/oVS	1				
	Kitchen ventilator	SLEV KT-24	1				
	Filling boards	-	3				
77	Counter top of stainless steel "THOR"	A/v/200/65	1	1		30	Export
	Base frame for counter top	74/200	1				
	Flexible connecting pipe for ventilator	110 cm	1				
78	Enamelled hardboard 60 x 240 cm	VRM 15	2	1		20	Export
	Enamelled hardboard 60 x 120 cm	VRM 15	1				
79	Clothes cupboard	137/120 vk + vk	1	2		66	Export
80	Clothes cupboard	137/120 vk + Lk	1	2		68	Export
81	Top cupboard	Yk-120	2	2		67	Export

Total 173 parcels

Weight 16,900 kg

Case of accessories
(Parcel M 70)

Accessories	Dimension and quality	Quantity	Belongs to:
Contact mastic	Bostik A 3	1 kg	Plastic skirting
Console	TK 200 white	7 pcs	Flower boards
Hanging iron M 21		13 pcs	Porch beams
Iron pipe	Ø 3" L-120 mm	6 pcs	Post footings
Angle iron		8 pcs	Porch posts
Fastening iron	M 2	20 pcs	Roof trusses
Door handle with screws	Pr.22 alum.	7 pairs	Intern. doors
WC door handle with screws	Pr.42 alum.	1 pair	Bathroom door
Door pull	Pr.170/400 oak/crom.	1 pc	Entrance door
Door knob	Bb 1121 brass/crom.	1 pc	Entrance door
Handle	Pr.31/060 alum.	17 pcs	Window and attic door
Window lever with screws		5 pcs	Tilt-type windows
Wing nuts "Rawl"	3/16 in x 2 in nic.pl.	3 pcs	Clothes hanger
Wood screws	1½ in x 10 r.h./galv.	30 pcs	Console
Wood screws	3/4 in x 10 r.h./galv.	30 pcs	Console
Wood screws	2 in x 12 s.h/brass	34 pcs	Oak thresholds
Wood screws	1¼ in x 12 s.h/galv.	34 pcs	Angle irons
Wood screws	1½ in x 7 s.h/crom.	4 pcs	Door knob
Machine screws	3/16 in x 1½ in s.h/crom.	36 pcs	Window handles

PREFABRICATED COMPONENTS MUST BE TREATED WITH THE UTMOST CARE

Loading and unloading must be performed with ropes (not wires) and rope lifting nets. To avoid damage loads should not be too heavy or too large.

The ship's hold (and deck) *or the floor of the transport vehicle* must be level and clean.

The bottom-most cargo should consist of parcels or components capable of bearing a heavy load (for example, bundles of boards, joists and wall panels).

When stored, parcels or components should be placed according to kind. They should be carefully protected against moisture and warping. Parcels most sensitive to moisture should be labelled "ATTENTION! PROTECT FROM MOISTURE".

Parcels or components should not be stored on bare earth but should be placed on a firm and level base.

Annex 2

PROTECTIVE MEASURES AGAINST TERMITES

The basic principle for protection of wood structures against termites have been fairly well developed and generally accepted. For subterranean-type termites they involve: (a) clearing the building area of wood and other cellulosic material; (b) chemical treatment or poisoning of soil adjacent to the foundation and beneath cement slabs; (c) sound construction practices to eliminate all openings between soil and wood members; (d) treatment of the wood and other materials; and (e) systematic and frequent inspection and destruction of all termite tunnels to the building.

Sound construction practices are of primary importance in termite control. Among the basic requirements for good construction are adequate drainage for the building site, proper clearance between ground and wood, and proper sealing of all openings in foundations. Termite shields have been used as a construction feature but are not generally regarded as an adequate and dependable protective measure. In slab-on-ground type of construction it is not known whether the penetration of termites within the perimeter of the building can be prevented. Hence, it is general practice to give the soil beneath the slab a toxic treatment and to use impregnated wood in contact with the slab. In areas where the dry wood terminite also exists, it is considered good practice to treat all wood and fibre products in the building.

Suggestions and recommendations

The following recommendations are applicable to houses already built and to those that will be built:

1. Clean the area of all wood and other cellulosic material.
2. Place the water pipes leading to and around the houses several feet away from the foundations and preferably cover the pipes with several inches of soil. The entry point of pipes into the houses should be at least several feet above the foundation where entrance of termites is difficult and inspection is easy.
3. Treat the soil beneath the foundation slab and adjacent to the foundation walls with chemicals toxic to termites. The following protective chemicals and concentrations are considered effective for a

period of 5 years or more:

- Benzene hexachloride (technical) of 0.8 per cent gamma isomer concentration in water emulsion;
- Chlordane of 1.0 per cent concentration in water emulsion;
- Dieldrin of 0.5 per cent concentration in water emulsion;
- Lindane of 0.8 per cent concentration in water emulsion;
- Sodium arsenite of 10 per cent concentration in water solution.

Sodium arsenite is very effective against termites but is extremely toxic to humans, animals and plants, and should be used only where it cannot be leached to the surface and become hazardous. The water emulsions of the other chemicals listed, when properly applied, are generally non-toxic to plants and less toxic to humans and animals than are oil solutions of the same chemicals. All such products should, however, be handled with care and with proper precautionary measures.

Treatment of soil and foundation

The soil beneath the foundation slab and adjacent to the foundation walls or footings should be treated with one of the water emulsion type chemicals at its required concentration, as indicated above.

Within the periphery of the house it will be necessary to drill holes through the cement floor and into the aggregate and soil beneath at all anchor points, under the bath, toilet and kitchen areas and adjacent to floor drains, and near any cracks in the cement that extend beneath the walls. The required amount of chemical water emulsion should then be applied in the holes, using more than one application if necessary. The rate of application should be 2 gallons per 5 lineal feet or approximately 1 gallon per hole. The holes and cracks in the interior should be carefully grouted with cement.

Outside the periphery of the house and along the front and sides of the house, where the soil is covered with a cement slab, holes should be drilled along the wall approximately 18 inches apart and staggered with the holes on the inside of the wall. The chemical water emulsion should be applied at the rate described above and the holes filled with cement or coal-tar pitch.

On the outside of the foundation wall where the soil is exposed without concrete covering, the chemical water emulsion should be applied at the rate of 2 gallons per 5 lineal feet of wall. A trench approximately 12 inches wide and 6 inches deep should be dug along but not deeper than the wall. Half of the chemical should be applied in the bottom of the trench, then covered with 4 to 5 inches of soil before applying the remaining half of the required chemical.

The chemical and the layer of soil should be thoroughly mixed, then levelled and tamped. The trench should then be filled with 1 to [illegible] inches of soil.

Storage of materials

In the outdoor storage area the ground around and under the piles should be cleaned of bark and wood scrap materials. The bottom of the piles, the foundation members and the soil should be treated with chemicals to check the present attack of termites and to prevent further infestation. A 0.[illegible] per cent concentration of lindane water emulsion (or other approved chemical in suitable concentration) should be applied by spray at the rate of a gallon per [illegible] square feet of area. Frequent inspections should be made of the stored materials and if cases of infection are found, chemical treatment should be repeated. As material is moved from storage to the construction site, careful examination should be made to determine the presence of infested material. The infested pieces should be discarded or if they are in usable condition treated with chemicals to kill the termites.

Preparation of building site

In preparing the building site it is important to remove all vegetative material before grading. During and after grading, roots and other cellulosic material should be removed from lots and house sites. Care should be used to obtain adequate drainage of the area and in particular of the building sites.

Foundations

Great emphasis should be placed on sound construction practices. The design and construction of the foundation slab and walls, the anchoring of the house to the foundation, and the installation of the utilities as related to the foundation should receive careful consideration. Some of the more important construction features that need attention are:

(a) Elimination of cracks in and around the foundation slab. If "anden[illegible]s" or exterior cement slabs are provided, it is suggested that the cement slab, walls and andenes be poured in one operation or that the andenes be entirely separated from the slab and foundation.

(b) Placement, securing and careful sealing of anchors to avoid opening through which the termites may enter.

(c) Sealing of openings in foundation for water and drain pipes.

Void-free cement and coal-tar pitch when properly applied to openings are effective barriers to termites.

Use of chemicals for soil treatment

A list of recommended chemicals and concentrations for the treatment of the soil under the concrete slab and adjacent to foundation walls is given earlier in this report. After the house site is brought to grade, one of the toxic chemicals should be applied to the soil at the rate of 1 gallon per 10 square feet as an over-all treatment under the slab and within the foundation walls. Sodium arsenite is suggested, if the foundation construction prevents leaching to the outside of the wall; otherwise a chemical water emulsion should be used. In case the soil or fill is gravel or absorbent material, such as cinders, the treatment should be increased to 1.5 gallons per 10 square feet. Along the inside of the foundation walls the application should be at the rate of 2 gallons per 5 lineal feet or approximately twice that for the over-all treatment under the slab.

Along the outside of the foundation wall, one of the chemicals in water emulsion at the recommended concentration should be applied at the rate of 2 gallons per 5 lineal feet. A trench approximately 12 inches wide and 6 inches deep should be dug immediately adjacent to the wall. Half of the chemical should be applied in the bottom of the trench, covered with 4 to 5 inches of soil before applying the remaining half of the chemical. The chemical and the layer of soil should be thoroughly mixed, and then levelled and tamped. The trench should then be filled with 1 to 2 inches of soil. Where slabs (andenes) extend beyond the foundation wall, the soil beneath them should be treated with one of the chemicals in water emulsion at the rate of 1 gallon per 10 square feet. Beneath the foundation slab and andenes the chemical may be covered with partly decomposed limestone (caliche).

Inspection

In order to make and keep houses free of termite attack, it is recommended that careful inspection be established and maintained during construction and occupancy. Emphasis should be placed on inspection of the application of toxic chemicals to the soil beneath and around the foundation during its construction. It is important that regular and systematic inspections be maintained after erection, that any infestation be promptly eradicated, and that the occupants be made aware of the need for maintaining conditions that result in freedom from infestation.

Annex 3

SHOPS FOR WOOD-FRAME HOUSE PREFABRICATION

by R. E. Platts

Reprinted from Canadian Builder, Vol.XIV, No.12
Ottawa, December 1964

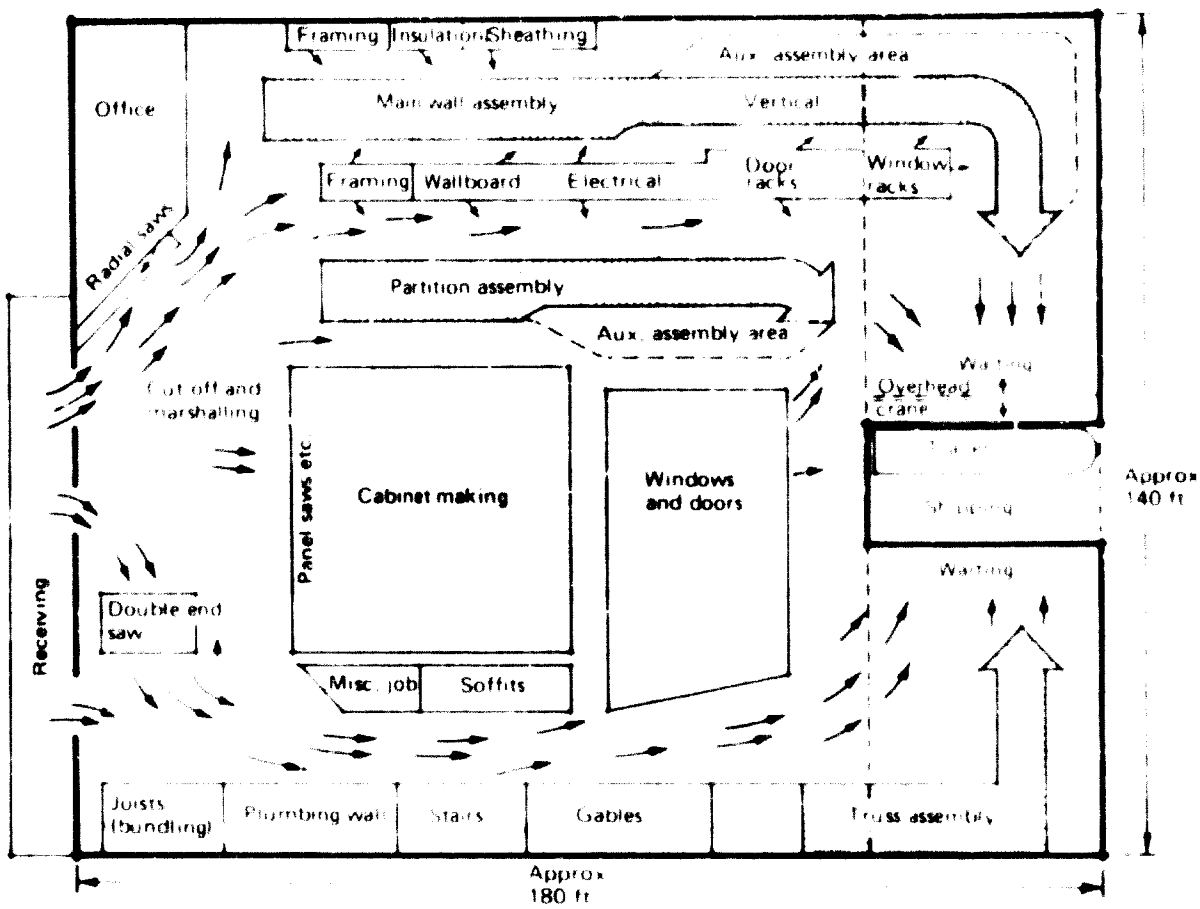
The availability and low cost of equipment for prefab shops (compared to factories producing any other "major appliance") may encourage builders and dealers to jump into prefabrication with little hard thinking on the actual role of the shop. The dominant aspect of wood-frame house construction, with its many trades and hundreds of varying pieces, is materials handling. This is the aspect that a simple, well-planned shop can improve most radically, both for shop and subsequent field operations, as was emphasized in the first Note in this series. Setting up a small shed or two and a bit of yard as a prefab "plant" does not readily allow rationalized handling and logistics, and the operation may gain little or nothing.

An industrial engineering study of wood-frame prefabrication is badly needed, but apparently none has yet been attempted. The publication "Prefabrication in Canadian Housing", (NRC 7856) attempts to draw conclusions from the many impressions gained on diverse shop practice in the survey across Canada. It also presents some discussion on production aspects of stressed skin, structural sandwich, and certain other innovations in house building. This Note considers these impressions only as they affect builders' needs at present, dealing with wood-frame construction alone.

Layout

The term "factory" always suggests a picture of a smooth "flow-line" or "assembly-line" layout, and indeed much of our economy is based upon the productivity attained by flow-line production of repetitive units. With wood-frame house production, the number and diversity of parts and the fluctuation in sizes, styles, and production volume make it very difficult to maintain a workable balance if a true flow-line layout is used. One product will "pile up" on the next; one process will fall behind the others. It should be best to use "layout by process" for most measuring, cutting, and marshalling, and to lead this into flow-line layout for handling and assembly. A hypothetical plant layout incorporating these and the following suggested points is presented below.

Preliminary layout for a wood-frame house plant
(Approximate capacity 3 to 5 houses/day, single shift)



Materials handling is all-important, but wood-frame production does not lend itself to complex, fixed handling equipment. It involves intermittent moves, many paths and cross-paths, and bulky materials with some feasibility of unit loads. Simple hand trucks fit these requirements best of all. Hand trucks do require large quarters and storage areas, but the prefab shop must be spacious and well laid out to allow high productivity.

Lift trucks can best serve the outside storage areas and sheds, but they need not work within the assembly plant itself, except to serve the cutting and marshalling area near the receiving end. Most of the hand trucks should be fitted with appropriate racks so that they can be loaded with the prepared and cut materials within the marshalling area, and then can be moved to the assembly area where the hand trucks themselves become the storage racks at the lines. Transfers are sharply minimized in this way.

The figure suggests that a transverse run of a light overhead crane (less than 10-ton capacity, and of about 40-ft. span) can allow its use for all loading of large parts and for transferring heavy items such as windows from subassembly to wall assembly lines.

Assembly jigs

The assembly jig is the core of wood-frame prefabrication. The marks of a good jig and its "feeder" racks are simple: the man at the table should rarely have to look for pieces or parts, alter them, look at drawings, use a tape or hold pieces in place. All parts should have a place at hand in suitable racks (the racks can best be on the hand trucks, avoiding transfers). The racks should be marked with the marking keyed to the foreman's working plans and to the "cut-off" sheets. The marking should include the number of parts per house to facilitate the orderly refill of racks. These simple points are important parts of optimum production in wood frame - as important as the part that can be played by high cost mechanization.

Although some use quite complex jig tables with hydraulic "popout" equipment, it appears that the very simple open jig tables work as well as any. These use guides or rails along the edges only, the guides set slightly wider apart than the width of the wall or partition section, with the flat table between them. Wooden wedges or other stops are readily driven into the gap to secure the plates against the studs for nailing, sheathing, etc. "Jig sticks" can be laid along the edge guides to allow the fast location of framing and openings for any model of house. These are long wooden sticks or tapes which are made in sets for a particular house model.

Complicated and expensive "flipover" rigs are sometimes installed to turn the wall or partition sections over, allowing them to be completed on both sides while on the flat. A sequence evolved by some mobile home manufacturers and house prefabricators avoids such a rig and is at least equally effective. The frame is assembled, insulation pushed in place, and sheathing applied on top, in the first few stations on the flat. This requires the use of friction-fit insulation batts and a separate vapour barrier applied later, which are recommended for Canadian conditions in any case. Then the panels are hoisted to a vertical position and moved along to subsequent stations where wiring, wallboard, windows, doors, and trim are set in, and siding may be applied.

Overhead monorail conveyors are often considered for this purpose but they involve a considerable investment in multiple-rails, sidings, and switch gear, since it is almost impossible to achieve balance in house prefabrication on a single line. Much lower costs and greater flexibility in scheduling and in the use of space can be gained by using small dollies to handle the panels on edge. Two men can readily handle the panels in this way, and vertical stations can then be set side by side. Lag screws set into the top plates of the panels allow loading on transport trailers by overhead cranes within the shop, and allow optimum unloading and handling on the site by truck-mounted boom cranes.

Equipment

It is difficult to envisage complete mechanization of wood-frame house production. The variability of the lumber, the number of pieces involved, and the low labour content of any one operation all work against high mechanization and automation. The gains achievable through proper organization of materials handling can scarcely be equalled by the adoption of high cost mechanical tools. A few of the larger machinery manufacturers are now concentrating on the wood-frame production field, with intriguing results, but the marginal nature of the mechanization question confirms the wisdom of many house manufacturers who lease all major equipment, rather than buying it at the outset.

Precise precutting is the most important process in wood-frame prefabrication. Most Canadian plants use an in-line arrangement of radial arm cut-off saws for this function. A recent time and motion study confirms this observer's general impression that the process is quite inefficient, due to the end-to-end handling that is involved. The radial saws are invaluable for job-cutting, but using them for standard, high-volume pieces such as common studs can create the worst and most wasteful bottleneck in the shop. In some areas it is now advantageous to buy pre-cut framing for common studs and other repetitive pieces.

Volumes of four houses and over per day for much of the year may justify the trial leasing of a double-end saw. The saw may cost from $7,000 to $20,000 but it can pre-cut all members for a house in a few hours. Outside sales of pre-cut common studs are desirable to use to the maximum the high production capacity of these saws. Setting up may take considerable time, so long production runs of any one piece are desirable. For this reason the saw should have good storage and marshalling areas around it.

Some pieces of equipment are basic to any shop, large or small. A panel saw is well justified for all sheet cutting. A selfguiding router, or at least a sabre saw mounted in a cradle, will be necessary for quickly cutting out window and door openings after the sheathing has been placed over the frame. And no one doubts the advantages of power staplers for securing all sheathing. Many are interested in the fast-improving pressure-sensitive adhesives for applying wallboard, but any adhesive appears difficult to apply rapidly on narrow frames with uniform results. Few yet use such adhesives, but many have adopted a proprietary power-screw method to apply drywall to reduce popping.

Roof trusses have greatly profited from advances in engineering criteria, fastening devices, and mechanization. Their costs have been sharply reduced and they are commonly used by prefabricators and others. The common method of fixing plates from both sides at two separate stations and then sliding the whole assembly through rollers suffers from the time consumed and from the space required. Other methods use a massive "beam press", or hydraulic "C" clamps to fix all the joints at one station, requiring much less time and space.

Nailing machines are still controversial items, especially the self-feeding types. Those that use common framing nails are subject to jamming, while those using special nails have less jamming trouble but the nails are costly. Pneumatic hammers are favoured by many. They are slow and must be "fed" one nail at a time, but they relieve fatigue.

The decision to incorporate a cabinet shop in the prefab operation will largely depend on the possibility of outside sales. Considerable space is required and the types of wood, production methods, and equipment are somewhat different than in house shell prefabrication. On the other hand, production of cabinetry allows profit to be taken on some of the highest cost items in the house package. This, of course, applies equally well to windows, doors, "built-ins", and all mill work.

Innovations

In contrast to wood-frame construction, the promising innovations in housing technology have in common an amenability to highly mechanized processes of production. The leading new systems are characterized by fewer pieces to be handled and assembled, fewer materials and processes, more controllable materials and processes, and a higher continuity of process, all favouring optimum machine production. Composite materials of structural sandwich form show great potential over the long range. Developments in bonded wood fibre materials may lead to complete floor, wall, partition, and roof components that satisfy all requirements at sharply competitive costs. Polyurethane cores may allow continuous belt production of sandwich enclosure components that can be thermally and structurally sound with a thickness of only one inch. But wood-frame construction continues to provide technical adequacy at low costs, and still remains a remarkably difficult yardstick against which proposed innovations must be measured. It will be very difficult to replace for the bulk of house structures.

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