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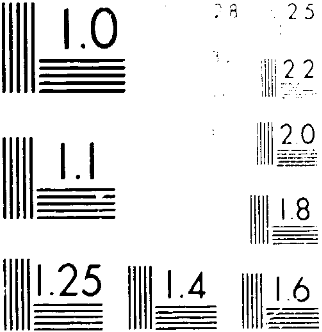
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PRODUCTION OF MEDIUM DENSITY FIBRE BOARD * 1/

by

Peter H. Wiecke **

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** Sunds Defibrator A.B., Stockholm, Sweden.

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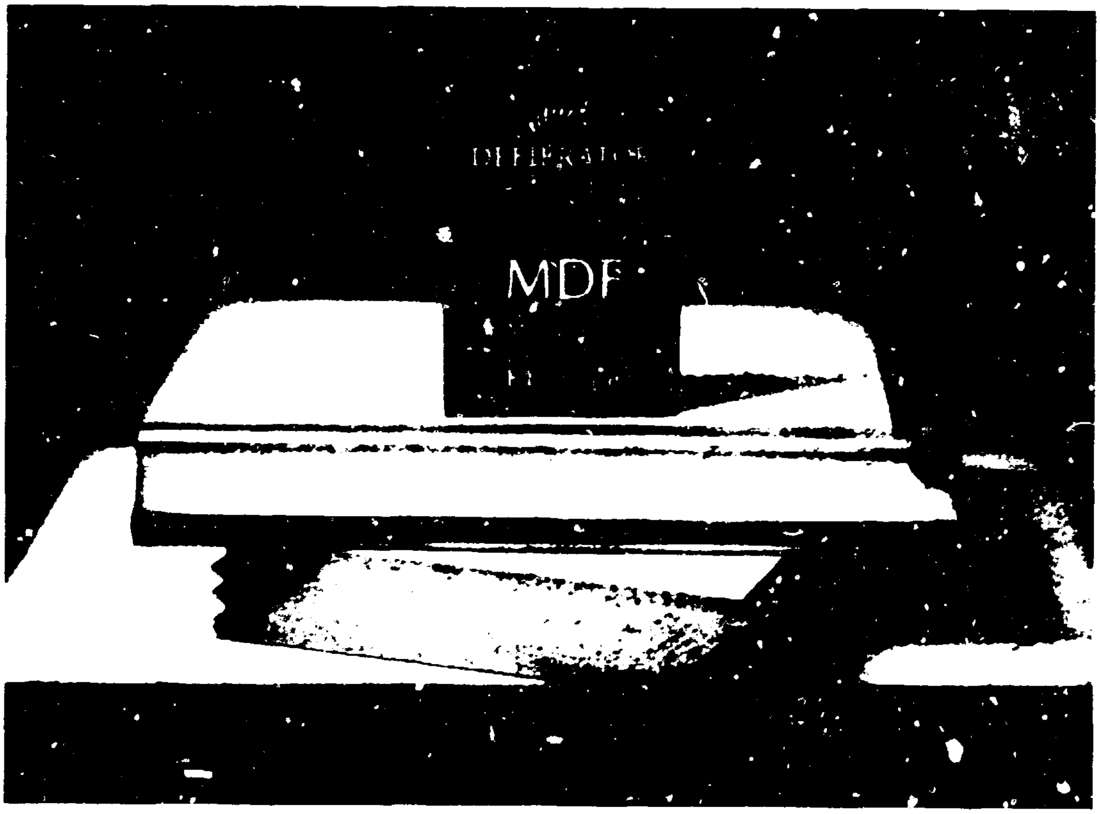
SECTION 1 - PROPERTIES OF MEDIUM DENSITY FIBREBOARD

A. WHAT IS MDF?

Medium density fibreboard, also commonly referred to as MDF, is a re-constituted wood product. The panel is produced in thicknesses from 4 mm to as high as 50 mm. The most outstanding feature of MDF is that it is made from wood fibre. The MDF process results in a uniform density distribution throughout the panel, with a tight smooth surface and a tight and even core. The panel has excellent machining and profiling characteristics, both on the surface and the edges. It is more consistant and uniform than natural wood and, in many of its applications, used as a substitute for solid lumber.



Two pieces of machined MDF on a particle board.

B. History

Medium density fibreboard in its present form was developed in the United States during the early 1960's. The first MDF plant was built in Deposit, New York, using Bauer pressurized double disc refiners, and a radio frequency heated hot press. In its initial conception, this plant was to produce exterior siding panels, a product very commonly used in the United States, in thickness of 12 mm. This product utilized a melamine reinforced urea resin, which was specially developed for this process. The result of the venture of making a medium density siding in competition with the well established hardboard industry, which used phenol formaldehyde resins, was a failure. Production on siding was discontinued in 1968 and the plant completely switched to panel production, which was marketed mainly in the furniture industry.

Several plants were built in the early 70's, mainly in the United States plus one in East Germany and one in Japan. By 1975, twelve MDF plants were in production with a total capacity of 1,333,000 m^3 per year, of this total only 300,000 m^3 per year were produced outside the United States.

Since 1975, another nineteen MDF plants have been built or are under construction at the present moment. The total capacity of these new plants is 975,000 m^3 per year. Most of these plants being of much smaller capacity than those built in the preceeding years, and except for one, all of them were built outside the United States.

From a historical point of view, the plants in the United States generally had a capacity in excess of 350 tons per day whereas the plants in the rest of the world had 200 tons or less per day.

C. <u>Physical Properties</u>:

The physical properties of MDF are quite similar to particle board, even though the appearance and the application of the product can vary considerably from those of the particle board.

The comparison of the different physical properties is shown in Table 1. The first column of the table shows the only existing standard for MDF, the one published by the National Particle Board Association in the United States under standard NPA 4-73. This is a very loose standard, as it does not make any differentiation between different board densities. Interesting to note however, is how closely it compares with American and also European particle board standards, which are in columns 2, 3 and 5. Columns 5 and 6 show some typical MDF board standards for very low density board and for board of flooring grade.

Table 1

<u>Comparison of Physical Properties/MDF versus Particle Board</u>

	USA NPA MDF	[illegible]	FRG V20 PB	FRG PBV 100 PB	Japan Hokushin Softwood MDF	New Zealand Canterbury Timber Products Pinus Radiata MDF
Density kg/m^3	500–800	590–800			507	700
Modulus of rupture kg/cm^2	264	168	160	180	250	390
Modulus of elasticity kg/cm^2	21,093	28,123			25,000	30,590
Internal bond kg/cm^2	7.03	4.22	3.5	4–5 1/	6	7.65
Linear expansion (50–90% RH) percent	0.30	0.30			0.16	0.25
Screw holding face, kg edge, kg	159 125	102 91				183 173

NPA: National Particle Board Association
PBV20: DIN standard "V20"
PBV100: DIN standard "V100"

1/ 1.5 after weathering

SECTION 2 - END USES AND MARKETS FOR MDF

A. General

The major end use for MDF is without doubt in the furniture industry. About 80 percent of the total production is used in this industry for various applications. The second most commonly encountered end use is in the cabinet industry. This industry utilizes MDF for kitchen cabinets but also for TV cabinets and Hi-Fi speaker enclosures. A third application for MDF is the use of the product for wall panelling. The final most commonly found application is in the form of trim and mouldings both in the home building industry and in other applications. In all of these applications MDF product is up-graded either through machining, printing, over-laying, veneering, embossing or other means.

B. Furniture:

The furniture industry was the first industry to utilize MDF, and has the greatest experience in its use and application. The development of this application is perhaps of some interest since it highlights a distinct characteristic of MDF, which particle board cannot share.

In the United States, where this development first occurred, lumber has been and is to a certain extent even today being used extensively for the manufacture of furniture. The use of particle board in this industry was quite advanced and was mainly applied to the cheaper grades of furniture, especially for table tops and other flat and square or rectangular surfaces. When furniture was built in a more refined fashion, the particle board was lumber banded, so that the edges could be treated in a more appealing fashion. It is in this application that MDF first made its great inroads. The furniture manufacturers found that they could replace the lumber banded particle board sheet for the table top by a raw and unbanded MDF panel. It was found first of all that the MDF panel has a much smoother and tighter surface than the particle board, which allowed direct printing or over-laying with veneer of a higher quality than it was possible with the particle boar Secondly, the edges of

MDF could be very easily machined, and due to its great uniformity it machined better than the solid lumber, where knot holes and other irregularities in the natural wood made machining sometimes difficult. Thirdly, the direct finishing of the edges after machining presented no major problem, since some fairly sophisticated painting processes had been developed to match the general appearance of the surface of the board to exotic veneer overlays. It was found that the final product of the total table top with the more expensive MDF was cheaper to produce than the previously considered lowest cost approach with edge banded particle board. The process also eliminated the additional step of banding and thus provided a faster turnover for the product.

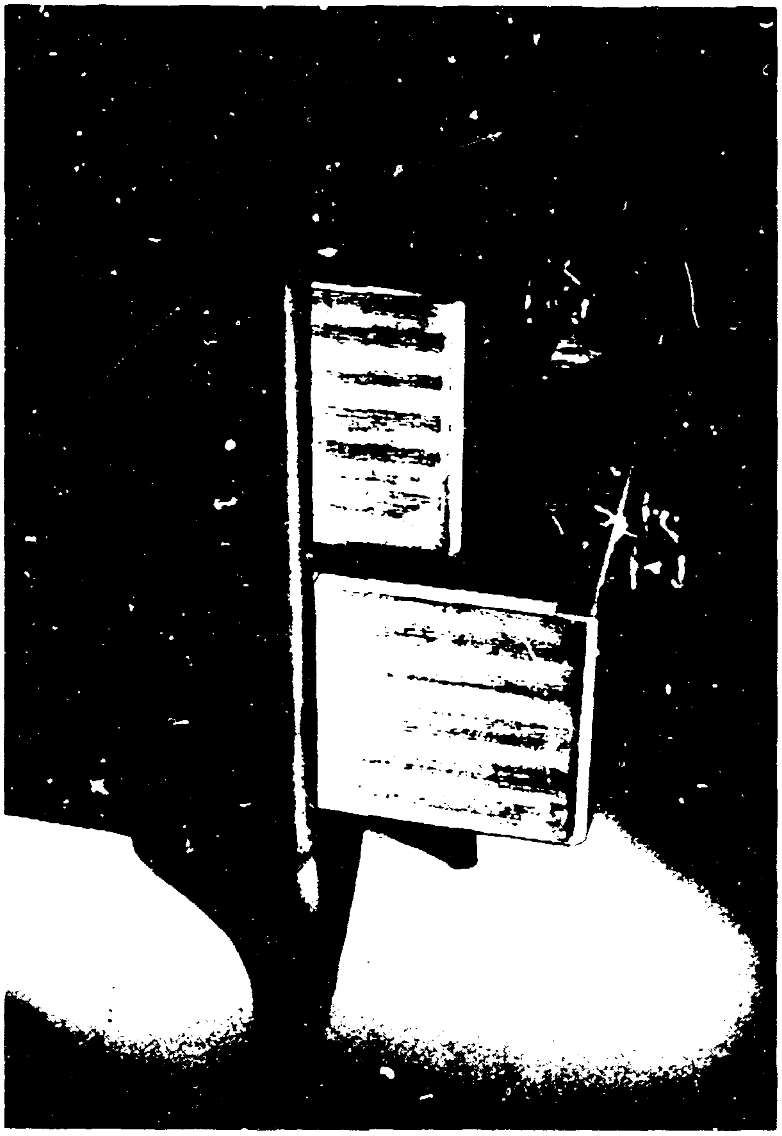
Table 100 percent MDF

After the method of producing table tops had been perfected, the next step was to replace by MDF drawer fronts, cabinet doors and any application where an exposed edge previously presented problems with particle board.

It is interesting to note here that MDF was applied in the United States first in expensive and decorative type furniture, probably because of the higher cost of MDF to the manufacturer.

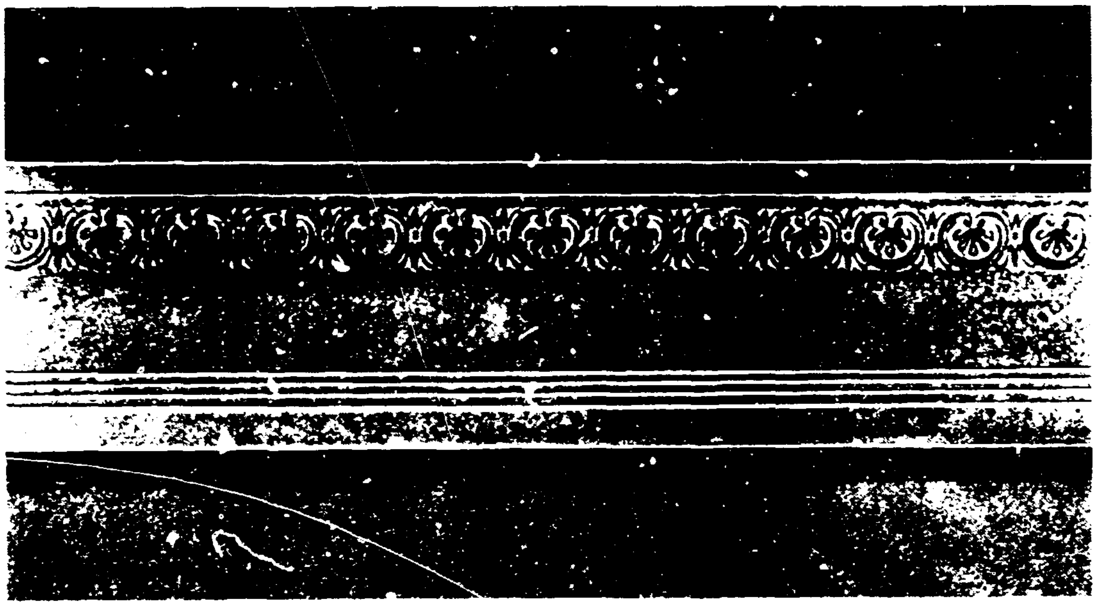
However, it became quickly evident to the furniture manufacturers that considerable savings could also be achieved in the low cost end of the furniture industry when using MDF instead of particle board. In the low cost end of the industry panels are only finished by painting. The ability of MDF to readily accept paint on both its surface and on the edges, without any special filling process, resulted in immediate savings to the furniture manufacturer.

The next step in the development process then rapidly became very obvious. MDF can be readily machined and profiled not only on the edges but also on the surfaces. Examples of this process can be seen in the accompanying pictures. The ability to machine the surface in addition to the edges is now being used in the many furniture lines both on the expensive and the less expensive types of productions. For more sophisticated furniture, the board is over-laid with veneers, patterns are machined into the surface for decorative effect, which are then specially treated by hand painting. In the case of the less expensive and somewhat simpler furniture, these engravings and machinings on the surface of the panel are painted using the same process as the rest of the board and then touched up by hand for special decorative features.



100 percent MDF

A further development of MDF use is the process of post embossing for decorative effect. The process can be applied in two ways. For relatively simple and decorative effects a pattern is pre-machined into the panel, and subsequently placed in a moulding press where it is compressed with the application of heat. This process burns the decorative pattern into the panel, which is subsequently enhanced by painting. This process is relatively straight forward, but is applied only with simple patterns and for a limited decorative effect.

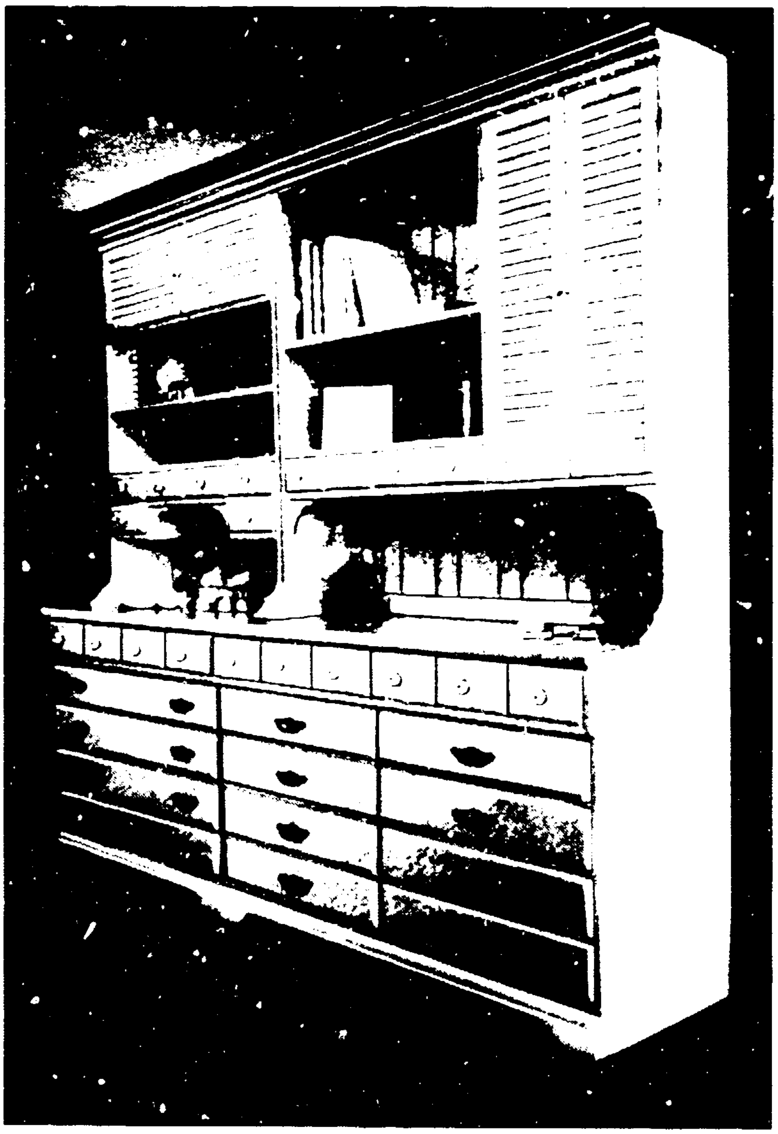


Embossing

A more sophisticated process has been developed recently, whereby whole panels are pre-cut to the size of table tops, which are then pressed under application of pressure as high as 180 kg/cm^2 in a moulding press with very little heat. The pattern is not burned into the surface but the surface material is textured to a depth of about 2 mm. The moulds designed for this process can be made very elaborate and are normally laid out to represent natural wood grains.

Another application in the furniture industry is the use of MDF in combination with plywood. Due to the much lower strength of MDF to that of natural wood or plywood its application in the manufacture of chairs was thought to be restricted. However, several furniture manufacturers have developed the process where MDF is laminated around a plywood core. This process allows the use of the MDF and its machining ability in the construction of chairs from the legs and back-rest of the chair to the sitting area of the chair.

Some applications of MDF in the production of furniture are quite sophisticated, this can be seen in the application of this product for giving a venetian blind effect, or particular lattice work or decoratively glazed display cabinets.

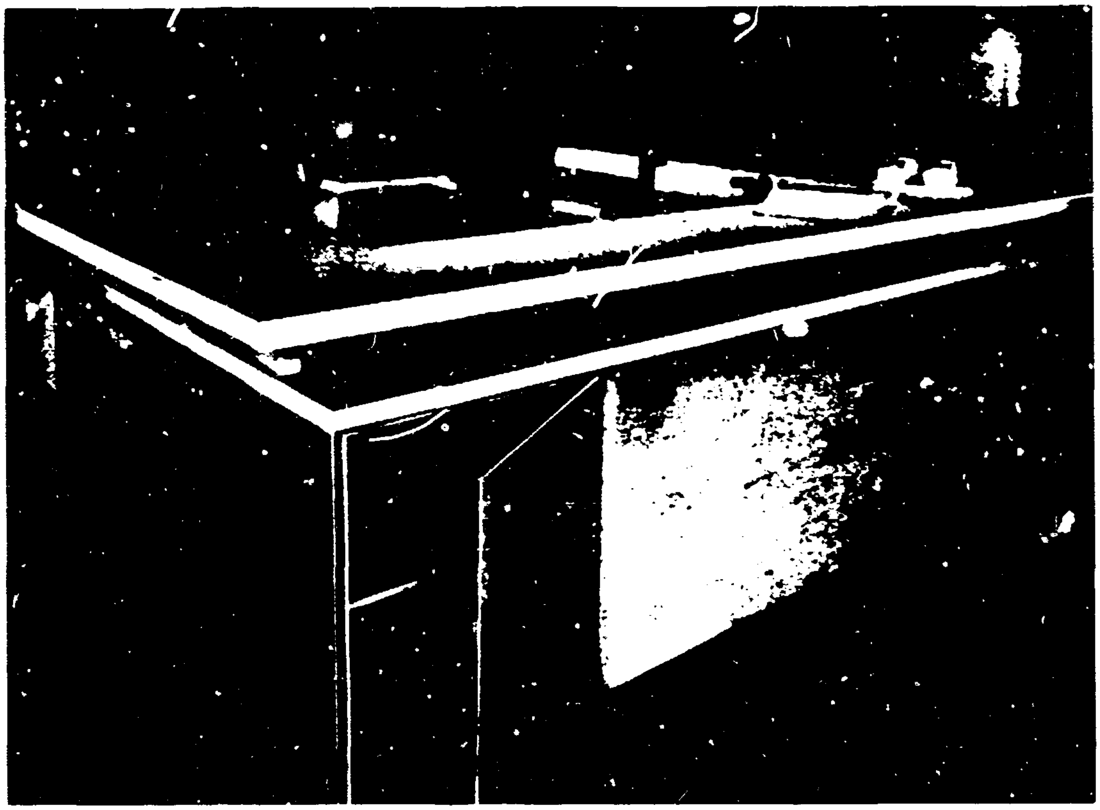


Venitian blind effect.

The worldwide application of MDF in the furniture industry is growing rapidly. The plants being presently built in Europe are all aimed towards this industry, which is presently importing board from as far as New Zealand and the United States. New applications are developed almost daily, and the demand for this product in the furniture industry will grow considerably in the next decade.

C. Cabinets:

From the foregoing description of the uses of MDF in the furniture industry, its application in the cabinet industry becomes obvious. Wherever there are exposed edges, MDF has the advantage over particle board. The step of edge banding can be eliminated, the edge can be treated artistically through machining and special painting techniques. In addition, the sawing of an MDF panel is a very smooth and easy process, and does not result in edge breakout. The edge is therefore clean and smooth. The edges are very strong and can take a considerable impact load. That such a panel found its use in the cabinet industry is very readily obvious to anyone who has ever sawn a particle board panel with a hand saw. The MDF panel saws very easily and straight and it does not ruin the saw as does the particle board. The screw-holding ability of the MDF panel both in the face and in the edge is superior to particle board. The ability to decorate the surface through machining in addition to having a decorative edge is applied more and more to the cabinet industry.



Kitchen cabinets

Since the cabinet industry used MDF it was natural for this product to enter the television cabinet and speaker enclosure for Hi-Fi or stereo market very rapidly. One very interesting additional feature of the MDF panel is that it has excellent acoustic characteristics, and all leading manufacturers of loud speakers will only use MDF for speaker enclosures.

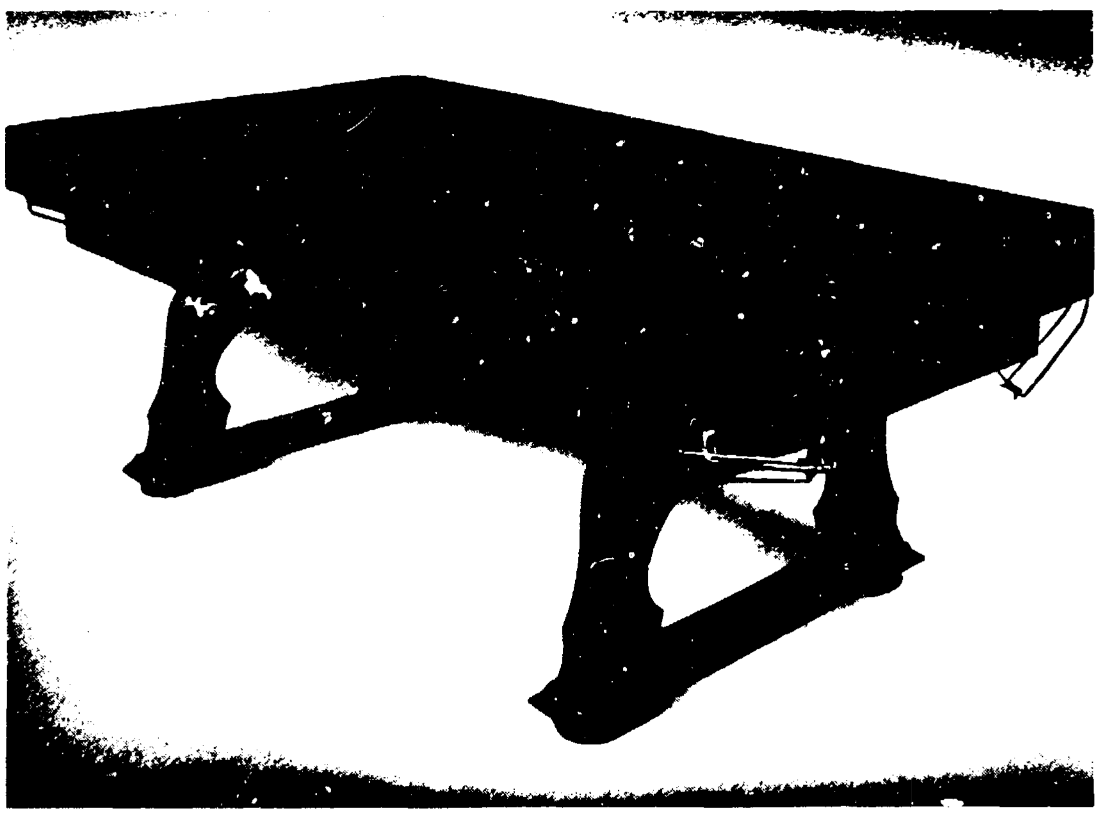
D. Panelling:

Because of its superior ability to accept direct print, some

MDF is finding its way in the panelling market especially in thicknesses of 4 mm and 6 mm. In this field MDF is in direct competition to hardboard, but has found acceptance due to lower cost, lower density and greater stiffness.

2. Trim and Mouldings:

It has already been mentioned, MDF is extensively applied as a lumber replacement. It is therefore quite natural that the product is being applied for trim and mouldings, a particular market of the solid lumber industry. The great uniformity of MDF, its ability to be machined into various shapes and patterns have made it a very attractive application in this field. It is used for window casing, door frames, floor and ceiling mouldings, picture frames (a very large market), and as door cores. The latter application is very popular, where the MDF is applied for its good screw holding ability.



100 percent MDF

In the manufacturing of the hollow core doors MDF is used in the area where hinges are attached and where the door handles and locks are inserted. MDF can be planed with ordinary carpenter planers normally used on lumber.

For trim and mouldings hot embossing, already described under furniture application, is extensively used for decorative effects.

F. Flooring:

MDF is used for flooring only in New Zealand. However, the use of MDF for flooring highlights its versatility, and shows how different manufacturing techniques can be applied.

As pointed out in the beginning, MDF is especially noted for its even density profile throughout the cross section of the panel. This density profile is controllable during the pressing process of the board and can be altered to suit particular applications. In the use of MDF as flooring, a press technique was developed which gave an extreme densification of the surface of the board and a relatively low densification in the core of the board. With high surface densification, the panel tends to simulate the structural characteristics of an I-beam, sometimes also referred to as double T-beam. The board thus created has a very high modulus of elasticity of 43,000 kg/cm^2. Under the New Zealand code this permitted the installation of the flooring at 600 mm joist centres. Board delivered in 20 mm thickness and sheet sizes of 3600 x 1200 mm allowed the installation of the flooring in a single layer. The resulting overall material and labour savings against the standard build-up floor are in the case of the New Zealand experience considerable.

SECTION 3 - RAW MATERIAL REQUIREMENTS

A. General

The raw material requirements of a medium density fibreboard plant are wood, urea formaldehyde resin, wax or paraffin additives to the binder in the form of hardners or buffers. These inputs may have to be supplemented by fuel, if the heat balance does not come out positive. In addition, supplies such as electricity and water, hydraulic and lubricating oils are needed, aside from wear parts such as refiner plates, sanding belts; packaging and strapping supplies are also needed.

B. Wood

In order to make a medium density fibreboard one needs a fibrous raw material. This may come from various species and in many different forms.

The most commonly used and preferred raw material for MDF is softwood or coniferous wood, either in roundwood or in chip form. Also the same raw material in the form of planer shavings, saw dust or plywood trim is being used. The second most commonly used raw material is soft hardwood such as beech, poplar, gum wood (very common in the United States) and some of the harder hardwoods such as birch and oak. Usually hardwoods are used in combination with softwood, as a mixture. Hardwoods are usually supplied in log form, which have to be debarked prior to chipping.

Also used for MDF are lauan, eucalyptus, bagasse and cuttings from grape vine. Other fibrous materials which are available in sufficient quantities and can be handled by normal means, are clean and free of dirt and sand, may also be suitable. For the latter category tests would have to be carried out to determine their suitability.

Tropical and sub-tropical hardwoods can be used however with caution. Usually the process can be tailored for almost any reasonable wood input, that is if the supply is constant and of a single species. If the raw material is very unstable and varies constantly, which is usually the case with tropical species, the manufacturing process becomes very complex and erratic. The problems with tropical hardwoods are their very high density and, in many cases, also their relatively high moisture content. The process can be adjusted to these two factors; however this becomes very difficult if together with the high density, species of lower density are to be used at the same time. The refiner cook time and refiner plate setting will suit one species and not the other which results in very difficult manufacturing conditions. Also for the end users of the MDF panel having a consistant panel quality and appearance is of very great importance. With constantly varying wood raw material input to the plant, such consistancy cannot be achieved, having a very detrimental effect on the success of the operation.

C. Resin, Paraffin, Additives:

The chemical requirements for a MDF plant are almost identical to those of a particle board plant. As a rule MDF requires somewhat more resin than particle board.

Urea formaldehyde resin is blended into the fibre at a rate of 9 to 10 percent resin solids based on the dry weight of the fibre. The resin is added in liquid form, at a concentration of 40 to 50 percent solids.

Wax can be added either in the form of molten paraffin or in the form of emulsion, and is required to a maximum of 1.5 percent solids based on the dry weight of the fibre.

SECTION 4 - PRODUCTION PROCESS

A. General

The production process of medium density fibreboard is similar to that of particle board. For anyone familiar with the caulless particle board operation, the difference starts at the milling section, where the raw material is defibrated under steam pressure, and ends at the outfeed of the forming machine, where a continuous belt type pre-compressor consolidates the formed fibre mat. In all other respects, the process flow through a medium density fibreboard is identical to that of a particle board plant.

The process flow can be summarized as follows: The raw material is received, stored, debarked and reduced in size (chips), screened, washed (if necessary) and fiberized in a pressurized refiner, resin is added to the fibre, it is dried in a flash tube dryer, and is transported from the intermediate storage to the forming machine where the mat is laid. After the mat is laid it is pre-compressed, trimmed, and cut into length suitable for transport to the hot press where the board is pressed. After pressing the board is cooled, sanded and trimmed and prepared for shipment.

B. Raw material receipt and preparation:

The requirements to be considered when building a MDF plant in this area of the plant are not particularly special. It is important that wood be freed from the bark in a debarker, as bark has a detrimental effect on the up-grading of the board. On the surface of the board bark particles tend to pop up as they absorb atmospheric moisture, or when they come in contact with paint or glue.

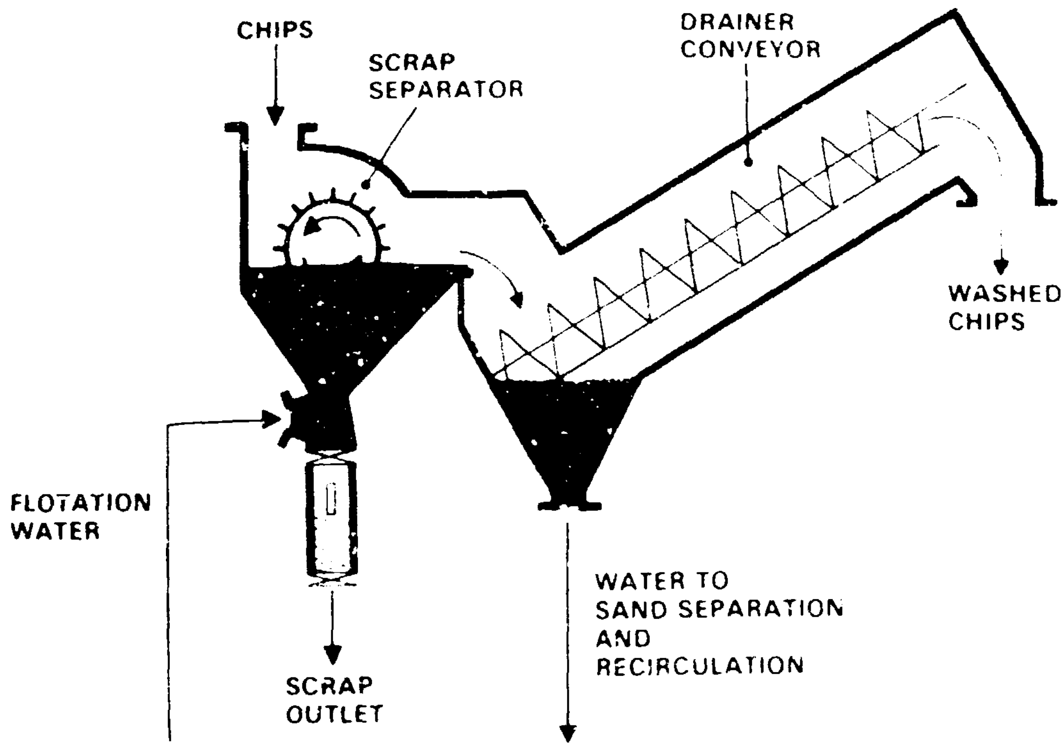
If wood chips are received in the plant with bark, every attempt must be made to separate the bark through screening or washing.

The incoming raw material should be stored separated by species, to facilitate feeding in constant species mix into the process.

Raw material received in roundwood or in some other bulk form, must be chipped and broken down in sizes suitable for the refining process. Normally, the chipping operation is performed during one, or at the most two, shifts per day with all of the output of the chipper going into storage. The preferred operation is to reclaim all material from storage, and to avoid chipping and debarking operation during night time and over the weekend. Keeping the raw material in storage for two to three days also tends to equalize the chip moisture, and the process of storing and reclaiming provide for a better mixing of the material.

C. <u>Screening and washing</u>:

The refining process is sensitive to rocks, sand and metals being introduced together with the wood chips. For this reason, MDF plants normally screen their raw material, to remove the fines fraction which contains most of the grit and to direct the over-sized chip material to a re-chipper for breakdown to proper size. The screening operation, by judicial selection of the screen size, can also be used to remove bark from chips. The screening operation is followed by chip washing, again for the removal of sand and grit and also the segregation of rocks or metal from the raw material. The most commonly used chip washer for this application is a de-fibrator chip washer.



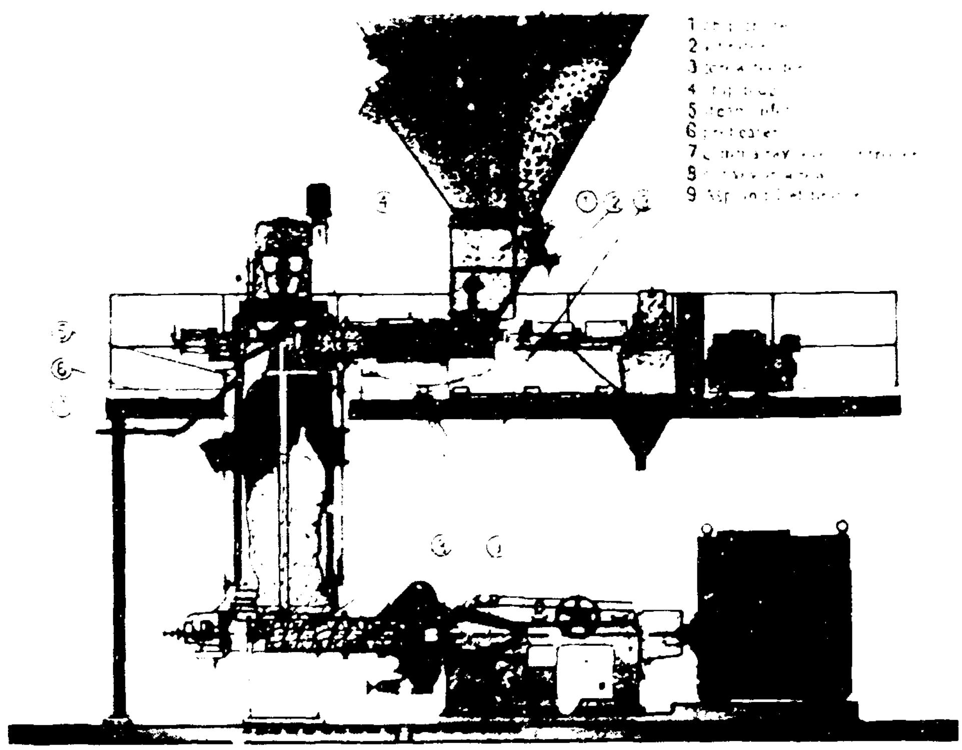
Chipwasher

D. Refining:

The wood chips are conveyed from the chip washer by be'‍t conveyor to the refiner infeed silo, here the chips are stored in a 40 m^3 hopper (for the 150 TPD plant) located directly over the digester feed screw. The feed hopper is made out of stainless steel, and is provided with a vibrating outfeed to keep the feed screw inlet shute filled at all times.

The Sunds Defibrator digester refiner system is the refining system most often used in MDF plants. Of the total 31 plants in the world presently in operation or under construction 21 use Sunds Defibrator refiners. Nine of the last ten plants built use Defibrator's refiners. This experience makes itself known through an excellent operating and maintenance record of these machines which by far exceeds other competitive units available.

The plug feed screw feeds chips into the steam pressurized digester or pre-heater. In the process of feeding the chips into the pre-heater the chips are compressed in the conical section of the feed screw housing to form a plug. This plug prevents the steam pressure inside the digester vessel from escaping. A pneumatically powered back-blow damper pushes constantly against this plug. In case the plug, for some reason, should disappear, the damper will seal the inlet opening of the screw to the digester to prevent excessive steam escaping from the digester vessel.



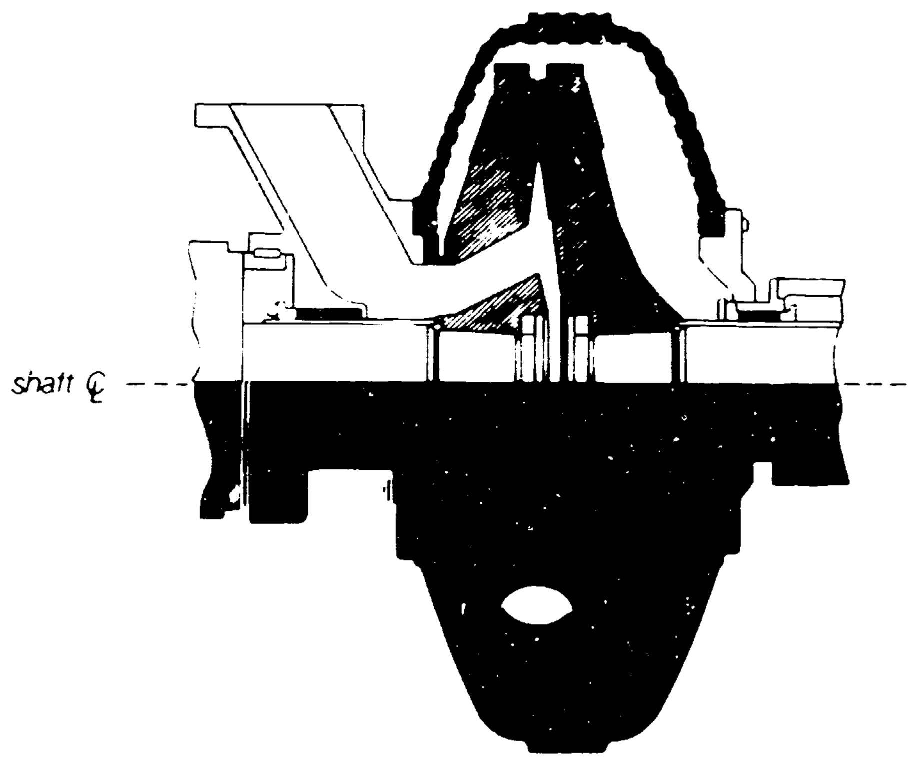
Defibrator

The digester vessel is directly connected to the refiner itself through refiner metering screw. The whole unit is kept at a steam pressure of about 7 kg/cm^2. For a refiner with 42 inch (1067 cm) diameter refining plates the digester vessel has a volume of 2,5 m^3. The chip level within the digester is controlled by an isotope level gauge. The gauge is mounted outside the digester vessel on tracks and wheels, to allow the hgight of the fill level to be adjusted to provide a 3 to 4 minute cook dwell time. The level gauge automatically controls the speed of the plug feed screw, and speeds up the screw when the level drops below the preset level and slows the screw down when the proper operating level has been reached. The fill level and therefore the cook time is controlled continuously automatically. The digester vessel is slightly conical in shape with diameter of about 700 mm on the top and 900 mm at the bottom and the total height is 5200 mm. The shell is made from 12 mm thick stainless steel. On the bottom of the vessel there is a horizontal rotating blade to sweep the material into a stainless steel double helix screw which feeds chips into the refiner. The speed of this screw is adjustable and controls the throughput of the refiner.

Steam is introduced into the digester at the top of the vessel and around the perimeter near the bottom of the vessel.

Refiners are available in two basic design concepts, the single and double rotating disc refiners. Single disc refiners used in the MDF industry are made by Sprout-Waldron company of Quincy Pennsylvania in the USA and Sunds Defibrator in Sweden. Bauer Brothers of Springfield, Ohio in the United States made a double disc refiner which has been used in several of the older MDF plants.

In the double-disc refiner chips are fed through a slot in one of the rotating discs to the fiberizing plates. The feeding of the refiner and the very high maintenance on the refiner shaft seals has resulted in a very poor reliability of this machine in dry process fibreboard industry. In most cases, the fibre produced on a double-disc machine is noted to have some unfiberized wood pieces. The industry has turned away from this type of refining and is now almost only using single-disc refiners.



Double-disc refiner

In the single-disc refiner, which has still two refining discs but only one of them is rotating, the fibre is introduced through a central opening in the stationary or fix l mounted disc. The pressure differential between the infeed into the refiner and the outside of the refining plate together with a flinger hub mounted on the centre of the rotating disc propell the chips between the refiner plates. Between the grinding plates the chips, already softened in the digester, are separated into fibre bundles. The grinding disc is rotating at 1500 rpm if the power supply is 50 cycles or at 1800 rpm at 60 cycles. A 150 tons/day refiner is driven by a 1500 kW motor. The fibres exit from the plates into the refiner housing and are constantly discharged through the refiner blow valve and blowline into the dryer.

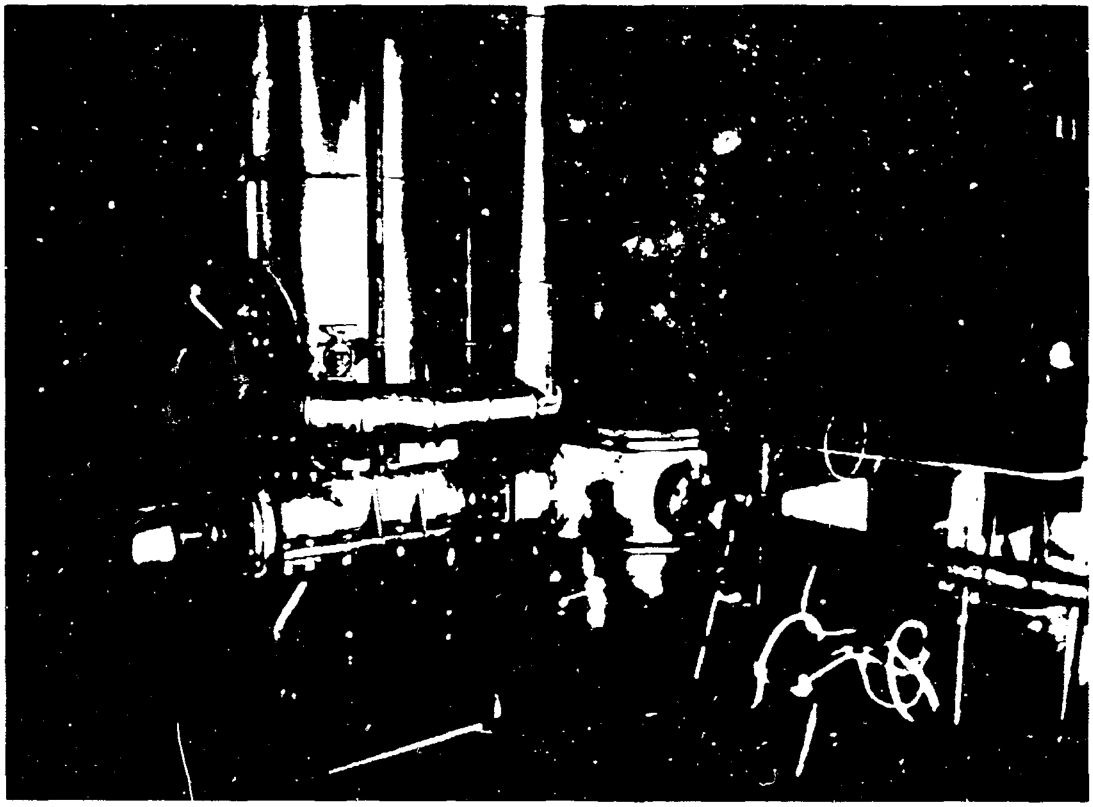
Fibre quality is basically a function of wood species, wood moisture content, cook time, refiner plate design, refiner pressure, refiner plate gap and blow valve discharge opening (steam flow). During a normal refining process all of the variables except the first two are controllable and adjustable. This flexibility of adjusting the variables allows the operator to compensate deficiencies which may be in either the species or the moisture content of the species when it deviates from the ideal.

Refiners come in different sizes and with different capacities. The most commonly used refiner in the industry is the Defibrator LVP42, which is a 42 inch (1067 mm) diameter disc machine with two and a half cubic metre volume digester. This machine has, on 50 cycles, a capacity in excess of 150 metric tons. A somewhat larger model is the LVP 44 (1118 mm) with a three cubic metre digester, this machine has a capacity in excess of 180 tons/day, both capacities rated on 22 hour-operating per day. There is also a 36 inch (914 mm) diameter machine with a 1.5 cubic metre digester, this machine is rated 100 tons/day capacity. However, it should be emphasized here that larger diameter refiners yield generally better fibre than the smaller diameter refiners. The design of this refiner is in appearance very similar to that of the Defibrator, however, its track record has not been as good as that of Defibrator. Defibrator has replaced Sprout equipment in several installations.

E. Blending:

There is still some question whether the blending section should be discussed following refining or whether it should follow the drying section. Sunds Defibrator has taken part in the development of blowline blending extensively, and of the plants supplied in recent years in which our company participated blowline blending has been used in every case.

When talking about blowline blending, it is understood by this the injection of the resin in the blowline after the refiner blow valve. This method of blending resin with fibre is used and proven in most of the dry process hardboard plants in the world. In day process hardboard, however, the resin is phenol formaldehyde. Phenol formaldehyde has a much higher curing temperature than urea formaldehyde, and the introduction of resin prior to drying has not presented a problem here. It was generally felt that this approach would not be feasible when using urea formaldehyde with its much lower curing temperature. However, this step was finally taken and the process was tried after very frustrating and costly experimenting with methods of blending resin with the fibre after drying.



Resin injection in the blowline

The problem with blending after drying is that the fibre encapsulates the resin droplets, and prevents the transfer of resin from one fibre to another through contact friction, as it is the case in particle board blenders. These encapsulated resin droplets are formed into the fibre mat, and the droplets are then pressed flat during the hot pressing operation. Unfortunately, the droplets have an affinity to combine and attach themselves to each other, resulting sometimes in fairly large resin concentrations in a single spot within the board. After the board has been sanded, the droplets would appear in the surface of the panel.

Aside from the fact that the resin spots would give the panel a spotted or speckled appearance, they have the further disadvantage that any post-finishing of the panel, especially painting or overlaying with veneer or vinyl, would result in very noticeable surface defects on the finish. Blowline blending, between the refiner and the dryer, eliminated this problem entirely, however with the penalty of a slightly increased resin consumption for the same properties. Experience has found that in blowline blending about one percent of the resin does not get in contact with the fibre, and is lost with the dryer exhaust air.

The resin addition is controlled fully automatically by a weigh scale conveyor located on the outfeed of the dryer. This weigh scale continuously measures the weight flowing through the refiner, and gives an electrical signal through a ratio controller into the DC motor which drives the resin and wax pumps.

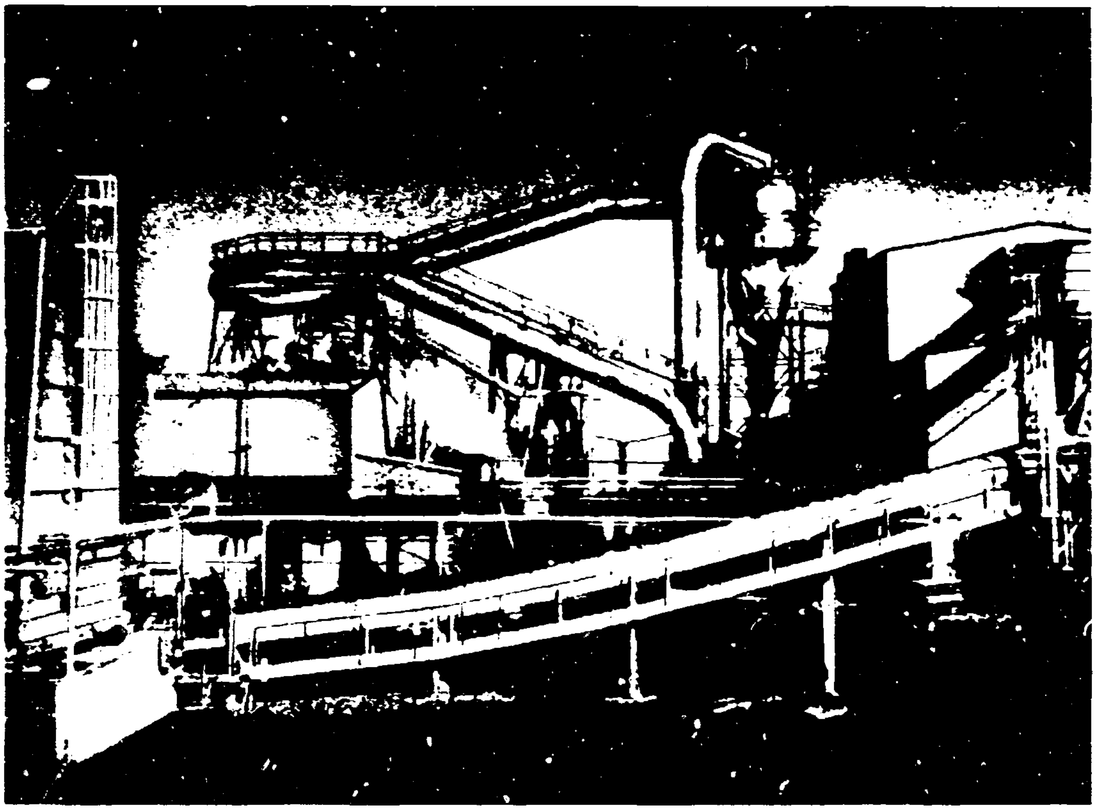
Resin is diluted from the consistency of 65 percent solids normally received down to about 40 percent solids for blowline blending. The formulation of the resin might vary slightly from that used in standard particle board to the extent that some buffering is added during the preparation of the resin.

Paraffin wax is added in the refiner housing where it disperses throughout the fibre to control the moisture absorption rate of the panel.

If any additives are used, these are mixed in with the resin and injected into the blowline.

F. Drying:

The refiner blowline discharges the fibre together with steam into the fibre dyrer. Fibre dryers operate with inlet temperatures of about 150° C, and outlet temperature to 70 - 95° C. The dryer tubes are usually about 1.2 metre in diameter, and 70 metres long. The velocity inside the dryer is about 32 to 35 metres per second.



Fibre dryer

The dryers are heated either with oil or gas, or the air heated through a steam to air heat exchanger, Alternative heat surces are sander-dust vortex-burners which can also be fired with hammer-milled board trim.

The dryers are designed to evaporate the water moisture in the fibre to an exit moisture content of between 8 to 10 percent on the dry basis. The average fuel requirement to evaporate one kilogram of water is about 1000 kcal.

At the dryer exit, the hot gases are separated from the fibre in the cyclone and discharged through a rotary airlock to a weight belt conveyor. Here the fibre weight is continuously monitored and the information is used to automatically control resin and wax addition to the fibre. A non-contact moisture analyser mounted above the weigh-belt is used to control the fibre moisture through adjustment of the dryer outlet temperature. The discharge of the weigh-belt is taken to a fibre bin for intermediate storage.

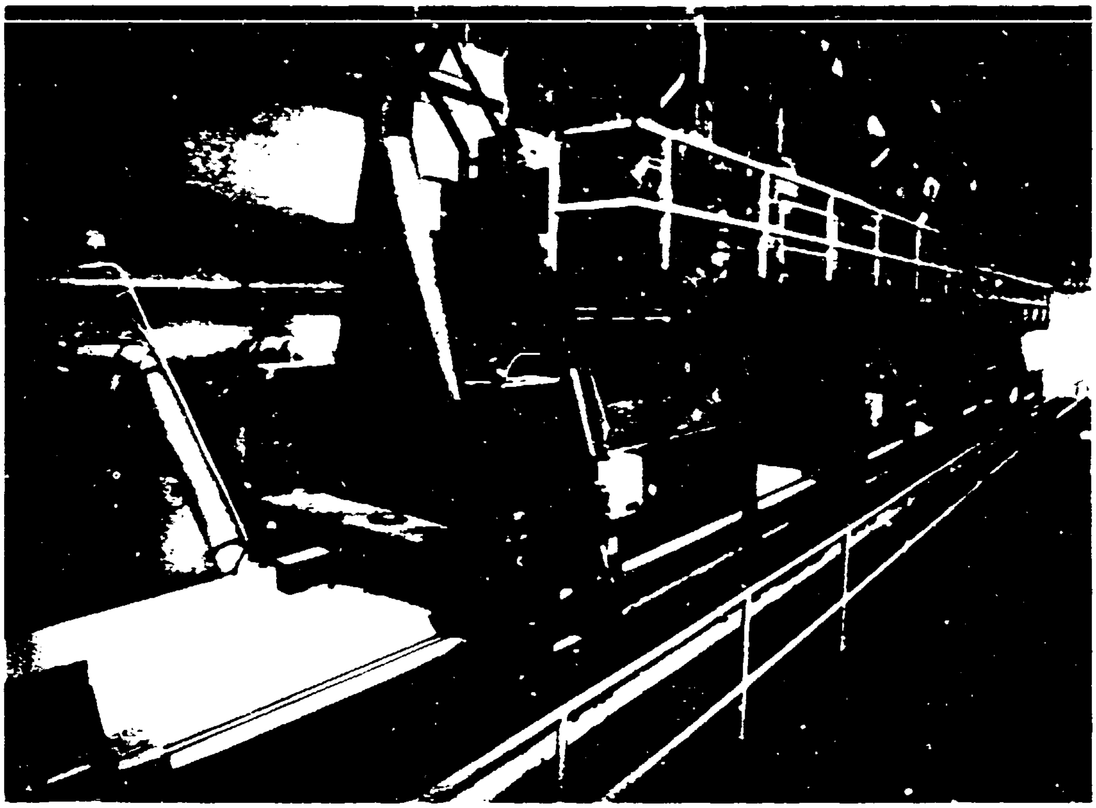
The 90 cubic metre fibre bin (for the 150 TPC capacity) serves both for intermediate fibre storage and for metering of the fibre from the bin to the forming station. In a normal operation this bin contains approximately 20 minutes of production. The bin is of a special design to handle the very low bulk density (16 kg/m^3) fibre. The fibre is dropped into the front third, nearest to the outfeed of the bin; rake-back screws or a rake-back conveyor takes the overflow to the rear of the fibre bin. The level in the fibre bin is monitored by isotope level controls. Depending on the number of forming heads which are supplied by the fibre bin, the outfeed of the bin is split in two or directed only to one head.

Both the dryer and fibre bin infeed are supervised by high speed infra-red spark detectors, which automatically activate fire prevention or extinguishing equipment.

G. Forming and pressing line:

The fibre is transported by an air conveyor system directly into the forming head. No cyclone separator is used on the infeed to the forming head of the Sunds Defibrator's Pendistor forming station.

The forming of the fibre mat in the forming station presents some special problems because of the very low bulk density of the fibre produced. Practically all forming stations used in the dry process utilize the vacuum forming method for this purpose.



Pendistor forming station

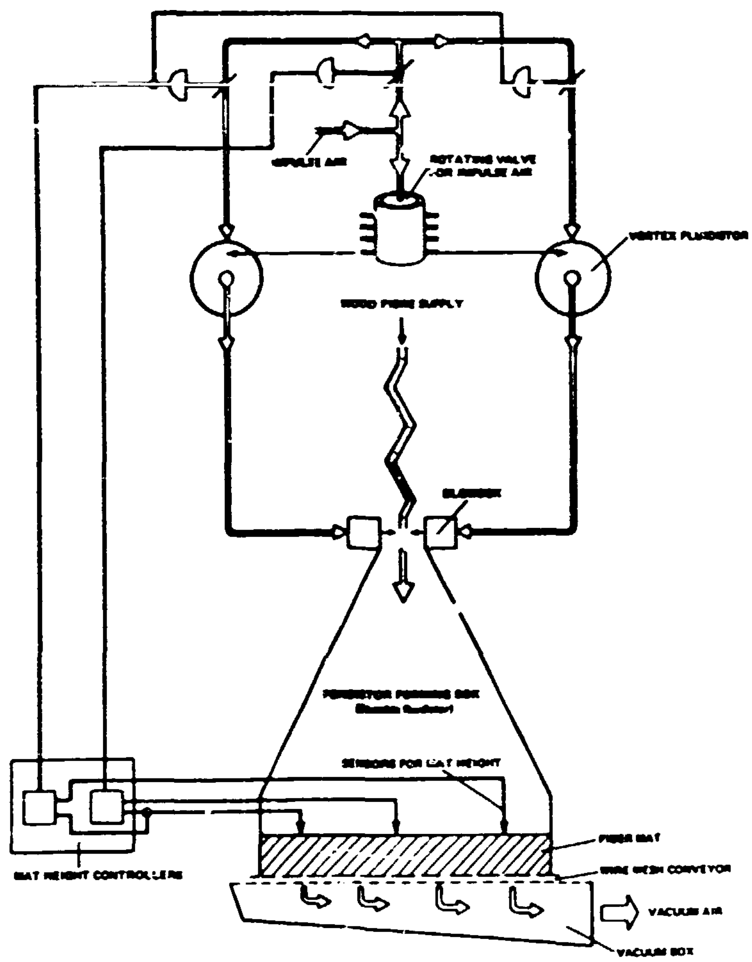
In the vacuum forming station a perforated belt either made out of steel, phosphor bronze, or plastic travels over a vacuum box which is connected to a suction fan. The fan has a vacuum of about 50 cm of water and is used to draw the fluffy fibre onto the belt and to evacuate air trapped within the fibre.

It is desirable to distribute the fibre very equally both across and along the forming station. Any adverse variation in mat deposition will result in density variation in the final panel. Several methods have been used to ensure equal distribution, and control over the fibre deposition. In the Sunds Defibrator Pendistor forming station an automatic control system allows to monitor and adjust constantly the fibre deposition and profile.

Forming machines vary in width from 1200 mm to 2700 mm, depending on the final panel size desired. The length of forming box is dependent on the desired capacity, and varies from 1800mm to 2500 mm. The capacity of the Pendistor former is about 460 g/m^2/sec.

The following is a brief description of the Sunds Defibrator Pendistor former:

As already mentioned, the fibre is transported by a pneumatic conveying system directed into the forming head where it first enters the zig-zag section. The zig-zag section performs the following two functions: First it distributes the fibre equally over the total length of the forming, and second it serves also to break up any fibre balls or bundles which may have formed during the drying, storage or transport of the fibre to the Pendistor forming head. The zig-zag section is lined to prevent the build-up of static electricity within the fibre.



Principle of Pendistor former.

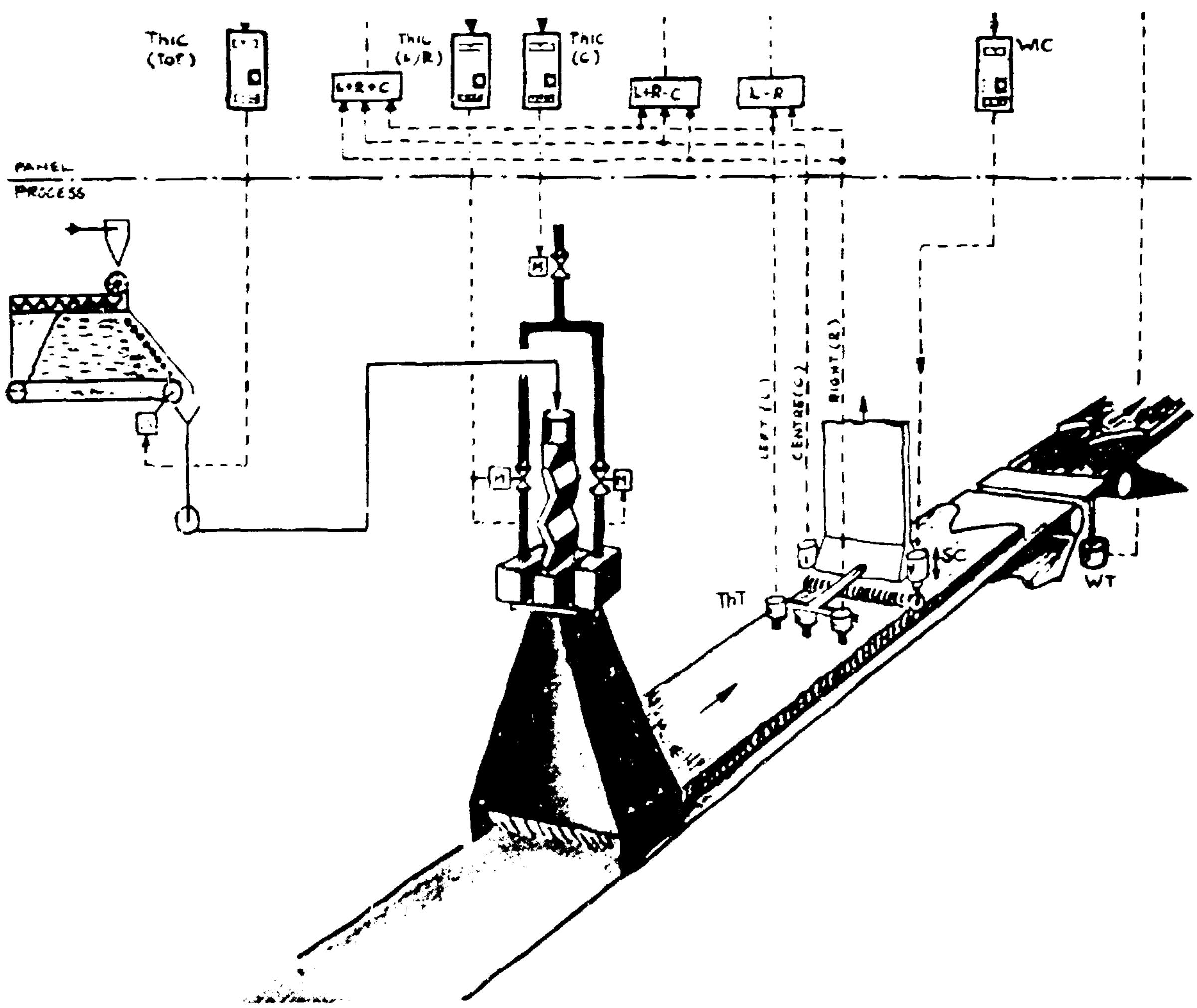
As the fibre leaves the zig-zag chute it enters the control air section. In this section high velocity air is introduced horizontally through slots on either side into the fibre stream. The air flow into each slot is remotely controlled by fluidistor valves, which can increase or decrease the amount of air. The air jets are arranged opposite each other and operate in such a way that when the air flow out of the slot on one side is at a maximum, the air flow on the other side is at a minimum. The fluidistors are connected to each other in such a way that in each adjacent nozzle the air flow is reduced in small steps from a maximum to a minimum or conversely is increased from a minimum to a maximum. If we picture the instantaneous flow of the air on one side of the control box we see it start on one end with a minimum, increasing from slot to slot to a maximum and then again decreasing to a minimum. In other words, the amount of air flow forms a sine wave from one end of the forming box to the other. On the opposite side of the control air box we have exactly the opposite picture, the sine wave is out of phase by 90°.

The control signal for the fluidistors to increase or decrease the air flow is given by a rotary valve, which is driven by a variable speed motor. As the valve rotates the controller impulses travel along the length of the Pendistor head, resulting in a travelling sine wave which deflects the fibre continuously from one side to the other of the forming box, oscillations up to 10 cycles per second can be achieved.

Three automatically adjustable air valves are in the air supply line to the control air boxes, the main valve controls the total air flow to the control jets, the secondary valves control the flow to either side of the nozzles.

The main valve controls the total air flow to both boxes as follows: When the valve is closed no control air flows to the nozzles, the fibre will fall onto the forming belt by gravity, assisted by the vacuum flow of the air going through the forming belt. The deposition pattern would be a pile of fibre concentrated in the middle of the forming belt. If the main control air valve is opened wide, a maximum flow of air through the nozzles would pile up the fibre on the edges of the forming box with very little fibre deposited in the centre of the box.

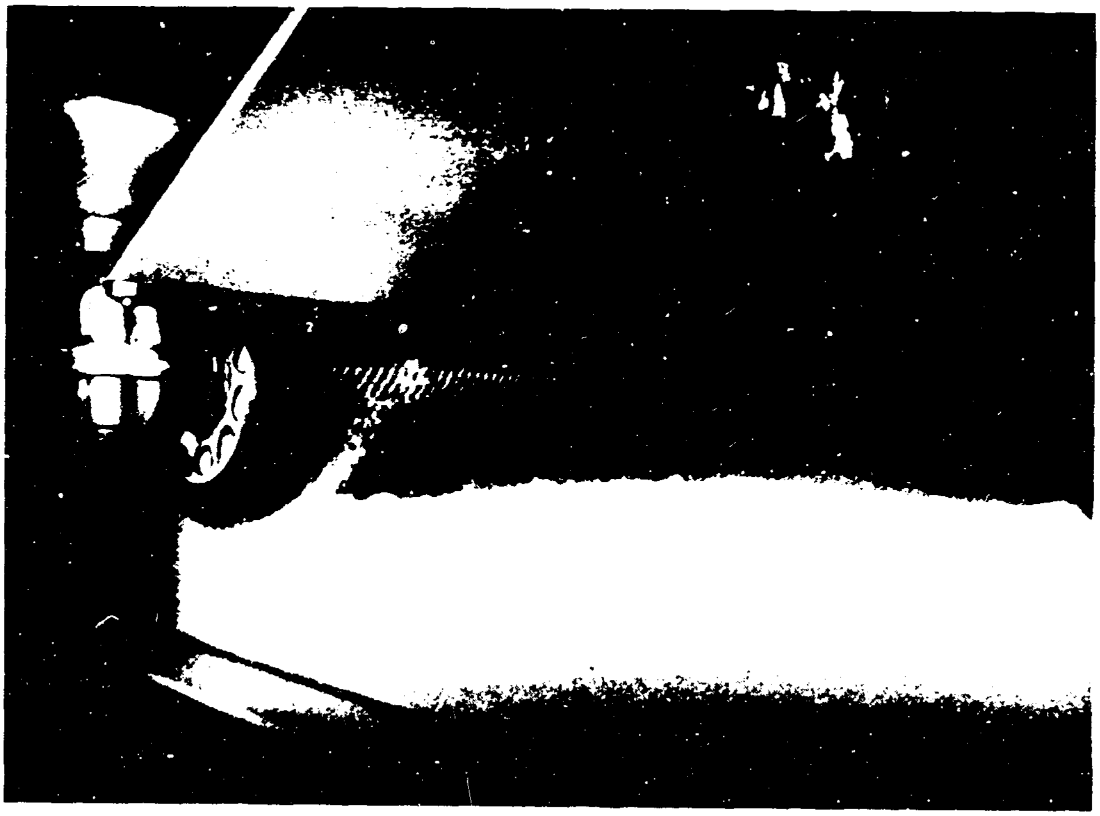
The two secondary valves are located on either side of the control air box, and are mechanically coupled together to arrange the control as follows: in the centre position the air flow to both sides to air control box is equal. If for some reason the pattern in the forming box becomes asymmetrical, the automatic system will activate these two valves simultaneously decreasing the air flow to one side of the control air box and at the same time increasing the flow to the other side, with the result that the forming pattern will shift from one side to the other. For instance, if the air flow on the right hand side is increased and the left side is decreased, more fibre will pile up on the left hand side and less will pile up on the right side of the forming box. As can be seen, this system allows for considerable flexibility and control on the fibre mat deposition.



Pendistor controls

To constantly ensure that an ideal pattern of fibre is deposited on the forming wire, three sets of mat height sensors are located on the outfeed side of the forming head. Two of the mat height sensors are placed near the edge of the mat and the third sensor is measuring the height in the centre of the mat. The output of these sensors is used to control the profile of the fibre mat laid down in the forming head.

The air flow coming into the forming head together with the fibre, and the control air added in the control air section is in balance with the amount of the air drawn out of the mat by the vacuum fan.



Shave-off rolls.

Following the forming head the surface of the mat laid down is made completely level and flat by the rotating spike roll of the shave-off head. This shave-off roll is mounted in an elevating frame which can be raised or lowered electrically, to control the final mat weight. The shave-off roll is equipped with a suction hood, and the shaved off fibre is returned to the fibre bin. Underneath the shave-off roll is a separate and completely independent vacuum box which is specially designed to ensure greater mat densification on both edges of the fibre mat. This feature is very important and is used to compensate for the mat squeeze-out which occurs on the edges when the mat travels through the precompressor and also when the mat is being pressed in the hot press. To provide the additional fibre for the greater densification of the mat on the edges the forming station is adjusted in such a way that a larger quantity of fibre is deposited on the edges than in the centre of the mat. Since the shave-off roll would make this profile flat again, and therefore practically negate the work done in the forming head, a special vacuum box had to be designed for the shave-off to provide greater densification on the edges.

The mat height sensors are attached to the elevating frame of the shave-off roll. Whenever the height of the shave-off roll is adjusted, the mat height sensors travel up and down with the shave-off roll. This feature allows the signal of the mat height sensors to control the outfeed rate of the fibre bin and keep the height of the mat to be shaved off constant regardless of the elevation of the shave-off roll.

A second moisture metre is located on the outfeed of the forming station to further supervise the fibre moisture content.

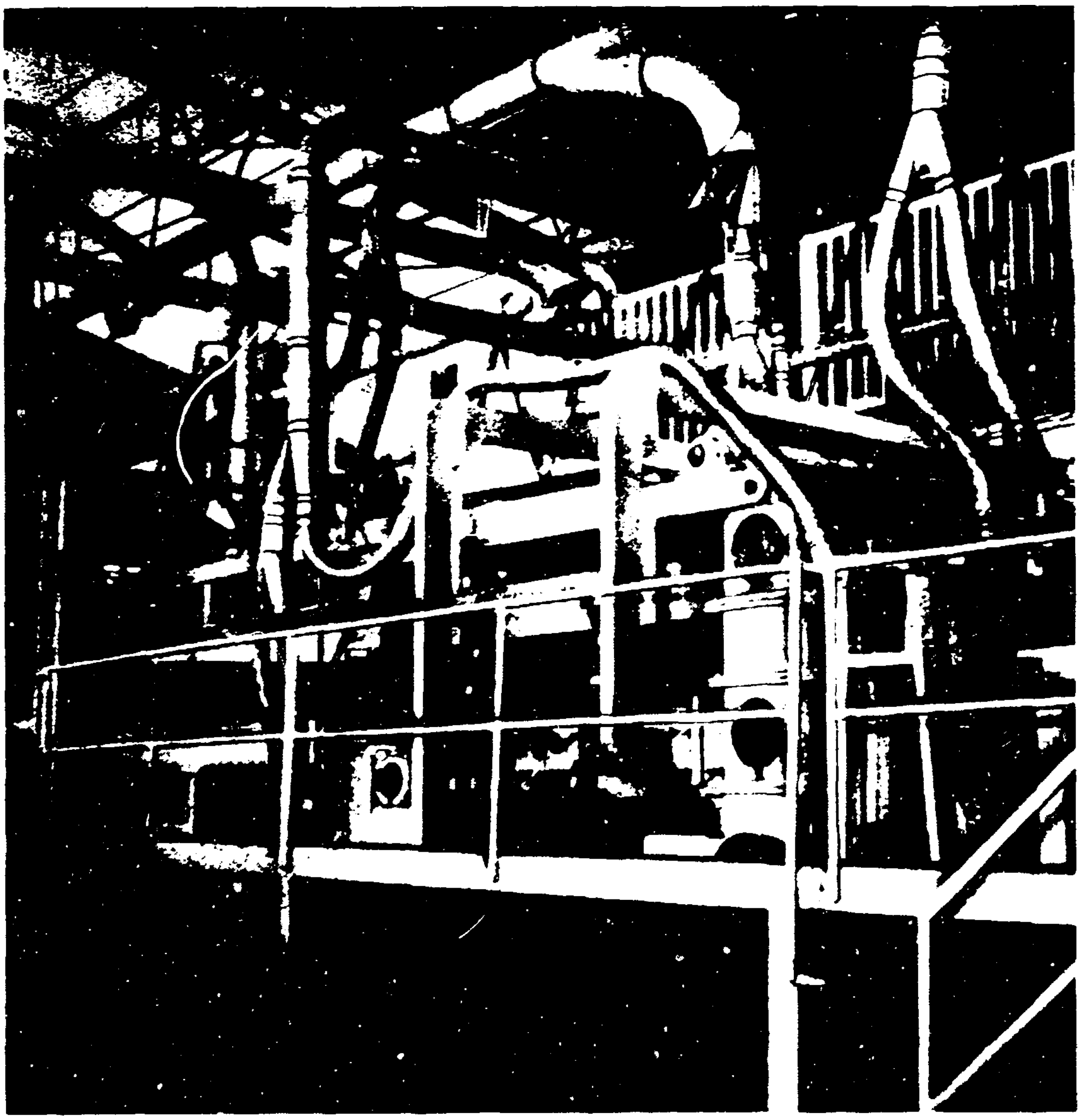
From the forming station, the mat is transferred over a slide plate into the precompressor. The slide plate is directly mounted on two load cells to continuously monitor the weight of the mat travelling across it. The output signal from the weigh-plate goes to a controller to automatically adjust the height of the shave-off roller for proper mat weight.

This brief description of the forming station shows a fully automated operation which results in a uniform mat, the mat compensated for edge squeeze-out resulting in a very tight cross- and length-panel density control of the final panel. The forming station has several additional features to ensure minimum trim and the shave-off is recycled, making the machine superior to other products on the market. The Washington Iron vacuum former utilizes a hydraulically or mechanically operated pendulum shute to achieve the right-left distribution. This pendulum has only limited influence on the left-right-and center distribution of the fibre introduced into the forming head. No mat sensors are provided since mat profile control cannot be exercised in any case. The vacuum on the forming head and the vacuum on the shave-off head is combined in one box. Densification can only be compensated for by forming a much wider mat and cutting the edge which has been thinned out in the precompressor and the hot press through excessive trim.

Of the last ten MDF plants delivered or under construction seven plants are equipped with Pendistor former, a very good record if one considers that the Pendistor former has been available only for the last four years.

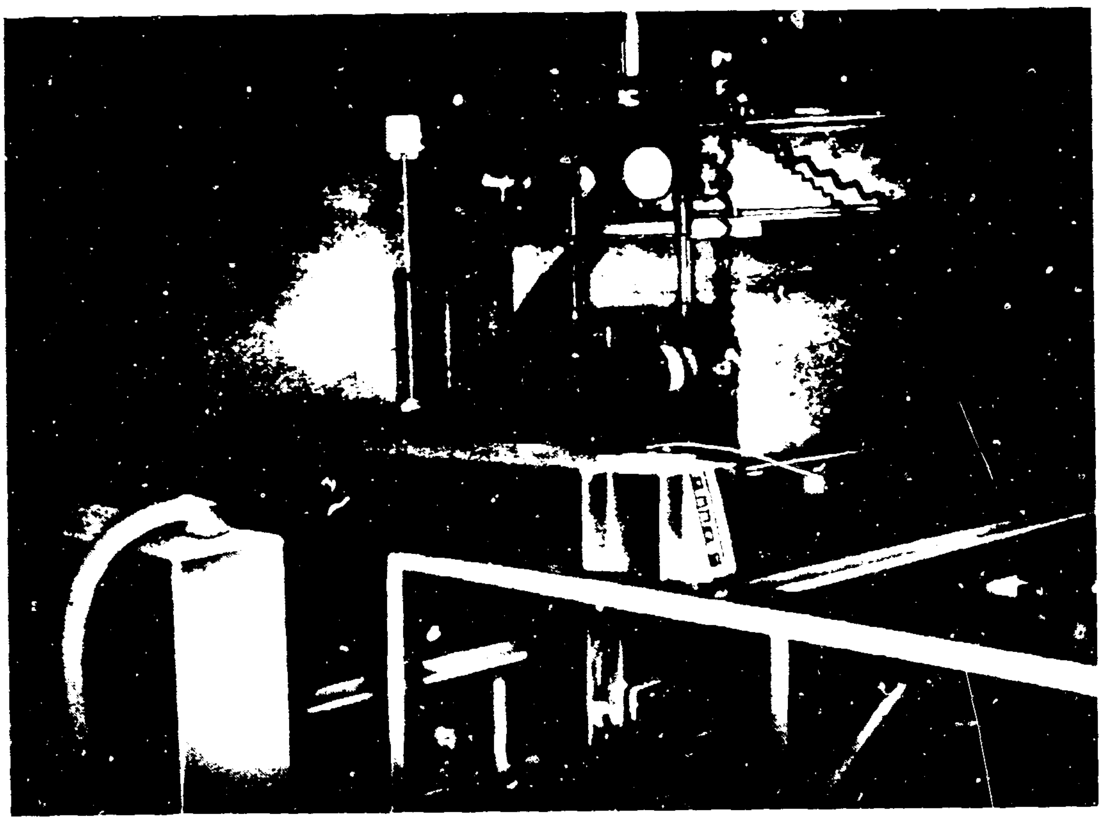
To give some idea as to the bulkiness of the material being formed it is of interest to note that a fibre mat for a board of 19 mm final pressed thickness leaves the forming station about 500 mm thick. Since the forming station forms the mat in a continuous ribbon, this ribbon will have to be divided to allow the loading of individual mats into the hot press. In order to be able to cut the mat into the proper length the mat must be pre-compressed. Such a mat consolidation is also desirable to reduce the required daylight opening in the press. For this purpose, a belt type pre-compressor is used, consisting of a long tapered inlet section which gently reduces the mat height and allows the air trapped within the fibre mat to escape. This inlet section is followed by a nip or a pressure roll, which applies pressure of about 180 kgs per linear centimeter onto the mat.

This nip is followed by a holding section of about 1.2 metres in length which maintains a pressure of 1 kg/cm^2 on the mat. After this consolidation the mat exits the pre-compressor and enters the saw conveyor. At this point, the mat is reduced in thickness from 500 to 100 mm.



Pre-compressor

The saw conveyor has three functions: first the mat is being side trimmed, approximately 50 mm on each side, and the trim is returned to the fibre bin. Second the mat is cut into individual length by a flying cut-off saw. Again the sawdust generated by this cutting operation is returned to the fibre bin for re-use in the process. Third a metal detector searches electrostatically the mat for any metal large enough to cause damage in the subsequent pressing operation. If the metal is detected, the mat is automatically diverted from the process.



Flying cut-off saw and metal detector.

The cut to separate the mats is made with a single saw blade. taking very little away from the total mat length. As these individual mats travel downstream they must be separated to provide the time for the loading operation into the press loader. This is accomplished in the following speed-up section, which consists of 300 mm long slide plate and three converyor sections of sizes which vary in the ratio of 1:3. The mat travels onto the speed-up section at forming speed from the saw conveyor section. Then the cut made by the flying cut-off saw reaches the slide plate between the saw conveyor and the speed-up section, the speed-up section goes into high speed and creates a gap. By the time the following mat reaches the first speed-up section, it has been disengaged from the high speed section and has reverted back to forming speed. The mat coming from the forming station then travels onto the first speed-up section while the previous mat is still moving at three times the forming speed towards the press loader. By the time the following mat reaches the second speed-up section, it also has been disengaged from the high speed drive and connected again to the forming speed drive to allow the mat coming from the forming station to continue travelling forward at slow speed. This technique allows a gap to be created between mats sufficient to charge the individual loader trays and also subsequently for the loader to ch[illegible] the press.

The third speed-up section is normally designed in such a way that it can lift out of the way of the oncoming mat. This allows for rejecting of mats which either may contain metal, or which have to be rejected because of some other defect. In normal operation this occurs only when the first mat is being formed at the beginning of the forming run, or with the last mat coming out of the forming station at the end of the run. Both these may not have the required mat weight for the particular panel being produced. The fibre that is rejected falls into a hopper which returns the fibre through an air system back into the fibre bin, this reject material is then re-used in the process.

In case metal is contained in the mat, a special switch-gate directs the mat containing metal to a waste silo. It should be noted that occurance of metal in the mat is very rare and happens in normal operation perhaps once in every two months. It is however desirable during the start-up of the plant or when maintenance has to be done on the plant to prevent metal objects accidentally getting into the press or into the board.

Following the speed-up section, the mat is transported over two storage conveyors into the press loader. The whole forming system is caulless, and the mats are transported throughout their conveyance into the press on belt conveyors. These belts are of nylon reinforced plastic belt material, not heavy but long lasting.

The press loader is of the tray-belt type, and as usual for multi-opening hot presses, of the hydraulically elevating type. Each mat is positioned accurately on each tray, in each level of the loader. When the loader is completely filled and the press is ready to be charged the loader with all mats positioned on each tray enters the press completely and then reverses. During the reverse operation, the belts in the loader trays are engaged and travel forward with the same speed as the loader cage is travelling out of the press backwards. The mats appear to be standing still and are thus deposited in the hot press.

The loader trays are designed to be as thin as possible to minimize the amount of opening between press platens. Each loader tray is provided with a nose piece, which is used in the subsequent press cycles to push pressed board out of the press. These nose pieces are also drilled and provided with air nozzles connected to a compressed air system. During the entry of the loader into the press the air nozzles are activated to clean the press platens from fibre or any other debris left in the press from the previous pressing operation.

The hot presses are of very similar design to those used in the production of particle board, the only significant difference being the much larger opening between the platens necessary for receiving the relatively low density mats and the loader trays during the charging cycle.

The hydraulic pressure commonly used in the production of MDF is 35 to 50 kg/cm^2 on the mat. American presses a rule have a mat pressure of about 50 kg/cm^2 since the American manufacturers tend to produce board of higher density (750 to 800 kgs/m^3) than does the rest of the world. European presses operate usually at 35 kg/cm^2, reflecting the tendency to produce lower density boards on that continent. Perhaps as a side note the lower density is due to the significant difference in the wood costs in the two continents. Normal press temperatures for MDF are around 165°C, quite similar to those used for particle board.

It is very desirable in the production of MDF to have a hydraulic press system which allows the control of the closing of the press both with respect to pressure and time. Very rapid closing of a multi-opening MDF press will result in very high surface densification and sometimes poor bounding of the fibres in the core. Both of these features are not desirable and the MDF cycle has been adjusted to avoid these.

To make a board of uniform density profile the presses close fairly rapidly within 20 to 15 percent of final thickness and are closed slowly to final thickness. This technique results in an even density distribution throughout the board, however, it has the tendency to length the press cycle. Compared with particle board, MDF has longer pressing times. For planning purposes press cycles between 8 and 8 and 1/2 minutes are used, even though in practice press cycles around 7 minutes are achievable for 19 mm board.

The loader discharges the platens from the press into the unloader. The unloader is an elevating type receiving one panel per opening. The unloader is hydraulically operated, of the indexing type discharging one panel after the other as it descends downwards.

Some presses (11 of 31) in the MDF industry use radio frequency (RF) assisted curing of the board, at an intensity of 16 kW/m^2 of press area. RF can only be used on board thicknesses of above 15 mm, and is advantageous for thicknesses above 30 mm. RF shortens the press cycles to about 50 percent of the equivalent non-RF heated cycle time. The power consumption per cubic metre increases by about 70 kwh. Operating experience has been negative for this process, and is of interest only if a large demand for board thicknesses above 19 mm is expected. The capital cost of such a plant is higher by 10 percent than that of a plant of equivalent capacity not using RF.

H. Sawing and sanding:

After the unloader outfeed the panels are often pre-trimmed or trimmed to final dimensions and then proceed into a cooler. The cooler can be of a wheel type or of the wicket type, usually designed to hold two press loads of board or more. Subsequent to cooling the board is stacked. In some installations the trimming operation is put behind the cooler. After stacking the board may be either kept in storage for a day or two before sanding or may be sanded directly. Which method is most appropriate depends to a large extent on species and environment in the particular location where the plant is located. In practice there has been no general rule on timing of the sanding operation. Most plants were initially designed for intermediate storage and were subsequently changed to sanding right after the boards came out of the cooler.

The sanding operation for MDF is a critical function and requires some care in layout and design for any plant that would like to compete in the international market with MDF customers in the international field using the board expect to receive the board with a first class finish which requires in many locations the sanding with very fine grade paper. A 75 or 150 tons/day plant requires a 4-head sander (2 bottom, 2 top) and 300 tons/day plant a six-head sander.

Most MDF plants have a cut-up operation, to cut panels into sizes required by the end-user.

The sander dust and the saw trim is directed from this operation into a storage silo and hence used as fuel either to heat the boiler or to provide heat for the dryer.

I. Buildings:

In talking about production process and describing the machinery it may be of some interest to know what the building requirements are. For the refining, glue preparation, forming and pressing line one needs approximately a building 12 metres wide by 140 metres long. For tne in-process storage, sanding and saw line, auxilliary areas such as electrical rooms, press hydraulic rooms, compressor rooms, repair shops and offices one requires a space of about 120 x 30 metres. These building requirements are sized for a 150 tons/day plant. The total plant size for a 150 tons/day plant including log storage and chip storage and equipment area for screen and chip washer, dryers and fibre bin would require a total area of about 15 hectare. Over the forming station and the press one will need a clear height of about 9.5 metres, for the rest of the equipment and warehouse height of six metres under trusses is normal.

J. Raw material and utility requirements:

To complete the description of the production process this paragraph will briefly describe the raw material and utilities required. Table 2 gives some very general figures for a typical 150 tons/day plant, using a finished panel size of 1,220 mm x 4,480 mm produced on a press for a nominal board size out of the press of 1,220 mm x 9,760 mm. To adjust these numbers for different board sizes and different plant capacities a certain judgement must be applied, which will be of course somewhat obvious to everybody familiar with this field.

It should be noted that the last two figures are given as a consumption per minute and are not related to the consumption figure per ton.

The installed motor load for 150 tons/day plant is about 5000 kW, the largest single motor is the motor for the refiner, which has a rating of 1,750 to 1,500 kW. The boilder capacity should be around 20,000 kg/hr with the boiler steam pressure rated at 16 bar.

Table 2:

Raw material and utility requirements for a typical 150 tons/day Medium Density Fibreboard plant:

Per ton of production:	
Finished board weight (trimmed and sanded)	1,000 kg/ton
Density	700 kg/m^3
Resin consumption (100 percent solids)	100 kg/ton
Paraffin consumption (100 percent solids)	5-15 kg/ton
Wood input (100 percent dry), without bark	1,100 kg/ton
Electric power consumption	400-450 kWh/ton
Steam requirements (16 atm) (at min. 0°C ambient temperature, without any other fuel input into the plant)	2,500 kg/ton
Use per minute:	
Water requirement (excluding recirculation of cooling water. With recirculation:1201/min	270 l/min
Compressed air	6 nm^3/min

K. Manpower requirements:

Table 3 gives the manpower requirements for a typical 150 tons per day plant with roundwood input as raw material, operating on a seven-day four-shift schedule. The manpower requirement will not vary greatly for a plant double or three times the capacity. The only additional requirements would be in the wood finishing of the panel products, and in the plant and vehicle maintenance crew, all other requirements would stay about the same.

Table 3:

Manpower requirements for a 150 tons/day MDF plant, with roundwood input:

	shift				
Raw material receipt	1	2	3	4	Total
Log loader operator	2	1			3
Barker operation	1				1
Yard man	3				3
Total raw material receipt	6	1			7
Screening-washing-refining-drying					
Bucket loader operator	1	1	1	1	4
Utility man	1	1	1	1	4
Total screen-drying	2	2	2	2	8
Forming and pressing to cooler					
Operator	1	1	1	1	4
Utility operator	1	1	1	1	4
Utility man and fork lift operator	2	2	2	2	8
Total forming and pressing	4	4	4	4	16
Sawing and sanding					
Saw operator	1	1			2
Sander operator	1	1			2
Sander grader	1	1			2
Fork lift operator	1	1			2
Total sawing and sanding	4	4			8

	Shift 1	2	3	4	Total
Strapping and shipping					
Strappers	2				2
Shipping utility man	2				2
Forklift operator	2				2
Total strapping and shipping	6				6
Maintenance:					
Boiler operator	1	1	1	1	4
Mechanics	3	1	1	1	6
Electricians	2	1	1	1	5
Vehicle maintenance	1				1
Clean-up	2	1			3
Greaser and knife sharpner	1				1
Total maintenance	10	4	3	3	20
Quality control:					
Quality control operator (Total)	1	1	1	1	4
Foremen:					
Shift foreman	1	1	1	1	4
Maintenance foreman	1				1
Finishing foreman	1				1
Total foremen	3	1	1	1	6
Total labour force	36	17	11	11	75
Supervisors:					
Scheduler	1				1
Plant superintendent	1				1
Plant quality control supervisor	1				1
Plant manager	1				1
Sales manager	1				1
Assistant sales manager	1				1
Purchasing manager	1				1
Clerks	3				3
Total supervisory staff	10				10

SECTION 5 - PROCESS AND QUALITY CONTROLS

A. Process control:

The production process beginning from the reclaiming of chips in the wood storage pile and ending on the outfeed of the cooler or directly coupled saws on the end of the pressline is essentially automatic. The process between those two points is controlled from one control room under the supervision of one or two operators together with two or three people on the floor. One of the floor people looks after the refiner blender and forming section, and the second floor man looks after the trimming section at the outfeed of the line. He may also operate the fork life truck to take the boards away from the board stacker into intermediate storage. Three poeple may be required if the trimming operation on the outfeed of the press produces final trimmed board size.

The controls supervised or operated by the operators are electrical controls through out, and require the operators' action only to make adjustments to the preset parametres as the process requires it. Once the line is operating the only function still requiring operator's action is the initiation of the closing of the press. This function has been kept for manual initiation since any failure in the mat loading or board unloading sequence could cause severe damage to the loader or to the press.

The control logic and control hardware in modern plants consist of electronic solid state programmable controllers and micro-processor analog control system. In locations where services for such are difficult to get, one would still recommend the old standard relay system. Property maintained both systems run equally well. The advantage of the modern programmable controller system in conjunction with micro-processor analog control is a much more flexible and precise control of the process. The programmable controller makes maintenance, supervision, checkout, modification, and adjustment very easy. It is today preferred over relay systems also because of its reliability. However, in more remote locations it must be seriously considered whether this alternative may be used. Parts for repair have to come from the supplier of the equipment and are not readily duplicated outside the original manufacturer's factory. In spite of the great reliability of the solid state electronics, repairs and replacements will be required from time to time and an ample supply of spare modules will have to be kept to prepare for any unforeseen breakdown.

B. Quality controls:

Quality controls for MDF production are similar to those used in particle board production. A MDF plant has a laboratory where the board properties such as modulus of rupture, modulus of elasticity, internal bond, thickness swell, board density and weight can be measured with great accuracy. In most plants the quality control staff consist of a supervisor and a minimum of one man per shift. This shift man takes board samples from the pressline every hour or two hours for testing of physical properties. In addition to which he will take periodic samples of fibre to determine fibre moisture content and quality. The data continuously obtained by the quality control personnel is used to modify the production process to ensure the best results required for the end product.

SECTION 6 - ECONOMICS OF PRODUCTION

A. General

To discuss the economics of production, certain ground rules and parametres have to be agreed upon, to make the discussions in the following paragraphs meaningful.

Briefly, the following items will be covered: capital costs, for which tables will be given comparing 75, 150 and 300 tons/day plant cost based on roundwood raw material input, 50 percent in the form of softwoods and 50 percent in the form of soft hardwoods. The incoming wood moisture content is 100 percent on a dry basis, and it is assumed the bark of both the soft and hardwoods can be used for fuel. Any supplementary fuel requirements could be made up by either the purchase of additional bark from other sawmills or through the purchase of gas or fuel oil.

For equipment pricing international competitive prices have been used with delivery to a port on the China Sea. All prices are expressed in US Dollars. Building costs and land costs are based on prices currently prevalent in North America. To translate these prices into other locations should be relatively easy.

The second paragraph will cover manufacturing cost, and here somewhat modified U.S. prices were used throughout. All the costs are based on unit costs which enable the reader to apply his own unit cost relatively easily to calculate his own cost.

In the third paragraph exfactory sales recovery cost will be discussed. Here a table is included with current prices for MDF in various parts of the world. All the prices are expressed in US Dollars per cubic metre.

The last paragraph discusses the profit potential, which is mainly of interest for people who will work in the export market, and the data given is presented in graph form to show potential recovery achievable.

Additional information and explanations are given to each section.

B. Capital costs:

Table 4 gives typical capital costs for various plant sizes as shown. The 75 tons/day plant size shown in the first column represents the minimum practical unit, followed by plants with capacities of 150 and 300 tons/day. With regard to the plant capacity, the capacities quoted are base capacities, ultimately it would be expected that the plant would produce 10 to 20 percent above the capacities indicated. However, to achieve such production rate would require probably 1 1/2 to three years of operation before al˘ ,ersonnel is sufficiently trained and familiar with the operation of the unit.

The table lists the rated capacity of the three plant sizes and gives a proposed press size for each capacity. The press size of course can be varied to suit the particular requirements of the producer.

The equipment costs listed in the table follow the general outline of the process flow described in section 4 of this paper. The raw material receipt assumes roundwood logs delivered by truck to the plant site, the trucks being weighed then unloaded by a mobile grapple hoist. Logs are placed in storage, reclaimed and placed on a logdeck by grapple hoist, debarked and chipped. The chips will be stored in an outside storage pile. The barker and chipper are laid out for moderate log diameter of maximum 400 mm. For the 75 and 150 tons plant a single shift operation is projected and for the 300 tons plant a two-shift operation is projected, going five days a week.

The screening, refining and drying section is based on a refiner configuration of a Sunds Defibrator LVP36 refiner with 914 mm discs for the 75 tons plant, for the 150 tons plant for a Sunds Defibrator LVP42 refiner with 1067 mm discs and for the 300 tons per day plant for two Sunds Defibrator LVP42 refiners.

The 75 tons plant will have a single Pendistor forming head, the 150 tons per day plant and 300 tons per day plant will each have two Pendistor heads. The press sizes for different tonnage are indicated on the capital cost sheet.

The finishing section of the 75 tons and 150 tons per day plants will each have a four-head sander and only one trimming saw system. The 300 tons/day plant will have a six-head sander, that is three bottom and three top sanding belts and will have two saw systems. One to cut the panel into standard sheet sizes, and a second sawing system for cut-up operation. The finishing equipment for the 300 tons per day plant is provided with automatic packaging and strapping equipment whereas the 75 and 150 tons per day plants have manual strapping facilities.

In each case, the heating plant consists of a wood-waste burning boiler which will utilize the waste produced by the plant as fuel. The boiler is designed to burn sander dust, saw trim, chip fines and bark. Since the energy balance in most of the plants of this type works out slightly negative, that there is not sufficient fuel generated in the process, this will have to be supplemented either by fuel oil, gas or wood waste purchased from other sources.

Mobile equipment includes fork lift trucks, grapple loaders for logs, bucket loader for chip reclaim and two trucks. Auxilliary equipment first of all includes all the electric equipment, power transformation and switch gear, air compressors, laboratory equipment, repair shop machinery, water coolers, etc...

The installation costs are based on current pricing in North America for plants of the indicated capacity.

Site and site preparation include the cost of the land, the preparation of the land for the factory site including roads, fencing, drainage ditches, ponds, a moderate amount of earth moving to level the site and some landscaping. The area required for different capacities is approximately 12 hectares for 75 tons per day plant, 15 hectares for the 150 tons per day plant and 28 hectares for the 300 tons/day plant.

Buildings, structures and foundations, are based on prices currently prevalent in North Amercia and include all of the buildings, their interior finishing, offices, shops and enclosures such as guardhouse, enclosure for barker and chipper area, enclosure for screen and chip washers, electric rooms, sprinklers and fire hydrants, etc. Also included in the cost are the cost of steel supports for various equipment items, walkways, access platforms and all the footings, foundations and pits both for the buildings and for the machinery. The main building areas are approximately as follows: For the 75 tons plant the total building area will be about 4,300 m^2, for the 150 tons plant 5,300 m^2 and for the 300 tons plant 9,000 m^2.

The spare parts allowances are normal for plant sizes quoted.

A contingency allowance of 15 percent is included for cost escalation and other unforeseen factors which generally apply in North America and in Europe in recent years. In other locations such large contingency factors may not be needed since such unknown quantities as requirements for environmental impact, rapid escalation due to inflation and similar often unpredictable events are more closely controlled.

Table 4

Capital costs for MDF plants with capacities of 75, 150 and 300 tons/day

Rated capacity	75 tons/day 107 m^3/day	150 tons/day 214 m^3/day	300 tons/day 429 m^3/day
Press size	1.22x2.44m-12opg.	1.22x4.88m-12opg.	2.44x4.88-12opg.
Annual capacity (85 percent budget)	29,143 m^3/year	58,286 m^3/year	116,571 m^3/year
	US Dollars	US Dollars	US Dollars
EQUIPMENT			
Raw material receipt	509,000	814,000	1,417,000
Screening,refining,drying	1,870,000	2,372,000	3,936,000
Forming and pressing	5,276,000	6,218,000	7,990,000
Finishing	1,476,000	1,568,000	2,063,000
Heating plant	1,213,000	2,122,000	2,945,000
Mobile equipment	295,000	374,000	471,000
Auxilliaries	1,760,000	2,480,000	3,142,000
Total equipment	12,399,000	15,948,000	21,964,000
Installation	2,260,000	2,880,000	3,860,000
Total equipment installed	14,659,000	18,828,000	25,824,000
Site and preparation	650,000	870,000	1,400,000
Buildings,structures,foundations	2,570,000	3,149,000	4,620,000
Total	17,879,000	22,847,000	31,844,000
Spare parts	450,000	640,000	870,000
Contingency,cost escalation (15%)	2,681,000	3,423,000	4,776,000
Total capital costs	21,010,000	26,910,000	37,490,000
Capital cost \$/ton/day	280,133	179,400	124,967
Capital cost \$/m^3/year	721	462	322

The bottom two lines compare the cost for daily tonnage and the cost per cubic metre of annual production of various plant sizes. As is to be expected, based on daily output or annual output, the larger the unit the more economical it is.

The cost for such plants has escalated very rapidly over the last eight years, and we are nearing the point where the capital costs of these plants have tripled compared with plants built ten years ago. The effect of this tremendous cost escalation on an established industry like the medium density fibreboard industry in the United States has been very severe. Perhaps this is the reason that no new MDF plants have been built in the United States in the last five years.

C. Manufacturing costs:

The manufacturing costs are shown in Table 5 for plant capacities of 75, 150 and 300 tons per day. The table lists the annual plant capacities for the three configurations together with capital cost as they have been worked out in table 4.

Under the heading of raw material the amounts listed behind wood, resin and wax represent the weight of the material required to produce one ton of finished board. Under the heading unit cost the price per ton or kg of wood, resin or wax respectively is given. The unit price does not vary for the three capacities, even though in actual practice those costs would probably decrease for larger plant size.

Labour costs of US$ 12,000 per year per man has been used in this calculation. For each plant size the total labour requirement, including maintenance labour, is shown.

Power cost has been based on 6 ¢/kwh, with kwh requirement per ton shown for each plant size.

To make up for the shortcomings of fuel for the operation of the plant, 22 litres of fuel oil per ton of board has been included in this cost summary.

Maintenance supplies are costs used for repair and replacement for worn out equipment, lubrication and hydraulic oils, packaging and stapping materials, and other costs found in practical operation.

Wear parts are costs for such items as refiner plates, sander belts, saw blades and chipper knives.

The administrative and sales cost includes the costs for all supervisory staff, managers and the sales organization, including sales literature and advertising and the cost for running these offices.

Under general overhead such items as property taxes, insurance and other costs which may vary widely from location to location are shown.

The depreciation costs are taken on a straight line basis over a period of 15 years, based on the capital cost shown on the top of the page, In this calculation no cost for interests during construction or for money borrowed has been included.

The total manufacturing costs represent the cost incurred by the plant per ton or cubic metre produced during the year.

MANUFACTURING (MFG) COSTS - MDF PLANTS

Daily Capacity	75 tons/day
Annual plant capacity (320 Days)	29,143 m³/yr
Capital Cost	US$ 20,670,000

Cost - US $ (19mm basis)	unit cost	$/ton	$/m³
RAW MATERIAL			
Wood - 1.1 ton/ton	75 /ton	82.50	57.75
Resin - 100 kg/ton	0.45 /kg	45.00	31.50
Wax - 10 kg/ton	0.53 /kg	5.30	3.71
TOTAL RAW MATERIAL		132.80	92.96
Labour (12,000 $/man yr.)	68 men	40.00	28.00
Power (0.06 $/KWH)	470 KWH/t	28.20	19.74
Fuel - 22 ltr/ton	1.50/ltr	33.00	23.10
Maintenance Supplies(%MFG Cost)	2.8%	7.31	5.12
Wearparts (% MFG costs)*	2.3%	6.02	4.20
Administration & Sales(%MFG cost)	3.1%	8.09	5.67
General Overhead (% MFG cost)	2.2%	5.74	4.02
TOTAL OTHER COST		128.36	89.85
TOTAL COST, Excluding Depreciation		261.16	182.81
DEPRECIATION-15yr Straight Line		68.61	48.06
TOTAL MANUFACTURING COST		392.81	230.87

* Unit cost expressed as % of total cost, excludi

TABLE 5

150 tons/day			300 tons/day		
58,285 m^3/yr			116,571 m^3/yr		
US$ 26,910,000			US$ 37,490,000		
unit cost	$/ton	$/$m^3$	unit cost	$/ton	$/$m^3$
75 /ton	82.50	57.75	75 /ton	82.50	57.75
0.45 /kg	45.00	31.50	0.45 /kg	45.00	31.50
0.53 /kg	5.30	3.71	0.53 /kg	5.30	3.71
	132.80	92.96		132.80	92.96
75 men	22.06	15.44	100 men	14.71	10.29
430 kWH/t	25.80	18.06	380 kWH/t	22.80	15.96
1.50/ltr	33.00	23.10	1.50/ltr	33.00	23.10
2.6%	6.08	4.26	2%	4.34	3.04
2.2%	5.15	3.60	1.8%	3.91	2.74
2.4%	5.60	3.93	1.6%	3.47	2.43
1.5%	3.51	2.46	1%	2.17	1.52
	101.21	70.85		84.40	59.08
	234.01	163.81		217.20	152.04
	43.97	30.78		30.63	21.44
	277.98	194.59		247.83	173.48

ng depreciation.

D. Prices of goods sold:

The current pricing of MDF on the international market is presented in the following table 6.

The first column of the table gives the current ex-factory list prices in the major producing countries of MDF. Of all the countries listed only the United States has a truly competitive position internally, since Japan, New Zealand, Italy and Spain each has only one plant currently in production. There are eleven plants in production in the United States. It should also be noted that the majority of the U. S. plants were built before 1975 with a much lower capital cost than all of the plants built subsequently in the world. The ex-factory list prices do not only reflect the actual cost for producing the board within the various countries, but also very strongly reflect the competitive position of these plants in those countries. The ex-factory prices include profit for the producer.

The second column shows the wholesale list prices in various European countries, and also in Japan, Canada and the United States. The difference between the wholesaler's prices and the ex-factory prices is freight cost from the manufacturer to the wholesaler's location, and the profit to the wholesaler. Again it is very noticeable the cost difference between almost all of the other countries and the United States and Canada. In both of these latter countries the location of the existing plants close to the major end users and competition between the various plants tend to hold the prices down. Of course various costs, especially wood, resin and energy, are lower in North America than in most other countries.

The prices quoted are current average prices and may vary from point to point at the time this paper is presented.

Table 6

Ex-factory and wholesalers' list prices for MDF

All prices quoted are in US$ per m^3 - 19 mm board

Prices include profit for producer.

Country	Ex factory	Wholesaler
Italy	300	340
Japan	340	370
New Zealand	270	345
Spain	285	360
United States of America	180	215
England		360
Federal Republic of Germany		370
Canada		265
France		380
Sweden		450
Australia		420

E. Profit potential

Perhaps the best way to indicate profit potential is to express it in a graph form showing the potential return on investment from various product prices ex-factory. The following Graph no.1 shows this relationship.

The bottom line of the graph shows the product price ex-factory in US$/$m^3$ and the vertical part of the graph shows the profit as return on capital invested, expressed as percentage of that investment before payment of profit taxes. In most western countries for a plant to be economically justifiable a return before taxes of 15 percent is considered to be a minimum. Using a return of 20 percent it can easily be seen that the ex-factory price for

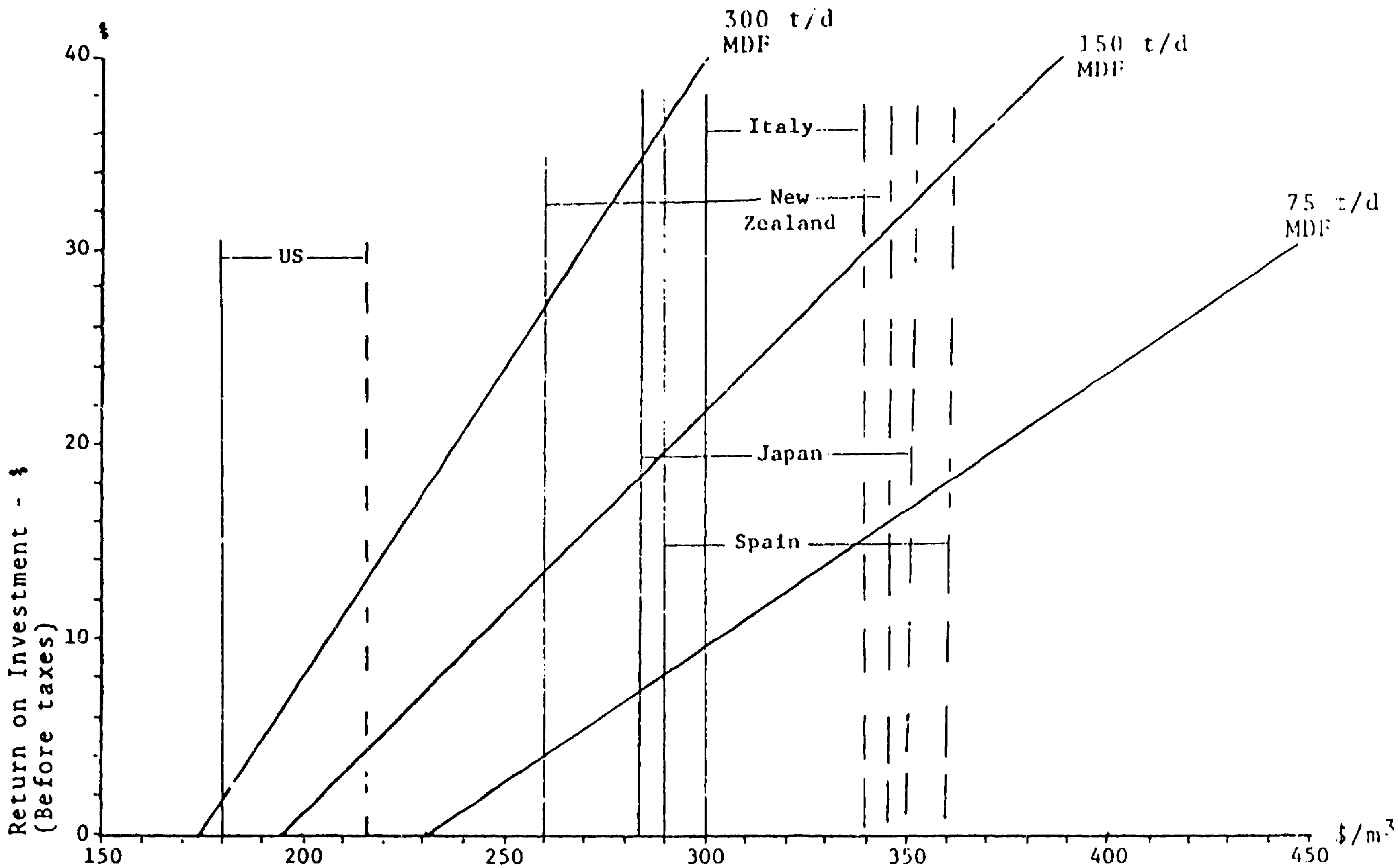
75 tons/day plant with the manufacturing cost as calculated in paragraph C of this Section would have to be about \$ 380/m^3. for the 150 tons/day plant this amount would have to be \$ 295 and for a 300 tons/day plant the net to mill recovery would have to be \$ 238. It demonstrates very graphically how much the plant size influences its profitability. Of course against such reasoning the argument of the greater difficulty of selling such large quantities of board must be carefully studied. Also shown in the graph are two additional pieces of information, the vertical solid lines representing current manufacturers' list prices ex-factory, and the broken lines representing typical wholesalers' selling prices in the countries named (it should be noted that both the ex-factory list prices and the selling prices include profits to the manufacturer and/or the wholesaler respectively).

The prices levels shown in solid and broken lines tell us very quickly that an export of board to the United States or New Zealand from any other country could not be justified at the current price levels in these countries. How competitive a unit would be in the European or Asian market depends very much on the location and size of the plants. It is clear that for any export facility a close proximity to a sea port is mandatory, to reduce inland freight cost as much as possible.

A much more interesting approach to the profitability of such a plant would be to look at the internal up-grading of the board within the country where the board is manufactured. The export of furniture, cabinets and similar goods produced from MDF represents a much better return than the sale of raw board.

GRAPH NO. 1

Product Price - Return on Investment



Product - Price, Ex-Mill - US $/m^3

Note: 1. Solid vertical lines, typical manufacturers' ex factory list price
2. Broken vertical lines, typical wholesalers' list price