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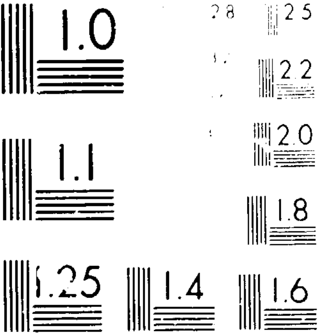
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ECONOMIC EVALUATION OF WOOD DERIVED PANEL PRODUCTS FOR DEVELOPING COUNTRIES *

by

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Abstract

This subject includes four parts:

The first part will define the different types of this kind of panel. Furthermore, this part will include a systematic survey on the different panel types to compare the varying characteristics required for their production.

The second part will deal with the different properties of the several types of panels, which allow to distinguish between the respective suitable applications.

In part three different methods of production of wood derived panel products are explained by means of a few examples suitable for developing countries.

The latter part is a summary of the conclusions for an economic utilization of the raw material wood.

1. wood derived panel products and the basic features for their production

1.1 definitions of wood derived panel products

Annex no. 1 gives a list of the known wood derived panel products with definitions.

Under I, items a) to g), the wood based panels are listed. The sequence of listing follows the continuously increasing degree of wood disintegration, the smallest degree of disintegration being of course the one used for producing boards from solid wood as per a). Further disintegration is involved with the production of plywood, resp. blockboard as listed under b). As you know wood disintegration increases considerably with the hogging or chipping processes applied for the production of particle board as specified under e). When surfaces suitable for improvement processes shall be achieved, such as they are needed for furniture production, a much higher disintegration is required than it is applied with the production of particle board for building purposes. For fiberboard panels as indicated under g), the wood is even more disintegrated by a milling process partly producing particles of a size reduced to the natural wood fiber size.

The list of annex 1 shows however that the "gaps" between the mentioned, widely known panel products were meanwhile filled by novel type products. Interesting tendencies can be observed, and they should be considered when selecting the type of panel suitable for the envisaged application:

The waferboard mentioned under c) is a panel produced of mostly square, big-size wood particles, so-called wafers, of 0,6 - 1 mm thickness and an edge length of 35 - 7_ mm.

The so-called strands used for the oriented strand board, OSB, are also of relatively big size. Their thickness varies between 0,4 and 0,6 mm, and their surface in grain direction ranges between 35 and 80 mm, while it is up to 25 mm in cross grain direction.

By using quite consciously such big-sized wooden particles for both these types of panels, the natural wood resistance is to a very great extent conserved in the product. As far as OSB is concerned, it is furthermore possible to influence panel resistance as well as its strain characteristics by orienting the strands in the wanted direction.

Also the product mentioned under f) is a new one. The size of its particles ranges between that for particle board and that for fiber board. Though thin particle board does not quite reach the mechanical properties of fiber board, which for many applications are even not necessary, it is a substitute for certain fiber board applications and permits to suppress the great and expensive amount of defibration works when compared with fiber board.

We should particularly note the type of fiber board produced according to the dry process. For reasons which we will refer to later, the tendency is to abandon the wet in favour of the dry process.

Under II of Annex 1 the two most important of the minerally bonded boards are cited. The wood-cement sheets of item h) will be the topic of a separate lecture. Gypsum fiberboard as per i) will increasingly gain importance in the next years. It will mainly be used for interior building constructions.

Under III panels made from annual plants are specified. Depending on the raw material used, the panels produced can have the characteristics specified under I d) to I g) for wood derived panel products. On this subject matter too some examples will be given on the occasion of a separate lecture.

1.2 features required for the production of wood derived panel products

We will now look more closely at the types of panels listed under I in Annex 1, especially as regards the requirements to be met with for their production with regard to raw wood (annex 2), energy consumption (annex 3), and resin consumption (annex 4), and as regards pollution (annex 5).

1.2.1 raw wood quality requirements

We hold it reasonable to classify wood derived panel products according to their respective degree of wood disintegration, because, naturally, requirements concerning the raw wood are the higher the bigger are the wood fragments used for their production. This is shown in detail in annex 2.

1.2.2 energy consumption

Every disintegrating process requires energy. It is consequently not surprising that electric energy consumption for one ton of finished product increases as the degree of wood disintegration increases. This is proved by the table of annex 3. Nevertheless, saving possibilities exist especially with fiber board, for which energy consumption is indeed high. We will refer to this in detail under item 3.3, where the respective production methods are described.

Apart from the electric energy required for driving disintegrating machines and conveyor means, a great amount of heat energy is required, which mostly is produced in a boiler plant.

In view of the considerably raised energy costs the in fact optimum solution has to be found when planning industrial plants for the mentioned products, and this under consideration of the respective local situation as well as of the energy supply means to be selected for reducing energy consumption. Every investigation in this respect should at least include the following cardinal questions:

- What degree of disintegration is in fact technologically required ?

- What kind of conveying means shall be installed ?

  Many of the transporting operations performed in industrial plants for wood products can be carried through by mechanical (e.g. scraper conveyors, conveyor belts, screws, or similar means) as well as by pneumatical equipment. Generally pneumatical conveyors require less capital expenditure, but considerably more energy. It is therefore of growing importance to check their use critically. Besides, many developing countries dispose of the means for manufacturing suitable mechanical conveyors in their own country, eventually with the assistance from outside.

- What type of construction is the most suitable for chip drying ?

  In the same way as it applies for conveyors, energy consumption of chip driers can in many cases be reduced by a higher equipment investment. Consequently, in each individual case the rentability of an eventually more expensive type of drier and/or of the additional installation of a heat recuperation system (implying a reduction of waste heat) should be carefully studied.

- Is it possible, and to what degree is it rational to substitute heat produced from expensive fuel (oil or natural gas) by heat generated from low-cost fuel (wood, wood waste) ?

  With each production plant wood waste material accrues by trimming or sizing or sanding the products, and it is increasingly profitable to use this waste for energy production (e.g. in combined fuel oil/wood dust firings). Some reflections even include the use of additional wood for firing. In situations where high costs are involved for making electric energy available and for supplying it, but where wood is rather cheap, the installation of a coupled power-heat system may already today be economical and efficient. Such a coupled power-heat system will then supply either the major part, or even the total electric and heat energy required. Certainly, investment costs for such systems are rather important.

1.2.3 resin consumption

A further raw material needed for the production of wood based panels is resin. Many developing countries dispose of a good, or at least sufficient raw wood basis, but quite often experience major problems with the procurement or manufacture of resin. For this reason the table of annex 4 should be looked at very closely. Complementarily the following considerations are of importance:

- As mentioned earlier already, the waferboard of item c) and the strandboard of item d) permit to maintain wood resistance properties almost undestroyed and to conserve same in the panel. This chance of producing a panel of high resistance with low resin consumption can of course only be made use of if large areas of their big surfaces are in direct contact and if thus, since resin-coated, wafers, resp. strands are bonded over large surface areas. Concerning the process technique for the manufacture of these types of panels, it is therefore essential to make sure that no fine wooden particles or dust mix between wafers or strands, because they would weaken the bonding. This refers particularly to the outer panel zones, i.e. to those near the surfaces, since these zones are decisive for the degree of bending strength. (Item 3.2 deals with solutions to this problem under the aspects of machinery technique.)

- If the customer wants to produce the resin locally, he must know that investment costs for producing liquid forms of urea-formaldehyde resin and phenolic resin are relatively low. Contrary to this, capital expenditure for the production of phenolic resin powder - as it is used for waferboards - is very high. Therefore, powdered resin must normally be imported as a ready-made product by the developing countries.

The next step which development needs to overcome until liquid resin can be used for waferboard production is however within reach, and it can be expected that it will soon be made.

- Resin consumption for particle board used in furniture production as per e) and for medium-density fiber board as per g) is almost equal.

- The very low resin consumption of thin fiber board is made possible by the application of pressing technologies using high specific pressures and high pressing temperatures. This way of proceeding permits to activate the wood's own binders, and to save resin this way. The process is however only economical with thin panels.

1.2.4 pollution

When an industrial plant shall be erected, it is important to know already in the planning stage what environmental pollution will be caused. Such knowledge may be essential for deciding on the plant location, or it may turn out that additional investment will be necessary for reducing pollution.

Annex 5 indicates the pollution involved with the manufacture of the several products. We chose an evaluation scale from 1 to 6, with reference 1 as the lowest and reference 6 as the highest degree of pollution. In relation to the respective legally admissible maximum values, value 6 on the scale must normally be considered as inadmissibly high; in some regions even value 5 may represent a too high degree of pollution. Value 4 is admissible.

Annex 5 indicates three figures each, one referring to the workplace, the other one to air and water pollution. The third column specifies the pollution total and thus permits a rough overall judgment.

The list makes the following apparent:

- Workplace pollution degrees are satisfactorily low with all types of production.
- With regard to fiberboard production those lines operating according to the wet process, according to today's standards cause a considerable degree of pollution of the air, and particularly of the drain water. Water preparation lines are of course feasible, but they are very expensive and, depending on their mode of operation, need great additional amounts of energy. Since these problems are eliminated with the dry process, the dry process technology should be given preference, as already mentioned.
- The pollution degrees involved with dry fiber board and particle board productions are practically equal.
- The low air pollution resulting from waferboard and OSB productions is due to the low dust portion in the wafer, resp. strand mix, which naturally entails only very little emission from the cyclones.

Generally it shows that all the mentioned technologies, except of the wet fiber board process, can be governed by adequate technical means.

Only where plants of this kind are located very close to densely populated areas, special measures might become necessary in some exceptional cases.

2. properties and applications of wood derived panel products

Logically, the respective characteristics of the different wood panel products decide on their applications. Their majority is used in the two huge fields of

- furniture production and
- building construction.

For the manufacture of furniture the panel surface is essential. Concerning the surface quality, always exactly defined requirements are stated: either it must be acceptable under optical aspects - as it is the case with the solid wood of a) and with the blockboard and plywood of b) - or it must be suitable for improvement, e.g. by veneering or laminating. This is true of the respective types of particle- and fiber board.

With regard to strength values (please see annex 6), furniture manufacture needs minimum requirements only. When excluding shelves, furniture panels are not subject to important static loads. Quite understandably, however, bending strength values must be higher with thin panels than with those of medium thickness.

Furniture elements are normally not exposed to humidity, so that no special measures must be taken to make them especially resistant against humidity.

When using wood derived panel products for house building, it is only logical that they must meet with different requirements. But distinction has to be made between those panels foreseen for interior constructions, and those panels to be subject to static loads. As far as interior construction panels are concerned, the requirements are very similar to those for furniture panels. On the other hand, when the panels have to fulfill statically resistant functions, there of course are no special requirements about their surface. But they must come up to extreme requirements in respect of strength values. (Therefore, as shown in annexes 6 and 8, waferboard and OSB strength values are made use of mainly in the building industry.)

It is reasonable that for house building a certain minimum resistance to moisture is often additionally required, although exterior applications of wood derived panel products are limited because of their principally restricted resistance to weather influences. Nevertheless, if they are suitably protected against the penetration of moisture, waferboard and phenolic-resin bonded OSB as well as MDF panels can be used for exterior applications, similar to solid wood.

When speaking of properties of wood derived panel products, one further technical parameter has to be dealt with, namely the linear expansion, and this especially with view to the economical processing of these products. This value indicates the degree to what panel dimensions change with varying humidities (please see annex 7).

For a profitable mass production of modern furniture, the individual elements need to have sufficient stability. Otherwise reworking becomes necessary. The stability of solid wood is, as you know, rather poor, in particular transverse to fiber direction. Linear expansion values of particle board and fiber board are sufficiently low in both directions.

Linear expansion is also important in the house building sector, all the more as often elements of large surfaces are used (wall panels, for example). Annex 7 shows that e.g. the new instrument of orienting the strands permits to achieve sufficiently low expansion values, and this in a very economical way. At the same time high strength values are reached without the need of using plywood, for which the raw wood requirements are rather high as we know (please see annex 2).

The different application sectors specified for the several panel products in annex 8 result from the preceding explanations.

3. production lines for wood derived panel products

In the following I wish to explain some examples of production lines for the manufacture of wood derived panel products. From the many known concepts we made our choice according to the following considerations:

- The plant layout should be suitable for production in developing countries, i.e. under mechanical and control technique aspects it should be relatively simple and unsensible as regards the technological sequence.
- Explanations to the examples should especially deal with the recently developed technologies of OSB and MDF.

3.1 particle board

Annex no. 9 gives a flow sheet of a particle board plant. This plant is designed for a production of 116 m^3/22 h with a panel size of 2.100 x 11.200 mm. The plant is suitable for producing thin particle board as well as particle board of normal thickness as per item e).

In the first part of the plant, the so-called preparation line, resin coated particles are produced: the wood is chipped, and the chips are stored in bunkers. Then they are dried down to a uniform low moisture value for being subsequently - by screening and sifting - separated into particle fractions suitable for surface-, resp. core layer.

Although the chip material for particle board is normally classified into core- and surface layer material, we here chose the simpler concept of a "one-line preparation", which means that the production and drying of all the chip material are effected in one line only. This simple concept, which can easily be surveyed, is for economical reasons omitted when advancing into the glue-spreading sector. The surface layer material needs a higher percentage of resin (approx. 10 - 12 %) than the core layer material (approx. 8 - 10 %). Consequently, in order to keep resin costs as low as possible, two glue-spreader units are mounted. This type of a preparation line represents a solution of relatively low investment costs, with a relatively simple sequence of operations, simplicity being however not pushed to such extent that it would imply an increased raw material consumption.

For a plant of this capacity, a single-daylight press is the optimum solution; when higher capacities are involved, multi-daylight presses are more advantageous.

With the single-daylight concept shown in annex 9 the chip mat is formed by a mobile forming machine, which must be switched off during its return travel. Annex 10 shows a newly developed concept of a single-daylight plant including a stationary, continuously operating forming machine. Of course, the continuous mode of operation has its advantages with regard to precision and uniformity of the particle mat and, consequently, of the finished product.

3.2 oriented strand boards (OSB)

The preparation line of plants for the production of OSB (resp. waferboard) consists - with the necessary modifications - of the same aggregates for wafer, resp. strand production, for drying, screening, sifting, bunker storage and glue-spreading as they are used for the particle board as per annex 9. We do not wish to go into details here, but principally preparation lines for strands and wafers have to be executed in a way that permits having a good control of the form of wafer or strand produced (please see also item 1.2.3). The expenditure involved for machinery is by approx. 20 % higher than it is for normal particle board.

The forming machine is of course the most interesting element of the process for OSB panel production. It shall therefore be looked at more detailedly. Annex 11 is an illustration of a forming machine for strand orientation in the long direction. Via bunker feed system (1) the strands reach within the bunker (2). The doffing roll bank (3) discharges them onto the dosing belt (4). Equalizing means (5) are provided to improve the uniformity of the strand flow. Then separating device (6) halves the strand flow, and each one half of the strand flow is spread by one of the two forming heads (7) to form the mat.
It can be seen from annex 11 that the forming heads are of the disc-type design. First the strand material falls onto rows of discs arranged closely adjacent one to the other. Only very few big-sized strands fall down between them, but the majority of the small strands. The spacing of the discs then increases, and the big-sized strands pass between them to form the mat. Due to the spacing geometry, the strands are oriented in the long direction.

As described, the forming heads perform two functions automatically, namely orienting <u>and</u> separating. This is a very advantageous solution for achieving high strength values despite of little resin consumption, because the small-sized strands are deposited in the mat center region, and this is most favourable in view of the panel strength characteristics.

Longitudinal orientation of the strands is used for applications such as

- constructional boards, e.g. for interior roof constructions and for flooring
- shelves in furniture manufacture
- plywood cores.

With the latter of these applications it is especially economical and therefore of interest that roundings and cores of veneer production as well as other waste material can be used for the core layer. This means that also less valuable veneer can be processed.

Most recently designed equipment also permits the cross orientation of strands by suitably executed forming heads. Consequently it is now possible to manufacture panels having some layers oriented in the long, other layers oriented in the cross direction. This results in high strength values and at the same time produces good inflexibility and stability features.

3.3 plant for the production of MDF and HDF board

By the abbreviations MDF, resp. HDF, medium-density, resp. high-density fiberboard is meant, which - as afore described - are manufactured according to a dry process.

The thinner HDF panels (with thicknesses below 8 mm) are within a density range of 0,8 to 1,2 g/cm^3m, while MDF panels of 8 mm thickness and more are always below 0,85 g/cm^3 density.

The main characteristic distinguishing MDF panels from particle board is the almost constant density of MDF panels throughout their thickness. Their suitability for certain particular applications is therefore best used where the close and dense structure of the panel core is required. Annex 12 shows the density distribution of a MDF board compared to particle board.

This development is relatively young. The first plant is running in the USA since 1964.

production sequence

The entire sequence of production for this type of panel is shown by annex 13.

Since MDF and HDF panels are "single-layer"boards, fiber preparation is rather simple and easy to survey. For a daily capacity of 100 and 180 tons only one unit of each the main aggregates (such as defibrator and drier) are required. At the same time their respective capacities are well used. Thus such a prod ction scheme as shown in annex 13, which is of simple structure and easy operation and maintenance, and consequently advantageous in practical operation.

he above refers to a production based on hogger chips. Of particular interest it is however, that such a plant allows to use considerable portions of low-value wood and waste material, such as e.g. sawdust, planer shaves or waste material from chair and furniture production.

In relation to particle board production, the qualitiy of the raw wood used has little influence on the final product qualitiy as well as its quantity output, a factor that allows the processing of inferior wood raw material. Thus even variations and changes in the wood raw material assortment are of less influence and can more easily be dominated.

Not all p nts clean their raw material from sand, stones or m tal enclosures, though this is often recommendable in view of the longer lifetime of the grinding segments of the defibrator.

After a secondary d sintegration of too big pieces, the material is fed into the pressure defibrator.

For the subsequent fiber glueing two methods are available:

Annex 13 shows a so-called "blowline glueing", where the glue is introduced into a blowline installed between defibrator and drier.

The second method uses a mixer-type glue spreader arranged between fiber bunker and forming machine.

Of the different drier types available the flash drier proved to be best suited. It can be heated either directly or indirectly. Because of the big surface of the fiber material, only a few seconds of duration in the drier are sufficient. Properly speaking the drier consists of a flow pipe. With such a simple drier shape deposits and material adhesions can easily be avoided, and this of course ensures sturdy and safe operation.

The fiber mat forming is a most essential production step, because it is decisive for uniform product quality.

On principle, forming can be executed according to two methods:

We know systems where a pneumatic circuit deposites the fibers on the conveying means to thus form the mat. We decided for a mechanic forming system as shown in annex 13, because this provides the following advantages:

Energy consumption in this part of the plant is very low (10 to 20 % of the energy consumption of a pneumatic system), dust emission is reduced, and the fire risk in the "dry" part of the preparation line is essentially reduced.
The relatively high fiber mat is continuously pre-pressed in the forming line. The resulting flat mat is highly felted (i.e. its fibers are tensely interlocked), and the mat is consequently rather insensible to the following transporting operations into the press.

Heat is supplied by the hot platens in the press. Especially when thick panels are to be produced, high-frequency heating is often installed additionally. Since, however, the energy produced by high-frequency is rather expensive, detailed cost accounting studies should be made before deciding for such equipment. With HDF production a complementary high-frequency heating is certainly not economical.

The equipment following the press is practically similar or equal to that unsed in particle board plants.

On the whole, the operation of a HDF or MDF production plant is uncomplicated for the operating as well as for the maintenance personnel, and this due to its relatively simple design, the insensibility against raw material variations and the rigidity of the fiber mat.

4. conclusions for an advantageous utilization of the raw material wood in developing countries

4.1 comparison of the economy of different lines for the production of wood based panels

When studying the economic utilization of the raw material wood and when deciding for a production line using this raw material, the following basic issues should be clarified:

- What is the amount of investment ?
- What is required from the raw material wood ?
- What chemicals are needed ?
- What energy volumes are required ?
- How many labour will be working in the production plant ?
- How is the increase in value of the raw material wood ?

Annexes 14 + 15 represent an assessment of the 6 above mentioned factors for the production lines of products a) to g). Mark 1 indicates always the smallest, mark 6 the biggest volume in annex 14.

It is understood that it is impossible to establish a rentability calculation of a general validity, say applicable for any market. On the contrary, the respective market situation must be taken into account with each specific project. Annexes 14 and 15 disclose however some tendencies, which we would summarize as follows:

- Products a) sawn timber
  and b) plywood
  require relatively low capital expenditure only, but need very good raw timber. For their manufacture quite a lot of labour is employed, when compared with the production of different wood based panel products. Due to these principal features this kind of production line differs basically from those for the products as per c) to g). It is consequently logical that - provided the raw wood basis is good - such production lines are often the first step towards an industrial utilization of this raw material. In view of the limited increase in value thus achieved for the raw material wood, it will normally be endeavoured to proceed to further processing or, on a more general scale, to aim at a higher increase in value over the long pull.

- Fiber board production lines operating according to the wet process do not only have to tackle the drain water problems explained under 1.2.4, but they overmore call for a high amount of investment. There will be only just a few exceptional cases where it will be appropriate to install a new production of this kind. With today's knowledge the decision will normally have to be in favour of a plant operating according to the dry process. (Under item 3.3 it is explained that also these plants can under technical as well as technological aspects be of rigid and simple design.)

- When comparing plants for MDF with those for particle board production, the investment to be made for a MDF plant is higher, but it will also produce a higher increase in value by the possibility of using inferior quality raw wood. The plus of capital expenditure amounts to approx. 20 %, and the sales prices for MDF panels range in the USA at 20 to 25 % above those for particle board.

- Where a very unfavourable raw wood basis is faced, and this e.g. also applies where great volumes of wood waste are used, it is a technologically simple solution to produce MDF for use in furniture production.

As mentioned earlier, it is absolutely necessary to analyze the respective market situation and to incorporate the results thus obtained in a profitability accounting to be in a position of making a valid statement for a specific case.

4.2 Increase in value and processing of wood derived panel products

It appears natural that a country happy to dispose of a sufficient source of the valuable raw material wood be interested in processing same as far as possible on the spot. Such an optimum utilization or resources offers the domestic market the advantage of having products, such as ready-made furniture, wall panels or flooring panels available without being in any way dependent. If wood-based products are exported, the high increase in value of the raw material pays by the high export value of the product without having consumed too much of the valuable raw material.

It is for these reasons that the processing possibilities of wood derived panel products are important.

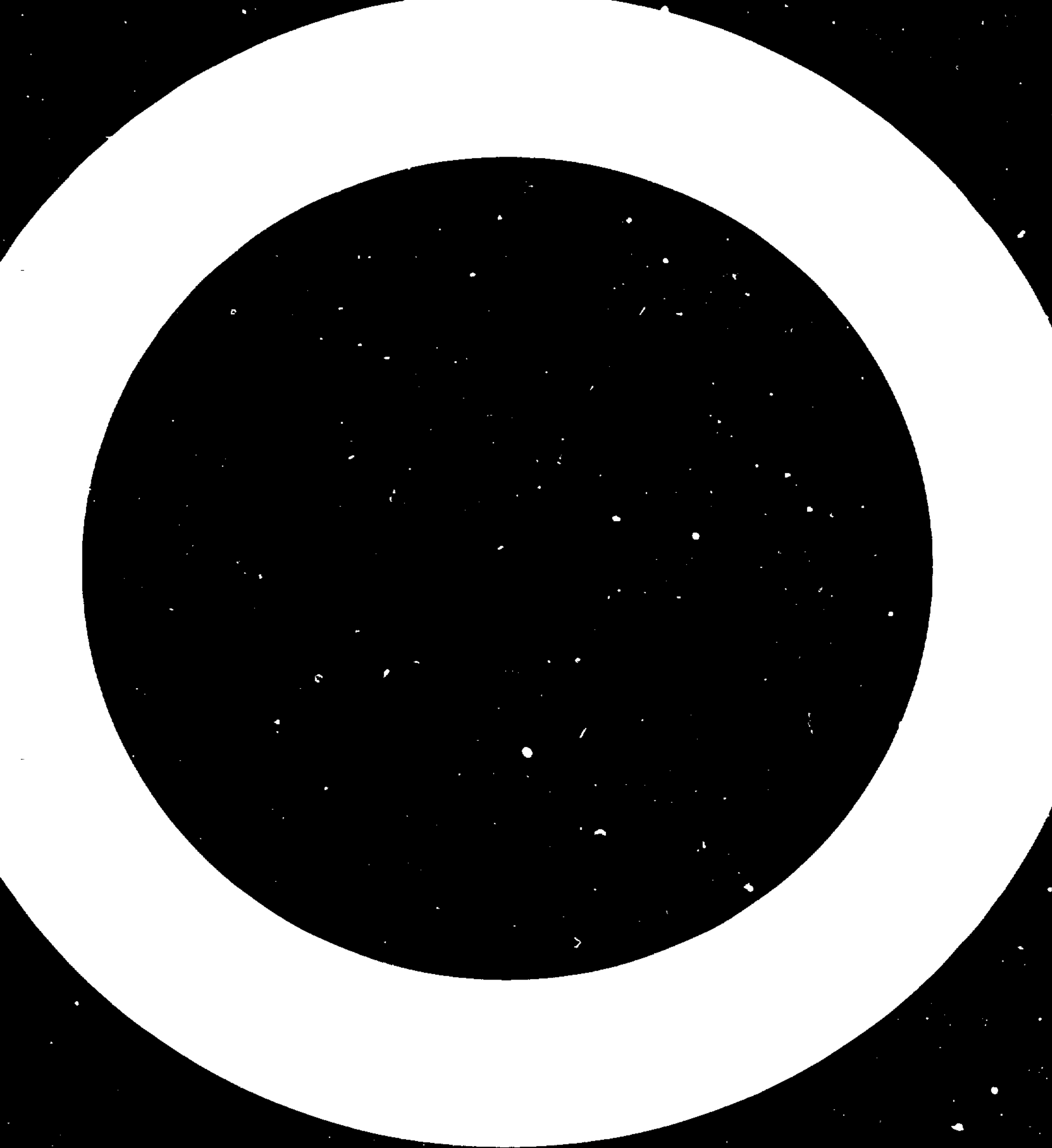
As already indicated, it is the panel surface, which is essential for furniture production and interior constructions. Particle board and fiber board is therefore normally improved. This is performed by different processes, the two most important of which are:

- the application of high-grade veneers in veneering plants:

  Especially in developing countries this complementary production step is often economical and thus reasonable, because the high-value wood is used for the product surface while the inferior-value raw material serves for producing the panel core.

- For applications demanding a surface unsensible to damage, panel coating with melamine-resin impregnated papers is preferred. Due to their simple operating method, short-cycle laminating plants have with good reasons found widest propagation.

It should furthermore be noted that the capital expenditure required for machinery technique for the manufacture of furniture from laminated panels is rather low when compared with the investments disbursed for panel production.



annex 1

PANEL DEFINITIONS

I. wood based panels

(sequence following the degree of wood disintegration)

a)	solid wood		
b)	plywood:	veneer board blockborard	
c)	waferboard:	waferboard waferboard plus	
d)	OSB	one oriented layer surface layer material oriented in the long direction / core layer material not oriented surface layer material oriented in the long direction / core layer material oriented in cross direction	
e)	particle board	for building purposes for furniture manufacture	
f)	thin particle board		
g)	fiber board	wet process	dry process
		insulation board ≤ 0,35 g/cm³	./.
		./.	medium density fiber-board = 0,85 g/cm³
		hardboard	high-density-fiberboard 0,8 - 1,2 g/cm³

II. mineral bonded panels

h) wood-cement-sheets

i) gypsum fiberboard

III. panels from anual plants

annex 2

RAW TIMBER QUALITY REQUIREMENTS

a) **sawn timber**

requirements:	debarked round timber of big diameter, with as little knots as possible, no irregular grain	
utilization:	56 - 68 %	
residues:	edgings, slabs:	can be used for particle board
	sawdust:	can partly be used for particle board
	bark:	for firing

b) **plywood**

requirements:	bebarked round timber of big diameter for veneers, almost free of knots and fissures	
utilization:	50 %	
residues:	veneer waste:	can be used for particle board or MDF
	peeler cores:	can be used for production of small-size boxboard

c) **waferboard**

requirements:	debarked rounf timber only aspen is used, suitable eventually birch
utilization:	75 - 80 %, no sanding losses bark can principally not be used
residues:	particles passing 6 mm screen suitable for particle board and coarse splinters

d) <u>strandboard</u>

requirements: round timber, small diameters also, in case of using wood species of thin bark, no debarking required
debarked slabs and edgings
peeler cores

utilization: 85 - 90 %
with thin bark being used

residues: eventually particles passing of 1 (2) mm suitable for particle board surface layers

e) <u>particle board</u>

requirements: low-value pulp wood and wood of firewood qualitiy
sawmill waste: slabs, edgings, coniferous sawdust (of hardwood saw-dust, small portions only)
hogger chips for core layer
anual plants: flax and hemp shives, sugar cane bagasse

utilization: 90 - 95 % (when re-introducing trimmings)

residues: sanding dust for firing, partliy also mixed to the furnish

f) <u>thin particle board</u>

requirements same as for particle board, but with the possibility of using a bigger portion of sawdust

utilization 100 %

g) <u>fiber board</u>

<u>wet-process fiber board</u>

requirements: hogger chips produced from round timber or sawmill waste, preferrably coniferous woods, annual plants, sugar cane bagasse, or straw

utilization:	80 - 85 %
residues:	dissolved hemicelluloses, etc.

dry-process fiber board

requirements:	hogger chips produced from round timber and sawmill- or veneer-mill wastes
	annual plants: sugar cane bagasse, straw
utilization:	HDF: 95 %
	MDF: 85 - 90 %
residues:	mainly sanding dust

A N N E X No. 3

ENERGY CONSUMPTION per ton

		electric energy kWh	heat G cal
a)	sawn timber		
b)	plywood		
c)	waferboard	200	1,6
d)	strandboard	200	0,9 - 1,0
e)	particle board	240	0,9 - 1,0
f)	thin particle board	250	0,9 - 1,0
g)	fiber board		
	wet-process fiber board (3,2 mm)	460 - 550	1,5 - 2,3
	dry-process fiber board HDF (3,2 mm)	400 - 500	1,2 - 2,0
	dry-process fiber board MDF	310 - 450	1,2 - 2,0

A N N E X No. 4

RESIN CONSUMPTION — % of solid resin for bone dry wood

a)	sawn timber:	---
b)	plywood: phenolic resin, urea-formaldehyde resin	8 - 10 %
c)	waferboard: phenolic powder resin	2,5 - 3 %
d)	strandboard:	
	for exterior applications, liquid phenolic resin	6 %
	for interior applications, liquid urea-formaldehyde resin (paraffine 0,5 %)	1,5 - 6 %
e)	particle board: SL 11 %) CL 6,5 - 8 %) average depending on panel thickness (paraffine 0,5 %)	8 - 9 %
f)	thin particle board: urea-formaldehyde resin (paraffine 0,5 %)	11 - 12 %
g)	fiber board:	
	wet-process fiber board: phenolic resin (paraffine 1 - 2 %)	1,5 - 2 %
	dry-process fiber board: HDF: urea-formaldehyde resin, phenolic resin	2,5 - 3,5 %
	MDF: urea-formaldehyde resin	9 - 10 %

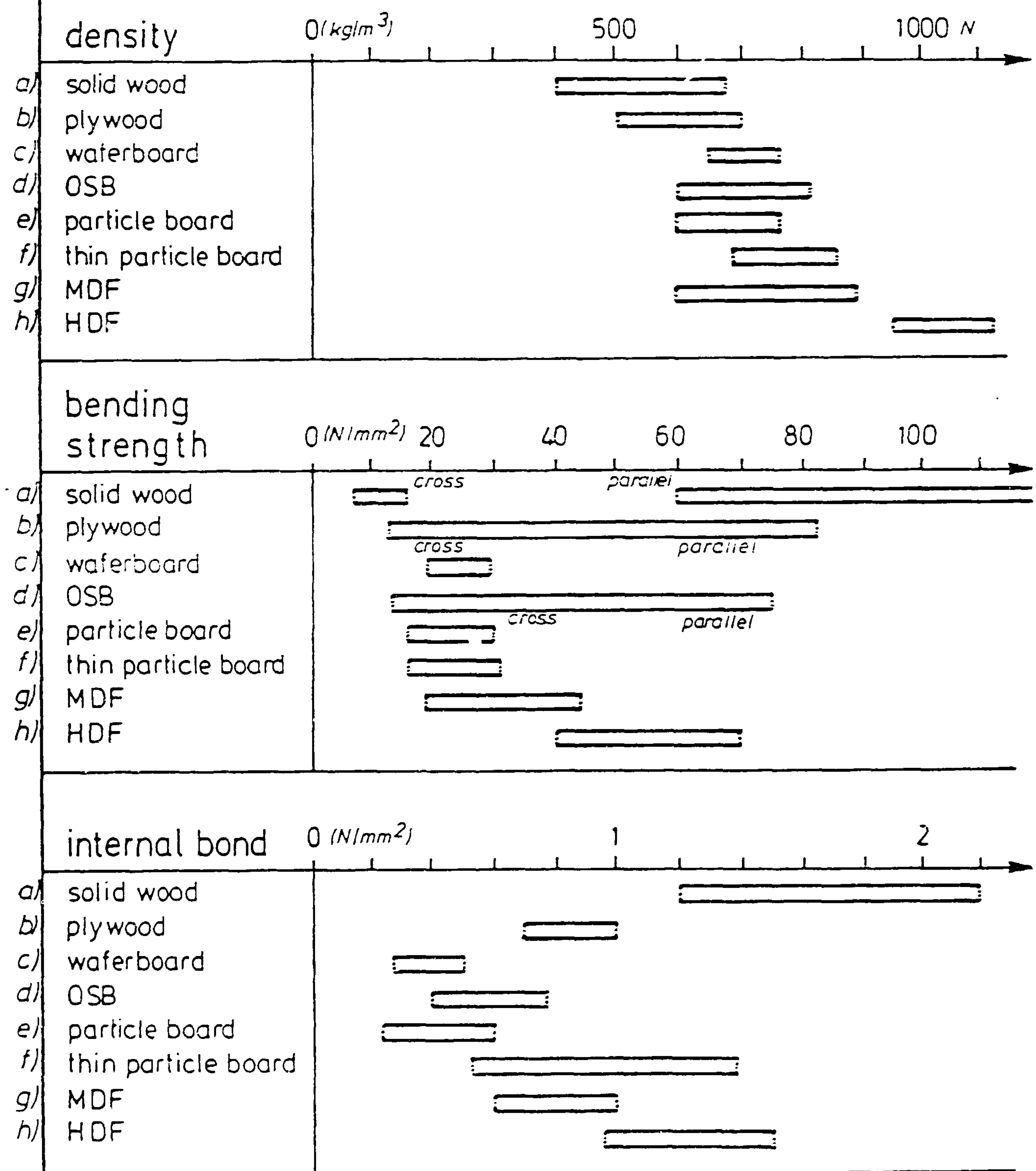
ANNEX No. 5

POLLUTION

		working place	air	water	total
a)	sawn timber	1	1	0	2
b)	plywood	2	2	1	5
c)	waferboard	3	2	1	6
d)	OSB	3	2	1	6
e)	particle board	3	4	1	8
f)	thin particle board	3	4	1	8
g)	fiber board				
	wet-process fiber board				
	- softboard	2	5	6	13
	- hard fiber board	2	5	6	13
	dry-process fiber board				
	- MDF	3	4	1	8
	- HDF	3	4	1	8

annex 6

Ranges of - density
- bending strength
- internal bond



annex 7

length variations (%)*

		parallel	vertical
a)	solid wood	0,04	1,0 - 2,5
b)	plywood CDX blockboard	0,06	0,12
c)	waferboard	0,16	
d)	OSB single-layer	0,05	0,27
	25/50/25	0,09	0,15
e)	particle board	0,35 - 0,40	
f)	thin particle board	0,35 - 0,40	
g)	MDF	0,40 - 0,50	
	HDF wet process	0,10 - 0,15	

*) relative air humidity changing from 50 % to 90 %
at a temperature of 20 °C

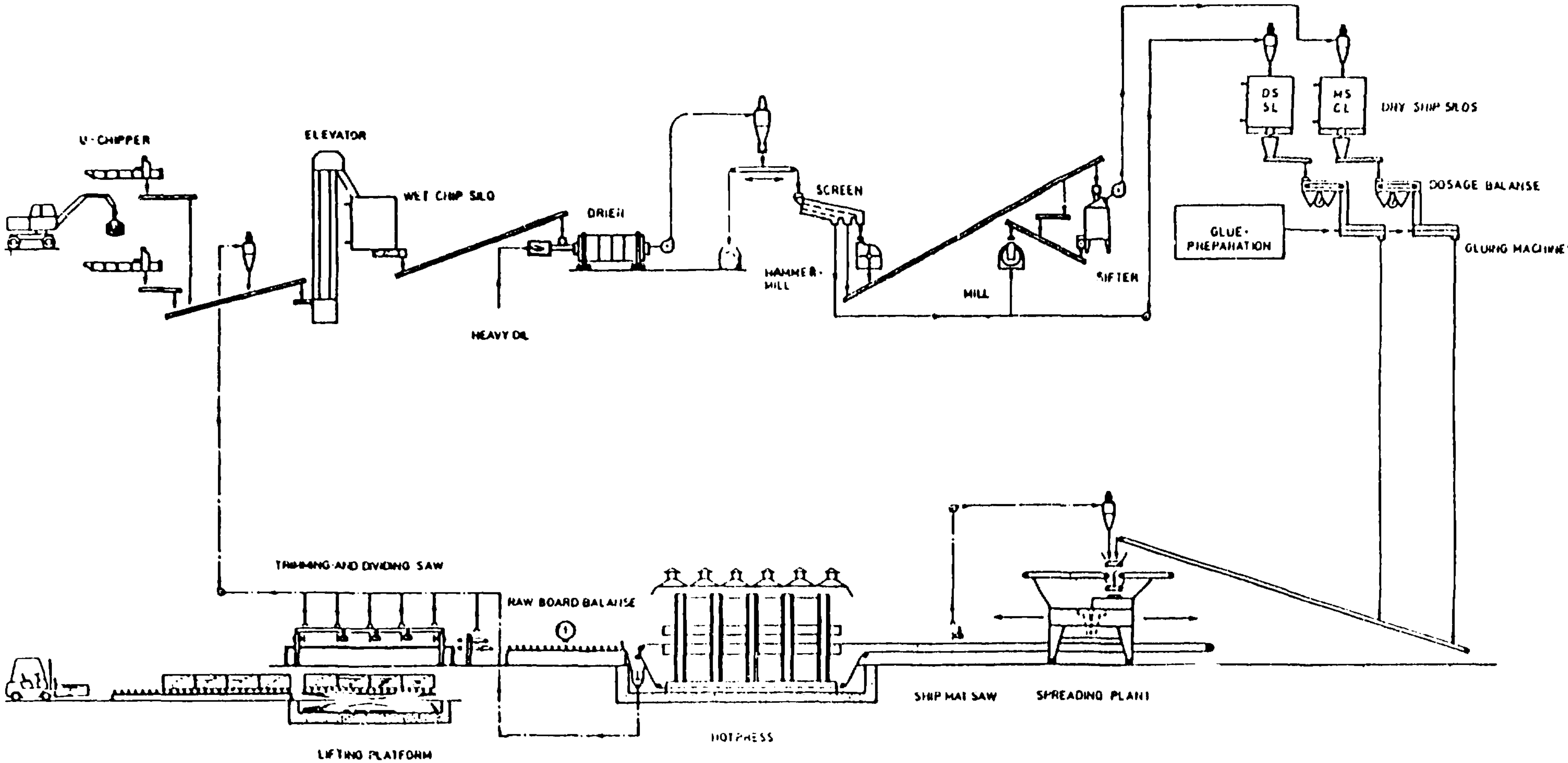
annex 8

applications of wood derived panel products

			furniture industry	building industry: interior constructions	building industry: for static loads
a)	solid wood		x	x	xx
b)	plywood		xx	x	xx[3]
	blockboard		xx	x	
c)	waferboard				xx
d)	OSB		x[4]	x[4]	xx
e)	particle board		xx	x	
f)	thin particle board		xx[1]	x[2]	
g)	fiber board	thin	xx	x	
		medium thickness	xx		

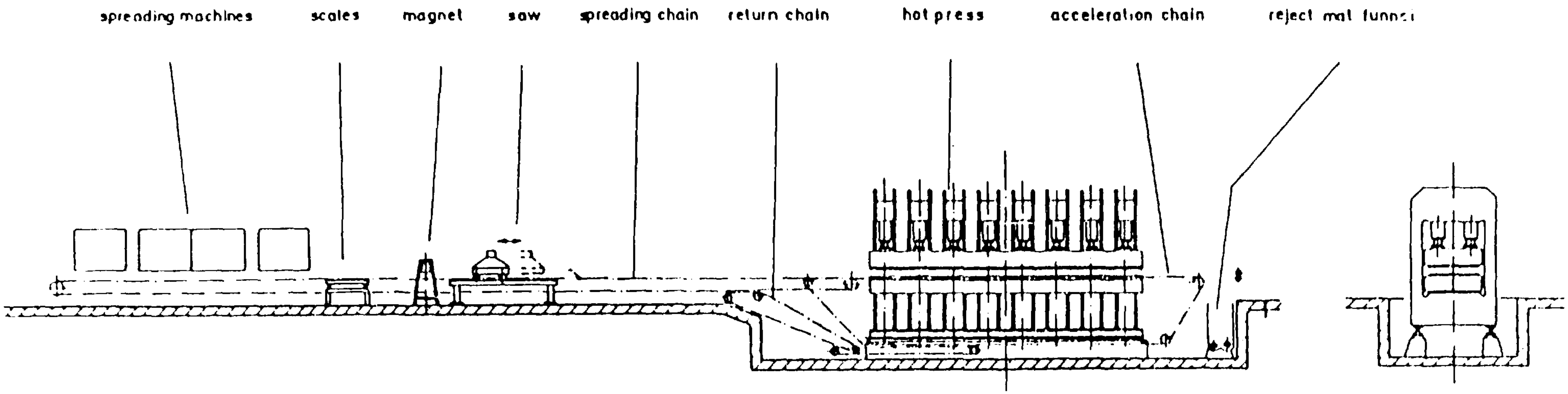
xx = wide range of applications
x = limited range of application

1) = primarily for board backs and drawer bottoms
2) = doorskins
3) = for building purposes
4) = thin OSB to serve as a plywood core

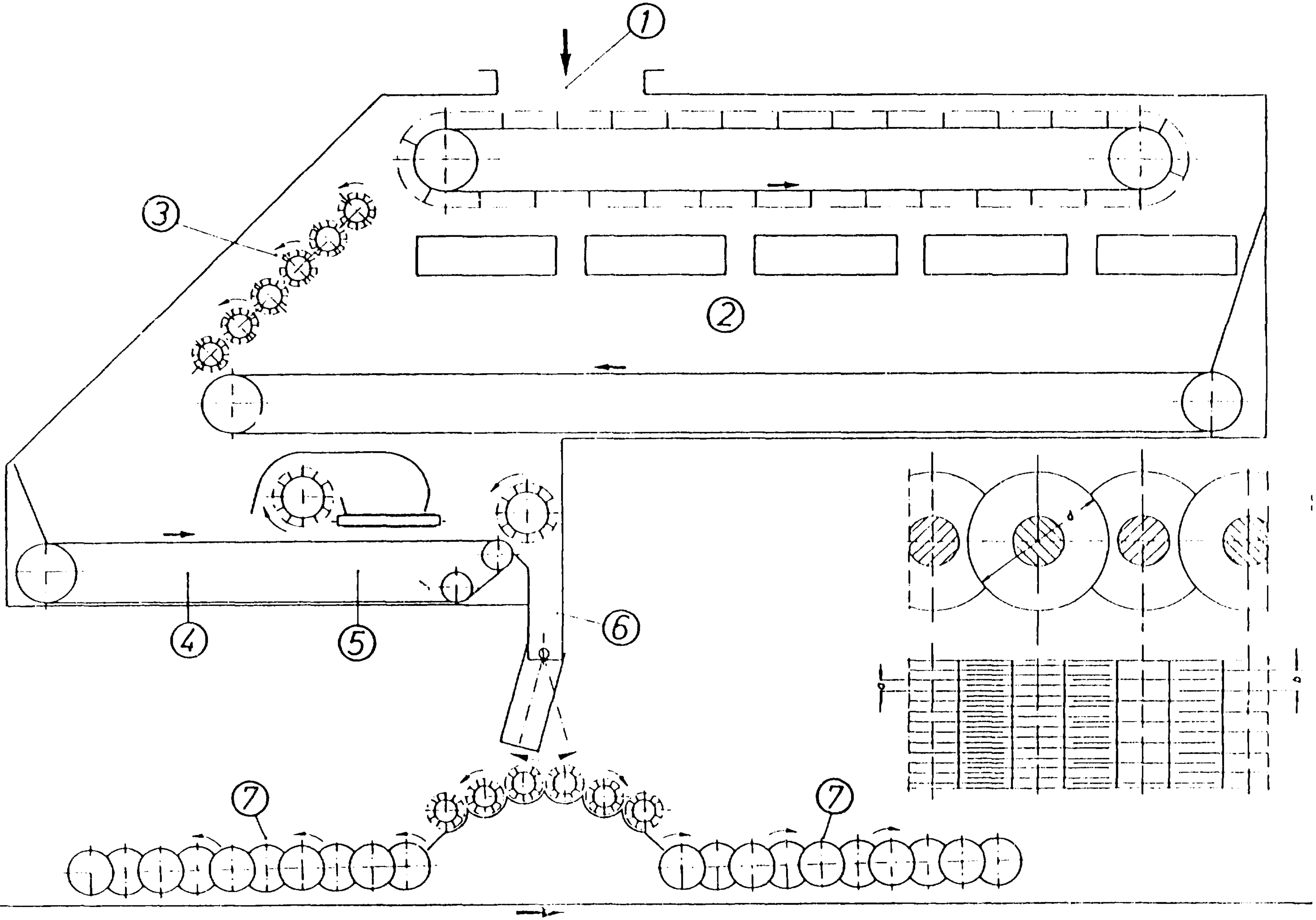


Flow-sheet of a Particleboardplant

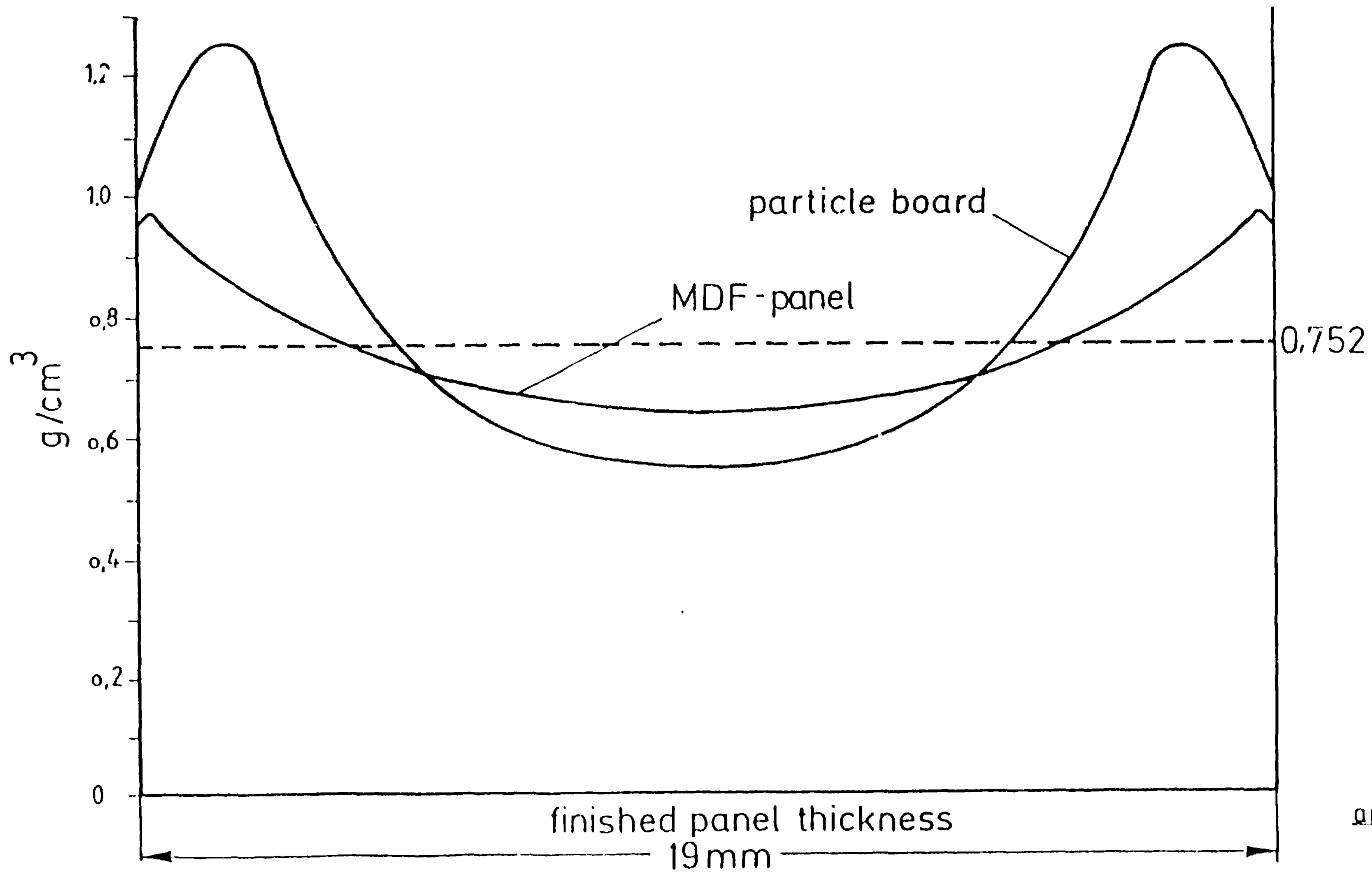
Cap: 116m³/22h Finishboardsize 2100×11200mm single daylight plant 3 K- system



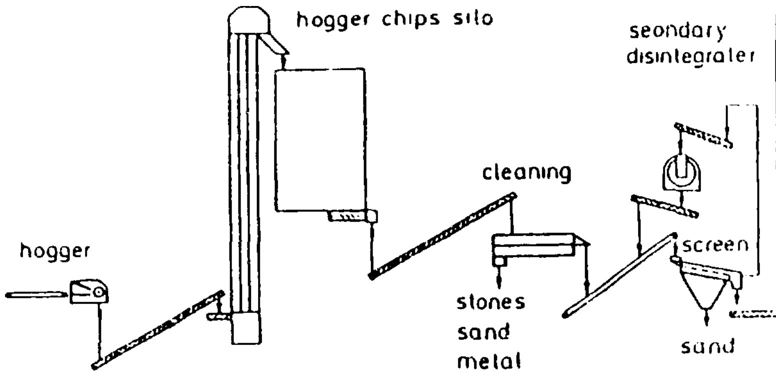
OSB orientation long direction / double hoad

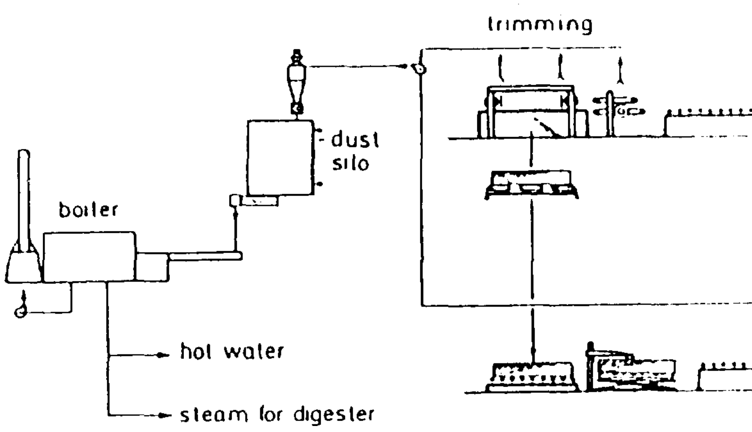


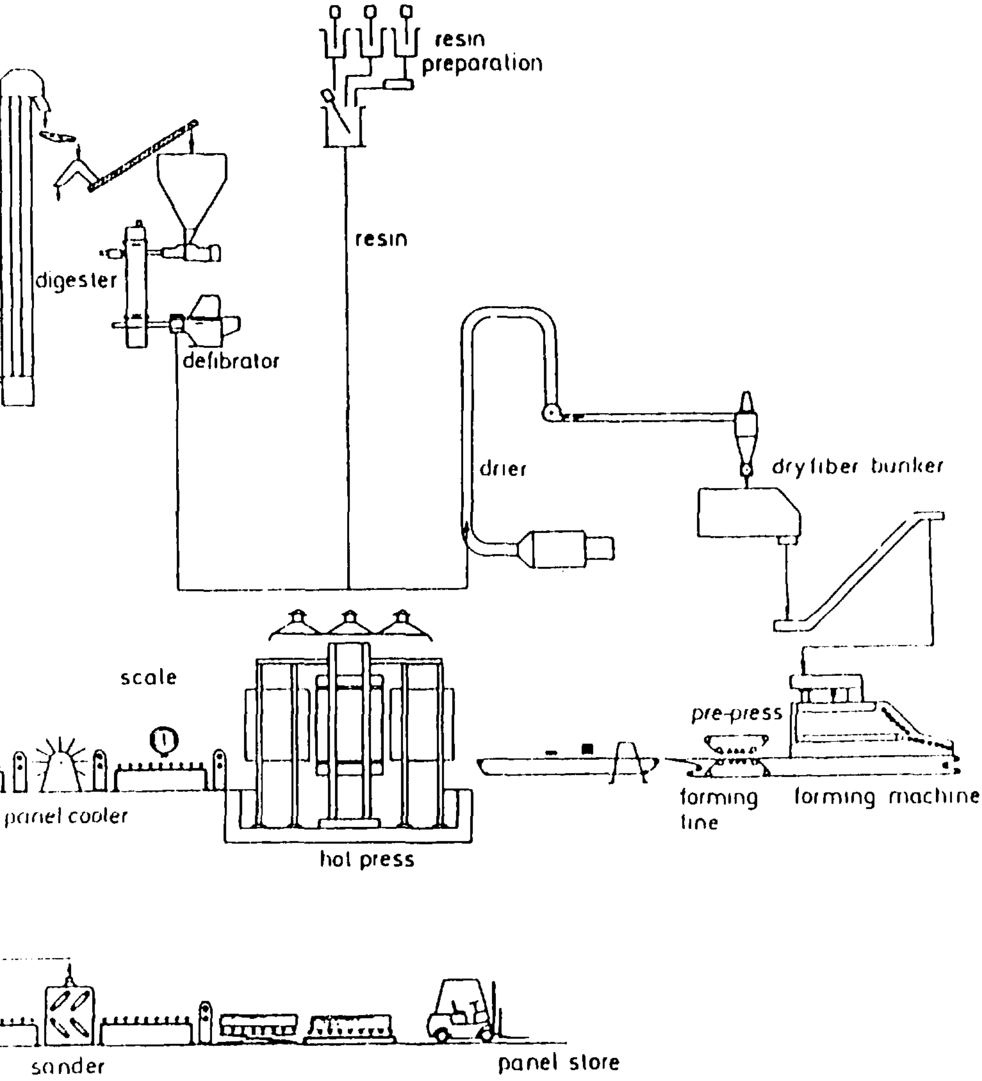
density profile: comparison particle board / MDF-panel



annex 12


hogger chips silo
seondary
disintegrater
cleaning
hogger
screen
stones
sand
metal
sand


trimming
dust
silo
boiler
hot water
steam for digester



MDF flow sheet

annex 13

annex 14

factors influencing profitability

	density kg/m³	invest-ments	material qual. wood	material + quant. chemic.	energy	labour	Σ
a) sawn timber	450	2	5	-	2	4	13
b) plywood	500	2	6	3	3	4	18
c) waferboard	650	4	4	2	3	2	15
d) strandboard	650	4	3	2	2	2	15
e) particle board	680	3	2	3	2	2	12
f) thin particle board	800	4	2	3	2	2	13
g) wet-process fiber board							
insulation board*	250	3	1	1	3	1	9
hard board	1100	6	2	2	4	2	16
dry-process fiber board							
MDF	750	5	1	3	3	2	14
HDF	1000	5	2	2	3	2	14

evaluation marks range: 1 - 6

* Insulation board has a low evaluation mark because of its poor density.

annex 15

ratio sales price / raw material costs (examples)

a) sawn timber	approx. 1,5 : 1 (FRG)
b) plywood	approx. 2,4 : 1 (FRG, Indonesia)
c) waferboard	approx. 2,5 : 1 (Canada)
d) strandboard	approx. 2,2 : 1 (USA)
e) particle board	approx. 2,1 : 1 (FRG. 19 mm)
f) thin particle board	approx. 3,5 : 1 (Austria)
g) fiber board	
wet-process fiber board (3,2 mm)	approx. 2,0 : 1 (FRG)
dry-process fiber board MDF	approx. 3,7 : 1 (Argentina)

All cost factors referring to one ton of finished product.