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section, the minimum loss will be as already mentioned 100 - 63,7 = 36.3 %. Tapered and unstraight growth will result more waste on long log sections than on shorter log section considering always the maximum top diameter. The taper differs on the various species and growth to regions. As a thumb rule, the taper is 10 mm at a length of 1 m. All calculations in this paper are based on this value. In Annex 2 and 3 the corresponding figures are listed which indicate the increase of waste when converting a tapered log into cylindrical one in relation to the log diameter, respectively increase of length.

It is advisable to produce sections as short as possible in order to decrease the share of waste, but bolt sections are hard to sell because of limited use.

For a rational production of long log sections it is, therefore, advisable first to cross-cut the log into short stock, classifying them according to the diameter and rejoin them. The list in Annex 3 indicates the raw material requirements when long sections are rejoined from stock of 2 m length in comparison to raw material requirements in case they are manufactured out of one piece. The only possibility to rejoin such stock sections is by finger jointing.

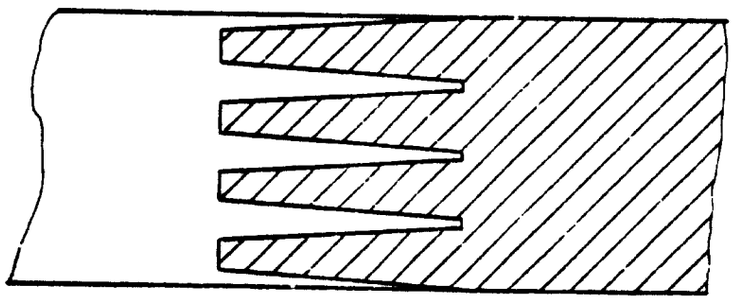

Fig. 3 - finger joint

Finger jointed profiled log components are manufactured with a certain amount of waste but yield of strength quality. The tendency of wood in twisting and cracking is thus reduced. The manufacture of finger jointed profiled log components of any desirable length, is very simple.

Finger jointed stock can be remanufactured for log components and can then be assembled. (See Annex 4 - Assembly of tongued and grooved log components). For the manufacture of prefab log houses components corner joints have to be moulded and drilled for assembly on the steel rods in about 1 mm distance (See Annex 4). Special is necessary for accurate machining of holes and corner joints to facilitate assembly work of the profiled log components for on the site erection of prefab buildings. (Annex 6 - 14).

In view of an economic production it is advisable to cross-cut incoming low grade lumber into stock of equal length. When considering finger jointing of stock production costs of component manufacture without finger jointing and the production costs of finger jointing stock have to be compared. Most calculations considered, have shown that the most economic length of log components to be finger jointed is within the range of 1.5 - 2.5 m. It is not easy to calculate the quality increase of finger jointed stock moneywise and is, therefore, omitted.

The techno-economical conception of a plant manufacturing profiled log components needs to be analysed. The investigations have to include availability of raw material, the raw material costs and the market situation analysing the most economic solution.

2.2 The component system

The component system is based on rounded timber. Raw material is low grade lumber and secondary species. Finger jointing renders possible to produce any desirable length of stock. Out of practical reasons it is advisable to reduce the number of diameters to be utilized viz:

30 mm
50 mm
60 mm
80 mm
100 mm
120 mm
140 mm
160 mm
180 mm
200 mm
220 mm
240 mm

Stock should be rounded before profiled. Machining of corner joints and drilling of holes for steel rods can be done at any point of the profiled log. It is even possible that these operations can be performed at any desirable angle instead of being in rectangular positions. Thus the combination of profiled logs will lead to unlimited variations which opens new viewsin design construction of prefab log houses. (Annex 6 - 14). This technology is of great flexibility which renders possible batch production not excluding individual design features. The building components are of accurate dimension to facilitate assembly and exchange of components. The assembled building components can also be bolted at their ends. In case all profiled log components are assembled in the same direction, it is not absolutely necessary to use pre-seasoned timber. Even green timber with high moisture content can be used. When a log house is erected by components with high moisture content, the timber will climatise without any risk of damages of the construction. The shrinkage can be precalculated and will be considered in construction and built in of wall units. Retightening of steel rod nuts is recommended after a period of final climatised adjustment.

2.3 The scope of the system for

2.3.1 Standardized houses

Designing of standardized houses is very easy and does not create any problem to the proposed system. If shape and dimensioning of a building is fixed, it is just necessary to list the shape and size of the profiled log components prior to manufacture. For reasons of easy assembling and minimum storage, it is advisable to use as many components of the same shape and dimension as possible. The profiled log components are factory sets for easy erection at the site. The assembling of a log house at 100 square meters will be done by four unskilled labourers within one to two days. Buildings based on other standardised materials offer a limited line of variations at its erection depending on the process applied, need weeks. They can be changed under considerable additional costs. Within the system of wooden profiled log components it renders possible to combine the advantages of standardized and individual building methods.

2.3.2 Traditional constructions

The wooden profiled log component system can be combined with other building systems, for example cellar area in concrete or blocks and log system on top. In other cases the roof storey might be built on the base of profiled log components.

2.3.3 The appropriate technology

The system of wooden profiled log components is based on a technology which meets the conditions in developing countries. The know-how of this technology can easily be transfered. It is a labour intensive system. The machining operation do not require skilled labourers and no special qualification for supervision staff. This kind of production and the range of products can be adjusted to the needs of various developing countries, and can be tailored to any specific requirements in these countries. The system therefore, offers the appropriate technology in three directions:

- the appropriate production process;
- the appropriate quality building material, viz: the profiled log component;
- flexibility in application.

It can also be expected that the production and the sales of building components will generate new markets.

3. Production machinery and equipment

Local conditions for the erection of a production plant have to be evaluated carefully to manufacture wooden profiled components from low grade lumber and secondary species. To avoid wrong investment a feasibility study has to be prepared covering the following investigations:

- quality and quantity of raw material available;
- dimensions of low grade lumber;
- testing the suitability as building component;
- fixing sequence of machining operations;
- possibility for preservation of profiled log components;
- skill of labour force and basic wages;
- market conditions;

- size of production plant;
- evaluation of mechanised and automated equipment.

Planning of projects have to be considered individually, thus the selection of machinery and equipment can only be proposed in general. Three plant sizes are here described.

3.1. Production of profiled log components based on log diameter from 100 - 140 mm

Capacity: 20 cubic meters of finished stock, 8 hours shift.

Raw material requirements: approximately 40 cubic meter, finger jointing is not included, it is therefore necessary to use logs of 5 m in length, but adding a certain amount due to unstraight growth of the lumber. The project is based on long timber of straight growth. In general projects without finger jointing operations can only be economic under special conditions.

Production steps and requirement of machinery:

1. Classification of logs;
2. Squaring of logs on a double circular saw or slab;
3. Rounding and profiling of the log component a combined round and profiling machine;
4. Cross-cutting, trenching and drilling line.

Rough estimation of investment cost for machinery, equipment and tools approximately US$ 200.000. The equipment as described is only of limited economy. The consumption of raw material and machining costs are relatively high.

3.2 Production of profiled log components as in 3.1, however, with a capacity of 30 cubic meters of finished product in 8 hours shift

In addition to the machinery described under 3.1, finger jointing equipment is included so that profiled log components of any length can be machined.

Raw material requirements: approximately 45 cubic meters, about 1/3 less than compared to example 3.1.

Production steps and machinery requirement:

1. Cross-cutting of logs into sections of standardized length or according to natural growth;
2. Classification of the cross-cut stock on diameter range;

3. Squaring logs on a double circular saw or slab saw;
4. Open air drying;
5. Finger jointing equipment for milling, glue spreading and pressing;
6. Rounding and profiling of the log sections on a combined rounding and profiling machine;
7. Cross-cutting, trenching and drilling line.

Rough estimation of the investment cost for machinery, equipment and tools, approximately US$ 300.000.

3.3 Production of profiled log components using logs of 30 to 240 mm diameter
Capacity: 60 cubic meter of finished products, in 8 hours shift.

Raw material requirements: 87 cubic meter.

Compared to the project under item 3.2, further two rounding machines and one double spindle adjustable circular saw as well as a finger jointing plant and drilling unit has to be installed. The double spindle circular saw should be combined with a profile chipping machine which is uncomplicated but works with high speed and is chipping all slab material which are not usable for the finished product.

Rough estimate of the investment cost for machinery, equipment and tolls are approximately US$ 550.000. The various plants under 3.1, 3.2 and 3.3 are linked with gravity conveying units for easy manually handling of stock.

3.4 Additional equipment for plant mechanization

The mechanization and automation of a plant up to the automation step can be performed which is in certain relation to the level of investment and is not appropriate to operations in developing countries. In any case detailed investigations should be considered.

3.5 Selection of alternative equipment investment

Instead of slabbing along on the double circular saw, a profile chipper can be installed for slabbing (profiling). The investment costs for this machine are in the range of US$ 150.000 which is double compared to circular saw slabber. Comparing circular saw slabbing and profile chipping, the latter works on higher speed, is simple in operation and more economical provided the high capacity can be utilized. Another advantage is that the tools can easily be re-sharpened. The profile chipping machine converts

all slab materials into waste which can be removed in one pass. The chipped material can be sold either to particle board mills or to the pulp and paper industry.

3.6 Recommended additional equipment

For the protection of profiled log components against fungicides, decay and insects, it is recommended that preservation on the base of unpoisonous cromium salts, copper and boron in under vacuum and high pressure is performed for long lasting protection. A preservation plant for profiled log components up to about 12 m requires an investment of approximately US$ 60.000.

To improve the quality of profiled log components, it is recommended to install kiln drying equipment to shorten seasoning time of the finished product especially for beams, girders and floor material. The capacity of kiln drying equipment has to be calculated individually.

3.7 Investment costs for the production of specialized profiled log components

If the production includes furniture, furniture components, commodity articles or prefabricated beams and girders, standard equipment has to be added to run the production efficiently.

3.8 Standard production facilities

All plants should include a range of production facilities for wood processing and workshop equipment for metal working for jig production and maintenance. The necessary investment varies from US$ 15.000 to US$ 50.000.

4. Cost calculation

4.1 Prerequisites

Cost calculation have to be prepared for each individual case. Planning values should be based on corresponding and qualified estimations to justify a certain project. Step by step estimation data should be improved by recalculations because conditions may change considerably within the different developing countries.

The additional implementation of finger jointing lines within a plant for the manufacture of wood profiled log components depends on the material available especially when standardized components are stored.

A comparison of manufacturing costs for profiled finger jointed log components will not indicate all cost advantages or disadvantages. Finger joints improve quality of the profiled log components and will yield capacity.

Machines and equipment described under item 3 can be estimated as follows.

For 3.1 - Land: 5.000 square meters US$ 5/sq. m =	US$	25.000
Buildings	US$	50.000
For 3.2 - Land: 7.000 square meters US$ 5/sq. m =	US$	35.000
Buildings	US$	60.000
For 3.3 - Land: 15.000 square meters US$ 5/sq. m =	US$	75.000
Buildings	US$	120.000

As very often the machining area is roofed, only costs for buildings are less than indicated here.

4.2 Investment costs for project 3.2 (page 11)

Capacity: 30 cubic meter in 8 hours shift.

Machinery and equipment	US$ 300.000
Preservation plant	US$ 60.000
Production, machines, equipment and tools	US$ 50.000
Office equipment	US$ 10.000
Vehicles	US$ 30.000
Land and buildings	US$ 95.000
Power line costs	US$ 10.000
Financing, engineering	US$ 40.000
Cost for establishment and consulting	US$ 20.000
Cost for assembling and building up of the plant	US$ 20.000
Start up losses	US$ 30.000
Safety equipment, etc.	US$ 50.000
	US$ 715.000

4.3 Raw material cost

The cost for the procurement of raw materials can differ considerably. The price of raw wood is often calculated on the value of fuel wood.

Higher prices have to be calculated in case of competitive demand, for example the manufacture of chipboard or pulp and paper. In all forest areas, the raw material demand of low grade lumber which is regularly cut under supervision of the forestry department is more or less a by-product of commercial timber. This raw material is average priced at US$ 15 per cubic meter. The quantity of chemicals for preservation of the wood is tuned to local conditions and the wood specie. Some of the tropical woods need not to be preserved but others low or higher rated preservation. The average preservative costs are US$ 10 per cubic meter.

Annual costs of raw material for the project

Production of 6.000 cubic meters building components made out of low grade lumber and secondary species.

Logs, 9.000 cubic meter (US$ 15/cubic meter)	US$ 135.000
Preservatives	US$ 60.000
Adhesives, approx. 7.500 kg (US$ 2.50/kg)	US$ 18.750
Miscellaneous material	US$ 20.000
	US$ 233.750

4.4 Wages and salaries

Production		Annual costs
Labourers		
Unskilled	22 (US$ 100 per man/month)	US$ 26.400
Skilled	3 (US$ 200 per man/month)	US$ 7.200
Fore-men	2 (US$ 250 man/month)	US$ 6.000
Technician	1 (US$ 500 man/month)	US$ 6.000
Engineer	1 (US$ 1000 man/month)	US$ 12.000
Management and administration		
General Manager	1 (US$ 1.200 man/month)	US$ 14.400
Sales Managers	2 (US$ 500 man/month)	US$ 12.000
Office employees	3 (US$ 200 man/month)	US$ 7.200
		US$ 91.200

Social benefits and costs for general administration (estimated) US$30.000,-

4.5 Manufacturing

Estimated annual manufacturing costs including depreioation and calculated interest

Log input	US$ 234.000
Power supply	US$ 20.000
Salaries and wages	US$ 90.000
Social costs	US$ 30.000
Depreciations	US$ 100.000
Tools, maintenance	US$ 20.000
Administration costs	US$ 30.000
Advertising and marketing	US$ 90.000
Interests	US$ 70.000
Expenses, fees, taxes	US$ 20.000
Miscellaneous costs	US$ 30.000
	US$ 734.000

4.6 Turnover, profit, pay-back calculation

The annual turnover of this is calculated on an estimated sales rate of US$ 150 per cubic meter of finished products. This amount includes preservation of the profiled log components. A log house of 50 sq. meter living area will cost US$ 1.800 which is a competitive price compared to other building material of the same quality.

Annual turnover

6.000 cubic meters of building components US$ 150/cubic meter US$ 900.000

Profit for the project example

Annual turnover	US$ 900.000
minus annual sum of total cost	US$ 734.000
Profit before taxes	US$ 166.000

It oan be expeoted that the initial phase for the project example takes about 1.5 years. Production start up after ten months. This requires a total oapital within peak of about US$ 965.000. The peak requirement of capital will be 1.5 years after establishment of the enterprise. (Details see cash flow).

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EVALUATION OF LOW GRADE LUMBER AND SECONDARY SPECIES FOR THE PRODUCTION OF WOODEN COMPONENTS FOR LOG HOUSES, LOG CABINS AND LOG SILOS APPROPRIATE FOR DEVELOPING COUNTRIES *

by

H. Siller **

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4.7 Cash flow - Capital requirement for four years

without depreciation and capital interest in US$ 1.000

	1. year				2. year				3. year				4. year			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Machinery, tools equipment	100		100	225												
land, building	30	30	30	15												
cost of the initial phase	40	20	20	30	20	20										
total fixed assets	170	50	150	300	20	20										
total fixed assets summarized	170	220	370	670	690	710										
logs and lumber			30	30	10	58	59	58	59	58	59	58	59	58	59	58
power, supply, fuel, water			1	1	2	5	5	5	5	5	5	5	5	5	5	5
wages and saleries	5	10	20	25	30	30	30	30	30	30	30	30	30	30	30	30
miscellaneous	10	10	20	30	50	55	55	55	55	55	55	55	55	55	55	55
total costs	15	20	71	86	85	148	149	148	149	148	149	148	149	148	149	148
total costs summarized	15	35	106	192	277	425	574	722	871	1019	1168	1316	1465	1613	1762	1910
sales				20	50	100	200	225	225	225	225	225	225	225	225	225
sales summarized				20	70	170	370	595	820	1045	1270	1495	1720	1945	2170	2395
capital requirements	185	255	476	842	897	965	919	842	766	689	614	536	450	383	317	240

4.8 Cost summary

For the project example it can be expected that the capital return flow starts at the 6th quarter to after 4 years and 9 months (19 quarters) of establishing the plant and about 3 years after normal production, the capital requirements will be covered by capita return flow. (Interest and depreciation not included). All costs are calculated with a margin of safety, the results of a realised project will come out at a better rate.

5. Possibilities for applying wooden profiled log components

Profiled log components can be utilized in all branches of the building industry with unlimited possibilities (Annex 6 - 14). Annexes 6 to 10 show variations of log houses and log huts, Annex 11 shows the application of a double bunk bed with partition walls which fits into the building using the same profiled log components.

Also luxury and multi-storey houses could be established according to the same system. Houses based on profiled log components are suitable where high stability is required. Log houses are earthquake proned. However, another example where the profiled log components are used, is the hexagonal shaped silo shown in Annex 14. The silo is built up a standardised profiled log component having two cross trenches under 60° respectively 120° degrees. Assembling is a foolproof operation, just setting up component by component connected with steel rods. Such silos have a net volume of more than 1000 cubic meters, they are very rigid and solid, they are available as single construction or connected as double or multi-construction.

As the rough log input due to natural growth has different diameters, the finished profiled component has also different diameters. This broadens the field of application.

The following outline is not a complete list but gives a lot of ideas for use of the profiled log component.

- Log houses also with covered walls for dwelling and for commerical purposes;
- Units, such as floors also uncovered, walls and roofs within conventionally built houses;
- Parts for prefabricated houses;

- Beams and girders for a free span up to 15 m.;
- Silos;
- Swimming-pools;
- Shelves for storage of goods being portable or built on to walls
- Playground equipment;
- High quality fences;
- Noise pollution walls;
- Furniture and furniture parts;
- Indoor and outdoor plant troughs;
- Decorative implementation;
- Floors;
- Commodity articles.

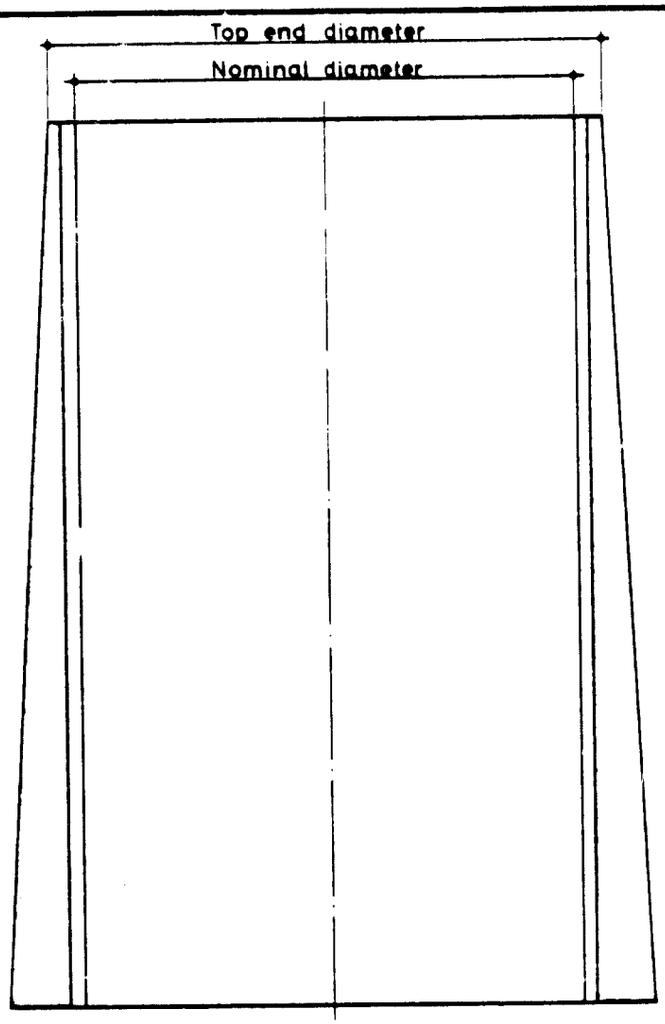
Planning and projecting of plants for the manufacture of building components in developing coutries where sufficient wooden raw material is available are by no means limited to the domestic markets. To a certain extent profiled log components can be exported to neighbouring countries. The processing of low grade log dimensions having a high commercial value are of interest for production facilities appropriate for developing countries. It enables to produce a technically valuable product by low cost material. There are chances for medium-sized factories to make reasonable profits, creating labour intensive manufacturing plants and avoid exchange for their countries.

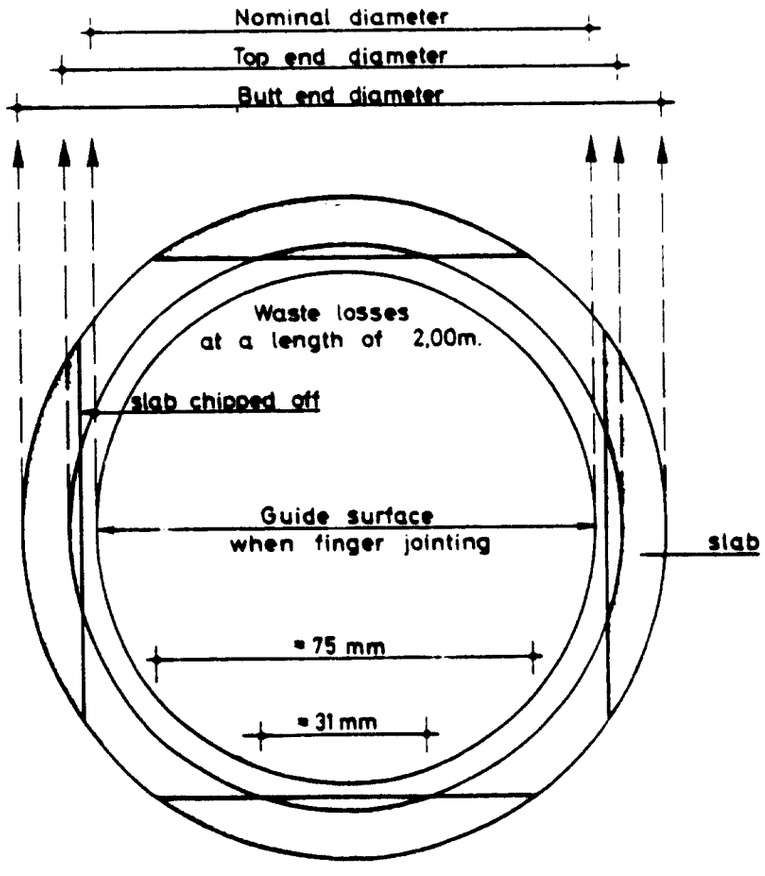
6. Final notes

Low grade lumber and secondary species being usually of a very low market value, can be converted into high grade products for the building trade. The system enables to process profiled log components with less waste at low costs in manufacturing.

The building components are of accurate dimension. Their application is universal and almost unlimited. The joining and assembly of profiled log components to erect buildings, or parts of buildings and to specialize producing, is very simple and does not need much skill and know-how. This system proposed is labour intensive, highly economic, projects can be realized at medium-sized or even small scale basis. The individual production machinery and the total concept of a project needs detailed investigation and can then be adapted to various conditions. The production of wooden components for buildings made of low grade lumber and secondary species is recommended for factories in developing countries appropriate to local conditions.

Annex 1


Top end diameter
Nominal diameter


Nominal diameter
Top end diameter
Butt end diameter
Waste losses
at a length of 2,00m.
slab chipped off
Guide surface
when finger jointing
slab
≈ 75 mm
≈ 31 mm

Loss of raw material due to the tapered growth of logs

ø in cm	net.Vol./ running m of finished product m³	Vol.of raw material in m³ necessary for processing pieces of 2 m length each	Volume of raw material in percent necessary to produce a certain length of profile measured in m out of one piece based on the volume of the finished product = 1oo %					
			2	4	6	8	1o	12
3	o,ooo7o7	o,oo1963	278	4oo	544	711	9oo	1111
4	o,oo1257	o,oo2827	224	3o6	4oo	5o6	625	756
5	o,oo1963	o,oo3848	196	256	324	4oo	484	576
6	o,oo2827	o,oo5o27	177	225	277	336	4oo	47o
7	o,oo3848	o,oo6362	165	2o4	247	294	345	4oo
8	o,oo5o27	o,oo7854	156	189	225	264	3o6	352
1o	o,oo7854	o,o1131o	144	169	196	225	256	289
12	o,o1131o	o,o15394	136	156	178	2o1	225	251
14	o,o15394	o,o2o1o6	13o	147	165	184	2o4	225
16	o,o2o1o6	o,o25447	127	141	156	172	189	2o7
18	o,o25447	o,o31416	123	136	149	163	178	193
2o	o,o31416	o,o38o13	121	136	144	156	169	182
22	o,o38o13	o,o45239	119	129	14o	151	162	174
24	o,o45239	o,o53o93	117	127	136	146	156	167

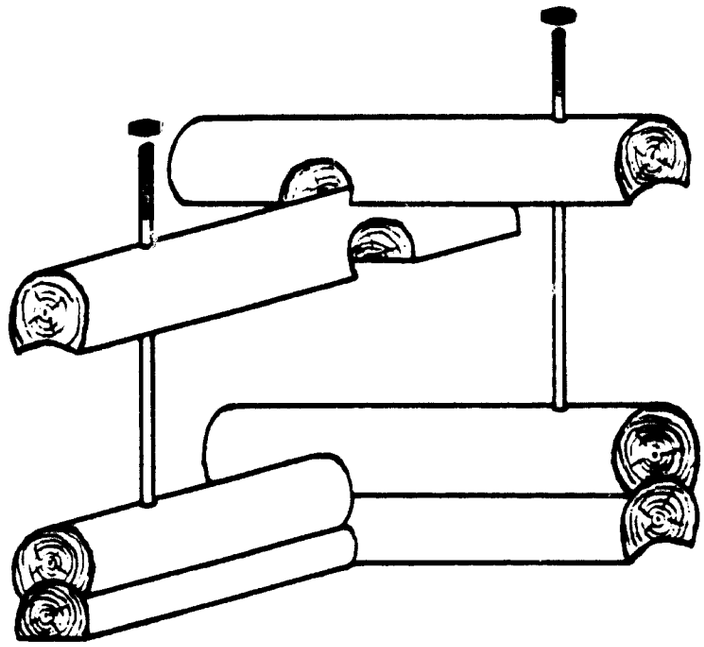
Annex 2

Required raw material in m3 for the production of one meter rounded log section in relation to the total length of section

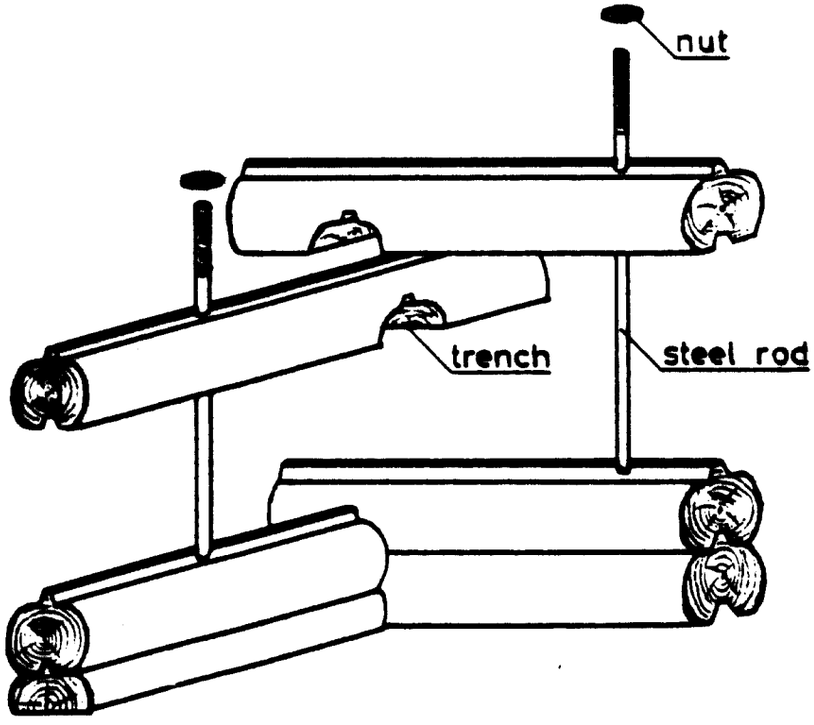
- length in m -

	2		4		6		8		10		12	
	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
in cm												
ø 3	o,oo1963	1oo	o,oo2827	144	o,oo3848	196	o,oo5o27	256	o,oo6362	324	o,oo7854	4oo
6	o,oo5o27	1oo	o,oo6362	127	o,oo7854	156	o,oo95o3	189	o,o1131o	225	o,o13273	264
8	o,oo7854	1oo	o,oo95o3	121	o,o1131o	144	o,o13273	169	o,o15394	196	o,o17671	225
1o	o,o1131o	1oo	o,o13273	117	o,o15394	136	o,o17671	156	o,o2o1o6	178	o,o22698	2o1
12	o,o15394	1oo	o,o17671	115	o,o2o1o6	131	o,o22698	147	o,o25447	165	o,o28353	184
14	o,o2o1o6	1oo	o,o22698	113	o,o25447	127	o,o28353	141	o,o314[illegible]	156	o,o34636	172
16	o,o25447	1oo	o,o28353	111	o,o31416	123	o,o34636	136	o,o38o13	149	o,o41548	1o3
18	o,o31416	1oo	o,o34636	11o	o,o38o13	121	o,o41548	132	o,o45239	144	o,o49o87	156
2o	o,o38o13	1oo	o,o41548	1o9	o,o45239	119	o,o49o87	129	o,o53o93	14o	o,o57256	151
22	o,o45239	1oo	o,o49o87	1o9	o,o53o93	117	o,o57256	127	o,o61575	136	o,o66o52	146
24	o,o53o93	1oo	o,o57256	1o8	o,o61575	116	o,o66o52	124	o,o7o686	133	o,o75477	142

Annex 3



ASSEMBLY OF PROFILED LOG COMPONENTS
WITHOUT TONGUE AND GROOVE

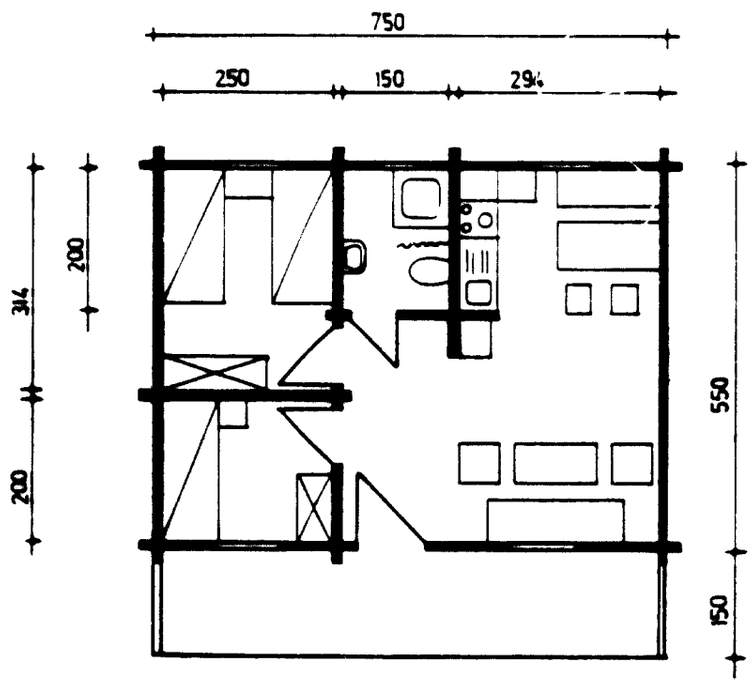


ASSEMBLY OF TONGUED AND GROOVED
LOG COMPONENTS

Volume of round log sections

ø in cm	vol.in m³ per running m round timber	round timber running m necessary for 1 m²	round timber running m necessary for 1 m³	loghouse profiled component running m necessary for 1 m²
3	o,ooo7o7	33,oo	1414	38,49
4	o,oo1257	25,oo	796	28,86
5	o,oo1963	2o,oo	5o9	23,1o
6	o,oo2827	16,67	354	19,25
8	o,oo5o27	12,5o	199	14,43
1o	o,oo7854	1o,oo	127	11,55
12	o,o1131o	8,33	88	9,62
14	o,o15394	7,14	65	8,25
16	o,o2o1o6	6,25	5o	7,22
18	o,o25447	5,56	39	6,42
2o	o,o31416	5,00	32	5,77
22	o,o38o13	4,55	26	5,25
24	o,o45239	4,17	22	4,81

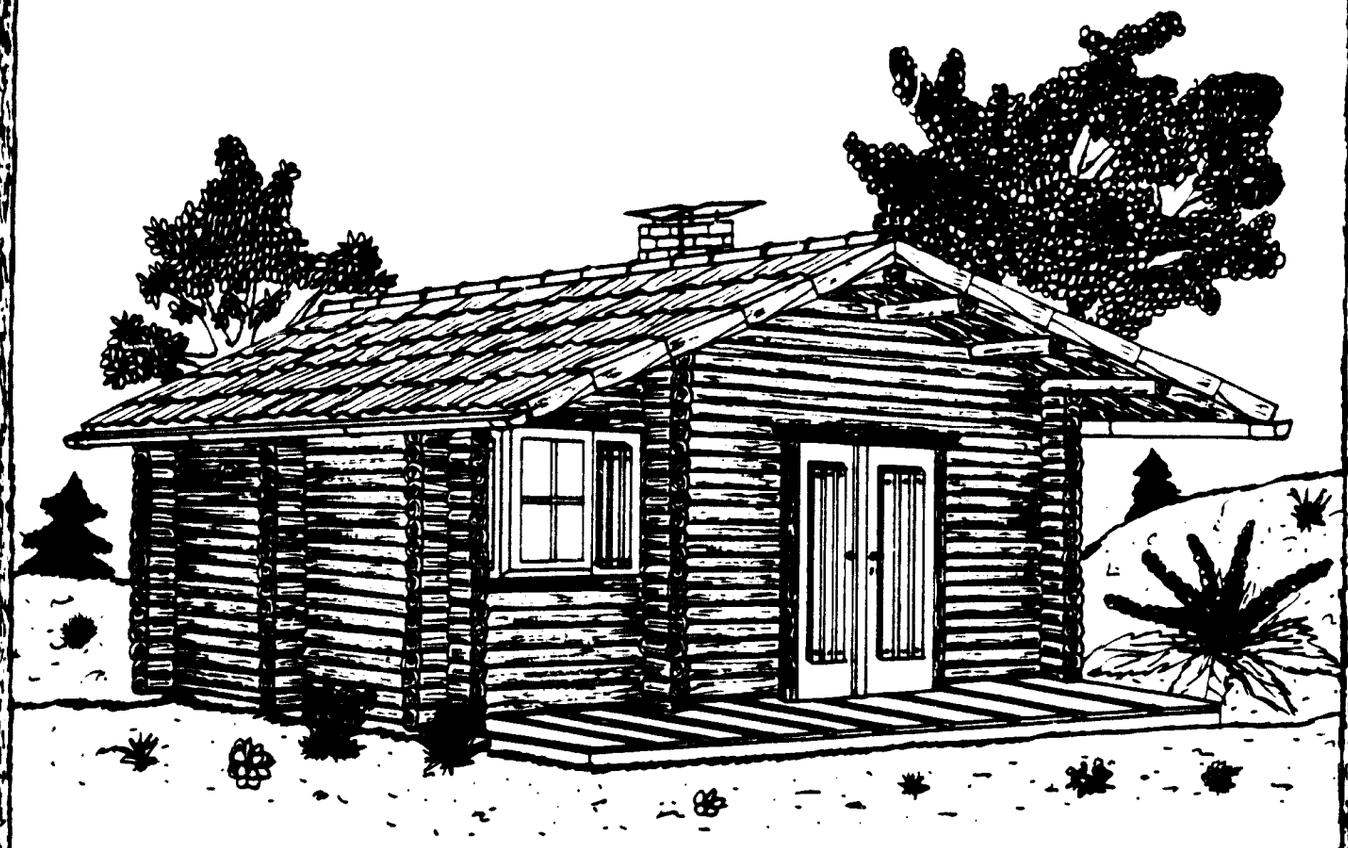
Annex 6

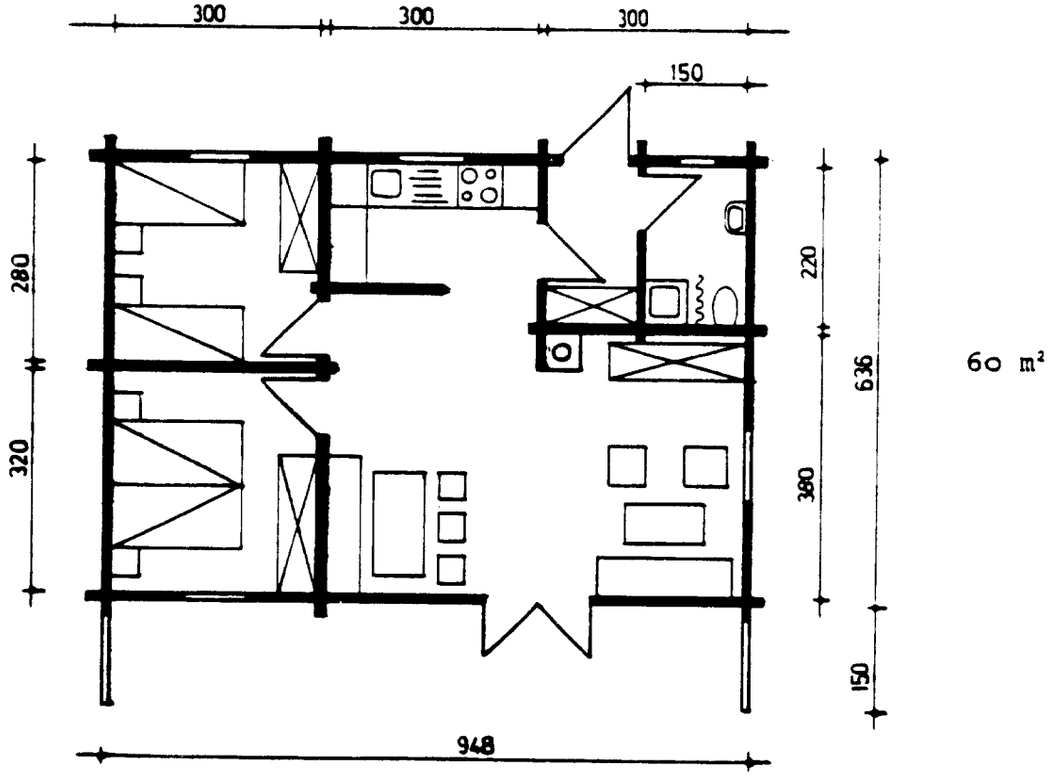


40 m²

LOGHOUSE WITH 40 SQUARE METER
LIVING AREA AND ROOFED OUTDOOR SPACE

Annex 7

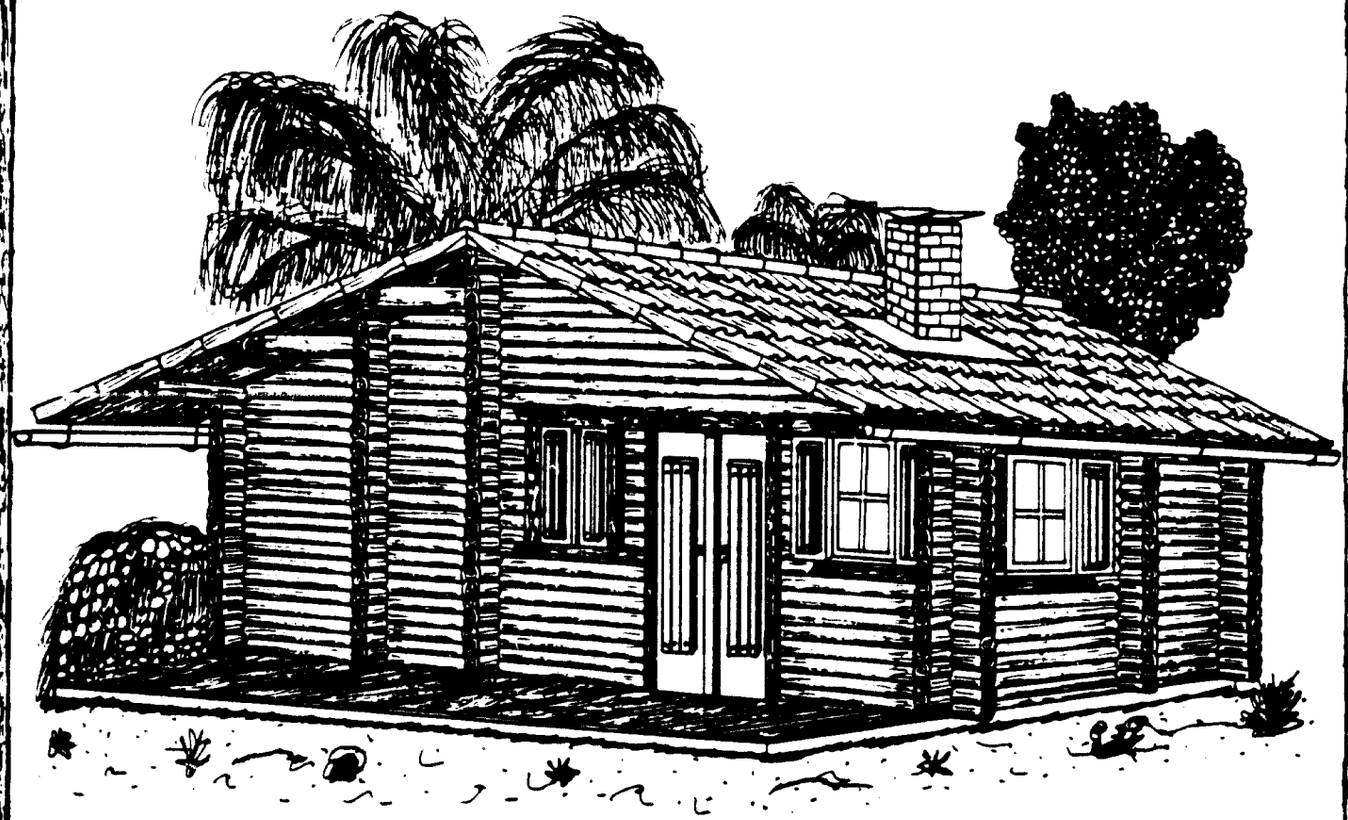


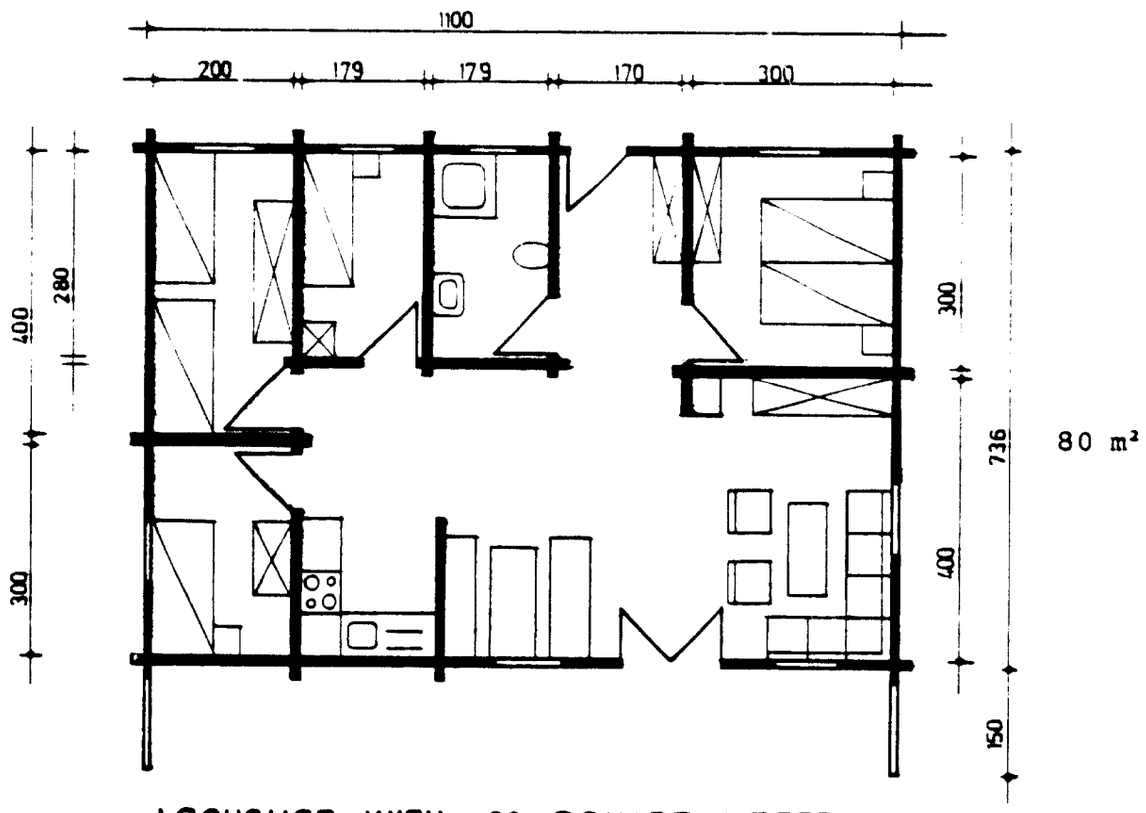


LOGHOUSE WITH 60 SQUARE METER
LIVING AREA AND ROOFED OUTDOOR SPACE

CONTENTS

Annex 8

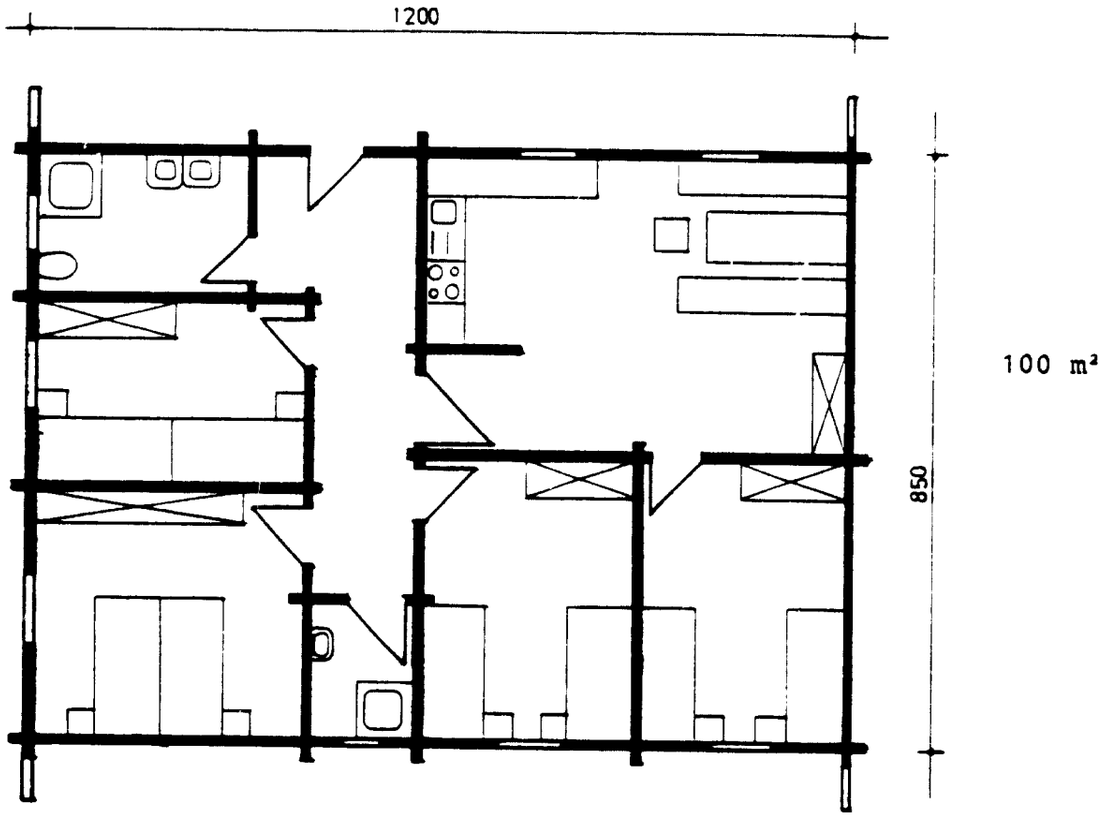


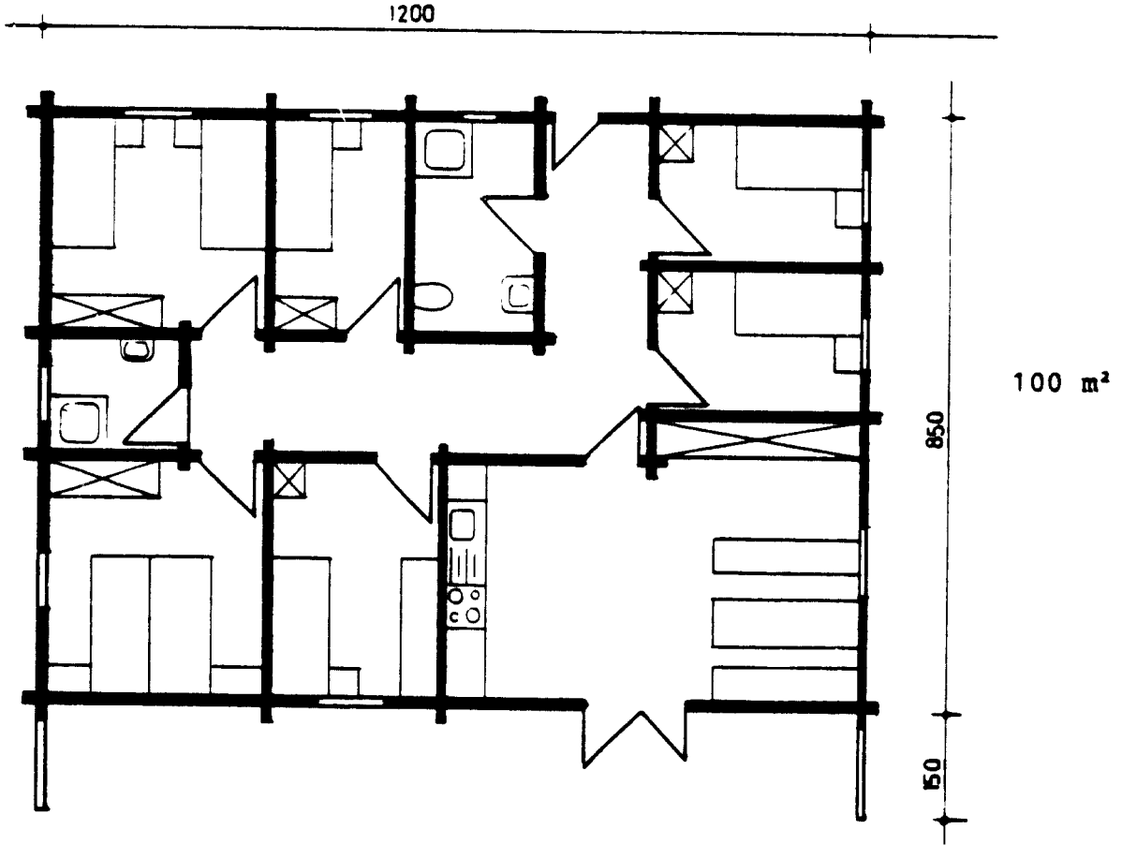


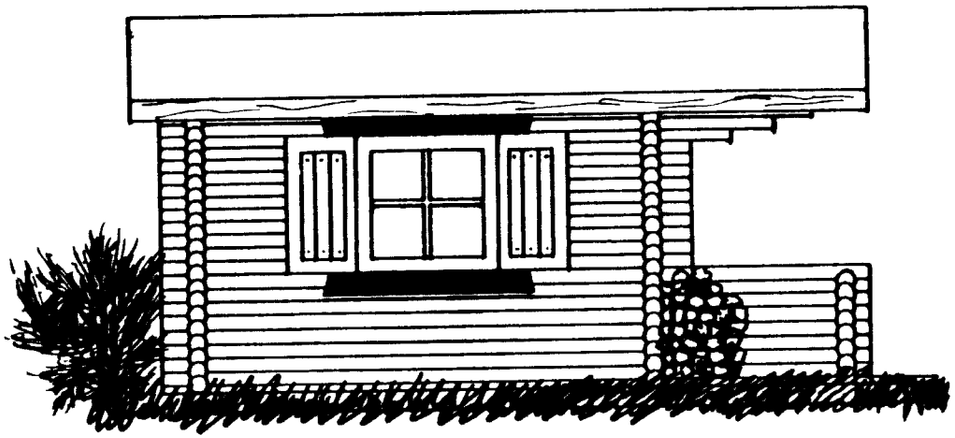
LOGHOUSE WITH 80 SQUARE METER
LIVING AREA AND ROOFED OUTDOOR SPACE

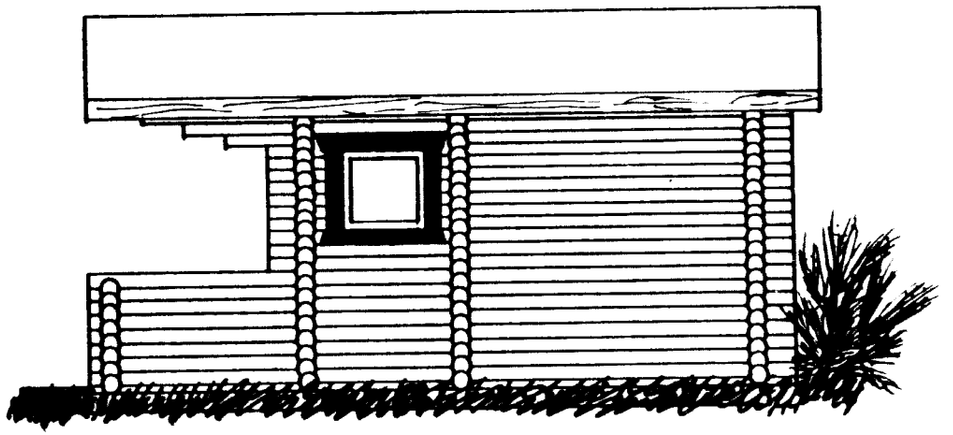
EXAMPLES OF DIFFERENT ROOM ARRANGEMENTS FOR 100 SQUARE METER LIVING AREA.

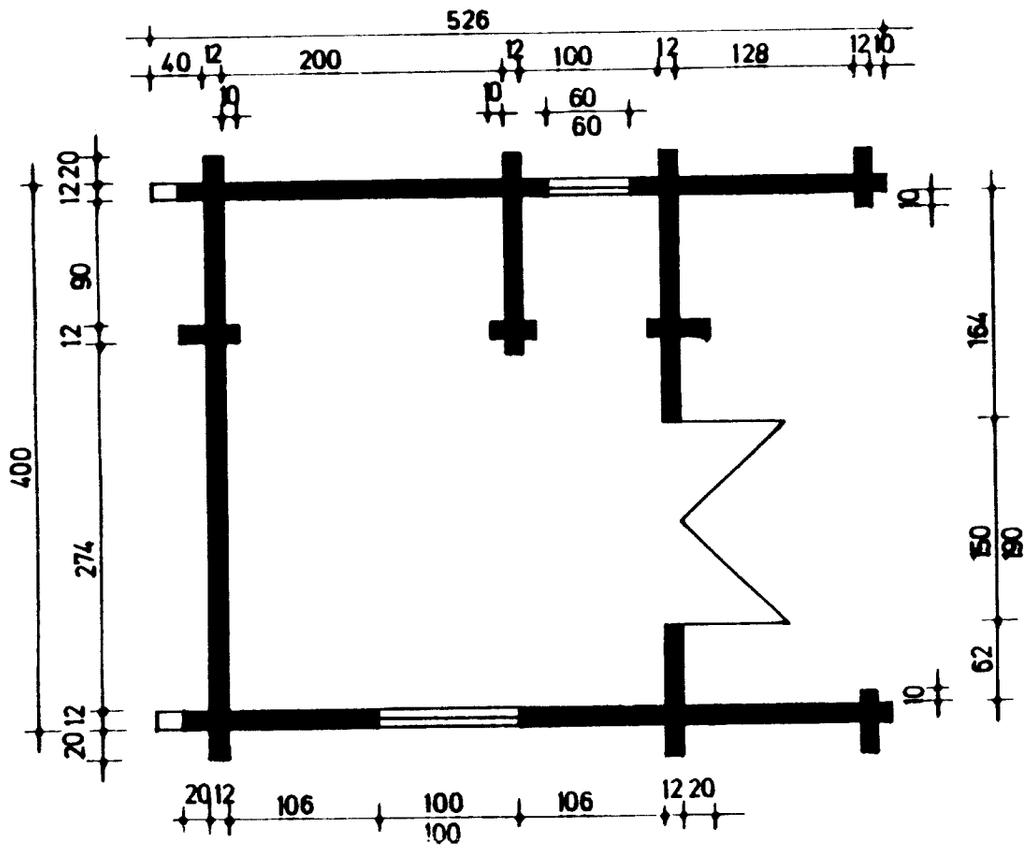
Annex 9.



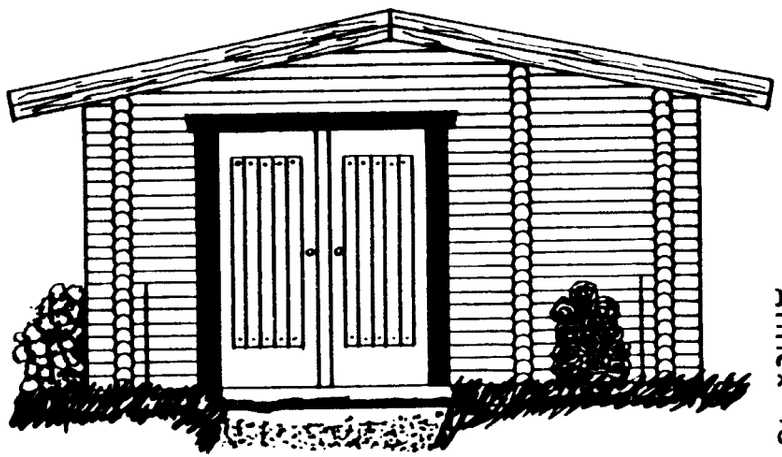








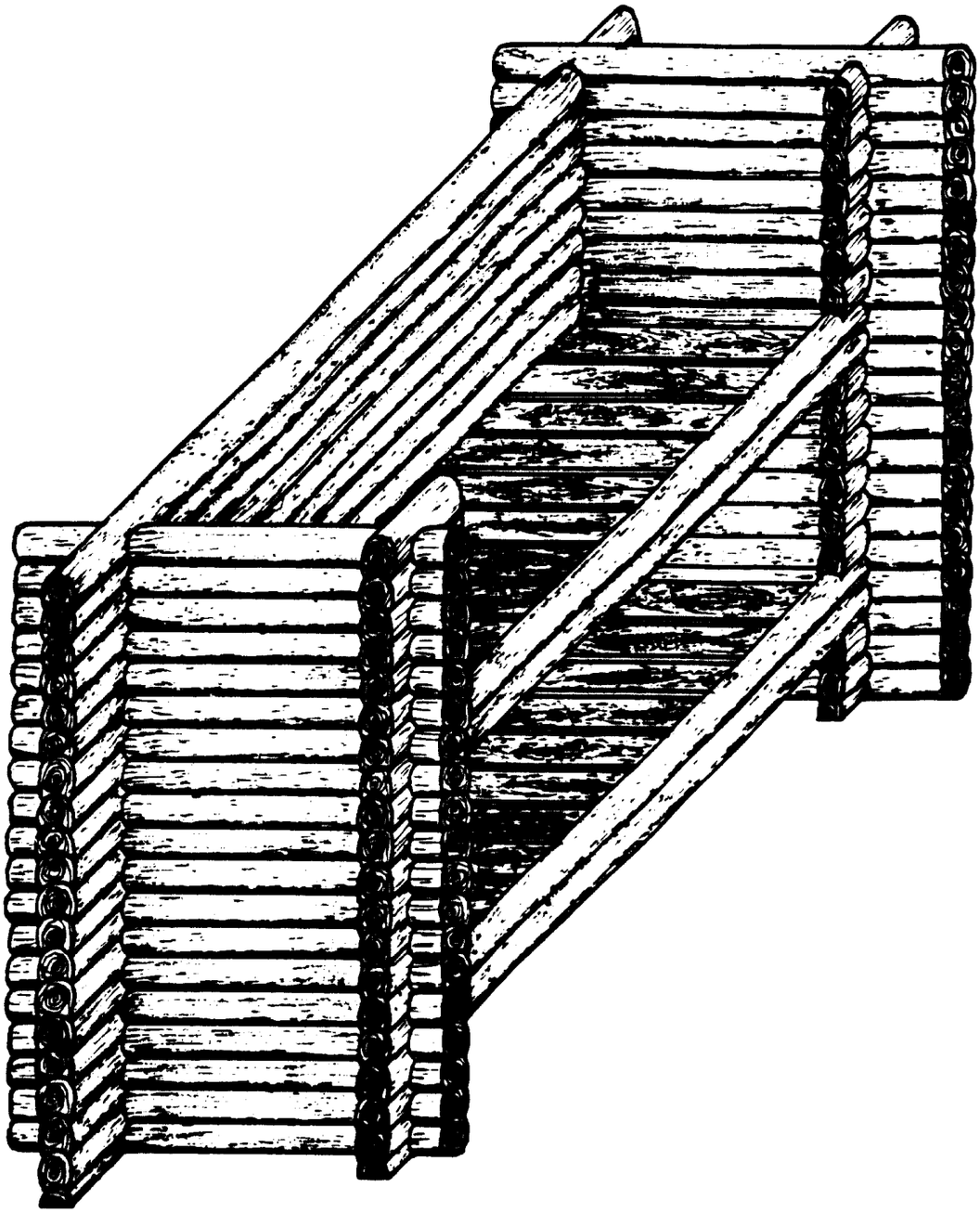
LOG HUT WITH
ROOFED OUTDOOR SPACE



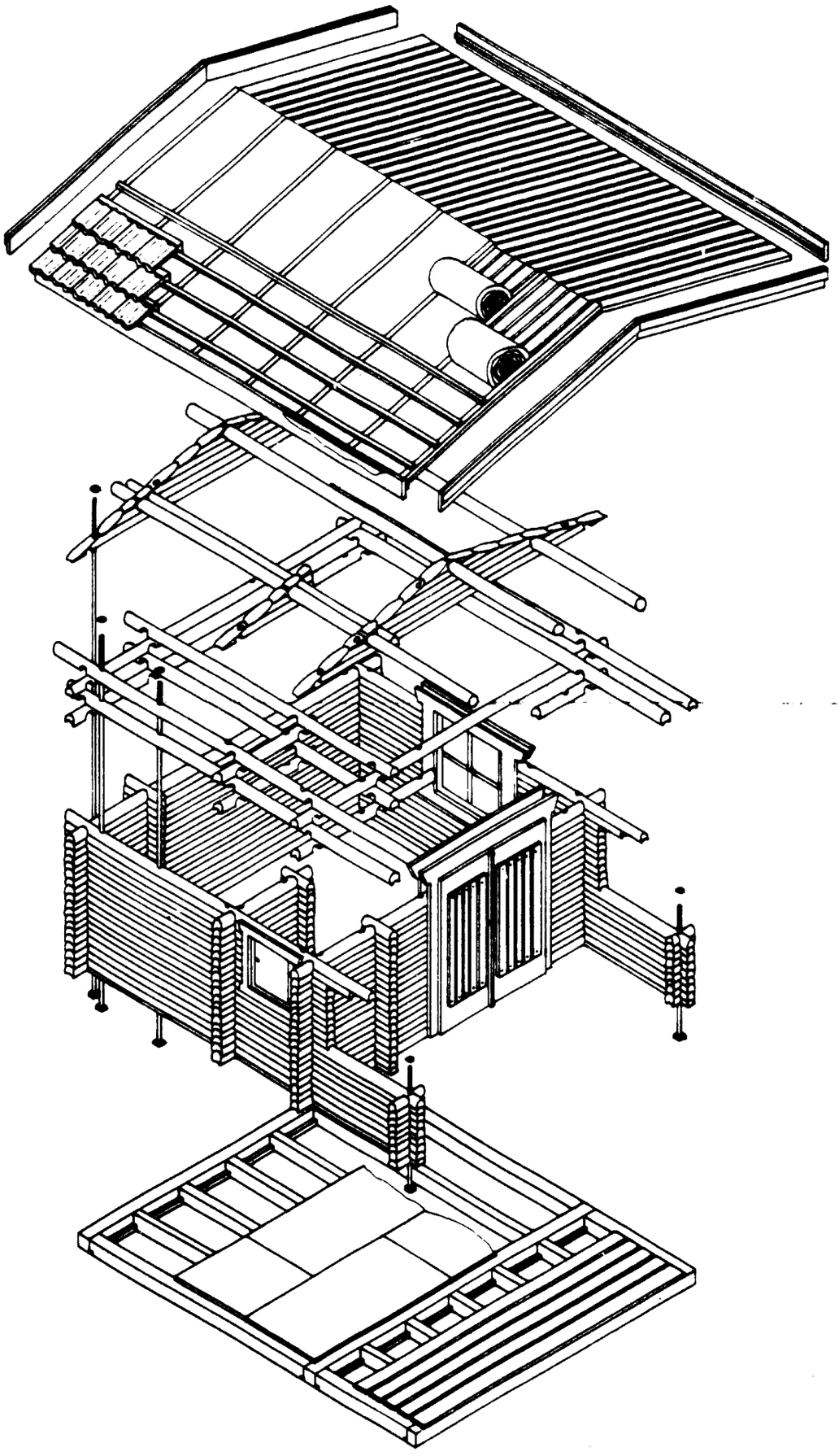
Annex 10

DOUBLE BUNK BED
ASSEMBLED BY PROFILED LOG COMPONENTS
AS PARTITION UNIT INTEGRATED TO THE
OUTSIDE WALL.

Annex 11



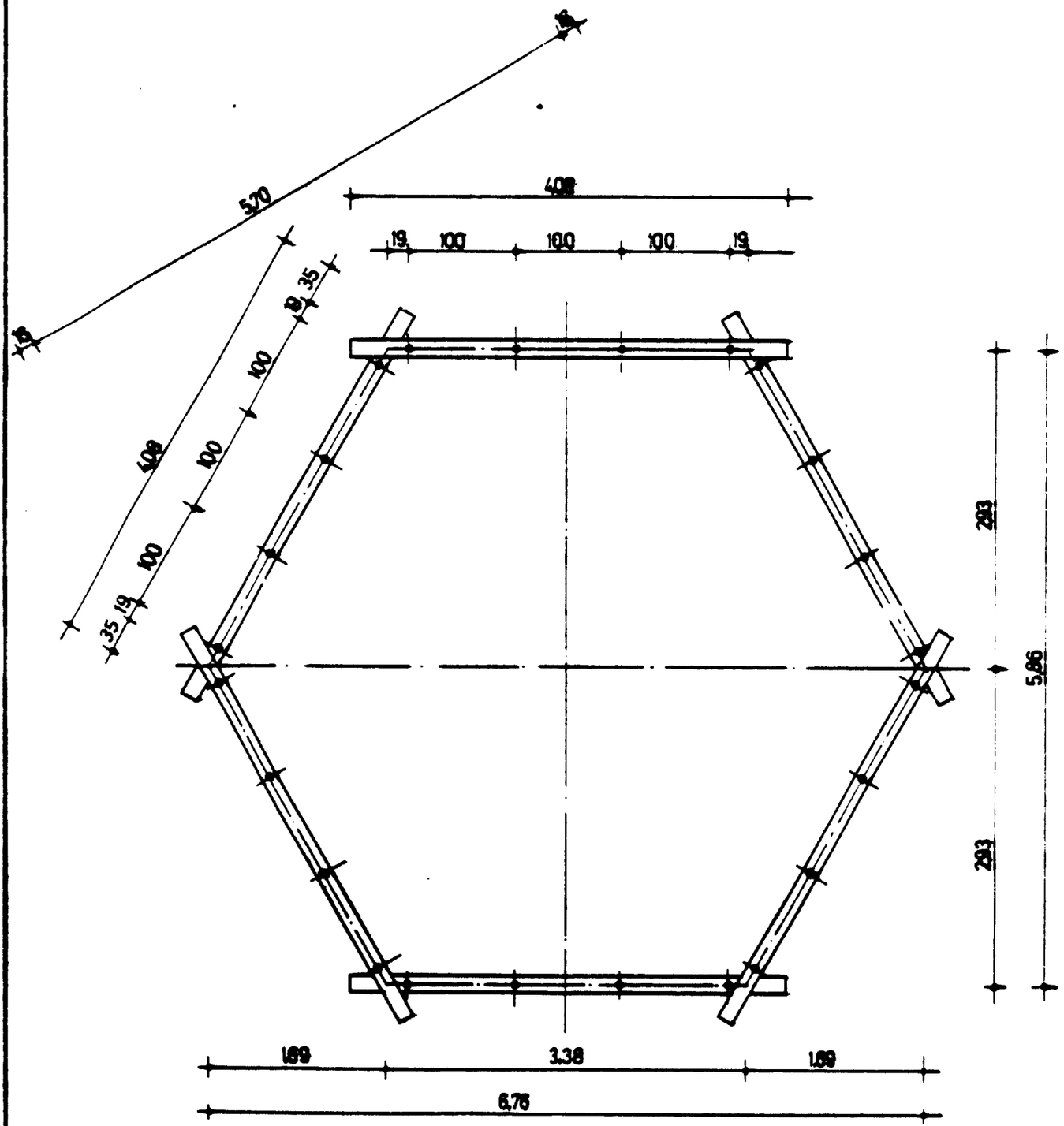
ASSEMBLY INSTRUCTION FOR A LOG HOUSE



EXPLODED VIEW OF A LOG HOUSE

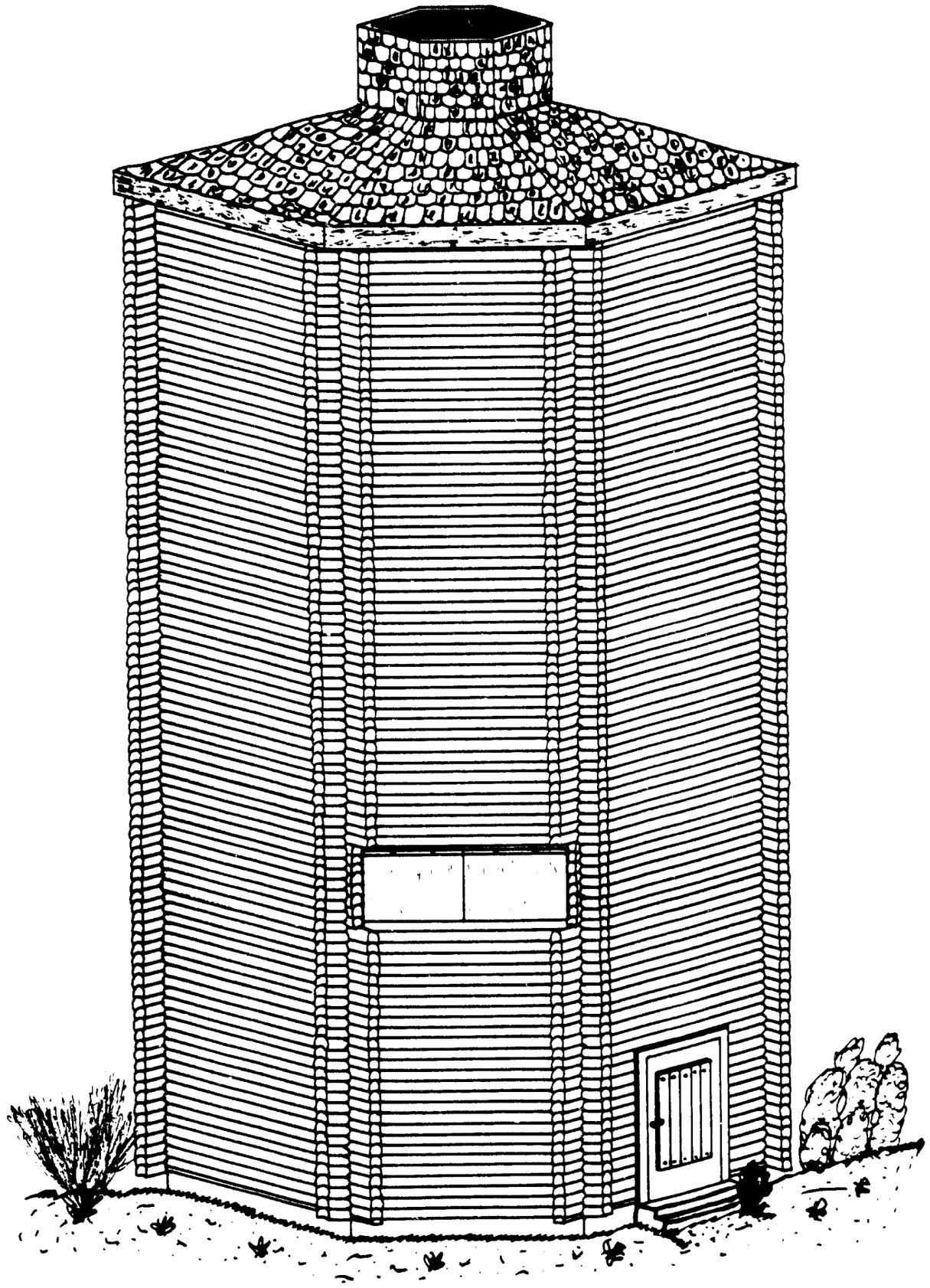
Annex 13

FLOOR PLAN OF A SILO



Annex 14

LOG SILO
ROOFED WITH SHINGLES



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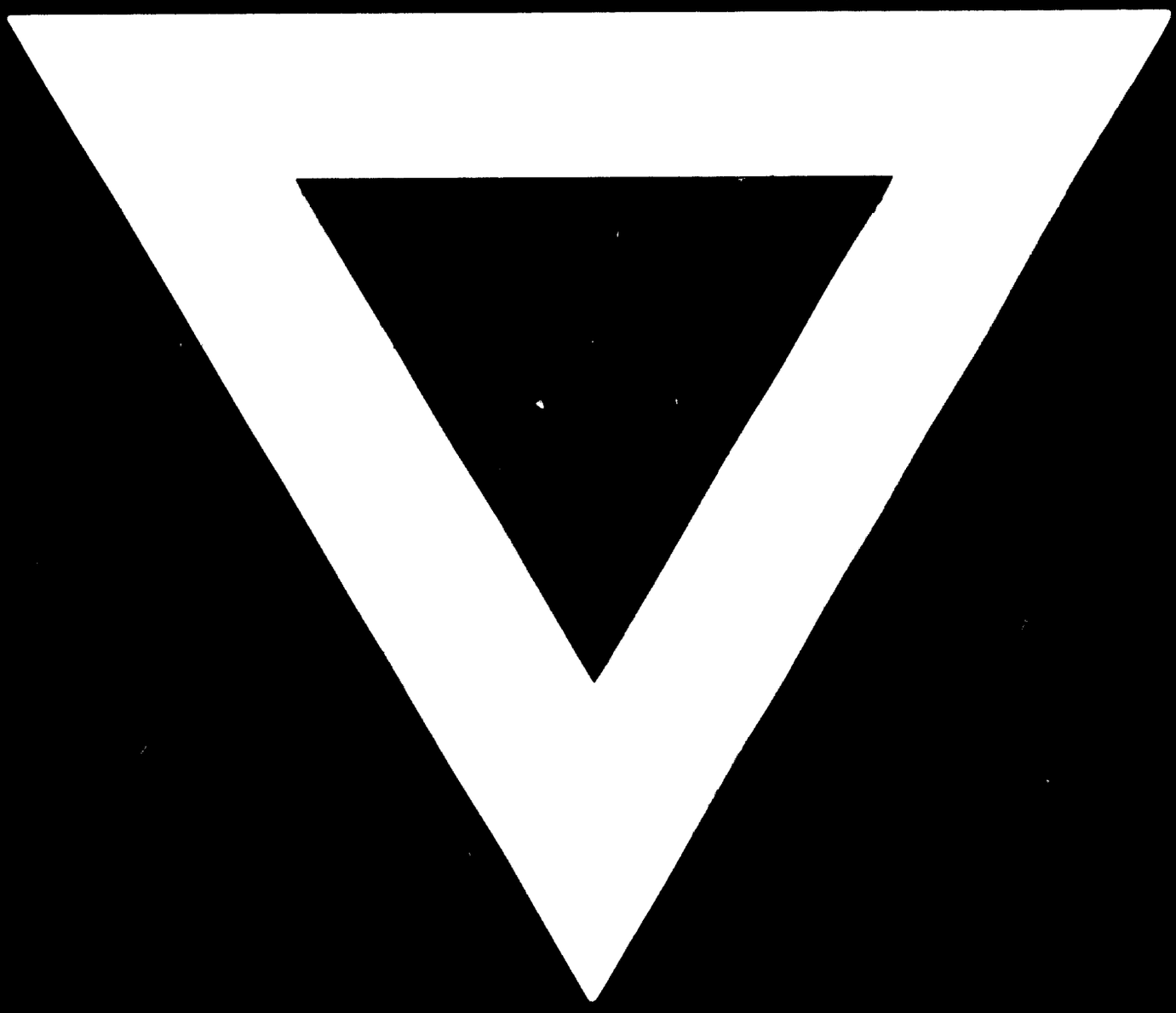


80.04.23

Introduction

Wood is one of the most important raw material existing in our world. There is hardly any other material which has been of comparable importance in the history of human life.

Wood has always been of importance within the erection of huts buildings, and similar purposes. The favourable characteristics of wood in connection with a high standard of technical development are reasons why the utilization of wood in the building trade will inorease in the future. It can also be expected that according to modern building standards new applications will be developed.

There are wooden houses erected hundred years ago which are still in good condition.

There are glued structures with a span more than hundred meters available. The reason for this great importance of wood as a raw material is due to its availability and its favourable characteristics.

The main characteristics of wood suitable for building material are:

- Durability
- Stability
- Load bearing
- Elasticity
- Safety
- Easy to machine
- Resistance against chemicals
- Thermal insulation

Wooden building components are materials for the economic erection of houses, huts and similar constructions safely is of main importance within buildings for human life, but dwellings made of wood contribute to good environmental living conditions. Log cabins and log huts are some of the oldest building types known. Especially in Russia and Scandinavia are examples of log houses well manufactured which are more than hundred years old. A detailed view on log houses, gives ideas of the highly skilled craft in carpentry to erect a log house made of logs. Reasons for not having developed log house production earlier are the difficulty and up to date know-how for machining logs into profiled log house components.

Log house components require selected, straight grown long trunks. Therefore, it is difficult to built up house walls of long length or it renders necessary to make lengthening joints on the profiled components for longer units.

There is a world wide demand of suitable building material which can be manufactured economically. This is especially the case in developing countries with their increased population growth rate. In these countries it is a must to produce low cost housings of technical suitability, easy to handle, to transport and to utilize.

In many countries low grade lumber and secondary species are in great quantities available and can hardly be utilized economically. Traditional saw-mills are in most cases not equipped to break-down small diameter logs. The conversion of low grade lumber for the production of building panels requires considerable investment and is only economically operating large production plants. Therefore, low grade lumber and secondary species are frequently unutilized, used as fuel wood or even burned as undesirable waste. In this connexion it has to be mentioned that the high amount of burned wood in clear felling areas for cultivation, is a most undesirable contribution to pollution and is also disturbing natural biology.

With the adapatation modern technologies it becomes possible to convert low grade lumber and secondary species into high quality building components. The investments necessary is relatively small, and easy to establish manufacturing facilities in the vicinity of the market to decrease transport problems.

1. The importance in utilizing low grade lumber and secondary species

1.1 Present utilization of low grade lumber

It is very difficult to estimate the yearly production of low grade lumber, because of no market research results are available. Low grade lumber is in most oountries available even in countries with small forest regions. The largest amount of low grade lumber is harvested in virgin forests and reafforested areas where trees are felled for clearing purposes.

Considerable amounts of low grade lumber are also produced as a by-product while felling trees for saw logs and clearing forests to gain agricultural land. In addition to these considerable quantities of low grade timber trees from clearing sites can be utilized. A further source is the afforestation of fast growing species viz.: Eucalyptus or Kiri. A rough idea on the yearly amount of low grade lumber available is compared with the annual quantity of commercial timber produced world wide which was 1.277.000.000 cubic meter in 1976. 235.000.000 cubic meter have been produced in developing countries. It can be assumed that the annual quantity of low grade lumber is considerably higher as compared to the world production of commercial timber. Reforestration of fast growing species would further increase the quantities of low grade lumber which can be harvested at a suitable size within 3 to 4 years.

So far low grade lumber is hardly utilized. This is most obvious as FAO investigations consider about half of all timber felled in the world as fuel wood. According to FAO this percentage is even increasing to 85 per cent within developing countries. This means that a valuable raw material is mainly unutilized. The utilization of wood as fuel material is of low economic value, if it is just burned as undesirable waste, this means spoiling of raw material in combination with pollution.

In developing countries valuable raw material is just spoiled, but an enormous demand of building material is required. Very often the production of these materials is possible only under consumption of energy being of high cost and are often related to oil imports burdening the foreign exchange of these countries.

Low grade timber is very often converted into pulp and paper. This is, however, economical only when transport distances of the raw material are reasonable.

Low grade wood is also used for the manufacture of building panels on the base of resin or cement binders.

The cement based particle panels can be produced in small industrial plants but cement must be available. The production of chip-boards, based on resin binders require adhesives which are relatively high and have

usually to be imported from industrialized countries, consuming foreign exchange.

The utilization of chip-board is limited in numerous developing countries. One of the reasons is the lack of the market for a relatively expensive product and the limitation of application. Without specialized hardwares and hinges it is for example almost impossible to use chip-boards for the production of furniture.

The traditional saw-mills are to a certain extent only able to breakdown low grade lumber. Due to the small log diameter the breakdown capacity is uneconomic. The tapered and unstraight growth of trees and the waste arising while processing is relatively high. The possible length of profiled log components is also limited. As the demand of long profiled logs is very high, short stock is of low value.

Although low grade lumber is a raw material so far hardly utilized, it is anyhow a valuable raw material, when comparing the properties of small diameter logs and the quality of commercial timber. The only reason why low grade lumber is unutilized is the lack of economic machining facilities.

To process low grade lumber into building components, the following conditions have to be fulfilled which are especially of importance for developing countries:

- It is necessary to adapt a simple technology with relatively low investment and the possibility of small scale on the site production. The plant location has to be based on evaluation of a cost analysis and marketing;
- The technology must be easy to apply and has to assure a reduced waste rate;
- It must be possible to produce profiled components of sufficient length, accurate dimensions and good quality surface;
- The handling, assembling and further processing of building components must be simple and should not require highly skilled labourers;
- Whenever necessary, the building components have to be preserved against decay, fungicides and insects.

1.2 Building situation in developing countries

Developing countries have an extremely high demand for low cost housing which can often not be realized because of a low purchasing power. The demand is concentrated, mainly on low-cost-housing, but also for public buildings, farm buildings and similar constructions. The existing buildings and the usual building methodology is not up to date. Even relatively modern buildings often have defects or are of low quality. The reason for these conditions is the lack of suitable building materials as well as lack of know-how for planning and setting up buildings.

Thermo insulations are often poor. Insufficient insulation of building components against humidity are frequently the reason for unhealthy living conditions and poor building quality. The production are relatively expensive in developing countries. The lack of know-how is sometimes the reason for over-dimensioning or the contrary is the case which means danger. The poor infra-structure is often influencing transport costs resulting in increase of building costs, especially rural areas of developing countries.

Under prevailing conditions of developing countries a system is desirable which enables to erect high quality buildings of different sizes and for different purposes based on raw materials available in the country which can be processed at low cost. The adaptation of the building materials must be simple. Buildings should be erected by unskilled labourers within a very short time. Planning and engineering of buildings especially calculation of statics should be simple and without any risk. It is also of great importance that the building components can be combined with other materials than wood, under these conditions one can optimise the building efficiency.

A new system is utilizing low grade lumber for building components specifically for developing countries is the log profile construction.

2. The universal component system

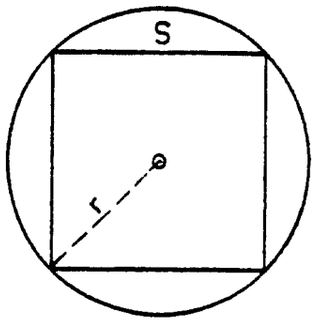
2.1 Methodology of economic production

To achieve economic processing of low grade lumber production costs have to be decreased by a maximum yield of raw material input.

The main possibilities to achieve this target, are to reduce machining operations and waste. The cross-section of a grown tree is approximately round, but tapered (Annex 1). Apart from unregular growth of a tree, the cross-section can be considered round but tapered in length. Profiles have to be machined on a cylindrical log only. The traditional log break down is to saw squared flitches, or boards with approximately the same rectangular cross-section all over the length.

When sawing flitches losses are of a maximum when the cross-section equals a square. The volume difference of the cross-sections of a circle and a square where the diagonal equals the circle diameter the volumes are 100 : 637 (See fig. 1).

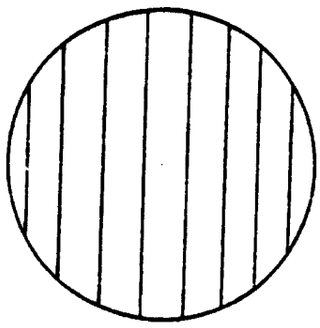
Fig. 1 - Volume comparison of circle and square



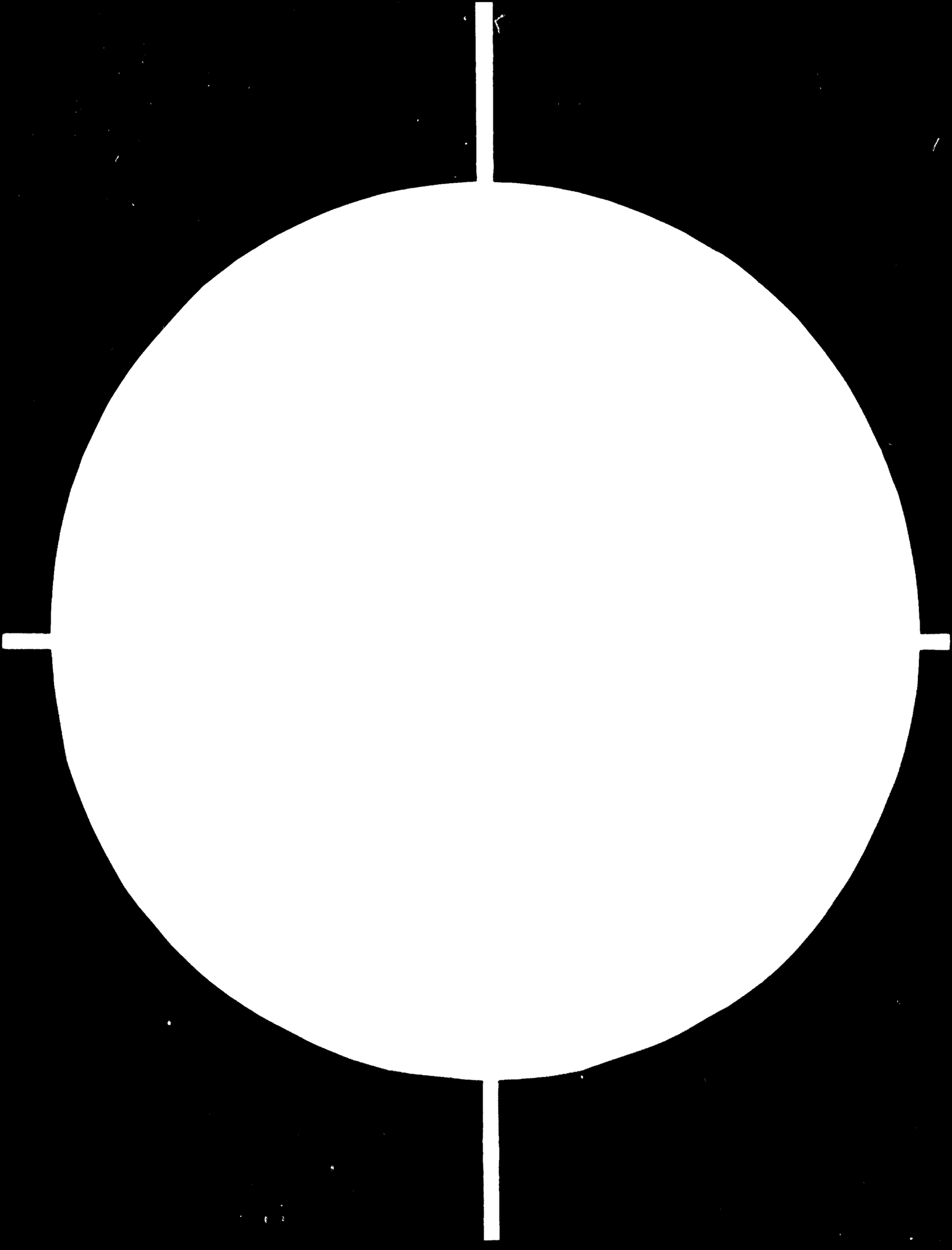
V circle = r^2 = 100 %
V square = S^2 = $2r^2$ = 63,7 %

The losses can be reduced when making parallel cuts (see Fig. 2).

Fig. 2



This method is, however, hardly adaptable for low grade lumber and mostly uneconomical. In case a round piece of lumber has to be transferred alternatively into a profile of square shaped or circular shape cross-



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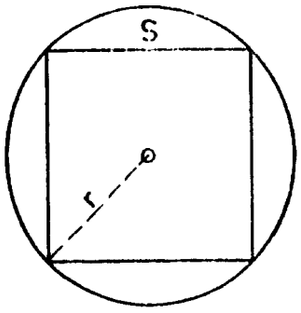

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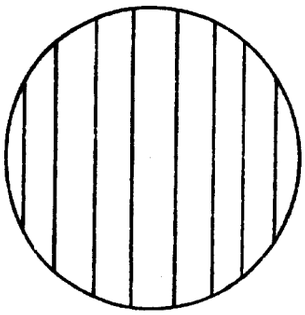

This method is, however, hardly adaptable for low grade lumber and mostly uneconomical. In case a round piece of lumber has to be transferred alternatively into a profile of square shaped or circular shape cross-

section, the minimum loss will be as already mentioned 100 - 63,7 = 36.3 %. Tapered and unstraight growth will create more waste on long log sections than on shorter log section considering always the maximum top diameter. The taper differs on the various species and growth to regions. As a rule of thumb, the taper is 10 mm at a length of 1 m. All calculations in this paper are based on this value. In Annex 2 and 3 the corresponding figures are listed which indicate the increase of waste when converting a tapered log into a cylindrical one in relation to the log diameter, irrespective of the increase of length.

It is advisable to produce sections as short as possible in order to decrease the share of waste, but bolt sections are hard to sell because of limited use.

For a rational production of long log sections it is, therefore, advisable first to cross-cut the logs into short stock, classifying them according to the diameter and rejoin them. The list in Annex 3 indicates the raw material requirements when long sections are rejoined from stock of 2 m length in comparison to raw material requirements where they are manufactured out of one piece. The only possibility to rejoin such stock sections is by finger jointing.

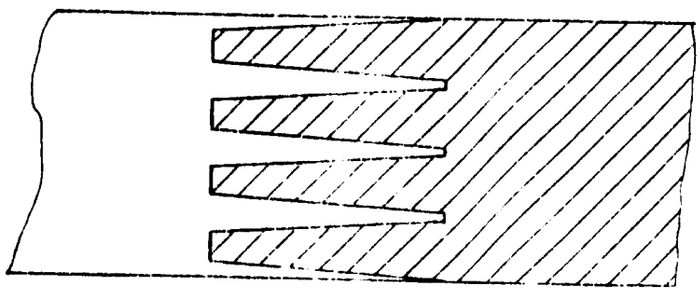

Fig. 3 - finger joint

Finger jointed profiled log components are manufactured with a certain amount of waste but yield of strength quality. The tendency of wood in twisting and cracking is thus reduced. The manufacture of finger jointed profiled log components of any desirable length, is very simple.

Finger jointed stock can be remanufactured for log components and can then be assembled. (See Annex 4 - Assembly of tongued and grooved log components). For the manufacture of prefab log houses components corner joints have to be moulded and drilled for assembly on the steel rods in about 1 mm distance (See Annex 4). Special care is necessary for accurate machining of holes and corner joints to facilitate assembly work of the profiled log components for on the site erection of prefab buildings. (Annex 6 - 14).

In view of an economic production it is advisable to cross-cut incoming low grade lumber into stock of equal length. When considering finger jointing of stock production costs of component manufacture without finger jointing and the production costs of finger jointing stock have to be compared. Most calculations considered, have shown that the most economic length of log components to be finger jointed is within the range of 1.5 - 2.5 m. It is not easy to calculate the quality increase of finger jointed stock moneywise and it is, therefore, being omitted.

The techno-economical conception of a plant manufacturing profiled log components needs to be analysed. The investigations have to include availability of raw material, the raw material costs and the market situation analysing the most economic solution.

2.2 The component system

The component system is based on rounded timber. Raw material is low grade lumber and secondary species. Finger jointing renders possible to produce any desirable length of stock. For practical reasons it is advisable to reduce the number of diameters to be utilized viz:

30 mm
50 mm
60 mm
80 mm
100 mm
120 mm
140 mm
160 mm
180 mm
200 mm
220 mm
240 mm

Stock should be rounded before profiled. Machining of corner joints and drilling of holes for steel rods can be done at any point of the profiled log. It is even possible that these operations can be performed at any desirable angle instead of being in rectangular positions. Thus the combination of profiled logs will lead to unlimited variations which opens new viewsin design construction of prefab log houses. (Annex 6 - 14). This technology is of great flexibility which renders possible batch production not excluding individual design features. The building components are of accurate dimension to facilitate assembly and exchange of components. The assembled building components can also be bolted at their ends. In case all profiled log components are assembled in the same direction, it is not absolutely necessary to use pre-seasoned timber. Even green timber with high moisture content can be used. When a log house is erected by components with high moisture content, the timber will climatise without any risk of damage of the construction. The shrinkage can be precalculated and will be considered in construction and when installing wall units. Retightening of steel rod nuts is recommended after a period of final climatised adjustment.

2.3 The scope of the system for

2.3.1 Standardized houses

Designing of standardized houses is very easy and does not create any problem to the proposed system. If shape and dimensioning of a building is fixed, it is just necessary to list the shape and size of the profiled log components prior to manufacture. For reasons of easy assembling and minimum storage, it is advisable to use as many components of the same shape and dimension as possible. The profiled log components are produced in factory sets for easy erection at the site. The assembling of a log house at 100 square meters will be done by four unskilled labourers within one to two days. Buildings based on other standardised materials offer a limited line of variations at its erection depending on the process applied, need weeks. They can be changed under considerable additional costs. Within the system of wooden profiled log components it makes it possible to combine the advantages of standardized and individual building methods.

2.3.2 Traditional constructions

The wooden profiled log component system can be combined with other building systems, for example cellar area in concrete or blocks and log system on top. In other cases the roof storey might be built on the base of profiled log components.

2.3.3 The appropriate technology

The system of wooden profiled log components is based on a technology which meets the conditions in developing countries. The know-how of this technology can easily be transfered. It is a labour intensive system. The machining operation does not require skilled labourers and no special qualification for supervision staff. This kind of production and the range of products can be adjusted to the needs of various developing countries, and can be tailored to any specific needs in these countries. The system therefore, offers an appropriate technology in three directions:

- the appropriate production process;
- the appropriate quality building material, viz: the profiled log component;
- flexibility in application.

It can also be expected that the production and sales of building components will generate new markets.

3. Production machinery and equipment

Local conditions for the erection of a production plant have to be evaluated carefully to manufacture wooden profiled components from low grade lumber and secondary species. To avoid wrong investment a feasibility study has to be prepared covering the following investigations:

- quality and quantity of raw material available;
- dimensions of low grade lumber;
- testing the suitability as building component;
- fixing sequence of machining operations;
- possibility for preservation of profiled log components;
- skill of labour force and basic wages;
- market conditions;

- size of production plant;
- evaluation of mechanised and automated equipment.

Planning of projects have to be considered individually, thus the selection of machinery and equipment can only be proposed in general. Three plant sizes are described as follows.

3.1 Production of profiled log components based on log diameter from 100 - 140 mm

Capacity: 20 cubic meters of finished stock, 8 hours shift.

Raw material requirements: approximately 40 cubic meter, finger jointing is not included, it is therefore necessary to use logs of 5 m in length, but adding a certain amount due to unstraight growth of the lumber. The project is based on long timber of straight growth. In general projects without finger jointing operations can only be economic under special conditions.

Production steps and requirement of machinery:

1. Classification of logs;
2. Squaring of logs on a double circular saw or slab saw;
3. Rounding and profiling of the log component, a combined round and profiling machine;
4. Cross-cutting, trenching and drilling line.

Rough estimation of investment cost for machinery, equipment and tools approximately US$ 200.000. The equipment as described is only of limited economy. The consumption of raw material and machining costs are relatively high.

3.2 Production of profiled log components as in 3.1, however, with a capacity of 30 cubic meters of finished product in 8 hours shift

In addition to the machinery described under 3.1, finger jointing equipment is included so that profiled log components of any length can be machined.

Raw material requirements: approximately 45 cubic meters, about 1/3 less than compared to example 3.1.

Production steps and machinery requirement:

1. Cross-cutting of logs into sections of standardized length or according to natural growth;
2. Classification of the cross-cut stock on diameter range;

3. Squaring logs on a double circular saw or slab saw;
4. Open air drying;
5. Finger jointing equipment for milling, glue spreading and pressing;
6. Rounding and profiling of the log sections on a combined rounding and profiling machine;
7. Cross-cutting, trenching and drilling line.

Rough estimation of the investment cost for machinery, equipment and tools, approximately US$ 300.000.

3.3 Production of profiled log components using logs of 30 to 240 mm diameter Capacity: 60 cubic meter of finished products, in 8 hours shift.

Raw material requirements: 87 cubic meter.

Compared to the project under item 3.2, further two rounding machines and one double spindle adjustable circular saw as well as a finger jointing plant and drilling unit has to be installed. The double spindle circular saw should be combined with a profile chipping machine which is uncomplicated but works with high speed and is chipping all slab material which is not usable for the finished product.

Rough estimate of the investment cost for machinery, equipment and tools is approximately US$ 550.000. The various plants under 3.1, 3.2 and 3.3 are linked with gravity conveying units for easy manual handling of stock.

3.4 Additional equipment for plant mechanization

The mechanization and automation of a plant up to the automation step can be performed which is in certain relation to the level of investment and is not appropriate to operations in developing countries. In any case detailed investigations should be considered.

3.5 Selection of alternative equipment investment

Instead of slabbing along on the double circular saw, a profile chipper can be installed for slabbing (profiling). The investment costs for this machine are in the range of US$ 150.000 which is double compared to circular saw slabber. Comparing circular saw slabbing and profile chipping, the latter works on higher speed, is simple in operation and more economical provided the high capacity can be utilized. Another advantage is that the tools can easily be re-sharpened. The profile chipping machine converts

all slab materials into waste which can be removed in one pass. The chipped material can be sold either to particle board mills or to the pulp and paper industry.

3.6 Recommended additional equipment

For the protection of profiled log components against fungicides, decay and insects, it is recommended that preservation on the base of unpoisonous cromium salts, copper and boron under vacuum and high pressure is performed for long lasting protection. A preservation plant for profiled log components up to about 12 m requires an investment of approximately US$ 60.000.

To improve the quality of profiled log components, it is recommended to install kiln drying equipment to shorten seasoning time of the finished product especially for beams, girders and floor material. The capacity of kiln drying equipment has to be calculated individually.

3.7 Investment costs for the production of specialized profiled log components

If the production includes furniture, furniture components, commodity articles or prefabricated beams and girders, standard equipment has to be added to run the production efficiently.

3.8 Standard production facilities

All plants should include a range of production facilities for wood processing and workshop equipment for metal working for jig production and maintenance. The necessary investment varies from US$ 15.000 to US$ 50.000.

4. Cost calculation

4.1 Prerequisites

Cost calculation have to be prepared for each individual case. Planning values should be based on corresponding and qualified estimations to justify a certain project. Step by step estimation data should be improved by recalculations because conditions may change considerably within the different developing countries.

The additional implementation of finger jointing lines within a plant for the manufacture of wood profiled log components depends on the material available especially when standardized components are stored.

A comparison of manufacturing costs for profiled finger jointed log components will not indicate all cost advantages or disadvantages. Finger joints improve quality of the profiled log components and will yield capacity.

Machines and equipment described under item 3 can be estimated as follows.

For 3.1 - Land: 5.000 square meters US$ 5/sq. m	= US$	25.000
Buildings	US$	50.000
For 3.2 - Land: 7.000 square meters US$ 5/sq. m	= US$	35.000
Buildings	US$	60.000
For 3.3 - Land: 15.000 square meters US$ 5/sq. m	= US$	75.000
Buildings	US$	120.000

As very often the machining area is roofed, only costs for buildings are less than indicated here.

4.2 Investment costs for project 3.2 (page 11)

Capacity: 30 cubic meter in 8 hours shift.

Machinery and equipment	US$ 300.000
Preservation plant	US$ 60.000
Production, machines, equipment and tools	US$ 50.000
Office equipment	US$ 10.000
Vehicles	US$ 30.000
Land and buildings	US$ 95.000
Power line costs	US$ 10.000
Financing, engineering	US$ 40.000
Cost for establishment and consulting	US$ 20.000
Cost for assembling and building up of the plant	US$ 20.000
Start up losses	US$ 30.000
Safety equipment, etc.	US$ 50.000
	US$ 715.000

4.3 Raw material cost

The cost for the procurement of raw materials can differ considerably. The price of raw wood is often calculated on the value of fuel wood.

Higher prices have to be calculated in case of competitive demand, for example, the manufacture of chipboard or pulp and paper. In all forest areas, the raw material demand of low grade lumber which is regularly cut under supervision of the forestry department is more or less a by-product of commercial timber. This raw material is average priced at US$ 15 per cubic meter. The quantity of chemicals for preservation of the wood is tuned to local conditions and the wood specie. Some of the tropical woods need not to be preserved but others, particularly softwoods require such treatment. The average preservation costs are US$ 10 per cubic meter.

Annual costs of raw material for the project

Production of 6.000 cubic meters building components made out of low grade lumber and secondary species.

Logs, 9.000 cubic meter (US$ 15/cubic meter)	US$ 135.000
Preservatives	US$ 60.000
Adhesives, approx. 7.500 kg (US$ 2.50/kg)	US$ 18.750
Miscellaneous material	US$ 20.000
	US$ 233.750

4.4 Wages and salaries

Production		Annual costs
Labourers		
Unskilled	22 (US$ 100 per man/month)	US$ 26.400
Skilled	3 (US$ 200 per man/month)	US$ 7.200
Fore-men	2 (US$ 250 man/month)	US$ 6.000
Technician	1 (US$ 500 man/month)	US$ 6.000
Engineer	1 (US$ 1000 man/month)	US$ 12.000
Management and administration		
General Manager	1 (US$ 1.200 man/month)	US$ 14.400
Sales Managers	2 (US$ 500 man/month)	US$ 12.000
Office employees	3 (US$ 200 man/month)	US$ 7.200
		US$ 91.200

Social benefits and costs for general administration (estimated) US$30.000,-

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EVALUATION OF LOW GRADE LUMBER AND SECONDARY SPECIES FOR THE PRODUCTION OF WOODEN COMPONENTS FOR LOG HOUSES, LOG CABINS AND LOG SILOS APPROPRIATE FOR DEVELOPING COUNTRIES *

by

H. Siller **

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4.5 Manufacturing

Estimated annual manufacturing costs including depreciation and calculated interest

Log input	US$ 234.000
Power supply	US$ 20.000
Salaries and wages	US$ 90.000
Social costs	US$ 30.000
Depreciations	US$ 100.000
Tools, maintenance	US$ 20.000
Administration costs	US$ 20.000
Advertising and marketing	US$ 90.000
Interests	US$ 70.000
Expenses, fees, taxes	US$ 20.000
Miscellaneous costs	US$ 30.000
	US$ 734.000

4.6 Turnover, profit, pay-back calculation

The annual turnover of this is calculated on an estimated sales rate of US$ 150 per cubic meter of finished products. This amount includes preservation of the profiled log components. A log house of 50 sq. meter living area will cost US$ 1.800 which is a competitive price compared to other building material of the same quality.

Annual turnover

6.000 cubic meters of building components US$ 150/cubic meter	US$ 900.000

Profit for the project example

Annual turnover	US$ 900.000
minus annual sum of total cost	US$ 734.000
Profit before taxes	US$ 166.000

It can be expected that the initial phase for the project example will take about 1.5 years. with production start-up after ten months. This requires a total maximum capital outlay of about US$ 965.000. The peak requirement of capital will be 1.5 years after establishment of the enterprise. (Details see cash flow).

4.7 Cash flow - Capital requirement for four years

without depreciation and capital interest in US$ 1.000

	1. year				2. year				3. year				4. year			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Machinery, tools equipment	100		100	225												
land, building	30	30	30	15												
cost of the initial phase	40	20	20	30	20	20										
total fixed assets	170	50	150	300	20	20										
total fixed assets summarized	170	220	370	670	690	710										
logs and lumber			30	30	10	58	59	58	59	58	59	58	59	58	59	58
power, supply, fuel, water			1	1	2	5	5	5	5	5	5	5	5	5	5	5
wages and saleries	5	10	20	25	30	30	30	30	30	30	30	30	30	30	30	30
miscellaneous	10	10	20	30	50	55	55	55	55	55	55	55	55	55	55	55
total costs	15	20	71	86	85	148	149	148	149	148	149	148	149	148	149	148
total costs summarized	15	35	106	192	277	425	574	722	871	1019	1168	1316	1465	1613	1762	1910
sales				20	50	100	200	225	225	225	225	225	225	225	225	225
sales summarized				20	70	170	370	595	820	1045	1270	1495	1720	1945	2170	2395
capital requirements	185	255	476	842	897	965	919	842	766	689	614	536	460	383	317	240

4.8 Cost summary

For the project example it can be expected that the capital return flow starts at the 6th quarter to after 4 years and 9 months (19 quarters) of establishing the plant and about 3 years after normal production, the capital requirements will be covered by capita return flow. (Interest and depreciation not included). All costs are calculated with a margin of safety, the results of a realised project will come out at a better rate.

5. Possibilities for applying wooden profiled log components

Profiled log components can be utilized in all branches of the building industry with unlimited possibilities (Annex 6 - 14). Annexes 6 to 10 show variations of log houses and log huts, Annex 11 shows the application of a double bunk bed with partition walls which fits into the building using the same profiled log components.

Also luxury and multi-storey houses could be established according to the same system. Houses based on profiled log components are suitable where high stability is required. Log houses are earthquake proned. However, another example where the profiled log components are used, is the hexagonal shaped silo shown in Annex 14. The silo is built up a standardised profiled log component having two cross trenches under 60° respectively 120° degrees. Assembling is a foolproof operation, just setting up component by component connected with steel rods. Such silos have a net volume of more than 1000 cubic meters, they are very rigid and solid, and are available as single construction or connected as double or multi-construction.

As the rough log input due to natural growth has different diameters, the finished profiled component has also different diameters. This broadens the field of application.

The following outline is not a complete list but gives a lot of ideas for use of the profiled log component.

- Log houses also with covered walls for dwelling and for commerical purposes;
- Units, such as floors also uncovered, walls and roofs within conventionally built houses;
- Parts for prefabricated houses;

- Beams and girders for a free span up to 15 m.;
- Silos;
- Swimming-pools;
- Shelves for storage of goods being portable or built on to walls;
- Playground equipment;
- High quality fences;
- Noise pollution walls;
- Furniture and furniture parts;
- Indoor and outdoor plant troughs;
- Decorative implementation;
- Floors;
- Commodity articles.

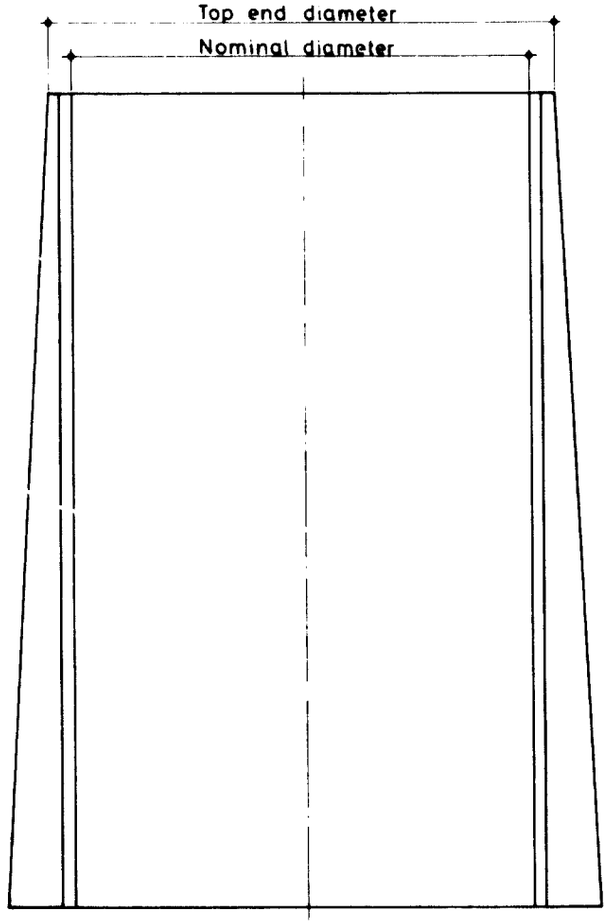
Planning and projecting of plants for the manufacture of building components in developing countries where sufficient wooden raw material is available are by no means limited to the domestic markets. To a certain extent profiled log components can be exported to neighbouring countries. The processing of low grade log dimensions having a high commercial value are of interest for production facilities appropriate for developing countries. It allows for the production of a technically valuable product with low cost material. There are opportunities for medium-sized factories to make reasonable profits, creating labour intensive manufacturing plants and conserving hard currency exchange for their countries.

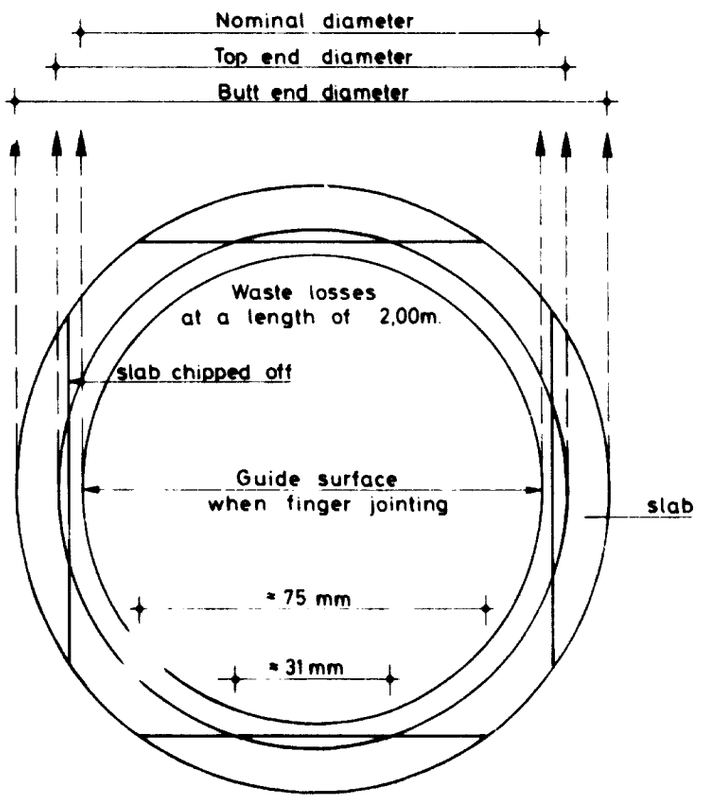
6. Final notes

Low grade lumber and secondary species being usually of a very low market value, can be converted into high grade products for the building trade. The system enables the processing of profiled log components with less waste at low cost in manufacturing.

The building components are of accurate dimension. Their application is universal and almost unlimited. The joining and assembly of profiled log components to erect buildings, or parts of buildings and to specialize producing, is very simple and does not need much skill and know-how. This system proposed is labour intensive, highly economic, projects can be realized at medium-sized or even small scale basis. The individual production machinery and the total concept of a project needs detailed investigation and can then be adapted to various conditions. The production of wooden components for buildings made of low grade lumber and secondary species is recommended for factories in developing countries appropriate to local conditions.

Annex 1


Top end diameter
Nominal diameter


Nominal diameter
Top end diameter
Butt end diameter
Waste losses
at a length of 2,00m.
slab chipped off
Guide surface
when finger jointing
slab
≈ 75 mm
≈ 31 mm

Loss of raw material due to the tapered growth of logs

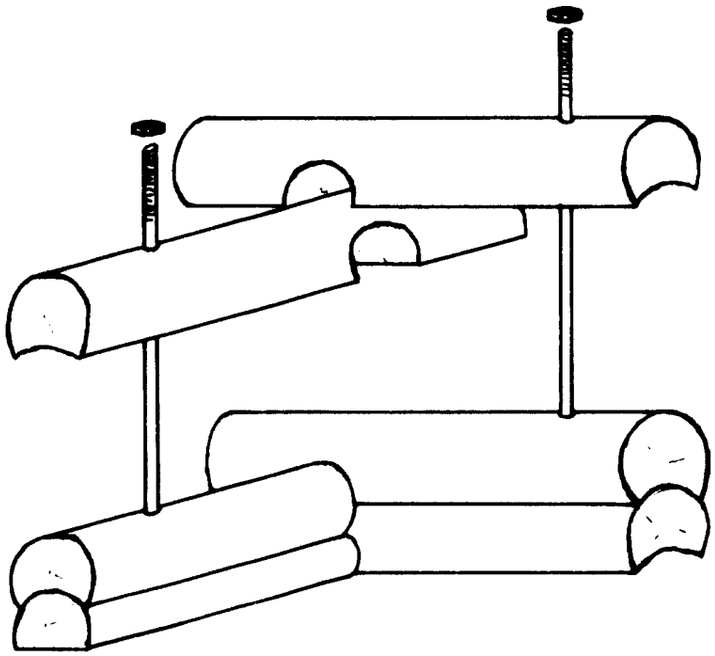
ø in cm	net.Vol./ running m of finished product m³	Vol.of raw material in m³ necessary for processing pieces of 2 m length each	Volume of raw material in percent necessary to produce a certain length of profile measured in m out of one piece based on the volume of the finished product = 1oo %					
			2	4	6	8	1o	12
3	o,ooo7o7	c,oo1963	278	4oo	544	711	9oo	1111
4	o,oo1257	o,oo2827	224	3o6	4oo	5o6	625	756
5	o,oo1963	o,oo3848	196	256	324	4oo	484	576
6	o,oo2827	o,oo5o27	177	225	277	336	4oo	47o
7	o,oo3848	o,oo6362	165	2o4	247	294	345	4oo
8	o,oo5o27	o,oo7854	156	189	225	264	3o6	352
1o	o,oo7854	o,o1131o	144	169	196	225	256	289
12	o,o1131o	o,o15394	136	156	178	2o1	225	251
14	o,o15394	o,o2o1o6	13o	147	165	184	2o4	225
16	o,o2o1o6	o,o25447	127	141	156	172	189	2o7
18	o,o25447	o,o31416	123	136	149	163	178	193
2o	o,o31416	o,o38o13	121	136	144	156	169	182
22	o,o38o13	o,o45239	119	129	14o	151	162	174
24	o,o45239	o,o53o93	117	127	136	146	156	167

Required raw material in m3 for the production of one meter rounded log section in relation to the total length of section

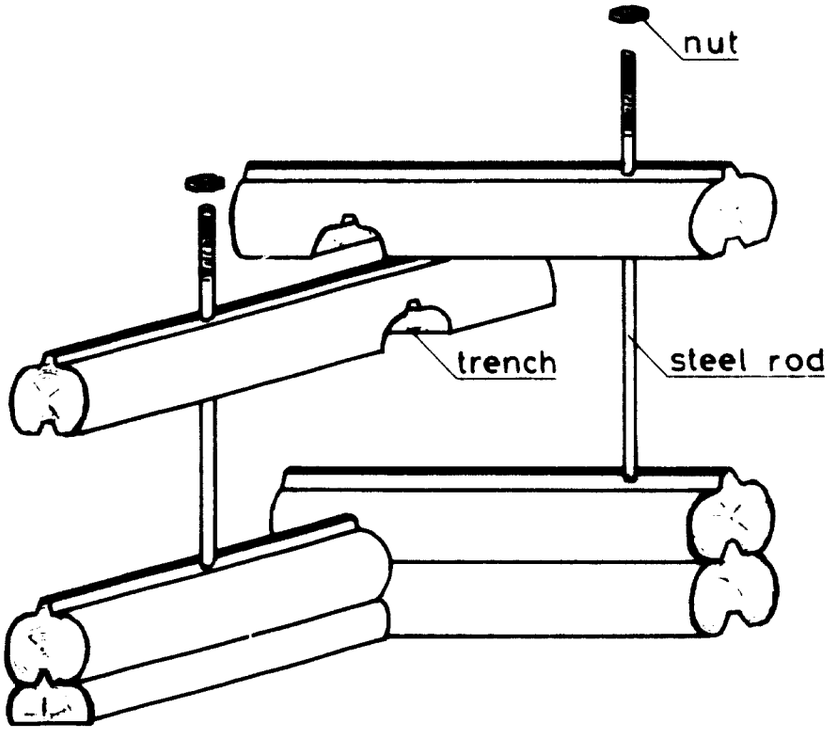
- length in m -

	2		4		6		8		10		12	
	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
in cm												
ø 3	o,oo1963	1oo	o,oo2827	144	o,oo3848	196	o,oo5o27	256	o,oo6362	324	o,oo7854	4oo
6	o,oo5o27	1oo	o,oo6362	127	o,oo7854	156	o,oo95o3	189	o,o1131o	225	o o13273	264
8	o,oo7854	1oo	o,oo95o3	121	o,o1131o	144	o,o13273	169	o,o15394	196	o,o17671	225
1o	o,o1131o	1oo	o,o13273	117	o,o15394	136	o,o17671	156	o,o2o1o6	178	o,o22698	2o1
12	o,o15394	1oo	o,o17671	115	o,o2o1o6	131	o,o22698	147	o,o25447	165	o,o28353	184
14	o,o2o1o6	1oo	o,o22698	113	o,o25447	127	o,o28353	141	o,o31416	156	o,o34636	172
16	o,o25447	1oo	o,o28353	111	o,o31416	123	o,o34636	136	o,o38o13	149	o,o41548	163
18	o,o31416	1oo	o,o34636	11o	o,o38o13	121	o,o41548	132	o,o45239	144	o,o49o87	156
2o	o,o38o13	1oo	o,o41548	1o9	o,o45239	119	o,o49o87	129	o,o53o93	14o	o,o57256	151
22	o,o45239	1oo	o,o49o87	1o9	o,o53o93	117	o,o57256	127	o,o61575	136	o,o66o52	146
24	o,o53o93	1oo	o,o57256	1o8	o,o61575	116	o,o66o52	124	o,o7o686	133	o,o75477	142

Annex 4



ASSEMBLY OF PROFILED LOG COMPONENTS
WITHOUT TONGUE AND GROOVE



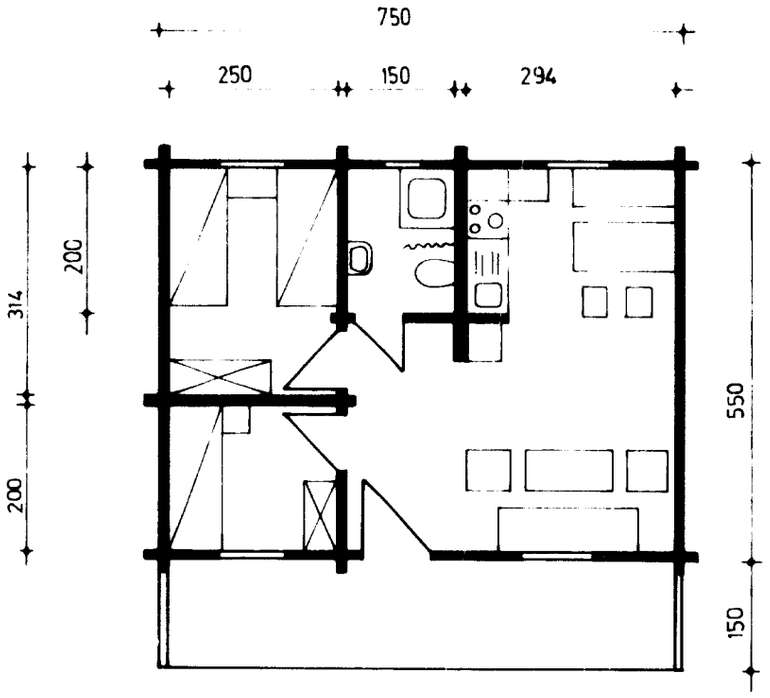
ASSEMBLY OF TONGUED AND GROOVED
LOG COMPONENTS

Annex 5

Volume of round log sections

Ø in cm	vol. in m³ per running m round timber	round timber running m necessary for 1 m²	round timber running m necessary for 1 m³	loghouse profiled component running m necessary for 1 m²
3	o,ooo7o7	33,oo	1414	38,49
4	o,oo1257	25,oo	796	28,86
5	o,oo1963	2o,oo	5o9	23,1o
6	o,oo2827	16,67	354	19,25
8	o,oo5o27	12,5o	199	14,43
1o	o,oo7854	1o,oo	127	11,55
12	o,o1131o	8,33	88	9,62
14	o,o15394	7,14	65	8,25
16	o,o2o1o6	6,25	5o	7,22
18	o,o25447	5,56	39	6,42
2o	o,o31416	5,00	32	5,77
22	o,o38o13	4,55	26	5,25
24	o,o45239	4,17	22	4,81

Annex 6

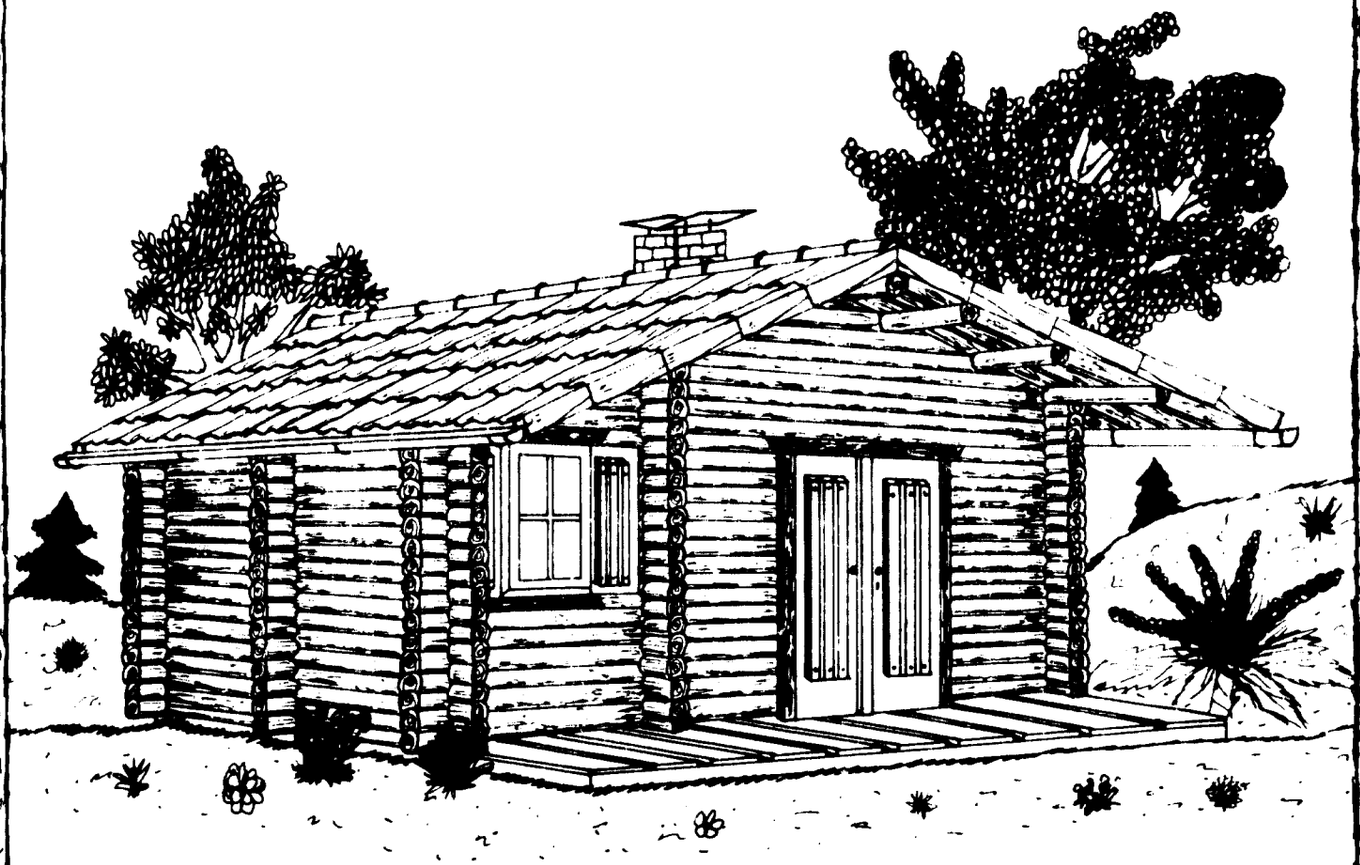


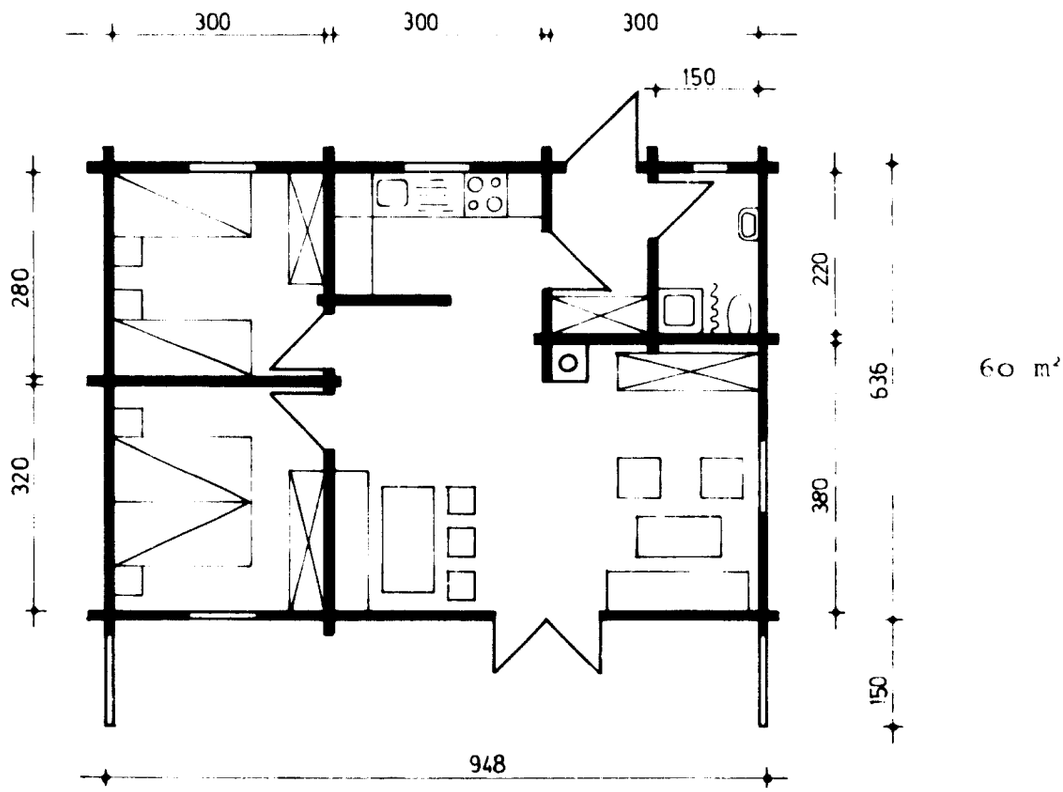
40 m²

LOGHOUSE WITH 40 SQUARE METER
LIVING AREA AND ROOFED OUTDOOR SPACE

CONTENTS

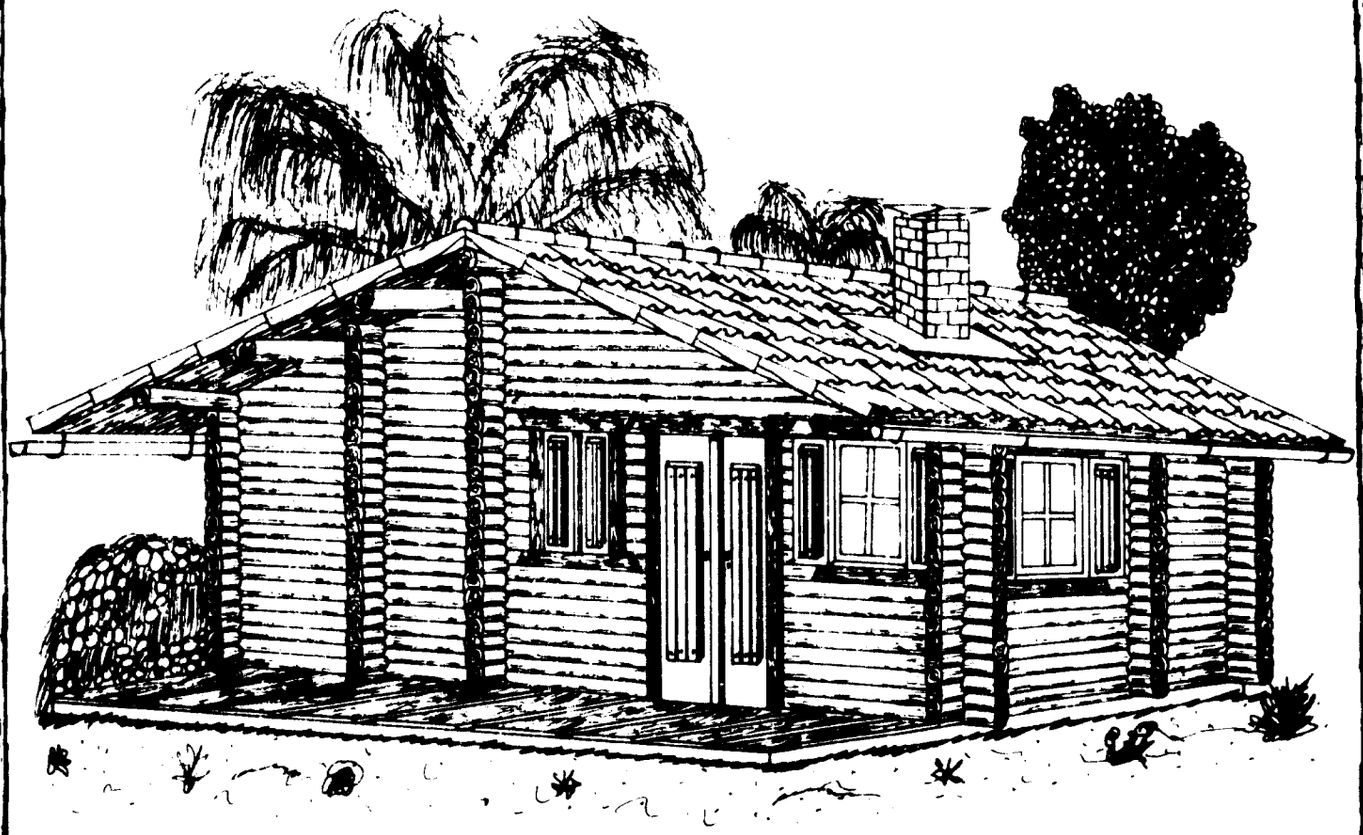
Annex 7

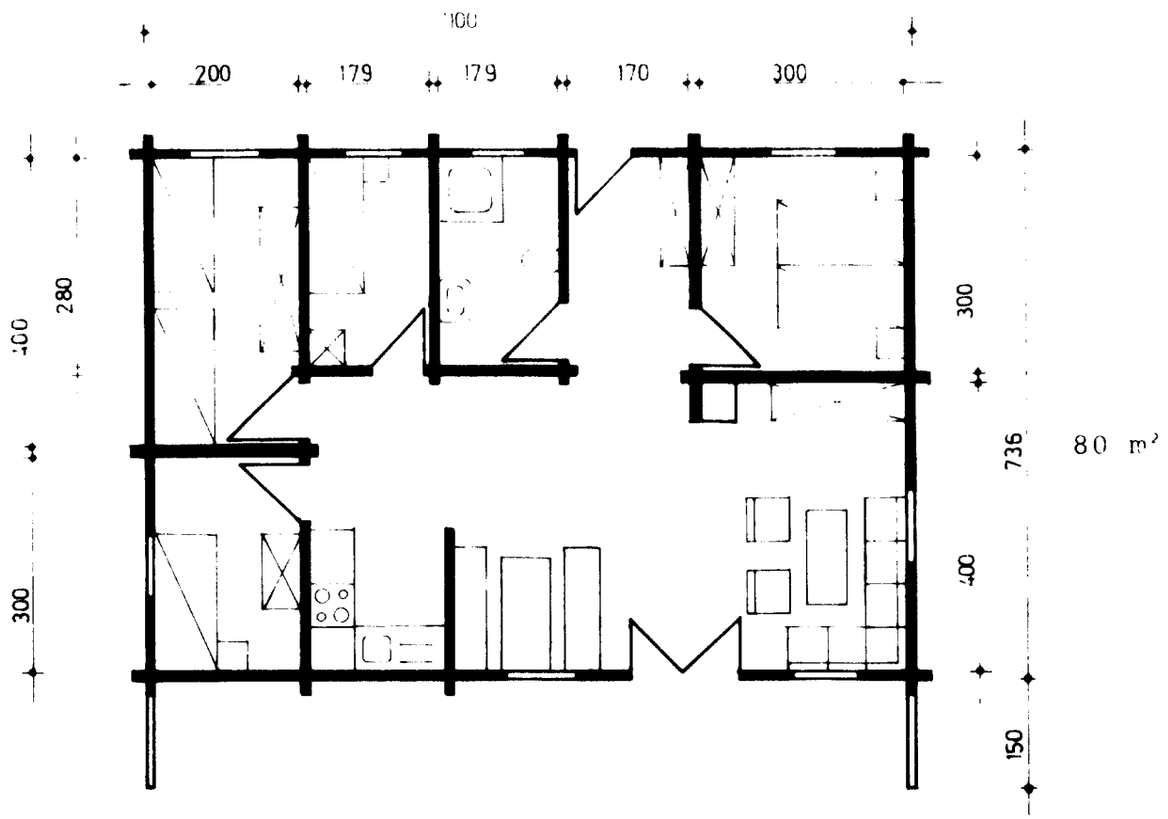




60 m²

LOGHOUSE WITH 60 SQUARE METER
LIVING AREA AND ROOFED OUTDOOR SPACE

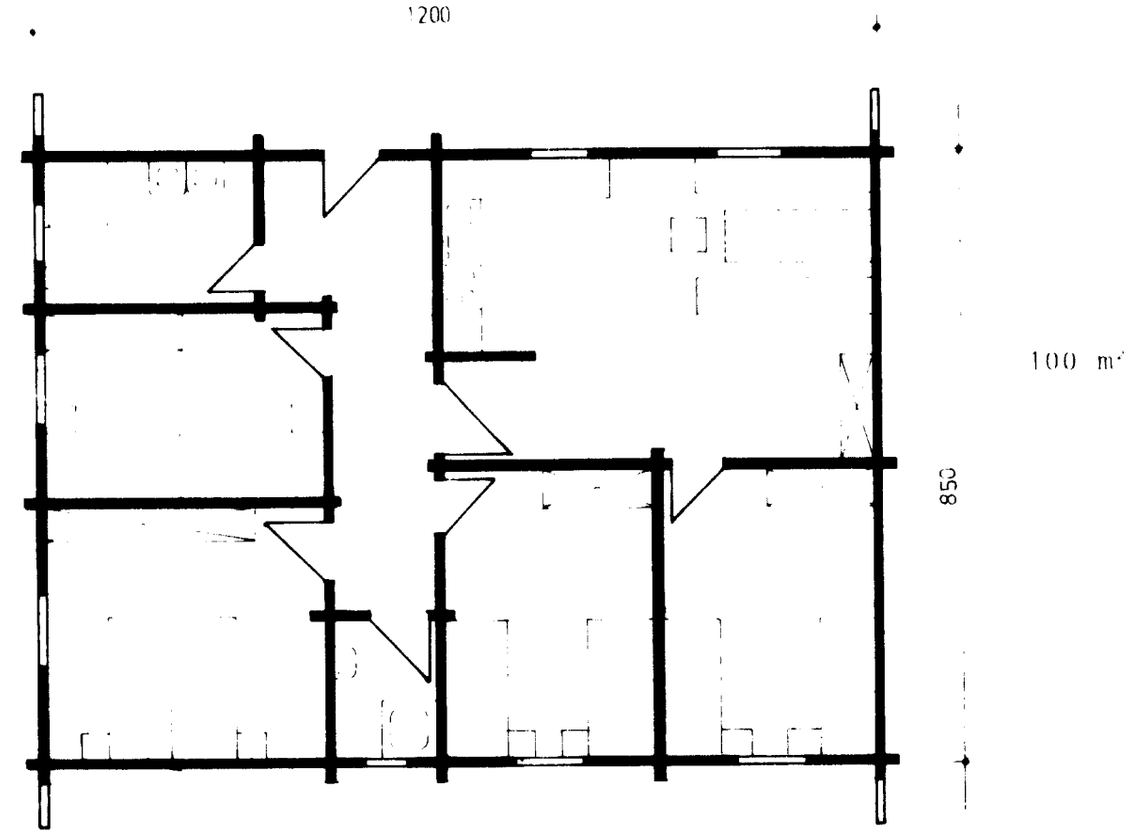


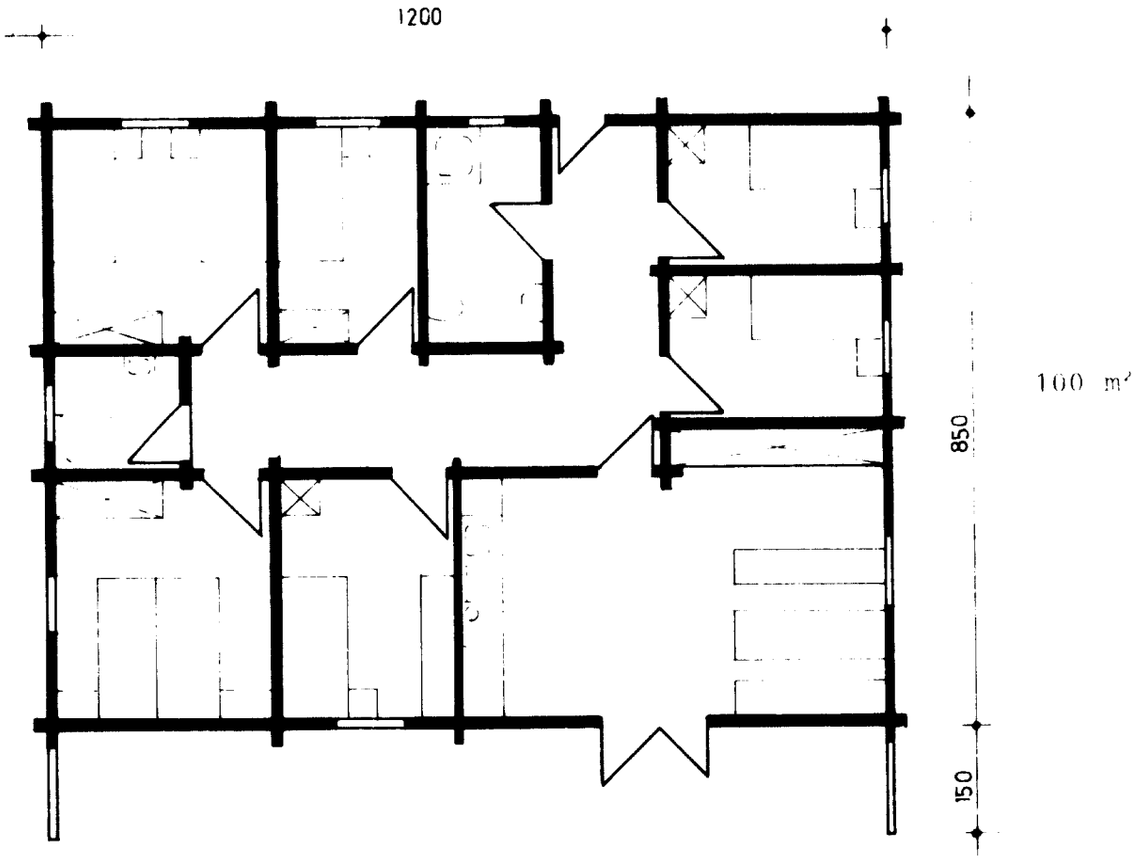


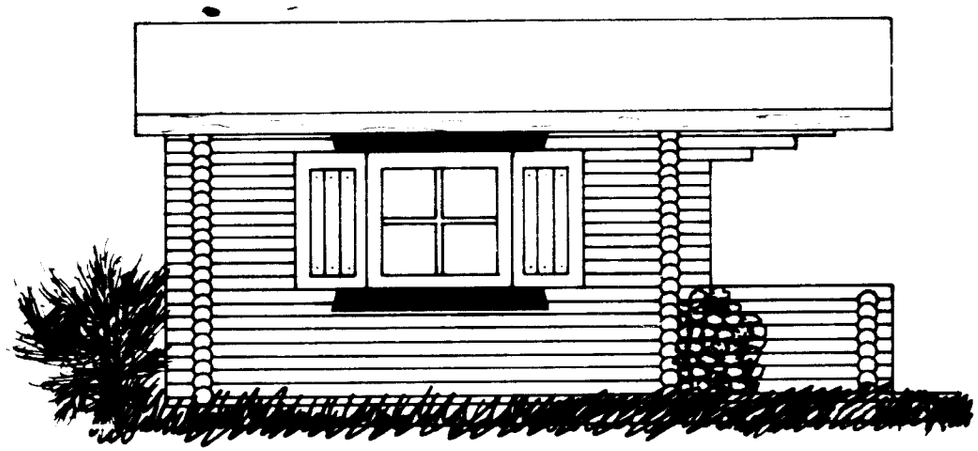
LOGHOUSE WITH 80 SQUARE METER
LIVING AREA AND ROOFED OUTDOOR SPACE

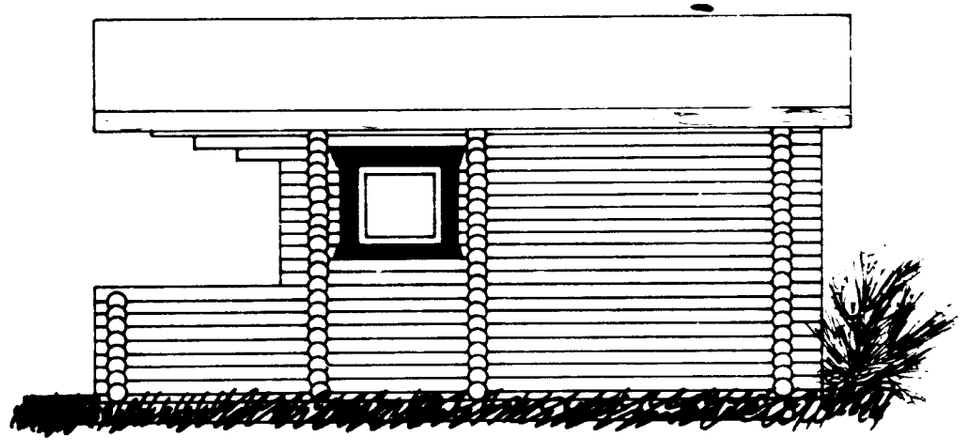
EXAMPLES OF DIFFERENT ROOM ARRANGEMENTS FOR 100 SQUARE METER LIVING AREA.

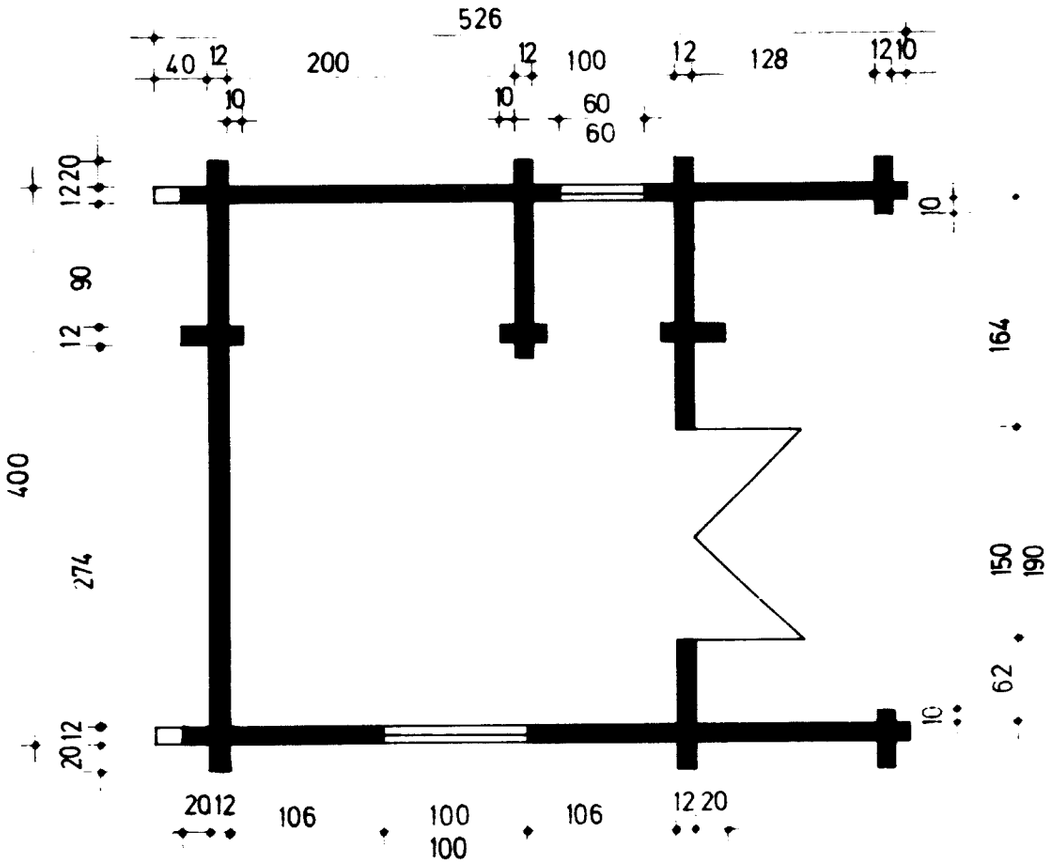
Annex 9



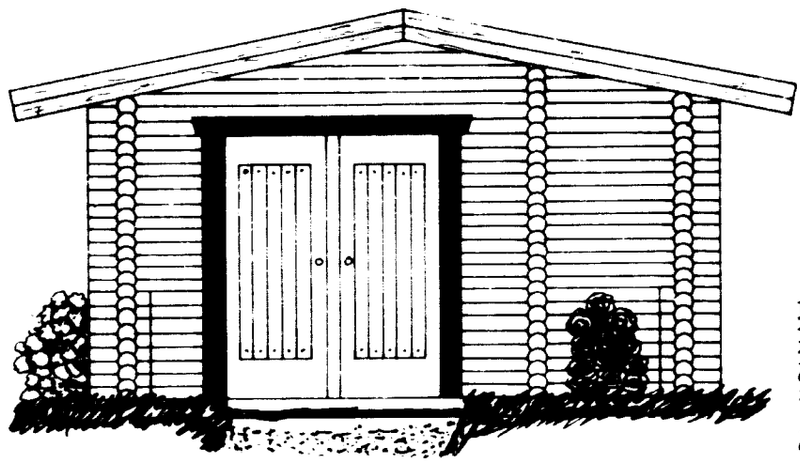








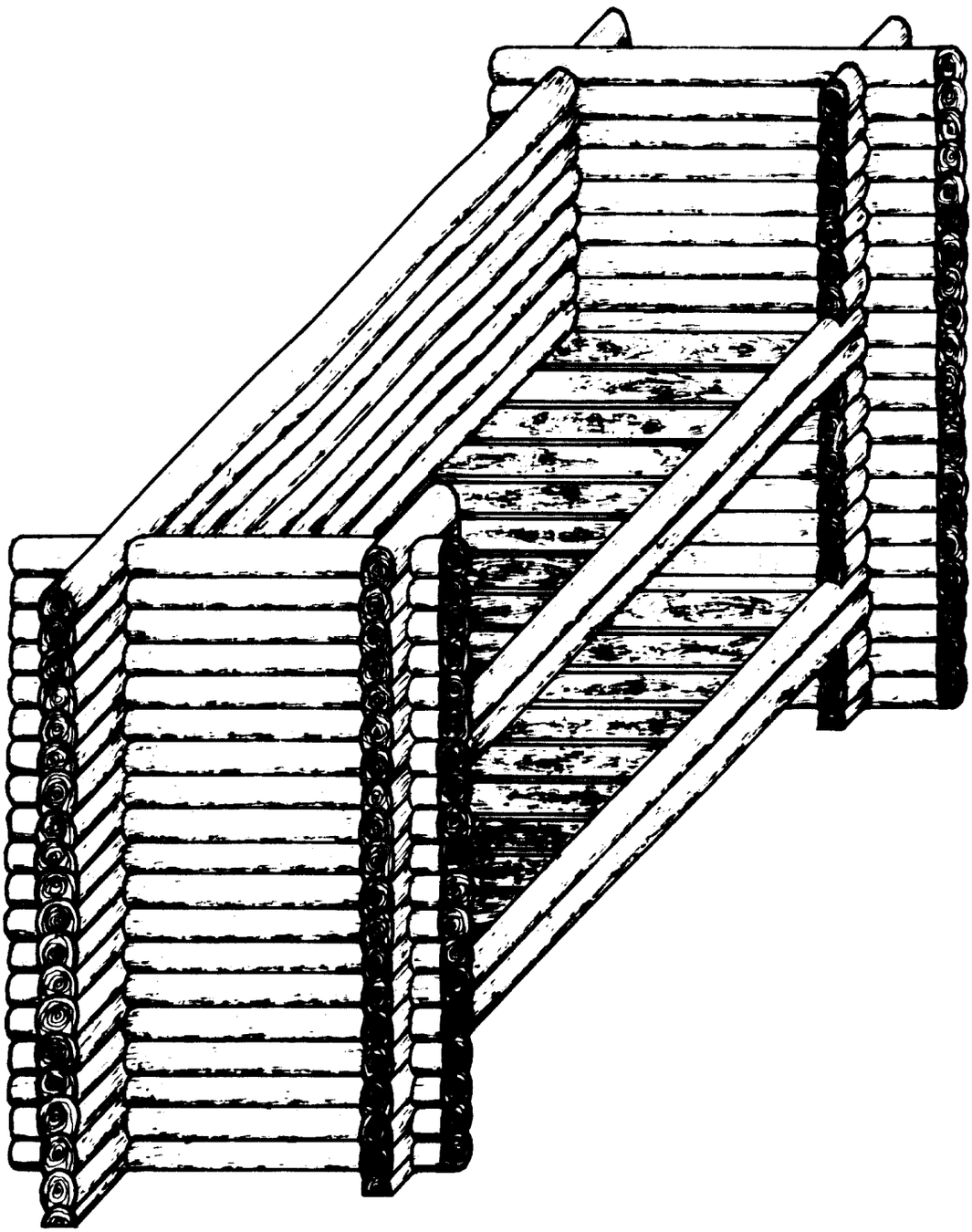
LOG HUT WITH
ROOFED OUTDOOR SPACE



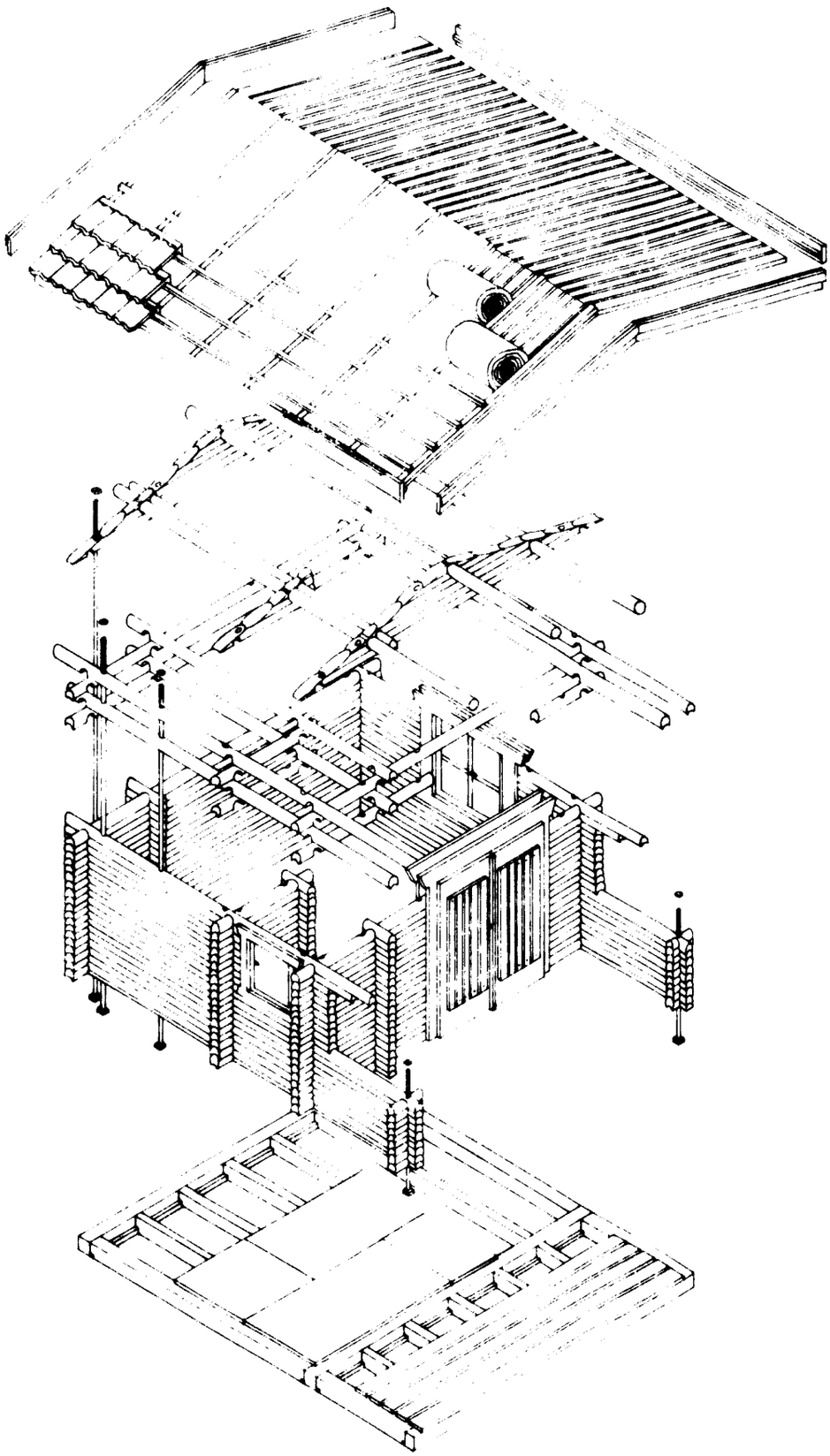
Annex 10

DOUBLE BUNK BED
ASSEMBLED BY PROFILED LOG COMPONENTS
AS PARTITION UNIT INTEGRATED TO THE
OUTSIDE WALL

Annex 11



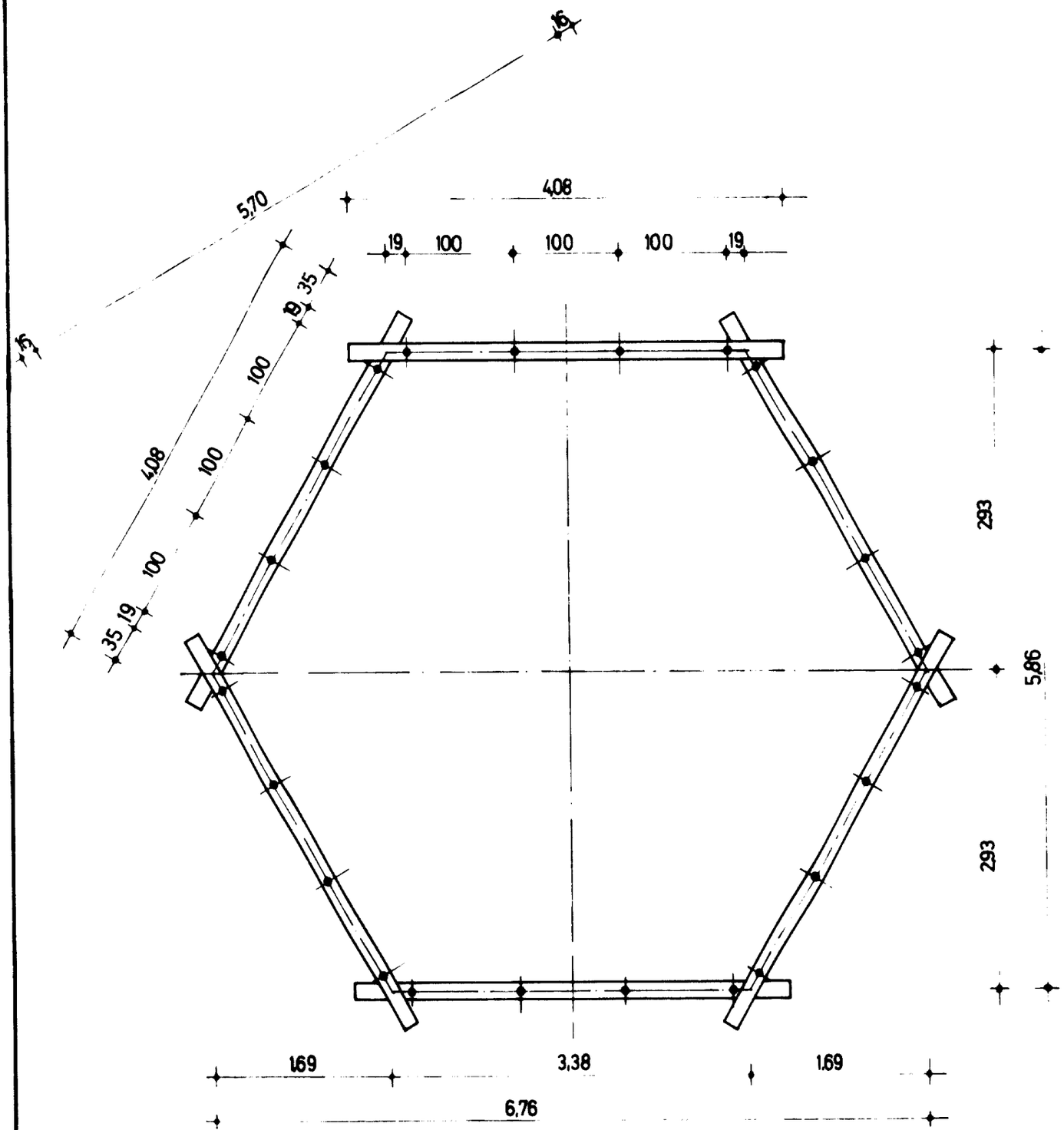
ASSEMBLY INSTRUCTION FOR A LOG HOUSE



EXPLODED VIEW OF A LOG HOUSE

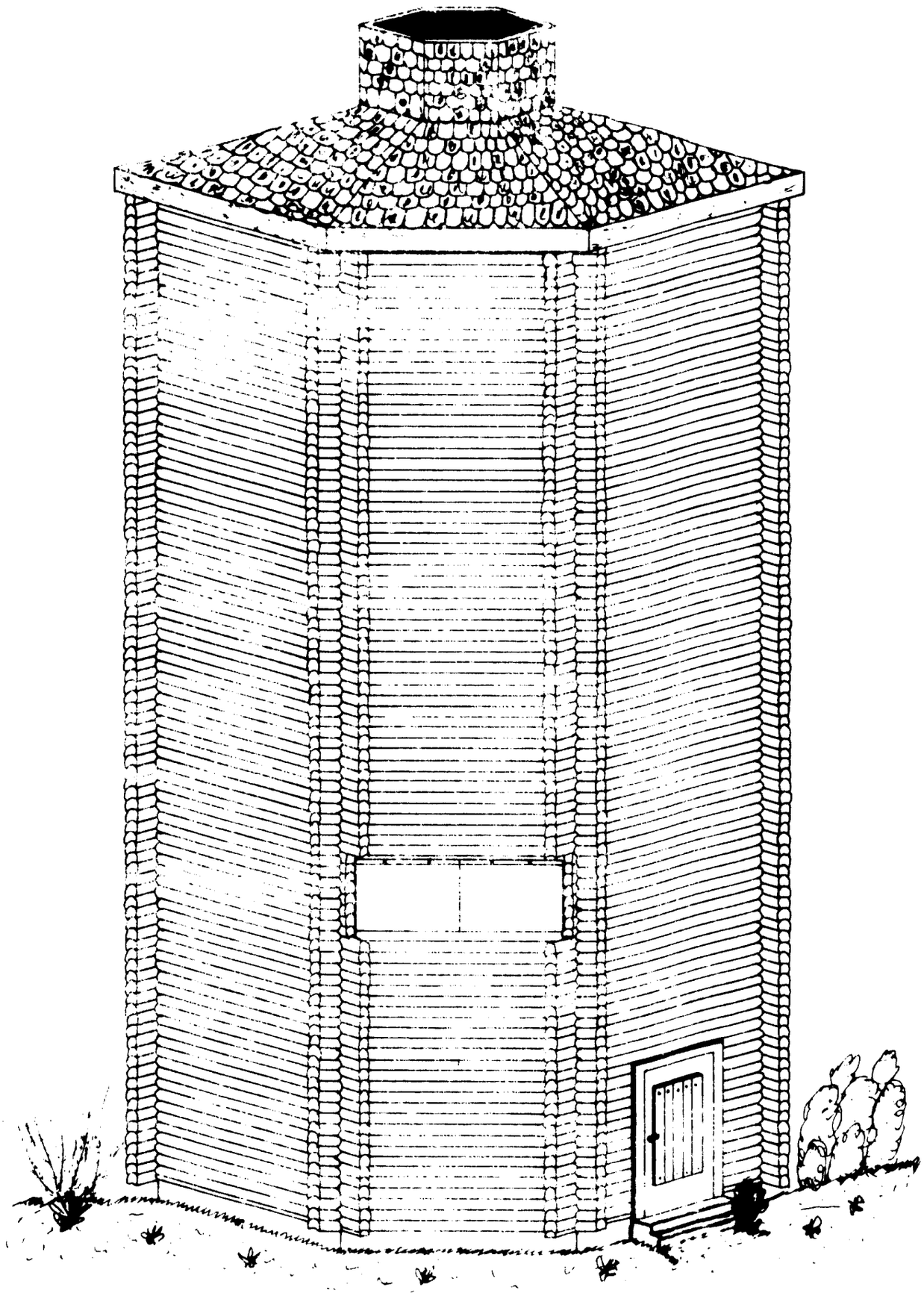
Annex 13

FLOOR PLAN OF A SILO



Annex 14

LOG SILO
ROOFED WITH SHINGLES



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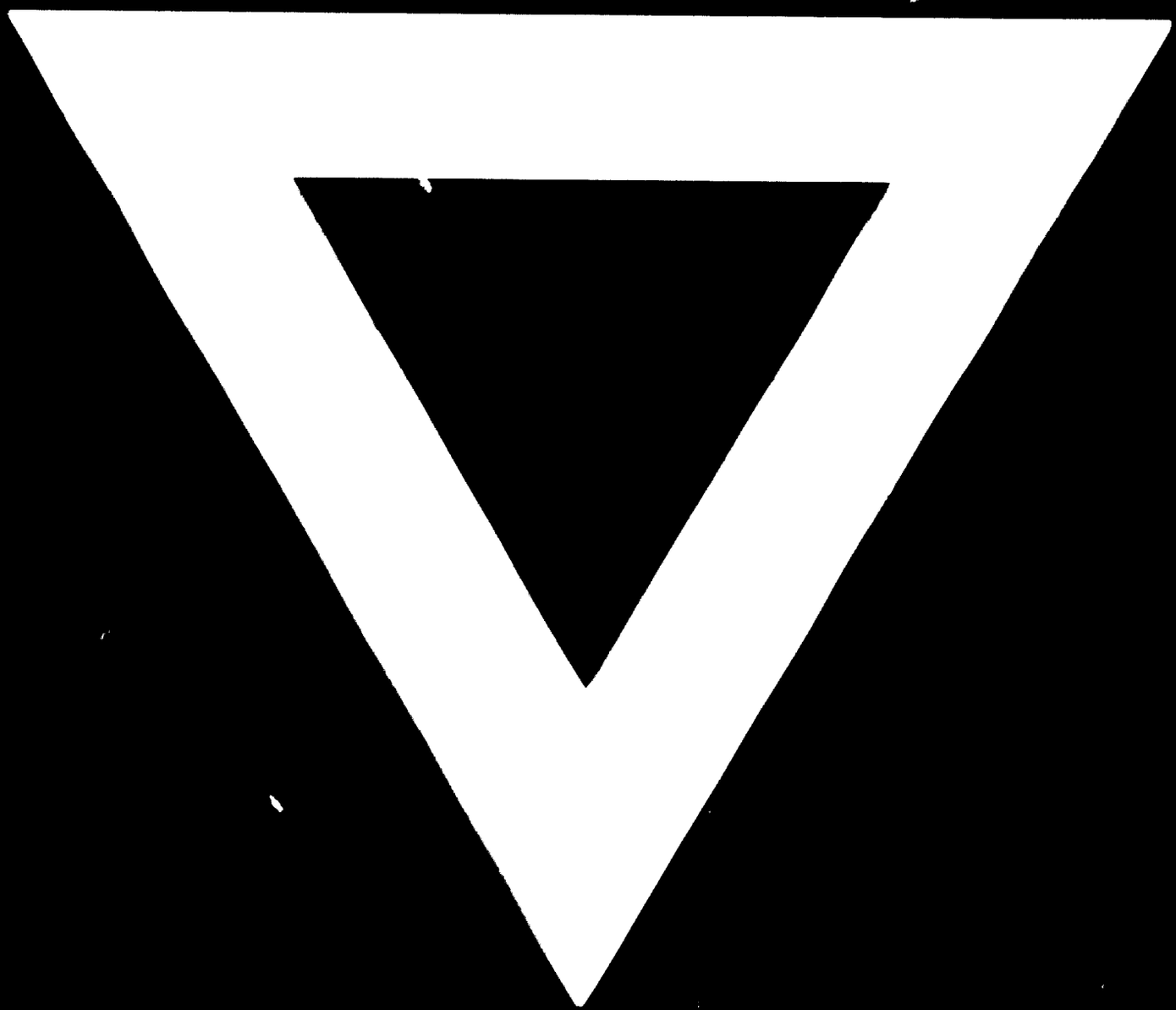

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CONTENTS

(Continued)

Introduction

Wood is one of the most important raw material existing in our world. There is hardly any other material which has been of comparable importance in the history of human life.

Wood has always been of importance in the erection of huts buildings, and similar purposes. The favourable characteristics of wood in connection with a high standard of technical development are reasons why the utilization of wood in the building trade will increase in the future. It can also be expected that according to modern building standards new applications will be developed.

There are wooden houses erected one hundred years ago which are still in good condition.

There are glued structures with a span more than a hundred meters available. The reason for this great importance of wood as a raw material is due to its availability and its favourable characteristics.

The main characteristics of wood suitable for building material are:

- Durability
- Stability
- Load bearing
- Elasticity
- Safety
- Easy to maohine
- Resistance against chemicals
- Thermal insulation

Wooden building components are materials for the economic erection of houses, huts and similar constructions safely which is of main importance within buildings for human life, but dwellings made of wood contribute to good environmental living conditions. Log cabins and log huts are some of the oldest building types known. Especially in Russia and Scandinavia are examples of log houses well manufactured which are more than one hundred years old. A detailed view on log houses, gives ideas of the highly skilled craft in carpentry to erect a log house made of logs. Reasons for not having developed log house production earlier was the difficulty and lack of up-to-date know-how for machining logs into profiled log house components.

Log house components require selected, straight grown long logs. Therefore, it is difficult to built up house walls of long length or it renders necessary to make lengthening joints on the profiled components for longer units.

There is a world wide demand of suitable building material which can be manufactured economically. This is especially the case in developing countries with their increased population growth rate. In these countries it is a must to produce low cost housings of technical suitability, easy to handle, to transport and to utilize.

In many countries low grade lumber and secondary species are in great quantities available and can hardly be utilized economically. Traditional saw-mills are in most cases not equipped to break-down small diameter logs. The conversion of low grade lumber for the production of building panels requires considerable irvestment and is only economically operating large production plants. Therefore, low grade lumber and secondary species are frequently unutilized, used as fuel wood or even burned as undesirable waste. In this connexion it has to be mentioned that the high amount of burned wood in clear felling areas for cultivation, is a most undesirable contribution to pollution and is also disturbing natural biology.

With the adapatation modern technologies it becomes possible to convert low grade lumber and secondary species into high quality building components. The investments necessary is relatively small, and easy to establish manufacturing facilities in the vicinity of the market to decrease transport problems.

1. The importance in utilizing low grade lumber and secondary species

1.1 Present utilization of low grade lumber

It is very difficult to estimate the yearly production of low grade lumber, because of no market research results are available. Low grade lumber is in most countries available even in countries with small forest regions. The largest amount of low grade lumber is harvested in virgin forests and reafforested areas where trees are felled for clearing purposes.

Considerable amounts of low grade lumber are also produced as a by-product while felling trees for saw logs and clearing forests to gain agricultural land. In addition to these considerable quantities of low grade timber trees from clearing sites can be utilized. A further source is the afforestation of fast growing species viz.: Eucalyptus or Kiri. A rough idea on the yearly amount of low grade lumber available is compared with the annual quantity of commercial timber produced world wide which was 1.277.000.000 cubic meter in 1976. 235.000.000 cubic meter have been produced in developing countries. It can be assumed that the annual quantity of low grade lumber is considerably higher as compared to the world production of commercial timber. Reforestration of fast growing species would further increase the quantities of low grade lumber which can be harvested at a suitable size within 3 to 4 years.

So far low grade lumber is hardly utilized. This is most obvious as FAO investigations consider about half of all timber felled in the world as fuel wood. According to FAO this percentage is even increasing to 85 per cent within developing countries. This means that a valuable raw material is mainly unutilized. The utilization of wood as fuel material is of low economic value, if it is just burned as undesirable waste, this means spoiling of raw material in combination with pollution.

In developing countries valuable raw material is just spoiled, but an enormous demand of building material is required. Very often the production of these materials is possible only under consumption of energy being of high cost and are often related to oil imports burdening the foreign exchange of these countries.

Low grade timber is very often converted into pulp and paper. This is, however, economical only when transport distances of the raw material are reasonable.

Low grade wood is also used for the manufacture of building panels on the base of resin or cement binders.

The cement based particle panels can be produced in small industrial plants but cement must be available. The production of chip-boards, based on resin binders require adhesives which are relatively high in cost and have

usually to be imported from industrialized countries, consuming foreign exchange.

The utilization of chip-board is limited in numerous developing countries. One of the reasons is the lack of the market for a relatively expensive product and the limitation of application. Without specialized hardwares and hinges it is for example almost impossible to use chip-boards for the production of furniture.

The traditional saw-mills are to a certain extent only able to breakdown low grade lumber. Due to the small log diameter the breakdown capacity is uneconomic. The tapered and unstraight growth of trees and the waste arising while processing is relatively high. The possible length of profiled log components is also limited. As the demand of long profiled logs is very high, short stock is of low value.

Although low grade lumber is a raw material so far hardly utilized, it is, however, a valuable raw material, when comparing the properties of small diameter logs and the quality of commercial timber. The only reason why low grade lumber is unutilized is the lack of economic machining facilities.

To process low grade lumber into building components, the following conditions have to be fulfilled which are especially of importance for developing countries:

- It is necessary to adapt a simple technology with relatively low investment and the possibility of small scale on the site production. The plant location has to be based on evaluation of a cost analysis and marketing;
- The technology must be easy to apply and has to ensure a reduced waste rate;
- It must be possible to produce profiled components of sufficient length, accurate dimensions and good quality surface;
- The handling, assembling and further processing of building components must be simple and should not require highly skilled labourers;
- Whenever necessary, the building components have to be preserved against decay, fungicides and insects.

1.2 Building situation in developing countries

Developing countries have an extremely high demand for low cost housing which can often not be realized because of a low purchasing power. The demand is concentrated, mainly on low-cost-housing, but also for public buildings, farm buildings and similar constructions. The existing buildings and the usual building methodology is not up to date. Even relatively modern buildings often have defects or are of low quality. The reason for these conditions is the lack of suitable building materials as well as lack of know-how for planning and setting up buildings.

Thermo insulations are often poor. Insufficient insulation of building components against humidity are frequently the reason for unhealthy living conditions and poor building quality. The production is relatively expensive in developing countries. The lack of know-how is sometimes the reason for over-dimensioning or the contrary is the case which means danger. The poor infra-structure is often influencing transport costs resulting in increase of building costs, especially rural areas of developing countries.

Under prevailing conditions of developing countries a system is desirable which enables to erect high quality buildings of different sizes and for different purposes based on raw materials available in the country which can be processed at low cost. The adaptation of the building materials must be simple. Buildings should be erected by unskilled labourers within a very short time. Planning and engineering of buildings especially calculation of statistics should be simple and without any risk. It is also of great importance that the building components can be combined with other materials than wood, under these conditions one can optimise the building efficiency.

A new system is utilizing low grade lumber for building components specifically for developing countries is the log profile construction.

2. The universal component system

2.1 Methodology of economic production

To achieve economic processing of low grade lumber production costs have to be decreased by a maximum yield of raw material input.